

ENERGY & SUSTAINABILITY ASSESSMENT

Proposed Residential Development
Gas Works Road, READING

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Galliard Homes

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Annex A – Sample SAP Modelling Output

EXECUTIVE SUMMARY

This report has been compiled in order to provide an Energy and Sustainability Assessment for the proposed residential development at Gas Works Road, Reading.

This document has been compiled by Sol Environment Ltd on behalf of Galliard Homes (*'the applicant'*). The Energy and Sustainability Assessments have been formulated in order to provide a sustainable energy solution and sustainability appraisal for the proposed site in accordance with *National Planning Policy Framework* and the *Reading Borough Council's Core Strategy* with particular reference to *Core Strategy Policy CS1: Sustainable Construction and Design*.

The Sustainability assessment confirms that overall, the redevelopment of the site at Gas Works Road can be considered to be contributing positively to the sustainability of its immediate surroundings as well as within the local and regional government areas, by bringing life back to a currently derelict site.

The Energy assessment and subsequent strategy has been prepared such that it is aligned with the Energy Hierarchy (see Section 2.1), with particular focus on sustainable building design (reduction of energy consumption at source), provision of energy efficiency measures and installation of building-integrated LZC technologies.

The strategy has been derived in order to ensure compliance with current energy planning policy, in particular, *Core Strategy Policy CS1: Sustainable Construction and Design*. CS1 states all developments of more than 10 residential units, *will be required to incorporate on-site generation of energy from renewable sources and energy efficient design measures to off-set at least 20% of the predicted carbon dioxide emissions*.

The below table provides an overview of the provisional energy strategy, based on the objectives detailed throughout this report.

Gas Works Road Site: Energy Strategy Overview			
Area	Objective Ref	Section	Description
Passive Solar Design	A	2.2.2	Minimising overshadowing
	B	2.2.2	Passive design principles
	C	2.2.2	Landscaping
	D	2.2.2	Limiting excessive solar gain
Energy Management & Efficiency	E	2.2.3	Building energy efficiency measures
Renewable Technologies	F	2.3.3	Integration of LZC technologies

The proposed strategy is based on utilising passive design measures, **super insulated and air tight building fabric, community heat network** with a high efficient gas fuelled boiler heating system and the installation of **Photovoltaic Panels** for the provision of supplementary renewable energy generation such that a significant reduction in CO₂ emissions is achieved through LZC/renewable technology. To meet building regulations and achieve a >20% reduction in CO₂ emissions through LZC technologies and energy efficiency measures (as required by the Local Authority) a **~7kWp roof mounted solar PV array** evenly distributed across the 2 roofs, equating to approximately 0.2kWp per dwelling, is required. This is the equivalent of a total roof area of approximately 50m² of panels.

Specific detail relating to the predicted reductions in annual CO₂ emissions is detailed within the table below.

Gas Works Road Site: Energy Strategy Summary			
Scenario	Regulated CO ₂ Emissions (kgCO ₂ / year)	Emissions saving on previous scenario achieved (%)	Ave DER (kgCO ₂ / m ² / year)
Baseline Building (BRUKL min. u-values)	39,556	-	29.59
After Energy Demand Reduction ('Residual' Scenario)	33,507	15%	25.06
After On-Site Renewables (savings compared to 'Residual Scenario')	30,674	8%	22.94
TOTAL SAVING	8,882	22%	-

Based on the above and in accordance with *Core Strategy Policy CS1: Sustainable Construction and Design*, the proposed development will endeavour to achieve a >20% reduction in CO₂ emissions (22% compared to the baseline scenario) through energy efficiency measures and the installation of a ~7kWp roof mounted solar PV array.

A graphical representation of the cumulative reduction in CO₂ emissions through implementation of various stages of the Energy Hierarchy is provided in Figure E1.

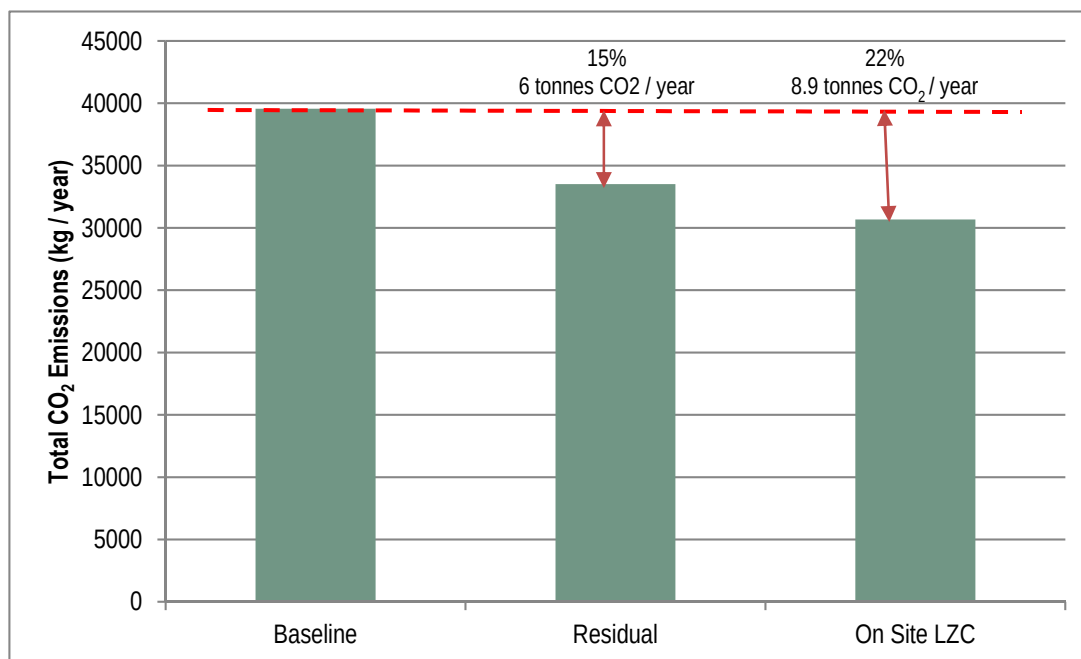


Figure E1: Implementation of the Energy Hierarchy for the Gas Works Road, Reading residential development.

1. INTRODUCTION

1.1 Background

Sol Environment Ltd ('Sol' hereafter) were engaged by Entran Ltd on behalf of Galliard Homes ('the applicant' hereafter) to undertake an assessment of site sustainability, energy use and production of an energy strategy for the proposed residential development at Gas Works Road, Reading.

This report has been prepared by Sol Environment Ltd in cooperation with the applicant and in accordance with the following policies and guidance published by Reading Borough Council;

- Core Strategy; and
- Supplementary Planning Documents.

This Energy and Sustainability Assessment has been prepared in association with a new planning application for the development.

1.2 Policy Review

Reading Borough Council most current relevant documentation is the *Reading Borough Council Local Development Framework Core Strategy (Adopted January 2008 with alterations Adopted January 2015)* and *Revised Sustainable Design and Construction Supplementary Planning Document (Adopted July 2011)*. The following policies are relevant to the proposed energy and sustainability criteria of the development.

Core Strategy Policy CS1: Sustainable Construction and Design

Proposals for new development, including the construction of new buildings and the redevelopment and refurbishment of existing building stock, will be acceptable where the design of buildings and site layouts use energy, water, minerals, materials and other natural resources appropriately, efficiently and with care and take account of the effects of climate change.

To meet these requirements:

- All new housing is required to meet the most up to date Eco-Homes 'Very Good' as a minimum standard, and all new commercial developments are required to meet the most up to date BREEAM 'Very Good' as a minimum standard;
- On larger developments of more than 10 dwellings or 1,000 m² of floor space, ensure that 50% of the provision meets the most up to date Eco-Homes and BREEAM 'Excellent' standards;
- All new developments maximise the use of energy efficiency and energy conservation measures in their design, layout and orientation to reduce overall energy demand;
- All developments of more than 10 dwellings or 1000m² floor space incorporate on-site generation of energy from renewable sources and energy efficient design measures (including the use of CHP where appropriate) to off-set at least 20% of predicted carbon dioxide emissions from the estimated energy usage of the completed and occupied development;
- All developments reduce mains water use and demonstrate that water conservation measures are incorporated so that predicted per capita consumption does not exceed the appropriate levels set out in the Code for Sustainable Homes or BREEAM Standards

- Developments incorporate sustainable urban drainage facilities and techniques as part of the layout of a development as appropriate and as advised by the Environment Agency, including minimising the size of impermeable areas so that peak run-off and annual water run-off is reduced where possible and in any case is no greater than the original conditions of the site. Particular care will be needed in areas of flood risk where different solutions may be required.

Core Strategy Policy CS2: Waste Minimisation

Policy CS2 of the Core Strategy: Waste Minimisation, requires that development should demonstrate measures to minimise the generation of waste in the construction, use and life of buildings. Development should also promote more sustainable approaches to waste management, including the re-use and recycling of construction waste and the promotion of layouts and designs that provide adequate space to facilitate waste storage, re-use, recycling and composting.

Summary of relevant policy requirements: all developments of more than 10 dwellings are to incorporate on-site generation of energy from renewable sources and energy efficient design measures to off-set at least 20% of the predicted carbon dioxide emissions.

NOTE: The Code for Sustainable Homes ('CSH') has been repealed by the UK Government and can no longer be conditioned by planning authorities. Therefore, this assessment does not need to address the CSH / Eco-Homes requirements.

1.3 Proposed Development

A new planning application will be made for the refurbishment and redevelopment of land on Gas Works Road in Reading. The site currently houses 2 derelict masonry warehouse buildings which will be refurbished and expanded to provide 34 new residential units – 17 will be located within the envelope of the existing buildings and 17 will be new build either above or adjacent to the existing buildings.

A schedule of the overall site information use and associated gross internal areas is provided in Table 1.1 below.

Table 1.1: Proposed Gross Internal Areas				
Apartment Type	No. of Beds	New build or Existing	No. of Dwellings	Total Area (m²)
1 bed existing	1	Existing	7	249.9
1 bed new	1	New	15	557.1
2 bed existing	2	Existing	10	431.1
2 bed new	2	New	1	40.8
3 bed new	3	New	1	58.1
TOTAL			34	1337



Fig 1.1: Proposed Masterplan prepared by E3 Design

In accordance with the Core Strategy Policy CS1: Sustainable Construction and Design of the Reading Borough Council Local Development Framework the residential dwellings will assess the development against the energy hierarchy to show reduced energy use and target at least 20% reduction in carbon dioxide emissions through on-site generation of energy from renewable sources and energy efficient design measures.

This assessment has been prepared in order to demonstrate how this target can be achieved.

2. ENERGY ASSESSMENT

This section comprises the Energy Assessment for the proposed development, in accordance with the Reading Borough Council Local Development Framework.

2.1 The Energy Hierarchy

The Energy Hierarchy adopts a set of principles to guide design development and decisions regarding energy, balanced with the need to optimise environmental and economic benefits. The Hierarchy, which is a widely accepted approach amongst many Councils, seeks to ensure that developments meet the Council's objectives of incorporating energy efficiency through the approach detailed in Figure 2.1.

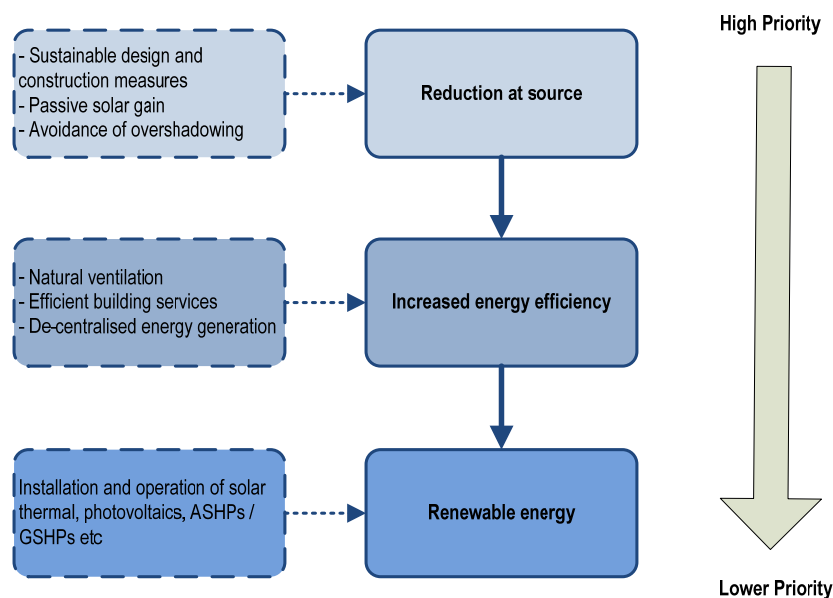


Figure 2.1: The Energy Hierarchy

It is considered that the above principles for carbon reduction form the most appropriate approach from both a practical and financial perspective. The industry is broadly in agreement that energy efficiency and low carbon technologies have the greatest impact in offsetting CO₂ emissions. Therefore, it is logical to encourage enhanced mitigation through energy efficiency and low carbon technologies in the first instance, with the application of renewable energy technologies as a secondary measure to reduce the primary energy requirements of a building.

Consequently, as a result of the above principles, the first stage in the energy strategy for the proposed development is the consideration of energy efficiency measures to ensure that the baseline energy demand is minimised.

2.2 Site Layout & Building Design

2.2.1 Overview

It is stated within the Part L1A and L1B of the 2013 Building Regulations that *'measures to make the building energy efficient must be incorporated within the scheme design.'*

Typically, passive energy efficient design measures can bring about a significant improvement upon the Dwelling Emission Rate ('DER') in new built projects, as a result of energy efficiency measures alone.

2.2.2 Passive Solar Design

Passive design measures manage internal heating through solar gain and as such reduce the need for cooling. Buildings that are aligned in a north-south orientation are observed to maximise daylight and sunlight (i.e. solar gain), subsequently reducing energy consumption associated with excessive heating and lighting requirements.

Due to the existing fixed building footprint on the site there is limited opportunity to orientate buildings (new or existing) to benefit from passive solar measures. That said, the alignment of the existing buildings (large south facing façade), the stepped building mass (tallest building to the north of the site) and the large amount of south facing glazing, will all allow the buildings to benefit from passive solar heating.

A benefit of the design of the buildings is the high levels of natural light and solar gain afforded by the large windows on all building aspects. In order to optimise this design feature, the design team have attempted to further optimise solar gain through the consideration of the solar orientation of internal facilities. Accordingly a majority of the unoccupied building service areas and stairwells have been incorporated wherever possible, into the areas which are not served by high levels of natural light.

The site has been designed in consideration of the parameters detailed within Table 3.1 and performance has been maximised in the absence of any constraints. Specific objectives related to overshadowing are referenced in Box 2.1 below.

Box 2.1: Objective A – Minimising Overshadowing

A1 – Where no restrictions apply due to internal site layout, service and auxiliary areas (ie those that do not require heating) shall be located to the north of the building or in areas not served by high levels of natural light, therefore maximising the utilisation of solar gain for living spaces and subsequently lower residual energy consumption.

A2 – The inherent nature of the site ensures potential overshadowing issues are alleviated, with the southern of the 2 building lower than the northern, hence limited overshadowing from one of the other will occur.

A3 – Where possible dwelling internal layouts have been arranged to ensure the maximum amount of southern aspect (and passive solar heating) for the main living space.

The internal aspects of the development shall be designed (wherever possible) to further maximise the benefits provided by solar orientation. Subsequently, the building shall be constructed to specified design briefs and the principles detailed in Box 2.2 below.

Box 2.2: Objective B – Building Design Principles

B1 – Where orientation provides favourable conditions and no physical restrictions are provided by surrounding buildings, the glazing ratios within the development shall be designed such that potential for solar gain is maximised.

B2 – Consideration will be given to the design of the internal envelopes of the proposed development, which will seek to utilise materials that not only provide high insulation values, but also have a high thermal mass.

B3 - Accredited Construction Details will be used where possible to ensure thermal bridging is limited to achieve a maximum Y-value of 0.08W/m²K.

B4 – Consideration will be given to the selection of insulation materials for the building, ensuring the following heat loss parameters (U-Values) as a minimum:

Component	U Value
New External Walls	0.15
Retained External Walls	0.30
Roof	0.13
Floor	0.13
Doors	1.3
Windows	1.3

B5 – The new dwellings shall not exceed a maximum air permeability of 5 m³ / (hr.m²). Dwellings within the existing building envelop will target a maximum air permeability of 10 m³ / (hr.m²). This shall be achieved through the following measures;

- Adequate sealing between openings / windows and panels;*
- Adequate sealing of ceiling-to-wall joints;*
- Provision of a continuous air barrier over ceiling areas and adequate sealing of service ducts (where appropriate);*
- High specification openings (see Objective B4);*
- Brick / block construction will be mitigated against through application of wet plastering / parging / dry lining.*

B6 – The internal layout of the dwellings shall be constructed in consideration of building orientation and achieving maximum solar gain. Where no restrictions apply due to internal site layout (i.e. orientation of road infrastructure), the internal design of dwellings shall typically comprise the following:

- The most heated and frequently used rooms (i.e. master bedrooms and living rooms) shall be placed on the south side of the dwelling (where appropriate).*

- *Rooms that benefit little from sunlight (i.e. hallways, utility rooms, bathrooms and storage areas) are placed on the north side of the dwelling.*
- *Wherever relevant and possible, the dining-room will be linked with the living-room in each proposed dwelling (in preference to the kitchen in order to maximise solar gain).*

Due to the tight, urban nature of the site there is limited opportunity to use topography or landscaping to improve the passive thermal design of the site. That said there are some general landscaping and topographical measures (detailed in Box 2.3) that will be used in order to improve the amenity of the scheme with regards to landscape strategy.

Box 2.3: Objective C – Landscaping

C1 – Maximising the amount of soft landscaping around the base of the buildings will have a generally positive effect with respects to the urban heat island affect.

C2 – The majority of planted trees on-site (particularly those south of proposed buildings) will be of a deciduous variety, such that solar obstruction is minimised and penetration of low-level winter sun is allowed.

Consideration has also been given to minimising excessive solar gain and subsequent building overheating, thus avoiding excessive use of mechanical cooling systems in the summer months. Mechanical (forced draught) ventilation systems can account for a significant percentage of building energy use due mainly to the forced draught and fan plant required to maintain sufficient through-flow of internal air.

The majority of the dwellings have good opportunities to benefit from natural cross ventilation. But given the constricted site it is assumed that some mechanical ventilation will be required in a number of the areas of the building (kitchens and bathrooms) to ensure sufficiently ventilated conditions.

Box 2.4: Objective D – Limiting Excessive Solar Gain

D1 – In order to limit the requirement for excessive mechanical cooling. Cross-ventilation shall also be provided where possible and practicable, in the form of operable (secure) windows and trickle vents, such that night cooling can be encouraged without compromising building security.

D2 – Natural ventilation shall be utilised within all buildings on-site (unless specific conditions require the use of mechanical ventilation such as wet rooms / trickle vents etc).

D3 – Where the external envelope has large glazed areas, the windows shall be inset from the main external building facade (wherever possible) or fitted with low emissivity coatings such that potential overheating is minimised.

2.2.3 Energy Efficiency Measures

In addition to regulated emissions (heating, cooling and ventilation), energy consumed by ancillary activities (primarily electricity consumption derived from the use of lighting and electrical appliances) is anticipated to account for approximately 30-40% of the overall CO₂ emissions from the development.

Significant energy efficiency measures shall be installed such that unnecessary energy consumption is reduced at source (in accordance with the Energy Hierarchy).

Box 2.5: Objective E – Energy Efficiency Measures

E1 – All fixed lighting will comprise dedicated low energy fittings (i.e. those which are only capable of accepting low energy lamps with a luminous efficacy of ≤ 40 lumens per circuit Watt).

E2 – The building shall be fitted with AMR energy display devices for the provision of half hourly energy consumption data.

E3 – All occupants shall be provided with a 'Home User Guide', which shall provide information on energy systems within the building and details on best practice and energy saving techniques.

2.3 Low-Zero Carbon Technologies Appraisal

2.3.1 Overview

In accordance with the Reading Borough Council Local Development Plan the inclusion of on-site generation of energy from renewable sources and energy efficient design measures are required to contribute >20% reduction in carbon dioxide emissions.

In order to achieve this, the applicant has commissioned a high level feasibility study to ascertain the predicted energy consumption (and associated carbon dioxide emissions) for the site and select appropriate renewable technologies and energy efficiency measures.

2.3.2 Baseline Energy Assessment

In order to determine the type and size of LZC technology suitable for the site, a detailed baseline modelling and assessment exercise was undertaken.

Proprietary energy demand calculations for the proposed development have been undertaken using SAP modelling software. In accordance with L1A and L1B of the current Building Regulations (2013) a notional building will be used as the minimum benchmark for the dwellings housed within the existing building as well as the new building dwellings. (The benchmark for the 'new build' dwellings is to be based on minimum Building Regulations fabric performance and the benchmark for the dwellings located within the existing envelope are to be based on the performance of the existing building fabric). The total emissions combined will form the baseline standard for the assessment for regulated emissions (heating, lighting and ventilation). Pursuant to this, initial energy demand calculations for the building have been undertaken

to provide a 'baseline' building from which further calculations based on energy measures, efficient supply and renewable energy systems can be progressed. SAP modelling was undertaken for each dwelling.

Upon calculation of a baseline SAP output, the dwellings were then remodelled in order to account for the various stages of the Energy Hierarchy and subsequently demonstrate the reduction in regulated CO₂ emissions.

Table 2.1 provides a summary of the various modelled scenarios.

Table 2.1: Summary of SAP Modelled Scenarios						
Parameter			Scenario			
			Baseline	Residual		After LZC
<i>Dwelling</i>	<i>Emission</i>	<i>Rate</i>	24.50 – 39.37	20.27 – 34.32		18.34 – 31.69
<i>(kgCO₂/m²/year)</i>			<i>Ave. – 29.59</i>	<i>Ave. – 25.06</i>		<i>Ave. – 22.94</i>
U-Values (W/m ² .K)	Walls		0.3	0.15 (<i>existing 0.3</i>)		0.15 (<i>existing 0.3</i>)
	Roofs		0.2	0.13		0.13
	Floors		0.25	0.13		0.13
	Doors		2.0	1.3		1.3
	Windows		2.0	1.3		1.3
Y-Values			0.15	0.08		0.08
Air permeability (m ³ /(hr.m ²) @ 50 Pa)			10.0	5.0 (<i>existing 10</i>)		5.0 (<i>existing 10</i>)
Heating / Domestic Hot Water (DHW)	Type		Notional Gas Boiler	Community Heating via Gas-fuelled Boiler		Community Heating via Gas-fuelled Boiler
	Efficiency		90%	>90%		>90%
	Fuel		Gas	Gas		Gas
	Controls		Room thermostats; programmer	Room thermostats; programmer		Room thermostats; programmer
DHW			From Main Heating System	From Main Heating System		From Main Heating System
Cooling			-	-		-
Internal Lighting			50% non-dedicated low energy	100% dedicated energy	non- low	100% dedicated low energy
Electricity			Grid Supplied	Grid Supplied		Grid Supplied
Renewable Technologies			-	-		PV (~7kW array)

The baseline emissions for the dwellings are captured within the Dwelling Emission Rate (DER) calculated on a building with a mixture of existing building fabric and minimum building regulations compliant building fabric, services and performance in accordance with Approved Documents L1A and L1B.

Table 2.6 below details the 'baseline case' scenarios for the development regarding CO₂ emissions.

Table 2.2: Baseline CO ₂ Emissions		
Scenario	Regulated CO ₂ Emissions (kgCO ₂ / year)	Ave DER (kgCO ₂ / m ² / year)
'Baseline' scenario	39,556	29.59

The above baseline case assumes an operating scenario based on those parameters detailed within the Baseline Scenario Column of Table 2.5.

The utilisation of a community heat network is proposed with an energy centre/plant room in the basement of the smaller building. A site wide heating loop will provide heat to all dwellings in both buildings. Combined Heat and Power (CHP) was considered (in accordance with the energy hierarchy) but the development is only residential and the constant heating and power loads required to get the greatest efficiency out of CHP are not available (more suitable to mixed use developments).

It is considered the most preferred solution to utilise a high efficiency gas fired boiler to supply the heat for the community heat network. If at a future point in time the utilisation of a renewable heating system (CHP, biomass, etc) becomes more financially viable the gas boiler could be replaced and community heat network could be retained as a suitable distribution network.

In accordance with Core Strategy Policy CS1 of the Reading Borough Council Planning Policies, the development is required to reduce carbon emissions by at least 20% through on-site generation of energy from renewable sources and energy efficient design measures. The next 2 scenarios outline how this is achieved.

Table 2.7 below details the 'residual' scenario for the development regarding energy and CO₂ emissions nominating the savings achieved through energy efficient design measures.

Table 2.3: Residual CO ₂ Emissions			
Scenario	Regulated CO ₂ Emissions (kgCO ₂ / year)	Saving achieved on baseline CO ₂ emissions (%)	Ave DER (kgCO ₂ / m ² / year)
'Residual' scenario	33,507	15%	25.06

The above residual case assumes an operating scenario based on those parameters detailed within Residual Scenario Column of Table 2.5, (i.e. excluding the installation of renewable energy measures).

Table 2.8 below details the 'renewable' scenario for the development regarding CO₂ emissions. The below scenario has been modelled on the technologies proposed in Section 3.3.4 (summarised in After LZC Scenario Col, Table 2.5)

Table 2.4: LZC Technologies CO₂ Emissions

Scenario	Regulated CO ₂ Emissions (kgCO ₂ / year)	Saving achieved on residual CO ₂ emissions (%)	Ave DER (kgCO ₂ / m ² / year)
'LZC Technologies' scenario	30,674	8%	22.94

Table 2.8 details an approximated overall 8% reduction in CO₂ emissions for the development through installation of low/zero carbon technologies when compared to the residual scenario.

Table 2.9 below provides a tabular summary of the energy assessment conducted for the proposed site, detailing a significant reduction in energy consumption (and subsequent CO₂ emissions) through the installation of photovoltaic panels.

Table 2.5: Energy Strategy Summary

Scenario	Regulated CO ₂ Emissions (kgCO ₂ / year)	Emissions saving on previous scenario (%)	Ave DER (kgCO ₂ / m ² / year)
Baseline Building (BRUKL min. u-values)	39,556	-	29.59
After Energy Demand Reduction ('Residual' Scenario)	33,507	15%	25.06
After On-Site Renewables (savings compared to 'Residual Scenario')	30,674	8%	22.94
TOTAL SAVING	8,882	22%	-

Based on the above and in accordance with Core Strategy Policy CS1, the proposed development will endeavour to achieve a >20% reduction in CO₂ emissions (22% compared to the baseline scenario) through energy efficiency measures and the installation of a ~7kWp roof mounted solar PV array.

A graphical representation of CO₂ emissions savings provided by the various assessment stages for the development is detailed in Figure 2.2 below.

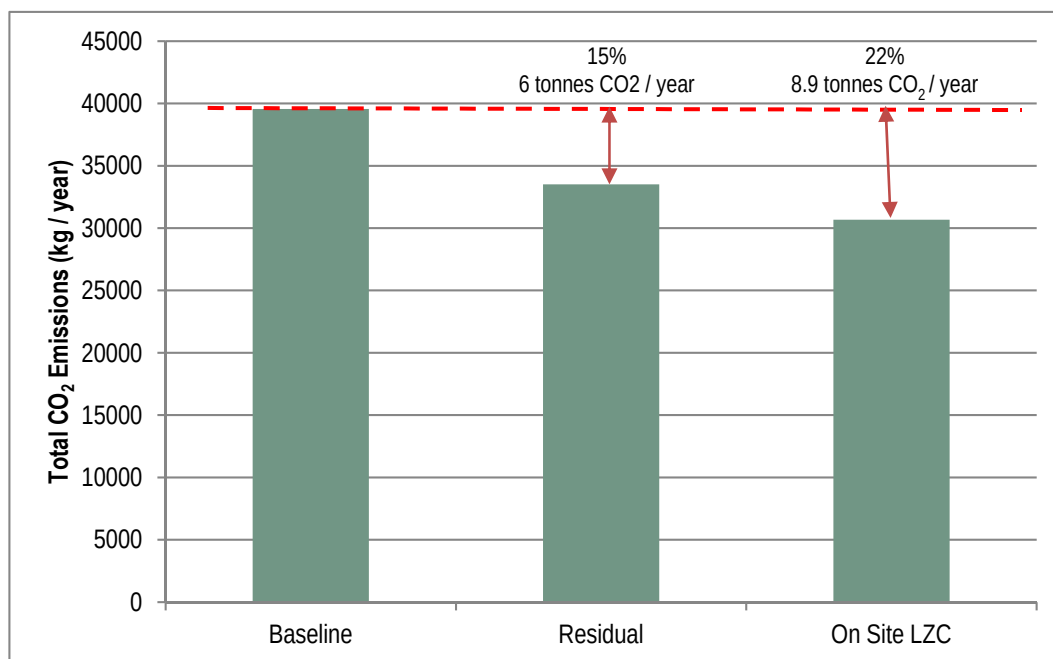


Figure 2.2: Implementation of the Energy Hierarchy for the Gas Works Road, Reading residential development.

2.3.3 High-Level Feasibility Review

Combined Heat & Power

CHP comprises combination of the generation of electricity for general consumption, with the recovery of exhausted heat energy (otherwise emitted from power stations / generators as waste heat) which can be used to provide heating for domestic and industrial processes.

Although not considered a renewable source (excepting biofuel-fired plants), CHP plants (typically 75% - 80% efficient) are significantly more efficient than a typical oil / gas fired power station (35% - 45% efficient), even when it is used in combination with fossil fuels such as gas and diesel. Therefore they are viewed as being more efficient than obtaining energy from the National Grid ('the grid').

In addition, transmission losses (typically 5% when consuming electricity from the grid) are minimised by on-site generation and, as such, a gas-fired CHP can be seen as a relatively carbon efficient means of energy supply.

Box 2.6: Feasibility Summary – CHP

Combined Heat and Power (CHP) was considered (in accordance with the energy hierarchy) but the development is only residential and the constant heating and power loads required to get the greatest efficiency out of CHP are not available (more suitable to mixed use developments).

As such it has been concluded that the proposed development is neither appropriate in use nor sufficient in scale to warrant CHP.

Solar Thermal Heating / Hot Water

Solar thermal panels are typically used in order to provide supplementary heat for the purposes of space heating or domestic hot water (DHW).

These systems consist of solar collectors, a pump, a control unit, connecting pipes, hot water tank and a conventional heat source (gas / oil fired boiler). The collectors are usually mounted on the roof and provide heat to a fluid circulated between the collectors and a water tank. The efficiency of solar collector panels depends on a number of factors, including the type of collector, correct installation, location and orientation.

Installing solar thermal heating panels could reduce energy consumption and carbon impacts through significant reductions in electric water heating and typically produce approximately 5-600 kWh/m² of hot water.

Although evacuated tube systems are about 30% more efficient, they have a corresponding increased capital outlay. A collector area of 4–5 m² will normally save approximately 230kg of CO₂ emissions per

year. A well designed system should satisfy 70-80% of the hot water demand in the summer and 20-30% in the winter.

Box 2.7: Feasibility Summary – Solar Thermal

Based on the orientation of the dwellings and the limited roof space DHW heating via installation of solar thermal is not considered to be the most feasible option.

Utilising the limited roof space for PV is considered a more preferable approach.

Ground Source Heat Pumps

Ground Source Heat Pumps (GSHPs) operate by the removal of residual heat from the ground by using various 'loops' containing a water and glycol fluid mix, heat from the ground is absorbed into this fluid and is pumped through a heat exchanger in the heat pump. Low grade heat passes through a compressor and is concentrated into a higher temperature gas capable of heating water for DHW and central heating systems.

There are a number of configurations for GSHP systems. A vertical collector system is considered to be the most appropriate in the context of the proposed development given the large scale of the system and limited area available for horizontal collectors. Vertical collectors can be between 15 – 180m deep and minimum spacing between adjacent boreholes should be maintained at 5 - 15m to prevent thermal interference.

The heat yielded from GSHPs is relatively small (collecting approximately 14 - 20W_{th} per metre of collector loop), therefore the adequacy of the accompanying heat exchanger is vital in ensuring greater heat transfer (although more efficient exchangers have a significantly larger capital cost).

The performance of a GSHP system is entirely dependent on the appropriateness of the ground conditions (i.e. depth of soil cover, the type of soil or rock, ground temperature and thermal conductivity), which would be established subject to a ground survey.

'Reversible' heat pumps systems are also available that give the potential for provision of space cooling, if required. Groundwater can also be used to cool buildings where a suitable source exists, abstraction and discharge permissions can be obtained from the Environment Agency and test bores are favourable.

Box 2.8: Feasibility Summary – Ground Source Heat Pumps

Installation of GSHPs for the provision of primary space / DHW heating for the building is not considered feasible due to financial reasons and the large amount of ground works required to install a GSHP system.

Air Source Heat Pumps

Air source heat pumps (ASHPs) absorb heat from ambient air in order to provide heat for the purposes of space heating and domestic hot water. An evaporator coil, mounted outside absorbs the heat; a

compressor unit then drives refrigerant through the heat pump and compresses it to the right level to suit the heat distribution system.

Finally, a heat exchanger transfers the heat from the refrigerant for use, depending on which of the two main types of systems (identified below) is installed;

- Air to air system - produces warm air which is circulated by fans to heat a home; and
- Air to water system - uses heat to warm water. Heat pumps heat water to a lower temperature than a standard boiler system; therefore, these systems are more suitable for underfloor heating systems than radiator systems, requiring less space to incorporate, compared with an air to air system.

The efficiency of ASHPs is measured by a coefficient of performance (CoP) i.e. the amount of heat produced compared to the amount of electricity needed for them to operate.

ASHPs are often a more popular (and technically / financially viable) alternative to GSHPs due to lack of requirement for extensive excavation, requiring far less space and easier installation.

Box 2.9: Feasibility Summary – Air Source Heat Pumps

The utilisation of Air Source Heat Pumps as the primary space and water heating source was not considered feasible due to the limited opportunities for the system to be integrated into a future community heat network and the lack of external wall and roof space required for plant.

Biomass Heating

Biomass boilers replace conventionally powered boilers with an almost carbon neutral fuel (such as wood pellets). In addition, the installation and operation of a biomass boiler in new-build developments could yield significant revenue from the forthcoming Renewable Heat Incentive, a government funded clean energy cashback scheme.

Although many biomass burners will meet Clean Air Act requirements, combustion of woody biomass releases higher quantities of NO_x compared to a comparable system fuelled by natural gas. As a consequence, many Local Authorities, particularly in urban areas have concerns about the potential impact on air quality that the widespread uptake of biomass boilers would have. Therefore, a large number of Councils generally approve of the specification of biomass when linked to a large-scale biomass CHP as opposed to being used for individual boilers.

Box 2.10: Feasibility Summary – Biomass Boilers

The use of an energy centre with a biomass boiler was considered a feasible option but due to the significant space required to store the feedstock and the potential impact on air quality in such a densely urban area it was not considered a viable option at this point in time.

Photovoltaic Cells

Solar Photovoltaics (PVs) are solar panels which generate electricity through photon-to-electron energy transfer, which takes place in the dielectric materials that make up the cells. The cells comprise layers of semi-conducting silicon material which, when illuminated by the sun, produces an electrical field which generates an electrical current. PVs can generate electricity even on overcast days, requiring daylight, rather than direct sunlight. This makes them viable even in the UK, although peak output is obtained at midday on a sunny summer's day. PVs offer a simple, proven solution to generating renewable electricity.

Box 2.11: Feasibility Summary – Photovoltaic Cells

Given the sites condensed nature and unshaded south facing roof pitches, a roof mounted solar PV array is considered the **preferred option** for the incorporation of LZC technologies on the site.

A ~7kWp solar array is proposed (c. 0.2kWp per dwelling)

South facing pitched roofs to both building shall be fitted with recessed photovoltaics cells for the provision of renewable electricity. All roof detailing shall ensure that the PV panels are recessed and architecturally sympathetic.

Micro Wind Turbines

Large wind turbines are an established means of capturing wind energy and converting it into usable electricity. Wind turbines come in various sizes depending on the location and electrical load of a particular site. A wind turbine usually consists of a nacelle containing a generator connected, sometimes via a gearbox, to a rotor generally consisting of three blades.

Box 2.12: Feasibility Summary – Micro Wind Turbines

Owing to site-constraints, micro-wind turbines have not been considered as part of this feasibility study. Constraints also include low wind speeds in this area, averaging **< 4.6 ms⁻¹**. Wind turbines are also likely to have a significant visual impact on local environment, as well as health and safety implications for occupiers or users on-site and on adjacent areas as a result of noise and light flicker associated with the wind turbines.

2.4 Summary

The installation of a CHP system has been discounted on the basis that the inconsistent load requirements of the residential development are not suited to a CHP plant. Of the remaining options, ground source heating, solar thermal, air-source heat pumps and wind turbines have been excluded with the preference for a roof mounted solar array.

The proposed strategy is based on utilising passive design measures, **super insulated and air tight building fabric, community heat network** with a high efficient gas fuelled boiler heating system and the installation of **Photovoltaic Panels** for the provision of supplementary renewable energy generation such that a significant reduction in CO₂ emissions is achieved through LZC/renewable technology. To meet building regulations and achieve a >20% reduction in CO₂ emissions through LZC technologies and energy efficiency measures (as required by the Local Authority) a **~7kWp roof mounted solar PV array** evenly distributed across the 2 roofs, equating to approximately 0.2kWp per dwelling, is required. This is the equivalent of a total roof area of approximately 50m² of panels.

A summary of the proposed energy efficiency measures and LZC technologies, in accordance with the Reading Borough Council Core Strategy, are provided in Box 2.11 below.

Box 2.13: Objective E – Site-integrated renewable technologies & Energy efficiency measures

Energy Efficiency Measures

The developer will install the following energy efficiency measures are installed

Element	U-Value
Walls	0.15 (existing 0.3)
Roofs	0.13
Floors	0.13
Doors	1.3
Windows	1.3
Air Tightness and Thermal Bridging	
Y-Values	0.08
Air permeability (m ³ /(hr.m ²) @ 50 Pa)	5.0 (existing 10)
Heating	Efficiency
Gas-fuelled Boiler distributed via a Community Heat Network	>90%

On-site Renewable Technologies

The developer will install a roof mounted Photovoltaic array distributed across the south-facing roof pitches of both buildings. The Photovoltaic system shall be installed to the following guideline specification or similar;

Parameter	Value
Capacity	~7kWp (c. 50m ² PV panels)
Orientation	South (where possible)
Pitch	c. 30°
ECA List	Yes

3. SUSTAINABILITY ASSESSMENT

This section comprises the Sustainability Assessment for the proposed development outlining the measures proposed in order to ensure compliance with Reading Borough Council Local Development Framework, with a particular focus on the following parameters;

- Water conservation and resource efficiency;
- Building materials;
- Waste minimisation & recycling; and
- Flood mitigation and resilience.

3.1 Water Conservation and Resource Efficiency

The conservation of water resources and maximising resource efficiency is a central theme within the Adopted Core Strategy, particularly Core Policy CS1. All developments are required to reduce mains water use and demonstrate that water conservation measures are incorporated

The development will include low water consumption measures for sanitary ware and appliances where applicable. All of which are detailed below.

Box 3.1: Water Conservation

- 1 – Toilets will be dual flush and flow capacity; taps will have flow restrictors and / or dosage control or sensor control, as will urinals.
- 2 – Low water consumption appliances will be specified in kitchen areas where appliances are installed (such as dishwashers).
- 2 – Fixtures and fittings will be installed to ensure water consumption will be restricted to a maximum of **≤105 litres per person per day**. This is the mandatory limit required to achieve Code Level 3 or 4.

3.2 Building Materials

All materials associated with the development shall be sourced with consideration for the embodied construction impacts. As such the site building shall comprise a sufficiently robust construction (as designed by a suitably qualified and contracted structural engineer) and utilise sustainable building materials.

Box 3.2: Building Materials

- 1 – All primary building materials utilised for any new-build elements of the development shall be rated A+ to B in accordance with the BRE Green Guide.
- 2 – The selection of materials will meet the following criteria:

- Preferentially selected those materials with a lesser environmental impact;
- Review alternative materials that have a lower environmental impact when developing material specification, including recycled materials; and
- Review the embodied energy within potential building materials and reduction of the embodied energy where feasible.

3 – The design team will ensure that materials for key building elements are purchased in accordance with the following;

- All timber will be sourced from legally logged and sustainable sources (FSC / CSA / PEFC verified timber with a full chain of custody (CoC);
- Supplier environmental credentials form an essential element of the selection criteria (particularly certifications such as ISO 14001 / EMAS etc); and
- The developer will request and evaluate the environmental policies of its suppliers.

4 – Based on the above, it is assumed that all materials utilised for the construction of the site building will be covered by certifications (such as ISO 14001 / EMAS) and achieve at least a 'Good' performance rating under British Standards BES 6001:2008.

3.3 Waste Minimisation and Recycling

The development site will utilise sustainable design and construction to minimise the impact the building has on the environment. Good site practices will be employed during the construction phase in order to minimise potential impacts, such as noise and dust nuisances.

Box 3.3: Encourage the use of a recycled, recyclable and durable products

1 – Any demolition and alteration works required to facilitate the addition of an extra floor will include the separation of demolished materials and retention of the existing materials (where appropriate).

2 – Materials for re-use will be stored on site. Materials for disposal will be segregated into recyclable streams and waste for landfill and removed by licensed waste handling contractors for recycling or disposal.

Box 3.4: Construction Site Waste Management Plan

1 – During the construction works, adequate space will be provided for the separation, storage, collection and recycling of waste.

2 – Effective site waste management will also be implemented through the use of a Site Waste Management Plan that has been designed to comply with the WRAP guidelines. The SWMP will meet all regulatory requirements and;

- set actions to prevent, reduce and recover waste;
- identify waste reductions at the design stage;

- forecast the waste arisings;
- record waste carriers and waste management facilities;
- prepare waste management actions;
- record actual waste movements; and
- benchmark against Standard, Good and Best Practice.

Box 3.5: Waste Management System

1 – The constructed site shall operate a site-wide waste management system which will incorporate waste segregation and recycling facilities.

2 – Provision shall be made for the users of the development to separate out recyclable waste from non-recyclable, and to store a number of waste streams close to source and within easy reach of collection and disposal arrangements.

3 – The development will utilise recycling facilities in line with best practice.

3.4 Sustainable Urban Drainage Systems (SUDS)

The development site will utilise Sustainable Urban Drainage Systems (SUDS) where possible. The existing building foot print will not be increased and the proposed landscaping is likely to increase the overall extent of permeable surfaces across the site.

3.5 Biodiversity

The proposed development is located on a site that currently houses two disused, early 1900s, red-brick buildings. Directly to the north of the site lies the River Kennet. An Extended Phase 1 and Bat Risk Assessment has been conducted on the site by 'Total Ecology'.

The following summary includes recommendations outlined in the Ecologists Report

Box 3.6: Biodiversity

1 – Ensuring that any building works are conscientious to the surrounding Environment, such as timing construction to mitigate any effects on breeding birds.

2 – Specifying a species rich plants and shrubs within the amenity space that will enhance biodiversity within the local area.

3 – The main buildings have low bat roost potential and it is recommended that the buildings are subject to a nocturnal emergence or re-entry survey by suitably qualified ecologists to determine roost presence or absence.

4 – Further recommendations include enhancing the ecological potential of the site by the installation of a bat access tile or a wall mounted Schwegler bat box on the exterior of B4 once the conversion of the building has taken place.

3.6 Summary

The Sustainability assessment confirms that overall, the redevelopment of the site at Gas Works Road can be considered to be contributing positively to the sustainability of its immediate surroundings as well as within the local and regional government areas, by bringing life back to a currently derelict site.

Reading Borough Council is committed to achieving sustainable development. As a result, the current planning policies for this area emphasise the importance of sustainable growth with particular emphasis on the encouragement of energy efficiency and green energy and industry. It is important, therefore, that the proposed development site contributes to the Council's sustainability aims as well as meeting regional and national objectives for sustainable development. This sustainability statement demonstrates that the proposals satisfy a number of key objectives, responding to local needs and requirements and conforming to current good practice.

In summary, the sustainability statement has informed the design process by identifying opportunities and constraints for sustainable development, and the process has highlighted the proposals sustainability performance against national, regional and local planning policy.

Annex A –Sample SAP modelling output

SAP WorkSheet: New dwelling design stage

User Details:			
Assessor Name:	Stroma Number:		
Software Name: Stroma FSAP 2009	Software Version:	Version: 1.5.0.69	
Property Address: House Type 2B			

Address : , , , , ,

1. Overall dwelling dimensions:

	Area(m ²)	Ave Height(m)	Volume(m ³)
Basement	78.9 (1a)	2.9 (2a)	228.81 (3a)
Total floor area TFA = (1a)+(1b)+(1c)+(1d)+(1e)+.....(1n)	78.9 (4)		
Dwelling volume		(3a)+(3b)+(3c)+(3d)+(3e)+.....(3n) =	228.81 (5)

2. Ventilation rate:

	main heating	Secondary heating	other	total	m ³ per hour
Number of chimneys	0	0	0	0	0 (6a)
Number of open flues	0	0	0	0	0 (6b)
Number of intermittent fans				1	10 (7a)
Number of passive vents				1	10 (7b)
Number of flueless gas fires				0	0 (7c)

		Air changes per hour
Infiltration due to chimneys, flues and fans = (6a)+(6b)+(7a)+(7b)+(7c) =		20 + (5) = 0.09 (8)
<i>If a pressurisation test has been carried out or is intended, proceed to (17), otherwise continue from (9) to (16)</i>		
Number of storeys in the dwelling (ns)		0 (9)
Additional infiltration	[(9)-1]x0.1 =	0 (10)
Structural infiltration: 0.25 for steel or timber frame or 0.35 for masonry construction		0 (11)
<i>if both types of wall are present, use the value corresponding to the greater wall area (after deducting areas of openings); if equal user 0.35</i>		
If suspended wooden floor, enter 0.2 (unsealed) or 0.1 (sealed), else enter 0		0 (12)
If no draught lobby, enter 0.05, else enter 0		0 (13)
Percentage of windows and doors draught stripped		0 (14)
Window infiltration	0.25 - [0.2 x (14) ÷ 100] =	0 (15)
Infiltration rate	(8) + (10) + (11) + (12) + (13) + (15) =	0 (16)
Air permeability value, q50, expressed in cubic metres per hour per square metre of envelope area		6 (17)
If based on air permeability value, then (18) = [(17) ÷ 20] + (8), otherwise (18) = (16)		0.39 (18)
<i>Air permeability value applies if a pressurisation test has been done or a degree air permeability is being used</i>		
Number of sides on which sheltered		0 (19)
Shelter factor	(20) = 1 - [0.075 x (19)] =	1 (20)
Infiltration rate incorporating shelter factor	(21) = (18) x (20) =	0.39 (21)

Infiltration rate modified for monthly wind speed											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly average wind speed from Table 7											
(22)m= 5.4	5.1	5.1	4.5	4.1	3.9	3.7	3.7	4.2	4.5	4.8	5.1
Wind Factor (22a)m = (22)m ÷ 4											
(22a)m= 1.35	1.27	1.27	1.12	1.02	0.98	0.92	0.92	1.05	1.12	1.2	1.27

SAP WorkSheet: New dwelling design stage

Adjusted infiltration rate (allowing for shelter and wind speed) = (21a) x (22a)m

0.52	0.49	0.49	0.44	0.4	0.38	0.36	0.36	0.41	0.44	0.46	0.49
------	------	------	------	-----	------	------	------	------	------	------	------

Calculate effective air change rate for the applicable case

If mechanical ventilation:

0 (23a)

If exhaust air heat pump using Appendix N, (23b) = (23a) x Fmv (equation (N5)), otherwise (23b) = (23a)

0 (23b)

If balanced with heat recovery: efficiency in % allowing for in-use factor (from Table 4h) =

0 (23c)

a) If balanced mechanical ventilation with heat recovery (MVHR) (24a)m = (22b)m + (23b) x [1 - (23c) + 100]

(24a)m= 0 0 0 0 0 0 0 0 0 0 0 0 (24a)

b) If balanced mechanical ventilation without heat recovery (MV) (24b)m = (22b)m + (23b)

(24b)m= 0 0 0 0 0 0 0 0 0 0 0 0 (24b)

c) If whole house extract ventilation or positive input ventilation from outside

if (22b)m < 0.5 x (23b), then (24c) = (23b); otherwise (24c) = (22b) m + 0.5 x (23b)

(24c)m= 0 0 0 0 0 0 0 0 0 0 0 0 (24c)

d) If natural ventilation or whole house positive input ventilation from loft

if (22b)m = 1, then (24d)m = (22b)m otherwise (24d)m = 0.5 + [(22b)m² x 0.5]

(24d)m= 0.64 0.62 0.62 0.6 0.58 0.57 0.56 0.56 0.58 0.6 0.61 0.62 (24d)

Effective air change rate - enter (24a) or (24b) or (24c) or (24d) in box (25)

(25)m= 0.64 0.62 0.62 0.6 0.58 0.57 0.56 0.56 0.58 0.6 0.61 0.62 (25)

3. Heat losses and heat loss parameter:

ELEMENT	Gross area (m ²)	Openings m ²	Net Area A, m ²	U-value W/m ² K	A X U (W/K)	k-value kJ/m ² ·K	A X k kJ/K
Doors			2.1	1.2	2.52		
Windows Type 1			26.2	1/1/(1.2)+0.04	30		
Windows Type 2			2.7	1/1/(1.2)+0.04	3.09		
Windows Type 3			1.1	1/1/(1.2)+0.04	1.26		
Floor			78.9	0.15	11.84		
Walls Type1	33.2	0	33.2	0.19	6.31		
Walls Type2	40.5	0	40.5	0.19	7.69		
Walls Type3	26.2	0	26.2	0.19	4.98		
Roof	78.9	0	78.9	0.14	11.05		
Total area of elements, m ²			289.8				

* for windows and roof windows, use effective window U-value calculated using formula 1/[(1/U-value)+0.04] as given in paragraph 3.2

** include the areas on both sides of internal walls and partitions

Fabric heat loss, W/K = S (A x U) (26)...(30) + (32) = 78.73 (33)

Heat capacity Cm = S(A x k) ((28)...(30) + (32) + (32a)...(32e) = 28370.1005 (34)

Thermal mass parameter (TMP = Cm + TFA) in kJ/m²K Indicative Value: Medium 250 (35)

For design assessments where the details of the construction are not known precisely the indicative values of TMP in Table 1f can be used instead of a detailed calculation.

Thermal bridges : S (L x Y) calculated using Appendix K 23.18 (36)

if details of thermal bridging are not known (36) = 0.15 x (31)

Total fabric heat loss (33) + (36) = 101.92 (37)

Ventilation heat loss calculated monthly (38)m = 0.33 x (25)m x (5)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
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SAP WorkSheet: New dwelling design stage

(38)m=

48.08	46.96	46.96	44.92	43.71	43.14	42.6	42.6	44	44.92	45.91	46.96
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 (38)

Heat transfer coefficient, W/K

(39)m = (37) + (38)m

(39)m=

150	148.88	148.88	146.84	145.62	145.06	144.52	144.52	145.92	146.84	147.83	148.88
-----	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

Average = Sum(39)_{1..12} / 12 = 146.98 (39)

Heat loss parameter (HLP), W/m²K

(40)m = (39)m + (4)

(40)m=

1.9	1.89	1.89	1.86	1.85	1.84	1.83	1.83	1.85	1.86	1.87	1.89
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Average = Sum(40)_{1..12} / 12 = 1.86 (40)

Number of days in month (Table 1a)

(41)m=

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
31	28	31	30	31	30	31	31	30	31	30	31

 (41)

4. Water heating energy requirement:

kWh/year:

Assumed occupancy, N

2.44

if TFA > 13.9, N = 1 + 1.76 x [1 - exp(-0.000349 x (TFA - 13.9))] + 0.0013 x (TFA - 13.9)

if TFA ≤ 13.9, N = 1

Annual average hot water usage in litres per day Vd,average = (25 x N) + 36

92.19

Reduce the annual average hot water usage by 5% if the dwelling is designed to achieve a water use target of not more than 125 litres per person per day (all water use, hot and cold)

Hot water usage in litres per day for each month Vd,m = factor from Table 1c x (43)
(44)m=

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
101.41	97.72	94.03	90.35	86.66	82.97	82.97	86.66	90.35	94.03	97.72	101.41

Total = Sum(44)_{1..12} = 1106.27 (44)

Energy content of hot water used - calculated monthly = 4.190 x Vd,m x nm x DTm / 3600 kWh/month (see Tables 1b, 1c, 1d)

(45)m=

150.75	131.84	136.05	118.61	113.81	98.21	91.01	104.43	105.68	123.16	134.44	145.99
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Total = Sum(45)_{1..12} = 1453.97 (45)

If instantaneous water heating at point of use (no hot water storage), enter 0 in boxes (46) to (61)

(46)m=

22.61	19.78	20.41	17.79	17.07	14.73	13.65	15.66	15.85	18.47	20.17	21.9
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 (46)

Water storage loss:

a) If manufacturer's declared loss factor is known (kWh/day):

0

Temperature factor from Table 2b

0

Energy lost from water storage, kWh/year

(47) x (48) =

0

If manufacturer's declared cylinder loss factor is not known:

Cylinder volume (litres) including any solar storage within same

150

If community heating and no tank in dwelling, enter 110 litres in box (50)

Otherwise if no stored hot water (this includes instantaneous combi boilers) enter '0' in box (50)

Hot water storage loss factor from Table 2 (kWh/litre/day)

0.01

Volume factor from Table 2a

0.93

Temperature factor from Table 2b

0.78

Energy lost from water storage, kWh/year

((50) x (51) x (52) x (53) =

1.12

Enter (49) or (54) in (55)

1.12

Water storage loss calculated for each month

((56)m = (55) x (41)m

(56)m=

34.64	31.29	34.64	33.52	34.64	33.52	34.64	34.64	33.52	34.64	33.52	34.64
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 (56)

If cylinder contains dedicated solar storage, (57)m = (56)m x [(50) - (H11)] + (50), else (57)m = (56)m where (H11) is from Appendix H

(57)m=

34.64	31.29	34.64	33.52	34.64	33.52	34.64	34.64	33.52	34.64	33.52	34.64
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 (57)

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Primary circuit loss (annual) from Table 3 610 (58)

Primary circuit loss calculated for each month (59)m = (58) + 365 × (41)m

(modified by factor from Table H5 if there is solar water heating and a cylinder thermostat)

(59)m=

51.81	46.79	51.81	50.14	51.81	50.14	51.81	51.81	50.14	51.81	50.14	51.81
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 (59)

Combi loss calculated for each month (61)m = (60) + 365 × (41)m

(61)m=

0	0	0	0	0	0	0	0	0	0	0	0
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 (61)

Total heat required for water heating calculated for each month (62)m = 0.85 × (45)m + (46)m + (57)m + (59)m + (61)m

(62)m=

237.19	209.93	222.5	202.27	200.26	181.87	177.46	190.88	189.34	209.61	218.1	232.44
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 (62)

Solar DHW input calculated using Appendix G or Appendix H (negative quantity) (enter '0' if no solar contribution to water heating)

(add additional lines if FGHRs and/or WWHRs applies, see Appendix G)

(63)m=

0	0	0	0	0	0	0	0	0	0	0	0
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 (63)

Output from water heater

(64)m=

237.19	209.93	222.5	202.27	200.26	181.87	177.46	190.88	189.34	209.61	218.1	232.44
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 (64)

Output from water heater (annual) = 2471.84

Heat gains from water heating, kWh/month $0.25 \times [0.85 \times (45)m + (61)m] + 0.8 \times [(46)m + (57)m + (59)m]$

(65)m=

91.57	81.27	86.68	79.55	79.29	72.76	71.71	76.17	75.25	82.4	84.81	89.99
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 (65)

include (57)m in calculation of (65)m only if cylinder is in the dwelling or hot water is from community heating

5. Internal gains (see Table 5 and 5a):

Metabolic gains (Table 5), Watts

(66)m=

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
146.5	146.5	146.5	146.5	146.5	146.5	146.5	146.5	146.5	146.5	146.5	146.5

 (66)

Lighting gains (calculated in Appendix L, equation L9 or L9a), also see Table 5

(67)m=

48.39	42.98	34.96	26.46	19.78	16.7	18.05	23.46	31.48	39.97	46.66	49.74
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 (67)

Appliances gains (calculated in Appendix L, equation L13 or L13a), also see Table 5

(68)m=

324.07	327.43	318.96	300.92	278.14	256.74	242.44	239.08	247.55	265.59	288.37	309.77
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 (68)

Cooking gains (calculated in Appendix L, equation L15 or L15a), also see Table 5

(69)m=

52.09	52.09	52.09	52.09	52.09	52.09	52.09	52.09	52.09	52.09	52.09	52.09
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

 (69)

Pumps and fans gains (Table 5a)

(70)m=

0	0	0	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---

 (70)

Losses e.g. evaporation (negative values) (Table 5)

(71)m=

-97.67	-97.67	-97.67	-97.67	-97.67	-97.67	-97.67	-97.67	-97.67	-97.67	-97.67	-97.67
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 (71)

Water heating gains (Table 5)

(72)m=

123.08	120.94	116.51	110.48	106.57	101.06	96.38	102.38	104.51	110.75	117.79	120.95
--------	--------	--------	--------	--------	--------	-------	--------	--------	--------	--------	--------

 (72)

Total internal gains = (66)m + (67)m + (68)m + (69)m + (70)m + (71)m + (72)m

(73)m=

596.46	592.28	571.35	538.79	505.42	475.43	457.79	465.84	484.47	517.24	553.74	581.38
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------

 (73)

6. Solar gains:

Solar gains are calculated using solar flux from Table 6a and associated equations to convert to the applicable orientation.

Orientation:	Access Factor Table 6d	Area m ²	Flux Table 6a	g _L Table 6b	FF Table 6c	Gains (W)
North	0.9x 0.77	x 2.7	x 10.73	x 0.72	x 0.7	= 10.12 (74)
North	0.9x 0.77	x 2.7	x 20.36	x 0.72	x 0.7	= 19.2 (74)

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North	0.9x	0.77	x	2.7	x	33.31	x	0.72	x	0.7	=	31.41	(74)
North	0.9x	0.77	x	2.7	x	54.64	x	0.72	x	0.7	=	51.53	(74)
North	0.9x	0.77	x	2.7	x	75.22	x	0.72	x	0.7	=	70.93	(74)
North	0.9x	0.77	x	2.7	x	84.09	x	0.72	x	0.7	=	79.3	(74)
North	0.9x	0.77	x	2.7	x	79.12	x	0.72	x	0.7	=	74.61	(74)
North	0.9x	0.77	x	2.7	x	61.56	x	0.72	x	0.7	=	58.06	(74)
North	0.9x	0.77	x	2.7	x	41.09	x	0.72	x	0.7	=	38.74	(74)
North	0.9x	0.77	x	2.7	x	24.81	x	0.72	x	0.7	=	23.4	(74)
North	0.9x	0.77	x	2.7	x	13.22	x	0.72	x	0.7	=	12.47	(74)
North	0.9x	0.77	x	2.7	x	8.94	x	0.72	x	0.7	=	8.43	(74)
South	0.9x	0.77	x	26.2	x	47.32	x	0.72	x	0.7	=	433.05	(78)
South	0.9x	0.77	x	26.2	x	77.18	x	0.72	x	0.7	=	706.3	(78)
South	0.9x	0.77	x	26.2	x	94.25	x	0.72	x	0.7	=	862.44	(78)
South	0.9x	0.77	x	26.2	x	105.11	x	0.72	x	0.7	=	961.89	(78)
South	0.9x	0.77	x	26.2	x	108.55	x	0.72	x	0.7	=	993.33	(78)
South	0.9x	0.77	x	26.2	x	108.9	x	0.72	x	0.7	=	996.52	(78)
South	0.9x	0.77	x	26.2	x	107.14	x	0.72	x	0.7	=	980.41	(78)
South	0.9x	0.77	x	26.2	x	103.88	x	0.72	x	0.7	=	950.62	(78)
South	0.9x	0.77	x	26.2	x	99.99	x	0.72	x	0.7	=	915.01	(78)
South	0.9x	0.77	x	26.2	x	85.29	x	0.72	x	0.7	=	780.5	(78)
South	0.9x	0.77	x	26.2	x	56.07	x	0.72	x	0.7	=	513.09	(78)
South	0.9x	0.77	x	26.2	x	40.89	x	0.72	x	0.7	=	374.19	(78)
West	0.9x	0.77	x	1.1	x	19.87	x	0.72	x	0.7	=	7.64	(80)
West	0.9x	0.77	x	1.1	x	38.52	x	0.72	x	0.7	=	14.8	(80)
West	0.9x	0.77	x	1.1	x	61.57	x	0.72	x	0.7	=	23.65	(80)
West	0.9x	0.77	x	1.1	x	91.41	x	0.72	x	0.7	=	35.12	(80)
West	0.9x	0.77	x	1.1	x	111.22	x	0.72	x	0.7	=	42.73	(80)
West	0.9x	0.77	x	1.1	x	116.05	x	0.72	x	0.7	=	44.59	(80)
West	0.9x	0.77	x	1.1	x	112.64	x	0.72	x	0.7	=	43.28	(80)
West	0.9x	0.77	x	1.1	x	98.03	x	0.72	x	0.7	=	37.66	(80)
West	0.9x	0.77	x	1.1	x	73.6	x	0.72	x	0.7	=	28.28	(80)
West	0.9x	0.77	x	1.1	x	46.91	x	0.72	x	0.7	=	18.02	(80)
West	0.9x	0.77	x	1.1	x	24.71	x	0.72	x	0.7	=	9.49	(80)
West	0.9x	0.77	x	1.1	x	16.39	x	0.72	x	0.7	=	6.3	(80)

Solar gains in watts, calculated for each month

(83)m = Sum(74)m ... (82)m

(83)m= 450.8 740.3 917.5 1048.54 1106.99 1120.4 1098.3 1046.35 982.03 821.92 535.04 388.92 (83)

Total gains – internal and solar (84)m = (73)m + (83)m , watts

(84)m= 1047.27 1332.58 1488.85 1587.33 1612.42 1595.83 1556.09 1512.18 1466.5 1339.16 1088.78 970.3 (84)

7. Mean internal temperature (heating season)

Temperature during heating periods in the living area from Table 9, Th1 (°C)

21 (85)

Utilisation factor for gains for living area, h1,m (see Table 9a)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
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(86)m=	0.97	0.94	0.89	0.82	0.71	0.54	0.37	0.38	0.6	0.82	0.95	0.97	(86)
--------	------	------	------	------	------	------	------	------	-----	------	------	------	------

Mean internal temperature in living area T1 (follow steps 3 to 7 in Table 9c)

(87)m=	19.77	20.03	20.3	20.53	20.75	20.87	20.91	20.91	20.85	20.61	20.1	19.78	(87)
--------	-------	-------	------	-------	-------	-------	-------	-------	-------	-------	------	-------	------

Temperature during heating periods in rest of dwelling from Table 9, Th2 (°C)

(88)m=	20.05	20.06	20.06	20.07	20.08	20.08	20.08	20.08	20.08	20.07	20.06	20.06	(88)
--------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	------

Utilisation factor for gains for rest of dwelling, h2,m (see Table 9a)

(89)m=	0.96	0.93	0.87	0.8	0.66	0.48	0.29	0.3	0.54	0.78	0.94	0.97	(89)
--------	------	------	------	-----	------	------	------	-----	------	------	------	------	------

Mean internal temperature in the rest of dwelling T2 (follow steps 3 to 7 in Table 9c)

(90)m=	18.93	19.18	19.44	19.67	19.88	19.98	20	20	19.95	19.75	19.27	18.94	(90)
--------	-------	-------	-------	-------	-------	-------	----	----	-------	-------	-------	-------	------

$$fLA = \text{Living area} \div (4) = 0.31 \quad (91)$$

Mean internal temperature (for the whole dwelling) = $fLA \times T1 + (1 - fLA) \times T2$

(92)m=	19.2	19.45	19.71	19.94	20.15	20.26	20.29	20.29	20.23	20.01	19.53	19.2	(92)
--------	------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	------	------

Apply adjustment to the mean internal temperature from Table 4e, where appropriate

(93)m=	19.2	19.45	19.71	19.94	20.15	20.26	20.29	20.29	20.23	20.01	19.53	19.2	(93)
--------	------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	------	------

8. Space heating requirement

Set Ti to the mean internal temperature obtained at step 11 of Table 9b, so that Ti,m=(76)m and re-calculate the utilisation factor for gains using Table 9a

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
--	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	--

Utilisation factor for gains, hm:

(94)m=	0.96	0.92	0.86	0.79	0.66	0.49	0.31	0.32	0.55	0.78	0.93	0.96	(94)
--------	------	------	------	------	------	------	------	------	------	------	------	------	------

Useful gains, hmGm, W = (94)m x (84)m

(95)m=	1003	1222.52	1284.45	1257.29	1070.29	780.14	484.04	483.45	804.13	1046.11	1010.5	934.23	(95)
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Monthly average external temperature from Table 8

(96)m=	4.5	5	6.8	8.7	11.7	14.6	16.9	16.9	14.3	10.8	7	4.9	(96)
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Heat loss rate for mean internal temperature, Lm, W = [(39)m x ((93)m - (96)m)]

(97)m=	2204.34	2151.17	1922.39	1650.53	1230.63	820.52	489.76	489.69	865.87	1353.09	1851.93	2129.58	(97)
--------	---------	---------	---------	---------	---------	--------	--------	--------	--------	---------	---------	---------	------

Space heating requirement for each month, kWh/month = $0.024 \times [(97)m - (95)m] \times (41)m$

(98)m=	893.8	624.05	474.63	283.13	119.29	0	0	0	0	228.4	605.83	889.34	
--------	-------	--------	--------	--------	--------	---	---	---	---	-------	--------	--------	--

$$\text{Total per year (kWh/year)} = \text{Sum}(98)_{1..12} = 4118.47 \quad (98)$$

Space heating requirement in kWh/m²/year

$$52.2 \quad (99)$$

9a. Energy requirements – Individual heating systems including micro-CHP

Space heating:

Fraction of space heat from secondary/supplementary system

$$0 \quad (201)$$

Fraction of space heat from main system(s)

$$(202) = 1 - (201) =$$

$$1 \quad (202)$$

Fraction of total heating from main system 1

$$(204) = (202) \times [1 - (203)] =$$

$$1 \quad (204)$$

Efficiency of main space heating system 1

$$175 \quad (206)$$

Efficiency of secondary/supplementary heating system, %

$$0 \quad (208)$$

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	kWh/year
--	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----------

Space heating requirement (calculated above)

(211)m =	893.8	624.05	474.63	283.13	119.29	0	0	0	0	228.4	605.83	889.34	
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$$(211)m = \{[(98)m \times (204)] + (210)m\} \times 100 \div (206) \quad (211)$$

	510.74	356.6	271.22	161.79	68.17	0	0	0	0	130.51	346.19	508.19	
--	--------	-------	--------	--------	-------	---	---	---	---	--------	--------	--------	--

$$\text{Total (kWh/year)} = \text{Sum}(211)_{1..12} = 2353.41 \quad (211)$$

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Space heating fuel (secondary), kWh/month

= $\{[(98)m \times (201)] + (214) m\} \times 100 \div (208)$

(215)m=

0	0	0	0	0	0	0	0	0	0	0	0
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Total (kWh/year) = Sum(215)_{1..12} =

0 (215)

Water heating

Output from water heater (calculated above)

237.19	209.93	222.5	202.27	200.26	181.87	177.46	190.88	189.34	209.61	218.1	232.44
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Efficiency of water heater

175 (216)

(217)m=

175	175	175	175	175	175	175	175	175	175	175	175
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

 (217)

Fuel for water heating, kWh/month

(219)m = $(64)m \times 100 \div (217)m$

(219)m=

135.54	119.96	127.14	115.58	114.43	103.93	101.4	109.07	108.19	119.78	124.63	132.82
--------	--------	--------	--------	--------	--------	-------	--------	--------	--------	--------	--------

Total = Sum(219a)_{1..12} =

1412.48 (219)

Annual totals

Space heating fuel used, main system 1

2353.41 kWh/year

Water heating fuel used

1412.48 kWh/year

Electricity for pumps, fans and electric keep-hot

central heating pump:

130 (230c)

Total electricity for the above, kWh/year

sum of (230a)...(230g) =

130 (231)

Electricity for lighting

341.85 (232)

10a. Fuel costs - individual heating systems:

	Fuel kWh/year	Fuel Price (Table 12)	Fuel Cost £/year
Space heating - main system 1	(211) x	11.46 x 0.01 =	269.7007 (240)
Space heating - main system 2	(213) x	0 x 0.01 =	0 (241)
Space heating - secondary	(215) x	0 x 0.01 =	0 (242)
Water heating cost (other fuel)	(219)	11.46 x 0.01 =	161.87 (247)
Pumps, fans and electric keep-hot	(231)	11.46 x 0.01 =	14.9 (249)
(if off-peak tariff, list each of (230a) to (230g) separately as applicable and apply fuel price according to Table 12a			
Energy for lighting	(232)	11.46 x 0.01 =	39.18 (250)
Additional standing charges (Table 12)			0 (251)

Appendix Q items: repeat lines (253) and (254) as needed

Total energy cost

(245)...(247) + (250)...(254) =

485.645 (255)

11a. SAP rating - individual heating systems

Energy cost deflator (Table 12)

0.47 (256)

Energy cost factor (ECF)

$[(255) \times (256)] \div [(4) + 45.0] =$

1.8422 (257)

SAP rating (Section 12)

74.3008 (258)

12a. CO2 emissions – Individual heating systems including micro-CHP

Energy kWh/year	Emission factor kg CO2/kWh	Emissions kg CO2/year
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Space heating (main system 1)	(211) x	0.517	=	1216.71	(261)
Space heating (secondary)	(215) x	0	=	0	(263)
Water heating	(219) x	0.517	=	730.25	(264)
Space and water heating	(261) + (262) + (263) + (264) =			1946.97	(265)
Electricity for pumps, fans and electric keep-hot	(231) x	0.517	=	67.21	(267)
Electricity for lighting	(232) x	0.517	=	176.74	(268)
Total CO ₂ , kg/year	sum of (265)...(271) =			2190.91	(272)
CO₂ emissions per m²	(272) ÷ (4) =			27.77	(273)
El rating (section 14)				76	(274)

13a. Primary Energy

	Energy kWh/year	Primary factor		P. Energy kWh/year	
Space heating (main system 1)	(211) x	2.92	=	6871.95	(261)
Space heating (secondary)	(215) x	0	=	0	(263)
Energy for water heating	(219) x	2.92	=	4124.44	(264)
Space and water heating	(261) + (262) + (263) + (264) =			10996.4	(265)
Electricity for pumps, fans and electric keep-hot	(231) x	2.92	=	379.6	(267)
Electricity for lighting	(232) x	0	=	998.2	(268)
*Total Primary Energy	sum of (265)...(271) =			12374.2	(272)
Primary energy kWh/m²/year	(272) ÷ (4) =			156.83	(273)