SCHOOL OF ENGINEERING AND BUILDING ENVIRONMENT

BUILDING PERFORMANCE 3

BSV11134

COURSEWORK 2

FUTURE PROOFING BUILDING PERFORMANCE

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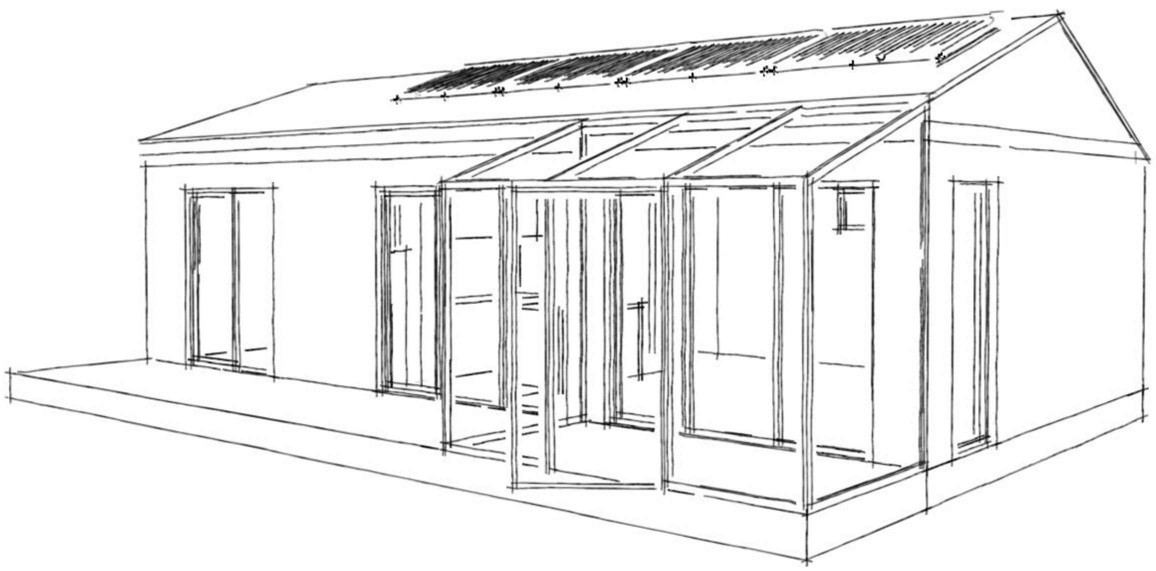

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1 INTRODUCTION

In the concern of new age of environment and desire for more sustainable forms of construction, timber has risen to become an important material of choice (Wilson,2007). If appropriately sourced, timber can be considered truly sustainable and, with good sylvicultural practices, trees can also improve land quality and soil fertility. The forms of timber construction have evolved over time due to mechanisation and the invention of new timber products and connection methods. Modern procurement methods and building regulations have also influenced building forms. Off-site construction is the manufacture and pre-assembly of components, elements or modules before installation into their final location. Urbanisation and colonial expansion prompted the need for efficiency and quality of product, resulting in the first major exploitation of off-site techniques (Hairstans, 2010). Addressing the environmental performance and sustainability of buildings are becoming critical. Significant methods to reduce energy demand by requiring the use of low energy building technology have been conceived differently by each member state of Europe after an agreement in 2007 by the European Council which set precise, legally binding targets on climate and energy policy marked a turning point in tackling climate change. The focus was for each member states to provide secure, sustainable and competitive energy and to make the European economy a model for sustainable development in the 21st century (COM,2008) One method developed since 1991 is the Passive House (PH) standard which seeks to improve energy efficiency through improving the building envelope and allowing substantial simplifications of the heating system. It achieves this by utilising passive and active solar use and loss reduction; for example, introducing air-tight envelopes with a whole-house ventilation system with heat recovery. In the UK, the National Calculation Methodology (NCM) was created which required dwellings to be evaluated using the Standard Assessment Procedure (SAP) to assess the energy efficiency of new buildings and by generating an Energy Performance Certificate (EPC) (Bros Williamson et al. 2014). In Scotland, the specifications for energy efficiency is defined closely in the sections 6-7 of Scottish Building Standards (SBS).

Figure 1 – 8 Aspects of Section 7(SBS)

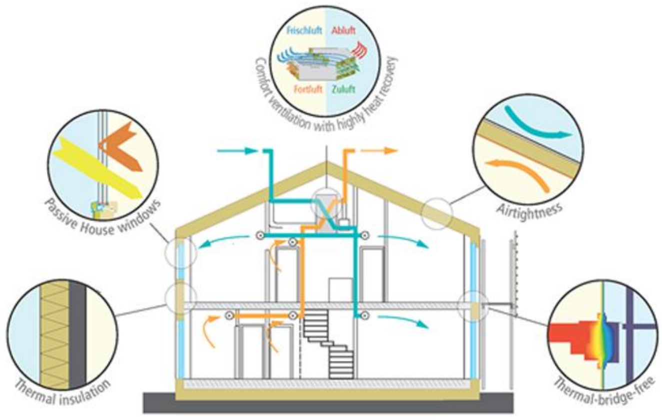


Figure 2 – Passivhaus Principles

CCG is an independent Scottish construction firm who manufacture timber frame dwellings for both the private and social housing sector by the "Off-Site" manufacture of timber systems, bespoke mechanical and electrical services and planned maintenance to existing buildings. The firm wants to be in the running ahead of the rivals by seeking to develop their present range of timber frame kit houses which are based around an 89mm timber stud size and which fulfil 2009/2010 Building Standard requirements.

1.1 Objectives

The purpose of this report is to create a design a timber frame kit house for CCG. The main criteria reaching high standards in building energy performance within the frame of Scottish Building Standards Section 6 & 7 aiming for the Gold level. The improvements applied has been assessed with SAP.

2 BUILDING REGULATION SCENARIO

2.1 Overview

The Building (Scotland) Act 2003 allows Scottish Ministers to regulate for the purpose of furthering the achievement of sustainable development. Whilst the standards within Sections 1 - 6 of the 2013 Technical Handbooks deliver a level of sustainability in a number of areas such as energy efficiency, surface water drainage and sound insulation. Defining higher standards to measure sustainability will enable higher quality buildings to be created and for such benefits to be formally recognised. The introduction of Section 7 is the next step in encouraging the sustainable design and construction of all new buildings within a broader context of sustainable development. Further reductions in carbon dioxide (CO_2) emissions from new buildings will also assist in meeting targets within the Climate Change (Scotland) Act 2009.

In the context of this project following sections (6 & 7) requirements summarized are implemented project by the supply of FSAP 2012 sofware.

Fisrtly the intention of Section 6 is to ensure that effective measures for the conservation of fuel and power are incorporated dwellings and buildings consisting of dwellings. In addition to limiting energy demand, by addressing the performance of the building fabric and fixed building services, a carbon dioxide emissions standard obliges a designer of new dwellings to consider building design in a holistic way.

Improvements set out within this section will result in a greater need to consider the benefits which localised or building-integrated low carbon equipment (LCE) (e.g. photovoltaics, solar water heating, combined heat and power and heat pumps) can make towards meeting standards. Although the focus is primarily on lowering carbon dioxide emissions from dwellings in use, the measures within this section are intended to reduce energy demand and continue to ensure that, for new homes and new building work, use of energy and fuel costs arising from this are both minimised.

The intention of the standard in Section 7 is to:

• Recognise the level of sustainability already achieved by the building regulations. By setting the 2010 Standards as the benchmark level, credit is given to meeting the standards within Sections 1 - 6 of the building regulations. This will emphasise that a degree of sustainable design and construction is not a niche market but must be achieved in all new buildings'
• Encourage more demanding sustainability standards through enhanced upper levels.
• Encourage consistency between planning authorities that use supplementary guidance to promote higher measures of sustainable construction in their geographical areas.

Aspect is a term used for a subject area of sustainability. Due to the coverage of building standards and the position of the warrant process in the overall development process, aspects covering resource use and performance are more prominent in this standard. The eight aspects of Section 7 are:

1 CO_2 emissions
2 Energy for space heating
3 Energy for water heating
4 Water use efficiency
5 Optimising performance
6 Flexibility and adaptability
7 Well-being and security
8 Material use and waste

Level is the term used as a banding, where all the aspects of sustainability have reached a certain cut-off point. The specified level of sustainability for a dwelling should be selected from the following:

• Bronze or Bronze Active
• Silver or Silver Active
• Gold

As this project aims "Gold Level", the dwelling should meet all the standards in Sections 1 – 6 that apply to the building for the bronze level and in addition the dwelling should comply each of the eight aspects below.

2.2 Aspects

Aspect 1: Carbon dioxide emissions

Under the guidance to Standard 6.1, the carbon dioxide emissions (Dwelling Emission Rate) is to be 27% lower than the Target Emission Rate set by the 2015 Standards.

Aspect 2: Energy for space heating

Maximum annual demand for useful energy for space heating should be:
• 30 kWh/m2 for houses

Aspect 3: Energy for water heating

a. Renewables and heat recovery: At least 50% of the dwelling or domestic building's annual energy demand for water heating should be from:

• Heat recovery and/or renewable sources with little or no associated fuel costs (e.g. solar thermal water heating and associated storage or heat recovery from greywater) that are allocated for water heating.

b. Water heating display: A display showing the performance of the primary renewable source, such as a solar collector, should be mounted in easily accessible space, for instance alongside controls for heating equipment or near the bathroom/shower room door.

Aspect 4: Water use efficiency

Enhanced or additional products should be provided to encourage water efficiency as follows:

• 1 water butt (with a min. capacity of 200 litres) for outdoor use per dwelling. Dwellings without a garden or landscaped area, or if there is no access to rainwater collection (for example if there is no external rainwater pipe within the curtilage) are excluded, and
• 3 of the following 5 items:
  • water meter
  • WCs of average flush volume to be not more than 3.5 litres
  • wash hand basin taps of flow rates not more than 4 l/m and to kitchen or utility room sinks to be not more than 6 l/m
  • shower heads with maximum flow rate not more than 6 l/m
  • rainwater harvesting or greywater recycling system designed to provide water for toilet flushing.

Aspect 5: Optimising Performance

a. Quick start guide: Provide guidance to the occupants on the ways in which the specific dwelling is intended to function and how to optimise its performance on the scope, format and contents of the guide for occupants. Plus: Direct 'easy release' adhesive labels on all key heating and ventilation equipment including (where fitted): trickle ventilators, extract fans, mechanical ventilation with heat recovery (MVHR), heating controls (programmers, Thermostatic Radiator Valves (TRVs)).

b. Resource use display: Install a real-time resource use monitor that displays electricity use, located in an easily accessible and readable position, plus the real-time resource display indicates gas use (if gas is used for heating), displaying gas use at least at a daily period.

Aspect 6: Flexibility and Adaptability

a. Home office: Provide a home office space dedicated for home working/study to include:
• A clear space, against a wall or partition, where a desk of 1800mm long x 600mm deep could be placed. Alternatively, the desk space could be 'L' shaped in plan as long as each leg of the 'L' is a minimum length of 1200mm. Diagrams below show the two desk options with associated activity spaces.

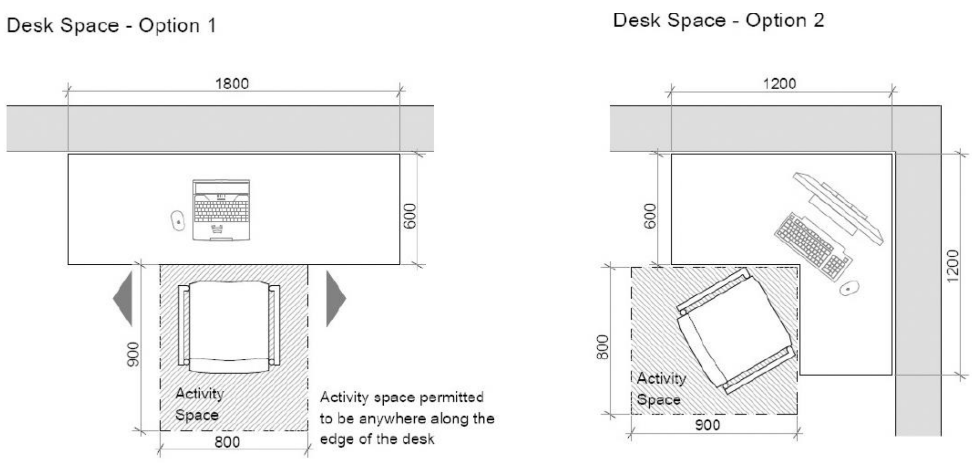


Figure 3 – Desk Space

b. Mobility space: Provide convenient secure mobility space to accommodate an electric wheelchair(s) and that could also be suitable for pram storage and the storage of a bicycle(s). The size is defined in the figure 4.

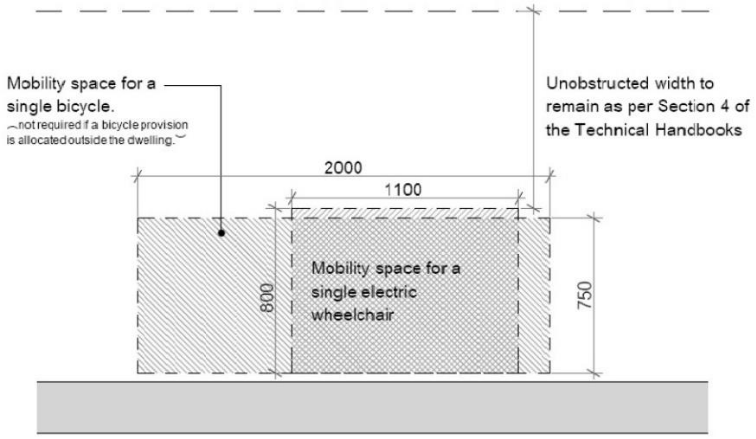


Figure 4 – Mobility Space

Aspect 7: Well-being and security & Aspect 8: Material use and waste

Aspect 7 covers acoustic limitations, rules natural lighting, security requirements and defines garden spaces for Golden Level buildings. Aspect 8 indicates the recycling of solid waste and design for re-construction. The notional building will be explained in the following section assumes the site area which single dwelling going to be built provide enough space for outdoor regulation.

3 BUILDING SPECIFICATIONS & SOLUTIONS IMPLEMENTED

A notional building is created regarding the architectural programme described by the company and relevant aspects of SBS Section 6&7 requirements. In the process of producing kit house, SBS Section 4 was also referenced due to the fitting of dimensions (hallway wide etc.) to the regulations. The proposed dwelling is assumed a design open for development in terms of first five sections of building regulations.

3.1 DESIGN STRATEGY

Building Form

The compactness of a building is indicated by the surface area to volume (A/V) ratio. This ratio, between the external surface area and the internal volume of a building, has a considerable influence on the overall energy demand. Buildings with identical U-values and air change rates, and orientations could have significantly different heating demands simply as a result of their A/V ratio. The size of a building also influences the A/V ratio. Small buildings with an identical form have higher A/V ratios than their larger counterparts. It is therefore particularly important to design small detached buildings with a very compact form. Figure 1 illustrates the influence of form and size on the A/V ratio. A a favourable compactness ratio is considered to be one were the A/V ratio ≤ 0.7 m^2/m^3 (McLeod, R. et al. 2014).

Orientation

Site planning decisions are taken early in the design process and have a significant effect on overall energy efficiency. Orientation is closely linked to all other site planning decisions and is therefore considered in each of the four site planning sections.

In the Northern hemisphere a low energy demand building should be orientated along an east/west principle axis so that the building faces within 30 degrees of due south. This allows the building to derive maximum benefit from useful solar gains, which are predominantly available to south facing facades during the winter months. With good planned building can also be realised where a south facing orientation is not possible, although the annual heating demand may increase by 30-40% as a result (Pitts, J. & Lancashire, R. 2011). Generally, the house plan with a long east-west axis and optimized south-facing window wall will be the best. (Holloway, D. 2011)

Sun Space

In the northern hemisphere windows are facing south. Solar radiation, mostly the visible light spectrum, passes through the solar-oriented glass of windows or solar spaces, and is absorbed by surfaces of materials inside the insulated envelope of the building. As these heated surfaces re-radiate the energy into the interior of the house, the air temperature rises, but the heat is not efficiently re-radiated outside again through the glass, nor can the heated air escape, so the result is entrapped energy. Elements most commonly used to make maximum use of the sun's heat include direct-gain windows, direct gain glazed solariums, and indirect-gain Trombe walls and mass walls. Each of these elements will influence the design because they have specific requirements (Holloway, D. 2011). There is a risk of overheating due to lack of thermal mass. Overheating can be caused by external sources (ambient hot air, solar radiation, sunspace as within this project etc.) or internal sources (cooking, electrical equipment, the occupants etc.). According to Hairstans (2010), to overcome these problems, the design should be incorporated low electrical goods and lighting, insulated hot water systems and were well designed for solar gain and ventilation.

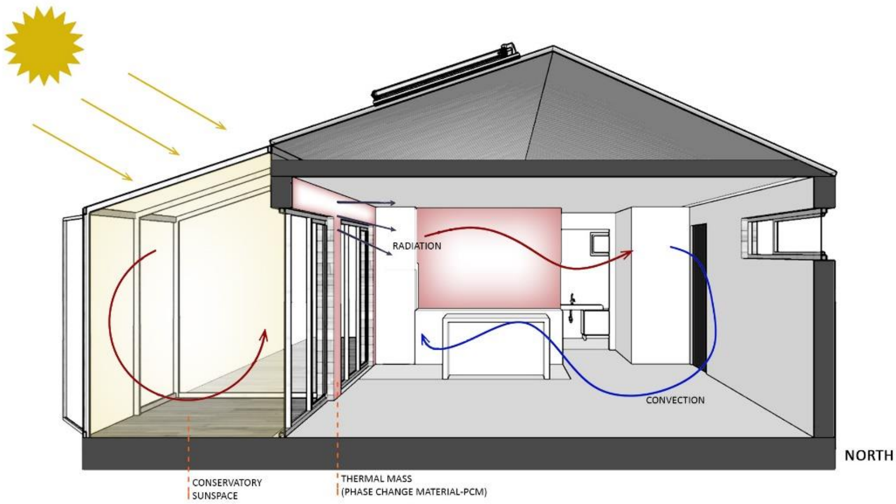


Figure 5 – Passive Solar Gain with Sunspace

The ability of materials with a high thermal mass can be exploited to minimise diurnal swings. In dwellings, a high thermal mass can help prevent overheating if the heat stored during the day can be effectively rejected at night. Compared to concrete or masonry materials, timber is not efficient to accommodate thermal mass (table 1). With developing technologies and techniques, phase change materials that provide heat capacity by changing phase. In our project, thermal mass capacity of the walls is increased by the selection of phase-change material instead of plasterboards inside.Furthermore, indoor quality is also supplied with employing mechanical ventilation system.

External wall	Internal finish	Admittance value
Timber frame (brick outer leaf)	Plasterboard	1.0
	Wet plaster	
Masonry cavity wall (100mm aircrete block)	Plasterboard	1.85
	Wet plaster	2.65
Masonry cavity wall (100mm dense aggregate block)	Plasterboard	2.65
	Wet plaster	5.04

Source: The Concrete Centre (calculated according to EN ISO 13786:2007)

Table 1– Admittance Values of Building Materials directly proportional with thermal mass ability

3.1.1. Building Characteristics

The design scenario of the proposed timber kit house was derived from the following data;

- It is a property of 2 people resident permanently, optimised building programme includes a livingroom, kitchen+dining, bedroom, bathroom, storage plus a porch and conservatory.

- The plan aligns in east-west direction.

- Efficient A/V ratio aims to be lower than 0.7 m^2/ m^3 (The A/V ratio in the proposed detached timber kit house is : 0.4 m^2/ m^3 (58,74 m^2/ m^3).

- 1800x1800mm gridlines indicated regarding company's 600mm grid system which depends all the building materials sizes and in consideration to create spaces ergonomically for residents.

Based on the scenario the same useful floor area are hold in each combination generates different typologyies seen it figure 6.

Figure 6 – Various Combinations in Proposed Plan

The change in organizational chart neither does not impact the surface area in all combinations. A/V ratios are aldo the same in combination 1 and 2, it means the same amount of insulation maintain the heating demand. Throughout in the term of MMC, standardization is the key word. The standardization mean does not need to be inflexible. Regarding to the site to build dimensions, orientation needs and the demands of clients, the plan can offer variable solutions.

Combination 1 is the timber kit house design which is selected and detailed in order to measure energy efficiency achieves Scottish Gold Standart.

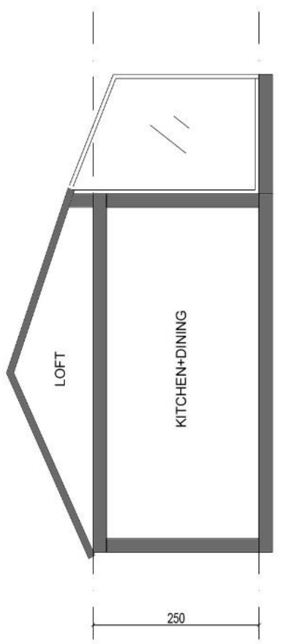


Figure 7 – Section

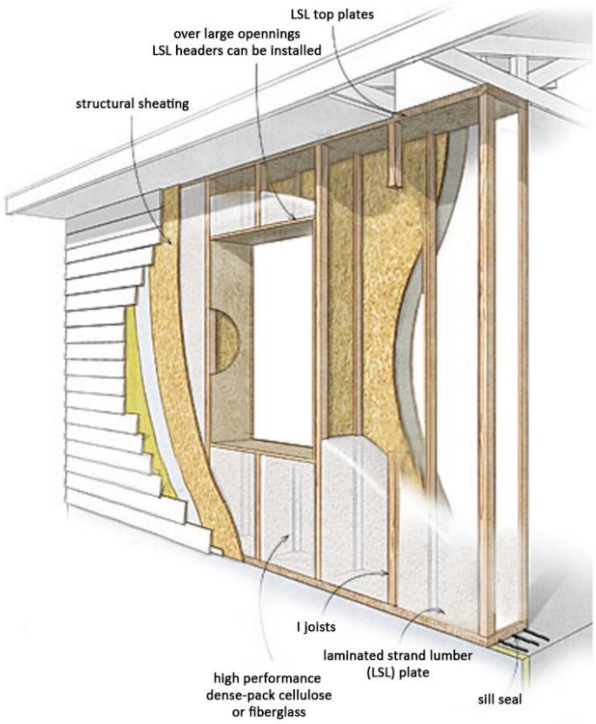
Figure 8 – Ground Plan

3.2 SOLUTIONS IMPLEMENTED

3.2.1. Building Fabric Specifications

Walls

The first strategy in thermal bridge free detailing is to identify all of the possible thermal bridges at the outset and design them out systematically. Double stud walls are becoming more common as the need to add extra insulation and avoid thermal bridging is recognized. A variety of methods have been proposed to meet this goal, for example, SIPs, Larsen truss walls, thick exterior foam sheathing, or the use of I-joists as studs. Most builders settle on the most affordable option, which is to use double 2x4 walls with a total wall thickness of 20 to 35 centimetres. Double stud walls can be connected each other with a strip of pywood or LSL plates at bottom and top (fig 9).



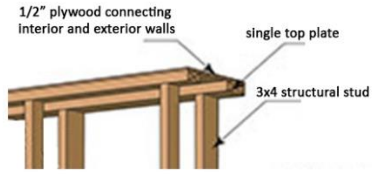


Figure 9 – Double Stud Connections with Each Other

In this system, two frames are built for each wall, one for exterior and one for interior, with a gap separating them. While this may seem more lumber intensive at first glance, a double stud frame with 2x4 studs in both side exterior and interior uses less amount of wood as one current 89mm timber stud size wall system while offering superior thermal performance (Magwood, C. 2013).

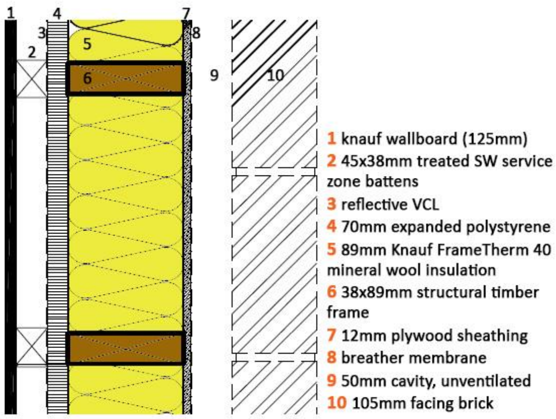


Figure 10 –Wall Panel Section Cut as Current

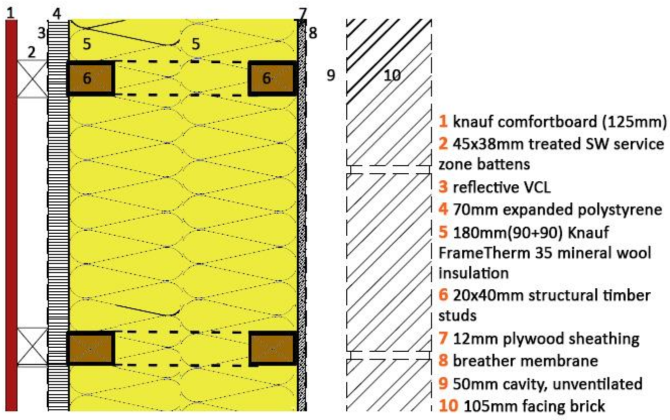


Figure 11 –Wall Panel Section Cut as Proposed

The rest of the layers of wall were hold as the same except the insulation type and plasterboard material. According to CCG OSM Standards booklet the finish layer of wall is employed by 125mm Knauf Wallboard. To provide thermal mass, PCM featured material Knauf Comfortboard with the same thick was proposed. The material contains tiny microscopic glass balls filled with wax. As the room temperature rises the heat energy transfers to the board and heats the wax changing it from a solid to a liquid within the glass beads (melting point at 23°C). This means that the board is essentially taking the heat out of the room allowing it to remain at a constant comfortable temperature. At night, the board will cool back down, especially if the windows are open for ventilation, and the wax will return to a solid, meaning that the next day it will be ready to absorb the heat energy once more. Secondly, Knauf Frame Therm 35 with the lower thermal conductivity (0.035 W/m.K) was used instead of was Knauf Frame Therm 40 (0.040 W/m.K) to upgrade wall U value.

The system has improved U value down to 0.13 W/m^2.K from 0.24W/m^2.K of it is current form.

Wall construction (inside to outside)

Bridged	Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
		Rsi							0.13	
☐	1	Plasterboard	12.5	0.210			700	1000	0.060	
	2	Vapour control layer								
☐	3	expanded polystyrene	70	0.039					1.795	
☑	4	insulation / timber frame	40	0.035	0.120	0.150	12	1030	1.143	0.333
☐	5	insulation	120	0.035					3.429	
☑	6	insulation / timber frame	40	0.035	0.120	0.150	12	1030	1.143	0.333
☐	7	Plywood sheathing	12	0.130			500	1600	0.092	
	8	Breather membrane								
☐	9	Cavity unventilated	50	R 0.180			1	1000	0.180	
☐	10	Brick outer leaf	105	0.770			1700	800	0.136	
		Rse							0.04	

**U value
0.13 m2.K**

Figure 12 – Wall Panel U Value Calculation as Proposed

Roofs

The roof consisted of 170mm mineral wool quilt insulation above 100mm insulation between timber battens.Current U value is remarked as 0.16 W/m^2.K which is upgraded by replacing the 170mm loft insulation with two layer of 150mm same type of product which is Knauf Earthwool Loft Roll according to CCG OSM Standards booklet. 0.11 W/m^2.K of U value has been achieved by the following works described.

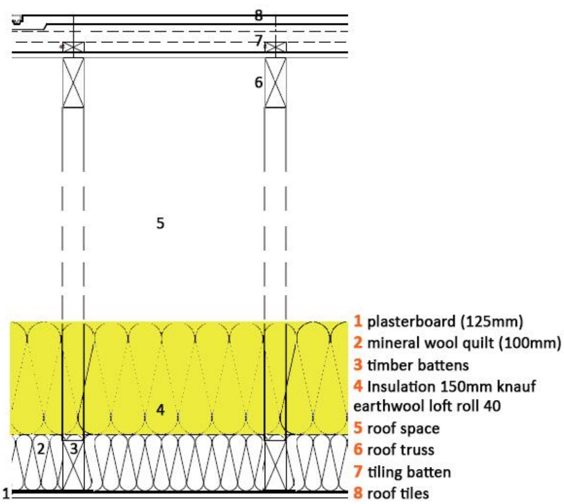


Figure 13 – Roof Section Cut as Current

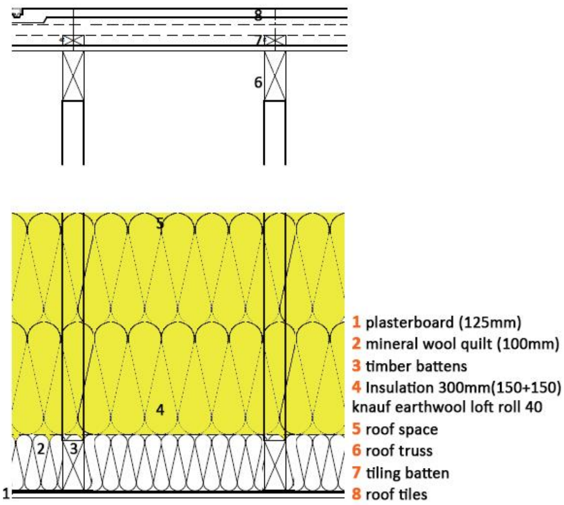


Figure 14 – Roof Section Cut as Proposed

Roof construction (inside to outside)

Bridged	Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
		Rsi							0.10	
☐	1	Plasterboard	12.5	0.210			700	1000	0.060	
☑	2	Mineral wool quilt	100	0.044	0.130	0.0900	12	1030	2.273	0.769
☐	3	Mineral wool	300	0.044			12	1030	6.818	
	4	Roof space		R 0.200			1	1000	0.200	
		Rse							0.04	

**U value
0.11 m2.K**

Figure 15 – Roof U Value Calculation as Proposed

Floors

The suspended timber floor comprises the chipboard rest over i joists with insulation between. Upgrading the conductivity of timber suspended floor is provided with developing 150mm I joists to 285mm(see fig16) I joists, therefore insulation thickness between joist becomes widener. The product used is Knauf Loft Roll 40 is the same as the pre-intervention phase.

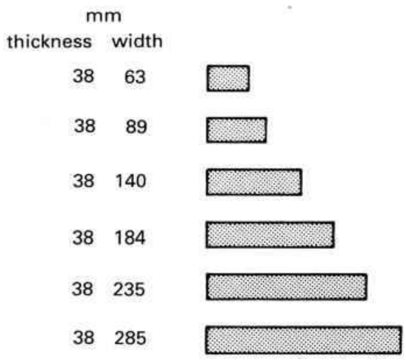


Figure 16 – Typical Sawn Sizes of Softwood are employed as I joists (source: TRADA)

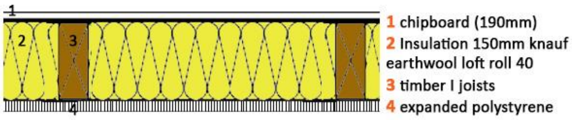


Figure 17 – Floor Section Cut as Current

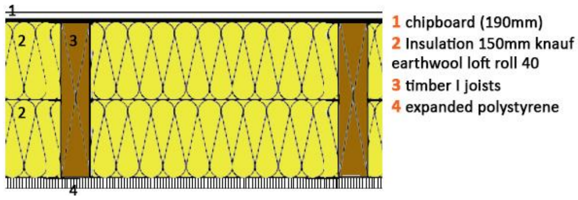


Figure 18 – Floor Section Cut as Proposed

Floor construction (top to bottom)

Bridged	Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
		Rsi							0.17	
☐	1	Chipboard	19	0.130			600	1600	0.146	
☑	2	Insulation / joists	300	0.040	0.130	0.110	20	1030	7.500	2.308
☐	3	expanded polystyrene	20	0.040			20	1450	0.500	
		Rs (underfloor)							0.17	

U value
0.12 m2.K

Figure 19 – Floor U Value Calculation as Proposed

Windows

In more temperate climates such as parts of Southern European it is possible to achieve low energy demand using good quality double glazing. In the UK however buildings need one step further to reduce unwanted heat losses through the window and use triple glazed windows to increase the surface temperature of the inner pane thereby reducing radiant the sensation of cold draughts from the glass and the possibility of mould growth.

Solar gains make up a significant component of the free heat gains available during the heating season. To make optimum use of the useful solar gains in winter in addition to good orientation the glazing must have low installed U values to reduce heat losses and good solar transmittance (G values). The G-Value measures the degree to which glazing blocks heat from sunlight. It is the fraction of the heat from the sun that enters through a window, expressed as a number between 0 and 1. The lower G-value, the less solar heat it transmits. In the dwelling presented, triple glazed argon filled glazing has been placed with the 0.68 g-value.

Type of glazing	Total solar energy transmittance, $g_{\perp}$ (for calculation of solar gains in section 6 of the worksheet)	Light transmittance, g_L (for calculation of lighting requirement in Appendix L)
Single glazed	0.85	0.90
Double glazed (air or argon filled)	0.76	
Double glazed (low-E, hard-coat)	0.72	0.80
Double glazed (low-E, soft-coat)	0.63	
Window with secondary glazing	0.76	0.80
Triple glazed (air or argon filled)	0.68	
Triple glazed (low-E, hard-coat)	0.64	0.70
Triple glazed (low-E, soft-coat)	0.57	

Table 2 – Solar Transmittance (G) Values Accordingly Glazing Type

The other significant point which effects solar gain is the frame factor which represents the glazed fraction of the window. Frame factors were assigned in SAP particularly where window areas differ on different facades on the dwelling. It was observed that the lower FF value causes the higher energy consumption. Accordingly, metal frame for window with 0.8 FF value has been selected.

Frame type	Frame factor (proportion of opening that is glazed)
Wood	0.7
Metal	0.8
Metal, thermal break	0.8
PVC-U	0.7

Table 3 – Frame Factor (ff) Values Accordingly Frame Type

CCG Opus AluClad Triple glazing window gives 0.89 W/m^2.K of U value according to BRE Certified. In addition to good orientation, glazing system with low U value will reduce to reduce heat losses.

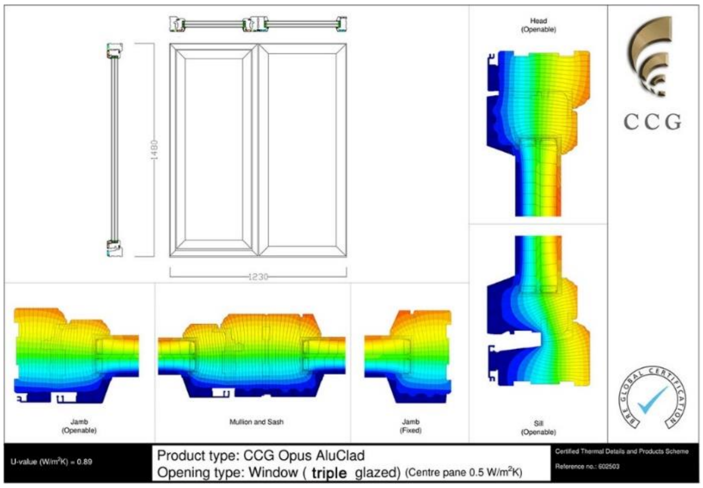


Figure 20 –Thermal Detail of Window Frame as Proposed

	CURRENT U VALUE (W/m2K)	IMPROVED U VALUE (W/m2K)
WALL	0.24	0.13
ROOF	0.2	0.11
FLOOR	0.16	0.12
WINDOWS	1.5	0.89

Table 4 – Comparison Between Current and Improved U Values

3.2.2. Ventilation

The WHO guidance on thermal comfort states that temperatures above 24°C cause discomfort and, in the more fragile and susceptible members of the population, can cause harm (Ormandy and Ezratty, 2011). Although for practical purposes it is generally the air temperature that is used to assess overheating, there are other environmental factors associated with overheating, such as a lack of air movement, relative humidity, radiant heat and the period of exposure (Dengel, A. et al).

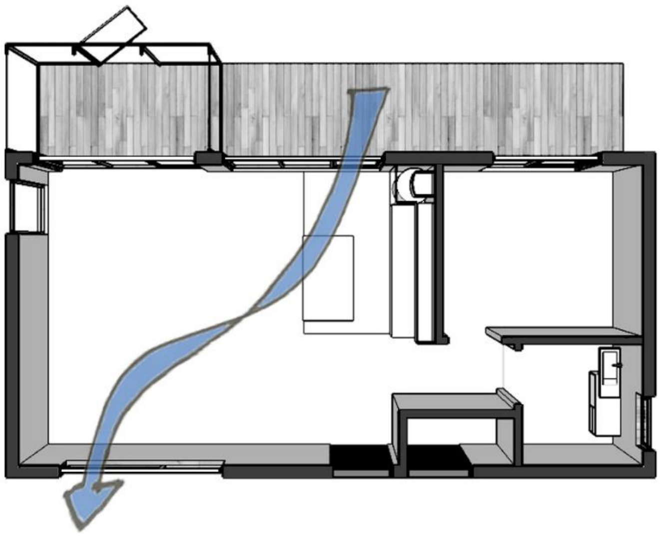


Figure 21 –Openings Placed on Opposite Walls in Living Area Provides Wind

Natural ventilation strategy was considered as a part of design stage. But opening windows when the outside temperature is equal to or above the indoor temperature is at the least of no benefit and may be detrimental and increase overheating problems. Furthermore, outdoor noise and pollution does enter the building where possible through the windows face streets. Air conditioning is an alternative, but this increase energy demand of building which is unwanted while aiming gold level energy efficient building. In this case, mechanical ventilation would be more suitable regarding to reduce energy consumption and more effective than natural ventilation because it provides a more homogeneous effect due to a more even distribution of air. To achieve comfortable indoor climate through the all year mechanical ventilation were provided with positive input ventilation system using.

Positive input ventilation (PIV) is a fan driven ventilation system, which provides ventilation to the dwelling from the loft space. Some positive input ventilation systems supply the air directly. Positive pressure units provide whole house ventilation by continuously introducing fresh air into the dwelling via a mechanical input fan which is usually installed in the loft space in a house. With a continuous supply of air into the dwelling it becomes positively pressurised. This in turn forces moisture and airborne particles to leave through natural paths in the dwelling's facade. Once installed and working, the continuous ventilation leaves the home free of high levels of humidity and creates an environment where condensation and mould can't form.While requires few penetrations on building envelope and very limited ducting, its costs are as little as a penny a day to run.In this project Axco Air-Source PIV unit has been selected with 0.14 W/(litre/sec) medium fan power and rigid ducting type (Beam Ventilation Product Brochure). It has the facility to source cooler air from outside the building when the temperature in the loft space rises above 24°C. Detecting the rise in temperature, the unit starts to draw air from atmosphere via a temperature controlled diverter mechanism. This provides efficient perception cooling into the property during warmer weather, but also maintains the required level of ventilation continuously throughout the year.

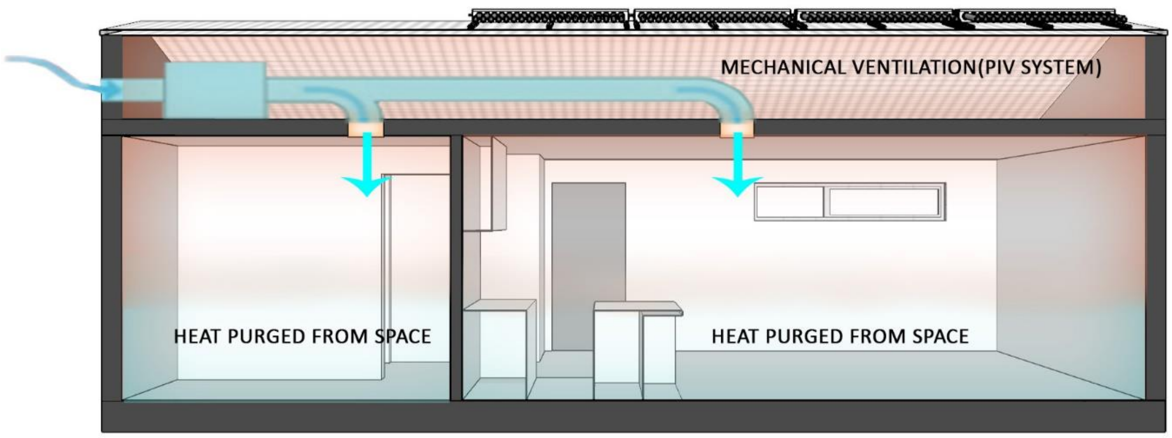


Figure 22 –PIV Ventilation System Principle of The Timber Kit House Proposal

3.2.3. Space & Water Heating

Based on gold level water heating aspects mentioned building regulation scenario in section 7, aspect 3, at least 50 % of water heating should be supplied by renewable sources. In addition to presented flue gas heat recovery system, solar thermal water heating and heat recovery from greywater were the options assessed for single dwelling proposed. In waste water recovery system, it was observed that heat recovery units in market are placed vertical at basement level, a few possible horizontal options found were low in efficiency. Because the waste water heat recovery system is not suitable for the proposed timber kit house, to attain golden requirement only solar panel system presented in SAP calculation. 10.56m^2 evacuated tube solar panel been placed on the south side of the roof with 30° angle. The total area of collectors have been calculated as if there are 4 seperate units 150cmx176cm based on relevant manufacturers catalogues.

	Worksheet reference	Positive values	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Energy content of hot water (annual)	(45)	1222.19												
Distribution loss	(46)	183.32	19.01	16.62	17.15	14.96	14.35	12.38	11.47	13.17	13.32	15.53	16.95	18.41
Energy lost from cylinder in kWh/day	(55)	1.27												
Primary circuit loss (annual)	(58)	366.88												
if solar water heating, primary loss each month	(59)		31.16	28.15	29.29	21.11	14.02	9.91	10.24	11.17	17.11	29.29	30.16	31.16
Combi loss	(61)	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			saving in primary loss			104.11								
Annual energy demand for hot water		**2052.61**												
		Negative values												
Renewable or heat recovery sources														
Solar water heating	(63)	-877.91												
reduction in primary loss		-104.11												
Waste water heat recovery	eq. (G10)	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flue gas heat recovery	eq. (G*)	-61.26	-14.33	-9.49	-5.22	-0.30	0.00	0.00	0.00	0.00	-0.95	-5.41	-11.13	-14.43
	* can be G1, G2, G5 or G6													
Appendix Q (value identified in App.Q spreadsheet)														
Other technology 1				These boxes are used only to allow for technologies not included in the SAP calculation and which have been authorised for the purposes of standard 7.1 (see Note 1 below)										
Other technology 2														
Other technology 3														
Total from renewable or heat recovery sources		**-1043.28**												
Percentage from renewable or heat recovery sources		**50.8%**	Gold level (G3) attained											

Table 5 – Water Heating Calculation For SBS Golden Level

A gas system-boiler has been chosen as they are compatible with solar panel systems. The dwellings water and space heating were powered by an gas system-boiler to a manufacturer's quoted 89.8% seasonal efficiency, and the boiler complemented with suitable a pre-insulated unvented 191lt cylinder to store water. Storage volume has been sized according to 90 litres per person in a day which is higher than typical UK benchmark for water consumption which is assuming 70 litres per person in a day.

Greenstar 9i System Boiler | Greenstar TC Cyclinder (191lt) | Greenstar Comfort digital programmer

Figure 23 – Selected Heating Components (Worcester/BOSCH)

4 SAP2012 CALCULATION

4.1. Reports

The solutions for improvement were implemented under SBS Section 6 & 7. The measures generated by SAP software shows the Golden Level of sustainability is achieved. The requirements mentioned in aspect1 and aspect2 which restrict the amount of cover carbon dioxide emissions and energy for space heating consecutively are remarked in the SAP results below.

TER WorkSheet: New dwelling as built

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

	Energy kWh/year	Emission factor kg CO2/kWh		Emissions kg CO2/year	
Space heating (main system 1)	(211) x	0.298	=	912.48	(261)
Space heating (secondary)	(215) x	0.019	=	9.91	(263)
Water heating	(219) x	0.298	=	571.56	(264)
Space and water heating	(261) + (262) + (263) + (264) =			1493.95	(265)
Electricity for pumps, fans and electric keep-hot	(231) x	0.519	=	67.47	(267)
Electricity for lighting	(232) x	0.519	=	118.89	(268)
Energy saving/generation technologies Item 1		0.519	=	-209.39	(269)
Total CO2, kg/year	sum of (265)…(271) =			1470.92	(272)
TER =				29.88	(273)

DER WorkSheet: New dwelling as built

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

	Energy kWh/year	Emission factor kg CO2/kWh		Emissions kg CO2/year	
Space heating (main system 1)	(211) x	0.298	=	458.19	(261)
Space heating (secondary)	(215) x	0.519	=	0	(263)
Water heating	(219) x	0.298	=	351.32	(264)
Space and water heating	(261) + (262) + (263) + (264) =			809.51	(265)
Electricity for pumps, fans and electric keep-hot	(231) x	0.519	=	125.77	(267)
Electricity for lighting	(232) x	0.519	=	118.65	(268)
Total CO2, kg/year	sum of (265)…(271) =			1053.93	(272)
Dwelling CO2 Emission Rate	(272) ÷ (4) =			21.41	(273)
EI rating (section 14)				85	(274)

DRAFT

To assess Aspect 1 of Gold Level within the scope of Section 7, the TER from SAP 2012 calculation should be multiplied by 0.73, give a revised figure which the DER should not exceed. Accordingly; 29,88 x 0.73 = 21,81 which is the maximum amount for DER. As it observed in the result obtained as 21.41 of Dwelling CO_2 Emission Rate (DER) which meets the requirement as being lower than benchmark amount.

SAP WorkSheet: New dwelling as built

(92)m=	19.44	19.75	20	20.2	20.28	20.32	20.32	20.33	20.31	20.2	19.84	19.41	(92)

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

(93)m=	19.29	19.6	19.85	20.05	20.13	20.17	20.17	20.18	20.16	20.05	19.69	19.26	(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=	0.93	0.85	0.76	0.62	0.48	0.33	0.22	0.24	0.39	0.65	0.86	0.94	(94)
Useful gains, hmGm , W = (94)m x (84)m													
(95)m=	679.79	794.43	809.94	719.3	565.11	369.75	238.14	250.1	404.73	599.56	657.32	640.34	(95)
Monthly average external temperature from Table 8													
(96)m=	4.3	4.9	6.5	8.9	11.7	14.6	16.6	16.4	14.1	10.6	7.1	4.2	(96)
Heat loss rate for mean internal temperature, Lm , W =[(39)m x [(93)m– (96)m]													
(97)m=	1079.15	1052.11	950.06	770.82	579.23	371.58	238.36	250.41	409	649.75	875.89	1059.69	(97)
Space heating requirement for each month, kWh/month = 0.024 x [(97)m – (95)m] x (41)m													
(98)m=	297.13	173.16	104.25	37.09	10.5	0	0	0	0	37.34	157.37	312	

Total per year (kWh/year) = Sum(98)$_{1...5,9...12}$ = 1128.84 (98)

Space heating requirement in kWh/m²/year 22.93 (99)

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

Space heating:

Fraction of space heat from secondary/supplementary system		0	(201)
Fraction of space heat from main system(s)	(202) = 1 – (201) =	1	(202)
Fraction of total heating from main system 1	(204) = (202) × [1 – (203)] =	1	(204)
Efficiency of main space heating system 1		90.8	(206)
Efficiency of secondary/supplementary heating system, %		0	(208)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	kWh/year
Space heating requirement (calculated above)	297.13	173.16	104.25	37.09	10.5	0	0	0	0	37.34	157.37	312	
(211)m = {[(98)m x (204)] } x 100 ÷ (206)	327.23	190.71	114.81	40.85	11.57	0	0	0	0	41.13	173.31	343.61	(211)

Total (kWh/year) =Sum(211)$_{1...5,10...12}$= 1243.22 (211)

Space heating fuel (secondary), kWh/month

= {[(98)m x (201)] } x 100 ÷ (208)

(215)m=	0	0	0	0	0	0	0	0	0	0	0	0

Total (kWh/year) =Sum(215)$_{1...5,10...12}$= 0 (215)

Water heating

Output from water heater (calculated above)

	159.12	122.88	104.19	58.86	29.37	12.88	9.99	36.88	61.32	111.57	140.77	159.18	
Efficiency of water heater												80.1	(216)
(217)m=	86.76	86.03	85.12	83.92	82.67	80.1	80.1	80.1	80.1	82.54	85.41	86.88	(217)

Fuel for water heating, kWh/month

(219)m = (64)m x 100 ÷ (217)m

(219)m=	183.41	142.83	122.41	70.13	35.53	16.08	12.47	46.04	76.55	135.17	164.81	183.22

Total = Sum(219a)$_{1...12}$ = 1188.65 (219)

Aspect 2 of Gold Level requires 30 kWh/m^2 as maximum annual demand for useful energy for space heating for the dwellings. Proposed dwelling annual demand is seen as 22.93 kWh/m^2 provides as it no more than figure remarked.

4.2. Comparisons

PHASE - 1		
U Value (W/M2K)	Annual energy requirements	
wall: 0.24	Total space heating:	44.95 kWh/m2/year
roof: 0.16	CO2 Emissions per m2:	26.73 kg/CO2/year
floor: 0.20	Primary energy:	109.71kWh/m2/year
windows:1.50		

PHASE - 2			
U Value (W/M2K)	Annual energy requirements		reduction ratios
wall: 0.13	Total space heating:	38.94 kWh/m2/year	13%
roof: 0.16	CO2 Emissions per m2:	24.79 kg/CO2/year	7%
floor: 0.20	Primary energy:	102.56kWh/m2/year	6%
windows:1.50			

PHASE - 3			
U Value (W/M2K)	Annual energy requirements		reduction ratios
wall: 0.13	Total space heating:	22.09 kWh/m2/year	50%
roof: 0.11	CO2 Emissions per m2:	19.69 kg/CO2/year	26%
floor: 0.12	Primary energy:	83.72kWh/m2/year	14%
windows:0.89			

Table 6 The Effects of Building Fabric's Thermal Efficiency to Annual Energy Requirements

The tables present how building fabric's thermal efficiency affects the annual energy requirements by changing the material values in each phase while all the rest of conditions are as given currently. The proposed improvements in all materials indicate %50 reduction of total space heating, %26 reduction of CO_2 emission per m^2, %14 reduction of primary energy per year. Which remarks the importance of overall building airtightness to reduce energy demands. As the wall system is the aimed building component for improvement, Phase-2 presents the effects of wall enhancement. According to Phase-2, wall improvement contributes %13 of total space heating, %7 of CO_2 emission per m^2 and %6 primary energy per year.

SOLAR PANELS	TOTAL WATER HEATING FUEL USED	reduction ratio
IN ABSENCE	2297.79 kWh/year	48%
IN PRESENCE	1188.65 kWh/year	

Table 7 - The Effect of Solar Panels to Water Heating Fuel Use

In the table above, total water heating energy demand compared in both cases respectively, in presence of solar panel systems and in absence of the solar panel systems. A %48 lower consumption in the total water heating is explained by the existance of evacuated collectors in the designed.

5 SUMMARY TABLES OF COMPLIANCE

The solutions implemented under SBS Section 6 & 7 and the SAP results related to Gold Level Aspects summarized in the tables below.

	U Value (W/M2K)	Components
Walls	0.13	125mm knauf comfortboard 45x38mm treated SW service zone battens reflective VCL 4 70mm expanded polystyrene 180mm(90+90) Knauf FrameTherm 35 mineral wool insulation 20x40mm structural timber studs 12mm plywood sheathing breather membrane 50mm cavity, unventilated
Roofs	0.11	plasterboard (125mm) mineral wool quilt (100mm) timber battens Insulation 300mm(150+150) knauf earthwool loft roll 40
Floors	0.12	chipboard (190mm) Insulation 150mm knauf earthwool loft roll 40 timber I joists expanded polystyrene
Doors	1.2	Metal Frame Transmittance factor : 0.65 Frame factor : 0.80
Windows	0.89	Metal Frame Triple glazed argon filled(low-E, EN=0.05, soft coat) Transmittance factor : 0.68 Frame factor : 0.80

Table 8 - U Values and Construction Details of Building Elements

Ventilation	Natural ventilation provided by opennings placed on opposite walls Mechanical ventilation provided with positive input ventilation (PIV) is a fan driven ventilation system, which provides ventilation to the dwelling from the loft space. Details; Ducting Type : Rigid Specific Fan Power : 0.14 W(litre/sec)
Space & Water Heating	Space heating provided by system - boiler with radiators Boiler features: gas powered, %89.8 seasonal efficiency, complemented with 191lt water storage %50.8 of Water heating supplied by solar panels at which side of roof faces south and Flue Gas Heat Recovery System Solar panel collector type: Evacuated Tube Area : 10,56 m2
Renewable Technology	Not presented

Table 9 - Ventilation, Space and Water Heating, Renewable Technology Systems Summarizes as Proposed

SAP OUTCOMES	
Dwelling TER (Target Emission Rate)	29.88
Dwelling DER (Dwelling Emission Rate)	21.41
Space Heating requirement kWh/m2/year	22.93
CO2 Emission per m2	19.69
Primary energy kWh/m2/year	83.72

Table 10 - SAP Outcomes Relevant to SBS Section 7 Under Implemented Solutions

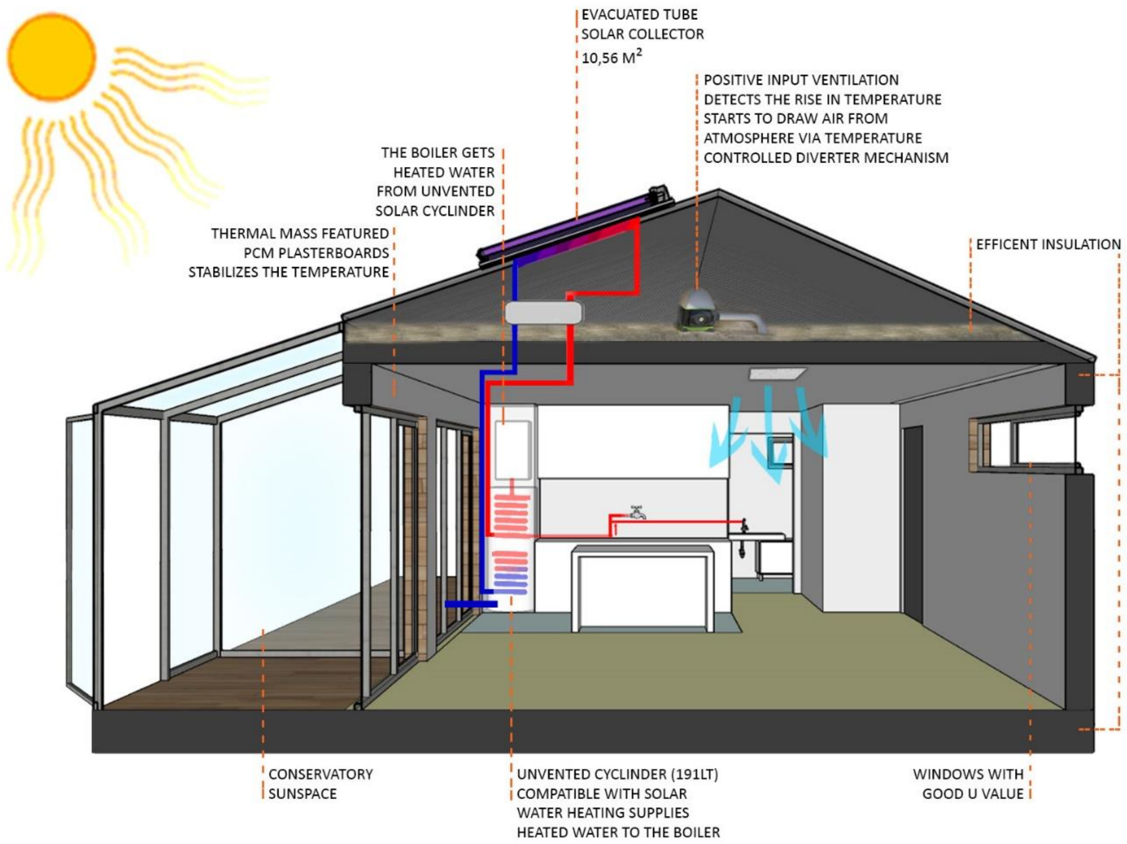


Figure 24 – SBS Golden Level Achieved Timber Kit House Principles

6 CONCLUSIONS

The outcomes show; it is possible to drive higher performing homes built with off-site techniques. The performance due to energy demands of building is achieved was enhanced with well-insulated building envelope by the supply of renewable sources. As a result, it fulfils current Scottish Building Standards (SBS) Section 6 & 7 with achieving the Gold level. Furthermore, with the help of modern technology, phase-change material addition to finish wall layer inside, the potential for providing thermal mass to timber frames was examined in this work. It is an affordable and easy to handle solution which is mostly suitable for MMC systems without adding too much weight on the structure. This is also evidence how timber frame buildings are open to development in terms of energy performance and thermal comfort.

How can be varied the plan alternatives with the same architectural programme were a part of this work brought to attention and assessed briefly if a standardization is possible still with flexible solutions come together along the client demands and site typology in most case. As it been achieved few combination for this scale of project, it indicated that is more encouraging in bigger scale dwellings.

Superior quality, through factory-based quality control, precision engineering and design standardisation is the key advantage of MMC systems over conventional forms. Through the CCG is the company which is able to offer full construction capability complimented by the 'Off-Site' manufacture of timber systems, with a further work for standardization of the stages examined in this report, there is going to be foresight that the firm will be capable of dominating the market of timber kit manufacturers.

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8 APPENDIX : SAP WORKSHEET

SAP WorkSheet: New dwelling as built

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

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
(38)m=	30.72	30.31	29.91	27.89	27.49	25.47	25.47	25.07	26.28	27.49	28.3	29.1		(38)

Heat transfer coefficient, W/K (39)m = (37) + (38)m

(39)m=	71.97	71.57	71.17	69.15	68.75	66.73	66.73	66.33	67.54	68.75	69.55	70.36		
										Average = $Sum(39)_{1...12}$ /12=			69.05	(39)

Heat loss parameter (HLP), W/m²K (40)m = (39)m ÷ (4)

(40)m=	1.46	1.45	1.45	1.4	1.4	1.36	1.36	1.35	1.37	1.4	1.41	1.43		
										Average = $Sum(40)_{1...12}$ /12=			1.4	(40)

Number of days in month (Table 1a)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
(41)m=	31	28	31	30	31	30	31	31	30	31	30	31		(41)

4. Water heating energy requirement: kWh/year:

Assumed occupancy, N 1.67 (42)
if TFA > 13.9, N = 1 + 1.76 x [1 - exp(-0.000349 x (TFA -13.9)2)] + 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 77.68 (43)

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

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Hot water usage in litres per day for each month Vd,m = factor from Table 1c x (43)														
(44)m=	85.45	82.34	79.23	76.13	73.02	69.91	69.91	73.02	76.13	79.23	82.34	85.45		
										Total = $Sum(44)_{1...12}$ =			932.15	(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=	126.72	110.83	114.36	99.7	95.67	82.55	76.5	87.78	88.83	103.53	113.01	122.72		
										Total = $Sum(45)_{1...12}$ =			1222.19	(45)
If instantaneous water heating at point of use (no hot water storage), enter 0 in boxes (46) to (61)														
(46)m=	19.01	16.62	17.15	14.96	14.35	12.38	11.47	13.17	13.32	15.53	16.95	18.41		(46)

Water storage loss:

Storage volume (litres) including any solar or WWHRS storage within same vessel		382	(47)
If community heating and no tank in dwelling, enter 110 litres in (47)			
Otherwise if no stored hot water (this includes instantaneous combi boilers) enter '0' in (47)			
Water storage loss:			
a) If manufacturer's declared loss factor is known (kWh/day):		0	(48)
Temperature factor from Table 2b		0	(49)
Energy lost from water storage, kWh/year	(48) x (49) =	191	(50)
b) If manufacturer's declared cylinder loss factor is not known:			
Hot water storage loss factor from Table 2 (kWh/litre/day)		0.01	(51)
If community heating see section 4.3			
Volume factor from Table 2a		0.86	(52)
Temperature factor from Table 2b		0.6	(53)
Energy lost from water storage, kWh/year	(47) x (51) x (52) x (53) =	1.27	(54)
Enter (50) or (54) in (55)		1.27	(55)

Water storage loss calculated for each month ((56)m = (55) × (41)m

(56)m=	39.47	35.65	39.47	38.19	39.47	38.19	39.47	39.47	38.19	39.47	38.19	39.47	(56)

Stroma FSAP 2012 Version: 1.0.4.6 (SAP 9.92) - http://www.stroma.com Page 3 of 9

WORKSHEET 1 *indicates values used for water heating calculation of Golden Level (Table 5)*

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=	39.47	35.65	39.47	38.19	39.47	38.19	39.47	39.47	38.19	39.47	38.19	39.47	(57)

Primary circuit loss (annual) from Table 3 | 0 | (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=	31.16	28.15	29.29	21.11	14.02	9.91	10.24	11.17	17.11	29.29	30.16	31.16	(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	(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=	197.34	174.62	183.12	159.01	149.16	130.65	126.2	138.42	144.14	172.28	181.36	193.35	(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=	-25.46	-42.48	-72.35	-96.96	-119.79	-117.77	-116.22	-101.54	-79.53	-54.31	-30.2	-21.3	(63)
FHRS	14.33	9.49	5.22	0.3	0	0	0	0	0.95	5.41	11.13	14.43	(63) (G2)

Output from water heater

(64)m=	159.12	122.88	104.19	58.86	29.37	12.88	9.99	36.88	61.32	111.57	140.77	159.18	

Output from water heater (annual)1...12 | 1006.99 | (64)

Heat gains from water heating, kWh/month 0.25 ´ [0.85 × (45)m + (61)m] + 0.8 x [(46)m + (57)m + (59)m]

(65)m=	67.06	59.37	61.46	50.04	43.03	35.37	33.62	38.12	43.22	57.86	61.7	65.73	(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

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
(66)m=	100.03	100.03	100.03	100.03	100.03	100.03	100.03	100.03	100.03	100.03	100.03	100.03	(66)

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

(67)m=	32.36	28.75	23.38	17.7	13.23	11.17	12.07	15.69	21.05	26.73	31.2	33.26	(67)

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

(68)m=	216.73	218.98	213.31	201.25	186.02	171.7	162.14	159.89	165.56	177.62	192.85	207.17	(68)

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

(69)m=	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	(69)

Pumps and fans gains (Table 5a)

(70)m=	12.69	12.69	12.69	12.69	12.69	12.69	12.69	12.69	12.69	12.69	12.69	12.69	(70)

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

(71)m=	-66.69	-66.69	-66.69	-66.69	-66.69	-66.69	-66.69	-66.69	-66.69	-66.69	-66.69	-66.69	(71)

Water heating gains (Table 5)

(72)m=	90.14	88.34	82.61	69.5	57.83	49.13	45.19	51.24	60.03	77.76	85.69	88.35	(72)

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

(73)m=	431.93	428.77	411.99	381.14	349.78	324.7	312.1	319.51	339.35	374.82	402.45	421.48	(73)

6. Solar gains:

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

***WORKSHEET 2** indicates values used for water heating calculation of Golden Level (Table 5)*

SAP WorkSheet: New dwelling as built

Annual totals		kWh/year	kWh/year	
Space heating fuel used, main system 1			1243.22	
Water heating fuel used			1188.65	
Electricity for pumps, fans and electric keep-hot				
mechanical ventilation - balanced, extract or positive input from outside		27.32		(230a)
central heating pump:		120		(230c)
boiler with a fan-assisted flue		45		(230e)
pump for solar water heating		50		(230g)
Total electricity for the above, kWh/year	sum of (230a)…(230g) =		242.32	(231)
Electricity for lighting			228.62	(232)

10a. Fuel costs - individual heating systems:

	Fuel kWh/year	Fuel Price (Table 12)		Fuel Cost £/year	
Space heating - main system 1	(211) x	5.44	x 0.01 =	67.63	(240)
Space heating - main system 2	(213) x	0	x 0.01 =	0	(241)
Space heating - secondary	(215) x	11.09	x 0.01 =	0	(242)
Water heating cost (other fuel)	(219)	5.44	x 0.01 =	64.66	(247)
Pumps, fans and electric keep-hot	(231)	0	x 0.01 =	31.66	(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)	13.24	x 0.01 =	30.28	(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) =			194.23	(255)

11a. SAP rating - individual heating systems

Energy cost deflator (Table 12)		0.42	(256)
Energy cost factor (ECF)	[(255) x (256)] ÷ [(4) + 45.0] =	0.87	(257)
SAP rating (Section 12)		87.92	(258)

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

	Energy kWh/year	Emission factor kg CO2/kWh		Emissions kg CO2/year	
Space heating (main system 1)	(211) x	0.298	=	370.48	(261)
Space heating (secondary)	(215) x	0.519	=	0	(263)
Water heating	(219) x	0.298	=	354.22	(264)
Space and water heating	(261) + (262) + (263) + (264) =			724.7	(265)
Electricity for pumps, fans and electric keep-hot	(231) x	0.519	=	125.77	(267)
Electricity for lighting	(232) x	0.519	=	118.65	(268)

***WORKSHEET 3** looks overall energy requirements (used in table 7)*

SAP WorkSheet: New dwelling as built

Total CO2, kg/year		sum of (265)…(271) =		969.11	(272)
CO2 emissions per m²		(272) ÷ (4) =		19.69	(273)
EI rating (section 14)				86	(274)

13a. Primary Energy

	Energy kWh/year	**Primary** factor		**P. Energy** kWh/year	
Space heating (main system 1)	(211) x	1.1	=	1367.54	(261)
Space heating (secondary)	(215) x	3.07	=	0	(263)
Energy for water heating	(219) x	1.1	=	1307.51	(264)
Space and water heating	(261) + (262) + (263) + (264) =			2675.05	(265)
Electricity for pumps, fans and electric keep-hot	(231) x	3.07	=	743.93	(267)
Electricity for lighting	(232) x	0	=	701.86	(268)
‘Total Primary Energy		sum of (265)…(271) =		4120.84	(272)
Primary energy kWh/m²/year		(272) ÷ (4) =		83.72	(273)

WORKSHEET 3 *looks CO_2 emissions and primary energy consumption (used in tables 6&9)*