Elmsbrook Phase 4

Crest Nicholson Chiltern

Sustainability Statement

AES Sustainability Consultants Ltd

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Revision	Author	Date	Comment
-	Andrew McManus	06.04.21	Initial issue
	Andrew McManus	30.06.22	Zero carbon assessment, embodied carbon and daylighting calculations incorporated

This statement has been commissioned by Crest Nicholson to detail the proposed approach to delivering zero carbon development and address additional sustainability related planning requirements for Phase 4 at Elmsbrook Ecotown. It should be noted that the details presented, including the proposed specifications, are subject to change as the detailed design of the buildings progresses, whilst ensuring that the overall commitments will be achieved.

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1. Introduction

Preface

1.1. This Sustainability Statement has been prepared on behalf of Crest Nicholson Chiltern in support of the revised application for the development of Phase 4 at Elmsbrook.

Development Description

1.2. A hybrid application under ref 10/01780/HYBRID was originally submitted in 2010 for the exemplar phase of the wider Elmsbrook Eco Town development:

Development of Exemplar phase of NW Bicester Eco Town to secure full planning permission for 393 residential units and an energy centre (up to 400 square metres), means of access, car parking, landscape, amenity space and service infrastructure and outline permission for a nursery of up to 350 square metres (use class D2), a community centre of up to 350 square metres (sui generis), 3 retail units of up to 770 square metres (including but not exclusively a convenience store, a post office and a pharmacy (use class A1)), an Eco-Business Centre of up to 1,800 square metres (use class B1), office accommodation of up to 1,100 square metres (use class B1), an Eco-Pub of up to 190 square metres (use class A4), and a primary school site measuring up to 1.34 hectares with access and layout to be determined.

1.3. The proposals addressed within this statement constitutes a replan of the proposed Phase 4 of the development, comprising an amended housetype mix and a change in the total number of dwellings within this phase from 54 to 57, under application reference 21/01227/F

Purpose and Scope of the Statement

1.4. This statement provides detail on the proposed energy and sustainability strategy for this residential parcel, addressing Conditions 14, 15 and 16 of the planning approval concerning the achievement of zero carbon standards, good levels of internal daylight and reduction in embodied carbon emissions

1.5. The statement additionally describes measures undertaken to address overheating risk and consider a changing future climate. A full overheating risk assessment has been undertaken in accordance with CIBSE TM59 guidance and is appended to this document.

Figure 1. Elmsbrook Phase 4 site plan

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2. Planning Policy and Conditions

Cherwell Local Plan 2011-2031

2.1. The Cherwell Local Plan 2011-2031 was adopted in July 2015. Section B.3 contains a number of policies aimed at ensuring sustainable development, with ESD2- ESD6 as extracted being of principle relevance to this statement:

> Policy ESD 2: Energy Hierarchy and Allowable Solutions
>
> In seeking to achieve carbon emissions reductions, we will promote an 'energy hierarchy' as follows:
>
> - Reducing energy use, in particular by the use of sustainable design and construction measures
> - Supplying energy efficiently and giving priority to decentralised energy supply
> - Making use of renewable energy
> - Making use of allowable solutions.

Allowable Solutions

2.2. In relation to the final stage of the energy hierarchy, the text supporting ESD2 notes:

Carbon emissions reductions can be achieved through a range of "allowable solutions"; measures which secure carbon savings off site. These have yet to be defined by the government but could potentially include investment in off site low and zero carbon technologies. The concept is relatively new and is seen as a way to enable developments to become carbon neutral where it is not possible to deal with all carbon emissions through on site measures.

It will not always be cost effective or technically feasible to meet the zero carbon standard through on site measures and the government is therefore proposing that the zero carbon standard could be achieved by mitigating the remaining emissions off-site through the use of allowable solutions. The Council will support the implementation of the national approach to allowable solutions once defined

> Policy ESD 3: Sustainable Construction
>
> All new residential development will be expected to incorporate sustainable design and construction technology to achieve zero carbon development through a combination of fabric energy efficiency, carbon compliance and allowable solutions in line with Government policy.
>
> Cherwell District is in an area of water stress and as such the Council will seek a higher level of water efficiency than required in the Building Regulations, with developments achieving a limit of 110 litres/person/day.
>
> All new non-residential development will be expected to meet at least BREEAM 'Very Good' with immediate effect, subject to review over the plan period to ensure the target remains relevant. The demonstration of the achievement of this standard should be set out in the Energy Statement.
>
> The strategic site allocations identified in this Local Plan are expected to provide contributions to carbon emissions reductions and to wider sustainability
>
> All development proposals will be encouraged to reflect high quality design and high environmental standards, demonstrating sustainable construction methods including but not limited to:
>
> - Minimising both energy demands and energy loss
> - Maximising passive solar lighting and natural ventilation
> - Maximising resource efficiency
> - Incorporating the use of recycled and energy efficient materials Incorporating the use of locally sourced building materials
> - Reducing waste and pollution and making adequate provision for the recycling of waste
> - Making use of sustainable drainage methods
> - Reducing the impact on the external environment and maximising opportunities for cooling and shading (by the provision of open space and water, planting, and green roofs, for example); and
> - Making use of the embodied energy within buildings wherever possible and re-using materials where proposals involve demolition or redevelopment.

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The strategic site allocations identified in this Local Plan are expected to provide contributions to carbon emissions reductions and to wider sustainability

All development proposals will be encouraged to reflect high quality design and high environmental standards, demonstrating sustainable construction methods including but not limited to:

- Minimising both energy demands and energy loss Maximising passive solar lighting and natural ventilation
- Maximising resource efficiency
- Incorporating the use of recycled and energy efficient materials Incorporating the use of locally sourced building materials
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- Making use of sustainable drainage methods
- Reducing the impact on the external environment and maximising opportunities for cooling and shading (by the provision of open space and water, planting, and green roofs, for example); and
- Making use of the embodied energy within buildings wherever possible and re-using materials where proposals involve demolition or redevelopment.

Policy ESD 4: Decentralised Energy Systems

The use of decentralised energy systems, providing either heating (District Heating (DH)) or heating and power (Combined Heat and Power (CHP)) will be encouraged in all new developments.

A feasibility assessment for DH/CHP, including consideration of biomass fuelled CHP, will be required for:

- All residential developments for 100 dwellings or more
- All residential developments in off-gas areas for 50 dwellings or more
- All applications for non-domestic developments above 1000m2 floorspace.

The feasibility assessment should be informed by the renewable energy map at Appendix 5 'Maps' and the national mapping of heat demand densities undertaken by the Department for Energy and Climate Change (DECC) (see Appendix 3: Evidence Base).

Where feasibility assessments demonstrate that decentralised energy systems are deliverable and viable, such systems will be required as part of the development unless an alternative solution would deliver the same or increased benefit.

Policy ESD 5: Renewable Energy

The Council supports renewable and low carbon energy provision wherever any adverse impacts can be addressed satisfactorily. The potential local environmental, economic and community benefits of renewable energy schemes will be a material consideration in determining planning applications.

Planning applications involving renewable energy development will be encouraged provided that there is no unacceptable adverse impact, including cumulative impact, on the following issues, which are considered to be of particular local significance in Cherwell:

- Landscape and biodiversity including designations, protected habitats and species, and Conservation Target Areas
- Visual impacts on local landscapes
- The historic environment including designated and non designated assets and their settings
- The Green Belt, particularly visual impacts on openness
- Aviation activities
- Highways and access issues, and
- Residential amenity.

A feasibility assessment of the potential for significant on site renewable energy provision (above any provision required to meet national building standards) will be required for:

- All residential developments for 100 dwellings or more
- All residential developments in off-gas areas for 50 dwellings or more
- All applications for non-domestic developments above 1000m^2 floorspace.

Where feasibility assessments demonstrate that on site renewable energy provision is deliverable and viable, this will be required as part of the development unless an alternative solution would deliver the same or increased benefit. This may include consideration of 'allowable solutions' as Government Policy evolves.

Planning Policy Statement: EcoTowns

2.3. The PPS1 EcoTowns supplement contains the following policy relating to zero carbon standards in eco-towns:

ET 7.1	The definition of zero carbon in eco-towns is that over a year the net carbon dioxide emissions from all energy use within the buildings on the eco-town development as a whole are zero or below. The initial planning application and all subsequent planning applications for the development of the eco-town should demonstrate how this will be achieved.
ET 7.2	The health and social care needs of residents, and the resulting energy demand, should be taken into account when demonstrating how this standard will be met.
ET 7.3	This standard will take effect in accordance with a phased programme to be submitted with the planning application. It excludes embodied carbon7 and emissions from transport but includes all buildings – not just houses but also commercial and public sector buildings which are built as part of the eco-town development. The calculation of net emissions will take account of:
	(a) emissions associated with the use of locally produced energy
	(b) emissions associated with production of energy imported from centralised energy networks, taking account of the carbon intensity of those imports as set out in the Government's Standard Assessment Procedure, and
	(c) emissions displaced by exports of locally produced energy to centralised energy networks where that energy is produced from a plant (1) whose primary purpose is to support the needs of the eco town and (2) has a production capacity reasonably related to the overall energy requirement of the eco town.
ET 7.4	This standard attempts to ensure that energy emissions related to the built environment in eco-towns are zero or below. Standards applicable to individual homes are set out in policy ET 9.

2.4. In March 2015 the EcoTowns PPS was withdrawn for all areas previously covered by the policy with the exception of North West Bicester. The relevant policies were brought into the North West Bicester Supplementary Planning Document.

North West Bicester SPD

2.5. The North West Bicester SPD was adopted in February 2016, to expand on Policy Bicester 1 of the Local Plan and set the minimum standards to be achieved by the proposed development. It includes the following 'Development Requirements' (condensed) relevant to this strategy:

> Development Principle 2 – "True" zero carbon development
>
> 4.23 In accordance with the Local Plan the definition of true zero carbon is that over a year the net carbon dioxide emissions from all energy use within buildings on the eco-town development as a whole are zero or below. It excludes embodied carbon and emissions from transport but includes all buildings – not just houses but also commercial and public sector buildings.
>
> 4.24 Development at North West Bicester must achieve zero carbon emissions as defined in this SPD.
>
> 4.5 Each full and outline application will need to be supported by an energy strategy and comply with the definition of true zero carbon development.
>
> 4.26 Energy strategies should identify how the proposed development will achieve the zero carbon targets and set out the phasing.
>
> 4.28 Applicants will be encouraged to maximise the fabric energy efficiency of buildings
>
> Development Requirement 3 - Climate Change Adaptation
>
> 4.41 Planning applications will be required to incorporate best practice on tackling overheating.
>
> 4.44 Planning applications should:
>
> - Provide evidence to show consideration of climate change adaptation

Planning Conditions -

2.6. The relevant planning conditions attached to the Full application ref 21/01227/F are extracted below:

> 14. No development shall commence until full details of the measures to achieve zero carbon energy use, as defined by Policy Bicester 1 of the Cherwell Local Plan Part 1 2011-2031, through on site solutions, have been submitted to and approved in writing by the Local Planning Authority. Should it be demonstrated to the satisfaction of the local planning authority that it is not possible to achieve zero carbon on site, a scheme for off site mitigation in Bicester shall be provided, prior to the first residential occupation, for that portion of the energy use that cannot be met on site.
>
> Reason: For the avoidance of doubt, to ensure that the development is carried out only as approved by the Local Planning Authority and to comply with Policy Bicester 1 of the Cherwell Local Plan Part 1 2011-2031. This information is required prior to the commencement of any development as it is fundamental to the acceptability of the scheme.
>
> 15. No development shall commence until details of how each dwelling within that phase achieves good day lighting by achieving at least 2 points of the former Code for Sustainable Homes level 5 for day lighting shall be submitted to and approved in writing by the Local Planning Authority. The development shall thereafter be carried out in accordance with the approved details such that each dwelling achieves good day lighting.
>
> Reason: To prevent increased energy use and to enable zero carbon development to be achieved in accordance with Policy Bicester 1 of the Cherwell Local Plan Part 1 2011-2031. This information is required prior to the commencement of any development as it is fundamental to the acceptability of the scheme.
>
> 16. No development shall take place until a report outlining how carbon emissions from the construction process and embodied carbon have been minimised has been submitted to and approved in writing by the Local Planning Authority. The development shall thereafter be carried out in accordance with the recommendations contained in the approved report. Reason: To ensure that the development achieves a reduced carbon footprint in accordance with Policy Bicester 1 of the Cherwell Local Plan Part 1 2011-2031. This information is required prior to the commencement of any development as it is fundamental to the acceptability of the scheme.

3. Energy Strategy

3.1. Condition 14 requires the development to achieve zero carbon energy. Additional conditions attached to the original outline application require the development parcel to connect to the district heating scheme that is currently operational and serving the existing housing on the development, and provide solar PV systems to all dwellings.

3.2. The overall energy supply approach is therefore relatively constrained, requiring the minimisation of energy demand, supply of heat and hot water via the energy centre (supplied by CHP plant) and offset of additional emissions through individual PV systems.

3.3. In order to deliver the zero carbon requirements, the first stage of the energy strategy will be to minimised energy demand, accordance with the Energy Hierarchy as referenced in Policy ESD 2.

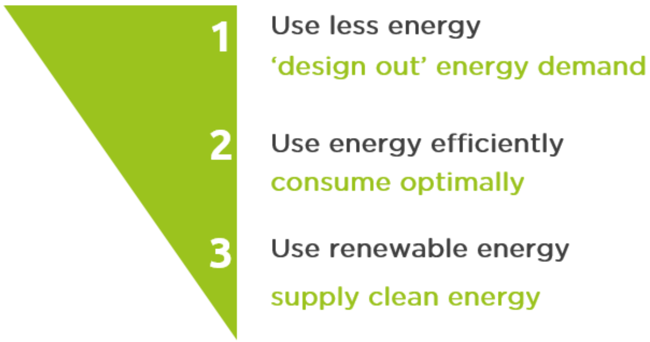


Figure 2. The Energy Hierarchy

3.4. As this hierarchy demonstrates, designing out energy use is weighted more highly than the generation of low-carbon or renewable energy to offset unnecessary demand. Applied to the development of new housing, this approach is referred to as 'fabric first' and concentrates finance and efforts on improving U-values, reducing thermal bridging, improving airtightness, and installing energy efficient ventilation and heating services.

Be Lean

3.5. The design of a development - from the masterplan to individual building design - will assist in reducing energy demand in a variety of ways, with a focus on minimising heating, cooling and lighting loads. Key considerations include:

- Building orientation – maximise passive solar gain and daylight
- Building placement – control overshading and wind sheltering
- Landscaping – control daylight, glare and mitigate heat island effects
- Building design – minimise energy demand through fabric specification

Be Clean

3.6. The design and specification of building services to utilise energy efficiently is the next stage of the hierarchy, taking into account:

- High efficiency heating and cooling systems
- Ventilation systems (with heat recovery where applicable)
- Low energy lighting
- High efficiency appliances and ancillary equipment

Be Green

3.7. Low carbon and renewable energy systems form the final stage of the energy hierarchy and can be used to directly supply energy to buildings, or offset energy carbon emissions arising from unavoidable demand. This may be in the form of:

- Low carbon fuel sources – e.g. biomass
- Heat pump technologies
- Building scale renewable energy systems
- Small-scale heat networks
- Development-scale heat networks

3.8. This approach has been widely supported by industry and Government for some time, with the Zero Carbon Hub[1] and Energy Savings Trust[2] having both stressed the importance of prioritizing energy demand as a key factor in delivering resilient, low energy homes.

3.9. There is further explicit acknowledgement of the benefits of this approach through the introduction of Fabric Energy Efficiency Standards into Part L of the Building Regulations 2013,

[1] Zero Carbon Hub, Zero Carbon Strategies for tomorrow's new homes, Feb 2013.

[2] Energy Saving Trust, Fabric first: Focus on fabric and services improvements to increase energy performance in new homes, 2010

which is intended to "discourage excessive and inappropriate trade-offs… for example… poor insulation standards being offset by renewable energy systems with uncertain service lives."[3]

3.10. The benefits to prospective homeowners of following the Fabric First approach are summarised in Table 1.

Table 1. Benefits of the Fabric First approach

	Fabric energy efficiency measures	Bolt-on renewable energy technologies
Energy/CO_2/fuel bill savings applied to all dwellings	✓	×
Savings built-in for life of dwelling	✓	×
Highly cost-effective	✓	×
Increases thermal comfort	✓	×
Potential to promote energy conservation	✓	✓
Minimal ongoing maintenance / replacement costs	✓	×
Significant disruption to retrofit post occupation	✓	×

Construction Specification

3.11. The proposed construction specification to reduce energy demand from the development is shown in Table 2.

Table 2. Proposed construction specification – main elements

	Part L1A Limiting Fabric Parameters	Proposed Fabric Specification
External wall – u-value	0.30 W/m²K	0.21 W/m²K
Party wall – u-value	0.20 W/m²K	0.00 W/m²K
Plane roof – u-value	0.20 W/m²K	0.11 W/m²K
Ground floor – u-value	0.25 W/m²K	0.12 – 0.14 W/m²K
Windows – u-value	2.00 W/m²K	1.3 W/m²K
Air permeability	10 m³/h.m² at 50 Pa	5.01 m³/h.m² at 50 Pa
Thermal Bridging	Y = 0.150 (default)	Y = ~ 0.055

Air leakage

3.12. After conductive heat losses through building elements are reduced, convective losses through draughts are the next major source of energy wastage. It is assumed at this stage that the dwellings will be designed to achieve an airtightness standard of no greater than 5.01 m³/h.m²@50Pa, a significant enhancement on Part L1A minimum requirements.

3.13. Pressure testing in accordance with Building Regulations and ATTMA standards will be undertaken to all units on completion to confirm that the design figure has been met.

[3] The Building Regulations 2010, Approved Document L1A

Fabric Energy Efficiency

3.14. In addition to the CO_2 reduction targets, the importance of energy demand reduction as a first principle was further supported by the introduction of a minimum fabric standard into Part L1A 2013, based on energy use for heating and cooling a dwelling. This is referred to as the 'Target Fabric Energy Efficiency' (TFEE), and expressed in $kWh/m^2/year$.

3.15. This standard enables the decoupling of energy use from CO_2 emissions and serves as an acknowledgement of the importance of reducing demand, rather than simply offsetting CO_2 emissions through low carbon or renewable energy technologies.

3.16. The TFEE is calculated based on the specific dwelling being assessed with reference values for the fabric elements contained within Approved Document L1A.

3.17. The proposed dwellings have been modelled in approved SAP software using the fabric specification described, demonstrating that the proposed construction specification will deliver savings of approximately 8-12% over the Part L compliance target as shown in Table 3.

Table 3. Fabric Energy Efficiency by housetype

	Target FEE ($kWh/m^2/yr$)	Dwelling FEE ($kWh/m^2/yr$)	% Reduction
Cromer (Mid)	44.67	39.41	11.77
Cromer (Semi)	53.33	48.56	8.93
Evesham	52.18	47.58	8.82
Marlborough	59.41	53.3	10.29
Dartford	56.34	51.79	8.07
Romsey	57.66	52.52	8.91
Dorking	55.25	50.44	8.71
Roydon	54.73	50.15	8.38
Windsor	58.86	53.65	8.84
Buckingham	54.69	49.29	9.86

Energy Centre

3.18. The dwellings are required to connect to the existing energy centre on the development, which is operational and serving the rest of the exemplar development site through a combination of gas-fired CHP with back-up gas boilers.

3.19. The design system performance as supplied by the plant operator and utilised for the SAP calculations is shown in Table 4:

Table 4. CHP and Boiler efficiencies

	CHP	Gas boilers
Percentage of heat	90	10
Heat/power ratio	1.03	-
Electrical efficiency	41.43	-
Thermal efficiency	42.67	87.02

Elmsbrook current Zero Carbon status

3.20. A regular monitoring report is undertaken by Bioregional, to assess annual data from the development and current status with respect to achieving zero carbon development.

3.21. The report notes that the system is extremely dynamic, with ongoing construction and changing loading on the existing energy centre as well as annual weather and sunlight variations affecting the overall system balance.

3.22. The October 2019 Final Report concluded that during 2018/2019, the development as a whole did not quite meet true zero carbon, however substantial savings were realised and the total emissions for the residential development, energy centre and school equated to circa 115 tonnes net CO_2 emissions, higher than the previous year of -25 tonnes CO_2.

3.23. The reasons for the shortfall in 18/19 were summarised as follows

- Higher than designed heat losses due to Phase 3 & 4 commissioning losses
- CHP outages, some due to contractor error leaving underground bypass open following work on future phase leading to high return temperatures

- Inverter failures leading to lost PV output, including a block of flats where output was lost for the entire year
- Incomplete PV data due to meter failures

3.24. The report additionally stated: "By the end of phase two, the proportion of heat supplied by CHP as compared with gas boiler split was intended to be 90:10 but this is currently not the case.

> *"Re-running the site wide carbon emissions calculations with the intended 90% CHP utilisation the development does achieve its true zero carbon status over the monitoring period."*

3.25. Due to the previous year demonstrating a positive net carbon balance, and clear reasoning for the shortfall in the 2018/19 figures, it is therefore considered that continuing the strategy of connecting to the existing heat network, reducing energy demand and maximising solar PV systems constitutes an appropriate approach for Phase 4 of the development to individually and collectively achieve Zero Carbon.

4. As Designed Performance - After Fabric and CHP

4.1. The SAP calculations demonstrate that by following the strategy set out, all dwellings will deliver savings of circa 75% over the Part L compliant baseline through demand reduction and connection to the heat network serving the development.

Table 5. Dwelling emissions after fabric and CHP

	Target Emission Rate ($kgCO_2/m^2/yr$)	Dwelling Emission Rate ($kgCO_2/m^2/yr$)	% Reduction
Cromer (Mid)	17.33	4.53	73.86
Cromer (Semi)	19.00	4.83	74.58
Evesham	17.79	4.59	74.2
Marlborough	17.37	4.24	75.58
Dartford	16.52	4.09	75.24
Romsey	17.51	4.35	75.15
Dorking	16.06	4.24	73.6
Roydon	15.38	3.75	75.62
Windsor	15.99	4.14	74.11
Buckingham	15.83	3.93	75.17

4.2. Solar PV systems are therefore required to deliver further offset in accordance with the zero carbon objective and Condition 5.

Additional Fabric Measures

4.3. In lieu of high levels of PV generation, additional fabric measures have been modelled to establish if these are able to provide an effective approach to meeting the zero carbon objective. A sample calculation is presented for the 'Windsor' housetype, selected as it represents the largest of the proposed units and therefore most likely to benefit from an improved thermal envelope. All fabric elements have been improved, the,air pressure test target lowered and an MVHR system introduced.

Table 6. Additional fabric uplifts modelled

	Proposed Fabric Specification	Potential Uplifted Specification
External wall – u-value	0.21 W/m^2K	0.15 W/m^2K
Plane roof – u-value	0.11 W/m^2K	0.09 W/m^2K
Ground floor – u-value	0.12 – 0.14 W/m^2K	0.11 W/m^2K
Windows – u-value	1.3 W/m^2K	1.2 W/m^2K
Air permeability	5.01 $m^3/h.m^2$ at 50 Pa	3 $m^3/h.m^2$ at 50 Pa
Thermal Bridging	Y = 0.043	Y = 0.036

4.4. This demonstrates that due to the reduction in benefit gained from the CHP plant, additional fabric measures do not improve the overall carbon balance of the dwellings based on the SAP calculation of carbon emissions and therefore a PV-led approach in accordance with Condition 5 will be pursued.

Table 7. Sample unit uplift testing

	Target Emission Rate ($kgCO_2/m^2/yr$)	Dwelling Emission Rate ($kgCO_2/m^2/yr$)	% Reduction
Windsor – proposed	15.99	4.14	74.11
Windsor - uplift	15.99	4.76	70.23

5. As Designed Performance - After Solar PV

5.1. It is proposed that solar PV systems are installed to all dwellings, an extract from the solar PV plan is shown in Figure 3 below:

Figure 3. Extract from PV plan

5.2. The dwelling emissions after solar PV systems are shown per housetype (typical result) in Table 8 demonstrating that the majority of units are able to deliver negative emissions using the proposed approach.

Table 8. Dwelling emissions after fabric, CHP and solar PV

	Average TER $kgCO_2/m^2/yr$	Average $kgCO_2$ offset from PV	Emissions $kgCO_2/Yr$ after PV	% Reduction
Cromer (Mid)	1235	1087	-770	162 %
Cromer (Semi)	1330	1108	-773	158 %
Evesham	1519	1440	-1054	169 %
Marlborough	2068	1956	-1450	170 %
Dartford	2106	1925	-1413	167 %
Romsey	1908	2597	-2131	211 %
Dorking	2247	1940	-1353	160 %
Roydon	2425	2050	-1480	160 %
Windsor	2592	636	20	99 %
Buckingham	2215	1940	-1400	163 %

5.3. Table 9 demonstrates the site-wide savings achieved:

Table 9 Site-wide carbon reductions

	Site wide $kgCO_2/yr$	Site wide savings $kgCO_2/yr$	% Reduction
Part L	103,757		
Before PV	25,657	78,100	75.27%
After PV	-73,658	177,415	170.99%

6. Overheating Risk

6.1. Condition 10 of the outline approval states:

10. Prior to commencement of residential development in each phase a study, by a suitably qualified person, shall be submitted to and approved in writing by the local planning authority, demonstrating that the design of the dwellings within that phase is such that overheating will not occur and that heat island effects have been minimised. The development shall thereafter be carried out in accordance with the agreed details.

Reason: To address the impacts of climate change in accordance with Planning Policy Statement 1: Eco Towns

6.2. The dwellings on Phase 4 are all two storey housing and are proposed to be of traditional masonry construction. They are therefore considered inherently at lower risk of overheating than some other dwelling typologies, notably lightweight structures and single aspect apartments.

6.3. In order to demonstrate this, a full dynamic simulation has been undertaken to assess two dwellings with different characteristics – a smaller attached unit and a detached dwelling with substantially larger glazed areas -under both currrent and future predicted weather scenarios.

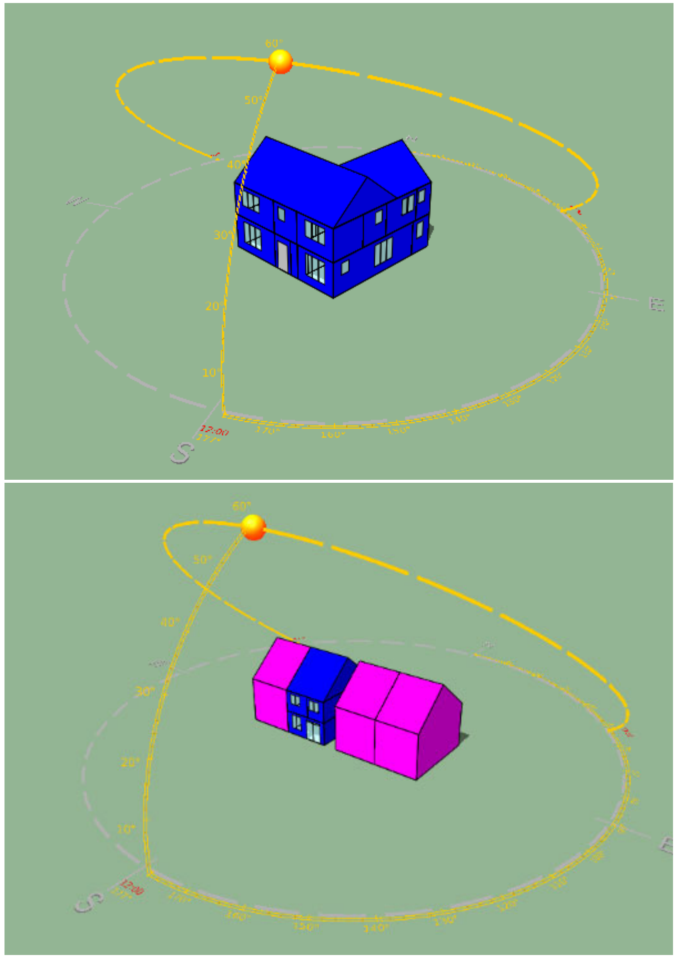
6.4. Initial results indicate that there is a risk of overheating using the base specification with a window U value of 1.40 / g-value of 0.72.

Table 10: Thermal modelling (CIBSE Location DSY 1 - 2050, high emissions, 50% scenario)

	Results Evesham / Royden
Base case (g-value 0.72)	Kitchen / Dining / Family (KDF) Fail
Mitigation Option 1 - (g-value 0.63)	KDF / Living Fail
Mitigation Option 2 - (g-value 0.50)	Pass to all rooms

6.5. The modelled Mitigation measure 2 is shown to be effective for all rooms (Living/ Kitchen/ Bedrooms) on dwellings at ground floor level.

6.6. Based on these results the window specification has been revised to incorporate a g- value of 0.50 in order mitigate the high risk of overheating. The full report is appended to this statement and may be referred to for further details.



Figures 4 & 5. 3D Model (IES VE) for sample housetypes

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7. Daylighting

7.1. Condition 15 states: "No development shall commence until details of how each dwelling within that phase achieves good day lighting by achieving at least 2 points of the former Code for Sustainable Homes level 5 for day lighting shall be submitted to and approved in writing by the Local Planning Authority. The development shall thereafter be carried out in accordance with the approved details such that each dwelling achieves good day lighting."

7.2. A daylighting assessment has been carried out to all dwellings, to calculate daylighting credits in accordance with CSH criteria. The results per housetype are summarised in Table 11 based on the worst case of each housetype – i.e. in closest proximity to relevant obstructions.

7.3. Credits are scored where:

- Kitchen ADF at least 2%
- 80% of working plane living/dining/study must receive direct light from the sky
- Living/dining/study much achieve ADF of at least 1.5

Table 11: Daylighting credits per housetype (worst case)

House type	Kitchen ADF	View of Sky 80%	Living/Dining/Study Room ADF (min)	Code Credits
Buckingham	2.9	N	1.5	2
Dartford	3.0	Y	<1.5	2
Dorking	3.1	N	1.5	2
Marlboroough	2.8	Y	<1.5	2
Romsey	2.3	N	2.3	2
Windsor	3.4	N	2.2	2
Cromer	1.5	Y	3.0	2
Evesham	1.6	Y	1.6	2
Roydon	2.3	Y	2.2	3

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8. Embodied Carbon

8.1. Condition 16 states: “No development shall take place until a report outlining how carbon emissions from the construction process and embodied carbon have been minimised has been submitted to and approved in writing by the Local Planning Authority. The development shall thereafter be carried out in accordance with the recommendations contained in the approved report.

8.2. An embodied carbon assessment has been undertaken and is attached to this document as Appendix B

8.3. The calculations were performed with One Click LCA calculation tool. The assessment methods conform with BS 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings

8.4. The LCA analysis includes the following elements:

- Substructure
- Superstructure
  - Frame
  - Upper floors incl. balconies
  - Roof
  - Stairs and ramps
  - External Walls
  - Windows and External Doors
  - Internal Walls and Partitions
  - Internal Doors

8.5. A range of carbon footprint reduction measures are described within the main report, including:

- Using construction products that are made from locally available raw materials, through energy efficient and low emission processes and by manufacturers local to the construction site.
- Transporting materials with low carbon vehicles.
- Designing the construction process to minimize waste and reuse or recycle products where possible.
- Reused materials such as brick, metal, wood and even broken concrete can make a big reduction in embodied carbon emissions. Due to the fact that the carbon used to make them is already accounted for in the manufacturer for its first use, reused materials have a much lower carbon footprint. Steel that's brand new has an embodied carbon footprint up to five times greater than recycled content steel.
- Use low-carbon concrete mixes.
- Concrete can be the biggest source of embodied carbon for any new site, using lower-carbon concrete is an easy change to make. Examples include using higher percentages of fly ash, slag, calcined clays or lower-strength concrete if possible.
- By designing a building to be able to change its use over time through flexible internal layouts to easily adapt to future use of occupants will minimize the need for future refurbishments.

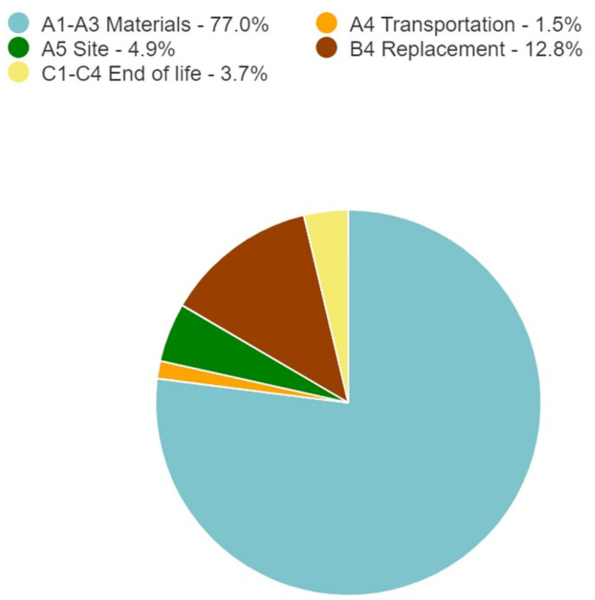

Figure 6. Total $kgCO_2e$ by life-cycle stage

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9. Conclusions

9.1. This Energy and Sustainability Statement has been prepared by AES Sustainability Consultants Ltd on behalf of Crest Nicholson Chiltern.

9.2. The proposals addressed within this statement constitutes a replan of the proposed Phase 4 of the Elmsbrook Eco Town development, comprising an amended housetype mix and a change in the total number of dwellings within this phase from 54 to 57.

9.3. This statement provides detail on the proposed energy and sustainability strategy for the residential parcel, confirming that the development will accord with the strategy required by Conditions 14, 15 and 16 concerning the zero carbon strategy, achievement of good internal daylight levels and embodied carbon emissions respectively.

9.4. It demonstrates that the development will follow the Energy Hierarchy approach to sustainable construction, reducing energy demand before considering energy supply and renewable energy systems to offset residual emissions.

9.5. Calculations are presented which demonstrate that through good standards of thermal insulation and connection to the existing site energy network, the dwellings will deliver a circa 75% saving on current Part L 2013 emissions standards.

9.6. Solar PV systems will then be specified to all dwellings in order to meet the site wide zero carbon target, in accordance with Condition 14

9.7. Calculations in accordance with the Code for Sustainable Homes procedure for the assessment of internal daylight levels have been carried out to all plots on the development, and the results demonstrate that all dwellings achieve at least the required 2 credits.

9.8. An embodied carbon assessment has been undertaken, describing the materials choices and providing an assessment of overall emissions associated with the building fabric.

9.9. The statement additionally describes measures undertaken to address overheating risk and consider a changing future climate. A full overheating risk assessment has been undertaken in accordance with CIBSE TM59 guidance and is appended to this document. The results of this assessment recommend a glazing specification designed to reduce unwanted solar gain.

Appendix A – Overheating Assessment

Elmsbrook NW, Bicester

Crest Nicholson Chiltern

Residential Summer Overheating Analysis
CIBSE TM59:2017

AES Sustainability Consultants Ltd

March 2021

	Author	Date	E-mail address
Produced By:	Silvio Junges	11.03.2021	Silvio.Junges@aessc.co.uk
Reviewed By:	Mitchell Bennellick	12.03.2021	Mitchell.Bennellick@aessc.co.uk

Revision	Author	Date	Comment
-	Silvio Junges	12.03.2021	Initial Issue

This report has been commissioned by Crest Nicholson Chiltern to assess the potential risk of overheating to a number of plots at Elmsbrook NW, Bicester. It should be noted that the details presented, including the proposed specifications, are subject to change as the detailed design of the dwellings progresses, whilst ensuring that the overall commitments will be achieved.

Contents

List of figures & tables

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1. Executive Summary

Purpose and scope of the statement

1.1. AES Sustainability Consultants Ltd has undertaken calculations to identify whether houses (Evesham or Royden) within Elmsbrook NW, Bicester will be at significant risk of overheating. The samples have been selected as their orientation and glazing areas represent a worst case for the proposed development.

1.2. This report uses room profiles assessed against CIBSE benchmarks outlined in CIBSE TM52:2013 and TM59:2017 for the analysis of the risk of overheating by using CIBSE weather files.

1.3. CIBSE TM59 provides a methodology to assess the risk of overheating in homes and has been used to carry out this analysis.

1.4. Compliance is based on passing BOTH of the following 2 criteria:

1) TM52 Criterion 1 must pass (Operative temperature cannot exceed the upper comfort limit for more than 3% of the occupied summer hours).

2) TM59 Bedrooms only - An additional requirement must be checked for the bedrooms to guarantee comfort during the sleeping hours. The resultant temperature in the bedroom from 10pm to 7am cannot exceed 26°C for more than 1% of annual hours (1% of hours between 22:00-07:00 for bedrooms is 32 hours).

1.5. The modelling has been conducted using design weather data taken from the file CIBSE Swindon Weather Centre - Design Summer Year 1 (CIBSE Swindon DSY 1 - 2050s, high emissions, 50% scenario). The weather files have been chosen as most appropriate following guidance from TM59:2017 and the CL2.1 SBEM Weather location lookup.

Figure 1. Proposed Site Layout

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CIBSE Location DSY 1 - 2050s, high emissions, 50% scenario

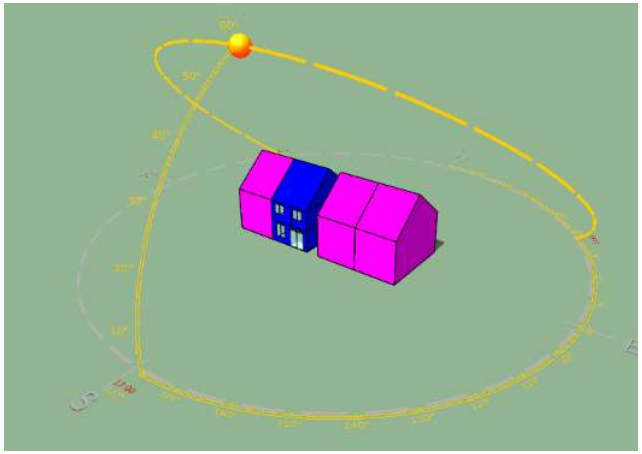
1.6. Initial results indicate that there is a risk of overheating using the base specification with a Windows U value of 1.40 / g-value of 0.72.

Table 1: Thermal modelling results (CIBSE Location DSY 1 - 2050, high emissions, 50% scenario)

	Results Evesham / Royden
Base case (g-value 0.72)	Kitchen / Dining / Family (KDF) Fail
Mitigation Measure 1 (g-value 0.63)	KDF / Living Fail
Mitigation Measure 2 (g-value 0.50)	Pass to all rooms

1.7. The modelled Mitigation measure 2 is shown to be effective for all rooms (Living/ Kitchen/ Bedrooms) on dwellings at ground floor level.

1.8. Based on these results we would recommend that the window specification is revised to incorporate a g- value of 0.50 in order mitigate the high risk of overheating.



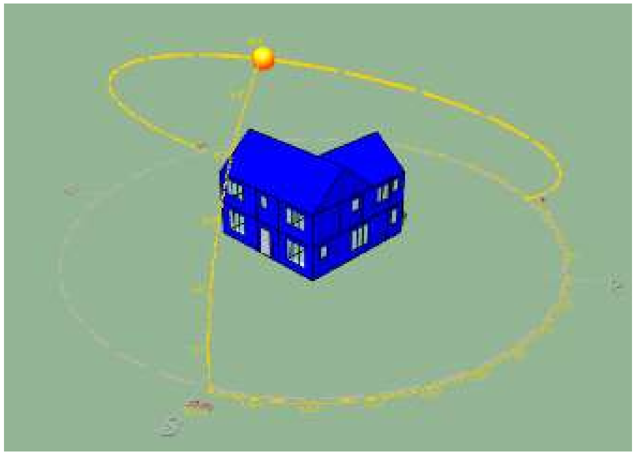


Figure 2 & 3. 3D Model (IES VE)

2. Scope and Limitations

2.1. Part L1A – Building Regulations 2013 Criterion 3 – Limiting the effects of solar gains during the summer states that reasonable provision should be made to limit solar gains. This can be achieved by an appropriate combination of window size and orientation, solar protection through shading and other solar control measures, ventilation (day and night) and high thermal capacity.

2.2. This is assessed within SAP in terms of regulatory compliance, however, this is a not a particularly sensitive analysis. Assessing the risk in accordance with CIBSE guidance provides a more in-depth analysis.

2.3. Living areas and bedrooms are the rooms that should be considered most closely as it is envisaged that these will be the rooms occupied for significant periods of time. Bedroom temperatures are likely to be most critical as people find sleeping difficult in the heat. Rooms such as bathrooms, circulations spaces, store rooms and kitchens do not have overheating criteria or a suggested maximum temperature as it is envisaged that no one will occupy these rooms for a significant period of time.

2.4. The purpose of this report is to ascertain whether internal temperatures are likely to exceed the criterion recommended in CIBSE TM59:2017 – Design methodology for the assessment of overheating risk in homes.

2.5. This methodology provides a baseline for all domestic overheating risk assessments. and will:

1) Allow different designs to be compared with a common approach based on reasonable assumptions.
2) Support design decisions that improve comfort without cooling.
3) Provide consistency across the industry as all consultants will be using the same methodology for overheating risk prediction.

2.6. This methodology will not:

1) Guarantee that people will always be comfortable, however they act.
2) Take into account unusual use.

2.7. Compliance is based on passing BOTH of the following 2 criteria:

a) TM52 Criterion 1 must pass (Operative temperature cannot exceed the upper comfort limit for more than 3% of the occupied summer hours)
b) TM59 Bedrooms only - An additional requirement must be checked for the bedrooms to guarantee comfort during the sleeping hours. The resultant temperature in the bedroom from 10pm to 7am cannot exceed 26°C for more than 1% of annual hours (1% of hours between 2200-0700 for bedrooms is 32 hours).

2.8. If a dwelling fails above criteria, measures should be investigated to reduce internal temperatures and therefore reduce the likelihood of overheating.

2.9. To ensure that the CIBSE standards are met it is necessary to use appropriate simulation software in the design process and introduce adequate measures to ensure it is maintained within the completed dwellings. In order to assess the overheating risk IES Virtual Environment has been used. IES Virtual Environment is a state-of-the-art dynamic modelling software tool for assessing building energy, carbon, lighting and thermal comfort.

2.10. IES version 2019 'Apache Sim' has been used to carry out dynamic simulation to analyse the thermal comfort likely to be experienced within dwellings. The full dynamic simulation in accordance with CIBSE TM59:2017 combines the effects of:

- Annual Design Summer Year (DSY) weather data as produced by CIBSE;
- Casual, lighting and people heat gains;
- Thermal mass of the building;
- Solar heat gain.

2.11. All results and strategies are directly affected by the inputs listed in this document. Any deviations from these will affect the results. It is important to note that with any modelling exercise there are assumptions and approximations that have to be made. Details of all assumptions made and approximations used are supplied as part of the report.

2.12. The results give an indication of the predicted environmental conditions based on weather data and the anticipated operation strategy of the building.

2.13. The predicted simulated internal temperatures generated by the software may not match the actual internal air temperatures due to several reasons, for example, change in space function, use of equipment, natural wear and tear of building elements, global climate change and metrological changes, change in operation management of apertures etc.

3. Introduction to Overheating in Modern Dwellings

3.1. The project team should consider the risk of overheating in their building designs very early in the design process as it has the potential to not only cause discomfort for building occupants, but also cause potentially harmful medical conditions such as dehydration or heat exhaustion.

3.2. People may feel hot, uncomfortable and show lower productivity when temperatures reach between 25-28°C. Indoor operative temperatures that stay at or over 28°C for long periods of the day will result in dissatisfaction for many occupants. This can be expressed as the occupant experiencing thermal discomfort and in some cases thermal stress. Thermal discomfort is where occupants feel uncomfortable as they are too hot (or cold). Thermal stress is where the thermal environment will cause potentially harmful medical conditions such as dehydration or heat exhaustion. Vulnerable people, such as the elderly are particularly susceptible to health problems due to overheating.

3.3. Homes in the UK have not historically been associated with overheating. This is most likely due to a combination of the heavyweight materials from which they were constructed, a low level of thermal insulation and high levels of uncontrolled ventilation through minor gaps in the fabric.

3.4. The use of heavyweight materials provides high thermal mass within the building envelope. This ensures that external daily temperature variations are not reproduced as quickly inside the building because the fabric will absorb heat during the day and release it slowly when temperatures drop at night. In this way, the impact of maximum heat levels reached during the day is delayed by the thermal mass of the building and can be counter-balanced by strategies that make use of the cool of the night.

3.5. Modern homes are usually constructed from lightweight materials, are highly insulated, have been built to high standards of air tightness and have double-glazed windows that have coatings specifically designed to trap the sun's heat. This results in more heat being retained within the homes which is not able to be absorbed by the lightweight fabric.

3.6. Rooms with large glazing areas to their South and West facades are likely to be those at highest risk of overheating. South facades receive the highest amount of direct sunlight when the sun is highest, whilst West facades experience unwanted solar gains from low-level sun in the evenings. Proposed mitigation measures need to take account of the difference in the position of the sun during the day as some measures will work on certain facades but not on others. For example, overhangs can block out the sun when it is high in the sky but will have little effect if installed on West facing elevations when the sun is low in the sky.

3.7. Overheating in apartments is a greater risk where apartments are designed with a single-aspect and where community heating pipework is routed through corridors and common spaces. In these situations, high internal temperatures are often caused by a combination of inadequate ventilation and excessive heat discharged by heating pipework.

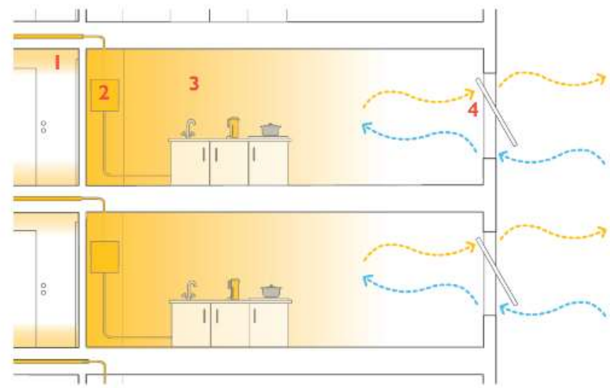


Figure 4. Service design in apartments, cumulative effects of individual heat gains

3.8. Mechanical services installed in apartments cause heat gains in the same way as in houses; however with limited scope for ventilation their impact becomes more significant. Consequently, a different strategy is required to ensure that unwanted heat is removed. In blocks where space and water heating is provided by a community heating system, the CIU is permanently charged with hot water all year round to meet the hot water demand. This unit, particularly if not well insulated, may effectively emit heat like a radiator in the dwelling. It is often positioned in an unventilated cupboard or kitchen so heat transfers directly to the living spaces.

3.9. In addition, the distribution pipework for the community heating system often runs through the corridors and common spaces. Since this pipework is constantly emitting heat, it can cause high temperatures in these spaces, especially when there is insufficient ventilation. Even well-insulated heating systems will emit heat, albeit at a slower rate. Unless there is a strategy to remove this heat it will be transferred from common areas into the adjacent apartments.

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4. Methodology and Key Assumptions

Methodology

4.1. CIBSE has undertaken considerable consultation and research on the impact of climate change on the indoor environment and weather data. TM52:2013, TM59:2017, CIBSE Guide A 2015, AD Part L1A 2013, AD Part F 2013 and SAP 2012 provide data on maximum average temperatures, ventilation rates and overheating criteria for areas of dwellings as illustrated below. We have used this data as the basis for our analysis and the recommendations presented in this report.

4.2. Building Regulations Part F 2013 states that for dwellings the whole dwelling ventilation rate for the supply of air to the habitable rooms should be no less than the rates detailed in the Table 2 below.

Table 2: Part F minimum standards for new dwellings

Room	Intermittent extract	Continuous extract	
	Minimum rate	**Minimum high rate**	**Minimum low rate**
Kitchen	30 l/s adjacent to hob; or 60 l/s elsewhere	13 l/s	Total extract rate should be at least the **whole dwelling ventilation** rate given in Table 5.1b
Utility room	30 l/s	8 l/s	
Bathroom	15 l/s	8 l/s	
Sanitary accommodation	6 l/s	6 l/s	

4.3. The proposed ventilation for all of the houses on this development is intermittent. These units individually extract air from wet rooms, such as bathrooms and kitchens.

4.4. Intermittent fans are operated by the occupant and for the purpose of this assessment, they have been ignored.

Weather Data

4.5. Our analysis has been carried out using average weather data appropriate to the location of the proposed development. The weather files that have been used are CIBSE Swindon Weather Centre:

- CIBSE Swindon DSY 1 - 2050s, high emissions, 50% percentile scenario

4.6. Figure 5 below shows a typical metrological year for Swindon using DSY 1 2050 weather data. Dry bulb temperature excees 31.6°C in August and the maximum adaptive temperature is exceeded 46 hours over the course of a year..

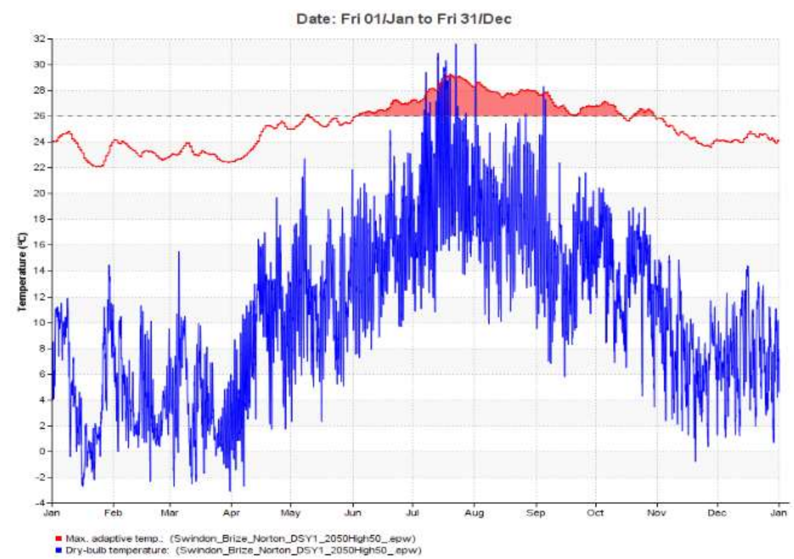

Figure 5: Temperature profile CIBSE Swindon DSY 01 2050, high emissions, 50% percentile scenario [Screenshot - Climate consultant v6.0]

Development Design

4.7. The modelling has been based upon the architectural plans: issue dated 18.01.2021 provided by PAD Architects, on 26.02.2021 to AES. For more detailed designs, please see Appendix B of this report.

4.8. The following design criteria have been used in the modelling software to perform the calculations and modelling to assess the risk of summertime overheating.

Building Fabric

4.9. The building elements were modelled according to the construction specification detailed in the table below, with derivation of an overall U-value calculated using the BRE U-value calculator, or by the software used for the overheating analysis.

Table 3: Baseline Building Fabric

Construction Elements	U-value in [W/m2K]	Kappa in (kJ/m²K)
Ground Floor	0.12	83
External Wall	0.25	60
Main Roofs	0.11	9
Int. Ceiling & Floor	N/A	9
Party Wall	N/A	60
Internal Partitions	N/A	9
Windows	U=1.40	g=0.72
Infiltration	CIBSE A 2015 - Table 4.24	0.25 ACH

*Kappa values stated for structural element only. DSM model accounts for low thermal mass including the plasterboard of the suspended ceiling.

Lighting Gains

4.10. The following table summarises the assumed lighting gains used in the base model. Light energy is assumed to be proportional to the floor area. Only summer months are assessed from 6pm to 11 pm.

Table 4: Lighting Gains

Area	Lighting Gains in (W/m2)	Notes
All rooms	2.0	TM59

Natural Ventilation

4.11. One of the most effective ways of addressing the risk of overheating in homes is to have a well thought out strategy for purge ventilation (supply of large amounts of fresh air in a short period of time).

4.12. This can be achieved by providing means for cross-ventilation, circulating large amounts of air through the home. Where mechanical ventilation is used, occupants should still be able to open windows adequately and in a secure manner, even if only for a short period of time.

Table 5: Ventilation & Shading Strategy

	Notes
Ventilation Strategy	Calculated natural ventilation (MacroFlo). Windows / doors are allowed to be open when internal temperatures are higher than ambient temperatures and internal dry-bulb temperature exceeds 22°C.
Shading Strategy	Shade from neigbouring dwellings included

4.13. Natural ventilation via openable windows has been allowed during times when the room being assessed is occupied. For a more detailed schedule of ventilation assumptions, please see Appendix D of this report.

Occupancy Gains

4.14. Maximum Sensible Gain assumptions are based on CIBSE Guide A 2015 at 75 W/person and Maximum Latent Gain of 55 W/person. See Appendix C for full occupancy profiles.

Equipment Gains

4.15. It is assumed that dwellings with the same number of occupants and bedrooms are usually provided with the same appliances, therefore any gains resulting from them is assumed to be independent of floor area.

4.16. The following equipment gains have been assumed for the rooms being assessed. Equipment gains for the living room are based on CIBSE TM59. Variation profiles are shown in Appendix C.

Table 6: Equipment gains

Room	Equipment gains (W)	
Living/Kitchen	450	ICT (information and communications technologies), Audio-visual and Kitchen appliances and others
Bedroom	80	Laptop or TV
HIU (in cupboard)	78	Cupboard pipework for gain and HIU 50W

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5. Results – Summertime Overheating Modelling

5.1. The following table illustrate the results using the design specification, mechanical and natural ventilation. The results are compared with the recommendations from TM59:2017 as stated earlier in this report.

Items within the table:

- Items in Red DO NOT comply with the CIBSE recommendations
- Items in Green DO comply with the CIBSE recommendations

5.2. Natural ventilation via openable windows has been allowed once the internal air temperature exceeds a comfortable temperature, which is modelled as 22°C.

5.3. Compliance is based on passing BOTH of the following 2 criteria:

1) TM52 Criterion 1 must pass (Operative temperature cannot exceed the upper comfort limit for more than 3% of the occupied summer hours)

2) TM59 Bedrooms only - An additional requirement must be checked for the bedrooms to guarantee comfort during the sleeping hours. The resultant temperature in the bedroom from 10pm to 7am cannot exceed 26°C for more than 1% of annual hours. (1% of hours between 22:00-07:00 for bedrooms is 32).

Results - Natural Ventilation - (Base Case)

5.4. The below table shows the detailed results against CIBSE TM59:2017 criteria when using a glazing g-value of 0.50 to all elevations.

Table 7. Results – Natural Ventilation (Base Case)

Houses	Room Name	Criteria 1	Criteria 2	Pass / Fail
Eavesham	Living	4.1	N/A	Fail
	Kitchen	2.5	N/A	Pass
	Bedroom 01	1.8	27	Pass
	Bedroom 02	1.1	14	Pass
	Bedroom03	2.1	20	Pass
Royden	Living Room	2.9	N/A	Pass
	Kitchen / Dining / Family	3.5	N/A	Fail
	Bedroom 01	1.9	29	Pass
	Bedroom 02	1.5	23	Pass
	Bedroom 03	1.3	22	Pass
	Bedroom 04	2.1	25	Pass
	Bedroom 05	1.6	21	Pass

5.5. The results show there is a significant risk of overheating within the living & Kitchen / Dining / Family when compared with CIBSE TM59. The maximum hours of exceedance are not above the 3% threshold.

5.6. The results show that the predicted hours over and above 26°C in Bedrooms between 10pm and 7am are less than 32 hours in total and therefore the second design criteria is met.

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Results - Natural Ventilation - (Mitigation 1)

5.7. The below table shows the detailed results against CIBSE TM59:2017 criteria when using a glazing g-value of 0.63 to all elevations.

Table 8. Results – Natural Ventilation (Mitigation 1)

Houses	Room Name	Criteria 1	Criteria 2	Pass / Fail
Eavesham	Living	3.8	N/A	Fail
	Kitchen	2.3	N/A	Pass
	Bedroom 01	1.6	26	Pass
	Bedroom 02	1.1	14	Pass
	Bedroom03	1.9	20	Pass
Royden	Living Room	2.7	N/A	Pass
	Kitchen / Dining / Family	3.2	N/A	Fail
	Bedroom 01	1.7	29	Pass
	Bedroom 02	1.4	21	Pass
	Bedroom 03	1.2	20	Pass
	Bedroom 04	2.0	25	Pass
	Bedroom 05	1.5	20	Pass

5.8. The results show there is a significant risk of overheating within the living & Kitchen / Dining / Family when compared with CIBSE TM59. The maximum hours of exceedance are not above the 3% threshold.

5.9. The results show that the predicted hours over and above 26°C in Bedrooms between 10pm and 7am are less than 32 hours in total and therefore the second design criteria is met.

Results - Natural Ventilation - (Mitigation 2)

5.10. The below table shows the detailed results against CIBSE TM59:2017 criteria when using a glazing g-value of 0.50 to all elevations.

Table 9. Results – Natural Ventilation (Mitigation 2)

Houses	Room Name	Criteria 1	Criteria 2	Pass / Fail
Eavesham	Living	2.9	N/A	Pass
	Kitchen	1.9	N/A	Pass
	Bedroom 01	1.4	24	Pass
	Bedroom 02	1.0	13	Pass
	Bedroom03	1.6	13	Pass
Royden	Living Room	2.4	N/A	Pass
	Kitchen / Dining / Family	2.9	N/A	Pass
	Bedroom 01	1.4	28	Pass
	Bedroom 02	1.3	21	Pass
	Bedroom 03	1.1	20	Pass
	Bedroom 04	1.6	24	Pass
	Bedroom 05	1.3	18	Pass

5.11. The results show there is no significant risk of overheating within any rooms when compared with CIBSE TM59. The maximum hours of exceedance are not above the 3% threshold.

5.12. The results show that the predicted hours over and above 26°C in Bedrooms between 10pm and 7am are less than 32 hours in total and therefore the second design criteria is met.

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Appendix A – TM59 Risk factors

Risk Factors

A simple list of risk factors is provided below to assist in determining developments that have low risk of overheating and therefore do not require dynamic thermal modelling.

It is recommended that the risk factors are used for the assessment of all units and properties are identified as being at risk when they have answered 'yes' against any one of the risk factors below.

☐ Site location – South East England, Urban e.g. central London or in a high density urban area (UHI effect)

☐ Occupancy – Vulnerable people (elderly, disabled, young children), occupants likely to be at home during the day (e.g. students)

☐ Dwelling type – top floor, single aspect

☒ Fabric type – lightweight, dark colour facades, air tight constructions

☒ Orientation – South, south east/west

☒ Glazing – glazing ratio greater than 25%, roof lights

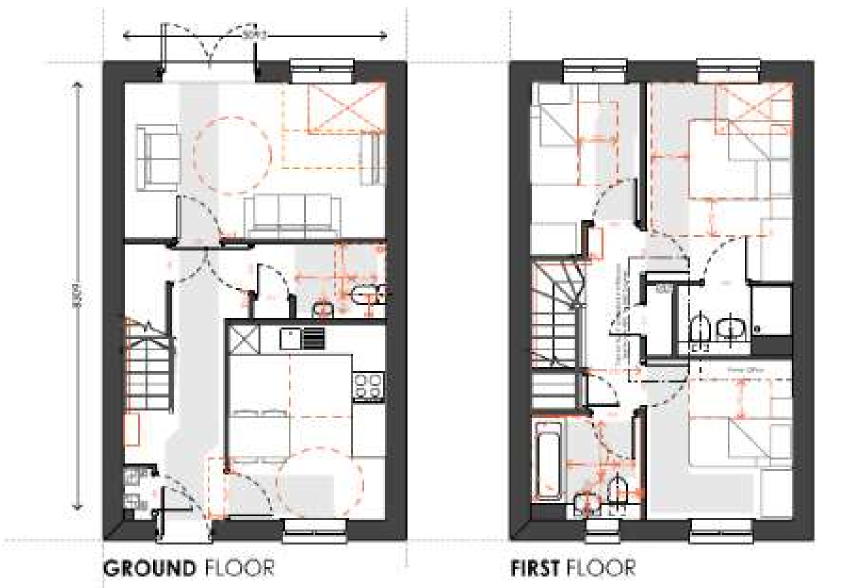
☐ Environmental factors that restrict the opening of windows – noise and air quality (e.g. near busy roads, railways, airports and flight paths, industrial activities, security (e.g. ground floor flats)

Appendix B – Dwelling designs

Development Design

The modelling has been based upon the architectural plans: issue dated 18.01.2021 provided by PAD Architects, on 26.02.2021 TO AES.

Floor Name:	Ground / First Floor
Plot Number:	Evesham



Floor Name:	Elevations
Plot Number:	Evesham

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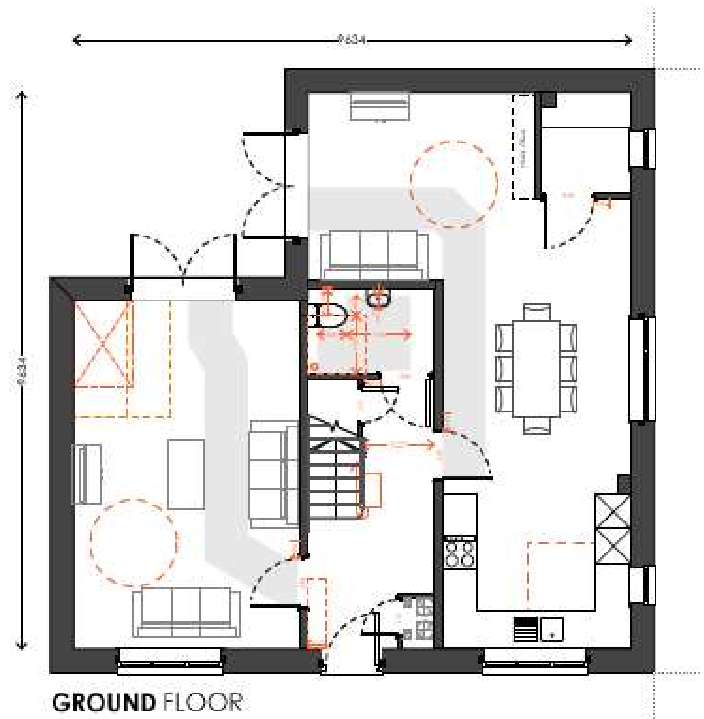
Floor Name:	Ground Floor
Plot Number:	Royden



Floor Name:	First Floor
Plot Number:	Royden

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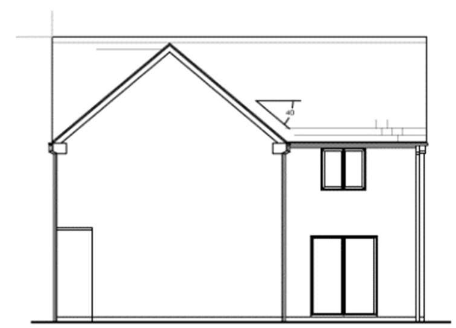
Floor Name:	Front / Side Elevation
Plot Number:	Royden

Floor Name:	Rear / Side Elevation
Plot Number:	Royden



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Appendix C – Modelling schedules

It is noted that the CIBSE TM59 method only assesses the overheating risk during occupied hours. The occupancy assumed is based on a typical lifestyle pattern for the occupants of each storey. The graphs illustrate the hours during which occupancy gains have been assumed.

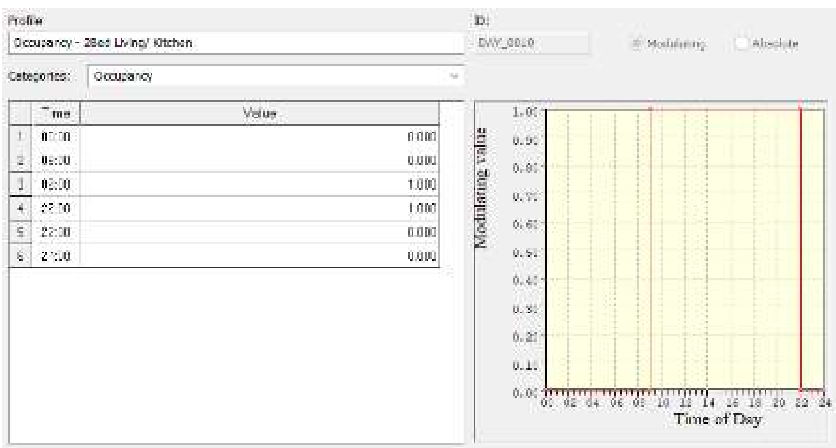
The houses have been modelled as occupied for 24 hours a day.

Kitchen / Living Rooms

Kitchen/Living rooms will be unoccupied during the sleeping hours and occupied during the rest of the day. This is the worst case scenario since the room will be modelled as occupied during the hottest hours of the day.

No differences between weekdays and weekend are considered.

Living / Kitchen occupancy



1, 2 bed dwelling kitchen/living

1 person from 9am to 10pm at 100% gains

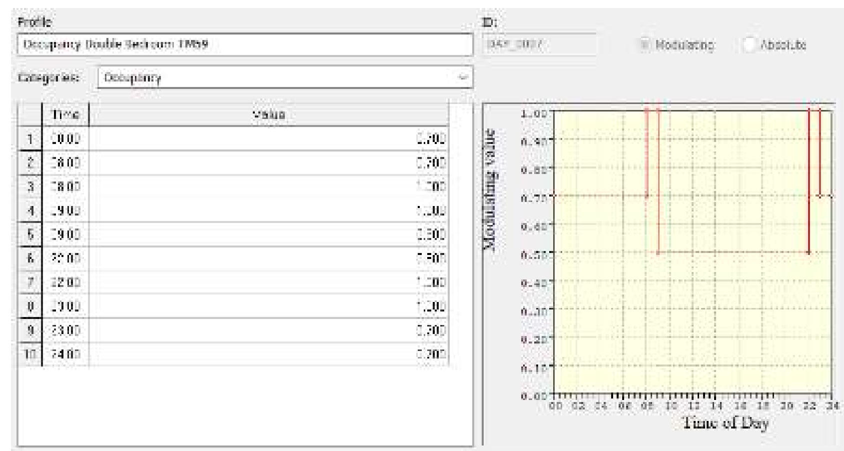
Room is unoccupied for the rest of the day

Double bedrooms

Bedrooms will be set with a 24h occupancy profile which means that 1 person is always considered inside the room during the daytime, and two people in each double bedroom at night.

For dwellings with more than 1 bedroom, 1 person will be considered during the daytime in both the bedrooms in order to assess the worst case scenario. This means that one excess person to the real number of occupants will be considered in the dwelling during the day (a visitor).

Double Bedroom occupancy



2 people are in the bedroom with 30% reduced gains from 11pm to 8am and with full gains from 8am to 9am and from 10pm to 11pm; 1 person at full gain is in the bedroom from 9am to 10pm

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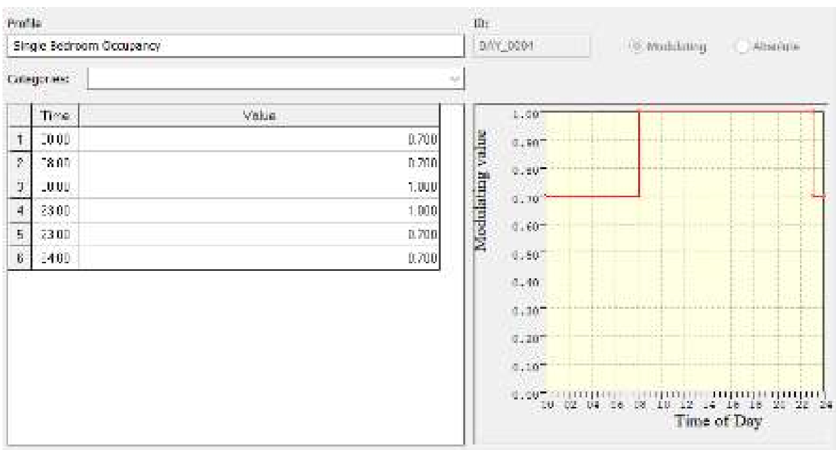
Single bedrooms

Bedrooms will be set with a 24h occupancy profile which means that 1 person is always considered inside the room during the daytime, and two people in each double bedroom at night.

For houses with more than 1 bedroom, 1 person will be considered during the daytime in both the bedrooms in order to assess the worst case scenario. This means that one excess person to the real number of occupants will be considered in the dwelling during the day (a visitor).

Single Bedroom occupancy

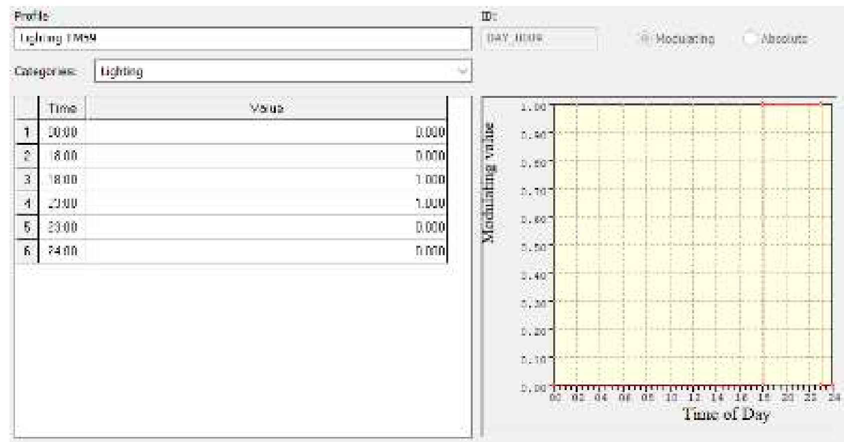


1 person is in the bedroom with 30% reduced gains from 11pm to 8am and with full gains from 8am to 11pm

Lighting

Light energy is assumed to be proportional to floor area, so W/m² is used for lighting load. 2 W/m² from 6pm to 11pm is used as default to reflect an efficient new build.

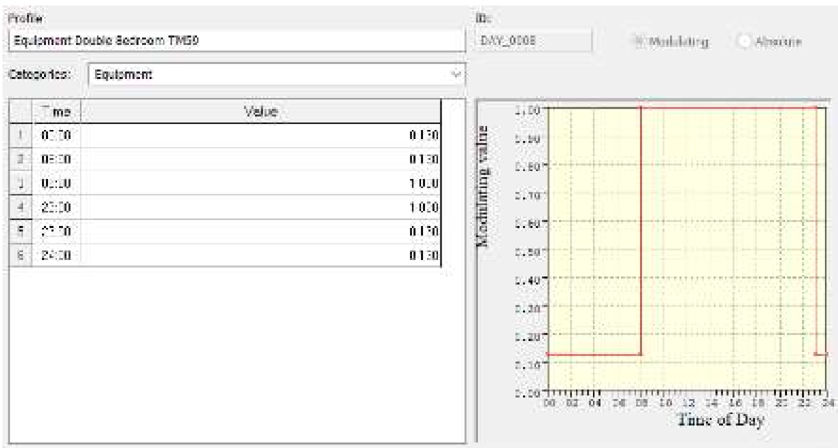
Lighting



Equipment loads and profiles

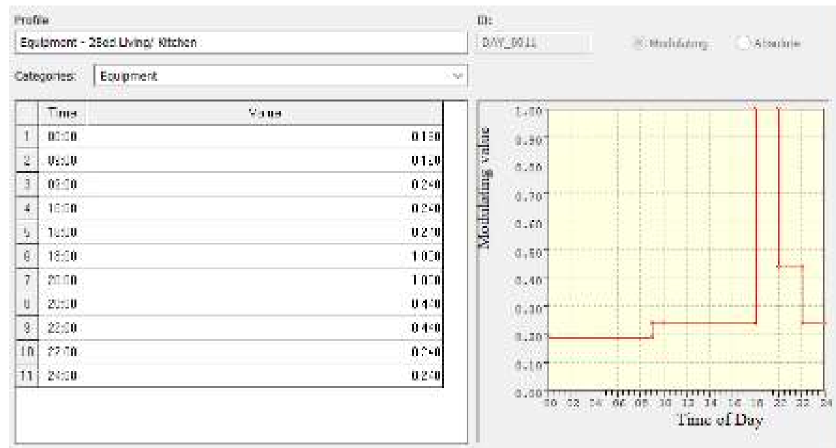
It is assumed that houses with the same number of occupants and bedrooms are usually provided with the same appliances, therefore the heat load from appliances is assumed to be independent of floor area for the purpose of overheating risk assessment. Heat loads from appliances are defined in Watts.

Single/ Double Bedrooms



Assumed equipment in the bedroom (e.g. laptop or TV) with a peak load of 80 W from 8am to 11pm and a base load of 10 W during the sleeping hours.

Living/Kitchen room – 1 Bedroom, 2 Bedroom Apartments



Peak load of 450 W from 6pm to 10pm. 200 W is assumed from 8pm to 10pm. 110 W is assumed from 9am to 6pm and from 10pm to 12pm. For the rest of the day a base load of 85 W is assumed.

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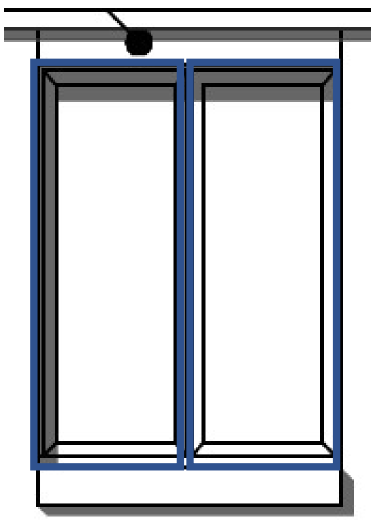
Appendix D - Assumptions for Natural Ventilation

In order to address the risk of security at ground floor level windows have been assumed closed when the rooms are not occupied.

In absence of a security risk above this level, all windows have been assumed openable 24/7 if the below conditions are met. The window schedule details below refer only to the openable parts of the windows. Glazing area which is not openable has been characterised as such in the software.

Evesham / GF Kitchen Window



Exposure Type:
Exposed wall

Category:
Window – side hung

Openable Area:
70% (frame factor 70%)

Max Angle Open:
30°

Proportions:
0.50 < Length/Height < 1

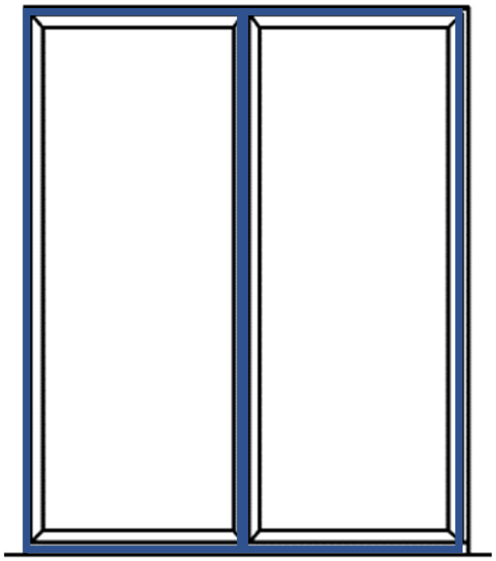
Equivalent area:
41%

Assumed openable::
09:00 – 22:00

Opening threshold 22°C, and internal temperature higher than ambient temperature

Notes: Closed during unoccupied night hours

Evesham / GF French Door



Exposure Type:
Exposed wall

Category:
Door – side hung

Openable Area:
70% (frame factor 70%)

Max Angle Open:
30°

Proportions:
Length/Height < 1

Equivalent area:
41%

Assumed openable::
09:00 – 22:00

Opening threshold 22°C, and internal temperature higher than ambient temperature

Notes: Closed during unoccupied night hours

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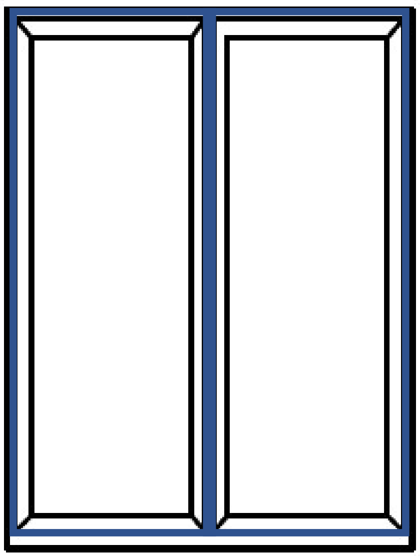
Evesham / GF LDK window



Exposure Type:
Exposed wall

Category:
Window – side hung

Openable Area:
70% (frame factor 70%)

Max Angle Open:
30°

Proportions:
0.50 < Length/Height < 1

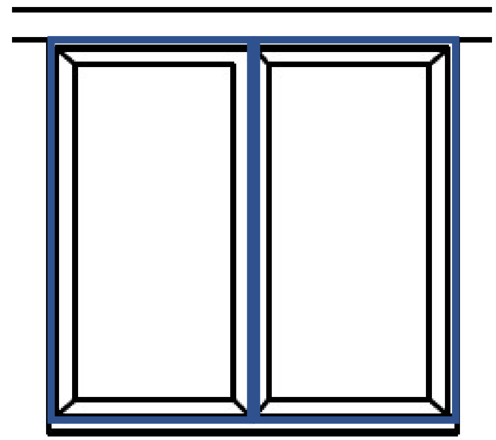
Equivalent area:
41%

Assumed openable::
09:00 – 22:00

Opening threshold 22°C, and internal temperature higher than ambient temperature

Notes: Closed during unoccupied night hours

Evesham / FF Bedrooms



Exposure Type:
Exposed wall

Category:
Window – side hung

Openable Area:
70% (frame factor 70%)

Max Angle Open:
30°

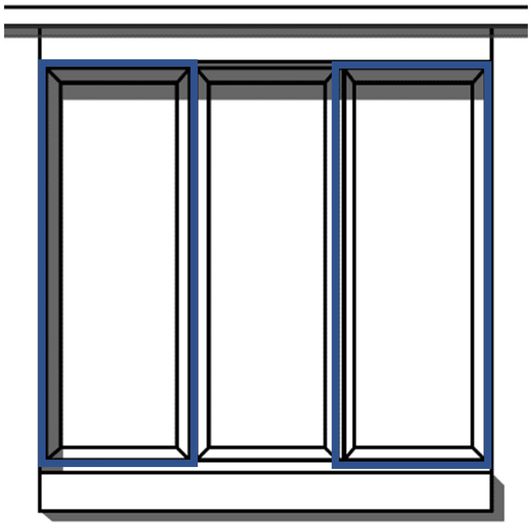
Proportions:
0.50 < Length/Height < 1

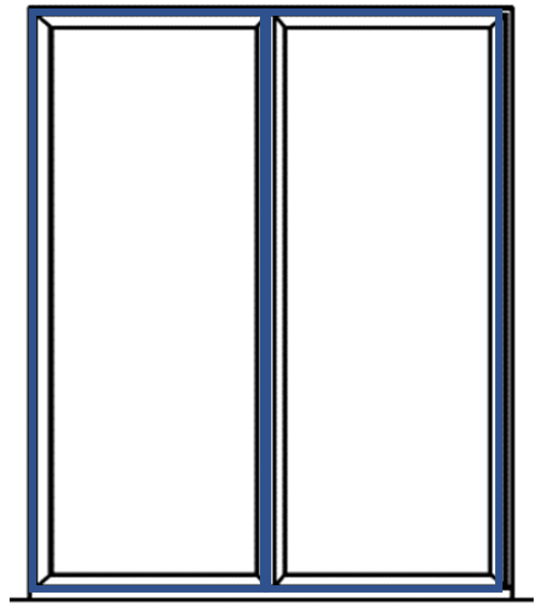
Equivalent area:
41%

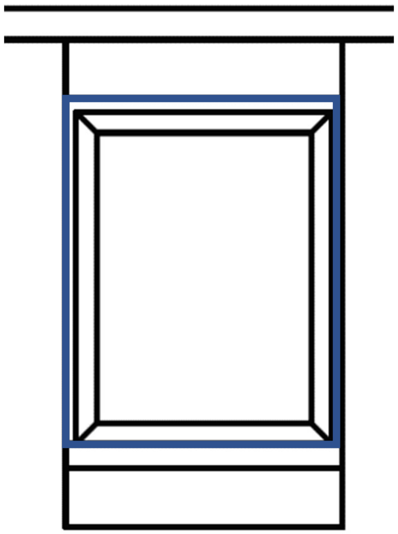
Assumed openable::
24/7

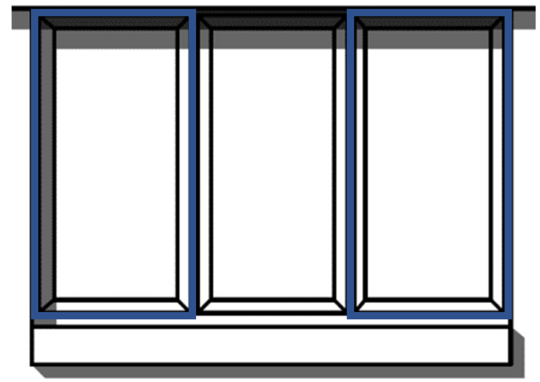
Opening threshold 22°C, and internal temperature higher than ambient temperature

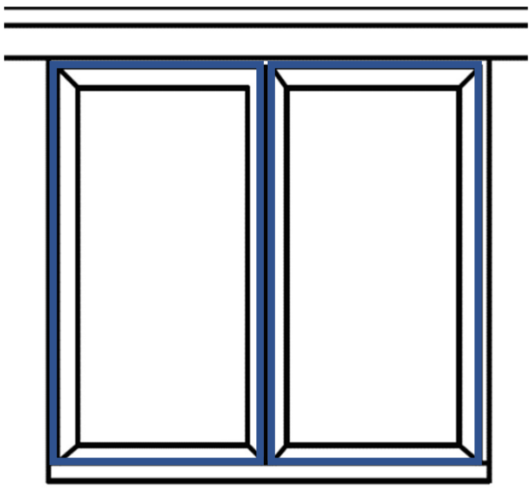
Notes: N/A

Royden / GF Living & LDK	
	Exposure Type: Exposed wall Category: Window – side hung Openable Area: 70% (frame factor 70%) Max Angle Open: 30° Proportions: 0.50 < Length/Height < 1 Equivalent area: 41% Assumed openable:: 09:00 – 22:00 Opening threshold 22°C, and internal temperature higher than ambient temperature
Notes:	Closed during unoccupied night hours

Royden / GF Living & LDK	
	Exposure Type: Exposed wall Category: Door – side hung Openable Area: 70% (frame factor 70%) Max Angle Open: 30° Proportions: 0.50 < Length/Height < 1 Equivalent area: 41% Assumed openable:: 09:00 – 22:00 Opening threshold 22°C, and internal temperature higher than ambient temperature
Notes:	Closed during unoccupied night hours

Royden / GF LDK	
	Exposure Type: Exposed wall Category: Window – side hung Openable Area: 70% (frame factor 70%) Max Angle Open: 30° Proportions: 0.50 < Length/Height < 1 Equivalent area: 41% Assumed openable:: 09:00 – 22:00 Opening threshold 22°C, and internal temperature higher than ambient temperature
Notes:	Closed during unoccupied night hours

Royden / FF Bedrooms	
	Exposure Type: Exposed wall Category: Window – side hung Openable Area: 70% (frame factor 70%) Max Angle Open: 30° Proportions: 0.50 < Length/Height < 1 Equivalent area: 41% Assumed openable:: 24/7 Opening threshold 22°C, and internal temperature higher than ambient temperature
Notes:	N/A

Royden / FF Bedrooms	
	Exposure Type: Exposed wall Category: Window – side hung Openable Area: 70% (frame factor 70%) Max Angle Open: 30° Proportions: 0.50 < Length/Height < 1 Equivalent area: 41% Assumed openable:: 24/7 Opening threshold 22°C, and internal temperature higher than ambient temperature
Notes:	N/A

Appendix B – Embodied Carbon Assessment

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Sustainability
Consultants

Elmsbrook, NW Bicester Phase 4

Crest Nicholson Chiltern

Embodied Carbon

AES Sustainability Consultants Ltd

June 2022

AES Sustainability Consultants

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Revision	Author	Date	Comment
Rev0	Sergio Pendas	24/06/2022	Sergio.Pendas@aessc.co.uk

This statement has been commissioned by Crest Nicholson Chiltern to detail the proposed approach to Embodied Carbon House type at Elmsbrook, NW Bicester. It should be noted that the details presented, including the proposed specifications, are subject to change as the detailed design of the buildings progress, whilst ensuring that the overall commitments will be achieved.

Contents

List of figures & tables

AES Sustainability Consultants

1. Introduction

1.1. AES Sustainability Consultants Ltd. has been appointed to undertake an embodied carbon assessment of a proposed Elmsbrook, NW Bicester Phase 4; Marlborough- House type which is being developed as part of the Bicester Eco Town. This report has been written to summarise the process and results of the analysis as part of discharging Planning Condition 16.

1.2. The relevant planning condition attached to application is extracted below:

> 16. Carbon Emissions Report
>
> No development shall take place until a report outlining how carbon emissions from the construction process and embodied carbon have been minimised has been submitted to and approved in writing by the Local Planning Authority. The development shall thereafter be carried out in accordance with the recommendations contained in the approved report.
>
> Reason - To ensure that the development achieves a reduced carbon footprint in accordance with Planning Policy Statement 1: Eco Towns. This information is required prior to the commencement of any development as it is fundamental to the acceptability of the scheme

1.3. The proposals addressed within this statement constitutes a replan of the proposed Phase 4 of the development, comprising an amended house type mix and a change in the total number of dwellings within this phase from 54 to 57. The Marlborough House type analysed consists of 2 above ground floors.

1.4. Life cycle greenhouse gas emissions (kgCO_2eq.) for each element are reported based on a 60-year building life.

Development Description

1.5. A hybrid application under ref 10/01780/HYBRID was originally submitted in 2010 for the exemplar phase of the wider Elmsbrook Eco Town development:

Development of Exemplar phase of NW Bicester Eco Town to secure full planning permission for 393 residential units and an energy centre (up to 400 square metres), means of access, car parking, landscape, amenity space and service infrastructure and outline permission for a nursery of up to 350 square metres (use class D2), a community centre of up to 350 square metres (sui generis), 3 retail units of up to 770 square metres (including but not exclusively a convenience store, a post office and a pharmacy (use class A1)), an Eco-Business Centre of up to 1,800 square metres (use class B1), office accommodation of up to 1,100 square metres (use class B1), an Eco-Pub of up to 190 square metres (use class A4), and a primary school site measuring up to 1.34 hectares with access and layout to be determined.

Figure 1. Marlborough House type – Front Elevation

2. Embodied Carbon Assessment

2.1. The life cycle assessment of buildings seeks to expand the boundaries of construction sustainability. Rather than simply examining operational energy demand and associated emissions, this methodology allows a sustainability appraisal to incorporate the energy and emissions associated with the extraction of raw materials, the manufacturing process, transport, application, and the energy used in recycling or replacement of the material at end of life.

2.2. Increasingly it is being demonstrated that as operational energy demand of buildings is being reduced through Building Regulations, this is accounting for a decreasing proportion of the overall Whole Life Cycle (WLC) energy and CO_2 emissions[1]. As such, the necessity for consideration of the embodied carbon of construction is becoming more apparent in order to continue to reduce the climate impacts of the built environment.

2.3. The calculation and reduction of whole-life CO_2e emissions has the potential to;

- Ensure that a significant source of emissions from the built environment are accounted for which is necessary in achieving a net zero-carbon development.
- Achieve resource efficiency and cost savings by encouraging the re-use of existing materials instead of new materials and the retrofit and retention of existing structures and fabric over new construction.
- Identify the carbon benefits of using recycled material and the benefits of designing for future reuse and recycling to reduce waste and support the circular economy.
- Encourage a 'fabric first' approach to building design thereby minimising mechanical plant and services in favour of natural ventilation.
- Identify the impact of maintenance, repair and replacement over a building's life-cycle which improves life-time resource efficiency and reduces life-cycle costs, contributing to the future proofing of asset value.
- Encourage durable construction and flexible design, both of which contribute to greater longevity, reduced obsolescence of buildings and avoiding carbon emissions associated with demolition and new construction.

2.4. Embodied carbon is regularly described as the total impact of all the greenhouse gases emitted by the construction and materials of our built environment. It includes the impacts of sourcing raw materials, manufacturing, transport, and wastage in the process2.

2.5. Carbon emissions associated with energy consumption (embodied energy) during the manufacture, transportation, assembly, replacements and deconstruction of construction materials or products. Embodied carbon is typically measured from cradle-to-gate, which is reflected by life cycles A1-A3 the product stage as detailed in this report.

Modelling Methodology

2.6. The calculations were performed with One Click LCA calculation tool. The assessment methods conform with BS 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings

2.7. The LCA analysis includes the following elements:

- Substructure
- Superstructure
    - Frame
    - Upper floors incl. balconies
    - Roof
    - Stairs and ramps
    - External Walls
    - Windows and External Doors
    - Internal Walls and Partitions
    - Internal Doors

[1] Sansom, M. and Pope, R., 2012. A comparative embodied carbon assessment of commercial buildings. The Structural Engineer,.

[2] The Embodied Carbon Review, 2018, Bionova Ltd, www.embodiedcarbonreview.com

2.8. The following items are to be excluded; balconies, stair finishes, fixtures and fittings (e.g. handrails, cubicles etc.), all furniture and equipment, including building and external services are excluded from the LCA.

2.9. Building life cycle stages are the different periods of a building's lifetime. For instance: raw material harvesting, manufacturing of products, use phase of the building, end of life. In the European markets, the building life cycle stages are defined by EN 15978 and EN 15804 standards, which can be included in LCAs.

2.10. The following table lists all life cycle stages according to EN standards:

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

Figure 2. Life-cycle stages according to the EN standard

2.11. The following life-cycle stages have been included within the analysis:

- A1: raw material extraction and processing, processing of secondary material input (e.g. recycling processes)
- A2: transport to the manufacturer
- A3: manufacturing

2.12. Module A1, A2 and A3 may be declared as one aggregated module A1-3. All stages include the provision of all materials, products, and energy, as well as waste processing up to the end-of-waste state or disposal of final residues during the product stage. The assessment takes only the building and its parts into account, but not furniture or appliances, for example.

2.13. Raw material supply (A1) includes emissions generated when raw materials are taken from nature, transported to industrial units for processing and processed. Loss of raw material and energy are also taken into account.

2.14. Transport impacts (A2) include exhaust emissions resulting from the transport of all raw materials from suppliers to the manufacturer's production plant as well as impacts of production of fuels.

2.15. Production impacts (A3) cover the manufacturing of the production materials and fuels used by machines, as well as handling of waste formed in the production processes at the manufacturer's production plants until end-of-waste state.

- A4: transport to the building site

2.16. A4 includes exhaust emissions resulting from the transport of building products from manufacturer's production plant to building site as well as the environmental impacts of production of the used fuel.

- B4: replacement

2.17. The environmental impacts of maintenance and material replacements (B1-B5) include environmental impacts from replacing building products after they reach the end of their service life. The emissions cover impacts from raw material supply, transportation and production of the replacing new material as well as the impacts from manufacturing the replacing material as well as handling of waste until the end-of-waste state.

- C1: de-construction, demolition
- C2: transport to waste processing
- C3: waste processing for reuse, recovery and/or recycling
- C4: disposal

2.18. All C stages include provision and transport, provision of all materials, products and related energy and water use.

2.19. The impacts of deconstruction include impacts for processing recyclable construction waste flows for recycling (C3) until the end-of-waste stage or the impacts of pre-processing and landfilling for waste streams that cannot be recycled (C4) based on type of material. Additionally, deconstruction impacts include emissions caused by waste energy recovery.

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2.20. However, it should be noted that A4, B4 and C1-C4 should be ignored for the purposes of an embodied carbon assessment. In line with BS EN 15978 A1-A3 – the product stage (cradle to gate), are the pertinent figures required to show embodied carbon.

Project Data Sources and Assumptions

Material Quantities (A1-A3)

2.21. A 3D model of the building has been built using the dynamic thermal software developed by Integrated Environmental Solutions (IES). The building geometry has been modelled using drawn information produced by Crest Nicholson dated November 2021

2.22. Fabric elements have been entered as per the External Fabric Materials Spec provided by Crest Nicholson revision C8 dated July 2020.

2.23. Data for all materials in the analysis has been collated from the One-Click database, including manufacturer specific data (where available), as well as generic data which represents the industry average for the selected material.

Building Material Transport Distances (A4)

2.24. The case specific transport distances were used when available. Other transport distances were estimated based on typical average transport distances based on material type provided by calculation tool.

Material Service Life (B1-B5)

2.25. The service life information for each material was checked and project specific values were used when available. Otherwise default values from One Click LCA database were used.

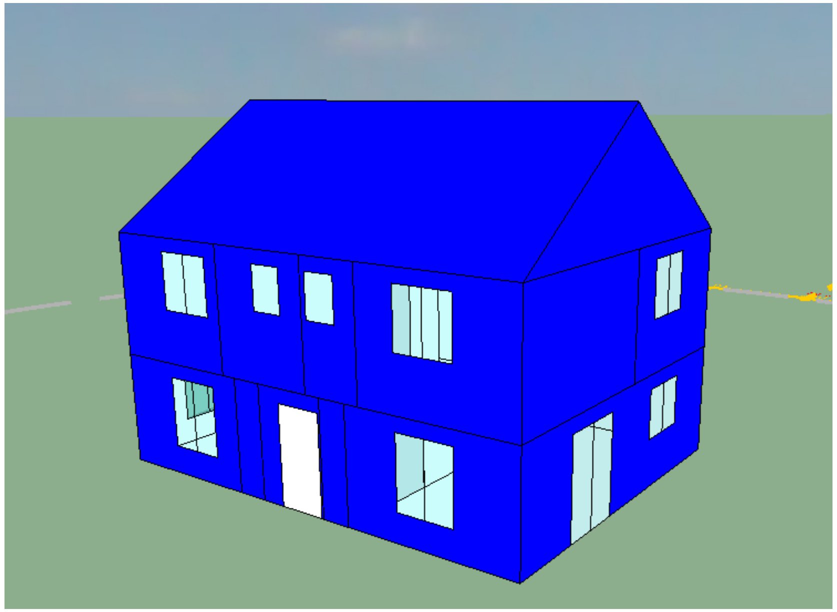

Figure 3. IES Model

Assessed Impact Categories

2.26. Global warming potential is a relative measure of how much heat a greenhouse gas traps in the atmosphere. The global warming potential is calculated in carbon dioxide equivalents meaning that the greenhouse potential of emission is given in relation to CO_2.

2.27. The global warming potential for each material specified is reported in a measure of $kgCO_2e$ per kilogram of material used. This is an aggregate measure, which incorporates the greenhouse gases listed below, and converts these to an equivalent quantity of carbon dioxide, in order to facilitate easier comparison between materials with varying impacts[3].

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxides (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

[3] Moncaster, A. and Symons, K., 2013. A method and tool for 'cradle to grave' embodied carbon and energy impacts of UK buildings in compliance with the new TC350 standards. Energy and Buildings, 66, pp.514-523.

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3. Results

3.1. An embodied carbon review over the life cycle of the building was carried out for the Marlborough house type using OneClick LCA software and based on the supporting information provided. Where detailed information on materials or quantities is unavailable industry standards and default assumptions have been made.

3.2. The life cycle assessment was assessed using One Click LCA. The results are summarized in the following table. The results represent the total life cycle impact during a 60-year service life.

Results for Global Warming Potential (GWP), $kgCO_2$ eq

3.3. The results show that based on the life cycle stages, stage A1-A3 Materials is the most contributing stage. This is the stage that is taken into account for embodied carbon.

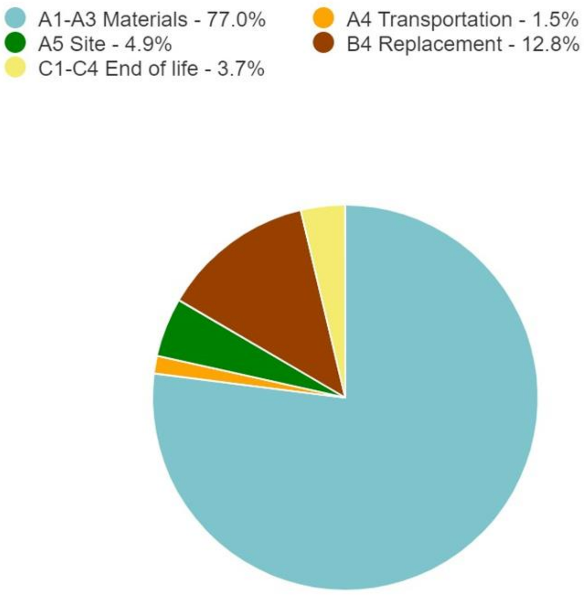

Figure 4. Total $kgCO_2e$ by life-cycle stage

3.4. The analysis concluded that the currently specified materials have a total embodied carbon impact of 44,689 $kgCO_2$ eq.

Table 1. Total embodied carbon - A1-A3 Materials

Impact category	Unit	Results
Global warming potential (greenhouse gases)	$kgCO_2$ eq	44,689

3.5. This figure has been achieved through the specification of low impact products and manufacturers.

3.6. This figure can be further disseminated to show the major resource contributors. Results show that bricks contribute to over 14% of the buildings total kgCO2e for the building.

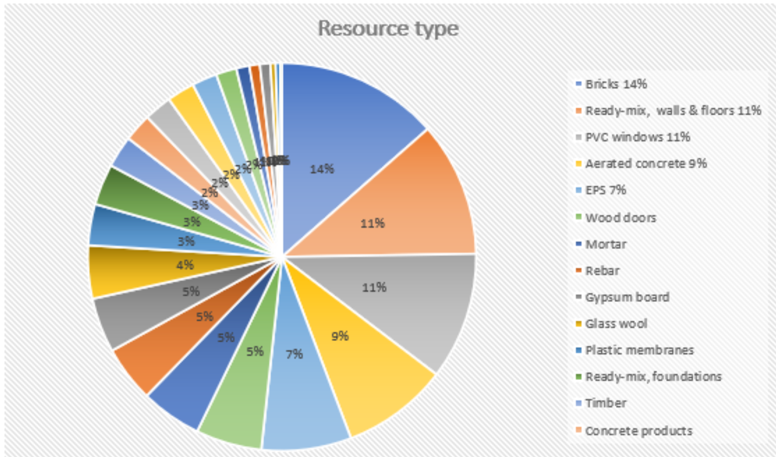

Figure 5. Total kgCO2e by resource type

3.7. Figure 5 shows clearly that the materials with the highest impact on the embodied carbon are the bricks (shown in blue), which are prevalent within the dwelling.

3.8. Bricks are one of the main contributors to the embodied carbon footprint of most masonry brick outer dwellings but it can also offer a number of possible routes to embodied carbon reduction. The specification of reclaimed bricks has great potential to reduce the carbon footprint in dwellings Also the use of sand-lime bricks would benefit the final carbon footprint savings.

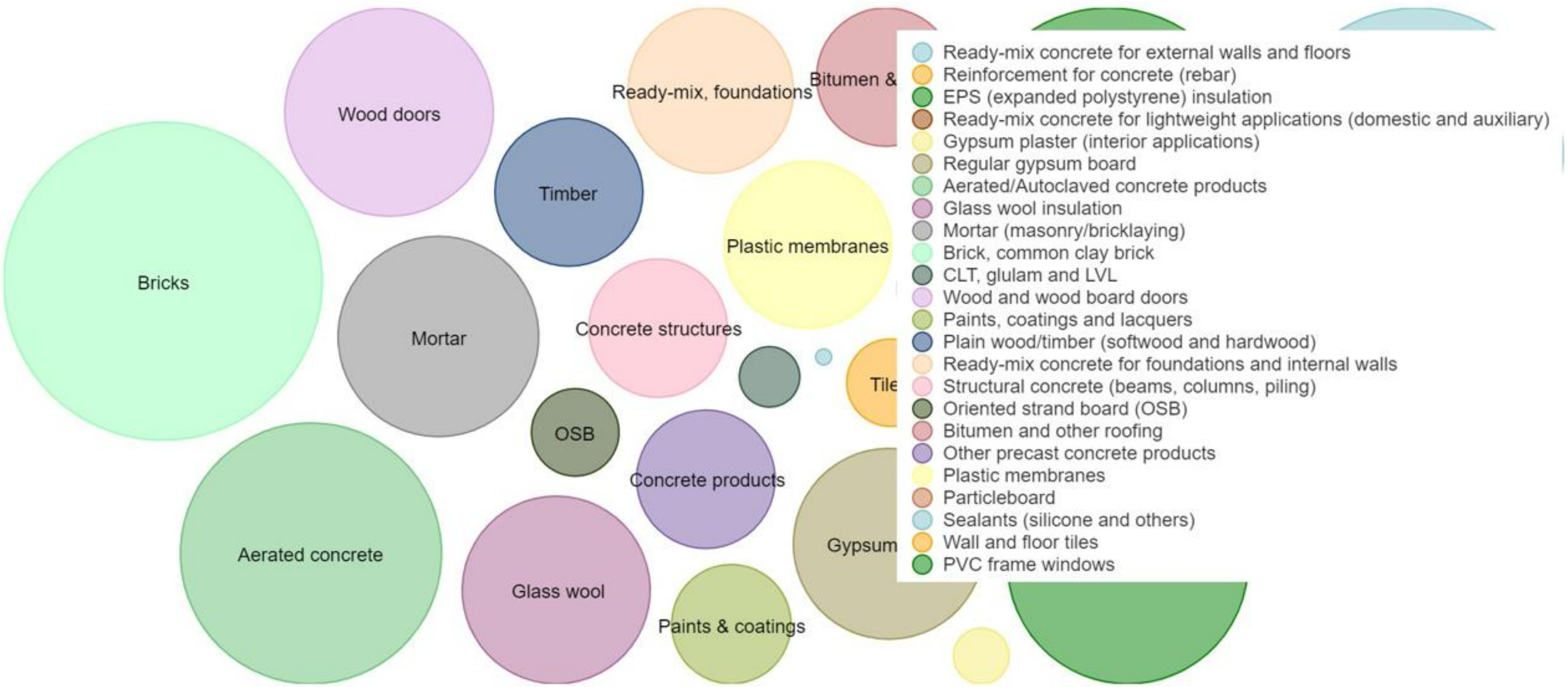

Figure 6. Total life cycle impact by resource type and subtype - $kgCO_2e$

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Strategies to Reduce Embodied Carbon

3.9. A range of approaches may be used to further reduce the assessed embodied carbon of the dwellings, which may include the following, subject to feasibility:

- Using construction products that are made from locally available raw materials, through energy efficient and low emission processes and by manufacturers local to the construction site.
- Transporting materials with low carbon vehicles.
- Designing the construction process to minimize waste and reuse or recycle products where possible.
    - Reused materials such as brick, metal, wood and even broken concrete can make a big reduction in embodied carbon emissions. Due to the fact that the carbon used to make them is already accounted for in the manufacturer for its first use, reused materials have a much lower carbon footprint. Steel that's brand new has an embodied carbon footprint up to five times greater than recycled content steel.
- Use low-carbon concrete mixes.
    - Concrete can be the biggest source of embodied carbon for any new site, using lower-carbon concrete is an easy change to make. Examples include using higher percentages of fly ash, slag, calcined clays or lower-strength concrete if possible.
- By designing a building to be able to change its use over time through flexible internal layouts to easily adapt to future use of occupants will minimize the need for future refurbishments.

3.10. Appendix A outlines a number of strategies that could be used to reduce the embodied carbon of the materials.

4. Conclusion

4.1. AES Sustainability Consultants Ltd. have been appointed to undertake an embodied carbon assessment of the proposed Elmsbrook, NW Bicester Phase 4 Marlborough- house type as required by Planning Condition 16.

4.2. By using IES VE and OneClick LCA software, the analysis has found that the total embodied carbon of the proposed materials is 44,689 $kgCO_2$. With bricks being the major contributing material.

4.3. Embodied carbon will be monitored throughout the design in order to further inform any selection of materials, products and suppliers throughout the project to further influence the impact and potential reduction of embodied carbon

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Appendix A - Carbon footprint reduction options

ID	Name	Description	Total 60-year impact (KgCO2eq)	Change in Impact	Conclusions
1	Marlborough base case	Based on information provided the following were chosen at very early design stage: • Beam And Block Ground Floor • Masonry external wall • Plane ceiling	44,689	-	Initial design
2	Reclaimed Bricks	Using reclaimed bricks for external walls Brick manufacturing requires the firing of products to around 1,000 °C. Achieving such temperatures makes brick production an energy-intensive process The use of reclaimed bricks can reduce more than 10% the total embodied carbon footprint	38,791	-5.898	The use of reclaimed bricks has not been selected for use in the project as the base case calculations have been set up on the use of standard UK red bricks However, consideration should be given to the inclusion at detailed design
3	Recycled reinforcement Steel	Using Reinforcement steel (rebar) with a higher recycled content for foundations, floor slabs and other structures such as stairs Virgin steel can have an embodied carbon footprint that is up to five times greater than high-recycled content steel	43,928	-761	High recycled steel has not been selected for use in the project as the base case calculations have been set up on the use of standard steel measures However, consideration should be given to the inclusion at detailed design
4	Concrete with recycled binders	Using a ready-mix concrete with a higher recycled binders content for foundations, floor slabs, and another structures such as stairs can have an embodied carbon footprint that is up to 25% less than standard Ready-mix concrete	42,633	-2,056	Ready-mix concrete with high recycled binder content has not been selected for use in the project as the base case calculations have been set up on the use of standard Ready-mix concrete However, consideration should be given to the inclusion at detailed design