Monmouthshire County Council

Net Zero Carbon Homes
Feasibility Study and Cost Assessment

Work Stage 2 Methodologies & Technologies

Project Ref: 2774

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Revision: -

Architecture
Low Energy Consultancy
Civil Engineering
Structural Engineering
Urban Design

Contents

Section 1: Introduction

1.1 Introduction

Spring Design Consultancy Limited are appointed to assist Monmouthshire County Council in developing an appropriate evidence base for the progressed Net Zero policy to guide, assess and determine applications for new-build residential and non-residential development within the emerging Replacement Local Development Plan 2018-2033.

This process has been divided into distinct work stages:

Work Stage 1.1 Policy Review
2 Policy Approach
3 Evidence Base

Work Stage 2.1 Methodologies
2 Technical Feasibility

Work Stage 3.1 Cost Analysis

Work Stage 4.1 Evidence
2 Cost Implications
3 Scrutiny Skillset

Work Stage 5 Examination

This report builds upon the previously issued Work Stage 1 Policy Review and presents proposals for Work Stage 2.1 Methodologies & Technologies to inform the modelling of Work Stage 2.2 Technical Feasibility.

Section 2: Methodology

2.1 Energy Modelling for Buildings

It is proposed that the methodology applied to energy modelling aligns with the internationally recognised RICS WLCA methodology, based on EN 15978 and adopted by RIBA, CIBSE and IStructE. This WLCA standard provides the detailed methodology to enable consistent measurement and quantification of whole life carbon emissions, inclusive of all embodied and operational carbon throughout the whole life cycle of a building, from initial design to end of life.

RICS Whole life carbon assessment for the built environment 2nd edition (2023) requires operational energy use predictions to be completed by a suitably qualified professional using the guidance outlined either in CIBSE's TM54, NABERS, ASHRAE Standard 90.1 or the Passivhaus Planning Package (PHPP). Approved Document L 2021/ 2022 calculations via the SAP methodology are explicitly forbidden as they are not considered an appropriate prediction of energy consumption.

All modelling is therefore proposed to be undertaken in the Passivhaus Planning Package (PHPP), an Excel-based design tool introduced in 1998 and subjected to continual refinement since. PHPP is produced by the Passivhaus Institute and aimed for use by architects, engineers and building designers to determine compliance with multiple low energy building standards.

The reliability of calculated results has been established over the last twenty-five years and tens of thousands of built projects. Extensive post-occupancy evaluation and scientific analysis of completed projects in various climates has compared measured operational heating demand with the calculated outputs. This process demonstrated a high correlation between the demand calculated using PHPP and the in-use performance of the building, proving that an appropriate understanding of building physics applied to building design can eliminate the performance gap.

The sophistication of PHPP enables it to consider a wide range of variable characteristics which affect heat loss, energy use and internal comfort, allowing for a superior fit between predicted energy use and real-world performance. Detailed modelling by suitably qualified person results in outputs that can be used to assess and optimise the latent efficiency of building proposals. Key to establishing energy efficiency is the heating demand and heating load which can be used to assess a building's fundamental need to consume energy.

Output from the PHPP analysis will enable regulated and unregulated energy use to be distinguished from one another.

An additional output of PHPP is overheating risk, defined as the percentage of time the indoor environment is calculated to exceed 25°C. Integrated overheating assessment is critical to the success of highly insulated buildings to ensure well-intentioned strategies to boost solar gains in winter and therefore decrease heating demand don’t result in excessive indoor temperatures during the summer months.

2.2 Assumptions & Principles

Establishing technical feasibility and economic viability requires the modelling exercise to broadly represent the average development delivered by the RLDP.

Monmouthshire County Council's Replacement Local Development Plan 2018-2033: Updated Preferred Strategy (2023) proposes where and how new development will take place to 2033. It outlines potential site allocations for different land uses such as housing and employment and policies to help tackle the declared climate and nature emergencies, safeguard the environment and secure high-quality design. When adopted the RLDP will be used as the basis for determining and approving planning applications.

1,660-2,125 dwellings are anticipated to be approved and built following adoption of the RLDP including 830-1,035 new affordable homes. Conservative GIA estimates translate this into 175,000 m^2+ of residential development.

Strategic Growth Areas suggests 86% of these new dwelling allocations are anticipated within primary settlements with 600 in Abergavenny, 145 in Chepstow, 330 in Monmouth and 825 in Caldicott/ Severnside.

Identification of these Strategic Sites is critical to the analysis of the Net Zero Carbon Homes as it informs the climatic assumptions, including altitude, used for PHPP modelling. Due to the variable topography of Monmouthshire, sites share few general characteristics and so modelling will adopt the worst-case scenario: this will provide conservative guidance on the required specification for buildings to comply with the proposed Net Zero policy.

Within the BRE defined climate region (Severn) this establishes the most appropriate climate data set. It also confirms an altitude of 140m (Abergavenny East) as worst-case for development on the strategic sites: the majority of allocations within the RLDP are for lower altitude sites which will be subject to milder winter conditions, lowering the resultant space heating demand.

All new residential developments will be required to contribute towards the provision of an appropriate mix of market and affordable housing with MCC aiming to deliver 50% social tenure across all development sites.

To reflect the anticipated growth within the RLDP a representative selection of building typologies were identified for modelling. This comprises three open market residential typologies - HT 900, HT 1600 and HT 2200 - and three social rent residential typologies - HT 211, HT 212 and HT 641.

General principles applied to the modelling continue to emulate the worst-case scenario and therefore provide conservative guidance on what would be required to achieve the agreed operational standards. As such, all typologies are proposed to be modelled facing East-West and to account for units of the same scale 15.0m from the front elevation and 21.0m from the rear.

East-West orientation is the least favourable for solar gains: in winter it excludes the majority of sunlight, limiting the free heat gains that could otherwise offset space heating demand; in summer it exposes buildings to low angle solar gain that is difficult to control and can exacerbate issues with overheating.

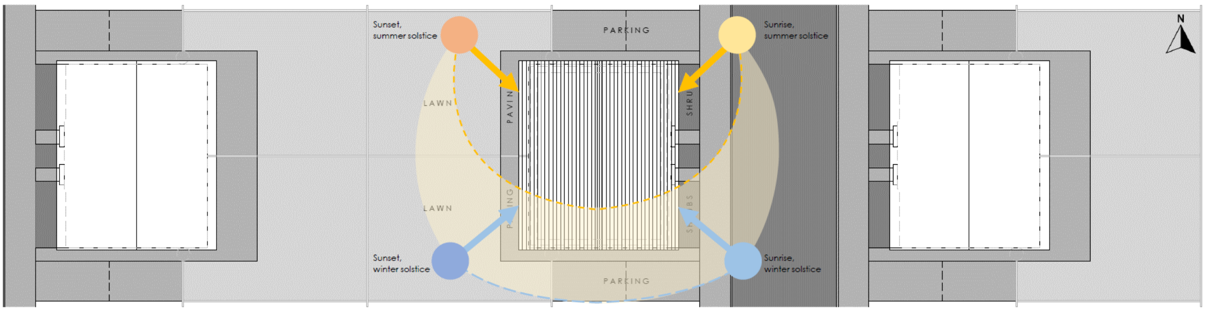

Fig. 01: Example East-West oriented layout

East-West facing roofs have lower generation potential than an equivalent South facing roof. This provides a conservative kWp array sizing. However, East-West oriented photovoltaics can help reduce grid stress as output peaks are different to South-facing arrays.

Distances between buildings are derived from the principles established by Manual for streets (2007). Similar units are positioned to both the East and West to establish horizon shading objects and ensure the assessment remains conservative: unshaded building models would overestimate the potential of solar gains to offset space heating demand.

Section 3: Technologies

3.1 Heating

Heat strategy for Wales (2024) reviews the policy context for affordable warmth and decarbonisation of heating across the built environment. This document recognises heat pumps as the most suitable pathway for decarbonising heat and commits to review permitted development rights to facilitate their widespread adoption.

To align with Welsh Government aspirations, heating and hot water needs are therefore to be modelled as supplied by electrically-powered air source heat pump technologies. Vaillant aroTHERM ASHPs with coefficients of performance (COP) c. 3.66 at 40°C flow temperature will be specified to enable costing to inform viability. COP relates to the efficiency of the unit averaged across the year: this translates into every 1 kWh of electrical energy input producing 3.66 kWh of heat energy.

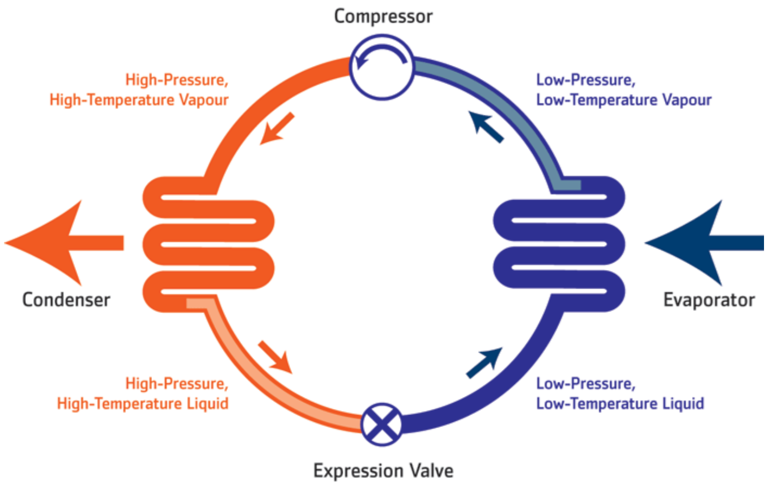

Fig. 02: Diagram illustrating principle of heat exchange, property of Carmichael Browns

These high-efficiency, electrically powered heating systems are appropriate fossil fuel alternatives that contribute to the decarbonisation of dwellings. While the delivery system has no bearing on the assessed space heating demand, ASHPs are able to realise a significant reduction in regulated energy demand.

Individual ASHPs are to be modelled within PHPP for all typologies. It is recognised this is unlikely to be the most cost-effective way of heating flatted development - where air or ground heat pumps could feed communal heating and hot water circuits - but this approach provides a replicable specification across typologies. Flats of a suitably high level of performance could utilise exhaust air heat pumps (EAHP).

3.2 Ventilation

Where design air permeability is 5.0 $m^3/(h^{-1}m^2)$ or less at 50Pa, natural ventilation is disqualified from consideration as unsuitable for a more airtight dwelling: instead, constant mechanical ventilation is required. Two distinct ventilation strategies are represented within the assessed scenarios.

Mirroring The Future Homes and Buildings Standard: 2023 consultation published in England, AD: L (Wales) 2025 implements mechanical extract ventilation (MEV).

MEV continuously extracts stale air from areas of moisture and odour generation (bathrooms and kitchens) within a building. This leads to depressurisation of these spaces with air flowing from habitable rooms (living and bedrooms) to equalise the pressure difference, resupplied with fresh air from outside drawn through trickle vents within the habitable rooms.

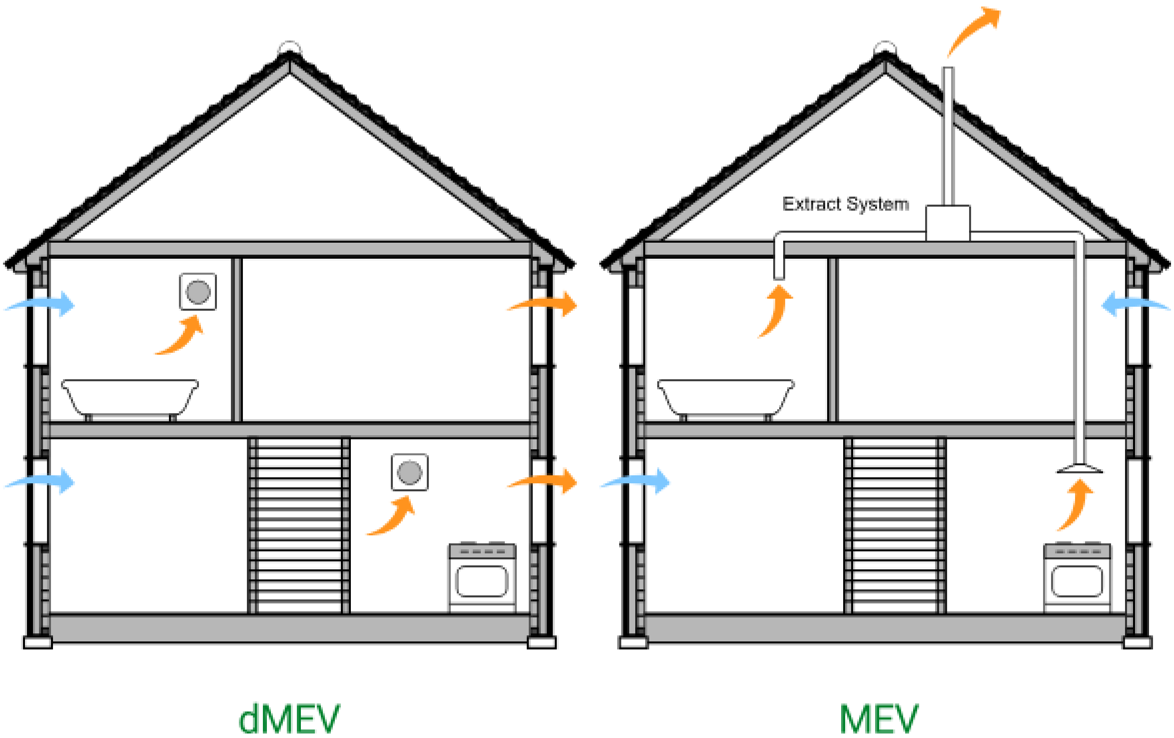

Fig. 03: Diagram illustrating decentralised and centralised MEV, property of CEF

Decentralised MEV (dMEV) is to be modelled within PHPP for all typologies.

AECB CarbonLite, MCC and LETI scenarios have all been developed to incorporate mechanical ventilation with heat recovery (MVHR) to leverage significant reductions in space heating demand.

MVHR is a ventilation system that continuously extracts stale air from areas of moisture and odour generation (bathrooms and kitchens) within the building and supplies fresh, filtered air to habitable areas. Integral heat exchangers ensure the incoming fresh air is warmed by the outgoing exhaust air to reduce the heating requirement. As the threshold for space heating demand reduces within the modelled scenarios, MVHR units with higher rates of heat recovery are specified.

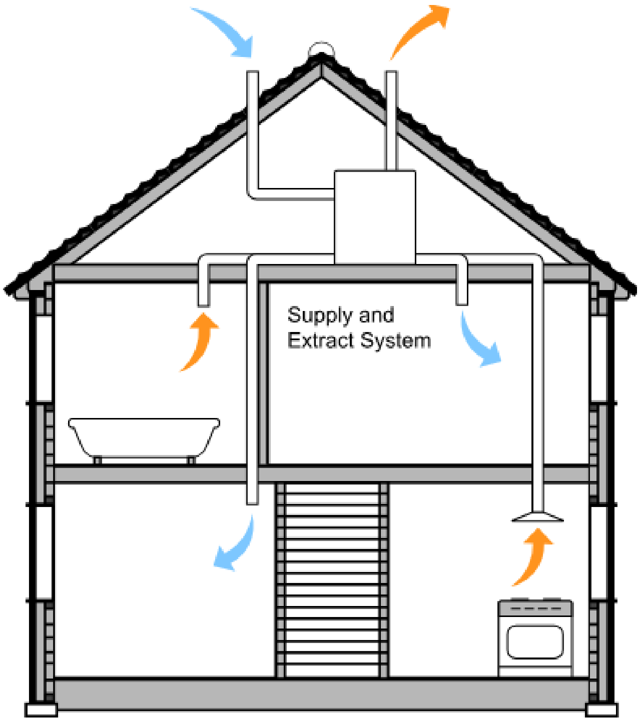

Fig. 04: Diagram illustrating centralised MVHR, CEF

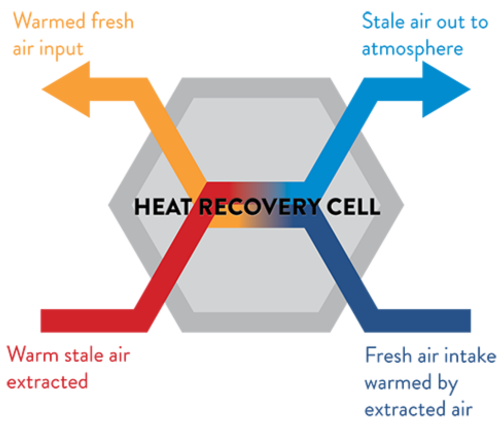

Fig. 05: Diagram illustrating principle of heat recovery, Xpelair

Centralised MVHR is to be modelled within PHPP for all typologies.

3.3 Renewables

Wales Net Zero 2035 Challenge Group's How could Wales meet energy needs whilst phasing out fossil fuels by 2035? (2024) identifies wind and solar as the dominant forms of renewable energy generation available in Wales. Photovoltaics are recognised as the most widely applicable building-mounted technology.

Photovoltaic cells harness solar energy and convert it to a direct electrical current. This can then be delivered directly to a battery for storage or routed through an inverter for conversion to alternating current: once AC it can be used on the mains circuit within the building or exported to the grid. Panels are typically roof-mounted and optimised in a southerly orientation but can usefully contribute to load-shifting if facing in a more easterly or westerly direction.

Batteries and other emerging forms of energy storage are not considered within this assessment because while they can also be used to load-shift and save money via accessing favourable tariffs, they do not address the need of the building to consume energy or achieve any reduction in energy consumption.

Section 4: Operational Scenarios

4.1 Introduction

Four distinct operational scenarios are proposed for modelling to be resolved with Monmouthshire County Council.

Operational emission scenarios	
Reference	Space heating demand
AD: L (Wales) 2025	N/A
AECB CarbonLite	40 kWh/m²/yr
MCC	25 kWh/m²/yr
LETI	15 kWh/m²/yr

Due to the high quality fabric required by Approved Document L (Wales) Volume 1 - Dwellings 2022 Appendix E, identical u-values are applied to the building fabric across all typologies and within all scenarios.

Appendix E u-values	
Element	u-value threshold
Floor	0.110 W/m²K
External wall	0.130 W/m²K
Roof	0.110 W/m²K
Party wall	0.000 W/m²K

The variations that will differentiate operational performance, and therefore emissions, are instead quality of build (improved airtightness and mitigation of thermal bridging), quality of external door and window specification and the efficiency and optimisation of the technological installations. Only physical window specification and applied technologies are likely to significantly impact the related construction costs which will be assessed in Work Stage 3.1 Cost Analysis

Specifications developed for these four scenarios are listed in 4.1.1 AD: L (Wales) 2025, 4.1.2 AECB CarbonLite, 4.1.3 MCC and 4.1.4 LETI.

Photovoltaic provisions will be tailored to balance the calculated regulated energy portion of the EUI of each assessed house type to deliver the policy objective. It is anticipated that significantly different numbers of photovoltaics will be required to balance the regulated energy of lower performance scenarios - where regulated consumption should be higher - versus high performance standards.

Monocrystalline photovoltaic panels with a nominal output of 400W per panel are assumed for the purposes of calculation.

4.1.1 AD: L (Wales) 2025

The fabric parameters for Approved Document L (Wales) 2025 are speculative, reflecting the pre-consultation state of the emerging legislation and that such detail has not been published. Fabric u-values are therefore based upon applying those of Approved Document L (Wales) Volume 1 - Dwellings 2022 Appendix E with the ventilation strategy adjusted to MEV to align with proposals within The Future Homes and Buildings Standard: 2023 consultation published in England.

Building Fabric	
Air permeability Thermal bridges	5.00 $m^3/m^2/hr$ 0.200 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	1.400 W/m^2K uPVC 0.040 W/mK 1.120 W/m^2K double low-e glazing 16mm Ar 0.64 0.040 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/ exhaust)	$30m^3$ per person per hour via MEV MEV N/A (extract only)
Heating	
ASHP Controls	Vaillant aroTHERM plus On/off

Appendix E currently establishes the minimum specification to be applied to grant-funded social housing built in Wales. Using this as the baseline fabric responds to the Welsh Government aspiration to align market and social housing performance requirements[1].

[1] *"By 2025 all new affordable homes in Wales will be built to net zero carbon, and our ambition is that our net zero standards are adopted by developers of all new homes regardless of tenure by this date."*
Welsh Government (2021) Net Zero Wales Carbon Budget 2 (2021-2025) [online]. Cardiff: Welsh Government. Available from: https://www.gov.wales/sites/default/files/publications/2021-10/ [Accessed 10.09.2024]. Page 104.

4.1.2 AECB CarbonLite

AECB CarbonLite Building Standard has been developed by the Association for Environment Conscious Building (AECB) to apply a less onerous demand-based performance standard than Passivhaus for the UK context. Excepting airtightness and ventilation rate, the values below are not prescribed by the AECB but are proposed to ensure the least favourable typologies can still achieve the defined space heating targets.

Building Fabric	
Air permeability Thermal bridges	1.50 $m^3/m^2/hr$ 0.050 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	0.810-0.850 W/m^2K Rehau Artevo uPVC 0.040 W/mK 1.190 W/m^2K double glazing (4w-16Ar-KS4) 0.64 0.025 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/ exhaust)	30m^3 per person per hour via MVHR EnviroVent energiSava 300 84% Semi-rigid radial 50mm closed cell Armaflex
Heating	
ASHP Controls	Vaillant aroTHERM plus On/off

4.1.3 MCC

The Monmouthshire County Council heating demand target reflects the proposed policy aspiration of the local authority, developed through extensive engagement with the local development industry. The values below are not prescribed by the policy but are proposed to ensure the least favourable typologies can still achieve the defined space heating target.

Building Fabric	
Air permeability	1.25 $m^3/m^2/hr$
Thermal bridges	0.025 W/mK
Doors & Windows	
Frames U_f	0.810-0.850 W/m^2K Rehau Artevo uPVC
Installation thermal bridging	0.040 W/mK
Glazing U_g	0.55 W/m^2K triple glazing (4-18Ar-4-18Ar-4)
Glazing g-value	0.63
Glazing edge	0.025 W/mK
Ventilation Strategy	
Ventilation rate	30m^3 per person per hour via MVHR
Ventilation unit	EnviroVent energiSava 300
Heat recovery efficiency	84%
Ducting	Semi-rigid radial
Duct insulation (inlet/exhaust)	50mm closed cell Armaflex
Heating	
ASHP	Vaillant aroTHERM plus
Controls	Acc. to ambient temperature

4.1.4 LETI

LETI performance standards were developed by the Low Energy Transformation Initiative (LETI), formerly the London Energy Transformation Initiative, as net zero building standards applying demand-based performance targets within the UK context. Excepting ventilation rate, the values below are not prescribed by LETI but are proposed to ensure the least favourable typologies can still achieve the defined space heating target.

Building Fabric	
Air permeability Thermal bridges	0.50 $m^3/m^2/hr$ -0.050 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	0.810-0.850 W/m^2K Rehau Artevo uPVC 0.009-0.023 0.55 W/m^2K triple glazing (4-18Ar-4-18Ar-4) 0.63 0.025 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/ exhaust)	30m^3 per person per hour via MVHR Zehnder ComfoAir 225 92% Semi-rigid radial 50mm closed cell Armaflex
Heating	
ASHP Controls	Vaillant aroTHERM plus Acc. to ambient temperature

Unit 2
Chapel Barns
Merthyr Mawr
Bridgend
CF32 0LS

T: 01656 656267
W: www.spring-consultancy.co.uk

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Civil Engineering
Structural Engineering