



Critical Evaluation and PHPP Analysis of M&E Design Improvements for a Net Zero Residential Dwelling in Wales

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14 May 2026

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Module Number: ACBA5017

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INTRODUCTION

The transition towards Net Zero Carbon housing presents a significant challenge for the residential construction sector in Wales, where new dwellings are increasingly expected to balance regulatory compliance, affordability, occupant comfort and environmental performance. Although current Welsh Building Regulations establish minimum energy efficiency standards, compliance alone does not necessarily deliver low operational energy demand or Net Zero performance (Welsh Government, 2025).

This report evaluates the mechanical and electrical (M&E) design of a proposed new-build dwelling in Wales (HT641) and assesses how the baseline specification could be improved to better align with low-energy and Net Zero principles. The dwelling comprises a four-bedroom, six-person residential property with a treated floor area (TFA) of 101.94m², designed broadly in accordance with Approved Document L (Wales) requirements.

The baseline specification incorporates low-carbon technologies, including an air source heat pump (ASHP); however, opportunities remain to reduce operational heat losses associated with ventilation, airtightness, glazing performance and thermal bridging. Consequently, this report critically evaluates the existing M&E specification and identifies targeted interventions to improve building performance.

Building performance was assessed using the Passive House Planning Package (PHPP), a modelling methodology commonly used to evaluate low-energy building performance (Passive House Institute, 2023). A comparative assessment was undertaken between a baseline regulatory-compliant model and an upgraded low-energy scenario. The upgraded model incorporated improvements to airtightness, ventilation strategy and building envelope performance whilst maintaining the same geometry and occupancy assumptions to ensure comparability.

PHPP modelling demonstrated that annual heating demand reduced from 83.5 kWh/m²/yr to 30.2 kWh/m²/yr, representing a 64% reduction, whilst Primary Energy Renewable (PER) demand reduced by approximately 29%. The findings demonstrate that meaningful improvements towards Net Zero residential performance can be achieved through a fabric-first and performance-led approach rather than reliance on increased heating capacity or renewable offsetting alone.

LEGISLATIVE AND LOW-ENERGY DESIGN CONTEXT

The Welsh Government has committed to achieving Net Zero greenhouse gas emissions by 2050, increasing pressure on residential buildings to reduce operational energy demand and carbon emissions (Welsh Government, 2021). Whilst the baseline dwelling complies with Approved Document L (Wales), which establishes minimum standards for energy efficiency and low-carbon heating provision, regulatory compliance alone does not necessarily result in low-energy performance (Welsh Government, 2025).

Similarly, Approved Document F (Wales) establishes ventilation requirements to maintain indoor air quality; however, extract-only ventilation systems may contribute to operational heat loss where heat recovery is not incorporated (Welsh Government, 2025).

To assess performance beyond minimum compliance, Passivhaus and LETI principles were considered. Both promote a fabric-first approach, prioritising improved airtightness, reduced thermal bridging and efficient ventilation before reliance on renewable technologies (LETI, 2020; Passive House Institute, 2023). Although the upgraded dwelling did not achieve the Passivhaus heating demand target of 15 kWh/m²/yr, PHPP modelling demonstrated substantial performance improvements through targeted M&E and envelope interventions.

The design approach adopted within this report therefore prioritised improved airtightness, reduced ventilation heat loss, enhanced glazing performance and lower operational heating demand. A detailed overview of relevant legislation and low-energy standards is included within Appendix A.

EXISTING M&E SPECIFICATION

The case study building assessed within this report is the HT641 residential dwelling, representing a proposed new-build domestic property located in Wales. The dwelling comprises a four-bedroom, six-person household with a treated floor area (TFA) of 101.94m², designed broadly in accordance with current Welsh Building Regulations, particularly Approved Document L (Wales) (Welsh Government, 2025).

The dwelling is positioned on an east–west orientation, reducing opportunities for passive solar gain when compared with more favourable south-facing layouts. Orientation can significantly influence building energy demand, particularly during winter months where solar gains may offset heating requirements (LETI, 2020). Consequently, the retained orientation may be considered a conservative modelling condition, ensuring that performance improvements demonstrated through PHPP are attributable to specification changes rather than favourable environmental assumptions.

The baseline dwelling incorporates several low-carbon technologies aligned with contemporary Welsh housing delivery. Table 3.1 summarises the principal M&E systems included within the baseline specification.

Table 1 – Baseline Building Specification

Element	Baseline Specification
Building Type	HT641 residential dwelling
Occupancy	6 persons
Treated Floor Area	101.94m ²
Orientation	East–West
Space Heating	Vaillant aroTHERM Plus 5kW ASHP
Ventilation	Mechanical Extract Ventilation (MEV)
Glazing	Double glazing
Airtightness	4.74 ACH
Thermal Bridging	Standard regulatory detailing

The primary heating system consists of a Vaillant aroTHERM Plus 5kW Air Source Heat Pump (ASHP), reflecting the wider transition away from fossil fuel heating systems towards electrically powered low-carbon alternatives (Energy Saving Trust, 2024). Ventilation is provided through a Mechanical Extract Ventilation (MEV)

system to satisfy indoor air quality requirements in accordance with Approved Document F (Welsh Government, 2025).

Although compliant with current regulation, the dwelling adopts a specification representative of minimum compliance rather than high-performance low-energy design. The use of double glazing, moderate airtightness levels (4.74 ACH) and extract-only ventilation indicates opportunities for further performance improvement. PHPP modelling established a baseline annual heating demand of 83.5 kWh/m²/yr and Primary Energy Renewable (PER) demand of 123.0 kWh/m²/yr, indicating a comparatively high operational energy requirement despite regulatory compliance. Full dwelling specifications, drawings and PHPP baseline outputs are included within Appendix B and Appendix E.

CRITICAL APPRAISAL OF THE EXISTING M&E DESIGN

Although the baseline dwelling satisfies current Welsh Building Regulations, PHPP modelling demonstrates that regulatory compliance alone does not necessarily equate to low operational energy demand. The dwelling achieved an annual heating demand of 83.5 kWh/m²/yr, significantly exceeding the Passivhaus benchmark of 15 kWh/m²/yr (Passive House Institute, 2023). This suggests that avoidable heat losses remain present within the building envelope and M&E strategy.

Heating Strategy

The inclusion of an air source heat pump (ASHP) represents a positive aspect of the baseline design and aligns with broader Welsh decarbonisation objectives (Welsh Government, 2021). Heat pumps typically operate more efficiently than direct electric heating by extracting ambient heat from external air (Energy Saving Trust, 2024). However, heating system performance is heavily influenced by building heat demand. Whilst the ASHP itself is efficient, elevated operational demand suggests that the building envelope continues to lose heat through infiltration, glazing and thermal bridging. Consequently, the baseline strategy may be considered technology-led rather than performance-led, whereby efficient equipment compensates for avoidable fabric inefficiencies rather than minimising demand at source.

Ventilation Strategy

The baseline dwelling adopts a Mechanical Extract Ventilation (MEV) system to satisfy indoor air quality requirements. Whilst compliant with Approved Document F, extract-only systems exhaust warmed internal air directly to atmosphere without recovering useful thermal energy (CIBSE, 2022).

As buildings become more airtight, ventilation heat loss becomes increasingly significant within total building energy demand. Consequently, the absence of heat recovery within the baseline dwelling represents a limitation from a low-energy perspective. The ventilation strategy therefore satisfies minimum compliance but falls short of recognised best practice associated with low-energy standards such as Passivhaus and LETI (LETI, 2020).

Airtightness and Building Fabric Performance

The baseline dwelling demonstrates an airtightness level of 4.74 ACH, representing compliance with regulatory expectations but remaining substantially above levels associated with high-performance dwellings. Uncontrolled infiltration contributes to avoidable heat loss, increasing the quantity of energy required to maintain internal comfort (Passive House Institute, 2023).

Similarly, the use of double glazing and standard thermal bridge detailing contributes to transmission losses through the building envelope. Although compliant with regulation, these measures are less effective than contemporary low-energy alternatives and may negatively affect thermal comfort and operational efficiency.

Building Orientation and Passive Performance

The retained east–west orientation reduces opportunities for beneficial winter solar gain, increasing dependence upon mechanical heating systems (LETI, 2020). However, this conservative condition strengthens the validity of the PHPP assessment, as performance improvements within the upgraded model cannot be attributed to favourable site conditions.

Overall, the baseline dwelling demonstrates several positive low-carbon characteristics, particularly through the adoption of ASHP technology. However, the specification remains constrained by a minimum compliance approach, resulting in avoidable operational heat losses and elevated heating demand.

The principal limitations identified include:

- Elevated heating demand despite low-carbon heating provision;
- Heat loss associated with extract-only ventilation;
- Moderate airtightness performance;
- Transmission losses through glazing and thermal bridges;
- Limited passive solar gain due to orientation.

Detailed technical appraisal of the baseline M&E systems is included within Appendix C.

PHPP METHODOLOGY AND ASSUMPTIONS

Building performance was evaluated using the Passive House Planning Package (PHPP), a detailed building energy modelling tool developed by the Passive House Institute and widely used to assess low-energy residential buildings (Passive House Institute, 2023). PHPP was selected because it enables a more detailed assessment of operational energy demand than standard regulatory compliance calculations by accounting for factors such as heat loss, solar gains, ventilation performance, occupancy assumptions and thermal bridging. A comparative modelling approach was adopted to evaluate the operational performance of the proposed dwelling under two scenarios:

- Baseline Model – representing compliance with current Approved Document L (Wales) requirements; and
- Enhanced Low-Energy Model – incorporating targeted interventions to improve operational performance.

To ensure comparability, both scenarios retained the same building geometry, occupancy, orientation and floor area. This ensured that performance differences observed within PHPP outputs were attributable to specification improvements rather than external variables.

Parameter	Baseline Model	Upgraded Model
Treated Floor Area	101.94m ²	101.94m ²
Occupancy	6 persons	6 persons
Orientation	East–West	East–West
Heating	5kW ASHP	5kW ASHP
Ventilation	MEV	MVHR
Glazing	Double glazing	Triple glazing
Airtightness	4.74 ACH	0.60 ACH

Table 2 – Key PHPP Modelling Assumptions

The baseline model produced an annual heating demand of 83.5 kWh/m²/yr and PER demand of 123.0 kWh/m²/yr, which established the performance benchmark for subsequent analysis.

Whilst PHPP provides a robust method for evaluating operational energy performance, modelling outcomes remain dependent upon assumptions relating to occupancy behaviour, heating patterns and construction quality. Consequently, the upgraded airtightness performance of 0.60 ACH should be considered an achievable design target rather than a guaranteed operational outcome. Full modelling assumptions, verification sheets and PHPP outputs are provided within Appendix D and Appendix E.

PROPOSED DESIGN IMPROVEMENTS TO ACHIEVE NET ZERO PERFORMANCE

PHPP modelling identified several opportunities to improve operational performance and reduce energy demand. Rather than relying solely on additional renewable technologies, the upgraded proposal adopted a fabric-first methodology, prioritising reductions in heat loss before increasing energy generation (LETI, 2020).

Airtightness Improvements

The baseline dwelling achieved an airtightness level of 4.74 ACH, contributing to uncontrolled infiltration heat loss. To reduce operational demand, the upgraded design improved airtightness to 0.60 ACH, approaching recognised Passivhaus performance levels (Passive House Institute, 2023).

This intervention would require improved construction detailing, membrane continuity and greater quality assurance during delivery. However, unlike technology-based interventions, improved airtightness primarily depends upon workmanship rather than substantial material cost increases.

The reduction in infiltration contributed significantly towards lowering annual heating demand to 30.2 kWh/m²/yr, whilst also improving thermal comfort through reduced draughts and temperature instability.

Ventilation Upgrade: MEV to MVHR

The baseline Mechanical Extract Ventilation (MEV) system was replaced with Mechanical Ventilation with Heat Recovery (MVHR) to reduce ventilation-related heat loss.

MVHR systems recover thermal energy from extracted air and transfer it to incoming fresh air, reducing heat loss whilst maintaining indoor air quality (CIBSE, 2022). This intervention becomes particularly effective when combined with improved airtightness, as ventilation losses account for a greater proportion of total heat demand in low-energy buildings.

Although MVHR increases upfront capital cost, PHPP modelling indicates that reduced ventilation losses contributed towards significant reductions in operational heating demand.

Glazing and Thermal Bridge Improvements

The upgraded design replaced double glazing with triple glazing to reduce transmission heat losses and improve internal comfort. Triple glazing improves thermal resistance and reduces localised cold discomfort around openings (Passive House Institute, 2023).

Additionally, thermal bridge detailing was improved to reduce heat transfer at junctions between walls, floors, roofs and openings. Whilst individual thermal bridge improvements may appear minor, their cumulative impact across the building envelope can significantly influence overall energy demand.

Heating System Optimisation

The upgraded strategy retained the existing 5kW ASHP, but reduced reliance upon mechanical heating through improved fabric performance. This reflects a key principle of low-energy design:

Reducing heating demand is often more effective than increasing heating capacity.

PHPP modelling demonstrated that annual heating demand reduced from 83.5 kWh/m²/yr to 30.2 kWh/m²/yr, whilst PER demand reduced from 123.0 kWh/m²/yr to 87.4 kWh/m²/yr, representing an approximate 29% reduction.

Table 3 – Summary of Proposed Design Improvements

Upgraded	Baseline	Upgraded
Airtightness	4.74 ACH	0.60 ACH
Ventilation	MEV	MVHR
Glazing	Double glazing	Triple glazing
Thermal Bridging	Standard detailing	Improved detailing
Heating Demand	83.5 kWh/m ² /yr	30.2 kWh/m ² /yr
PER Demand	123.0 kWh/m ² /yr	87.4 kWh/m ² /yr

Collectively, these interventions demonstrate that substantial reductions in operational energy demand can be achieved through targeted improvements to building fabric and M&E integration, moving the dwelling closer

towards low-energy and Net Zero operational performance. Further technical discussion relating to detailing and implementation is included within Appendix F.

PHPP RESULTS AND COMPARATIVE ANALYSIS

To evaluate the effectiveness of the proposed interventions, comparative modelling was undertaken using PHPP between the baseline dwelling and the upgraded low-energy scenario. As both models retained the same floor area, orientation and occupancy assumptions, performance differences may be attributed directly to specification improvements rather than external variables.

Table 4 – Comparative PHPP Results

Performance Indicator	Baseline Dwelling	Upgraded Dwelling	Change
Heating Demand	83.5 kWh/m ² /yr	30.2 kWh/m ² /yr	↓64%
PER Demand	123.0 kWh/m ² /yr	87.4 kWh/m ² /yr	↓29%
Airtightness	4.74 ACH	0.60 ACH	↑87% improvement
Overheating Frequency	1%	3%	Slight increase

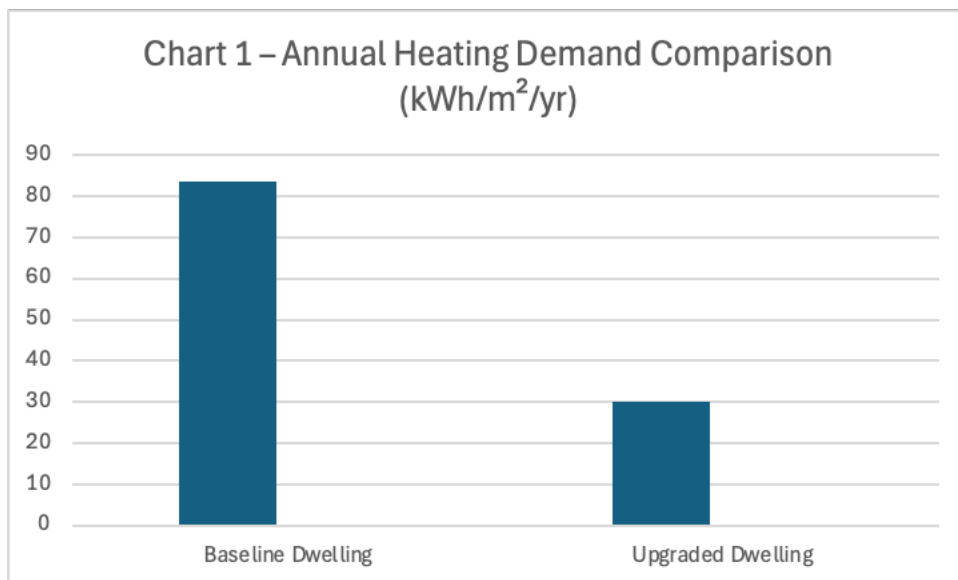
Full PHPP verification sheets and supporting outputs are included within Appendix E.

Heating Demand Performance

The most significant improvement observed within the upgraded model relates to annual heating demand. The baseline dwelling recorded a heating demand of 83.5 kWh/m²/yr, indicating that substantial energy was required to maintain internal comfort despite compliance with Approved Document L (Wales) (Welsh Government, 2025).

Following the proposed interventions, annual heating demand reduced to 30.2 kWh/m²/yr, representing a 64% reduction. This demonstrates the effectiveness of a fabric-first design approach, whereby improvements to airtightness, ventilation efficiency, glazing and thermal continuity reduce operational demand before increasing heating provision (LETI, 2020).

Although the upgraded dwelling did not achieve the Passivhaus heating demand benchmark of 15 kWh/m²/yr, the reduction achieved remains significant and demonstrates meaningful progress beyond minimum compliance (Passive House Institute, 2023). Importantly, these improvements were achieved whilst maintaining the same building geometry and east–west orientation, suggesting that the performance gains result directly from improved M&E integration and envelope performance rather than favourable site conditions.

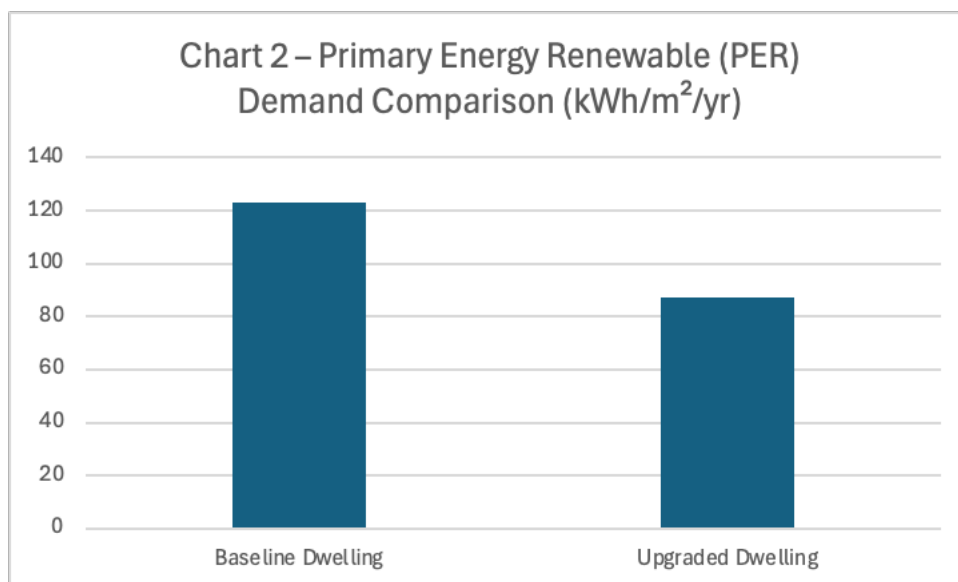


Primary Energy Renewable (PER) Performance

The upgraded model also demonstrated improvements in Primary Energy Renewable (PER) demand, reducing from 123.0 kWh/m²/yr to 87.4 kWh/m²/yr, representing an approximate 29% reduction.

The proportional reduction in PER demand is lower than the reduction observed for heating demand because total building energy use also includes domestic hot water, appliances and occupant-related loads (Passive House Institute, 2023). This demonstrates an important limitation of low-energy design: reductions in space heating alone do not eliminate wider operational energy demand.

Nevertheless, the reduction achieved remains important from a Net Zero perspective, as lower energy intensity reduces the scale of renewable technologies required to offset annual operational demand.



Airtightness and Internal Comfort

Airtightness improvements represented one of the most influential interventions within the upgraded model. The reduction from 4.74 ACH to 0.60 ACH significantly reduced uncontrolled infiltration losses, contributing toward lower heating demand and improved thermal stability.

Improved airtightness also supports occupant comfort through reduced draughts and more consistent internal temperatures. However, airtight buildings become increasingly dependent upon planned ventilation systems to maintain indoor air quality, reinforcing the importance of the transition from MEV to MVHR (CIBSE, 2022).

PHPP modelling also indicated a slight increase in overheating frequency from 1% to 3%. Whilst this suggests marginally greater summer heat retention, overheating remained relatively low and may be considered acceptable when balanced against the substantial reduction in winter heating demand. This finding reinforces the importance of balancing winter performance with summer comfort in low-energy buildings.

Overall, the PHPP outputs demonstrate that coordinated improvements to building fabric and M&E systems can significantly reduce operational energy demand without major alterations to building form or occupancy assumptions.

WHOLE-LIFE IMPLICATIONS, COST, CARBON AND NET ZERO JUSTIFICATION

Achieving Net Zero residential performance requires consideration beyond operational energy demand alone. Whole-life performance also includes embodied carbon, lifecycle cost, occupant wellbeing and long-term resilience (LETI, 2020).

The upgraded dwelling demonstrated clear operational advantages through a 64% reduction in annual heating demand and 29% reduction in PER demand, reducing long-term energy consumption and operational carbon emissions. Lower operational demand may also reduce vulnerability to future energy price increases, improving affordability and reducing lifetime running costs.

Whilst interventions such as MVHR and triple glazing may increase upfront capital cost, several proposed measures—particularly improved airtightness and thermal bridge detailing—depend primarily on enhanced workmanship and quality assurance rather than substantial material expenditure. Consequently, modest increases in capital cost may be offset through operational savings over the building lifecycle.

Embodied carbon considerations must also be acknowledged. Triple glazing and MVHR systems introduce additional material and manufacturing impacts when compared with baseline alternatives. However, these impacts may be justified through long-term operational energy reductions, particularly where interventions contribute to lower lifetime carbon emissions.

The upgraded dwelling also offers benefits relating to occupant comfort and indoor environmental quality. Improved airtightness, enhanced glazing and MVHR may contribute to more stable internal temperatures, reduced draughts and improved ventilation performance (CIBSE, 2022).

Although the dwelling did not achieve full Passivhaus performance, the results demonstrate that substantial improvements towards Net Zero residential delivery are achievable through targeted and realistic interventions. This is particularly relevant within contemporary Welsh housing, where complete redesign is often constrained by cost, planning and programme considerations.

Further discussion relating to embodied carbon and lifecycle considerations is included within Appendix F.

CONCLUSION

This report critically evaluated the mechanical and electrical (M&E) design of the proposed HT641 residential dwelling and assessed how the baseline specification could be improved to better support low-energy and Net Zero residential performance.

Although the baseline dwelling satisfied Approved Document L (Wales) requirements and incorporated low-carbon heating through an air source heat pump (ASHP), PHPP modelling demonstrated that regulatory compliance alone did not achieve low operational energy demand. The dwelling recorded a heating demand of 83.5 kWh/m²/yr, highlighting limitations associated with airtightness, ventilation strategy, glazing performance and thermal bridging.

To address these limitations, a fabric-first design strategy was adopted, prioritising reductions in operational demand before increasing heating provision or renewable offsetting. Key interventions included improved airtightness, replacement of MEV with MVHR, upgraded glazing and improved thermal bridge detailing. PHPP modelling demonstrated that these interventions reduced annual heating demand to 30.2 kWh/m²/yr, representing a 64% reduction, whilst PER demand reduced by approximately 29%. These findings demonstrate that significant improvements in operational performance can be achieved through coordinated M&E and envelope optimisation without major redesign.

Whilst the upgraded dwelling did not fully achieve Passivhaus heating demand thresholds, the improvements remain substantial and demonstrate realistic progress towards Net Zero housing delivery within a Welsh residential context.

Ultimately, the findings reinforce the importance of moving beyond minimum regulatory compliance towards a performance-led and fabric-first approach, whereby reductions in energy demand are prioritised before renewable compensation. Through targeted interventions and improved M&E integration, new-build dwellings can become significantly more efficient, resilient and aligned with long-term Net Zero objectives.

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APPENDIX A – LEGISLATIVE AND LOW-ENERGY DESIGN CONTEXT

A.1 Welsh Net Zero Policy Context

The Welsh Government has committed to achieving Net Zero greenhouse gas emissions by 2050, placing increasing emphasis on reducing operational energy demand and carbon emissions within the residential sector (Welsh Government, 2021).

The Well-being of Future Generations (Wales) Act 2015 established a long-term sustainability framework requiring public decision-making to consider environmental resilience and resource efficiency. Within housing delivery, this supports improved building performance and reduced operational energy demand.

Similarly, the Environment (Wales) Act 2016 introduced legally binding carbon reduction pathways, reinforcing the transition away from fossil fuel heating and increasing reliance on low-carbon technologies such as Air Source Heat Pumps (ASHPs).

The Welsh Government's Net Zero Wales Carbon Budget 2 (2021–2025) identifies low-energy residential buildings as essential to meeting national decarbonisation targets, emphasising the importance of reducing energy demand before relying on renewable generation (Welsh Government, 2021).

A.2 Approved Document L (Wales)

Approved Document L (Wales) establishes minimum performance standards relating to:

- Energy conservation;

- Building fabric performance;
- Thermal efficiency;
- Carbon emissions;
- Heating system efficiency.

Whilst Part L represents a considerable improvement upon historic housing standards, it remains a minimum compliance benchmark rather than a high-performance building standard (Welsh Government, 2025).

Consequently, buildings satisfying Part L may continue to experience avoidable operational heat losses through:

- Air leakage;
- Thermal bridging;
- Ventilation inefficiencies;
- Moderate glazing performance.

A.3 Approved Document F (Wales)

Ventilation requirements are governed by Approved Document F, which aims to maintain:

- Indoor air quality;
- Moisture control;
- Condensation prevention;
- Occupant health.

The baseline dwelling utilised Mechanical Extract Ventilation (MEV) to achieve compliance. However, unlike Mechanical Ventilation with Heat Recovery (MVHR) systems, extract-only ventilation exhausts warmed internal air without recovering thermal energy, potentially increasing operational heating demand.

A.4 Low-Energy Building Standards

Passivhaus

Passivhaus principles prioritise:

- Exceptional airtightness;
- Reduced thermal bridging;
- High-performance glazing;
- Efficient heat recovery ventilation.

A commonly recognised Passivhaus benchmark limits annual heating demand to:

15 kWh/m²/yr

(Passive House Institute, 2023)

Although the upgraded dwelling did not achieve this threshold, PHPP modelling demonstrated meaningful improvements toward low-energy performance.

LETI

The London Energy Transformation Initiative (LETI) advocates a fabric-first methodology, prioritising reductions in operational demand before renewable offsetting (LETI, 2020).

APPENDIX B – SCENARIO BUILDING INFORMATION

B.1 Dwelling Overview

Element	Specification
Dwelling Type	HT641 Residential Dwelling
Occupancy	6 Persons
Bedrooms	4
Treated Floor Area (TFA)	101.94m ²
Orientation	East–West
Heating System	Vaillant aroTHERM Plus 5kW ASHP
Ventilation	Mechanical Extract Ventilation (MEV)
Glazing	Double Glazing
Airtightness	4.74 ACH

B.2 Building Orientation

The dwelling retained an east–west orientation, limiting passive solar gain opportunities when compared with south-facing arrangements (LETI, 2020).

Whilst less favourable from a passive design perspective, retaining this orientation throughout PHPP modelling strengthened the reliability of comparative outputs by ensuring performance improvements resulted from specification changes rather than environmental assumptions.

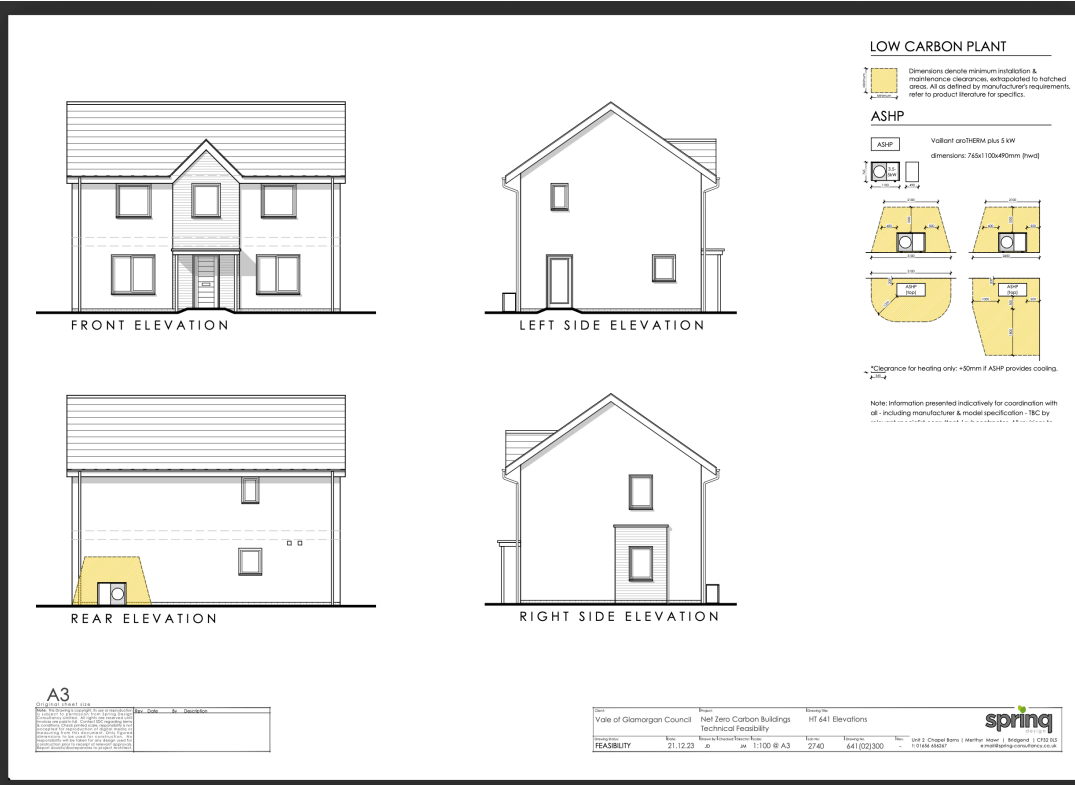
B.3 Baseline Building Fabric

The baseline dwelling was designed to satisfy Approved Document L (Wales) and incorporated:

- Insulated masonry wall construction;
- Part L compliant roof insulation;
- Part L compliant floor insulation;
- Double glazing;
- Standard thermal bridge detailing.

Although compliant, these measures remain below high-performance low-energy benchmarks.

Figure B.1 – Building Elevations



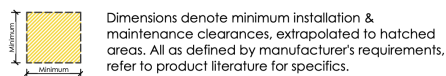
APPENDIX C – TECHNICAL APPRAISAL OF EXISTING M&E SYSTEMS

C.1 Air Source Heat Pump (ASHP)

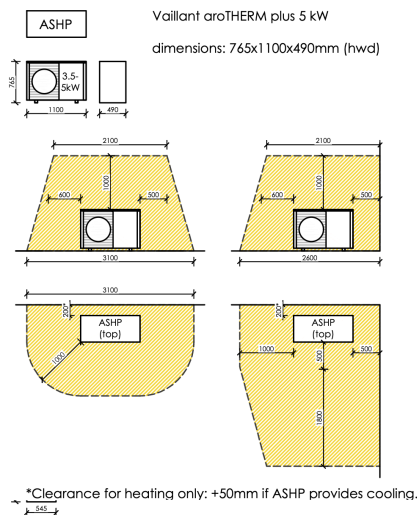
The baseline dwelling utilised a Vaillant aroTHERM Plus 5kW ASHP.

ASHP systems extract ambient heat from external air and transfer this into the building, offering significantly improved operational efficiency when compared with direct electric heating (Energy Saving Trust, 2024). However, system efficiency remains dependent upon building heat demand. Elevated infiltration and transmission losses may reduce overall system effectiveness by increasing operational heating requirements.

LOW CARBON PLANT



ASHP



C.2 Mechanical Extract Ventilation (MEV)

The baseline ventilation strategy utilised Mechanical Extract Ventilation (MEV).

MEV systems extract stale air from wet areas including:

- Kitchens;
- Bathrooms;
- Utility spaces.

However, extract-only systems discharge warmed internal air externally without reclaiming thermal energy, contributing toward avoidable heat loss (CIBSE, 2022).

C.3 Airtightness

The baseline airtightness level of 4.74 ACH satisfied minimum regulatory requirements but remained substantially above low-energy standards.

Improved airtightness reduces:

- Heat loss;
- Cold draughts;
- Energy demand.

Achieving airtightness levels approaching 0.60 ACH would require:

- Improved membrane continuity;
- Enhanced junction sealing;
- Reduced service penetrations;
- Pressure testing and quality assurance.

C.4 Glazing and Thermal Bridging

The baseline dwelling utilised double glazing, which generally demonstrates higher thermal transmittance values than modern triple-glazed systems.

Thermal bridges located at junctions between floors, walls and openings may also contribute to localised heat loss and internal comfort issues.

Improved detailing may reduce operational heat losses and improve thermal continuity.

APPENDIX D – PHPP MODELLING ASSUMPTIONS

D.1 Baseline Model Assumptions

Parameter	Baseline Model
Occupancy	6 Persons
TFA	101.94m ²
Orientation	East–West
Ventilation	MEV
Glazing	Double Glazing
Airtightness	4.74 ACH

D.2 Upgraded Model Assumptions

Parameter	Upgraded Model
Occupancy	6 Persons
TFA	101.94m ²
Orientation	East–West
Ventilation	MVHR
Glazing	Triple Glazing
Airtightness	0.60 ACH

D.3 Modelling Limitations

PHPP modelling remains dependent upon assumptions relating to:

- Occupancy behaviour;
- Appliance use;
- Heating schedules;
- Construction quality;
- Seasonal weather conditions.

Consequently, modelled performance should be considered indicative rather than guaranteed operational performance.

APPENDIX E – PHPP OUTPUTS

E.1 Baseline PHPP Verification Sheet

AutoSave PHPP_EN_V10.6_Assignment - Baseline

Home Insert Draw Page Layout Formulas Data Review View Automate

Search (Cmd + Ctrl + U)

Comments Share

Passive House-Verification

Photo or drawing

Building: 3 Bed Detached Dwelling
Street: Crymch Avenue
Postcode/City: Vale of Glamorgan GB-Vereinigtes Königreich
Province/Country: 1-Freestanding single family house
Climate data set: GB0023a-Swamsea, Altitude corrected
Climate zone: 3: Cool-temperate Altitude of location: 50 m

Home owner / Client: Billie Jean
Street: Lower Street
Postcode/City: SA1 Swamsea
Province/Country:

Mechanical engineer: Davies and
Street:
Postcode/City:
Province/Country:

Certification:
Street:
Postcode/City:
Province/Country:

Architecture: Davies and Son's Ltd
Street: Blaenffos
Postcode/City: SA37 0HU
Province/Country: Pembrokeshire GB-Vereinigtes Königreich

Energy consultancy: Davies and Son's Ltd
Street: Blaenffos
Postcode/City: SA37 0HU
Province/Country: Pembrokeshire GB-Vereinigtes Königreich

Year of construction: 2026
No. of dwelling units: 1
No. of occupants: 6.0

Interior temperature winter [°C]: 20.0
Internal heat gains (IHG) winter [W/m²]: 2.6
Specific heat capacity [Wh/K per m² TFA]: 60

Interior temp. summer [°C]: 25.0
IHG summer [W/m²]: 3.7
Mechanical cooling:

Project settings
Please select

Energy standard / Criteria
New building / Retrofit
1-New building
Planned energy standard
10-Passive House
Class | Primary energy method
10-Classical PER (renewable)
Primary energy demand criterion
1-Standard

Building use
10-Residential building: Residential
Internal heat gains (IHG)
2-Standard

No. of occupants
Standard (only for residential buildings)
User-defined

Specific building characteristics with reference to the treated floor area

	Treated floor area m²	Criteria	Alternative criteria	Fulfilled?²
Space heating	101.9	15	-	No
Heating demand kWh/(m²a)	83	-	10	
Heating load W/m²	33	-		
Space cooling	-	-	-	-
Cooling & dehum. demand kWh/(m²a)	-	10		Yes
Frequency of overheating (> 25 °C) %	1	20		Yes
Frequency of excessively high humidity (> 12 g/kg) %	2			

Ready Accessibility: Investigate

AutoSave PHPP_EN_V10.6_Assignment - Baseline

Home Insert Draw Page Layout Formulas Data Review View Automate

Search (Cmd + Ctrl + U)

Comments Share

Street: Blaenffos
Postcode/City: SA37 0HU
Province/Country: Pembrokeshire GB-Vereinigtes Königreich

Year of construction: 2026
No. of dwelling units: 1
No. of occupants: 6.0

Interior temperature winter [°C]: 20.0
Internal heat gains (IHG) winter [W/m²]: 2.6
Specific heat capacity [Wh/K per m² TFA]: 60

Interior temp. summer [°C]: 25.0
IHG summer [W/m²]: 3.7
Mechanical cooling:

Specific building characteristics with reference to the treated floor area

	Treated floor area m²	Criteria	Alternative criteria	Fulfilled?²
Space heating	101.9	15	-	No
Heating demand kWh/(m²a)	83	-	10	
Heating load W/m²	33	-		
Space cooling	-	-	-	-
Cooling & dehum. demand kWh/(m²a)	-	10		Yes
Frequency of overheating (> 25 °C) %	1	20		Yes
Frequency of excessively high humidity (> 12 g/kg) %	2			
Airtightness	Pressurisation test result n ₅₀ 1/h	0.6		No
4.7				
Non-renewable Primary Energy (PE)	PE demand kWh/(m²a)	-		-
145				
Primary Energy	PER demand kWh/(m²a)	60	75	No
Renewable (PER)	Renew. energy generation (in rel. to projected building footprint area) kWh/(m²a)	-	21	
0				

² Empty field: data missing; -: No requirement

I confirm that the values given here have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification.

Passive House Classic? No

Ready Accessibility: Investigate

E.2 Upgraded PHPP Verification Sheet

Excel File Edit View Insert Format Tools Data Window Help

PHPP_EN_V10.6_Assignment - Upgraded

Home Insert Draw Page Layout Formulas Data Review View Automate

Comments Share

Passive House-Verification

Photo or drawing

Building: 3 Bed Detached Dwelling
Street: Crymch Avenue
Postcode/City: SA37 0HU
Province/Country: Vale of Glamorgan GB-Vereinigtes Königreich
Building type: 1-Freestanding single family house
Climate data set: GB0023a-Swansea, Altitude corrected
Climate zone: 3: Cool-temperate Altitude of location: 50 m

Home owner / Client: Billie Jean
Street: Lower Street
Postcode/City: SA1 Swansea
Province/Country:

Mechanical engineer: Davies and Son's Ltd
Street: Blaenffos
Postcode/City: SA37 0HU
Province/Country:

Certification:
Street:
Postcode/City:
Province/Country:

Architecture: Davies and Son's Ltd
Street: Blaenffos
Postcode/City: SA37 0HU
Province/Country: Pembrokeshire GB-Vereinigtes Königreich

Energy consultancy: Davies and Son's Ltd
Street: Blaenffos
Postcode/City: SA37 0HU
Province/Country: Pembrokeshire GB-Vereinigtes Königreich

Year of construction: 2026
No. of dwelling units: 1
No. of occupants: 6.0

Interior temperature winter [°C]: 20.0
Interior temp. summer [°C]: 25.0
Internal heat gains (IHG) winter [W/m²]: 2.6
IHG summer [W/m²]: 3.7
Specific heat capacity [Wh/K per m² TFA]: 60
Mechanical cooling:

Project settings
Please select
Energy standard / Criteria
New building / Retrofit
1-New building
Planned energy standard
10-Passive House
Class | Primary energy method
10-Classic | PER (renewable)
Primary energy demand criterion
1-Standard

Building use
10-Residential building: Residential
Internal heat gains (IHG)
2-Standard

No. of occupants
Standard (only for residential buildings)
6 User-defined

Specific building characteristics with reference to the treated floor area

	Treated floor area m²	Criteria	Alternative criteria	Fulfilled?²
Space heating	101.9	15	-	No
Heating demand kWh/(m²a)	30	-	10	
Heating load W/m²	14	-	10	

Verification Check Climate U-values Areas Ground Components Windows Shading Ventilation Add vent Annual heating Heating

Ready Accessibility: Investigate

Excel File Edit View Insert Format Tools Data Window Help

PHPP_EN_V10.6_Assignment - Upgraded

Home Insert Draw Page Layout Formulas Data Review View Automate

Comments Share

Year of construction: 2026
No. of dwelling units: 1
No. of occupants: 6.0

Interior temperature winter [°C]: 20.0
Interior temp. summer [°C]: 25.0
Internal heat gains (IHG) winter [W/m²]: 2.6
IHG summer [W/m²]: 3.7
Specific heat capacity [Wh/K per m² TFA]: 60
Mechanical cooling:

Specific building characteristics with reference to the treated floor area

	Treated floor area m²	Criteria	Alternative criteria	Fulfilled?²
Space heating	101.9	15	-	No
Heating demand kWh/(m²a)	30	-	10	
Heating load W/m²	14	-	10	
Space cooling	-	-	-	-
Cooling & dehum. demand kWh/(m²a)	-	-	-	-
Frequency of overheating (> 25 °C) %	3	10	-	Yes
Frequency of excessively high humidity (> 12 g/kg) %	5	20	-	Yes
Airtightness	0.6	0.6	-	Yes
Pressurisation test result n ₅₀ 1/h	0.6	-	-	-
Non-renewable Primary Energy (PE)	110	-	-	-
PE demand kWh/(m²a)	110	-	-	-
Primary Energy Renewable (PER)	87	60	75	No
PER demand kWh/(m²a)	87	-	21	-
Renew. energy generation (in rel. to projected building footprint area) kWh/(m²a)	0	-	-	-

² Empty field: data missing; -: No requirement

I confirm that the values given here have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification.

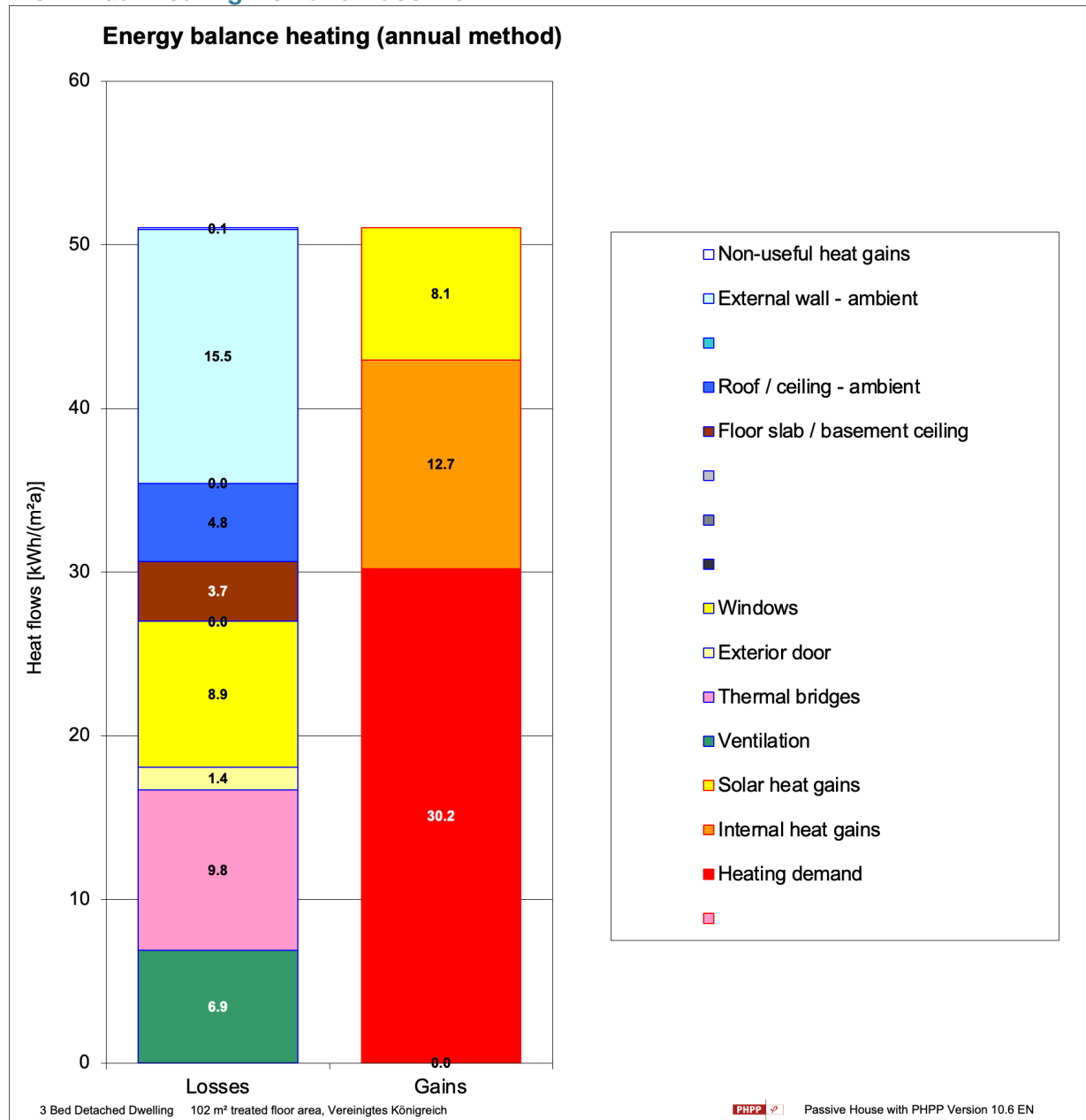
Task: First name: Deian Surname: Davies
Certificate-ID: Issued on: City:

Passive House Classic? No
Signature:

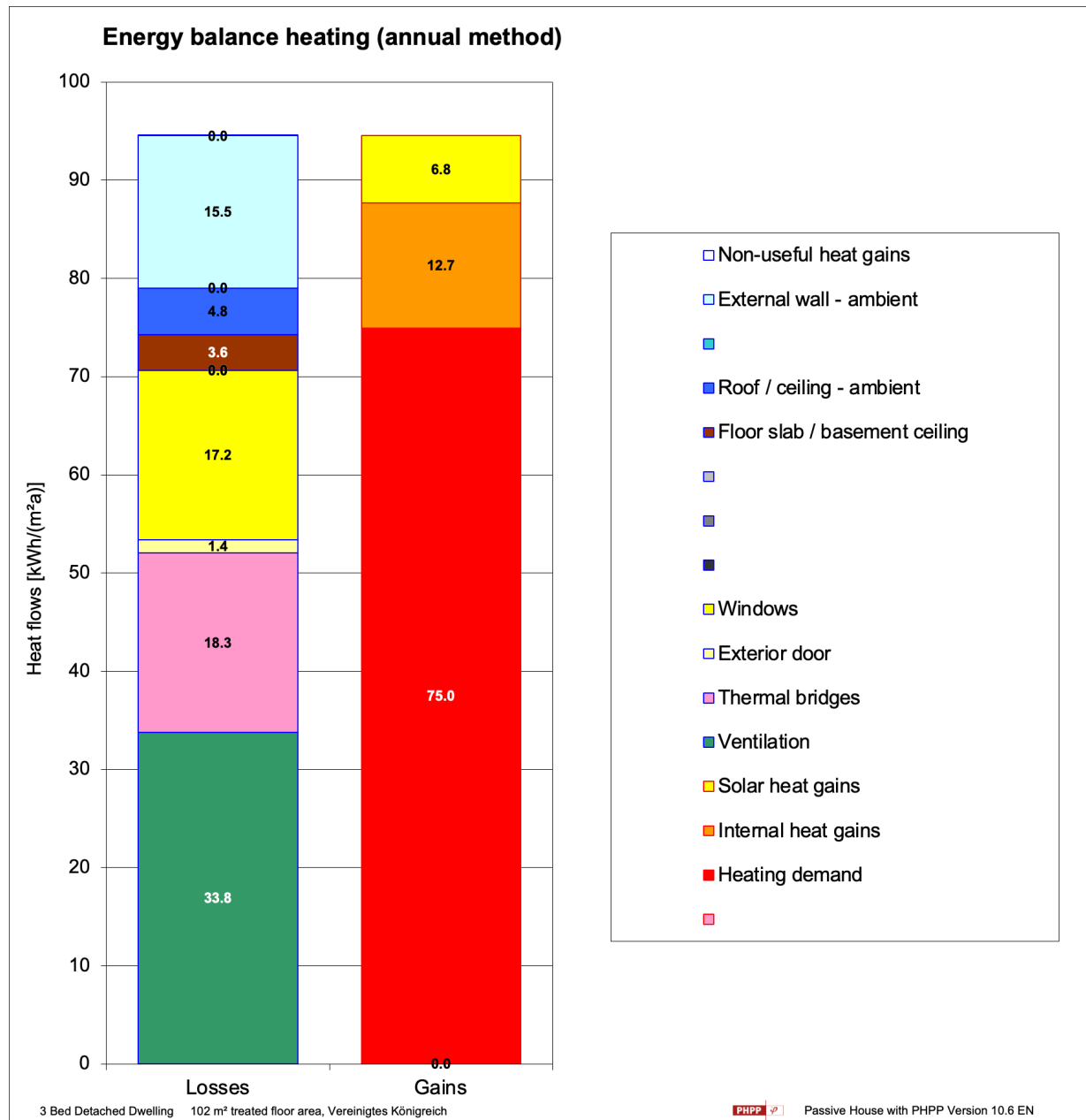
Verification Check Climate U-values Areas Ground Components Windows Shading Ventilation Add vent Annual heating Heating

Ready Accessibility: Investigate

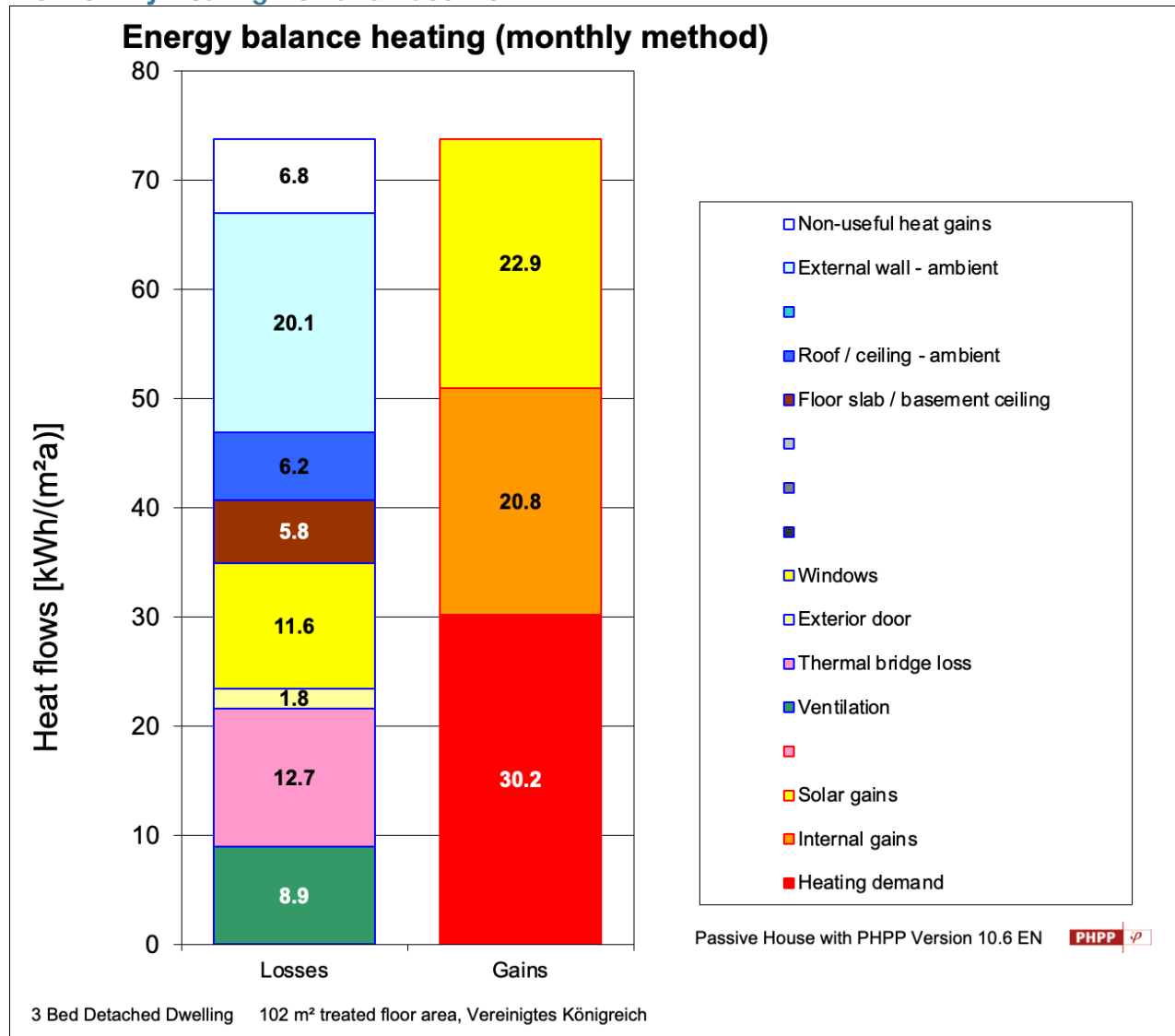
E.3 Annual Heating Demand Baseline



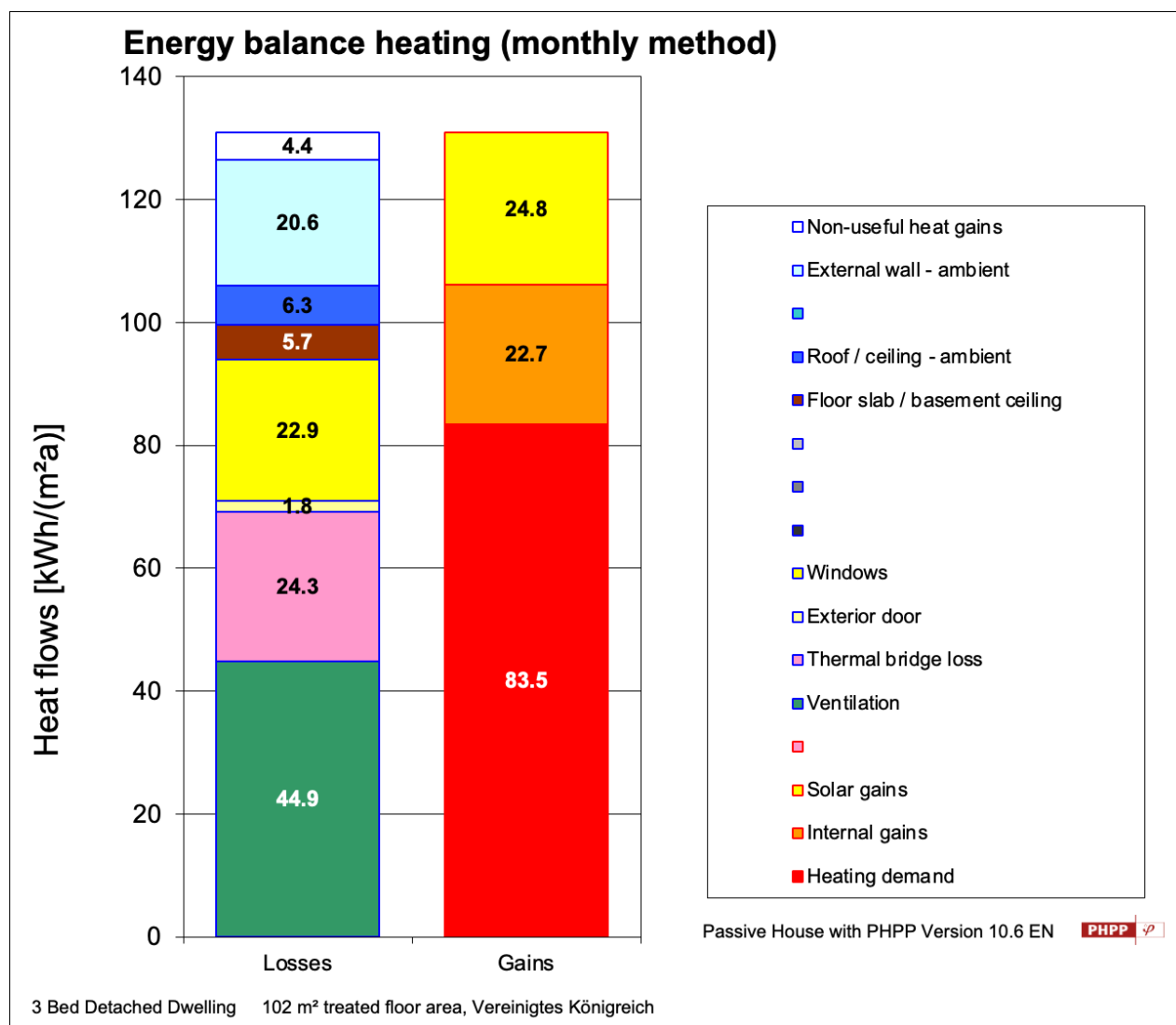
E.4 Annual Heating Demand Upgraded



E.5 Monthly Heating Demand Baseline



E.6 Monthly Heating Demand Upgraded



APPENDIX F – WHOLE-LIFE AND TECHNICAL CONSIDERATIONS

F.1 Embodied Carbon Considerations

Whilst operational energy reductions were prioritised, interventions such as triple glazing and MVHR may increase embodied carbon due to additional material requirements.

However, these impacts may be offset through long-term reductions in operational energy demand.

F.2 Occupant Comfort and Indoor Air Quality

The upgraded specification may improve:

- Internal thermal comfort;
- Temperature stability;
- Indoor air quality;

- Moisture control.

MVHR systems may also reduce condensation risk through balanced ventilation.

F.3 Construction Quality Requirements

Achieving upgraded performance would likely require:

- Enhanced workmanship;
- Improved detailing;
- Construction quality assurance;
- Airtightness testing;
- Effective commissioning.