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A Case Study of Nine Post-Hydrocarbon Ready Homes

Summarising In-Use Building Performance Data, Benchmarking Against UK Building Regulation Standards

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Abstract. A typical 2bed dwelling at Howgate Close, after 16months of occupation, has a daily average energy bill of 10pence/day/dwelling [1] It is proffered that Howgate Close may be the most energy efficient group of dwellings of its type, in the UK [2].

Howgate Close is a residential neighbourhood of nine single storey dwellings, operating free of fossil fuels, they are post-hydrocarbon ready. The development is located in Nottinghamshire, UK, and was completed in June 2022.

All nine homes are a net annual generator of surplus renewable energy, with little to no heating demand. Six of the nine homes remain naturally heated, with no resort to the electric underfloor heating system. Exceptionally high levels of energy efficiency have been achieved with third-party verification, the As-Built SAP Rating of 143A [3] Such a rating places these homes in the top 0.01% of the 12million registered UK Energy Performance Certificate's (EPC) [4].

This paper provides a building Case Study that evidences performance standards making comparisons with the UK Building Regulation Compliance Standards [5] Howgate Close's exceptional energy efficiency can be described as an aggregation of marginal gains [6] This paper is a prelude to more forensic analysis of Howgate's in-use building performance, with the installation more advanced monitoring equipment in May 2024 for a period of two years.

EWI Pro, Dr Harrall and Nottingham Trent University (NTU) are to undertake further data dissemination, providing a more forensic Howgate Case Study for ISEC 2025.

Keywords: Energy Efficient, Post-Hydrocarbon, SAP Ratings

1. Introduction

Howgate comprises, nine homes, 5no. 2beds (63m^2) and 4no.1beds (41m^2) with a gross development floor area of 479m^2. The projects financial viability has been tested in the open market with construction costs of £2,100 m², costs that compare favourably with £1,800 m² for a conventional dwelling and £2,200-2,400 m² for a Passive House. As a result, Howgate's development Return On Investment is 4.6% [7]

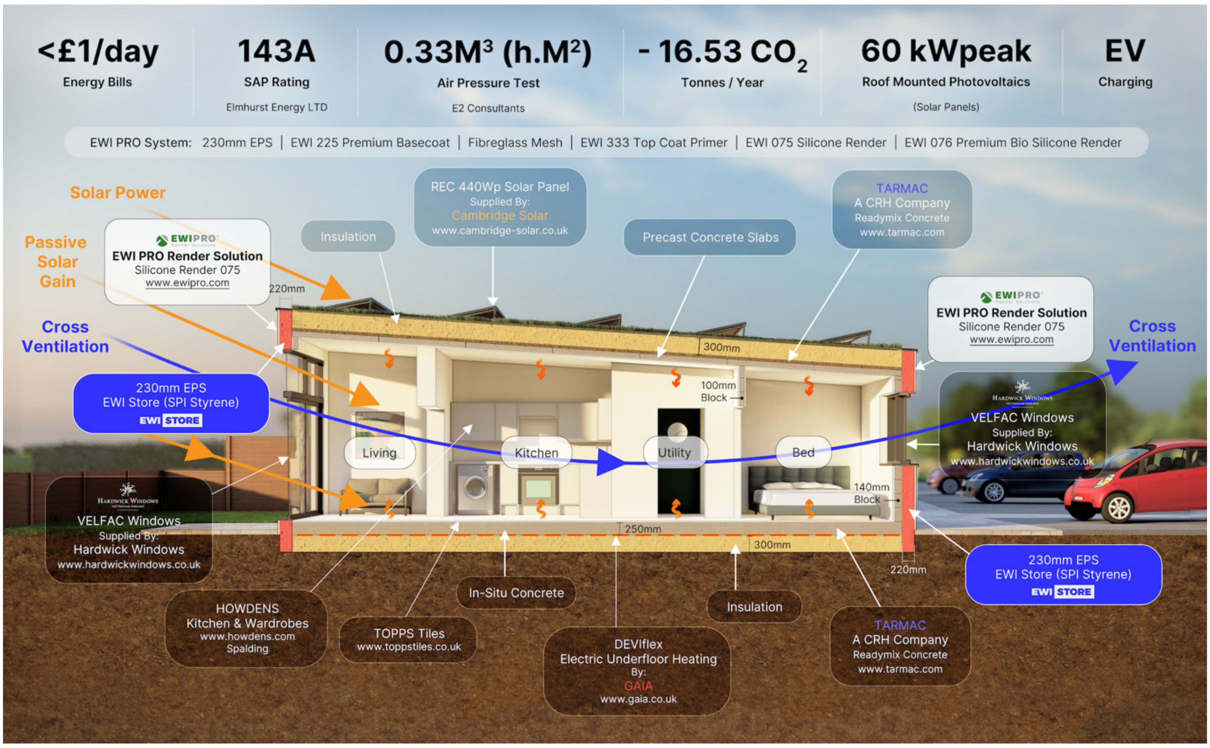

Figure 1. *Annotated Typical Cross-Section Of Howgate Close 2Bed Home (Provided by EWI Pro)*

1.1 Location

Howgate Close is located at latitude 53^0 North, centrally located in the British Isles which straddles between the mid-latitudes of 49^0 and 61^0. The climatic conditions of these Isles are largely related to the influence of the Atlantic Ocean, as such, experiences a temperate maritime climate. Ordnance Survey report, nowhere in the UK is located more than 70miles from the coast.

1.2 The Committee on Climate Change – *Setting The Scene*

Lord Deben, Chairman of The Committee on Climate Change [8] has advised the UK government that no new homes should be connected to the gas grid after 2025. Presently, 40 per cent of the UK's energy consumption is for heating buildings, with 85 per cent using fossil-fuel based natural gas.

Howgate Close aspires to operate beyond the UK Governments 'Zero Carbon' ambitions for 2050 [9]

1.3 'One-In-A-Million'

Third-party verification [10] of 'Howgate's' predicted energy efficiency and carbon emissions, produced an As-Built SAP Rating of 143A. Of the 15million registered EPC's in the UK, Howgate's' SAP Rating are ranked in the top 0.01% of the country's most energy efficient dwellings, better than one in a million!

2. Design Principles

The original project design was undertaken by the Hockerton Housing Project [11] using the design principles applied at HHP by its Architects, Professors Brenda and Robert Vale (The Vale's).

These design principles were first published in The Vale's, 1975 book, 'The Autonomous House', and implemented at their former Southwell home, featured in their other book 'The

New Autonomous House'. In 1991was the UK's first dwelling to export photovoltaic-generated renewable energy to the National Grid.

Dr Chris Parsons, Howgate's owner/developer, further advanced the buildings performance specification (see Figure 1) Intrinsic to that improved performance, is the utilisation of Passive Solar Design (PSD) principles; *southerly orientation, high thermal mass superstructure, super-insulated building envelope, triple glazing and roof mounted photovoltaics.* Other differentiating construction specifications include; solid external walls (no cavities) floating slab (no foundations) contiguous external insulated envelope (no cold bridging) externally located window and door jambs (improved Psi values).

3. Post-Hydrocarbon Ready

The authors interpretation of a post-hydrocarbon era, is a time when societies primary fuel for heat and power is not derived from oil, gas or coal. The authors concur with the opinion that, *"The post-hydrocarbon era will not appear suddenly. Gradual change and individual decisions will aggregate into wide structures beyond the scope of the individual decisions."* [12]

Howgate Close demonstrates the traits of what a post-hydrocarbon neighbourhood could look like: energy independence, autonomy over essential resources, on-site waste management, transitioning towards fossil-fuel-free lifestyles and a strong community spirit. These homes are fossil-fuel-free in operation, generating a surplus of energy, managing their own waste water on site with most homes not experiencing heating bills. It is maintained that elevating energy efficiency is the key in transitioning buildings to operate without resort to fossil fuels.

4. Building Performance Specification

At Howgate, stable internal air temperatures of 21^{o}C (+/- 2^{o}C) have been recorded over the first 16months of occupation with little to no active heating. Variations in heating loads are due to occupational patterns, demographics and household numbers across the nine households. These are to be reported in detail in the sequel paper. Exceptionally low heating loads are achieved with the combination of Passive Solar Design (PSD) techniques, high thermal mass superstructure (total thermal mass 152MJ/K, 1.16MJ/k/m^2) and an externally super-insulated fabric (average building U-Value 0.2W/m^{2}K)

Howgate's building element specification, significantly out performs the UK Building Regulations 'Notional Building' (See Table 1) Improvements in fabric heat transmittance (U-Values) are 28% for its walls (0.13W/m^{2}K) 38% for its floors (0.08W/m^{2}K) and 36% for the roofs (0.07W/m^{2}K) The most significant improvement against the Compliance Standards is Howgate's Air Pressure Tests (APT) (0.67m^3@50Pascals) 87% reduced fabric air infiltration.

Table 1. *Howgate Close Fabric Performance Comparison With Notional Building (Compiled by Dr J Harrall)*

HOWGATE CLOSE VS UK BUILDING REGULATIONS NOTIONAL BUILDING					
Minimum Standards for Fabric Performance			**Notional Building**	**HOWGATE CLOSE**	**% Difference**
	Part L 2013	**Part L 2021**	**Part L 2021**		
External walls	0.3 w/m²k	0.26 w/m²k	0.18 w/m²k	**0.13 w/m²k**	**+28**
Floors	0.25 w/m²k	0.18 w/m²k	0.13 w/m²k	**0.08 w/m²k**	**+38**
Roofs	0.2 w/m²k	0.16 w/m²k	0.11 w/m²k	**0.07 w/m²k**	**+36**
Windows	2 w/m²k	2.2 w/m²k	1.2 w/m²k	**0.78 w/m²k**	**+35**
Doors	2 w/m²k	1.6 w/m²k	1.0 w/m²k	**0.9 w/m²k**	**+10**
Air Permeability	10 m³/m²/hr @ 50Pa	8.0 m³/m²/hr @ 50Pa	5.0 m³/m²/hr @ 50Pa	**0.67m³/m²/hr @50Pa**	**+87**

5. Residual Heat Reservoir

At Howgate it is the combined elements of low thermal bridge junctions, contiguous insulated envelope and high thermal mass superstructure, that optimise the buildings' residual heat reservoir [13] its retained body of heat energy within the building fabric. At Howgate, an uninterrupted layer of 220mm (XPS, walls) to 300mm (EPS, roof and floor) envelopes the building externally. Subsequently, sufficient heat is retained within the thermal mass to sustain elevated internal air temperatures of circa 21°C.

6. Thermal Bridges

Thermal bridges (aka cold bridges) are thermally weak junctions with significantly higher heat transfer than surrounding materials. These junctions form a bridge between inner and outer surfaces e.g. window jamb, where paths of least resistance for heat transference, can result in up to 30% of total building heat loss [14] As a consequence, thermal bridges are at risk of internal surface condensation formation, potentially leading to mould growth, presenting a health risk.

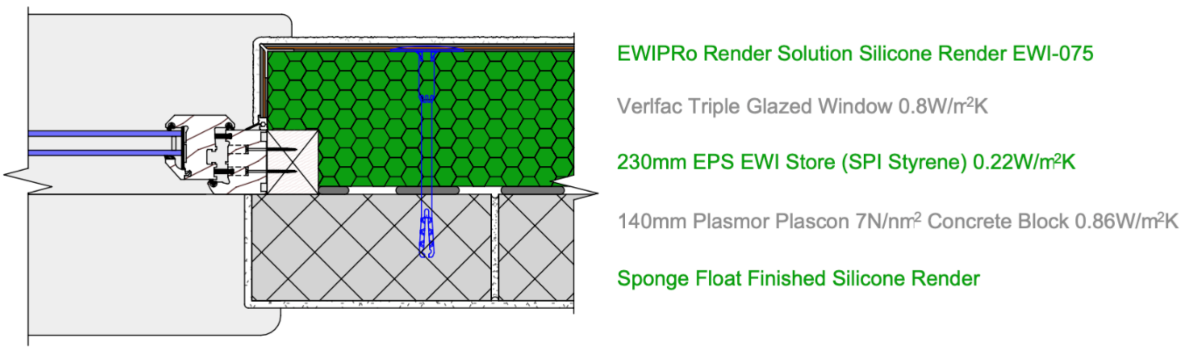

Figure 2. *Window Jamb Detail At Howgate Close (Provided by EWI Pro)*

Four principal categories of thermal bridge;

1) **Repeating thermal bridges** –regular interruptions in the building fabric e.g. brick mortar joints, wall ties and studs;- *U-Values*

2) **Linear (non-repeating) thermal bridges** –gaps in the insulation layer e.g. windows and doors – *Psi-Values*
3) **Geometrical thermal bridges** –meeting junctions different building elements e.g. external corners, where the heat loss area is greater than the internal surface – *Psi-Values*
4) **Point thermal bridges** –single penetrations in the thermal envelope flues, fastenings, brackets, stanchions – *Chi-Values*

6.1 Linear Thermal Transmittance

For the purposes of this paper, only linear and geometrical thermal bridges are calculated. The heat loss associated with these thermal bridges is expressed as Linear Thermal Transmittance (Ψ-value) – referred to as *psi-value*. At Howgate Close, there are no repeating thermal bridges and negligible point thermal bridges. A lower Psi-value indicates lower heat loss through a junction.

Calculated Psi-Values for Howgate Close [15] are compared to the UK Building Regulation 'Notional Building' (see Table 1) The 'notional building specification' is a recipe approach that will ensure minimum compliance if all standards are met.

Calculated perimeter heat loss from Howgate window and door frames, their average Linear Heat Transference (Psi-Value) is 0.024W/m.K. Heat transfer through Howgate's bespoke window/door junction is half that of the Notional Building compliance standard. Conversely, a building built to minimum Building Regulation standards, loses twice as much heat from its window/door junctions compared to Howgate Close.

***Table 2**. Comparison Table of Linear Heat Transference (Composed by Dr J Harrall)*

COMPARISON TABLE OF LINEAR HEAT TRANSFERENCE 2D PSI CALCULATION **Howgate Close & Notional Building** (UK Building Regulations 2023)			
	Notional Building * (Psi-Value W/m.K	**Howgate Close** (Psi-Value) W/m.K	**Condensation Risk**** (f-value) 1 = Zero Risk
Window Jamb	0.05	0.023	0.935
Window Lintel	0.05	0.027	0.956
Window Cill	0.05	0.023	0.927
Roof/Wall	0.08	0.067	0.965
**f-Value: risk of condensation forming on internal surface when external temperature is 0⁰C and internal room temperature is 20⁰C			
*Psi-Value: minimum building specification to ensure compliance with UK Building Regulation Standards			
Calculation undertaken by MES www.mesbuildingsolutions.co.uk and commissioned by EWIPro www.ewipro.com			

6.2 Surface temperature, mould growth and health

Calculated as part of the Psi-Value calculation is the *f-value*. The *f-value* estimates the risk of surface mould formation in a building. As the f-value approaches '1', the calculated incident of internal surface condensation formation at junctions reduces and with it, the risk of mould growth. For comparison, the Notional Building *f-value* compliance threshold is 0.75. At Howgate, its window/door junction average *f-value* is 0.94. The risk of internal surface condensation occurring on window/door junction detail at Howgate is reduced by 19% compared to the compliance standards for Building Regulations.

7. Interstitial Condensation

Interstitial condensation can occur between building construction interface layers of roofs, walls and floors. Persistent interstitial condensation within the building fabric can lead to degradation of materials, increased risk of mould formation and a reduction in air quality.

At Howgate, its modified solid externally insulated wall, designs out the cavity wall and locates the insulation on the external face of the solid block wall. A Condensation Risk Analysis [16] has evaluated the likelihood of interstitial condensation in Howgate's wall construction. These calculations demonstrate compliance with 'UK Building Regulation Part C'.

The analysis concluded that Howgate's external wall detail, avoided critical surface moisture, with no danger of mould growth. On the incidence of interstitial condensation, it concluded there was no risk of condensation forming at any interface in any month.

8. Summary

This paper articulates how Howgate Close's exceptional energy efficiency standards compare favourably to the UK Building Regulations 'Notional Building'. Included is evidence that demonstrates this performance can be ascribed to an aggregation of marginal gains.

Starting point is taking a 'fabric first' approach. Significant percentage point improvements in fabric heat transmittance compared to Building Regulations have been achieved, 28% to the walls, 38% to the floors and 36% for the roofs. Most notably, air permeability through the building fabric has been reduced by 87%.

Keeping on the theme of 'marginal gains', Howgate's window and door frame perimeter heat loss, is half that of the Notional Building compliance standard. Meaning a building built to minimum Building Regulation standards, loses twice as much heat from its junctions compared to Howgate Close. As a result of the associated detailing, the risk of internal surface condensation occurring, is reduced by 19%.

Such is the veracity of Howgate's fabric build up, the Condensation Risk Analysis concluded there was no risk of interstitial condensation forming at any interface, in any month.

It is hoped that this Howgate Close Case Study will play its part in informing building solutions transitioning to a post-hydrocarbon era. If so, the authors look forward to witnessing *"gradual change and individual decisions"* that may *"..aggregate into wide structures beyond the scope of the individual decisions."*

Data availability statement

All data referred to in the paper is either available via the References and their websites or has been uploaded as part of the submission.

Author contributions

Dr. J. Harrall is the principle author of the paper, has sourced and co-ordinated the papers composition.

Professor Anton Ianakiev has introduced the Conference opportunity, provided guidance on the paper format, Conference Proceedings and is actively engaged in formulating the Nottingham Trent University partnership with EWI Pro and Dr J. Harrall.

Nick Miles has provided the commercial support in commissioning the Psi calculations, Condensation calculations, resourcing staff to produce the Jamb detail and commissioned the annotated cross-section.

Competing interests

There are no competing interests.

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