## 1.0 ABSTRACT / ZUSAMMENFASSUNG

Detached single family dwelling in Radstock, UK

### 1.1 BUILDING DATA / GEBÄUDEDATEN

<table>
<thead>
<tr>
<th>Year of construction / Baujahr</th>
<th>Space heating / Heizwärmebedarf</th>
<th>U-value external wall / U-Wert Außenwand</th>
<th>Primary Energy / Primärenergie</th>
<th>Generation of renewable energy / Erzeugung erneuerbare Energie</th>
<th>Non-renewable Primary Energy (PE) / Nicht erneuerbare Primärenergie (PE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>13.9 kWh/(m²a)</td>
<td>0.084 W/(m²K)</td>
<td>104 kWh/(m²a)</td>
<td>20 kWh/(m²a)</td>
<td>73 kWh/(m²a)</td>
</tr>
<tr>
<td>U-value floor slab / U-Wert Bodenplatte</td>
<td>0.105 W/(m²K)</td>
<td>Primary Energy / Primärenergie</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-value roof / U-Wert Dach</td>
<td>0.076 W/(m²K)</td>
<td>Generation of renewable energy / Erzeugung erneuerbare Energie</td>
<td>20 kWh/(m²a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-value window / U-Wert Fenster</td>
<td>0.865 W/(m²K)</td>
<td>Non-renewable Primary Energy (PE) / Nicht erneuerbare Primärenergie (PE)</td>
<td>73 kWh/(m²a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat recovery / Wärmerückgewinnung</td>
<td>90.6%</td>
<td>Pressure test n50 / Drucktest n50</td>
<td>0.28/h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special features / Besonderheiten</td>
<td>PV array, SunAmp heat battery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1.2  BRIEF DESCRIPTION

Deasil is a self-build house to the south of Bath; constructed, managed and now lived-in by the architect and his family. Sited in a conservation area in the former Somerset coal fields, it required pitched roof forms and a low building height, leading to a challenging form heat-loss factor.

The Cross-Laminated Timber (CLT) frame, exposed internally, was erected in just 5 days and allowed a lightweight raft foundation to be used. Externally the building is clad in Brimstone Ash, a heat-treated timber, in a vertical board and batten arrangement redolent of rural barn buildings.

An integrated rooftop PV array & phase-change storage satisfies a substantial fraction of the annual domestic hot water demand.

1.3  RESPONSIBLE PROJECT PARTICIPANTS / VERANTWORTLICHE PROJEKTBETEILIGTE

| Architect/ Entwurfsverfasser | Tom Fowlie  
tom.fowlie@yahoo.com |
|-----------------------------|--------------------------|
| Building systems/ Haustechnik | Green Building Store (MVHR)  
www.greenbuildingstore.co.uk |
| Structural engineering/ Baustatik Building | Ramboll UK  
uk.ramboll.com |
| Craftspersons involved/ Handwerker | Coombes Carpentry, Earthwise Construction, EcoMirage (PV)  
G-frame Structures (CLT) |
| Certifying body/ Zertifizierungsstelle | WARM: low energy building practice  
www.peterwarm.co.uk |
| Certification ID/ Zertifizierungs ID | Project ID (ID 6329) |
| Author of project documentation / Verfasser der Gebäude-Dokumentation | Tom Fowlie  
tom.fowlie@yahoo.com |
| Date | 02.06.20 |
2.0 VIEWS OF THE PASSIVHAUS

South. The main elevation of the house faces mature trees, with glazing sized for views and adequate daylight.

East. This elevation faces the road with windows into the mezzanine and 3rd bedroom.
**North.** Rear elevation with minimal glazing. MVHR intake & exhaust terminals visible.

**West.** These elevations face open fields, with picture windows to the main bedroom and the living area.
**Interior.** View from the dining area towards the main living space and the view looking West.
3.0  TYPICAL SECTION

Typical Cross-Section. Indicating simple, continuous thermal envelope strategy. Blue line represents the weather barrier, the red line is airtightness. Dashed lines on the left (North) indicate penetrations for MVHR.
4.0 FLOOR PLANS

Ground Floor Plan.

First Floor Plan.
5.0 CONSTRUCTION DETAILS

5.1 GROUND FLOOR SLAB

The Ground Floor slab is constructed from a raft of reinforced concrete on an Isoquick insulation/formwork system with upstands (0.033 $\lambda$ W/(mK)). At thresholds, lengths of dense Compacfoam insulation (0.046 $\lambda$ W/(mK)) were laid with stainless steel threaded bar cast into the slab edge to reduce thermal bridging and provide adequate compressive strength.
<table>
<thead>
<tr>
<th>Material</th>
<th>λ W/(mK)</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Timber</td>
<td>0.160</td>
<td>25</td>
</tr>
<tr>
<td>Cement Screed</td>
<td>1.150</td>
<td>45</td>
</tr>
<tr>
<td>Concrete Slab</td>
<td>2.300</td>
<td>250</td>
</tr>
<tr>
<td>Insulation</td>
<td>0.033</td>
<td>300</td>
</tr>
</tbody>
</table>

**U-VALUE**

0.105 W/m²K
5.2 WALL CONSTRUCTION

The external walls are constructed from a structural frame of Cross-Laminated Timber, fire-treated and exposed on the inside face and wrapped in ProClima DA airtight vapour check on the outside face. This is overclad with mineral wool insulation slabs fitted between a ‘Larsen Truss’ system of engineered timber joists that support an outer sheathing board carrying the breather membrane.

The junction above indicates a typical opening (door/window) supported off a plywood box that cantilevers from the main frame (see section 5.4). The Larsen trusses above/below support these ply boxes and, aside from the openings and the trusses themselves, the insulation layer is continuous both around all corners of the building in plan and up and over the roof.

A sub-grid of battens and counterbattens carries the ventilated timber rainscreen. The mineral wool and trusses stop around 300mm above the external ground level and the remaining insulation is graphite EPS slabs to form a continuous thermal line from the isoquick upstands around the slab.
### WALL DATA

<table>
<thead>
<tr>
<th>Material</th>
<th>$\lambda$ W/(mK)</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT</td>
<td>0.130</td>
<td>100</td>
</tr>
<tr>
<td>Vapour Barrier</td>
<td>0.500</td>
<td>0</td>
</tr>
<tr>
<td>Rockwool (with timber fraction)</td>
<td>0.034</td>
<td>400</td>
</tr>
<tr>
<td>OSB</td>
<td>0.130</td>
<td>12</td>
</tr>
</tbody>
</table>

### U-VALUE

0.084 W/m²K

Construction photo showing the 'Larsen Trusses' with mineral wool infill.
Like the external walls, the roof is constructed from a structural frame of Cross-Laminated Timber. The ‘Larsen Trusses’ wrap up and over the ridge and the mineral wool fill continues in the same arrangement. Where the construction differs is an outer layer of 50mm graphite EPS slabs laid over the sheathing board to provide extra insulation, with the roof battens fastened using helical screws into the outer chord of the engineered joists. Ventilated slates and a roofing membrane complete the enclosure.
VERGE DETAIL

ROOF DATA

<table>
<thead>
<tr>
<th>Material</th>
<th>λ (W/(mK))</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT</td>
<td>0.130</td>
<td>100</td>
</tr>
<tr>
<td>Mineral wool insulation (with timber fraction)</td>
<td>0.034</td>
<td>400</td>
</tr>
<tr>
<td>Platinum EPS sarking</td>
<td>0.032</td>
<td>50</td>
</tr>
</tbody>
</table>

U-VALUE 0.076 W/(m²K)
Construction photo showing EPS sarking temporarily pinned over OSB sheathing, prior to roof battens and membrane fixing

Construction photo nearing completion of the roof, showing reclaimed slates and concealed gutter
The windows, sliding door and entrance door were supplied and installed by Internorm. HF310 windows are timber-aluminium composite with an average Uf-value of 0.790 W/(m²K). They open inward to allow wrapping of the frames externally with graphite EPS and are fixed into plywood boxes that cantilever out into the insulation zone and reduce the potential thermal bridging from installation. Glazing is triple glazed with warm edge spacers and an average Ug-value of 0.548 W/(m²K).

WINDOW DATA

Triple low-e glazing with argon gas and ISO warm edge spacer. Timber aluminium composite frame.

U-VALUE (average) 0.865 W/(m²K)
g-VALUE (average) 0.477
6.0 AIRTIGHTNESS RESULT

The airtightness strategy begins with the inherent air resistance of CLT panels - minimal joints due to large format components & multiple glued layers in different orientations. Junctions were designed as overlapped, then glued and over-taped on the external face by the frame contractor. Once the frame was in place, the roof and walls were covered in a ProClima DA membrane as a secondary airtight vapour check and temporary weatherproof line.

Windows and doors were surrounded with insulating foam by the installers and then sealed to their plywood ‘box’ surrounds and the main CLT frame with ProClima tapes.

The poured concrete structural slab completes the airtight line, laid over a radon membrane between the insulation and the concrete. The external wall membrane is sealed down onto the slab with ProClima Extoseal tape around the perimeter.
The airtightness was tested after these initial measures and then again at completion. Both tests were undertaken by Melin Energy Consultants and the final $n_{50}$ result averaged 0.28 h$^{-1}$ (0.27 pressurisation, 0.29 depressurisation) @ 50 Pa.
### Pressure Data Set

- **Test Dataset Date and Time:** 2019-09-25 10:22:00
- **Environmental Conditions:**
  - Wind speed: 0 from the
  - Operator Location: Inside the building
  - Initial Bas Pressure: 0.93 Pa
  - Initial Temperature: Indoor 23.9 °C, outdoor 16.1 °C
  - Final Bas Pressure: 0.93 Pa
  - Final Temperature: Indoor 24.2 °C, outdoor 17.4 °C
  - Barometric Pressure: 994.4 kPa

- **Test Analysis:**
  - Correlation, r²: 0.9367
  - Intercept, C₀: 2.8026 ± 1.36
  - Slope, n: 0.6006 ± 0.5194
  - Air flow at 50 Pa, Qₐ: 96.456 ± 1.65
  - A/C, U: 0.66 ± 1.6
  - Equivalent leakage area at 50 Pa: 7.494 ± 1.6
  - Permeability at 50 Pa, Δp₀: 0.2431 ± 1.6

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>AP1: -0.95</td>
</tr>
<tr>
<td>Final</td>
<td>AP4: 0.97</td>
</tr>
</tbody>
</table>

### Air Leakage Test Data Appendix

- **Depressurize Data Set**
  - **Test Dataset Date and Time:** 2019-09-25 10:46:34
  - **Environmental Conditions:**
    - Wind speed: 0 from the
    - Operator Location: Inside the building
    - Initial Bas Pressure: -1.27 kPa
    - Initial Temperature: Indoor 23.7 °C, outdoor 16.1 °C
    - Final Bas Pressure: -0.83 Pa
    - Final Temperature: Indoor 23.9 °C, outdoor 16.1 °C
    - Barometric Pressure: 864.4 kPa

- **Test Analysis:**
  - Correlation, r²: 0.9926
  - Intercept, C₀: 6.0535 ± 6.600
  - Slope, n: 0.6666 ± 0.7819
  - Air flow at 50 Pa, Qₐ: 100.22 ± 1.69
  - Air changes, U: 0.3689 ± 1.69
  - Equivalent leakage area at 50 Pa: 18.88 ± 1.69
  - Permeability at 50 Pa, Δp₀: 0.2662 ± 1.69

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>AP1: -1.02</td>
</tr>
<tr>
<td>Final</td>
<td>AP4: 0.93</td>
</tr>
</tbody>
</table>

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**Induced Pressure vs. Flow (Pressure Data Set)**

- Graph showing the relationship between induced pressure and flow for the pressure dataset.

**Induced Pressure vs. Flow (Depressurize Data Set)**

- Graph showing the relationship between induced pressure and flow for the depressurize data set.

**Building Gauge Pressure (Pressure Data Set)**

- Graph displaying the building gauge pressure over time for the pressure dataset.

**Building Gauge Pressure (Depressurize Data Set)**

- Graph displaying the building gauge pressure over time for the depressurize data set.
7.0 VENTILATION

Ground Floor ventilation layout

First Floor ventilation layout
A Paul Novus 300 MVHR unit is located in the Utility Room at Ground Floor in order to be close to the external wall and roughly central in plan. The cooker hood is recirculating with a charcoal filter. The intake and exhaust are wrapped in 15mm pre-formed EPS insulation and a layer of 25mm taped armaflex lagging. The effective heat recovery efficiency is 90.6% with a specific power input of 0.24 Wh/m³.

Lindab rigid steel spiral wound ducts are used for distribution, with cross-talk attenuation to habitable rooms. The structural frame connections between First Floor, roof and walls are notched to allow larger ducts to pass over. This keeps all services within the eaves perimeter zone below 1m height, which is ignored in TFA calculations, thus maximising usable floor area.

Fresh air is supplied to all bedrooms, the living area and the mezzanine floor. It is extracted from wet rooms (bathroom, en-suite, kitchen), using the lobby as a transfer path.
Construction photos of the duct install and terminal commissioning and a photo of the MVHR unit in place.
8.0 HEAT SUPPLY

Space heating is supplied by two 600w electric panel heaters (Mill NE600) which are Wi-Fi controlled with manual override. One is located in the hallway outside the three bedrooms, the other in the main living space.

Domestic hot water is supplied through two SunAmp UniQ heat batteries. The larger 6kWh unit is located in the Utility room and feeds the kitchen and main bathroom. A secondary 3kWh unit is located in the En-Suite bathroom to supply the shower and sink here. Both store excess electricity from the roof-integrated PV array.

Construction photo of a panel heater (living space) and heat battery (en-suite) installed.
# 9.0 PHPP Calculations

## Passive House Verification

**Building:** Deasill  
**Street:** The Downs  
**Postcode / City:** BA3 3DD Clandown  
**Country:** United Kingdom  
**Building type:** Detached House  
**Climate:** [UK] - Severn (Lyneham)  
**Altitude of building site (in [m] above sea level):** 140  
**Home owner / Client:** Tom Fowlie  
**Street:** Deasill, The Downs  
**Postcode/City:** BA3 3DD Clandown  
**Architecture:** Tom Fowlie  
**Street:** Deasill, The Downs  
**Postcode / City:** BA3 3DD Clandown  
**Mechanical system:** Green Building Store  
**Street:** Heath House Lane, Golcar  
**Postcode / City:** HD7 4JW Huddersfield

<table>
<thead>
<tr>
<th>Year of construction:</th>
<th>2018</th>
<th>Interior temperature winter:</th>
<th>20.0 °C</th>
<th>Enclosed volume $V_e$ $m^3$:</th>
<th>402.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of dwelling units:</td>
<td>1</td>
<td>Interior temperature summer:</td>
<td>25.0 °C</td>
<td>Mechanical cooling:</td>
<td></td>
</tr>
<tr>
<td>No. of occupants:</td>
<td>3.3</td>
<td>Internal heat sources winter:</td>
<td>2.5 W/m²</td>
<td>Ditto summer:</td>
<td>2.4 W/m²</td>
</tr>
<tr>
<td>Spec. capacity:</td>
<td>72 W/k per $m^2$ TFA</td>
<td></td>
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</tr>
</tbody>
</table>

### Specific building demands with reference to the treated floor area

<table>
<thead>
<tr>
<th>Space heating</th>
<th>Treated floor area</th>
<th>Requirements</th>
<th>Fulfilled?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating demand</td>
<td>14 kWh/(m²·a)</td>
<td>15 kWh/(m²·a)</td>
<td>yes</td>
</tr>
<tr>
<td>Heating load</td>
<td>9 W/m²</td>
<td>10 W/m²</td>
<td>yes</td>
</tr>
<tr>
<td>Frequency of overheating (&gt; 25 °C)</td>
<td>0.8 %</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary energy</th>
<th>Requirements</th>
<th>Fulfilled?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances</td>
<td>104 kWh/(m²·a)</td>
<td>120 kWh/(m²·a)</td>
</tr>
<tr>
<td>DHW, space heating and auxiliary electricity</td>
<td>73 kWh/(m²·a)</td>
<td>73 kWh/(m²·a)</td>
</tr>
<tr>
<td>Specific primary energy reduction through solar electricity</td>
<td>20 kWh/(m²·a)</td>
<td>20 kWh/(m²·a)</td>
</tr>
</tbody>
</table>

| Airtightness | Pressurization test result $n_50$ | 0.3 1/h | 0.6 1/h | yes |

* **Passive House?** yes

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**We confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this application.**

**Name:** Sally  
**Surname:** Godber  
**Company:** WARM  
**PHPP Version 8.5**

**Issued on:** 20/12/2019  
**Signature:** [Signature]
10.0 CONSTRUCTION COSTS

Including fit-out, the total construction cost was approximately £2,800/m² of Treated Floor Area.

11.0 MEASURED RESULTS

11.1 MEASURED ENERGY CONSUMPTION VALUES

Total electricity consumption (space heating, lighting, appliances, DHW etc.) was metered at 4064 kWh for the period January 2019 - January 2020, which equates to approx. 36 kWh/(m²a) when divided by the TFA (114m²).

In the same period the rooftop PV generated around 3700 kWh, but we do not have the data to determine how much of this was utilised directly on site vs. exported to the grid.

11.2 CONSTRUCTION PERIOD

November 2017 to December 2018

11.3 USER SATISFACTION

Gemma Fowlie, project manager and occupant:

The internal temperature of the house is incredibly stable, not dipping below 17°C overnight in the coldest months even when the heaters are off and it’s sub-zero outside. During the winter we obtain all the heat we need from two small panel heaters and the residual heat from our usual appliances, taking that 17°C to a comfortable 21°C on average. We don’t aim to heat the house much more than that, preferring to add an extra jumper! We run the panel heaters during the day so the PV takes whatever solar energy is available, and then turn them off when we are in bed to minimise the running cost.

During the summer, in full sun it is necessary for us to shade our largest windows in the middle of the day to minimise solar gain. We often open the windows for a breeze and the smells and sounds of the country. The through-draft gained from opening windows on the shaded side of the house is adequate to ensure that the house is cooler inside than outside.

Air quality overall is very good, it never feels stale, and we have no problems with dampness or mould. Clothes and even large duvet covers dry quickly and smell fresh. Paul, our MVHR unit, has been a trouble-free friend with no issues, and the sound of the MVHR is very unobtrusive - if we ever hear it, the filters probably need a clean. We live in a quiet place here, but never suffer from noise even when our neighbours are being loud, because of the triple glazing. We’re also fairly exposed on the edge of a valley, but there are no draughts even when in the windiest weather.