



PH15 THE ARCHITECT'S

DESIGN GUIDE

PH15



Cover Photo: Buckingham Passivhaus Plus built using the PH15 System and achieving net zero energy in use

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INTRODUCTION

Building to the Passivhaus standard can be a creative process for the designer. To achieve it cost effectively it must be integrated into the design approach from the outset. Passivhaus is a holistic concept and cannot be achieved simply by meeting each separate technical standard. Aiming for a target u-value on the floor, walls and roof, in isolation to the size, performance and orientation of windows for instance may mean that overall the Passivhaus target isn't met. When designing a Passivhaus building thought has to be given to the final structure to avoid cold bridges and space has to be allocated for the required ventilation system. Also, crucially, a consistent air-tightness strategy needs to be evolved that will enable the completed building to meet the stringent 0.6ach air-tightness test.

PH15 is a Passivhaus suitable construction solution which delivers fully insulated, airtight and thermal bridge free buildings using simple, UK friendly, construction details. The PH15 System is flexible enough to enable bespoke designs and to meet the many and varied planning requirements in the UK. It comprises all the component parts needed to create a weather tight, airtight shell (walls and roofs), alongside the glazing package and ventilation system.

By using PH15 all of the technical fabric aspects of achieving the standard have already been incorporated into the system – low fabric u-values, cold-bridge free junctions and a simple to execute air-tightness strategy that has never failed to achieve 0.6ach or below. Standard details are available for all of the common junctions¹ which avoids the use of untried or

tested ad-hoc design solutions. If the design goes beyond these set details, we can work with you to arrive at additional solutions.

With these details as a starting point it is up to the designer's skill to meet their client's brief. However, it is essential that the design is modelled using PHPP (see page 31) at the earliest opportunity, to test key design decisions. The PHPP is a powerful design tool that will aid the development of the building design and can be re-tuned to provide economical as well as technical solutions. The PH15 system package includes PHPP modelling and we can advise on ways to tailor the design to achieve these ends and to meet the more ambitious Passivhaus Plus target.

We are keenly aware of our responsibilities as part of the building industry to meet the challenges of climate change and of the **2030 carbon challenge**². The PH15 System uses natural, low carbon materials, including an off-site, pre-cut timber frame. The PH15 timber frame is vapour permeable; this means moisture within walls and roofs can escape to the external air as maintaining vapour permeability is critical when working with natural materials. Because of this PH15 Passivhaus+ already meets the embodied carbon targets set for 2030 and we are constantly looking at ways to improve this further.

If you wish to design to the best possible standard and be part of the growing movement to drive UK building standards up, then working with us will enable you to achieve this **now**.

¹ Full details provided when 10% deposit paid toward PH15 system
²RIBA 2030 Climate Challenge for operational energy and embodied carbon

By choosing to build with PH15 you can address now our need to build net zero energy houses by 2030.

PH15 achieves this level of performance while also using natural construction materials.

PH15 BASICS



The PH15 system uses components primarily from renewable or re-cycled sources. Frame I-Joists are manufactured utilising 100% of the raw material* with 0% wastage

0.6
ach

The system has been designed to make airtightness details easy to carry out with a narrow range of products. This gives consistent air-tightness results below the required 0.6 ach.



The PH15 system is vapour permeable with the racking layer on the inside and vapour open wood fibre boards on the outside. This stops the frame being damaged by a build up of moisture.



We use only European, certified timber from well managed forests. Almost all the system components are certified FSC, PEFC or Nature Plus. We are also members of the Alliance of Sustainable Building Products (ASBP)



The PH15 system can readily be net zero in use and uses low embodied carbon materials. A carbon audit A1-A4 is provided and the resultant offset by UK tree planting through the Woodland Trust and Woodland Trust Scotland.

The PH15 System has been developed to optimise Passivhaus design, and to provide full technical, building physics, backup to architects, contractors and clients. The PH15 timber frame solution further robustly addresses building biology with a vapour open construction that allows moisture to move safely through the walls and roof.

On site pre-cutting of the frame ensures your build goes up fast and with accuracy. A standard house shell can be erected within three to four weeks, with a small team, without heavy lifting equipment.

PH Homes support projects with Passivhaus suitable architectural details and Passivhaus related performance and specification support. Contractor training addresses the 'fear factor' and avoids unnecessary labour cost escalation

* From 2.3m³ of log wood, 1m³ used for LVL, 0.5m³ for woodfibre insulation, 0.2m³ for transport pallets and 0.6m³ to power the factory

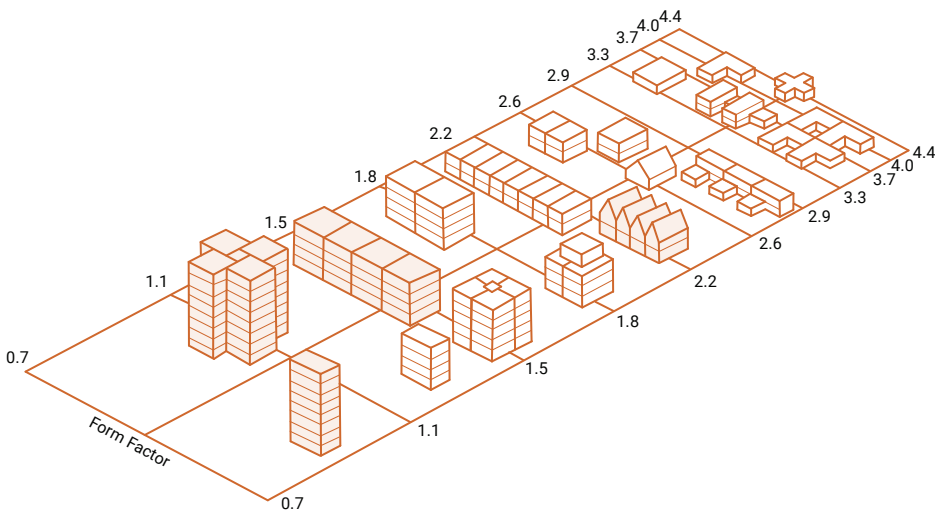


Cost effective builds start with a good form factor

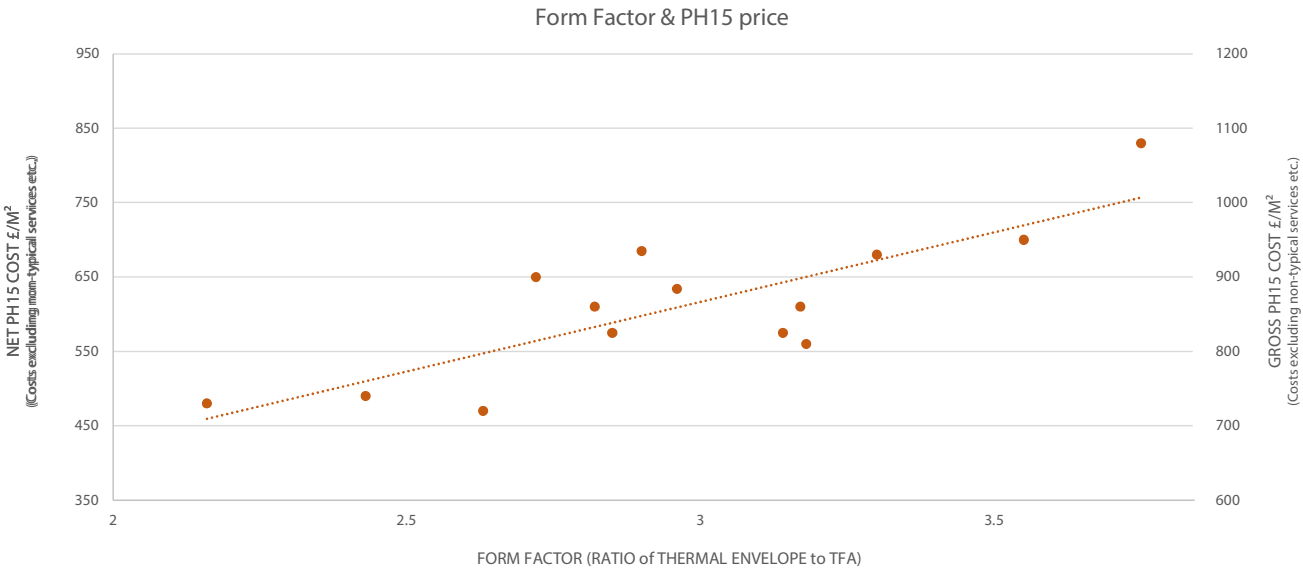
PH15 build, Akerman Rd for Lambeth Council

FORM FACTOR & COST

FF is the ratio of the thermal envelope area to the treated floor area (TFA). The thermal envelope is the area of walls/roof and floor measured to the outside face of each thermal element e.g. if you are insulating under the ground floor slab it will be measured to the under-side of the insulation. TFA is the usable floor area as calculated in the Passivhaus PHPP software. It is typically about 90% of the gross internal floor area (GIA). GIA is all internal floor area inside your external walls/roof/floor, including internal walls & stairs. It excludes any areas below 1.5m high, that are not related to staircase.



Calculate the FF early, as this will give you a good guide on whether your project costs are at the cheaper or expensive ends of the spectrum. Aim to design a detached house with a FF of below 3.0, if costs are critical. Our guide below gives an indication of how form factor effects costs. Net costs exclude non-typical supplier services, e.g. PHPP consultancy.



PH15 Services

The embedded cost saving in PH15

PH15 is more than just a timber frame, it is a pathway to low carbon passivhaus that includes expert design consultancy, construction detailing, thermal modelling, overheating analysis, quantifying, costing and training. These services are included in the PH15 price, offering both offset and net savings across other parts of the project from tried and tested practice. The table below outlines the potential offset costs and net savings that PH15 offers at each RIBA work stage.

Project stage and activity	Other consultant	PHH	Estimated savings per house, ex VAT, divided into: 1. Net savings from choosing PH15. 2. Duplicated fees/ costs to be removed from other parts of the project.	Description of PHH services at each stage.
Stage 0-1 Brief <i>Initial meetings with your designers and development of objectives and constraints. Preparation of a brief.</i>			Integrating passivhaus design from the start of a project can encourage SMART decisions that could save 5-15% of the contract sum . Using a tried and tested system like PH15 can also limit complexity in design and construction.	Early stage discussions with PHH can be very beneficial to help embed cost effective decisions from the outset, including advice on siting, orientation, form-factor and wall thickness. For further guidance refer to the PH15 Design Guide .
Topographical/ Site Survey	●			
Environmental surveys (trees, soil etc.)	●			
Brief	●			
Feasibility Study	●			
Stage 2 Concept Design				Early PHPP modelling and overheating checks offer more cost certainty and enable cost and comfort optimization from the start. *If suitable scaled plans, elevations and sections available.
Concept design options	●			
PHPP modelling - initial check*	●	●		
Overheating check (Part O)*	●	●		
Cost Estimate*	●	●		
Stage 3 Spatial Coordination <i>Development of design concepts for planning submission.</i>			It is recommended PHPP modelling, overheating checks and the cost estimate occur pre-planning when design adjustments can be made easily and more cheaply.	An independent certifier can check the project at this stage.
Planning drawings and documents	●			
PHPP modelling - design stage check	●	●		
Overheating check (Part O)	●	●		
Cost estimate	●	●		
Planning application	●			
Passivhaus certification check	●			

Project stage and activity	Other consultant	PHH	Estimated savings per house, ex VAT, divided into: 1. Net savings from choosing PH15. 2. Duplicated fees/ costs to be removed from other parts of the project.	Description of PHH services at each stage.
Stage 4 -Technical Design <i>Preparation of construction drawings and information for tender/ pricing.</i>				
Foundations etc.	●		-	PHH provide line and point loads, plus slab to wall details for foundations to be designed by others.
Engineering pack (above ground)	●	●	£3,000-£5,000 reduction on engineer's fees for detail design, specification & calculations.	PH15 is a tried and tested system with all principle junctions fully designed and detailed at 1:10.
Construction detail pack	●	●	£6,000-£10,000 omitted from architects/designers fees.	All U-values and Psi values are calculated for standard junctions. Bespoke junctions are charged separately.
Window and door schedule	●	●		
Psi value calculations (PHPP)	●	●	£2,400 for 8 standard junctions.	
Psi value calculations (SAP)	●	●	£1,200 for 8 standard junctions.	MVHR is fully coordinated with the structure, reducing risk of clashes on site.
Ventilation design (MVHR)	●	●	£500-£1,000 design fees omitted from others	
Mechanical & Electrical layouts	●		£500 design fees. >£3,000 potential saving through simplified/reduced heating system.	Passivhaus homes require so little energy to heat that direct electric becomes a viable option for both heating and hot water. Consequently more expensive ASHP or GSHP systems can be avoided, and the money invested elsewhere.
Renewable Energy	●		If using direct electric, upwards of £5,000 saved by omitting an air source heat pump (ASHP).	
Plumbing and drainage	●		-	Details by others. Coordination included., where applicable, e.g., floor finishes and ceiling heights.
Finishes (internal and external)	●		-	
Fixture, Fitting & extras	●		-	
Landscaping	●		-	
Stage 5 Construction				
Training		●	Contractor training does not typically occur but on PH15 projects adds enormous value by upskilling local labour and protecting the quality of construction. Avoid mistakes on site saves time and money.	PHH provide online training and ongoing support to the main contractor on sequencing, coordination and construction of PH15.
Material supply/coordination	●	●	-	PH15 documents includes detailed supply, delivery and construction information for the main contractor to plan the works.
Mechanical, electrical and plumbing (MEP)	●		-	By others
Site inspections/valuations	●		-	
Airtightness testing (2 tests)	●	●	An independent test is minimum £750 for multiple houses and £1,000 for individual houses.	PHH organise airtightness testing using a Passivhaus expert. PH15 has a proven track record of achieving an airtightness result 2-3 times better than the Passivhaus requirement without additional effort.
Stage 6 Handover and Close out				
M&E commissioning	●	●	An independent commissioner may charge upwards of £500 per MVHR system.	PHH commission the MVHR providing certificates both for building control and Passivhaus certification.
Client pack	●	●	-	PHH supply all product information for the main contractor to handover.

PH15 Supply

More than just a timber frame

PH15 is a low carbon route to passivhaus and focuses on supplying all elements that protect quality in construction, performance in use and occupier comfort. PH15 therefore extends beyond typical timber frame suppliers and includes the thermal shell, glazing, doors, airtightness products and ventilation system as well as design, energy consultancy and training.

The summary below lists the common work clauses (CAWS) that PH15 supply falls under to asisst your quantity surveyor and tendering contractor when costing the project. Further information is available on request.

Scope of Works (CAWS)	Others	PHH	Description of supply
Prelims			
Tin hat to full scaffold Monarflex sheathing	●		Recommended to protect timber frame during construction. Tin hat est. additional £10,000. However, this is offset by enabling all weather working and reducing the need for site adjustments. No crane required for PH15 erection, unlike general MMC systems.
Storage	●		Materials should be stored level and covered. PHH supply guidance on suitable use of tarpaulins for covering timber.
Tele-handler, glass suction lifting equipment.	●		Equipment required to offload heavy items, such as windows. Lifting equipment may also be required for glazing installations. Note: timber frame cut to lengths that can be typically lifted by hand.
E. In situ concrete			
E05. In situ slab	●		Performance specification provided.
E20. Formwork for in situ concrete	●		On non-clay soils formwork is created using sub-slab insulation so no separate formwork required. On clay, beam and partially filled block used as formwork.
E30. Reinforcement for in situ concrete	●		Performance specification provided.
F. Masonry			
F10. Substructure wall, incl. mortar	●		Performance specification provided.
F30. Structural insulation, doors	●		Compacfoam specified, supplied by others.
F30. Structural insulation, walls		●	Foamglas supplied. Estimated cost £800-£1,200 per house included.
G. Structural carcassing/timber			
G20. Timber frame, external walls and roof		●	Supplied pre-cut and coded for assembly. Reduced wastage and delivery costs from supplying pre-cut elements.
G20. Timber frame, beams and lintels		●	
G20. Intermediate floor joists		●	Metal web joists, pre-cut and engineered for each house.
G20. Internal partitions and posts		●	Uncut lengths supplied. Fixings as per main contractor's preference. Party wall ties supplied.
G20. Party wall studwork		●	
H. Cladding/coverings			
H11. Structural glass assemblies		●	Supplied as part of glazing package, through PHH partners.
H30. Vapour control layer		●	Embedded in racking board. Intelligent membrane also supplied as required.
H60. etc. Roof coverings	●		Designed, specified and supplied by others.
H92. External wall coverings/finishes	●		Designed, specified and supplied by others.

Scope of Works (CAWS)	Others	PHH	Description of supply
J. Waterproofing			
J30. Waterproof treatment for base plate		●	Provided for sites where base plate may be exposed to the elements.
J31. Flat roof coverings	●		Designed, specified and supplied by others.
J40. Damp proof membrane & course	●		Performance specification provided.
J40. Breather and wind membranes, incl. tapes		●	Wall and roof membranes supplied. Fire resistant membrane available.
K. Linings/Sheathing/dry partitioning			
K10. Fire resistant linings for party walls		●	Supplied as sheets, to be cut on site. Fixings supplied.
K11. Racking boards		●	Supplied as sheets, to be cut on site. Fixings supplied.
K11. Service void battens		●	Supplied in uncut lengths, to be cut on site. Fixings supplied.
K20. Timber deck for intermediate floors		●	Supplied as boards.. Glue and fixings supplied.
L. Windows/doors/stairs			
L10. Windows and rooflights		●	High performance triple glazed, airtight windows and doors. Supplied with sills and fixings.
L20. Doors (external only)		●	
N. Furniture and equipment			
N40. External blinds		●	Louvres, roller shutters and zip screens. Supplied with window package. Integrated to building design to appear invisible when retracted.
P. Building fabric sundries			
P10. below slab insulation	●		Performance specification provided.
P10. Wall & roof insulation - blown		●	Material supplied and installed.
P10. Wall & roof insulation - boards		●	Woodfibre boards and thermally broken fixings supplied.
P10. Party wall insulation		●	Mineral wool supplied for fire and acoustic separation.
P10. Airtightness products		●	All tapes, membranes, adhesives and grommets supplied.
P21. Doors and window ironmongery		●	Supplied with window and door package
T. Mechanical Heating/cooling	●		Heating and cooling load supplied. System design, specification and supply by others.
U. Ventilation/air conditioning			
U90. Mechanical ventilation with heat recovery (MVHR)		●	System fully designed, coordinated and itemized, reducing waste on site. Supply includes all distribution boxes, semi-rigid ducting, valves and attenuators.
U90. Recirculating cooker hood	●		Designed, specified and supplied by others.
W. Communications/ security/ control systems.			
W90. Smart controls for MVHR		●	Wired controls supplied. To enable direct use or pairing with smart/integrated EN home management systems.
W90. Electrically operated rooflights		●	Wired or wireless controls supplied. To enable direct use or pairing with smart/integrated EN home management systems.
W90. Smart controls for external blinds		●	
Z. Building fabric specification			
Z20. Fixings and adhesives		●	All fixings for external walls and roof, party walls, beams, lintels, posts, racking, woodfibre insulation boards, service void battens, intermediate floors, windows, doors, rooflights. Adhesives for gusset plates, airtightness tapes, floor deck. No other adhesives required.
Z21. Mortars	●		Performance specification provided.



THE 2030 CLIMATE CHALLENGE

The RIBA have joined the industry wide declaration of both environmental and climate emergency. In support of this aim they have developed the RIBA Climate Challenge (Version 2, 2021), which sets a series of targets for both operational energy use and embodied carbon to guide designers in delivering net zero buildings. The 2030 target for operational energy envisages the space heating demand portion to be in the region of 15-20kWh/m²/y.

Domestic/Residential Targets

RIBA Sustainable Outcome Metrics	Business as Usual	2025 Targets	2030 Targets	Notes
Operational Energy kWh/m ² /y 	120 kWh/m ² /y	< 60 kWh/m ² /y	< 35 kWh/m ² /y	Targets based on GIA. Figures include regulated & unregulated energy consumption irrespective of source (grid/renewables). BAU based on median all electric across housing typologies in CIBSE benchmarking tool. 1. Use a 'Fabric First' approach 2. Minimise energy demand. Use efficient services and low carbon heat 3. Maximise onsite renewables
Embodied Carbon kgCO ₂ e/m ² 	1200 kgCO ₂ e/m ²	< 800 kgCO ₂ e/m ²	< 625 kgCO ₂ e/m ²	Use RICS Whole Life Carbon (modules A1-A5, B1-B5, C1-C4 incl sequestration). Analysis should include minimum of 95% of cost, include substructure, superstructure, finishes, fixed FF&E, building services and associated refrigerant leakage. 1. Whole Life Carbon Analysis 2. Use circular economy strategies 3. Minimise offsetting and use as last resort (accredited and verifiable) BAU aligned with LETI band E; 2025 target aligned with LETI band C and 2030 target aligned with LETI band B.
Potable Water Use Litres/person/day 	125 l/p/day (Building Regulations England and Wales)	< 95 l/p/day	< 75 l/p/day	CIBSE Guide G.

RIBA 
Architecture.com

Embodied Carbon

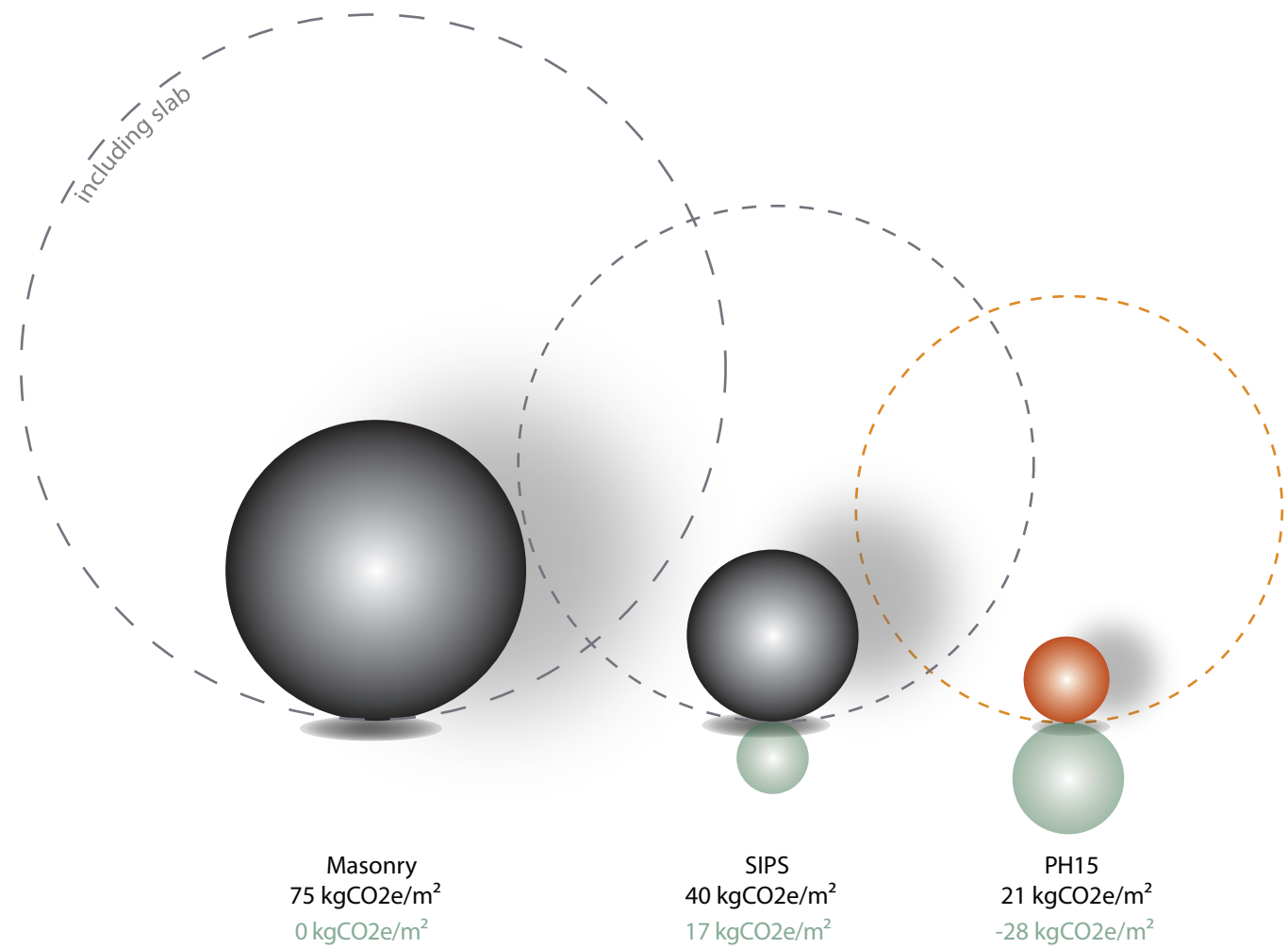
To achieve the RIBA targets not only will we need to move toward the Passivhaus standard but also carefully select the building materials we use to achieve it, or the target of <625kgCO₂e/m² may not be met.

Using PH Ribbon, it is possible to model and compare the upfront emissions associated with two typical construction types - cavity walls and SIPs - against the PH15 system (see overleaf). Cavity walls have the highest embodied carbon at almost 3.5 times higher than PH15. This is mainly due to the high embodied carbon associated with the concrete blockwork and brick. However, petroleum-based insulations are also a contributing factor, which result in SIPs having almost double the upfront emissions of PH15.

These calculations exclude the benefits of sequestration. If sequestration is included, PH15 has negative net upfront carbon emissions and SIPs net upfront carbon emissions are reduced by almost half. However, the cavity wall emissions remain static. It is important to note that at end of building's life the sequestered emissions would be released to atmosphere, unless the timber is re-used or incinerated using carbon capture technology. Using natural resources efficiently, building for long-life and designing for re-use are critical for ensuring the whole life carbon emissions remain low also.

More significant than the walls, is the embodied carbon within the concrete foundations and ground slab. In a PH15 building the slab alone has approximately fourfold the carbon intensity of the walls, per m2 of surface area. This can be almost halved by using cemfree or high GGBS content concrete. Adopting a suspended timber cassette floor (if feasible) can also significantly reduce the upfront emissions associated with the groundworks.

In a masonry building the embodied carbon of the groundworks is exacerbated by the need to support a heavier weight construction system. This is why industry guidance recommends building lightweight, such as timber frame construction, to reduce overall embodied carbon.



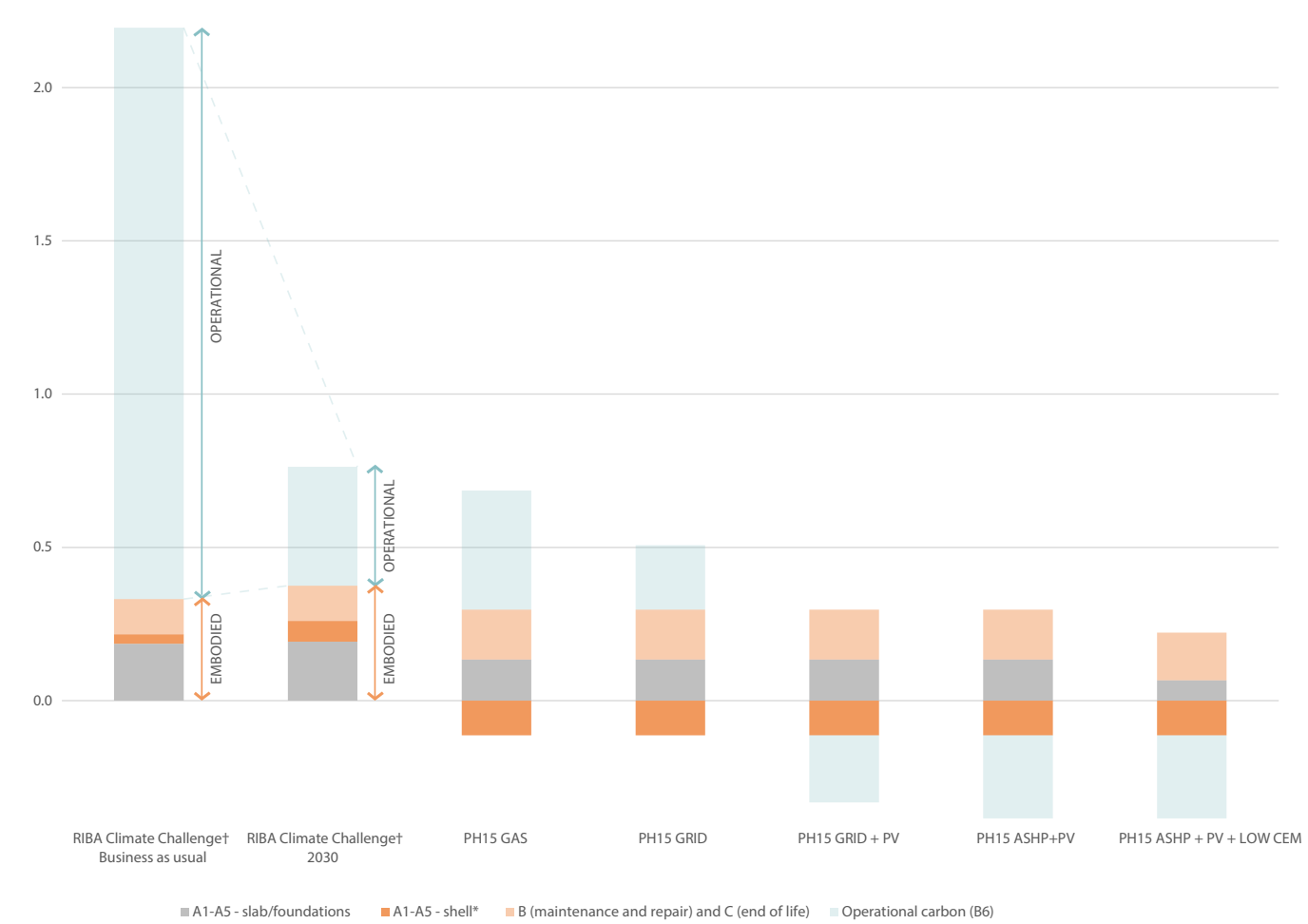
Embodied CO2e for different wall construction methods - dotted line includes slab
PHH analysis using PH ribbon. A1-A4 (Cradle to site) only. Sequestration excluded/indicated in green.

PH Ribbon, a plug-in software for PHPP enables us to measure embodied energy (it gathers lots of the ICE and EPD data for you). With each PH15 project where we are commissioned to provide the PHPP we also provide an Embodied Carbon Analysis of the whole shell giving the designer greater confidence that they are meeting the 2030 targets.

Operational Carbon

When considering the operational carbon, both the demand and the fuel source impact the level of carbon emissions, as the bar chart below shows. in a Passivhaus, an all-electric solution is now less carbon intensive than gas because of the de-carbonisation of the grid in recent years. However, the grid does not have the capacity to heat all our homes so reducing the burden through utilizing air-source-heat-pumps and on site PV is critical to maintaining sufficient grid capacity for all energy uses.

The charts below show the step change from ‘business as usual’ to the passivhaus standard on operational emissions (in blue). The third and fourth bars show the potential reduction from selecting an electric heating system instead of a gas boiler. Adding PV and/or an ASHP can result in negative operational emissions.



Embodied CO2e (tCO2e/m2) for different building types and fuel strategies

† Based on brick & block envelope to building regulations fabric standards, for ‘business as usual’ and to the passivhaus standard for 2030.
* Shell includes foundations, slab, external walls, external windows and doors, roof structure (excluding finishes), internal partitions, intermediate floors and ventilation system.
** PV gross emissions shown by dashed line. Net emissions shown by solid colour.

SUPPORTING BIODIVERISTY

PH15 utilizes the awesome power of timber for its multiple benefits to the occupants and the construction team, but also to minimize the carbon impact of our projects and help contribute to a circular economy.

We source our timber from Poland where over 30% of the country is covered by sustainably managed forests. We use responsibly sourced, quick growing, high grade timber that will soon be replaced with new trees. Trees help to clean our air, reduce flood risk, provide homes for wildlife, store carbon and have been proven to boost our own health and well being.

UK forests only cover around 13% of our land area. We now urgently need to plant trees - the estimated need is 1.5 billion new trees by 2050 to become carbon neutral - and we should revitalize our timber industry too.

As a thank you for building using the PH15 System we invest in UK forestry through the Woodland Trust and Woodland Trust Scotland by offsetting the equivalent emissions of all PH15 supplied items generated from cradle-to-site (including extraction of raw materials, manufacture and transport). The Woodland Trust invest in planting of native woodland and restoring and protecting existing and ancient woodland.

At completion, each PH15 project receives a certificate with information on the emission calculated and the equivalent area of UK forestry your PH15 house has helped support. We also supply information on operational carbon and invite all our customers to join us in supporting UK forestry in the drive to decarbonize and save our threatened natural environment.

This was the first time we had used this system which uses timber I beams for the main structure, which for us as carpenters and joiners proved to be a dream to erect.

Every detail and calculation had been meticulously covered and any questions we had answered promptly.

Once we had an understanding of the process and the accuracy required to install the PH15 system it proved to be a quick and easy process.

Passivhaus Homes Ltd have really turned a clients dreams into reality.

Great system backed up by a fantastic team, absolute pleasure to work alongside.

*Mark Murray
yourhaus.uk*

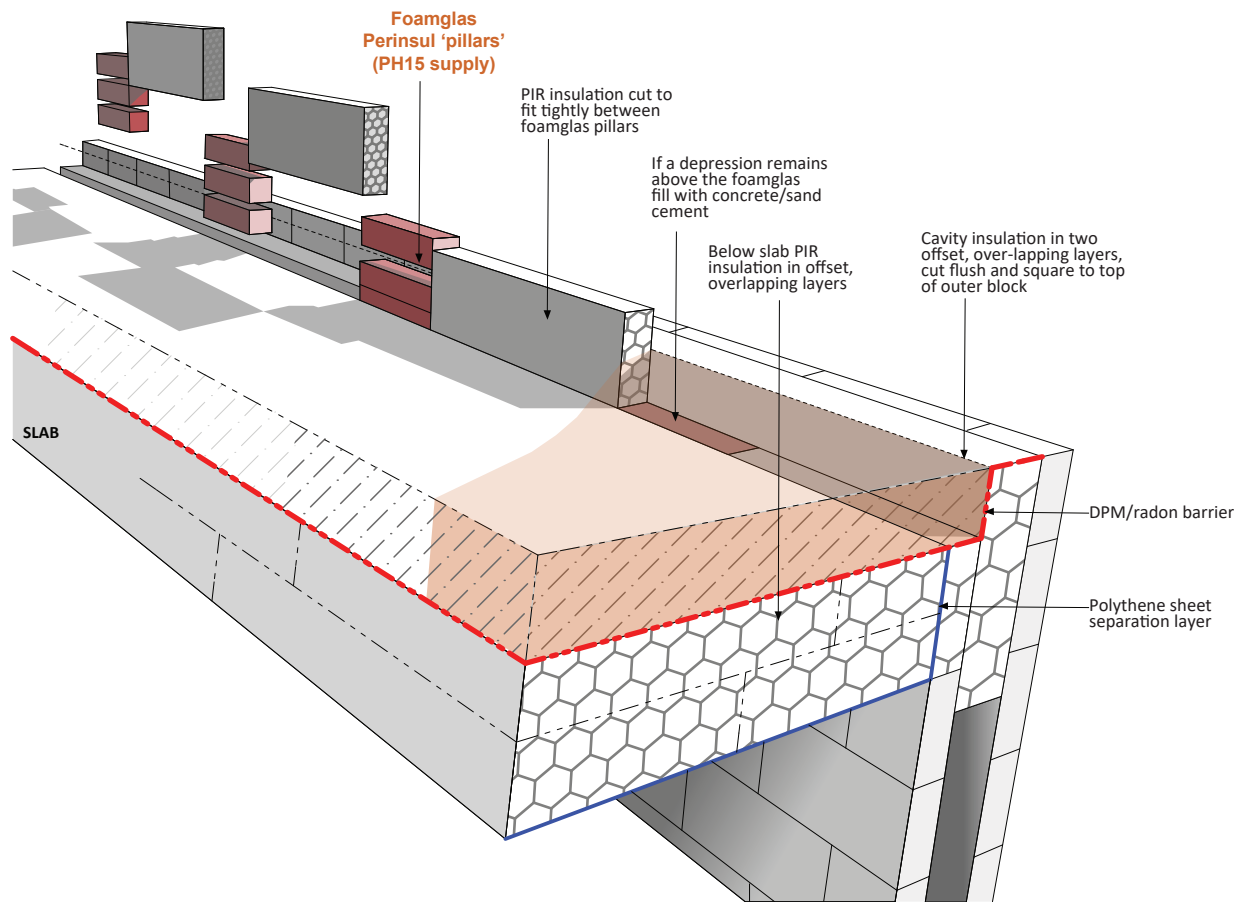
PH15 SYSTEM

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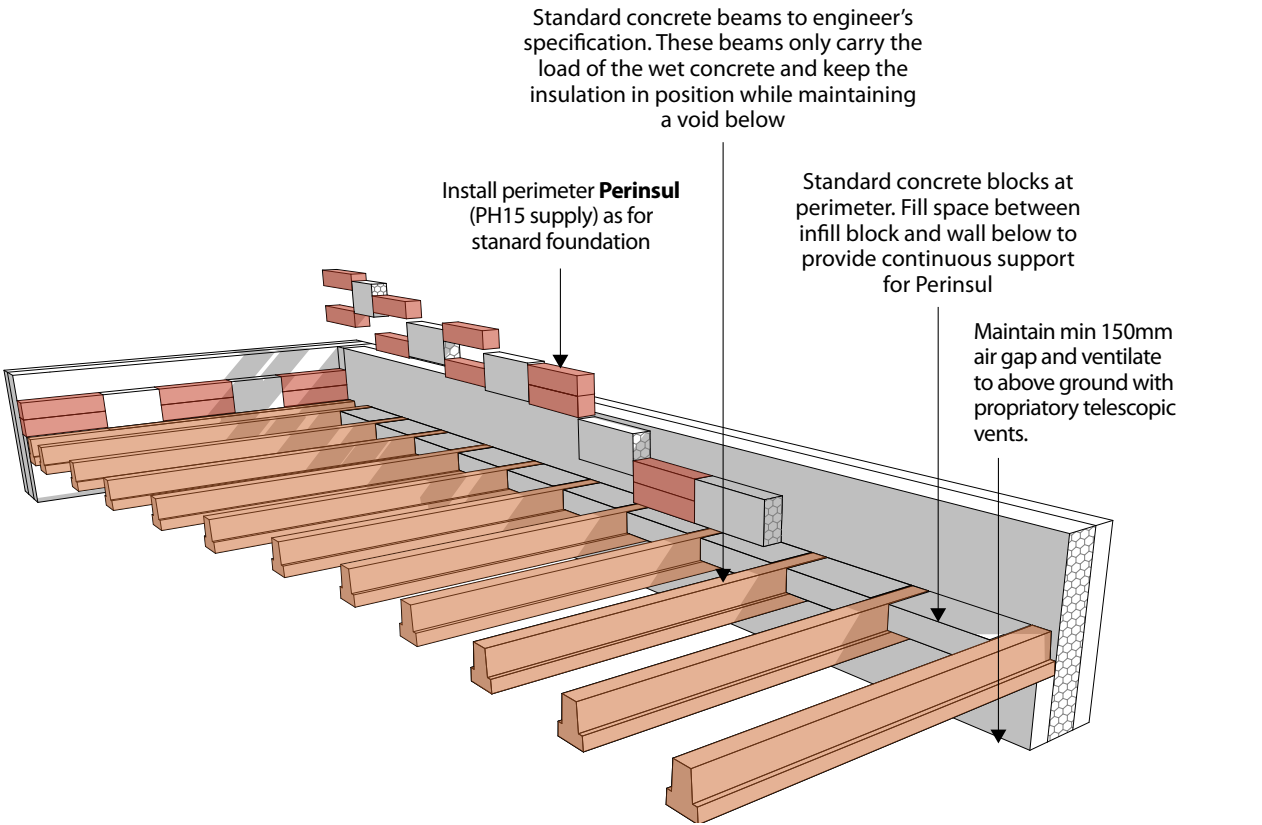
CONCRETE FOUNDATIONS

The foundations use a strip footing familiar to all ground workers with a fully filled 150mm cavity and foamglas pillars made from recycled car windscreens to support the loads of the slab without causing a cold bridge. This arrangement allows the base plate to fixed to the slab and outer block for greater stability unlike preformed polystyrene tray systems where the frame often ‘hangs’ over the insulation. Subject to engineers specification we recommend GGBS or Cemfree concrete to make savings on the CO2 content of the foundation.

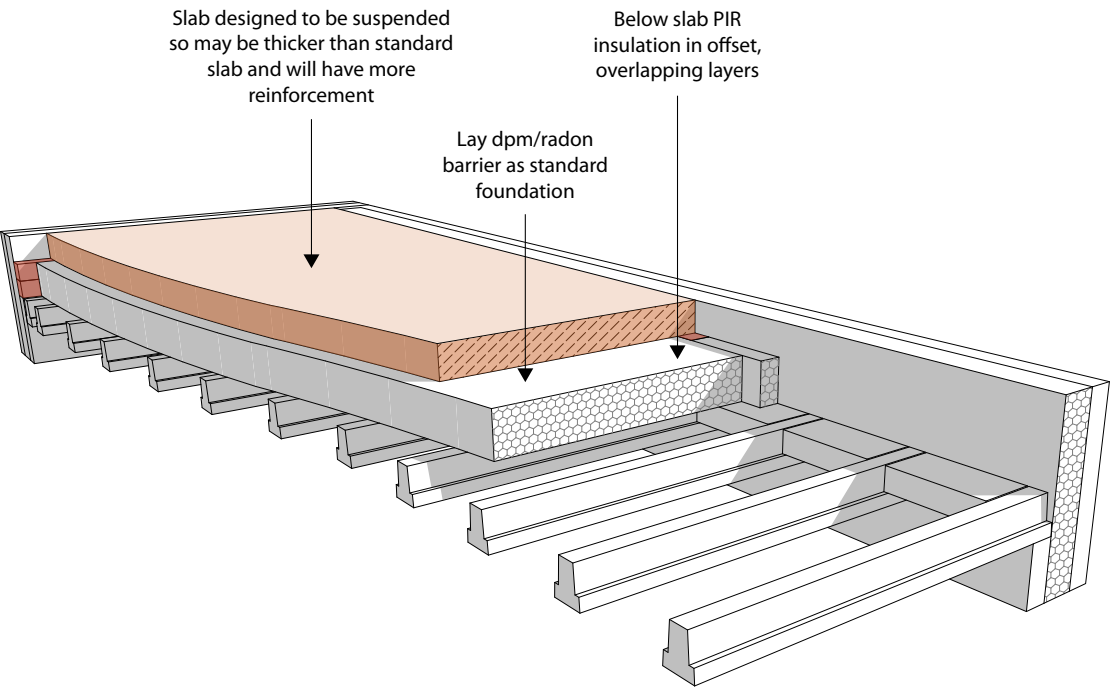
This method can also be modified for use in soils with heave potential by introducing Clayboard under the insulation and suspending the insulation from the slab. This foundation approach gives extremely good linear psi values at the intersection between the slab and outer wall. However, it does present some challenges in execution on site and is particularly difficult on wet sites as the Clayboard can collapse prematurely if it gets unintentionally wet. A safer solution is a beam and block floor where most of the blocks can be omitted as the beams are only supporting the weight of the wet concrete until it sets and thereafter keeping the insulation in place. **This is a higher carbon content solution than the Clayboard.**



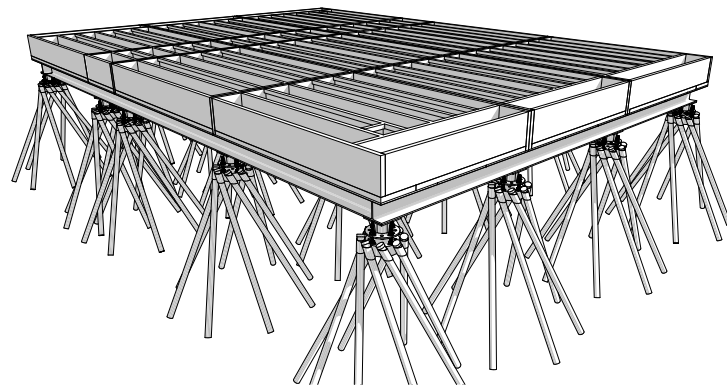
CONCRETE FOUNDATIONS WITH SUSPENDED FLOOR



Standard heave protection (Claymaster) to sides of footings may be required



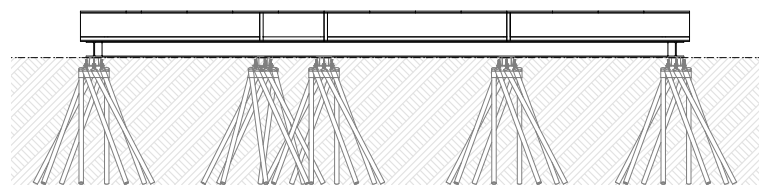
LOW CARBON FOUNDATIONS



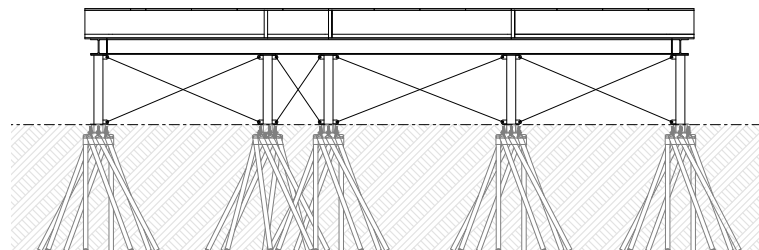
CONCRETE FREE, PILED FOUNDATION FOR A WIDE RANGE OF SOIL TYPES AND GRADIENTS.

Omitting the concrete slab and foundations can result in significant savings in embodied carbon and time.

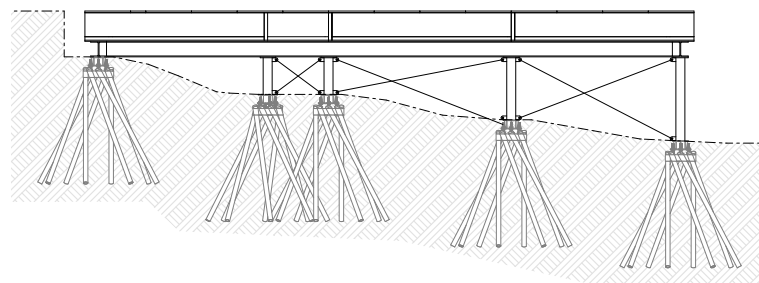
This system uses a robust timber cassette floor bearing on steel beams supported on a Magnapile, radial pile foundation system. The installation of the pile foundation is provided as part of the PH15 system on ground pre-prepared by the project contractor. System floor performance from 0.127 W/m²K.



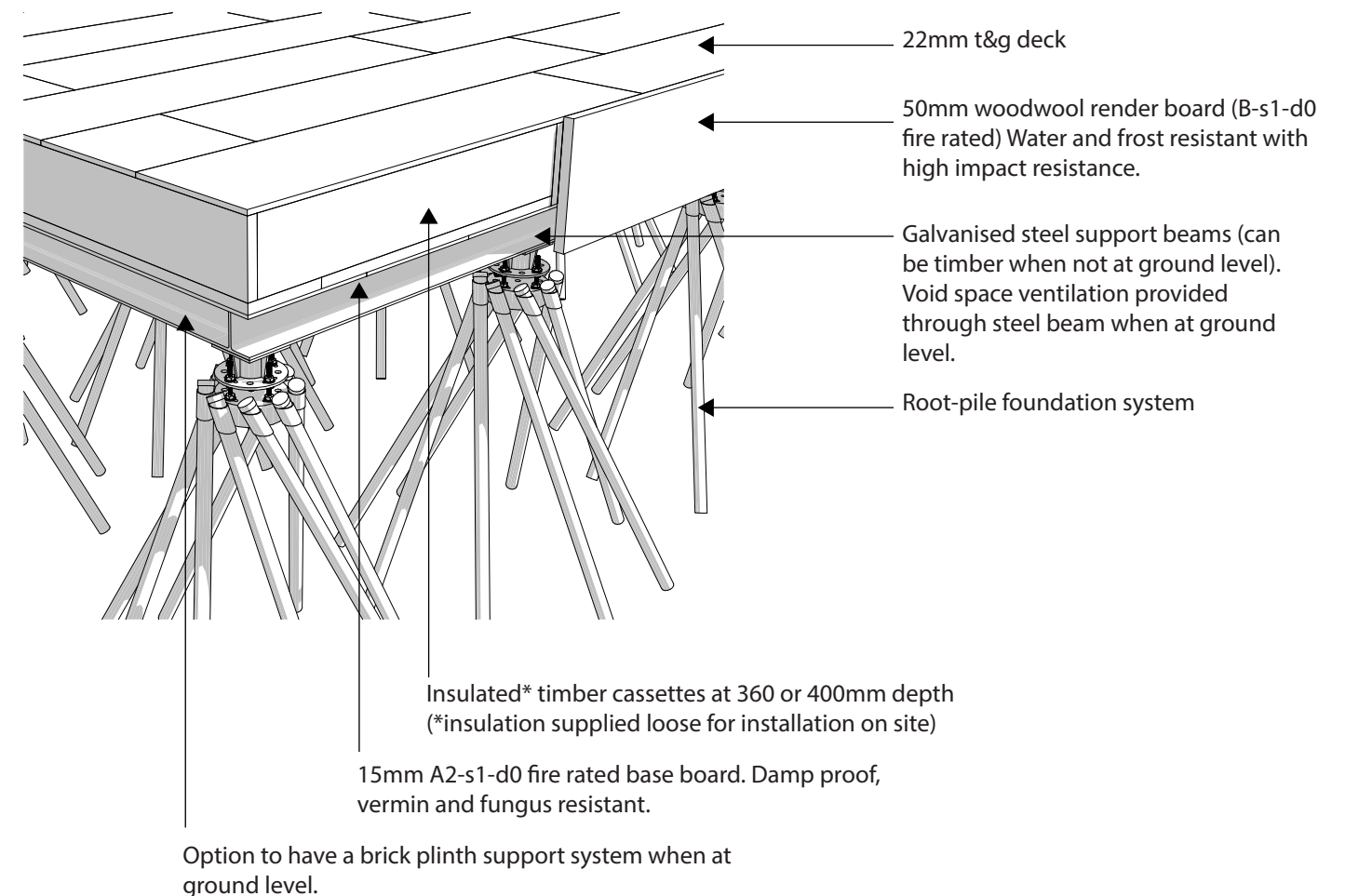
In this configuration the (interior) ground floor level is typically +600mm above the external (draining) ground level. The perimeter down to ground level can be finished with a renderable wood wool skirt or optionally with a brick plinth.



With additional steel work added to the pile caps the system can be used to raise the house above the surrounding ground level. Combine with a raised parking platform for protection in periodic flood zones.



A similar approach allows for rapid, cost effective builds on sloping ground. Additionally the system can be used close to trees without significant damage and will not interfere with ground water movement. The piles can be specified to over 100 year design life (soil dependant) thanks to the magnesium alloy coated steel. The system is fully removable for high level recycling.



Minimally the project contractor prepares the site as per our instructions, installs drainage and services and lays a geotextile membrane with a clean gravel topping (or other finish to architects specification).

The piles and steel supports are supplied and installed via PHH. Timber cassettes are supplied assembled but without decking ready for on site fitting. On top of the 22mm deck there is a further 30mm of woodfibre insulation which is incorporated into the floor finish zone of 60mm. This allows for a variety of internal floor finishes to be installed level with one another and provide level access at doorways (external levels are the responsibility of the architect and must be at least 150mm below the PH15 frame unless separated by a gravel filled trench (standard details are available for this).

Like all parts of the PH15 system the floor cassettes are vapour permeable and will dry out if moisture enters; but for complete peace of mind we recommend installing the Grohe Sense Guard system to protect against damage from pipe leaks.

If you feel this option might be suitable for your project please contact PHH at an early stage to discuss. Some pre-design appraisal work is usually necessary which is chargeable. We would advise for any of the foundation approaches a geosurvey is commissioned to determine the ground conditions.

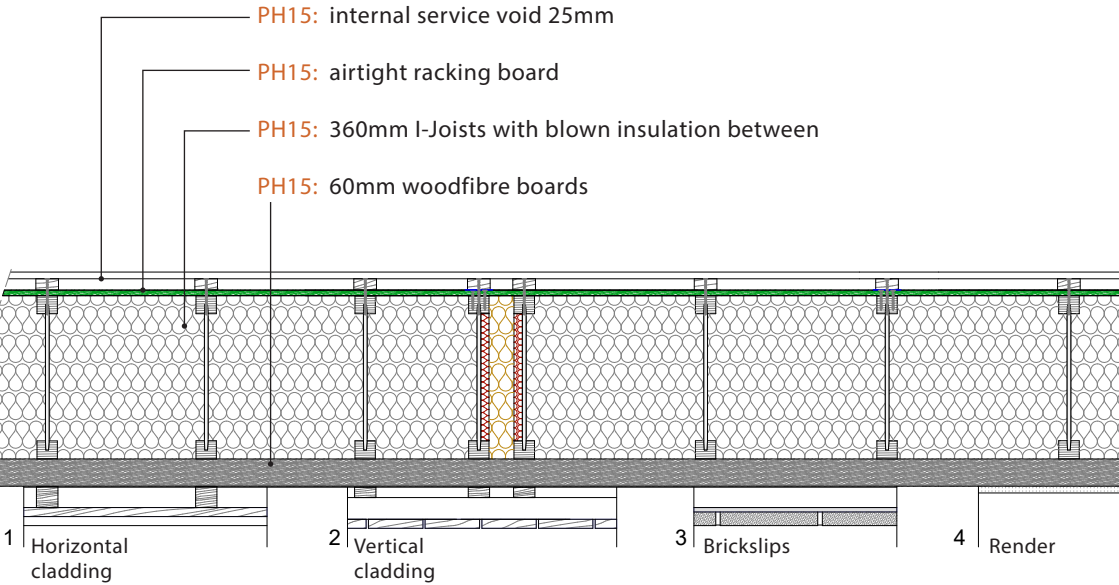
EXTERNAL WALLS

These are built using timber I-joists at between 400-450mm centres, depending on the structural loading characteristic of the specific house design. For Passivhaus performance for most areas of the UK a 360 mm I-joist will be required. These are clad externally with 60mm of wood fibre as standard and internally with a 12mm airtight racking and vapour control board. The core of the wall is insulated with blown cellulose or woodfibre.

Standard 360 wall with 22mm rain screen cladding: overall thickness circa 540mm, U-value 0.098 W/m²K*
Standard 360 wall with a lime/silicate render finish: overall thickness circa 485mm, U-value 0.101 W/m²K

It is possible in London and some southerly parts of the UK and at lower altitude that a 300mm I joist may be used. This will limit pitched roof spans however, as the wall and roof depth have to be the same.

*Due to better performance of woodfibre board



FINISHES

Finishes are not part of the PH15 System supply but details are available for rendered, rain screen or brick finishes. It is essential that what ever finish is specified it does not restrict the breathability of the wall construction. If required we can supply a suitable lime/silicate render finish.

Whilst a brick finish with a full brick skin of 100mm in front of the PH15 timber frame is possible, the resultant wall will be very thick and adds extra loading and width onto your foundations. Alternatively, a brick slip system can be installed in a similar way to a timber rain screen. The brick slips (say 25mm depth) are typically glued onto a 12mm backer board and then the joints mortared in the normal way. Brick slip requires a ventilated void of 47mm, as any other rainscreen solution. Brick finishes require careful detailing around any door and window openings to avoid poor thermal installation details. Passivhaus Homes can advise and provide standard detail



It is essential that we are made aware of heavy facade options such as brick slip as they may effect the engineering of the frame.



INTERNAL WALLS

The system includes supply of all internal studwork in uncut lengths, as standard 97x47 or 147x47 C16.

INTERMEDIATE FLOORS

Intermediate floors are open webbed joists so you can run services through the floor depth easily. Joist depth is typically supplied at 254mm deep, with 22mm decking board over. The floor is fixed to the external walls via a perimeter ledger beam which maintains a continuous service void between floors. All required joists, beams, hangers, strongbacks, peel clean deck and glue is supplied. Staircases are not included.



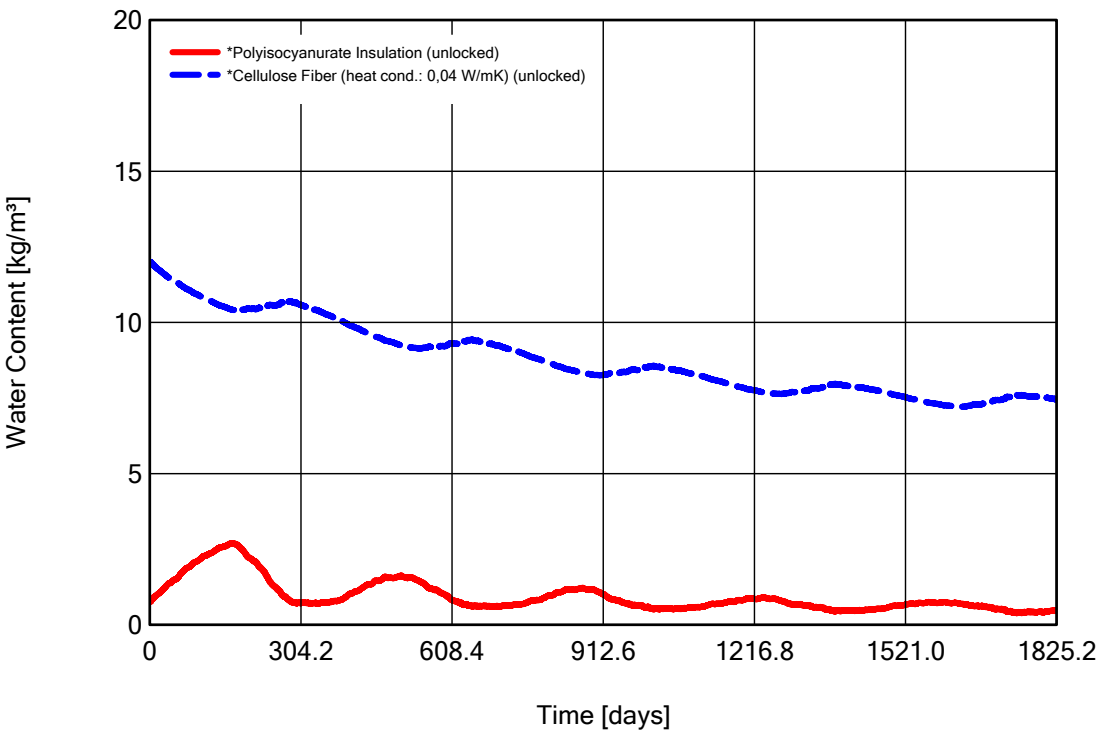
PITCHED ROOFS

Roofs can be at any pitch to suit your preferred roof finish. Finishes can be tiles, slates, metal seamed (zinc etc...) or any other standard roof finish. The PH15 roof is made up of timber I-joists and is always the same depth as the walls. The wall and roof structure is connected with ply inserts to reduce any thermal bridge at their junction, creating a portal frame. We recommend the roof also has a 25mm internal service void if it is within the living spaces. Without your external roof finishes, but with an internal service void, the roof is circa 470mm thick. The maximum span in the direction of the portal frame is eight meters, in which case may be no need for additional support. If your design exceeds this parameter, we can still design a PH15 frame solution but there will be additional structure, typically a beam sitting under the I-joists.



FLAT ROOFS (rubber, resin or living roofs)

The I-joist depth will typically be 300/360mm depending on span (up to 400mm if required), with a timber tilting fillet laid over it to create the small gradient needed for any flat roof (minimum depth of fillet 25mm). Due to the impermeable membrane on the roof it is difficult to ascertain when detailing a warm roof that the structure will dry out to the inside during the summer months. This requires a large amount of heat to develop within the structure to ensure that the vapour gradient in the summer is reversed and moisture can pass back through the Intello membrane on the inside of the roof. This situation is further complicated when a green roof is specified as the moisture reservoir can prevent sufficient heat build-up. To obtain a clearer picture we carried out moisture transport simulations using WUFI software to model the annual fluctuations with various build ups. This showed the safest approach was a 200mm cellotex build-up above the roof deck and with no insulation between the joists for a warm roof or using the same build-up of cellulose and woodfibre as the walls and including a ventilated gap for a cold roof. Large flat roofs with a single pitch can become very deep (over 600mm in extreme cases) so care should be taken when designing them especially where upstands to adjoining walls may be difficult to achieve below first floor windows. Adding a living roof on top (substrate + plants) will be a further depth of 35-100mm, depending on the specification. The airtight layer internally would normally be an intelligent membrane which will allow some vapour movement to the interior. The U-value of a typical PH15 at roof is circa 0.087 W/m2K



PH15 MVHR and VENTILATION DESIGN

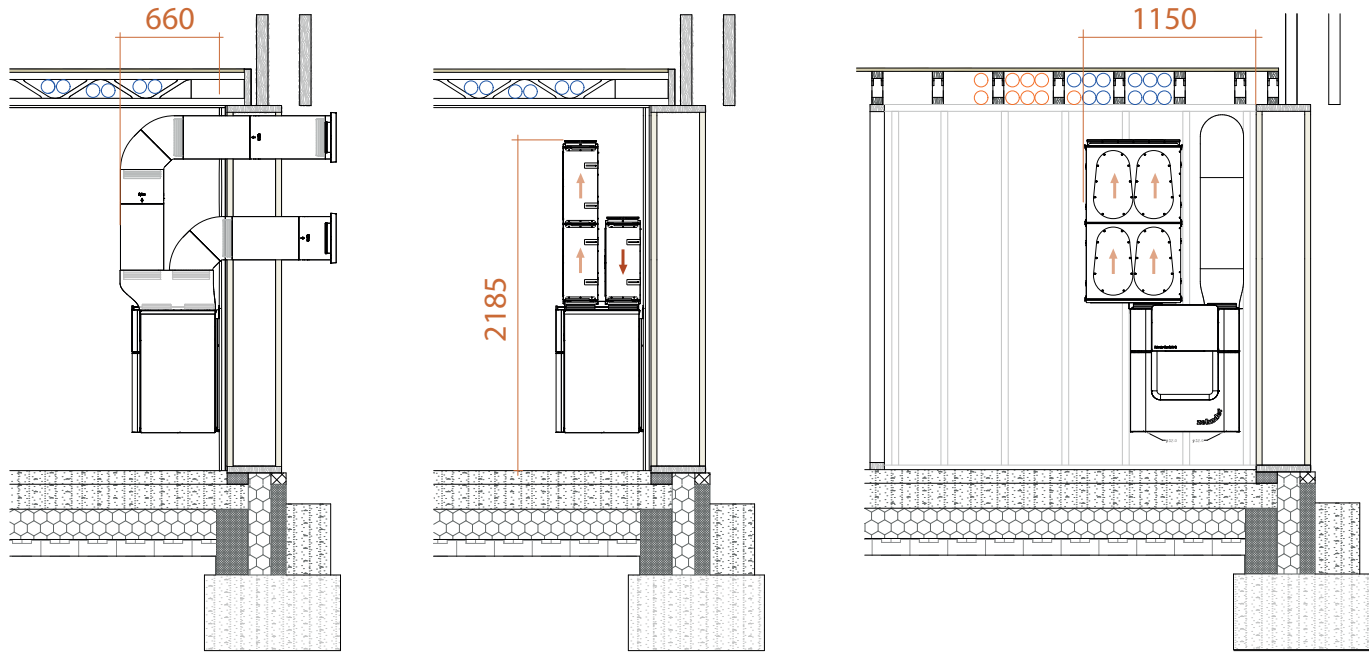
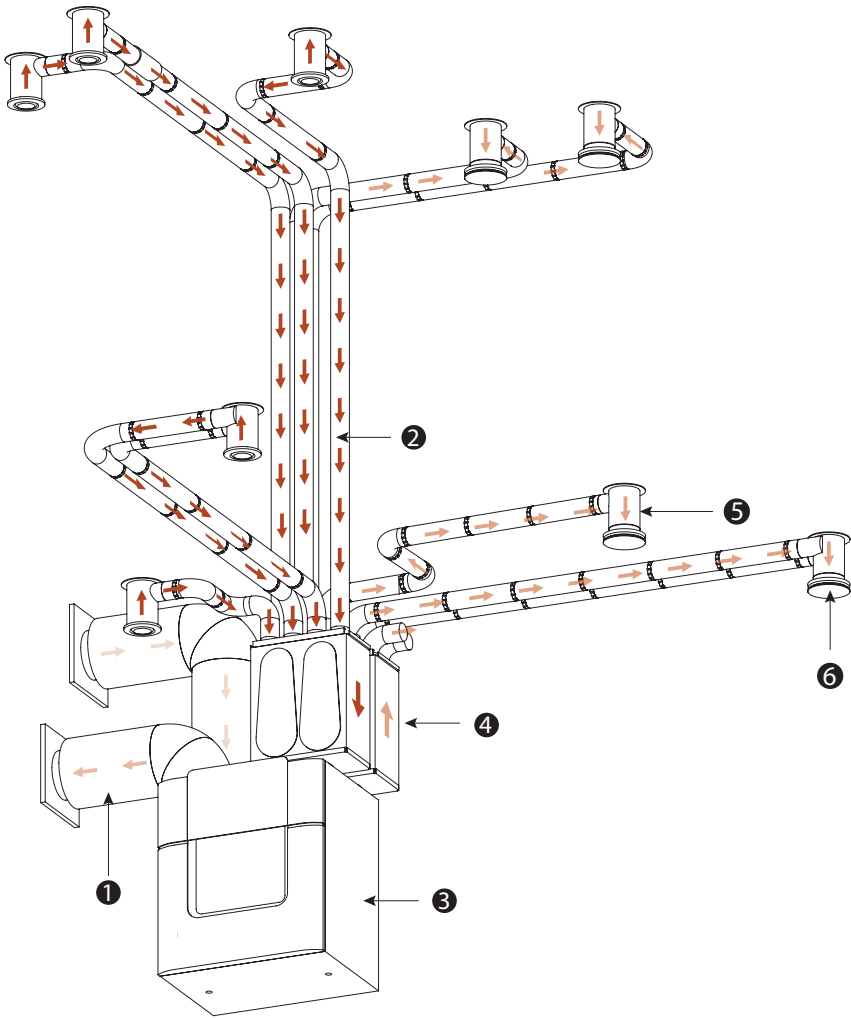
The ventilation system is radial and is designed and commissioned as part of PH15 supply. At design stage, enough room needs to be allocated for the main MVHR unit and associated distribution boxes and ducts. This can be installed within the roof void though easy access will be required for routine filter changes and general servicing. DO NOT UNDER ESTIMATE THE AMOUNT OF SPACE NEEDED. IT WON'T NECESSARILY FIT IN A KITCHEN CABINET!

Keep the duct runs from the main unit to the external air minimal in length. In practice this means you will need to allow space on an outside wall for the MVHR unit. Avoid intake/out-take near any potentially polluted air or where you need silence (e.g. next to a terrace) as there can be some noise at the external outlets. There are two distribution boxes (one for supply air and one for extract air) that can be located on the MVHR unit - if additional attenuation is required the boxes are fitted remote from the machine.

Every serviced room will have at least one semi-rigid, 90mm diameter duct running from a distribution box to the room valve (kitchens and main bathroom typically two). Outlets can be wall or ceiling mounted. The kitchen extract ideally located approximately 1.5mt from the hob. A separate recirculating cooker hood may be unnecessary. PHH can look at your early design and advise on best locations. We supply ZEHNDER Passivhaus certified units and system components.

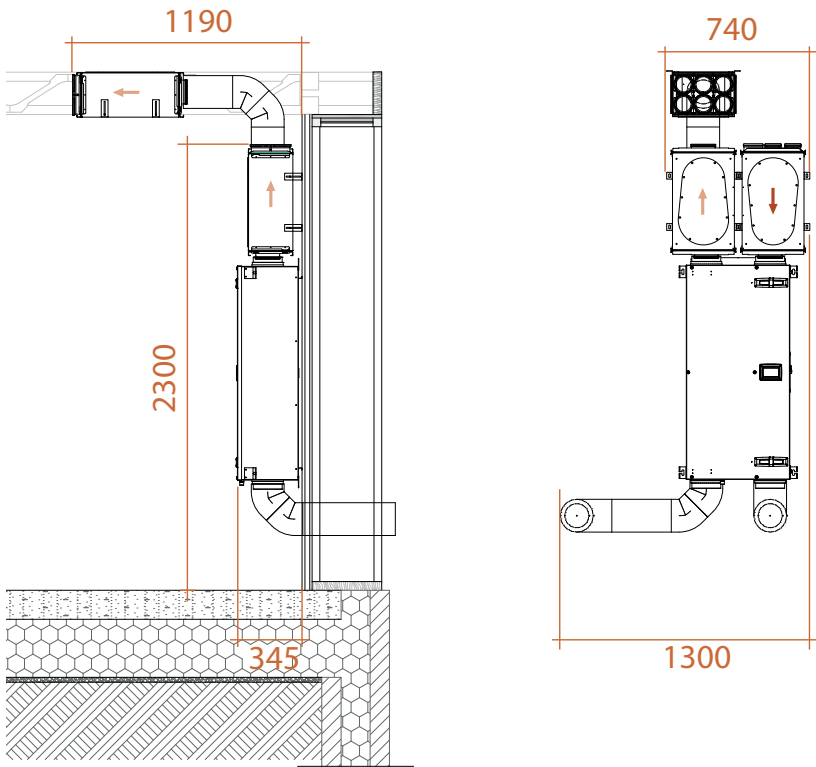
Typical main unit dimensions, 570x725x850mm. Typical installed heat recovery efficiency 85-90%

- 1 The intake and exhaust air ducts - Comfopipe Plus. 200 or 160mm internal, 286 or 246mm external.
- 2 The supply and extract air ducts - 90mm Comfotube. single or double depending on the volume required.
- 3 MVHR unit - ComfoAir/ComfoAir Q.
- 4 The supply and extract distribution boxs - Comfowell.
- 5 Comfotube TVA housing 90 to 125mm valve adaptors. Require a minimum depth of 130mm
- 6 Supply/extract valves. Haelix flow adjustable with round or square plate.



Comfoair Q450 with CW-K625 Comfowells. Attenuation in Comfowell only.

The system above allows for the maximum number (12 each) supply and extract ducts. The Q350, Q450 and Q600 machines have the same dimensions but the Q450 and Q600 require approximately 265mm more height due to an additional adaptor. Where the frame can't be amended, allow for the neccessity of moving the the machine so that the extenal ducts can align with the frame.



Comfoair 200 with CW-K320 Comfowells. Attenuation in Comfowell only.

This smaller system is suitable for a two bed property with kitchen, utility, wc, and two bathroom/showers.

When designing allow for some space around the components for servicing.

Design for connection to a 32mm condensate drain.

There will also be a large concentration of the flexible ducts, especially on larger systems which have to be accommodated close to the distribution boxes. Consider a localised dropped ceiling to enable this.

The main thing is don't under estimate the amount of space required



PH15 WINDOWS & DOORS

There is a wide range of Passivhaus suitable windows and doors available as part of the PH15 System. The range includes Katzbeck Design/DesignPlus and Flat (from Austria) fixed and tilt:turn windows and their Fix-flat all glass system which internally allows for edge to edge glass between the reveals. All are timber with aluminium cladding. Also available is the all timber Massiva range. More information is available on the Katzbeck range in our separate catalogue.

Ultra from GBS is available with or without aluminium cladding externally. All are inward tilt turn or fixed.

U-values of glazing from 0.5 – 0.6 W/m²K typical install U-values 0.89 W/m²K

Solid doors come in a variety of styles and are available with aluminium panel or without. When designing the house bear in mind that solid doors can be twice as expensive as fully glazed and will perform less well thermally.

Also available in these ranges are inward and outward opening French Doors and Lift and Slide Doors. Our window range comes with optional external blinds (box hidden in the wall) & 'clear view' fly screens.

PH15 provides the option of a folding/sliding door from Lacuna which provides the required airtightness for passivhaus construction. We also supply PH Certified, all timber 'sash' window by BEWISO for a more traditional look.

Finally we supply electrically operated, triple-glazed roof lights from Fakro for flat and pitched roofs or Lamilux where larger rooflights and access windows are required. We can discuss the options available to you at the design stage.

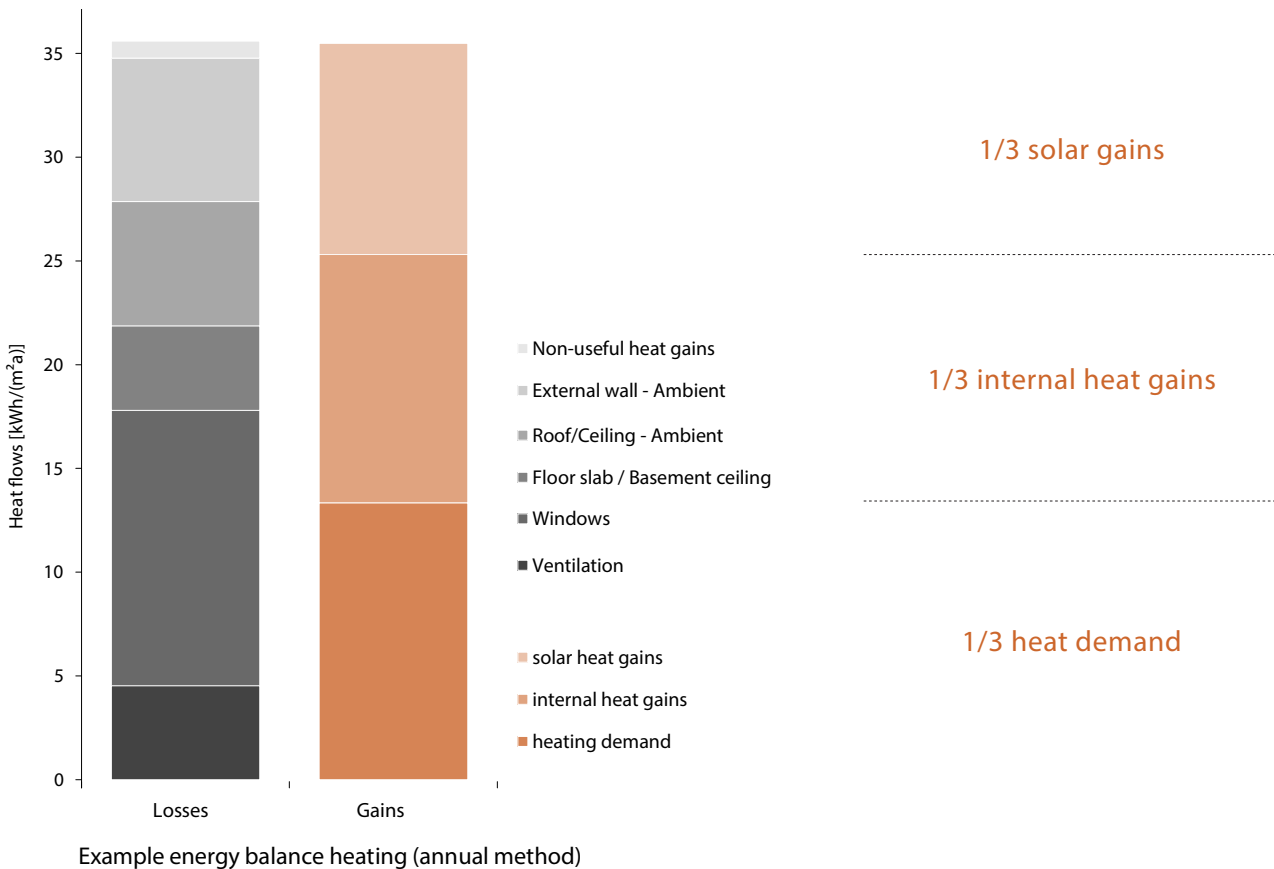


GLAZING & ENERGY BALANCE

There are two rules of thumb that can be applied to windows early on in the design.

- 1. The amount of solar gain should be roughly 1/3 of the energy inputs, with 1/3 heating + 1/3 incidental gains.
- 2. The glazing fraction as a percentage of the TFA should be in the range 15-20%.

Beyond this over-heating will potentially become an issue. Allow at least one opening window in each room and if possible include a roof light as night time ventilation can help control over heating.



Overheating should always be tested against both current and future climate scenarios to ensure the building will continue to operate comfortably in at least the next 20 years. At PHH we recommend keeping overheating below 1% of annual hours above 25°C. This should first be achieved by limiting the glazing fraction and managing the energy balance as advised above. In some cases additional mitigation measures may be required. These include external blinds, which can be a very effective way to significantly reduce solar gain. Katzbeck windows can be specified to include external blinds by Schlotterer. These are available as louvres or shutters and have a number of control options, discussed further below.



Consider the overheating risk and keep this down to <1%. Stress testing for a rise of 1.5 °C in the local climate demonstrates the urgent need to minimise this risk as the climate warms.

EXTERNAL MOTORISED BLINDS

Shutters & Louvred blinds

External, motorised blinds made of stable, powder-coated aluminium slats ensure pleasant shading and cooling in summer, cosy sun warmth in winter and optimal room lighting with natural light every day. At the same time, they prevent unwanted intrusion from outside.

Almost all Katzbeck external blinds can be enhanced with integrated or combined IGI insect protection systems as roller blinds, rotating, sliding or stretching frames.

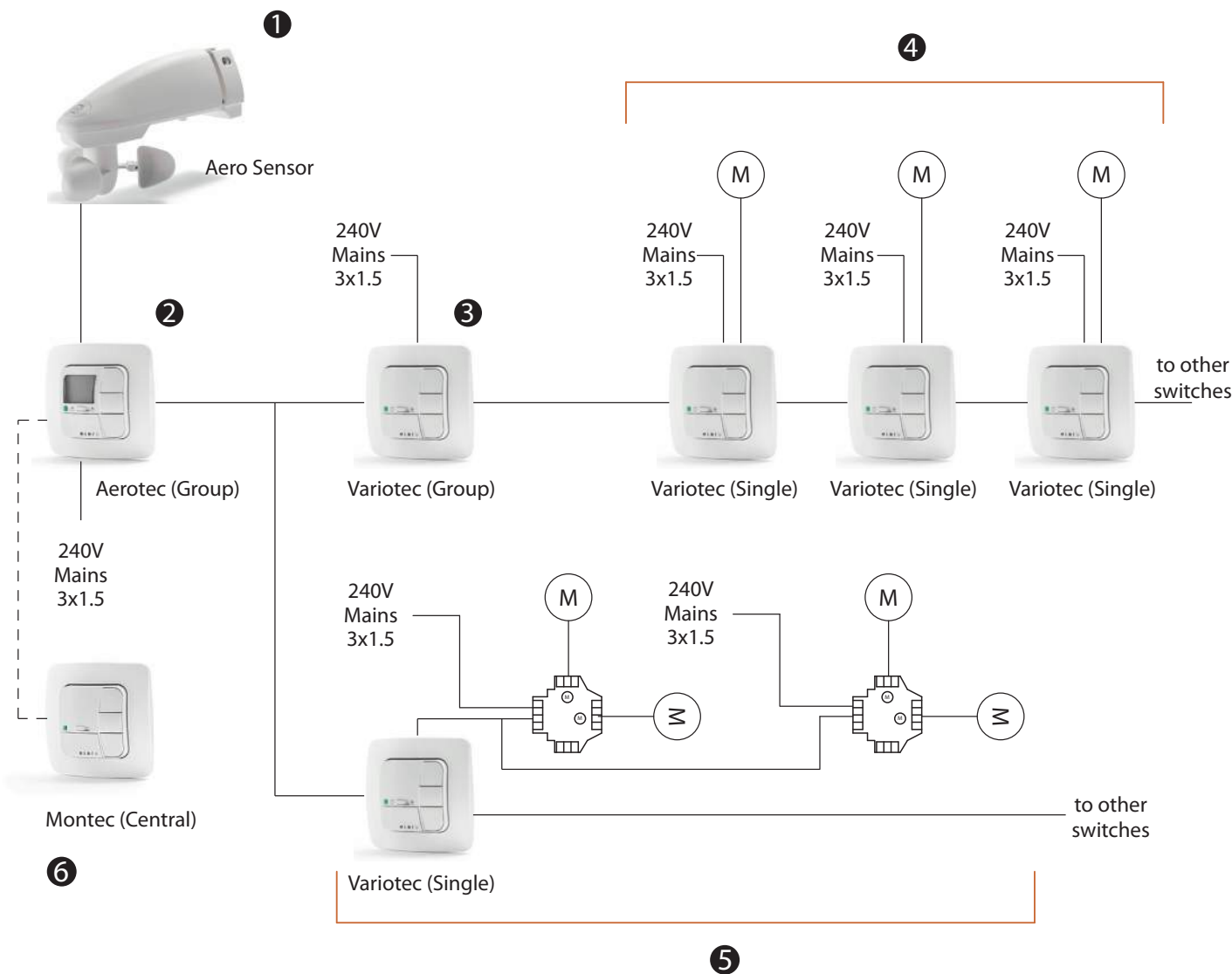
The cost of blinds and controls is not given at the PH15 estimate stage, For the final costing a specification of the number of blinds and control type will need to be agreed with PHH.



Controls

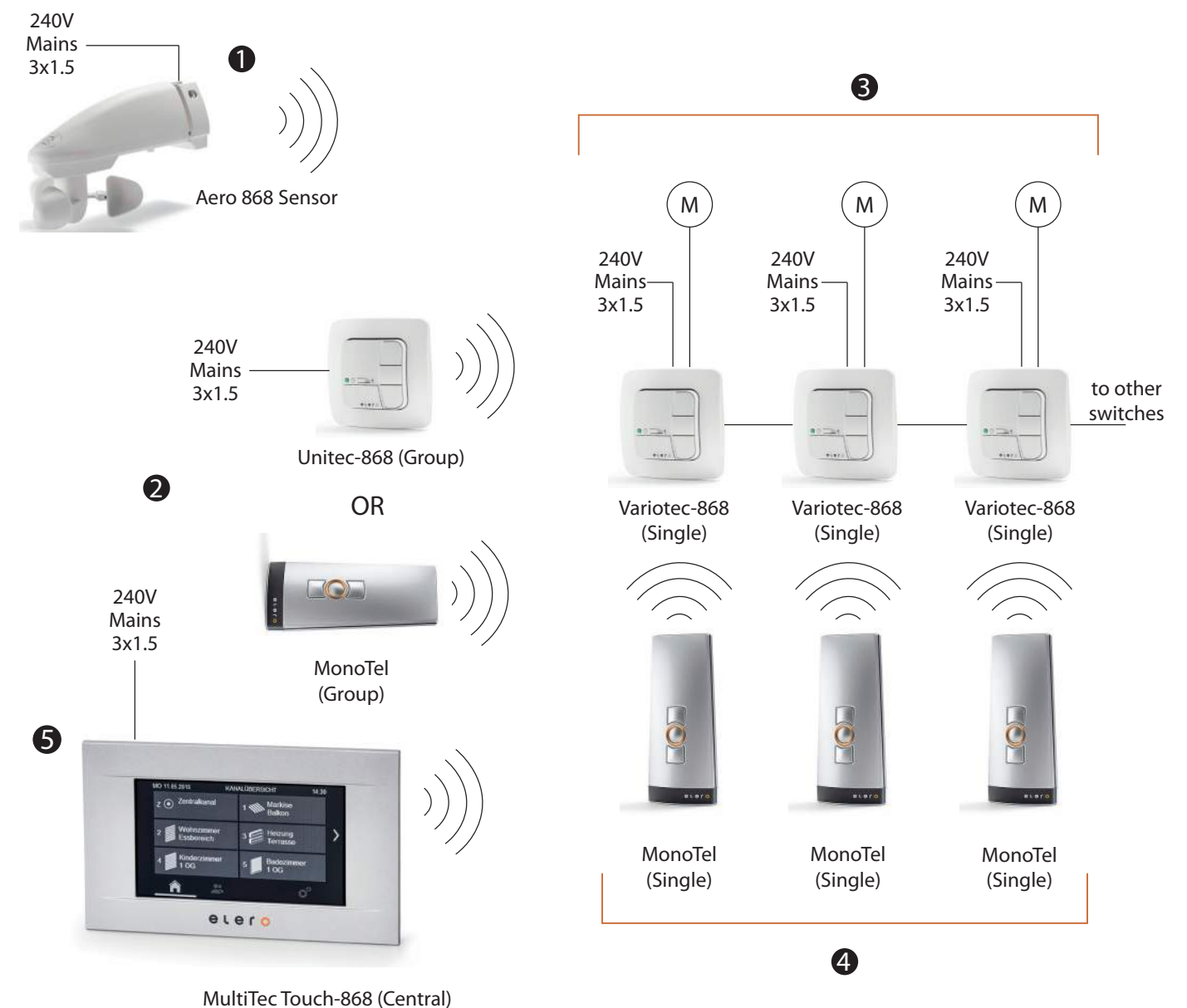
All external blinds are electronically controlled. This can be via a wired wall switch, a radio control system or a centralised touch screen control panel. Overleaf are control options PHH can supply. Whole Home management systems which can control blinds must be specified, designed and supplied by the architect and/or relevant subcontractor and is outside the scope of PH15. Please discuss with us before placing the window order.

EXAMPLE FOR WIRED ONLY CONTROLS



- 1 External light and wind sensor controls the blinds via;
- 2 Aero switch set to operate in group mode. This then controls all the blinds connected to it. Has a separate mains connection.
- 3 A Variotec switch can also be added to operate blinds in group mode in just one particular room for example. In this example the Variotec (Group) operates three blinds via three individual switches. Requires a separate mains connection.
- 4 Each Variotec in single mode can control one blind motor. Each requires a separate mains connection.
- 5 It is often required for a single switch to operate more than one motor (on split Lift & Slide door blinds for example). For this a relay is added which can control two blind motors. Multiple relays can be used.
- 6 By adding a Monotec set to Central mode it is possible to operate all the blinds in the above example (max two groups). The monotec could be placed by the front door so that all the blinds could be shut when leaving the house for example.

EXAMPLE FOR WIRED/REMOTE CONTROLS



- 1 External light and wind sensor controls the blinds.
- 2 Unitec-868 switch set to operate in group mode. This then controls all the blinds paired to it. Has a separate mains connection. Alternatively a hand-held controller in group mode can be used.
- 3 Variotec-868 switch is a receiver only and is hardwired to a single motor . Requires a separate mains connection.
- 4 Blinds can be controlled directly using the Varitec buttons or with a handheld controller. Individual controllers with multiple channels are available
- 5 A touch screen central controller with programmable functions is also available.

CRITICAL SITE CONSIDERATIONS

Exposed locations

If designing for an exposed or coastal location it is recommended that the external walls are finished using a rain-screen. If a rendered finish is desired, this can be applied to a backing board. We advise not to apply direct to the woodfibre boards. This is to protect both the finish and the frame. For coastal locations, suitable marine grade finishes and hinges can be specified for the windows and doors.

Scaffold

It is recommended PH15 be constructed under a tin hat. This is estimated to add 30-40% to the total scaffold cost, but can be recouped by almost eliminating delays from inclement weather and by providing an ideal and dry working environment.



Full scaffold with tin hat and monarflex sheathing

Cost for a 'tin hat' will vary around the country [...]. The cost of our tin hat was recouped with only 3 to 4 days of inclement weather. When you add the improved comfort for the trades people to the equation the tin hat is a very small price to pay for a dry, comfortable, and happy workforce.

*Alan Hosey,
Cost Engineer and Project
Manager*

Deliveries

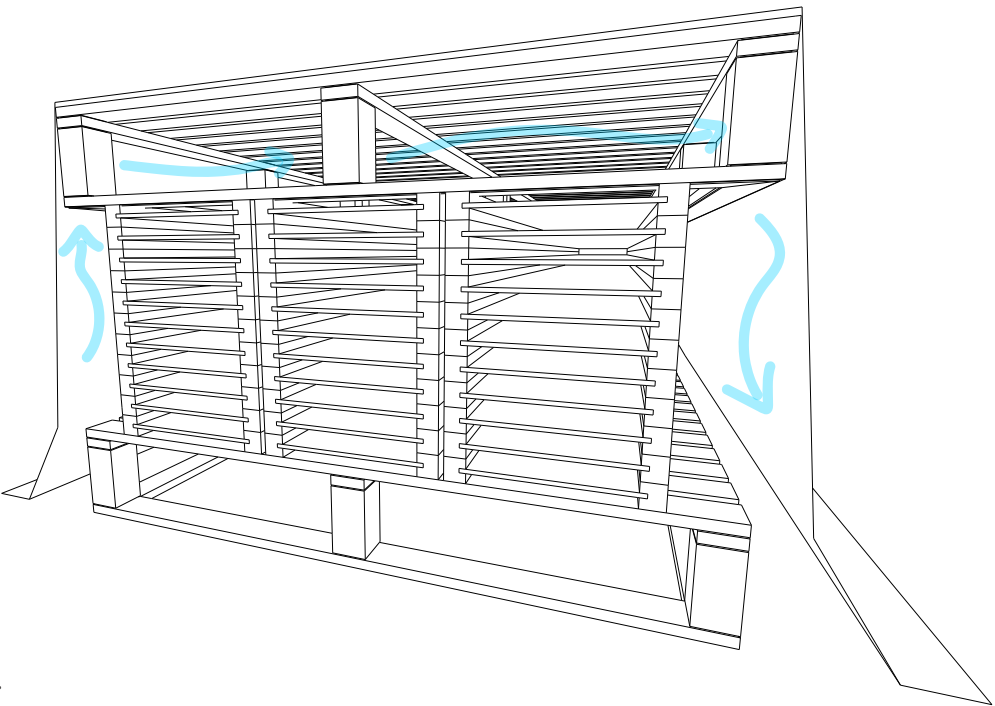
PH15 can be delivered using medium-sized lorries, excluding the Katzbeck windows, which arrive on an articulated lorry. If your site is not accessible by articulated lorry and/or has other access restrictions that might impact deliveries, let PHH know as early as possible so that this can be incorporated into the design.

Storage

The PH15 frame is made predominantly of engineered timber. This can be stored outside, if covered. However, it should be protected from repeat rain/snow and/or excessive heat/sunshine.

If tarpaulins are used to cover materials, these tarpaulins should not be in contact with the PH15 materials. This is to avoid condensation. It is further recommended an empty pallet (or similar) be placed on the material stack, between it and the tarpaulin, to ensure ventilation around the materials can be maintained.

If the PH15 frame is stored outside for prolonged periods (> 1month) in humid conditions and/or cold conditions the PH15 frame may expand in both length and width. It is therefore advisable to time your frame delivery close to the start of frame construction, unless dry storage is available.



Indicative section through stored i-joists.

Home owner / Client:
Street:
Postcode/City:
Province/Country:

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

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

Interior temperature winter [°C]:
Specific capacity [Wh/K per m² TFA]:

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

Created floor area:
103.8
7.1
7.7
-
-
0.1
0
0.3
74
53
45

Criteria	Alternative criteria	Fulfilled? ²
15	-	yes
-	10	-
-	-	yes
-	-	yes
10	-	-
20	-	-
0.6	-	-
-	-	yes
60	60	-
-	-	-

passive House Classic? ☒ yes

First name: Surname: City: Components Windows Shi

PHPP is a powerful design tool that should be put to use early in the design process.

PHPP

PHPP can appear daunting to those not used to using it but it should be embraced as early as possible in the design process. Avoid relying on 'low level' PHPP results as these may leave out key information like shading that will impact the eventual overheating level. Discovering you have a problem post planning can make it difficult to resolve without returning to the planning office.

We are happy to work with and assist architects who wish to carry out their own PHPP, and a full set of input data for the PH15 System is available at the back of this document. For those who do not, part of the PH15 System offering is a PHPP analysis of the design with a report on over-heating risk and an accompanying mitigation strategy.¹ We have to make assumptions on the size and type of heating for space and hot water requirements but the results will give you a confident position from which to move towards a planning application. Bear in mind that the results will only be as good as the data you supply us, particularly in terms of the amount of shading from near-by trees and buildings which will effect the building's performance.

As a starting point for all designs we run the PHPP to see if the Passivhaus Plus standard is achieved. This indicates whether the building will be net zero energy and is dependant on the amount of PV generation as a function of the footprint of the building. A bungalow with a GIA of 180m² will require more PV to meet the standard than a two storey building with the same GIA.



As a secondary analysis and as an addition to the passivhaus requirements we provide a carbon audit of the PH15 System shell.²

¹ The fee for PHPP will depend on the complexity of the project but is refunded against the cost of the whole system when an order is placed.

² Using PH Ribbon, a plug-in software for PHPP to measure embodied energy which utilizes the latest ICE and EPD data.

CERTIFICATION

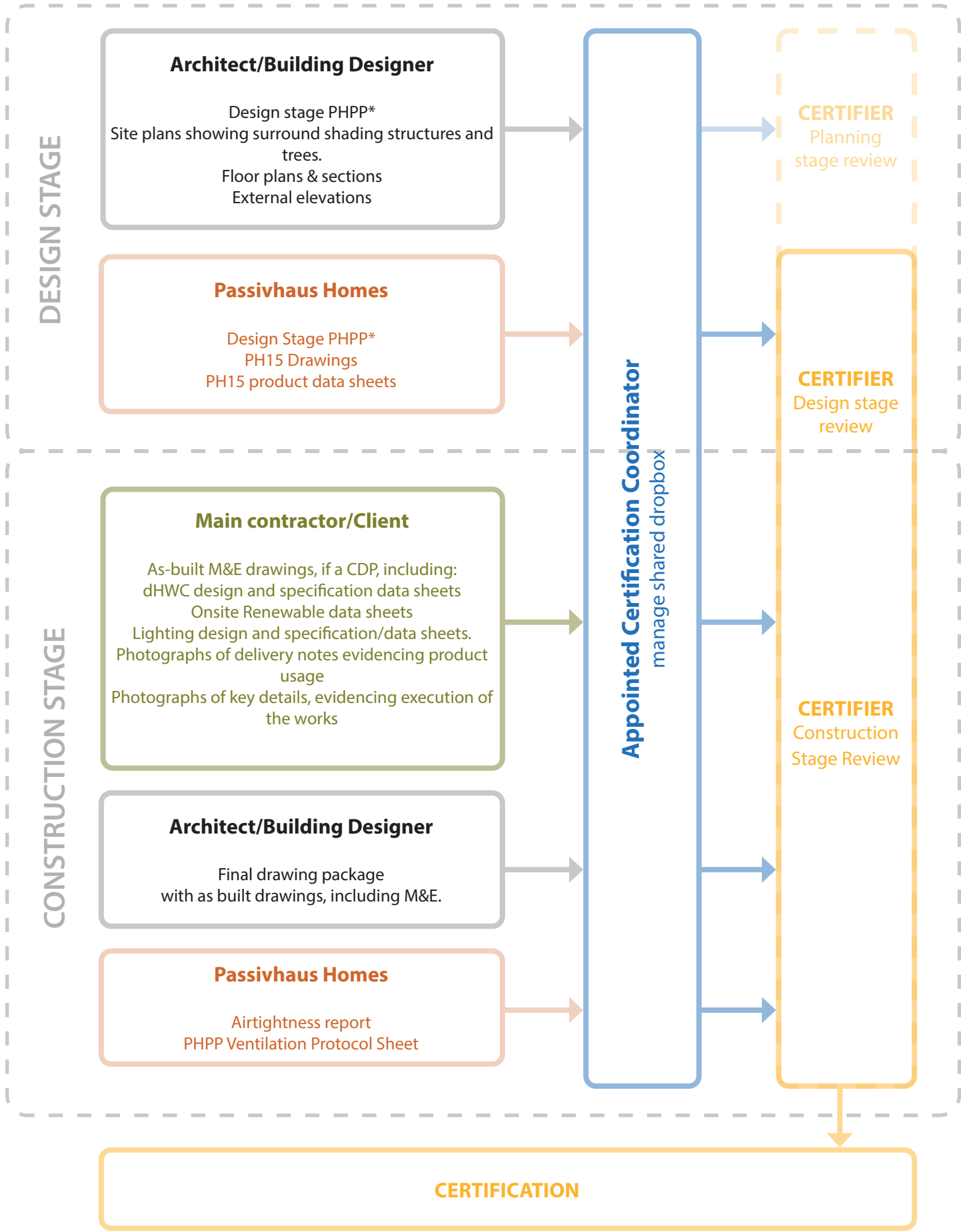
Certification is part of the quality assurance process of passivhaus buildings and provides homeowners with confidence that the building will perform as designed. At PHH we provide a great deal of information to help make it quicker and more straight-forward.

The process is carried out by an accredited certifier who will review both the design and construction evidence to ensure the building meets the passivhaus standard. The evidence required will typically come from many sources including the homeowner/client, the architect/building designer, PHH, the main contractor and sub-contractors/suppliers.

It is recommend someone involved closely in the project is appointed as the certification coordinator to ensure all the relevant evidence is gathered and passed to the certifier at the right time. To support the co-ordinator we provide an online shared folder system and key checklists to guide you through.

The flow chart overleaf shows the delineation of responsibilities across the certification process. There are broadly two stages at which information is passed to the certifier, although there may be more. The first is the design stage and the second the construction stage.

PH15 CERTIFICATION FLOW CHART



* PHPP designer may be the responsibility of the architect or Passivhaus Homes.

THERMAL PERFORMANCE ANALYSIS

THERMAL PERFORMANCE ANALYSIS

The calculation of an energy balance is required for all passivhaus buildings. In addition to the envelope U-values the thermal bridges need to be considered. Thermal bridges (psi-value) are caused by the geometry effects (e.g. corners) or penetrations. As one of the main passivhaus principles is thermal bridge free design, interruptions to the thermal envelope need to be minimised. For the analysis the junctions were evaluated for two parameters:

psi-value, for an energy evaluation of the detail

fRsi factor, for a hygiene and efficiency evaluation of the detail

The table below gives the psi-values for all the principle PH15 junction details. To be considered thermal bridge free a junction must have a psi-value of better than 0.01W/mK). Negative psi-values are better than positive psi-values. For each junction the minimum surface temperature was calculated as well. The results are given through the fRsi factor, which is determined as follows:

$$f_{Rsi} = \frac{(\theta_{si} - \theta_e)}{(\theta_i - \theta_e)}$$

where θ_{si} is the minimum interior surface temperature, θ_e is the minimum outside temperature (assumed to be -10°C) and θ_i is the interior temperature (assumed to be 20°C). The θ_{si} is calculated considering $R_{si} = 0.25$ (m₂K)/W as the internal surface resistance.

The f_{Rsi} factor is the parameter chosen to easily identify the risk of mould growth and condensation. The hygiene criterion identifies the minimum f_{Rsi} factor that a component can tolerate in relation to the risk of mould growth. The efficiency criterion establishes the minimum f_{Rsi} factor that needs to be reached to ensure thermal comfort. Fanger's theory¹ explains that one of the causes of thermal discomfort is radiant temperature asymmetry in the room.

The PHI have established values for each depending on climate zone, which for the UK are 0.65 for the hygiene criterion and 0.82 for the efficiency criterion.

The analysis was carried out using Flixo v8.1 Finite Elemental Analysis software. This software has been developed for 2 dimensional steady state thermal simulation according to EN ISO 10077-2.

¹ Fanger, P. Ole, "Thermal Comfort: Analysis and applications in environmental engineering", 1970

THERMAL BRIDGE VALUES

Thermal Bridge Detail		Ψ-value (W/m·K)	f _{Rsi} factor	
TB01a	Floor Slab-Exterior Wall -200mm insulation	-0.009	0.953	10
TB01b	Floor Slab-Exterior Wall -250mm insulation	-0.014	0.956	11
TB01c	Floor Slab-Exterior Wall -300mm insulation	-0.013	0.958	12
TB01d	Suspended Floor Slab-Exterior Wall -200mm insulation	-0.015	0.950	14
TB01e	Suspended Floor Slab-Exterior Wall -250mm insulation	-0.013	0.951	15
TB01f	Suspended Floor Slab-Exterior Wall -300mm insulation	-0.012	0.952	16
TB02	Floor Slab-Internal wall ¹ - see note below			
TB03a	Pitched Roof Eaves	-0.020	0.987	17
TB03b	Pitched Roof Eaves (with extended rafters)	-0.023	0.975	18
TB03c	Pitched Roof Eaves (with box lintel)	-0.007	0.976	19
TB04a	Ridge (without beam)	-0.032	0.978	20
TB04b	Ridge (with beam in roof plane)	-0.028	0.973	21
TB04c	Ridge (with beam below roof plane)	-0.034	0.975	22
TB05a	Pitched Roof Verge	-0.055	0.960	23
TB05b	Pitched Roof Verge (with gable ladder)	-0.056	0.967	24
TB06	Flat Roof Verge	-0.040	0.968	25
TB07	Flat Roof-Wall	0.024	0.987	26
TB08	External Corner	-0.056	0.967	27
TB09	Internal Corner	0.029	0.987	28
TB10	Partywall-Exterior wall	0.017	0.968	29
TB11	Partywall-Roof	0.021	0.970	30

¹The foamglas perinsul pillars beneath load bearing internal walls can vary greatly from project to project and can be dealt with in the PHPP U-value entry for the slab. A value for the percentage of foamglas below the slab is given for each project.

Window Psi values also available.

SUMMARY

- PH15 provides a complete shell to passivhaus compliance
- All components costed at an early stage to high level of certainty
- Junction detail available for CAD
- Airtightness details rigorously tested and proven to meet better than 0.6ach
- Full support for PHPP
- Proven thermal modelling of junctions to EN ISO 10077-2
- All projects stress-tested for predicted 2050 climate data
- Shell meets RIBA 2030 carbon targets
- Contractor training provided for teams unfamiliar with PH15



APPENDIX -

EXAMPLE THERMAL BRIDGES

TB1a FLOOR SLAB: EXTERIOR WALL

TB3a PITCHED ROOF EAVES

TB4c RIDGE WITH BEAMS

TB5b PITCHED ROOF GABLE VERGE

TB8 EXTERNAL CORNER

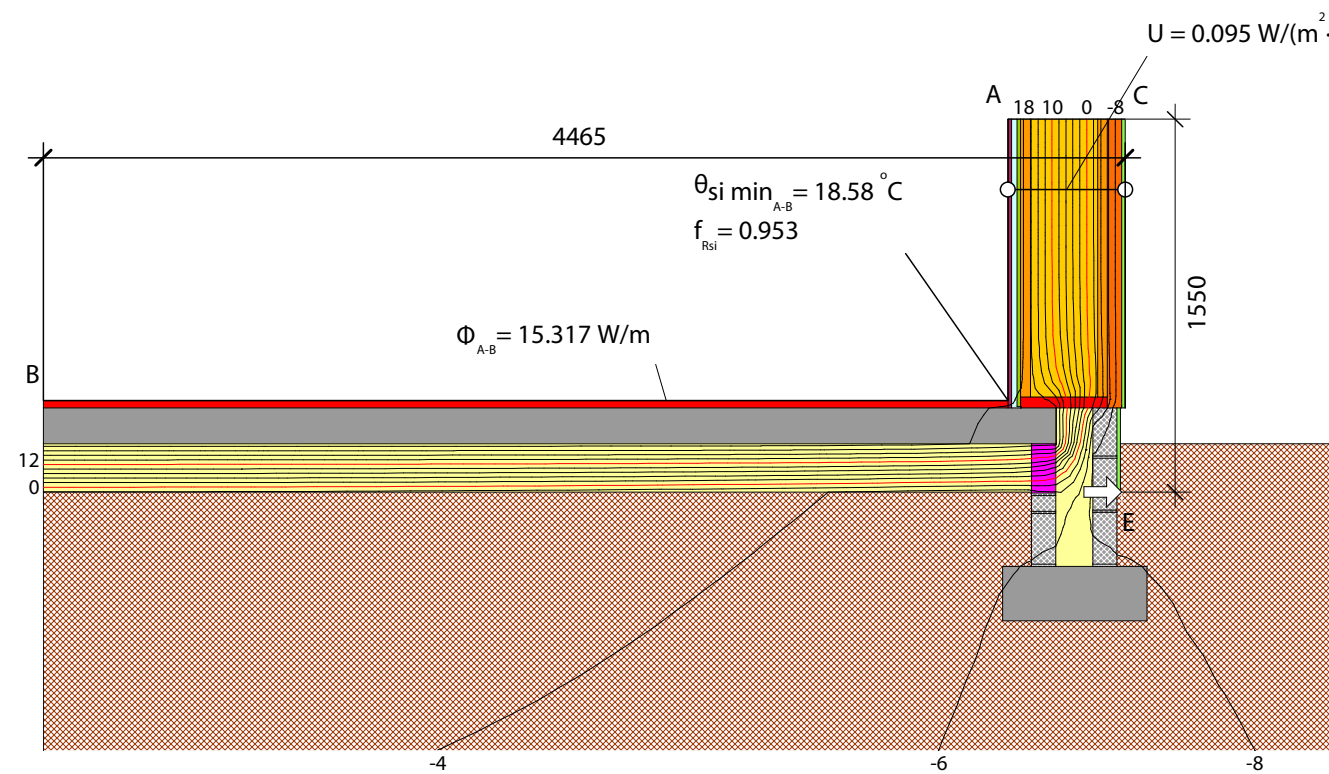
TB9 INTERNAL CORNER

TB10 PARTY WALL - WALL

TB11 PARTY WALL - ROOF

Full set of standard Psi calculations are available on request.

TB1a FLOOR SLAB:EXTERIOR WALL
Slab and wall with insulation at 200mm

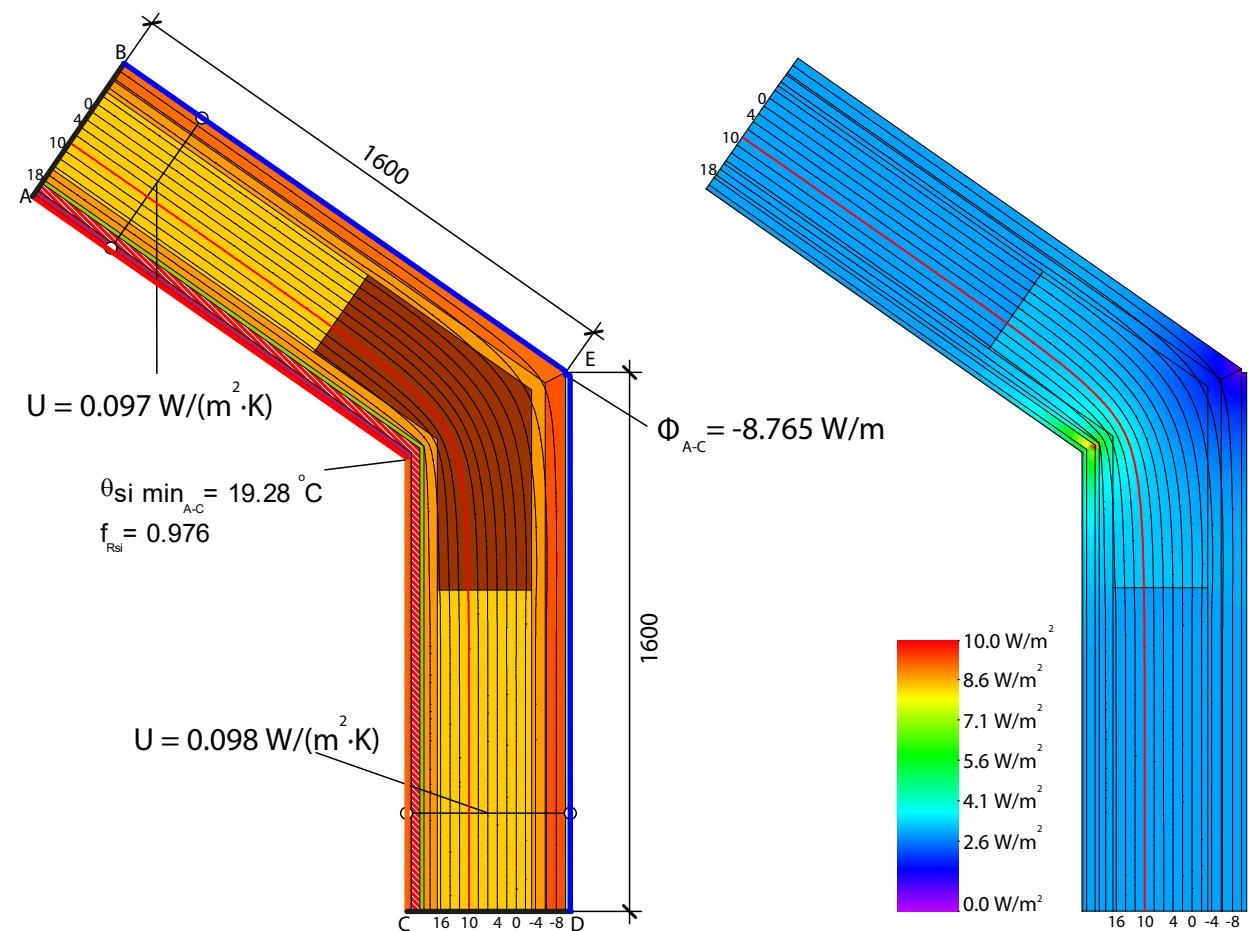


$$\psi_{A-E,B,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{15.317}{30.0} - 0.095 \cdot 1.55 - \frac{11.184}{30.0} = -0.009 \text{ W/(m·K)}$$

Material	λ [W/(m·K)]	Boundary Condition	q [W/m²]	θ [°C]	R [(m²·K)/W]
Celcon standard block	0.150	Exterior, normal	-10.000	0.040	
Celotex GA4000	0.022	Interior, heat flux, downwards	20.000	0.170	
Clay or silt	1.500	Interior, normal, horizontal	20.000	0.130	
Concrete, reinforced (with 2% steel)	2.500	Adiabatic/Model section	0.000		
Durelis 740 kg/m³	0.130				
FOAMGLAS/Celotex	0.031				
Gypsum plasterboard	0.250				
Plaster, cement, sand	1.000				
Plaster, lime, sand	0.800				
STEICO Zell/Flange	0.045				
STEICO Zell/Web	0.041				
STEICO SpecialDry	0.041				
Timber 700kg/m³	0.180				
Unventilated air cavity*					

Consider EN ISO 10211 requirements: YES
Min. element angle: 20
Min. element size: 1/70
Mesh refinement: 0
Method: relative error AND relative heat flow error
Max. rel. error: 1e-30
max. heat flow error: 0.0001
Max. relative changes (material properties): 20%
Max. nr. iterations (material properties): 1

TB3a PITCHED ROOF EAVES
Eaves without rafter extensions

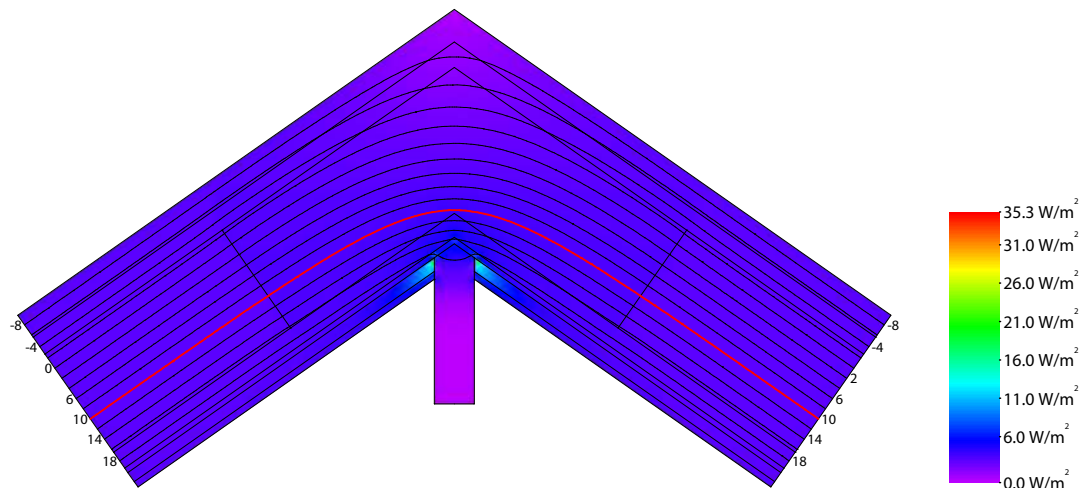
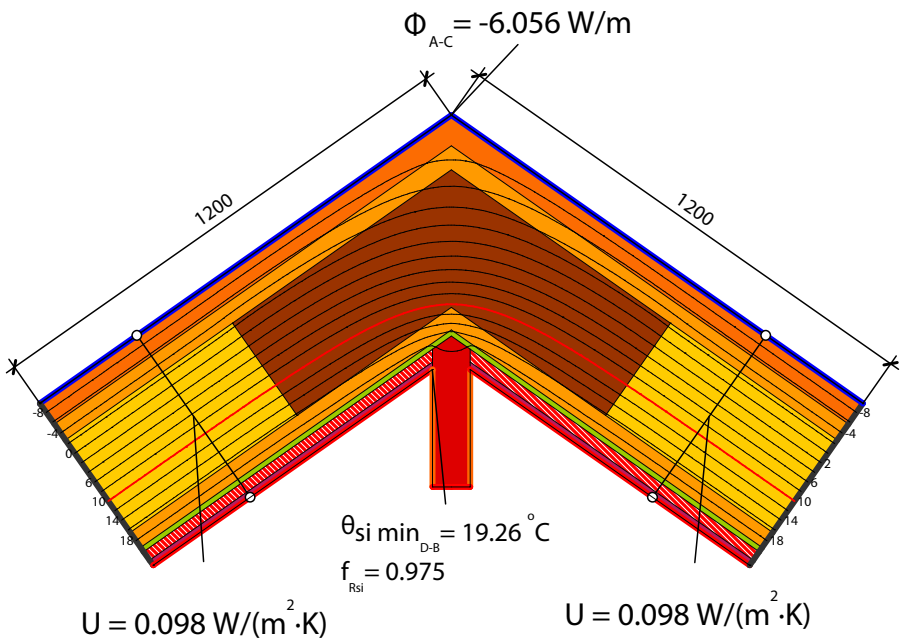


$$\psi_{A-E,C} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - U_2 \cdot b_2 = \frac{8.765}{30.0} - 0.098 \cdot 1.6 - 0.097 \cdot 1.6 = -0.020 \text{ W/(m·K)}$$

Material	λ [W/(m·K)]	Boundary Condition	q [W/m²]	θ [°C]	R [(m²·K)/W]
Durelis 740 kg/m³	0.130	Exterior, normal	-10.000	0.040	
Gypsum plasterboard	0.250	Interior, heat flux, downwards	20.000	0.170	
Plaster, lime, sand	0.800	Interior, normal, horizontal	20.000	0.130	
STEICO Duodry	0.043	Adiabatic/Model section	0.000		
STEICO Zell/Flange	0.048				
STEICO Zell/Plate Zone	0.046				
STEICO Zell/Web	0.041				
STEICO SpecialDry	0.041				
Timber 500kg/m³/Air	1.491				

Consider EN ISO 10211 requirements: YES
Min. element angle: 20
Min. element size: 1/70
Mesh refinement: 0
Method: relative error AND relative heat flow error
Max. rel. error: 1e-30
max. heat flow error: 0.0001
Max. relative changes (material properties): 20%
Max. nr. iterations (material properties): 1

TB04c RIDGE WITH BEAMS
Beams set below roof

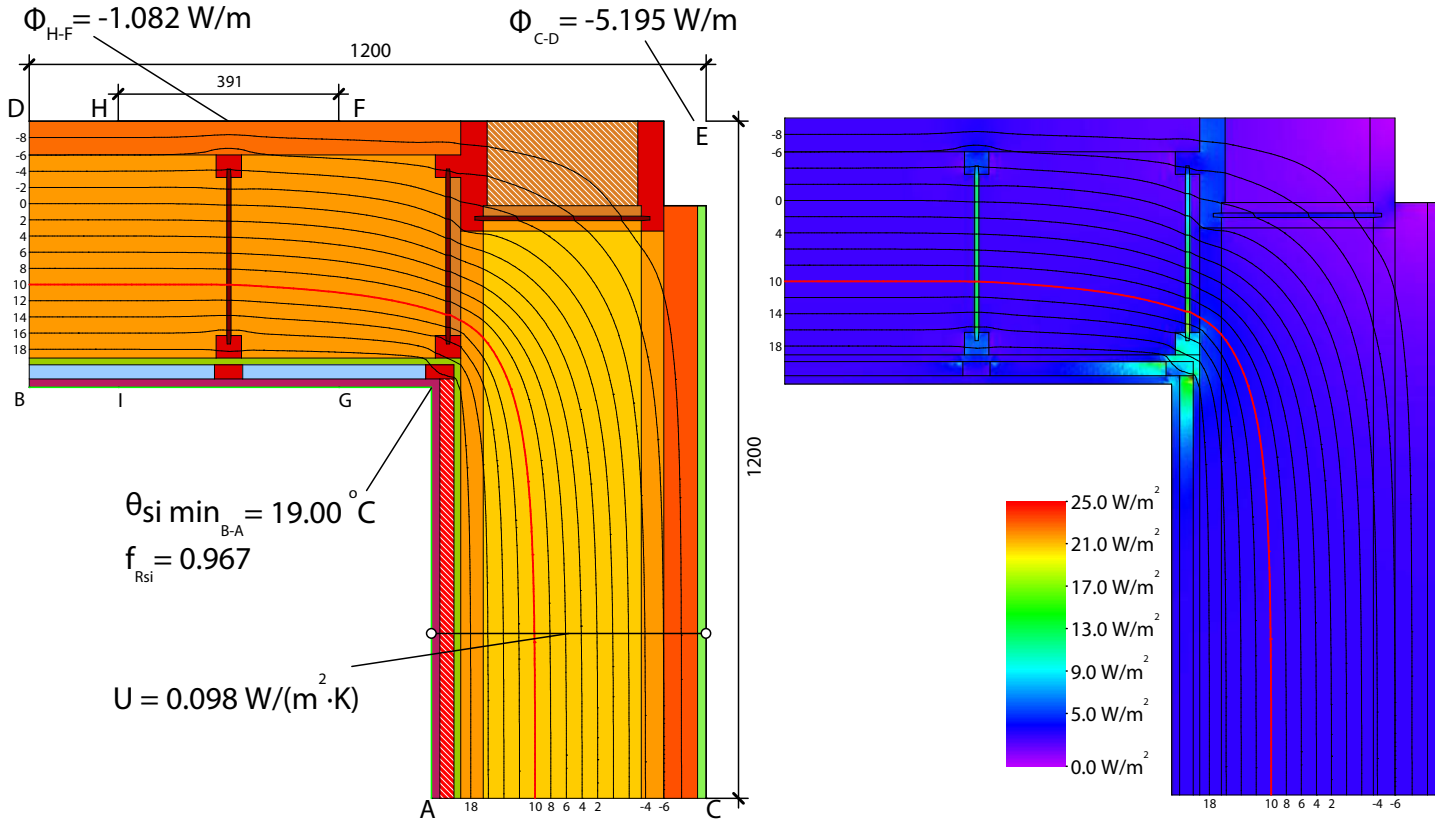


Material	λ [W/(m·K)]	Boundary Condition	q [W/m²]	θ [°C]	R [(m²·K)/W]
Durelis 740 kg/m³	0.130	Exterior, normal	-10.000	0.040	
Gypsum plasterboard	0.250	Interior, heat flux, upwards	20.000	0.100	
STEICO Zell/Flange	0.049	Interior, normal, horizontal	20.000	0.130	
STEICO Zell/Plate Zone	0.046				
STEICO Zell/Web	0.041				
STEICO SpecialDry	0.041				
Timber 500kg/m³/Air	1.491	Adiabatic/Model section	0.000		

Consider EN ISO 10211 requirements: YES
Min. element angle: 20
Min. element size: 1/70
Mesh refinement: 0
Method: relative error AND relative heat flow error
Max. rel. error: 1e-30
max. heat flow error: 0.0001
Max. relative changes (material properties): 20%
Max. nr. iterations (material properties): 1

$$\psi_{A-E-C} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - U_2 \cdot b_2 = \frac{6.056}{30.0} - 0.098 \cdot 1.2 - 0.097 \cdot 1.2 = -0.034 \text{ W/(m·K)}$$

TB05b PITCHED ROOF GABLE VERGE
With gable ladder



$$U_{eq\,F-H} = \frac{1.082}{30.0 - 0.391} = 0.0922 \text{ W/(m²·K)}$$

Section heat flux: 17.0%

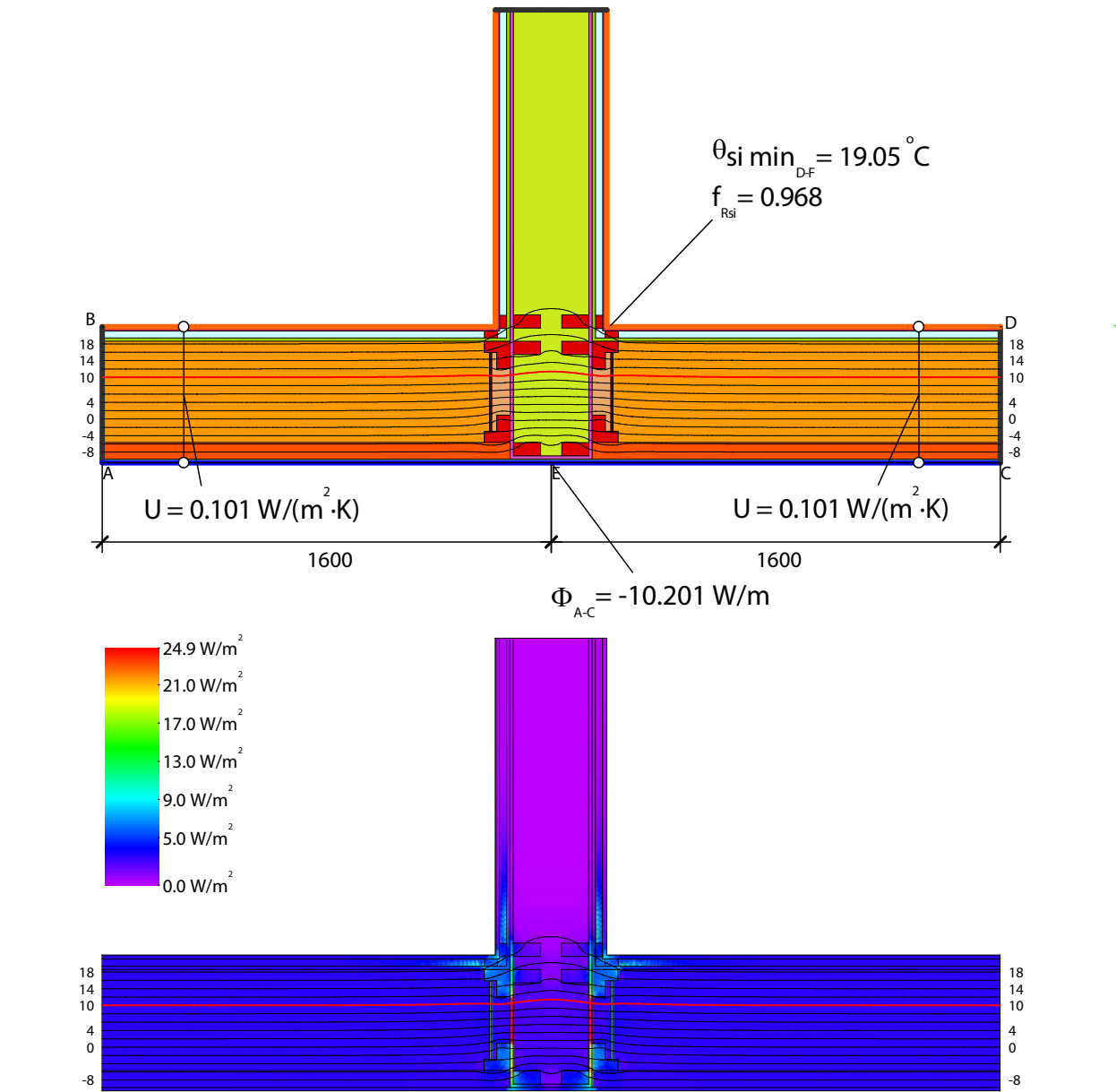
Material	λ [W/(m·K)]	Boundary Condition	q [W/m²]	θ [°C]	R [(m²·K)/W]
Durelis 740 kg/m³	0.130	Exterior, normal	-10.000	0.040	
Fibreboard 900 kg/m³	0.140	Interior, heat flux, upwards	20.000	0.100	
Gypsum plasterboard	0.250	Interior, normal, horizontal	20.000	0.130	
Plaster, lime, sand	0.800				
STEICO flex/timber	0.044	Adiabatic/Model section	0.000		
STEICO Zell/Flange	0.049				
STEICO Zell/Web	0.041				
STEICO flex036	0.038				
STEICO protect M	0.046				
STEICO SpecialDry	0.041				
STEICO zell	0.038				
Slightly ventilated air cavity*					
Timber 500 kg/m³ (softwoods)	0.130				
Timber 500kg/m³/Air	1.491				

*Simplified approach

Consider EN ISO 10211 requirements: YES
Min. element angle: 20
Min. element size: 1/70
Mesh refinement: 0
Method: relative error AND relative heat flow error
Max. rel. error: 1e-30
max. heat flow error: 0.0001
Max. relative changes (material properties): 20%
Max. nr. iterations (material properties): 1

$$\psi_{C-E-D} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - U_2 \cdot b_2 = \frac{5.195}{30.0} - 0.099 \cdot 1.2 - 0.092 \cdot 1.2 = -0.056 \text{ W/(m·K)}$$

TB10 PARTYWALL:EXTERIOR WALL



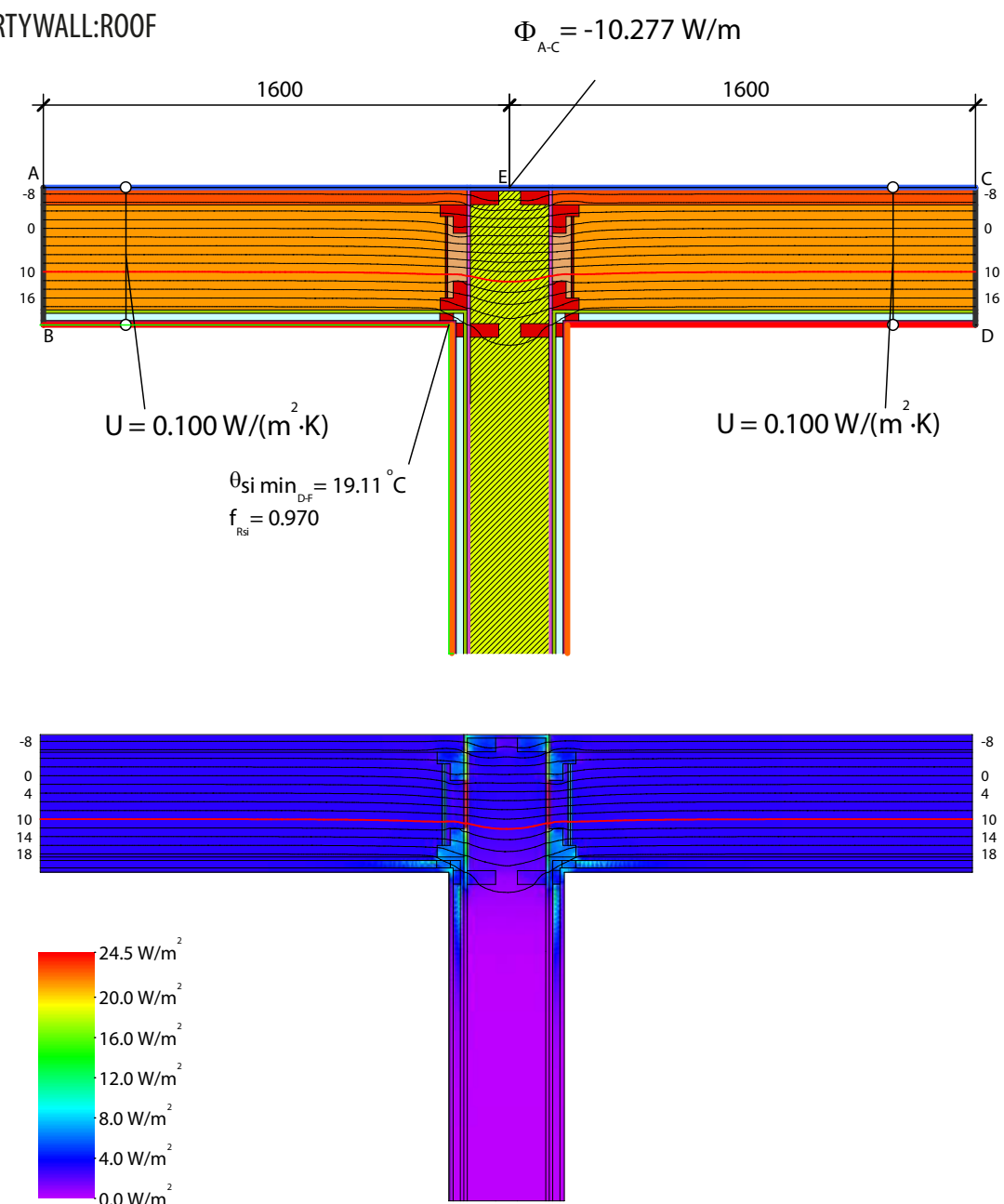
Material	λ [W/(m·K)]	Boundary Condition	q[W/m ²]	θ[°C]	R[(m ² ·K)/W]
Durelis 740 kg/m ³	0.130	Exterior, normal	0.000	0.000	0.040
Fermacell A2	0.320	Interior, normal, horizontal	20.000	20.000	0.130
Fibreboard 900kg/m ³	0.140	Adiabatic/Model section	0.000		
Gypsum plasterboard	0.250				
Plaster, lime, sand	0.800				
Rockwool A1	0.034				
STEICO DuoDry	0.043				
STEICO Zell/Flange	0.045				
STEICO flex036	0.036				
Timber 500 kg/m ³ (softwoods)	0.130				
Unventilated air cavity*					

*Simplified approach

Consider EN ISO 10211 requirements: YES
Min. element angle: 20
Min. element size: 1/70
Mesh refinement: 0
Method: relative error AND relative heat flow error
Max. rel. error: 1e-30
max. heat flow error: 0.0001
Max. relative changes (material properties): 20%
Max. nr. iterations (material properties): 1

$$\psi_{A-E-C} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{10.201}{30.0} - 0.101 \cdot 1.6 - 0.101 \cdot 1.6 = \mathbf{0.017 \text{ W/(m} \cdot \text{K)}}$$

TB11 PARTYWALL:ROOF



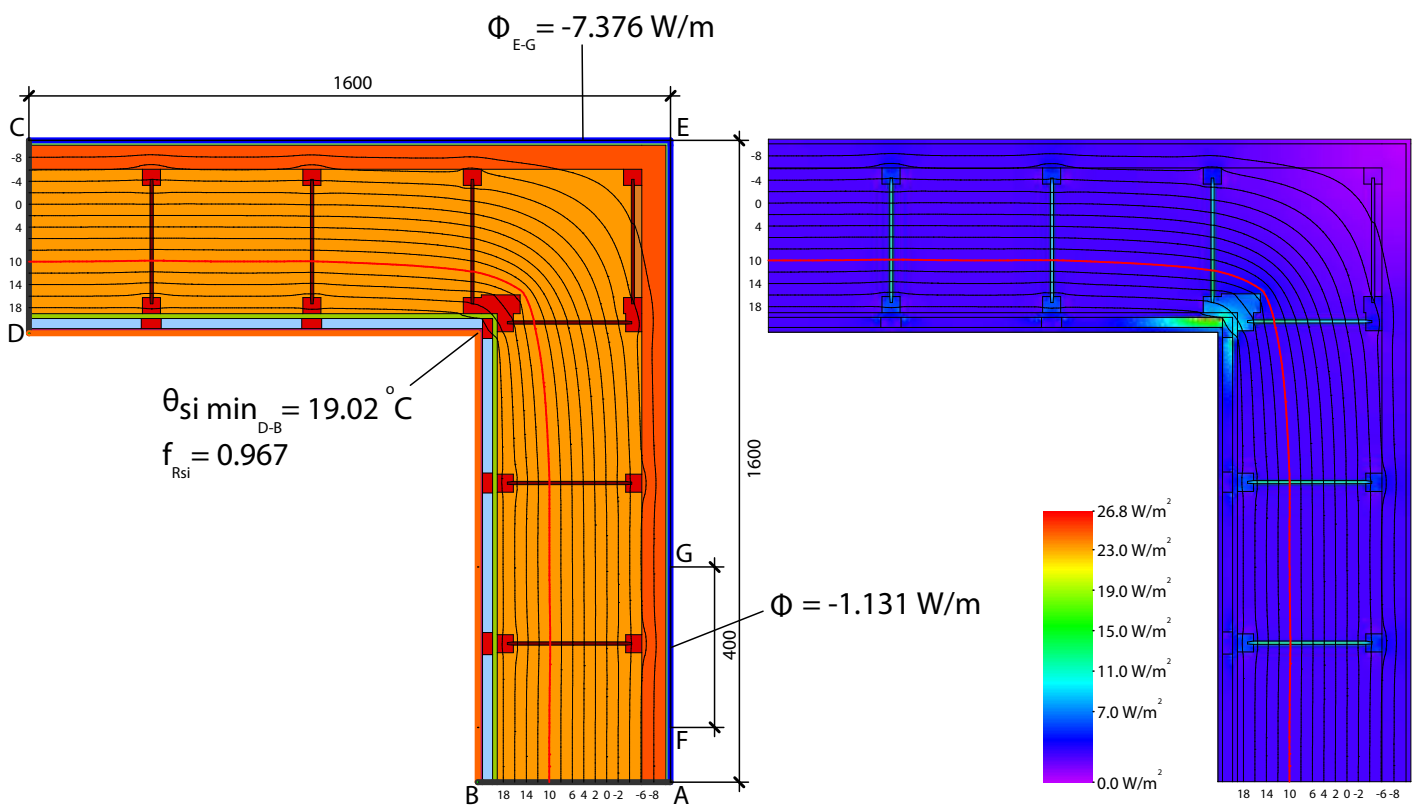
Material	λ [W/(m·K)]	Boundary Condition	q[W/m ²]	θ[°C]	R[(m ² ·K)/W]
Durelis 740 kg/m ³	0.130	Exterior, normal	0.000	0.000	0.040
Fermacell A2	0.320	Interior, heat flux, upwards	20.000	20.000	0.100
Fibreboard 900kg/m ³	0.140	Interior, normal, horizontal	20.000	20.000	0.130
Gypsum plasterboard	0.250	Adiabatic/Model section	0.000		
Plaster, lime, sand	0.800				
Rockwool A1/Timber	0.045				
STEICO DuoDry	0.043				
STEICO Zell/Flange	0.045				
STEICO flex036	0.036				
Timber 500 kg/m ³ (softwoods)	0.130				
Unventilated air cavity*					

*Simplified approach

Consider EN ISO 10211 requirements: YES
Min. element angle: 20
Min. element size: 1/70
Mesh refinement: 0
Method: relative error AND relative heat flow error
Max. rel. error: 1e-30
max. heat flow error: 0.0001
Max. relative changes (material properties): 20%
Max. nr. iterations (material properties): 1

$$\psi_{A-E-C} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{10.277}{30.0} - 0.1 \cdot 1.6 - 0.1 \cdot 1.6 = \mathbf{0.021 \text{ W/(m} \cdot \text{K)}}$$

TB08 EXTERNAL CORNER



$$U_{eq \text{ F-G}} = \frac{1.131}{30.0 \cdot 0.4} = 0.0943 \text{ W}/(\text{m}^2 \cdot \text{K})$$

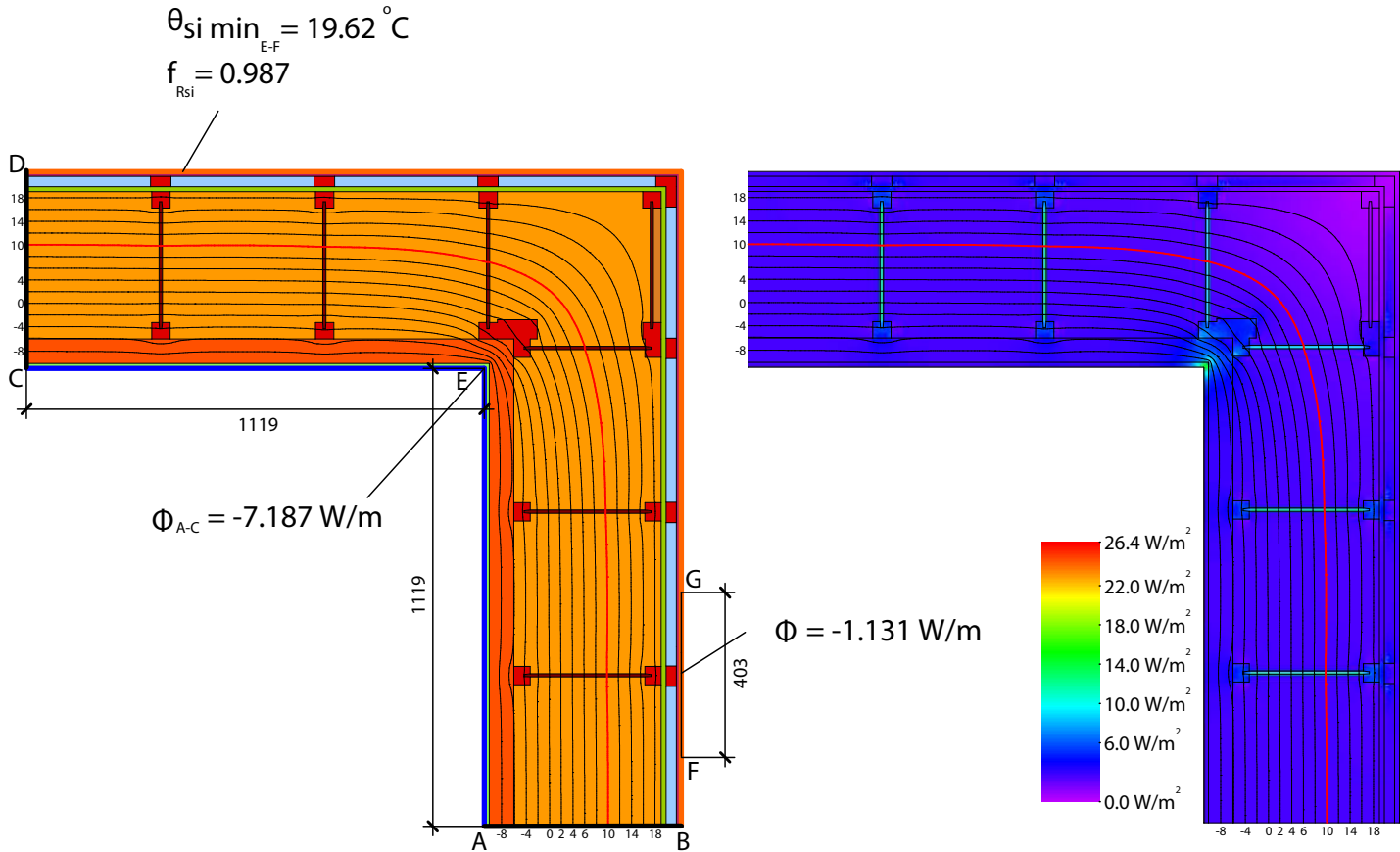
Material	λ [W/(m·K)]	Boundary Condition	q [W/m²]	θ [°C]	R [(m²·K)/W]
Durelis 740 kg/m³	0.130	Exterior, normal	-10.000	0.040	
Fibreboard 900 kg/m³	0.140	Interior, normal, horizontal	20.000	0.130	
Gypsum plasterboard	0.250	Adiabatic/Model section	0.000		
Plaster, lime, sand	0.800				
STEICO DuoDry	0.043				
STEICO flex036	0.036				
STEICO zell	0.038				
Slightly ventilated air cavity*	0.130				
Timber 500 kg/m³ (softwoods)					

*Simplified approach

Consider EN ISO 10211 requirements: YES
Min. element angle: 20
Min. element size: 1/70
Mesh refinement: 0
Method: relative error AND relative heat flow error
Max. rel. error: 1e-30
max. heat flow error: 0.0001
Max. relative changes (material properties): 20%
Max. nr. iterations (material properties): 1

$$\psi_{A-E-C} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - U_2 \cdot b_2 = \frac{7.376}{30.0} - 0.094 \cdot 1.6 - 0.094 \cdot 1.6 = -0.056 \text{ W}/(\text{m} \cdot \text{K})$$

TB09 INTERNAL CORNER



$$U_{eq \text{ F-G}} = \frac{1.136}{30.0 \cdot 0.403} = 0.0940 \text{ W}/(\text{m}^2 \cdot \text{K})$$

Material	λ [W/(m·K)]	Boundary Condition	q [W/m²]	θ [°C]	R [(m²·K)/W]
Durelis 740 kg/m³	0.130	Exterior, normal	-10.000	0.040	
Fibreboard 900 kg/m³	0.140	Interior, normal, horizontal	20.000	0.130	
Gypsum plasterboard	0.250	Adiabatic/Model section	0.000		
Plaster, lime, sand	0.800				
STEICO DuoDry	0.043				
STEICO flex036	0.036				
STEICO zell	0.038				
Slightly ventilated air cavity*	0.130				
Timber 500 kg/m³ (softwoods)					

*Simplified approach

Consider EN ISO 10211 requirements: YES
Min. element angle: 20
Min. element size: 1/70
Mesh refinement: 0
Method: relative error AND relative heat flow error
Max. rel. error: 1e-30
max. heat flow error: 0.0001
Max. relative changes (material properties): 20%
Max. nr. iterations (material properties): 1

$$\psi_{A-E-C} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - U_2 \cdot b_2 = \frac{7.187}{30.0} - 0.094 \cdot 1.119 - 0.094 \cdot 1.119 = 0.029 \text{ W}/(\text{m} \cdot \text{K})$$



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