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Joseph Little Architects

Monkstown Enerphit Extension and Refurbishment

Sets Deep Retrofit Example

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FIGURE 1

view of front elevation after retrofit (2-storey extension is on right side of downpipe)

Deep retrofit is the near future but we've a lot to learn

Unlike new buildings which can be sequenced to maximise thermal continuity, airtightness and speed; the very existence of sub-optimal orientation and constructon methods, old rising walls, intermediate floors, decorative features of a bygone era etc., all complicate the works and impinge upon the performance possible in deep energy-efficient retrofits[1].

It is clear that the *more* that is stripped away of the old fabric, the more 'sins of the past' can become evident and the *more* control is gained (which ensures the standard is met); yet the building becomes less and less an *old building* and, if the issue isn't addressed the associated carbon emissions can rise significantly (albeit alongside a great reduction in energy in use).

Though energy costs are constantly rising they may still be too cheap to prompt enough owners to take the action that is needed to meet national climate change targets, and, provide sufficient security against future fuel prices, under normal market conditions. Highlighting the value gained in comfort, health

[1] Internationally the term *deep retrofit* refers to an energy-efficiency upgrade that achieves dramatic savings on existing use of between 50 to 90%. Use of super insulation (i.e. lower than 0.15 W/m^{2}K) is common. Importantly deep retrofit is often promoted as an integrated approach looking closely at airtightness, summer overheating and ventilation, not just insulation.

and quality now – and greater financial security thereafter – will only galvanise so many private building owners. Governments know deep retrofit is the most sensible approach per building[2] and they know this needs to be implemented everywhere. Philip Sellwood of the UK Energy Saving Trust[3] estimates that one UK dwelling must be retrofitted per minute and the interventions *done right each time* if the UK's 2050 targets are to be met: Ireland must be similar. Yet Irish energy efficiency grants end in 2013 and the Government is following the UK in obliging energy providers to take a central role in this space while encouraging energy users at every scale to get the right works done right. Not an easy task.

FIGURE 2

rear elevation and internal hallway after retrofit

As scale is a great way to make deep retrofit more affordable per square metre the authorities could focus on terraces and districts with building types that allow a collective approach, many in older suburbs and disadvantaged areas. Such work could be used as a key way to massively reduce Ireland's oil dependency, while aiding community resilience and alleviating fuel poverty (a chronic, under-reported condition in Ireland). This is not to mention the value in up-skilling construction workers, increased tax take, encouraging Irish innovation in the sector, etc. An additional challenge is to carry out energy efficiency focused retrofits without losing the character of traditional buildings and the districts or urban blocks they're in[4]. All in all it is clear that deep retrofit (to EnerPHit standard or equivalent) throws up a host of issues. To understand and start to resolve these we need built examples.

Ireland's first certified EnerPHit

A 1950s semi-D in Monkstown, Co. Dublin (111 m^2), which was recently retrofitted to the EnerPHit standard and extended (48 m^2) to the Passive house standard, is a good example of the issues at the centre of deep retrofitting to a clear standard. The architects were the writer's own practice, Joseph Little Architects. The building has just been certified Ireland's first and the world's fifth EnerPHit standard project. The house's owner Pauline Conway first approached us because we were the first practice to be accepted into ÉASCA. She wanted partners in a plan to make her house an educational tool and an example of genuinely sustainable retrofit. The project started on site in April 2011.

[2] Shallow energy-efficient retrofits are problematic in that earlier measures may prevent, or may have to be stripped-out to facilitate, later measures – a more expensive and inefficient approach long term. If the EU's building stock is to be made 'nearly climate neutral' by 2050 yet the building fabric of most buildings is only retrofitted once every 30-40 years it is clear that all energy-efficient retrofits undertaken now should meet the targets and compensate for those buildings that won't or can't.

[3] *The Retrofit Challenge: Delivering Low Carbon Buildings*, from Centre for Low Carbon Future and Energy Saving Trust, 2011. Available at http://www.energysavingtrust.org.uk.

[4] Several EU-funded projects have focused on exactly this, e.g. 3Encult, Susref and Refurban.

While we knew that achieving this standard would set an important example of energy conservation for ordinary semi-detached houses we also wanted to promote healthy ventilation, water conservation and low carbon forms of construction: we strongly believe energy should not be pursued in isolation. Pauline grew up in a remote part of rural Ireland: "until the age of eight years I lived in a house without piped water, where we had to carry buckets of drinking water from a nearby stream and harvest rainwater for laundry". She grew up with a keen sense of the importance of natural resources. Later she spent 13 years working in African countries. In Ethiopia she saw at first hand the horrific impact of recurrent droughts which are increasing in frequency due to climate change, largely caused by developed countries. She wanted her home to be an example of genuine sustainability.

The side bar (of original article – see base of this document) gives the buildups and performance values. An extended version of this article is downloadable on our website (www.josephlittlearchitects.com). Our aim was that from the street the retrofitted, extended semi-detached house would continue to fit into its suburban context, while small elements such as the juliette balcony and anodised rainwater goods would suggest that something special was within. The rear extension is more clearly different as it orientates exactly to south then curves away to frame a dining table within and a deck without.

Sunpipes, rooflights, windows extended downwards to become patio doors, a glass screen between hall and kitchen and an open riser stairs with glass balustrade all contribute to even light distribution throughout the house. All services are clustered in the extension, simplifying services runs. A solar panel faces south west on rear roof. A Paul HRV unit provides ventilation and a small modulating gas boiler provides any additional heat needed.

Before and after, values, monitoring

Given the project's aspirations we established a baseline with a before BER, an airtightness test and thermographic study. Architect Helena McElmeel is carrying out a study pre- and post-works (as part of the RIAI 3Twenty 10 research project). Despite 10,000s of published BERs there is extraordinarily little known about how Ireland's dwellings *actually* perform and are *actually* used after retrofit. Her study will be published at a later date.

We established that the initial airtightness of the house was 5.6 ACH@50Pa. While this seems an amazing value for an old house, values close to this may be more common than realised for older buildings that were well built and have not been interfered with - even if there isn't a shred of insulation[5]. The AVASH study[6] of thirty-two social housing dwellings in Leinster established an average airtightness for the existing, untouched housing stock it studied (mostly from '50 – '60s) of 7.98 ACH@50Pa while those that had been retrofitted averaged an appalling 13.3. Heat is lost quicker through gaps and cracks than in conduction through insulation, especially in windy countries like Ireland, so it is very important that baseline conditions are understood and improved upon in retrofit work.

Low carbon and timber

A key low carbon approach in the project was using wood-based products when possible. Using wood in construction ensures that carbon captured through photosynthesis (becoming the very *stuff* of trees) remains bound-up: it's also a great insulant. We love the fact that cellulose insulation *was* newspapers which *had been* trees: well-read material saved from burning and landfill!

We used 220mm FSC-certified timber studs for the extension's walls, clad internally with 18mm OSB3 as a racking board and airtightness barrier, and slabbed externally with 80mm thick Diffutherm woodfibre external wall insulation. We then blew cellulose into the resulting cassettes between[7]. The flat roof was similar except that Gutex woodfibre slabs were used over joists. The main cold roof buildup

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[5] The air barrier of the semi-detached house is mostly the original wet plaster. The attic had been very carefully-insulated in the mid-80s (with now mostly collapsed mineral wool) and had been carefully re-glazed more recently. Surprisingly, for the airtightness value achieved, the timber floors were suspended: presumably the underlay was thick and dust-filled!

[6] AVASH stands for *Advanced Ventilation Approaches for Social Housing*. DW EcoCo were the Irish partners of the three country project that ended in 2008. Papers can be found at *www.brighton.ac.uk/avash/*

[7] This is very different to the poor practice of slabbing EPS insulation outside timber frame which has caused failures in Canada and Sweden. The BBA-approved Diffutherm system for timber frame has been extensively tested and simulated for use throughout the UK. We believe this is the first time it's been used in Ireland.

featured 400mm of cellulose. In all 56 m^3 of cellulose and 11 m^3 of woodfibre were used.

Higher embodied energy - low carbon response

Before adopting EnerPHit we had intended to insulate under the suspended timber floor in the usual retrofit manner. In moving to EnerPHit we realised that the resulting U-values would not be good enough. In any case as the insulation depth increased beyond the joist depth the repeat thermal bridges would get worse. Instead we stripped out the joists and tassel walls, laid a radon barrier on the original subfloor and built up 300mm of EPS300, then poured 150mm of concrete with 70% GGBS (i.e. Ecocem) cement mix on top. This gave us a retrofit floor U-value of 0.11 W/m^{2}K.

Clearly the thermal performance and ability to control quality greatly increased, however we knew that the amount of floor and sub-floor materials items going to landfill also increased because of this decision: we knew the use of low carbon concrete, woodfibre and recycled products would be in our favour but it is striking to see in Figure 3 that the EPS300 slab insulation had a far greater carbon impact than expected. Its higher density results in greater amounts of EPS and therefore embodied carbon: we would like to see if there are lower carbon alternatives in future projects. The embodied carbon of the uPVC window frames are also worthy of note.

Figure 1 should only be considered a rough, incomplete estimate of associated CO_2 (eq.) emissions: the impact of the timber frame, membranes, renders and finishes, for example, are omitted. We deliberately show a few alternatives (such as mineral wool in the attic or brick rainscreen) to illustrate how a low carbon focus and specification can allow an equal or better performance. We look forward to the publication of SEAI's 'Embodied Energy and Carbon Measurement Methodology and Database' in 2013 which should make this kind of analysis, and resulting low carbon-focused specification, more common and more Ireland specific.

FIGURE 3

embodied carbon in materials used[8]

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[8] Green bars show materials used, red bars show materials and emissions avoided. Concrete values came from Ecocem Ireland Ltd, woodfibre values came from Natural Building Technologies. All other values taken from *Ökobilanzdaten im Baubereich 2009/1* jointly researched and published in Switzerland by KBOB, Eco Bau and IPB: www.kbob.ch

The steel column – a key point thermal bridge

A key technical issue that had to be resolved was how to bring the load of the rear corner of the upstairs of the house to ground in a 'thermal bridge free' way[9] once the ground floor walls were removed to make way for an open plan space below. Figure 4 shows the column, the wall its supporting above and the footing below. It also shows how the line of thermal continuity and water management are separated at the roof-light, minimising thermal bridging and air-tightness issues there.

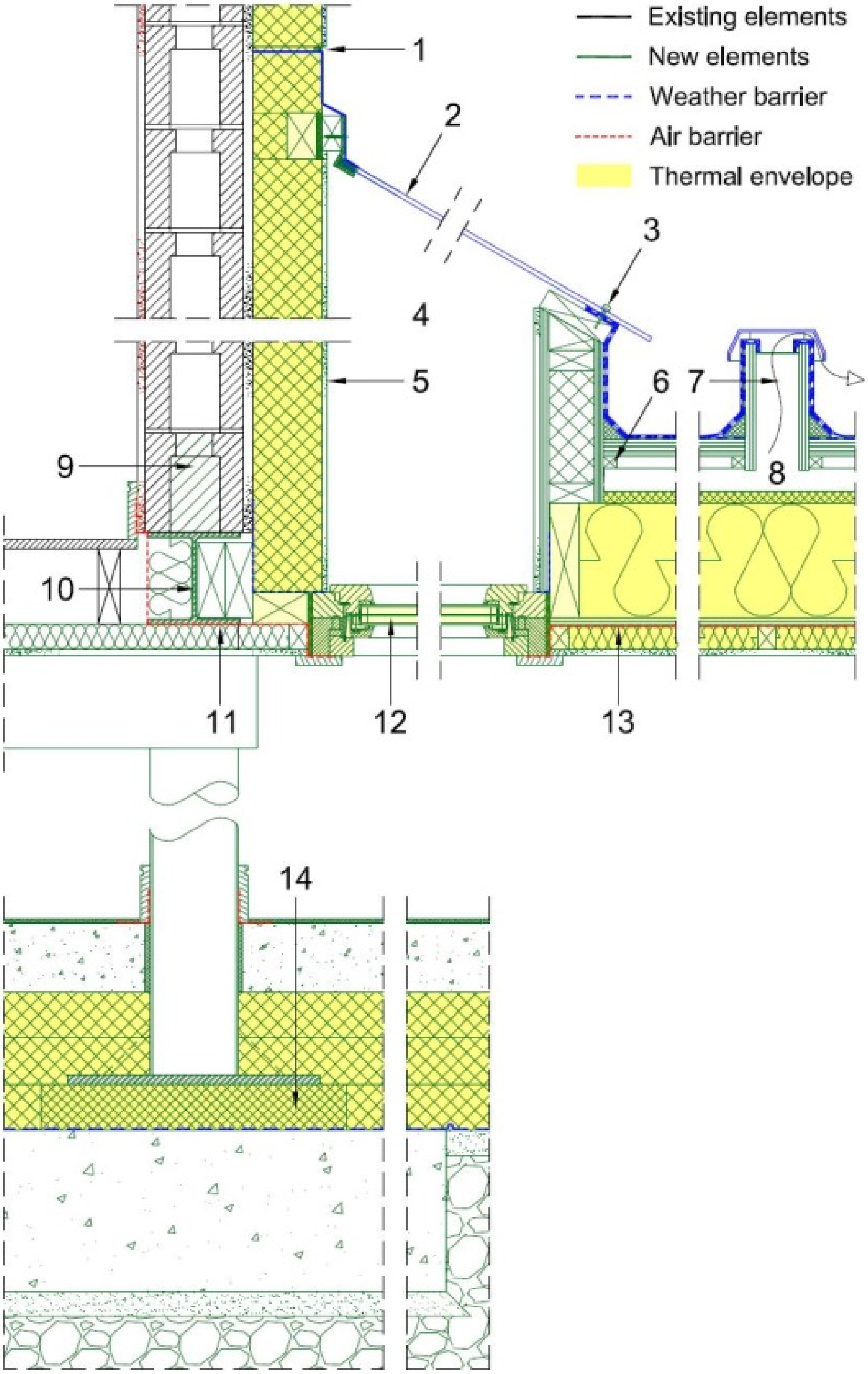

FIGURE 4

Detail showing how the upper floor of house is supported and differentiation of weather barrier and insulation continuity at the roof-light

We worked closely with engineers Malone O'Regan to arrive at a final solution featuring an unusually large base plate that transferred a uniformly distributed load of the column onto a 100mm Perinsul Foamglas layer onto a

[9] As the Passivhaus Institute, in common with many states in Europe, measure buildings from the outside a junction that they consider 'thermal bridge free' (i.e. <0.01 W/mK) may have a higher value when measured from the inside as per UK and Irish regulatory standards.

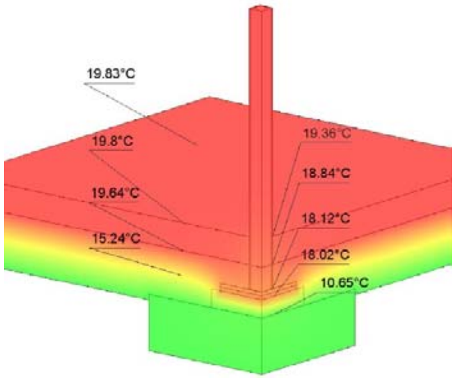

FIGURE 5

point thermal bridge analysis of column base plate. χ-value = 0.041 W/K
Note: air temp 20°C, ambient ground 10°C

concrete pad. Figure 5 shows an output from a point thermal bridge evaluation using the newly translated Psi-Therm software. Note the temperature at the junction of floor and column (19.36 °C) is only 0.5 K cooler than the floor elsewhere.

Managing airtightness & delivering quality

In this project Joseph Little Architects ensured only builders that had already built below 2.5 ACH@50Pa could tender. We provided a detailed airtightness specification, clear red-lined drawings and toolbox talks with technical support from Ecological Building Systems. Prime cost sums were allowed against each of three tests: one just after the air barrier had been formed (but before first fix), the second after second fix and the third before practical completion was certified. Signing the latter certificate was contingent on the builder meeting the design values.

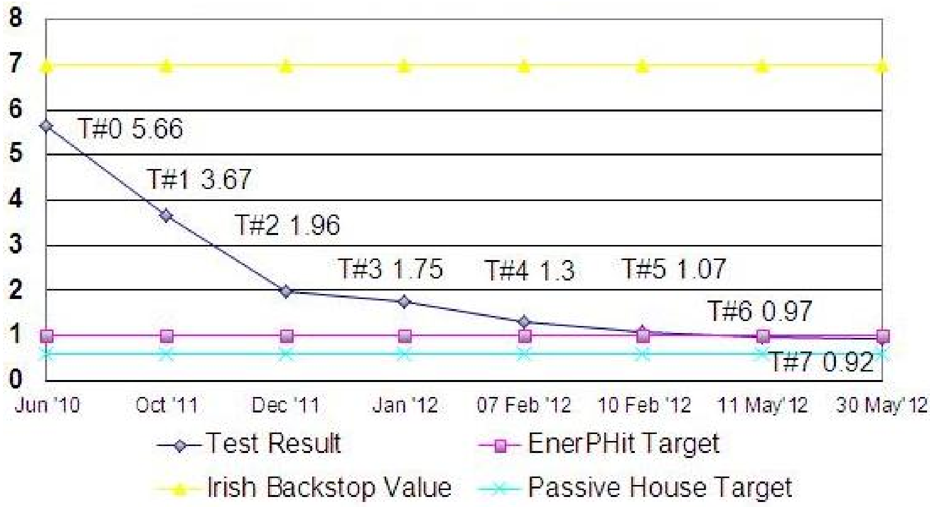

FIGURE 6
the progress of airtightness tests

Because the focus on air-tightness was consistent and clear, and because the builder was facilitated and supported to reach the value through the support material and process created, there was little 'wriggle room' allowed. It's critical a builder understands this beforehand, prices soberly and puts his 'A' team forward. Design teams and clients need to judge this equally soberly and recognise that skilled teams and great care on site don't come with 'bargain basement' tender prices. Perhaps knowing a project *must* reach the EnerPHit standard gives all sides support at the critical tendering and contract signing stages too.

We realised early on the 18mm OSB3 boards were failing during tests[10]. To avoid a costly variation to the client if new AVCL membrane and tape were applied to the boards we contacted Remmers, a company that delivers conservation and breathability focused treatments and plasters. They suggested two roll-on coats of Induline ZW-400 might improve the airtightness of the boards. We advised the client and agreed to take a gamble on this approach. Ó Sé was able to prove that this restored the airtightness of the boards.

At the first construction stage airtightness test (3.67 ACH@50Pa) it was clear that Bourke Builders had started to move ahead, slabbing insulated plasterboard at the party wall thermal bridges and first fixing. We instructed them to stop until the design airtightness value was reached. If it's not reached at this stage, when the layers of buildups and number of penetrations are relatively few and easily accessed, *it never will be*: later tests are to ensure the value is *maintained*. There was clearly a learning curve on the specific difficulties of airtightness in retrofits. Diagnostic airtightness tests were crucial in helping us learn where under-performance was

[10] Katholieke Universiteit Leuven has carried out an interesting study on the airtightness of OSB boards from eight different manufacturers. They found that even within the same brand variation in airtightness can occur. It appears that even 18mm OSB3 cannot be trusted to act as an air barrier at these design values.

occurring and Bourkes took the appropriate corrective actions. We graduated from whole house testing to room-by-room testing using our hands, anenometers, and smoke. It was only after the fourth construction stage test (1.3 ACH@50Pa) that we allowed them to proceed to first fix (as there were a few areas where improvements could yet be made unhindered by other works). In the end there were 7 formal tests during the project and many more informal tests by the foreman using a Wincon fan. Bourkes paid for the additional tests. Their commitment to getting it right was central to the team's achievement of EnerPHit certification.

Water conservation

Dual flush toilets, low volume bath and bowls and sprinkler taps feature. We also worked closely with Ollan Herr of Reedbeds Ireland on the rainwater harvesting strategy. The location of tank and specification changed more than once but we were committed to a small gravity-fed tank within the building envelope. Herr is critical of the current vogue of overly large tanks buried in gardens requiring pumping over 2 - 2.5 storeys.

The system at Wynberg Park serves an outside tap and three toilet cisterns only. It's located in an upper press of a walk-in-wardrobe. An outside leaf filter and two fine filters inside ensure the water is fit for purpose. Toilet usage typically comprises ~35% of a person's daily water demand. By focusing on supplying water for this function the size of the tank could be minimised at 450 litres and electrically powered UV filtration could be avoided. By locating the tank below gutter level (but above toilet cistern height) the system could be gravity fed. By having it inside the house the tank requires no insulation. By using a simple water trap the supply is airtight. Finally fail-safe measures ensure the tank never over fills or empties. We liked the simplicity and technical elegance of this approach, of course not everyone has a walk-in wardrobe!

Moving forward

This project contained a range of innovations from timber frame wall system to overall performance specification, to rainwater harvesting approach. There was lots of learning - some through mistakes. The team got a number of things, such as meeting the EnerPHit standard, right *and can prove it*. That itself is a great message for building in Ireland.

The construction industry needs many more example cases of deep retrofit to a clear standard. All relevant bodies need to actively explore the challenges of deep retrofit and community scale retrofits, and then engage with others in transforming the construction industry. If we are serious about the 2020 and 2050 targets, reducing our oil and gas dependency and genuine sustainability, we need to make significant changes in focus, policy, education and building culture in the next two years.

SHORT BIO

Joseph Little is the principal of Joseph Little Architects and of Building Life Consultancy. He is a strong advocate of the use of scientific principles, better evaluation tools and rigour in designing and constructing new build and retrofit. The practice was an early adopter of low energy design principles. The consultancy is the Irish co-operation partner (of the Fraunhofer Institute for Building Physics) for use and development of Wufi software, and the promotion of numerical hygrothermal assessment in Ireland. He provides training courses within the RIAI and in industry. He has written and lectured on a wide range of construction, retrofit and evaluation issues in the UK and Ireland.

Project overview

Building type

1960s semi-detached dwelling. EnerPHit retrofit to existing and passive house extension to side and rear.

Location

Wynberg Park, Monkstown, Co Dublin

Completion date: April 2012

Budget: €270k

EnerPHit certification: first certified on the island of Ireland, fifth in the world

BER (DEAP)

Before: G (494.88 kWh/m^2/yr)

After: A3 (51.19 kWh/m^2/yr)

89.7% reduction in energy value

Space heating demand (PHPP)

Before: n/a

After: 17 kWh/m^2/yr

Heat load (PHPP)

Before: n/a

After: 12 W/m^2

Primary energy demand (PHPP)

Before: n/a

After: 109 kWh/m2/yr

Airtightness (at 50 Pascals)

Before: 5.66 ACH

After: 0.93 ACH

Walls

Original walls: Rendered 215mm concrete hollow block wall. On ground floor (front elevation only) uninsulated cavity wall with exposed brick. All internally plastered. Average U-value: 2.40 W/m^2K

Retrofitted walls: Mineral render finish on 150mm Baumit Platinum EPS EWI on existing. On front ground floor cut-down brick slips to match existing brick over EWI & cavity filled with platinum bonded blown bead. Renovated and extended existing wet plaster finish used as main air barrier. In rooms adjoining party wall 50mm insulated plasterboard IWI used additionally to minimise thermal bridging. Average U-value: 0.13 W/m^2K

Extension walls: External render, on 80mm Diffutherm woodfibre EWI with mineral render, on 220mm open panel timber frame filled with cellulose, on 18mm OSB-3 board, on 50mm Thermafleece PB20 sheepswool service cavity, on plasterboard. Taped OSB-3 used as main AVCL. U-value: 0.12 W/m^2K

Roof

Original roof: Pitched cold roof with 100mm mineral wool insulation between joists. U-value: 0.40 W/m^2K

Retrofitted roof: 350mm cellulose blown between and over joists, on Intello membrane AVCL, on plasterboard. U-value: 0.10 W/m^2K

Extension pitched roof: Pitched roof as per retrofitted roof.

Extension flat roof: Double butyl membrane on double layer of marine plywood, on 50mm ventilated air gap, on Solitex membrane, on 24mm Gutex woodfibre sheathing board, on 250mm timber joists filled with cellulose, on 18mm OSB-3 board, on Intello membrane AVCL, on 50mm insulated service cavity, on plasterboard. U-value: 0.13 W/m^2K

Ground floor

Original floor: Uninsulated suspended timber floor over ventilated undercroft with tassel walls and sub-slab

Retrofitted floor: Existing sub-slab under 300mm Aerobord EPS-300, under 150mm concrete slab with 70% GGBS. U-value: 0.11 W/m^2K

Extension floor: Clause 804 aggregate with radon sumps under, radon barrier under, 400mm Aerobord EPS-300, under 150mm concrete slab. U-value: 0.08 W/m^{2}K

Windows & doors

Original: double-glazed, air-filled PVC windows and doors to most of house. U-value: ~ 2.80 W/m^{2}K

New triple-glazed windows and doors: Munster Joinery triple-glazed Future Proof uPVC sash windows (not Passivhaus certified). U-value: 0.80 W/m^{2}K

Roof windows: Velux GGL/GGU thermally broken triple glazed roof windows with thermally broken timber frames. U-value: 1.9 W/m2K

Space heating system

Before: 20 year old oil boiler (est. efficiency 70%) serving radiators in every room and 2 open fires.

After: The primary heating involves post-heating the HRV supply air. A 12kW modulating gas boiler providing back-up heat to a network of 3 small radiators, and 2 towel radiators zoned separately due to daily use.

Hot water

Before: Oil boiler (see above) and 110L partially-insulated copper cylinder

After: a 3.2m^2 Kingspan Thermomax HP 200 3M2 evacuated tube array on main rear roof facing south-west supplies hot water to a 300L 100mm factory-insulated cylinder (with triple coil allowing additional future heat source). 12kW modulating gas boiler supplies shortfall.

Ventilation

Before: rapid ventilation supplied by windows, no trickle vents, extract via pull chord unit in kitchen and chimney in living room

After: Paul Novus 300 VL (Passivhaus certified) HRV system, with recovery rate of 92.4% as installed. Primary air ducts are limited to 0.5m long with 100mm insulation.

Selected project details

Architect: Joseph Little Architects (JLA)

Passive house consultant & BER assessor: Ann-Marie Fallon in JLA

Civil / structural engineers: Malone O'Regan

Quantity surveyors: Walsh Associates

Main contractor: Bourke Builders Ltd

Airtightness tester: Greenbuild (NSAI certified)

GGBS cement: Ecocem Ireland

EPS300: Kingspan Aerobord

Foamglas: Thermal Insulation Distributors Ltd (TIDL)

Timber frame: Bourke Builders

OSB-3 board: Coillte

Breathable sealing coat for OSB-3: Remmers

Blown cellulose: Ecological Building Systems

Cellulose installation: Clioma House (Roman Szypura)

EPS external wall insulation: CPI (then Heiton Buckley)

Diffutherm external wall insulation: Natural Building Technologies (NBT)

Brick slips: Ibstock Brick (Ireland)

Windows & doors: Munster Joinery

Airtightness products: Ecological Building Systems

Gutex woodfibre insulation: Ecological Building Systems

Roof windows: Velux

Sun pipes: Fakro

Solar thermal supplier: Kingspan Renewables

Heat recovery ventilation: Pure Renewable Energy

Rainwater harvesting: Reedbeds Ireland

Flow Limiters: Armitage Shanks

Water conserving sanitaryware: Sandringham Fittings