ZETLAND PASSIVE HOUSE

ecospheric

6 & 8 ZETLAND ROAD

Manchester

Construction:	Timber frame/ masonry
Completion:	03/2019
Occupied since:	No.6 03/2019 & No. 8 12/2020
Certification Date:	11/2018
Gross External Area:	484m^2
Treated Floor Area:	374 m^2
Form Factor Ratio:	2.17
Heat Source(s):	2kW electric post heater on Paul Novus 300 MVHR (per dwelling) (surplus to PHPP requirements - 5kW DiBT accredited wood burning stove for backup).

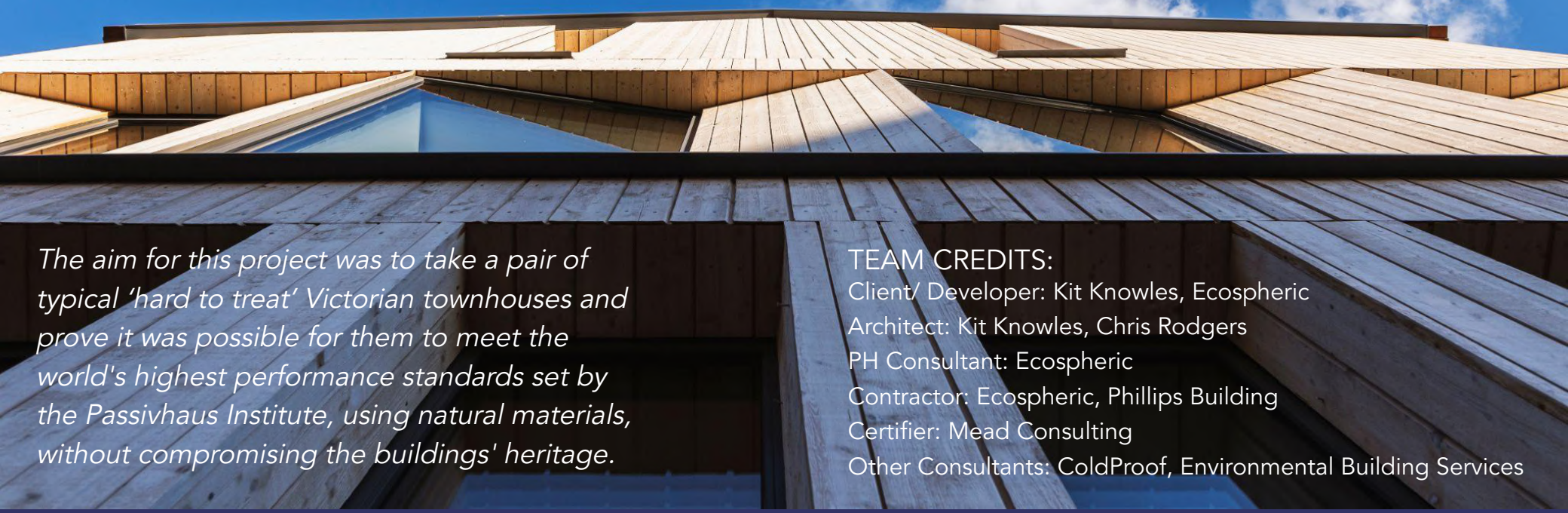
Primary Energy (PER) Generation:
(55 kWh/m^2/a)

Primary Energy (PER) Demand:
(43 kWh/m^2/a)

Heating Demand:
(12 kWh/m^2/a)

Heating Load:
(11 W/m^2)

Air Changes/Hr:
(0.86ach @50pascals)



The aim for this project was to take a pair of typical 'hard to treat' Victorian townhouses and prove it was possible for them to meet the world's highest performance standards set by the Passivhaus Institute, using natural materials, without compromising the buildings' heritage.

TEAM CREDITS:
Client/ Developer: Kit Knowles, Ecospheric
Architect: Kit Knowles, Chris Rodgers
PH Consultant: Ecospheric
Contractor: Ecospheric, Phillips Building
Certifier: Mead Consulting
Other Consultants: ColdProof, Environmental Building Services

PROJECT OVERVIEW

Year of construction:	1894	Interior temperature winter [°C]:	20.0	Interior temp. summer [°C]:	25.0
No. of dwelling units:	2	Internal heat gains (IHG) heating case [W/m²]:	2.4	IHG cooling case [W/m²]:	2.4
No. of occupants:	6.1	Specific capacity [Wh/K per m² TFA]:	204	Mechanical cooling:	

Specific building characteristics with reference to the treated floor area

					Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area	m²	374.3				
Space heating	Heating demand	kWh/(m²a)	12	≤	15	-	yes
	Heating load	W/m²	10	≤	-	10	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-	≤	-	-	-
	Cooling load	W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C)	%	0	≤	10		yes
	Frequency of excessively high humidity (> 12 g/kg)	%	0	≤	20		yes
Airtightness	Pressurization test result n_{50}	1/h	0.6	≤	0.6		yes
Moisture protection							
	Smallest temperature factor $f_{Rsi=0.25\ m²K/W}$	-	-	≥	0.70		-
Thermal Comfort	All requirements fulfilled?	-			yes		yes
	U-value	W/(m²K)		≤	1.19		
	U-value	W/(m²K)		≤	1.42		
	U-value	W/(m²K)		≤	1.55		
	U-value	W/(m²K)		≤	0.65		
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	100	≤	-		-
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	42	≤	45	42	yes
	Generation of renewable energy (in relation to projected building footprint area)	kWh/(m²a)	53	≥	60	53	

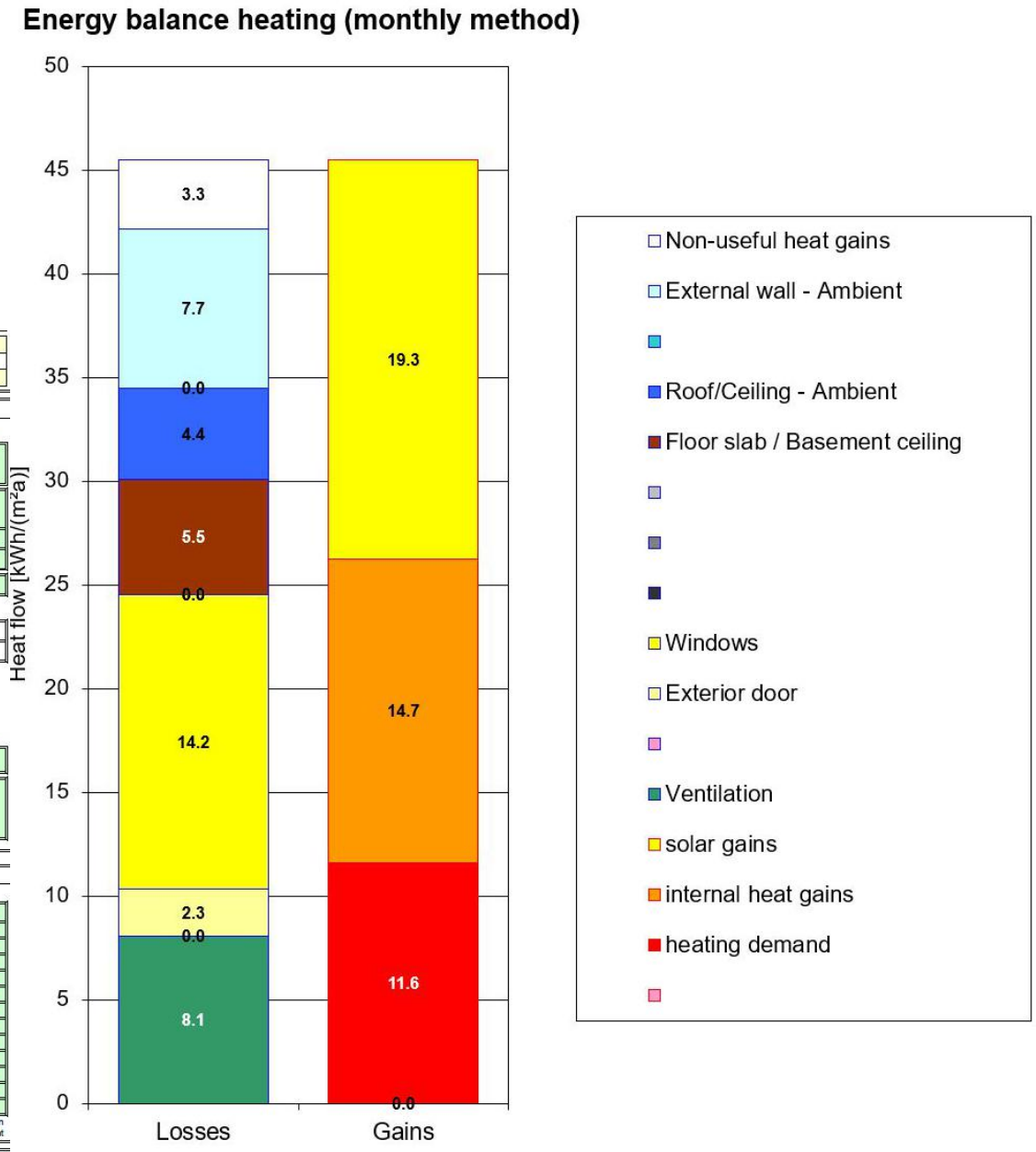
EnerPHit (retrofit): Component characteristics

Building envelope to exterior air[1] (U-value)	W/(m²K)	0.15	≤	-
Building envelope to ground[1] (U-value)	W/(m²K)	0.16	≤	-
Wall w/int. insulation in contact w/exterior air (U-value)	W/(m²K)	0.17	≤	-
Wall w/interior insulation in contact w/ground (U-value)	W/(m²K)	-	≤	-
Flat roof (SRI)	-	-	≥	-
Inclined and vertical external surface (SRI)	-	33	≥	-
Windows/Entrance doors ($U_{W/D,installed}$)	W/(m²K)	0.77	≤	-
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	-
Windows ($U_{W,installed}$)	W/(m²K)	1.10	≤	-
Glazing (g-value)	-	0.51	≥	-
Glazing/sun protection (max. solar load)	kWh/(m²a)	199	≤	-
Ventilation (effective heat recovery efficiency)	%	91	≥	-
Ventilation (humidity recovery efficiency)	%	0	≥	-

[1] Without windows, doors and external walls with interior insulation
[2] Empty field: Data missing; "-": No requirement

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

Passive House Plus? yes

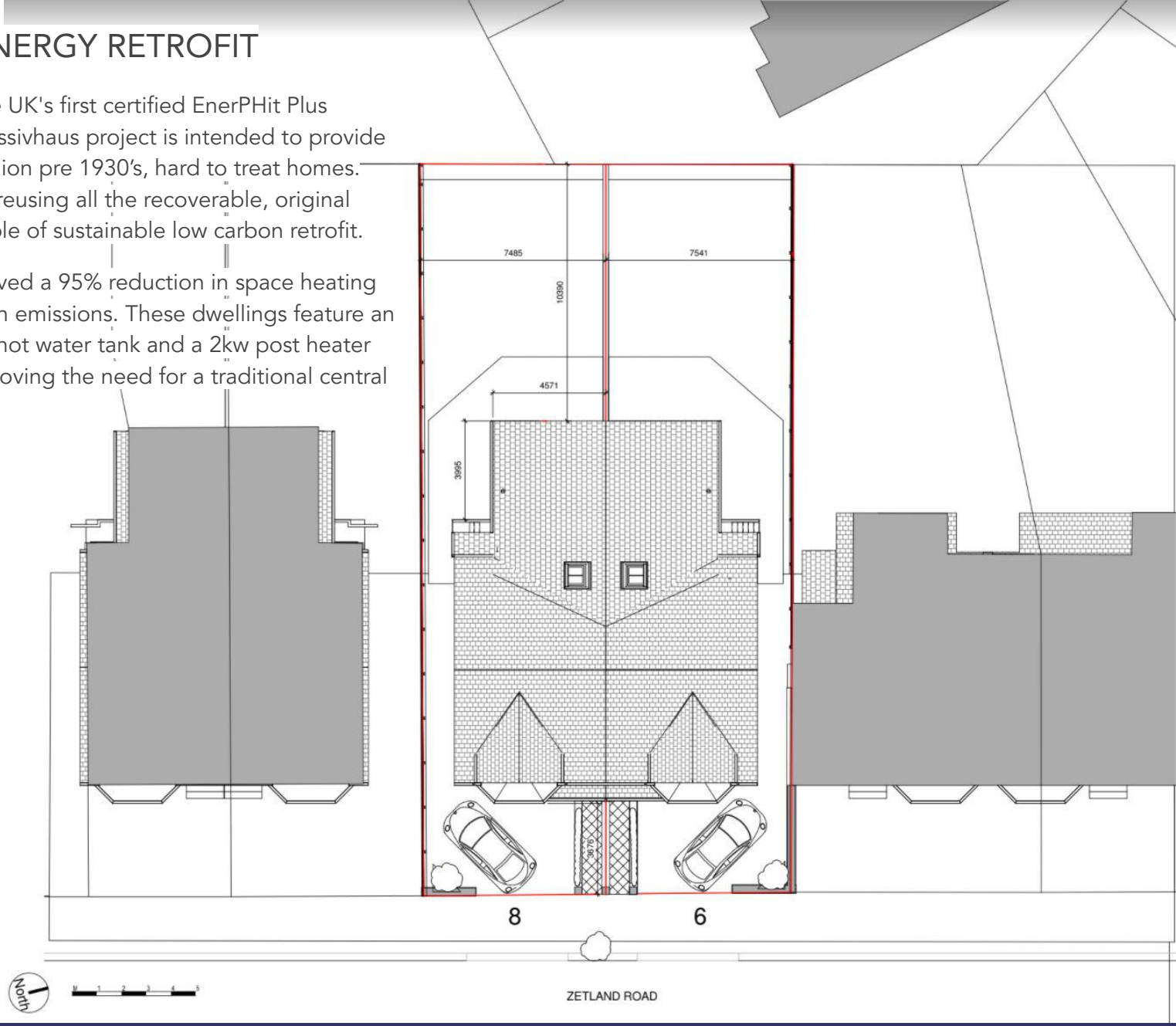


PHPP VERIFICATION AND ENERGY BALANCE SHEET

A BLUEPRINT FOR LOW ENERGY RETROFIT

The Zetland Passive House project is the UK's first certified EnerPHit Plus building. Originally built in 1894, this Passivhaus project is intended to provide a blueprint for retrofitting the UK's 8 million pre 1930's, hard to treat homes. Using natural, breathable materials and reusing all the recoverable, original fabric, the project is a pioneering example of sustainable low carbon retrofit.

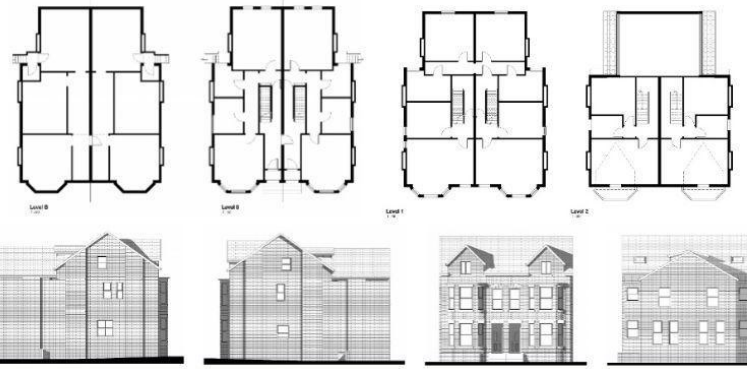
These semi-detached townhouses achieved a 95% reduction in space heating demand and a 7-fold reduction in carbon emissions. These dwellings feature an 11kW PV system powering an AI driven hot water tank and a 2kw post heater piggybacking on the MVHR system, removing the need for a traditional central heating system.



DESIGN PHILOSOPHY & SITE PLAN

From HMO's to Passivhaus

Passivhaus Enerphit Plus Homes



Existing

'Marrying the beauty and character of a Victorian period property with the world's highest standards of energy efficiency'

The vision

ARCHITECTURAL DESIGN & AESTHETICS

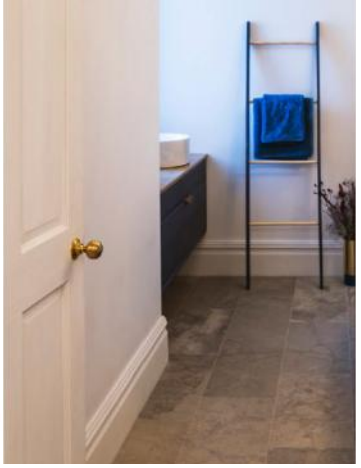






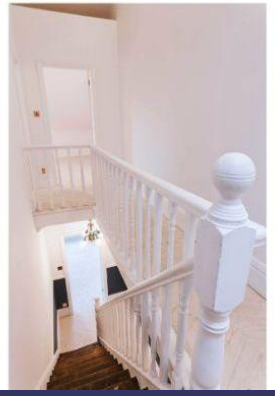
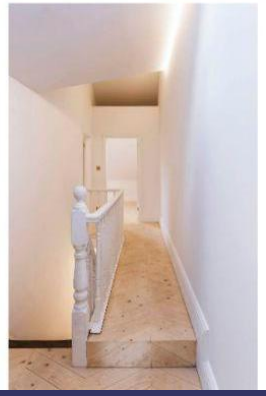
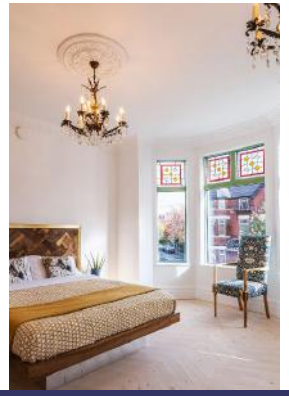



ARCHITECTURAL DESIGN & AESTHETICS

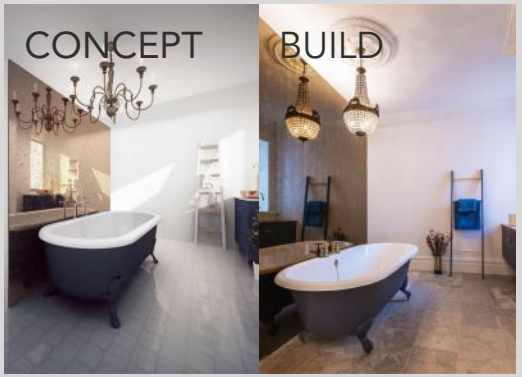




ARCHITECTURAL DESIGN & AESTHETICS

CGI DESIGN TO REALITY



WORKING WITHIN THE EXISTING FOOTPRINT

60% of the UK domestic construction industry services 'modernisation' which typically involves extensions that on average add £125k to a build cost. This often leaves little in the budget for deep retrofit, considerably worsens the form factor of a given building and typically more than doubles the embodied carbon of the project.

Ecospheric was keen to explore an alternative design approach to feed into the Greater Manchester ambitions to utilise localised planning governance to decarbonise the region. With a radical reorganisation of the layout Zetland Road adopts a Tiny House philosophy which utilises the full 3D space to meet the demands of modern family living whilst avoiding the need for an extension. With the money saved on an extension, Passivhaus Certification could be afforded.

ARCHITECTURAL DESIGN & AESTHETICS

No. Occupants:
3.05 per house

Overheating/ year: 0% now & against future climate models

Glazing as % of TFA: 15.5%

DESIGN STRATEGY

The design does not rely on window opening, external louvres or active cooling. Not easy to achieve in retrofit with a predefined massing and orientation.

Key design elements to make this possible.

1) 200 tonnes of brick bought into the thermal envelope to regulate temperature fluctuations
2) Windows on the first floor rear facade were angled within external insulation thickness to increase solar gains earlier in the day
3) Glazing staged carefully across three floors to maintain stable temperatures whilst maximising solar gains potential. The anti-stratification approach places the greatest potential for solar gains lower in the building to counteract heat rising naturally within.
4) Internal glazing used to compensate for smaller glazed units on the top floor improves natural light.

Looking forward to increasingly unpredictable climates and to enable greater flexibility in lifestyle (e.g parties), the following contingency was also designed in.

- Very effective vertical through draft ventilation can be achieved by opening the cellar door at the bottom of the stairwell and the rooflight at the top of the second floor stairwell.
- The same rooflight (with temperature and rain sensor) also has the ability to be programmed to autovent if the internal temperature ever exceeded 25°C.
- Insulated ductwork installed ready for 'piggyback' air conditioning unit
- Dibt Wood Burning stove (very useful in getting property up to temperature post construction ready for occupation).

SUMMER COMFORT & VENTILATION

ENERGY PERFORMANCE DATA

The Zetland Passive House contains two semi-detached homes No.6 on the North side and No.8 on the South. No.6 was occupied for 18 months whilst No.8 was used as an educational facility, before finally being sold in December last year. The original building form prevented significant party wall U-Value upgrade, this effect combined with the reduced solar gains of a Northerly aspect can be seen in the measured energy demand of No. 6 whilst No.8 was vacant.

	6 Zetland Road	8 Zetland Road	Combined
Date of occupancy	March 2019	December 2020	
Winter comfort	Outside temp: -5°C Inside temp: 16°C without heating	Average temp 19-20.5°C without heating (after initial period of warming up the thermal envelope)	n/a
Summer comfort	Outside temp: Max 32°C (Max daily average 23.5°C) Inside temp: 26-27°C	Not yet been occupied over summer	n/a
Avg. Internal Temp week of April 14-20 2021 (avg. external high: 14.5°C) (avg. external low: 0.5°C)	18°C no heating used (thermostat kept in ground floor utility in middle of house)	21°C no heating used (thermostat kept in 1st floor West-facing room)	n/a
Predicted Annual Energy Demand as calculated in PHPP (kWh/m²(TFA))	32.4	32.4	32.4
Measured Annual Energy Demand (kWh/m² (TFA))	Y1 = 42.2 (30% higher than predicted) Y2 = 36.1 (11% higher than predicted)	Y1 = Unoccupied Y2 = 32.0 (1% lower than predicted) Y2 figure based on extrapolation from incomplete data as No.8 has only been occupied over the last winter	Y1 = 42.2 (30% higher than predicted) Y2 = 34.0 (5% higher than predicted)
Predicted Annual Energy Generation (kWh)	3446	4863	8329
Measured Annual Energy Generation (kWh) (The PV system had several problems which affected generation for the first 18 months. The figures listed here are based on incomplete data)	2778	5063	7841 (94% of predicted)

Note: As Ecospheric no longer have ownership of the properties we can only access combined energy consumption data, which is not broken down into space heating, DHW, lighting & unregulated energy. As such it is not possible for us to determine how much of the additional energy being consumed vs the PHPP model predictions is attributable to space heating. We do know, for example, that PHPP underestimates the amount of energy consumed by DHW and that everyone has been working from home a lot more in the last 12 months.

PERFORMANCE & USER FEEDBACK

CONSIDERATION OF EMBODIED CARBON

We are working on a research project with The University of Liverpool to calculate the embodied carbon of our project. The aim is to allow us to compare the embodied and operational carbon over an agreed nominal life span for the building (say 60 years) for the following case:

- Retrofit to Part L standards using common building materials
- Retrofit to PH plus standard using standard petrochemical based insulation and gypsum plaster.
- The actual project, retrofit to PH plus standard using natural and low EC materials including lime plaster

This work is still in progress with the aim to complete in June 2021.

POST OCCUPANCY TESTING

Prior to sale, we conducted air quality, wall moisture and true U-Value tests with the help of the University of Salford and Zero Energy's Jesus Menendez, to measure how well our moisture shedding CO2 sequestering building fabric was performing.

We found that our real time U-Value measurements matched our modelled U-values predictions as per PassivHaus Planning Package (PHPP)

Building element	PHPP modelled U-value (W/m²K)	U-value as measured (W/m²K)	% difference
Front brick wall	0.175	0.144	-17.7%
Roof	0.148	0.154	+4.1%

Initially we were concerned about the timing associated with our construction activated moisture (Aw) measurements. The worst time of the year to measure moisture is late winter and we were taking our readings in February. Additionally the external brickwork had not long been lain and the internal lime plaster finished which in typical environments can take upto 12 months to dry. Amazingly our walls came back 30-50% dryer than a typical wall. Zetland Road measured Aw varies from 0.45 - 0.6. A value above 0.7 would warrant further investigation and above 0.8 would be at risk of damage from moisture.

Initial air quality measurements which were taken during decoration (normally the worst time to measure!) were excellent. Measured RH varies from 47% and 59%. Fitting nicely inside the recommended zone for comfort and health. Indoor air was found to have significantly lower particulate matter and CO2 readings when compared to a typical dwelling supporting lime interiors and MVHR make for a winning combination. It was found that 60% of the time it would have been more unhealthy to open a window.

Note: The U-value and Aw were measured shortly after wet trades (lime plaster and mortar) had finished and further improvement is to be expected as the building continues to dry out. The measurements were also taken in Jan-Feb, which is the time of year likely to give the worst Aw results.

We met with Kit and the Ecospheric team and went on a journey ourselves - understanding (as best you can) the process of the build, what it's like to live in a Passive House - and really thinking about how we wanted to live going forward without compromising our lifestyle, behaviour, or our love of traditional architecture. Our biggest fear was how we would live in it, what we would need to do and learn; but the fact is, you don't need to do anything - the house does it all for you. It is warm, comfortable, fresh, and each space in the house offers something unique due to its layout. If anything, the house has changed us rather than us changing for the house. We have become more aware, more considered & more respectful of everything around us.

So here we are, almost a year to the day and the biggest compliment we can give is that it's our home and we love living in it. Our stamp is firmly on it and we often joke about the fact we couldn't go back to a 'traditional house'."

New owner Zetland Road Passivhaus

PERFORMANCE & USER FEEDBACK

THE TRANSITION TO PASSIVHAUS LIVING - COMMENTS FROM HOMEOWNERS

WINS

- Thermal comfort - "We were able to maintain a temperature...in the range [of] 19 - 20.5 deg. C. with the only heating source being intermittent use of the log burner. Once warmed up we found the temperature comfortable throughout winter." - Resident of No. 8
- Ease of use - "Overall, very easy to use the house as there is little that needs 'operating' - one of the reasons for purchasing the house. The fact there is no complex heating system makes life a lot easier as does having only one utility to concern ourselves with. In short, it needs nothing other than an understanding of how it works." - Resident of No. 6
- Air quality - "The indoor air quality is excellent at all times - very impressed with the MVHR operation and filtration." - Resident of No. 8
- Energy bills - "We have reduced our costs by 31% in year 2 as we've become more adept at living with the house and the benefits of having a neighbour, working PV etc." - Resident of No. 6

FRUSTRATIONS

- Solar PV - "What has been most difficult (and continues to be) is the PV. We are still having issues with it and due to the height of the roof, it's very expensive to get it looked at. It's been a costly exercise to get it fixed and we are about 2.5k down in maintenance so far with it which is a real shame." - Resident of No. 6
- Electrics and cabling - "It's very difficult to install cabling through a passive house envelope without compromising it...Recommend the design considers the whole life cycle of the property and allows for future cables to be run into and out of it." - Resident of No. 8

IT'S ALL IN THE DETAIL....

Striving to get a Victorian property to EnerPHit Plus performance levels presented many challenges and required a huge amount of innovation and collaboration with 100+ suppliers (predominantly local), consultants and professionals. Eight world first technologies and methodologies were developed/trialled. The envelope was constructed of 28 different fabric build-ups, joined together with 106 construction details with associated U-values, thermal bridges and moisture profiles calculated.

The world's first Passivhaus stained glass. Based upon a heritage analysis of street vernacular made by Manchester artisans and assembled in Estonia

Hidden in the roof is another world first use of Siga's Majrex intelligent building membrane adopting cactus inspired biomimicry to keep the building fabric dry and airtight.

Twisting the West facing glazing on the first floor further to the south within the construction build up was modelled to show a 15% increase in the amount of solar gains.

Structural timber V & A's for lateral stability in place of steel tio drive down embodied carbon and reduce thermal bridging

IWI system developed to retain the original bay proportions and window apertures of the victorian facade, high enough performance to achieve PH and retain full breathability avoiding petrochemical insulants

Blown cellulose insulation made from recycled newsprint salt treated for fungicide and fire offered very fast and flexible solution with enhancement of both U-Value and airtightness. Great for complex spaces.

Breathable construction details throughout including lime grout and adhesive tiled floors

CONSTRUCTION APPROACH

Thermostatically controlled roof light with rain sensor, connected to a tilt and turn cellar door for automated, rapid, passive cooling potential

Sustainable Urban Drainage (SUDS) featuring recycled tyres and recycled stone aggregate for driveway and building surround greatly reducing potential water ingress to the cellar and provide mild flood resistance for the building

Mixergy 300L unvented hot water tanks with world first stratification technology and cloud based AI assisted control, halves energy consumption. Further, the Ecospheric developed legionella control enables water to be stored at just 43°C!

36 x 330-Watt Panasonic HIT modules over two systems. Tigo voltage optimiser to efficiently manage any shading effects and optimise even Northerly aspect panels. Wiring design optimised for later addition of on-site energy storage or EV charging.

Paul Novus 300 heat recovery ventilation system - 93-94% heat recovery with a specific fan power of just 0.24 Wh/m³

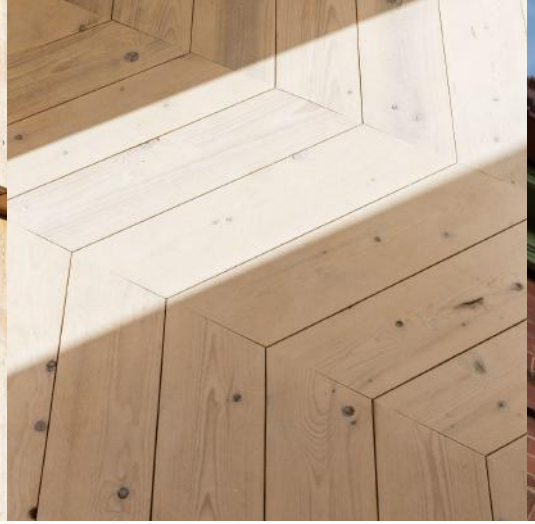
5kW DiBT accredited Log Burning Stove for backup (heat input not included in PHPP calculations).

World first use of graphene enhanced lime paints and plaster replacing typical membrane based approaches to vapour control and airtightness. In addition this wonder material offers leak testing benefits, anti cracking, moisture buffering, anti-microbial and carbon and VOC sequestering properties

Caroma profile 5 grey water recycling toilets as a great space and water saving solution utilising flow restriction and aeration technologies

CONSTRUCTION APPROACH

Articulated cladding is “pre-fossilised”, to resist rot and UV degradation for over 30 years maintenance free



No extension to footprint and reuse of over 200 tonnes of brick the entire existing roof, stairwell and floor structures throughout with repurposed floor boards or in an effort to reduce embodied carbon and reduce landfill.

The copper guttering and downpipes are expected to last over 120 years!

Ionic and alkaline surfaces help prevent the spread of bacteria, virus and fungus.

Insulated sidewall disguised by heritage sensitive, subtle copper coping that blends into the traditional brickwork.

Electromagnetic field-free design using shielded cables and radial spur wiring with LED lighting throughout.

Working with local artisans to dress the property with petrochemical free furnishings and upcycled fittings.

Over-door windows next to a landing roof light spread additional light into the shower room and study enabling further reduced top floor window apertures for anti-stratification overheating prevention strategy

CONSTRUCTION APPROACH

KEY LEARNINGS - SPECIFIC TO PH IN REFURB SETTING

Pigeons and PV

Voltage optimisation is a key technology especially for non ideal arrays (which is almost all!). Don't go cheap though. For years I worked with Solar Edge and for the first time trialled Tigo optimisers. Out of the 36 optimisers installed 30 of them were replaced.

PV panels also make for the perfect pigeon home and as such only the best protection satisfies. 3 times protection was reinstalled as the pesky birds kept finding their way in. In the end we treated it as a chicken run, rigid wire frame solution.

Blown insulation works well

Blowing insulation works fantastically and is great for filling awkward gaps. We purchased a blowing machine as knew we couldn't line all our requirements up for an external contractor especially given the 100 pallets of insulation installed. This worked out to be very cost efficient approach in the end as we could take direct from manufacturer arctic loads and also provided additional function for sound proofing and as a giant hoover!

Keeping a close eye is imperative

You need a PH experienced representative on sites at all time to avoid rework and non performance. Due to the number of unknowns, retrofit projects rarely go exactly to plan and experienced builders are generally excellent at problem solving on the fly. This however can cause issues with PH as often these solutions are not PH compliant! Being constantly accessible to answer questions is critical.

Frequent air testing - dont need result but leak test just to pressurise building. Works fantastically with thermographics

Use the existing building to your advantage

Repurposing chimneys as service voids - smashing out the faces and replacing with simple timber ring beams offered perfect full height conduits for seamless, boxing-less duct integration.

Using the existing brickwork as thermal mass offer distinct advantages over new builds. Other than period charm there are not many advantages when it comes to retrofitting to PH, so grab the ones you can! We have 24 million more to go...

You will need contractors with specialist skills

Lime is a fantastic material and was used on our project in many guises. But it is a specialist skill that is worth some training early doors to ensure a quality finish at a decent pace. In particular some fibrous limes cannot be applied with a standard float method. We also found lime is fantastic for fixing leaks (better than sealant, membranes and tapes)

LESSONS LEARNED

KEY LEARNINGS - SPECIFIC TO PH IN REFURB SETTING

Be prepared for an atypical schedule

When aiming for a high level of airtightness, the order of works on site is far from standard and requires careful scheduling. The airtightness membrane for example is often best done after electrics but before stud walling! Balloon structures are very useful. It is also often tricky to complete involvement of entire trades in order and work programme gets chopped up.

Having multi skilled tradesmen on site and buying second hand or specialist equipment instead of hiring (where possible) provided a critical flexibility.

Always design in a first fix pause and pressure test. Allow 6 days to scan the building with a 360 camera, tagging all snags and assigning responsible parties. Pressurise the space then leak test and fix until the desired result is achieved. This method gets as close as possible to ensuring the only aspect of Passivhaus you can never guarantee...airtightness!

Moisture in the Cellar

When we think of ventilation for cellars or sub floor voids we think of air bricks and cross flow ventilation. However in reality all the air bricks typically allow air to be drawn in and air flow carries this moisture laden vapour stream into the rooms above. In making the floor airtight you cut this flow off. Use Fireplace direct air feeds and humidistat controlled mechanical fans to assist the passive air brick solutions.

LESSONS LEARNED

WHAT MAKES THIS PROJECT UNIQUE

The townhouses succeeded in becoming Europe's first Passivhaus Enerphit Plus homes. Featuring Nobel prize winning super material graphene and a host of world first technologies and unique solutions, the 125 year old properties seamlessly marry the beauty and character of a period property with the world's highest standards of energy efficiency.

From the street the building looks classically Victorian with its decorative path, finials, stone steps and ornate porch. The only hint of the wealth of technology within is a subtle copper strip that blends into the traditional Victorian brickwork to disguise a super-insulated sidewall. Even a world first Passivhaus stained glass solution has been carefully incorporated.

The modernised rear facade consists of slimline glazing units set in Organowood cladding, angled towards the sun to maximise solar gains. This articulated cladding is “pre-fossilised”, resisting rot and UV degradation for 30 years untreated; just one of many examples of extreme durability. The copper guttering and downpipes are expected to last over 120 years!

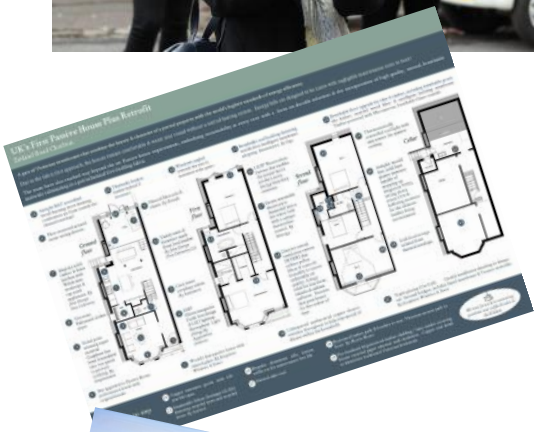
Pushing boundaries and driving technological change is at the heart of this project. Another world first, hidden in the roof, is Siga Majrex intelligent building membrane. Adopting biomimicry, it uses cactus inspired technology to keep the building fabric dry and airtight. The DHW solution halves typical consumption, through the adoption of a sterilisation cycle that drops the temperature set point from 70°C to just 43°C, whilst another world first ‘tank with thermocline control’, halves energy consumption again! The tiny amount of energy required is easily covered by the 11kW PV system.

These exemplar homes are designed to remain comfortable and warm year round without a central heating system, whilst maintaining superb air quality. The team have also exceeded the Passivhaus Institute’s requirements by specifying a petrochemical free building fabric, focusing on natural, breathable materials that avoid harmful off-gassing.

The properties revolutionise occupants’ lifestyles, with wonderfully comfortable and healthy environments wrapped up in Victorian charm. With Zero energy bills and minimal maintenance costs, they can expect to save £50,000 over the first 10 years of ownership (applies BRE’s standard figures for average annualised maintenance costs).

The Zetland Road Passive House project was always intended as a valuable case study to not only inspire others to follow suit but share vital information on how it can be achieved. Pushing for the world's highest standard has led to the creation of hundreds of techniques, details and products that Ecospheric freely share with the construction community.

With national media coverage, the homes have become a talking point, initiating discussion amongst building industry professionals. With over 200 architects, policy makers, developers and RSL’s touring the properties thus far and a further 12 months of open days planned, this project is achieving its goal of influencing and spreading sustainable building practices.



LESSONS LEARNED