passivhaus & retrofit - an introduction

An introduction to Passivhaus and approaches to retrofit

Paul Testa

what makes a sustainable home?

what makes a sustainable home?

Solar panels? Heat pumps? Green roofs? Smart thermostats?

BedZed by Bill Dunster

what makes a sustainable home?

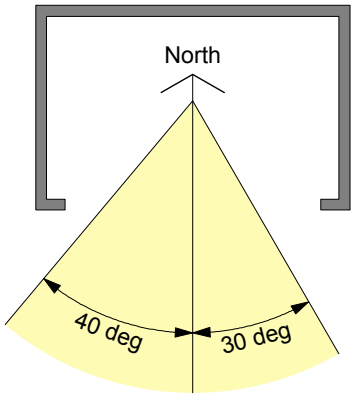
A sustainable home is one that has high comfort combined with low energy use.

This cannot be achieved by green bling alone.

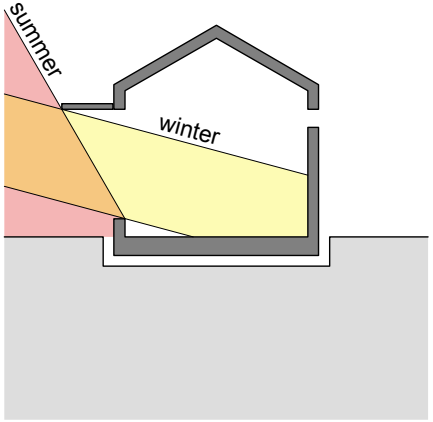
We must design sustainable buildings with a Fabric First approach

Denby Dale Passivhaus by the Green Building Company

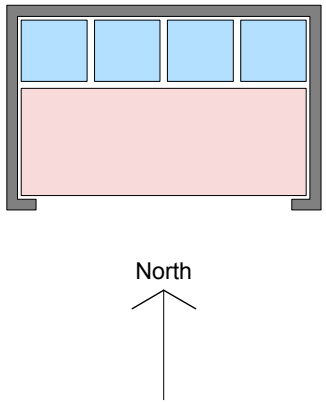
passive strategies for comfort & low energy use



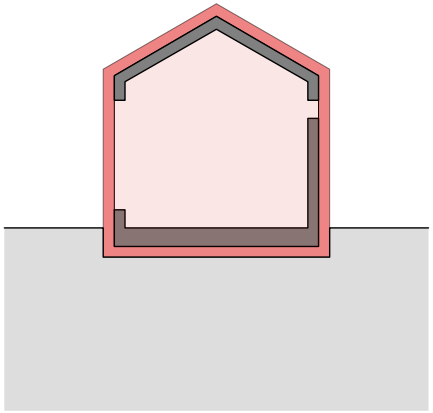
orientation



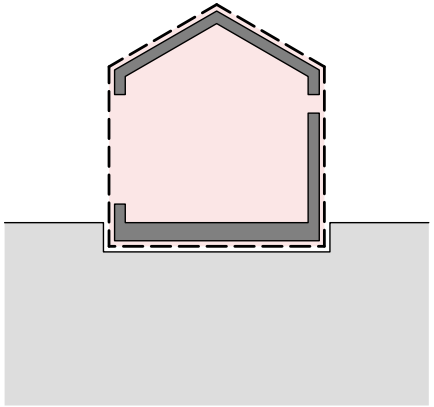
passive solar gain



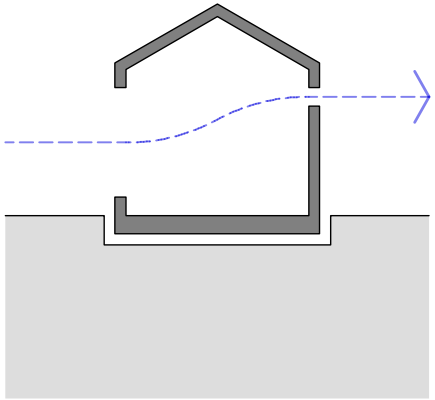
organisation



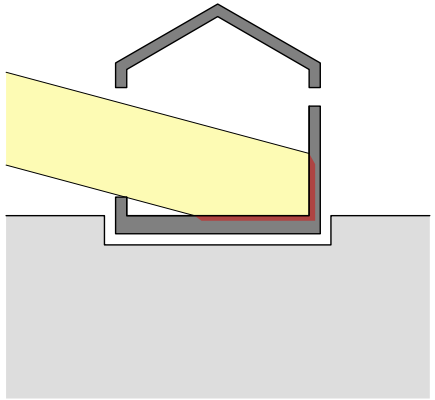
super insulation



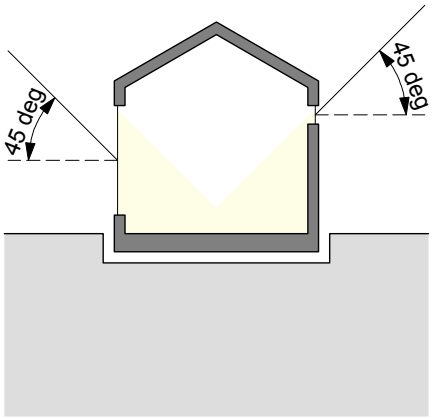
air-tightness



natural ventilation



thermal mass



daylight

what are the drawbacks of the “traditional” passive approach?

what are the drawbacks of the “traditional” passive approach?

Variable Air Quality

Heat and energy loss through winter ventilation

The “performance gap”

the discrepancy between design aspiration and as-built performance for many new buildings in the UK can be as much as 50-100%

architects journal “mind the gap” breakfast event

what is Passivhaus?

what is Passivhaus?

Passivhaus should be designed considering all of the above.

... But it's also more...

Passivhaus is an energy standard

a maximum space heating and cooling demand of less than 15 kWh/m2.year or a maximum heating and cooling load of 10W/m2.

a maximum total primary energy demand of 120 kWh/m2/year.

an air change rate of no more than 0.6 air changes per hour @ 50 Pa.

Passivhaus is a comfort standard

17 degC minimum internal surface temperature of building elements

ventilation rate of 30m3 per hour per person

to achieve Passivhaus in the UK typically involves:

very high levels of insulation

extremely high performance windows with insulated frames

airtight building fabric

'thermal bridge free' construction

a mechanical ventilation system with highly efficient heat recovery

what does a Passivhaus look like?

it could be this:

larch house by bere architects (images www.passivhaustrust.org.uk)

this:

crossways by Hawkes architects (images www.aecb.net & www.inhabit.com)

or this:

the burrows by paul testa architecture

what does a Passivhaus look like?

Passivhaus is a performance standard

Passivhaus is a methodology

Passivhaus is a quality assurance system

Passivhaus is not a construction system

Passivhaus is not an architectural style.

self build on a shoestring - a design competition

the brief:

Design a single family home to be self-built with your own labour for less than £50K.

Costs only include specialist labour (assumed the tradional notion of "self-build").

passivhaus on a shoestring

key approaches:

off | onsite prefabrication:

carry out as much construction on the ground as possible prior to assembly

modular / standardised construction:

to make the above possible and to minimise costs keep within plywood sheet sizes and minimise variation in windows etc.

maximise material function:

OSB = structure | air-tightness | internal finish
(reduces cost but issues with protection on site)

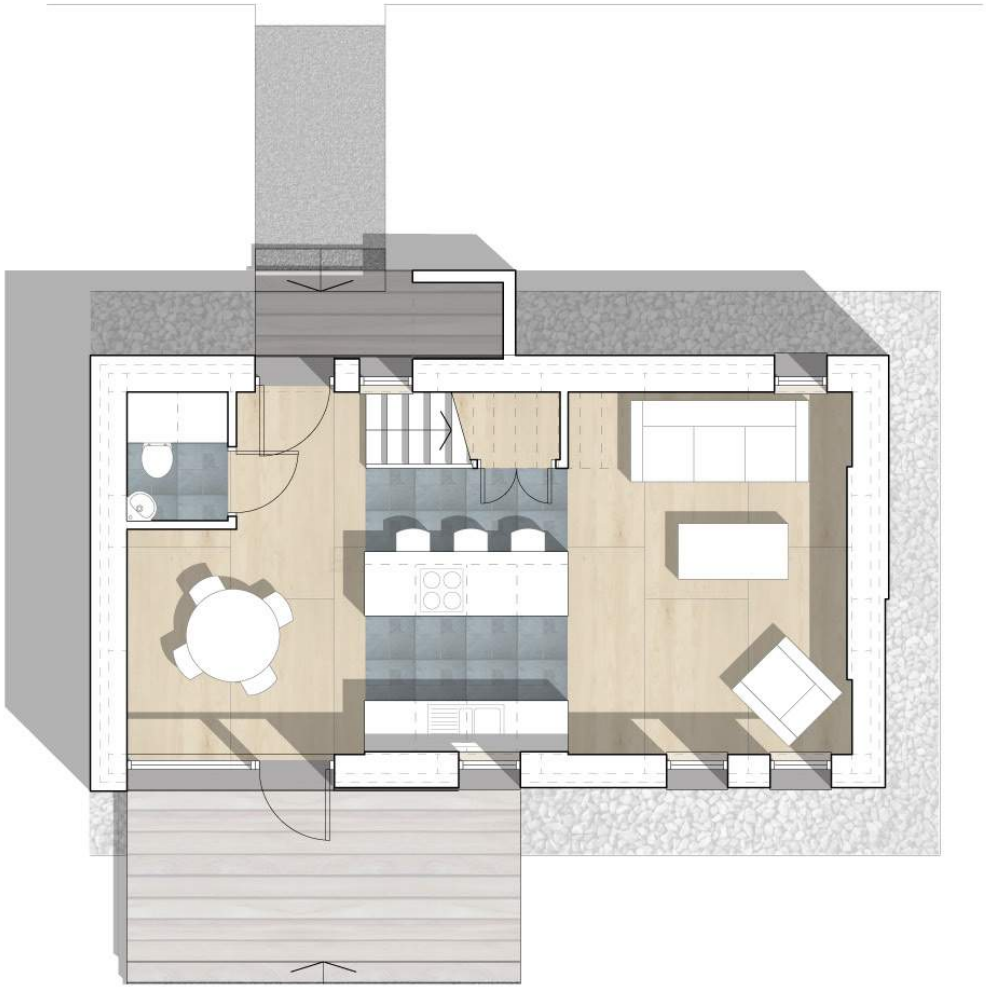
passivhaus performance:

a fine balance between cost and performance

passivhaus energy balance pushed cost down eg. reduced size of windows

...and pushed cost up eg. specification of insulation

floor plans



construction

roof: the roof is clad in fibre cement slate tiles. To achieve a more enjoyable volume, the trusses have a mid-height tie to allow a sloping soffit.

The roof uses the same total construction as the walls with air-tightness provided by an intelligent vapour control membrane. This is over-clad with an OSB soffit to match the internal surface of the external walls.

air-tightness: as the OSB 3 board is the surface finish as well as the air-tightness layer taping vertical joints is not an option. Instead these will be mechanically sealed with OSB loose tongues sealed into routed slots in the wall panels.

Horizontal joints are masked by floor and roof constructions so can be sealed with proprietary air-tightness tapes.

The roof is sealed with an intelligent vapour control membrane and the ground floor foil faced insulation & OSB deck are taped.

Off[on]site wall panels: the external walls of the dwelling are made of low-tech prefabricated panels constructed on or off site.

There are 52 panels in the project with 11 different types. The panels are designed to a standard 8'x4' sheet size to minimise wastage.

OSB forms the airtightness line, internal finish and tie the structure together.

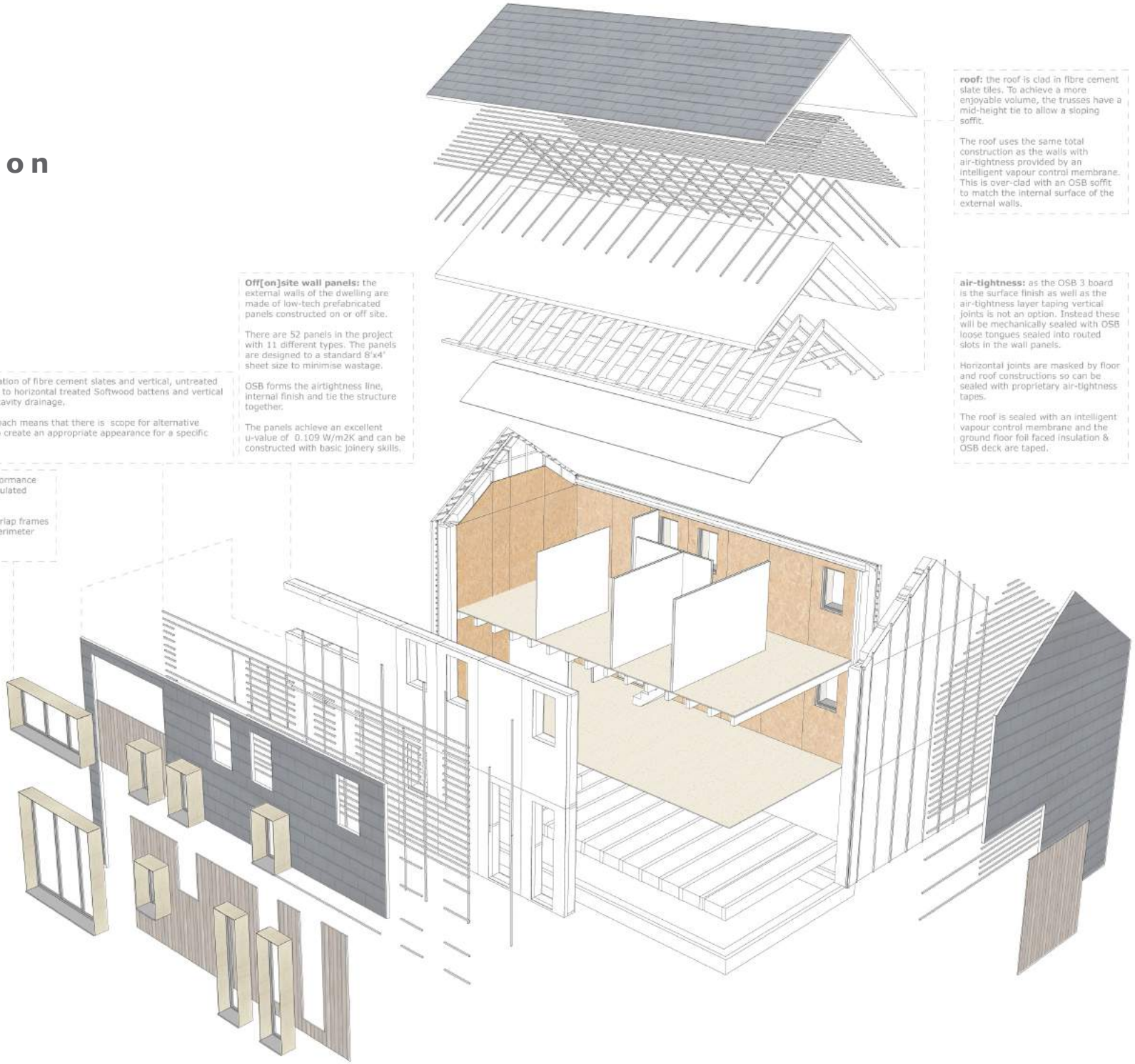
The panels achieve an excellent u-value of 0.109 W/m2K and can be constructed with basic joinery skills.

cladding: a combination of fibre cement slates and vertical, untreated larch boarding. fixed to horizontal treated Softwood battens and vertical counter battens for cavity drainage.

The rainscreen approach means that there is scope for alternative cladding materials to create an appropriate appearance for a specific context.

windows: high performance triple glazed with insulated frames.

reveal insulation overlap frames by 35mm to avoid perimeter cold bridging



the numbers

Works Package	Construction Element	Materials	Labour	Total
Works Package 1	Set up, Clearance, Demolitions….	£ -	£ -	£ -
Works Package 2	Foundations *(up to DPC)*	£ 1,580.65	£ -	£ 1,580.65
Works Package 3	Ground Floor Slab or Suspended Floor	£ 1,694.39	£ -	£ 1,694.39
Works Package 4	Drainage & Service Trenchwork	£ 763.00	£ -	£ 763.00
Works Package 5	Specialist Building System *(eg timber frame, SIPs, etc if applicable)*	£ 4,062.35	£ -	£ 4,062.35
Works Package 6	External & Internal Walls	£ 3,973.45	£ -	£ 3,973.45
Works Package 7	Intermediate Floor Zone (if applicable)	£ 999.84	£ -	£ 999.84
Works Package 8	Fireplace & Chimney (if applicable)	£ -	£ -	£ -
Works Package 9	Roof Structure, Insulation & Covering	£ 3,126.93	£ -	£ 3,126.93
Works Package 10	Joinery *(Windows, doors, stairs, skirtings…)*	£ 12,260.54	£ -	£ 12,260.54
Works Package 11	Specialist Products *(eg; Eco products…)*	£ 4,300.00	£ 500.00	£ 4,800.00
Works Package 12	Electrical Installation	£ 1,287.84	£ 150.00	£ 1,437.84
Works Package 13	Plumbing Installation	£ 1,665.00	£ -	£ 1,665.00
Works Package 14	Heating Installation	£ 1,200.00	£ 800.00	£ 2,000.00
Works Package 15	Plastering *(or dry-lining)*	£ 123.84	£ -	£ 123.84
Works Package 16	Kitchen and Utility Units *(+ appliances)*	£ 3,000.00	£ -	£ 3,000.00
Works Package 17	Decorations & Wall Ceramics	£ 1,174.00	£ -	£ 1,174.00
Works Package 18	Floor Finishes	£ 665.00	£ -	£ 665.00
	TOTAL	£ 41,876.83	£ 1,450.00	£ 43,326.83

Total project costs:

Total materials costs: £41,876.83

Total Labour costs: £1,450

Total: £43,326.83

Total GIFA: 70.14m2

Total cost per m2: £617.72

Treated Floor Area:	66.4	m^2				
	Applied:	**Annual method**		**PH Certificate:**		**Fulfilled?**
Specific Space Heating Demand:	**14**	**kWh/(m²a)**		**15**	**kWh/(m²a)**	**Yes**
Heating Load:	**10**	**W/m²**		**10**	**W/m²**	
Pressurization Test Result:	**0.6**	**h^{-1}**		0.6	h^{-1}	**Yes**
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):		**kWh/(m²a)**		120	kWh/(m²a)	
Specific Primary Energy Reduction through Solar Electricity:		**kWh/(m²a)**				
Frequency of Overheating:	**0**	**%**	over	25	°C	
Specific Useful Cooling Energy Demand:		**kWh/(m²a)**		15	kWh/(m²a)	
Cooling Load:	**2**	**W/m²**				

Total heating costs:

Average UK kWh cost: 4.21p/kWh (energy saving trust)

kWh per m2 per year: 14kWh/m2.a

Total treated floor area: 66.4m2

Total heating costs: £39.14 p/a

elevations

inside

outside

passivhaus & self build resources

www.passivhaustrust.org.uk

www.aecb.net

www.greenbuildingstore.co.uk

www.elrondburrell.com

www.nasba.org.uk

www.selfbuildportal.co.uk

www.thebuildhub.co.uk

different approaches to deep retrofit

external insulation

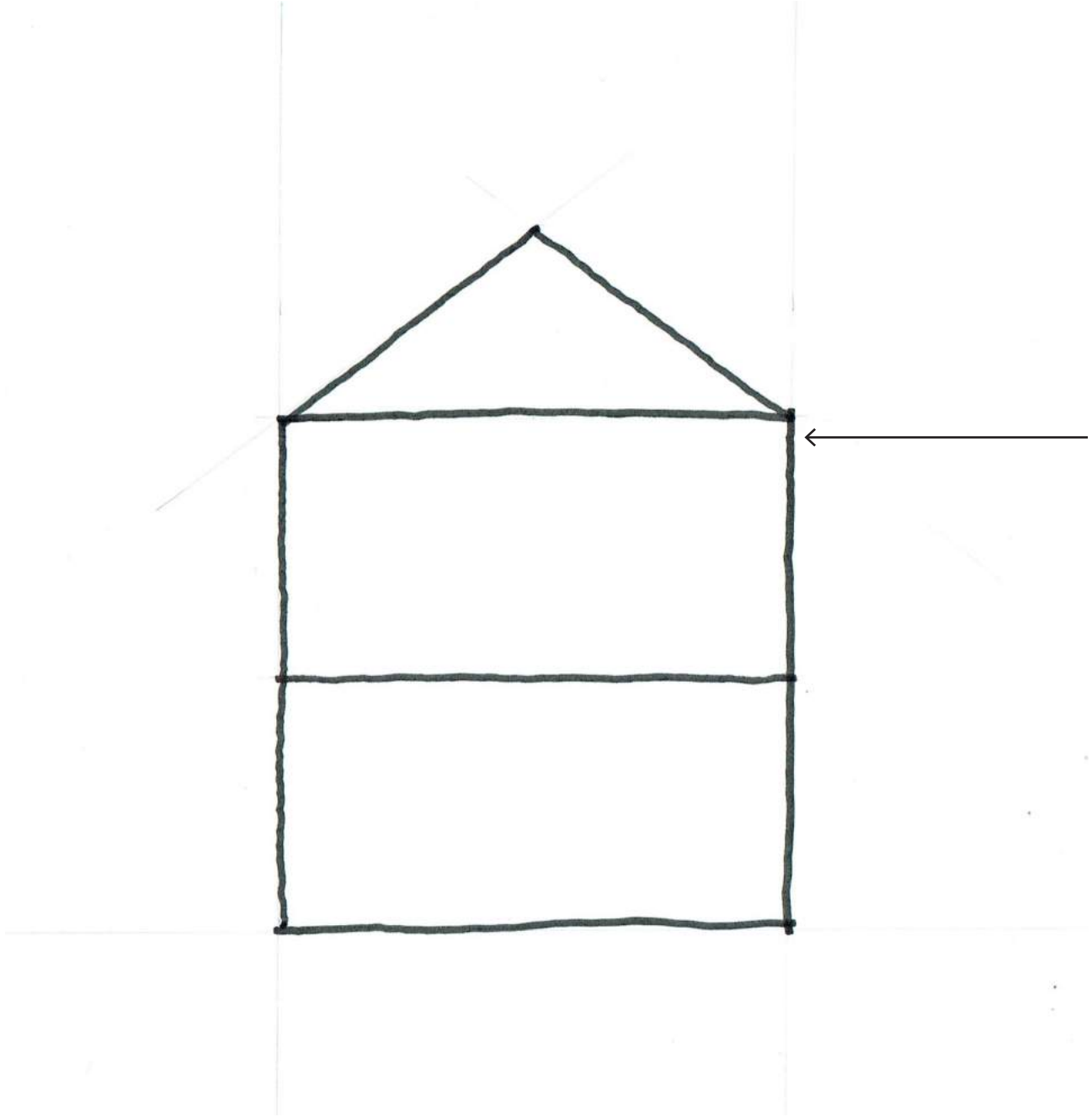
Maintains all of the existing structure within the new thermal envelope

Difficult to achieve at foundation / ground level

Air-tightness line can be inside or outside the existing structure

Potential for fewer cold bridges

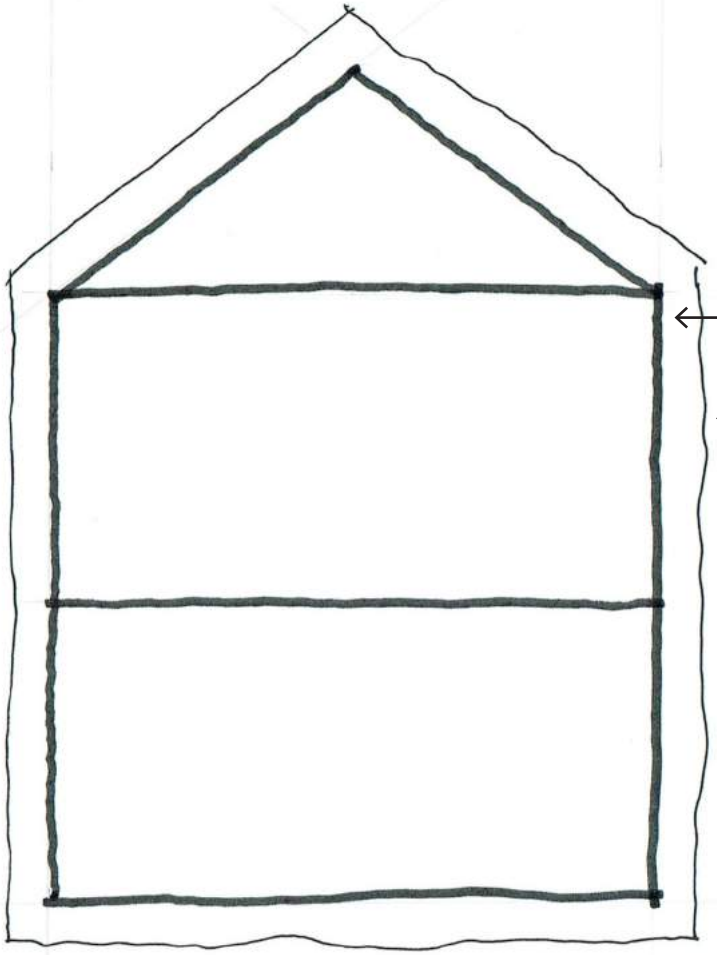
Changes the external appearance of the building



external insulation

Existing Structure

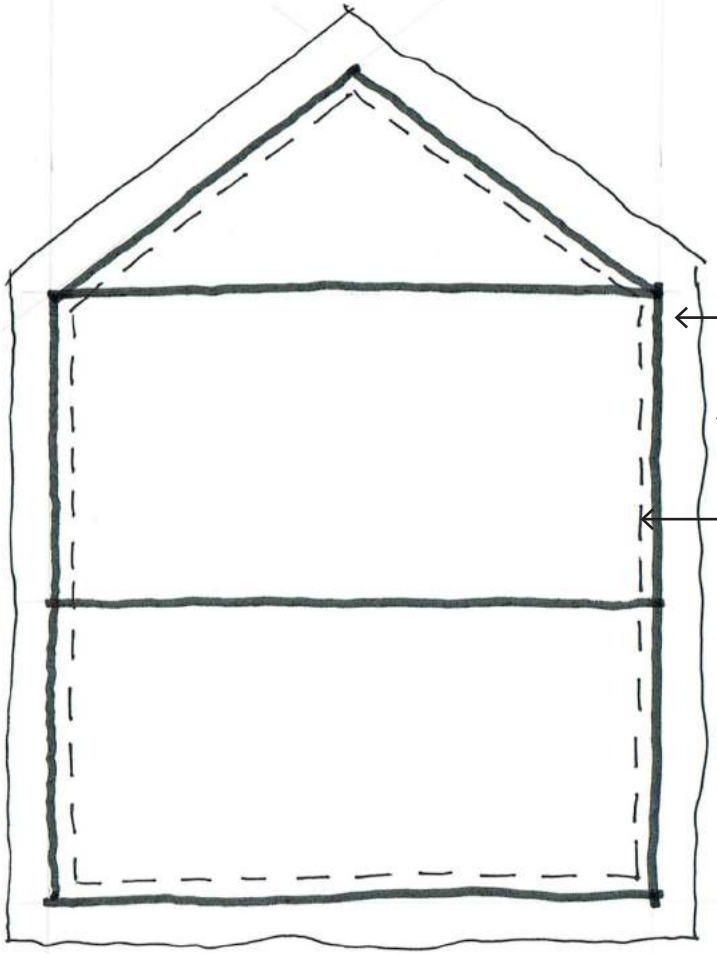
external insulation



Existing Structure

Insulation wrap

external insulation

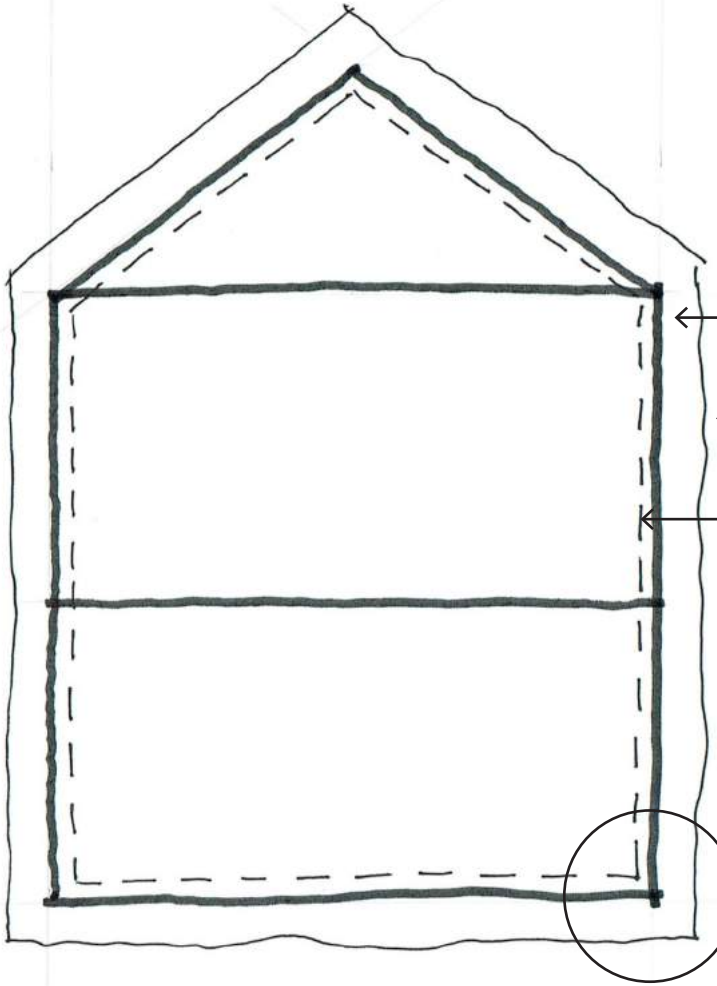


Existing Structure

Insulation wrap

Air-tightness layer

external insulation



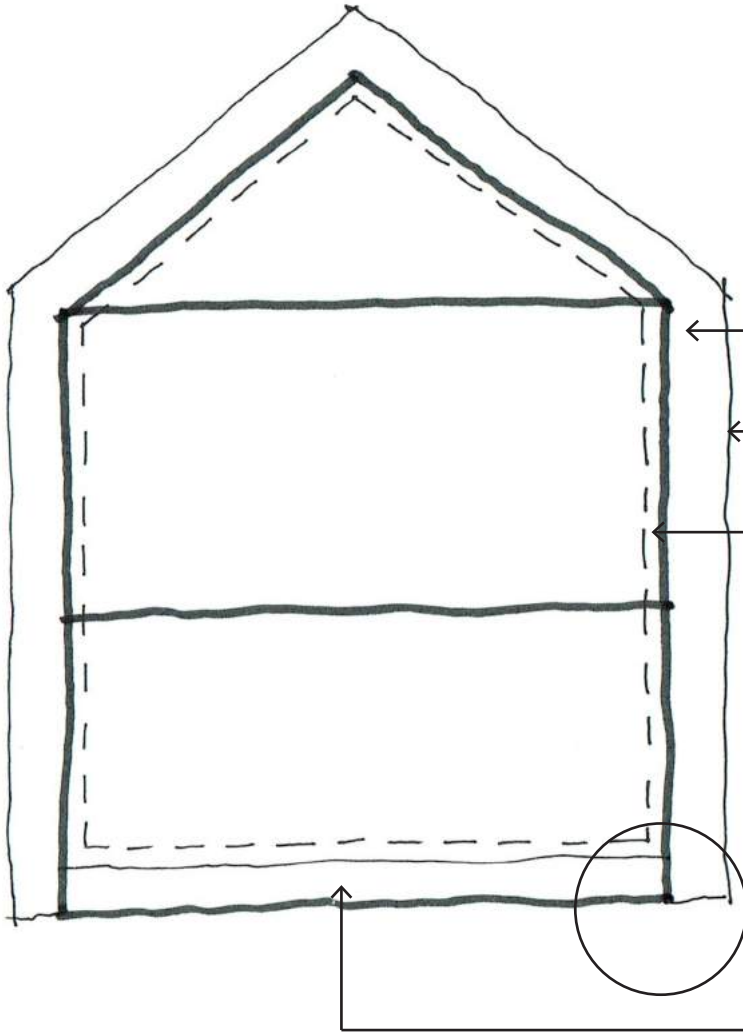
Existing Structure

Insulation wrap

Air-tightness layer

Tricky Junction

external insulation



Existing Structure

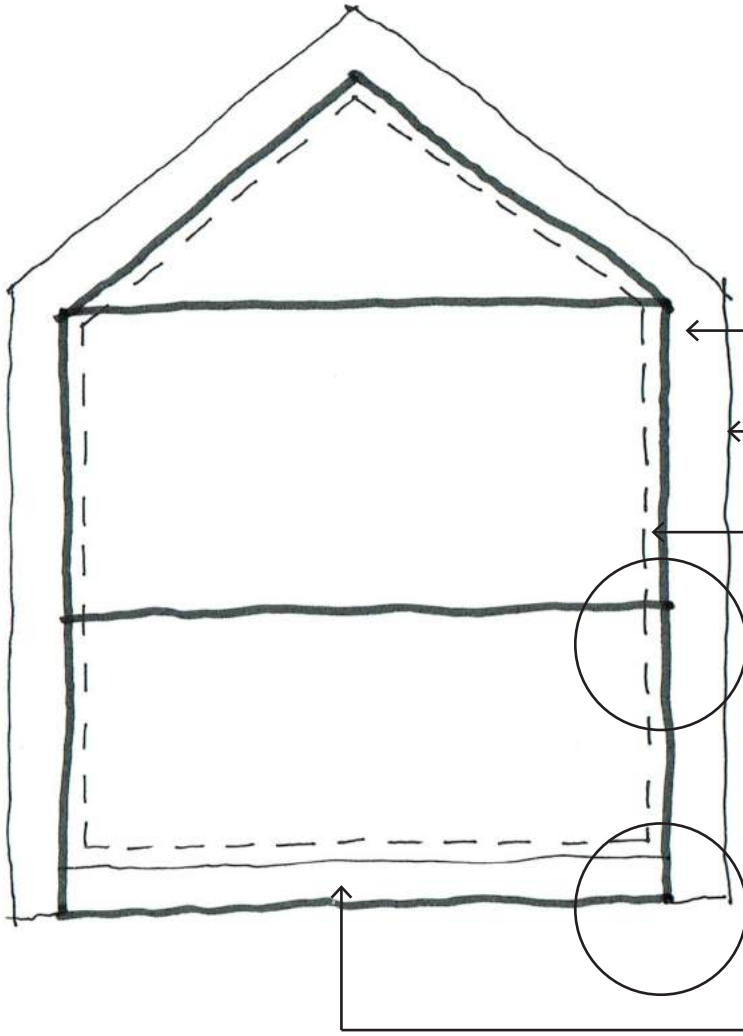
Insulation wrap

Air-tightness layer

Thermal Bridge

Internal Floor Insulation

external insulation



Existing Structure

Insulation wrap

Air-tightness layer

Air-tightness detail issue

Thermal Bridge

Internal Floor Insulation

internal insulation

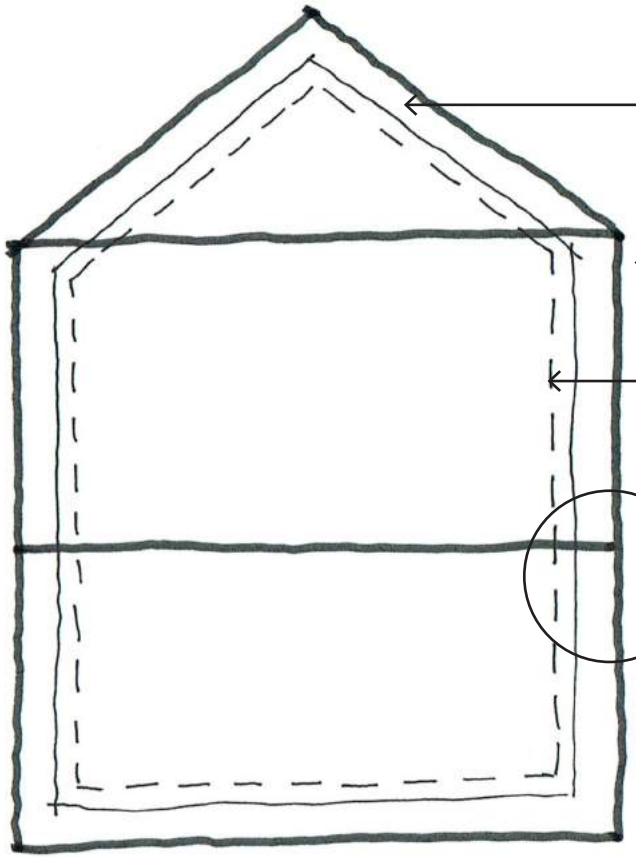
Puts all of the existing structure outside the new thermal envelope

It's possible to keep the insulation continuous but there may be cold bridges where existing walls and floors meet the external envelope

Air-tightness line will be inside the new insulation

Retains the external appearance of the building

internal insulation



Internal Insulation

Existing Structure

Air-tightness layer

Air-tightness detail issue
&
Thermal Bridge

Extending as Part of a Retrofit Strategy

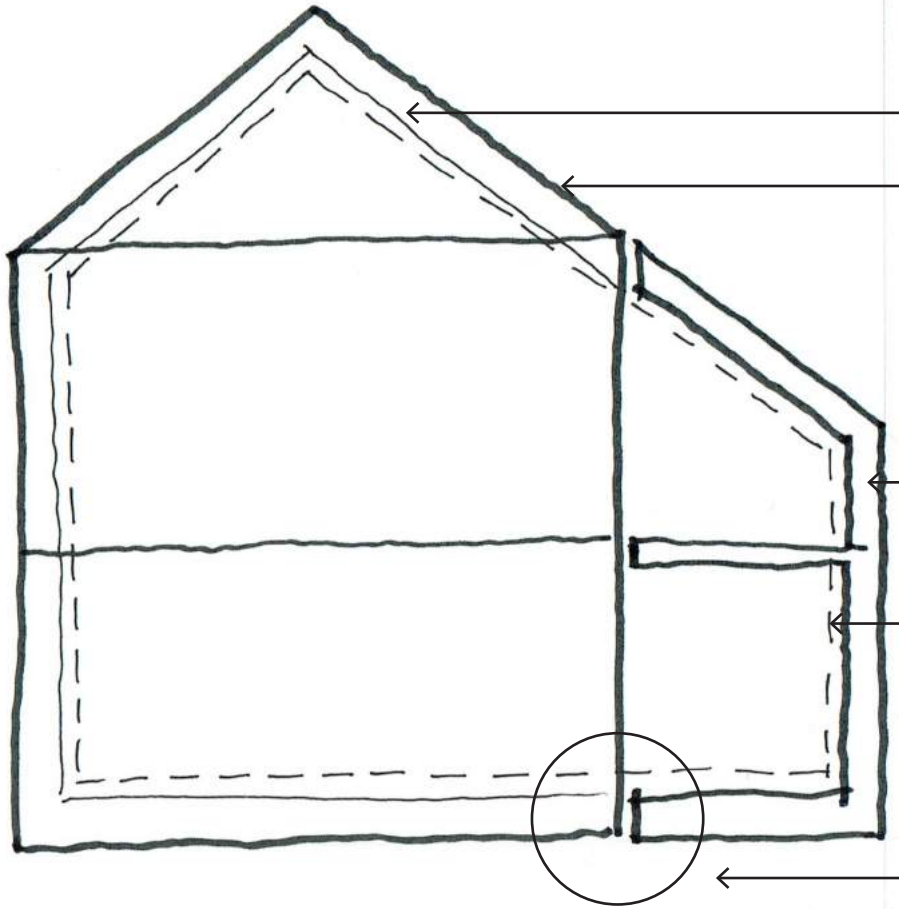
An extension can decrease the heat loss form factor ratio

An extension may mean that a large part of the thermal envelope is now new, very efficient construction

Needs careful detailing with the existing building

Ideally thermal approach (internal or external insulation) is the same as the retrofit

extending as part of a retrofit strategy



unintended consequences

Moisture

Moisture

Moisture...!!

Best Practice Retrofit Examples

Lower Royd Radical Retrofit

By the Green Building Store

https://www.greenbuildingstore.co.uk/lower-royd-retrofit-whole-house-radical-refurbishment/

Very Careful consideration of moisture

Experimental use of new materials and very open approach to disseminating lessons learned.

Lower Royd Radical Retrofit

Exposed Location (damp)

Attractive Barn

Solid Stone Walls

Internal Wall Insulation

(images courtesy Green Building Store)

Lower Royd Radical Retrofit

Diathonite Insulation

Sprayed on up to 100mm

Deals well with moisture

Deals well with uneven walls

Air-tight

(images courtesy Green Building Store)

Lower Royd Radical Retrofit

Careful Consideration of Thermal Bridging

CompacFoam spacers

(images courtesy Green Building Store)

Lower Royd Radical Retrofit

Careful Consideration of Thermal Bridging

Foamglas "pocket" in stone wall for steel beam

(images courtesy Green Building Store)

Lower Royd Radical Retrofit

Careful Consideration of Thermal Bridging & air-Tightness for windows & doors

CompacFoam theshold

Window frames taped before Diathonite sprayed to reveals

(images courtesy Green Building Store)

Lower Royd Radical Retrofit

Mechanical Ventilation with Heat Recovery (MVHR)

Careful duct route design

Ducts all inside thermal envelope

(images courtesy Green Building Store)

Lower Royd Radical Retrofit

(images courtesy Green Building Store)

Sycamore Hall Retrofit and Extension

By Paul Testa Architecture

http://paultestaarchitecture.co.uk/portfolio/sycamore-hall/

High thermal performance

Very poor heat loss form factor made very low kWh/m2.a very difficult

Hugely improved daylight

Sycamore Hall Retrofit and Extension

Exposed location (damp)

Unattractive bungalow

Near Peak District

Narrow cavity walls

Internal wall Insulation

Sycamore Hall Retrofit and Extension

Complete Remodel

Two small extensions

Sycamore Hall Retrofit and Extension

Conventional insulation

Internal insulated dry-lining with insulated studs

Highly insulated roof

Insulated suspended timber floor

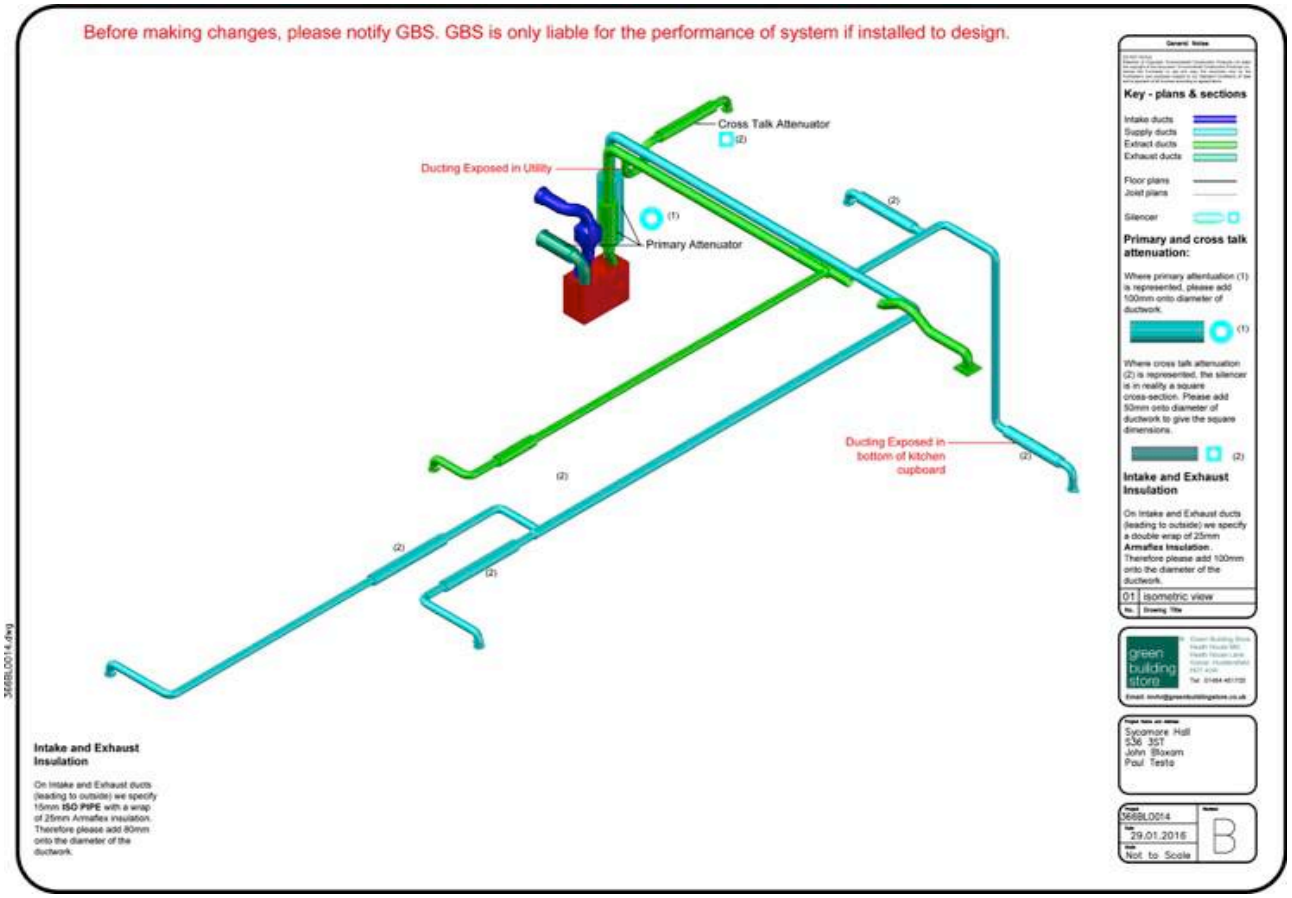
Sycamore Hall Retrofit and Extension

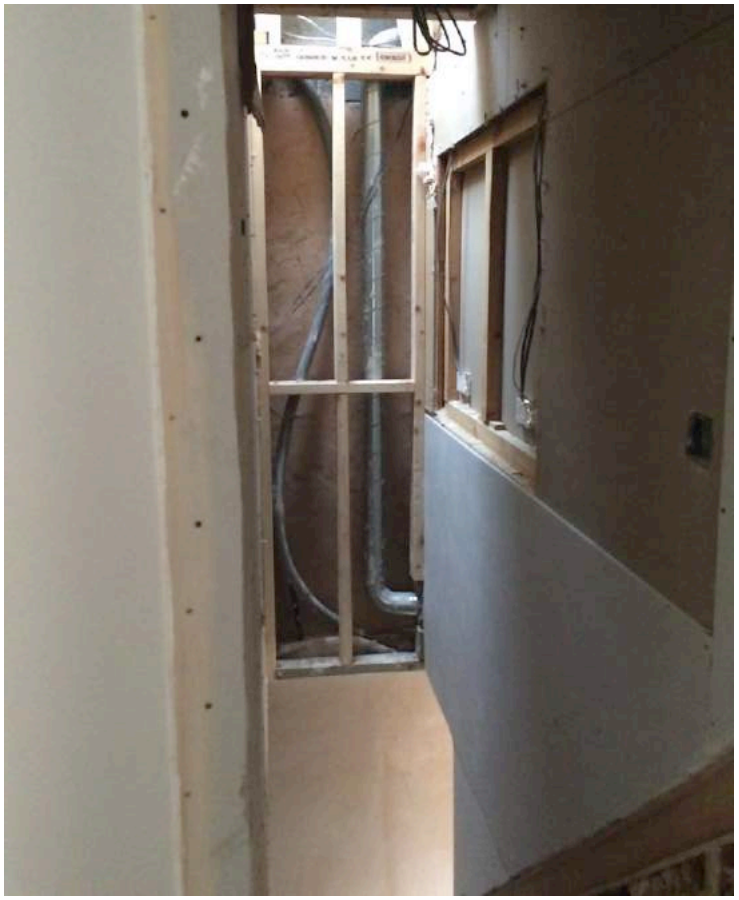
Careful air-tightness strategy

Some issues with existing walls inside the thermal envelope

Sycamore Hall Retrofit and Extension

MVHR Careful duct route planning





Sycamore Hall Retrofit and Extension

Improved Daylight very important

Sycamore Hall Retrofit and Extension

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