Practical Considerations in Wet and Windy Wales

The SUSREF research and afterwards

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SUStainable REFurbishment of Existing Facades *SUSREF*

INTRODUCTION TO SUSREF

PURPOSE: To develop a systematic method of assessing the optimum way of upgrading existing external walls

taking into account

- physical characteristics of the existing wall
- outside climate
- indoor air quality
- durability of the refurbishment
- buildability
- carbon dioxide emissions avoided
- embodied energy and other resource use over the life-time of the refurbishment;
- financial costs and savings
- social parameters such as restrictions on change to historic buildings

humidity

All partners recognised that

•Improvements must **deliver real energy savings over their lifetime** without costing too much (money, energy or resources) or causing pollution or hazards

•Current mandatory **static models** of heat flow (SAP U-Values) and moisture movement (Glaser condensation risk analysis) give false security

Wales' focus was on real, traditional buildings

Why?

Wales has largest proportion of pre 1919-stock in Europe so **energy efficiency of existing stock** must be improved to meet carbon-reduction targets & reduce fuel poverty

How?

We used SUSREF research to explore gaps –

•**Thick solid stone walls** not considered in UK standard guidance, which is based on cavity wall construction in middle-England

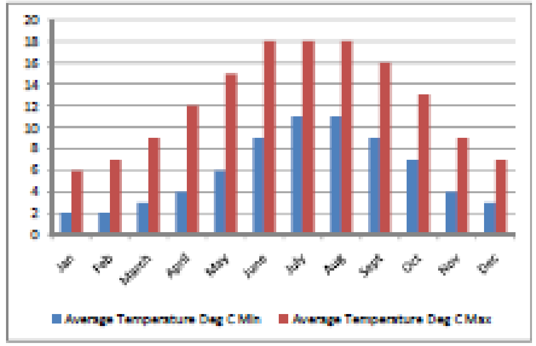
•**Western maritime climate** not considered in manufacturers' R & D – many products certified to German norms

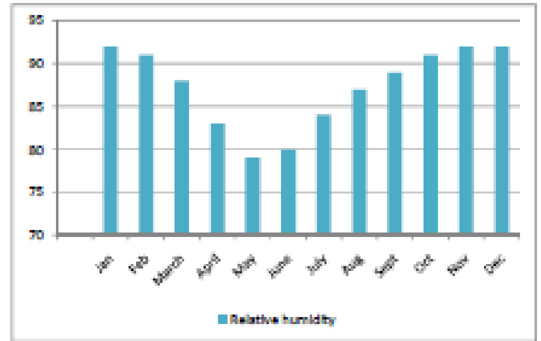
Wales was the only partner to use field trials

Average Temperature / Relative Humidity Data for UK Ireland

Belfast, United Kingdom

Month	Average Temperature Deg C		Record Temperature Deg C		Relative humidity	Average Rain fall (mm)
	Min	Max	Min	Max		
Jan	2	6	-13	13	92	80
Feb	2	7	-12	14	91	52
March	3	9	-12	19	88	50
April	4	12	-4	21	83	48
May	6	15	-3	26	79	52
June	9	18	-1	28	80	68
July	11	18	4	29	84	94
Aug	11	18	1	28	87	77
Sept	9	16	-2	26	89	80
Oct	7	13	-4	21	91	83
Nov	4	9	-6	16	92	72
Dec	3	7	-11	14	92	90



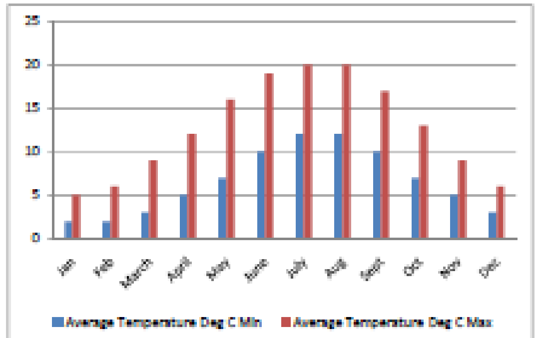


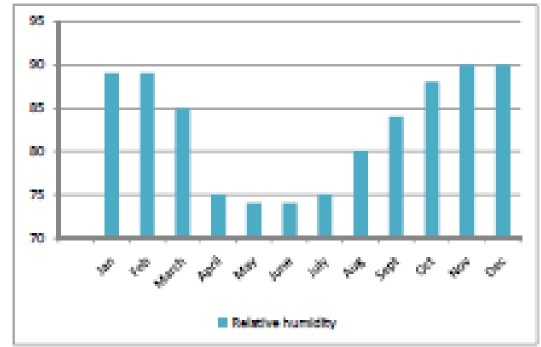
77%

12 months

Birmingham, United Kingdom

Month	Average Temperature Deg C		Record Temperature Deg C		Relative humidity	Average Rain fall (mm)
	Min	Max	Min	Max		
Jan	2	5	-12	13	89	74
Feb	2	6	-9	16	89	54
March	3	9	-7	21	85	50
April	5	12	-2	24	75	53
May	7	16	-1	29	74	64
June	10	19	3	31	74	50
July	12	20	6	32	75	69
Aug	12	20	6	33	80	69
Sept	10	17	3	27	84	61
Oct	7	13	-2	25	88	69
Nov	5	9	-4	19	90	84
Dec	3	6	-6	14	90	67



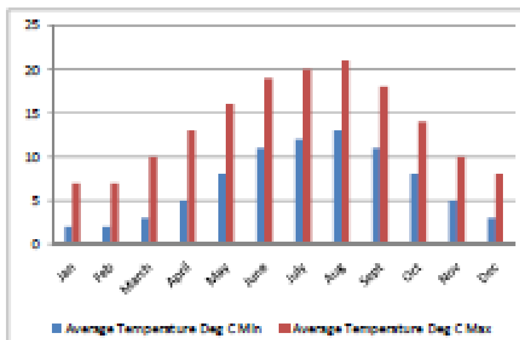


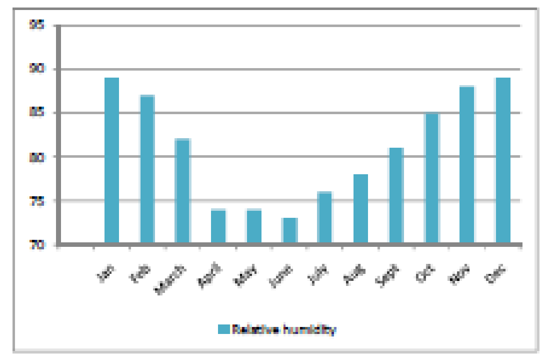
77%

8 months

Cardiff, United Kingdom

Month	Average Temperature Deg C		Record Temperature Deg C		Relative humidity	Average Rain fall (mm)
	Min	Max	Min	Max		
Jan	2	7	-17	15	89	108
Feb	2	7	-9	16	87	72
March	3	10	-8	20	82	63
April	5	13	-3	24	74	65
May	8	16	-1	29	74	76
June	11	19	4	31	73	63
July	12	20	7	31	76	89
Aug	13	21	6	33	78	97
Sept	11	18	2	28	81	99
Oct	8	14	-3	25	85	109
Nov	5	10	-3	18	88	116
Dec	3	8	-7	15	89	108





77%

7 months

Add effects of altitude and wind-driven rain….

RH, temperatures & materials starting to decay

18deg C

77%

12 (57)

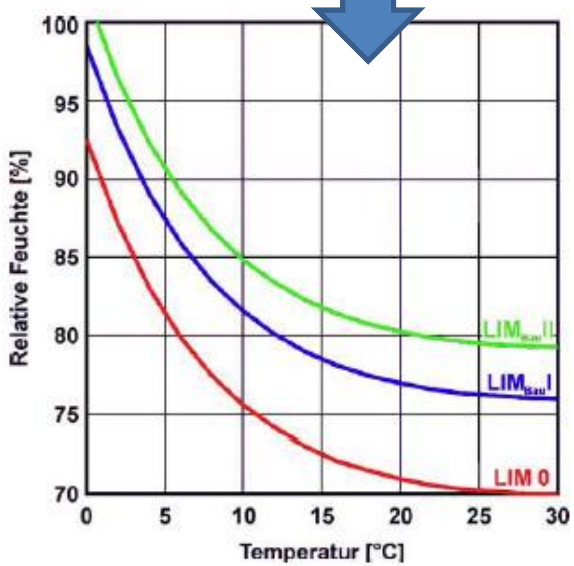


Figure 6: "Safe" limits for avoiding mould growth for different material classes.
LIM 0: Optimal culture medium, represents the maximum growth possible for any mould found in buildings.
LIM I: Bio-utilizable substrates, such as wall paper, plaster board, building products made of biologically degradable materials, materials for permanently elastic joints, strongly contaminated surfaces.
LIM II: Less bio-utilizable substrates with porous structure, such as plasters, mineral building materials, certain woods, insulating materials not belonging to group I.
Inert substrates such as metals, foils, glass and tiles are usually not affected by mould, unless contaminated. From WufiBio manual[13]

Red = Optimal Mould culture (pH 6.5)

Blue = Wallpaper, plasterboard, biological materials, contaminated surfaces

Green = Other porous building materials (timber, plaster, insulations

Indoor RH and Temperature – how much water?

deg C	**RH%**	**g water/Kg dry air**	**Comfort range** **RH 40-70%** **g water/Kg dry air**
14	100	10	4 - 7
16	100	11.25	4.5 - 8
18	**100**	**13**	**5.25 – 9.1**
20	100	15	5.8 – 10.25
22	100	17	6.7 – 11.7

If we call that **7** grammes water….

Water vapour in the dwelling

Background humidity

- If dwelling is 100m2 x 2.5 room height, V = 250m3 /0.8562 = 292kg dry air
- If room temp is **18C and RH is 55%,** 7g x 292 = **2.044 litres**

Occupant-added humidity

- Average household (2 parents, 2 children) emit **5-10 litres** per day breathing, cooking, showering

- On washdays if they dry the washing inside, add 2.0 – 2.5 litres (assuming 4-5kg dry weight, 2 washing machine loads)

Total 9 – 14.5 litres water

Uninsulated wall

- Mould will grow on most common building materials if surface temperature takes local RH above 77%

- Condensation occurs when the air is saturated (ie cannot hold any more moisture at this temperature) RH is 100%

- Example: A room with **55%RH at 18deg** C has *poorly insulated walls with surface temp 14degC* so at saturation 100% RH – high risk of mould and condensation

SUSREF Field Trials

Moelyci 1
Solid stone with render
Test wall (gable) faces west

(EWI 100mm sheeps wool between timber studs, breather membrane, counter battens and timber cladding)

Modelled result
Before: U=1.5 After: U= 0.28


Modelled result, both houses
Before: U = 1.5

Bodiwan 2 **Tanyfron 3**

Solid stone with render, test walls (fronts) face south

(EWI 100mm mineral wool + acrylic) (EWI 100mm EPS + acrylic render)

Bodiwan 2
Modelled result
After: U = 0.29

Tanyfron 3
Modelled result
After: U= 0.29

Bryn Marsli 4

Solid stone wall, pointed test wall (gable) faces south

(Shelter of dark-coloured steel sheet forming sealed air space)

Modelled result
Before: U=1.5 (no render but 900mm stone wall thickness)

Modelled result
After: U = 1.18

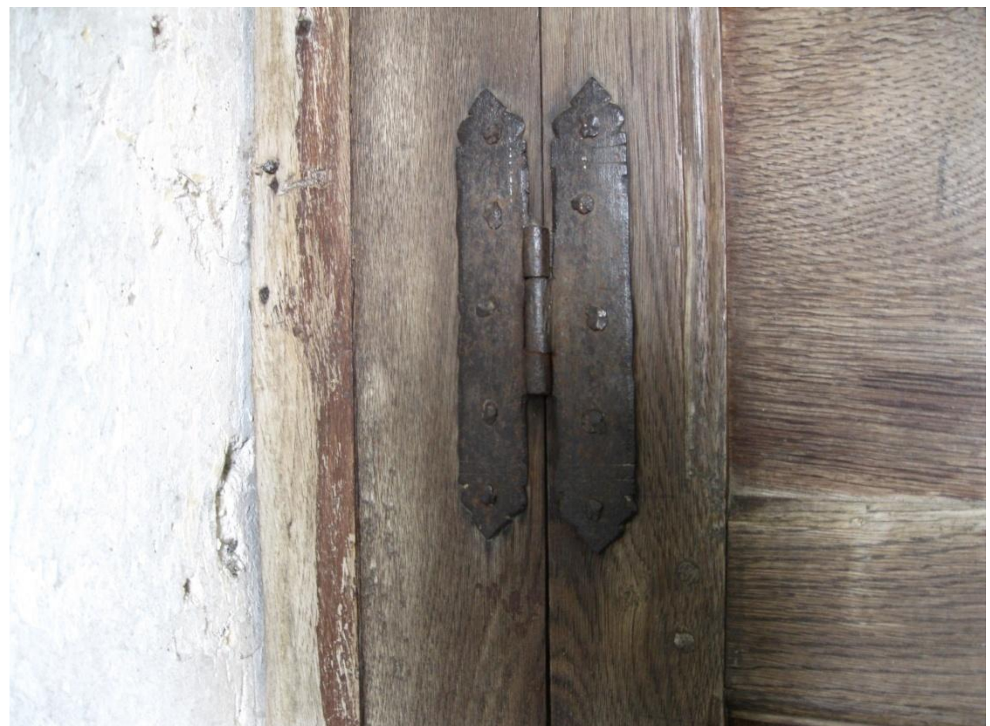
(Archive photo pre 1980)

Modelled results
Before: U=1.68 (when render is excluded)
After : U = 0.68 (with 50mm calcium silicate internal insulation board & plaster)

Plas Tirion 5
Solid stone with render, test wall (arrowed) faces NW

(Test wall fitted with internal insulation in 30mm calcium silicate board due to historic fittings, with hemp-lime plaster; external render removed, repointed in lime mortar)

When there is no room…



17C wig closet with original ironmongery

Plas Tirion externals completed Dec 2012

SUSREF Modelled predictions

- External **ventilated** rainscreen over vapour-open insulation would dry rapidly from both wall faces (Type 1, Moelyci)
- External **rendered** insulation would cause short term rise in internal surface RH until moisture in wall had dried out through inner face (Types 2 & 3, Bodiwan and Tanyfron)
- External unventilated rainscreen without insulation would provide only marginal benefits, not deemed viable financially or using Life Cycle Cost (Type 4, Bryn Marsli)
- Internal vapour-open insulation would be unable to dry enough in summer to compensate for winter wetting, so would reach saturation after a few seasons (Type 5, Plas Tirion)
- UK latitudes 100-200mm insulation is optimal in retrofit
- External insulation is at least 2% more efficient than internal insulation with the same U-value, because it uses the thermal mass of the wall whether for heating or cooling

SUSREF Monitored Results

- Weather affects only the outer 50mm of wall significantly

- Voids and varying materials in wall thickness are at least as significant in wall hygrothermal performance

- Voids and varying materials in random rubble stone wall construction cannot be detected except by opening up or drilling into wall

- Installation of **unventilated** external insulation caused initial **increase in RH** in internal face of wall

- Within 1 month of installing external insulation with **ventilated rainscreen**, **RH** in wall in Moelyci **halved** and then continued to drop gradually

Life Cycle Costs for the five examples in the Field Studies in Wales:

Solid stone wall	***U-value***	***LCC €/m2 per year over 20 years***	
Uninsulated	*1.6 w/m²degC average*	*214 averaged*	
100mm external of any quilt-type	*0.29*	*142 averaged*	£
50mm internal insulation	*0.68*	*169*	
Shelter	*1.18*	*210*	

Lifecycle costs have a number of built-in assumptions (such as internal temperatures; building costs inflation rates in general; fuel cost inflation rates.) If monetary considerations are put aside, the lowest

Carbon footprint	**thickness**	**kg-equiv per m² of wall per year over 20 years**
Natural Sheeps Insulation	*100mm*	*35*
Mineral wool	*100mm*	*120*
EPS	*100mm*	*130*
Calcium Silicate	*50mm*	*280*
Shelter	*N/A*	*400*

The lowest **consumption of non-renewables** over 20 years was also sheep wool with timber cladding

All the modelled results assume ***correct installation*** – there must be

•No voids, ventilated cavities or leaks in fully-bonded boards on inner or outer face of wall

• With non-breathing internal insulation with a Vapour Barrier, this must be sealed at all laps, at junctions around doors, floors, roofs, and service perforations

•With external insulation inside a ventilated cavity this must be protected by a wind-sealed breather membrane

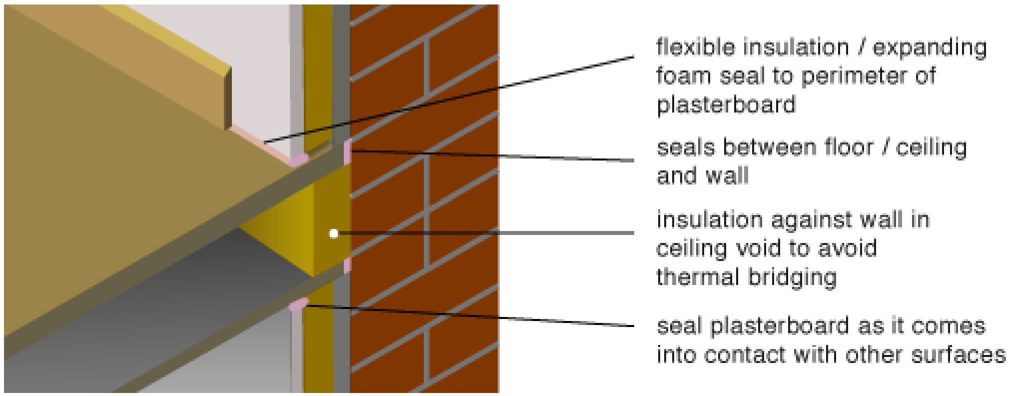
•Care must be taken with sequence of foamed plastic insulation types to avoid trapping moisture by installing the less permeable type on the cold side of the more permeable type - *beware with polyeurethane and phenolic foams!*

•Minimise cold bridging

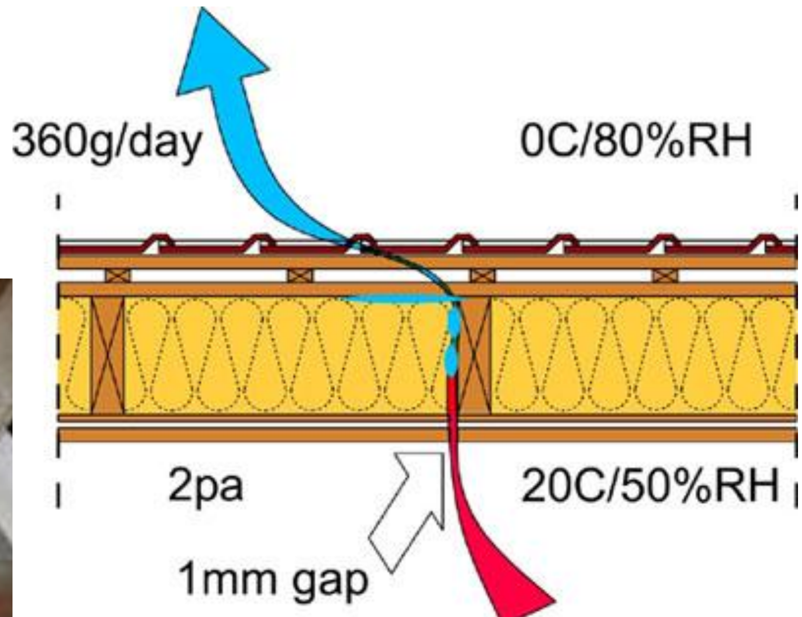
•In mid-latitude European climates, 100mm-200mm thickness of insulation of fleece-type is optimal in retrofit

•Controlled ventilation for internal air quality

Internal insulation in retrofit: Air tightness & vapour barrier practicalities



Condensation &mould behind dot & and dab insulation



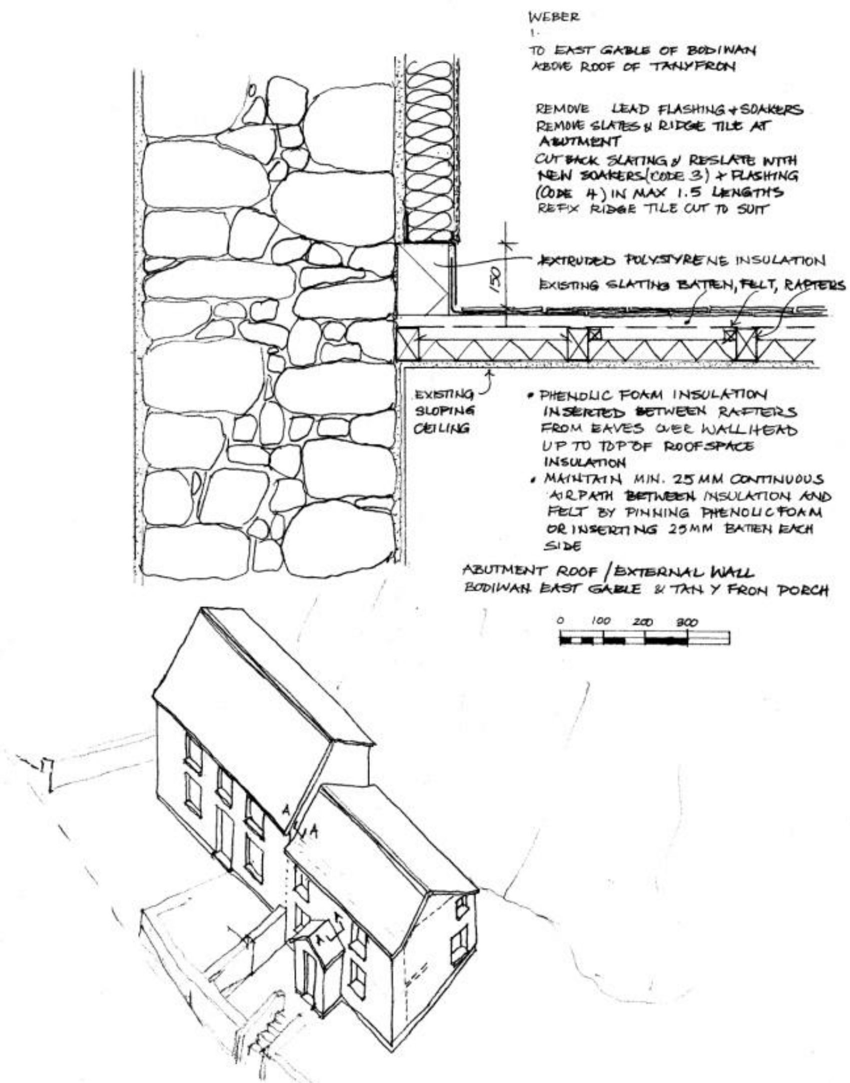
External insulation in retrofit – practicalities

Cold-bridging at abutments

2 locations

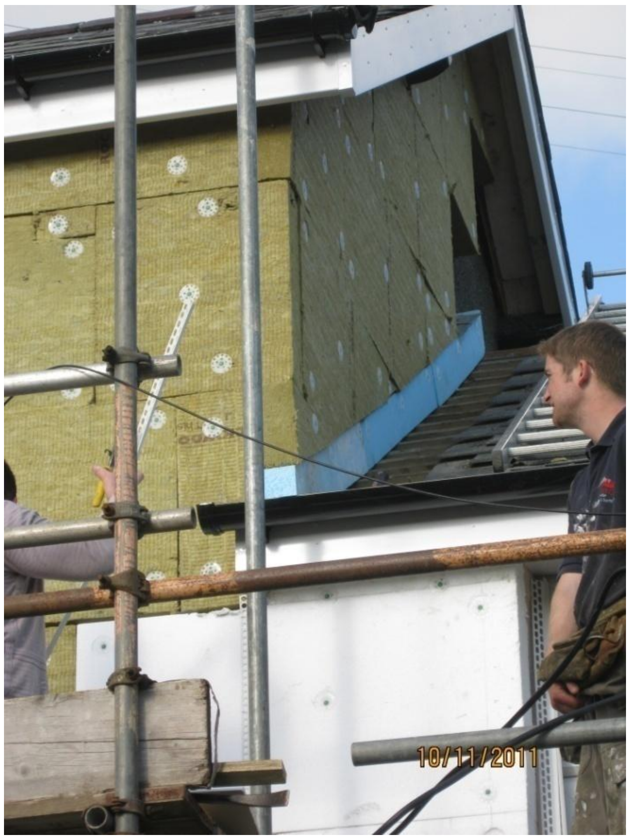
1) **Upper house gable and lower house roof**
2) **Front wall and porch of lower house**

Drawn detail



Abutments detail

PU slab in splash zone (on roof)



Lead soaker & flashing over PU slab (on porch)

Cut slab, dig trench, install drains…

(cut through rock in places, underpin in others)

Basecourse insulation in rendered XPS or PU

Insulation in splash zone carried down below ground level behind relief drain

Making room for the insulation outside

1. Alter all attached services drainage, cabling, lights, extract fans, flues…

Making room for the insulation outside

2. Extend eaves and cills

Making room for the insulation outside

3. Extend verge

Remove chimney & extend verge

Extend verge

Flanking at reveals
Existing windows – insulate reveals outside

Even after hacking off render & cutting stone, scant 20mm possible

Airtightness

1. at services

Duct for air-sourced heat pump connection

A knot of soil pipes…

Airtightness

2. Is this possible with foam?

New door to old stone lintel (boxing-in removed)

Old slate re-used, old lead retained, hopeful foam

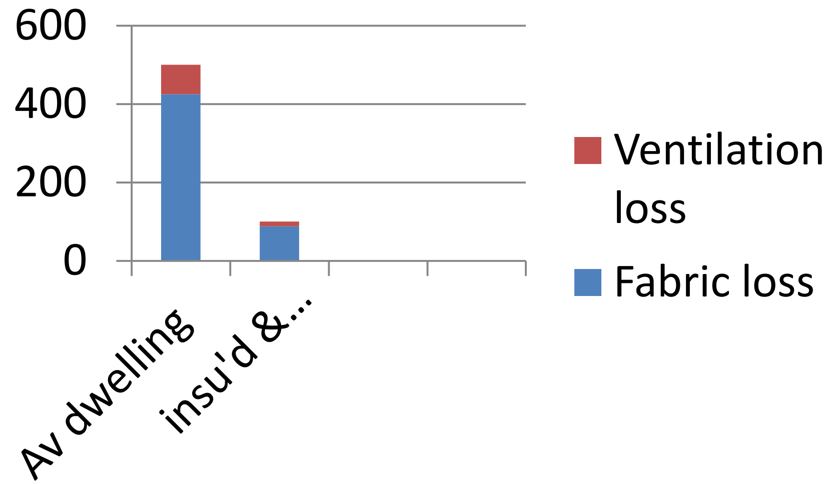
Roof ventilation

Insulation carried up to top of wall behind venting soffit but maintaining 25mm slot below existing felt

Insulation tightly tucked over wall head so roof has to be fitted with in-line ventilation slates

Ventilation of dwelling

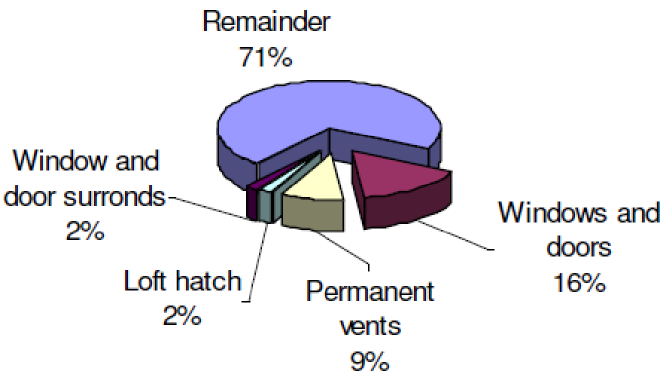
- *or infiltration?*



Average dwelling energy losses through fabric 85%, ventilation 15%

Best-practice dwelling with good insulation and controlled ventilation energy losses through fabric 88% ventilation 12%
BUT circa 5 x less energy consumed

Air Leakage Paths BRE IP 1/00



Infiltration is not the same as Ventilation – it is air leakage and it causes draughts

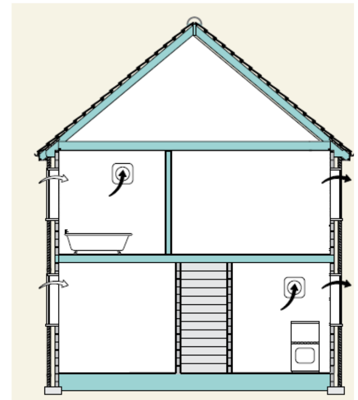
How much ventilation?

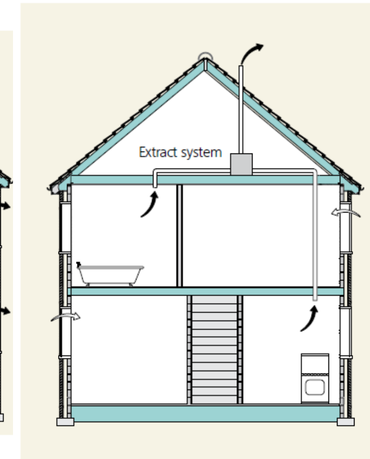
- Minimum for health is **0.5** air changes per hour, but depends on number of people & their activities
- Building Regulations for new dwellings currently (2010) require maximum infiltration rate of **10m3/h.m2** at 50 Pascals pressure. This is about **0.5** air changes per hour
- **Passivhaus** requires 3m3/h.m2 at 50 Pascals max infiltration rate, (**0.15** ac/h) so mechanical ventilation with heat recovery is essential

Controlled ventilation – A: with trickle vents

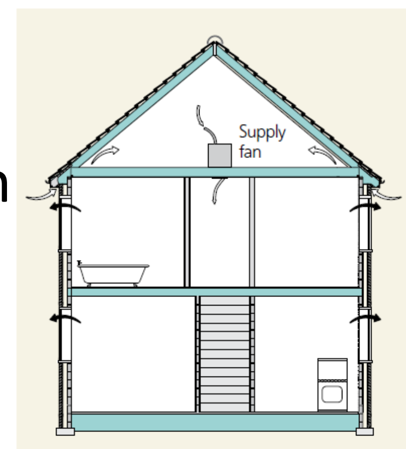
Principle - replace warm moist air with cooler air containing less moisture:

1. Directly, by simple extract fan from wet spaces exhausting hot damp air, pulling new drier air through *trickle vents* in other rooms





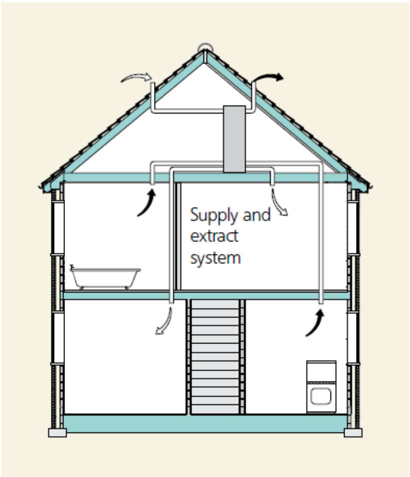
2. By dilution with positive input ventilation via loft, using cooler drier air from loft that has benefits from some heat gain



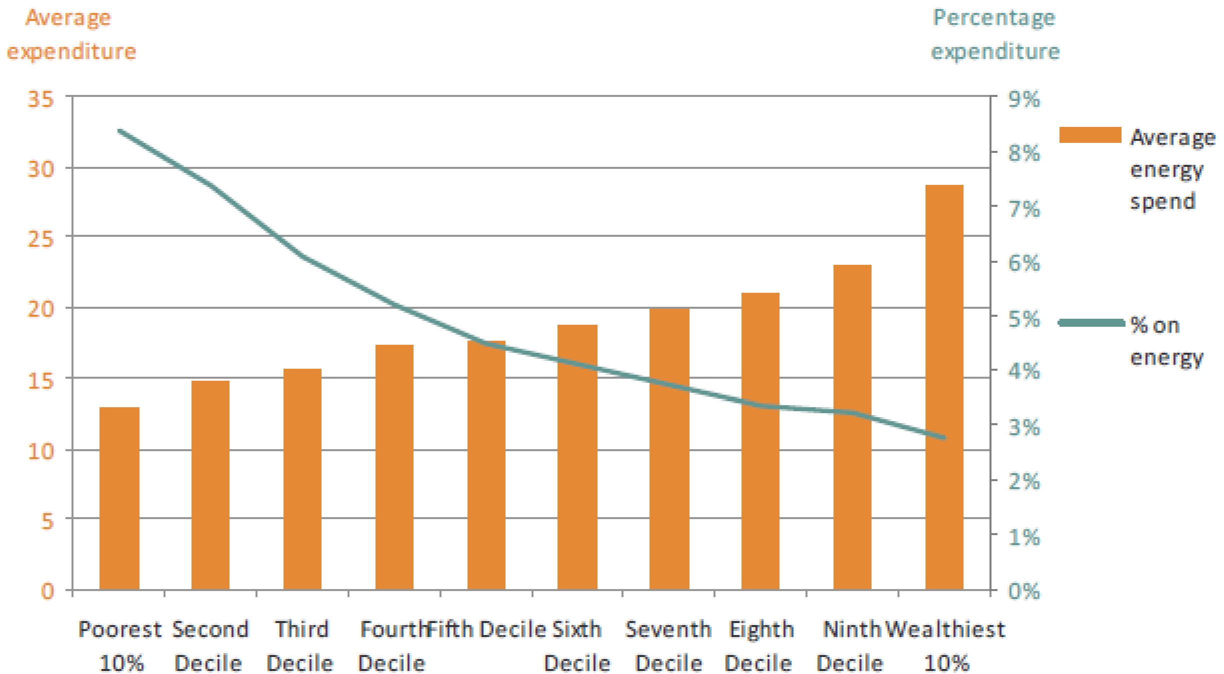
Controlled ventilation – B: heat recovery no tricklevents!

3. By mechanical ventilation with heat recovery (MVHR) in each wet space – extract fan takes heat from exhaust air and preheats incoming air to that space.

4. Whole house MVHR – ducted extraction from wet spaces to a central heat exchanger, drier preheated fresh air supplied to habitable spaces



kWhr/m2/per year-
per person?



Graph 4k: Average UK weekly expenditure on fuel, light & power, & income (£/wk/hh) 2008

Summary

Recognise that buildings can't stay as they are, because the weather is changing & fuel prices are rising - so

- Wrap up warm, put on a mac – and keep breathing!

Then

- Consider heating less space
- Consider sharing your space
- Consider if other things need changing too