Routes for Nearly Zero Energy

Cardiff

10th March 2015

Co-funded by the Intelligent Energy Europe Programme of the European Union

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Chief Executive

Constructing Excellence in Wales

Co-funded by the Intelligent Energy Europe Programme of the European Union

PassREg Project

Routes for Nearly Zero Energy

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Past President, Royal Society of Architects in Wales

Part of the BRE Trust

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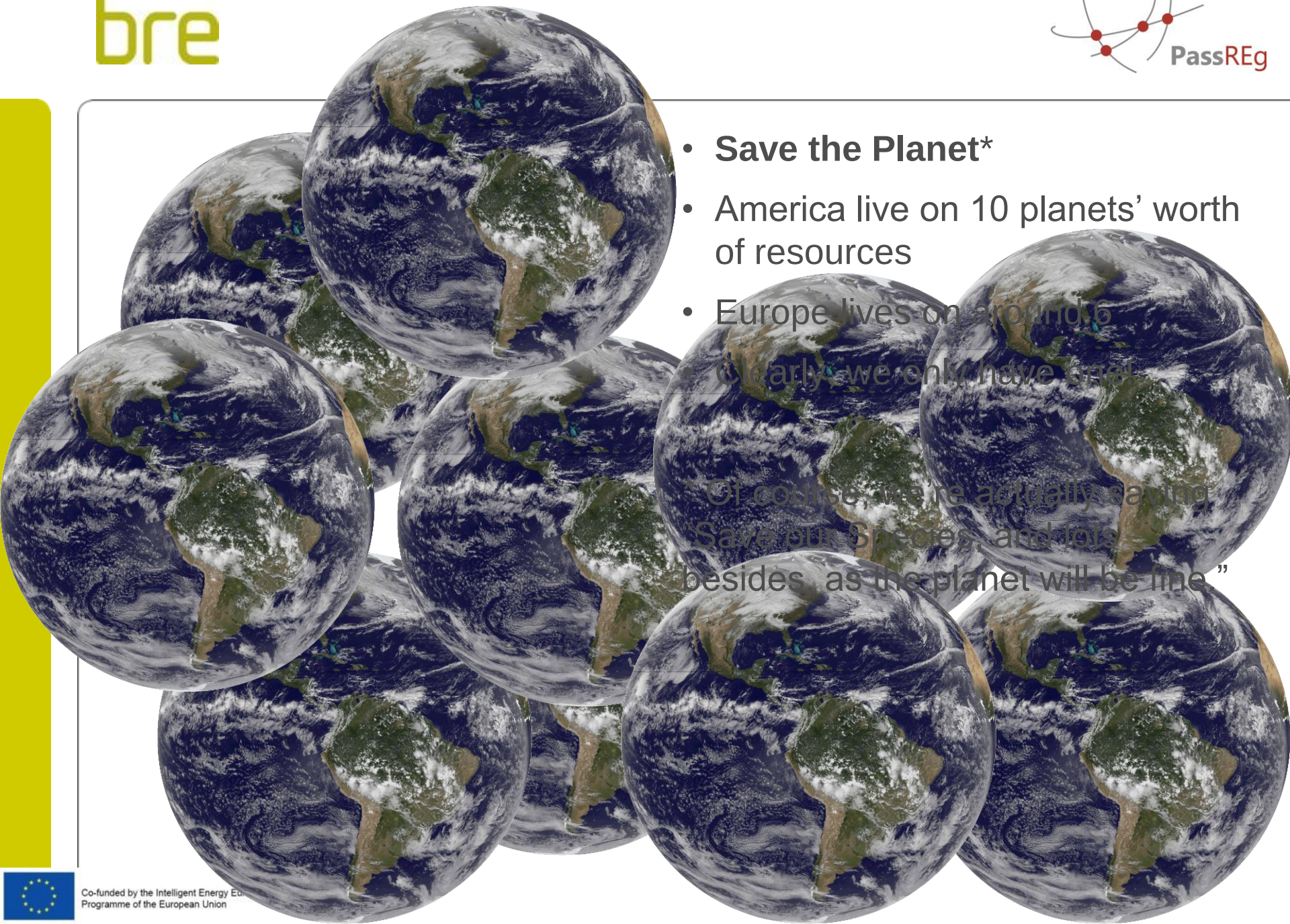

- **Save the Planet***
- America live on 10 planets' worth of resources
- Europe lives on around 6
- Clearly, we only have one
- Of course, we're actually saving "Save our Species, and lots besides, as the planet will be fine"

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- Ignore the planet, **it's the Law!**
- UK Legislation:
  Climate Change Act (2008)
- 80% reduction in Carbon emissions compared to 1990 levels
- Applies across the whole of UK, including construction sector

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- Ignore Law, **keep the Lights on!**
- Oil & Gas peaked in 2010
- Coal peaked before that
- Nuclear peaks in 2020
- Plus mostly imported – currently 40% Middle East, 40% Russia

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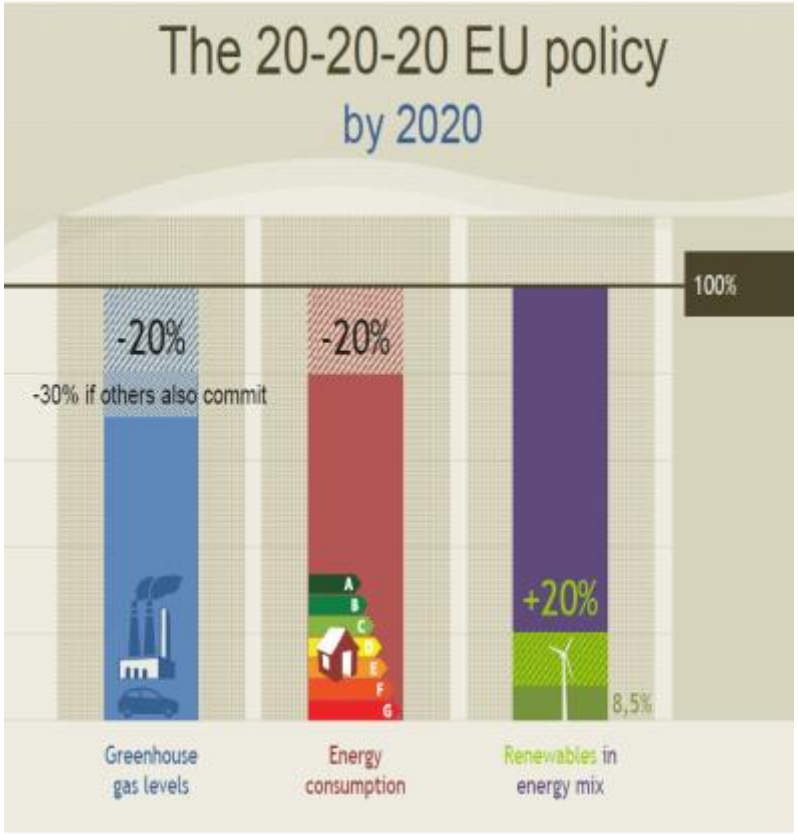

- EU Response: **20-20-20 Policy**
- Underpins many decisions
- 20% reduction in CO_2 levels
- 20% reduction in consumption
- 20% increase in renewables
- To be achieved by 2020

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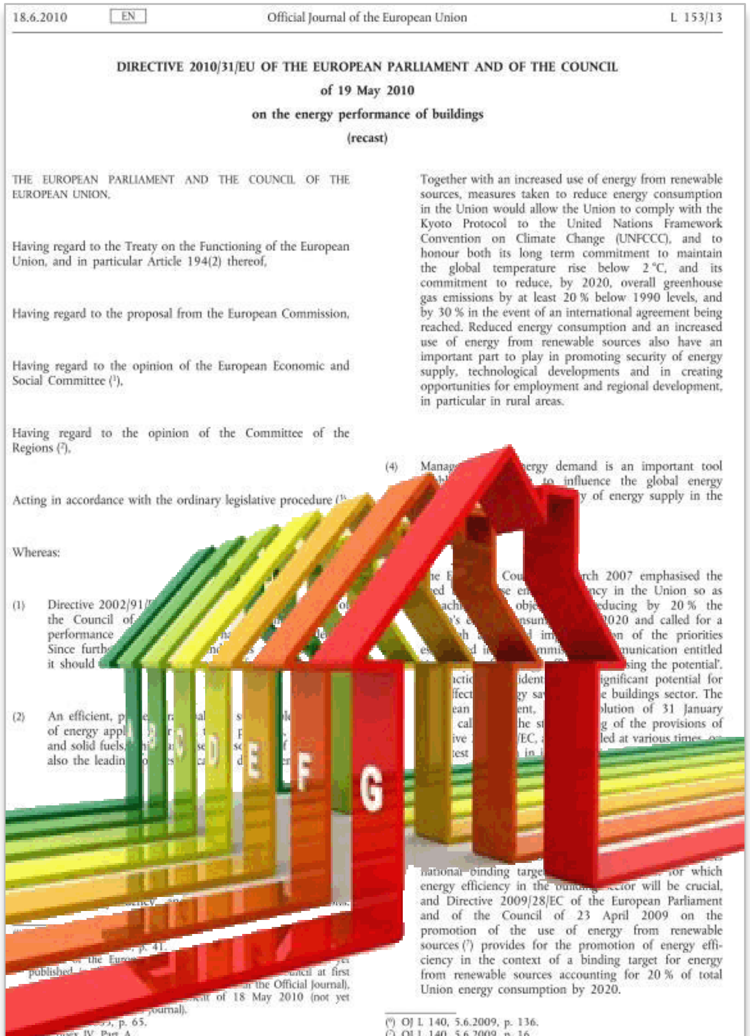
18.6.2010 EN Official Journal of the European Union L 153/13
DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 19 May 2010
on the energy performance of buildings
(recast)
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Having regard to the proposal from the European Commission,
Having regard to the opinion of the European Economic and Social Committee (¹),
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(⁶) OJ L 140, 5.6.2009, p. 136.
(⁷) OJ L 140, 5.6.2009, p. 16.
G

- For construction, this is EPBD: **Environmental Performance of Buildings Directive**
- Originally 2002, recast 2010/11
- EU Directives are Directives for Member States to act, not citizens
- For UK, this primarily means we see the change through our Building Regs., and mostly Part L.
- Part L changes so far in 2002, 2006, 2010, 2014… …and probably '16/'17 & '19/'20

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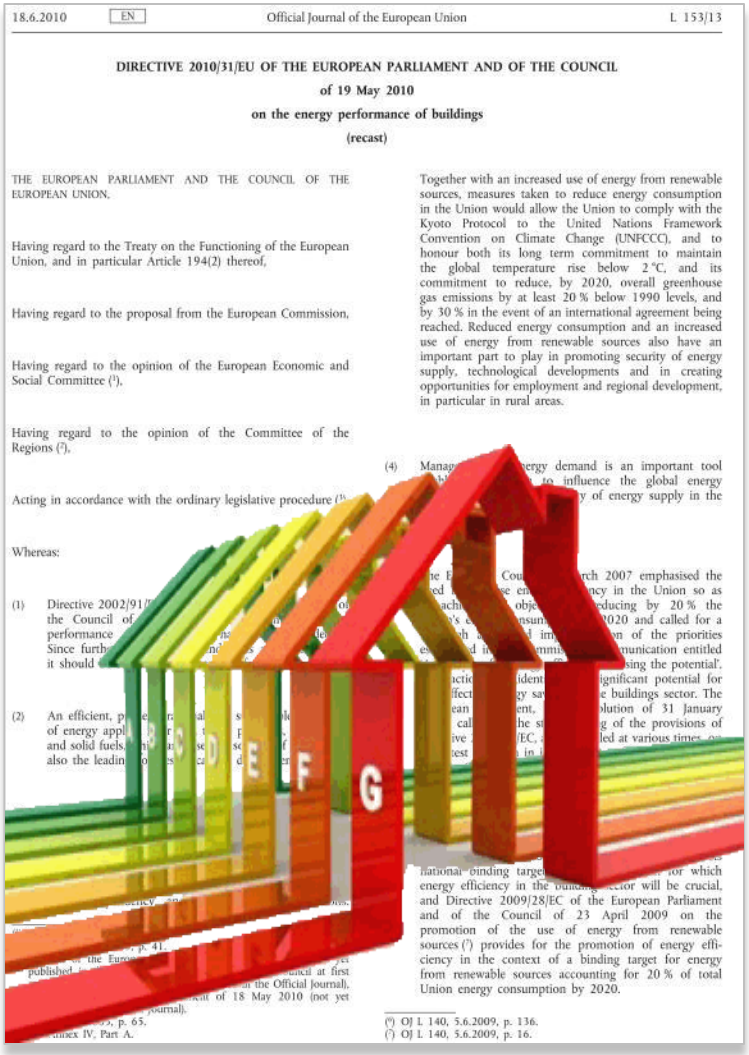

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, p. 65.
nnex IV, Part A.

(1) OJ L 140, 5.6.2009, p. 136.
(2) OJ L 140, 5.6.2009, p. 16.

- **EPBD** requires UK to deliver:
- **Nearly Zero Energy Buildings** (**nZEB**)
  for public use by December **2018**
- **Nearly Zero Energy Buildings** (**nZEB**)
  for all by December **2020**
  (i.e. a little over 2,000 days time)

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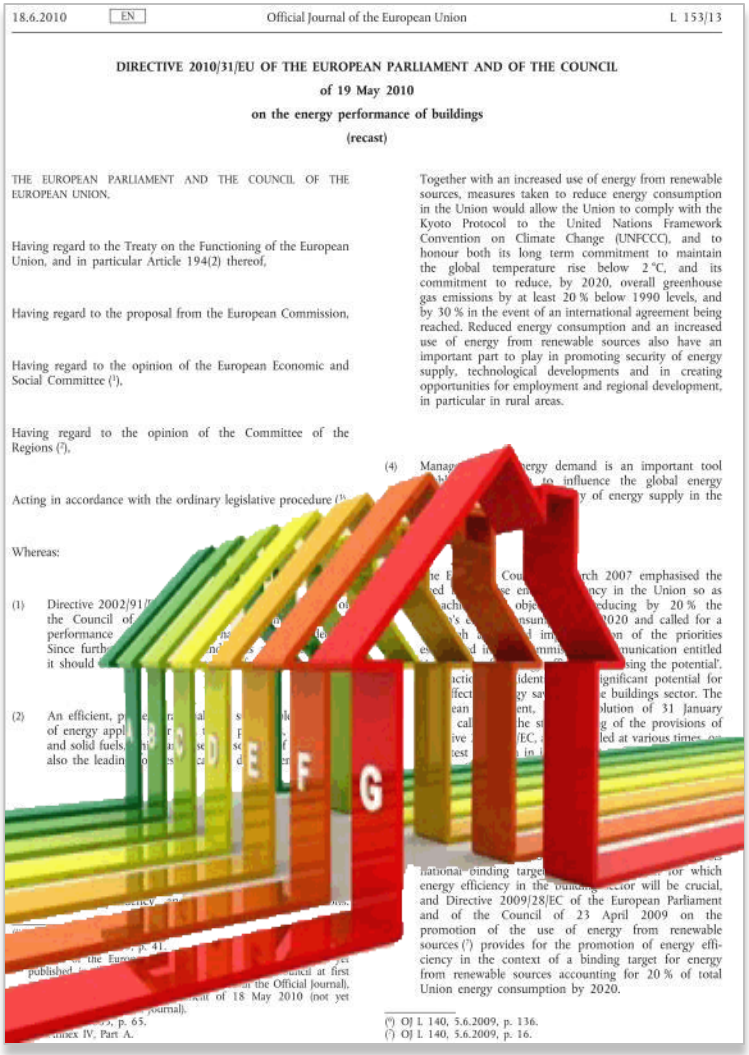

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Annex IV, Part A.

- So what is **Nearly Zero Energy**?
- **EPBD** say the technical method is defined by UK government
- Wales has devolved powers to set standards within UK method
- But, Wales has to achieve the overall EU target of nZEB and the overall EPBD;
  Any Standard as long as its Green!
- Expect **nZEB** to "feel" like;
  - CfSH 4+
  - BREEAM Excellent+
  - c.19% better than 2014 B Regs
- But subject to the May '15 Election

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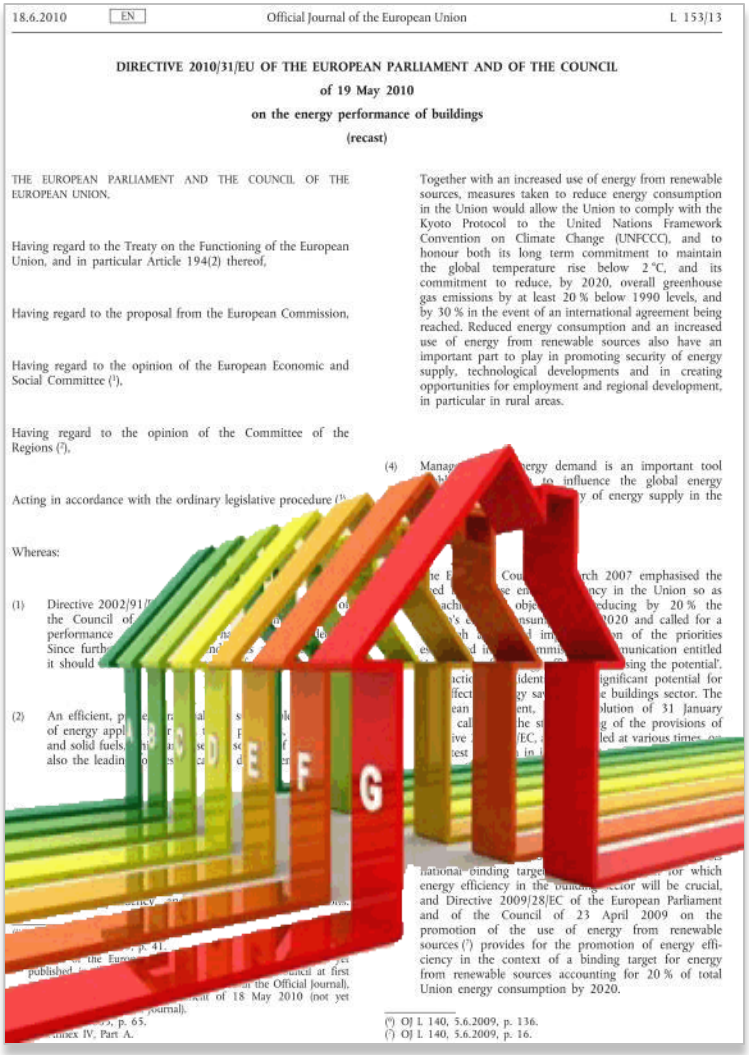

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- **EPBD** talks of “Energy” and in the UK we’re used to talking about “Carbon”, but similar implications
- **EPBD** also requires consideration of alternative energy systems when developing schemes
- After achieving **nZEB**, the EPBD requires that remaining energy demand should be met “to a very significant level” by renewables

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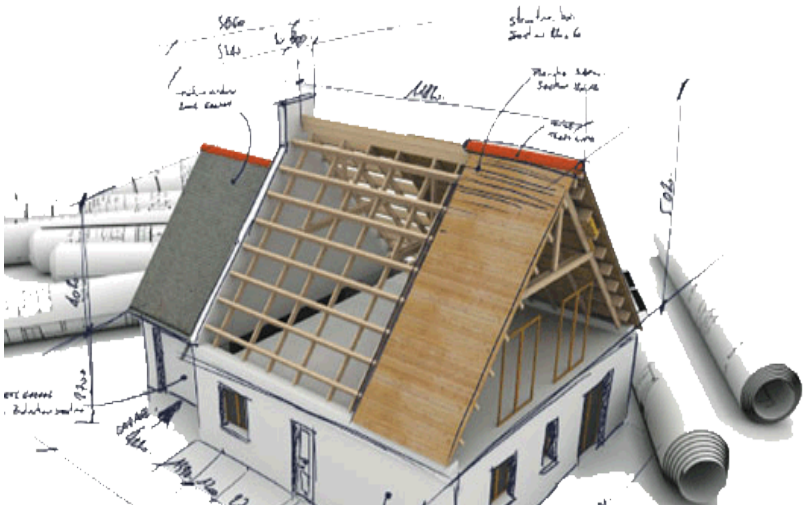

- *Possible* that **EPBD**, or **UK** interpretation may try to address the actual performance, not just the designed performance
- So what we actually build, not what we say we've built.

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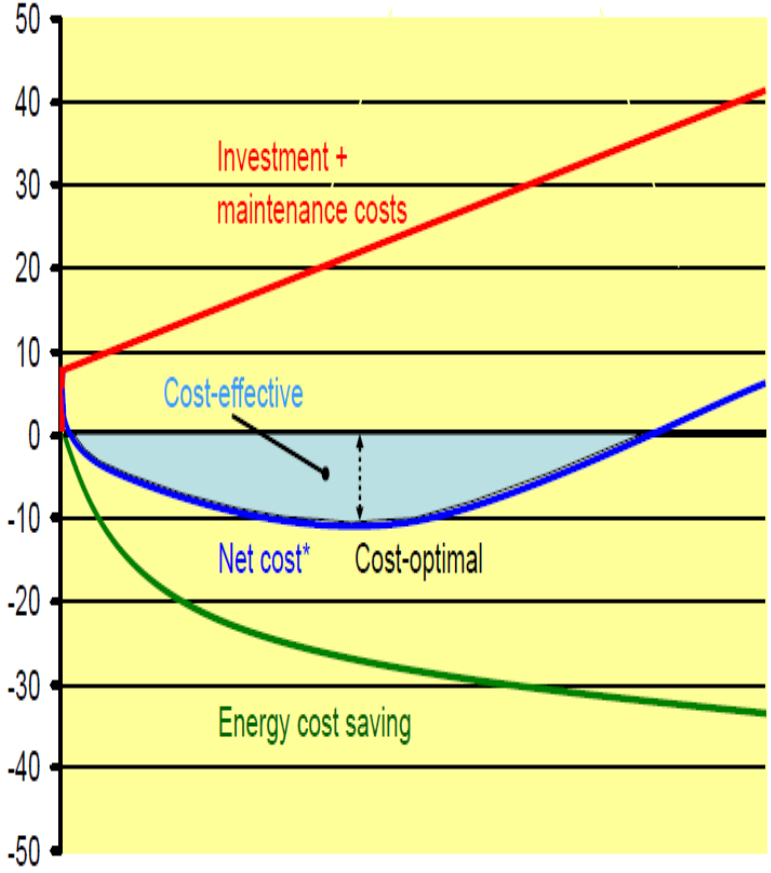

Simplified Cost / Time for "Cost Optimal"

- **EPBD** says all this must be done in a "**Cost Optimal**" fashion…
- That's not just Capital Cost; that's lifecycle cost, including:
  - Investment
  - Maintenance
  - Operation
  - Energy (inc. energy sales)
  - Disposal
- Nations that have more than a 15% gap between standards and cost optimal will be challenged
- But that's not all…

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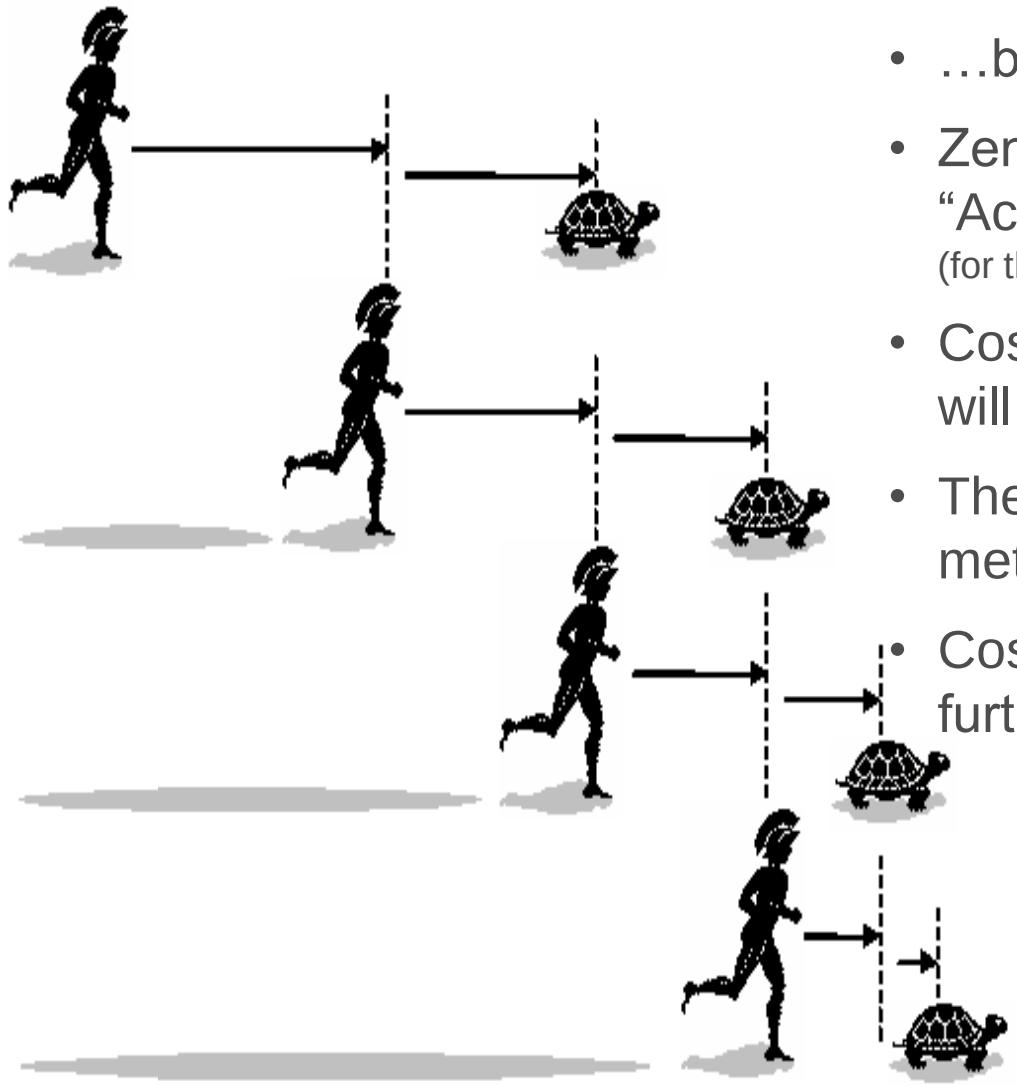

- …because **Cost Optimal** is tricky!
- Zeno's paradox -
  "Achillles & the Tortoise"
  (for the Greek literati in the audience!)
- Cost Optimal for nZEB currently will be set in Building Regs.
- The Industry will (should!) improve methods to achieve this target
- Cost Optimal will then move a little further ahead of us…

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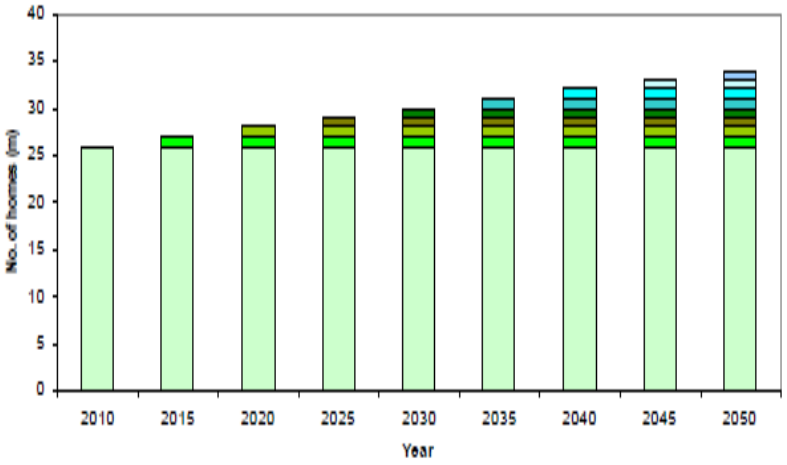
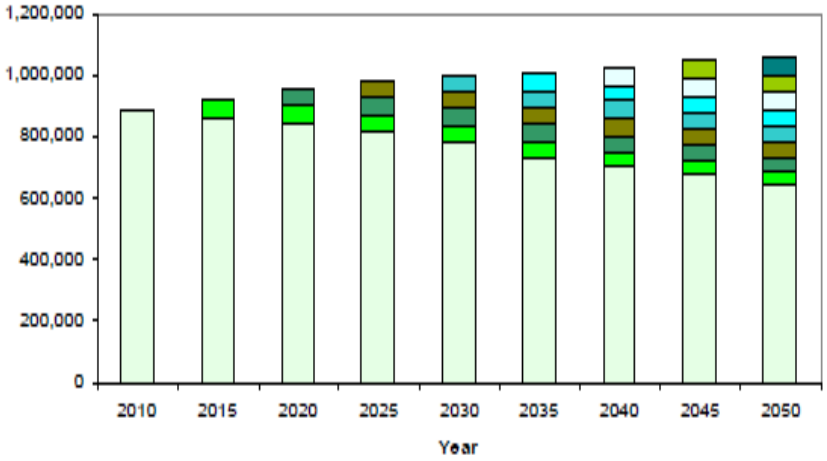


Domestic building rate



Non-Domestic building rate

- But isn't the real problem the existing stock?
- **EPBD** applies to refurbishment, so **UK Regs** will have to as well
- "Major Renovation" is defined as 25% of surface or of value
- Includes technical systems as well as building elements
- Caveated by "*technically, functionally and economically feasible*"
  (but you can bet this will be tied to Cost Optimal, not capital price!)

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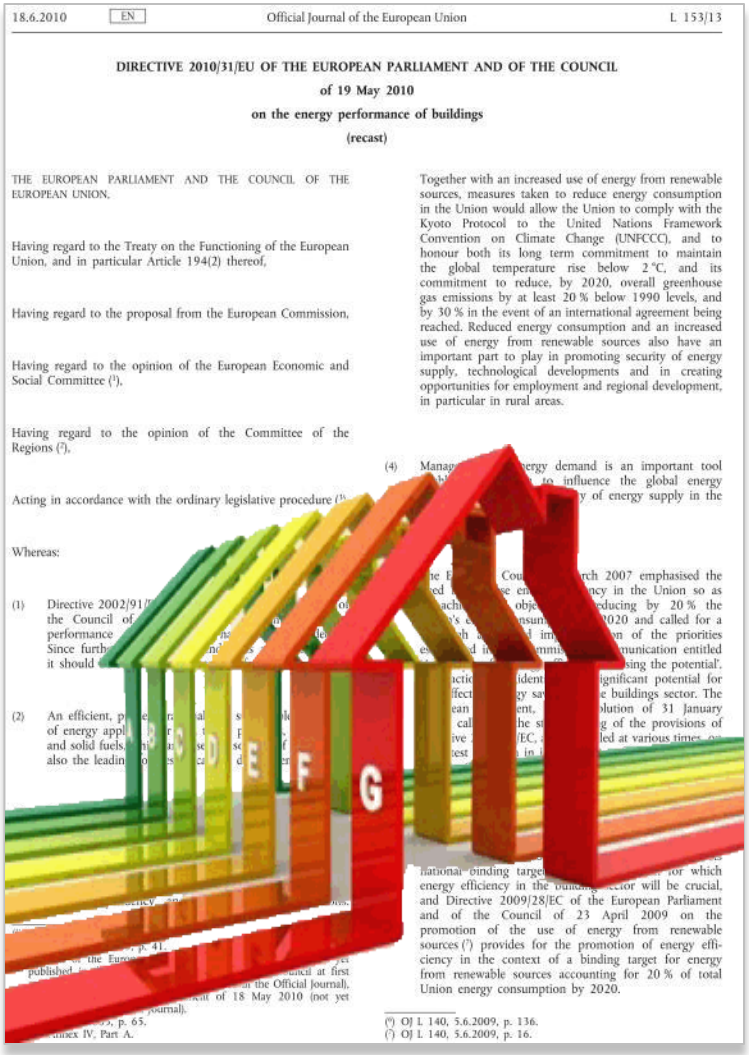

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- **EPBD;**
  - Nearly Zero Energy
  - New & major refurbishment
  - Remaining energy low carbon
  - Cost Optimal method
- **by End of 2020**
  (or 2018 for public)

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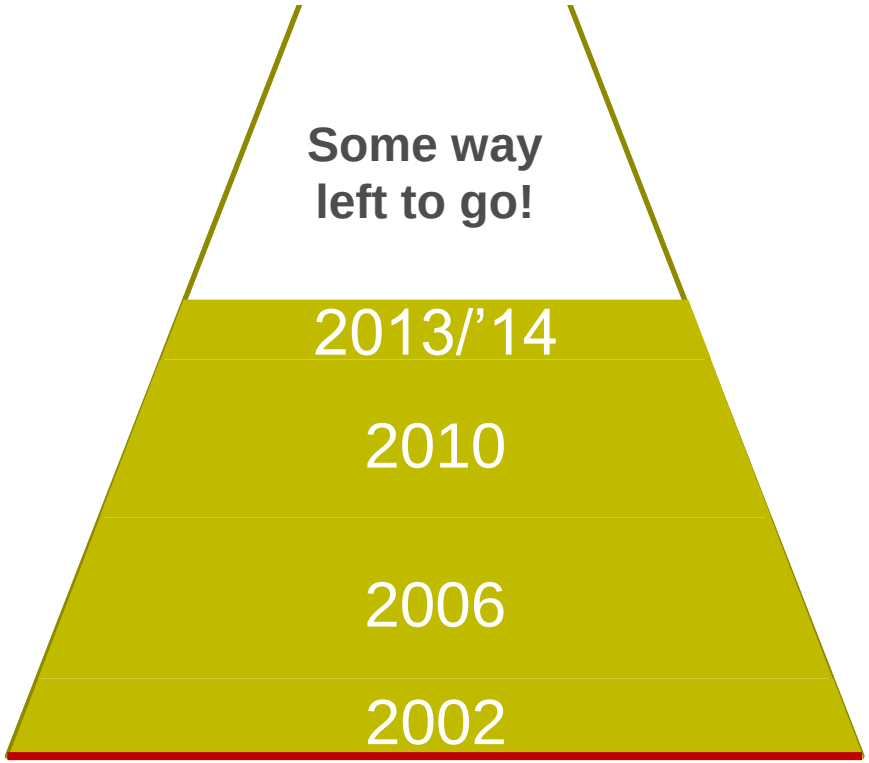
“Zero” Carbon



- **How far have we got so far?**
- “Zero Carbon” is not nZEB, but is roughly the goal with “significant renewables” requirement in EPBD
- 2002 improved around 10-15%
- 2006 improved c.25%
- 2010 improved c.25%
- Zero Carbon redefined to exclude unregulated energy
- 2014 improved c.9%

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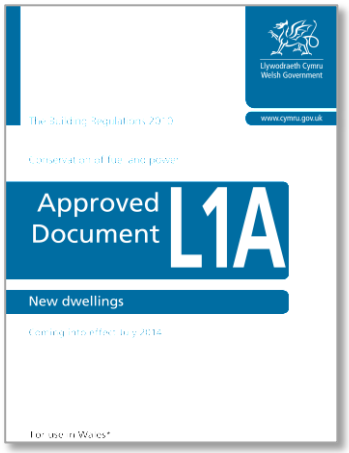

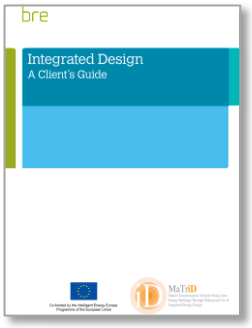

- **What next?**
- Wales has not yet set Standards to map out nZEB delivery
- Obliged to use SAP/SBEM tools
- Dropped TAN22 requirements, looking to deliver in Regs
- Some current topics that may be considered:
  - Performance Gap
  - Integrated Design

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- **What is England doing?**
- **Domestic first** (*slightly* clearer!)
- Intending to deliver "Zero Carbon" by 2016 (although the redefined version)
- Broken into 3 steps:
  - Fabric Energy Efficiency
  - Carbon Compliance
  - Allowable Solutions
- Has EPBD obligations for 2020 that may impact after this, given the "Cost Optimal" clause

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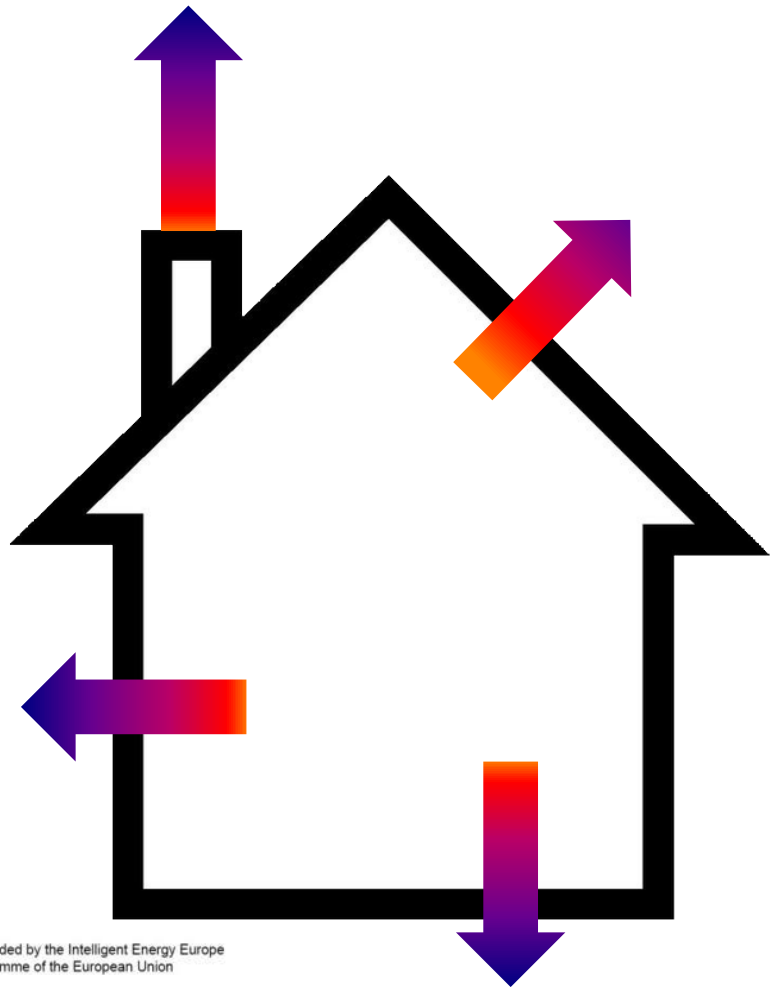

- Fabric Energy Efficiency Standard **FEEs**
- Minimum overall performance of building fabric & systems on site;
  - U-Values
  - Thermal bridges
  - Airtightness
  - Heating (& cooling) system(s)
  - Lighting
- Means the energy used to maintain internal comfort per year per m^2 of building; $kWh/m^2/annum$
- Not to be confused with nZEBs primary energy, which uses the same scientific units

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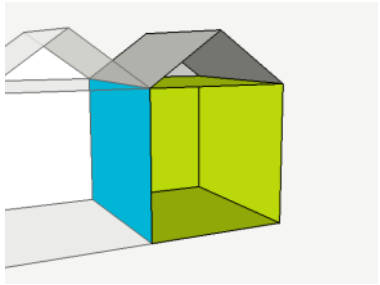
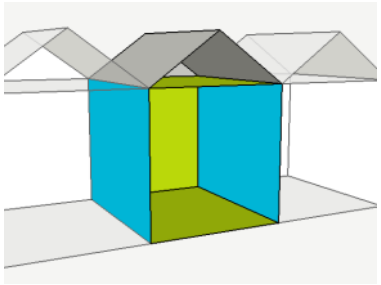


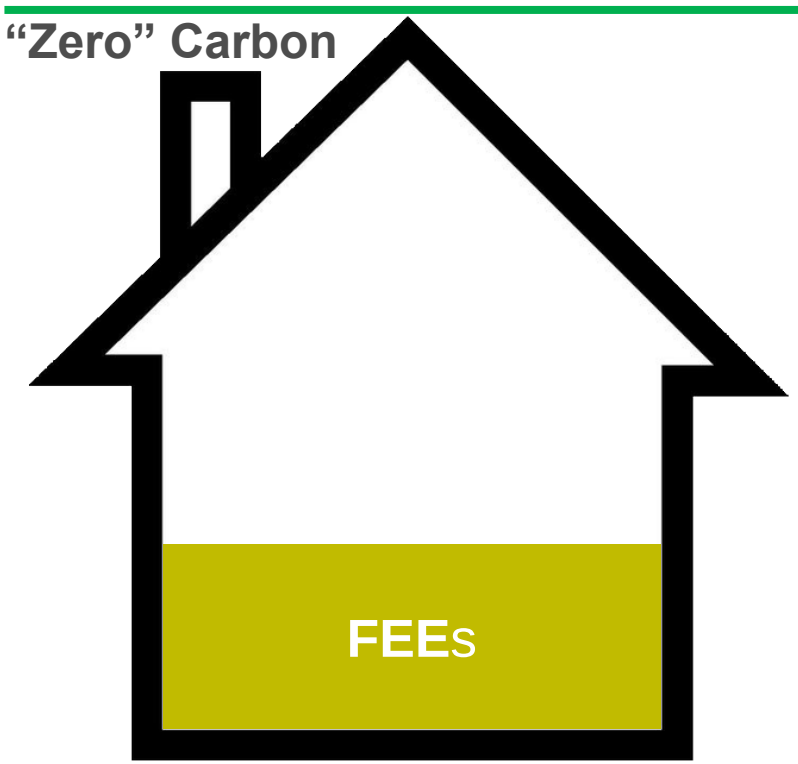


- Fabric Energy Efficiency Standard **FEEs**
- **Detached** or **Semi detached** **= c.46** kWh/m^2/annum (full)

  = c.52 kWh/m^2/annum (interim 15% relaxation)
- **Terraced & Apartments** **= c.39** kWh/m^2/annum (full)

  = c.43 kWh/m^2/annum (interim 15% relaxation)
- Backstops for worst performance of particular elements

  (Wales pushed these harder in 2014 B. Regs than England has done so far)



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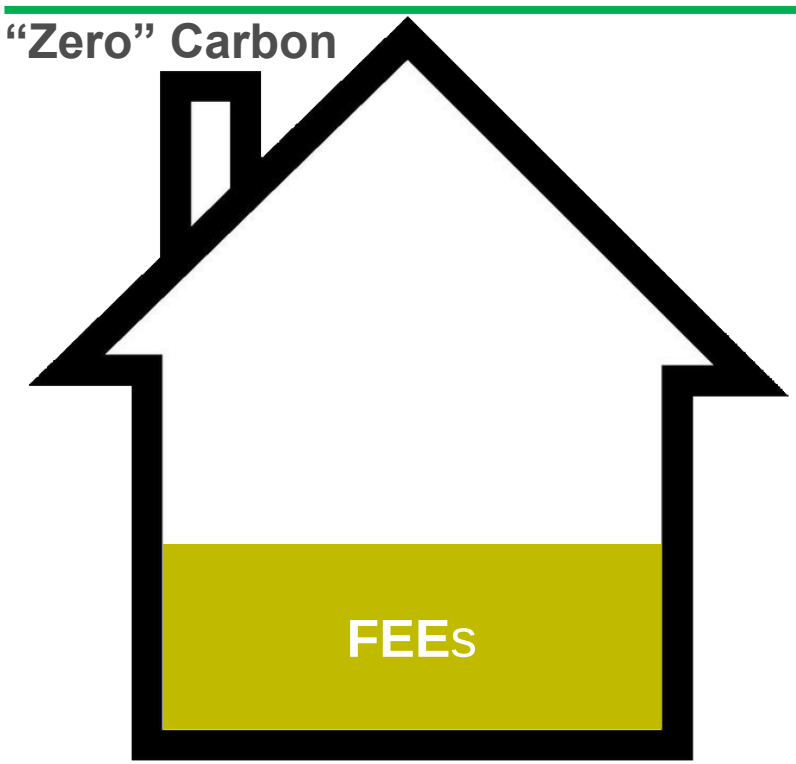

- **Carbon Compliance**
- Minimum energy demand of building fabric & systems on site
- Expressed as maximum energy demand per m^2 of building per year; $kg/CO_2/m^2/annum$
- Being seen as England’s interpretation of **near Zero Energy Buildings** under the EPBD
- All impacted by Election May ‘15!
  - Tory’s 19% over ‘13
  - Lib Dems possibly 19% too?
  - Labour 52% over ’10
  - Greens “zero” new & refurb.
  - UKIP will just abolish it all

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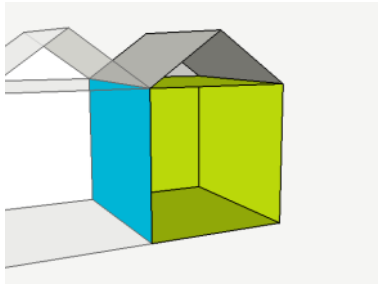
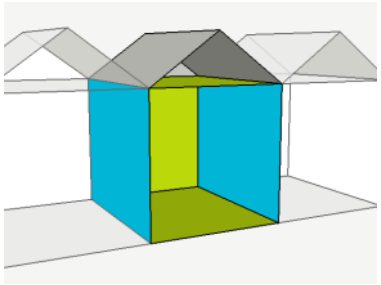
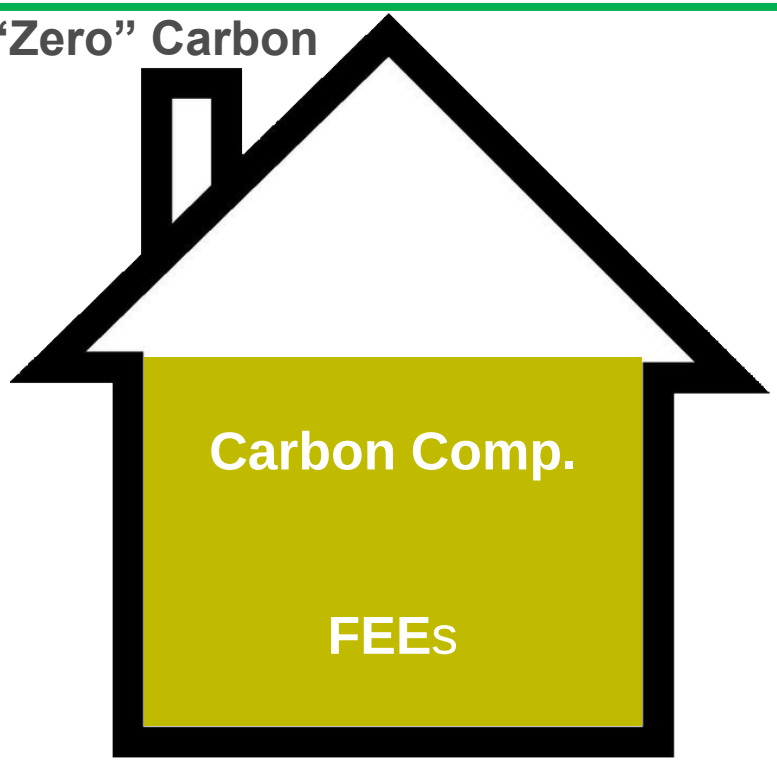




"Zero" Carbon



- **Carbon Compliance**
- Currently proposed as…
- **Detached**
  = 10 kg/CO_2/m^2/annum
- **Semi or Terraced**
  = 11 kg/CO_2/m^2/annum
- **Apartments**
  = 14 kg/CO_2/m^2/annum

(And all subject to an election!)

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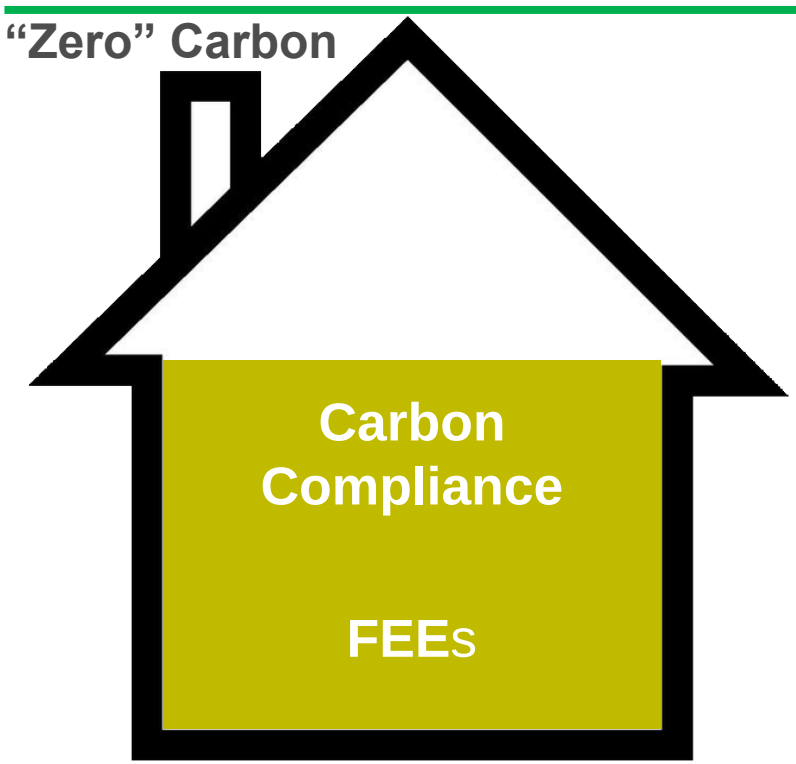

- **Allowable Solutions**
- One-off payment to ‘offset’ the remaining emissions to “zero” carbon
- Several types proposed:
  - DIY onsite or offsite abatement (including District Heating & local upgrade of other houses off site)
  - Independent carbon abatement contract with third party
  - Pay into a “Carbon Fund”

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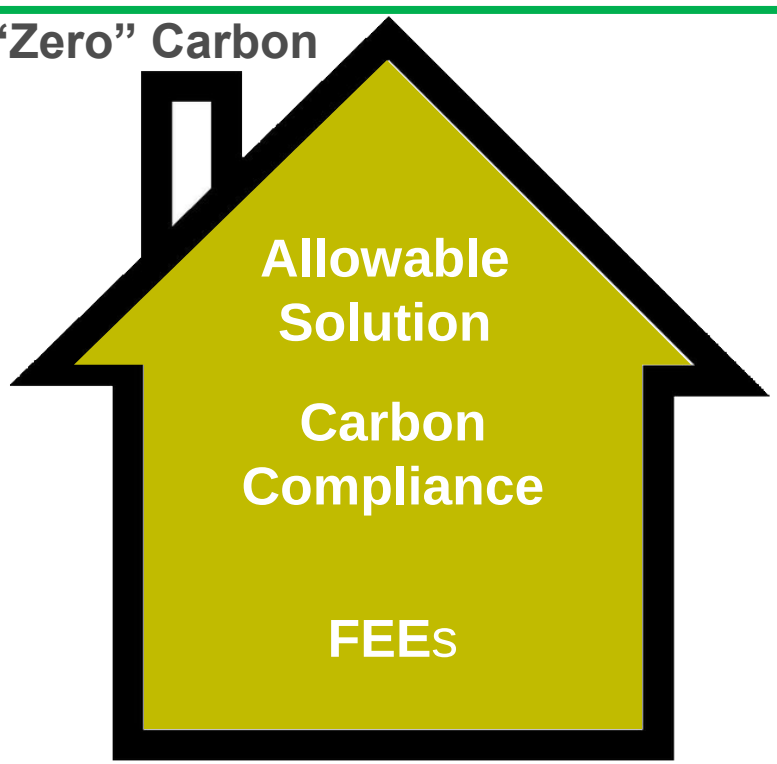

- **Allowable Solutions**
- Price cap for Carbon Fund likely to be set & reviewed every 3 years
- Cap anywhere between £36 / £46 / £60 / £90 per tonne
- Will be applied over a duration; 30 years currently proposed
- Allowable Solution price =
  - Carbon still 'emitted' from site
  - x m^2 of property
  - x cost of carbon (£60?)
  - x duration (30 years?)
- Price (& duration) yet to be set – big consequences for this!

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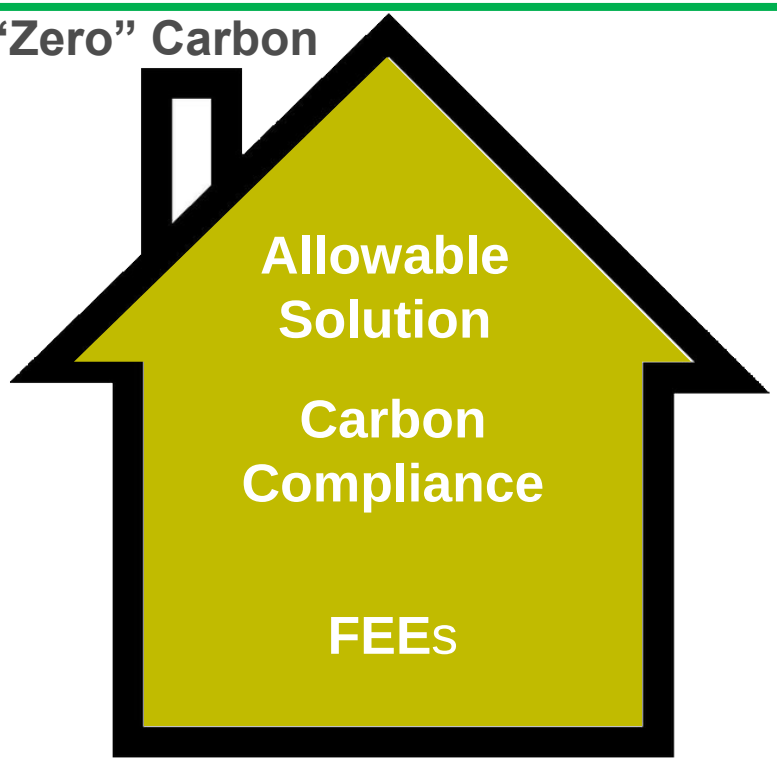

- **How does it work in reality?**
- FEEs has a minimum, no (theoretical) maximum but the law of diminishing returns
- Carbon Compliance + FEEs has a minimum but no maximum
- Allowable Solutions will have to make up the rest; no minimum requirement

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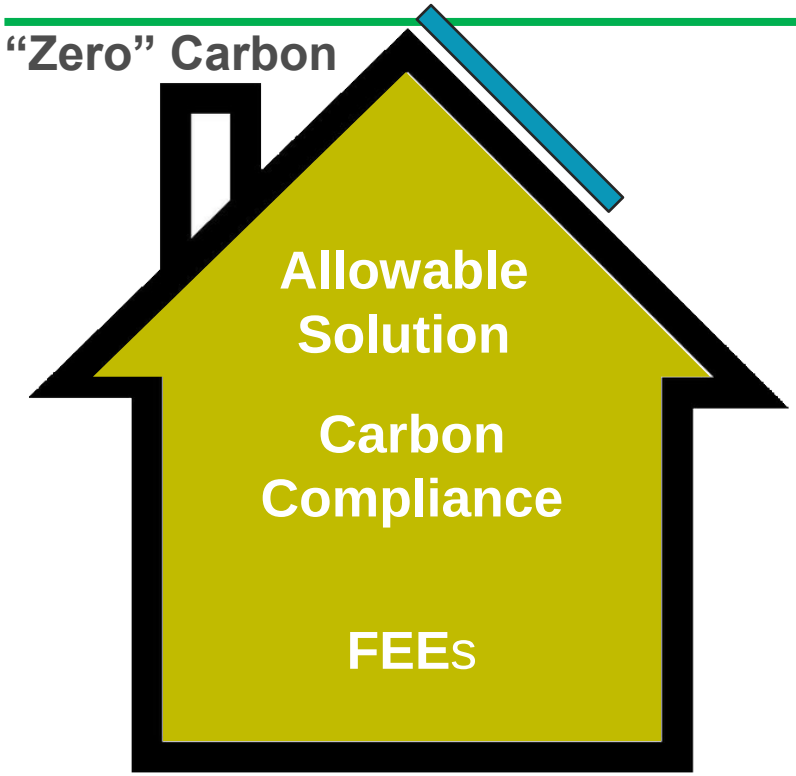

- **Option 1 – Staggered**
- Deliver FEEs to about **46** kWh/m^2/annum (detached)
- Deliver Carbon Compliance with some on-site renewables to **10** kg/CO_2/m^2/annum (detached)
- Pay your Allowable Solution fee i.e. **£1,800**

  Based on 100m^2 detached house & "central" carbon cost of £60/tonne over 30 years

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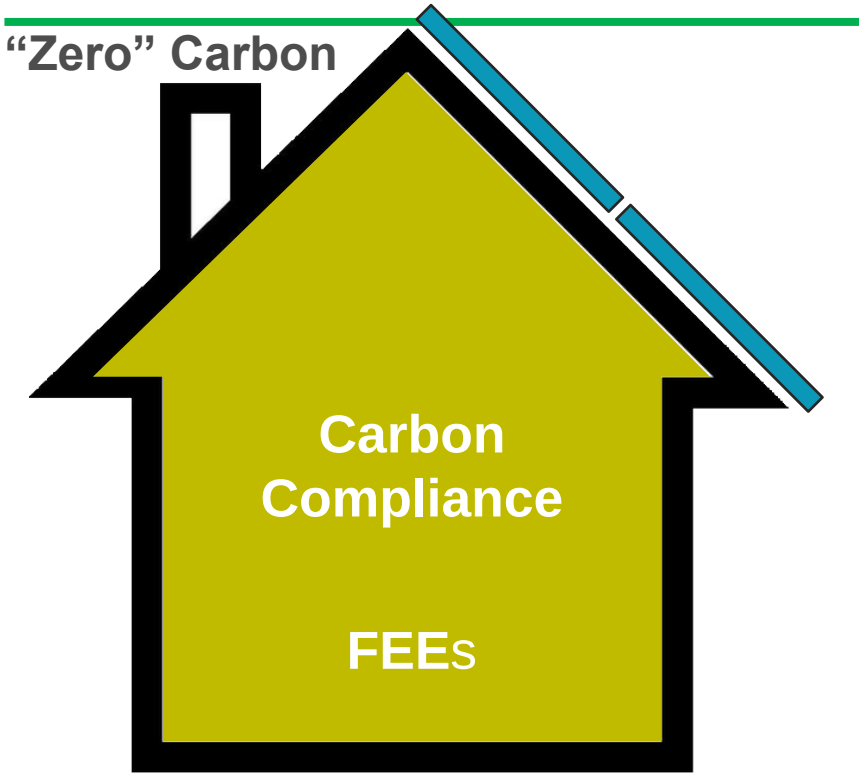

- **Option 2 – Max Renewables**
- Deliver FEEs to about **46** kWh/m^2/annum (detached)
- Push well beyond Carbon Compliance with some on-site renewables to **0** kg/CO_2/m^2/annum
- Don't pay any Allowable Solution **c.£0**

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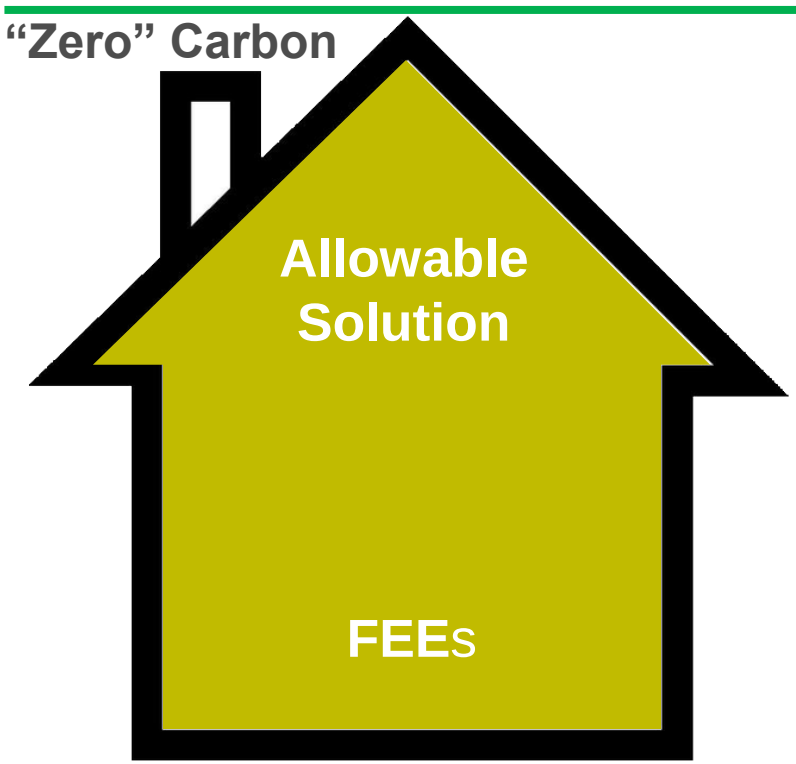

- **Option 3 – Max Fabric**
- Push well beyond FEEs to get as close to **0** kWh/m^2/annum as you can
- Don't do any on-site renewables with Carbon Compliance met at **10** kg/CO_2/m^2/annum (detached)
- Pay your Allowable Solution fee i.e. **£1,800**

  Based on 100m^2 detached house & "central" carbon cost of £60/tonne over 30 years

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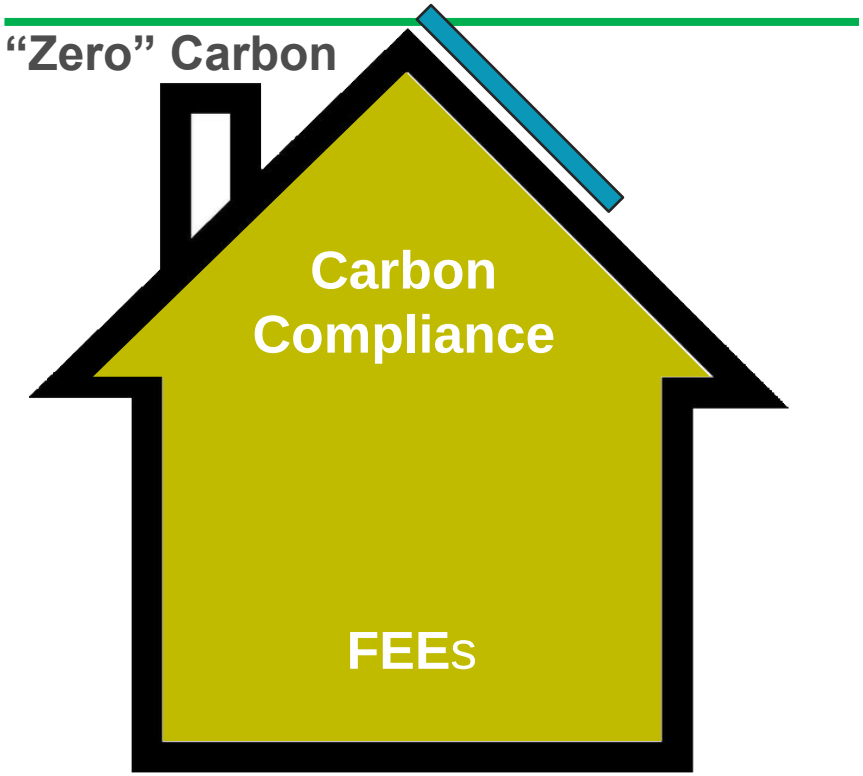

- **Option 4 – Max Everything!**
- Push well beyond FEEs to get as close to **0** kWh/m^2/annum as you can
- Push well beyond Carbon Compliance with some on-site renewables to **0** kg/CO_2/m^2/annum
- Don’t pay any Allowable Solution **c.£0**

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- **What is England doing?**
- **Non-Domestic**
- Significant challenge around the variety of building types
- Some types may have already reached optimal fabric, others have further they can go
- Likely to still be broken into the same three basic steps:
  - Fabric Energy Efficiency
  - Carbon Compliance
  - Allowable Solutions
- More appetite for ‘high level’ targets that require consultants to calculate compliance

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COUNTRY	ENERGY USES INCLUDED	ENERGY PERFOR-MANCE	RENEW-ABLE ENERGY SHARE
Cyprus	Regulated energy	180 kWh/m²/ year	25%
Belgium (Brussels)	Heating, DHW, appliances	45 kWh/m²/ year	-
France	Regulated energy	50 kWh/m²/ year	-
Denmark	Regulated energy	20 kWh/m²/ year	51-56%
Latvia	Regulated energy	95 kWh/m²/ year	-

- **What's everyone else doing?**
- England = FEEs c.43.6 kWh/m²/annum
- Denmark = 20 kWh/m²/annum
  (and renewables around 50+%)
- Brussels = 45 kWh/m²/annum
- France = 50 kWh/m²/annum
  (including unregulated energy too!)
- Latvia = 95kWh/m²/annum
  (and renewables at 25%)
- Cyprus = 180 kWh/m²/annum
  (you have to wonder if they'll manage to do this!)

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- **Wales has to decide!**
- Any questions on EPBD before we show examples from Europe?

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Passivhaus principles: influencing future construction

Caroline Weeks
BRE Wales & SW

Part of the BRE Trust

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Enhanced fabric performance standards: Lessons from Passivhaus

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Content: Part 2

- EU PassREg ‘Passive Regions’ project, aims and lessons
- What is Passivhaus? Key principles
  - Insulation
  - Thermal bridging
  - Windows
  - Airtightness
  - MVHR
- Beacon projects in Wales
  - Carmarthenshire school
  - Cardiff Council Housing Partnership Programme
- Quality Assurance to close the performance gap
- Passivhaus principles influencing future construction

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The PassREg project

14 Partners. 11 Countries. 3 Years. 1 Goal.

Supporting the growth of Passive House regions to implement EU ‘near zero energy’ goals in buildings from 2020

- PassReg helps aspiring regions succeed by:
  - Investigating successes
  - Making them known and accessible
  - Building up training, quality assurance and certification infrastructure
  - Stimulating the market for suitable products and professionals

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Key outputs of PassREg

- New Passive House buildings + RES throughout partner countries as case studies (*Carmarthenshire, Cardiff*)
- A ‘Success Guide’ detailing successes in frontrunner regions
- A ‘Set of Solutions’ detailing individual solutions and resources
- International and regional events and study tours
- Wider network of ‘Passivhaus aware’ professionals in the regions

See www.passreg.eu for further information

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Renewable sources limited by practical issues

- Renewable Energy Sources have a low energy density (the relative transfer of useful energy from the resource)
- Large areas are generally required (e.g. roof areas for PV, growing areas for biomass, etc)
- What about flats/ apartments?
- Focusing on energy efficiency to reduce demand is helpful to optimise the renewable resource
- For a typical family home built to Passivhaus standard, energy demand can often be offset by equivalent roof area of PV (approx.) (i.e. net zero energy onsite)

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PassREg Frontrunner Regions: already NZEB

Hannover, Germany

- Birthplace of PH concept
- Began in the 1980s
- Political consensus present / financial mechanisms in place

Brussels, Belgium

- Heart of EU
- Recent political commitment to the PH standard
- Rapid growth in PH new builds and retrofits

Tyrol, Austria

- Strong national and regional policies
- Social housing dominated construction market
- Vast improvements over last few years

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Drivers: Regulations and incentives

- Initially, introduced incentives/ subsidies based on energy performance (highest subsidy for Passivhaus standard)
- Example funding mechanisms: levy on energy prices to consumers to create national funds for subsidy (like UK FIT)
- Once capacity for delivering Passivhaus increased, Municipal Governments set minimum mandatory regulatory standards as Passivhaus for new construction
- Brussels report that it is now no more expensive to build Passivhaus (never lost skills of wet trades, so airtightness delivered at no extra cost)

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Key lessons from use of Passivhaus

- Standard successfully used all over the world (hot and cold climates)
- Used in all different types of building, not just houses (offices, schools, supermarkets, swimming pools…)
- Focus on design, detailing and onsite delivery; low/no cost elements transferrable to any scheme, particularly:
  - Thermal bridging
  - Airtightness
- Good reputation for meeting intended performance – minimal performance gap – thanks to Quality Assurance activities

http://www.passivhaustagung.de/Kran/Passivhaus_Kranichstein.htm

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What is Passivhaus?

- Internationally recognised building standard, originating in Germany
- Tried and tested over 2 decades
- Applicable to a variety of building types and climates
- Maximum comfort with minimal energy use and life cycle costs
- Assessed using the Passivhaus Planning Package (PHPP) calculation tool

Passivhaus buildings use up to 90% less energy than ‘typical’ buildings

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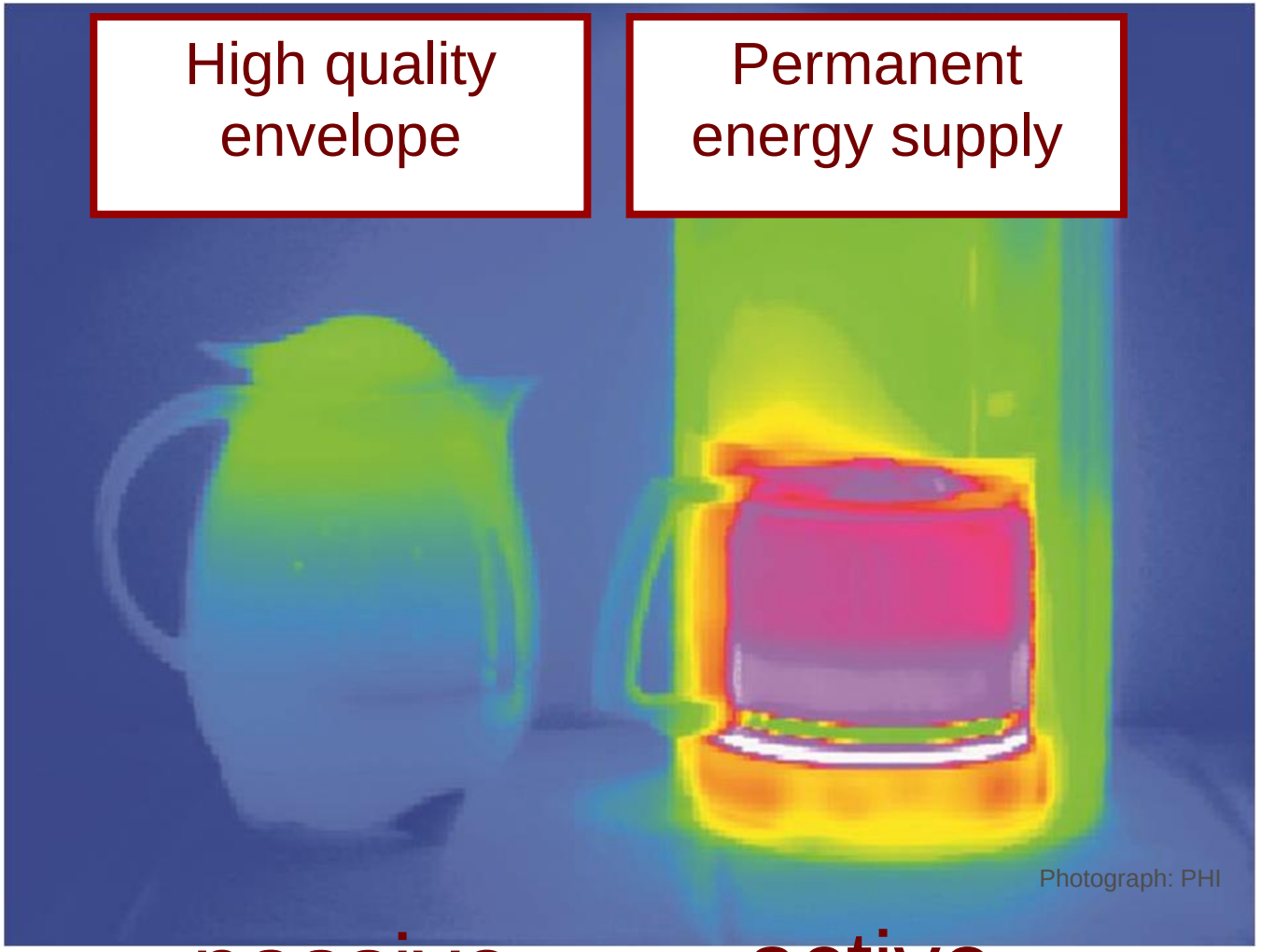
Why ‘passive’?



passive active

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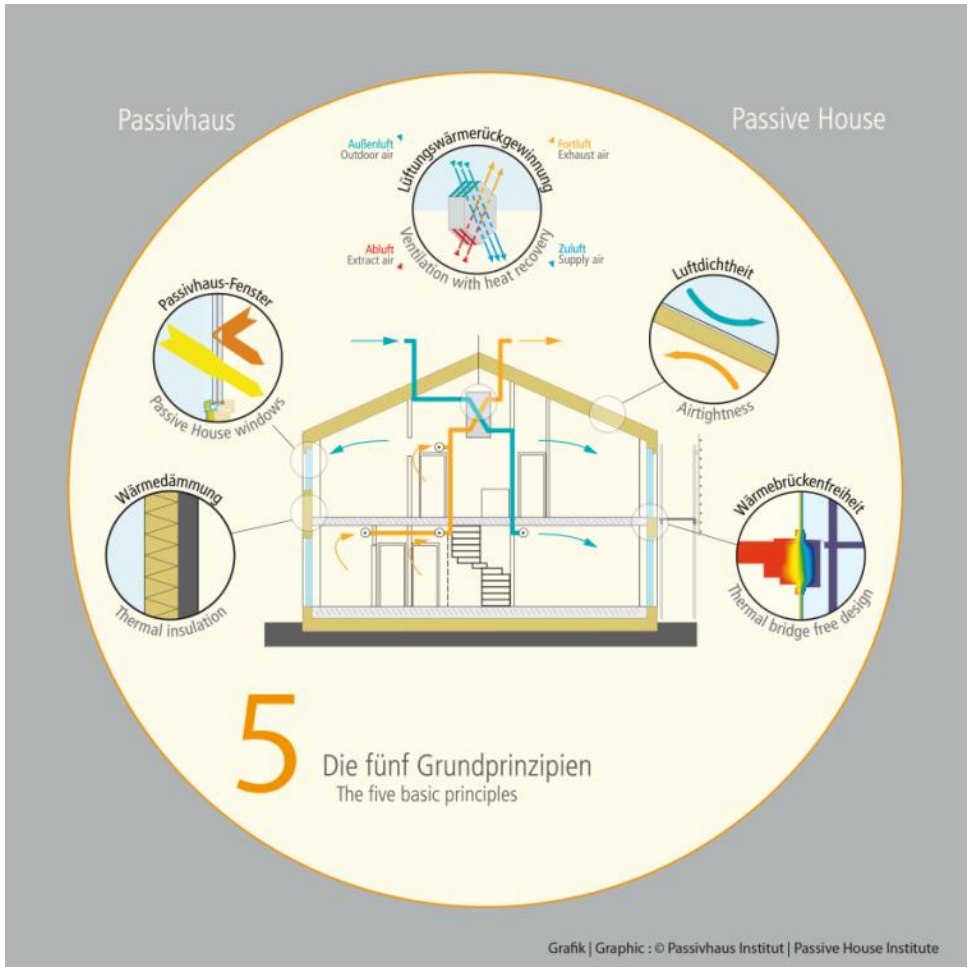
Key construction principles of Passivhaus: *Fabric first approach*

- Good thermal insulation (U values < 0.15 W/m^{2}K)
- Thermal bridge-free design
- Passivhaus windows (U_i values < 0.85 W/m^{2}K)
- Very good airtightness
- Ventilation with heat recovery



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Passivhaus Requirements

Energy (as measured by PHPP)

– Space heating demand: <15 kWh/m^{2}year

– OR, peak heating load: <10 W/m^2

– Primary energy: <120 kWh/m^{2}year

Comfort:

– Airtightness <0.6 ac/h @ 50Pa

– Overheating <10% over 25ºC

– Windows (installed) ≤0.8 W/m^{2}K (≤0.85 W/m^{2}K)

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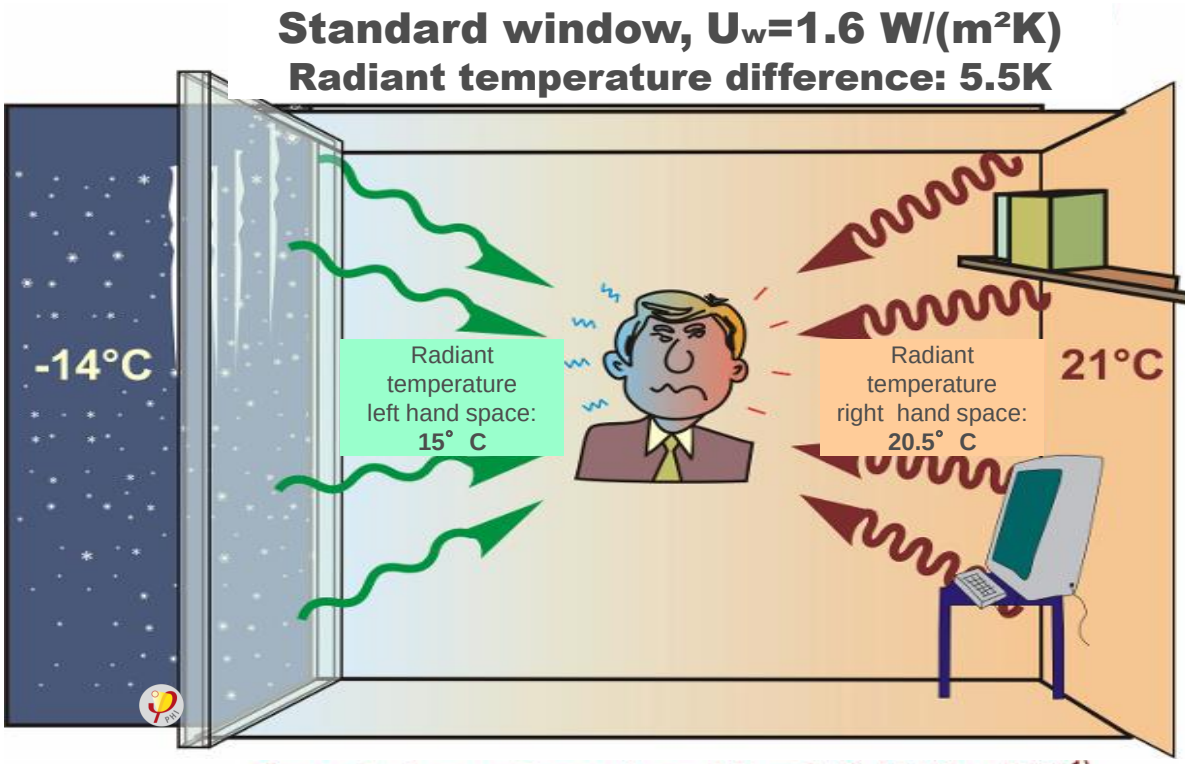
Glazing - Double glazed

Human comfort is significantly influenced by differences between surface temperatures



The radiant temperature asymmetry of 5.5 K is too high.
A radiator near the window would be required to compensate.

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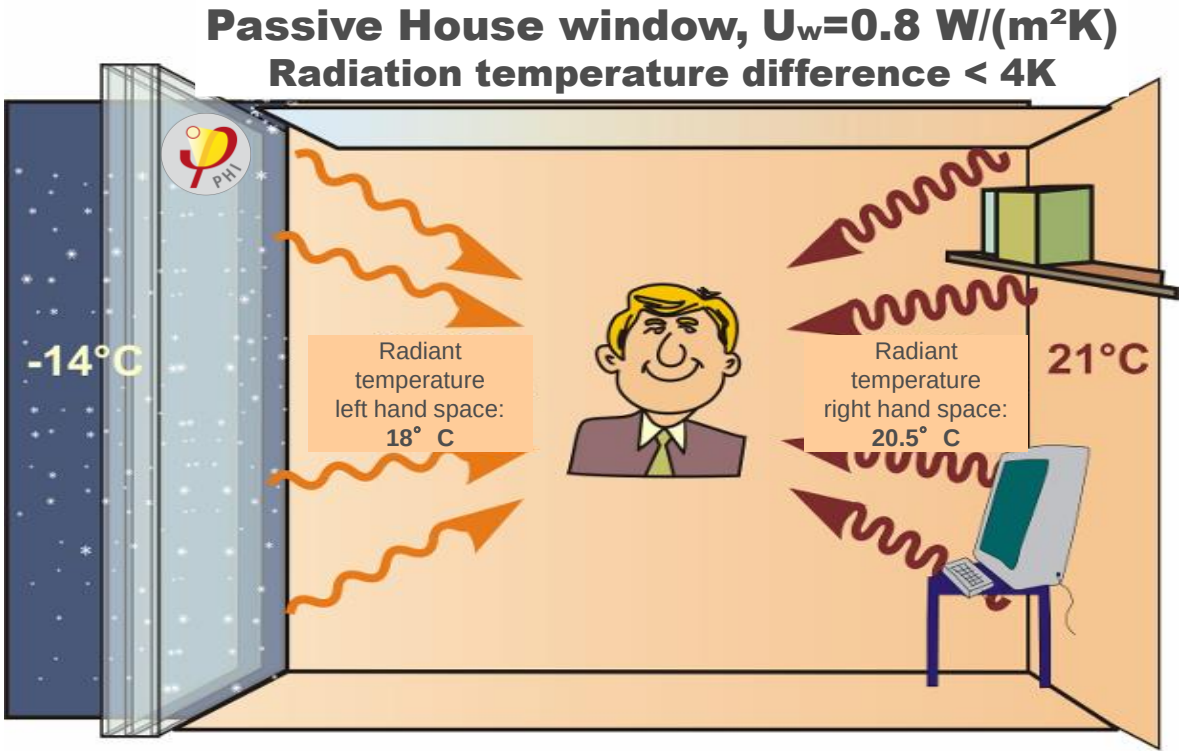
Glazing - Triple glazed

In a Passivhaus the time and location of the heat supply are arbitrary



With Passivhaus windows, the demanding requirements of the international standards for thermal comfort [ISO 7730] are met without a radiator placed under the window.

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Windows help deliver ‘free’ solar energy

- Some think of triple glazed PH windows as ‘radiators’ as they can provide the majority of heat for a building via solar gains
- Low window U value (triple glazing) to help prevent heat escaping
- Glazing ‘g’ value optimised to allow solar gains in winter
- Shading to reduce solar gains in summer
- Expensive component of a Passivhaus (but pays for itself over building life)

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Installation key to ensuring good performance

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How much fresh air is necessary?

A good quality of indoor air can be achieved with a continuous fresh air flow rate of
30m³ per hour for each person.

Window ventilation is insufficient

…and people don't like to open windows in winter!

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Comfort: MVHR

- ‘Uncontrolled’ air infiltration below 0.6 ac/h
- Fresh air delivered to occupants at 15-30 m^3/person.h through mechanical ventilation
- Constant circulation – no stagnant air
- Efficient heat recovery (>80%) provides fresh air with minimal heat loss, even in winter
- In summer, open the windows!

- Such low heating demand allows the space heating to be delivered via the ventilation air – no conventional heat distribution system (rads) required

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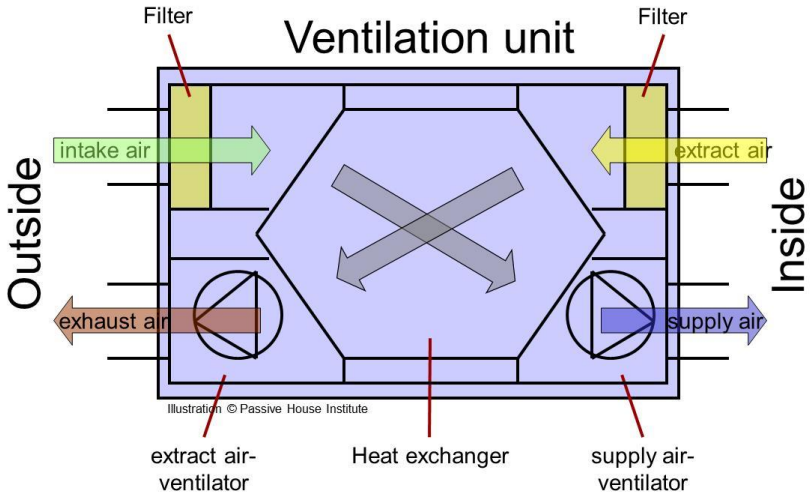
Accepting MVHR

- NHBC stats suggest significant number of new houses are now using MVHR (around a quarter in 2013)
- Concerns over quality of early installations in UK
- Passivhaus requires system to be balanced by a professional, with independent 3rd party check
- Need to get it right to be a trusted solution for the UK
- Need to drive down airtightness to allow MVHR systems to run as efficiently as possible



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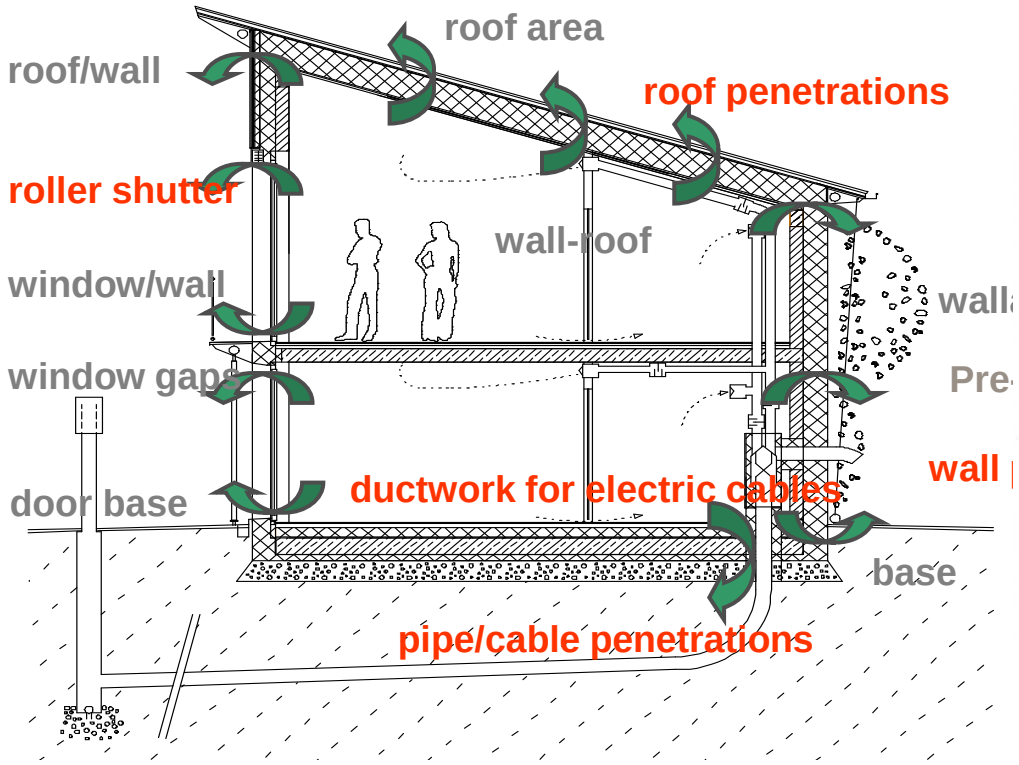
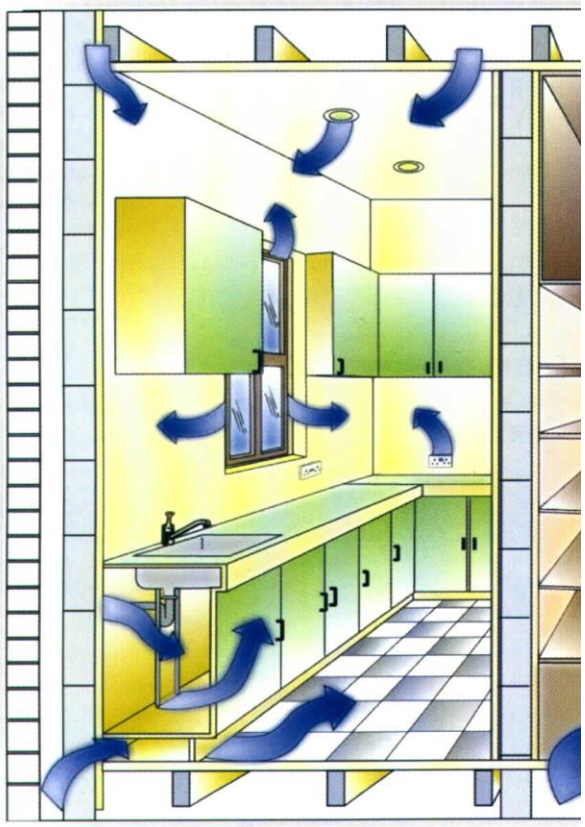
Airtightness: potential leaks & penetrations





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Source: Dr. Burkhard Schulze Darup [PHS 1.0]

Author: JS

Airtightness test

- Testing the building‘s air infiltration rate by means of an air pressure test
- Every property tested individusally! (not sample)
- Average of pressurisation and depressurisation
- 2+ tests likely rather than just at completion

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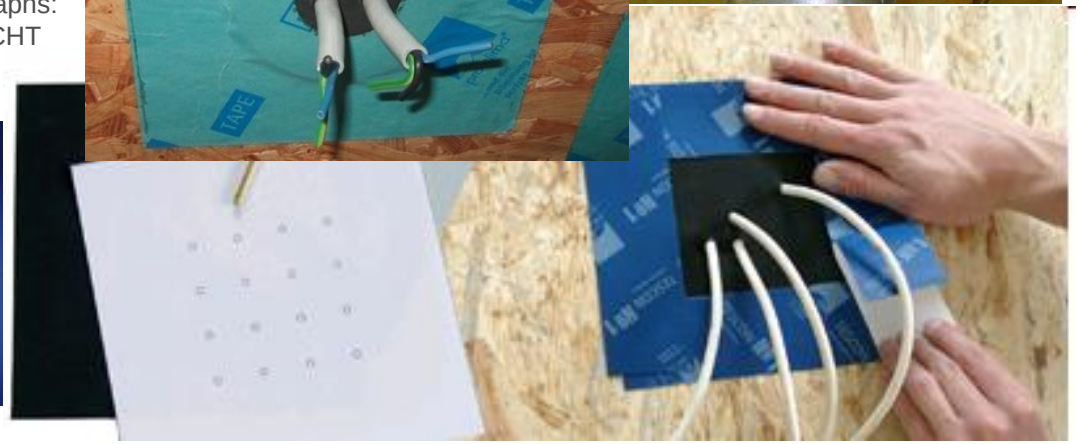
Airtightness solutions

- Some clever products
  - Tapes
  - Gaskets
- Mostly about detailing, workmanship and improving tolerances

Photographs: EISEDICHT



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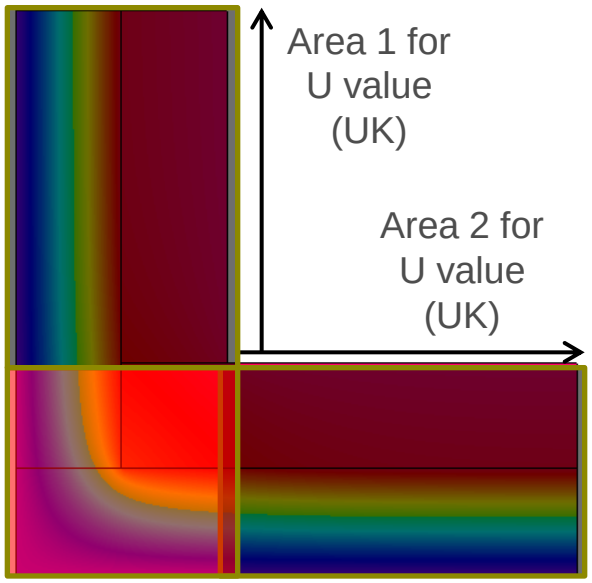
Note: Thermal bridges are calculated differently for Passivhaus and UK Regs!

- Due to external (PH) vs internal (UK) dimension conventions
- UK Regs U values will *underestimate* overall heat loss *(can be accurate if ψ calcs accurate)*
- PH will *overestimate* heat loss from U values *(so conservative approach)*
- Need to know wall thicknesses and U values to convert between values



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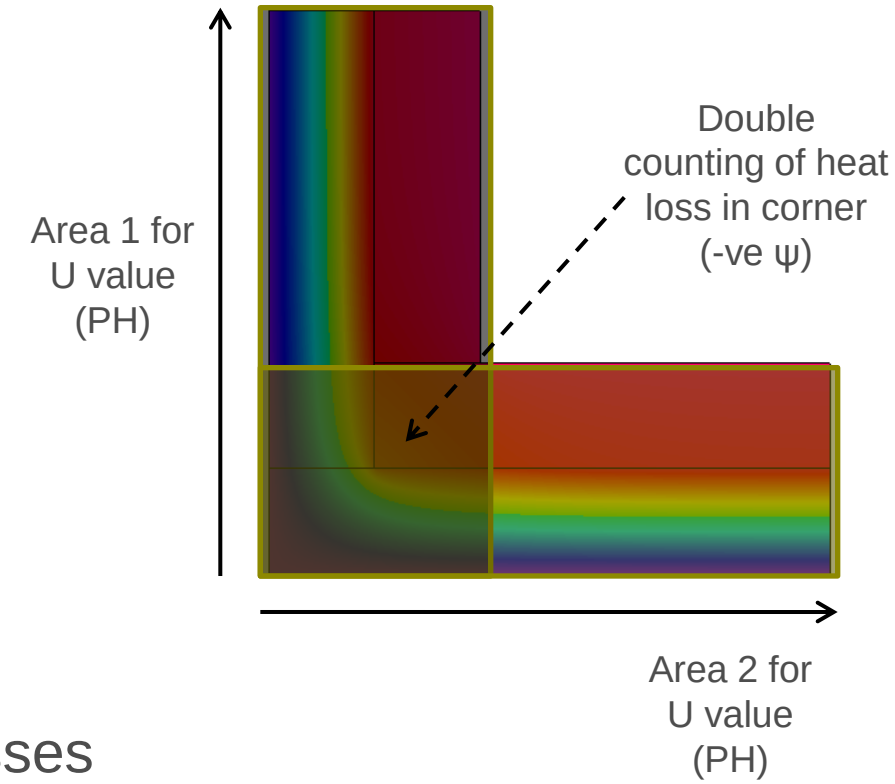

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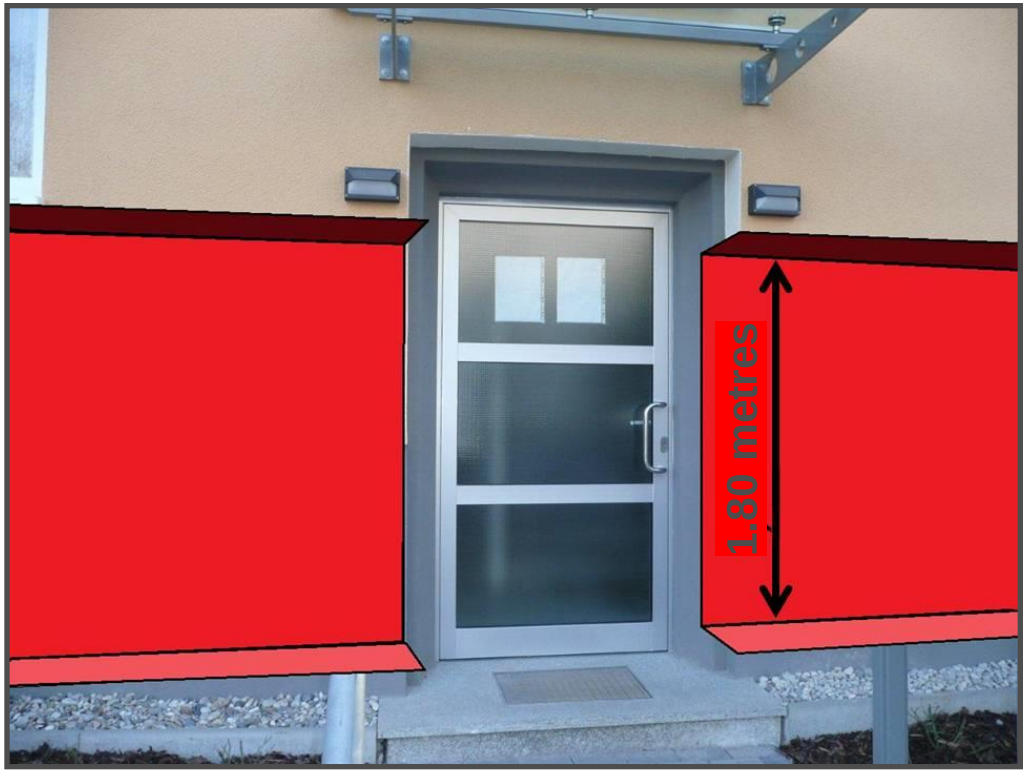
Bridging of the insulation layer – material choice

– Example: Aluminium profile at the plinth



➢ High heat losses!

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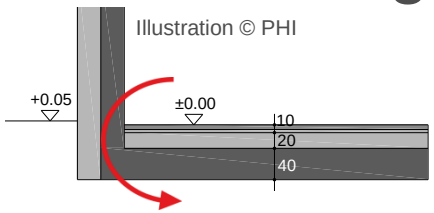
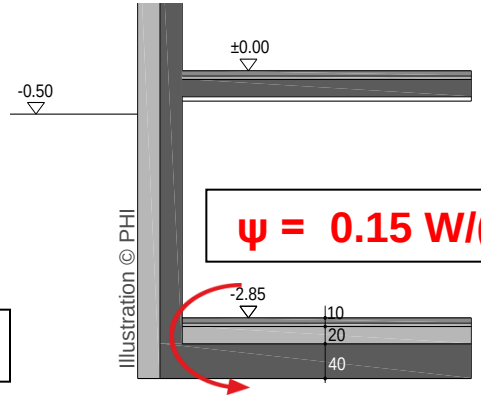
Thermal bridges: Floor slab / foundation



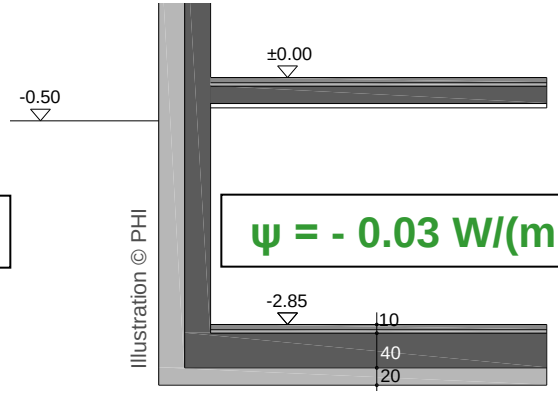
insulation on floor slab
- near surface

ψ = 0.19 W/(mK)



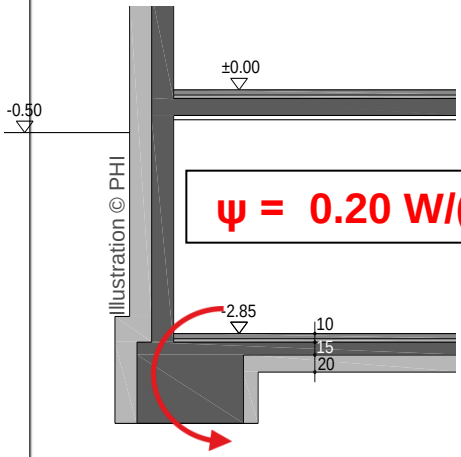
ψ = 0.15 W/(mK)

insulation on floor slab



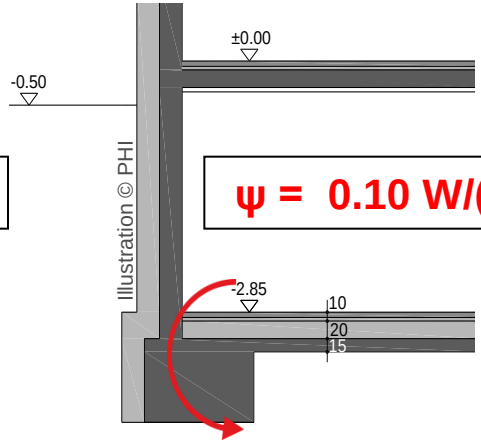
ψ = - 0.03 W/(mK)

insulation under floor slab



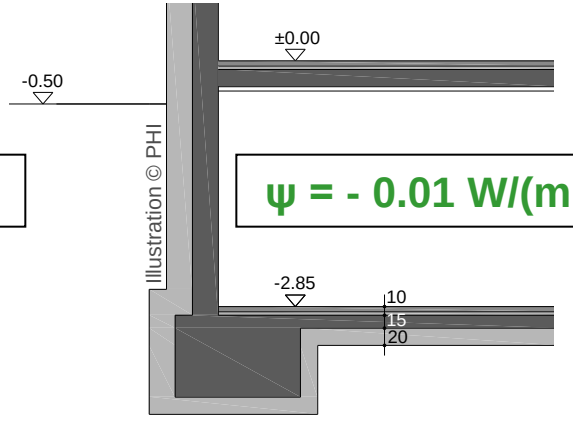
ψ = 0.20 W/(mK)

insulation under floor slab



ψ = 0.10 W/(mK)

insulation on floor slab



ψ = - 0.01 W/(mK)

insulation under floor slab and foundation

thermal bridge free: ψ ≤ 0.01 W/(mK)

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Distribution losses

Heating demand <	15 kWh/m²a	Heating
Heating load (ca.)	10 W/m²	
Heating demand DHW according to occupancy	12 ... 35 kWh/m²a	Hot water
Typical distribution losses	15 kWh/m²a (non-usable) 5 kWh/m²a (usable)	

Conclusion 1: Heat distribution losses will become relatively high.

Conclusion 2: Heat generation and heat distribution concepts must be reconsidered.

Conclusion 3: Pipes and components need a PH-suitable insulation!

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All pipes and ducts well insulated

Photographs © Passive House Institute

Co-funded by the Intelligent Energy Europe Programme of the European Union

Quality Assurance for MVHR

- PH Certification requires the ventilation system **to be balanced** by a professional
- Verified by 3rd party for Certificate
- Additional quality assurance

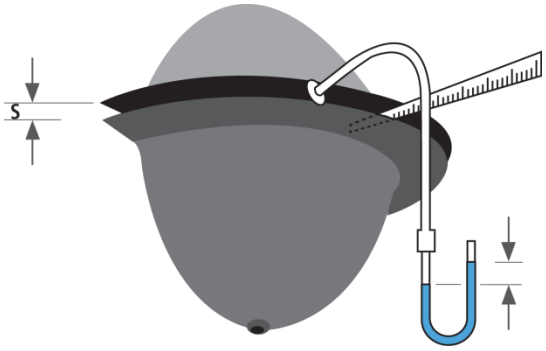

Illustration © PHI

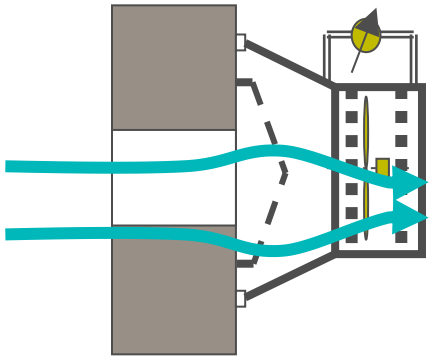

Illustration © PHI

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Airtightness test for QA

- Every property tested individusally! (not sample)
- Intermediate tests likely rather than just at completion?

- With these key checks (MVHR, airtightness, thermal bridging detailing verified onsite), evidently much less chance of experiencing a performance gap

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Passivhaus pilot: Burry Port Primary School

- Carmarthenshire Council piloting Passivhaus on a new primary school (extension, <1000m^2)
- **Justified by in-use savings more than compensating for any additional capital cost**
- Occupant comfort and internal environment important
- Test local supply chain issues (rural context: work here, work anywhere?!?)
- Intend to implement the principles (at least) on future projects

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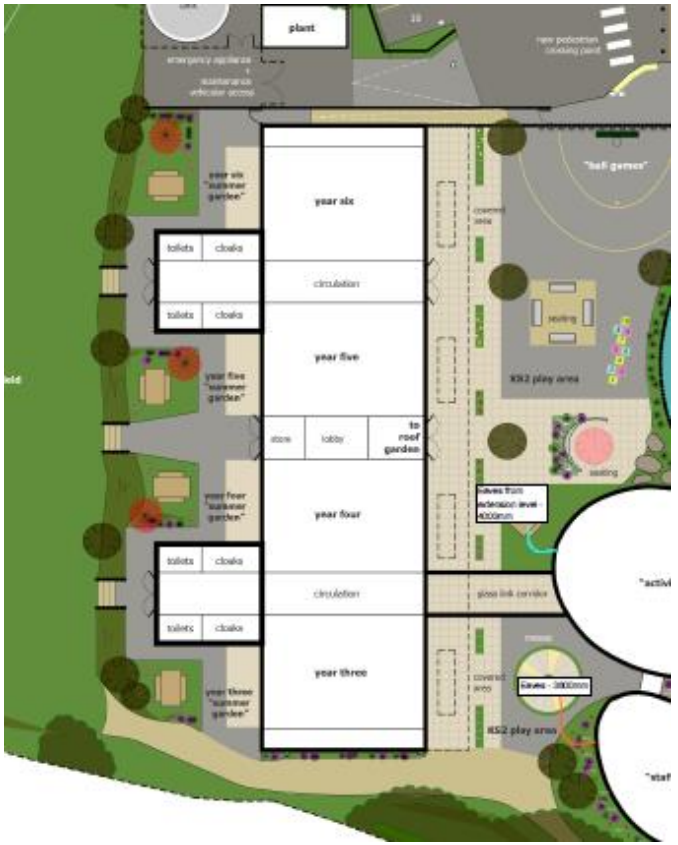
Key features of the school from initial feasibility

- Large southerly glazed area for winter solar gains (shading for summer)
- Partial two storey arrangement helped to improve surface area: volume ratio
- Very low U values:
  - Walls: 0.101 W/m^{2}K
  - Roof: 0.101 W/m^{2}K
  - Floor: 0.130 W/m^{2}K
- Very low (aiming for zero) thermal bridging
- Airtightness (max) 0.6 ac/h
- Architects (Archetype) will investigate cross flow and night cooling strategies



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Cardiff Council Housing Partnership Programme

- Council piloting Passivhaus on a new housing site within their Partnership Programme
- Houses will be for open market sale – test the market and price
- Demonstration for potential NZEB direction by 2020 (which will be within the Partnership period!)
- **Council prepared to accept reduced land value to facilitate the scheme and effectively cover any extra capital cost**
  - (Balance of risk – hopefully market sale prices will ultimately cover any increased capital cost)

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Summary: Benefits

- Ultra-low energy demand building, so **low ongoing running costs**
  - Should pay for any additional capital in relatively short timeframe
- Generally regarded as giving very realistic energy use forecasts compared to in-use
  - Reliable budgeting
- Healthy environment for building users
  - Fresh air, no draughts, stable comfortable temperatures, natural daylight
- If going for full PH Certification, the required 3rd party checks and verification provide extra quality assurance

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Summary: What can we expect in the coming years?

- Strong emphasis on building fabric so less renewables needed for NZEB and Zero Carbon – **secure carbon savings long term**
- Buildings without conventional heating systems?
  - Triple glazed windows
  - MVHR
- Thorough commissioning & balancing of MVHR
- DHW loads & losses more significant than heating loads
- Very low U values, elimination of thermal bridging, more extensive insulation of pipes & ductwork
- Airtightness testing on every building
  - New products and techniques being used
- More thorough workmanship to deliver these principles

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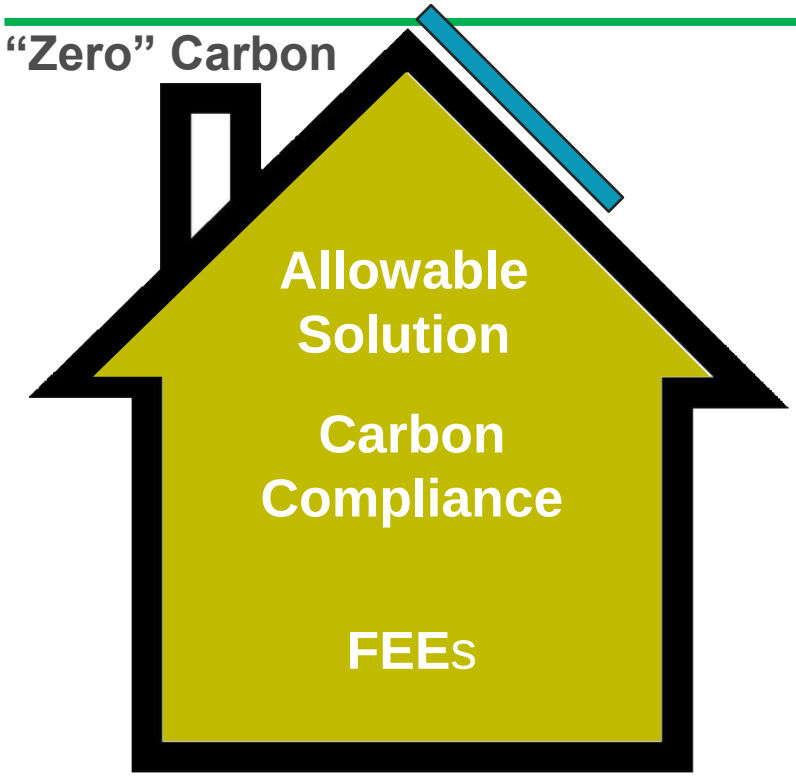
What's best for Wales?



- **Option 1 – Staggered**
- Backstops for FEEs and Carbon Compliance, plus Allowable Solutions
- **Option 2 – Max renewables**
- Backstop for FEEs, maximise onsite Carbon Compliance
- **Option 3 – Max fabric**
- Deliver best possible FEEs, backstop for Carbon Compliance, plus Allowable Solutions
- **Option 4 – Max everything**
- Deliver best possible FEEs, maximise onsite Carbon Compliance, no Allowable Solutions

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