Passivhaus
Schools & Larger Buildings
Some lessons learnt

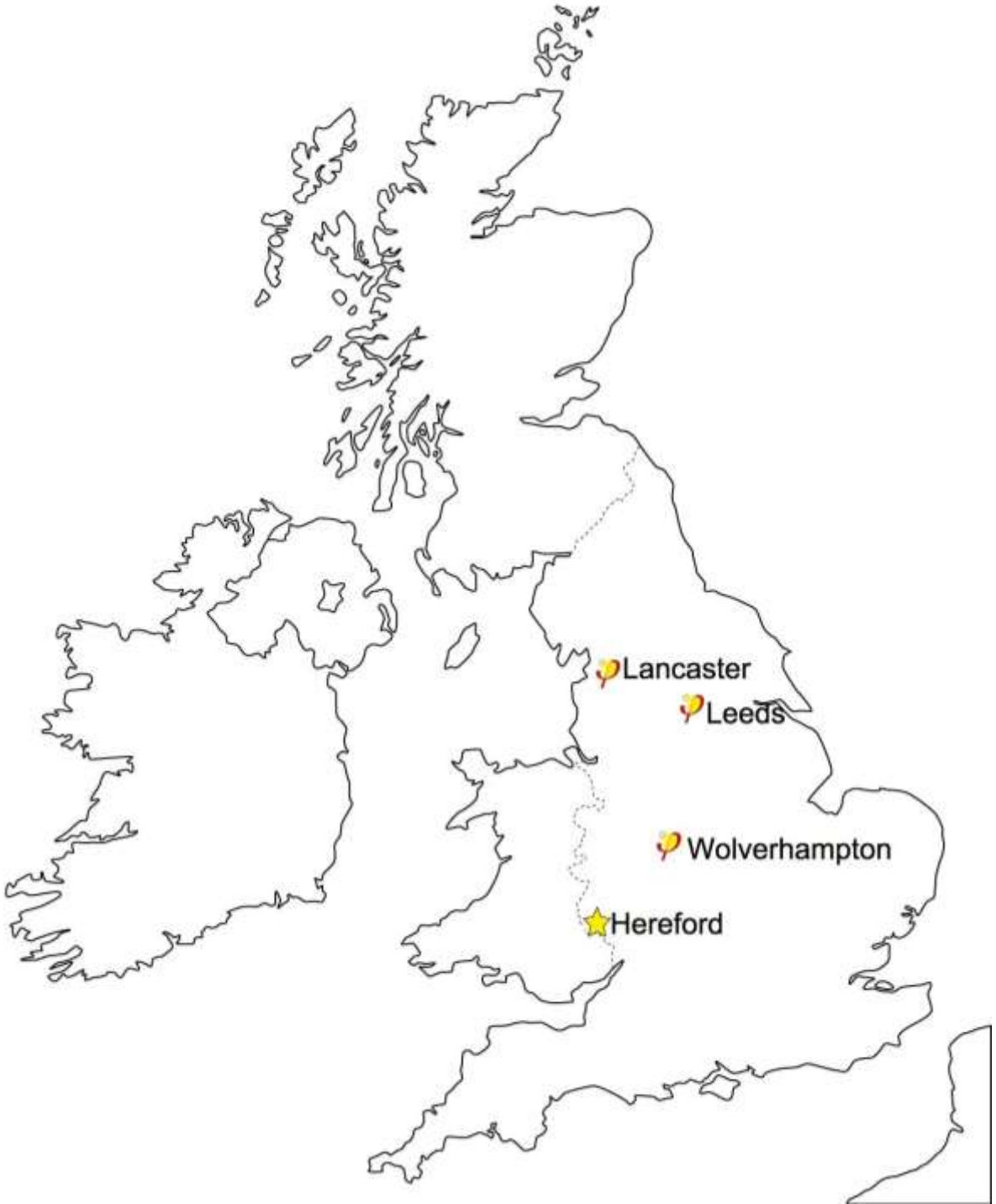
Building Carbon Zero

Santa Cruz March 2014

Nick Grant

Elemental Solutions

Technical Director UK Passivhaus Trust


Lancaster
Leeds
Wolverhampton
Hereford

3 schools with the same team
An opportunity to practice

Acoustics	Ion Acoustics
Architect	Architype West
Client	Wolverhampton City Council
Contractor	Thomas Vale
M&E	E3 Consulting engineers
Passivhaus	Nick Grant & Alan Clarke
QS	Jerry Thomas
Structures	Price & Myers

And many other companies and individuals

Bushbury Hill Primary School - Architype

Type: Mainstream Primary School

Build type: Timber frame

Location: Wolverhampton

Occupancy: Occupied since Oct 2011

Budget: £4.2 million

Standard budget, no extra funding or time for Passivhaus.

Bushbury Hill Primary School
Bushbury Hill
Primary School

Photo: Architype

Oakmeadow Primary School - Architype

Type: Mainstream Primary School
Build type: Timber frame
Location: Wolverhampton
Occupancy: Occupied since Oct 2011
Budget: £5.2 million

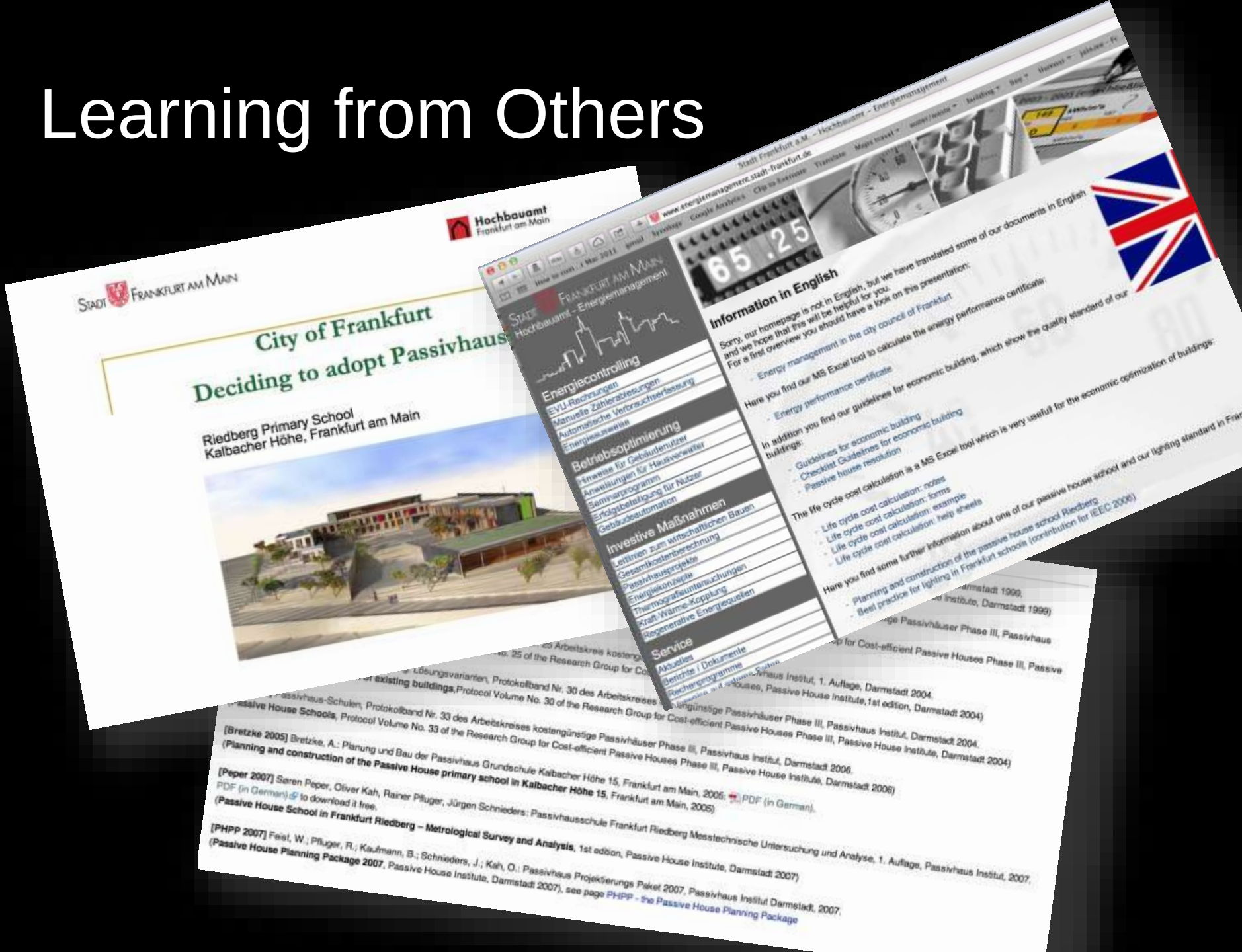
Standard budget, no extra funding or time for Passivhaus.

Photo: Architype

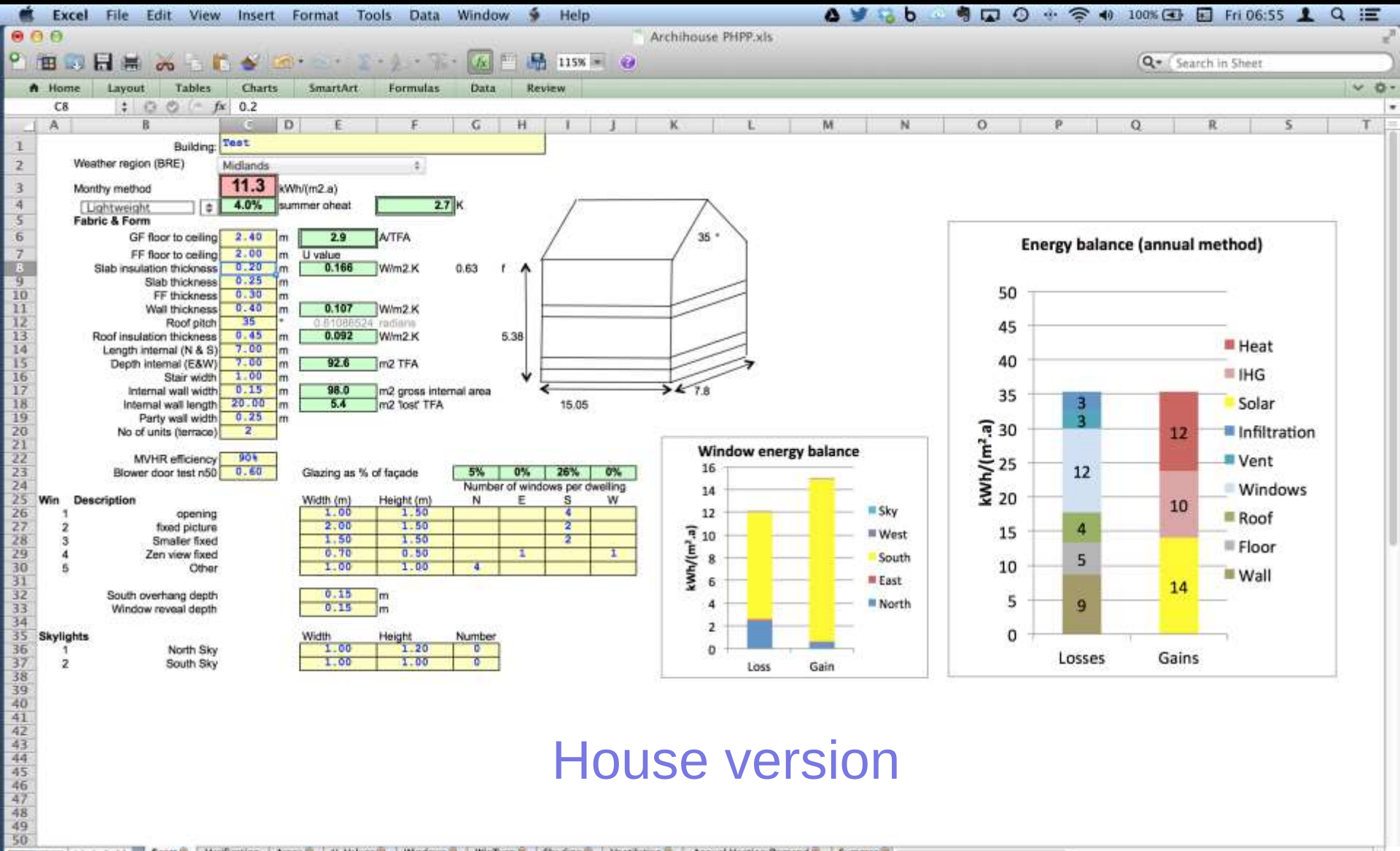
Photo: Architype

Details

Learning from Others



PHPP Tools Custom parametric sheet



House version

PHPP Tools Simple scenario tracker

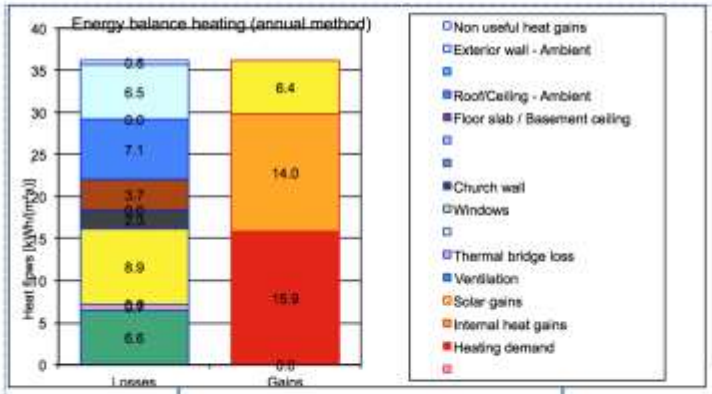
Excel File Edit View Insert Format Tools Data Window Help — Thu 21:20

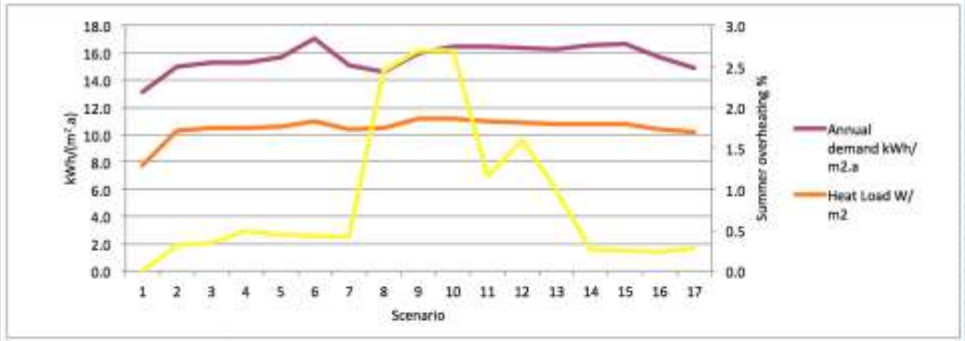
PHPP_ng 6 march for report.xls

Home Layout Tables Charts SmartArt Formulas Data Review

D18 Notes

Simple results sheet (c) Elemental Solutions 2014





scenario	Date	Notes	TFA m²	Dwel units	Form factor	Annual demand kWh/m².a	Heat Load W/m²	Sum O/Htg %	Daily temp swing K	Mass WhK/m² TFA	Glazing m²	Glazing % of TFA	Glazed fraction	Window avg U	Avg g	Window gain kWh/m2.a	Window losses kWh/m2.a	Net solar gain kWh/m².a
20	06/03/2014	Current	599	0	2.28	15.0	10.2	0.3	3.2	60.0	53.5	9%	64%	0.95	0.50	6.2	8.9	-2.5
1	25/02/2014	shell, no windows	617	0	2.17	13.1	7.7		n/a	60.0	0.0	0%	#DIV/0!	0.85	0.00	0.0	0.0	0.0
2	26/02/2014	windows approximated intermorm passiv edition	617	0	2.18	15.0	10.3	0.3	3.3	60.0	51.1	8%	61%	1.00	0.50	6.4	9.1	-2.5
3	26/02/2014	Janet's TFA	610	0	2.21	15.3	10.4	0.3	3.3	60.0	51.1	8%	61%	1.00	0.50	6.4	9.2	-2.6
5	02/03/2014	Ecocontract ultra win and doors	610	0	2.21	15.3	10.5	0.5	3.3	60.0	53.6	9%	64%	1.01	0.50	6.5	9.3	-2.6
6	03/03/2014	Partition 0.8 U value	610	0	2.21	15.7	10.6	0.4	3.4	60.0	53.6	9%	64%	1.01	0.50	6.5	9.3	-2.6
7	03/03/2014	vent increased	610	0	2.21	17.0	11.0	0.4	3.4	60.0	53.6	9%	64%	1.01	0.50	6.6	9.3	-2.6
8	03/03/2014	vent efficiency 84% from 75%	610	0	2.21	15.1	10.4	0.4	3.4	60.0	53.6	9%	64%	1.01	0.50	6.5	9.3	-2.6
9	03/03/2014	lobby in thermal envelope	610	0	2.24	14.6	10.5	2.5	3.7	60.0	60.1	10%	65%	0.99	0.50	8.1	10.0	-1.8
10	03/03/2014	cirulcation area subtraction	578	0	2.37	16.0	11.1	2.7	3.9	60.0	60.1	10%	65%	0.99	0.50	8.6	10.5	-1.7
11	03/03/2014	link rooflight 50% shaded	578	0	2.37	16.4	11.2	2.7	3.9	60.0	60.1	10%	65%	0.99	0.50	8.0	10.5	-2.3
12	03/03/2014	remove top floor rooflights	578	0	2.37	16.5	11.0	1.2	3.6	60.0	55.4	10%	65%	0.96	0.50	7.0	9.5	-2.3
14	03/03/2014	filled in ground sheet	578	0	2.37	16.3	10.8	1.6	3.6	60.0	55.4	10%	65%	0.96	0.50	7.0	9.5	-2.3
15	03/03/2014	Just two circulation rooflights	578	0	2.37	16.2	10.8	1.0	3.5	60.0	53.7	9%	64%	0.95	0.50	6.9	9.2	-2.1
16	03/03/2014	added ground floor café external shading	578	0	2.37	16.5	10.8	0.3	3.3	60.0	53.7	9%	64%	0.95	0.50	6.5	9.2	-2.5
17	06/03/2014	interim result	578	0	2.37	16.6	10.8	0.3	3.3	60.0	53.7	9%	64%	0.95	0.50	6.5	9.2	-2.5
18	06/03/2014	+ 21.6m2 on top floor	599	0	2.28	15.6	10.4	0.2	3.2	60.0	53.7	9%	64%	0.95	0.50	6.3	8.8	-2.4
19	06/03/2014	125mm floor insulation v 100mm	599	0	2.28	14.9	10.2	0.3	3.2	60.0	53.7	9%	64%	0.95	0.50	6.3	8.8	-2.4
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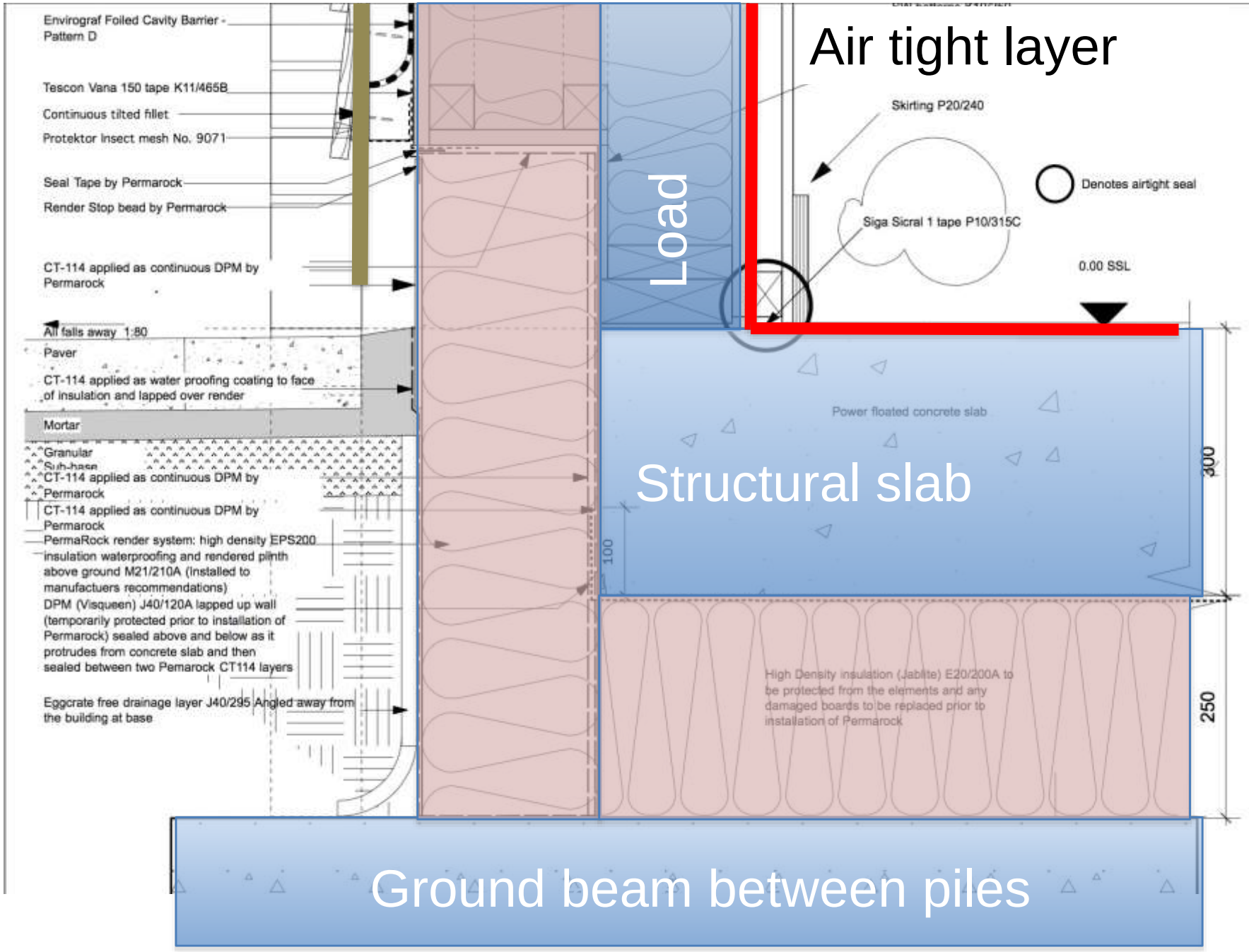
Summary Verification Overview U-Values Areas Ground Components Windows Shading Ventilation Additional vent Annual heating Climate Heating Heating load SummVent Summer

Page Layout View Select destination and press ENTER or choose Paste Sum=0


Envirograf Foiled Cavity Barrier - Pattern D
Tescon Vana 150 tape K11/465B
Continuous tilted fillet
Protektor Insect mesh No. 9071
Seal Tape by Permarock
Render Stop bead by Permarock
CT-114 applied as continuous DPM by Permarock
All falls away 1:80
Paver
CT-114 applied as water proofing coating to face of insulation and lapped over render
Mortar
Granular Sub-base
CT-114 applied as continuous DPM by Permarock
CT-114 applied as continuous DPM by Permarock
PermaRock render system: high density EPS200 insulation waterproofing and rendered plinth above ground M21/210A (installed to manufactuers recommendations)
DPM (Visqueen) J40/120A lapped up wall (temporarily protected prior to installation of Permarock) sealed above and below as it protrudes from concrete slab and then sealed between two Pemarock CT114 layers
Eggcrate free drainage layer J40/295 Angled away from the building at base
Load
Air tight layer
Skirting P20/240
Denotes airtight seal
Siga Sicral 1 tape P10/315C
0.00 SSL
Power floated concrete slab
Structural slab
100
300
High Density insulation (Jablite) E20/200A to be protected from the elements and any damaged boards to be replaced prior to installation of Permarock
250
Ground beam between piles

Standard details made airtight

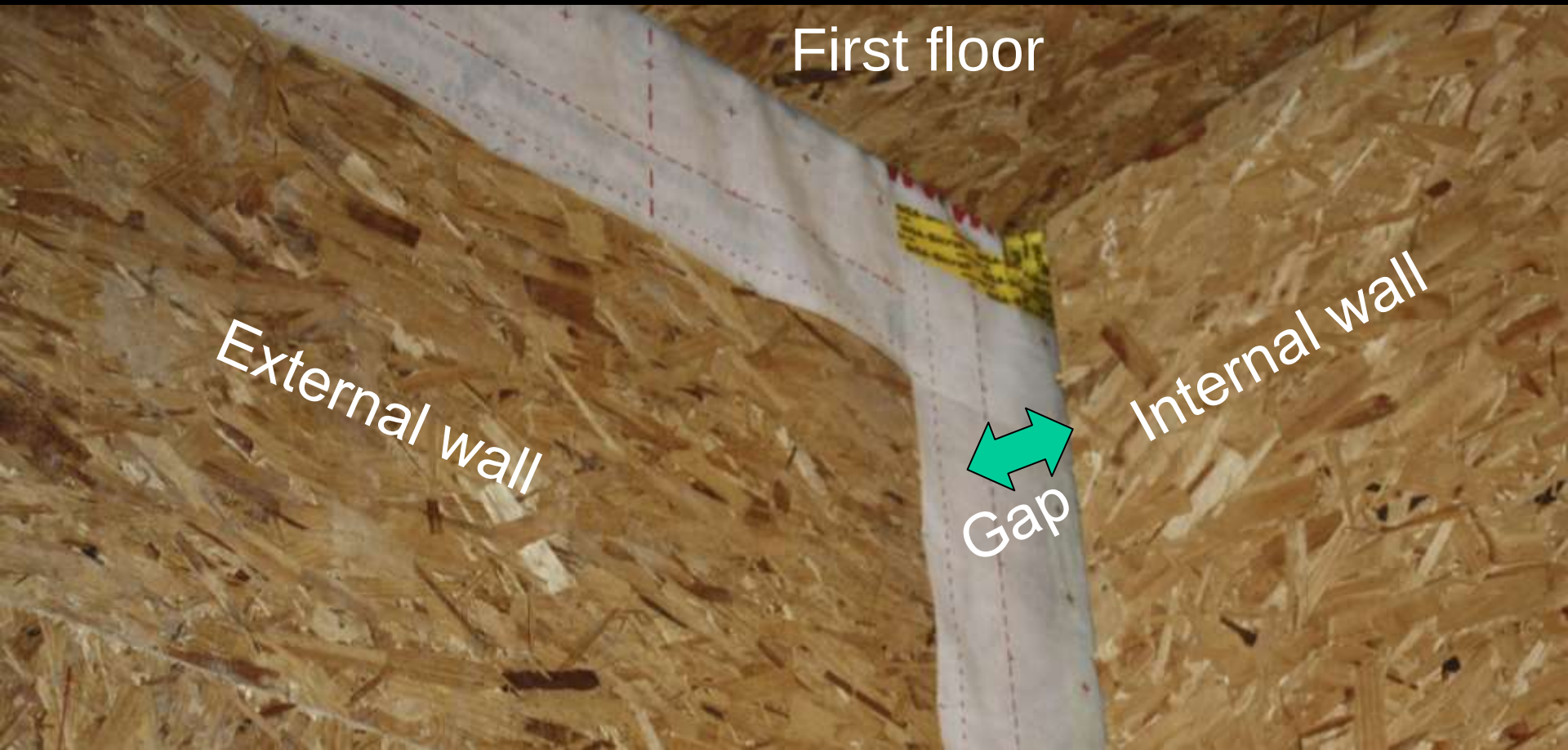
Contractor's standard detail with airtightness added: internal walls keyed into external walls.

Expensive on tape, time consuming on site & some unresolved junctions.

Lesson learnt.

Schools 2&3 followed the drawings!

- Much easier

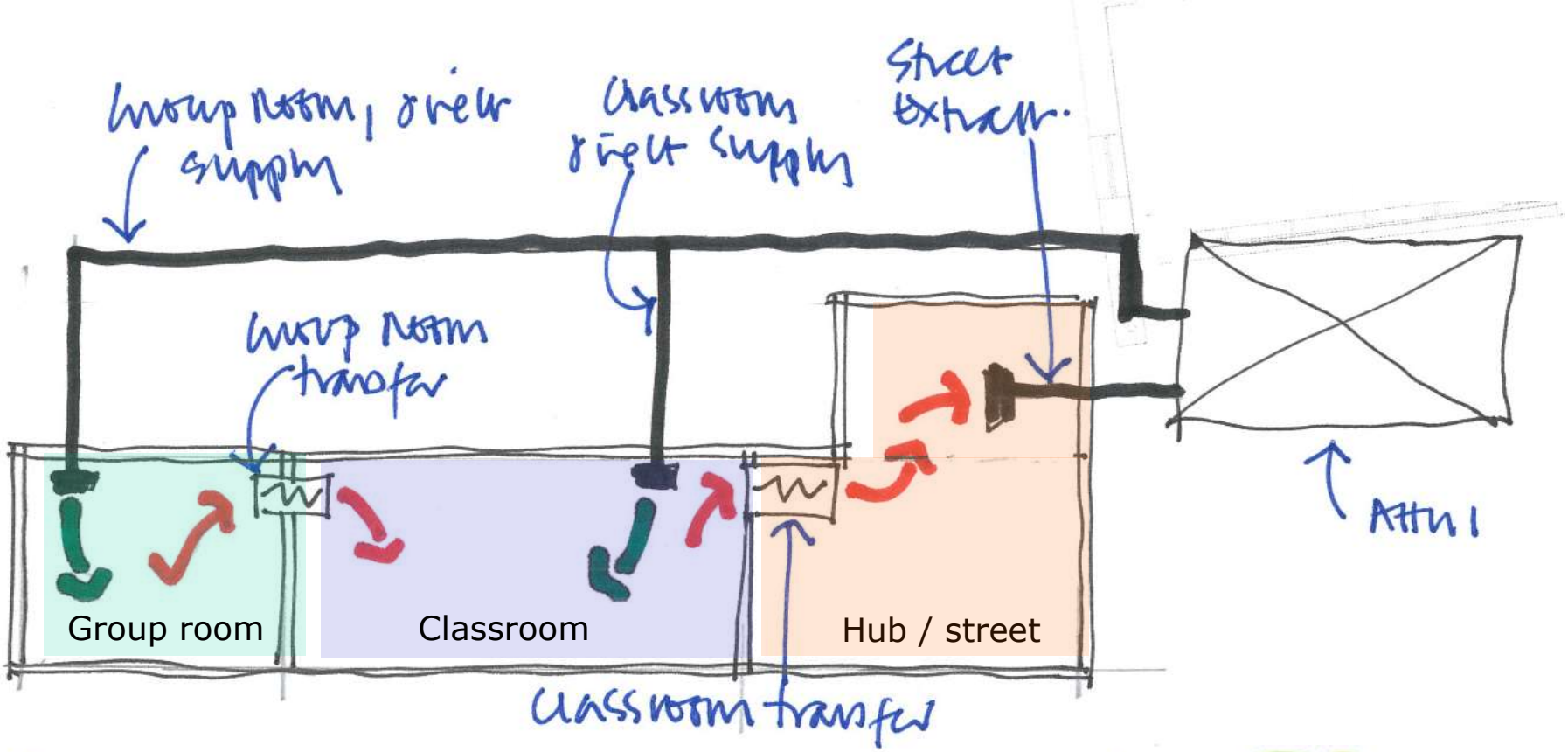


Walls split where single storey attaches

No penetration of wind barrier

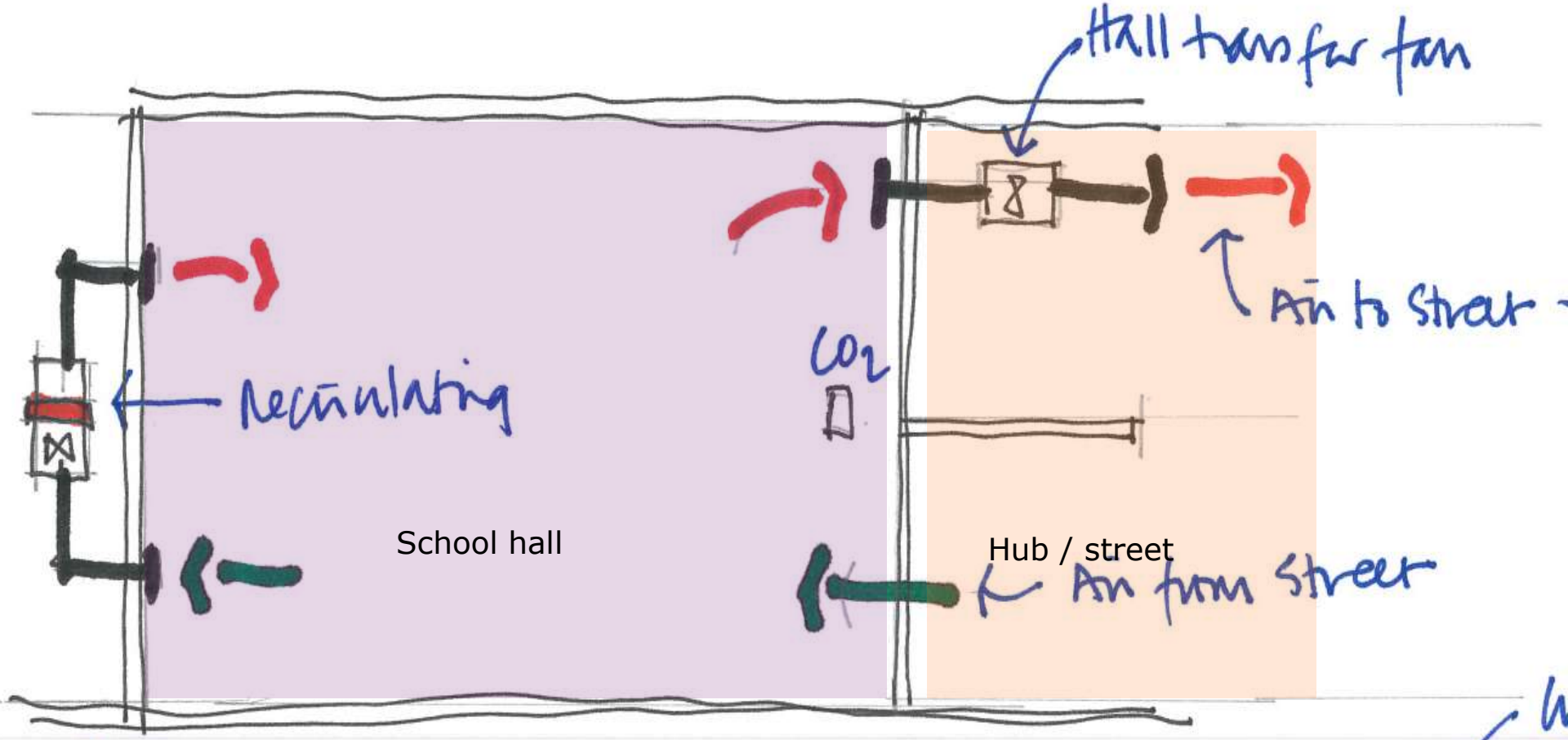
Simple Cascade Vent Strategy

Occupation constant but people move around.
Street as transfer zone



e3 consulting engineers

Hall fed from street when used



HALL → STREET VENTILATION.

e3 consulting engineers

Window opening limited by UK Code

An unwelcome constraint

Ambiguous interpretation of 100mm opening

German Primary School

Stunts: Alan Clarke

Kitchen ventilation

Initial design

- Main MVHR: 5400 m^3/h
- Kitchen ventilation: 3600 m^3/h
- No heat recovery on kitchen system – grease

Engineer concerned this wasn't enough
– risk of overheating based on previous experience - preferred kitchen rate of **4800** m^3/h!

Passivhaus energy balance cannot be achieved.

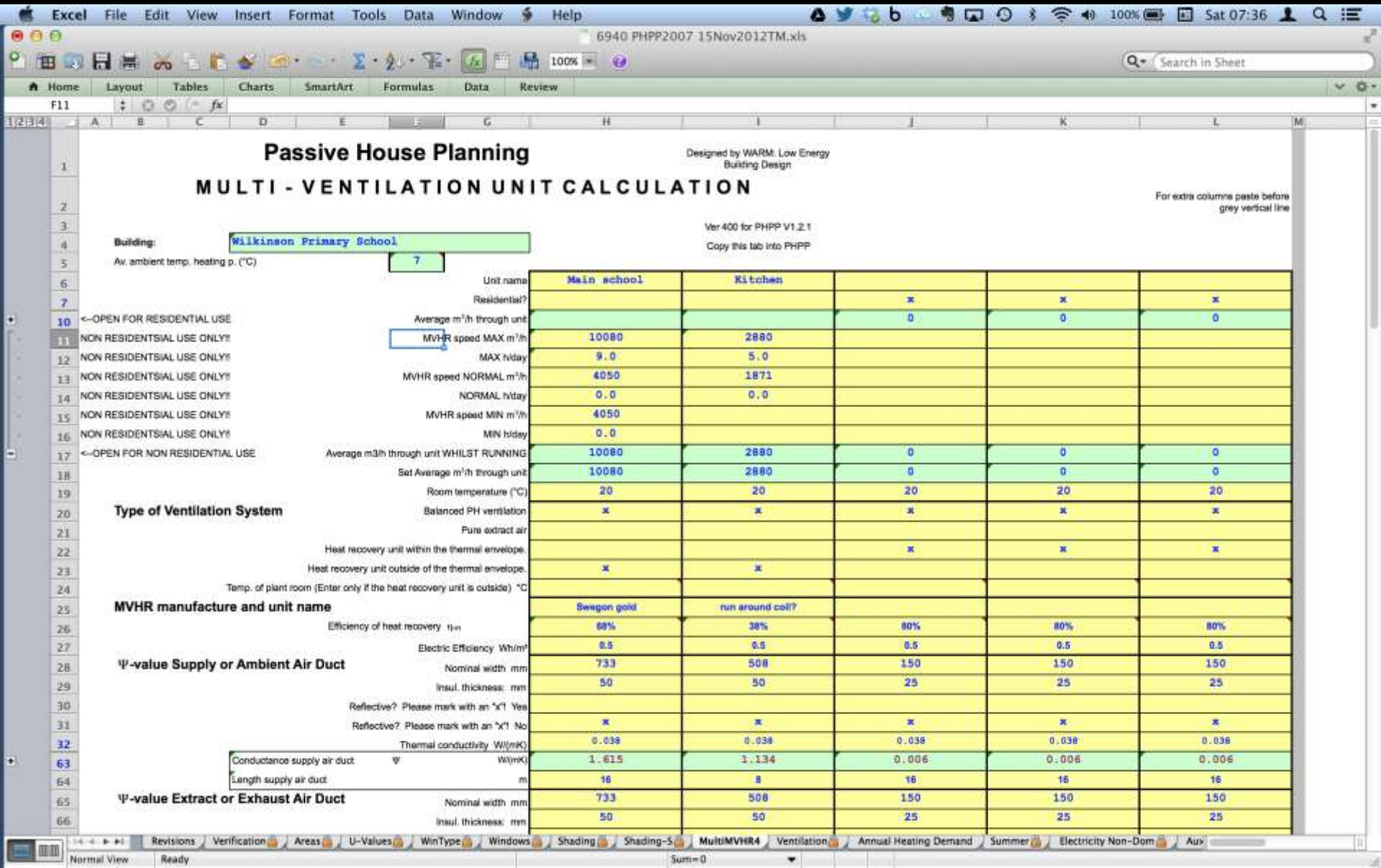
Our low energy strategy

- Only provide as much air as needed to remove excess heat
  - This was not compatible with gas cooking

- Recover heat to temper fresh air for comfort
  - A robust heat exchanger possible if no frying

- How to model in PHPP?
  - Developed multivent sheet

PHPP Tools Multivent sheet, Warm & Alan Clarke



Passive House Planning

Designed by WARM: Low Energy Building Design

MULTI - VENTILATION UNIT CALCULATION

For extra columns paste before grey vertical line

Ver 400 for PHPP V1.2.1

Copy this tab into PHPP

Building: Wilkinson Primary School

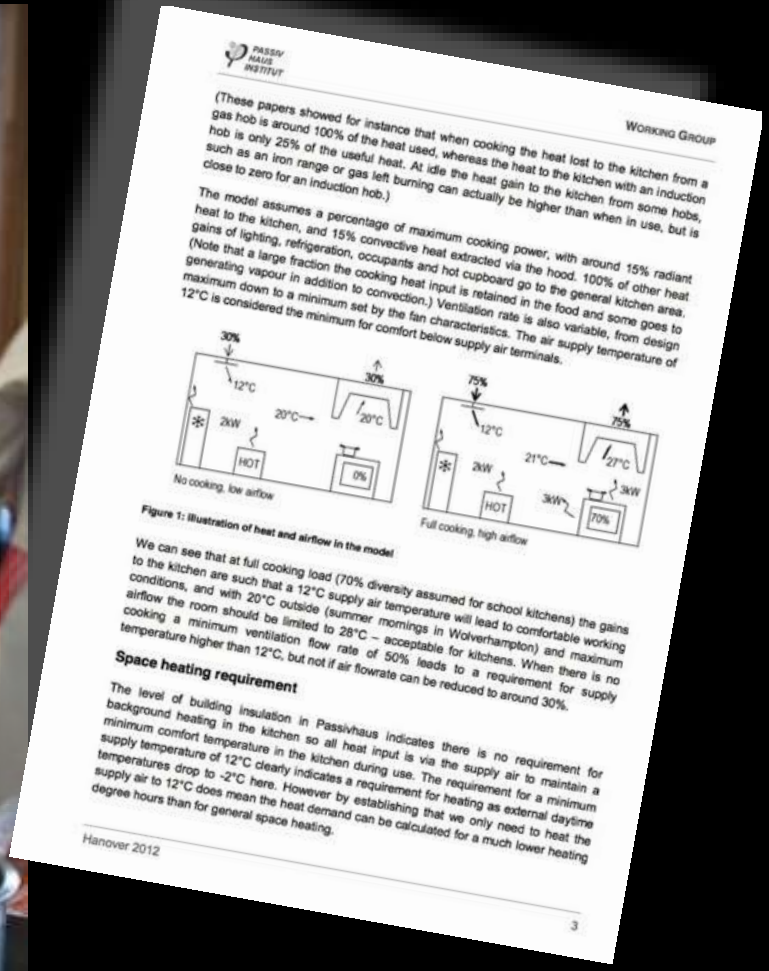
Av. ambient temp. heating p. (°C): 7

	Unit name		Main school	Kitchen		
	Residential?				x	x	x
<--OPEN FOR RESIDENTIAL USE	Average m³/h through unit				0	0	0
NON RESIDENTSIAL USE ONLY!!	MVHR speed MAX m³/h		10080	2880			
NON RESIDENTSIAL USE ONLY!!	MAX h/day		9.0	5.0			
NON RESIDENTSIAL USE ONLY!!	MVHR speed NORMAL m³/h		4050	1871			
NON RESIDENTSIAL USE ONLY!!	NORMAL h/day		0.0	0.0			
NON RESIDENTSIAL USE ONLY!!	MVHR speed MIN m³/h		4050				
NON RESIDENTSIAL USE ONLY!!	MIN h/day		0.0				
<--OPEN FOR NON RESIDENTIAL USE	Average m3/h through unit WHILST RUNNING		10080	2880	0	0	0
	Set Average m³/h through unit		10080	2880	0	0	0
	Room temperature (°C)		20	20	20	20	20
Type of Ventilation System	Balanced PH ventilation		x	x	x	x	x
	Pure extract air						
	Heat recovery unit within the thermal envelope.				x	x	x
	Heat recovery unit outside of the thermal envelope.		x	x			
	Temp. of plant room (Enter only if the heat recovery unit is outside) °C						
MVHR manufacture and unit name			Swegon gold	run around coil?			
	Efficiency of heat recovery η_{hr}		68%	38%	80%	80%	80%
	Electric Efficiency Wh/m³		0.5	0.5	0.5	0.5	0.5
Ψ-value Supply or Ambient Air Duct	Nominal width mm		733	508	150	150	150
	Insul. thickness mm		50	50	25	25	25
	Reflective? Please mark with an "x"! Yes						
	Reflective? Please mark with an "x"! No		x	x	x	x	x
	Thermal conductivity W/(mK)		0.038	0.038	0.038	0.038	0.038
	Conductance supply air duct Ψ	W/(mK)	1.615	1.134	0.006	0.006	0.006
	Length supply air duct	m	16	8	16	16	16
Ψ-value Extract or Exhaust Air Duct	Nominal width mm		733	508	150	150	150
	Insul. thickness mm		50	50	25	25	25

Revisions | Verification | Areas | U-Values | WinType | Windows | Shading | Shading-S | MultiMVHR4 | Ventilation | Annual Heating Demand | Summer | Electricity Non-Dom | Aux

Normal View | Ready | Sum=0

Lessons learnt: school kitchens



PASSIV HAUS INSTITUT

WORKING GROUP

(These papers showed for instance that when cooking the heat lost to the kitchen from a gas hob is around 100% of the heat used, whereas the heat to the kitchen with an induction hob is only 25% of the useful heat. At idle the heat gain to the kitchen from some hobs, such as an iron range or gas left burning can actually be higher than when in use, but is close to zero for an induction hob.)

The model assumes a percentage of maximum cooking power, with around 15% radiant heat to the kitchen, and 15% convective heat extracted via the hood. 100% of other heat gains of lighting, refrigeration, occupants and hot cupboard go to the general kitchen area. (Note that a large fraction the cooking heat input is retained in the food and some goes to generating vapour in addition to convection.) Ventilation rate is also variable, from design maximum down to a minimum set by the fan characteristics. The air supply temperature of 12°C is considered the minimum for comfort below supply air terminals.

Figure 1: Illustration of heat and airflow in the model

We can see that at full cooking load (70% diversity assumed for school kitchens) the gains to the kitchen are such that a 12°C supply air temperature will lead to comfortable working conditions, and with 20°C outside (summer mornings in Wolverhampton) and maximum airflow the room should be limited to 28°C – acceptable for kitchens. When there is no cooking a minimum ventilation flow rate of 50% leads to a requirement for supply temperature higher than 12°C, but not if air flowrate can be reduced to around 30%.

Space heating requirement

The level of building insulation in Passivhaus indicates there is no requirement for background heating in the kitchen so all heat input is via the supply air to maintain a minimum comfort temperature in the kitchen during use. The requirement for a minimum supply temperature of 12°C clearly indicates a requirement for heating as external daytime temperatures drop to -2°C here. However by establishing that we only need to heat the supply air to 12°C does mean the heat demand can be calculated for a much lower heating degree hours than for general space heating.

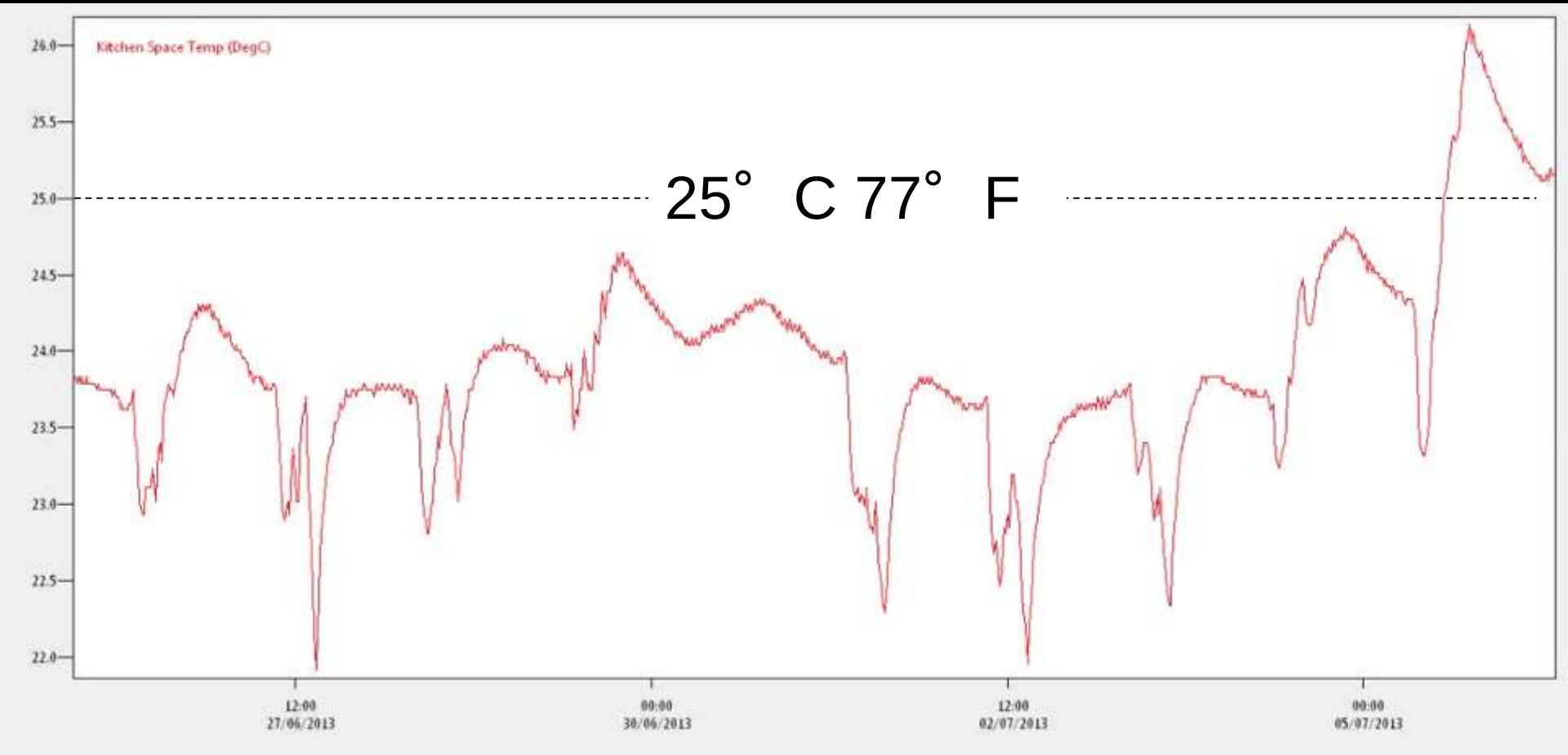
Hanover 2012

3

Download Paper:
www.elementalsolutions.co.uk

Use of induction hobs and low energy appliances to reduce surplus heat and primary energy

It works!
June-July 2013

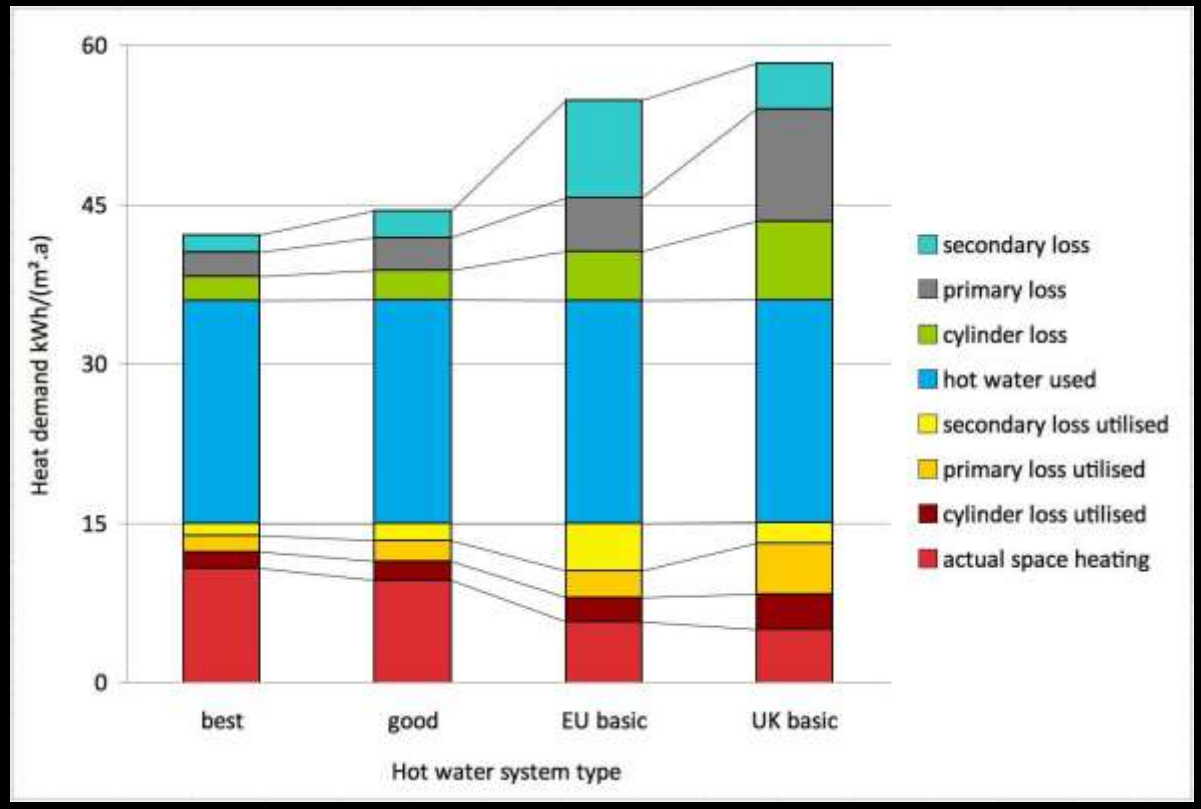


Heating

Simple radiators with thermostatic valves, one per room, not all rooms.

DHW

- Optimised pipe sizes and good insulation
- No hot water in classrooms for Bushbury
- Losses reduced to about 70%!!



Download paper & ppt

www.elementalsolutions.co.uk

Daylight and lighting - theory

What worked:

- Target 2W/m^2/100lux & max 300lux, so classrooms etc are limited to 6W/m^2

Less successful:

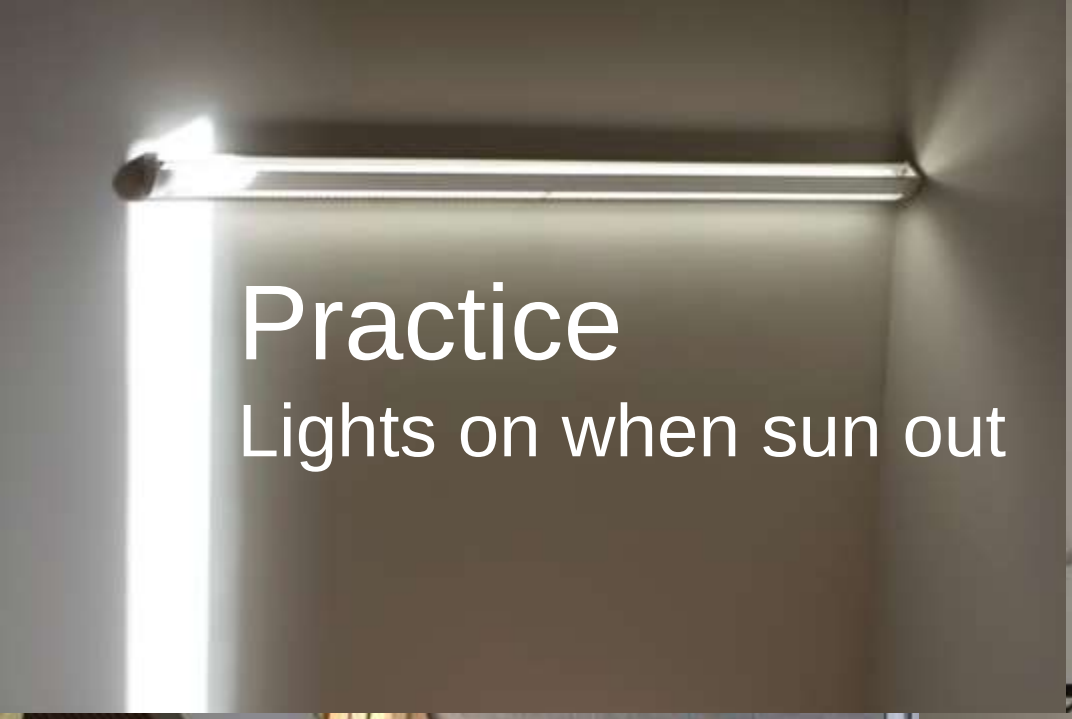
- Daylight optimised by 3D modelling
- Consideration of localised shade for whiteboard
- State of the art energy saving lighting controls

Practice

North classroom

Practice

Lights on when sun out



Measured Energy Use

Bushbury School (Oakmeadow very similar)

- 90% less than the old school

Figures are based first year readings.

Gas(x 1.1 for PE):

Space heating*: 14kWh/(m^2.a)

Hot water: 7kWh/(m^2.a)

Electric (x 2.7 for PE):

Lighting: 12kWh/(m^2.a)

Power & plant: 22kWh/(m^2.a)

Kitchen: 7kWh/(m^2.a) Sprinkler frost protect: 14kWh/(m^2.a)

Total primary energy: 169kWh/(m^2.a)

Comment:

Primary energy is higher than the target 120 kWh/(m^2.a)

Sprinklers = 38kWh/(m^2.a) PE ('frost' protection)

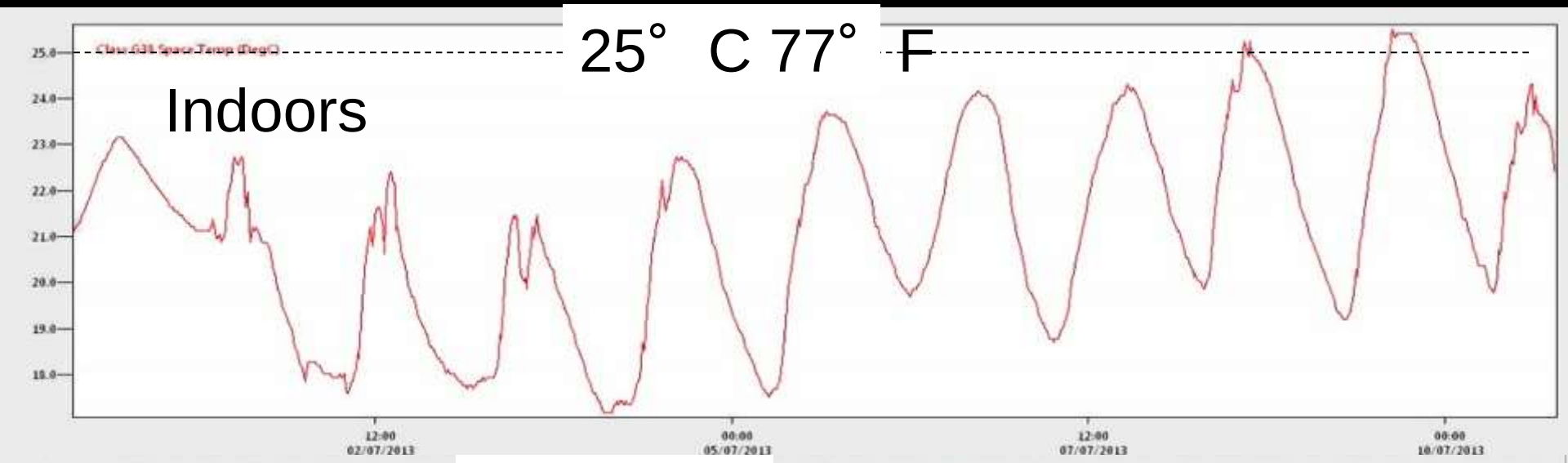
Main success:

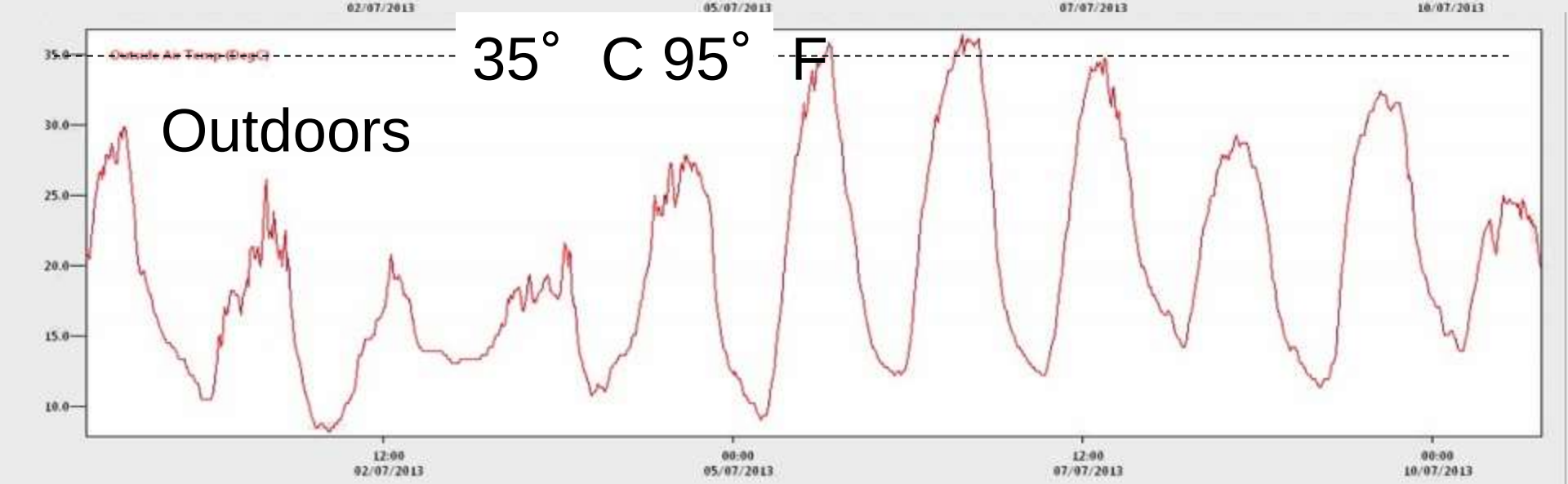
Kitchen energy & comfort

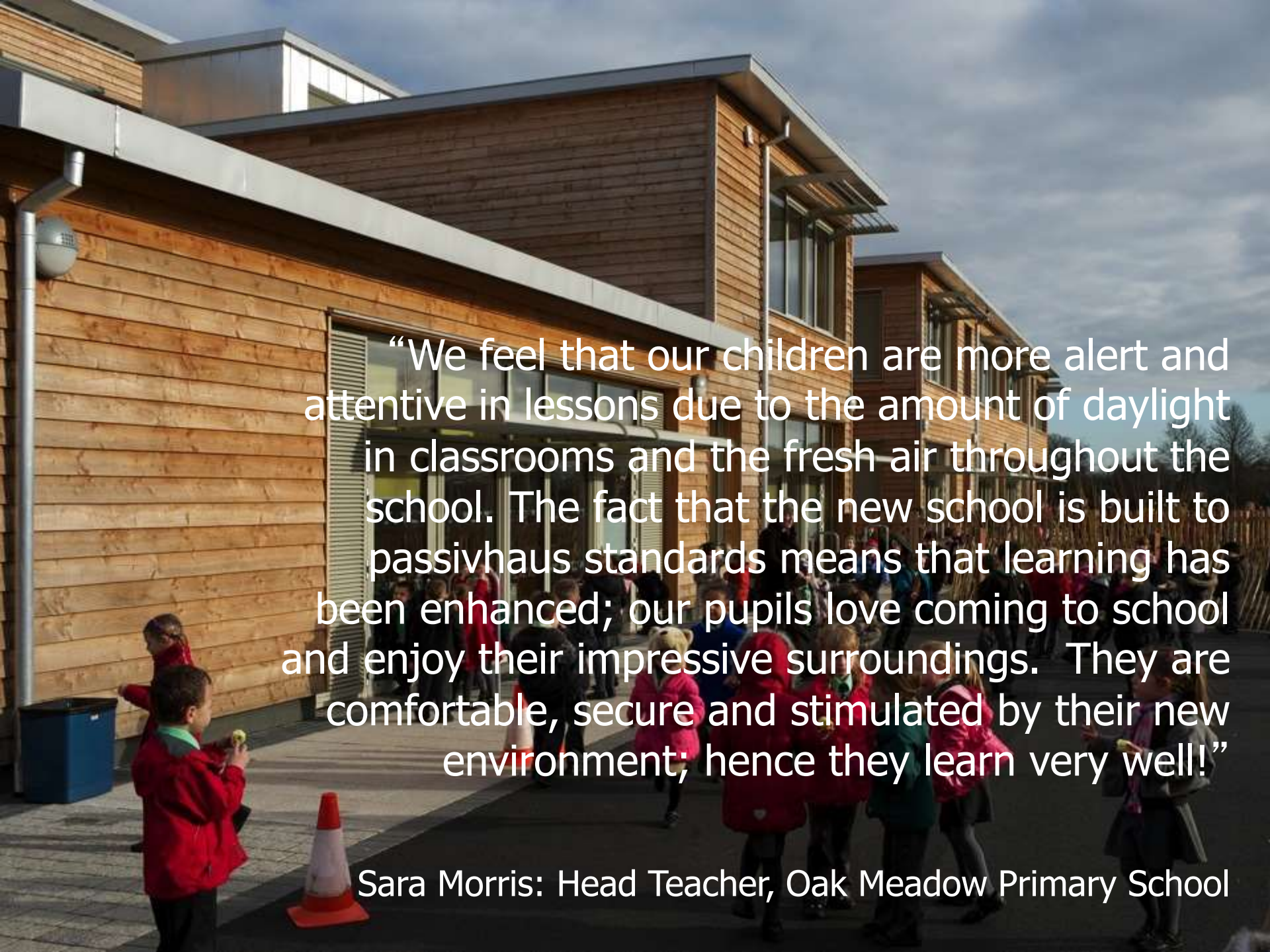
Main lessons:

Issues with automatic lighting controls and sprinkler systems.

South classroom summer comfort






“We feel that our children are more alert and attentive in lessons due to the amount of daylight in classrooms and the fresh air throughout the school. The fact that the new school is built to passivhaus standards means that learning has been enhanced; our pupils love coming to school and enjoy their impressive surroundings. They are comfortable, secure and stimulated by their new environment; hence they learn very well!”
Sara Morris: Head Teacher, Oak Meadow Primary School

School Number 4, Wilkinson

1. Council specified Passivhaus
   - Based on previous experience and the boast of no extra cost!

2. Planning require 10% renewables
   - Successfully challenged – negawatts

3. Contractor with no experience of PH
   - Experienced sub-contractor engaged

4. Timescale tight, Architect has new baby & not sleeping and 10% less budget

Wilkinson Ground floor plan

Classrooms clustered around two hub spaces, school also includes community use facilities

Wilkinson First floor plan

KiddyWatts

Metabolic Heat Gains

School	Children	TFA m^2	m^2/child
Bushbury Hill (UK)	240	1707	7.1
Oakmeadow (UK)	450	2205	4.9
Montgomery (UK)	446	2367	5.3
Swillington (UK)	240	1344	5.6
Wilkinson (UK)	459	2500	5.4
LH Hannover (D)	300	3507	11.7
Gronau (D)	336	2953	8.8
Reidberg (D)	500	5540	11.1

Average for UK examples 5.7 m^2/child

Average for German examples 10.5 m^2/child

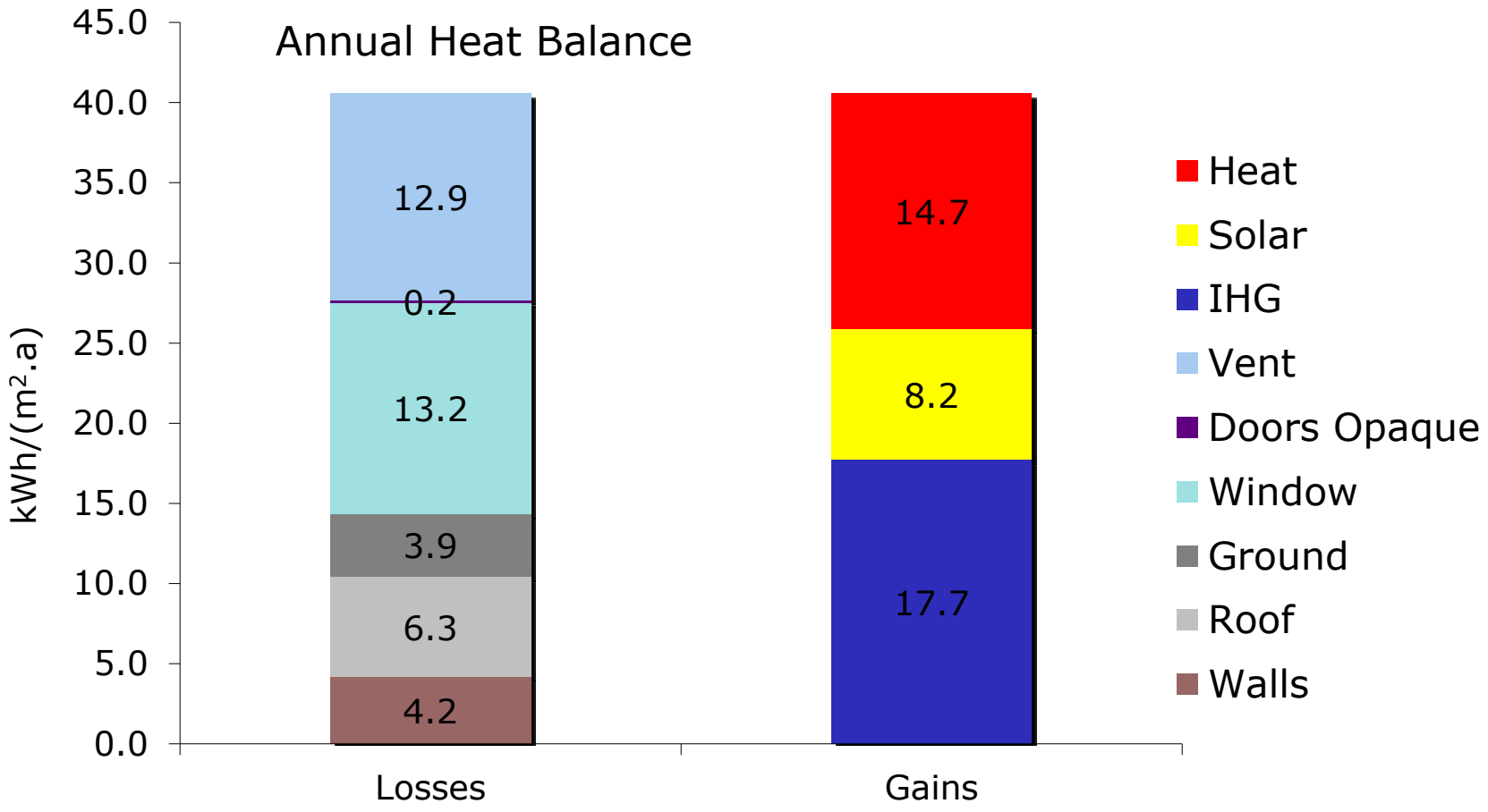
Difference +**1.32W/m^2**

+ 5-6 kWh/(m^2.a) of useful heating

Against 15kWh/(m^2.a) target

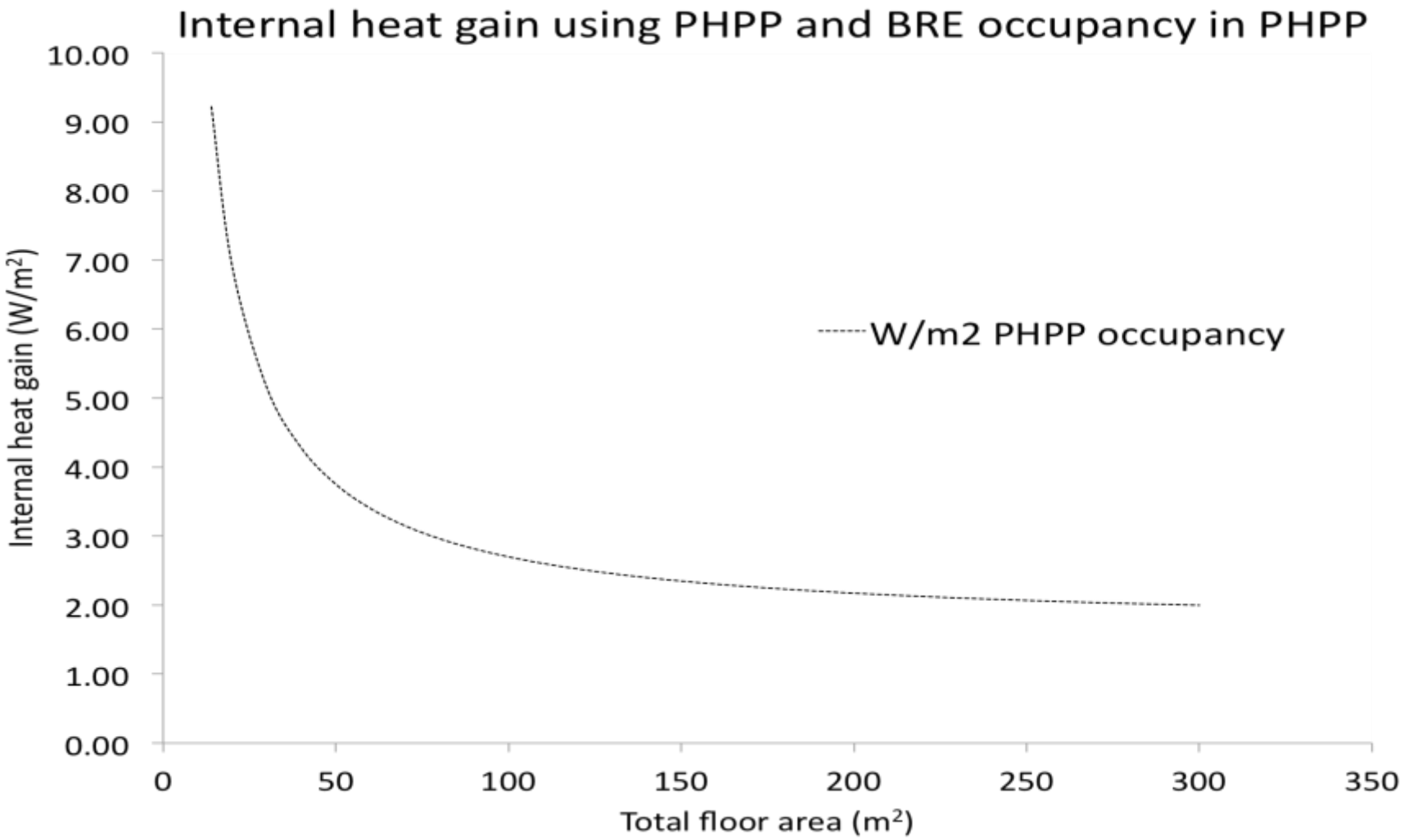
Less reliance on solar gain

Don't confuse Passivhaus & Passive solar – solar costs 10-20x gas!!
3.8W/m^2 v 2.8W/m^2 IHG
Means we designed a different building



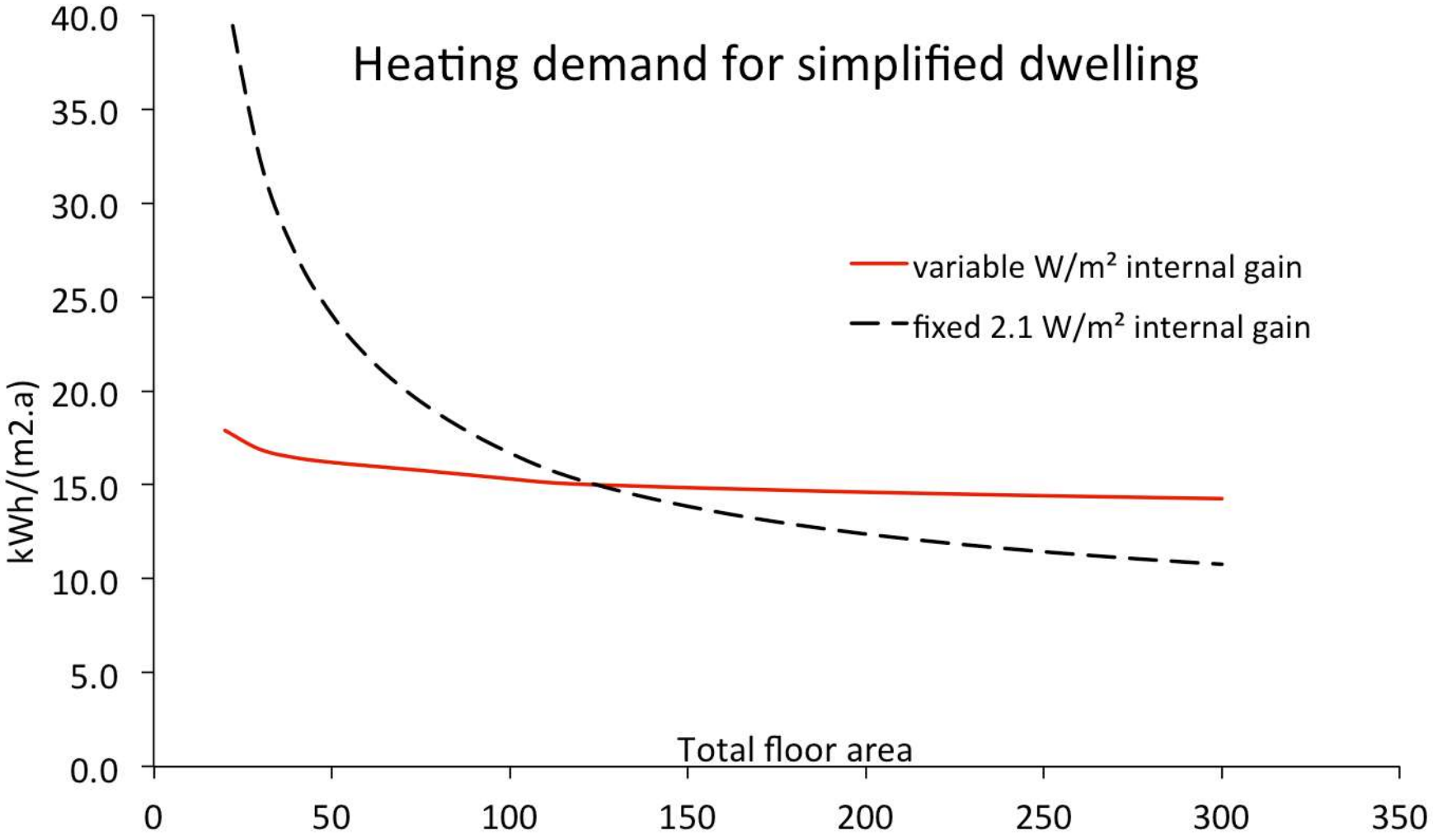
An aside – mall dwellings & IHGs

To be presented at Aachen, 2014



Small Buildings Sorted!

IHG = 71 $TFA^{-0.73}$ (curve fit for PHPP calculated IHGs)



“You sure we got the right boiler?”

2,400m^2 school, boiler still twice the size needed!

Summer vent and opening windows

Less and simplified actuators.

More manual operated windows and night vents

Glazing to ground omitted

- Big cost & time savings
- Better daylight
- Less overheating
- More useful space
- Architect likes it!

Simpler PH skylights

Big cost saving, less overheating, no leaks

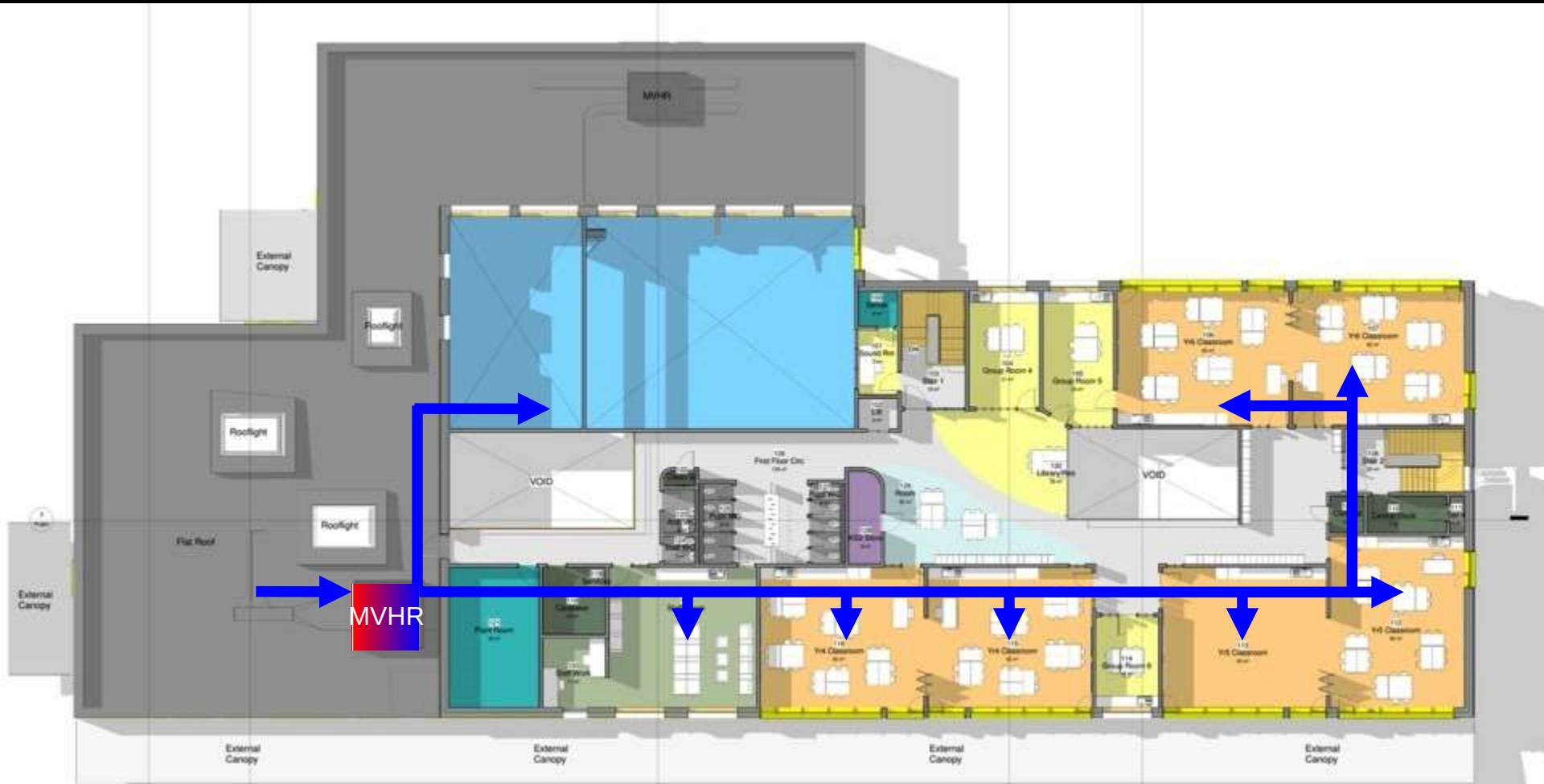
Windows replace curtain wall

- Big cost & time savings
- Quicker install
- Easier to make airtight
- Simplified structure
- Worked better with actuators.

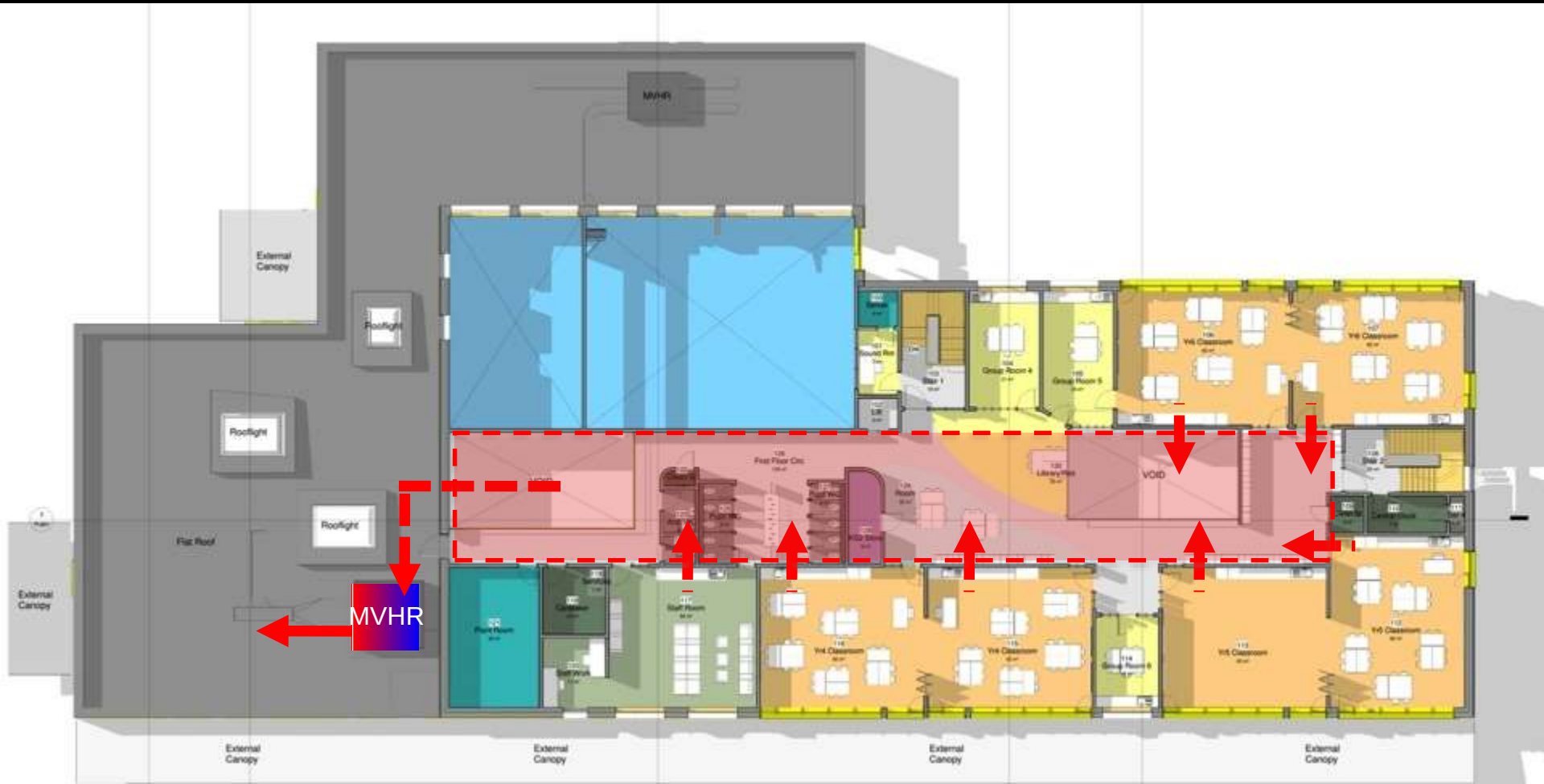
Local Hot Water

Electric DHW storage shared beween several areas.
8mm microbore, 0.5 gpm (1.7 l/min) sprays

Optimised MVHR ducts



Optimised MVHR layout



Effortless, robust air-tight details

Design team, contractor & sub-contractors learn how to over come previous construction issues

Photo: Tom Mason, Architype

Photo: Architype

Photo: Juraj Mikurcik

Photo: Architype

Photo: Architype

Photo: Architype

Hereford Archive & Records Centre

A very Eco-Minimal passive approach

Archive energy balance

No passive solar, no heat recovery ventilation, no cooling. Some dehumidification of supply air.

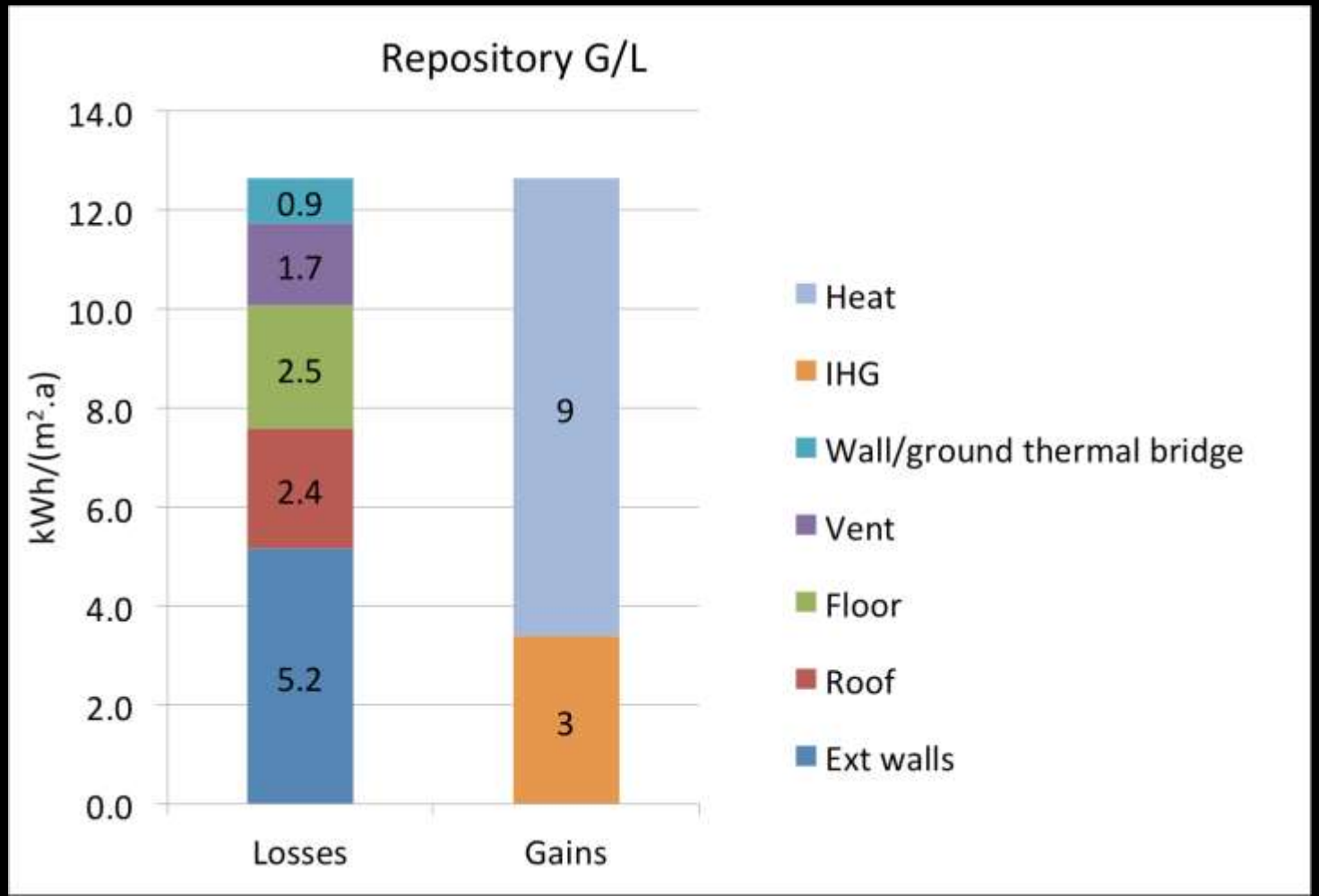


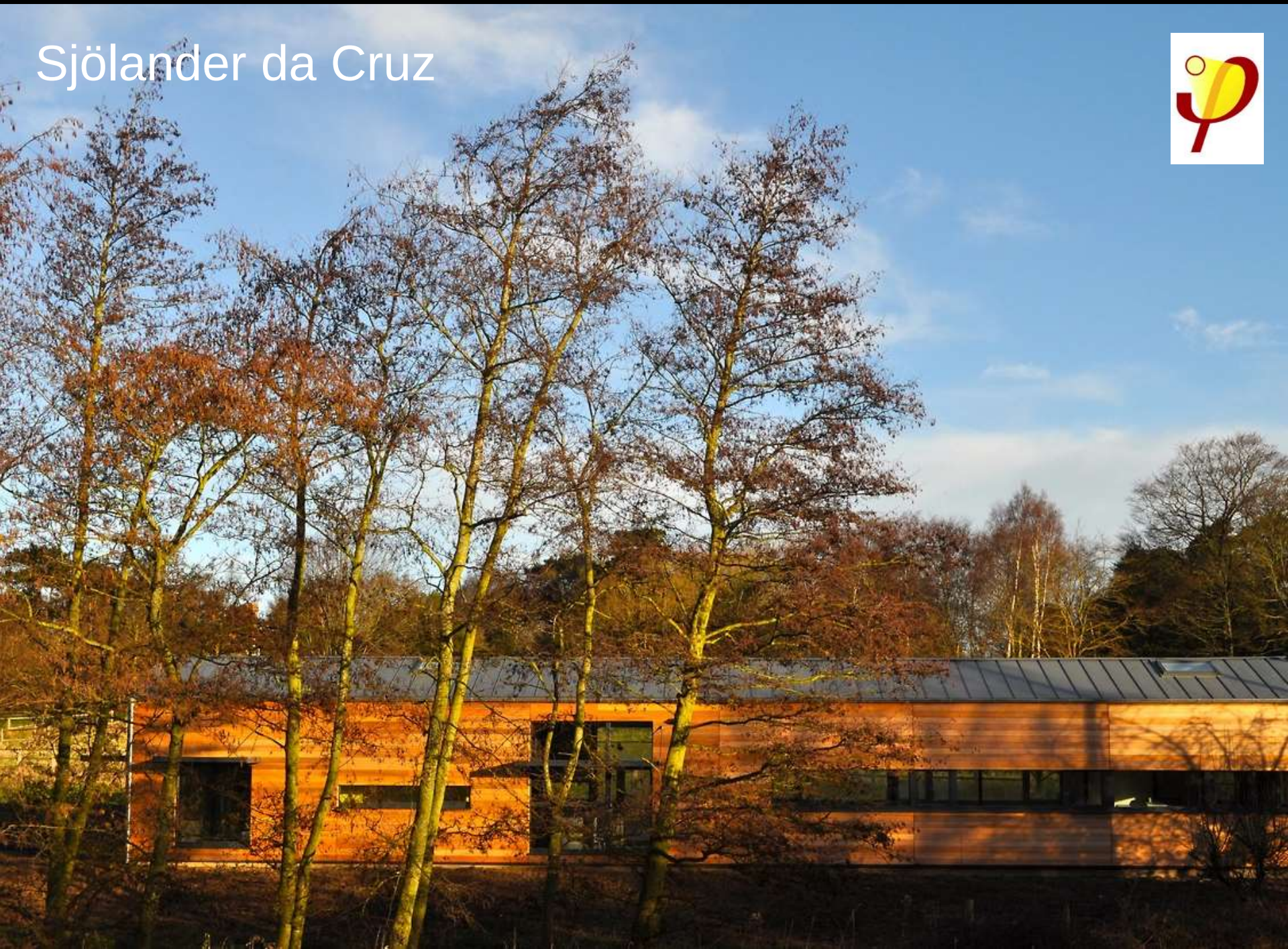
Photo: Juraj Mikurcik

River Studio

Sjölander da Cruz Architect's Office

EnerPHit
Certified Retrofit
Passive House Institute

Sjölander da Cruz



Sjölander da Cruz

Lancaster Cohousing Project

Passivhaus Community Housing Project

Andrew Yeats (Eco Arc Architects) & Alan Clarke

Project Overview

Name: Lancaster Cohousing Project

Type: 41 Owner Occupied Houses

Build type: Masonry & Timber frame

Location: Halton Lancaster

Occupancy: Phased Handover
Occupied since August 2012

Budget: £ 5.4m Inclusive of 41 Passive Houses / Shared Community buildings & site civil engineering works.

Terrace A Passive Houses & Common House Veranda

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Measured Energy Performance

Measured Performance:

(average across all houses)

DHW: 26kWh/m^2.a

Space heating: 13kWh/m^2.a

Electricity: 22kWh/m^2.a

Extra use in common facilities: 5kWh/m^2.a

Primary energy (at boiler room): 77kWh/m^2.a

Heating and hot water house demand are meeting predictions

Electricity use in the houses is unusually low, possibly thanks to communal usage.

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Occupant Feedback

Building User Survey (BUS) was undertaken with **100 % return of questionnaires.**

Residents were very positive about how well it performs. Responses for all eight main categories: **air quality, comfort, design, perceived health, lighting, needs, noise and temperature** were all higher or better than the UK 2011 BUS Housing benchmark.

In five of the categories the project was either the **highest or second highest performer** when compared against other studies.

"An exceptional achievement"

Professor Fionn Stevenson.

Occupant Feedback Quote

" The Lancaster passive house I live in has exceeded all my expectations with regard to comfort, warmth and air quality. The utility bills are exceptionally low and the systems are easy to use. From my personal experience I would have no hesitation to recommending these Passive House Designs to others "

Dr Jan Maskell Lancaster Cohousing Resident

Happy Home Owner Residents

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Aesthetics

Key lessons learnt

- Get the basics right early on
- Keep it simple
- Have confidence in Passivhaus performance
- Keep the same team, commit to learning!
- Small budget & more constraints can help!

"Making the simple complicated is commonplace, making the complicated simple – that's creativity" Charlie Mingus

“What you put in may make a building good
but it’s what you leave out that can make it great.”