Passivhaus
Schools & Larger Buildings
Some lessons learnt

Nick Grant
Elemental Solutions
Technical Director UK Passivhaus Trust
3 schools with the same team

<table>
<thead>
<tr>
<th>Role</th>
<th>Company/Individual</th>
</tr>
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<tbody>
<tr>
<td>Acoustics</td>
<td>Ion Acoustics</td>
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<tr>
<td>Architect</td>
<td>Architype West</td>
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<td>Wolverhampton City Council</td>
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<tr>
<td>Contractor</td>
<td>Thomas Vale</td>
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<td>M&amp;E</td>
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<td>Passivhaus</td>
<td>Nick Grant &amp; Alan Clarke</td>
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<td>QS</td>
<td>Jerry Thomas</td>
</tr>
<tr>
<td>Structures</td>
<td>Price &amp; Myers</td>
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</table>

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.
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.
Details
Learning from Others
PHPP Tools Custom parametric sheet

House version
## PHPP Tools

**Simple scenario tracker**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Notes</th>
<th>TFA m²</th>
<th>Dwell units</th>
<th>Form factor</th>
<th>Annual demand kWh/m².a</th>
<th>Heat Load W/m²</th>
<th>Sum of U &amp; H₂O</th>
<th>daily temp swing K</th>
<th>Mass Wh/kWh TFA</th>
<th>Glazing m²</th>
<th>Glazing % of TFA</th>
<th>Glazing % of Glazed fraction</th>
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<th>Avg g</th>
<th>Avg g</th>
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</tbody>
</table>

*Note: TFA = Total Floor Area, Dwell units = Number of dwellings, Form factor = Heat transfer factor, Annual demand kWh/m².a = Annual energy demand in kWh per square meter, Heat Load W/m² = Heat load in watts per square meter, Sum of U & H₂O = Sum of U and H₂O values, Daily temp swing K = Daily temperature swing in Kelvin, Mass Wh/kWh TFA = Mass in Wh per kWh TFA, Glazing m² = Glazing area in square meters, Glazing % of TFA = Glazing area as a percentage of TFA, Glazing % of Glazed fraction = Glazing area as a percentage of glazed fraction, Window avg U = Average U-value of windows, Avg g = Average solar heat gain factor, Window gain kWh/m².a = Window energy gain in kWh per square meter, Window losses kWh/m².a = Window energy loss in kWh per square meter, Net solar gain kWh/m².a = Net solar energy gain in kWh per square meter.*
Standard details made airtight

Standard detail: 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

- Group room
- Classroom
- Hub / street
Hall fed from street when used

School hall

Hub / street

Hall trans fan

Air from street

HALL -> STREET

VENTILATION
Window opening limited by UK Code
An unwelcome constraint

Ambiguous interpretation of 100mm opening

before

200mm after

Ambiguous interpretation of 100mm opening
German Primary School
Stunts: Alan Clarke
Kitchen ventilation

Initial design

- Bushbury: 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 means Passivhaus energy target not possible.
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
## Passive House Planning

### Multi-Ventilation Unit Calculation

**Building:** Wilkinson Primary School  
Av. ambient temp. heating p. (°C)  

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<th>Kitchen</th>
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Lessons learnt: school kitchens

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

Download Paper: www.elementalsolutions.co.uk
Kitchen comfort June-July

25°C 77°F
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%!!

www.elementalsolutions.co.uk
Daylight and lighting - theory

What worked:
• Target 2W/m²/100lux & max 300lux, so classrooms etc are limited to 6W/m²

Less successful:
• Daylight optimised by 3D modelling
• Consideration of localised shade for whiteboard
• State of the art energy saving lighting controls
Practice
Lights on when sun out
Measured Energy Performance
Bushbury Primary School
- 90% less than the old school

Figures are based first year readings.

Gas (x 1.1 for PE):
Space heating*: 14 kWh/(m².a)
Hot water: 7 kWh/(m².a)

Electric (x 2.7 for PE):
Lighting: 12 kWh/(m².a)
Power & plant: 22 kWh/(m².a)
Kitchen: 7 kWh/(m².a) Sprinkler frost protect: 14 kWh/(m².a)

Total primary energy: 169 kWh/(m².a)

Comment:
Primary energy is higher than the target 120 kWh/(m².a)
Sprinklers = 38 kWh/(m².a) PE (‘frost’ protection)

Main success:
Kitchen energy & comfort

Main lessons:
Issues with automatic lighting controls and sprinkler systems.
South classroom

25°C 77°F

Indoors

35°C 95°F

Outdoors
“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 team’s 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 plus 10% less budget
   - ‘To double creativity, halve the budget & the available time’!
Wilkinson Ground floor plan

Classrooms clustered around two hub spaces, school also includes community use facilities
Wilkinson First floor plan
## Metabolic Heat Gains

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

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 15 kWh/(m$^2$.a) target
Less reliance on solar gain

3.8W/m² v 2.8W/m² IHG
Means we designed a different building
An aside - Small Dwellings & IHG

Internal heat gain using PHPP and BRE occupancy in PHPP

- W/m² PHPP occupancy

- Total floor area (m²)

- Internal heat gain (W/m²)
Small Buildings & IHG

IHG = 71 TFA⁻⁰.⁷³ (curve fit for PHPP calculated IHGs)

Heating demand for simplified dwelling

- variable W/m² internal gain
- fixed 2.1 W/m² internal gain
How small can we go?
“You sure we got the right boiler?”

2,400m² 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 and less (PH) skylights

• Big cost & time savings
• Less overheating
• No leaks
Windows replace curtain wall

- Big cost saving
- Easier to install
- Easier to get airtight
- Simplified structure
- Worked better with actuators.
Optimised local hot water

Electric DHW storage shared between several areas. 8mm micro-bore, 0.5 US gpm (1.7 l/min) sprays
Optimised MVHR ducts
Optimised MVHR layout
Air-tightness detailing
50 = 0.3 \text{ m/s}

Celebratory cake!

Small fan for a big building
Hereford Archive & Records Centre

A very Eco-Minimal passive approach
Sjölander da Cruz
Lancaster Cohousing Project

Passivhaus Community Housing Project

Andrew Yeats (Eco Arc Architects) & Alan Clarke

International Passive House Conference 2014
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.
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.
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.

"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
Aesthetics
Aesthetics
Key lessons learnt

Get the basics right early on
Keep it simple
Trust Passivhaus performance
Keep the same team & invest in learning!
Go back an look for problems to fix
Small budget & more constraints can help!
“What you put in may make a building good, but it’s what you leave out that can make it great.”