Advanced Rural Eco Housing

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The ENERGY SHOWCASE Project

Herefordshire

Herefordshire

A small, agricultural county in the south-west Midlands. Population 178,000. Land area 2,180 km^2.

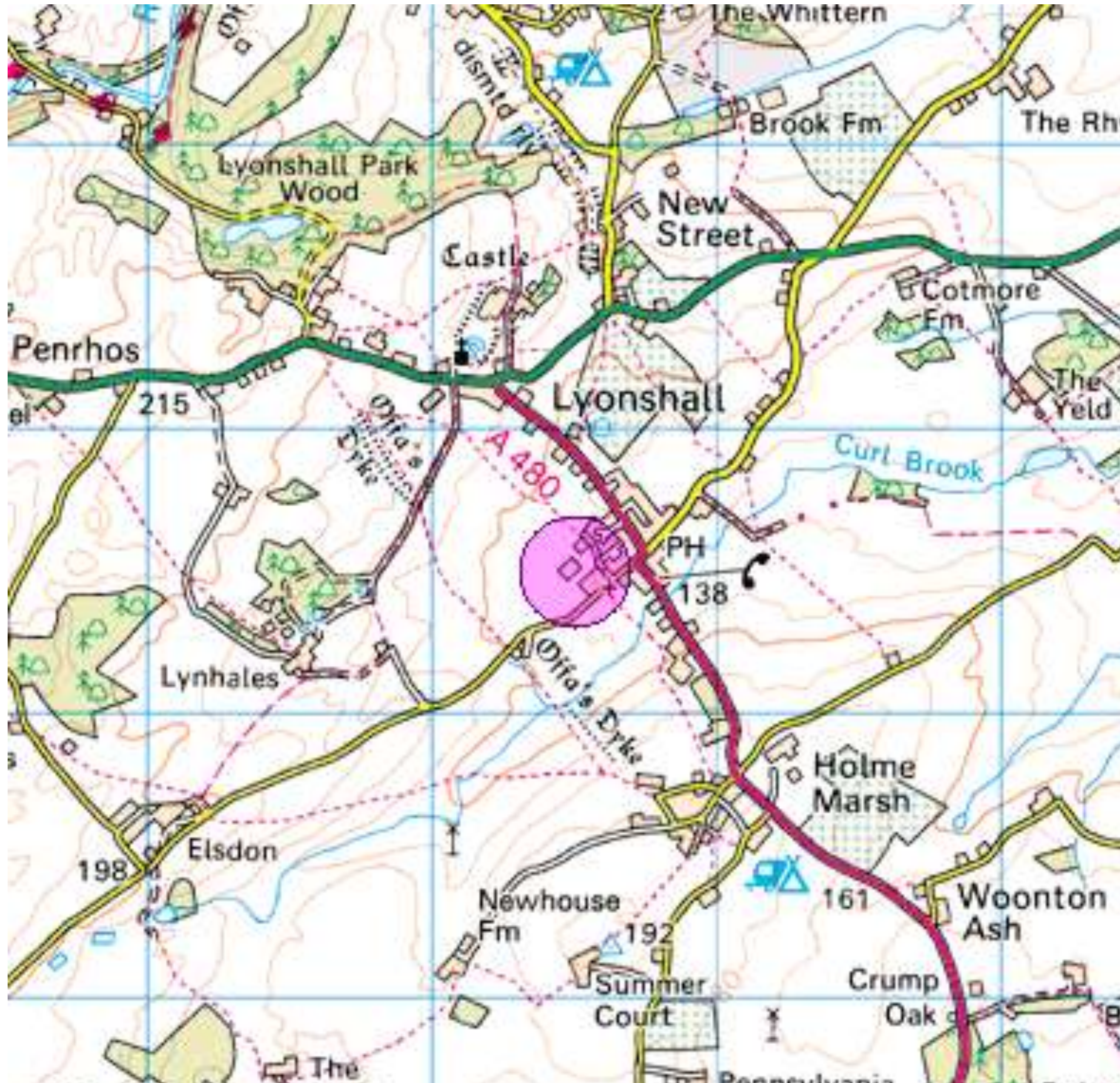
The most sparsely-populated county in England.

http://www.herefordshire.gov.uk/docs/research/hfds_facts_figs.pdf

Lyonshall

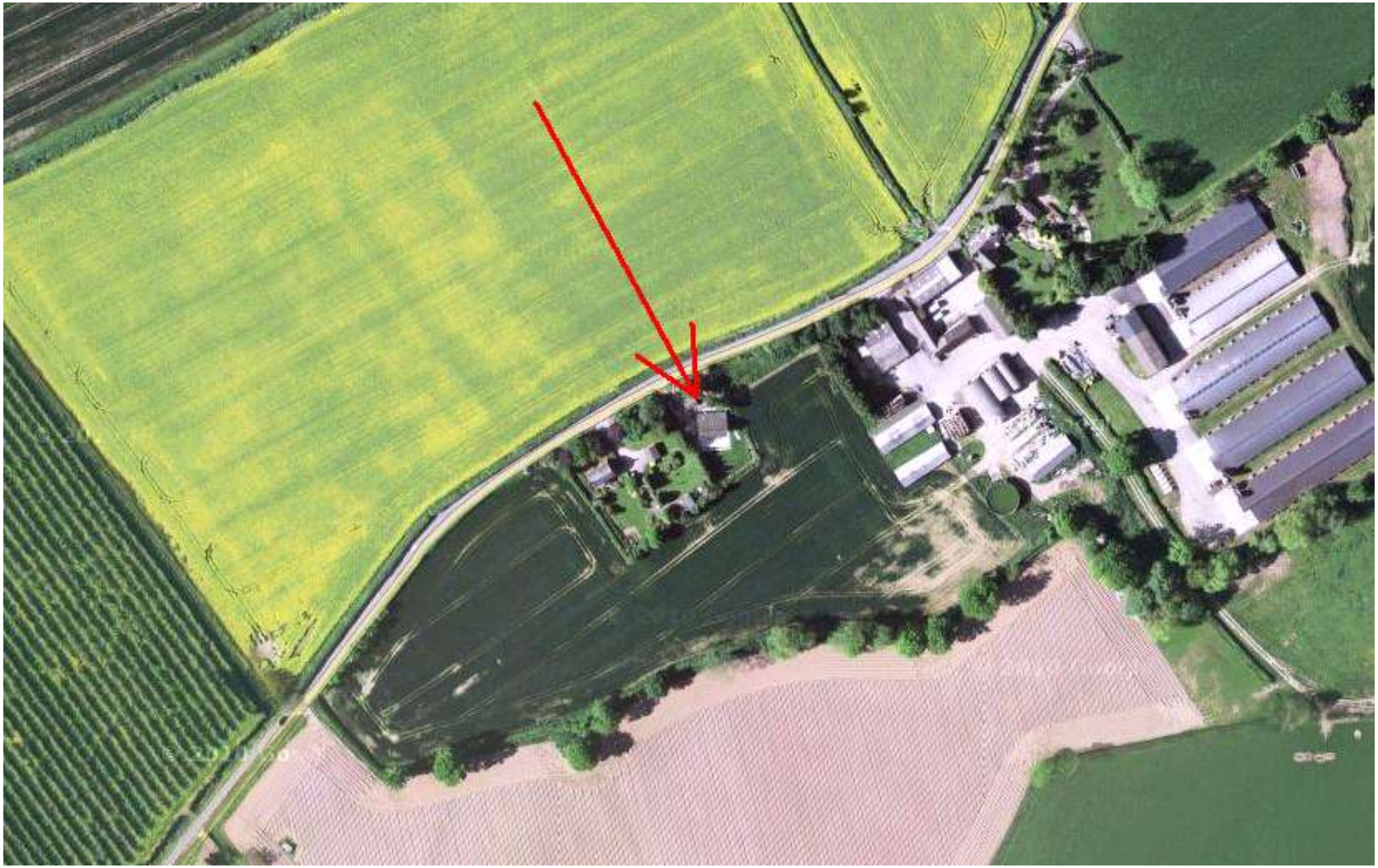
Small village 15 km W of Leominster, 25 km NW of Hereford

80 km WSW of Birmingham.



Aerial Photograph

Picture from Google maps



The ENERGY SHOWCASE Project

Summary

- Named after a 1980 project in Canada. Inspired by and recognises the lead set by Canada, followed by USA, Sweden and Denmark, in work on energy-efficient and solar-heated buildings after the oil crises of 1973 and 1979. This predated the development of the Passivhaus Standard.
- A 110 m^2 detached "cottage" on a rural 1,300 m^2 plot. The only mains services are electricity and telephone. Water is from a borehole. There is no mains gas or drainage. A very standard situation for rural parts of the county. There was no particular desire for autonomy, but the nature of the site dictated certain patterns of servicing and ruled out others.
- The site had detailed planning permission for a replacement dwelling. After a re-application, this was successfully amended to permit the rear façade to face due south.
- The building will eventually produce all its energy from renewables, mostly solar, as follows:

  Passive solar space heating; An experimental passive solar water heating system; Solar electricity for ventilation, lights & appliances, but this is interchanged with the national grid; solar is not used preferentially. Biofuels for cooking.

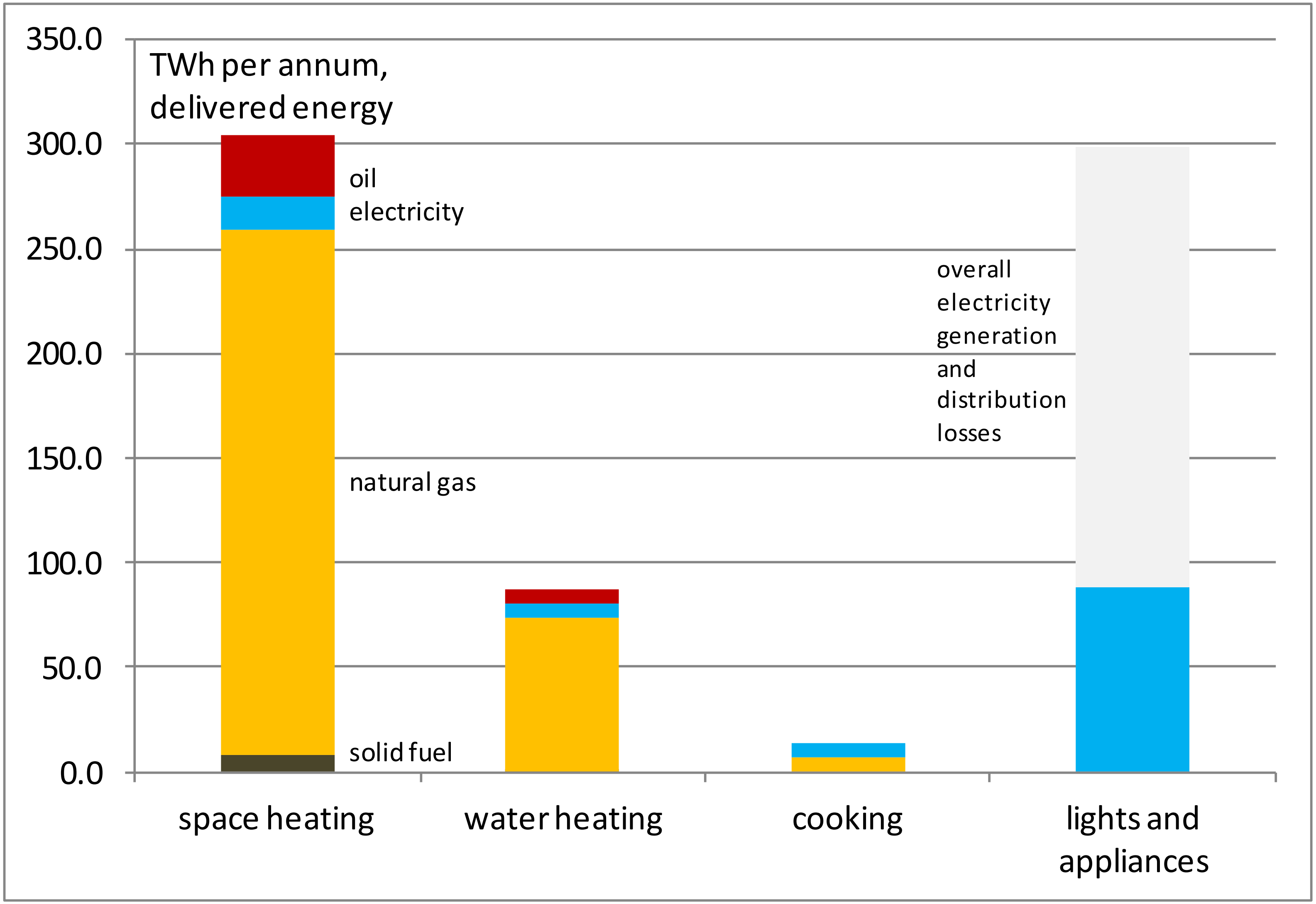
The ENERGY SHOWCASE Project

Aims

- Minimal use of purchased energy for space heating, without reductions in comfort.
- Similarly for water heating, after the solar system is complete.
- Drastically reduced electricity consumption, via the use of extremely energy-efficient large and small electrical appliances, lighting and mechanical ventilation systems, and by not cooking with electricity.
- Approx. 50% lower embodied energy and embodied CO_2 than a normal new house, despite the use of high thermal capacity, long-lived construction.
- Low if not zero use of materials with particularly adverse environmental impacts; e.g., lead, PVC, other halogenated hydrocarbons, toxic wood preservatives, "synthetic" paints, aluminium.
- Much-reduced maintenance and running costs via the use of durable claddings and finishes.
- An attractive and comfortable building which blends into the countryside of the English-Welsh border.

UK Domestic Energy Use, 2009

The baseline



View of the North Roof

A “catslide”. Clad in reclaimed, mostly purple Welsh slates. Fixed with Belgian stainless steel slate hooks and stainless steel screws. A more secure fixing than nails in high winds and permits the re-use of very old slates.

Two rooflights of an experimental design, giving greatly reduced heat loss. The larger one is above the house stairwell; the smaller one is above the porch.

The outer portion of both lights comprises a single pane of toughened low-e glass, an oak frame and stainless steel flashings.

Another View of the North Roof

View of the South Roof

Clad in ten toughened or heat-strengthened glass panels 1,180 x 2,950 mm:

1. Four panels made in Germany contain photovoltaic cells for electricity generation.
2. Two panels are blank.
3. Four panels will comprise part of the experimental solar water heating system.

The glazing bars between the panes are stainless steel. This has a lower embodied energy and longer life than the more common aluminium.

The lean-to greenhouse adjacent to part of the ground floor is not yet constructed.

External View of the Windows

Made by Thermotech Ltd. of Ottawa, Canada, who have been producing very high-performance glazing since 1991-92. Krypton-filled, double low-emissivity, warm-edge triple glazing, in insulated pultruded fiberglass frames. Very low frame profile, seen in elevation, hence higher passive solar gains than the majority of even today's European-made energy-efficient windows.

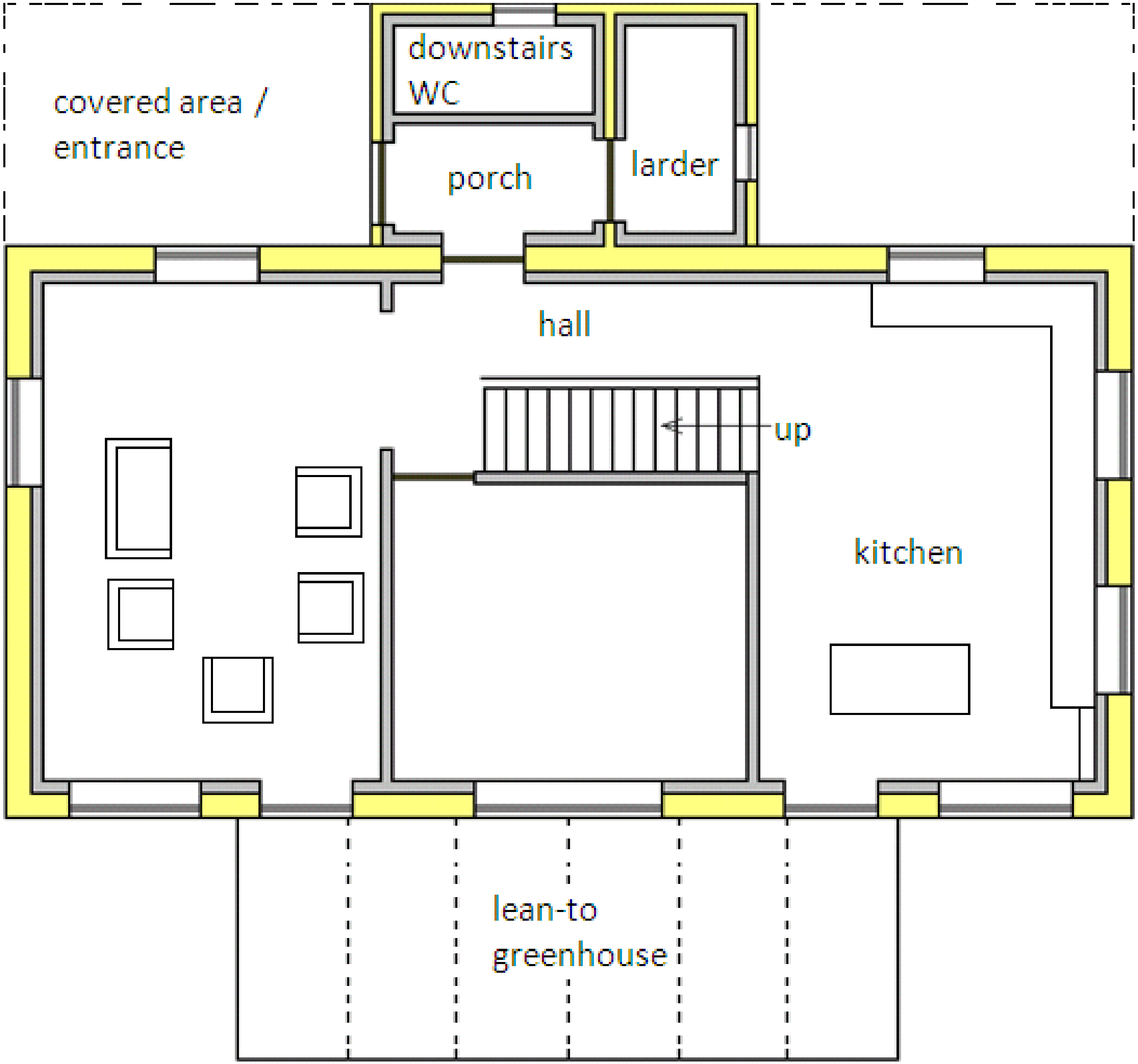
Some Views of the Interior

Left - The staircase, clad with green Lake District slate. The solid balustrade is topped with blue sandstone offcuts. The hall floor is clad with orthogneiss offcuts. *Right* - The kitchen floor, clad with granite offcuts from a kitchen worktop manufacturer. Had this material not been salvaged, it would have gone to landfill, as would another 70 m^2 of stone which is used elsewhere, internally and externally.

Note: Views of the construction site. May not fully reflect the appearance of the finished house.

Ground Floor Plan

A long, thin house with its principal rooms facing due south. Better thermal performance than a more compact plan.



Services Installation Underway

Left - Cold water piping

Centre - Hot water piping

Right - Ventilation duct

The small pipes in the picture are associated with the solar water heating system.

The same riser also now contains 230 V AC wiring and 290 V DC wiring from the roof-mounted PV system to the inverter.

230 V AC Wiring Underway

100% PVC- free, screened cable. Partly for EMF reduction, also to avoid interference with data cables.

Seemed to present a great challenge to existing suppliers. Long delays were encountered on orders for seemingly simple specifications .

Space Heating Energy Use

- House to be heated by passive solar and internal gains. No space heating system installed. Predicted standard of thermal comfort; e.g., hours below 20°C, on a par with an existing UK home with a conventional heating system.
- Factors contributing towards this goal:

(a) Very high thermal insulation;

(b) Very high thermal capacity;

(c) Very draughtproof construction; max. 0.4 ac/h @ 50 Pa;

(d) Mechanical ventilation with heat recovery, including an earth-buried tube to preheat fresh air in winter and precool it in summer, with novel techniques to augment the winter preheat;

(e) Windows on the south façade which gain more heat than they lose, even in a grey and gloomy December or January in southern England;

(f) Other techniques.

- Early dynamic computer modelling used historic Kew weather data. Since cross-checked with other more local temperature records and solar radiation data in the Meteorological Office's records.

The Sources of Thermal Capacity

Structure, including stairs and underfloor fill **85%**

Floor finishes **9%**

Plaster **2%**

Other, including fixtures and fittings **4%**

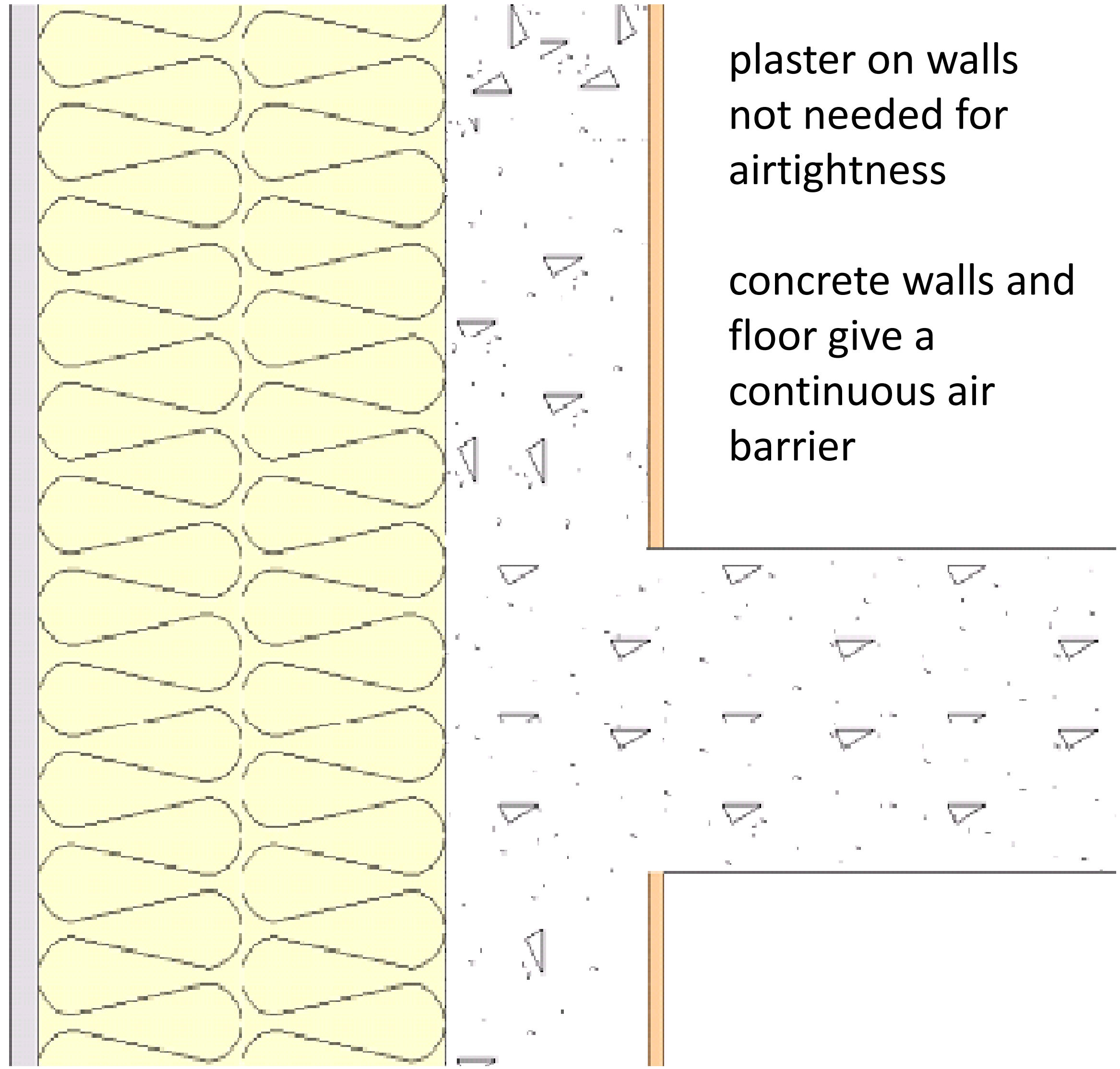
Element		Thermal Capacity	
		kWh/K	%
1	*In situ* concrete walls and floors	36.8	51.5
2	Dense blockwork	8.9	12.5
3	Fill under ground floor	14.4	20.1
4	Stone flooring and screeds	5.8	8.2
Sub-total, items 1-4		**66.0**	**92.2**
5	Plaster	1.3	1.8
6	Concrete stairs	0.4	0.6
7	Masonry balustrades	0.3	0.5
8	Tiled kitchen, bathroom and other walls	0.3	0.4
9	Water storage wall, office	0.2	0.3
10	Stone window sills	0.1	0.2
11	Stone skirtings downstairs	0.1	0.1
12	Kitchen worktop and units	0.1	0.2
13	Plasterboard	0.0	0.1
14	Timber T&G floors on battens	0.4	0.5
15	Stone shelving and kitchen unit plinths	0.1	0.1
16	Kitchen unit plinths	0.1	0.1
Sub-total items 5-16		**3.3**	**4.7**
16	Fitted furniture and house contents	1.6	2.2
17	Other finishes and components	0.5	0.7
16	**TOTAL**	**71.6**	**100.0**

First Floor Construction Detail

Schematic

Showing the externally-insulated and rendered *in situ* concrete structure.

The structural engineers were asked to reduce the volume of reinforcement steel to a minimum. The resulting concrete is 40-50% less energy-Intensive than fired Clay bricks, measured In kWh/m^3.



plaster on walls not needed for airtightness

concrete walls and floor give a continuous air barrier

Water Heating Energy Use

- A novel, building-integrated passive solar water heating system on the second floor, within the slope of the pitched roof. Directly fed by pressurised incoming water, with medium-term heat storage. Construction of the system is in progress. Expressions of outside industrial interest would be welcome.

- System design based *inter alia* on pioneering work by solar engineer Norman B Saunders in Weston, Massachusetts, USA from 1965 to 1995. His research and practice was popularised by the physicist Prof. William A Shurcliff, of Harvard University, Cambridge, Massachusetts, who worked in the solar energy field for 37 years after his “retirement” at 60.

- Aims for a solar fraction in the high 90s%, avoiding the need for major use of stored fuel; i.e., LPG or in future bio-DME. Hot baths in December?

Electricity Use for Lighting

- Will use ~97% fluorescent lighting, concealed by appropriate shades / luminaires. ~3% from LEDs in a few spotlights, task lights; e.g. in cooker hood. <<1% from halogen outside lights; the logical next step on these is not to fit LEDs but to fit energy-efficient PIR circuitry.
- Efficacy in lumens per watt (lm/W) including control gear = 100 lm/W for T5 fluorescent lamps (modern sizes 13, 19, 25 & 32 W), 55-70 lm/W for two-limb compact fluorescent lamps (CFLs) and 12-15 lm/W for GLS lamps.
- Present LEDs provide 40-50 lm/W if sized to give adequate light at the end of their 25,000-50,000 hr life. They excel at replacing halogen downlighters/spots, as long as those used have an adequate colour rendering index.
- Shades/luminaires with efficiencies (LORs) in the range 75-90%, not the common 30-70%.
- Overall target = lighting electricity consumption 86% below the UK average of ~1,000 kWh/year in a dwelling of the same size and occupancy pattern. Same amount of light, seven times the energy efficiency.

Energy Use for Cooking and Domestic Electrical Appliances

- With extremely energy-efficient electrical appliances and ventilation, a 1.2 kW(e) roof-integrated photovoltaic (PV) system will produce slightly more electricity than the house consumes, on an annual average basis. Estimated electricity generation = 1,020 kWh/yr, consumption = ~900 kWh/yr. For instance, the refrigerator-freezer intended to be used consumes 129 kWh/year as opposed to a typical 500 kWh/year.

- The house is connected to the national grid. In the long term, PV as produced here is expected to be just one of many different renewable electricity sources contributing to the UK national grid.

- Fossil propane for cooking, approx. 500 kWh/yr, until equivalent biofuels; e.g., DME, www.biodme.eu, are available in the UK.

- Residual CO_2 emissions offset by on-site CO_2 sequestration measures. In the fossil fuel stage, a combination of *clean* fossil fuel combustion and biological CO_2 sequestration is considered less environmentally-damaging than small-scale wood combustion.

Electricity Use for Ventilation

- Mechanical ventilation and heat recovery (MVHR) system based on energy-efficient backward-curved fans, a low pressure drop ductwork system, generously-sized silencers and F8 particle filters. Estimated thermal efficiency 84/92/96% at high/normal/low air flow. Note that high thermal efficiency is not worthwhile if it only comes at the expense of a poor specific fanpower.
- Site-built air-to-air heat exchanger of recycled glass tubes, formerly used in an East Anglian maltings. Very low pressure drop versus equipment on the market, even "Passivhaus"-certified systems. Constructed, some of system incomplete.
- Displacement ventilation layout, to give an improved ventilation efficiency and fresher internal air per unit of airflow.
- Earth preheating tube for intake air, based on prior experience in, *inter alia*, Germany and Switzerland. Two novel features incorporated to give a higher level of winter preheating, especially in "coldwaves", and an improved summer cooling performance in heatwaves.
- Projected specific fanpower 0.12 Wh/m^3. This is one-quarter that of Passivhaus-certified MVHR systems (0.45 Wh/m^3) and one-tenth that of normal to poor UK systems (1.0-2.0 Wh/m^3).

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Knauf Drywall Ltd.
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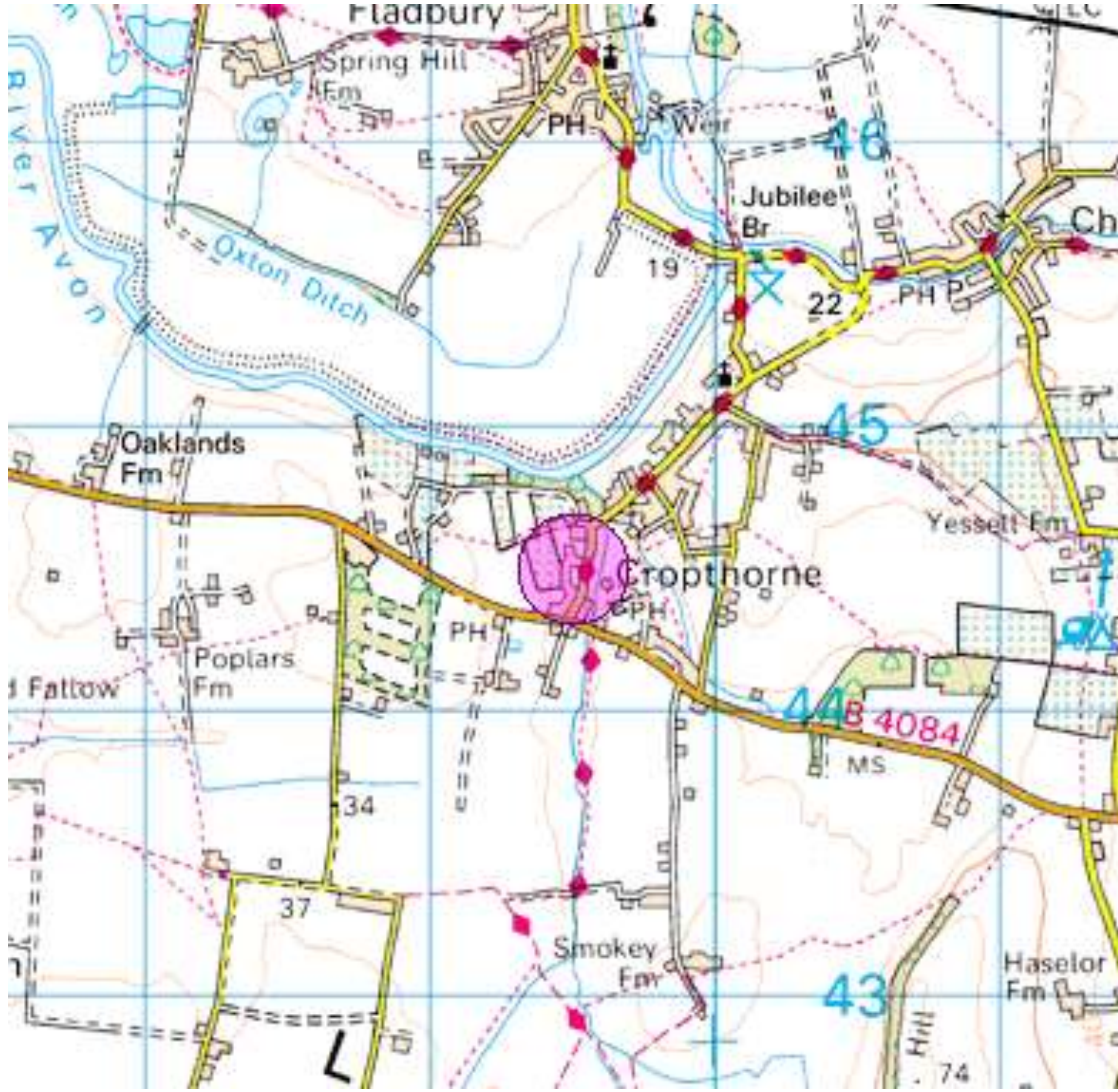
The Cropthorne Automomous House

Worcestershire

Cropthorne

Small village 20 km E of Worcester, 5 km W of Evesham

50 km S of B'ham



The Finished Building from the South-West

Following three pictures are by either Neill Lewis, Chartered Architect or Mike Coe

From the South-East

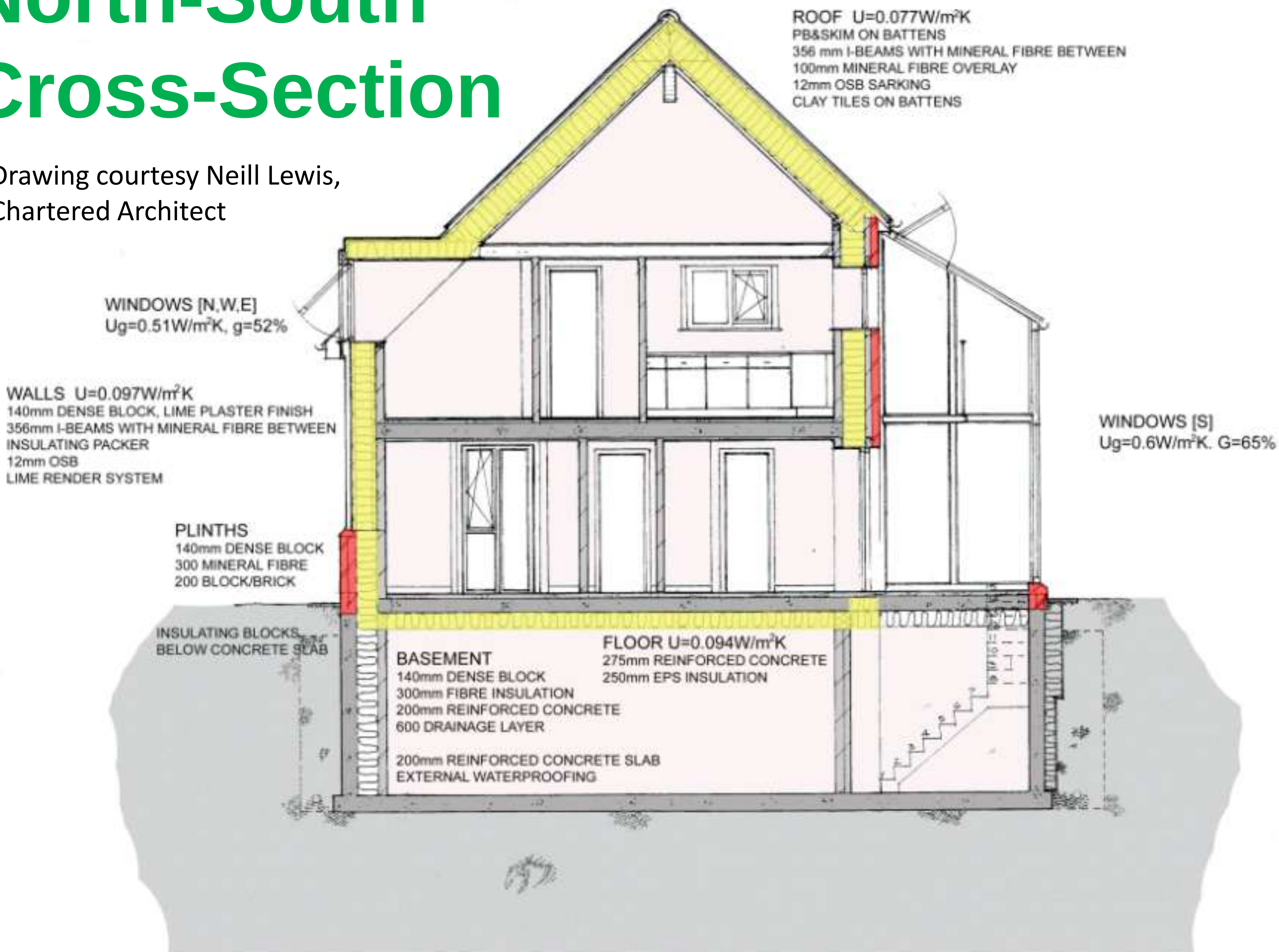
Some of the Thermal Capacity Being Installed

Some More Thermal Capacity

Internal Wall of Scrap Electric Storage Heater Bricks

North-South Cross-Section

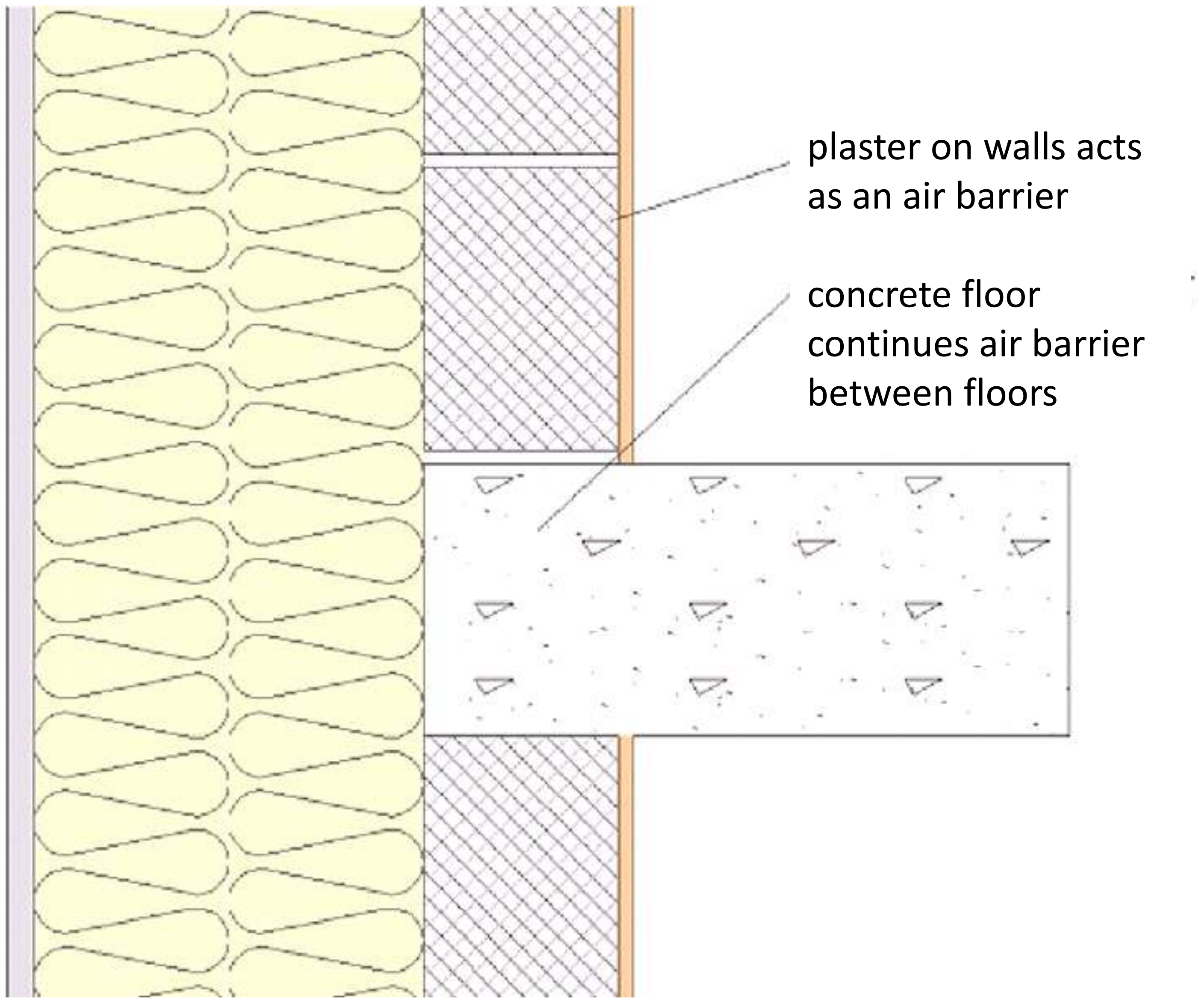
Drawing courtesy Neill Lewis, Chartered Architect



First Floor Construction Detail

Schematic

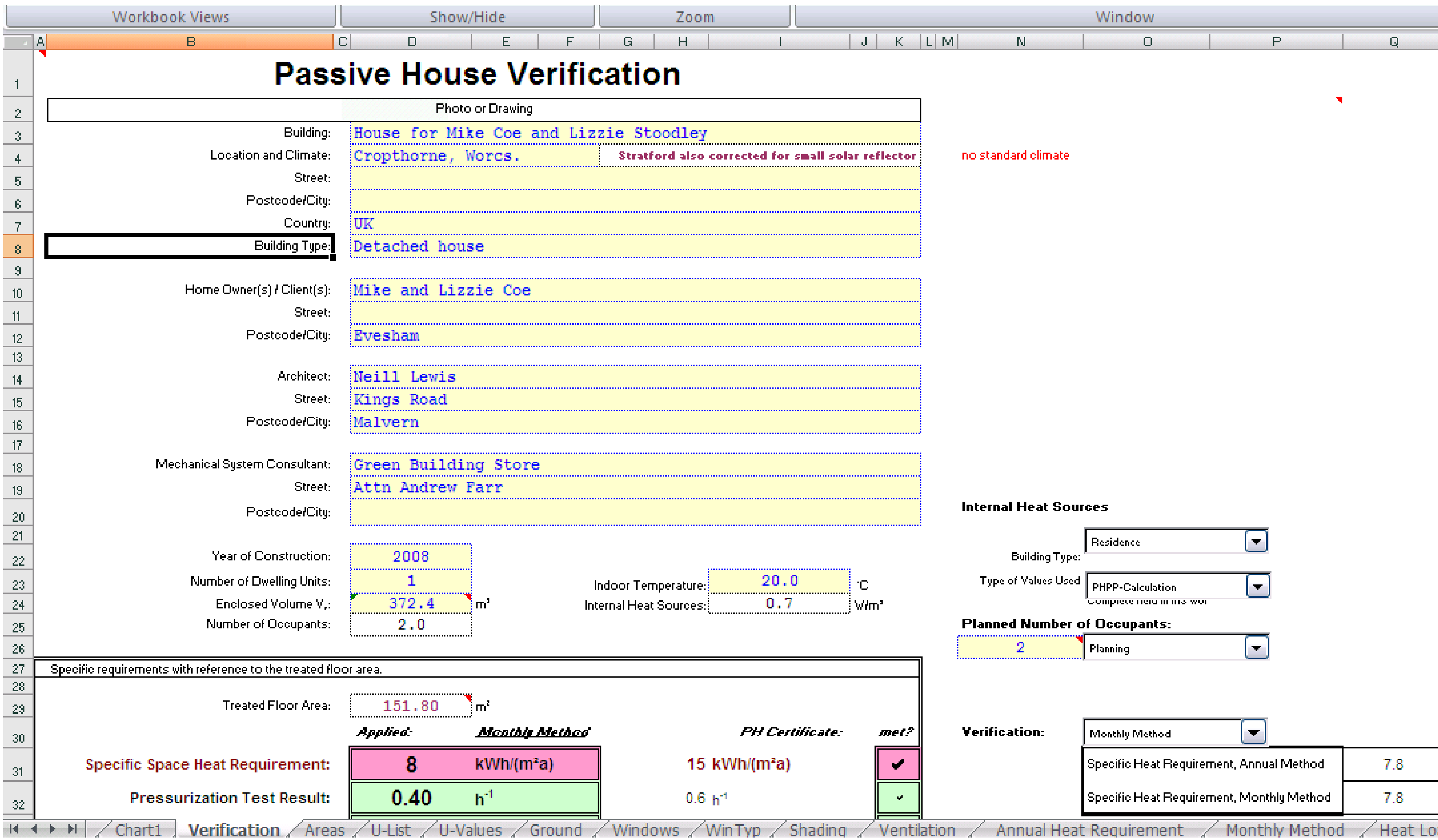
Externally-insulated and rendered structure. Dense aggregate concrete block walls and *in situ* concrete floor



Thermal Modelling with PHPP

Predicted Space Heat Consumption 8 kWh/m^{2}yr at 20^{0}C.

Based on extremely energy-efficient lights and appliances. Lower if temperature fluctuations are permitted.



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