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It looks ordinary.

But it isn't.

It's what an extreme low carbon domestic refurbishment looks like. James Parker visits 89 Culford Road to find out whether today's extreme is tomorrow's normal

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Just how low can we go?

While we fret about making new homes zero-carbon, it's easy to forget about the refurbishment market. James Parker visits 89 Culford Road in London to see what can be done to make existing dwellings extreme low carbon

BSRIA MODEL PROJECT

BSRIA model projects report on the more interesting and influential building projects designed by BSRIA Members. It is also BSRIA's intention to re-visit the projects and report on their performance over time.

A building worthy of a re-visit is either a construction project notable for its contribution to design innovation and sustainability, or a project that demonstrated a step-change in delivering improvement through the supply chain.

89 Culford Road is the family home of building physicist Robert Cohen and Bronwen Manby. Robert is technical director of energy advisor Camco, and one of the prime movers behind the PROBE post-occupancy research project.

If you look through any estate agents window you can always find a house "in need of modernisation". In most cases this means a new kitchen or bathroom suite, and maybe a lick of paint over horrible wallpaper from the 1970s.

Never does it say "opportunity to become zero-carbon." At least, not yet. New houses may be being built to more stringent energy and environmental targets, but refurbishment is where the emphasis should truly lie. Of the housing stock that will exist in 2050 (the date at which the UK intends to reduce carbon emissions by 80 per cent), over two thirds have already been built.

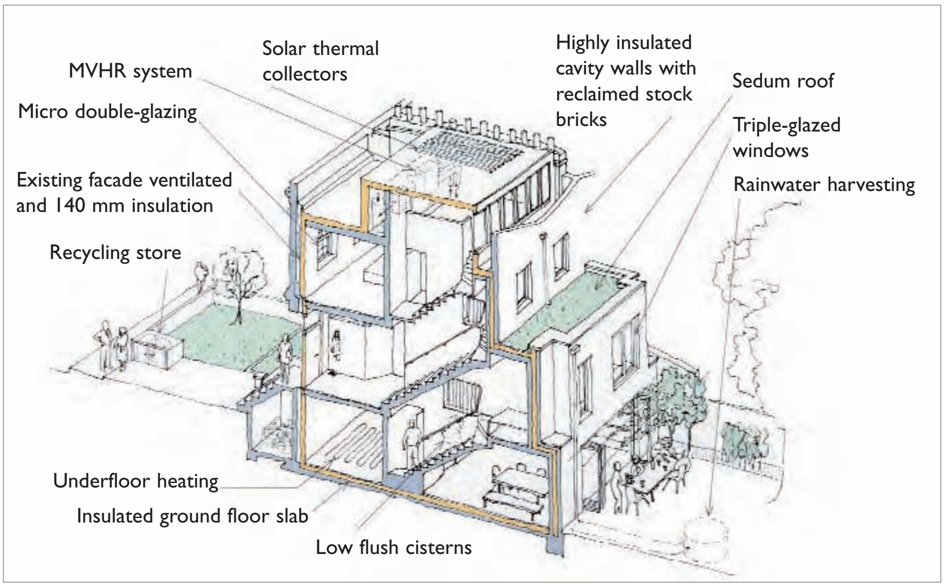
The British love of Victorian villas and Georgian terraces means that the straightforward approach of demolition and rebuilding is not an option. In fact in many areas it would be virtually impossible to get planning permission to do this. This means extreme low energy refurbishments are tomorrow's new build, and should become the definition of Estate Agents' "modernisation".

A pioneer in attempting extreme low carbon refurbishment is Camco technical director Dr Robert Cohen. Robert, with his partner Bronwen Manby, chose a three-storey Victorian town house in the very conservative De Beauvoir Conservation Area of Hackney, North London. The aim was to refurbish an old house in dire need of modernisation and in so doing reduce its carbon emissions by 80 per cent.

The design, by architect Robert Prewett of Prewett Bizley Architects (a runner-up in *Building* magazine's Sustainability Awards), involved major work to the fabric of the building, while retaining the front façade. While it was never intended to change the structural elevation facing the street, the same cannot be said of the rear of the house which has been completely rebuilt.

There were various motives for this, but notably it was driven by the need to increase and improve the existing accommodation space, which had significantly been reduced by the addition of high levels of thermal

Right: The many extreme low carbon features of 89 Culford Road. The dwelling has all-new floors, and the staircases were reversed to enable better use of the space.



insulation and other internal changes. The new rear wall was also built to provide a small extension for the ground and first floors along with a small roof extension.

Despite the fact that the rear of the house was not viewable from the street, it caused the most problems with the planners, with worries about overlooking neighbouring properties for example. Ironically, had the house been in the next street the story may have been very different. The London Borough of Islington is much more engaged in the low carbon refurbishment agenda, even offering grants. By contrast, Hackney's planning practices are running somewhat behind its policies on carbon dioxide emission reductions.

While the front elevation was kept original, an internal frame was constructed inside the front wall to support rebuilt floors and also to eliminate thermal bridges. The gap between the existing façade and the internal frame is filled with 140 mm of insulation, with a small ventilated space between the façade and the insulation. Extra insulation was also added to the floor (100 mm) and to the roof (180 mm).

Airtightness issues

Passive measures sorted, attention then turned to the building's airtightness. Surprisingly, for such an old building, the team managed to get a very low air permeability rate of 1·1 air changes per hour (ach) prior to plastering – a remarkable achievement. This creditable performance started with the architect lecturing the building team on the importance of airtight detailing. This led to more care being taken with wall, floor, window and roof junctions.

The initial target of 1·5 ach was always going to be a challenge, as the first test proved with a result of 5 ach. Taping and sealing brought this down to 3·5 ach, with a third and final push (before plastering) bringing it down to 1·1 ach. The final value will be a fraction of that.

However, an airtight house with negligible ventilation would soon become unliveable. Kitchen fumes (which may contain NOx if using gas hobs) and humid air from the bathroom would combine with volatile organic compounds released from materials in the house, and of course natural smells from the human (or animal) occupants to produce a very unpleasant environment.

The high level of airtightness therefore justified the use of a mechanical ventilation and heat recovery unit (mvhr). The product chosen was the Itho HRU Eco 4.

This plant, installed on the top floor adjacent to what will be Bronwen's home office, will suck out stale air from the bathroom and kitchen, transferring

Above: Architect Robert Prewett with 89 Culford Road's Itho HRU Eco 4 mechanical ventilation with heat recovery unit. This is said to possess a reclaim efficiency of up to 91 per cent, predicted to give a cut of 4264 CO_2kg per annum compared to the dwelling's original heat requirements.

WAYS TO GO EXTREME LOW

The micro double-glazed windows retained their sash features, albeit replaced with new frames with improved seals (four draught seals per sash) to help with airtightness. This gives the front of the house a virtually original appearance

The original back wall was completely removed and rebuilt with reused brick to minimise the environmental damage and 200 mm of insulation to improve its thermal performance. Rainwater from the roof is captured by copper drains on this elevation. Standard triple-glazed windows were acceptable as the rear elevation was not governed by local authority conservation rules

Left: Robert Cohen with a model of 89 Culford Road, showing clearly how the new structure extends out beyond the original building boundary. One lesson learned is never to underestimate how much living space can be lost through installing deep thicknesses of internal thermal insulation - on party walls as well as front and rear elevations. Interstitial space is also required for ducts that link the mechanical ventilation system with bathrooms and the kitchen.

the heat to outside supply air, then distribute it throughout the house via a system of flexible ducts run down an interstial gap adjacent to the party wall.

As the mvhr manufacturer claims an heat reclaim efficiency of up to 91 per cent, the Cohens accepted the fan power penalty as the mvhr should considerably reduce the dwelling's heating requirements. (See tables 1-3 for energy savings and paybacks.)

Energy savings

For Robert Cohen, the ventilation strategy was the key feature of the refurbishment in terms of reducing energy demands. Looking at the figures calculated for before and after the work was carried out, it is clear where most of the savings will come from.

A reduction of 210 kWh/m^2 per annum or 92 per cent is outstanding, and would not have been possible without the mvhr/airtightness combination. In fact, this saving is three times the total predicted energy use of the house.

The build team is so confident of the thermal capability of 89 Culford Road, that they have only installed underfloor heating on the lower ground floor, with two small towel rails in the bathroom to make sure towels dry out.

Glazing

In addition to the walls, careful choices had to be made with the windows. To complement the rest of the house, they had to have very good seals and very low U-values. This was not easy to fit into a façade in a strict conservation zone. The solution was micro (or slim) double-glazing. These have a small argon-filled gap of only 4 mm. This gave a glazing profile very close to the original. Heat retention is improved with a low-e coating that reflects heat back into the room.

The front windows also kept the sash opening, albeit reproduced with improved seals (four draught seals per sash) to help with the airtightness. This gives the front of the house a virtually original appearance. The rear of the house, without the strict levels of conservation to observe, is equipped with a more traditional low energy window: triple glazing with double edge seals.

This all sounds quite ground-breaking in the UK, but really it's nothing new. In general Robert Cohen's approach follows the guiding principles of Passivhaus, developed in Germany by the Passivhaus Institut in the 1990s. Indeed, the architect Robert Prewett used the Passivhaus Institute's PHPP software to predict the performance of 89 Culford Road as the building's design developed.

Due of the nature of Passivhaus, the PHPP tool is much better at estimating the effects of things like window design, cold bridging and risk of summer overheating than the UK's SAP calculation tool.

Right: Spot the difference. Despite being a conservation area, the house next to 89 Culford Road has standard double-glazed units, whereas Robert Cohen retained the original style sash windows. Extreme low carbon refurbishment doesn't need to look radically different, although what is visible here was just about the only part of the house retained. The entire rear wall and all suspended floors were replaced.

Renewables

No self-respecting low energy house would look complete without some kind of renewable energy technology. But having said that, with this development there was an agreement from the outset to avoid overt eco-bling. This was not only because of the conservation zone, but also because the team believed that they were neither appropriate nor cost-effective. That is not to say that there aren't any.

The original plan was to have installed a heat pipe solar-thermal system. However, to be effective it would have been visible from the street – a consequence of the lack of space to hide it. But luckily for the Cohens the government announced feed-in tariffs that benefited micro-generation. They quickly jumped on this and with a few calculations found that installing solar photovoltaics could be the answer.

The feed-in tariff of 36p/kWh reduces the payback period of photovoltaics from 30 to 40 years down to just 10 to 15 years. The photovoltaics at 89 Culford Road, were installed at a cost of around £5000. They are calculated to provide 1.2 kWp and to meet around 30-40 per cent of the electrical load of the house.

Refurbishment verses new build

How does 89 Culford Road compare to a new house? The current benchmarking system for new homes is the *Code for Sustainable Homes*. However, it is important to note that this system can only assess new dwellings. At present the only (BRE-backed) assessment tool that can be used for refurbished homes is Ecohomes, although this hasn't been updated since 2006. BRE is in the process of developing a domestic refurbishment assessment scheme, but this is not yet available.

Looking at the *Code for Sustainable Homes* and making small adjustments (not possible in a real assessment), the house would achieve a rating of Level 4. While a lot of the *Code* looks at the periphery of the construction process, the key elements of a rating are the energy and water categories. These have mandatory levels to reach to receive a rating at a particular level.

The 80 per cent reduction of energy use at 89 Culford Road has helped score highly here, but to reach the Level 5 rating a 100 per cent improvement would be needed, and even more for Level 6. The water issue would also pass the requirements of the higher levels of the *Code* because of the rainwater harvesting strategy.

The AECB Carbonlite silver and gold standards were also used, with the house

Above: Roof timbers were retained where possible.

Above: The front wall rendered and awaiting insulation.

Above: An internal frame was constructed inside the front wall to support rebuilt floors and also to eliminate thermal bridges. The gap between the existing façade and the frame is filled with 140 mm of insulation.

FACTS AND FIGURES

Table 1: Emissions before and after the refurbishment.

Energy end use	Prior to refurb CO_2kg/y	After refurb CO_2kg/y	Cut in CO_2kg/y	Percentage reduction	Energy
Space heating gas	4683	419	4264	91	Regulated
Water heating gas	765	742	23	3	
Pumps and fans electricity	74	124	-50	-68	
Lighting electricity	387	228	159	41	
Other electricity	633	633	0	0	Unregulated
Total regulated (excluding PV)	5909	1513	4396	74	
Total (excluding PV)	654	2146	4396	67	
Contribution from photovoltaics and the effect on total emissions					
Photovoltaics (PV)		-516	516		
Total regulated energy use including PV[1]	5909	997	4912	83	
Total including PV	6542	1630	4912	75	

1 If all photovoltaic output was allocated to regulated emissions.

Table 2: Annual energy costs before and after the refurbishment.

Energy end use	Prior to refurb £/y	After refurb £/y	Reduction in £/y	Percentage reduction	Energy
Space heating gas	845	76	769	91	Regulated
Water heating gas	138	134	4	3	
Pumps and fans electricity	26	44	-18	-68	
Lighting electricity	138	81	57	41	
Other electricity	225	225	0	0	Unregulated
Total regulated (excluding PV)	1147	335	812	71	
Total excluding PV	1372	560	812	59	
Photovoltaics		-468	468		
Total regulated (including PV)	1147	-133	1280	112	
Total including PV	1372	92	1280	93	

Table 3: Breakdown of annual energy consumption by end use.

Energy end use	Prior to refurb kWh/y	After refurb kWh/y	Cut in kWh/y	Percentage reduction	Energy
Space heating gas	24 139	2160	21 979	91	Regulated
Water heating gas	3943	3825	119	3	
Pumps and fans electricity	175	294	-118	-68	
Lighting electricity	917	540	377	41	
Other electricity	1500	1500	0	0	Unregulated
Photovoltaics		-908	908		

falling in between the two levels. These standards use the German PHPP software to calculate energy usage as it is more capable of predicting energy use accurately in low energy buildings compared to the current version of SAP.

Leaving aside the assessment methods (which are only tools of prediction), 89 Culford Road will be monitored to provide a real measure of performance. Its lessons can then be rolled out across the domestic sector, with hopefully the anticipated energy savings achieved in practice. The first set of monitoring equipment has been installed by the insulation manufacturer Knauf.

Sensors have been installed into the walls, particularly on the front wall, and at the interface between different materials to give a temperature gradient through the wall. This should provide an evidence base and allow Knauf to make recommendations as to how its product could be better used. The house could also be the subject of MSc theses.

What 89 Culford Road illustrates is the sheer degree to which the UK's existing domestic housing stock must be improved if the country is to have any chance of meeting its carbon targets. The effective refurbishment of our existing housing stock is non-negotiable. It's a standard that must apply to all domestic dwellings, not just the small fraction of new homes that will be built – probably sporadically given normal economic cycles of growth and recession – between now and the next 40 years.

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