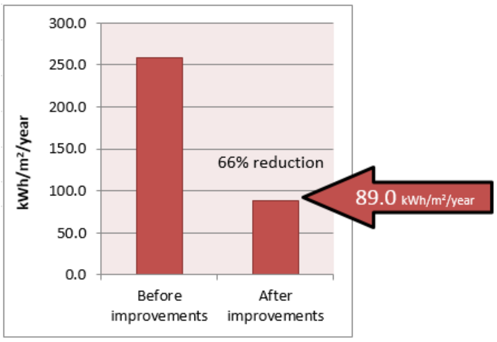
Ladybarn, Manchester

Project description	Whole house retrofit of mid-terrace house, built c.1888.
Treated Floor Area	60.5 m^2
Dates of work	2013
Project team	Myself (PHPP analyst, project coordinator & builder labour), a local contractor team (Expert Home Extensions), plus additional contractors for plumbing, electrics and plastering.
Introduction	The house was cold and draughty, with several air bricks at various points in the walls. The bathroom in particular was always cold. The client borrowed some temperature sensors, and we estimated an average temperature in the house of around 15°C, since the client heated only some rooms and not others. The renovation was done as a full-blown learning exercise, where the client agreed to take the risk with us regarding the measures being suggested and projected costs (which ended up being double what I originally estimated). However, accurate timesheets with allocated hours per job has allowed me to have a much better estimate of what various improvements cost (e.g. cost of internal wall insulation per m^2).

Space heating demand & carbon emissions – before and after according to PHPP

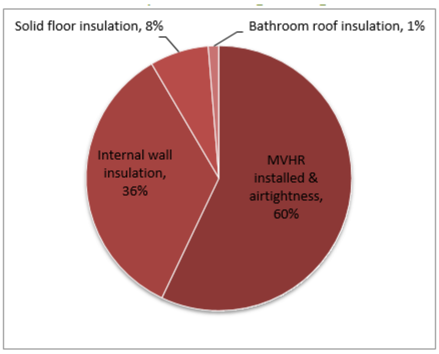
	Before	After	% reduction
Space heating (kWh/m^2/yr)	258.9	89.0	66%
CO2 (kg/m^2/yr)	91.7	39.3	57%

Space heating demand before & after:



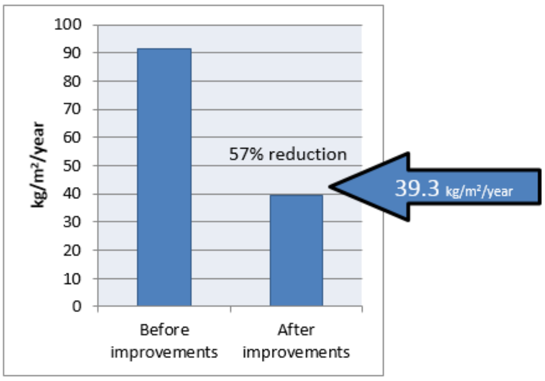
This is the space heating demand before and after the retrofit. Note that this was based on assuming the house was being heated to 20°C before and after. In reality, with a previous average temperature of 15°C and yet planning on heating the house to 20°C after, space heating demand saved reduces to 29%.

Breakdown of savings in space heating demand:



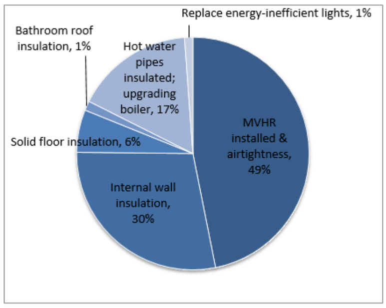
This is the breakdown of the 66% savings in space heating demand (assuming the house was being heated to 20°C before and after). The biggest saving is due to airtightness and MVHR.

Carbon emissions before & after:



This is level of carbon emissions before and after the retrofit. Note that this was based on assuming the house was being heated to 20°C before and after. In reality, with a previous average temperature of 15°C and yet planning on heating the house to 20°C after, carbon emissions saved reduces to 26%.

Breakdown of carbon savings:



This is the breakdown of the 57% savings in carbon emissions (assuming the house was being heated to 20°C before and after). The biggest saving is due to airtightness and MVHR.

Fuel use before and after

Data from 2011-2013 (pre-retrofit):

- Gas use averaged 6,245 kWh per year
- Electricity use averaged 753 kWh per year

Data from 2014 (post-retrofit):

- Gas use averaged 4,396 kWh per year (29.6% drop)
- Electricity use averaged 801 kWh per year (6% increase)

Analysis: PHPP predicted a 36% drop in gas used for space heating and hot water, taking into account the boiler efficiency – this was for a scenario where the house was colder before and warmer after retrofit. The actual drop was 29.6%, so quite close. For electricity, PHPP predicted a 15% increase in electricity use but in the end it was only about 6%.

Improvement	**U-values / information**
Insulation	
Bathroom loft	- Mineral wool 320mm thick, u-value 0.127 W/m²K
Loft	- Mineral wool 300mm thick, u-value 0.134 W/m²K
Solid floor	- Extruded polystyrene (Marmox) 20mm thick, laid with tile grout on solid floor, followed by underlay and 8mm laminate, u-value 1.062 W/m²K - This was one compromise we made to avoid digging up the existing floor. Insulation thickness was dependent on the existing door thresholds.

	Internal walls (external-facing – i.e. not party walls)	- Wood fibre boards 80mm thick fixed direct to wall with concrete screws and plastic washers, u-value 0.36 W/m^2K - Keim Lotexan mineral paint applied on external wall face (2 coats) to reduce rain-driven moisture into brickwork  - Insulation was continuous through floor void, which entailed cutting out floorboards and ceiling plasterboard to accommodate it. 

<table>
<tr><td rowspan="2"></td><td colspan="2">Airtightness</td></tr>
<tr><td>A combination of plastering and vapour-permeable Intello membrane (used with relevant tapes & adhesives)</td><td>
- Vapour-permeable Intello membrane was used on insulated internal walls, and bathroom & bedroom ceilings. Tescon 1 tape was used to join sheets, and Orcon F was used to fix membranes to ground floor and party walls. Tescon Primer RP was used to prime solid surfaces prior to tapes or Orcon F being used.
- All service penetrations (e.g. wires, ducts, boiler flue, etc) had to be dealt with using grommets or tapes.
- A 25mm service zone was added in front of membrane on walls for pipes and wires.
- The same type of baton was used for one of the bedroom ceilings in order to aid plasterboard fixing. For the other bedroom ceiling, the membrane was fixed to a more substantial wood frame which was installed to remedy an old sagging ceiling (along with purlin supports in the loft).


- Naidec (black double-sided sticky tape) was used prior to service zone batons being fixed, in order to maintain airtightness after the drill had created a hole for the concrete screw.

- The stud wall next to one of the bedrooms opened directly into loft, so this had to be
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trimmed off in order to allow the membrane to pass in a continuous layer from the external wall through to the solid partition wall next to the stairs.

- No membrane was used on the ground floor or party walls – here we relied on the existing surfaces, but for the party wall, this had to be re-plastered in places, and previously unplastered areas (e.g. between floor voids) also had to be plastered.
- After plastering, joist ends were taped to plaster, with a second skim coat over the tapes (we had joist ends going into both party wall and external wall in this house).

- Airtight loft hatches were installed to access bathroom and bedroom lofts.

		- The final air test result was 1.635 air changes per hour (see below)
	Ventilation	
	Mechanical Ventilation with Heat Recovery (MVHR) unit installed	- Brink Renovent Sky 300 unit installed on bathroom ceiling and boxed out o 85% effective dry heat recovery rate (as per Passivhaus test criteria) o Frost pre-heater installed on intake duct o 180mm insulated ductwork connects the unit to external wall cowls. o Condensate is connected to sink waste, with Hepworth valve installed as trap.  - 180mm insulated ductwork also connects unit to 2 manifolds installed on the kitchen wall. From each manifold, air is either extracted from kitchen & bathroom or supplied to 2 bedrooms & lounge via 50 x 100mm green oval-shaped ductwork. - These ducts run to each terminal on separate runs. According to the design, restrictors are placed at the connection of most ducts with the manifold – this is in order to regulate flow rates as per the design.  - The design and measured flow rates differed slightly. I wanted to ensure that the house was not over-ventilated given that there was only one

occupant, especially in winter, when dry air can be the result.

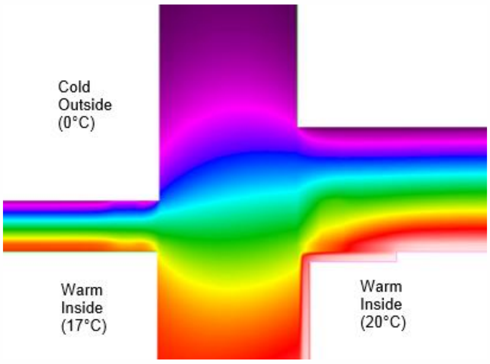
- Actual flow rates recorded and equivalent air changes per hour of commissioned air speeds are:

	m^3/hour	air changes per hour
Speed 1	45	0.30
Speed 2	55	0.35
Speed 3	72	0.47

Thermal bridges

Thermal bridges at problem junctions were reduced according to modelling results

- All junctions were modelled using THERM. Where the junction was losing heat, a solution was modelled in order to reduce the heat loss so that it was close to zero.



- Problem junctions that needed a specific solution included:
    - Party wall to loft (= model above)
    - Party wall to ground floor
    - Party wall to external-facing wall (in vertical profile)
- Modelling showed that using Spacetherm-P (plasterboard bonded to aerogel, a high-grade insulation material) solved the problem while also allowing the thermal bridge solution to blend in and not be too bulky. In most cases, a 20cm strip of Spacetherm-P was required.

		- The end result with plastering (and skirting in front) produced a surprisingly pleasing visual result that blended in well. 
	Chimney	
	Chimney breasts were made airtight and safe in the longer-term from moisture accumulation risk	- As part of the airtightness strategy all chimney breasts had to be checked to make them airtight. Often this meant opening them up in order to brick them up properly. - In order to address any longer-term issues of moisture tracking down the chimney breasts and accumulating (a possible risk when vents are blocked up), we had the following strategy: o Chimney flues were cleaned by a chimney sweep o Chimney breasts were bricked up while leaving a small inspection hole in each one to check the Leca beads o Leca (fired clay balls) was then added into each flue up to the level of the loft floor – we used the inspection holes to ensure that it had reached all parts of the flue.

Leca has some insulating properties, but also allows moisture regulation.

- The part of the chimney flue in the loft space up to the stack was kept empty, and air was allowed to circulate in this void by taking a brick out of each flue in the loft space. This is the part of the flue with most damp potential, so this part was where we ventilated.

- We added a chimney cap on the cowl to prevent rain ingress into the flue, while allowing ventilation.
- As a final touch, we also applied 2 coats of Keim Lotexan mineral paint to the chimney stacks in order to reduce rain-driven moisture into the brickwork.

Heating system

	Condensing boiler	- Replaced old boiler with Remeha Avanta Plus Exclusive 28C condensing boiler
	Radiators & pipes	- Old radiators were kept, and they already had TRVs - Water pipes that went via the bathroom loft space were lagged
	Appliances & electrics	
	Appliances	- Appliances were kept, but a new gas cooker had to be installed – this was because the old one had an eye-level grill function which would not work well with the recirculating extractor hood (which we had to install to trap cooking grease, to avoid this going into the MVHR ducts).
	Lighting	- Low energy CFLs and LEDs in all fittings
	Water	
	Sink, toilet & bath	- Existing sink and bath kept, but toilet was replaced with a slimmer model to allow a shower screen and shower (run off the boiler) to be installed. The toilet saves water by design (e.g. toilet flush 4 or 6 litres) 
	Non-energy efficiency work carried out	
	Other jobs not related to energy efficiency were also carried out as part of the refurbishment	- New kitchen cabinets - Plastering & painting - Roof and chimney repairs - Gutter repairs - New cupboards made

		- Floors sanded down and stained
What would I have done differently?	- Although we got an admirable result from the final air test, I would next time consider how we could get a better result by eliminating problem areas for air leakage which we had found during the test. These were related to areas of walls that we could not plaster (e.g. where water pipes were too close to an unplastered wall). So next time I think it could be beneficial to: o Be more brutal in the initial stages to cut the house fabric back to the shell on all surfaces, and do airtightness plastering in one go. Although this might add some material costs, it should save significantly on labour time and costs with fiddly junctions. o I would also consider resetting first floor joists on joist hangers – this would allow a better/quicker airtight solution to be made, as well as ensuring a lower risk solution for joist ends where walls are insulated. - On-site container storage would have helped a lot, so that we had more space to work in the house. - I would recommend the client moves out during the work – this is to reduce costs (a significant amount of time was spent cleaning up daily), but also for health reasons for the client. - If I did it again, I think I would find some solution for insulation on the bathroom walls – along with the floor, this was a compromise in terms of cost. The bathroom extension has one wall in the communal alley and one next to the neighbour's yard, meaning external wall insulation was not really an option. Internal insulation was only possible using Spacetherm due to the narrow width of the room, but the cost-benefit ratio was very low in terms of energy savings, so we decided to leave it and rely on the existing cavity wall insulation. However, the bathroom is now the coldest room in the house due to this (albeit much better than before). - I would never again use dot and dab to adhere plasterboard to an unplastered wall as part of the airtightness strategy. Air leaks through unplastered brickwork, and consequently also leaks through the dot and dab plasterboard where the final plaster coat is not perfect, or where subsequent penetrations are made (e.g. when bathroom pipes were clipped on). - The bathroom loft loft hatch was low quality (TimLoc) and had air leaking at various places during the air test as the latch is only designed at one point and does not provide enough pressure to keep the door against the draughtstripping on all edges. We therefore had to modify it ourselves to make it function correctly. - I would consider if possible to replace the window glazing with 16mm gap argon-filled panes – this would additionally reduce the space heating demand from 89 kWh/m^2/year currently, to 69 kWh/m^2/year. Windows and doors had recently been replaced prior to the refurbishment, so given the other work to do, the client understandably did not feel like spending more money on this element.	

Fan test results		Air changes per hour	m^3 / hour / m^2
	Test 1: before	17.45	12.725
	Test 2: after insulation	1.87	1.365
	Test 3: after plastering	1.635	1.19
Cost	Not to be disclosed, but in terms of breakdown: - 75% was related to energy efficiency work - 25% was spent on things like new kitchen, bathroom fittings, carpets, paint, etc.		