bere:architects
73 Poets Road
London N5 2SH
T +44(0)20 7359 4503
www.bere.co.uk

Energy in Use and Cost Analysis

Mayville Community Centre

Passivhaus Certified Refurbishment

March 2012

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Introduction

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Mayville Community Centre - before retrofit

The Mayville Community Centre is the first fully certified Passivhaus retrofit community centre in the UK, designed by bere:architects and completed in August 2011. The building achieves full Passivhaus Certification, and exceeds the EnerPhit standard which is the usual Passivhaus standard for refurbishment. Achieving full certification was a significant accomplishment as retrofitting to such a level is widely acknowledged as being more difficult than a new build to the standard.

Bere:architects were commissioned by the Technology Strategy Board to work closely with Roderic Bunn of BSRIA, in order to complete a Building Performance Evaluation for a period of two years. The aim of the BPE study is to assemble a substantial body of data which will enable us to draw conclusions on the performance of the building, based on information regarding the building fabric, target performances, construction methods and occupancy patterns, handover and operational practices.

BSRIA's Delta magazine published an initial analysis of the design aspirations in 2011.

Subsequently, the building has been monitored for four full months so far: November & December 2011, January and February 2012. This preliminary monitoring data has been compiled and analysed, and the results provide reliable initial indications that the building is performing better than predicted during design stage (through the Passivhaus Planning Package - PHPP) in its first winter season.

A further 'before & after' energy consumption and CO_2 emissions analysis has been undertaken to compare the annual energy costs and CO_2 emissions before refurbishment, as built, and if it had been built to minimum Building Regulations standards.

1: Project Overview

Mayville Community Centre - south elevation - after retrofit

Winner: UK Passivhaus Award, Retrofit category 2012;
Winner: Best Public Building, 3R Awards 2011 ;
Winner: Green Build Awards, Leisure category 2012

The Mayville Community Centre, built circa. 1890 as a generating station for London's tram network, was rescued from dereliction in 1973 by the Mildmay Community Partnership. Located in one of London's most deprived areas, the centre was in urgent need of total renovation, being uninsulated, inaccessible and only 60% usable. The building refurbishment increased usable space by 35% without increasing the building footprint and a fabric first approach has at the same time reduced the building's energy consumption by around 90%. The building work has been 100% funded by grant aid and by two generous local benefactors who chose to remain anonymous.

Energy consumption and CO_2 emissions are minimised by excellent levels of insulation, draught free construction, triple glazed windows and by a substantial onsite renewables installation. All junction details are designed to prevent or minimise thermal bridges which are important factors in the Passivhaus Planning Package energy calculations.

The building is all - electric, with heating provided by a ground source heat pump linked to radiators for any extra space heating needed. Electricity is provided via connection to the grid and by 126m^2 of photovoltaic panels which generate 18kWp of electricity. Other renewable technologies include: a 3m^2 vacuum tube panel providing most hot water; two rainwater harvesting tanks, totalling 11,500 litres of water, take clean water from the zinc roofs for recycling in the lavatories and water from the two wildflower meadow roofs for the garden and community food growing projects.

Swift, sparrow, wren and bat boxes have been installed within the external insulation layer to encourage local native bird populations and blackthorn, hawthorn and English oak have been planted in the garden.

Ultimately, the Mayville is a comfortable and healthy centre that has been embraced by and is serving the needs of the local community without wasting financial resources on large energy bills and as such it is a building that acts as a model for urban sustainability. We hope the retrofit project will help demonstrate how deep retrofit of existing buildings rather than demolition, is an achievable and viable solution for much of the UK's existing building stock.

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1: Project Overview

Mayville Community Centre - during construction

New entrance floor slab	300mm foamglas insulation + concrete slab
Existing basement floor slab	300mm existing slab + 80mm Kingspan insulation and floating floor
Walls below ground	200mm external XPS insulation to existing brick walls
Walls above ground new blockwork walls	290mm/320mm external EPS insulation and render finish to existing brick/
Pitched roof	300mm rockwool + 100mm rockfall overlay board + zinc roof finishes
High level flat roof covering and 100mm	300mm foamglas insulation on existing concrete roof slab with asphalt of soil for native wild flower meadow green roof planting
Low level flat roof layer and 100mm soil	300mm foamglas insulation on new timber roof structure with asphalt for native wild flower meadow green roof planting
Heat Recovery Ventilation	PAUL Maxi 2000 (for main building) PAUL Focus (to be installed as part of fitout for 2no. basement recording studios)

Annual Heat Demand	13 kWh/(m^2a)
Primary Energy Demand	120kWh/(m^2a)
Total CO_2 emissions	6.2kg/(m^2a) (excl. appliances)
Air test result	< 0.43h^{-1} at 50Pa (average of compression & decompression)

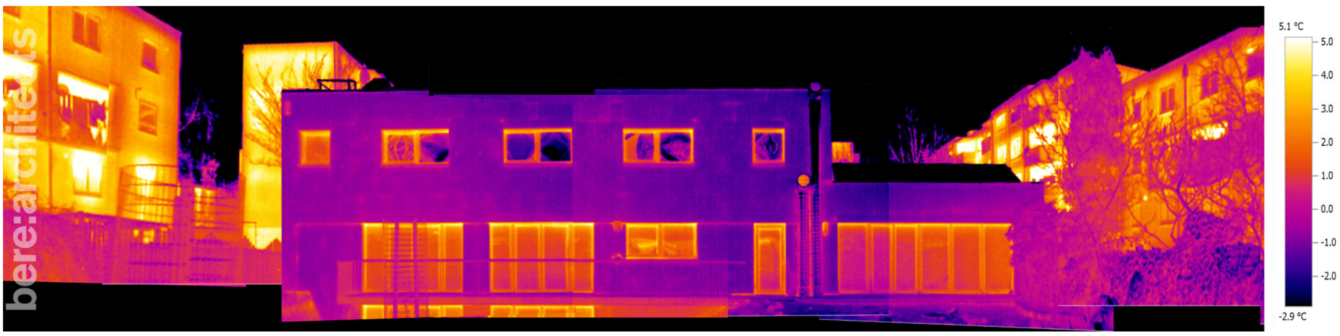

Image reference: (300mc) Mayville Community Centre, passivhaus retrofit

Mayville Community Centre - thermal image showing the Centre and adjacent residential units

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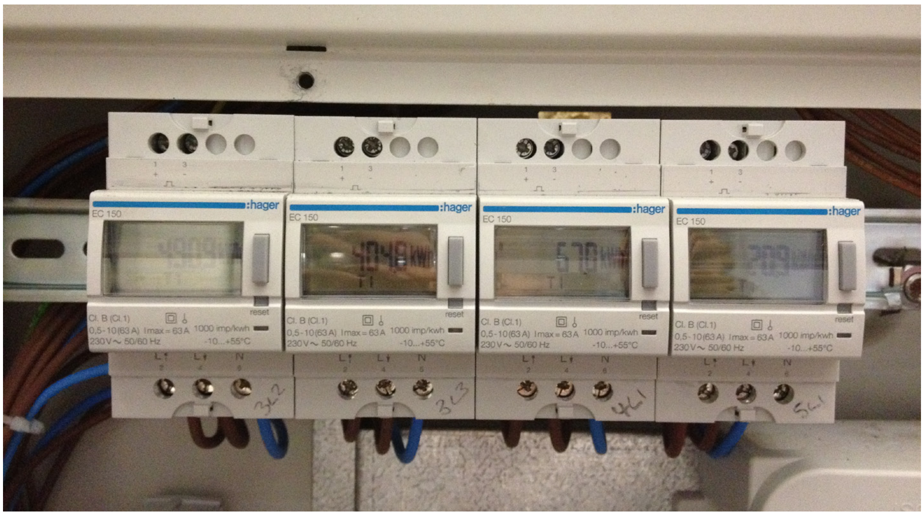
Methodology

STEP (1): The installed sub-meters are recording the energy consumption of the following: Ground Source Heat Pump (GSHP) compressor, Ventilation Heater Battery, Kitchen, Lights and sockets, GSHP boost heater, Heat Recovery Ventilation unit, Sewage pump, Rainwater system, EDF meter - grid consumption.

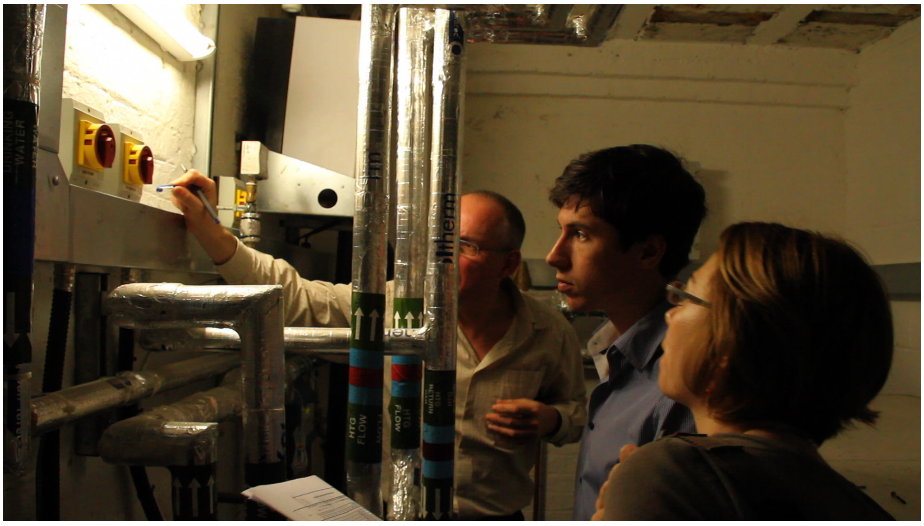


Mayville Community Centre - sub-meters

STEP (2): Data is meticulously recorded and collected on a weekly basis.

STEP (3): Increments of the energy used between the readings are calculated.

STEP (4): Data is plotted and analysed in conjunction with a daily account of occupancy levels, events and anomalies recorded by Mayville staff members.



Energy Consultant and Building Services Engineer with bere:architects in Mayville plant room

Bere:architects are working closely with Roderic Bunn (BSRIA) who is an independent consultant on the BPE study, to gain a full understanding of the building energy consumption and the sub-metering outputs.

Using the TM22 spreadsheet Roderic will be able to analyse the building energy loads and cross reference them with our sub-metered data to identify the actual energy use of each of the building's systems.

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Data Record

Time	Date	GSHP compressor	Ventilation heater (Frost coil)	DBI PV plant room	DB Kitchen riser	DB Basement	GSHP boost heater	Ventilation (fan)	Sewage pump	Rain water	**Total sub metered**	**MCCB Panel**	EDF meter rate 1	EDF meter rate 2	EDF meter total
		Sub-metering													
		1L1/2/3	2L1/2/3	8L1/2/3	9L1/2/3	10L1/2/3	3L2	3L3	4L1	5L1		**main**	supply	supply	supply
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	**kWh**	**kWh**	kWh	kWh	kWh
17:30:00	21/10/2011	57	0	411	0	1277	41.5	69.8	16.5	4.5	**1877.3**	**2105**	-	-	-
10:30:00	24/10/2011	85	0	432	0	1357	51.1	74.5	17.4	4.5	**2021.5**	**2252**	-	-	-
10:30:00	31/10/2011	143	0	492	0	1594	73.9	94.2	19.7	5	**2421.8**	**2598**	-	-	-
10:30:00	07/11/2011	204	0	624	0	1830	96.7	115.3	22.3	5.4	**2897.7**	**3026**	641	229	870
10:30:00	14/11/2011	242	0	741	0	2086	110.1	134.3	24.4	6.7	**3344.5**	**3450**	965	315	1280
10:30:00	21/11/2011	248	0	876	0	2292	114.1	156.5	26.6	7.4	**3720.6**	**3784**	1222	370	1593
10:30:00	28/11/2011	371	0	951	0	2558	139.4	182	28.7	8.6	**4238.7**	**4241**	1596	443	2039
10:30:00	05/12/2011	480	0	1036	0	2791	164.4	197.1	31	9.1	**4708.6**	**4670**	1952	510	2462
10:30:00	12/12/2011	548	0	1181	9	3081	182.1	216	33.5	10	**5260.6**	**5162**	2356	588	2945
11:07:00	19/12/2011	669	0	1298	23	3368	209.6	237.3	36.2	11.2	**5852.3**	**5693**	2804	668	3473
11:52:00	04/01/2012	1032	0	1417	73	3816	284.4	270.4	43.4	11.7	**6947.9**	**6720**	3655	841	4496
10:39:00	09/01/2012	1081	0	1489	94	3979	300.2	281.1	45.6	12	**7281.9**	**7026**	3896	898	4794
11:00:00	16/01/2012	1158	1	1575	126	4216	322.7	300.4	48.7	12.7	**7760.5**	**7465**	4235	973	5209
11:30:00	23/01/2012	1264	2	1682	160	4464	350.2	320	51.8	13.4	**8307.4**	**7961**	4646	1051	5697
11:30:00	30/01/2012	1364	2	1763	189	4692	377.2	339.3	54.8	14.1	**8795.4**	**8403**	5008	1121	6130
11:11:00	06/02/2012	1516	38	1831	222	4903	409.9	355.5	57.9	15.2	**9348.5**	**8873**	5389	1190	6580
13:00:00	14/02/2012	1630	115	1951	266	5137	438.8	372.5	61.1	16.8	**9988.2**	**9437**	5867	1258	7125
06:14:24	20/02/2012	1742	115	2156	313	5399	469	386.2	63.5	19.3	**10663**	**10024**	6313	1372	7686
09:43:00	27/02/2012	1753	115	2171	317	5441	483.4	397.6	65.7	20.3	**10764**	**10084**	6586	1459	8046
14:10:00	01/03/2012	1760	115	2259	339	5560	490.1	403.8	66.7	20.9	**11014.5**	**10297**	6742	1497	8240
12:13:00	12/03/2012	1814	115	2490	393	5834	520.6	422.5	70.3	22.5	**11681.9**	**10922**	7133	1609	8743

Sub-metering data record for lighting, kitchen appliances and auxiliary electrical demand

Kitchen installed

Sub-meters were switched off accidentally; data for the week might be incomplete

Time	Date	PV Exp (+)	PV Exp ( )	Inver 1 E total	Hours-total worked 1	Inver 2 E-total	Hours-total worked 2	Inver 3 E-total	Hours-total worked 3	Total	PV plant room
		Sub-metering									
		7L1/2/3									
		kWh	kWh	kWh	h	kWh	h	kWh	h	kWh	kWh
17:30:00	21/10/2011	2075	6	643.8	-	762.4	-	689.6	-	2095.8	2111
10:30:00	24/10/2011	2144	6	655.8	-	789.9	-	719.1	-	2164.8	2180
10:30:00	31/10/2011	2278	7	682.6	-	841.6	-	772.5	-	2296.7	2315
10:30:00	07/11/2011	2364	8	704.4	-	873.4	-	803.8	-	2381.6	2402
10:30:00	14/11/2011	2430	9	720.4	-	897.7	-	828	-	2446.1	2468
10:30:00	21/11/2011	2525	10	739.2	-	934.6	-	866.4	-	2540.2	2565
10:30:00	28/11/2011	2613	11	754.8	901	968.8	894	902.8	904	2626.4	2653
10:30:00	05/12/2011	2676	12	766.4	952	993.5	946	927.9	955	2687.8	2716
10:30:00	12/12/2011	2763	13	780.5	1003	1028	998	964.4	1007	2772.9	2804
11:07:00	19/12/2011	2843	14	791	1054	1061	1049	999.4	1059	2851.4	2884
11:52:00	04/01/2012	2944	17	811	1167	1100	1163	1038	1172	2949	2986
10:39:00	09/01/2012	2993	18	821.2	1202	1119	1198	1058	1208	2998.2	3036
11:00:00	16/01/2012	3090	19	835.1	1257	1158	1253	1101	1263	3094.1	3134
11:30:00	23/01/2012	3166	20	850.4	1311	1186	1308	1131	1318	3167.4	3210
11:30:00	30/01/2012	3241	21	865	1368	1215	1365	1162	1375	3242	3286
11:11:00	06/02/2012	3351	22	878.8	1419	1261	1418	1211	1427	3350.8	3396
13:00:00	14/02/2012	3451	23	892.4	1469	1297	1479	1260	1491	3449.4	3497
06:14:24	20/02/2012	3598	24	927.1	1535	1351	1546	1317	1558	3595.1	3646
09:43:00	27/02/2012	3794	25	962.5	1602	1424	1613	1404	1625	3790.5	3843
14:10:00	01/03/2012	3872	25	982.3	1637	1452	1648	1433	1660	3867.3	3922
12:13:00	12/03/2012	4168	27	1057	1752	1558	1762	1547	1775	4162	4221

Sub-metering data record for PV electrical generation

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Data Record

Date		GSHP compressor	Ventilation heater (Frost coil)	DBI PV plant room		DB Kitchen riser	DB Basement (lights and sockets)	GSHP boost heater	Ventilation (fan)	Sewage pump	Rain water	**Total sub metered**	**MCCB Panel**	EDF meter rate 1	EDF meter rate 2	EDF meter total
		Increments of the energy used between the readings														
		1L1/2/3	2L1/2/3	8L1/2/3		9L1/2/3	10L1/2/3	3L2	3L3	4L1	5L1		**main**	supply	supply	supply
		kWh	kWh	kWh		kWh	kWh	kWh	kWh	kWh	kWh	**kWh**	**kWh**	kWh	kWh	kWh
21/10/2011	24/10/2011	28	0	21	-21	0	80	9.6	4.7	0.9	0	**144.2**	**147**	-	-	-
24/10/2011	31/10/2011	58	0	60	-60	0	237	22.8	19.7	2.3	0.5	**400.3**	**346**	-	-	-
31/10/2011	07/11/2011	61	0	132	-132	0	236	22.8	21.1	2.6	0.4	**475.9**	**428**	-	-	-
07/11/2011	14/11/2011	38	0	117	-117	0	256	13.4	19	2.1	1.3	**446.8**	**424**	324	86	410
14/11/2011	21/11/2011	6	0	135	-135	0	206	4	22.2	2.2	0.7	**376.1**	**334**	257	55	313
21/11/2011	28/11/2011	123	0	75	-75	0	266	25.3	25.5	2.1	1.2	**518.1**	**457**	374	73	446
28/11/2011	05/12/2011	109	0	85	-85	0	233	25	15.1	2.3	0.5	**469.9**	**429**	356	67	423
05/12/2011	12/12/2011	68	0	145	-145	9	290	17.7	18.9	2.5	0.9	**552**	**492**	404	78	483
12/12/2011	19/12/2011	121	0	117	-117	14	287	27.5	21.3	2.7	1.2	**591.7**	**531**	448	80	528
26/12/2011	04/01/2012	363	0	119	-119	50	448	74.8	33.1	7.2	0.5	**1095.6**	**1027**	851	173	1023
04/01/2012	09/01/2012	49	0	72	-72	21	163	15.8	10.7	2.2	0.3	**334**	**306**	241	57	298
09/01/2012	16/01/2012	77	1	86	-86	32	237	22.5	19.3	3.1	0.7	**478.6**	**439**	339	75	415
16/01/2012	23/01/2012	106	1	107	-107	34	248	27.5	19.6	3.1	0.7	**546.9**	**496**	411	78	488
23/01/2012	30/01/2012	100	0	81	-81	29	228	27	19.3	3	0.7	**488**	**442**	362	70	433
30/01/2012	06/02/2012	152	36	68	-68	33	211	32.7	16.2	3.1	1.1	**553.1**	**470**	381	69	450
06/02/2012	14/02/2012	114	77	120	-120	44	234	28.9	17	3.2	1.6	**639.7**	**564**	478	68	545
14/02/2012	20/02/2012	112	0	205	-205	47	262	30.2	13.7	2.4	2.5	**674.8**	**587**	446	114	561
20/02/2012	27/02/2012	11	0	15	-15	4	42	14.4	11.4	2.2	1	**101**	**60**	273	87	360
27/02/2012	01/03/2012	7	0	88	-88	22	119	6.7	6.2	1	0.6	**250.5**	**213**	156	38	194
01/03/2012	12/03/2012	54	0	231	-231	54	274	30.5	18.7	3.6	1.6	**667.4**	**625**	391	112	503
12/03/2012		-1814	-115	-2490		-393	-5834	-520.6	-422.5	-70.3	-22.5	**-11682**	**-10922**	-7133	-1609	-8743
		0	0	0		0	0	0	0	0	0	**0**	**0**	0	0	0
		0	0	0		0	0	0	0	0	0	**0**	**0**	0	0	0

Weekly electricity use (systems) and generation (PVs)

Date		PV Exp (+)	PV Exp ( )	Inver 1 E-total	Inver 2 E-total	Inver 3 E total	Total	PV plant room	PV (%)
		Increments of the energy generated by the PV between the readings							
		7L1/2/3							
		kWh	kWh	kWh	kWh	kWh	kWh	kWh	
21/10/2011	24/10/2011	69	0	12	27.5	29.5	69	69	
24/10/2011	31/10/2011	134	1	26.8	51.7	53.4	131.9	135	
31/10/2011	07/11/2011	86	1	21.8	31.8	31.3	84.9	87	
07/11/2011	14/11/2011	66	1	16	24.3	24.2	64.5	66	16.09756
14/11/2011	21/11/2011	95	1	18.8	36.9	38.4	94.1	97	30.99042
21/11/2011	28/11/2011	88	1	15.6	34.2	36.4	86.2	88	19.73094
28/11/2011	05/12/2011	63	1	11.6	24.7	25.1	61.4	63	14.89362
05/12/2011	12/12/2011	87	1	14.1	34.5	36.5	85.1	88	18.21946
12/12/2011	19/12/2011	80	1	10.5	33	35	78.5	80	15.15152
26/12/2011	04/01/2012	101	3	20	113	39	114	38.6	3.773216
04/01/2012	09/01/2012	49	1	10.2	35	19	35	20	6.711409
09/01/2012	16/01/2012	97	1	13.9	39	43	95.9	98	23.61446
16/01/2012	23/01/2012	76	1	15.3	28	30	73.3	76	15.57377
23/01/2012	30/01/2012	75	1	14.6	29	31	74.6	76	17.55196
30/01/2012	06/02/2012	110	1	13.8	46	49	108.8	110	24.44444
06/02/2012	14/02/2012	100	1	13.6	36	49	98.6	101	18.53211
14/02/2012	20/02/2012	147	1	34.7	54	57	145.7	149	26.55971
20/02/2012	27/02/2012	196	1	35.4	73	87	195.4	197	54.72222
27/02/2012	01/03/2012	78	0	19.8	28	29	76.8	79	
01/03/2012	12/03/2012	296	2	74.7	106	114	294.7	299	
12/03/2012		-4168	-27	-1057	-1558	-1547	-4162	-4221	
		0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	

Weekly electricity generation: PVs

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Preliminary Data Analysis

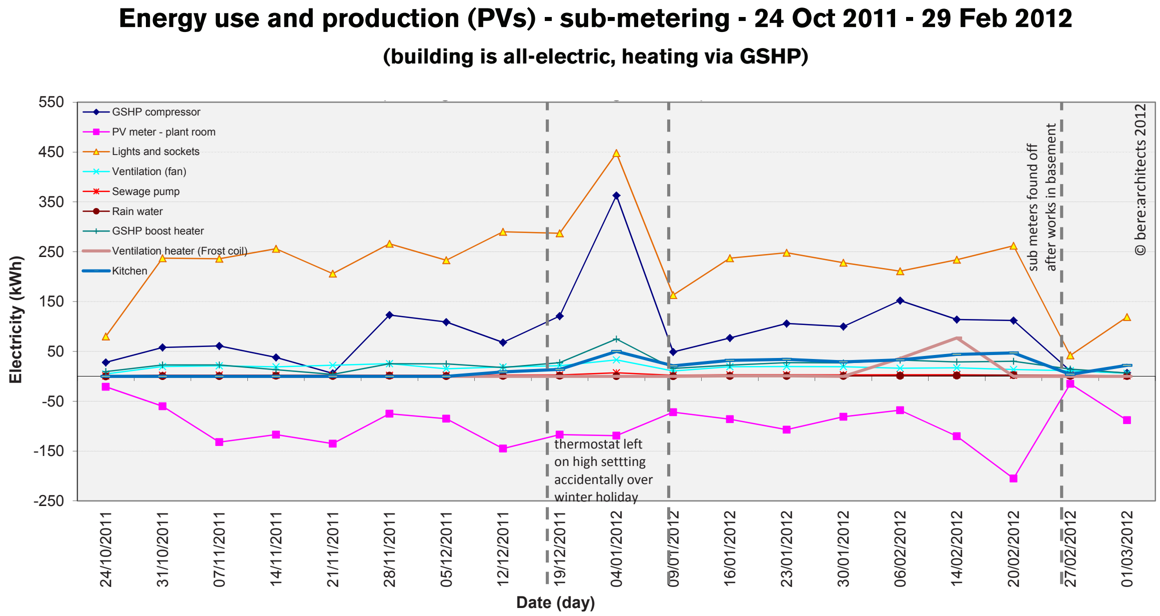
The graph below shows energy use and energy generation at the Mayville Community Centre for the winter months between 24 October 2011 and 29 February 2012.

The refurbished building is all-electric. Renewable systems include:

8.4kW Viessmann Vitocal 300-G Ground Source Heat Pump

3m2 Viessmann Vitosol 200 Solar Thermal Panel for heating and hot water demand

77no. NU235E1 Sharp Panels 235W = 18kW PV system installed.



Energy use and generation - data source: preliminary monitoring data

The unusual spike in the energy consumption shown above was caused by accidentally leaving the thermostat on a high setting throughout the Christmas holiday period after an elderly persons' party. Despite the anomaly during the Christmas holiday, the building is still performing better than was anticipated (see following pages).

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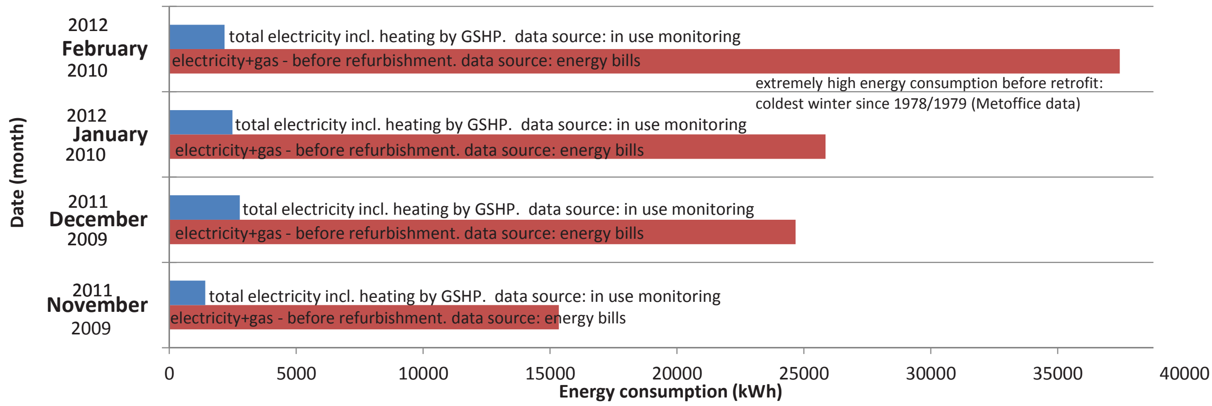
The graph below shows in red the energy consumption during the winter months before retrofit (calculated using the gas and electricity bills for November - February 2009-10) and after refurbishment in blue (using preliminary sub-metering data for November - February 2011-2012). A full set of energy bills can be found in Appendix A.

The data shows up to **95%** reduction in total operational energy consumption after refurbishment.

Energy consumption during winter months Before Retrofit (gas + electricity bills Nov 2009 - Feb 2010) and After Refurbishment (preliminary sub-metering data - building is an all-electric, heating via GSHP and using Solar Thermals and PV* - 24 Oct 2011 - 29 Feb 2012)

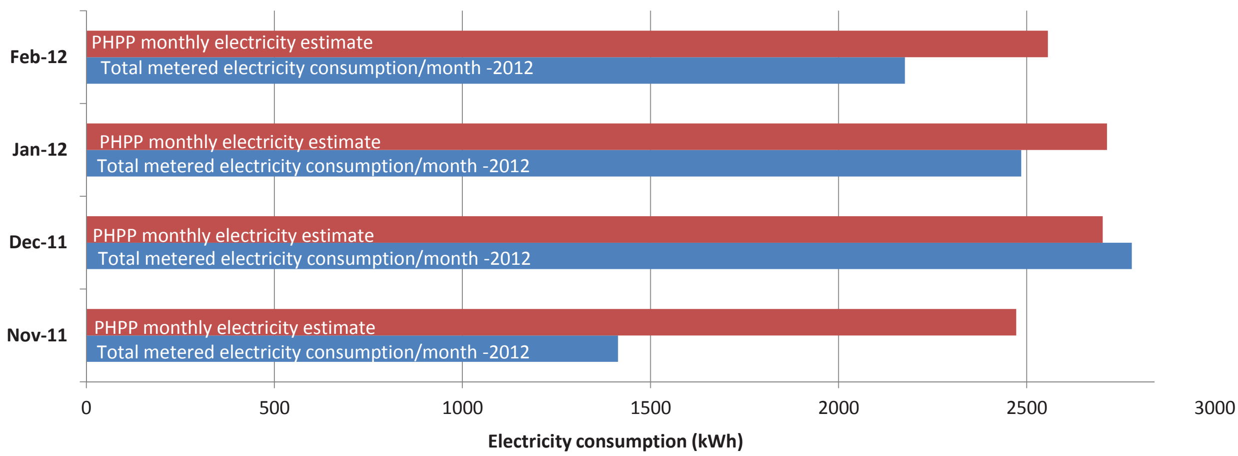


* data collected before PV export sub-meter installed; assumes all electricity generated by PVs was used in the building, nothing exported back to grid

We conducted a comparison between the preliminary monitoring data and the energy demand calculated during the design of the building using the Passivhaus Planning Package (PHPP) software, over four months.

The data shows that the building performance is better than predicted in its first winter season.

Comparision between PHPP and preliminary monitoring data - Nov 2011 - Feb 2012
(building is an all-electric, heating via GSHP)



Energy consumption during winter months before and after retrofit

It is worth noting that the basement is not yet occupied (although heated), and the kitchen was still being fitted out. Many of the rooms on the first floor were also not used during the monitored period. Full occupancy would make a difference to the total energy consumption. The additional people will reduce the heat load, the additional lighting and computers will add to the electricity demand. This useful balancing only happens in the winter months, so the additional people in the future will almost certainly have a negative impact on the total energy load.

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3: Extra Investment Costs , Annual Energy Consumption Costs and Carbon Emissions

Methodology

STEP (1): finding & comparing design energy consumption for each option:

(a) Headline list of changes in accordance with Building Regs Part L and ventilation rates;

(b) Four different PHPP documents were created, simulating refurbishment to: Building Regs, Passivhaus with gas boiler, Passivhaus with GSHP, Passivhaus with GSHP, Solar Thermals & PVs;

(c) Old energy bills (before refurbishment) were also analysed.

STEP (2): finding the Cost of an otherwise identical minimum standard community centre

Take detailed Bills of Quantities (As Built) and convert to Building Regs spec, item by item.

STEP (3): Comparison of extra investment cost of PH derived from step (2)

Percentage difference investment to achieve passivhaus standard

STEP (4): Comparison of Annual Energy Consumption derived from step (1)

STEP (5): Comparison of Annual CO2 emissions derived from step (1)

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Extra Investment Costs

Total building Costs were calculated using a tender bill of qualities that was broken down and reevaluated using a different set of parameters:

Option (1): Bills of Quantities (As Built) - Passivhaus with GSHP with Solar Thermals and PV installation;

Option (2): Passivhaus with GSHP without Solar Thermals and PV installation;

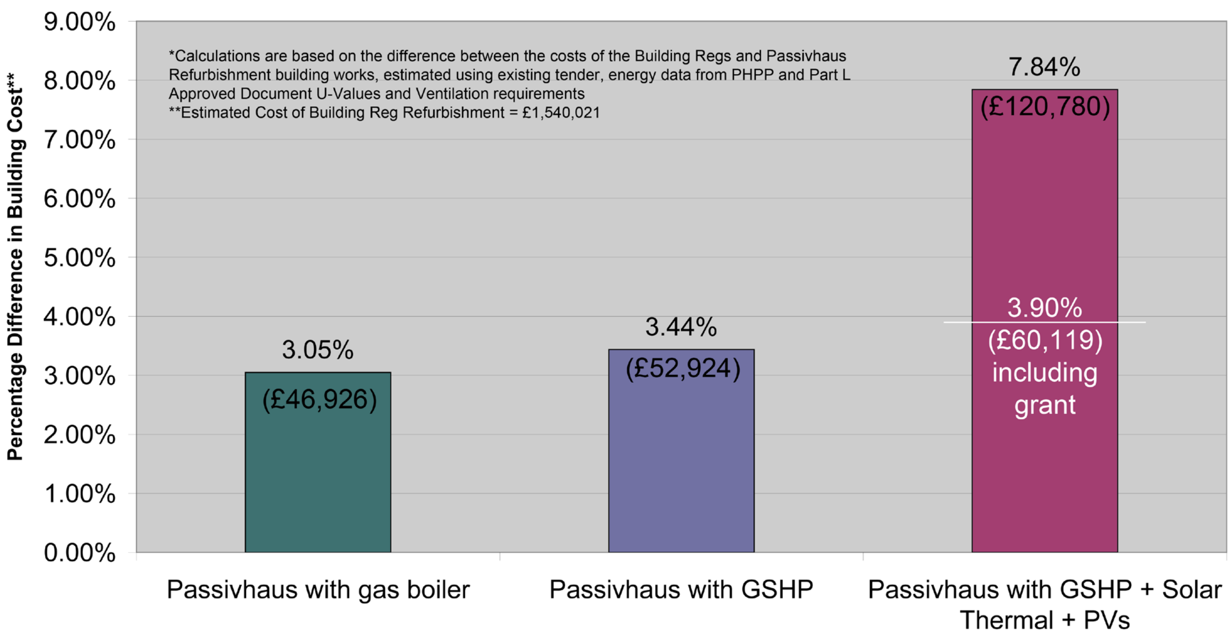
Option (3): Passivhaus with GSHP with gas boiler;

Option (4: Equivalent building to minimum Building Regulations Standards.

Mildmay Community Partnership Alteration and Improvements to Community Centre Mayville Community Centre, Woodville Road, London N16 8NA BILLS OF QUANTITIES	Tenderer: Option 1 - Buxton Building Contractors Contract Sum - Passivhaus with Heat Pump, Solar Thermal and PV Installations Date: 09-Mar-10	Tenderer: Option 2 - As Option 1 with Heat Pump Installation but excluding Solar Thermal and PV Installations Date: 09-Mar-10	Tenderer: Option 3 - As Option 1 but with a 8.4kW Gas Boiler and excluding Heat Pump, Solar Thermal and PV Installations Date: 09-Mar-10	Tenderer: Option 4 - Building Regulations with a 43.2kW gas boiler, additional radiators excluding Heat Pump, Solar Thermal and PV installations Date: 09-Mar-10
TOTAL COST EXCLUDING FEES AND VAT	£ 1,660,801.00	£ 1,592,944.94	£ 1,586,946.65	£ 1,540,020.74

Snapshot of the working spreadsheet.

Percentage Difference in Extra Investment to Achieve Passivhaus Standard*



Graph representing extra investment costs to achieve Passivhaus standard

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Annual Energy Consumption, Annual Energy Cost and CO2 emissions

The spreadsheet below summarises the data used in the analysis of the annual energy consumption, annual energy cost and CO2 emissions.

The energy consumption was estimated using pre-construction energy bills from 2009 (highlighted blue) and PHPP data for individual scenarios (highlighted red). Numbers in pink show energy savings for GSHP and Solar Thermals, which are already included in the total calculations. PVs are listed separately as they contribute to reduction of total energy bill.

Option (1): Passivhaus (As Built) - Passivhaus with GSHP with Solar Thermals and PV installation, refer to Appendix C1.

Option (2): Passivhaus with GSHP without Solar Thermals and PV installation, refer to Appendix C2.

Option (3): Passivhaus with GSHP with gas boiler, refer to Appendix C3.

Option (4): Equivalent building to minimum Building Regulations Standards, refer to Appendix C4.

Option (5): Before refurbishment, for energy bills and table summary refer to Appendix A.

	Option (5)			Option (4)			Option (3)					
	Before refurbishment			2010 Building Regs* + gas boiler			PH + gas boiler					
	with gas boiler without PV and solar thermals			with gas boiler without PV and solar thermals *using Part L Approved Document U-Value and Ventilation requirements			with gas boiler without PV and solar thermals					
ENERGY	Electricity		GAS	Electricity		GAS	Electricity		GAS			
	OTHER		Space heating only	OTHER		Space heating only	OTHER		Space heating only			
Total Energy demand, kWh/a	28,979		189,197	25,820		48,855	25,835		13,821	4,051	26,015	-8,605
ENERGY TOTAL, kWh/a			218,176			74,675			39,656		30,066	
GAS Cost per unit	£0.0985	£0.0000	£0.0408	£0.0985	£0.0000	£0.0408	£0.0985	£0.0000	£0.0408	£0.0985	£0.0985	
Energy priced, kWh	28,979	0	189,197	25,820	0	48,855	25,835	0	13,821			
Energy cost	£2,854	£0	£7,721	£2,543	£0	£1,994	£2,545	£0	£564	£399	£2,562	
Standard charge	£88		£0	£88		£0	£88		£0	£88		
	£2,942		£7,721	£2,631		£1,994	£2,632		£564			
COST TOTAL, £			£10,663			£4,625			£3,196			
CO2												
CO2 GEMIS 3.0, kg/kWh	0.68		0.25	0.68		0.25	0.68		0.25			
CO2 level	19706		47299	17558		12214	17568		3455			
CO2 TOTAL			67,005			29,771			21,023			

	Option (2)			Option (1)				
	PH + heat pump			PH + heat pump + PV + solar heating				
	with heat pump without PV and solar thermals			with heat pump with PV* and solar thermals *using existing building data. Calculations include XXKwp solar PV system				
ENERGY	ELECTRICITY		Contribution	ELECTRICITY		Contribution		PV
	HEAT PUMP used	OTHER used	HEAT PUMP contribution	HEAT PUMP used	OTHER used	HEAT PUMP contribution	SOLAR contribution	PV
Total Energy demand, kWh/a	4,051	26,015	-8,605	3,664	25,881	-7,784	-1,342	-14,400
ENERGY TOTAL, kWh/a		30,066	-8,605		29,545			15,145
GAS Cost per unit	£0.0985	£0.0985	£0.0985	£0.0985	£0.0985	£0.0985	£0.0985	£0.0985
Energy priced, kWh	[illegible]	26,015	-8,605	3,664	25,881	-7,784	-1,342	-14,400
Energy cost	£399	£2,562	-£848	£361	£2,549	-£767	-£132	
Standard charge	£88			£88				
					£2,998			-£1,418
COST TOTAL, £		£3,049						£1,580
CO2								
CO2 GEMIS 3.0, kg/kWh		0.68	0.68		0.68		0.68	0.43
CO2 level	19706	20445	-5852	17558	20091	-5293	[illegible]	-6192
CO2 TOTAL			20,445					13,899

Comparison of annual energy demand, cost and CO2 emissions for different scenarios

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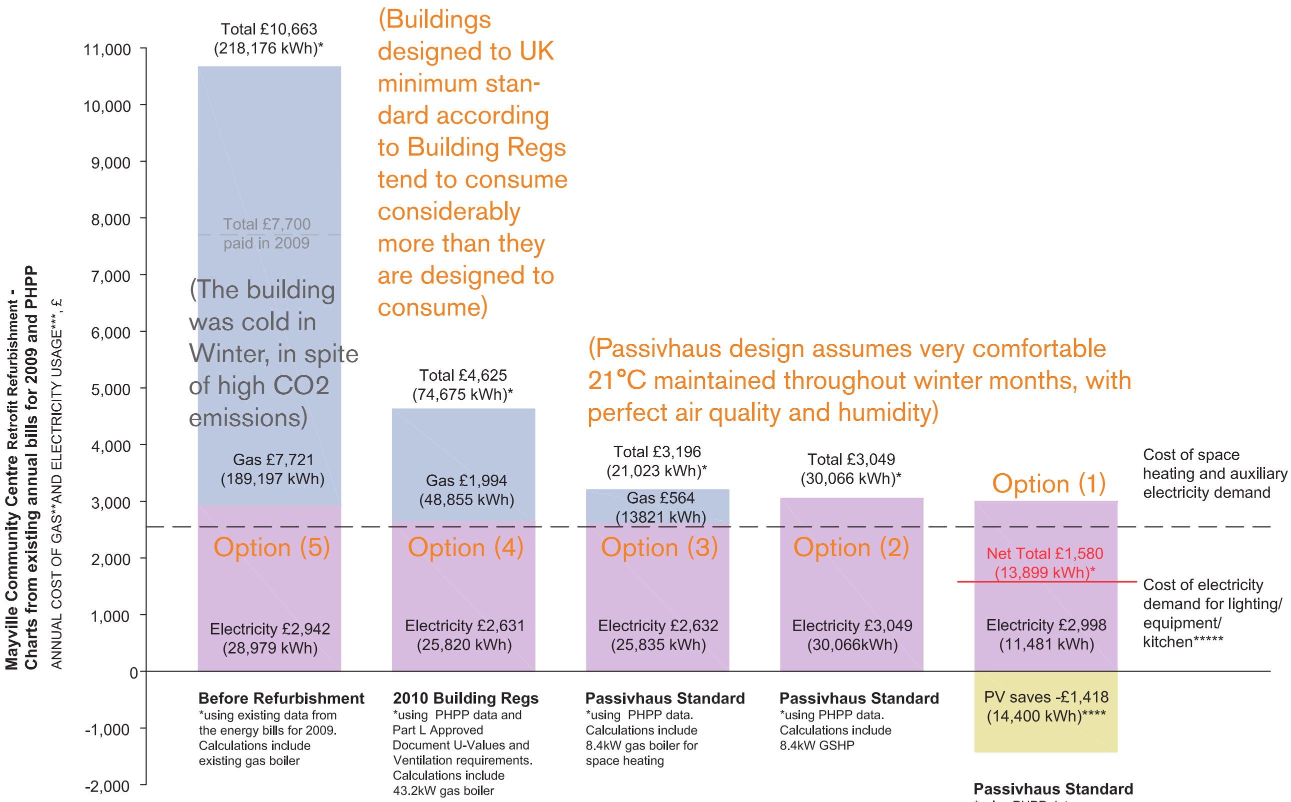
Annual Energy Cost Comparison for Mayville Community Centre: Before refurbishment, to 2010 Building Regulations with Gas Boiler, to Passivhaus Standards with Gas Boiler/ GSHP only/ GSHP with Solar Thermals + PV (As Built)



**Using gas unit calculation. Unit price taken from British Gas Website for Business Tariff (3p/kWh + standard charge 73p/day + 0.15p/kWh climate change charge), excluding VAT
***Using electricity unit calculation. Unit price taken from British Gas Website for Business Tariff (9.4p/Kwh + standard rate £24p/day 0.45p/kWh climate change charge), excluding VAT
****Feed in tariff payment is not used because EST offered a grant for all renewable installations, assume 100% PV energy feeds back into the building
*****Using data from PHPP, assume existing building had the same lighting/ equipment/ kitchen demand

The electricity and gas tariffs used for estimation of the total annual energy costs are up-to-date 2012 winter prices from EDF and British Gas providers. The energy bills for 2009 were converted to 2012 tariffs to provide accurate before and after energy cost comparison.

From the graph, it is clear that the building before refurbishment had energy bills far bigger than the estimated Passivhaus energy costs. Since the building performs better than predicted, the energy bills are likely to be even smaller than estimated. Most importantly, the building's comfort levels have improved hugely since despite the high energy bills the building was, in the past, cold in winter.

Ladies' Bingo night at Mayville Community Centre

Passivhaus design assumes a very comfortable 20° C is maintained through the winter months, with perfect air quality and humidity. All surfaces are warm to touch and the building is free of draughts.

When the first post-refurbishment Ladies' Bingo night was held at the centre, the response of the local community was very positive - "for first time we are able to take our coats off in the winter when playing games".

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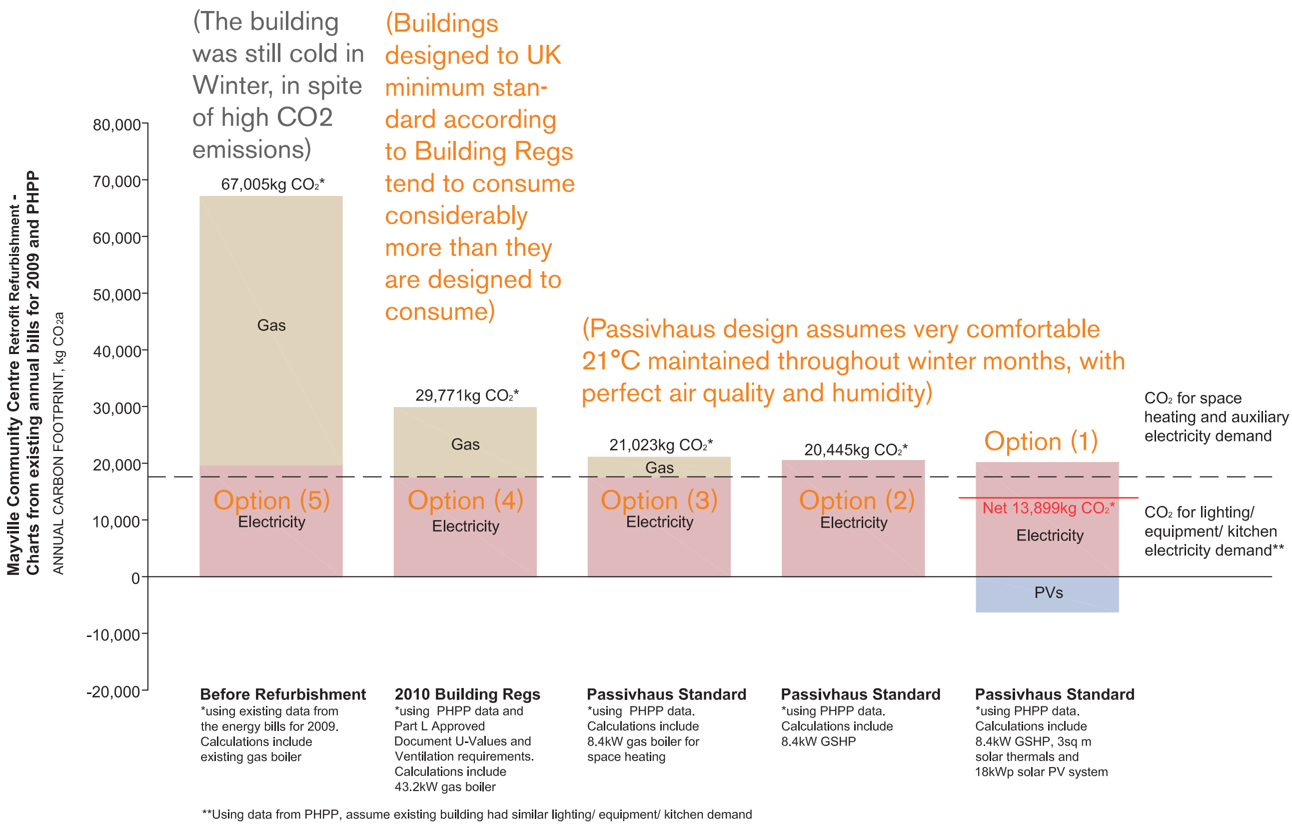
Annual Carbon Footprint Comparison for Mayville Community Centre Refurbishment: Before refurbishment, to 2010 Building Regulations with Gas Boiler, to Passivhaus Standards with Gas Boiler/ GSHP only/ GSHP with Solar Thermals + PV (As Built)



The carbon footprint graph above was estimated using the GEMIS 3.0 CO2 conversion factor: 0.68kg/kWh for electricity, 0.25kg/kWh for gas and -0.43kg/kWh for PVs. The net CO2 emission of the Mayville Community Centre as Built with the GSHP and solar renewable installations is nearly 5 times smaller compared to the building before refurbishment and over 3 times smaller without renewables due to the insulative properties of the envelope, high air tightness and heat recovery only.

The dashed line on both graphs illustrates cost/CO2 emissions associated with the electricity demand used for lighting/ equipment/ kitchen. We made an assumption that this electricity demand is consistent for all types of design as the building has the same shape and usage. Everything above the line is associated with the heating demand and associated equipment consumption such as circulation pump, DWH solar/ GSHP/boiler auxiliary energy. To compare the building fabric performance we need to compare the bars on the charts above the dashed line only. It becomes fairly evident that Passivhaus design is much improved, both in terms of cost and CO2 savings, compared to the 2010 Building Regulation building typology.

Additionally, the building designed to minimum building regulations tends to consume considerably more energy than designed. Malcolm Bell from the Centre of Built environment, Leeds Metropolitan University states that “there is a growing concern that the predicted energy/carbon performance of housing (and other buildings for that matter) is not matched by that realised in practice.”[1]

1 Bell, M, (2010) *Carbon Compliance for Tomorrow’s New Homes, Closing the gap between the designed and built performance*, Zero Carbon Hub, NHBC Foundation, London

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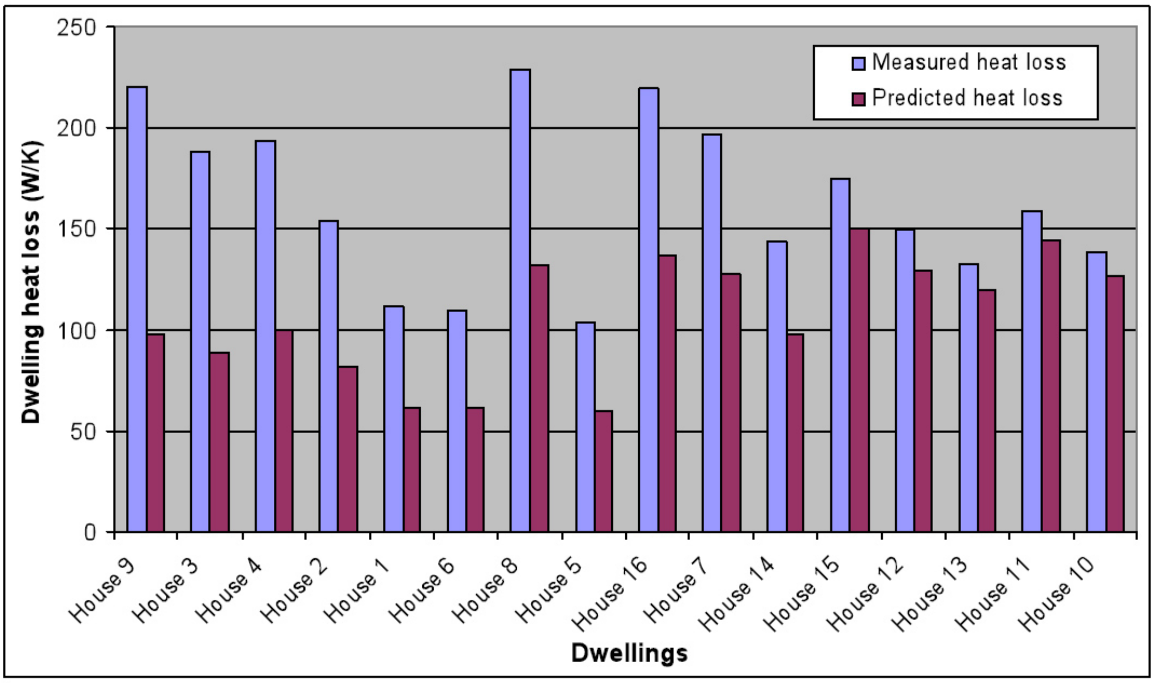
The graph below illustrates the results of the study that analysed the building fabric performance of 16 dwellings using the coheating test method[2]. The results were compared with what was predicted at design stage.

“The dwellings measured were designed to standards that ranged from the Part L 2006 Building Regulations to energy/carbon levels 4 and 5 in the code for sustainable homes (CLG 2008). The most striking picture is one of a large performance gap, which can be over 100% in some cases. Only 5 out of the 16 houses demonstrate even a reasonably close match at between 10 and 15%. None of the dwellings had a measured value that was less than the predicted value.”[3]



Measured versus predicted heat losses for 16 analysed dwellings

(Sources – Bell M., Smith M.B., and Palmer J. (2010) *Review of the implementation of Part L 2006*, BD 2702, Department for Communities al Government, London)

It appears from the study quoted above that, most of the time, the Building Regulations requirements are not met in practice, and we understand that the problem in non-domestic buildings is even worse than in the domestic sector. The Passivhaus standard, however, follows the project through construction up to completion, making sure that the building is not certified unless all the elements (fabric and services) comply with the design.

Mayville Community Centre provides an excellent example of performance of fabric and services, resulting in lower fuel bills and carbon footprint. The preliminary monitoring data shows the building operates better than predicted, and furthermore, offers a great comfort to the building users. We intend to continue to analyse the monitoring data, and to perform also a BUS survey to investigate the occupants’ satisfaction with the performance of the building.

We believe that this high standard of design already achieved by Passivhaus new-build and retrofit projects can be adopted and used in government building regulations, ensuring a better overall performance of the UK built stock.

2 Wingfield, J., Bell, M., Miles-Shenton, D., South, T & Lowe, R.J. (2008) Evaluating the Impact of an Enhanced Energy Performance Standard on Load-Bearing Masonry Construction – Final Report: Lessons From Stamford Brook - Understanding the Gap between Designed and Real Performance, PII Project CI39/3/663, Leeds Metropolitan University, Leeds

3 Bell, M, (2010) *Carbon Compliance for Tomorrow's New Homes, Closing the gap between the designed and built performance*, Zero Carbon Hub, NHBC Foundation, London

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