Report to UHMA

Calculation of the energy performance of two residential buildings typical for United Kingdom
The calculations are based on the CEN standards developed for the implementation of the Energy Performance of Buildings Directive (EPBD)

By

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The calculation are based on the procedure described in more detailed in the report to EURAY and some of the results are partly used in this report.
The calculations are done for two types of residential buildings (see Annex 1):

- An apartment on a single floor within a block of flats but not on the Ground Floor.
- A two-storey terraced house; one that has a Ground and First Floor with another dwelling on each side

The following building and heating system specifications were used:

- U values: -
  - External Walls 0.35.
  - Windows 2.20.
  - Ground Floor 0.25.
  - Ceiling/Roof 0.25.
  - Floor (and ceiling) in flat 0.35 (taking account of acoustic insulation).
- Climate - Manchester.
- Heat generation:
  - Condensing boiler
  - Air-source heat pump
  - Ground-source heat pump
- Floor heating
  - Type A (EN15377 and EN1264, (solid base with insulation over and then screed over).
  - Floor coverings – Resistance $\leq$ 0.1 m^2K/W
  - Supply/return water temperature 35/28
  - On-off (PI) room control)
- Radiator Supply/return water temperature
  - 75/55 with condensing boiler)
  - 55/35 with heat pump
  - Room control a thermostatic radiator valves with 2degC hysteresis (P(2))

Furthermore it is assumed that the distribution and generation losses in the heating system is recovered by 85% for the thermal energy.

The net energy (building energy demand) according to EN13790 is calculated. The results for the two buildings are presented as kWh/m^2 per year (see Annex 2). Then the losses in the heat emission system (EN15316-2.1), heat distribution system (EN15316-2.3), and heat generation systems (condensing boiler EN15316-4.1, and Heat pumps EN15316-4.2 are calculated. (see more detailed EURAY report)
The detailed results can be seen in Annex 3 and 4 and in the attached spread sheet.
Bothe the thermal energy and auxillary energy are calculated. To convert to primary energy the following conversion factors are used:

- Gas (condensing boiler), factor 1.1
- Electricity (auxiliary energy, heat pump), factor 2.8

The heat emission losses can according to EN15316-2.1 for a floor heating system be calculated assuming a floor on ground, a floor with extra insulation to the ground (like the UK requirements) or as a floor without any downward heat losses. The apartment building is calculated for an apartment in the middle of a building. That means additional downward heat losses from a floor heating is not considered. For a 2-Storey house the lower floor is calculated for a floor heating with extra insulation and the upper floor without downward losses.

The following table shows the primary energy use and CO2 emission. The conversion factors may differ from country to country depending on the primary energy sources for electricity and heating. Values for other conversion factors can be calculated using the attached spread sheet.

Appartment		Net Energy	Primary f	Primary f	Boiler	AW-HP	GS-HP	CO2 factor	CO2 factor	Boiler	AW-HP	GS-HP
Manchester	Qh = 35	Qh KWh/m²	Gas-heating	Elec-tricity	Primary KWh/m²	Primary KWh/m²	Primary KWh/m²	Gas-heating	Elec-tricity	CO2 Kg	CO2 Kg	CO2 Kg
Radiators (boiler) 70/55/20	P(2K)	35	1,1	2,8	47,6			0,198	0,29	8,4		
Radiators (HP) 50/35/20	P (2K)	35	1,1	2,8	44,6	57,0	51,9	0,198	0,29	7,8	5,9	5,4
Floor heating, No downwards loss	On-Off (PI-control)	35	1,1	2,8	41,4	41,9	31,6	0,198	0,29	7,2	4,3	3,3

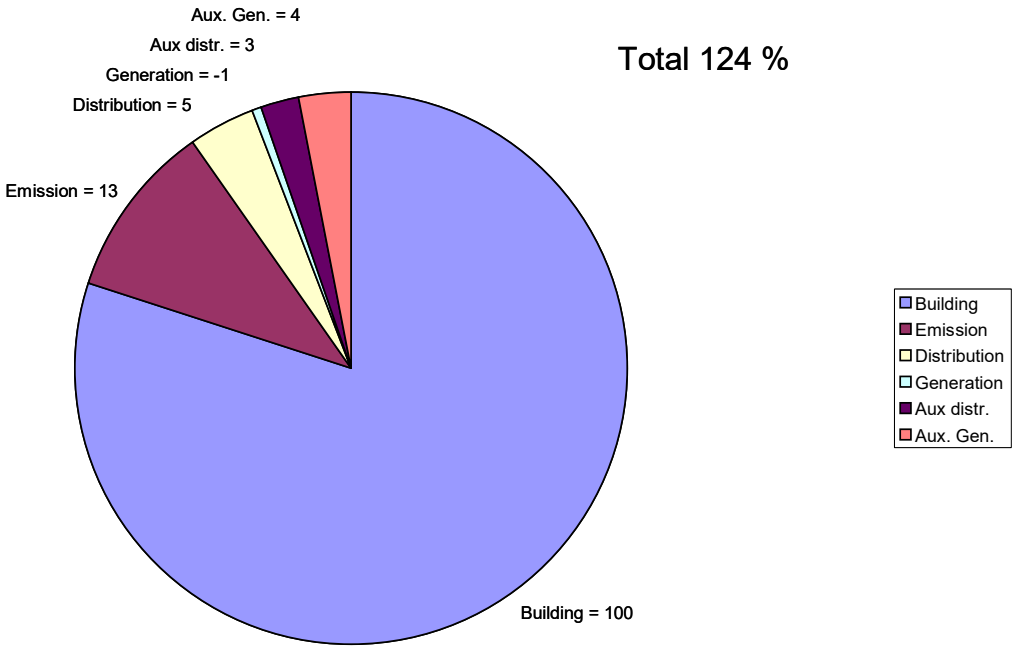
2-storey House		Net Energy	Primary f	Primary f	Boiler	AW-HP	GS-HP	CO2 factor	CO2 factor	Boiler	AW-HP	GS-HP
Manchester	Qh = 62	Qh KWh/m²	Gasheating	Electricity	Primary KWh/m²	Primary KWh/m²	Primary KWh/m²	Gas-heating	Elec-tricity	CO2 Kg	CO2 Kg	CO2 Kg
Radiators (boiler) 70/55/20	P(2K)	62	1,1	2,8	84,3			0,198	0,29	14,8		
Radiators (HP) 50/35/20	P (2K)	62	1,1	2,8	79,0	101,0	92,0	0,198	0,29	13,9	10,5	9,5
Floor heating, 2-storey	On-Off (PI-control)	62	1,1	2,8	74,7	75,6	57,0	0,198	0,29	13,0	7,8	5,9

The following table show the relative losses and the difference between the heat generators.
A radiator heated building with a condensing boiler will have additional 24 % losses, where half of this is due to the emission losses because of a non-perfect control.
The floor heating system with a condensing boiler has only additional 10 or 8% heat losses. The difference between the apartment and the house is very small. It should be noted that the condensing boiler has a negative loss because of the additional gain of energy from the condensation and because the upper value of the heat conversion factor for gas has been used.

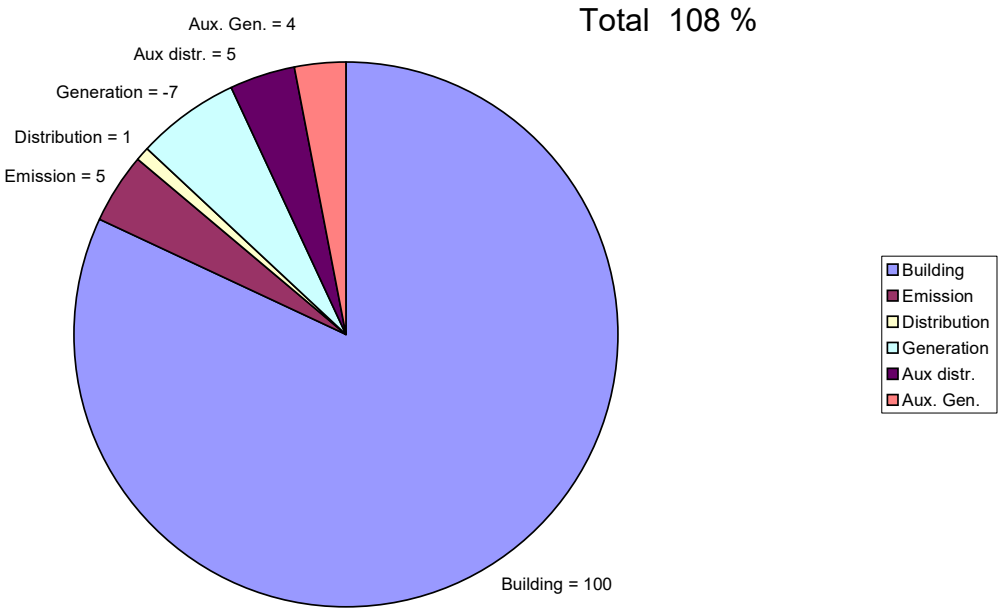
			Heating System distribution of primary losses with a condensing boiler							Heating System total energy use in relation to radiator with condensing boiler		
			Net energy	Emis-sion	Distri-bution	Gene-ration	Aux distri-bution	Aux gene-ration	conden sing boiler	conden-sing boiler	Heat pump, air-water	Heat pump, ground source
			%	%	%	%	%	%	%	%	%	%
Appartment and 2-storey house	Radiators (boiler) 70/55/20	P(2K)	100	13	5	-1	3	4	124			
Appartment and 2-storey house	Radiators (HP) 50/35/20	P (2K)	100	12	3	-5	3	4	116	100	128	116
Ground floor	Floor Heating, 35/28	On-Off (PI-control)	100	11	1	-7	5	4	114	98	99	75
Ground floor	Floor heating, extra insulation	On-Off (PI-control)	100	9	1	-7	5	4	112	96	97	73
Appartment	Floor heating, No downwards loss	On-Off (PI-control)	100	5	1	-7	5	4	108	93	94	71
2-storey house	Floor heating,	On-Off (PI-control)	100	7	1	-7	5	4	110	95	96	72

The distribution of losses for a condensing boiler is also shown in the following three pye-diagrams for radiator heating in an apartment or 2-storey house, floor heating in an apartment and floor heating in a 2-storey house.
The further examples are for houses heated by a heat pump. Either an air-to-water or a ground-source heat pump is used. In this case a radiator system with a lower water temperature is assumed.
The relative differences shown in the table are compared to a radiator system with a condensing boiler (100). It can be seen that for a low temperature radiator system the condensing boiler si a better alternative than the heat pump. For a floor heating the difference between a condensing boiler and an air-to-water heat pump is small. The best alternative is a ground-source heat pump.
These differences are also shown in the following diagram.

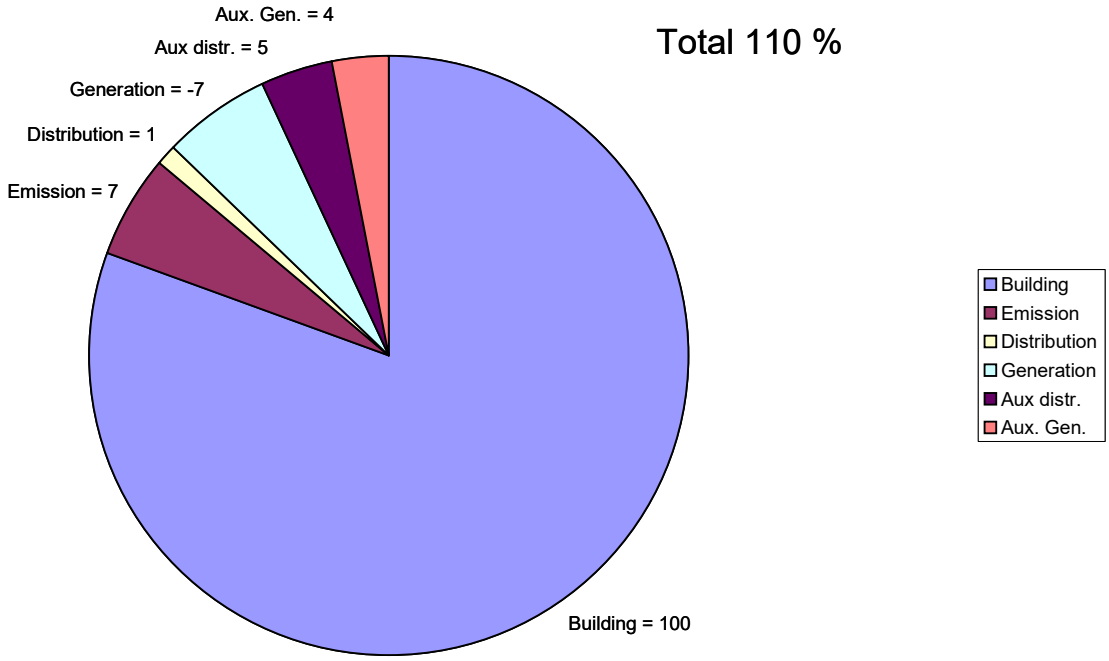
House/Appartment- UK Radiator 75/55 P(2) control- Condensing Boiler - Regulated Pumps



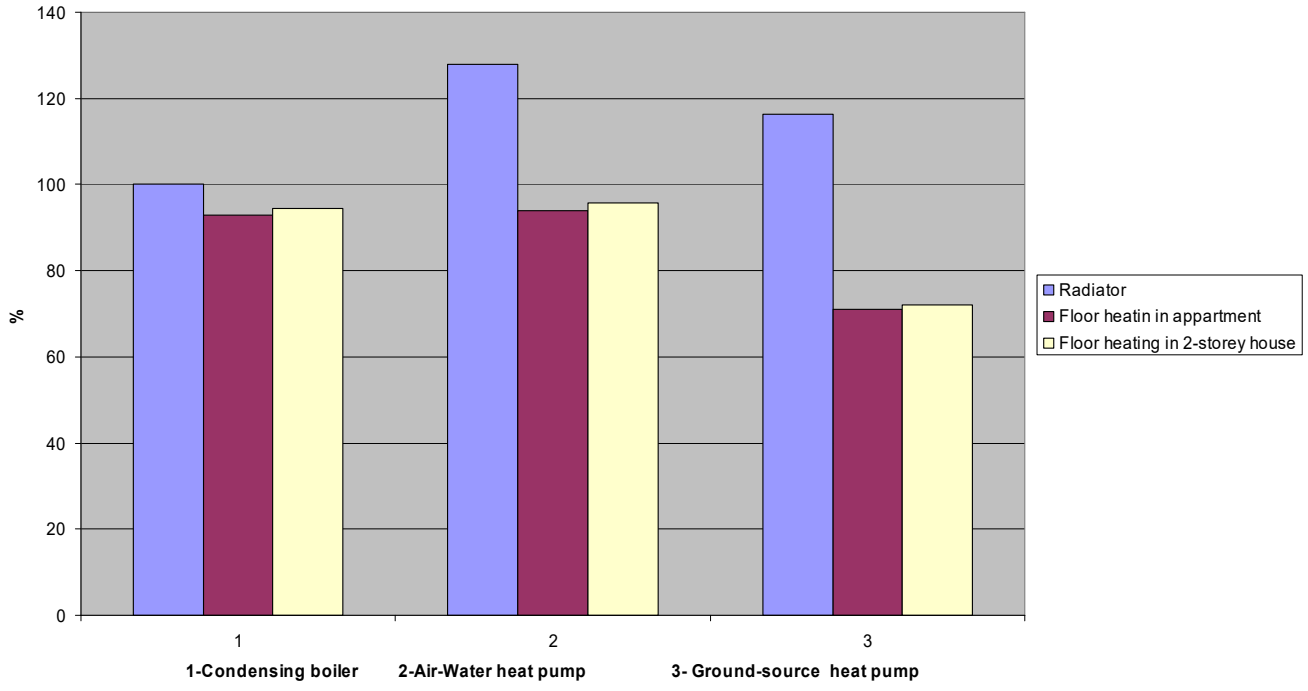
Appartment- UK -Floor heating 35/28 on-off (PI) control- Condensing Boiler - Regulated Pumps



2-Storey House UK Floor heating 35/28 on-off P(I) control- Condensing Boiler - Regulated Pumps

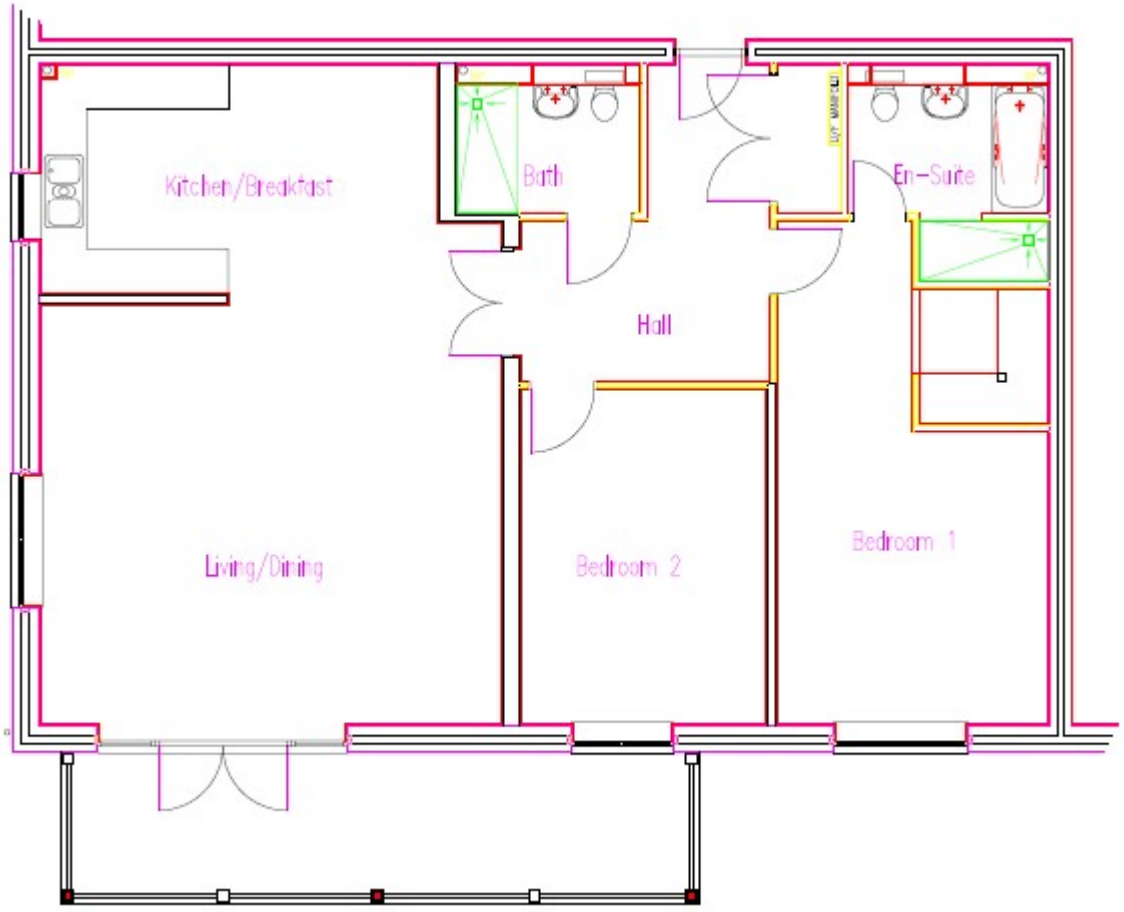


Total energy use in relation to a low temperature radiator



ANNEX 1: Description of the two buildings

Appartment with similar apartments above, below and to the sides.

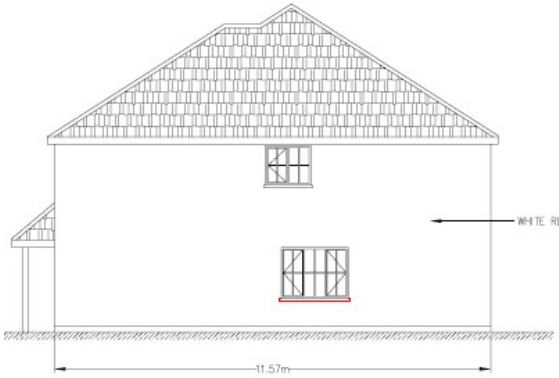


ELEVATIONS 4 BED HOUSE

WEST ELEVATION

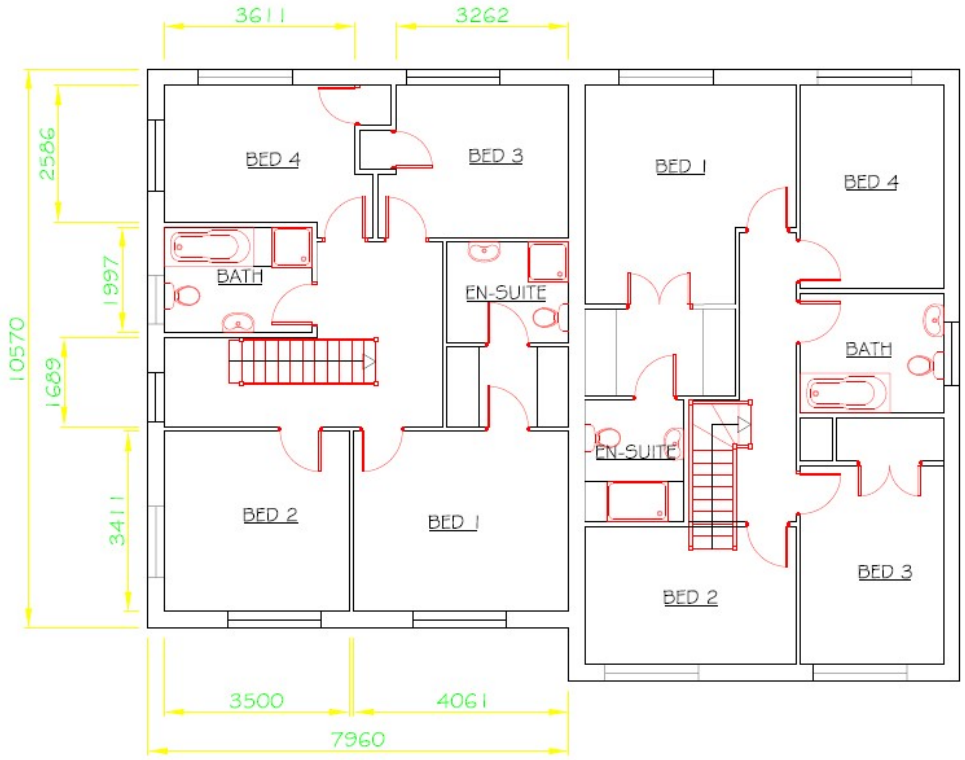
SOUTH ELEVATION

EAST ELEVATION

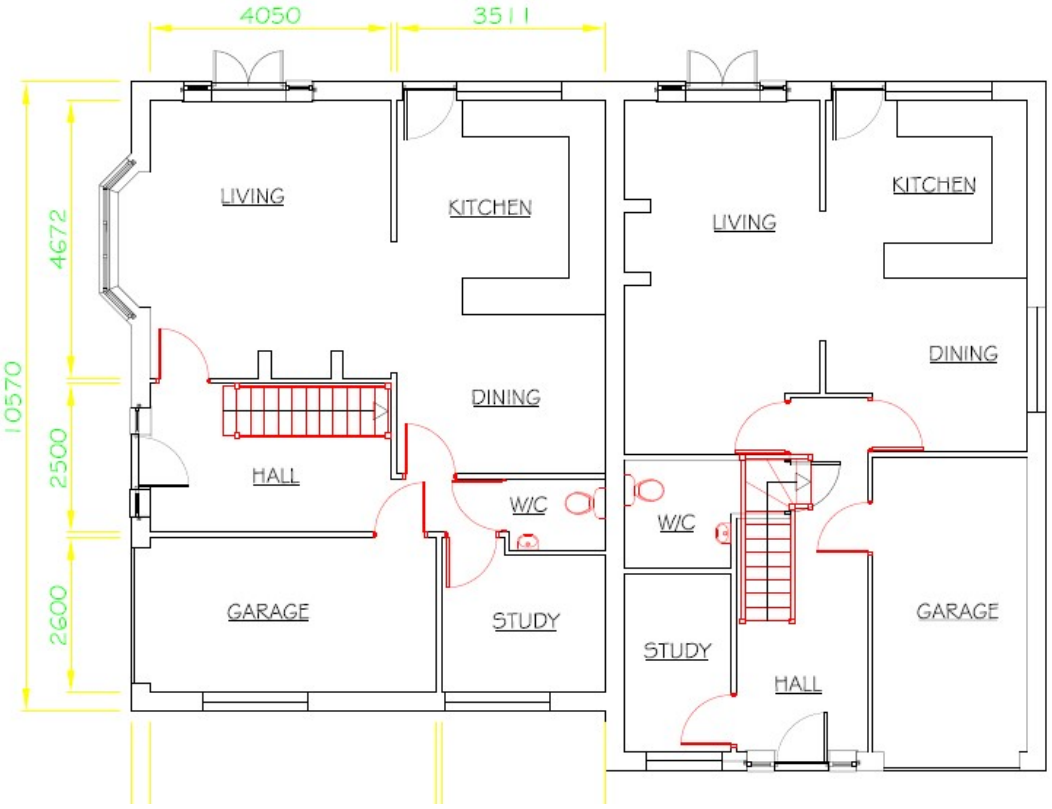


NORTH ELEVATION

FIRST FLOOR 4 BED HOUSE



GROUND FLOOR 4 BED HOUSE



ANNEX 2: Weather data

Monthly average temperature

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Average air temperature, °C	3,1	4	5,6	8,1	11,6	14,3	15,9	15,7	13,4	10,1	6,1	4,4

MANCHESTER AIRPORT UK data derived from GHCN 2 Beta - www.worldclimate.com

Global radiation on horizontal surface and external temperatures

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Global irradiation Wh/m^2 (daily values)	615	1224	2125	3463	4737	4760	4790	3857	2722	1508	715	419

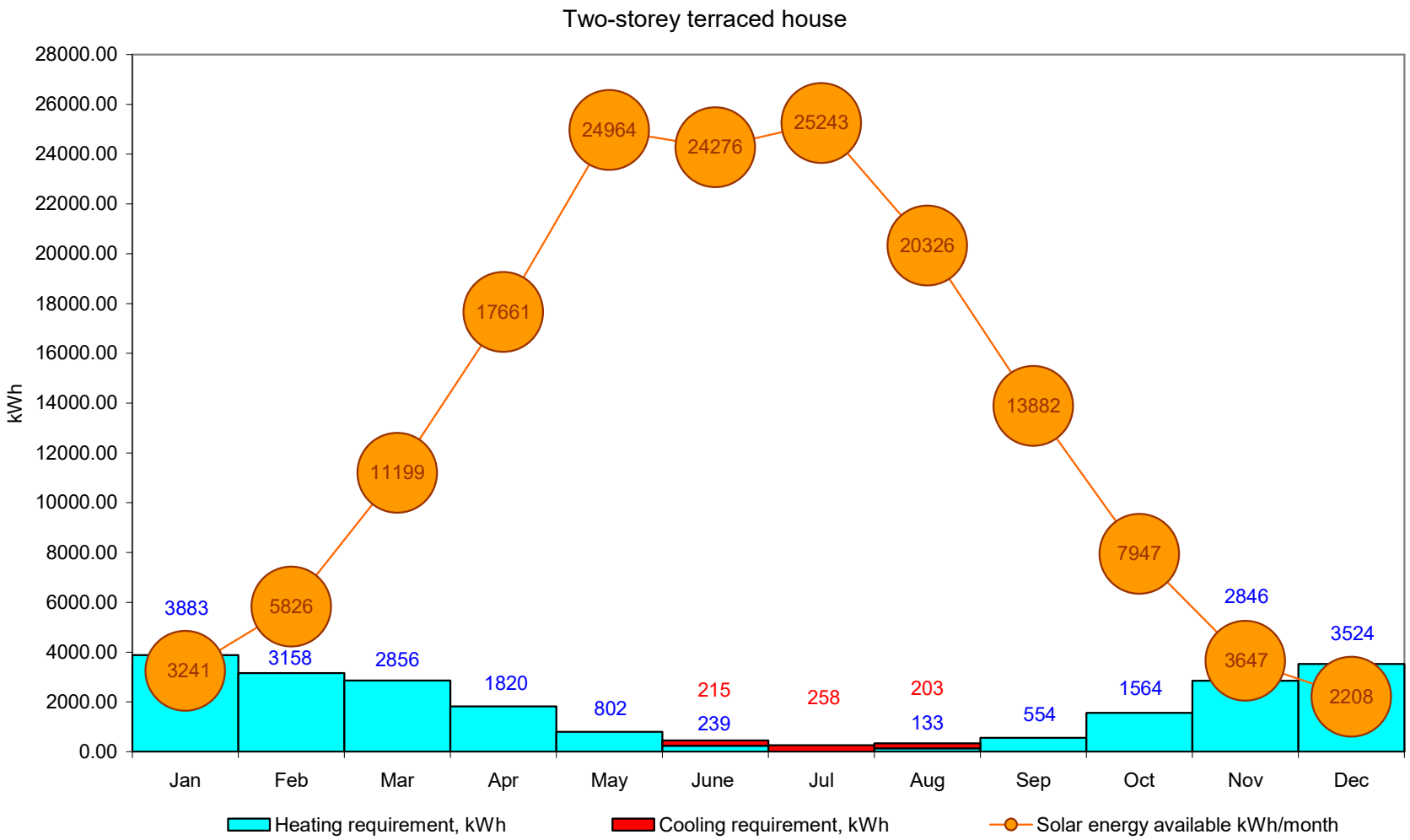
http://sunbird.jrc.it/pvgis/apps/radday.php?lang=it&map=europe - data for Manchester

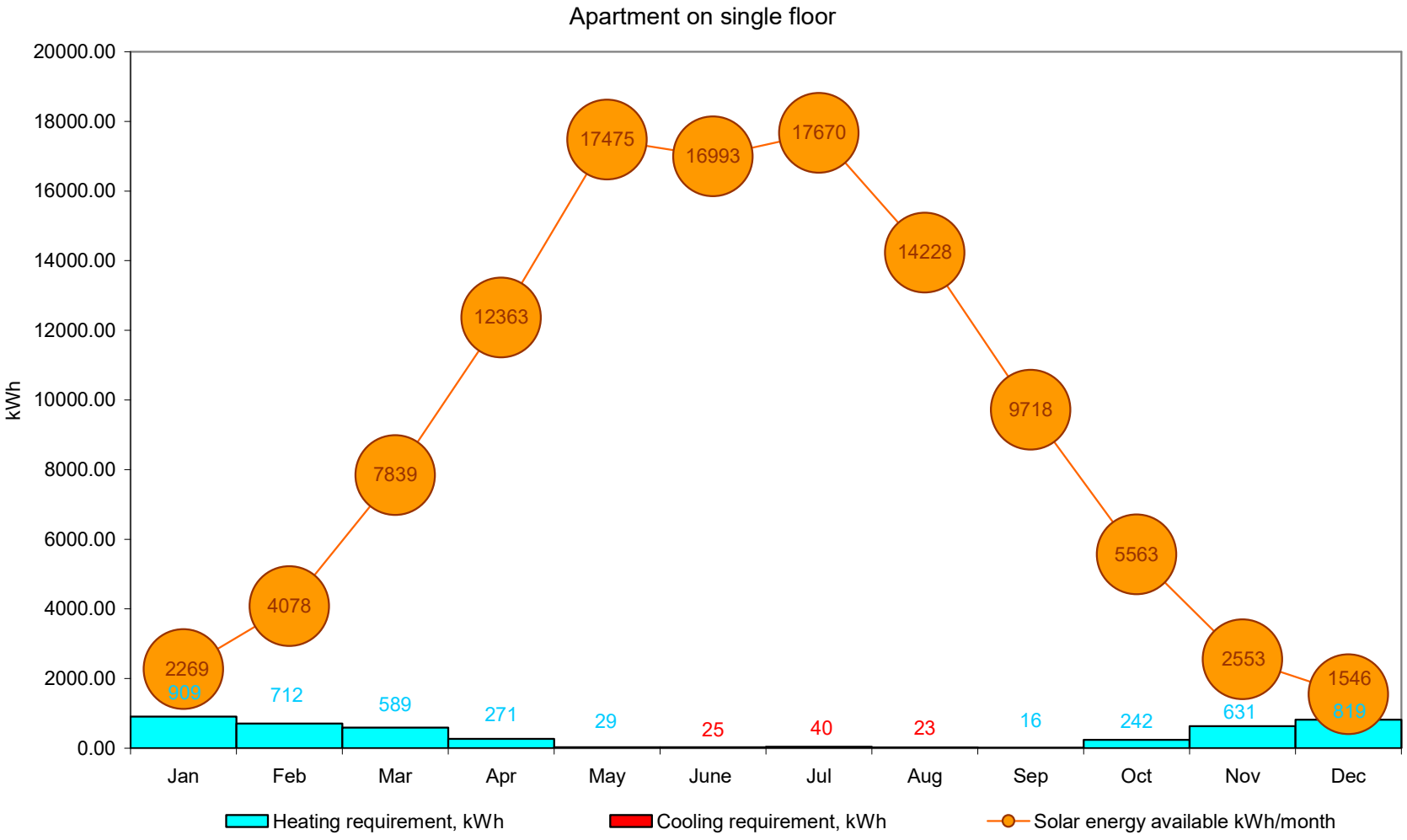
Radiation on vertical windows

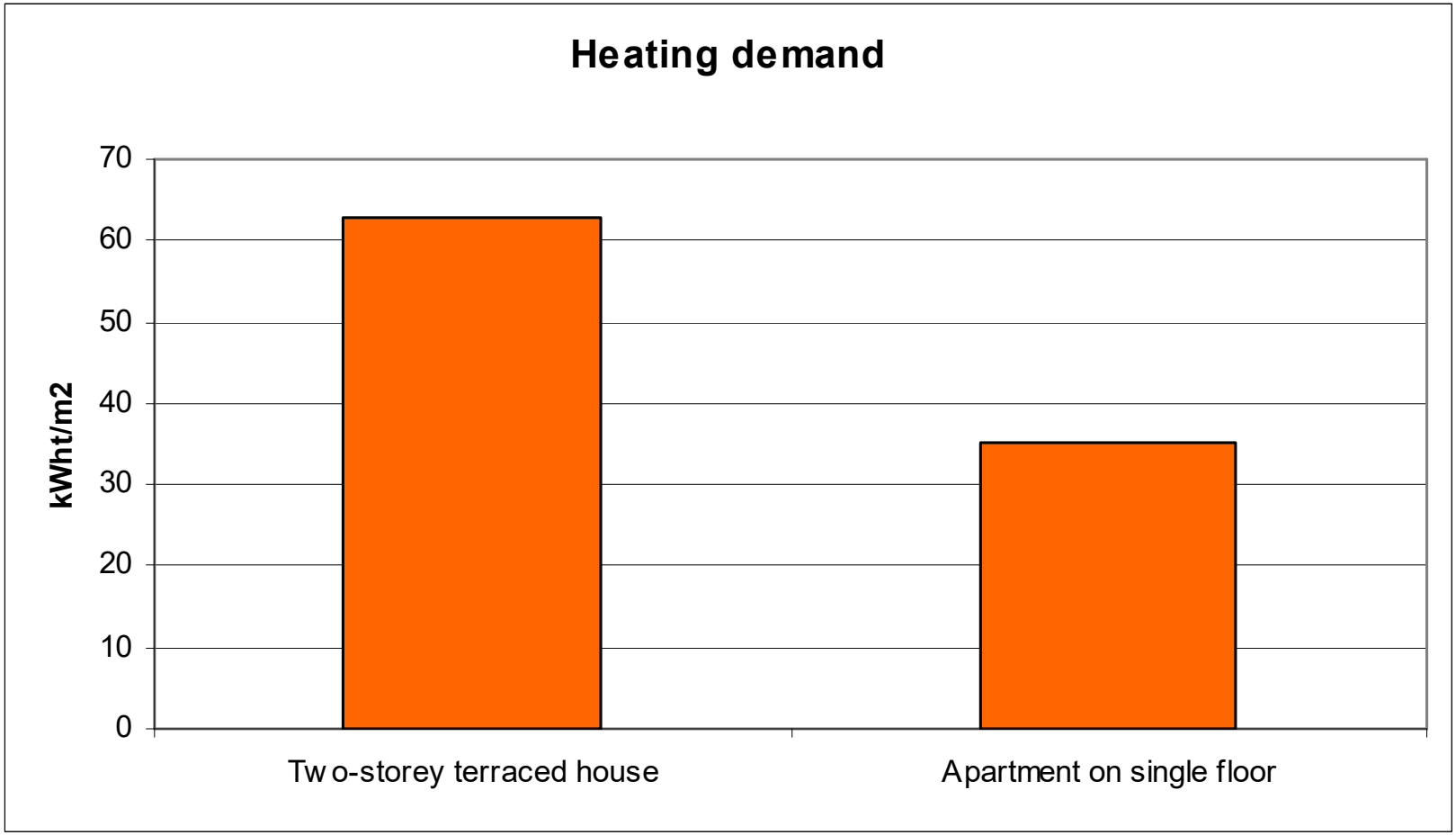
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
kWh/m2	0,29	0,48	0,75	1,21	1,62	1,91	1,7	1,44	1,02	0,65	0,31	0,21

data utilized in previous excel file for Brussels

ANNEX 3:Net Energy demand




Apartment on single floor
20000.00
18000.00
16000.00
14000.00
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
kWh
2269
4078
7839
12363
17475
16993
17670
14228
9718
5563
2553
1546
909
712
589
271
29
25
40
23
16
242
631
819
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Heating requirement, kWh
Cooling requirement, kWh
Solar energy available kWh/month


Heating demand
kWht/m2
70
60
50
40
30
20
10
0
Two-storey terraced house
Apartment on single floor

ANNEX 3: Detailed results for appartment

Appartment		Net Energy									Codensing boiler		Codensing boiler		Air-Water Heat Pump		Ground Source Heat Pump	
Manchester	Qh = 35	Qh KWh/m²	Qem,ls %	Qem,ls KWh/m²	$Q_{D\text{-}loss}$ %	$Q_{D\text{-}loss}$ KWh/m²	$Q_{D\text{-}aux}$ %	$Q_{D\text{-}aux}$ KWh/m²	$Q_{G\text{-}loss}$ %	$Q_{G\text{-}aux}$ %	$Q_{G\text{-}loss}$ KWh/m²	$Q_{G\text{-}aux}$ KWh/m²	$Q_{G\text{-}loss}$ KWh/m²	COP	$Q_{G\text{-}loss}$ KWh/m²	COP
Radiators (boiler) 70/55/20	P(2K)	35	13,0	4,6	4,7	1,6	1,2	0,4	-0,7	1,5	-0,2	0,5				
Radiators (HP) 50/35/20	P (2K)	35	11,5	4,0	2,6	0,9	1,2	0,4	-4,8	1,5	-1,7	0,5	20,0	2	18,1	2,2
Floor Heating, 35/28	On-Off (PI-control)	35	11,0	3,8	1,2	0,4	1,9	0,7	-7,3	1,5	-2,5	0,5	15,1	2,6	11,2	3,5
Floor heating, No downwards loss	On-Off (PI-control)	35	5,0	1,7	1,2	0,4	1,9	0,7	-7,3	1,5	-2,5	0,5	14,3	2,6	10,6	3,5

ANNEX 4: Detailed results for a 2-storey house

2-storey House		Net Energy									Codensing boiler		Codensing boiler		Air-Water Heat Pump		Ground Source Heat Pump	
Manchester	Qh = 62	Qh KWh/m²	Qem,ls %	Qem,ls KWh/m²	$Q_{D\text{-}loss}$ %	$Q_{D\text{-}loss}$ KWh/m²	$Q_{D\text{-}aux}$ %	$Q_{D\text{-}aux}$ KWh/m²	$Q_{G\text{-}loss}$ %	$Q_{G\text{-}aux}$ %	$Q_{G\text{-}loss}$ KWh/m²	$Q_{G\text{-}aux}$ KWh/m²	$Q_{G\text{-}loss}$ KWh/m²	COP	$Q_{G\text{-}loss}$ KWh/m²	COP
Radiators (boiler) 70/55/20	P(2K)	62	13,0	8,1	4,7	2,9	1,2	0,7	-0,7	1,5	-0,4	0,9				
Radiators (HP) 50/35/20	P (2K)	62	11,5	7,1	2,6	1,6	1,2	0,7	-4,8	1,5	-3,0	0,9	35,4	2	32,1	2,2
Floor Heating, 35/28	On-Off (PI-control)	62	11,0	6,8	1,2	0,7	1,9	1,2	-7,3	1,5	-4,5	0,9	26,7	2,6	19,9	3,5
Floor heating, extra insulation	On-Off (PI-control)	62	9,0	5,6	1,2	0,7	1,9	1,2	-7,3	1,5	-4,5	0,9	26,3	2,6	19,5	3,5
Floor heating, No downwards loss	On-Off (PI-control)	62	5,0	3,1	1,2	0,7	1,9	1,2	-7,3	1,5	-4,5	0,9	25,3	2,6	18,8	3,5
Floor heating, 2-storey	On-Off (PI-control)	62	7,0	4,3	1,2	0,7	1,9	1,2	-7,3	1,5	-4,5	0,9	25,8	2,6	19,2	3,5