Basement Force

Above Ground Extension and Subterranean Development

Life Cycle Carbon Review and Analysis

31 August 2013

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Issue Status

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1. Executive Summary

Ashmount Consulting Engineers Limited has been appointed by Basement Force to undertake an independent detailed review of the RBK&C Life Cycle Carbon Analysis Report[1] published as part of the Core Strategy 2010.

This review provides a detailed appraisal of the RBK&C report carried out and indicates the significant anomalies and misconceptions that the previous report incorporates in its findings, resulting in incorrect conclusions being drawn. Following the anomalies of the RBK&C report, this review establishes accurate and justified parameters for completing a true analysis of the total carbon emissions for each development.

Following a well-established, reasoned and justified basis, a true Life Cycle Carbon assessment was carried out for the relevant extensions. The analysis compares two developments of the same floor area of $75m^2$ as this reflects a true comparison for the same added residential space to a notional RBK&C residence.

As the actual lifespan of the above ground and below ground developments cannot be known this report fundamentally establishes a neutral or “net zero” time–frame when both development types have identical **accumulative** total carbon emissions.

In general the analysis concludes that subterranean basements have a **greater production and assembly phase** total carbon emissions than above ground extensions. The analysis also concludes that subterranean extensions have **lower occupied and use phase** total carbon emissions than above ground extensions. Following the full analysis of the above the subterranean and above ground extensions have the same total carbon emissions after **44 years**.

From this time onwards and for the remaining life of the extension the occupied and use phase **carbon emissions for subterranean basements are significantly lower than those of an above ground extension**.

Therefore it can be concluded that basement developments have lower Life Cycle Carbon Emissions than comparable above ground developments provided that on average reinforced concrete basements have a lifespan of more than 44 years.

[1] Life Cycle Carbon Analysis of Extensions and Subterranean Development in RBK&C - E167-report-1007-09jp

2. Introduction

This review provides a detailed independent appraisal of the RBK&C Life Cycle Carbon Analysis Report published as part of the Core Strategy 2010. The review indicates the significant anomalies and misconceptions that the previous report incorporates in its findings.

This review then establishes accurate and justified parameters for completing a true analysis of the total carbon for each development.

The analysis compares two developments of the same floor area of $75m^2$ as this will reflect a true comparison for the same added residential space to a notional RBK&C residence.

A quick guide to terminology:

- **Embodied CO_2 emissions**
  - These are emissions resulting from extraction and manufacture of construction materials, transport to site and assembly of building elements to create a finished dwelling, and subsequent refurbishment.
- **Life cycle assessment**
  - This accounts for and evaluates the environmental impacts of products, from the extraction of raw materials through manufacturing, distribution and use to recycling or disposal.
- **Dwelling life cycle**
  - This describes the complete cycle of building, occupying and maintaining; each stage leads to CO2 emissions.
- **Operational CO_2 emissions**
  - These are emissions resulting from space and water heating, ventilation, lighting, appliances and cooking within a living space.
  - SAP software was used to determine operational CO_2 emissions and BRE Global's Environmental Profile methodology to analyse total CO^2 emissions.
- **Standard Assessment Procedure (SAP) 2009**
  - The Government's Standard Assessment Procedure (SAP), which is used to determine whether a given housing design complies with the requirements of Building Regulations. SAP software is typically used, which provides information on expected CO2 emissions from heating, cooling, lighting and other impacts.

3. Review of RBK&C Life Cycle Carbon Analysis Report

Following a detailed assessment of the previous RBK&C Life Cycle Carbon Analysis Report - E167-report-1007-09jp published as part of the Core Strategy 2010 several basic elements of both the calculation method and reasoning behind the report have been found to be significantly flawed and inaccurate.

The main anomalies in the previous RBKC report can be listed but not limited to the following:

- **Life Cycle**
    - A Life cycle for a basement of 30 years is unrealistically short.
    - The BRE Global's Environmental Profile methodology estimates the lifespan of an above ground structure of around 60-120 years. The average life of housing units in England is 59 years[2]. A basement structures expected life is significantly longer than this. The design life is generally 100 years[3].
    - Demonstrated life of reinforced concrete structures supports a view that the likely life of modern reinforced concrete will be significantly greater than 100 years[4].
    - Reinforced concrete was only developed for broad use in the late 19th century. However concrete structures such as the London Sewers of the mid 19th century remain operational while some of the very earliest concrete structures such as the Pantheon in Rome built AD 127, are still in use.
    - Concrete basements are likely to have greater longevity than above ground concrete structures as the below ground environment is benign:
        - Structure is not subject to freeze / thaw.
        - Lack of exposure to air decreases the carbonisation of the concrete.

[2] English Housing Survey, Housing stock report 2008, Department for Communities and Local Government, ISBN 978-1-4098-2601-9
[3] British Standard BS 8500-1 Concrete. Complementary British Standard to BS EN 206-1Method of specifying and guidance for the specifier
[4] Concrete through the ages from 7000BC to AD2000, British Cement Association, 1999, ISBN 0 7210 1547 6

- The life span of an above ground extension may often be less than the 59 years average building life that might be expected. This would be due to above ground extensions being demolished and replaced for aesthetic reasons particularly in high value residential areas such as RBK&C.

- **Floor Area**

    - The floor area for the two extensions is too dissimilar to be accurately comparable. Even once converted to an m^2 basis comparing the construction elements of a $10m^2$ extension vs. 75 m^2 basement is not on a like for like basis.

- **Case Studies**

    - The basement chosen in the subterranean case study, 44 Markham Square, is not a "typical subterranean development". For this job specialist steel piles (Ischebeck Titan steel piles) were proposed. These have been proposed because of difficult ground conditions (groundwater) on the site, limited access, and possibly due to difficulties with making agreements with adjoining owners on other more efficient methods.

    - In general reinforced concrete underpinning is used for basement construction underneath buildings in RBKC. In over 200 basements built in across London Basement Force have never had to use Ischebeck Titan steel piles. These steel piles more than double the weight of steel compared to a normal job.

    - A typical $72m^2$ subterranean basement would have approximately 5.2 tonnes of reinforcement; as opposed to the Ischebeck Titan steel piles at 17.3 tonnes.

- **Whole life cycle**

    - The accurate Whole Life Cycle carbon emissions of the extensions has not been correctly determined. To correctly consider the carbon the “use phase” should also be taken into account including maintenance, repair and replacement, refurbishment.

- **SAP Calculation Anomalies**

    - On a true like for like comparison an above ground extension better would in no circumstances have lower occupied carbon emissions than the basement.

    - As stated on Page 37, para 11.5 of the Alan Baxter Report[5] instructed by RBKC states that - "Once constructed, basements tend to perform much better in environmental terms than above ground construction. They are not subject to extreme variations in temperature which result in high heating or cooling loads."

- **Error in Basement excavation allowed**

    - Detailed within the RBK&C report as having 1,200m^3 soil excavations.

    - Since basement has an area of 75m^2 the site would need, ignoring bulking, to be excavated vertically **16m** to get this volume of soil. This is clearly inaccurate for a single level basement.

- **Above ground extension steel work at 4 Dalgarno Gardens W10**

    - The previous RBKC / Eight Associates report includes no structural steel within the materials used. An extension to an existing property will generally require structural steelwork to be installed to create openings in existing walls.

[5] Alan Baxter - Royal Borough of Kensington and Chelsea Residential Basement Study Report March 2013

- The drawing on page 19 of the RBKC /Eight Associates report shows the ground floor plan for the proposed work at 4 Dalgarno Gardens W10. The plan would require at least two structural steel beams and probably two or three structural steel columns. The requirement to form structural opening can be seen from the aerial photograph of the property at what looks like a time after the extension has been built. The structural steel would be needed:
  - Under the line of the rear of the original building
  - Under the side wall of the original closet wing.
- An estimate of the actual minimum steel beams and columns in the above ground extension is 9.3m of steel, with a weight of 430-600kg.

- **Works Time-Frame Anomalies**
  - The works time-frame for the basement case study is inaccurate. A more realistic time frame for the construction phase would be 6 months. The 9 months work time for the fit out should not be included in the basement construction time. The internal fit out for the above ground and basement developments would be the same.

- **Anomaly in Works Time-Frame Carbon Factor**
  - A Works Time-Frame Carbon Factor of 2000kg/month is used in the RBK&C report. This figure cannot be unjustified and neither RBK&C nor Eight Associates has definitively provided the basis for this value[6].

- **Error in waste calculation**
  - Distance to landfill given as 5km. There are no landfill/recycling sites within 5kms of Chelsea.

[6] 14 August 2013 e mail from RBKC to Daniel Watt.

4. Basis of Analysis

Following the appraisal of the previous RBK&C report the fundamental principles of a true Life Cycle Carbon Analysis have been established.

This is largely in line with the BRE Global Environmental Profile[7] methodology to analyse construction CO_2 emissions and as defined in the NHBC Foundation report for operational and embodied carbon in new build housing[8].

The analysis includes impacts arising from two definitive time periods as below:

Build Carbon Emissions:

- **Production phase** – raw material extraction, transport, manufacturing of products, and all upstream processes the assembly process phase – transport to the assembly site and housing development.
- **Assembly phase** - transport to the assembly site and development

Operational Carbon Emissions:

- **Occupied phase** – the carbon emission associated with the heating, cooling, lighting and ventilation of the development.
- **Use phase** – maintenance, repair and replacement, refurbishment

Further to the above carbon emissions we have also considered the periodic rebuild of the different building types. The factors affecting the construction lifespan of the two building types is as follows:

Basement Lifespan

- Design life of reinforced concrete structures is 100 years.
- Demonstrated lifespan of reinforced concrete structures is greater than 100 years.
- The below ground environment is benign for reinforced concrete as:
    - Structure is not subject to freeze / thaw.
    - Lack of exposure to air decreases the carbonisation of the concrete.

[7] Anderson J, Shiers D, Steele K. The Green Guide to Specification. BRE BR 501, (4th ed). Bracknell, IHS BRE Press, 2009.
[8] NHBC Foundation report Operational and embodied carbon in new build housing - A reappraisal April 2012

Above ground extension Lifespan

- Demonstrated average life of above ground buildings of 60 years.
- Empirical occurrence of above ground extensions being demolished and replaced for aesthetic reasons particularly in high end residential market further lowering the expected life.

For the reasons given above the expected lifespan of an above ground building envelope, superstructure and substructure is 40 years and the expected lifespan of subterranean building envelope, superstructure and substructure is over 120 years.

It is well proven from historic constructions that the lifespan of reinforced concrete is certainly hundreds of years, rather tens of years[9]. For example, Joseph Bazalgette's London sewer system was built between 1859 and 1865 and used 670,000 cubic metres of concrete. These original underground sewers are in good working order today. Another example is that of the Eerie Canal in the US. Built from reinforced concrete in 1825, the Eerie Canal remains structurally sound and in good working condition.

However, rather than base the analysis purely on a subjective rebuild period this analysis primarily establishes when in terms of years since build completion the **accumulative** total carbon emissions for both development types are neutral or **"zero net"**. Consideration of this period is critical to assess the projected accumulative total carbon emissions for both types of development.

[9] Concrete through the ages from 7000BC to AD2000 - British Cement Association 1999

5. Life Cycle Carbon Analysis

The following section analyses the true total Carbon for the two developments.

In order to directly compare the two typical theoretical case studies, the life cycle carbon emission figures have been calculated in $KgCO_2/m^2$/year.

The Life Cycle Analysis has been completed by assessment of the following areas.

Build Carbon Emissions:

- **Production phase** – raw material extraction, transport, manufacturing of products, and all upstream processes the assembly process phase – transport to the assembly site and housing development.
- **Assembly phase** - transport to the assembly site and development

Operational Carbon Emissions:

- **Occupied phase** – the carbon emission associated with the heating, cooling, lighting and ventilation of the development.
- **Use phase** – maintenance, repair and replacement, refurbishment

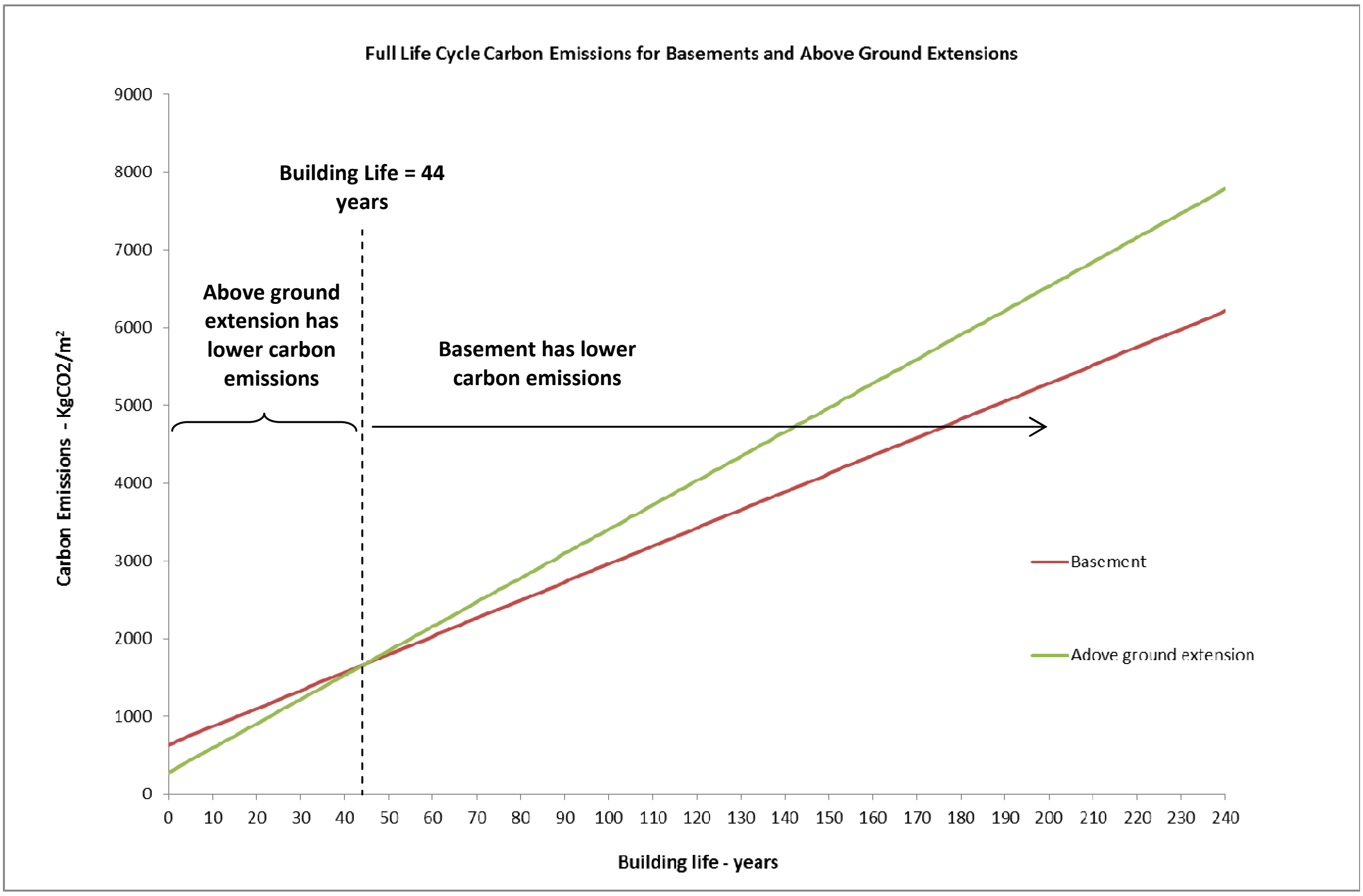
The below table summarises the specific inclusions under each section and highlights in red the inconsistencies in the previous RBKC report. A complete breakdown of the quantities and calculations can be found in Appendix 2.

Phase	75m^2 Basement Extension	Above Ground Extension	RBKC Report Comment
Production phase	Concrete Rebar Structural Steel Insulation Waterproofing	Concrete Brickwork Structural Steel Blockwork Insulation Roof	**Non typical basement construction used as example for case study with over x3 the steel needed for a typical basement** **No structural steel in above ground extension**
Assembly phase	Excavation Staff travel Deliveries & Collections Works Time-Frame	Excavation Staff travel Deliveries & Collections Works Time-Frame	**Inaccurate 1,200m^3 soil excavations** **Inaccurate time-frame** **Inaccurate travel distances**
Occupied phase	Occupied Carbon Emissions from SAP calculations	Occupied Carbon Emissions from SAP calculations	**Anomalies in SAP calculations with above ground carbon emissions being less than subterranean**
Use phase	10 Year Pump replacement 50 Year Membrane replacement	20 Year External painting and guttering 50 Year roofing works	**Not considered**

6. Conclusion

Subterranean basements have a **greater production** and **assembly phase** carbon emissions than above ground extensions.

Subterranean extensions have **lower occupied** and **use phase** carbon emissions than above ground extensions.

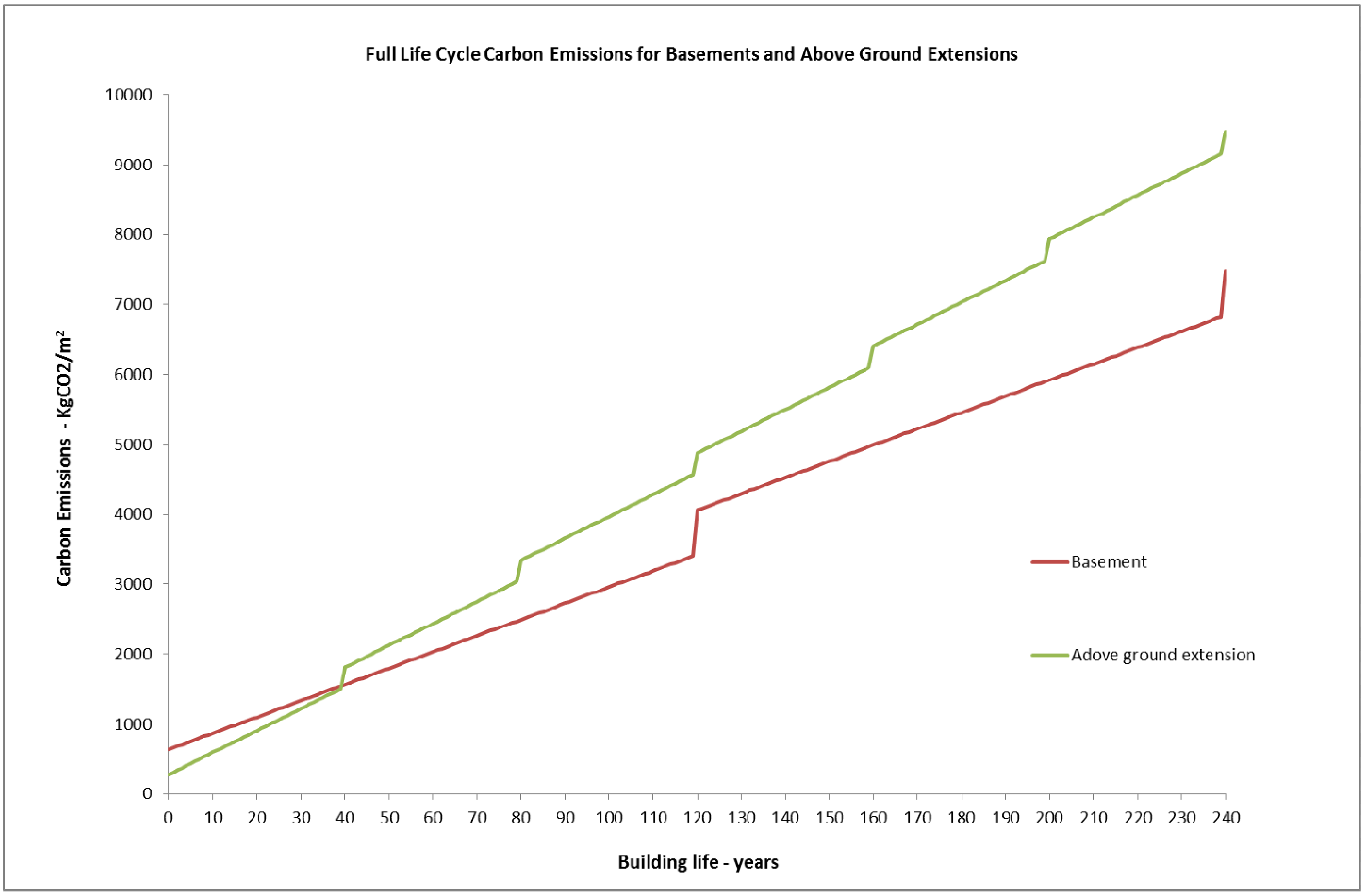


Further to this and as can be seen in the above graph it can be concluded that the subterranean and above ground extensions have the same total carbon emissions after **44 years**.

From this time onwards and for the remaining life of the extension the carbon emissions for subterranean basements are significantly lower than those of an above ground extension.

Therefore it can be concluded that basement developments have lower Life Cycle Carbon Emissions than comparable above ground developments provided that on average reinforced concrete basements have a lifespan of more than 44 years.

If the **periodic rebuild** carbon emissions are included every 40 years for an above ground extension and conservatively every 120 years for a subterranean extension the below graph is achieved.



The above further demonstrates that ad infinitum the total carbon emissions for the subterranean extension are well below the emissions for an above ground extension.

Appendix 1 - Basement and above Ground SAP calculations

SAP calculations have been carried out for the above ground and subterranean extensions. The inputted construction and design data for both is as follows:

- **Above Ground Extension – SAP Input Summary**

Construction U-Values (W/m^{2}K)	
Solid Doors	**None**
Windows	**15sqm @ 1.7**
Ground floor	**75sqm @ 0.15**
Walls	**61.25sqm @ 0.26**
Roof	**75sqm @ 0.18**

Build Air Permeability	
(m^3/(hm^2) @ 50Pa	**10**
Sheltered Sides	**2**

Mechanical & Electrical Specification

Lighting	
Percentage Lighting Low Energy fixed fittings:	**75%**

Hot Water Cylinder	
Cylinder Size (l)	**N/A**
Insulation thickness (mm)	**N/A**

Heating	
Boiler Fuel	**Mains Gas**
Boiler Efficiency	**74%**
Secondary Heating	**None**

Primary Heating Controls
Time & Temperature Zone Control

Ventilation
Natural Ventilation with intermittent extract to wet rooms

Resultant Occupied CO2 Emissions produced are:

12a. CO2 emissions – Individual heating systems including micro-CHP

	Energy kWh/year		Emission factor kg CO2/kWh		Emissions kg CO2/year	
Space heating (main system 1)	(211)	x	0.198	=	1394.27	(261)
Space heating (secondary)	(215)	x	0	=	0	(263)
Water heating	(219)	x	0.198	=	586.97	(264)
Space and water heating	(261) + (262) + (263) + (264) =				1981.24	(265)
Electricity for pumps, fans and electric keep-hot	(231)	x	0.517	=	90.48	(267)
Electricity for lighting	(232)	x	0.517	=	213.82	(268)
Total CO2, kg/year			sum of (265)...(271) =		2285.53	(272)
CO2 emissions per m²			(272) ÷ (4) =		30.47	(273)
EI rating (section 14)					74	(274)

- **Subterranean Extension – SAP Input Summary**

Construction U-Values (W/m^2K)	
Solid Doors	**None**
Windows & Rooflights	**10sqm @ 1.7 (Basement will have fewer glazed openings)**
Ground floor **(same insulation thickness)**	**75sqm @ 0.14 (resultant U-value of sheltered basement floor)**
Walls **(same insulation thickness)**	**61.25sqm @ 0.21 (resultant U-value of sheltered basement wall)**
Roof	**None**

Build Air Permeability	
($m^3/(hm^2)$ @ 50Pa	**5 (Basements have a more airtight construction)**
Sheltered Sides	**4 (Fully sheltered basement)**

Mechanical & Electrical Specification

Lighting	
Percentage Lighting Low Energy fixed fittings:	**75%**

Hot Water Cylinder	
Cylinder Size (l)	**N/A**
Insulation thickness (mm)	**N/A**

Heating	
Boiler Fuel	**Mains Gas**
Boiler Efficiency	**74%**
Secondary Heating	**None**

Primary Heating Controls
Time & Temperature Zone Control

Ventilation
Natural Ventilation with intermittent extract to wet rooms

Resultant Occupied CO2 Emissions produced are:

12a. CO2 emissions – Individual heating systems including micro-CHP

	Energy kWh/year	Emission factor kg CO2/kWh		Emissions kg CO2/year	
Space heating (main system 1)	(211) x	0.198	=	821.78	(261)
Space heating (secondary)	(215) x	0	=	0	(263)
Water heating	(219) x	0.198	=	593.03	(264)
Space and water heating	(261) + (262) + (263) + (264) =			1414.82	(265)
Electricity for pumps, fans and electric keep-hot	(231) x	0.517	=	90.48	(267)
Electricity for lighting	(232) x	0.517	=	230.23	(268)
Total CO2, kg/year		sum of (265)...(271) =		1735.52	(272)
CO2 emissions per m²		(272) ÷ (4) =		23.14	(273)
EI rating (section 14)				81	(274)

Appendix 2 - Life Cycle Carbon Analysis Calculations

75sqm Subterranean Extension

Production Phase

Item	Description	Qty	Unit	Comments	Density (kg/m^3)	Weight (kg)	Carbon Factor (kgCo2/kg)	Carbon Emission (kgCO2)	Carbon Emission per m2 floor area (kgCO2/m2)
1	Concrete	45.0	m^3		2,400.00	108,000.00	0.159	17,172.00	228.96
2	Rebar (assumes nil recycled)	5.4	T	Steel Reinforcement inside the reinforced concrete		5,400.00	1.710	9,234.00	123.12
3	Structural steel (assumes nil recycled)	3.2	T	Structural steel used to support internal walls		3,200.00	1.770	5,664.00	75.52
4	Blockwork	1.0	m^3	Might well be none - inner walls are stud.	2,400.00	2,400.00	0.074	177.60	2.37
5	Insulation	17.7	m^3	Based on 30.5 liner metres for wall & 2.8m high; 75m2 for floor and ceiling; all 75mm thick	40.00	708.00	1.050	743.40	9.91
6	Waterproofing		m^3	Cavity membrane - 30.5 liner metres for wall & 2.8m high at 0.5kg/m2; Floor 75m2 at 0.95kg/m2		113.95	2.500	284.88	3.80
							Total Embodied Energy	33,275.88	443.68

Assembly Phase

Item	Description	Qty	Unit	Comments	Lorries/Trips/ Months	Distance to Travel Return (Km)	KgCO2/100Km	Carbon Emission (kgCO2)	Carbon Emission per m2 floor area (kgCO2/m2)
7	Excavation	261.6	m^3	Unbulked	37	60.00	40.00	888.00	11.84
8	Staff Travel - site visits by Project Manager			22days per month for 6 months, PM runs two sites	66	30.00	24.44	483.91	6.45
9	Deliveries & collections - materials			Usually trip is shared with 3 or 4 sites - say 3 on average. One delivery per day; shared with two other sites -> 0.33 trips per day x 22 days per month x 6 =	51.60	50.00	40.00	1,032.00	13.76
10	Works Time-frame			2,000kg/month Carbon Factor - Months Build	6		2,000.00	12,000.00	160.00
							Total Embodied Energy	14,403.91	192.05

Occupied Phase

Item	Description	Qty	Unit	Comments	Years Occupied	kg CO2 / year		Carbon Emission (kgCO2)	Carbon Emission per m2 floor area (kgCO2/m2)
11	Occupied Carbon Emissions			Based on SAP Energy calcs	44	1,735.00		76,340.00	1,017.87
							Total Embodied Energy	76,340.00	1,017.87

Use Phase

Item	Description	Qty	Unit	Comments				Carbon Emission (kgCO2)	Carbon Emission per m2 floor area (kgCO2/m2)
12	Maintenance Lifetime Carbon Emissions							369.49	4.93
							Total Embodied Energy	369.49	4.93
							Total	124,389.28	1,658.52

75sqm Above Ground Extension

Production Phase

Item	Description	Qty	Unit	Comments	Density (kg/m³)	Weight (kg)	Carbon Factor (kgCo2/kg)	Carbon Emission (kgCO2)	Carbon Emission per m2 floor area (kgCO2/m2)
1	Concrete	18.75	m³	250mm Slab	2,400.00	45,000.00	0.159	7,155.00	95.40
2	Brickwork	8.54	T	100mm Brick	1,900.00	16,226.00	0.220	3,569.72	47.60
3	Structural steel	0.35	T	Structural steel used to support opening in external walls		350.00	1.770	619.50	8.26
4	Blockwork	8.54	m³	100mm Concrete Block	2,400.00	20,496.00	0.074	1,516.70	20.22
5	Insulation	23.54	m³	100mm Wall & Floor Insulation Rockwool	40.00	941.60	1.050	988.68	13.18
6	Roof	3.75	m³	Slate	2,400.00	9,000.00	0.056	504.00	6.72
						Total Embodied Energy		14,353.60	191.38

Assembly Phase

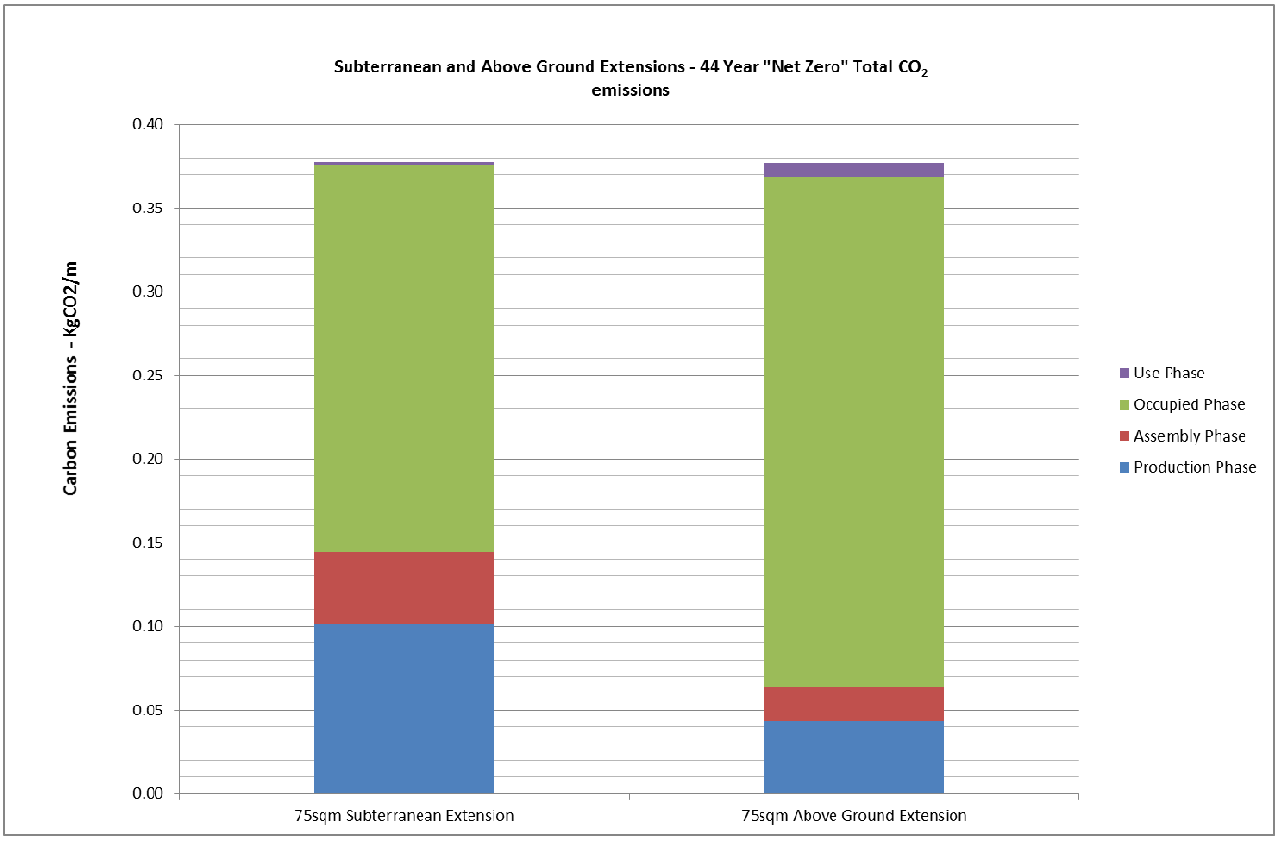
Item	Description	Qty	Unit	Comments	Lorries/Trips	Distance to Travel Return (Km)	KgCO2/100Km	Carbon Emission (kgCO2)	Carbon Emission per m2 floor area (kgCO2/m2)
7	Staff Travel			22days per month for 2 months	66.00	15.00	24.44	241.96	3.23
8	Construction Materials Site Removal	13.3	m³	8 Yard skips (6m3)	6.00	60.00	40.00	144.00	1.92
9	Deliveries & collections - materials			Usually trip is shared with 3 or 4 sites - say 3 on average. One delivery per day; shared with two other sites -> 0.33 trips per day x 22 days per month x 2 = 15	15.00	50.00	40.00	300.00	4.00
10	Works Time-frame			2,000kg/month Carbon Factor - Months Build	3		2,000.00	6,000.00	80.00
						Total Embodied Energy		6,685.96	89.15

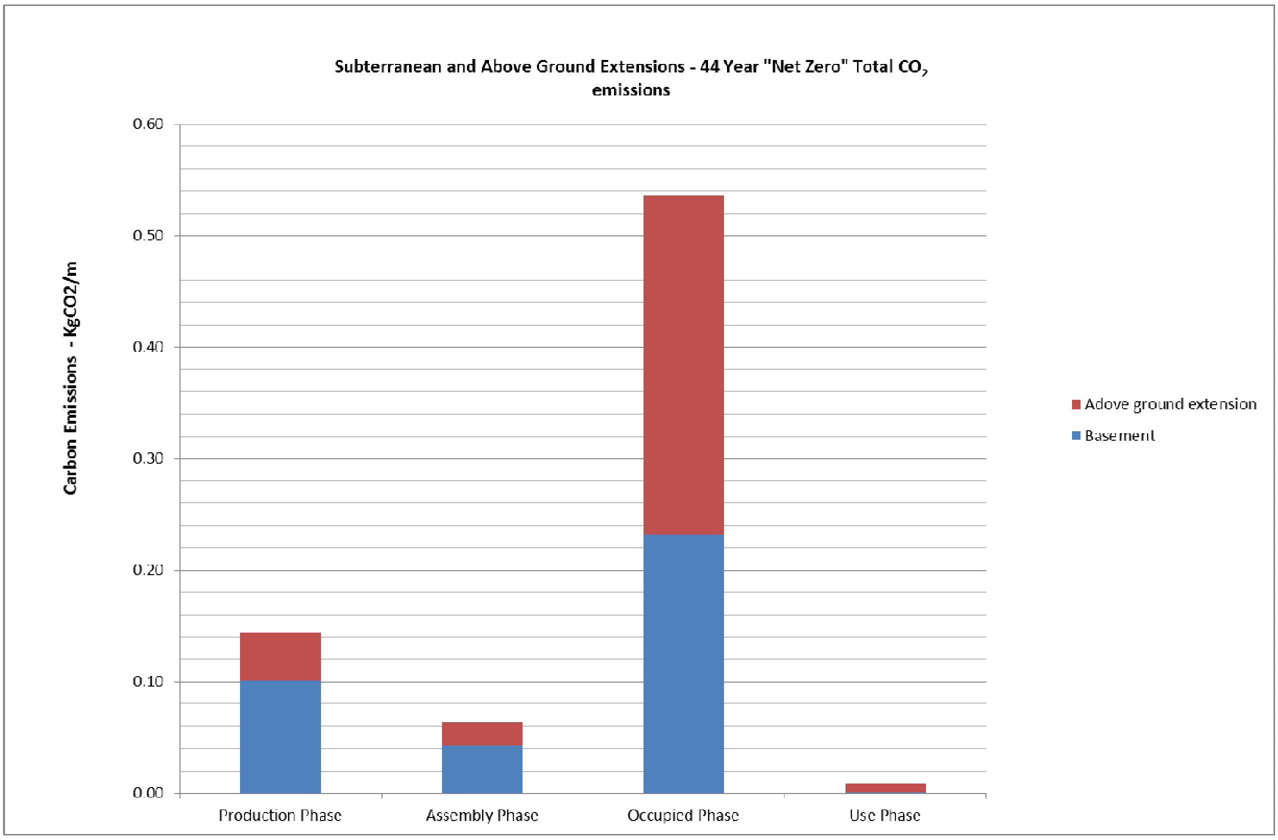
Occupied Phase

Item	Description	Qty	Unit	Comments	Years Occupied	kg CO2 / year		Carbon Emission (kgCO2)	Carbon Emission per m2 floor area (kgCO2/m2)
11	Occupied Carbon Emissions			Based on SAP Energy calcs	44	2,285.00		100,540.00	1,340.53
						Total Embodied Energy		100,540.00	1,340.53

Use Phase

Item	Description	Qty	Unit	Comments				Carbon Emission (kgCO2)	Carbon Emission per m2 floor area (kgCO2/m2)
12	Mainentance Lifetime Carbon Emissions			10,000kg every 50 years				2,643.52	35.25
						Total Embodied Energy		2,643.52	35.25
							Total	124,223.08	1,656.31





The above graphs show the total carbon for each development at the “Net Zero” 44 year mark.