Refurbished Modular Buildings Carbon Savings Report

Issued for

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Contents

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1 Executive Summary

It is widely recognized that a modular buildings have a number of sustainability advantages over traditional construction methods. A study undertaken by Arup & Partners "CO2 emissions from use, scrapping and manufacture of modular buildings" concluded:

- The embodied energy required to manufacture a typical (10 module) modular buildings at 4.9GJ/m² is significantly less than that required to construct equivalent buildings traditionally (5.0 – 15.0GJ/m²).
- Modular buildings offer an alternative and sustainable solution to traditional buildings in that they can be relocated and the embodied energy in them is preserved.
- The ability to relocate modular buildings minimizes the need for landfill. ▪ At end of life significant elements of the buildings can be recycled

This report provides further analysis to determine the carbon emissions savings that can be achieved by re-use and refurbishment of a typical five bay marketing suite when compared to the equivalent new modular building.

This report calculates the overall carbon savings associated with the re-use of the existing main steel structure of a 5 bay marketing suite and also includes the carbon emissions associated with the processing of waste from the existing modules that are forming the basis for the new building.

The overall carbon savings from the re-use / refurbishment of a typical 5 bay marketing suite has been calculated at **47.682 TCO^2** which represents a considerable saving when compared to the construction of a new modular building from 100% virgin components.

From a previous study undertaken in 2005 data can be extrapolate to indentify that a typical new five bay modular building would have **113.043 TCO^2** of embodied carbon and thus by the re-use and refurbishment of existing modules a carbon saving of approximately **42%** can be achieved.

2 Methodology

This section of the report details the typical building layout and final specification of the refurbished building together with the analysis of the waste produced during the refurbishment process. An overview of the carbon calculation methodology is also provided.

2.1 Typical Building Definition

The building used as this basis of this calculation is a 5 bay construction of 12m x 3m x 3.2m modules with a layout as detailed in the floor plan below:

The building is constructed from two end bays and three intermediate bays.

2.2 Pre-used Modules

The pre-used modules used as the basis of the refurbishment would typically be stripped of all internal fittings, windows, doors and wall panels. The floor and roof would be inspected and replaced or refurbished as necessary, up to 40% of the floor or roof materials may be retained in the final refurbished building. The steel frame is inspected and checked to ensure that the structure has not lost any of its integrity.

The picture below shows typical modules before and strip out work commences.

Typical 5 bay building would produce a total of 6.96 metric tons of waste. The following details the materials stripped out from the existing modules as part of the refurbishment process, analysis of the waste streams indicate that the majority of the material is re-cycled.

Waste type	% of Total	Weight	Recycled
Timber	20	1.392	Yes
Metal	10	0.696	Yes
Glass	10	0.696	Yes
Plasterboard	15	1.044	Yes
Floor Coverings	5	0.348	Yes
Electrical	5	0.348	Yes
Lighting Tubes [1]	1	0.069	Yes
Plastic (re-cycled)	20	1.392	Yes
Plastic (non-recyclable)	5	0.348	No
Composite Wall Panels	9	0.626	Yes (50%)

[1] Light tubes are disposed by specialist contractor in line with the WEEE Directive

From a study undertaken by American waste management consultants, Sound Resource Management Group, the energy required to recycle, process and make new products from 1 ton of mixed waste is approximately 3,000 kWh.

To recycle the materials from a typical 5 bay construction would result in the consumption of 18,896 kWh of energy.

2.3 Refurbished Building Specification

Following full refurbishment the building would have the following

specification: **Building Fabric**

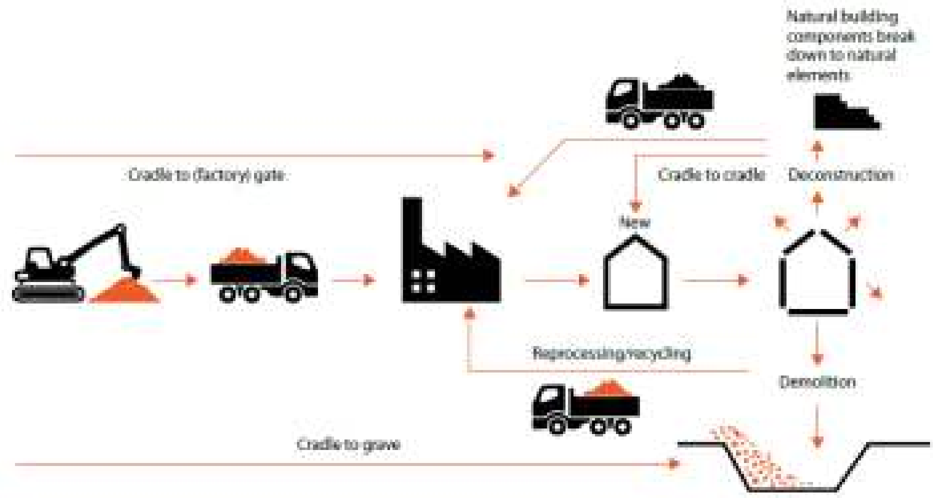
Element	Specification
External Walls	Brick slip cladding to exterior achieving an overall performance of 0.31 w/m2
Floor	Suspended ground floor achieving an overall performance of 0.20 w/m2
Roof	Mono pitch roof with full timber truss structural timber fitted with clay tile roof achieving an overall performance of 0.24 w/m2
Windows	Aluminum power coated frames with double glazing achieving a minimum efficiency of 1.31 w/m2
External Doors	Aluminum power coated frames with double glazing achieving a minimum efficiency of 1.75 w/m2

Building Services

Element	Specification
Heating & Cooling	Electric heat pump based heating and cooling systems to the primary sales areas with time, temperature and weather compensation controls; systems having a minimum SCOP 4.1 of and SEER of 7.0 Direct electric panel heaters to kitchen, WC, boot room and lobby with local time and temperature controls.
Domestic Hot Water	Localised point of use systems with maximum daily heat losses of 0.5 kWh per day
Lighting	LED fittings through achieving a minimum of 94 lumens / circuit watt
Lighting Controls	Presence detection controls to areas of in-frequent occupation – kitchen, store room, WC, boot room and lobby. Manual controls to the primary sales areas
Mechanical Ventilation	Local extract ventilation to the kitchen, WC, and boot room with control linked to lighting controls and achieving a minimum specific fan power of 0.4 w/l/s

2.4 Carbon Emission Calculation Methodology

The methodology employed to calculate the carbon savings from re-use and refurbishment of a 5 bay modular building consider all aspects of the strip down, disposal / recycling of waste materials, reconstruction / fit-out of the refurbished building and transport to site. This can be summarized in the diagram below:



It can be seen from the refurbished building specification detailed above that both the fabric and building services would be common to either a newly constructed modular building or a re-used / refurbished modular building. In addition transport of the building from manufacturing site to its final destination would also be the same.

As the build specification and transport are common to both a newly constructed modular building and a re-used / refurbished modular building it is only necessary to consider the carbon emissions associated with the following:

▪ Carbon savings from re-using and not re-cycling the main steel structure ▪ Carbon savings from not manufacturing a new main steel structure ▪ Carbon emissions from recycling of the waste from the refurbishment process

For the purposes of this calculation it is assumed that only the main steel structure is retained, if any other elements of the original building are retained this would increase the carbon savings associated with the re-use and refurbishment.

The overall carbon savings associated with re-using and refurbishing a 5 bay modular building can be calculated as follows:

Saving = CO^2 from steel re-use + CO^2 from eliminating the use of virgin steel
- CO^2 from waste processing

3 Carbon Saving Calculations

The carbon savings calculation is based upon the following source data:

Element	Factor
Virgin Steel CO^2 per Kg[1]	2.702
CO^2 to recycle steel per Kg[2]	1.194
Modular end bay steel frame weight (Kg)[3]	2,912
Modular building intermediate bay steel frame weight (Kg)[4]	2,516
Energy to process and re-cycle one tone mixed waste (kWh)[5]	3,000
Energy to CO^2 conversion factor $KgCO^2/kWh$[6]	0.234
Weight of re-cycled waste from 5 bay building (tones)	6.29

[1] Data source: British Research Establishment (BRE) (published in SCI Publication P-182, 'A comparative environmental life cycle assessment of modern office buildings', Appendix D, 1998 K J Eaton & A Amato)

[2] Data source: British Research Establishment (BRE) (published in SCI Publication P 182, 'A comparative environmental life cycle assessment of modern office buildings', Appendix D, 1998 K J Eaton & A Amato)

[3] Data source: Arup Report - MPBA (Modular and Portable Building Association) CO2 emissions from use, scrapping and manufacture of modular buildings

[4] Data source: Arup Report - MPBA (Modular and Portable Building Association) CO2 emissions from use, scrapping and manufacture of modular buildings

[5] Data source: Sound Resource Management Group, Morris J: Recycling versus incineration: an energy conservation analysis

[6] Data source: Assumed to be 50% gas and 50% electricity, conversion factors from Department for Business, Energy & Industrial Strategy 2019 reporting factors

Based upon the data above the carbon savings can be calculated as follows:

Weight of steel for 5 bay building ((2 x 2,912) + (3 x 2,516)) = 13,372 Kg
Carbon saving from not using virgin steel (13,372 x 2.702) = 36,131 $KgCO^2$
Carbon saving from not recycling used steel (13,372 x 1.194) = 15,966 $KgCO^2$
Carbon emitted recycling 5 bay building waste (6.29 x 0.234) = 4,415 $KgCO^2$

Carbon saving = 36,131 + 15,966 – 4,415 = 47,682 $KgCO^2$ or 47.682 tCO^2

4 References

The following sources of reference have been used in the production of this report:

- Arup Report - MPBA (Modular and Portable Building Association) CO2 emissions from use, scrapping and manufacture of modular buildings
- Morris J (1996): Recycling versus incineration: an energy conservation analysis
- Institute of Civil Engineers: Energy Briefing, Embodied Energy and Carbon
- UCL Embodied Carbon Factsheet
- British Research Establishment (BRE) (published in SCI Publication P-182, 'A comparative environmental life cycle assessment of modern office buildings', Appendix D, 1998 K J Eaton & A Amato)
- UK Green Building Council, Tackling embodied carbon in buildings