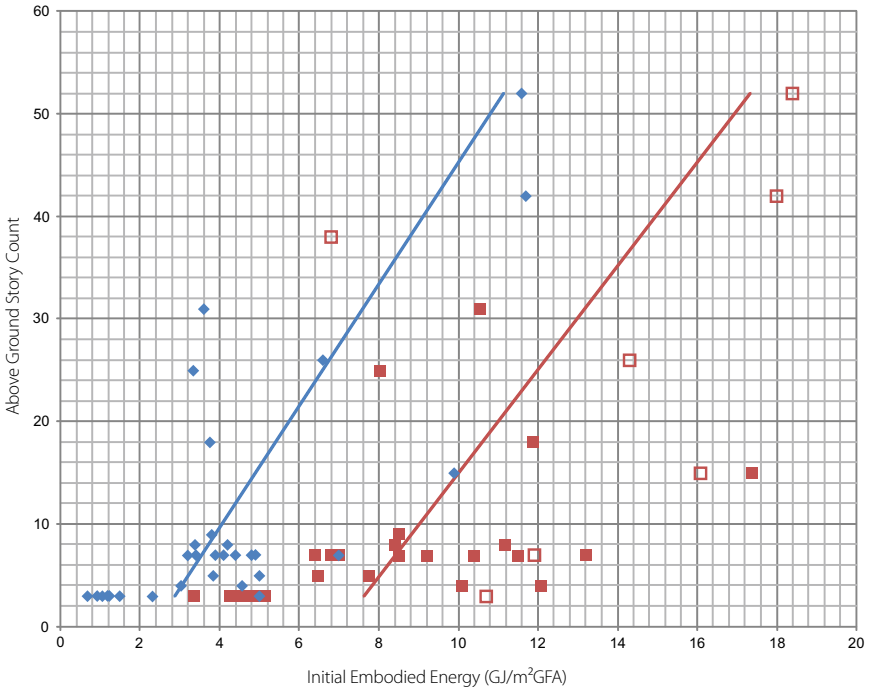
Tall Buildings In Numbers

Tall Buildings and Embodied Energy



Graph Showing Relationship Between Initial Embodied Energy[1] and Height: An Analysis of Published Studies

Tall buildings generally require a greater investment of initial embodied energy per unit gross floor area compared to low-rise buildings. Many published studies examining initial embodied energy in taller buildings exclude elements from the analysis, in particular the building services. As such, some of these studies will be underestimating embodied energy, and the pattern of increasing initial embodied energy with height may in fact be more extreme.

- Total initial embodied energy
- Initial embodied energy of structure only
- Denotes a study where significant building elements are excluded from the embodied energy analysis (e.g. services, finishes)
- Trendline: total initial embodied energy
- Trendline: initial embodied energy of structure only

Note: only published studies examining buildings three stories and greater in height included.

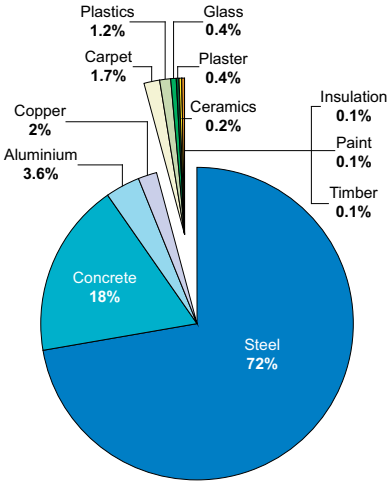
For further information on these studies, including a full list of references, definitions and expanded notes, see:
http://embodiedenergy.ctbuh.org

Typical Embodied Energy / Carbon Coefficients for Building Materials

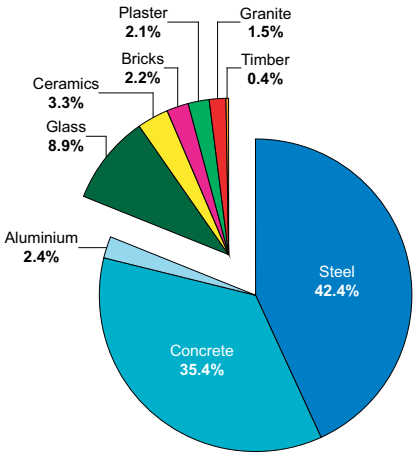
Cradle-to-Gate[2], UK. Source: Hammond & Jones, 2008

Material	Embodied Energy (MJ/Kg)	Embodied Carbon (Kg CO_2/Kg)
General Aluminum (typical % recycled content):	155	8.24
Plastic, General (inc. feedstock energy):	80.5	2.53
General Carpet:	74.4	3.89
General Paint:	68	3.56
Stainless Steel:	56.7	6.15
Copper:	40 - 55	2.19 - 3.83
Steel Section (typical % recycled content):	25.4	1.78
Toughened Glass:	23.5	1.27
Mineral Wool Insulation:	16.6	1.2
General Ceramics:	10	0.65
Facing Bricks:	8.2	0.52
Plasterboard:	6.75	0.38
Cement (General):	4.6	0.83
Concrete (Reinforced RC30 with 100Kg rebar per m^3):	2.12	0.241
Sand:	0.1	0.005

Embodied Energy and Materials in Tall Buildings



15-story office tower, steel structure, Australia
(analysis includes services, finishes, fittings and external elements)
Source: Treloar *et al.*, 2001a



38-story office tower, concrete structure, Thailand
(analysis includes only major construction elements)
Source: Kofoworola & Gheewala, 2009

The embodied energy of virgin aluminum (218MJ/Kg) is over seven and a half times greater than recycled aluminum (28.8MJ/Kg).

Every tonne of cement requires about 1.5 tonnes of raw materials, and about 4000 to 7500 MJ of energy for production. The cement industry is estimated to contribute 5% of all global anthropogenic CO_2 emissions.

The global production of concrete increased from 40 million m3 in 1900 to 6.4 billion m3 in 1997, making it the most widely used construction material in the world, with only fresh water utilized in larger quantities.

Embodied Energy and Operating Energy: A Comparison

Parameters of the Study

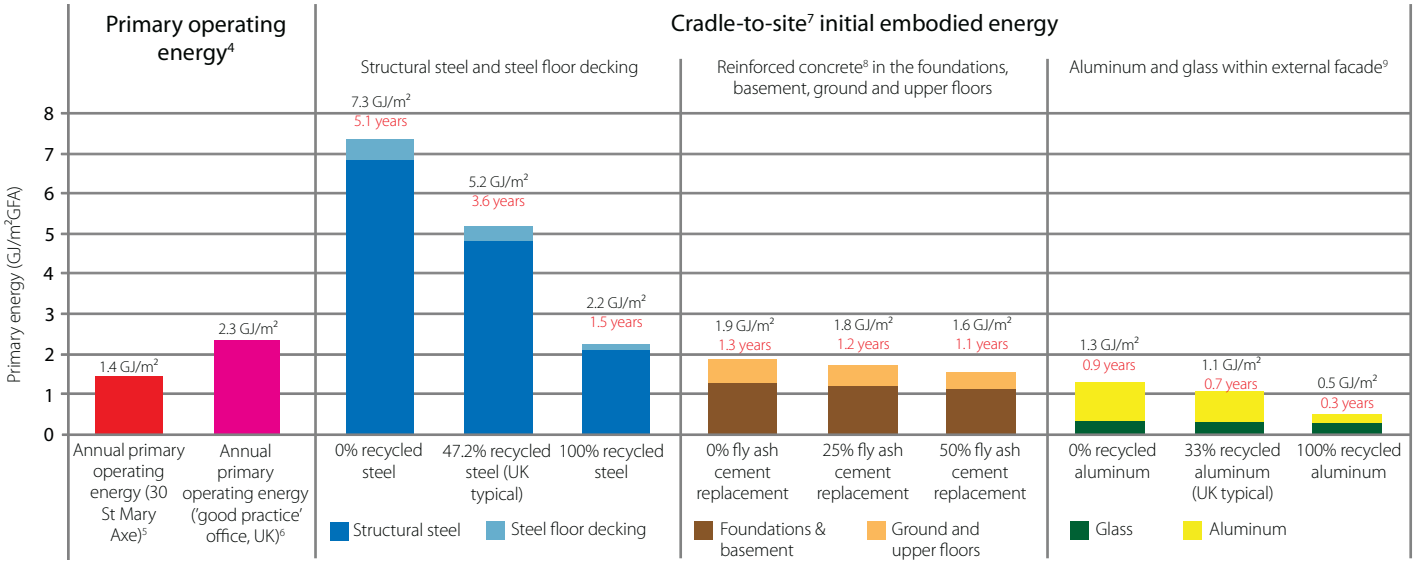
This study compares the primary operating energy of a tall, steel-structure office building in London with the primary embodied energy contained within some of its elements / materials. Operating energy data and building material quantities are based on both published and calculated data for 30 St Mary Axe, or 'Swiss Re' as it is more commonly known - a 180 meter-tall tower completed in the City of London in 2004. The operating energy of a typical 'good practice, air-conditioned, prestige' UK office building is also considered. For each material, three options regarding recycled content are examined to determine the potential energy savings through recycled material usage.

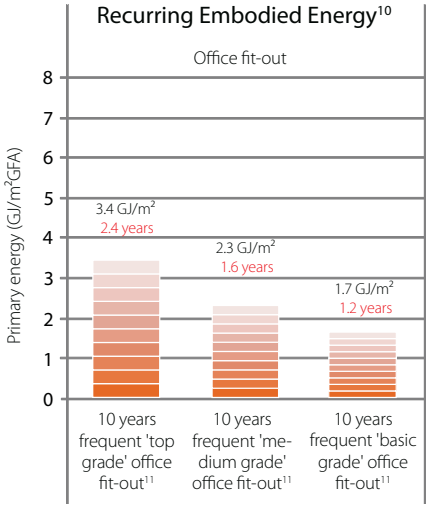
Building Data

Building height:	180m
Number of stories:	41
Gross Floor Area:	64,469m^2
Treated Floor Area[3]:	54,799m^2
Delivered energy consumption:	215kWh/m^2/Annum
Weight of structural steel:	11,000 tonnes
Weight of steel decking in floors:	738 tonnes
Weight of concrete in foundations:	14,778 tonnes
Weight of concrete in basement / ground floor level:	12,940 tonnes
Weight of concrete in floors:	13,538 tonnes
Area of external curtain walling:	24,000m^2

Initial Embodied Energy[1]: Steel, Concrete, Aluminum and Glass

Figures above the bars in red refer to the number of years of equivalent primary operating energy for 30 St Mary Axe embodied within each building element.

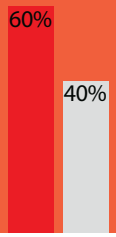




1. Initial embodied energy is the energy required to initially create the building and all its materials / components.
2. Cradle-to-gate refers to all the primary energy used until the product leaves the factory gate (e.g. excluding final transportation to site & construction).
3. Treated floor area is gross floor area less plant rooms and other ancillary areas (e.g. stores, covered car parking, and roof spaces) not directly heated. In this analysis treated floor area is estimated at 85% of gross floor area (BRECSU, 2000).
4. Primary energy is the energy embodied in natural resources (e.g. coal, crude oil, natural gas, uranium) that has not undergone any anthropogenic conversion.
5. 30 St Mary Axe is predicted by mechanical engineers Hilson Moran to use 215 kWh/m^2/Annum (Buchanan, 2007). This is assumed per unit treated floor area. Delivered electricty is assumed at 63% of the total, with delivered gas at 37% - the percentages outlined in a 'good practice' scenario for an 'air-conditioned prestige' office building in ECON19 (BRECSU, 2000).
6. The energy used by a 'good practice, air-conditioned, prestige' office building is 348 kWh/m^{2}treated floor area/Annum (BRECSU, 2000). See also (5)
7. Cradle-to-site refers to all the primary energy used until the product reaches the building site (e.g. excluding construction).
8. Concrete is assumed to be RC30 foundations, RC35 basement and R40 floor slabs. Reinforcement is assumed at 150Kg/m^3.
9. Assumes 31.7Kg glass/m^2 and 12.2Kg aluminum/m^2 of facade (figures courtesy of Harmon Inc / Viracon). Only includes the external double-glazed facade, not glazed inner screens. Excludes the energy required to fabricate the facade off-site.
10. Recurring embodied energy is the energy required to maintain, repair and refurbish the building over its effective life.
11. Office fit-out figures are taken from Cole & Kernan, 1996 and are equivalent to 0.17, 0.23 and 0.34 GJ/m^2/annum for basic grade, medium grade and top grade office fit-out respectively.

All embodied energy coefficients are taken from Hammond & Jones, 2008, unless otherwise noted.
Credit: Philip Oldfield, CTBUH Research Coordinator. A full list of references can be found at: http://embodiedenergy.ctbuh.org

The recurring embodied energy needed for typical 'top grade' office fit-out over the building's life is equivalent to almost a quarter of the lifetime primary operating energy requirements of 30 St Mary Axe



For R30 concrete with 150Kg of steel reinforcement per cubic meter, the steel reinforcement makes up approx 60% of the total embodied energy and 40% of the total embodied carbon.

Using 100% recycled steel in the structure and decking, and recycled aluminum in the façade, instead of virgin metals, would save 5.9GJ/m^{2}GFA, the equivalent of over four years primary operating energy for 30 St Mary Axe.