GREEN BUILDING RATING SYSTEM SCORES FOR BUILDING REUSE

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ABSTRACT

Green Building rating systems are the main vehicles for commercial application of ecologically sustainable design for buildings. Using less materials, modular design for deconstruction, long life structure, using recoverable materials are emerging concepts to reduce environmental impacts and increase the resource and economic efficiency of buildings. It has been argued that because of recent emergence of these concepts, Green Building rating systems do not fairly recognise the environmental benefits gained. This paper quantifies the impacts of the building reuse concept on the environment and the Green Building rating system scores and compares this with the energy category. It was found that lifecycle embodied greenhouse gas emission of approximately 20 kg $CO_{2\text{-}e}/m^2/$annum could be saved, if 80% of the office building components (structure, façade, wall, floor and roof) were reused in Australia. A second finding was that the current BREEAM 2008 and LEED 2009 tools do not provide fair recognition of the potential lifecycle embodied greenhouse gas emission reduction of building reuse compared to operational greenhouse gas emission reduction.

KEYWORDS

building reuse, embodied greenhouse gas emission, green building rating system

INTRODUCTION

In 2006–07 about 44 Mt of waste was generated in Australia. The most significant share, at 38%, of the waste came from the Construction and Demolition (C&D) waste stream (EPHC & DEWHA 2010). In Australia all solid wastes (municipal, commercial and industrial, and construction and demolition) is managed through recycling and landfill. Table 1 shows that approximately 45% of the C&D waste in Australia was disposed of to landfill in 2006–07, therefore, it can be assumed that less than 55% of C&D waste was recycled in this period.

This 55% recycling is much lower than that showed by Damptey *et al*. (2010). They showed for six building projects in Melbourne, Australia, whence priority was given to waste recycling, greater than 90% recycling rates were achieved.

The wastes hierarchy (Figure 1) is one of the main environment protection principles contained in the Environment Protection Act 1970 (Vic EPA 2011). It is an order of preference

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TABLE 1. C&D waste generation, recycling and disposal across the main states of Australia, 2006–07.

State/Territory	Generated (kt)	Recycled (kt)	Disposed (kt)	Landfill (%)
New South Wales	5 118	3 147	1 971	39
Victoria	4 086	2 947	1 139	28
Queensland	2 083	617	1 466	70
Western Australia	2 348	409	1 939	83
South Australia	1 460	1 155	305	21
Tasmania	249	229	20	8
Australian Capital Territory	251	0	251	100
Northern Territory	NA	NA	NA	NA
Total	15 595	8 504	7 091	45

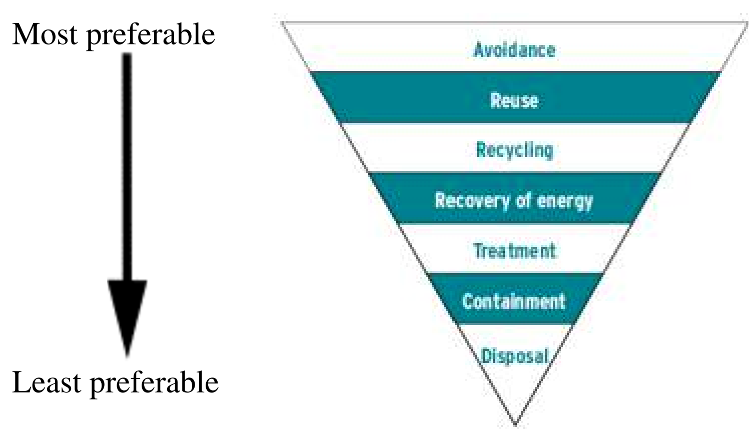
Source: Hyder Consulting 2008

of how waste should be managed. The most preferable approach is to *avoid* waste, followed by *reuse* and then *recycling*. Recycling is less preferable than reuse as it often requires process energy and potentially downgrades materials. Then the next option is the *recovery* of energy by composting or burning, with the least favoured options being treatment, containment and disposal in landfill. Yet as seen in Table 1, this least favoured option still makes up a large segment of the material stream in Australia. This is similar to other countries see for example US 40% (US EPA 2007), UK 75% (WRAP 2008) and EU 50% recycling of C&D waste (EEA 2010).

In terms of this paper, the most environmentally responsible approach or 'green building', other than not having buildings, is one that reuses as much as possible. That is encouraging building reuse over demolition through the equitable weighting of their benefit in the environmental ratings.

Several rating systems have been developed for targeting the commercial application of ecologically sustainable design to buildings. The major rating systems are Building Research Establishment Environmental Assessment Method (BREEAM) developed by UK Building Research Establishment (BRE Global Ltd 2010), Leadership in Energy and Environmental Design (LEED) developed by US Green Building Council (US GBC 2009), and Green Star environmental rating system developed by Green Building Council of Australia (GBCA 2008). They each use different methods and weighting systems for rating the environmental

FIGURE 1. Waste management hierarchy. (Source: EPA 2011)



performance of buildings. In general, all of them have some focus on construction and demolishing waste and recognise the benefits of avoidance, reuse, and recycling options.

There has been some criticism of the relative weightings given to building reuse (Appleby 2011, Lee *et al*. 2010), the preferred approach to the minimisation of waste to landfill. Appleby (2011) noted that in order to ensure all opportunities for reducing building construction and demolition waste are taken, the full list of waste groups in BREEAM needs to be reviewed. This paper contributes to this call by specifically looking at the reuse component and relating it in potential Carbon Dioxide (CO_2) saved per percentage contribution of the total rating tool score. That is asking: Out of a potential rating of 100%, what percentage is related to reuse compared to ongoing energy consumption and is this equitable to the potential benefit of the reuse? This is done by identifying the relative percentage contribution to the score within each tool and discussing this in relation to the potential CO_2 savings per point. This is outlined in detail below.

STUDY METHODOLOGY AND RESULTS

The relative contributions of reuse and operational energy and their relation back to annualised greenhouse gas saving was estimated using data reported in the literature based on the Life Cycle Energy Analysis (LCEA) method (Fay *et al*. 2000). The numerical percentage scores gained by the reuse aspect were compared with greenhouse gas emission performance scores. That is, this research took the energy savings per percentage point related to attaining 100% rating in the three tools and compared this to the equivalent embodied energy savings per percentage point for building components reuse to see if the relative weightings were appropriate or could be increased to support greater consideration of reuse.

Contributions of environmental categories across the rating tools

The largest contribution to the total score in BREEAM, LEED and Green Star rating systems is the energy and emissions category (see *Table 2*). That is the energy in the operation of the building. Rating systems for new buildings were selected because they can be purposely designed and built for the reuse.

TABLE 2. Category weighting (%) comparison for office new buildings.

	BREEAM[1] – UK	LEED[2] – USA	Green Star[3] – Vic, Australia
Establishment	1990	1993	2003
Management	12.0	0.0	9.0
Indoor environment quality	15.0	15.0	20.0
Energy & emissions	29.0	35.0	30.0
Transport	8.0	12.0	8.0
Water	6.0	10.0	15.0
Materials & waste	20.0	14.0	14.0
Land use & ecology	10.0	14.0	4.0
Subtotal weighting	100.0	100.0	100.0
Innovation	10.0	6.0	5.0
Regional priorities	0.0	4.0	0.0

[1] Source: BREEAM Offices 2008, Scheme document SD5055

[2] Source: LEED 2009 for new construction and major renovations

[3] Source: Technical Manual Green Star office design & office as built v3 2008

C&D relative contributions to the final score in the rating tools

Table 3 shows weightings of construction waste and materials saving strategies for the rating systems compared as a percentage of the potential. Each tool has slightly different terms and inclusions for what is considered under each category, which this paper has summarised under three headings in Table 3. The key focus of this paper is the reuse of the building components and this is a subset of the building and material reuse.

Greenhouse gas emission performance comparison over across the rating tools

Within the energy and emissions category outlined in Table 2, there is the detail of the specific operational energy scores. The scores awarded for greenhouse gas emission performance are shown in Table 4. These scores and their related values are needed to be able to compare the proportion of potential $CO_{2\text{-}e}$ saved in operation to that embodied in existing building components.

The number of BREEAM credits or scores achieved was determined by the building's CO_2 index taken from the Energy Performance Certificate (EPC). LEED applies energy cost saving compared with the baseline building performance rating (Column 4 in Table 4) as a criteria. On the other hand Green Star awards points where it is demonstrated that the building's predicted greenhouse gas emissions (GHGE) have been further reduced below the conditional requirement. To achieve the comparison the following assumptions needed to be made to translate a percentage score to kilograms of Carbon Dioxide equivalent per meter squared per year (kg $CO_{2\text{-}e}/m^2$/annum). This was done using the reference buildings that were provided for each of the tools:

- The reference building for BREEAM emits 93.4 kg $CO_{2\text{-}e}/m^2$/annum (Roderick *et al.* 2009).
- The baseline building for LEED emits 126 kg $CO_{2\text{-}e}/m^2$/annum (Roderick *et al.* 2009). Improvement on energy cost, which is directly proportionate to energy saving and greenhouse gas emission saving, is proportionate to energy saving for calculating LEED score.
- For Green Star no reference building was required as the tool also readily referred back to GHGE.

These factors (both for the Roderick *et al.* 2009 study and Green Star (GBCA 2008)) related well to the Australian context as shown by the range given in the National Australian Built Environment Rating System (NABERS) 5 stars office building emits between 60 and 172 kg $CO_{2\text{-}e}/m^2$/annum depending on the location of the building in Australia (NABERS 2011).

The information from Table 4 allowed the generation of Figure 2, which shows the comparison of the greenhouse gas emission performance scores between BREEAM, LEED

TABLE 3. Weighting (%) of reuse and recycling categories.

	BREEAM – UK	LEED – USA	Green Star – Vic, Aus
1. Construction waste management	4.0	2.0	4.0
2. Building and material reuse	2.0	5.0	6.4
– Reuse specifically	2.0	2.0	2.5
3. Recycling	1.0	2.0	3.8

TABLE 4. Scores awarded for greenhouse gas emission performance for new office buildings.

BREEAM			LEED			Green Star	
CO_2 index (EPC rating)	GHGE	Score (%)	Improvement on cost (%)	GHGE	Score (%)	GHGE	Score (%)
63	117.7	1	12	111.0	1	95	0.63
53	99.0	2	14	108.5	2	90	1.25
47	87.8	3	16	106.0	3	85	1.88
45	84.1	4	18	103.5	4	80	2.50
43	80.3	5	20	100.9	5	75	3.13
40	74.7	6	22	98.4	6	70	3.75
37	69.1	7	24	95.9	7	65	4.38
31	57.9	8	26	93.4	8	60	5.00
28	52.3	9	28	90.8	9	55	5.63
25	46.7	10	30	88.3	10	50	6.25
23	43.0	11	32	85.8	11	45	6.88
20	37.4	12	34	83.3	12	40	7.50
18	33.6	13	36	80.7	13	35	8.13
10	18.7	14	38	78.2	14	30	8.75
0	0.0	15	40	75.7	15	25	9.38
			42	73.2	16	20	10.00
			44	70.7	17	15	10.63
			46	68.1	18	10	11.25
			48	65.6	19	5	11.88
						0	12.50
GHGE = Greenhouse gas emissions (kg CO_2/m^2/annum)							

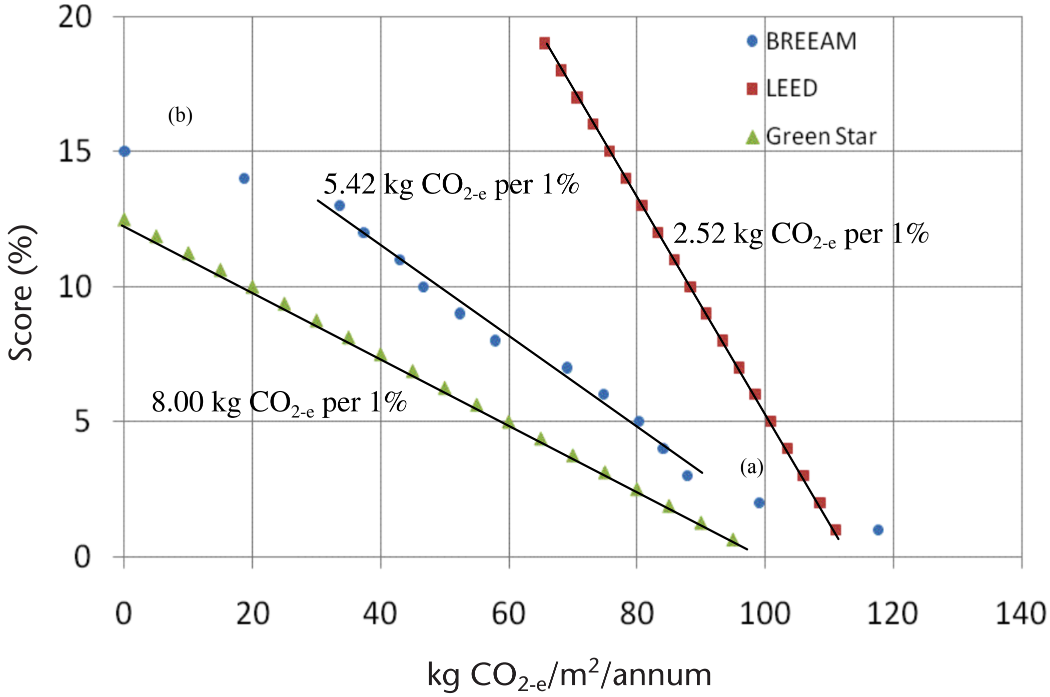
and Green Star rating systems. For BREEAM the midrange of the trendline was taken because it is designed to discourage small improvements (a in Figure 2), and it is more difficult to get the final improvements (b in Figure 2); while both LEED and Green Star have a consistent trend.

In can be seen from Figure 2 that for BREEAM a reduction of 5.42 kg $CO_{2\text{-}e}/m^2$/annum (mid range) is achieved per 1% score, while a reduction of 2.52 kg $CO_{2\text{-}e}/m^2$/annum and reduction of 8.00 kg $CO_{2\text{-}e}/m^2$/annum is required to gain 1% score for LEED and Green Star respectively.

Embodied Greenhouse gas emissions of buildings

Treloar (1993) and Tucker *et al*. (1993) reported that the embodied energy of office buildings in Australia to range from 8 000 MJ/m^2 to 9 000 MJ/m^2. To compare this to international figures, Cole and Kernan (1996) also reported that typical figures for initial embodied energy of office buildings ranging from 8 030 MJ/m^2 to 11 870 MJ/m^2 (for 8 to 31 stories office building made of different structural materials in different countries). The discrepancies are due to the type of construction and to the manufacturing practices and energy mix of a particular location or a country. Thus the figures reported by Treloar (1993) and Tucker *et al*. (1993)

FIGURE 2. Greenhouse gas emission performance scores compared.



are taken as representative and applicable for the purpose of the order of magnitude analysis which was done in this study.

By using the total greenhouse gas emission without land use, land use change and forestry in 2007 (Commonwealth of Australia 2010) and total primary energy input in 2006-07 (Commonwealth of Australia 2009) the weighted average greenhouse gas emission factor was estimated to be 0.088 kg $CO_{2\text{-}e}$/MJ of primary energy. It was assumed that this emission factor will not change significantly in the near future for Australia. Yet, it is expected that this energy intensity will be slightly lower in the more distant future, and this will slightly reduce the embodied greenhouse emissions but also energy use contribution. Based on these assumptions and the resulting numbers, the lifecycle embodied greenhouse gas emission for office buildings in Australia is estimated to range from 704 kg $CO_{2\text{-}e}/m^2$ to 794 kg $CO_{2\text{-}e}/m^2$.

To determine the typical lifespan of commercial building the work of Wilkinson *et al.* 2009 and JLL 2005 were looked at. The structure of commercial office buildings in Australia is typically designed to last 100 years; however the average service life of buildings in the Melbourne CBD is closer to 30 years.

To determine the percentage of potential building reuse the work of Crowther (2000) was looked at. Crowther (2000) reported that 50% to 88% of materials by weight recovered from residential building demolition in Melbourne. While the reuse percentages by weight of CBD office building demolition were 15% to 60%. It was found that the majority of materials and components from residential salvage were reused and the majority of materials from commercial salvage were recycled. Based on the residential figures, if office buildings are designed for reuse and disassembly, at least 80% of the materials is estimated to be reusable.

TABLE 5. Comparison of score.
(80% by mass reuse, greenhouse gas saving: 20 $CO_{2\text{-}e}/m^2$/annum)

	BREEAM – UK	LEED – USA	Green Star – Vic, Australia
Score gained for building reuse (%)	2.0	2.0	2.5
Greenhouse gas emission saving per 1% score (kg $CO_{2\text{-}e}/m^2$/annum)	5.4	2.5	8.0
Calculated equivalent score using lifecycle embodied greenhouse gas emission saving from reuse (%)	3.7	8.0	2.5

Comparison of the estimated contribution of building reuse to the contribution allocated by the rating tools

Thus using the above figures, if we assume a building life of 30 years and assume optimistically that 80% of the building is reused then: (80%*8000/30 = 213 & 80%*9000/30 = 240) 213 – 240 MJ/m^2 of embodied primary energy could be saved annually. The potential lifecycle embodied greenhouse gas saving of building reuse for the above case, calculated to kilograms of CO_2 would then be(213*0.088 = 19 & 240*0.088 = 21) 19 – 21 kg $CO_{2\text{-}e}/m^2$/annum. Taking the mid range of 20 kg $CO_{2\text{-}e}/m^2$/annum could then be used to assess the value of the rating tools weighting of building reuse. Table 5 compares the scores for building reuse and equivalent scores (last row) calculated back to the potential life cycle embodied greenhouse gas emission saving. For example, if the value per percent of the total BREEAM score is 5.4 kg $CO_{2\text{-}e}/m^2$/annum (Figure 2) and the potential value of building reuse is 20 kg $CO_{2\text{-}e}/m^2$/annum then the actual weighting for building reuse should be 3.7 not 2.

DISCUSSION AND CONCLUSIONS

This analysis shows that LEED (2009) has a heavy focus on operational energy cost saving compared to BREEAM (2008) and Green Star Offices V3 (2008). To achieve 1% score in LEED about 2.5 kg $CO_{2\text{-}e}/m^2$/annum reduction in greenhouse gas emission is required. About two times more of greenhouse gas emission reduction for BREEAM and about three times more of that for Green Star are required to achieve the same score as in LEED.

It should be noted that building reuse not only reduces the lifecycle embodied greenhouse gas emission but also reduces the other lifecycle negative impacts on the environment.

Followings are the findings from this study:

- Lifecycle embodied greenhouse gas emission of office buildings in Australia is estimated to be in the order of 750 kg $CO_{2\text{-}e}/m^2$ based on the embodied energy values reported by Treloar 1993 and Tucker *et al.* 1993.
- Lifecycle embodied greenhouse gas emission of about 20 kg $CO_{2\text{-}e}/m^2$/annum could be potentially saved, if 80% of the office building components (facade, structure, wall, floor and roof) were reused in Australia.
- Current BREEAM (2008) and LEED (2009) do not provide fair recognition of the potential lifecycle embodied greenhouse gas emission saving of building reuse compared to operational greenhouse gas emission saving. BREEAM underestimating the value of building component reuse by over 45% and LEED by 75%.

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