WHAT IS A "GREEN" BUILDING ACCORDING TO DIFFERENT ASSESSMENT TOOLS?

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Summary

Environmental assessment tools for buildings are rapidly developing in many countries. All of them claim that they measure "greenness" or "sustainability" of buildings, i.e. if maximum scores are awarded a building is sustainable in some respect. But so far there is no consensus on the interpretation of "green" or "sustainable" in terms of criteria and indicators.

This article explores if different tools point in different directions regarding "green" building design. It also investigates characteristics of assessment tools and consequences of different approaches.

Three distinctly different assessment tools, LEED-NC, Code for Sustainable Homes (CSH) and EcoEffect have been selected. They have three core assessment areas in common, namely Energy, Indoor Environment and Materials & Waste. The content however is different.

The tools have been compared with respect to aim, content and aggregation. They have been tested on a new multi storey residential building. Assessments within the core areas were compared. Measures to improve the overall judgement were explored. The diverging result raises the question how to design environmentally relevant and practically useful assessment tools for buildings.

1. Introduction

Building environmental assessment tools, have emerged to provide an objective evaluation of resource use, ecological loadings and indoor environmental quality (Cole, 2005). Much work has been done to develop a tool that predicts, calculates and estimates one or more environmental performance characteristics of a building (Sundkvist et al, 2006). These tools present different ways to define criteria for "green" building" They bring together a large number of environmental issues and aggregate them into overall judgments. What issues the tools address and give priority to indirect or direct might influence environmental building policies, design and building practices. Assessment methodologies play multiple roles; understanding the impact of buildings on natural systems, marketing "green" buildings, addressing sustainability (Cole, 2005), help decision makers and politicians, and being tools for environmental management primarily in architectural projects. What picture the tools mediate to their users influences "green" building designs. This may contribute to setting the agenda in a similar way as trade magazines and mass media (Gluch and Stenberg, 2006).

Environmental assessment tools consist of a number of indicators and criteria. Some also include life-cycle assessment (LCA) methodology (Assefa et al, 2007). Important for the outcome of the assessment are choice of indicators, measurement scales, aggregation and classification criteria. However the basis for these choices, which always are a balance between theoretical and practical aspects, is seldom presented in tool descriptions (Malmqvist, Glaumann, 2006). A lack of theoretic and systematic approach and a mix of different kinds of indicators make tool comparisons difficult as well as understanding what a final award means in terms of environmental impact.

2. Objective and delimitation

The objective with this paper is to compare different methodologies for environmental assessment of buildings and to explore in which direction they push new "green" building designs.

3. Methodology

Three completely different environmental assessments tools have been select to illustrate fundamental differences. These tools have been compared with respect to a limited number of aspects, namely; *aim, content* and *aggregation.* At last they have been applied on a new multi storey residential building to illustrate the differences between the tools.

The tools chosen for comparison are LEED®-NC, Leadership in Energy and Environmental Design for New Construction version 2.2, (USBC, 2005), Code for Sustainable Homes (DCLG, 2007) and EcoEffect (Assefa et al, 2007). The tools differ, in a number of ways, for example regarding where they are developed, for home they are developed, the methodology they use and the way they are used. The two first tools are internationally well-known and well documented. Besides being different EcoEffect is chosen because it is the one that we have the greatest experience from.

4. Method comparison

4.1 Different Aims

LEED is developed by U.S. Green Building Council (USGBC) committees with the aim to promote "green" design. It is argued that "Green design not only makes a positive impact on public health and the environment, it also reduces operating costs, enhances building and organizational marketability, potentially increases occupant productivity, and helps create a sustainable community" (USGBC, 2005). USGBC (2005) claims that LEED is "consensus-based, market-driven, based on accepted energy and environmental principles, balancing between established practices and emerging concepts."

Code for Sustainable Homes (CSH) is the first tool in the process of becoming a code (DCLG, 2008). It is a further development of the BRE's EcoHomes© scheme. "Adoption of the Code is intended to encourage continuous improvement in sustainable home building." The driving force behind establishing a code for sustainable building seems to be the wish of the British Government to act on climate change in combination with the fact that BRE (Building Research Establishment), has extensive experience with voluntary schemes in this field.

EcoEffect is an assessment tool developed by a group of researchers in Sweden. The task was to develop an holistic environmental evaluation method not a national classification system: The formulated objective was twofold: "1) to quantitatively describe environmental and health impact from real estate and the built environment 2) to provide a basis for comparison and decision making that can lead to reduced environmental impact. The method primarily target decision makers within the planning, designing and management of the built environment". (Sundkvist et al, 2006; Glaumann, Malmqvist, 2004)

LEED is voluntary and very market oriented. CHS involves the authorities and intends to integrate environmental assessment into the building code. EcoEffect is neither commercial as LEED, nor institutionalised as CSH. Focus is on methodology and understanding the significance of different types of environmental impacts.

4.2 Different content

All the tools have the areas Energy, Materials and Indoor Environment in common, but the content still vary a lot. Besides assessing issues related to these core areas LEED gives credits related to the issues: Water, Design Innovation and Site. CSH also specifically assess Water, Waste, Management and Ecology. EcoEffect includes Site assessment and calculation of Life Cycle Costs. The tools also measures issues differently. To be able to compare them we have ranged similar criteria and indicators under common areas (Table 1.). Only the issues within the core areas are presented in this paper.

4.2.1 Energy

About ¼ of the assessments in all the tools are devoted to energy. LEED (Table 1.) assesses energy performance, green power and management. CSH assesses CO_2 emissions for energy use and specific energy saving technical solutions. EcoEffect takes only the detrimental side of energy use into account assessing its associated negative emissions and depletion of resources. EcoEffect then uses a linear scale without a defined endpoint, which cannot be easily transferred to scores. Another difference between the tools is that CSH also assess the energy performance of white goods.

Table 1. Addressed issues and available scores or scale within the three areas; Energy, Indoor Environment and Material & Waste.

AREA		ASSESSED ISSUE	ASSESSMENT METHOD		
			LEED	CSH	EcoEffect
ENERGY	Energy use	Minimum Energy Performance	Mandatory		
		Optimize Energy Performance/ Energy cost savings	10		
	Kind of energy	On-Site Renewable Energy	3		
		Green Electrical Power	1		
		Resource depletion			Calculated
	Emissions	Low or Zero Carbon Technologies		2	
		Dwelling emission rate (CO_2)		15 /Mand.	
		Life cycle emissions from energy use			Calculated
	Technical solutions	Internal lighting		2	
		Drying space		1	
		Energy labelled white goods		2	
		External lighting		2	
		Home Office		1	
		Building fabric (Heat Loss Parameter)		2	
		Cycle storage		2	
	Management	Commissioning of the Building Energy Systems	1/ Mand		
		Measurement and verification	1		
		Available scores for this area	**16**	**29**	-
		Fraction of totally available scores	**23%**	**25%**	-
INDOOR ENVIRONMENT	Air quality	Air quality in general			0-3
		Minimum IAQ Performance	Mandatory		
		Environmental Tobacco Smoke (ETS) Control	Mandatory		
		Outdoor Air Delivery Monitoring	1		
		Increased Ventilation	1		
		Low-Emitting Materials	4		
		Radon			Assessed
	Thermal comfort	Design & Verification	2		
		Thermal Comfort in general			0-3
	Noise	Sound Insulation / Noise		4	0-3
	Daylight	Daylighting, views and sunlight	2	3	0-3
	Else	Electric environment			0-3
		Private space		1	
		Lifetime Homes		4	
		Legionaires diseas			Assessed
	Management & control	Construction IAQ Management Plan	2		
		Controllability of Systems, Lighting/Thermal comfort	2		
		Indoor Chemical & Pollutant Source Control	1		
		Home user guide		3	
		Available scores in this area	**15**	**15**	**0-15**
		Fraction of totally available scores	**22%**	**16%**	-
MATERIAL & WASTE	Recycling of materials	Building Reuse	3		
		Materials Reuse	2		
		Recycled Content	2		
	Household waste	Household Waste Storage & Collection of Recyclables	Mandatory	4 /Mand.	
		Composting		1	
	Construction waste	Site Waste Management		2 /Mand.	
		Construction Activity Pollution Prevention	Mandatory		
		Waste Management	2		
	Environmental Impacts	Environmental Impact of materials		15 /Mand.	
		Global Warming Potential - GWP of insulants		1	
		Emissions from material production			Calculated
		Resource depletions from mater. prod.			Calculated
		NOx emissions		3	
		Fundamental Refrigerant Management	Mandatory		
		Enhanced Refrigerant Management	1		
	Sourcing of materials	Certified Wood	1		
		Responsible sourcing of materials		9	
	Other	Regional Materials	2		
		Rapidly Renewable Materials	1		
		Available scores in this area	**14**	**35**	-
		Fraction of totally available scores	**20%**	**34%**	-

4.2.2 Indoor Environment

LEED covers Air Quality, Thermal Comfort, Daylight and Management of Indoor Air Quality but surprisingly not Noise. CSH addresses Noise, Daylight and the three features; Privacy, “Lifetime homes” and “Home user guide” measured in terms of accessibility, adaptability and information. EcoEffect assesses; Air Quality, Thermal Comfort, Noise, Solar Access and Daylight, Radon Legionella and Electric and Magnetic fields. EcoEffect has an inverted scale, i.e. high scores here mean risk for inconvenience.

4.2.3 Material and waste

LEED is very much focused on reuse and recycling. Typically credits are given for reuse and recycling without taking into account that the reduction of environmental impact vary with material, (for example between recovery of aluminium and wood). Other LEED issues are; Household Waste, Local Materials and Rapidly Renewable Materials.

CSH is concentrated to environmental impact from production of building materials and responsible sourcing but do also cover household waste. Material is about 1/3 of all assessed issues in CSH, compared to 1/5 in LEED. Concerning material EcoEffect evaluate negative environmental impacts from the production phase of used building materials. Reuse and recycling is rewarded by decreased emission, from processing, and material depletion.

Hazardous Substances is not addressed in LEED. In CSH and EcoEffect primarily toxic emissions from the materials and their production are covered by the LCA of the materials. Thus none of the tools assess the issue embedded hazardous substances. Even though hazardous substances are one of the most prominent sub-themes of “environmental impact” according to the building sector in Sweden (e.g. Swedish Environmental Advisory Council, 2000; The Ecocycle Council, 2007). The Swedish focus on hazardous substances has also been observed in other studies (e.g. Stenberg and Räisänen, 2004).

4.3 Differences in weighting and aggregation

All environmental assessment tools weight and aggregate results differently. According to Lee et al. (2002) weighting is the heart of all assessment schemes since it will dominate the final valuation of an assessed building. However, according to Grace K.C. Ding, (2008) there is at present neither a consensus-based approach nor a satisfactory method to guide the assignment of weightings. There are a number of techniques to set weights in a systematic way (Andresen, 1999).

Within LEED 69 points are available within 58 assessed issues organized in six assessment categories. Some indicator are of a *procedural nature***,** rewarding procedures and behaviour, like following a certain control plan, in contrast to *performance indicators*, which directly measure performance like amount of energy used for heating. Often there are optional ways to receive a point. Normally one point is available per issue except for two energy indicators, where more points can be gained (10 for “Optimization of Energy Performance” and 3 for “On Site Renewable Energy”, Table 1). This means that the points have the same “environmental” value and are tradable, with the exception of a few mandatory aspects. The awarded points are added and the total score tells which of four final rewards the building get (certified, silver, gold, platinum). The basis for assigning a certain number of points to an issue is not described. This aggregation system is simple and easily understood, but the environmental meaning of the final score is hazy (Humbert, 2007).

In CHS 104 credits can be awarded within 9 categories (Table 1). A total of 34 issues are assessed and the value of each issue varies between 1-15 credits (per issue), some mandatory while most tradable. Most assessed issues gives at maximum 1-4 credits, except the issues Dwelling Emission Rate and Environmental Impact of Materials, which can give up to 15 credits (Table 1). Each category has a weighting factor, which emanates from a survey among international “experts” and a consultation with industry representatives. Energy has a category weight of 1,26 while Materials only have 0, 33, which in reality says that the environmental value of energy scores are almost four times larger than those for materials. The sum of the credits results in a character represented by 1-6 stars. Since the aggregation is done by varying the credits per issue and by weighting the categories the meaning of the result is difficult to perceive. Special for CSH is that it evaluates dwellings and not buildings. A rating of a building is composed of the ratings for its dwellings. The final rating is achieved when the building has been erected and used to make sure that the performance complies with the intentions and the points received at the design stage.

The final rating in EcoEffect consists of results regarding external impacts and internal impacts. External impacts include energy and materials use. The basis is a life-cycle approach and equivalents for seven impact categories are calculated mainly using internationally well-known calculation algorithms. The external impact is measured per designed number of building users and divided by the corresponding value per capita in the country, i.e. in the end showing a percentage. This favours efficient space use, which is important from an environmental point of view (Wilson and Boehland, 2005). For each impact category weights have been established by estimating the potential harm the endpoint problems within each category might cause people. (Assefa et al, 2007). The assessment is based on the total amount of energy and materials used per resident or user.

Internal impacts cover indoor and outdoor problems on the property. Targets are categorized in 5 categories and assessed through risk assessment at the design stage considering 54 issues. The final assessment is completed at earliest one year after building completion. It is then based on a couple of measurements in the building along with a user questionnaire. A scale with four steps (0-3) is applied, punishing poor measurement results and discomfort. Originally there was an expert weighting system in three levels which is now being exchanged to disability/discomfort scale developed as an extension of the DALY (Disability Adjusted Life Years) system (Malmqvist, Glaumann, 2006).

EcoEffect is quite comprehensive and the aggregated values, although systematically applied, may be difficult to understand for a layman.

5. Case study

To illustrate differences in practical use and assessment result the three tools have been tested on a new residential building under construction, Gronskar, Stockholm, i.e. complete drawings and descriptions are available but no real performance data. No environmental assessment tools were used during the design. The results in the areas; Energy, Indoor environment and Material & Waste are presented. The EcoEffect results, which not are received in points or credits, are shown in relation to a reference building, built in 1990 in the same region. LEED and CSH scores are presented in relation to the maximum possible score.

> General information about the test building, GRONSKAR,
> *Gross area: 2893 m^2, 32 apartments, 8 storeys, Energy use for heating and hot water 80 kWh/m^2,yr. Energy supply: District heating and a heat pump on exhaust air.*
> *Structure: Prefabricated concrete elements with an insulation of polystyrene.*
> *Average U-value is 0,46 W/m^2,K, (window U-value is 1,3 W/m^2,K)*

5.1 Energy use

With LEED Gronskar receive 9 of 16 points on energy (i.e. corresponding to 56%). 6 of 10 available points are gained for energy optimization. Primarily due to the heat pump on exhaust air since the envelope is not exceptionally well insulated. No points are gained for on site renewable energy which corresponds to ~20% of the available points. Measures needed to gain all the 10 available points correspond to about 150m^2 solar collectors for 50% of the hot water or lowering the average U-value by ~20%, i.e. from 0,46 to 0, 37 W/m^{3}K. The first option also gives maximal points for renewables. Since LEED uses *cost indicators* for energy the solar collectors don't give any credits since they are more expensive than district heating for hot water. The option left is to lower the U-value, which would influence the construction of the building.

In CSH 16 credits are given out of 29 for energy, (i.e. corresponding to 55%). The CO_2 emissions per year are compared with emissions from a reference dwelling which has the same size, fixed U-values and is heated by gas. Gronskar uses 80 kWh/m^2,yr. while the reference building uses 146 kWh/m^2,yr mainly because it lacks the heat pump. Gronskar emits about twenty times less CO_2 compared to the reference building because district heating fed by bio fuel emits very little CO_2.

The remaining 3 points Gronskar gained for energy saving fittings and "home office" which implies certain space and support of electricity and telecommunication. More energy points are available for improved envelope, labelled white goods, drying space, bicycle storage etc. The last two and "home office" can be called *potential indicators* since they award possibilities to reduce the environmental impact, which may not happen. Energy saving technical solutions are credited at the same time as low overall energy use, which might lead to *double counting*, i.e. crediting both energy saving measures and overall energy use. Normally Gronskar could also receive two additional points for the heat pump which is considered as a low carbon energy technology. But in this case the heat pump gives no $CO_{2,}$ reduction according to our calculations, because the Swedish electricity mix emits much more CO_2 than the district heat. To improve the scores it would be better to exchange the heat pump with district heating and receiving more scores for low CO_2 emissions.

In EcoEffect, energy use is evaluated by measuring resource depletion and emissions influencing a number of effect categories. Although Gronskar uses 70% more electricity pr m^2 (the heat pump) than the reference building the overall energy use is 40% less than for the reference building which is also heated with district heating. The result is that the impact from emissions is only slightly larger for Gronskar. The largest impacts come from nutrification and radioactivity (nuclear waste from nuclear power). Contribution to nutrification origins to 70% from Swedish electricity mix and to 30% from the Stockholm district heating. Changing the heat pump here would only give a small reduction of environmental impact so the signal from EcoEffect is primarily to reduce the heat losses, i.e. improve insulation of the building envelop.

5.2 Indoor environment

Gronskar receives 12 out of 15 points (corresponding to 80%) in LEED, 6 credits out of 12 credits (corresponding to 71%) in CSH and is 30% better than reference values in EcoEffect, i.e. is good on indoor environment in all methods. The indoor indicators are different in all methods except from daylight, which still is calculated differently.

In LEED ventilation is the most dominant issue with 6 of the 15 points and two mandatory requirements: Air Quality in general and Minimum IAQ Performance. To receive a higher score Gronskar would have to meet the criteria for emissions from adhesives, sealants, paints and coatings. Low content of hazardous substances in building materials has been an important goal in the design, but emissions have not been measured. LEED is the only method, which uses indicators for management and control systems. Here Gronskar receives 4 out of 5 points because of the used management and control system. More documentation of specific measures and procedures would be needed to be able to gain the fifth point.

Air quality, ventilation and thermal comfort are not included in CSH. The tool uses a wider definition of sustainable building and includes social issues like “Private Space” and “Lifetime Home”. Lifetime Home contains a number of criteria, which all have to be met. Gronskar misses 4 lifetime home points because the buildings electric sockets are not placed at the right height. CSH also gives 3 credits for a “home user guide”, which is a specific document that is missing. Further more sound insulation is included in the assessment. To get the 4 available credits better sound insulation would be necessary.

EcoEffect addresses Air Quality, Ventilation, Thermal Comfort and Sound Environment. In EcoEffect Gronskar gets a rather high score in all these areas. The indoor environmental issues that are linked to comfort and health are included in the indoor environment area and Electric environment and Legionnaires disease are also included here. The scores for solar access and daylight are low because many dwellings face north. Directing balconies and some rooms in other directions would be needed to attain better scores.

5.3 Material and waste

Gronskar receives low scores in all the tools. In the category Material and Waste there was a wide variation in the type of indicators and criteria used. With LEED Gronskar received 4 out of 14 points (39%), with CSH it was estimated that it would receive 18 out of 35 credits (54%). The latest version of “Green Guide” and the Mat 1 and Mat 2 calculator tool, all necessary for the rating, were not available to other than approved CHS and BREEAM assessors.

With LEED the project doesn’t earn many credits because the lack of reused or recycled content. 7 points out of 14 can be gained in this category. There are also three mandatory criteria - Storage & Collection of Recyclables, Construction Activity Pollution Prevention and Fundamental Refrigerant Management. Using FSC, (Forest Stewardship Council) certified wood and local and rapidly renewable materials would also be needed to get the maximum scores.

The main targets in CSH are using materials with low environmental impact that are responsibly sourced.The low score with CSH primarily depends on the estimated high environmental impact from the used materials. The criteria for the indicator “Responsible Sourcing” was not met exactly as the method demanded EMS Certification and a third party control. Moreover the wood used was not FSC certified. For Household Waste Storage and Construction Waste Gronskar received high scores. The industrialized building processes applied minimize construction waste.

With EcoEffect the indicator for emissions from production of building materials was eight times higher than for the reference building and the indicator for resource use was twice as large as for the reference building. These high values are explained by the comparatively high use of concrete, steel and polystyrene, which demands a lot of energy for production and thus giving emissions. EcoEffect doesn’t assess means to recover household waste during operation as in LEED and CSH.

6. Concluding discussion

A “green” building according to LEED has a commissioned and cost optimized energy system and on site renewable energy. Low-emitting materials are used and management and control systems applied to secure a good indoor environment. Building materials are preferably reused, recycled and regional. Schemes for waste and pollution prevention are used.

CSH’s “green” building has low CO_2 emissions from energy use and specific technical solutions to reduce the households energy use. The walls and slabs are sound insulated and rooms daylit. The building is adopted for disabled and home office. Responsibly sourced building materials with low environmental impact are used and constructions and household waste is taken care of.

“Green” building according to EcoEffect has low energy use produced with low environmental impact. The indoor environment is designed to have good air quality, thermal comfort, daylight, sunlight and sound isolation and to prevent, electromagnetic fields, radon and legionnaires’ disease. Building materials with low environmental impact from production and transport are used and measures are taken for simplifying future recovery. The layout plan is designed for efficient use of space.

Further characteristics of the tools are summarised in Table 2. The differences in aim may influence the market penetration, Table 2. Official back up probably will become a strong incentive to use CHS for residential buildings, LEED is used by “green” forerunners and EcoEffect is mostly used for educational purposes. The dissemination is not a consequence of the content of the tools or their applicability but rather which forces push them into the market.

Table 2. Summary of significant characteristics of the tools

		LEED	CSH	EcoEffect
Aim	*Practical use*	Commercial tool	Policy tool	Analytical tool
	Environmental focus	Environmental sustainability	Climate change, (CO2)	Decreased emissions and depletion.
Content	*Energy*	Quantity and cost of energy use. Technical solutions	Quantity and quality of energy use. Technical solutions	Quantity and quality of energy use.
	Materials and waste	Quality and cost of materials use Recycling	Quality of materials used. Waste management	Quantity and quality of materials used
	Indoor environment	Air quality, Thermal comfort Daylight. Management	Noise, Daylight Management	Air quality, Noise, Daylight, Thermal comfort.,
Assessment & Aggregation	*Energy & materials*	Indicators, criteria	Indicators, criteria	Calculations
	Indoor environment	Indicators, criteria	Indicators, criteria	Indicators, criteria
	Within categories	Scores added	Scores added	Calculated equivalents for energy and materials, Indoor environment weighted
	Between categories	Scores added	Weighted	Weighted and added
	No of assessed issues	58	34	18
	No of final scores	1	1	2

The tools use different methods for measuring and different methodology for aggregating. For example regarding indoor environment both LEED and CSH awards good management for the building in operation while EcoEffect for this purpose relies on questionnaires. The basis for assigning scores for different issues and setting weights seems quite arbitrary in all three tools apart from the damage based weights in EcoEffect. The more issues involved in the weighting procedure the less influence is given to each indicator. A higher weight of one indicator means a lower of another. Finally, adding scores and weighting categories makes the meaning of the result difficult to understand. In this respect LEED, which is purely additive, is easier to understand.

The case study of Gronskar shows that the tools push the design of "green building" in different directions. CSH signals that the heat pump should be exchanged for district heating, since the tool concentrates on CO_2 emissions. Bicycle sheds and laundry lines and other technical solutions could be used to gain more scores for Energy in CSH. In LEED use of local and renewable energy sources are awarded, but since energy cost is decisive in this case solar collectors would probably mean too expensive scores. EcoEffect advocates better U-values and low emission fuels for heating, like the district heating in Stockholm. The huge quantity of concrete and expanded polystyrene insulation would have been avoided with EcoEffect and CSH. Applying LEED it would have been more important to use recycled concrete and insulation. Being a commercial tool may be the reason why LEED puts relatively more weight on the indoor environment and consequently might have produced a better indoor environment than CSH. EcoEffect would have influenced the architect to orientate the north facing balconies to a sunny direction. This exemplifies cultural and geographic differences between the places where the methods have been developed.

It is obvious that a technique encouraged by one tool is not always the best way to reduce environmental impacts according to another. A complete environmental assessment of a building ought to consider the whole life cycle, just like environmental assessments of products or services (Finnveden, 2000). The result of this comparison shows that the concept of "green building" is far from universal. The diverging result raises the question how to design environmentally relevant and practically useful assessment tools for buildings.

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