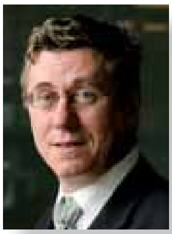
Life cycle assessment:

A question of getting the right BEAT?

Decision makers often assume that sustainable design is mainly about resource conservation - energy, water, and material resources. The last ten years, however, has seen a dramatic broadening of the definition of sustainability to include assurances for mobility and access - affected by land use and transportation, - health and productivity - affected by indoor environmental quality, and the protection of regional strengths [1]. This broader definition of sustainability is represented in the US by the LEED™ (Leadership in Energy and Environmental Design) standard of the US Green Building Council [1].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The Centre for Building Performance and Diagnostics at Carnegie Mellon University likes to expand this definition even further, to give greater emphasis to contextual and regional design goals, to natural conditioning, and to flexible infrastructures that support change and deconstruction [1].

The CBPD defines sustainable design as "*a transdisciplinary, collective design process driven to ensure that the built environment achieves greater levels of ecological balance in new and retrofit construction, towards the long term viability and humanization of architecture. Focusing on environmental context, sustainable design merges the natural, minimum resource conditioning solutions of the past (daylight, solar heat and natural ventilation) with the innovative technologies of the present, into an integrated "intelligent" system that supports individual control with expert negotiation for environmental quality and resource consciousness. Sustainable design rediscovers the social, environmental and technical values of pedestrian, mixed-use communities, fully using existing infrastructures, including "main streets" and small town planning principles, and recapturing indoor-outdoor relationships. Sustainable design avoids the further thinning out of land use, and the dislocated placement of buildings and functions caused by single use zoning. Sustainable design introduces benign, non-polluting materials and assemblies with lower embodied and operating energy requirements, and higher durability and recyclability. Finally, sustainable design offers architecture of long term value through 'forgiving' and modifiable building systems, through life-cycle instead of least-cost investments, and through timeless delight and craftsmanship*" [2].

The use of sustainable energy will soon be the major guiding principle for building and spatial planning practice. This asks for new sustainable energy infrastructures which need new design approaches. Design tools for the energy infrastructure of the built environment in the conceptual phase of design combined with multi-criteria decision making (MCDM) methods are presently lacking. Integral Design methodology is meant to help by providing methods to communicate the consequences of design steps on the building level for the energy infrastructure. In particular the use of Morphological Overviews, combined with the Kesselring method [3] as a decision support tool, will support the early conceptual steps within the design process and make decisions taken during the design process more transparent. The main object of this article is not so much to identify and exhaustively summarize all MCDM methods useful for assessment of sustainability, as to examine what parameters must be assessed when judging the merit of a decision making approach in connection with the design processes as part of life cycle assessment of buildings of the built environment. This leads to a way of thinking, by which energy consumption, pollution and waste can be reduced in existing and new constructions by a factor 4 and by which the quality of life within buildings is improved simultaneously [4].

There is a strong need for more efficient and more intelligent and green (sustainable) buildings. At present it is difficult to define the performance of buildings in terms of efficiency and sustainability in an objective way.

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GET THE RIGHT BEAT (BUILDING ENVIRONMENTAL ASSESSMENT TOOLS)

In November 2003 a project was started, in which students compared 15 Dutch and 15 German modern office buildings. As a result of this project, the six best Dutch and German buildings were compared more thorough with each other in November 2004, and it was examined to which extent the Dutch and the German buildings are sustainable [5]. Goal of this project was to examine and to understand differences between two different building rating systems approaches and to transfer the insights into the conceptual design phase of building design. This first examination was based on a method evaluating the intelligence of commercial offices on six principal aspects. The research was based on information provided by external parties. Where information needed for the appreciations was not available, the unknown aspects were valuated with a neutral score. The information from lectures, articles, internet, etc. might not always have been reliable, but was often the only source of information. The possible appreciations within each of the criteria were determined on basis of mutual deliberation among the project group. All of the appreciations are discussable, but all evaluations were done in a consistent way. The building scores gave an idea about the appreciation of the buildings but no absolute values. The consulting engineers with their own expertise mostly came from the country of the building itself. In most projects the consultants were involved in an early stage of the project.

The results of the analysis showed that what makes a good building is subject to multiple interpretations based on the different background, training and experiences of the people who answer the question about how good a building is. Still far more important the rating systems used for analysis are only making statements about the results of past design process. We should try to use them for design. To make this possible the evaluation criteria of the rating systems should be used during the design process. So the key to improvement lies in the connection of the rating systems with the design process itself. This 'integral design' approach contributes to an innovative building design process. In the present paper we analyze more in detail different rating systems.

Comparing seven Dutch buildings with buildings in Germany and England

As there are many building rating systems, with LEED and BREEAM being the most popular ones, we wanted to look into more detail in two alternative methods: Ecological Footprint and GreenCalc+. Important is of course also the right set of buildings by which we compare the different methods. In total fifteen buildings from the Netherlands (seven), Germany (six) and England (two) were selected for evaluation in the present research. The six best Dutch projects from the first research were taken and the WWF in Zeist (Netherlands) was added because it was designed as a sustainable building following the "one planet living" strategy. The WWF building has many renewable energy systems and many environmental friendly materials are used in the building. The three best German building from the first study were taken and three more German buildings were added from the EULEB (European high quality low Energy Buildings) project. In this EULEB project 25 buildings were analyzed throughout Europe [6]. From this collection also two excellent English buildings were selected. The selected buildings are located in Germany and in England because these countries have a climate similar to the Dutch one. With these fifteen buildings we looked into the sustainability assessment through Ecological Footprint and Greencalc+.

Ecological footprint

The Ecological footprint analysis compares human demand on nature with the biosphere's ability to regenerate resources and to provide services. It does this by assessing the biologically productive land and marine area required to produce the resources a population consumes and absorb the corresponding waste, using prevailing technology. This approach can also be applied to an activity such as the manufacturing of a product or driving of a car. This resource accounting is similar to life cycle analysis where in the consumption of energy, biomass (food, fibre), building material, water and other resources are converted into a normalized measure of land area called 'global hectares' (gha).

Per capita Ecological footprint (EF) is a mean of comparing consumption and lifestyles, and checking this against nature's ability to provide for this consumption. The tool can provide policy information by examining to what extent a nation uses more (or less) than is available within its territory or to what extent the nation's lifestyle would be acceptable worldwide. Ecological footprint is widely used around the globe as an indicator of environmental sustainability. It can be used to measure and manage the use of resources throughout the economy. It can be used to explore the sustainability of individual lifestyles, goods and services, organizations, industry sectors, neighbourhoods, cities, regions and nations. The footprint can also be a useful tool to educate people about carrying capacity and over-consumption, with the aim of altering personal behaviour. The Ecological footprint does not account for hazardous impacts of products such as the impact of dioxins released in the atmosphere, nor does it measure water usage against water availability.

The Office Ecological Footprint Calculator is a questionnaire that allows estimating how much land is needed to run and maintain an office. The input values for this program are divided in the following groups:

1. **Building and construction**: Floor area, number of storeys, ground area of the base of the building, area outside of the building, expected life of building in years and number of employees working in the building. Information is asked about any green design at building, (%) of recycled aggregate in concrete, (%) of extenders in concrete (fly ash or slag's), use of second hand building products (%), use of recycled materials (%).
2. **Energy & water**: How much electricity does the office use, is there any purchase of energy supplied from renewable sources, what is the use of natural gas and how much water is used each month?
3. **Food**: Estimate expenditure like catering and business lunches, beer, wine, spirits, milk, tea, coffee, sugar and biscuits.
4. **Travel**: How do people travel to

and from the office? By car on their own, car with others, bus, train, tram, light rail, motorcycle, scooter, walking and cycling? How many return trips are made at work? Does the office own or lease company vehicles? What are the total km/month travelled by people in the office? How many kilometres do staff travel by airplane for business?

5. **Consumable items**: Office paper consumption (imported or not), average recycled content of all office paper consumed, printed materials and publications produced, subscriptions to publications, number of computers, printer equipment and other stationary goods.
6. **Recycling**: What percentage of paper and other items used in the office is recycled or reused?

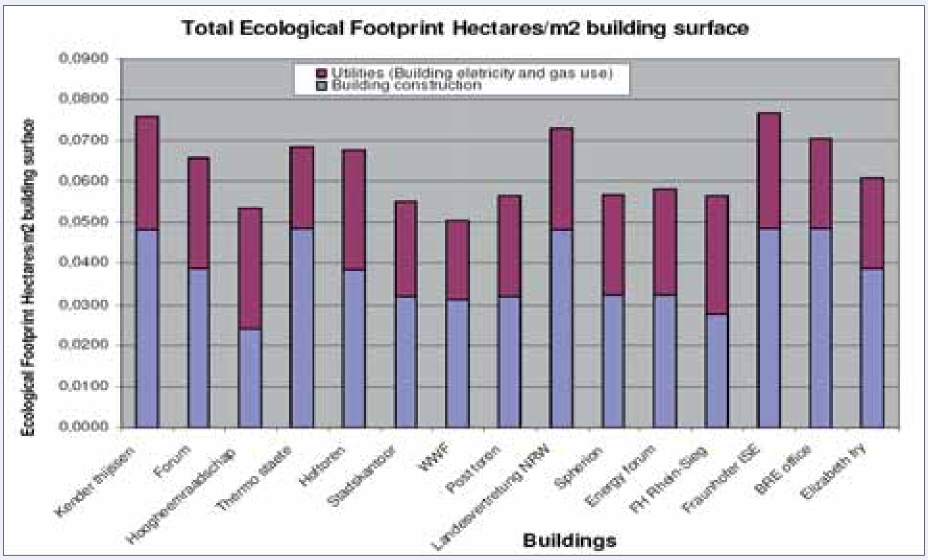
The influence on earth environment is analysed for each building using the six aspect groups that are mentioned before. The output values of Ecological footprint, the impact on earth's environment for each building, are given in figure 1 for the expected total life span of each building. Some input values are "building orientated" and other are "building organisation orientated". The scores are therefore separated into building construction and organisation oriented utilities. Figure 1 shows that there are buildings with a higher load on earth's environment than others. Looking closely at this overview the criterion "building constructions" has more influence on earth's environment than the subject "utilities". The results of figure 1 show that there is a large fluctuation between buildings per subject. This is probably caused by the main influence factor "life expectation of the building" for the aspect materials. This has a large impact on the load on earth's environment. Furthermore we see that the aspect Materials has a higher load on the earth's environment than energy. That looks strange because all LCA studies show that the energy has more impact than materials, especially on a biotic depletion. Still is not that strange if we remember that we look to a group of buildings with a very low energy consumption compared to normal buildings. The ecological footprint takes also biotic depletion into account that could be another part of explanation.

GreenCalc+

The development of GreenCalc started in 1997. After completion, the developers saw that one of its shortcomings was the inability to use the software for building types other than office buildings; this was the motivation to develop GreenCalc+, which suited also other building types, such as schools, health centres and stores, and urban development projects (Sureac Trust, 2008). The GreenCalc+ assessment method is a questionnaire that allows estimating how much land it takes to run and maintain a building. These data are used to calculate what the developers call the environmental index of the building. This is done by calculating the environmental impact of the buildings by Life Cycle Analysis (LCA). The development of GreenCalc+ is done by DGRM consultants and commissioned by the Sureac Trust. The GreenCalc+ software consists of four modules, each representing a different aspect of the building characteristics; mobility, materials, water and energy. The input values for this program [can be categorized into the following groups:

- **Materials**: Floor area, number of storeys, ground area of the base of the building, area outside of the building, expected life of building in years and number of employees working in the building, information about any green design, (%) of recycled aggregate in concrete, (%) of extenders in concrete, use of second hand building products (%), use of recycled materials (%).
- **Energy**: How much electricity does the office use, is there any purchase of energy supplied from renewable sources and what is the use of natural gas?
- **Water**: How much water is used per month?
- **Travel to and from work**: How do people travel to and from work, by car, public transportation, walking and cycling?

The results for Greencalc+ for the fifteen buildings are not given in this article and we restrict us here to a comparison between main aspect from Ecological footprint and Greencalc+. A more detailed comparison can be found later on in this article when seven buildings are compared using BREEAM, LEED, Greencalc+ and Ecological footprint.



Results of the Ecological footprint assessment.

- FIGURE 1 -

Comparing Ecological footprint and Greencalc+

The assessment methods Ecological footprint and Greencalc+ give similarly results for the aspect "expected life of the building". The longer the expected life of the building, the lower the load on earth's environment. There is only a large difference in both tools on the subject cooling. The total need for cooling is very high when calculated with Ecological footprint in comparison with GreenCalc+. Both methods show large differences in the respective shares of material and energy. Ecological footprint calculates

Hoogheemraadschap Leiden.
- Photo 1 -

Thermo-Staete Bodegraven.
- Photo 2 -

WWF Zeist.
- Photo 3 -

Spherion Düsseldorf.
- Photo 4 -

Energieforum Berlin.
- Photo 5 -

Cradle to cradle kantoor Amsterdam.
- Photo 6 -

XX kantoorgebouw Delft.
- Photo 7 -

the load on earth's environment from raw material until recycling with all needed equipment and transport. Greencalc+ looks only at the construction of materials on the building site and at transport to the site.
Employees who travel by cars or plane cause the most important part of the load on earth's environment. If more employees travel by public transportation, less global warming and human toxicity will be the result, according to Greencalc+. These results are similar for both programs. Still each assessment tool, Ecological footprint and GreenCalc+, has its own specific characteristics, which raises the question how both compare to the two most popular tools at the moment: BREEAM and LEED.

COMPARING BREEAM, LEED, GREENCALC+ AND ECOLOGICAL FOOTPRINT.

The first and second stages of the research were necessary to get a good understanding and experience of the evaluation of building performances. This also led to a selection of high performance buildings which could become leading examples in sustainable building design. This is of course an excellent group to test our final goal within this research: the comparison of 'green' building assessment tools such as BREEAM, LEED, Greencalc+ and Ecological footprint". It is necessary, when analyzing the tools, to use the same objects and aspects as a basis for comparison. We selected the five best buildings from our precedent study.
To look for sensibilities we added two buildings that were developed using specific sustainable design strategies: XX building in Delft (calculated life expectation twenty years) and the first Cradle-to Cradle office in Amsterdam. The buildings used for the comparison are:

- Hoogheemraadschap in Leiden (The Netherlands).
- Thermo-Staete in Bodegraven (The Netherlands).
- WWF in Zeist (The Netherlands).
- Spherion in Düsseldorf (Germany).
- Energy forum in Berlin (Germany).
- Cradle to cradle office in Amsterdam (The Netherlands).
- XX building in Delft (The Netherlands).

LEED

LEED was developed by the US Green Building Council (USGBC) for the US Department of Energy. The pilot version (LEED 1.0) for new construction was first launched at the USGBC Membership Summit in August 1998 [26]. In March 2000, LEED Version 2.0 based on modifications made during the pilot period was released. Since then, LEED continues to evolve to respond to the needs of the market and to expand to cover other building types. The most current LEED for New Construction Version 2.2 was released in November 2005.
Current versions for other building types, including schools, homes, etc. were either released in 2006 or scheduled to be released. So far LEED is one of the most recognized building environmental assessment schemes. LEED registered projects are in progress in 24 different countries, including Canada, Brazil, Mexico, India and China, and the World Green Building Council - an affiliation of seven national green building councils, including the US.
The results from the LEED assessment are given for all buildings and for each aspect in table 1. In LEED 2.2 a maximum of 69 credits can be earned. 26 points are needed to be certified, 33 points for a silver label, 39 for a gold label and 52 for a platinum label.

	Max. score	Hoogheem-raadschap	Thermo Staete	WNF	Spheri-on	Energy forum	XX	C-to-C office
Sustainable sites	14	10	10	12	11	11	12	12
Water efficiency	5	5	5	5	4	5	5	5
Energy & Atmosphere	17	11	14	15	11	14	11	13
Materials & Resources	13	7	10	10	9	10	12	12
Indoor Environmental Quality	15	14	14	14	14	14	14	14
Innovation & Design Process	5	5	5	5	4	5	5	5
Total	**69**	**52**	**58**	**61**	**53**	**59**	**59**	**61**

Complete results with the checklist of LEED.

- *Table 1* -

	Max. score	Hoogheem-raadschap	Thermo Staete	WNF	Spheri-on	Energy forum	XX	C-to-C office
Management	15,0	11,7	11,7	11,7	11,7	11,7	13,4	13,4
Health & wellbeing	15,0	11,5	12,7	12,7	11,5	11,5	11,5	10,4
Energy	13,6	12,9	12,9	12,9	12,9	12,9	12,9	12,9
Transport	11,4	6,1	6,1	7,6	7,6	7,6	6,1	6,1
Water	5,0	3,3	3,3	3,3	3,3	3,3	3,3	3,3
Materials	10,0	8,3	8,3	8,3	8,3	8,3	10,0	10,0
Land use & ecology	15,0	13,5	13,5	13,5	13,5	13,5	13,5	13,5
Pollutions	15,0	12,0	13,0	14,0	12,0	14,0	11,0	13,0
Total	**100,0**	**79,3**	**81,5**	**84,0**	**80,8**	**82,8**	**81,6**	**82,5**

Compete results with the checklist of Breeam.

- *Table 2* -

In the table 1 is shown that WWF and Cradle to cradle office have the highest score. These buildings are directly followed by the buildings "Energy forum" and Thermo-Staete . These buildings have a high score at the aspects "Energy & Atmosphere" and "Materials & Resources". All buildings can be marked as a "platinum" building, because all have the 52 credits or more, that are needed to get the Platinum label.

BREEAM

The first Building Research Establishment Environmental Assessment Method (BREEAM), launched and operated by the Building Research Establishment (BRE) in UK, came into prominence in 1990 [27]. It was also used as a basis for LEED. Version 1 of BREEAM for offices was first revised in 1993. The second revision was launched in September 1998. The current BREEAM version for non-domestic premises is BREEAM 2008. It covers a range of building types, including offices; industrial premises; eco-homes; courts; prisons; retail outlets; schools; multi-residential, etc. It is one of the best-known schemes and has embraced 15–20 % of the new office building market in the UK. BREEAM has also been taken as a reference model when similar schemes were developed in Canada, New Zealand, Norway, Singapore and Hong Kong. Results for all buildings in the program BREEAM are given in table 2. The labels are passing, good, very good or excellent. Table 2 shows that the WWF building has the highest score of all buildings. It has namely the highest score at each subject for the building evaluation, where other buildings have equal or lower score at all aspects. The checklist of BREEAM results that all buildings get the highest credit ("Excellent"). Each building has 75 credits or more.

BREEAM versus LEED

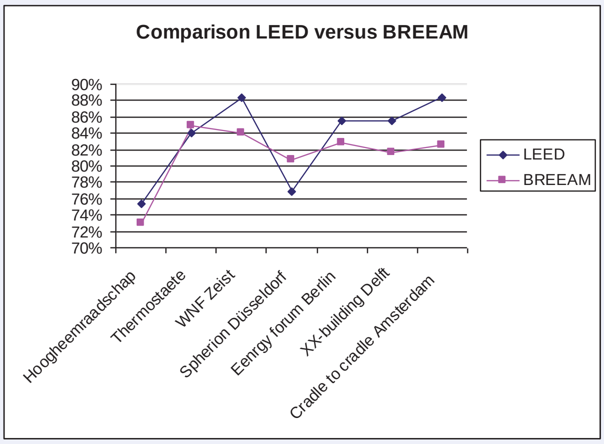
When looking into the results from LEED and BREEAM as a percentage of the maximum score we see similar results but there are also some differences, not only in absolute score but also in the resulting ranking of the buildings. However these differences are around 3 percent in a range from 1 % to maximal 5.5 %, see figure 2.

Comparison of all instruments

Many subjects are checked in LEED and BREEAM. But not all subjects can be used for to compare all instruments because Ecological footprint and Greencalc+ take only into account the aspects "materials, land use & ecology", "energy", "water" and "transport". All assessment methods are expressed in different values, namely:

- Global hectares for the program "ecological footprint".
- Earths environment costs (€) for Greencalc+.
- Credits for the checklists of LEED and BREAAM.

To fairly compare these assessment methods, we recalculated the scores of the buildings as a percentage of the maximum achievable in each category. This leads to a slightly higher score for some aspects than compared with table 1. The results are given in table 3. The results of the comparison on each specific aspect of the different



Comparison between the results of LEED and BREEAM.

- *Figure 2* -

assessment methods and buildings are given in the following sections.

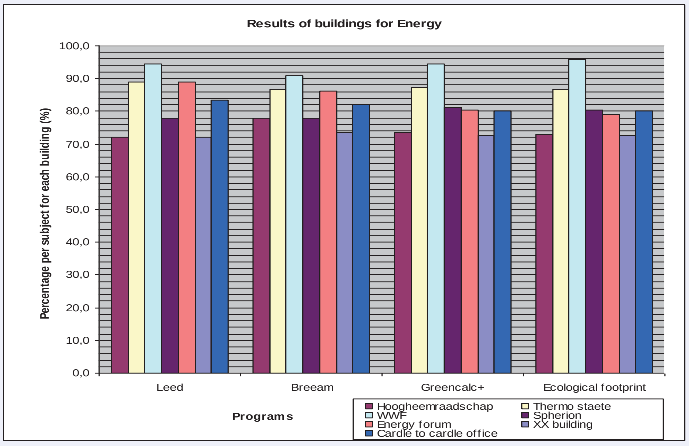
Energy
Figure 3 shows that the results for all instruments look similar. Despite the fact that LEED and BREEAM use credits in stead of real values (in kWh of kWhe) like Greencalc+ and Ecological footprint, only minor differences in energy reduction (score of percentages) are observed between the different tools.

Transport
Figure 4 shows that LEED and BREEAM show less variation than Greencalc+ and Ecological footprint. Only the building Thermo-Staete at LEED has no credit for "Alternative Transportation, parking Capacity" and has therefore a lower score. In BREAAM four have a lower score. This is namely caused by the amount of points for the subject "Transport) because both these tools do not look at the frequency use of transportation systems. This is probably why the results are different from the results with Greencalc+ and Ecological footprint. Greencalc+ has more variation between buildings than Ecological footprint. The effect of car use in Greencalc+ is the cause of these large fluctuations. The buildings WWF and Energy forum cause a high reduction of the load on earth's environment, because of the low car usage by employees of these buildings.

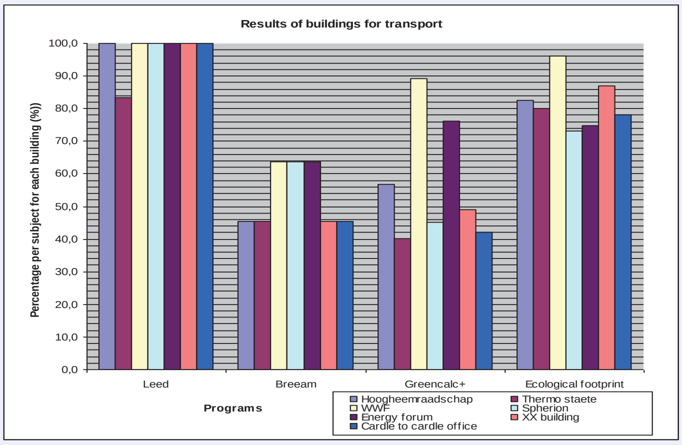
Water
Figure 5 shows that, for each instrument, there is little variation in the percentages of water used between all buildings. For Greencalc+ and Ecological footprint there are more variations, caused by the amount of water used. The buildings with low water use have only pantries. The other buildings have also cafeterias. BREEAM shows equal scores between all buildings because there is no difference in the amount of credits between one and another. For LEED one building is different, namely Spherion. This is because of less water use reduction measures in sanitary rooms. This gives a reduction of one credit to the maximum of five credits for the subject "Water".

	LEED	BREEAM	Green-calc+	Ecological footprint
Energy				
Hoogheemraadschap	72,2	77,8	73,5	72,9
Thermo staete	88,9	86,8	87,3	86,8
WWF	94,4	91,0	94,5	95,8
Spherion	77,8	77,8	81,1	80,3
Energy forum	88,9	86,1	80,4	79,1
XX building	72,2	73,6	72,7	72,7
Cradle to cradle office	83,3	82,0	80,0	80,0
Transport				
Hoogheemraadschap	100,0	45,5	56,7	82,6
Thermo staete	83,3	45,5	40,2	80,1
WWF	100,0	63,7	89,1	96,1
Spherion	100,0	63,7	45,3	73,1
Energy forum	100,0	63,7	76,1	74,7
XX building	100,0	45,5	49,0	87,0
Cradle to cradle office	100,0	45,5	42,0	78,1
Water				
Hoogheemraadschap	100,0	73,7	100,0	100,0
Thermo staete	100,0	73,7	80,0	80,0
WWF	100,0	73,7	80,0	80,0
Spherion	80,0	73,7	100,0	100,0
Energy forum	100,0	73,7	100,0	100,0
XX building	100,0	73,7	80,0	80,0
Cradle to cradle office	100,0	73,7	80,0	80,0
Materials, land use & ecology				
Hoogheemraadschap	55,6	87,7	95,0	85,9
Thermo staete	77,8	87,7	53,0	42,9
WWF	77,8	87,7	62,1	59,0
Spherion	72,2	87,7	73,4	64,5
Energy forum	77,8	87,7	73,1	64,5
XX building	88,9	94,4	78,0	95,4
Cradle to cradle office	88,9	94,4	83,0	95,4

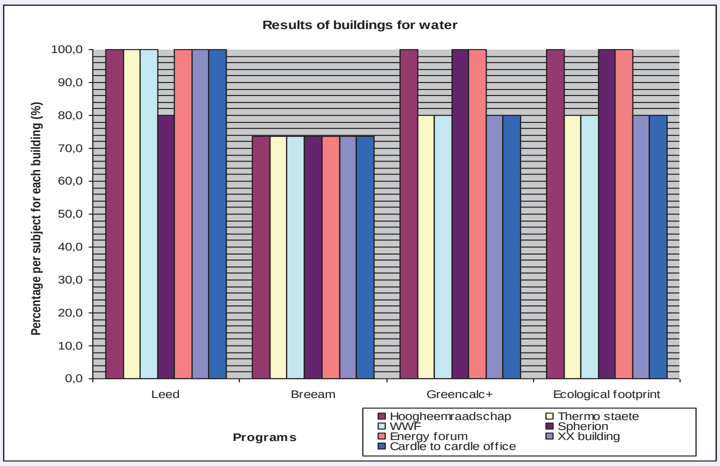
Results in percentages for all aspects from LEED BREEM, Greencalc+ and Ecological Foot Print.
- Table 3 -



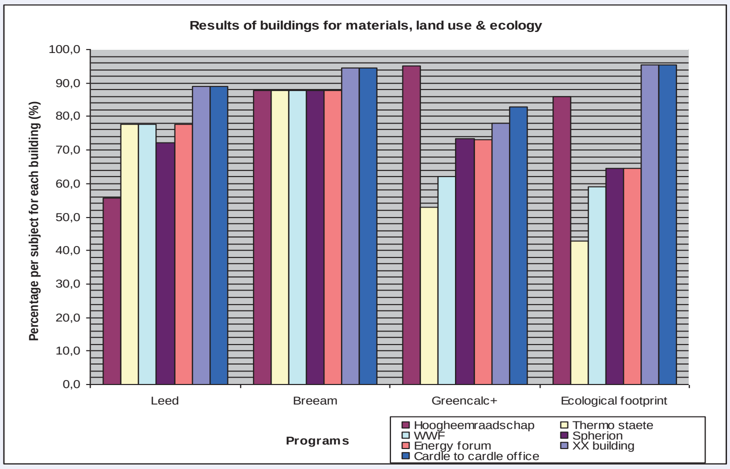
Results of all instruments for the aspect Energy.
- Figure 3 -



Results of all instruments for the subject "Transport.
- Figure 4 -



Results of all instruments for the subject "Water".
- FIGURE 5 -



Results of all instruments for the subject "Materials, land use and ecology".
- FIGURE 6 -

Materials, land use and ecology

Figure 6 shows that BREEAM has equal scores between most buildings, because it is not possible with this instrument to differentiate the measures applied. Therefore, there are almost no differences in the amount of credits between the buildings.
This is different from the results from LEED. Especially Hoogheemraadschap has a low score. This is because of the low score at the aspect "Materials". Other buildings give almost similar results.
The results for Greencalc+ and Ecological footprint look similar except for the buildings XX building and the Cradle to Cradle office. Use of recycled materials and use of second hand materials have a high positive effect, which results in less load on the earths environment and on reduced Ecological footprint. Greencalc+ does not incorporate these positive effects in its calculations.
The input of the expected life of the building causes the effect of differences in the results between Greencalc+ and Ecological footprint. This factor has a large influence on the load on earth's environment at the aspect Materials, land use and ecology. The score of Hoogheemraadschap is high because its expected life is 40 years. For example Thermo-Staete has a low score with its expected life of 20 years.
The percentage of energy in the total score for each building is almost similar in LEED and BREEAM. For the subjects transport and water, the percentage is higher in LEED than in BREEAM. This means that these subjects are more important for LEED than BREEAM. BREEAM finds the aspect Materials, land use and ecology, more important than LEED. But looking at the overall overview of these programs, they look similar. This is not strange because LEED is derived from BREEAM.
The results of the Greencalc+ assessment show that there is a large variation between buildings per subject. For instance the small buildings Thermo-Staete and WWF have the highest scores at the aspect Materials. But all building scores in this instrument are lower than in the other assessment tools.
In Greencalc+ the aspect Energy has a higher load on the earth's environment than materials. The large difference is probably caused by the fact that, for example, ecological footprint calculates the aspect materials from raw material till recycling with all needed equipment and transport. Greencalc+ looks only at the construction of materials on the building site and at transport to the site. The aspect transport has a large influence on the results. Ecological footprint shows similar results.

DISCUSSION

Maybe this is not the moment to discuss the true value of the different assessment tools, but it is necessary to know hat they are still under construction and have all some flaws. Still many people think that it is better to have something than nothing, while others say just let the market do its work and we will see what assessment tool will survive. However we have a different approach, but first let's look into some of the critiques and uncertainties related to the present assessment tools from literature.
Environmental building assessment methods contribute significantly to the understanding of the relationship between buildings and the environment [7]. However, the interaction between building construction and the environment is still largely unknown. The environmental building assessment methods all have limitations that may hamper their future usefulness and effectiveness in the context of assessing environmental performance of buildings as discussed below. [8]

Environmental building assessment methods are most useful during the design stage when any impairment for the pre-design criteria can be assessed and incorporated at design development. Environmental issues can be incorporated in the design process, which can minimise environmental damages. Even though these assessments are not originally designed to serve as design guidelines, it seems that they are increasingly being used as such ([8], [9], and [10])
The more effective way of achieving sustainability in a project is to consider and to incorporate environmental issues at a stage even before a design is conceptualised. It is important to separate project design and project assessment as building design takes place at an early stage and most of the outcomes of the design have already been established and incorporated into the final design. However, the assessment process is usually carried out when the design of the project is almost finalised ([10], [11]). Therefore, the use of environmental assessment methods as design guidelines cannot be sufficient. Consequently, in order for environmental building assessment methods to be useful as a design tool, they must be introduced as early as possible to allow for early collaboration between the design and assessment teams. They also need to be reconfigured so that they do

not rely on detailed design information before that has been generated by the designer ([8]).

Minimum certification, however, does not necessarily guarantee environmental improvements. Developers who purchase environmentally related products off a supplied checklist may produce a certified building, but the building's future impact on energy and resource use is unknown. The proposed revisions are the beginning of a transition toward buildings that earn their green marks based on performance rather than eco-marketing. The current LEED system allocates a maximum of 69 points for various environmental quality improvements. A building that receives 26 points is certified, and more points are necessary to receive the higher rankings of silver, gold, and platinum. While costly improvements such as solar panels are likely to boost a building's rankings, all categories are given equal weight, making some improvements less effective than others ([12]).

"LEED has been frequently criticized for not having a solid rationale for allocating credits," said Jerry Yudelson, a Tucson-based architect who teaches LEED-certification workshops. "The classic example is you get one point for putting in bicycle lockers and showers and one point for saving 7 percent of energy. Are those equivalent benefits?"([12])

"Regardless of the policy changes, some critics say a system like LEED does not do enough to improve the world's environmental woes.

Architect Jonathan Ochshorn, an associate professor at Cornell University, said LEED-certified buildings are anecdotal examples of improvements that ultimately serve a corporation's profit, not the environment. "LEED in general is a way for institutions and corporations to collect points from a public relations standpoint," Ochshorn said. "The world isn't getting any better because of LEED." "([12])

The organizations behind the assessment tools are of course not ignoring the critiques and as a result the green building standards are 'still' under construction [12]. Still a lot of good work is done, as can be concluded from this passage from Green Building, March 2009:"*LEED 2009 targets climate change impacts. The U.S. Green Building Council's Leadership in Energy and Environmental Design rating system is just completing its most exhaustive rewrite since LEED was launched a decade ago -and climate change figures prominently in this revision. LEED 2009, the technical rating portion of LEED Version 3 (LEED v3), will go from its current point system to a 100-point scale (plus 10 "bonus" points). LEED 2009 puts its greatest emphasis on Sustainable Sites (26 points) and Energy & Atmosphere (35 points).*

In earlier versions of LEED, Sustainable Sites accounted for 14 of 64 "base points" (not counting Innovation & Design Process), or less than 22 %; in LEED 2009, it represents 26 % of the 100 base points. E&A credits in LEED 2009 count for 35 % of base points, versus 27 % in previous versions. This was no arbitrary decision. The LEED Steering Committee, under chair Scot Horst and vice-chair Joel Ann Todd put LEED through a rigorous evaluation to determine the human and environmental impacts of LEED credits. This process, developed by the U.S. Environmental Protection Agency and known as TRACI (for "Tool for Reduction and Assessment of Chemical and Other Environmental Impacts"), enabled the LEED Steering Committee to rank "impact categories" - such as resource depletion, ecotoxicity, smog formation, indoor air quality, etc. - in terms of human and environmental considerations. From that exercise, the Steering Committee named climate change the number one TRACI impact category as far as LEED 2009 was concerned. Once that determination was made, the Steering Committee went through a "weighting" process developed by the National Institute of Standards & Technology which enabled the committee to put greater "weight" on those parts of LEED that could most readily impact climate change. This led to 61 % of the base points going to Sustainable Sites and Energy & Atmosphere. As for the 10 "bonus" points, up to six may be awarded for innovation and design. The other four will come from a list suggested by local USGBC chapters and alliances. In drought-stricken regions, for example, extra points might be given for water conservation. More information: www.usgbc.org/display-page. aspx?cmspageid=1849." [13]. To compensate for regional differences, the proposed standards grant local chapters "bonus points" that can be allocated toward design issues that would aid certification in that area. This seems a good way to give responsibility to local chapters of LEED - they're the ones who know the local issues - without jeopardizing the consistency of LEED overall. But several architects still consider the system lacking ([12]). "There is a tension between having a national system... and yet still allowing a lot of regional differences," said Yudelson, who chairs the USGBC's annual conference committee. "[A solution] is for LEED 2012... We're not ready to make that big of a leap." ([12])

"The changes in LEED are definite improvements, I think everyone is behind them, but we also need to improve the system," said Yudelson, a Tuscon-based architect who teaches LEED-certification workshops. ([12])

In Germany prof.dr.-ing Gerd Hauser of the Fraunhofer Institute and the Technical University of München also thinks that there is a real need for one clear methodology for the different kind of building types and the different stages of life phases of buildings. Therefore the SBAlliance was founded (a lot of European Stakeholders are member of these group, like BREEAM, LEED, DGNB(Deutsche Gesellschaft für Nachhaltiges Bauen), research centres, universities etc.) and their focus lies on developing one European approach within the seventh EU framework programme: the OPEN HOUSE project. OPEN HOUSE seeks to start with the need for transparency because true transparency at European Level has not yet been achieved in building sustainability assessment tools. There are many methodologies in the US and in the EU as mentioned before. However, there is little chance for stakeholders to look behind the scenes of these methodologies and to see the key assumptions on which they have been based upon. The calculation processes are not clear to the user. In this regard, it is not a problem of understanding, but one of lack of clarity - the instruments are "black boxes" - they give answers, but the method is not clear.

The overall objective of OPEN HOUSE is to develop and to implement a common European transparent assessment methodology for the planning and construction of sustainable buildings, complementing the existing ones or replacing them, by means of an open approach and a technical platform. The baseline will be existing

assessment methodologies for assessing building sustainability at international, European and national level. The most advanced and popular assessment methodologies like, DGNB (Deutsche Gütesiegel Nachhaltiges Bauen), BREEAM or LEED will have the main weight within the baseline.
The innovative and comprehensive methodology will be capable of combining and getting the interaction between the two market drivers of innovation appointed by the EC in the context of the Lead Market Initiative, which are as follows:

- The rational use of natural resources (energy, water and materials).
- The user's convenience and welfare (accessibility, indoor environment, health and security).

This is closely related with the latest news on BREEAM and LEED ([14]); *"BREEAM, LEED and Green Star are to collaborate in an effort to bring their environmental assessment rating tools into line The UK, US and Australian bodies will "map and develop common metrics to measure emissions of CO_2 equivalents from new homes and buildings". A working group will look at ways of achieving a better level of consistency in how and what the rating tools measure and how that information is reported. The agreement was signed at Could in London last month. The sustainability event also saw the launch of BREEAM In-Use, a scheme to help facilities managers reduce running costs and improve the environmental performance of buildings. It offers an online assessment tool and a third-party certification process. The scheme is in three parts:*

- *asset performance - inherent performance characteristics of the building based on its built form, construction and services;*
- *building management performance - policies, procedures and practices related to building operation; consumption of such resources as energy and water; environmental impacts such as carbon and waste generation; and*
- *organisational effectiveness - understanding/implementation of policies, procedures and practices; staff engagement; and delivery of key outputs."*

So clearly the world of sustainable assessment is on the move, but is it in the right direction? We looked around, thought about it and came up with a different approach.

A different approach from design to assessment

Synergy between design methods and assessment methods is necessary to really get tools for supporting decision making on sustainability issues in the conceptual phase of building design transparent and understandable.
Integral Design aims to support all the disciplines involved in the design process by structuring the process in steps and structuring the information flow about the tasks and decisions of other disciplines. Supplying explanation of this information will improve team members understanding about each other's tasks and results in combined efforts to further improve the design within the design process. In particular the use of the VDI 2225 method ([15]) as a decision support tool helps to structure the decision to be taken and make the decision process more transparent and understandable for all the designers from the different disciplines.

Design Methodology;

Evaluation and Decision making;
VDI 2225 decision support
In this section we describe a design method to focus especially on the decision phase of the design process: the VDI2225 with its Kesselring S-diagram.
Nowadays design is conducted more and more in multi disciplinary design teams with a wish towards integrating all aspects of t life cycle of a design. This makes design a complicated messy process ([16]). Designers are faced with numerous competing requirements and constraints. Achieving environmental goals makes the task more difficult for designers because for most consumers, energy efficiency and recyclability are less important product attributes. This means that designers cannot compromise other product attributes in becoming green ([16]). There is a need for a new integral design approach.
This makes decision-making even more complex. Most of the choices in the design process are made by intuition and according to simplified decision rules, which is necessary and inevitable [17]. This makes it almost impossible for the different design team members to understand the implicit argumentation of the decisions. Therefore there is a need for formalized discursive methods to structure the decision process and make the process transparent ([18]). This would make it easier to share the information and argumentation on which decisions are made within the team. The most important methods to date are Cost-Benefit Analysis and the combined technical and economical evaluation technique specified in Guideline VDI 2225, which essentially originates from Kesselring [19]. Kesselring developed a visualization technique, with which different variants can be compared with each other. Guideline VDI 2225 (1977) suggests a s-diagram (strength diagram) with the functional rating (all aspects related to the use of the building) as the abscissa and the realization rating (all aspects related to the building itself) as the ordinate ([19]). To visualize the scores, the criteria of the program of requirements are separated in groups with relating requirements. The first group of criteria has to do with the functionality of the design and the other group of criteria with the realization. Each group of criteria is evaluated and added to the total score of each group of criteria. These criteria are normally derived from the program of requirements, the design brief, but could also be derived from the different assessment tools criteria. The total score of the functional and realization criteria is expressed as a percentage of the maximum score to gain. In the diagram the percentage of the criteria for functionality is set out on the y-axis and the percentage of the criteria for realization on the x-axis. The best variants lie near the diagonal and have high scores. In the VDI 2225 s- diagram it is easy to see if the improvements must take place in the functional or on the realization side. Such diagrams are particularly useful in the appraisal of variants, because they show effects of design decisions very clearly ([19]).

Multi-criteria decision-making

Multi-criteria decision-making (MCDM) is a generic term for the use of methods that help people make decisions according to their preferences, in cases characterized by multiple conflicting criteria [20]. MCDM methods deal with the process of making decisions in the presence of multiple objectives. In most of the cases, different groups of decision-makers are involved in the process. Each group brings along different criteria and points of view, which must be resolved within a framework of understanding and mutual compromise [21]. MCDM techniques have two major purposes [22]:

- to describe trade-offs among different objectives;
- to help participants in the planning process define and articulate their values, apply them rationally and consistently, and document the results.

The object is to inspire confidence in the soundness of the decision without being unnecessarily difficult.
At present, MCDA is not that often used for building design [20]. A more common approach is to apply Cost-Benefit Analysis to a problem. The main principle in Cost-Benefit Analysis is that the performance values for the various criteria are translated into monetary values using commonly agreed-upon conversion factors. The favourable attribute values are summed together as the benefits of the alternative, while the sum of the unfavourable attributes constitutes the cost. The most desirable alternative is the one with the highest net benefit (benefits minus costs) [20].Pahl et al. (2006) [19] describe the similarities and difference between Cost-Benefit Analysis and Guideline VDI 2225. The Cost-Benefit Analysis has individual steps which are more highly differentiated and more clear-cut but involve more work than those of Guideline VDI 2225. Guideline VDI 2225 is more suitable when there are relatively few and roughly equivalent evaluations criteria, which is frequently the case during the conceptual phase of the design process. Guideline VDI 2225 is also more suitable for the evaluation of certain form of design areas during the embodiment phase of the design process.
Especially the focus is on decision making within the design process and how to support this, so that the decisions about fulfilling 'green' aspects in the design are made transparent for all shareholders within the design process. The integral design approach presents an outline that can be used to support sustainable decision making in multi-stakeholders contexts and would give stakeholders a holistic view that they otherwise may not have [23].
Whether using VDI 2225 or MCDA, the criteria to evaluate a design alternative with a decision support tools should relate strongly to the aspects differentiated in the rating system chosen. The BEATs (Building Environmental Assesssment Tools) evaluate different aspects which partly can be integrated in the selecting tools within the integral design methodology.

CONCLUSION AND FURTHER RESEARCH

Integral Design is proposed as a theoretical basis for design of the building, its building services systems and its energy infrastructure. We think that the proposed Integral Design is a support for Multi Criteria Decision Making in conceptual design. In addition to the direct design process support by Integral Design, it will be possible to supply information about the sustainability of building service applications at a much earlier stage in the design process. And, since this stage precedes the points where most decision-making takes place, these possible sustainable energy applications will have a much better chance of actually being implemented.
The best methods to support the decision step in the conceptual design phase of the building design process are the Guideline VDI 2225 and the Cost-Benefit Analysis. Both methods have the possibility to use the criteria of sustainability assessment rating systems for the evaluation of different design concepts. So aspects of the different rating systems can be chosen for incorporation within the design process and support the decision making during the design process itself.
Quality can only be determined by a multi-criteria, multi-disciplinary performance evaluation, which comprises a sum of several satisfaction/behaviour functions [24]. Synergy between sustainable energy sources, end-user comfort demand and the building energy demand is the ultimate goal. The TU/e (Technische Universiteit Eindhoven) together with Kropman, Installect and ECN (Energy research Centre Netherlands) work on research for user based preference indoor climate control technology. Central in this approach is the user focus of the integral building design process which makes it possible to integrate sustainable energy more easily in the energy infrastructure and reduce energy consumption by tuning demand and supply of the energy needed to fulfil the comfort demand of the occupants building. Taking the user as starting point for a new flexible sustainable energy infrastructure is being defined by using Integral Design methodology; Flex(ible)(en)ergy.

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