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# What is a green building?

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What is a green building? A large amount of definitions and green rating tools prove that an exact definition is still a point of discussion. To research the differences between green rating tools, four different buildings are assessed with: EPN, BREEAM, LEED, GreenCalc+ and EcoQuantum. These tools are national and international commonly used to assess (green) buildings.
A residential-, office-, sports- and school building are assessed. Each of these buildings consisted of a general and a green variant. The general variant represents the current state. And in the green variant measures are taken to make the building more energy efficient and sustainable.
The assessments show large differences between the evaluation results. The same building does not fulfil the requirements of a green building according to one tool, while another tool rates the building very “green”. The improvement between the general and green variant also show large differences. Based on the same input values, the office building is only 12% improved according to EPN and 45% according to LEED.
The differences are mainly caused by the environmental aspects taken into account. EPN considers only the energy performance. GreenCalc+ takes also material and water aspects into account, while LEED and BREEAM assess an even larger amount of building aspects. Even if the type and amount of building aspects correspond, differentiation in appreciation of these aspects causes other end results.

Keywords: green rating tool, sustainability

## 1. INTRODUCTION

Nowadays we cannot read a newspaper without being overwhelmed with information on sustainability and our environment. One report after another appears with new details on our common future. The main message ‘that we need to take appropriate action to save our planet’, is slowly penetrating our daily live.

In the built environment green buildings are becoming trendy among designers, engineers and property developers. Renewable energy sources and re-used materials are being used as signboards for companies all over the world to show their employers and the public they care about the environment.

In spite of this increased attention, the definition of a green building is still a point of discussion. A quick search on the internet shows twelve different explanations for a green building. And at least the same amount of green rating tools. The objectives of these rating tools differ from computing the energy consumption to an assessment of

all possible building aspects. Will a building have the same green rating when assessed with all these different tools?

In a Master project executed at the Eindhoven Technical University [1,2,3,4] we tried to answer this question. In this Master project five different green rating tools are used in four case studies to explore the differences among them. This paper discusses the results of this research project.

## 2. RESEARCH METHODOLOGY

### 2.1 Green rating tools

Out of all available green rating tools, the following five national and international commonly used tools are chosen:

- EPN (Dutch Energy Performance Standard) [7,8,9,10];
- BREEAM (Building Research Establishment Environmental Assessment Method) [11];
- LEED (Leadership in Energy and Environmental Design) [12];
- GreenCalc+ [13];
- EcoQuantum VO-tool [14].

The differences between these tools are researched in a literature study. Next, the rating tools are used in four different case studies. Each case study evaluated one building type with four different green rating tools. In these studies a residential-, office-, sports- and school building is evaluated. Every building type consisted of a general and green variant. The first mentioned variant considers the current state of the building. In the other variant, energy-low and sustainable measures are applied to make it a more green building.

Most of the green rating tools have separate versions per building type. Because LEED does not have a version for office- and sports buildings, LEED-NC (New Constructions) is used. In the sports building case study the BREEAM-industrial building version is used. Table 1 shows the versions of the rating tools used in the case studies.

**Table I**: green rating tool versions used in this research

| Case study | Rating tool versions |
|---|---|
| Residential | EPW v2.02 |
| | BREEAM-Ecohomes |
| | LEED-for homes |
| | EcoQuantum VO-tool |
| Office | EPU v2.02 |
| | BREEAM-Office |
| | LEED- NC v2.2 |
| | GreenCalc+ v2.1.0 |
| Sports | EPU v2.02 |
| | BREEAM- Industrial buildings2008 |
| | LEED-NC v2.2 |
| | GreenCalc+ v2.1.0 |
| School | EPU v2.02 |
| | BREEAM-school |
| | LEED-school |
| | EcoQuantum VO-tool |

### 2.2 Case studies

The residential building, named 'Fellowtel', is build in 1998 and consists of 115 dwellings. The building has a good thermal insulation and a heat recovery ventilation system. For heating and domestic hot water a high efficiency boiler is used.

The green variant has even better thermal insulation, sun-blinds and a decreased glass ratio. The heating and domestic hot water system is substituted by a heat pump. On the roof 100 $m^2$ of photovoltaic panels and solar collectors is installed.

The faculty building of Architecture, Building and Planning (figure 1) is used for the office building case study. The building, build in 1965, is thoroughly renovated in 2002. The construction consists mainly of glass provided with a screen print. A heat recovery ventilation system is applied and the building is connected to the campus district heating and cooling system (heat pump).

In the green variant only recycled materials are used for the building. On the roof 3.800 $m^2$ of photovoltaic panels are installed. The amount of parking spaces for disabled persons, car-poolers and environment friendly cars is increased.

**Figure 1**: faculty building of Architecture, Building and Planning

The University sports complex is used in the sports building case study. The complex is build in 1967 and renovated and expanded several times. Nowadays the building is four storeys high and has a total area of 9.200 $m^2$. Two large boilers generate domestic hot water. The building is mainly heated and ventilated through air heating. The water and air heating of the swimming pool is connected to the campus district system (heat pump).

In the green variant the whole building is connected to the campus district system. The showers have water-saving showerheads and the artificial lighting is replaced with more efficient lighting. To improve the indoor climate, the ventilation rate is increased. Renewable energy is generated with 4.000 $m^2$ of photovoltaic panels on the roof.

The university Auditorium (figure 2) is used in the school building case study. This building is build in 1966 and, after a fire in 1992, rebuild in 1996. The building consists mainly of un-insulated concrete constructions. The Auditorium is connected to the campus district system for heating and cooling. Domestic hot water is generated with a higher efficiency boiler and a heat recovery ventilation system is installed.

In the green variant the façades are insulated to save energy. The ventilation rate and heat recovery efficiency are increased. The artificial lighting is made more efficient.

**Figure 2**: the university Auditorium

## 3. RESULTS

### 3.1 Assessment general & green variant

Table 2 shows the score per rating tool for both the general and green variant of the residential building. In brackets the score compared to the minimal requirements is shown. The general variant fulfils the certificate requirements for EPN, BREEAM and LEED. In EcoQuantum an average new build dwelling scores between 150 and 175 point. With 86 points, the residential building can be considered twice as green.

The green variant of the residential building has better results according to all rating tools.

**Table 2**: rating results residential building

| Tool | general | green |
|---|---|---|
| EPN | 0,78 (+2,5%) | 0,53 (+34%) |
| BREEAM | 48% (+33%) | 55% (+53%) |
| LEED | 72 (+60%) | 89 (+98%) |
| EQ | 86 | 89,5 |

The results for the office building (table 3) show that none of the requirements are fulfilled. In BREEAM enough credits are gathered, but not all of the required criteria are met. Therefore the building cannot be certified.

The green variant scores a lot better. According to LEED and BREEAM this variant has enough credits for a certificate. In GreenCalc+ the minimum required level (2007) is with just a few points not achieved. And in EPN a couple of extra measures are needed to make the building green enough.

**Table 3**: rating results office building

| Tool | general | green |
|---|---|---|
| EPN | 2,01 (-34%) | 1,77 (-16%) |
| BREEAM | 36% (+20%) | 47% (+57%) |
| LEED | 22 (-15%) | 32 (+23%) |
| GC+ | 154; label E (-6%) | 158; label E (-3%) |

Table 4 shows the results for the sports building. According to EPN and LEED the sports building is not green enough for the minimum requirements. In BREEAM enough points are gathered, but the design does not fulfil the required criteria items. Because a good reference building was missing in GreenCalc+, the hidden environmental costs are given. Therefore a comparison to minimum requirements is not possible.

The green variant fulfils the minimal requirements of EPN and BREEAM. For a LEED certificate only three credits are missing.

**Table 4**: rating results sports building

| Tool | general | green |
|---|---|---|
| EPN | 1,76 (-76%) | 0,89 (+11%) |
| BREEAM | 32% (+7%) | 41% (+37%) |
| LEED | 18 (-31%) | 23 (-12%) |
| GC+ | 104.303,- | 63.686,- |

The results for the school building (table 5) shows that the design does not meet the requirements of EPN and LEED. According to BREEAM the building is green enough for a certificate. In EcoQuantum only comparison to an average dwelling is possible. With more than 200 points the school building scores worse.

The evaluation of the green variant shows enough credits are gathered for an EPN and BREEAM certificate. In LEED just a few credits are missing to get certified. The EcoQuantum score is improved with 39 points (18%).

**Table 5**: rating results school building

| Tool | general | green |
|---|---|---|
| EPN | 1,184 (-18%) | 0,864 (+14%) |
| BREEAM | 34% (+13%) | 37% (+23%) |
| LEED | 25 (-14%) | 27 (-7%) |
| EQ | 252 | 213 |

3.2 Comparing general & green variant

The results of the general and green variant assessments are compared per building type. Because the calculations made with EPN, BREEAM and LEED have the most available data, only these rating tools will be discussed.

The general and green variant of the residential building show a more sustainable result varying between 15% (BREEAM) and 32% (EPN). The office building case study shows even a larger spread of improvement: 12% (EPN) up to 45% (LEED). The sports building shows the largest average improvement between the general and green variant. The green variant scores from 28% (LEED and BREEAM) up to 49% (EPN) better. The school building shows the smallest improvements: from 8% (BREEAM) up to 27% (EPN).

Figure 3 shows the results for the general and green variant per building type compared to the minimal requirements (red dotted line). When the result is less than 100%, the requirements of the rating tool are not achieved.

## 4. DISCUSSION

4.1 General variants

Notable is that a building is green according to one rating tool and not green according to another. In this research all building types have enough points to get BREEAM certified. In some BREEAM versions certain criteria are required. This means having enough points will not automatically mean getting certified. The EPN tool seems to have the most severe assessment.

The results also show large differences in sustainability. The residential building just fulfils the minimal requirements of EPN while according to LEED the building scores 1,5 times better as required. The sports building will have to be twice as energy efficient to comply with the EPN standard, while LEED only requires a 30% better result.

**Figure 3a**: Results residential building

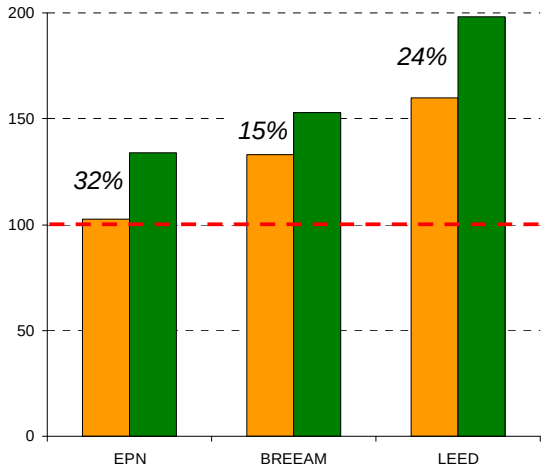



**Figure 3b**: Results office building

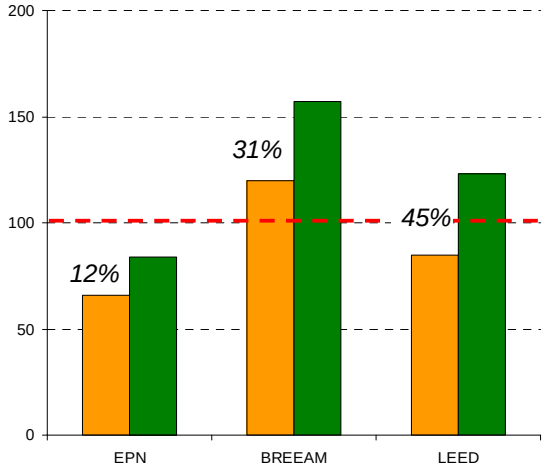



**Figure 3c**: Results sports building

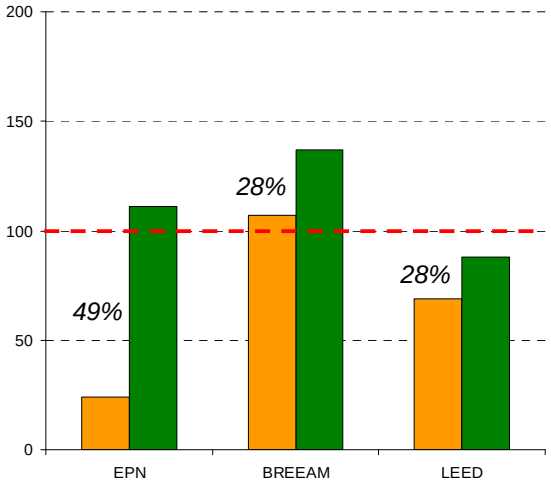
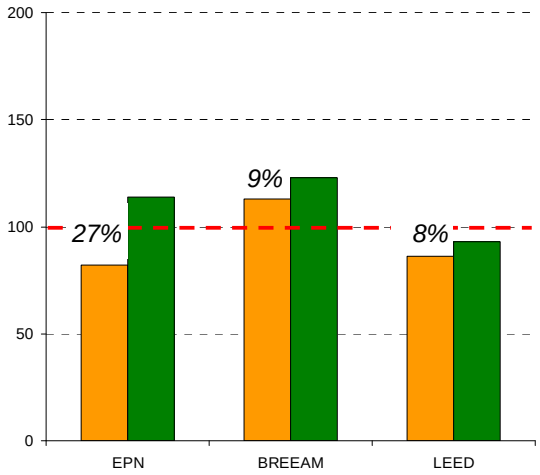


**Figure 3d**: Results school building




4.2 Green Variants

The green variants also show large differences between the results of the used rating tools. The office building is green according to BREEAM and LEED, but not according to EPN. On the other hand, the sports building fulfils the minimal requirements of EPN (and BREEAM) but not LEED. All the green variants can get a BREEAM certificate, this also account for EPN except for the office building. LEED seems to be the most strict rating tool for the green variants.

The assessments show differences in the sustainability of the building types. The residential building scores twice as much as required according LEED and only 1,3 times better according to EPN.

4.3 General vs. green

The improvements of the green variants compared to the general variants differ per building type and rating tool. The difference between general and green variant does not show an unequivocal trend. In some case studies the building is the greenest according to LEED while in other according to BREEAM. This can be explained by the diverse building types and/or different rating tool versions. And also the difference in energy efficient and sustainable measures applied in the green variants. This will be explained in more detail in the following text.

4.3.1 Residential building

In the green variant of the residential building mainly energy saving measures are taken. This explains why EPN has the largest improvement. LEED, BREEAM and EcoQuantum consider more environmental aspects which results in smaller improvements. Notable is the large difference between the results in BREEAM and LEED. Because LEED is based on BREEAM you would expect results of the same order of magnitude. This difference is caused by the rating of the photovoltaic panels and solar collectors. These techniques are appreciated much higher by LEED than BREEAM.

4.3.2 Office building

In the green variant of the office building measures are taken to improve the energy, material and mobility performance. The improvement according to EPN is much smaller compared to BREEAM and LEED. This is probably caused by the amount of environmental items taken into account. EPN is only focussed on energy and therefore not able to appreciate the other measures. In GreenCalc+ the improvement is only 3% while besides energy also material use is accounted for. The improvement for energy is made undone by the environmental load of the photovoltaic panels. Possibly negative or positive effects caused by combinations of measures influence the total score in GreenCalc+. In contrast to LEED and BREEAM, where the end result is an enumeration of measures.

4.3.3 Sports building

In the green variant of the sports building are, besides energy saving measures, also other environmental aspects improved. When the entire sports complex is connected to the campus district heat pump, the energy savings are so large, the EPN improves with almost 50%. The rating tools LEED and

BREEAM evaluate besides energy performance also other aspects. These tools appreciate the district heat pump less than the EPN, causing an improvement of only 28%. GreenCalc+ uses for the energy performance evaluation the EPN standard. Therefore a comparable improvement is expected. This improvement appears to be even better, caused by higher credits for water management.

4.3.4 School building

In the green variant of the school building mainly energy saving measures are taken. This explains the larger improvement of the EPN rating. Because LEED and BREEAM consider also other environmental aspects, the energy improvement is less appreciated.

## 5. CONCLUSION

The largest disadvantage of all these different green rating tools is that the same building is evaluated 'green' with some tools and 'not green' with other tools. Which one of these rating tools evaluates your building the best? The rating tools are among themselves difficult to compare because they consider and value other environmental aspects.

Except the rating tools LEED and BREEAM. These tools consider mainly the same environmental aspects. Nevertheless, the results of the case studies show (large) differences in their evaluations. While LEED is based on BREEAM, some criteria are valuated differently. This could be caused by the type of buildings and locations, being America and Great Brittan, for which these tools are developed. For instance, in LEED credits are awarded for ventilation rates that do not even fulfil the building regulations in Great Brittan. Every country defines its own important criteria, which will be rationally awarded with more credits.

In the sports building case study all of the rating tools except EPN did not have a special version for this type of building. The best fitting versions are chosen in this research project. Other versions of the rating tools could have given different results. The same accounts for EcoQuantum. This rating tool is initially used for dwellings and therefore less appropriate for a school building.

The EPN only considers the energy performance and is therefore less appropriate to evaluate the sustainability. GreenCalc+ shows that the eventual improvement can be disappointing. You would expect a green building when applying photovoltaic panels and solar collectors. But these techniques cause a severe environmental load because of the intense production process which requests a lot of energy and exhaustion of raw materials. The possibly negative and positive effects of combinations of measures influence the total score in GreenCalc+. In contrast to LEED and BREEAM, where the final result is determined by the sum of measures.

The required criteria in LEED and in some cases also BREEAM, are seen as an advantage. When a building design has gathered enough credits for a certificate, but does not fulfil these required criteria, the building cannot be certified. This offers opportunities to guide energy saving and sustainability in building without having to make building regulations out of it.

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