# ENVIRONMENTAL ASSESSMENT OF REAL ESTATES – WHERE NATURAL AND SOCIAL SCIENCES MEET: THE CASE OF ECOEFFECT

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## Summary

The EcoEffect method of assessing external and internal impacts of real estates is briefly described.

The external impacts of manufacturing and transport of the building materials, the generation of power and heat consumed during the operation phase are assessed using life cycle methodology. Emissions and waste; natural resource depletion and toxic substances in building materials are accounted for. Here methodologies from natural sciences are employed.

The internal impacts involve the assessment of the risk for discomfort and ill-being due to features and properties of both the indoor environment and outdoor environment within the boundary of the real estates. This risk is calculated based on data and information from questionnaires; measurements and inspection where methodologies mainly from social sciences are used.

Lifecycle costs covering investment and utilities costs as well as maintenance costs summed up over the life length of the building are also calculated.

The result presentation offers extensive layers of diagrams and data tables ranging from an aggregated diagram of *Environmental Efficiency* to quantitative *Indicators* of different aspects and factors. *Environmental Efficiency* provides a relative measure of the internal quality of a real estate in relation to its external impact vis-à-vis its performance relative to other real estates.

## 1. Background

Since some decades ago, there has been a concern for resource depletion and environmental pollution associated with real estates and surrounding infrastructures. In addressing such impact of the built environment, there is a recognition of the existence of alternative building materials, fuels for energy supply, source for water supply and options for wastewater waste handling and disposal. Nevertheless, for long time, the choice between such alternatives was dictated by factors such as differences in prices and aesthetic values.

A new important dimension in discriminating between different options is the environmental dimension. This aspect is important since buildings are not only one of the spatially big new additions to the natural environment but also they consume a lot of materials and energy during their long lifetime.

The building sector's energy consumption is significantly high.

According to UNEP's Sustainable building and construction (2003):

In OECD countries, the building and construction sector (including production and transport of building materials) consumes 25-40% of all energy used (as much as 50% in some countries). The utilities associated with the buildings represent a significant impact of the sector. The International Energy Agency estimates that, on average, one-third of energy end-use in the developed world goes for heating, cooling, lighting, appliances and general services in non-industrial (i.e. residential, commercial and public) buildings. Construction is believed to consume around half of all the resources humans take from nature. Besides, the built environment accounts for some 40% of world greenhouse gas emissions.

To give a full picture of the concern associated with real estates, the comfort aspect of building spaces should be combined with the demand for lower environmental impacts of the buildings on the immediate and remote environment, within and outside the used space. Comfort includes subtle components of wellbeing and indoor health concerns.

There is a need for tools focusing on assessment of the performance of buildings and generating valuable information that can be used by the actors in the building sector to produce real estates with habitable indoor environment and low environmental impact.

## 2. Assessment tools

During the last decade the building sector has witnessed the development of two types of environmental assessment tools.

The first group of these tools includes those, which purely are based on criteria system. The second group includes those tools that use life cycle assessment (LCA) methodology. The criteria-based tools have a system of assigning point values to a selected number of parameters on a scale ranging between "small" and "large" environmental impact. Among the criteria-based tools are BREEAM (Great Britain) - BREAM (2005); GBTool (Canada) - IISBE (2005); LEED (US)-USGBC (2005); EcoProfile (Norway)- Byggforsk (2005) and Environmental Status (Sweden) -Miljöstatusföreningen (2005).

Most of the LCA-based environmental assessment tools are used as in the selection of design options of the buildings and building material during the design phase. The advantage here is the ability to calculate the consequences of specific combinations of building materials, building designs and local utility options (energy supply, waste management and transport type).

Examples of tools of this second category that contain LCA component are: Bees (USA)-OAE (2004), Beat (Denmark)-DBRI (2005); Envest (UK)-BRE (2005); Athena (Canada) - ATHENA (2005); EcoQuantum (Netherlands) - IVAM (2005); Team (France) - Ecobilan (2004); Equer (France) -Center for Energy Studies (2005); and KCL Eco (Finland)- KCL (2005).

Almost all of these tools do not include indoor environment. There is thus a need for developing a method and tool that combines indoor and outdoor environment with the external environment.

## 3. EcoEffect

The EcoEffect method is an LCA-based tool for assessment of both internal and external environment of a real estate. It is useful in the assessment of existing buildings as well as buildings at design phase. The tool can be employed for two purposes. It is applied for environmental declaration where the focus is external communication and for environmental management where internal goals and measures for improvement are set and followed up by real estate companies etc.

The total system under assessment, including the object of study namely the real estate is referred to as the "environment". It is classified into internal environment defined by the jurisdictional boundary of the property and external environment covering everything else from local to global environment. The following sections will discuss the internal environment and the external environment and then the weighting between different categories.

## 4. The internal environment

The internal environmental impact defines the risk that people within the boundary of the building property (indoor and outdoor) will be affected or disturbed due to "surrounding conditions". "Surrounding condition" includes hard conditions such as the physical features of the building or and soft conditions such as vicinity to a source of nuisance.

The indoor part of the internal environmental impact is divided into two major categories namely discomfort and ill-being. Discomfort is about one-time nuisance from sources such as noise or draft. Experience of the problem associated with the sources cease once the affected people move away from the source or once the source disappears. Ill-being, on other hand, implies a prolonged effect on people's health even after a one-time exposure to the source e.g. allergy and arthritis.

There results from assessment of the indoor environment impact are presented in terms of health problems (both discomfort and ill-being) and internal environmental factors. The factors reflect controllable surrounding conditions that affect people e.g. indoor thermal climate.

The outdoor environment is part of the internal environment covering all parts of the real estate excluding the indoor part. It refers to the physical conditions on the ground that belong to the real estate - car parks, playgrounds, water surfaces, paths, resting areas - with benches with focus on its microclimate and biodiversity.

The internal impact categories in terms of health effects and environmental factors that are included in EcoEffect are shown below.

Table 1. Health effects, indoor and outdoor environment factors in EcoEffect

| Health effects | Environmental factors (Indoor) | Environmental factors (Outdoor) |
|---|---|---|
| Allergy | Air quality | Air pollutants |
| Arthritis | Thermal comfort | Electromagnetic field |
| SBS (Sick Building Syndrome) | Noise | Noise |
| Noise-driven sleeping difficulty | Day light | Shade |
| | Electromagnetic field | Wind |
| | | Biodiversity |
| | | Biological production |
| | | Storm water |

Besides, radon (indoor/measurement), warm water temperature (indoor/measurement), electromagnetic field (indoor and outdoor/measurement), PCB (outdoor/sampling) are measured and presented for the real estates. Each one of the aforementioned categories depends on a number of factors and parameters that make up a problem hierarchy. A real estate is assessed using parametric “load values”. Aggregation of the parameters is done using weights resulting in a weighted load value per category. For further description of the work on indoor environment refer Hult (1999, 2000). For full account of the work on outdoor environment refer Westerberg et al (2005).

## 5. The external environment

The external environmental impact assessment is carried out in terms of both emissions/waste and depletion of natural resources.

### 5.1 The emission problem

The contribution of each unit of emitted pollutant to different types of environmental problems expressed in terms of environmental impact categories is calculated. For a given real estate, an external environmental impact load value for each impact category is calculated according to the procedure in figure 1. This is due to the emission and waste related to the energy and material use of the real estate during its life time, normally 50 years.

Impact categories covered in the current version of EcoEffect are climate change, eutrophication, acidification, stratospheric ozone depletion, ground-level ozone, human toxicity and ecotoxicity. These are associated to emissions to air and water. Another group of solid waste includes: radiation from radioactive material, building and demolition waste, hazardous waste as well as slag and ashes.

The final result of the procedure shown in figure 1 is the weighted external environmental load value for a certain impact category. In reality the magnitude of the impact expressed in terms of each end-problem within the impact category depends, among other things, on where the emissions occur. In the presence of knowledge about the probability of occurrence of the impact caused by the emissions, a reduction factor with a value less 1 can be used. In the absence of such knowledge and in line with the precautionary principle, a reduction factor of 1 is used in the current version of EcoEffect. This implies that all the emitted substances are assumed to give rise to an environmental impact.

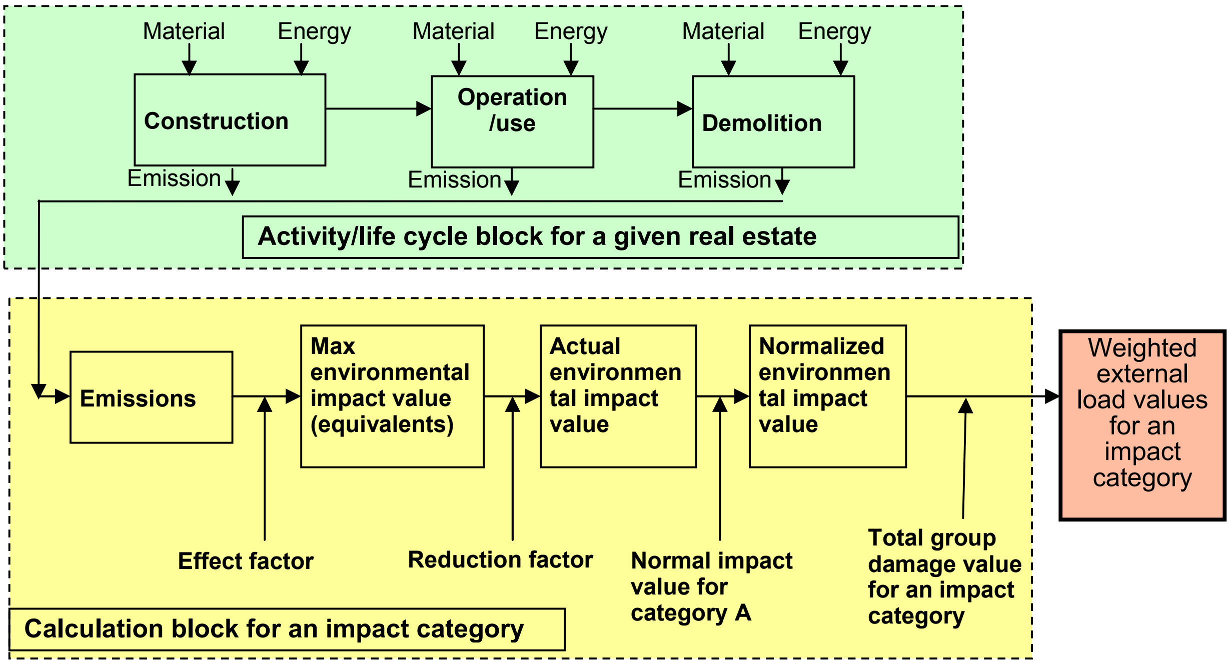


*Figure 1 The calculation steps of the weighted external impact load value for a given impact category*

Normalisation is done in order to make the environmental load values dimensionless through which weighted comparison becomes simplified.

### 5.2 Depletion of natural resources

The extent to which reduced availability of natural resources poses a problem to future generations depends on several factors such as rate of depletion, resource substitutability, resource recyclability, and regeneration time for renewable resources.

Different types of natural resources are grouped in the form of depletion categories. A relative value of depletion weight for aggregating the categories will be developed based on damage values as in the case of the emission and waste impact categories. This will simplify the aggregation of resource depletion with the rest of the external environmental impacts. The depletion categories considered in EcoEffect with corresponding references in brackets are metals (copper), fuel (oil), minerals (sand), and organic resources (wood).

## 6. Weighting

The damage value in terms of group damage value and personal damage value is the basis for the calculation of weights in both the external and internal environmental impact parts of EcoEffect.

In the case of external impact, the damage value describes the severity of a given damage/nuisance (also called end-problem), if it occurs, to the group of people considered to be exposed to the damage. It is, thus, called a group damage value. The sum of group damage values of all end-problems within a certain impact category results in the total group damage value for that category.

In the case of internal impact, damage value refers to individual's exposure to a given damage/nuisance. One of the major components in both the individual damage value and the group damage value is the description of how people's way of life is limited by different types of disabilities using the concept of DALY (Disability Adjusted Life Years) (Murray and Lopez, 1996). The difference in the calculation basis is that in the case of the external impact, data on the number of people affected within a certain area and under a certain time is required.

For each end-problem, a group damage value that reflects its relative significance in comparison with other problems is calculated. The total group damage value of each impact category can be multiplied with the corresponding environmental load value resulting in weighted environmental load values.

The DALY value, sum of YLD (Years Lived with Disability) and YLL (Years of Life Lost), plays a vital role in the calculation of damage values. The whole methodology of EcoEffect depends on retrieving DALY values for different end-problems. The range of end-problems includes from widely known diseases to subtle and milder nuisances of discomfort. A procedure for calculating the disability weight (dw), which is basis for calculating DALY values, is developed. This approach is based on a health descriptive system called European Quality of Life indicator or EuroQol (EQ-5D+) (Brooks, 1996).

In the external impact assessment part, for those end-problems where YLD values are not easily available, it is done by proxy using different types of economic loss as a basis. The types of loses include predictable actual economic loss (e.g. 10% reduction on the economy), those resulting in potential economic loss (reduced value of real estate on a beach due to noise disturbance) and those resulting in indirect economic loss (e.g. reduced recreation values due to impact on a forest or eutrophication).

For further description of the work on weighting refer Eriksson et al (2005).

### 7. Lifecycle costing and toxic chemicals

The real estates can also be compared based on their lifecycle costs. This covers investment and utilities and services (power, heating, water, wastewater and cleaning) as well as maintenance costs summed up over the life length of the building. Costs that have no evident connection to the real estates' environmental impact are here excluded.

The toxic substances in the building material are also included (Kindembe, 2004). Information about the location and mount of the toxic substances is used to describe the problem. This information pair would help characterize the whole building. This would serve as a learning tool for developers in the selection of material. For the tenants it gives an idea in selecting a place to live in.

### 8. Result presentation

The result presentation offers extensive layers of diagrams and data tables ranging from an aggregated diagram of *Environmental Efficiency* to quantitative *Indicators* of different aspects and factors*. Environmental Efficiency* provides a relative measure of the internal quality of a real estate in relation to its external impact vis-à-vis its performance relative to other real estates (figure 2).

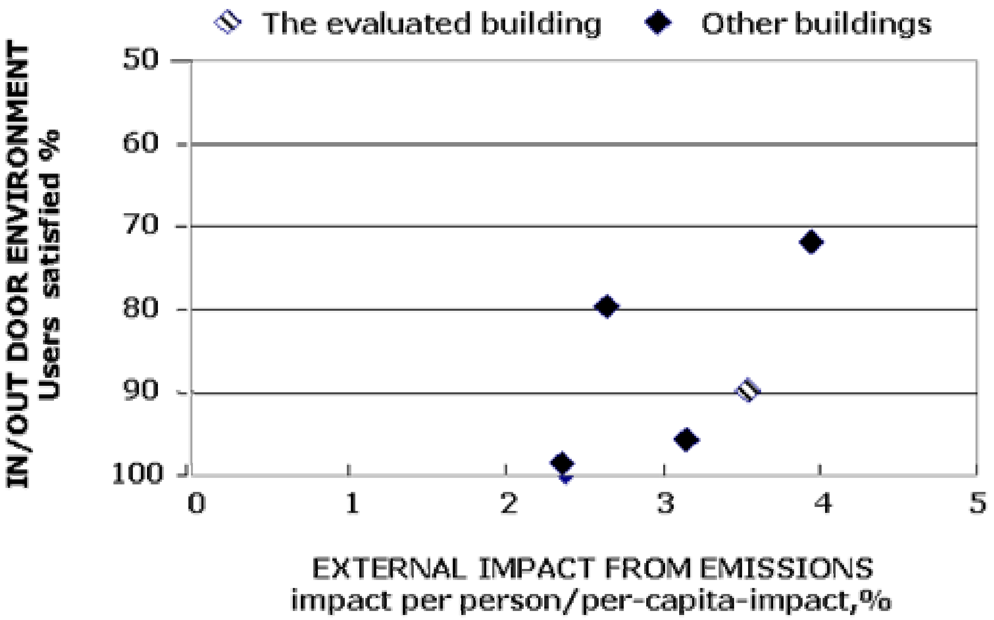


*Figure 2 The most simplified form of presenting an EcoEffect assessment*

The underlying parameters of this result and other layers of presentation can be seen down to the input data by clicking down the result window. Different indicators can be generated for comparing parts of the real estates using specific parameters and factors of interest. The results are presented in the form of assessing the impact versus quality of the indoor environment per person. Indicators can also give another perspective on the functional unit equivalence by generating selected parameters per $m^2$ and per person-hour (for office buildings).

In the EcoEffect method there is a direct association of the characteristics of buildings or activities to environmental impacts. A change in the flow or the physical environment can directly be shown as a change in environmental impact. This means also that the method can be used for formulating quantitative environmental goals for each impact category e.g. a certain building should not contribute to the problem of climate change more than a certain amount. The method can specifically be used by building property companies that use environmental management system according to ISO 14001 or EMAS. The method is developed so that it can be used in early phases of planning and design and as well as by managers of real estate during operation phase.

## 9. EcoEffect as a meeting place of the *Two Cultures*

The methodologies from the “Two cultures” (Snow, 1959) namely social sciences and natural science are used in the EcoEffect method in both in data collection and processing as well as in the use of the results generated.

The internal environmental part has to do with social science concepts and methodologies such as surveys on what people feel and think. The experience of the user is at the centre of the whole assessment work. The role of the assessor is to account for what the residents think and feel about the different aspects of the indoor and outdoor environment. The assessment results in understanding of the user’s subjective experience. This is in line with the social science view of socially constructed reality. It employs quantitative metrics to the different parts by combining questionnaires, measurements and inspection. In some cases a sort of triangulation of these three methods of collecting data can be used to explain why some results look the way they do.

The external assessment is based on knowledge from natural science drawing on the physics and chemistry of pollutants in the natural environment namely air, water, and the biosphere including the human body. It utilizes results and structures of models that incorporate conversion mechanisms, dose-response and other cause-effect relationships. The impact of the material and energy flows expressed in terms of emissions and natural resource depletion is determined using a number of models and concepts developed in different fields of research. In the aggregation part however it gives way to a combination of both social science and natural science based approaches.

## 10. Conclusion

The development phase of both the method and the computer tool that uses the method has been to a large extent carried out under a strong participation of the end-users, the actors in the building sector. This was done through representations in the board that was overlooking the research project. There were also seminars and workshops that were used as forums for dialogue between the research group and the stakeholders. The participants had the chance to explicitly express the requirements of different actors and users. They represented the knowledge about the business aspects, the legislation issues and to some extent the need of the users. To what level they reflected these different interests (sometimes conflicting) in a balanced way is difficult to articulate.

The areas covered, actors involved and the stages included in EcoEffect assessment can be mapped on Table 2 taken from *Sustainable Building and Construction* (UNEP, 2003). The bold ones are those included directly and indirectly when assessment is carried out using EcoEffect.

The challenge in developing the method and tool has been to simultaneously combine such a degree of comprehensiveness with an easy to understand approach in a user-friendly interface. For a building to perform best according to the EcoEffect assessment it has to have a higher indoor environment quality as experienced by the users and a lower environmental impact.

The fact that the method covers a large number of areas gives rise to uncertainties in the assessment work. The total uncertainty constitutes data uncertainty and method uncertainty etc. On the other hand, it avoids sub-optimization. Further work should be fine tuning the data and methods used. Some parts currently under development (either operationally or conceptually) include expanding the EcoEffect method to management of housing areas, evaluation and presentation of natural resource depletion, toxic chemicals, waste and wastewater, and possibilities of using CAD program as a vehicle for input data to the EcoEffect program.

Table 2 Stages, actors, environmental impact in the building process vis-à-vis EcoEffect's focus

| Stage | Siting/design | Construction/ refurbishment | Use | Demolition/ deconstruction |
|---|---|---|---|---|
| Actors | ▪ **Developers**<br>▪ **Owners**<br>▪ **Architects and engineers**<br>▪ Finance institutions<br>▪ Government authorities | ▪ Owners<br>▪ **Architects and engineers**<br>▪ **Contractors**<br>▪ Material suppliers<br>▪ Labourers<br>▪ Government authorities<br>▪ Finance institutions | ▪ **Owners**<br>▪ **Tenants**<br>▪ **Building managers**<br>▪ **Operation and maintenance personnel**<br>▪ Government authorities | ▪ Contractors<br>▪ Recyclers<br>▪ Salvagers<br>▪ Landfill/incinerator managers<br>▪ Government authorities |
| Actions and inputs | **Choices affecting:**<br>▪ **land use**<br>▪ **material use**<br>▪ **energy and water needs**<br>▪ aesthetics<br>▪ transport and mobility | ▪ **Building materials**<br>▪ **Chemicals**<br>▪ **Energy**<br>▪ **Water**<br>▪ Labour<br>▪ Equipment | ▪ **Chemicals**<br>▪ **Energy**<br>▪ **Water**<br>▪ Labour | ▪ Chemicals<br>▪ Energy<br>▪ Water<br>▪ Labour<br>▪ Equipment |
| Environment-related impacts and risks | ▪ **Landscape alteration**<br>▪ Transport patterns<br>▪ **Building performance (e.g. energy efficiency)** | ▪ **Raw material extraction and transformation impacts**[b]<br>▪ Waste<br>▪ **Run-off**<br>▪ Noise<br>▪ Traffic<br>▪ Landscape impairment<br>▪ Dust<br>▪ **Pollutant emissions and discharges** | ▪ **Indoor emissions**[c]<br>▪ Waste<br>▪ Wastewater<br>▪ Heat<br>▪ **GHGs**<br>▪ Soil compaction and contamination<br>▪ **Traffic** | ▪ Waste<br>▪ Noise<br>▪ Dust<br>▪ Release of hazardous materials<br>▪ Soil/water/air pollution (if landfilled/ incinerated) |

a) e.g. wood, steel and other metals, cement, stone, aggregate, bricks and other ceramic products, paint and other coatings, glass, plastics
b) e.g. air/water/soil pollution, deforestation, energy use, resource depletion
c) e.g. VOCs, formaldehyde, ammonia, carcinogens, fibres, dust, radiation

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