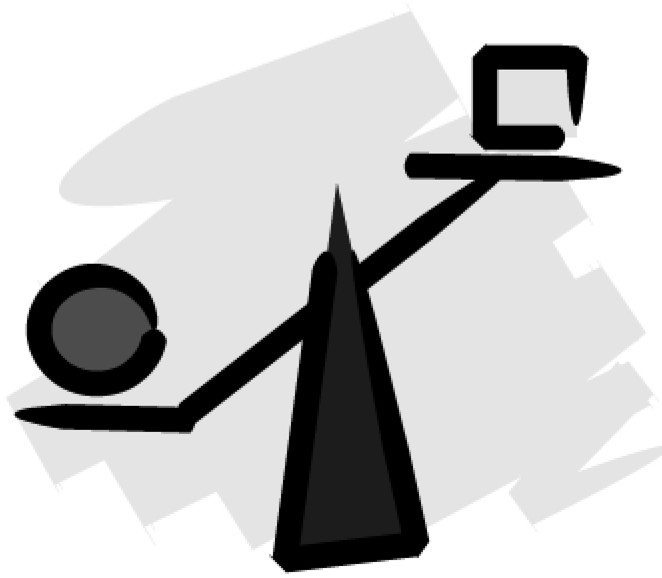
SENSITIVITY AND UNCERTAINTY



Annex 31

Energy-Related Environmental Impact of Buildings

International Energy Agency

Energy Conservation in Buildings and Community Systems Programme

ANNEX 31

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SENSITIVITY AND UNCERTAINTY ANALYSIS

Introduction

Sensitivity and uncertainty analysis can be used at many stages throughout the assessment of energy related environmental impacts from buildings. For example:

- To test the assumptions and data used for materials Life Cycle Assessment (LCA)
- To identify the key parameters affecting the embodied energy of an element or building
- To test the extent to which parameters are important to the life cycle of a buildings, e.g. maintenance and replacement rates
- To determine which materials require accurate data for transport energy to be compiled and which do not. This determines which materials are sensitive to location.
- To determine the importance of life cycle embodied energy compared to operational energy for a building

Sensitivity Analysis

The key purpose of sensitivity analysis is to identify and focus on key data and assumptions that have most influence on a result. It can be used to simplify data collection and analysis without compromising the robustness of a result or to identify crucial data that must be thoroughly investigated.

To undertake a sensitivity analysis, it is necessary to model the assumption and calculations to generate the required results. It is usually most convenient to do this in the form of a spreadsheet. The model should clearly identify all of the data and assumptions made and include the formulae leading to the result for which sensitivity is to be investigated.

Some of the parameters used will be known with a high degree of accuracy and these can remain fixed throughout the analysis. For other parameters or assumptions there may be varying degrees of uncertainty. These parameters are the ones to be varied. The starting point in the analysis is to set these parameters at the values considered most likely to be correct.

The sensitivity analysis then entails varying each parameter in turn within a plausible range by a geometric factor; for example the parameters could be varied between known maxima and minimum, or doubled or halved. With each range, the result is inspected. Where the result varies to a large degree, then the variable parameter must be accurate. Where the result varies only marginally, then an approximate value may be considered appropriate, or the parameter might even be excluded altogether. A useful discipline in sensitivity analysis is to initially set a target for variation in the result, e.g. ±5%, ±10%, ±20%. Trial and error or direct calculation can be used to estimate the required accuracy of the varied parameters.

Sensitivity analyses, when used skillfully, can dramatically reduce the quantity of data and work needed to arrive at robust estimates of the energy related environmental impacts of buildings.

For example, in assessing the embodied energy of profiled steel cladding systems, we may have uncertain data in the embodied energy of the coatings but accurate data for the steel. There may also be a large number of proprietary profile patterns. Sensitivity analysis showed that if we can accept a result that is accurate to ± 10%, we can ignore profile shapes completely but must know the profile thickness accurately. Then we can accept an approximate embodied energy value for the coating and a typical value for the coating.

In a lifecycle embodied energy study of fit-out elements in an office building, the replacement rates of a large number of parameters were varied according to best case and worst-case scenarios for replacement found from the literature. The most sensitive parameters were floor surfacing and its replacement with carpets and underlays as the most significant parameters.

A sensitivity analysis of the energy use during the life span of Swedish buildings "from cradle to grave" show that the occupational phase, excluding renovation, is responsible for about 85% of the total energy use, while manufacturing is responsible for about 10-15%. Renovation during the occupation phase is responsible for about 5 % while deconstruction in most cases has insignificant influence on the total energy use. Such a result indicates that the reduction of energy use should be aimed at the occupational phase, or if the aim is to obtain an accurate estimate of the energy use, efforts should be directed to this phase. Detailed sensitivity analyses of all parameters in each phase, especially the occupational phase when it is energy use that is studied, can reveal which parameters that should be aimed at either to reduce the environmental impacts or to decide more accurate results.

In the following example the sensitivity due to energy input values in the manufacturing phase is shown for two different raw materials in an asphalt roof coating.

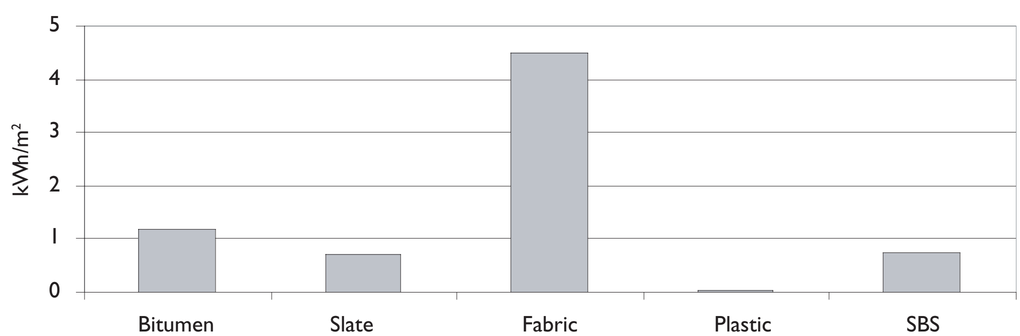

Figure 1 *The energy use per m² of asphalt roof coating split into the different raw materials*

Plastic has insignificant influence of the total energy use while all the contributions of other materials is significant. Hence, the plastic data could be neglected in the collection due to the energy use of the asphalt coating. This impression is reinforced when other data sources are used in the survey. Using other data sources for bitumen or plastic show that the sensitivity due to the plastic data is still insignificant while using correct data for bitumen is of great importance. This is shown in figure 2. The other material values remained fixed in all alternatives.

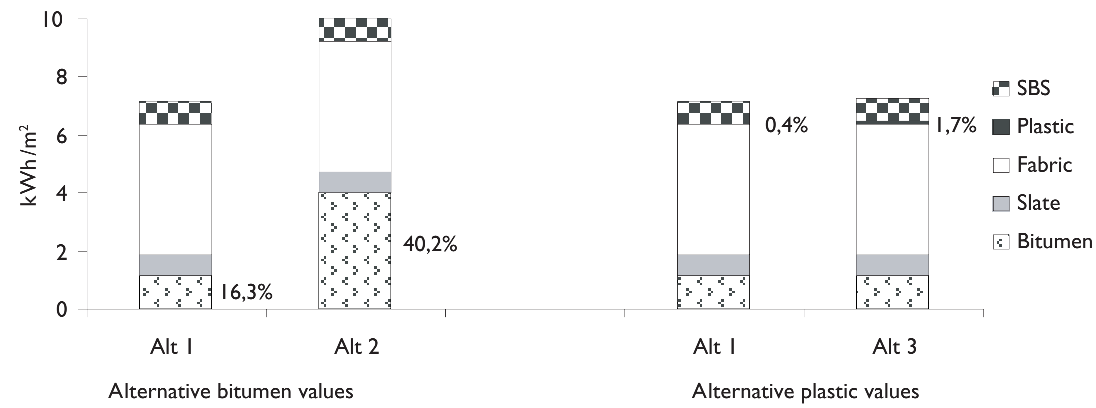

Figure 2 *Illustration of the influences that each material has on the total energy use per m² for 3 alternatives.*

Uncertainty Analysis

A parallel to sensitivity analysis is uncertainty analysis. Experience shows that uncertainty related to an LCA inventory, can be significant, especially for airborne emissions and liquid effluents. Since it is the difference between alternatives which is of interest, and not the absolute values, it is crucial to take uncertainty into consideration when performing comparative LCA's. An example, which illustrates this, can be seen in Figure 3, which shows the photochemical ozone creation potential (POCP) calculated for 10 different partition walls.

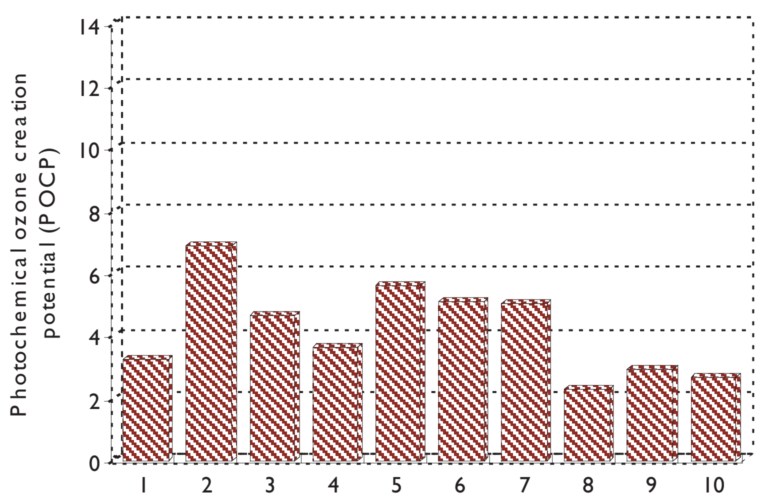

Figure 3 *POCP for ten different partition walls (mean value).*

It would appear to be easy to identify which partition walls are preferable from an environmental point of view, since there seems to be significant differences between the 10 alternatives. In Figure 4, however, the POCP for the same 10 walls is seen, but now standard deviation – in the form of the 95% confidence interval – is also included.

As Figure 4 clearly shows, the apparent differences between the 10 partition walls suddenly disappear. All confidence intervals clearly overlap, and it is no longer possible to identify one of the walls as being better then the rest. A conclusion based only on the mean values in Figure 1, might therefore result in the selection of a wall which in reality is no better, or in extreme cases even worse, than the one or more of the other nine alternatives.

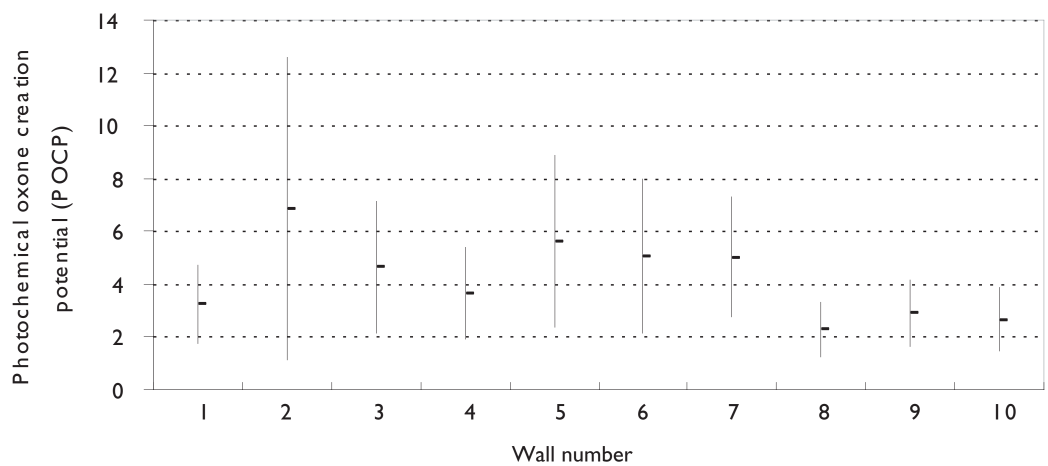

Figure 4 *POCP for ten different partition walls (mean value and 95% confidence interval).*

Handling uncertainty should therefore always be an integrated part of any LCA. Despite the fact that this is by no means a new realisation and that it is widely recognised that uncertainty is an essential part of a LCA, it is seldom treated in the LCA's which have been performed so far. The main reason for this is that there is no international consensus on how uncertainty should be treated or which method should be used. Another reason it that regardless of which method is chosen, it will require more data to handle uncertainty than what is presently collected when performing a LCA. Since data collection is time-consuming, just collecting the normal amount of data can be a problem.

In the few cases where uncertainty so far has been treated, it has often been on a qualitative basis, where the quality of the input data has been estimated as for example good, medium or bad. This type of evaluation is useful for describing the quality of data in a database in a simple, consistent and systematic way. It is, however, difficult or impossible, to say anything definite about the quality of an inventory if it is based on input data whose quality is described in this way. Since it is the quality of the inventory, which is of interest, whereas the quality of the individual input data in principle is unimportant, qualitative handling of uncertainty is only of limited value, when trying to determine the quality of an inventory.

The situation may, however, slowly be changing. Most LCA-inventory tools today can handle uncertainty and/or sensitivity analysis in some way. The biggest problem therefore seems to be the lack of data. This problem is also slowly being resolved, but it is not likely that sufficient data to perform an LCA for an entire building, including uncertainty will be available in the near future.