Identification of influential parameters in building energy simulation and life cycle assessment

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1. INTRODUCTION

Worldwide, the building sector is responsible for high environmental impacts which can be reduced by applying an eco-design approach in new construction and renovation. This requires dedicated tools for the dynamic building energy simulation (DBES) and the building life cycle assessment (LCA). However, the input variables or parameters of these models are uncertain and induce variability. Therefore, the reliability of the output has to be investigated, in order to make robust decisions in an uncertain context. A local sensitivity analysis method, Morris screening method and a global sensitivity analysis method based on the calculation of Sobol indices were applied and their results compared. Using *Pléiades*+COMFIE and novaEQUER, respectively for the DBES and LCA, the most influential parameters were identified, and the tools' robustness was tested.

2. MODEL DESCRIPTION

In *Pléiades*+COMFIE, the building is divided into thermal zones with homogeneous temperature (Peuportier and Blanc-Sommereux, 1990). The buildings elements are meshed and energy equations are solved to obtain the temperature, heating and cooling loads. Twelve environmental indicators are calculated using novaEQUER (Polster, 1995; Popovici, 2005). Energy load and geometry data are transferred from *Pléiades*+COMFIE. For the use phase, which is predominant due to the long building lifetime, information about water consumption, occupants' transportation, and waste production complement the energy loads. The LCA database ecoinvent provides inventories and impact assessment indicators related to these processes, and the fabrication and end of life building materials.

The model has a large number of equations that constitute a time-dependent non-linear system. Despite its physical nature, it is not possible to easily relate the outputs to the inputs. The computing time is decreased by reducing the order of the model. It ranges from a few seconds for a small house with few thermal zones, to a few minutes for an entire and complex district.

3. APPLICATION OF SENSITIVITY ANALYSIS METHODS

Pléiades+COMFIE was validated by software inter-comparisons (e.g. IEA's BESTEST) and against experimental data (Munaretto, 2014; Recht et al., 2014).

The robustness of building LCA results is also important because such tools aim at guiding the decision-making process towards more sustainable built environment. Before investigating the potential change in the ranking of several design alternatives, the influence of the uncertain factors was studied by applying and comparing three sensitivity analysis methods having different computation time versus precision compromise (Pannier et al., 2016). 22 uncertain factors from both energy and environmental models were investigated with an adapted local sensitivity analysis (ALSA), a Morris screening and a GSA. In this case study (single passive family house), the computation time varied between 4 min and 18 h depending on the method.

For the ALSA the difference between the model outputs at each boundary of the variation range was calculated. The indices were divided by the sum of all indices to get the factor's influence, instead of the sensitivity of the model to this factor as usually calculated with LSA. For the Morris screening, 6 levels and 50 OAT repetitions were chosen and the Euclidian distance to the Morris graph origin d_j^*

was calculated as in (1) to rank the uncertain parameters according to both the linear effects and the non-linear or interactions effects:

$$d_j^* = \sqrt{\left(\mu_j^{*2} + \sigma_j^2\right)} \qquad \textbf{(1)}$$

with μ_j^* the mean of the absolute value of the elementary effect for the j^{th} factor and σ_j the standard deviation of the elementary effect. Lastly, truncated normal distributions and 1000 samplings were chosen for almost all factors for the GSA. The ranking is based on Sobol's indices.

All three methods identify the same uncertain factors to be the most influential. In all cases, the type of the electricity production mix, the building lifetime, and some factors influencing the energy performance, are the drivers for almost all environmental indicators. However, the relative influence of the factors for all methods is different and the factor ranking change. This is due to methodological differences. The ALSA does not catch the interactions between parameters or the non-linearity. In Morris screening, using a regular grid is equivalent to making the assumption of a uniform distribution for the factors. However, truncated normal distributions were chosen in GSA. So the range boundaries are more explored than with the GSA. Lastly, ALSA and Morris screening evaluate the effect of the factors on the outputs whereas the GSA calculates the variances.

The choice of the most adapted method depends of the scope of the study and the knowledge of the studied building. If the building is well known and small uncertainty ranges are defined, an ALSA can be sufficient. Furthermore, if the factors' sensitivity must be precisely known, a Morris screening can be performed before a GSA in order to reduce the computation time.

4. CONCLUSION

The sensitivity analysis methods presented in this paper were applied in a DBES and a building LCA tool in order to identify the most influential factors of the models in the frame of model validation and robustness analysis. It can also be extended to optimisation (Recht et al., 2016) or model calibration as in Robillart (2015) where a Morris screening was used before an approximate bayesian computation.

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