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Combined Fire Safety and Comfort Study Using Moment Independent and Variance Based Method

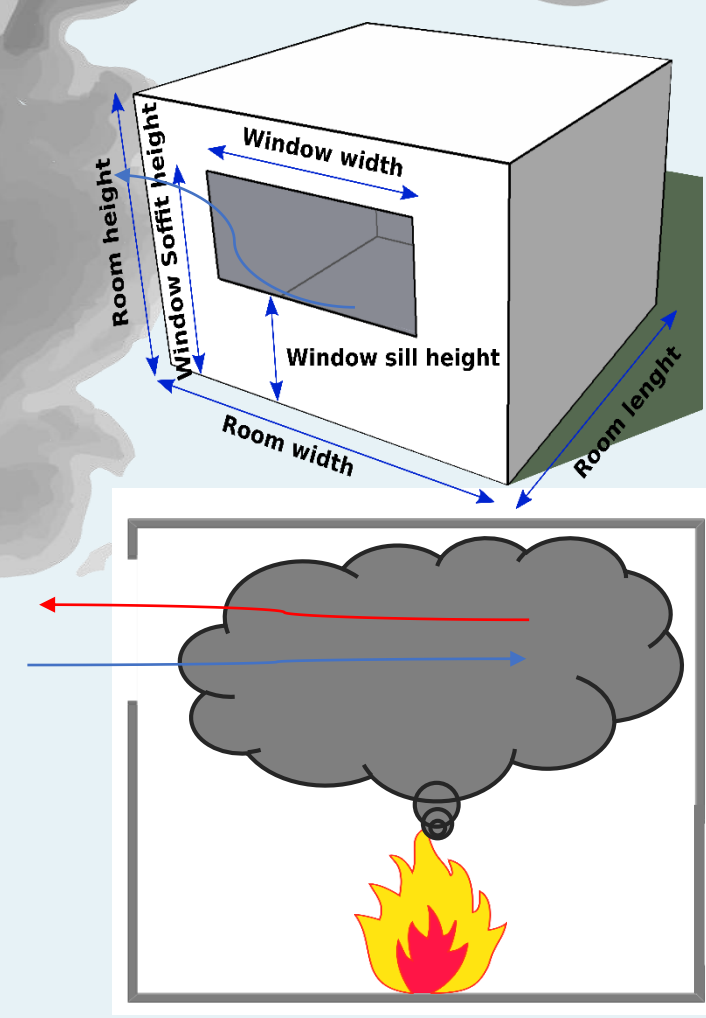
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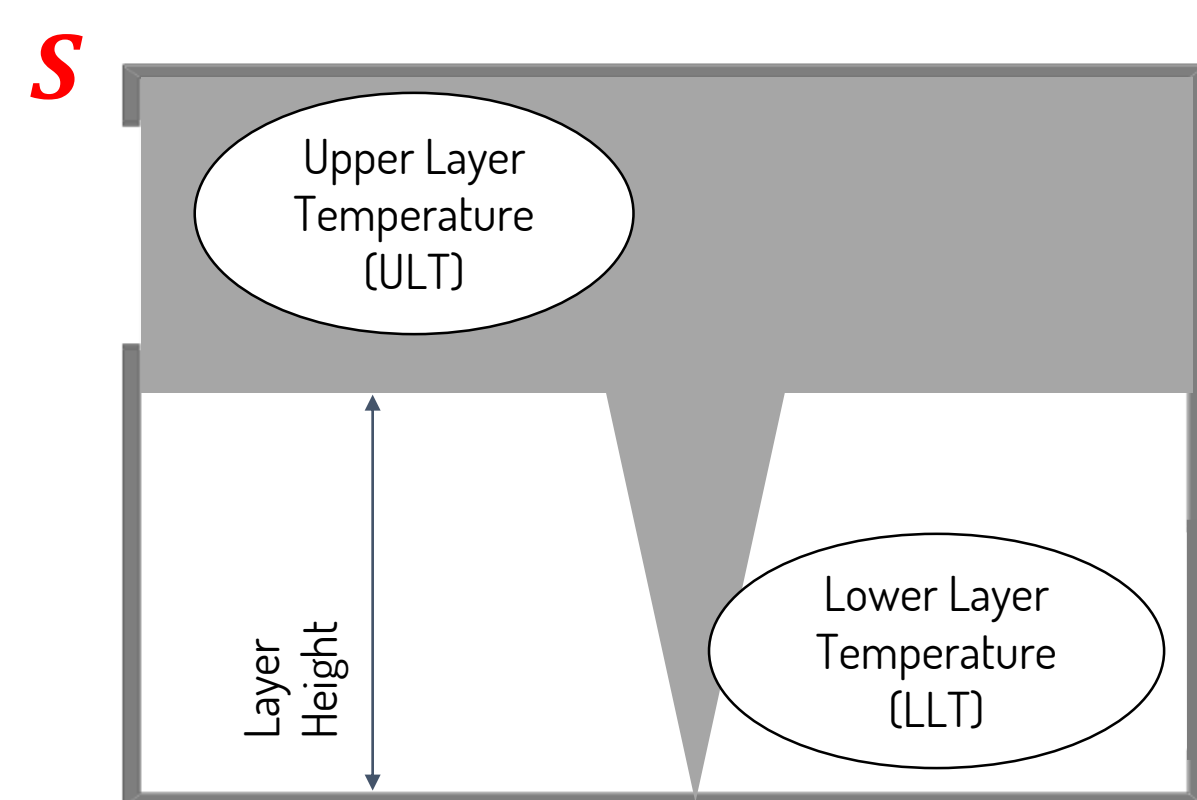
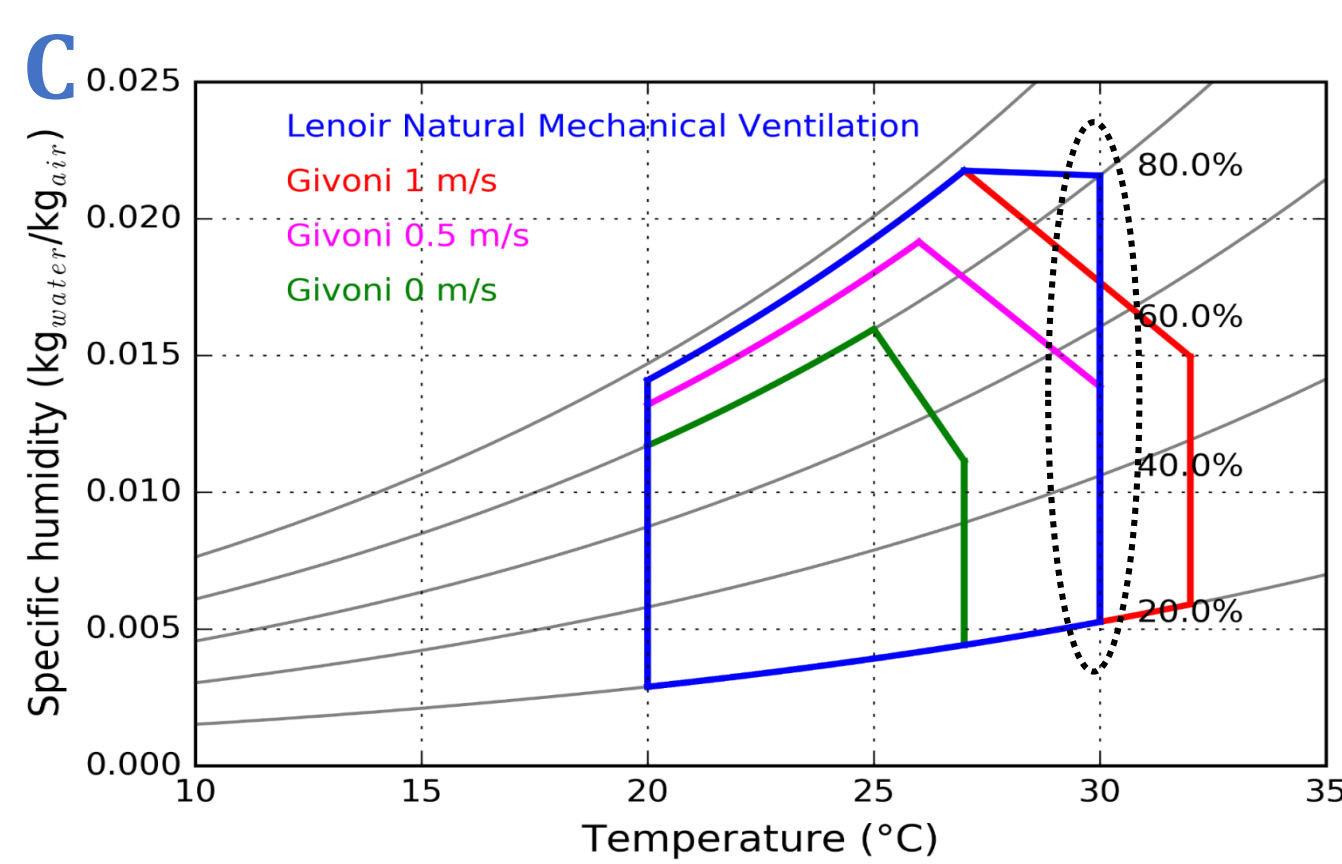
Introduction



Sustainable or safety design ?

New buildings must enhance passive design strategies, especially in tropical context, as well as a high safety level. Considering fire safety and thermal comfort as the root of a sustainable project, one should be careful of the interactions that can exist between these two key considerations, especially in passive buildings.

Comfort and safety measures



The extended Givoni's (Givoni, 1969) zones proposed by Lenoir (2013) are chosen here to define the thermal comfort index named C (1)

$$C = \frac{Nb_{values} - \sum_1^{Nb_{values}} Nb_{(T_{air} > 30^{\circ}C \text{ or } HR_{int} > 80\%)}}{Nb_{values}} \quad (1)$$

The index selected for fire safety evaluation, S (2), is based on three threshold values (Allard et al. 2011) : The maximal upper layer temperature (ULT), the lower layer temperature (LLT) and the minimal layer height (LH) with respect to the French fire safety regulation for LH.

$$S = \frac{Nb_{values} - \sum_1^{Nb_{values}} Nb_{(T_{ULT} > 206^{\circ}C \text{ or } T_{LLT} > 60^{\circ}C \text{ or } LH < 1,80m)}}{Nb_{values}} \quad (2)$$

Nb represents the number of values or number of simulation points.

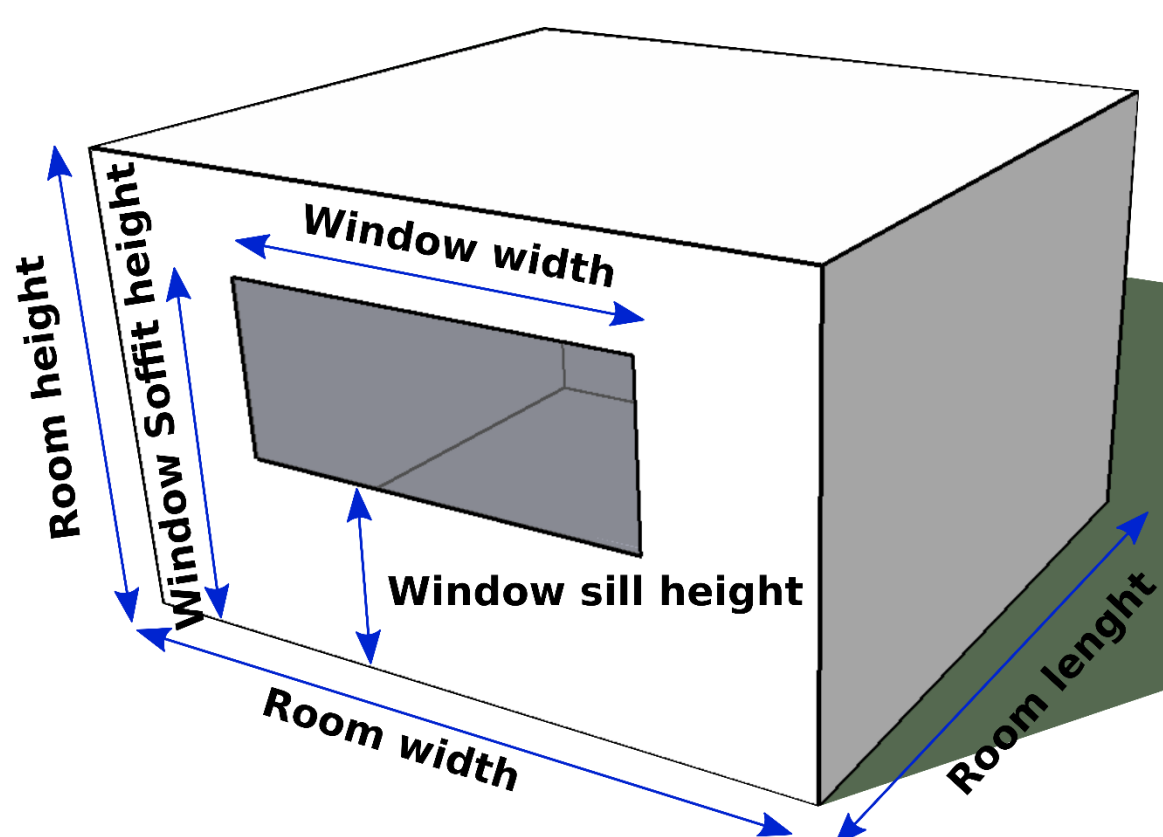
Normalized index (3) associating comfort and safety

$$I = \alpha \times S + \beta \times C \quad \beta = (1 - \alpha) \in [0,1] \quad (3)$$

Case Study

Common parameters

Window geometry : sill, soffit, width
Room geometry : sill height, soffit height, window width
Ventilation: flow rate

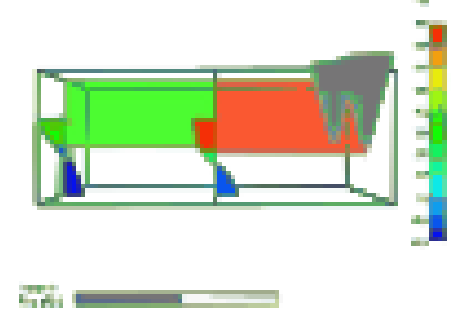


EnergyPlus parameters

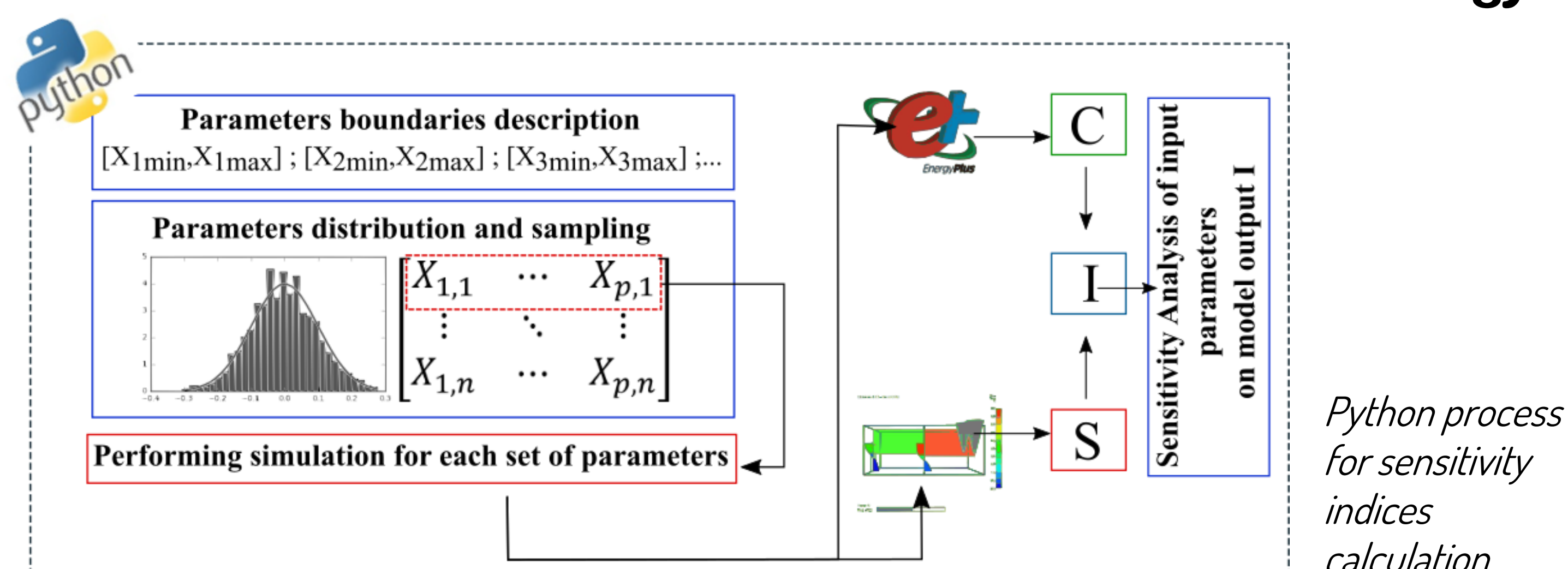
Wall material thickness: cladding, insulation, plasterboard
Roof material thickness: deck, insulation, plasterboard
Floor material thickness: concrete
Room orientation : 1 parameter

CFAST parameters :

Indoor conditions: Temperature, Relative Humidity
Outdoor condition: Temperature



Methodology



Sensitivity Analysis

The key idea consists in representing the output Variance V_Y (4) as a summation of increasing order terms:

$$V_Y = \sum_{i=1}^p V_i + \sum_{1 \leq i < j \leq p} V_{ij} + \dots + V_{1\dots p} \quad (4)$$

With V_Y the variance of the output distribution. The V_i (5) and V_{ij} (6) terms can be calculated as follows:

$$V_i = V(E[Y|X_i]) \quad (5) \quad V_{ij} = V(E[Y|X_i, X_j]) - V_i - V_j \quad (6)$$

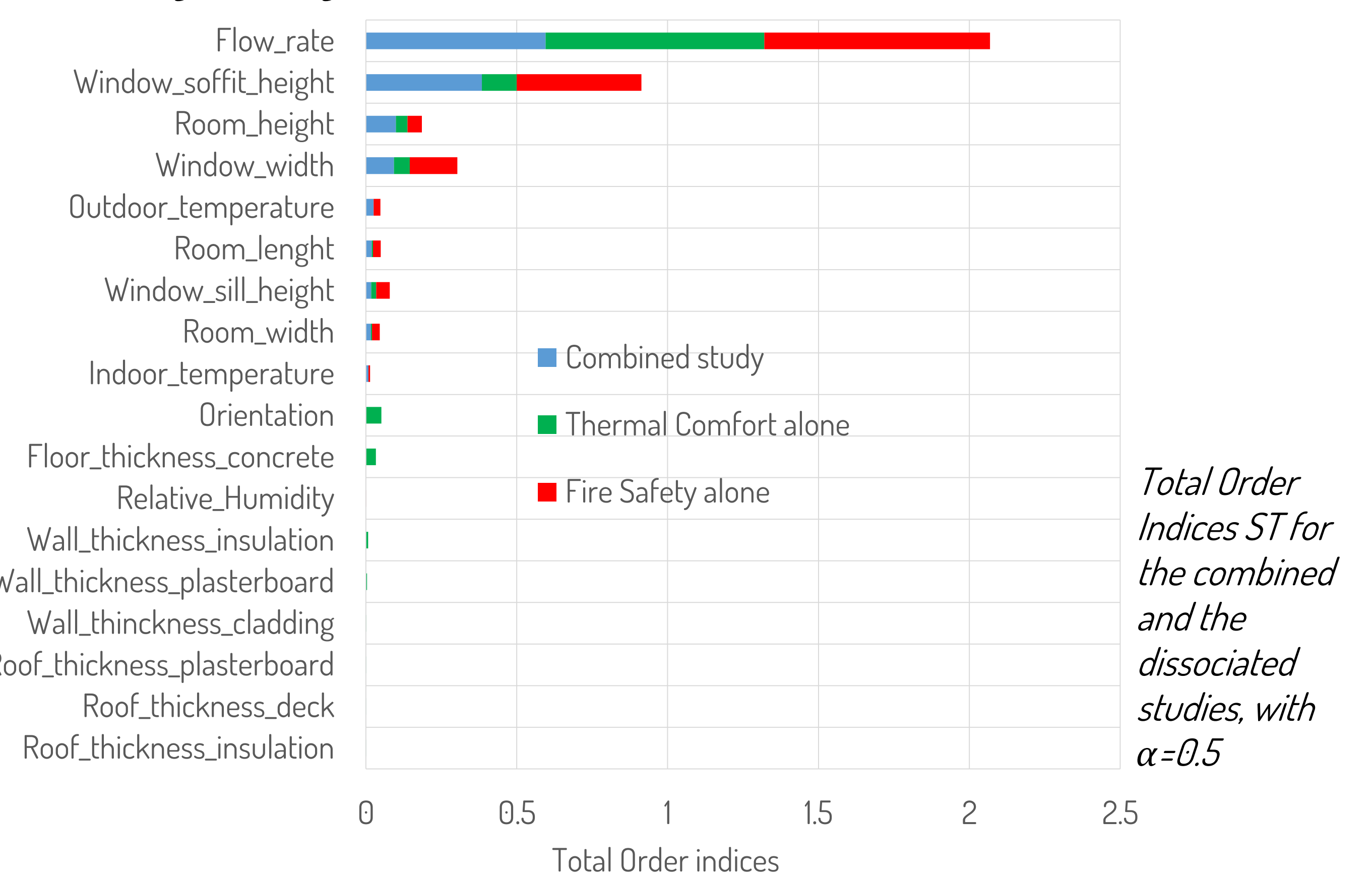
Sobol' (1990) introduced his first (7) and second (8) order indices while Homma and Saltelli (1996) worked on a total order index (9), which is define as the sum of all order sensitivity indices relative to the parameters X_i as follows:

$$S_i = \frac{V_i}{V_Y} \quad (7) \quad S_{ij} = \frac{V_{ij}}{V_Y} \quad (8) \quad S_{T_i} = \sum_{k \neq i} S_k \quad (9)$$

With #i, all the indices that contain i (i, ij, ijk, ijkl ...).

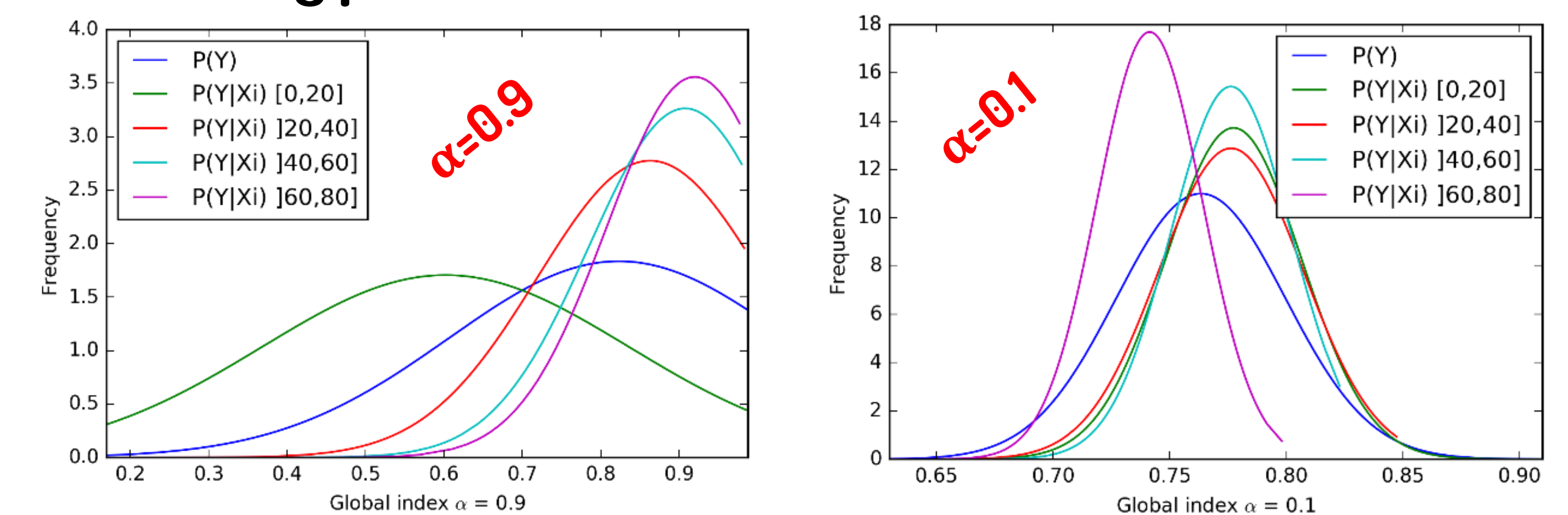
Results

Sensitivity Analysis / Total order measurements



The first two parameters are the same for the global and the dissociated studies.

Conflicting parameter



Conditional probability density function of global index I, for different ranges of flow rate ($\alpha=0.9$ or $\alpha=0.1$)

On the one hand, increasing flow rate also increases the global index when the emphasis is laid on fire safety ($\alpha=0.9$). On the other hand, it can be observed that the global index decreases, when considering thermal comfort with a greater weight ($\alpha=0.1$). The flow rate is identify here as conflicting

Conclusion

This study presented a combined study methodology in order to assess both thermal comfort and fire safety in buildings, using sensitivity analysis and probability density function analysis. The results obtained demonstrated the importance of considering both comfort and fire safety targets together, knowing that these two considerations have common inputs parameters. The use of probability density function allowed to identify the flow rate as a contentious parameter.

