Flame Spread Simulation Over PMMA Panels, Controlled by Material Pyrolysis

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Introduction

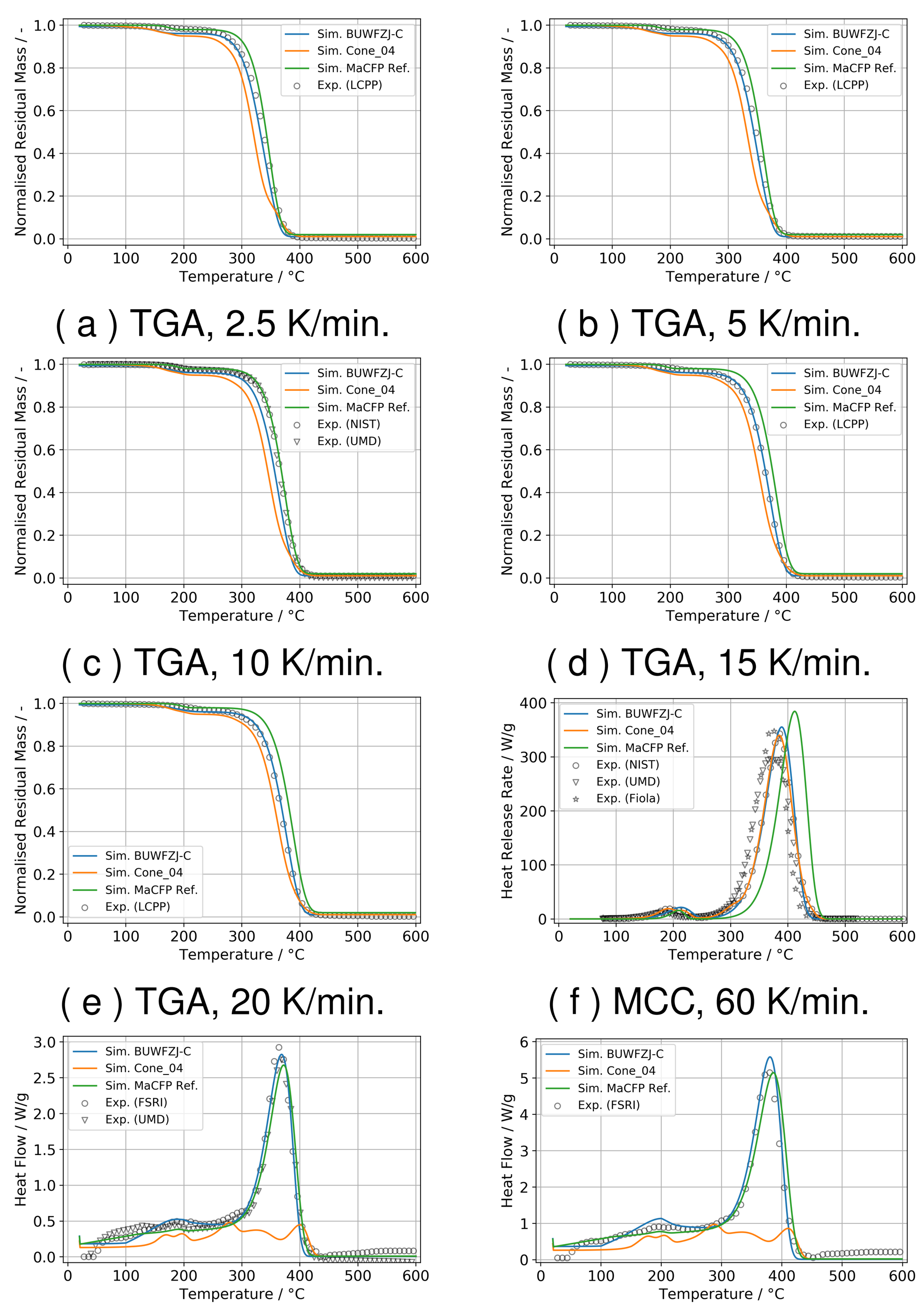
The pyrolysis parameter set is generated by an inverse modelling process (IMP), as outlined in [1]. Micro- and bench-scale experiment data from MaCFP is used as IMP targets [2]. The IMP is conducted in two steps. In the first step, the basic decomposition scheme of the solid sample material is generated. Micro-scale experiment data from thermogravimetric analysis (TGA), differential scanning calorimetry (DSC) and micro-combustion calorimetry (MCC) is used as simultaneous targets (Figure 1).

In the second step, the thermophysical parameters are determined from cone calorimeter data (Figure 3).

Note: During the first step also the released gas mixture (pyrolyzate) is determined. Here, a different strategy is used than reported in [1] or the other contributions to MaCFP-3.

Micro-Scale Experiments

For the decomposition scheme it is assumed that MCC and TGA were conducted under the same conditions. To match both, it is necessary to allow for a variable effective heat of combustion (eHOC) (Figure 2). As a simple model, two parallel pyrolysis reactions release methane and two release carbon dioxide.



(a) TGA, 2.5 K/min. (b) TGA, 5 K/min. (c) TGA, 10 K/min. (d) TGA, 15 K/min. (e) TGA, 20 K/min. (f) MCC, 60 K/min. (g) DSC, 10 K/min. (h) DSC, 20 K/min.

Figure 1: *Micro-scale experiment data [2] used as IMP targets for "BUWFZJ-C". Performance compared to Cone_04 [1] and the MaCFP reference (UMD), as implemented in the parallel panel FDS validation case.*

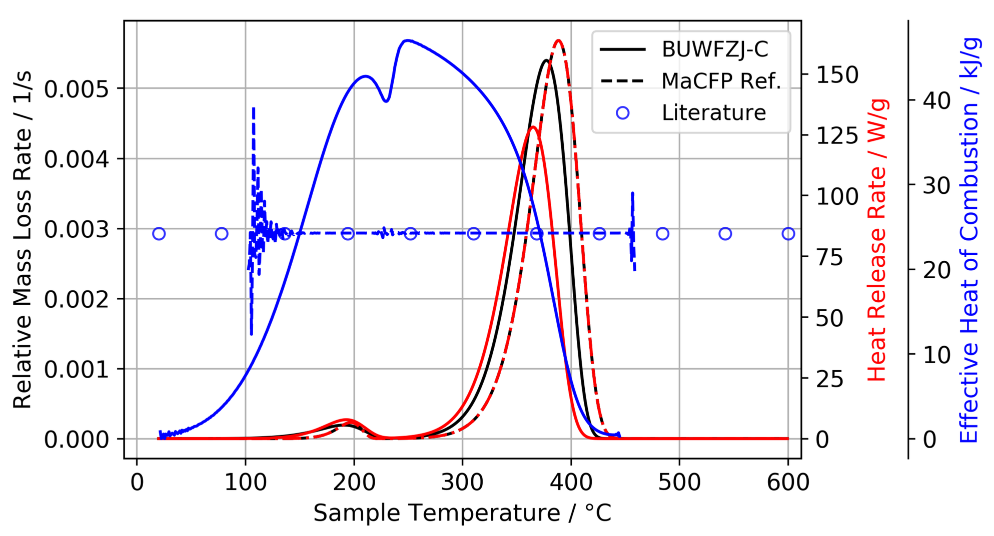


Figure 2: *A variable effective heat of combustion allows to match MCC and TGA data. This is achieved by dynamically mixing methane and carbon dioxide ("BUWFZJ-C") from parallel decomposition reactions.*

Bench-Scale Experiments

The thermophysical parameters of the solid sample material are determined via an IMP. Target is the heat release rate (HRR) of cone calorimeter experiment data from Aalto [2] (Figure 3). Performance in high resolution simulations compared for 65 kW/m^2 (Figure 3) and or 25 kW/m^2 (Figure 4). Simulation setup layouts are presented in Figure 7.

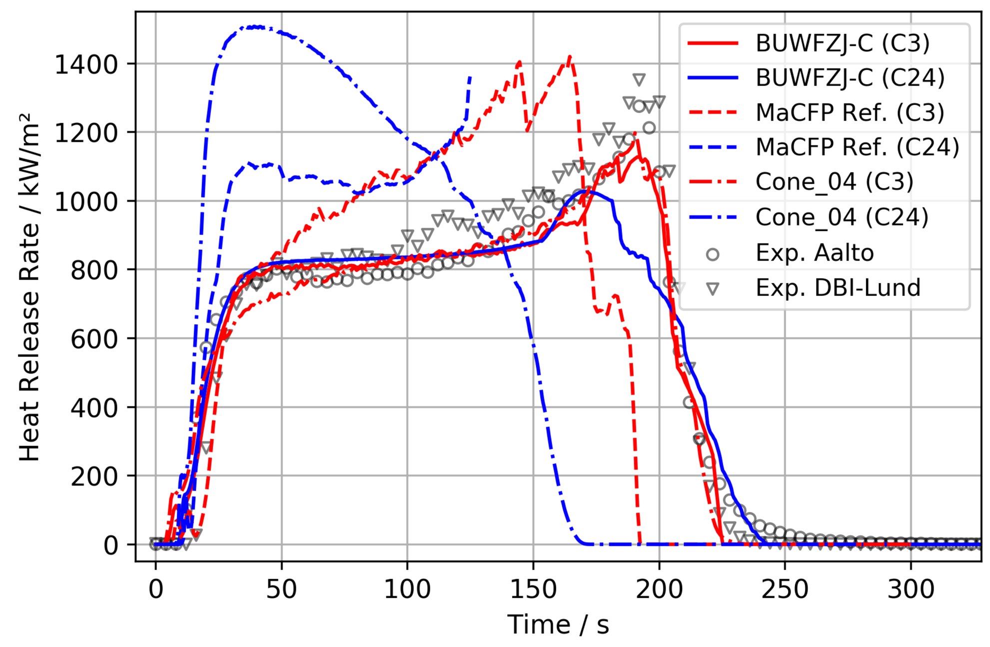


Figure 3: *Performance of parameter sets in 65 kW/m² cone calorimeter setups. Simplified setup (C3) used during the IMP, compared against high resolution setup (C24). Aalto experiment data as IMP target.*

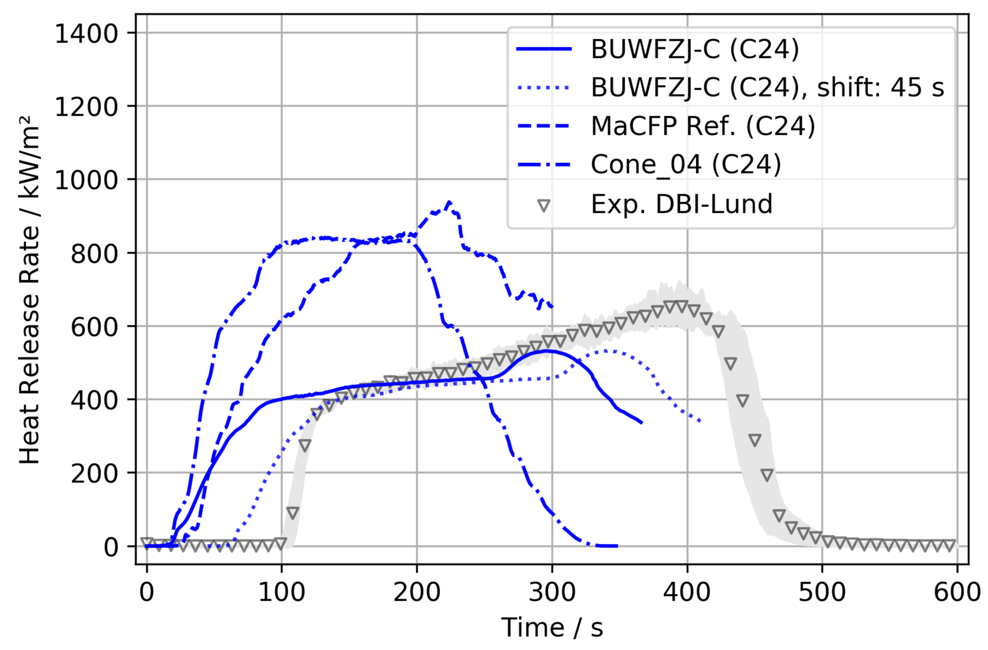
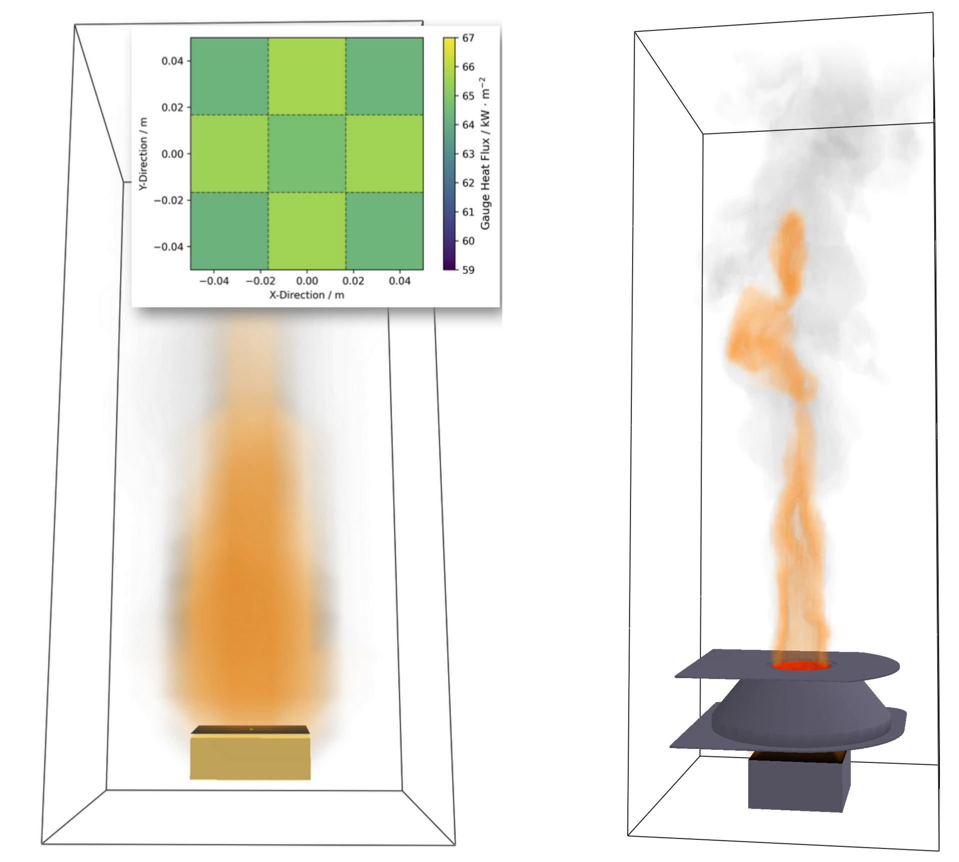


Figure 4: *Performance of parameter sets in 25 kW/m² high resolution (C24) cone calorimeter setup. Compared against DBI-Lund experiment data.*



(a) 33.3 mm (C3) (b) 4.12 mm (C24)

Figure 5: *Simplified (C3) and high resolution (C24) cone calorimeter simulation setup layouts. The "Cn" indicate number of divisions per 10 cm, i.e. "C3" = 3 divisions.*

Real-Scale Experiments

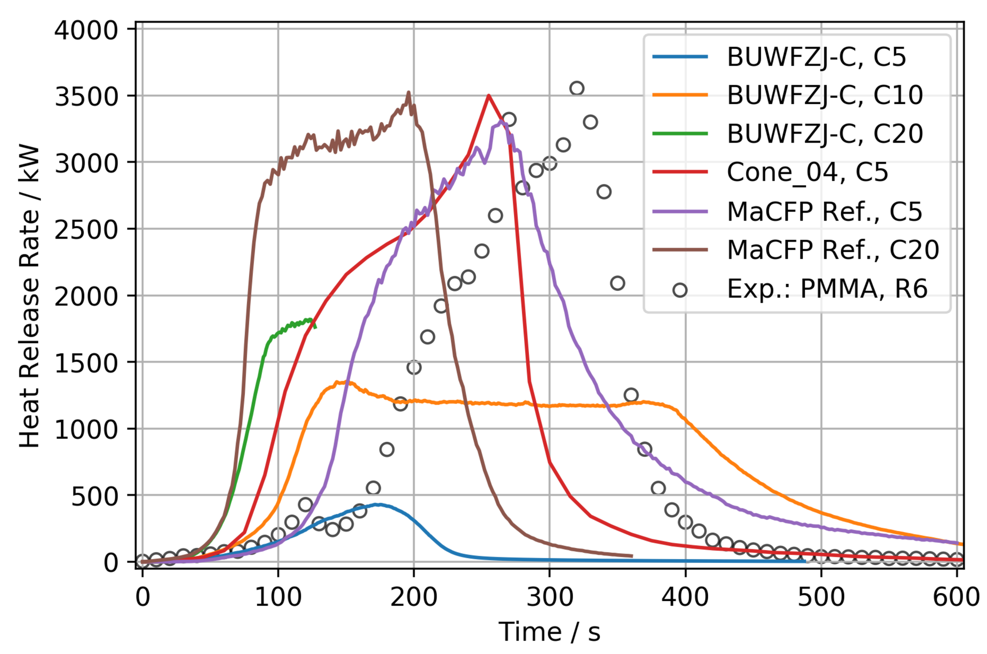
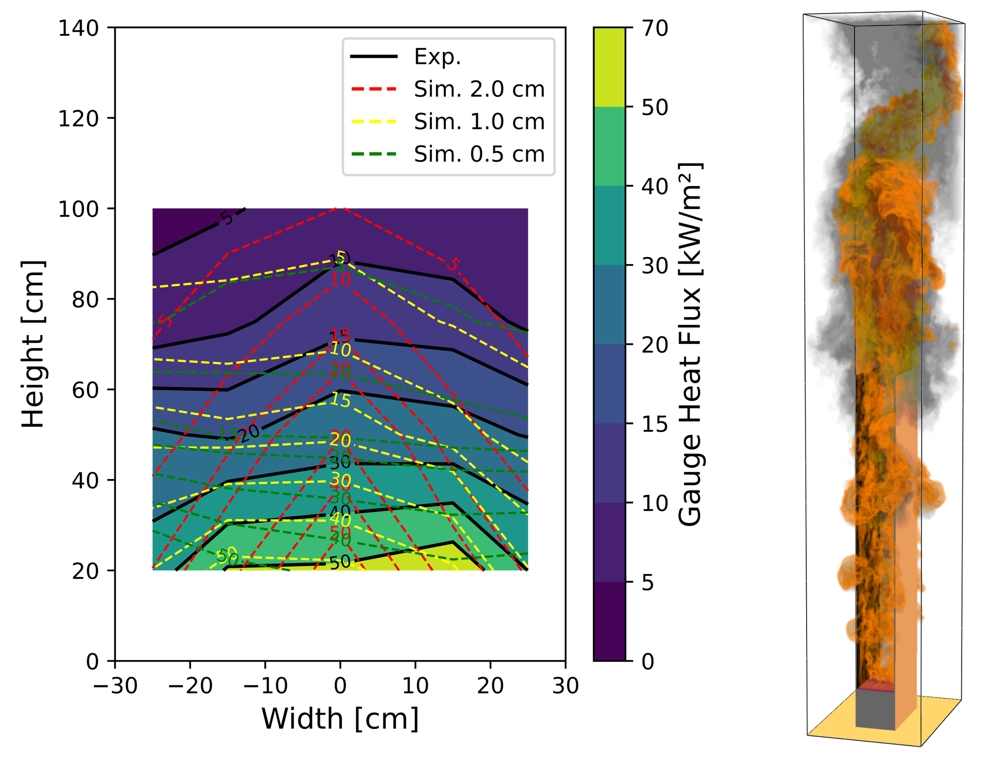


Figure 6: *Parallel panel simulations comparing the performance different parameter sets across different fluid cell sizes.*



(a) (b)

Figure 7: *(a) Gas burner flame heat flux to empty panel, experiment and simulation. (b) Snapshot of parallel panel simulation, C20.*

Sensitivities

Parameters necessary for self-sustained flame spread may not be captured accurately in the cone calorimeter [3], as indicated by varying sensitivities between setups and conditions (Figure 8).

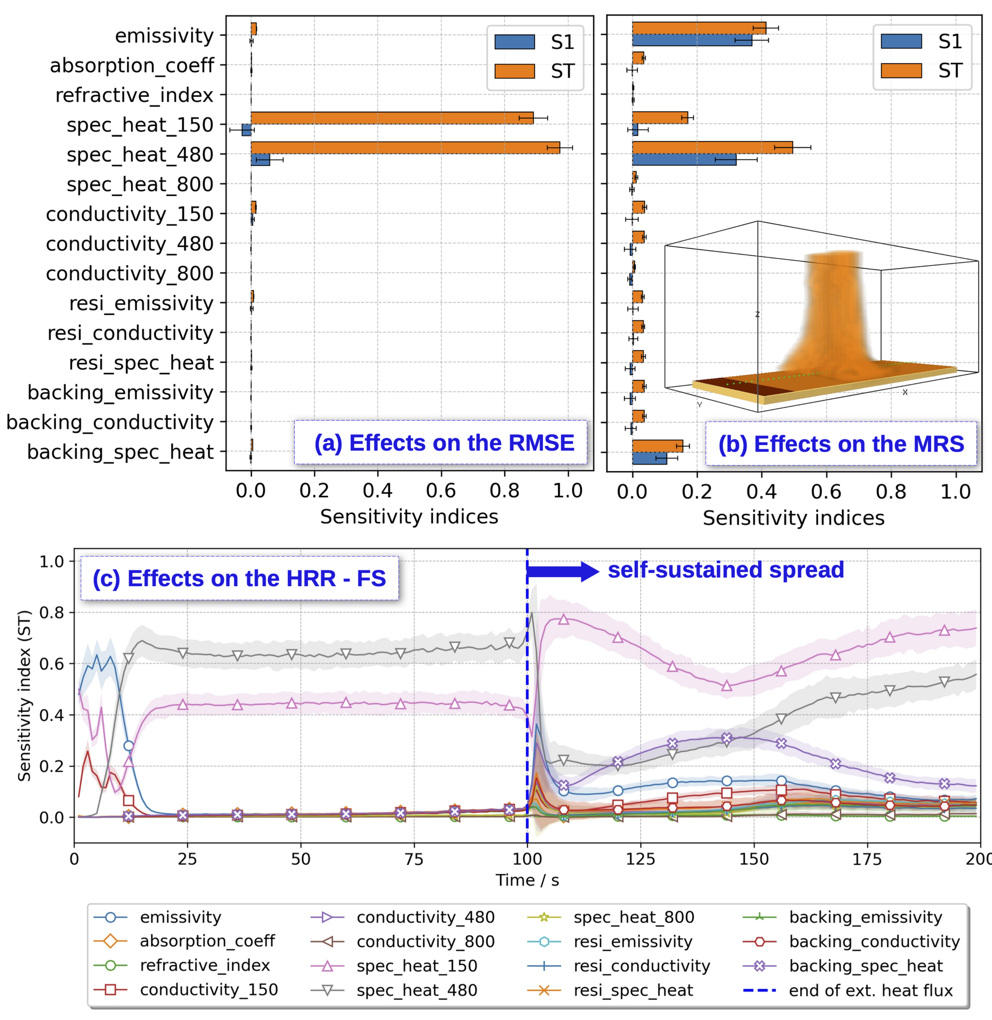


Figure 8: *Sensitivity analysis with total-order (ST) and first-order (S1) Sobol indices [3].*

Links

(a) Article [1] (b) Playlist (c) Article [3]

References

[1] T. Hehnen and L. Arnold. "PMMA pyrolysis simulation – from micro- to real-scale". In: *Fire Safety Journal* 141 (2023), p. 103926. ISSN: 0379-7112. DOI: https://doi.org/10.1016/j.firesaf.2023.103926.

[2] B. Batiot et al. *Measurement and Computation of Fire Phenomena (MaCFP) Condensed Phase Material Database*. https://github.com/MaCFP/macfp-db, Commit: 7f89fd85f75cd2d4999c262f9b39f2f8109e12ef, DOI: https://doi.org/10.18434/mds2-2586. 2022.

[3] T. L. Quaresma, T. Hehnen, and L. Arnold. "Sensitivity Analysis for an Effective Transfer of Estimated Material Properties from Cone Calorimeter to Horizontal Flame Spread Simulations". In: *Submitted to: Fire Safety Journal* (2023). DOI: https://doi.org/10.48550/arXiv.2310.02680.