Private park of a car rental company:

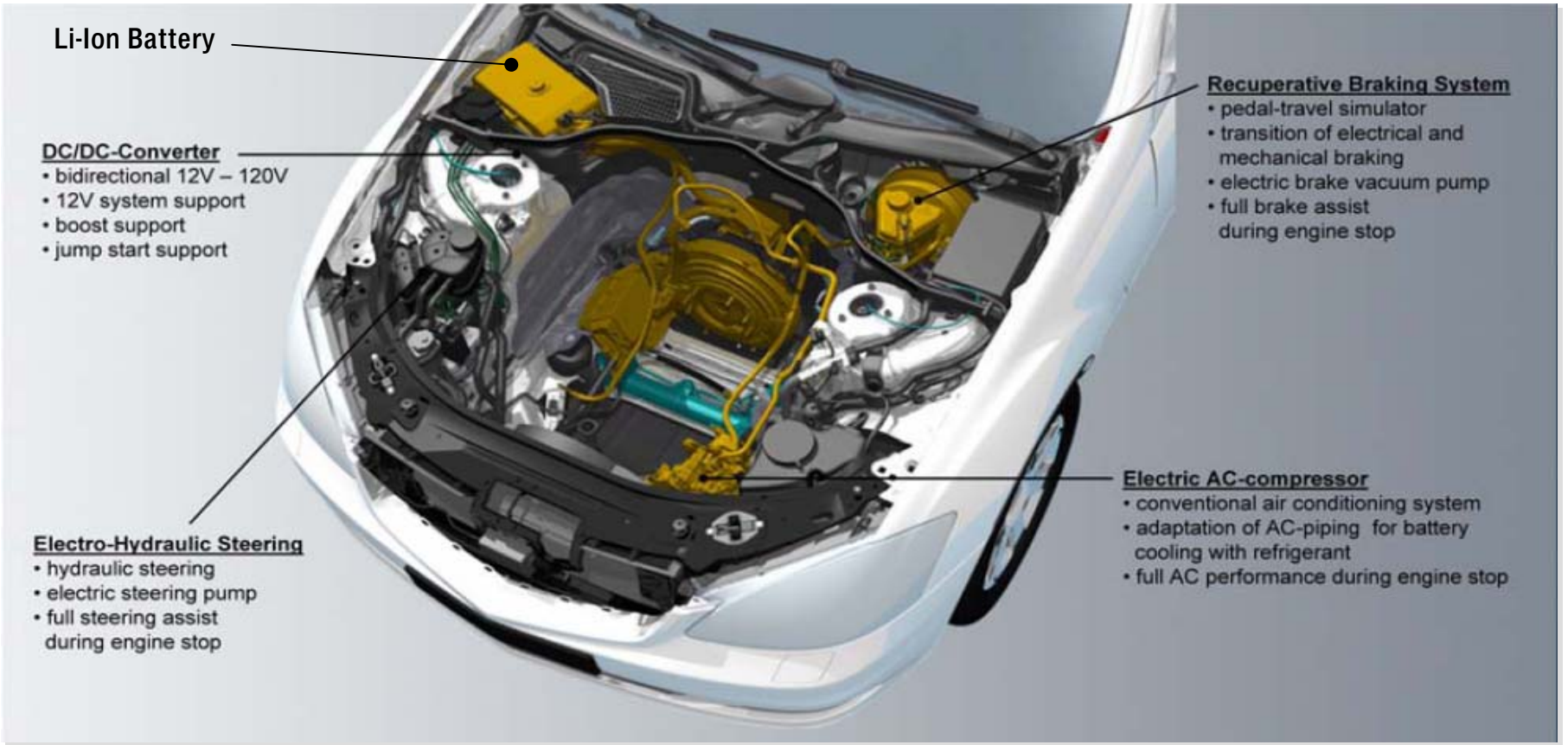
- cars parked on a small distance of each other
- All new cars (more plastic parts that can be ignited more easly and producing more heat)
- All fuel tanks completely filled
- Fuel tanks made of plastic - leaking - pool fires

- This justify the development of a relative simple model to predict the fire spread in a car park

The model is now *deterministic but* is intended to be used togheter with a *probabilistic approach*, because a large number of input parameters is quite uncertain and occurs in a wide range;

closer parking distance, large car, more cars, new energy carriers, application of more combustible materials, more electrical appliances (increasing the probability of short-circuits and self ignition) and so on....

The Mercedes-Benz S 400 HYBRID
Architecture and Technology of the Hybrid System



Combustion engine	: 3,5 lit. 6-Zylinder Otto	Combined torque	: 385 Nm
Electric motor	: 15 kW	Fuel consumption (NEFZ)	: 7,9 l/100 km
Combined Power	: 220 kW/299 PS	CO_2 emission (NEFZ)	: 186 g/km

HRR curves for single car and the time until the fire spread occurs originate from experimental research from the past years.

The model presented by Noordijk & Lemaire calculates the time until the fire spread assuming an HRR curve for a burning car and calculating the resulting Radiative Heat transfert to the other combustible surfaces

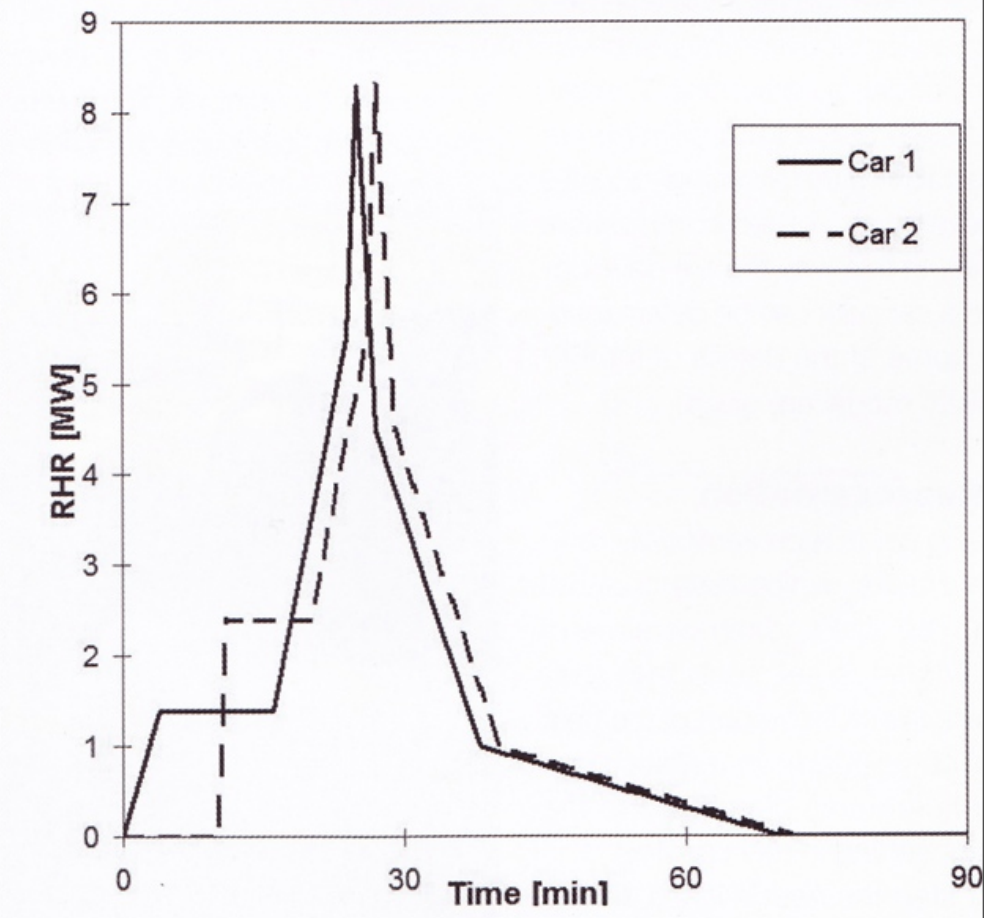


Figure 1. *Typical heat release rates for a car initially on fire (car 1) and a c that is ignited by the first car about 10 minutes later*

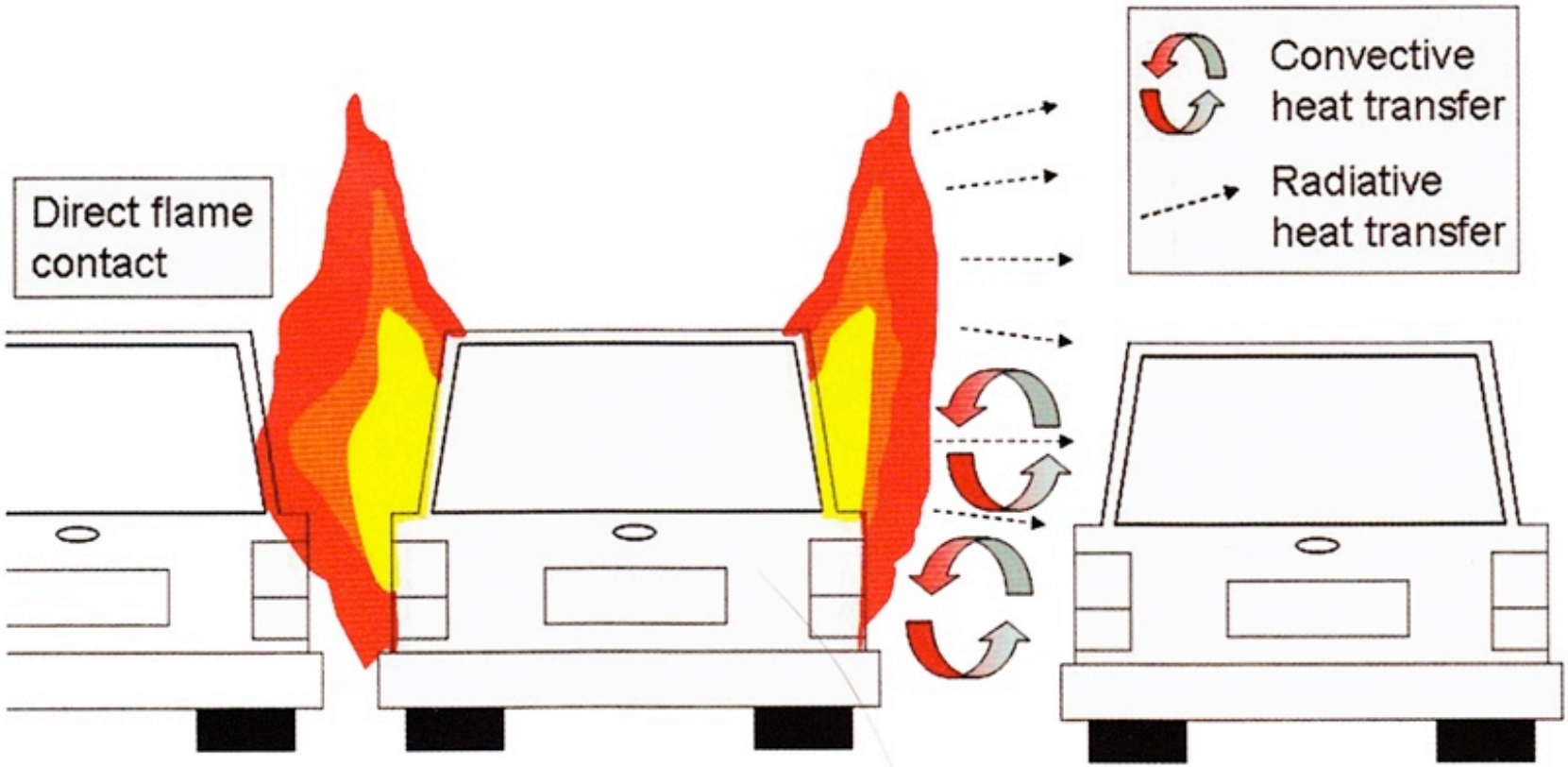


Figure 2. *Mechanisms involved in fire spread from car to car*

For the time being the model is *Deterministic* and mainly based on the fire spread by radiation heat transfer

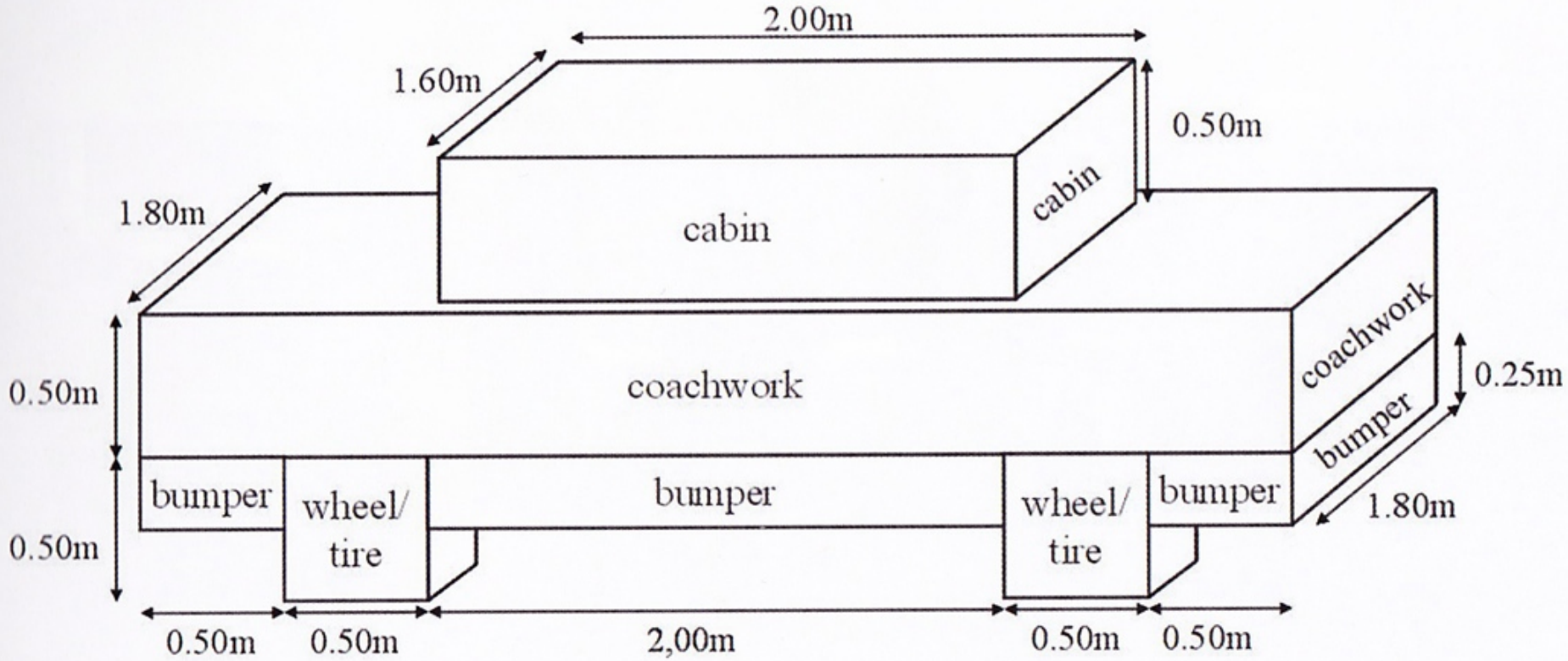


Figure 3. *Modelled car geometry, which can be refined when needed*

- *Emission of radiation* - 30-40% HRR
- *Heat Transfert by Radiation* - shape, orientation and position of two surfaces
- *Absorption of radation, heating and ignition of surfaces* - simplest way - critical heat flux

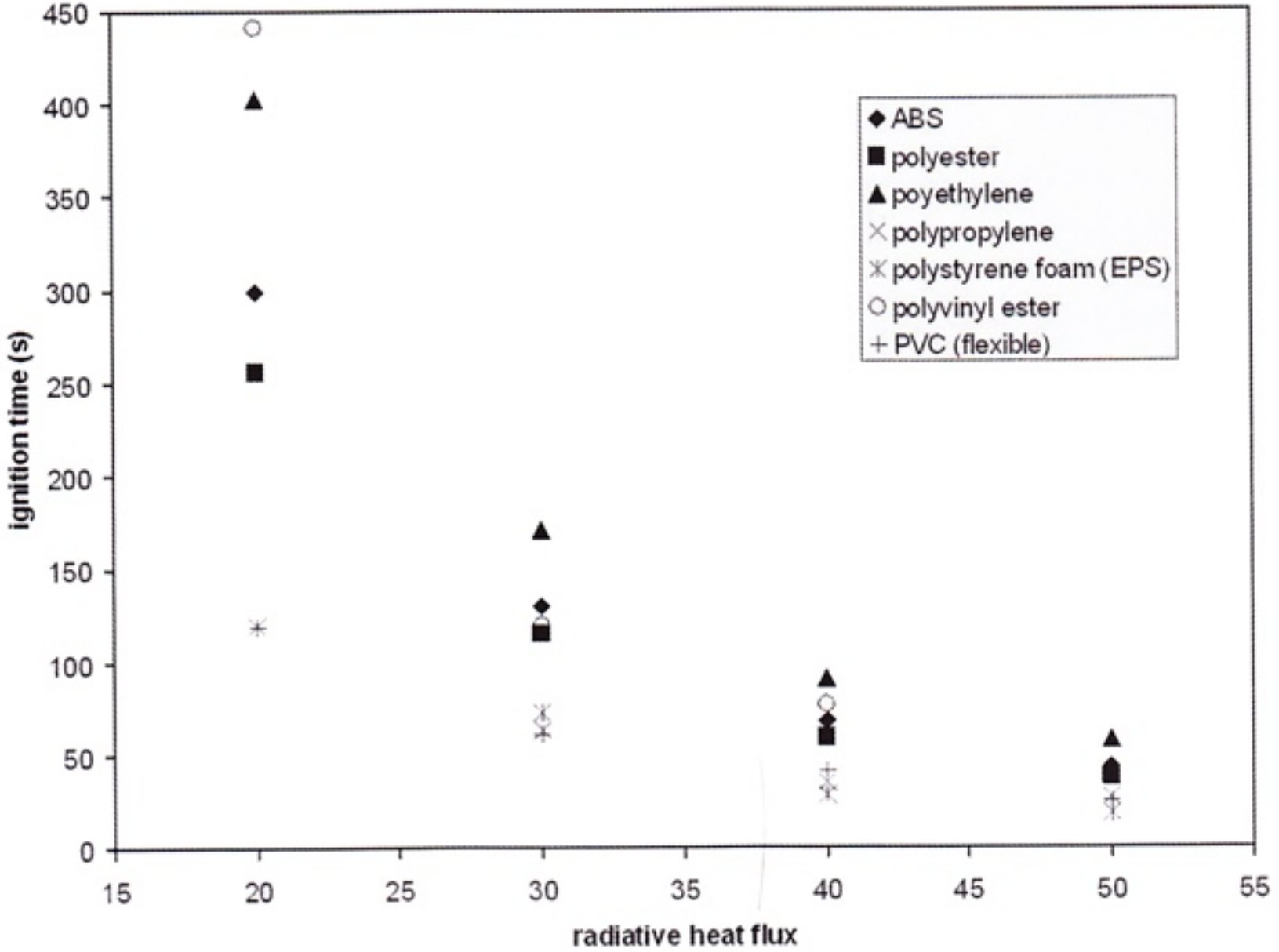


Figure 4. *Ignition time as a function of the radiative heat flux on the surface for different plastics [3]*

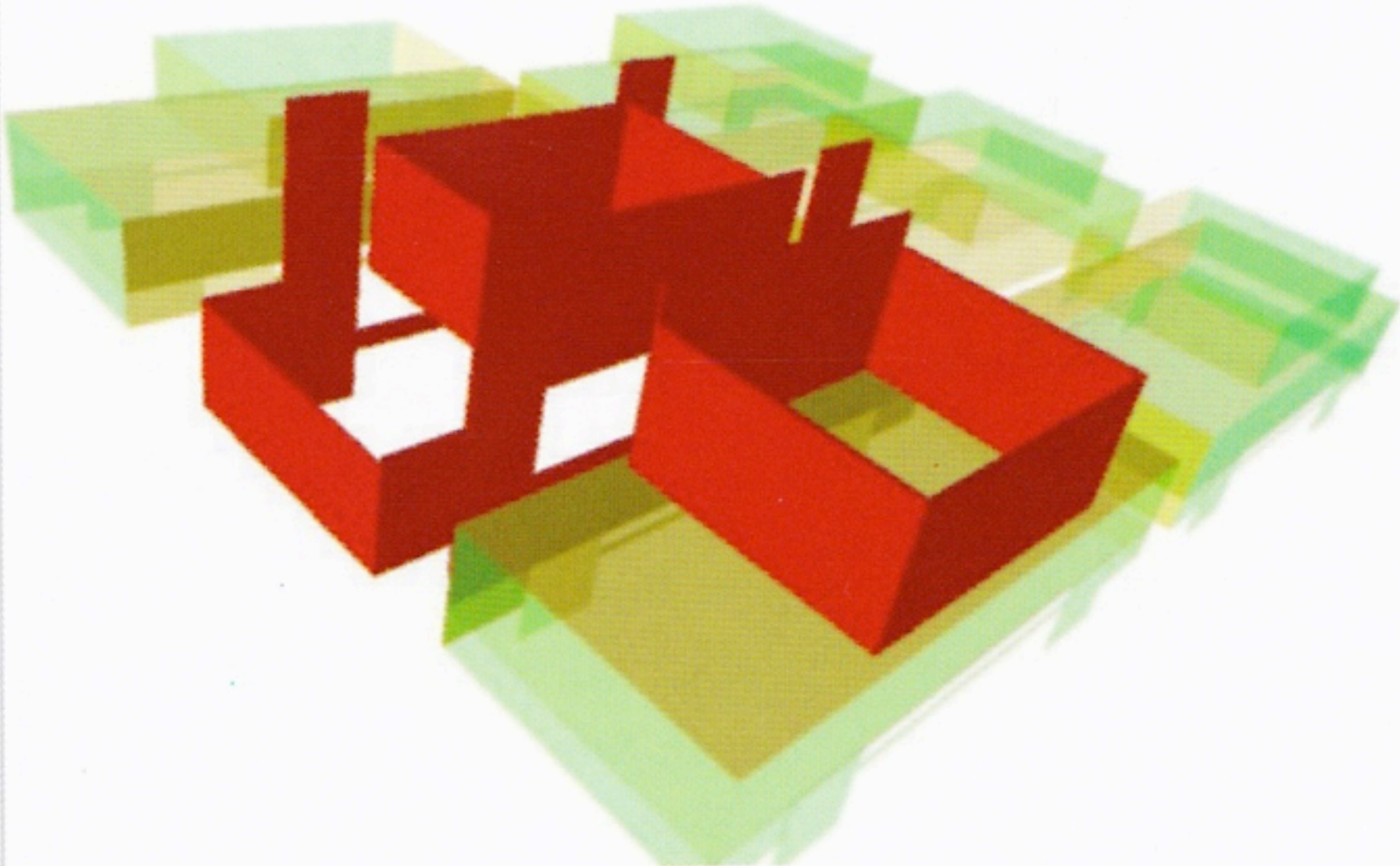


Figure 5. *The dark surfaces are on fire. The height of a burning surface represents the flame height and is based on the heat release rate*

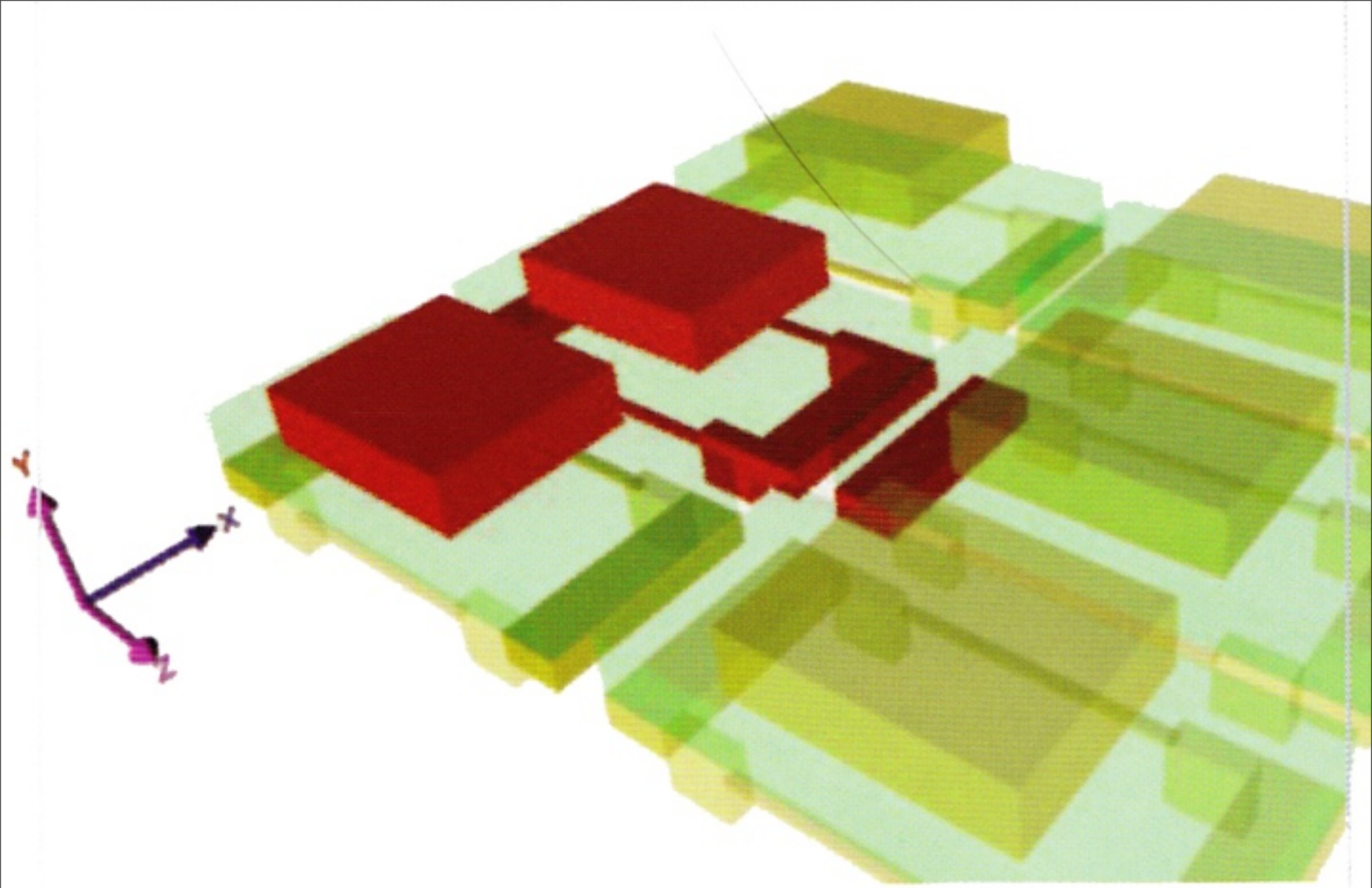


Figure 6. *Result of a simulation: the top centred car has ignited the two closest cars*

A quantitative assessment on the risk on structural collapse or loss of life can be performed by running a large number of parameter value combination in a *Monte Carlo* approach

In orded to achieve this, the relevant parameters (distance between cars, lay out, filling degree of garage, size and composition of the car, etc..) need to be identified (normal or Poisson distribution mostly..)

LIMITED COMPUTATIONAL COST

Working on uncertaines - FDS (modified) Parametric study on window glass breakage an fallout.

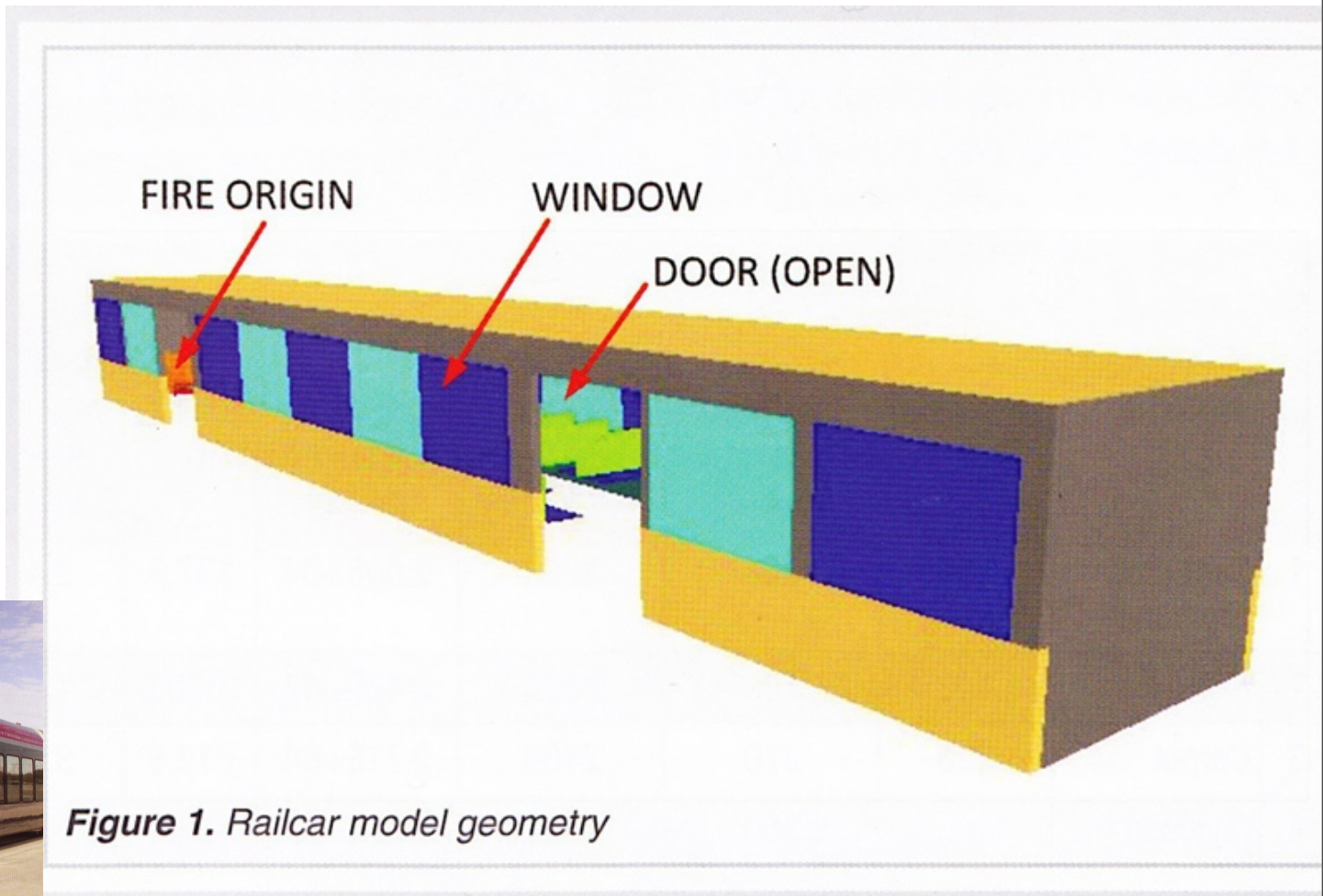


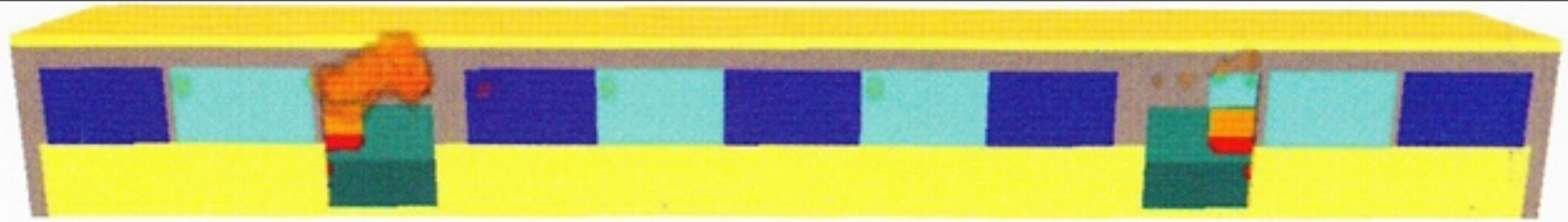
Figure 1. *Railcar model geometry*

- For parametric comparison purpose was considered a limited number of combustible materials (cealing panel, seat, wall finishing -upper and lower-, floor carpet.

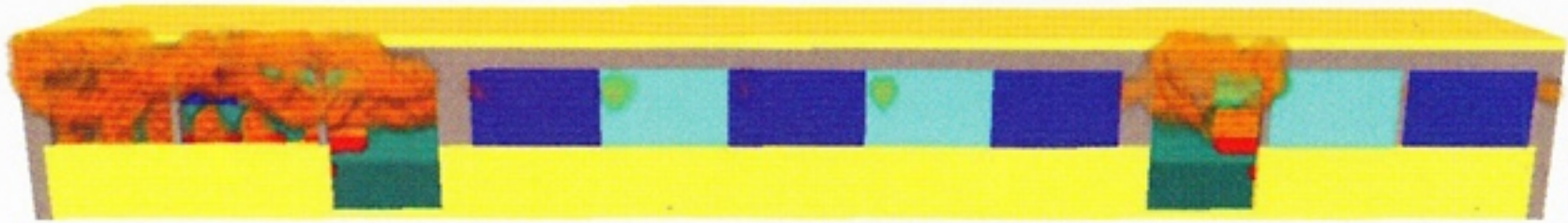
- ignition source - gas burner 138 Kw - below a corner seat

TABLE 1. THERMO-CHEMICAL PROPERTIES OF COMBUSTIBLE MATERIALS PRESCRIBED FOR THE CAR

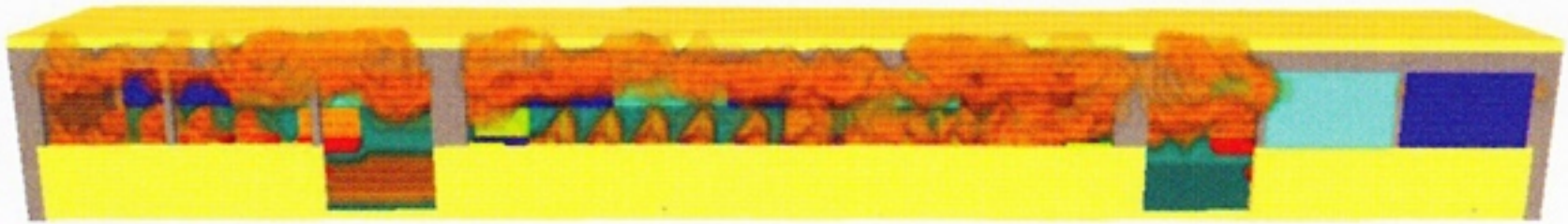
№	Material	Molecular Weight	Ignition Temperature (deg-C)	Heat of Gasification (kJ/kg)	Heat of Combustion (kJ/kg)	Density (kg/m^3)	Specific Heat (kJ/kg-K)	Heat Conductivity (W/m-K)	Combustion Yield (kg/kg-fuel)			
									Y_CO_2	Y_CO	Y_CH	Y_S
1	Seat (Poly-urethane)	130	258	3000	2.60E+04	137.3	2.4	0.09	1.520	0.031	0.003	0.130
2	GRP	102	409	3000	2.46E+04	1080.8	1.4	0.19	2.210	0.015	–	0.073
3	Carpet	226	270	2400	2.71E+04	519.6	3.0	0.16	2.060	0.038	0.016	0.075
4	Plywood		300	5000	1.08E+04	580.0	1.2	0.12				



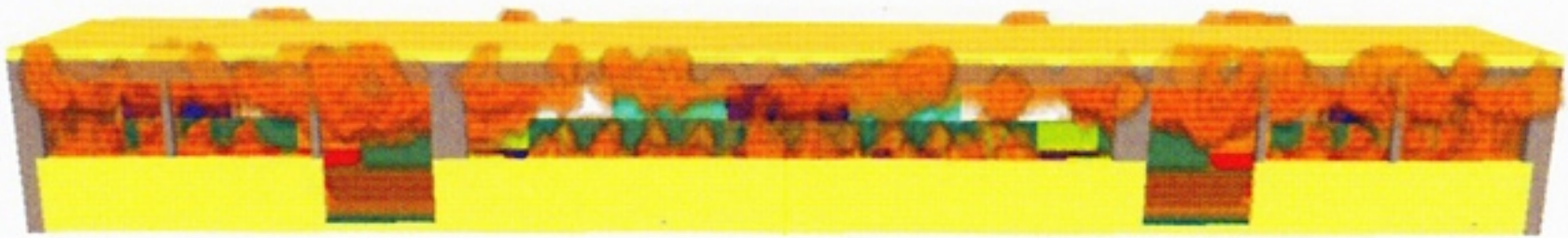
(a) t = 410 s



(b) t = 427 s



(c) t = 444 s



(d) t = 498 s

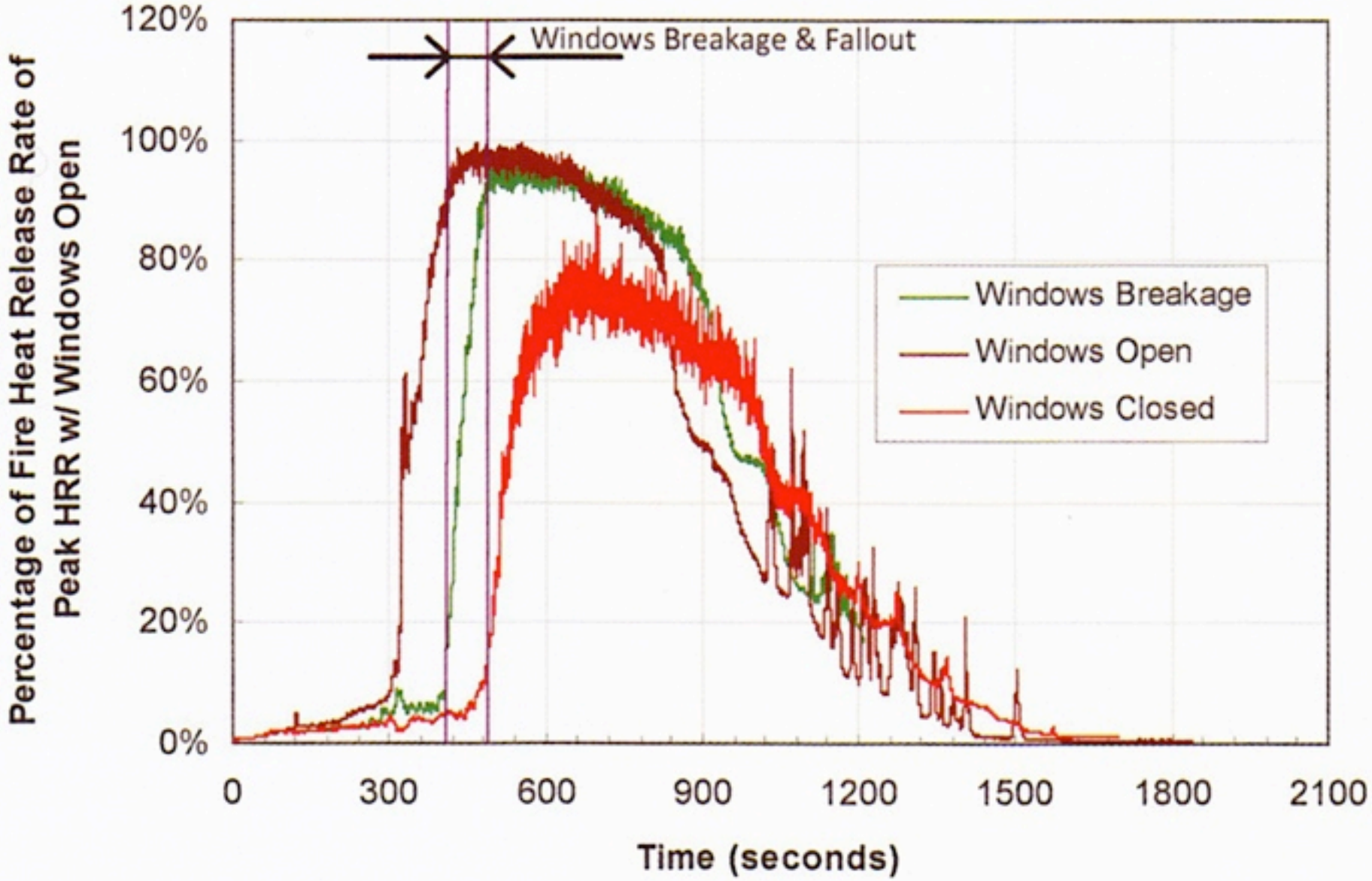
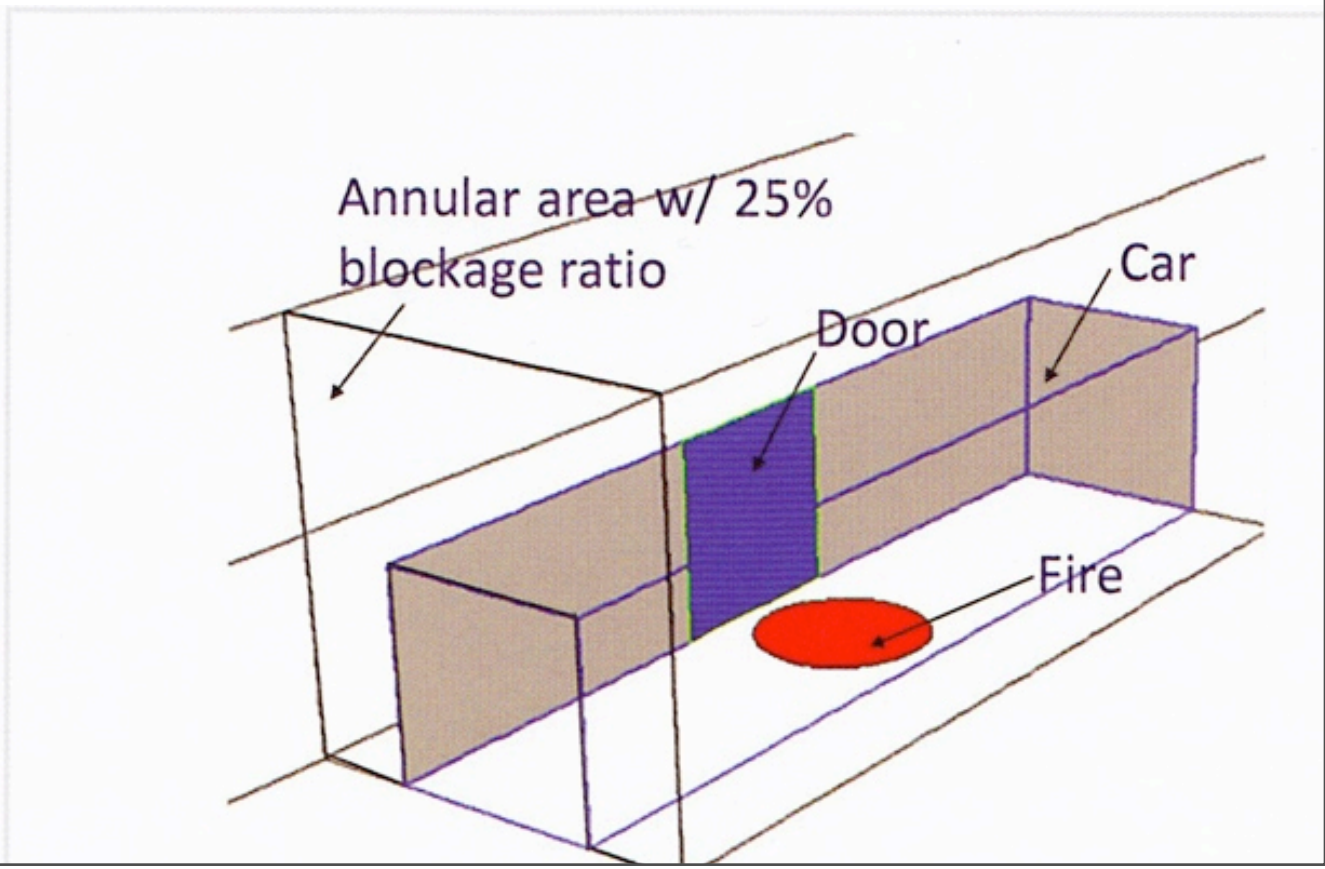


Figure 3. *Comparison of predicted fire HRR as a function of time at different ventilation conditions due to windows fallout*

Working on Uncertaines - Geometric Impact - the fire is affected by the environment

Small scale model used to simulate a fire in a tunnel under a longitudinal air flow.

The combustion reaction rate is modeled as dependent on turbolent mixing of the fuel and oxigen.



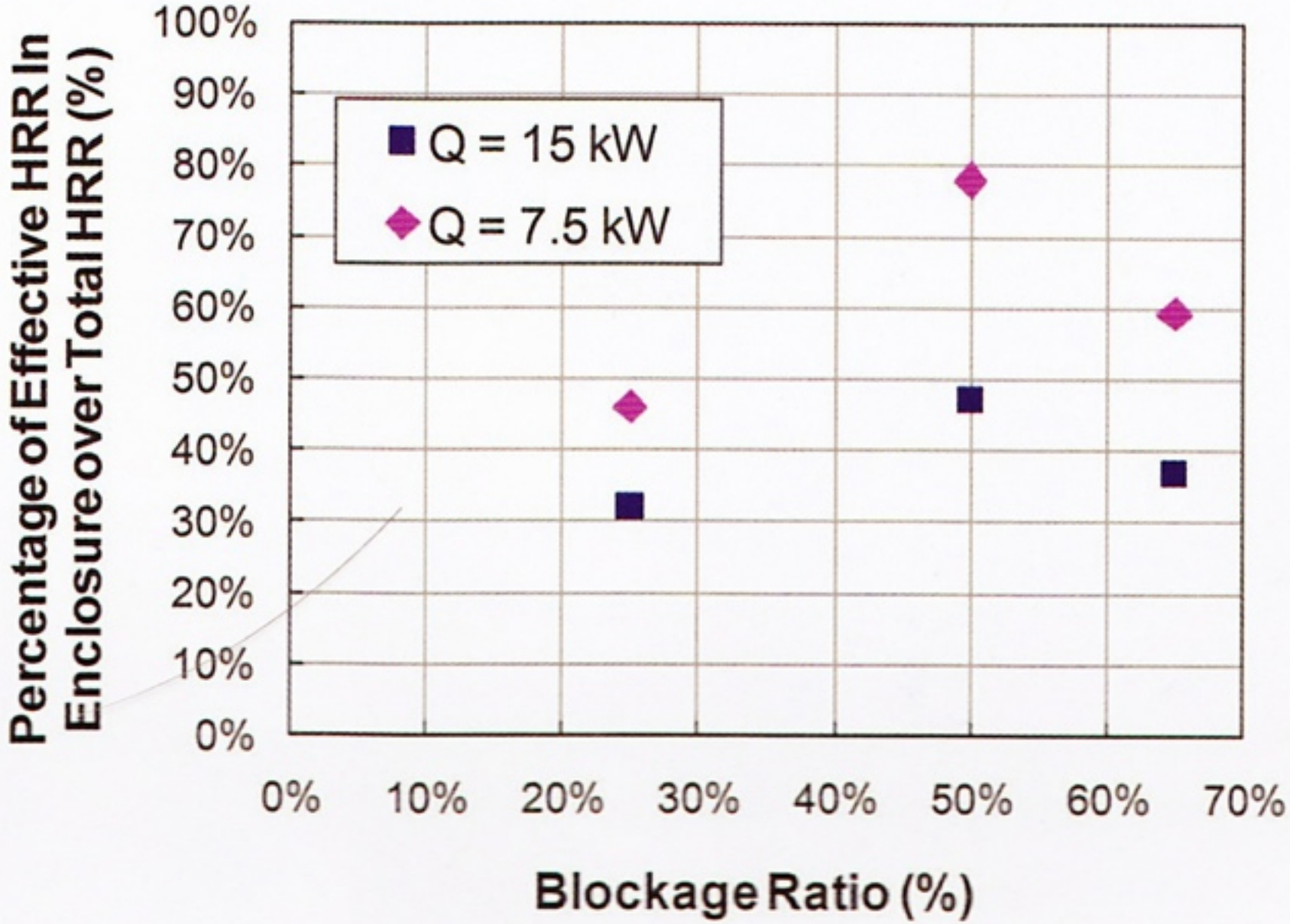


Figure 4. (b) *percentage of effective HRR in the compartment vs. blockage ratio*

- CFD can give an accurate and detailed solution for a fire modelled by a volumetric burner in a specific case, with specific parameters

- Also, we have many uncertain parameters, solutions should be evaluated by experts and validated by results from full scale tests

- Simulating the burning of combustible objects and the spreading of a fire adds further uncertaines...

- Perhaps better focus on keeping models as simple as possible, investing in more simulations...

Thank You.....