Low-energy buildings are increasing the risk of backdraft: myth or reality?

Better insulation and airtightness, today's building are more energy efficient. But could it be that those evolutions will lead to see the backdraft phenomenon more often? Myth or reality, Fire fighter magazine, via Efectis France and their engineer in fire science, throw lights on such matters.

If the casualty link between evolution of buildings content and modification of fire developments kinetics is not to prove anymore, it is still unclear if there's a link between constructive method evolution and backdraft increase. There is still not much in the literature about this subject.

To bring some pieces of answer, some fire dynamics simulations were realized at the beginning of 2013 with the software FDS 5 (fire dynamics simulator). This digital tool has been developed by the National Institute of Standards & Technology (NIST) in the United States of America, and is currently used to treat some tricky prevention case in the field of fire safety engineering.

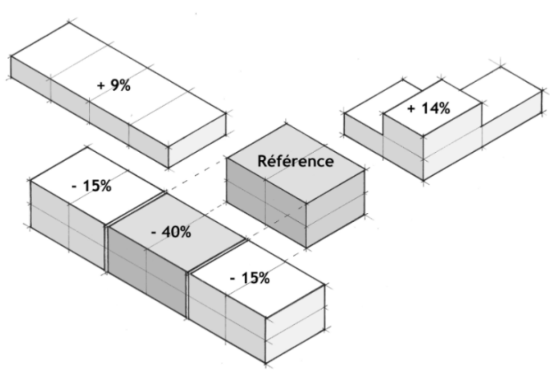
Contextual principles:
In France, 70 % of the energy used in a house is dedicated to heating. To lower this consumption the Minister of sustainable development rely on a tool which has been set up in the 70th following the first oil-shock: the thermal regulation (RT). Since 1974 this regulation set the minimal thermal performances that each new and renovated building must achieve in France. From 1974 to 2005 each regulatory development set expectation 15% to 20% higher than the previous edition, the Grenelle environment has accelerated things.

The RT 2012 (Thermal Regulation 2012) set objectives to lower energy consumption by 60% compared to the RT 2005. This remarkable step is just a transition, in the end the objective is to tend towards energy positive buildings (RT 2020), in other words, create a building stock which produces more energy than it consumes.

To reach this objectives some effort are still to be made to improve the building envelope conception.

Building evolution - The outlines of what's going to change.

Housing compactedness mastery
Limiting exchange surfaces is one basic principle allowing to reduce significantly heating needs for a building. The model conception is directed towards two levels structures, semi detached eventually, with living rooms downstairs and sleeping rooms upstairs. Thermal bridges (heat transfer by conduction) induced by the slab on the first floor must be treated (set up synthetic thermal breaker, floor made of wood or insulation from the outside). The openings have to be favored South and minimized North.



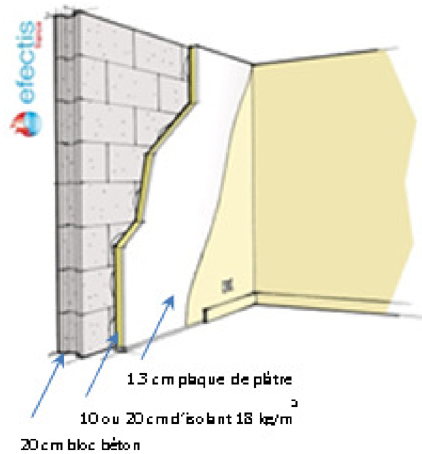
Comparison of heat loss due to the envelope of a building (for 96 m² housing). For the same surface, limiting faces in contact with the outside could result in non negligible savings. Semi detached two floor structure should become a model for standard construction.

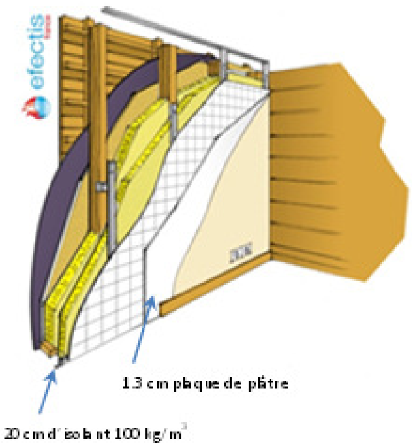
Thermal comfort mastery:
No matter what's the composition of a wall, the face in contact with the outside can be qualified as:

- Insulating
- Insulating-dephasing
- Insulating-dephasing-inertial

Insulating face:

Generic concept in France, the wall is insulated from the inside with a material of low density (<50kg/m^3). This can be, for example, a concrete block wall covered with a 100 mm thick mineral wool (RT 2005) or thicker (reinforced insulation). The insulation is more or less efficient depending of the implemented thickness.



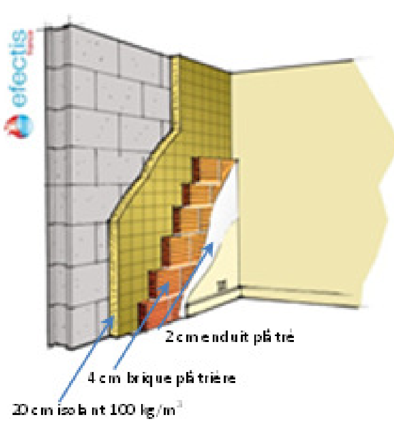


Insulating-dephasing face:

By increasing the density of the insulation material it's possible to slow down the temperature wave progression which crosses the wall, giving the face a dephasing characteristic. Thus, a concrete block wall covered with 200 mm thick mineral wool with a density of 20 kg/m^3 allow a dephasing of 7 hours. This can go to 12 hours for a density of 160 kg/m^3. By using this characteristic a temperature peak at noon would enter the house at midnight; an hour for which windows will be open to allow fresh air to come in. This effect is principally used to insure summer comfort and limit the effect of overheating inside buildings.

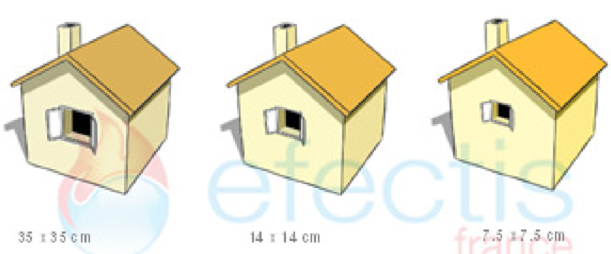
Insulating-dephasing-inertial face:

Thermal inertia will be favored for buildings using passive heating. That property is directly linked to the nature of inside faces covering. The thicker and the highest is the density of a wall, the more it will be able to keep heat and return it later.



Air permeability mastery:

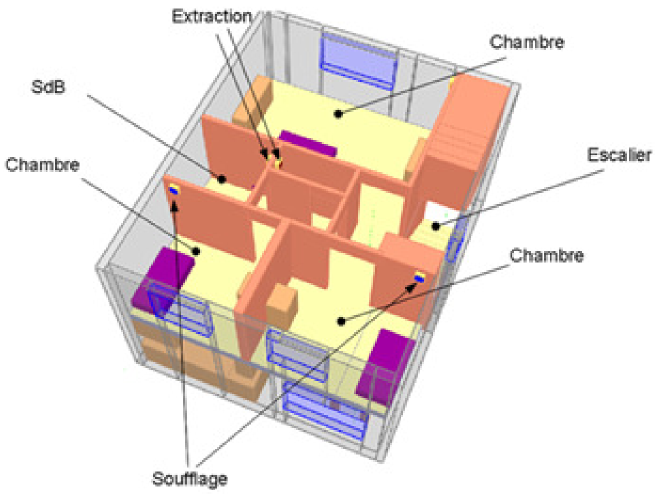
The RT 2012 introduces a new prescription allowing to verify the level of air leak inside a building. If the air leak ratio measurement is quite hard to apprehend, it is still possible to transcribe it into free equivalent surfaces. To do so suppose that all the leak existing for an envelope can be regrouped in one and only point. For housings built accordingly to the RT 2012 and 2020, those points have at most a dimension of 200 cm² and 56 cm² respectively (Or are equivalent of an open window of 14 x 14 cm and 7.5 x 7.5 cm).



A report published by the CETE (oct 2006) state that before application of the RT 2012 that equivalent value was at most of 1 225 cm² (open window of 35 x 35 cm).

Thus it's possible to conclude that envelopes are relatively airtight, from a fire point of view since at least a decade.

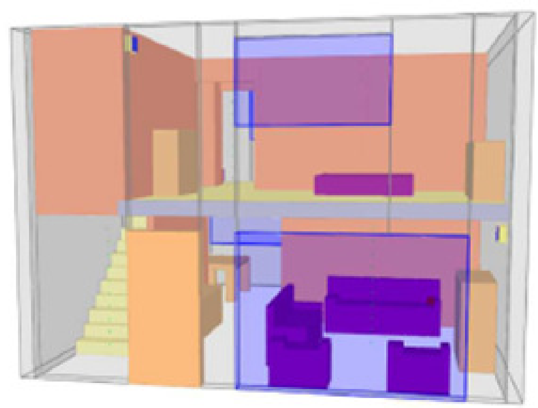
Fire building and the impact of envelope enhancement:



Based on the element presented above a mean standard building was defined as a model. The housing has 2 floors with a surface of 51.2 m² per floor; living rooms are on ground floor and sleeping rooms on first floor. The slab of the first floor is made of concrete and the dividing walls are made of alveolate plaster. The ventilation is insured by an extraction system which can be compared to controlled double flow mechanical ventilation. The peripheral walls are insulated from the inside following the 4 walls concept above:

- Insulating (standard/reinforced)
- Insulating-dephasing
- Insulating-dephasing-inertial

The global architectural conception of the housing will probably remind you of two unavoidable Retex* (feedbacks) which are the fire of Blaina and Keoluk. With no intention to reproduce these two interventions, it's however them which motivated the hypothesis to set the heart of the fire on ground floor. This case is maybe more subject to "accidentology".



In the selected scenario the fire begins in the right corner of a couch in the lounge (23.1 m²). To simulate fire development the simulation tool allows either to:

- Impose the power rise curve of fire which will adapt to its best to the level of ventilation in the damaged place.
- Predict the power rise curve of fire by indicating to the calculation model the properties of each flammable material (pyrolysis model).

Even though it needs more resources (power and calculation time), the second option has been chosen for this case.

**Blaina and Keokuk:*
Blaina's fire (UK) in 1996 was a kitchen fire in 2 floor housing. During the victim search a fast progression of the fire killed two fire fighters and one child.

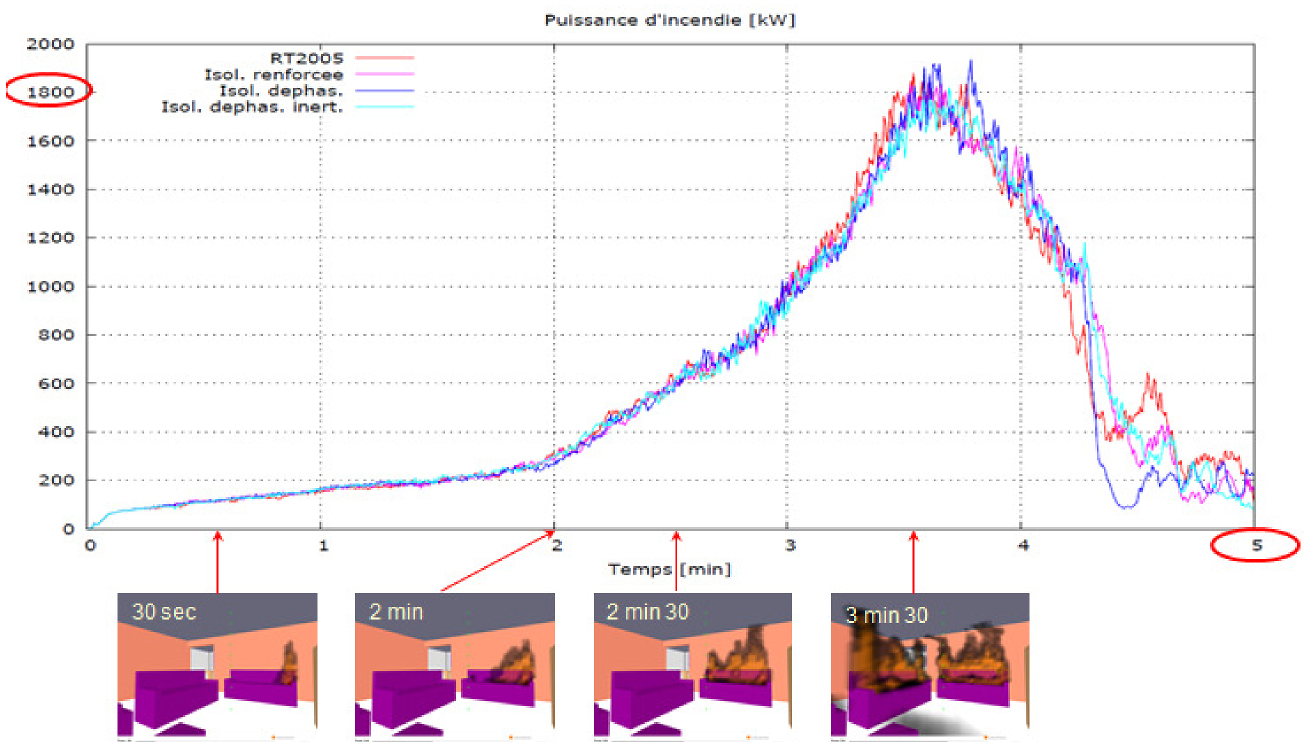
In December 1999 at Keokuk in the state of Iowa (United States) another kitchen fire in a 2 floor housing created a fast fire progression, even if two children were saved, 3 fire fighters and one child were trapped and killed.

These two interventions on 2 floor housing are often referred to as Retex (feedback). They happened in two different countries with three years separating them but the causes and results were the same. The housing compactedness to reduces energy consumption will favor 2 floor housing construction with sleeping rooms upstairs.

Results:

For a better understanding and an easier comparison most of the graphs show curves for each kind of wall simulated on the same drawing.

Power at the heart of the fire:

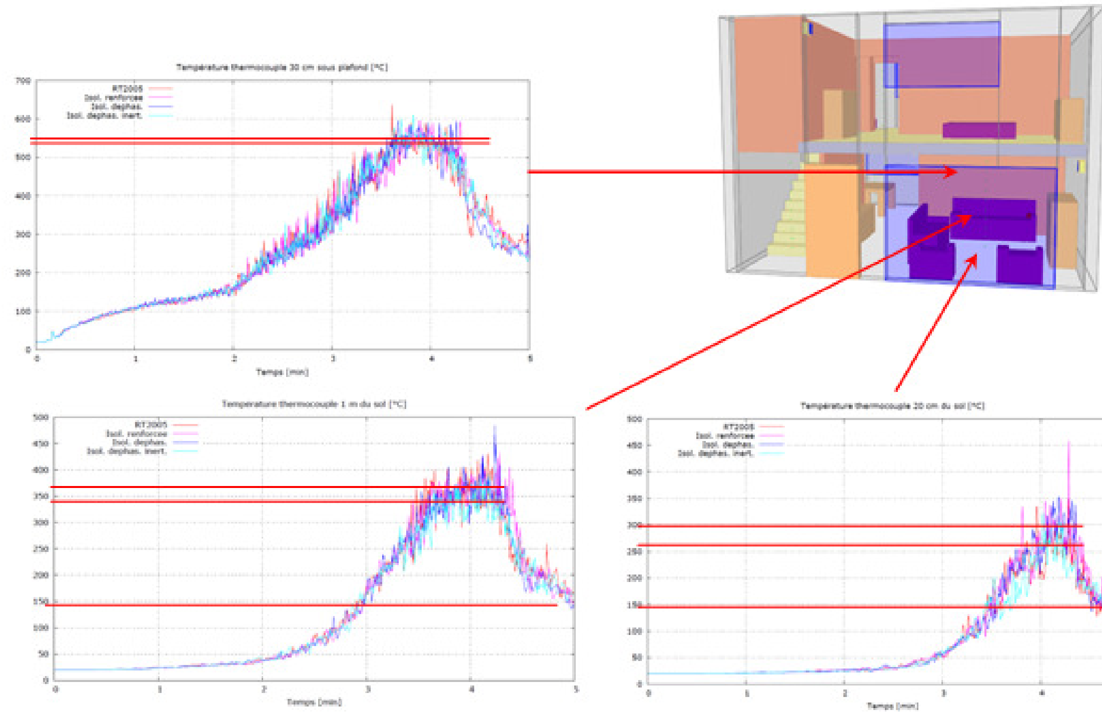


These curves show that in less than 4 min the fire becomes ventilation controlled. If 3 min 40 sec are necessary for the fire to reach his peak (roughly 1800 kW) due to oxygen depletion that power falls to 200 kW in 1min 20s. Walls composition influence over the fire power is not significant for this time scale. At most the difference between one wall and another is 100 kW, which is insignificant.

With that kind of kinetic development (less than 4 min), the walls have no time to play a part. This time is directly “controlled” by the housing capacity to allow fresh air in and reject smoke out. Despite different levels of permeability, transition times for fire control (fuel controlled vs. ventilation controlled) are quite similar.

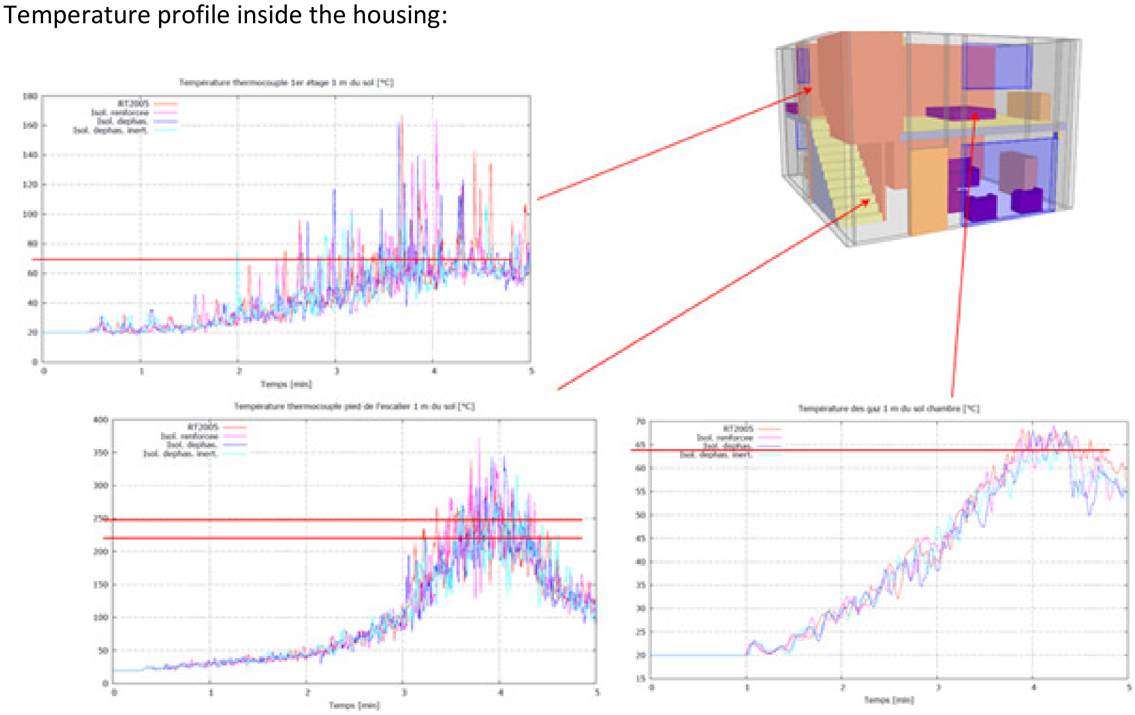
Temperature measurements were made with some thermocouples in the middle of the living room. For a better readability 3 measurements were followed and reported below:

- Measurement at 0.30 m below the ceiling
- Measurement at 1 m from the floor
- Measurement at 0.20 m from the floor



In the living room temperature differences between all the case studied are not really significant (50°C approximately). The three graphs above show that a victim lying on the floor has no chance to survive no matter what's the construction type. Curves at 1 and 0.2 m from the floor indicate a stabilized convergence around 150°C which will fall under 100°C after 15 minutes. It's interesting to know these temperatures because they form the thermal constraint level of materials placed at those heights (furniture, floor covering etc…).

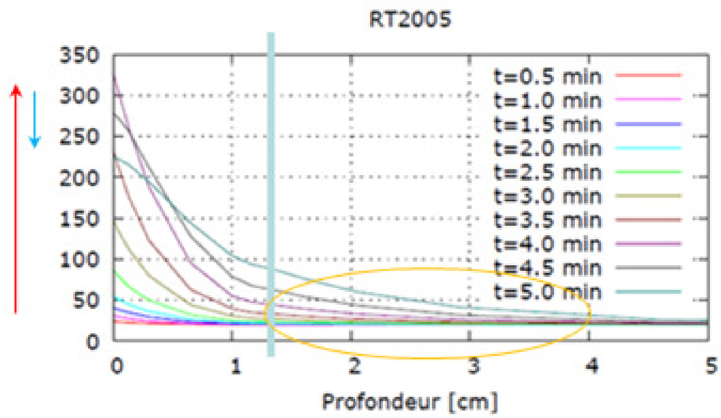
Temperature profile inside the housing:



Drawings above allow to see that no matter what's the insulation level of the peripheral walls the temperatures are roughly the same. A victim down the stairs will have almost no chance to be saved (intoxication / burn). A victim upstairs should not be heavily burnt.

Therefore engaging a team to save upstairs victim is entirely justified.

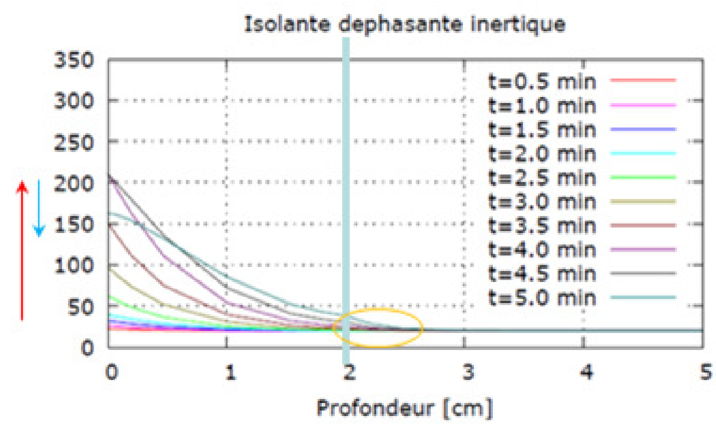
For a better understanding on the part played by the peripheral walls and how a temperature front spread inside those elements, temperature evolution inside the same wall was calculated.



This first graph shows the distribution profile of the temperature front progression in the thickness of the wall as a function of time. This wall is composed of a 13 mm plaster slab and 100 mm of mineral wool with a density of 18 kg/m^3. From a thermal point of view the most aggressive curve is obtained at 3 min 30 sec (almost 350°C). After crossing the 13 mm of plaster the residual temperature entering the insulation is below 100°C. After a progression of little less than 3 cm in the insulation, there is no more heat. This graph allows to understand why an insulation thickness higher than 5 cm will change nothing to what happen behind her. Therefore, an insulation of 5 cm, 20 cm or more will have no impact on temperature conservation in the housing.

To increase the dephasing factor insulation density was increased to 100 kg/m^3. After 3 cm of wall, heat transfer stopped because the temperature difference between the transferred wave and the insulation own temperatures are equal at that distance.

For the last case inside covering is realized with 4 cm of plasterwork brick covered with a 2 cm layer of plaster. The density of those two elements is superior to the density of plaster slab, so the wall need more thermal energy to increase its temperature. Energy is taken from hot fumes released by the fire, and is stocked inside dense materials and so is not able to heat deeper layer of the wall. That's why the attack on the inside face of the wall is done by hot fumes with a lower temperature (around 200°C). In the end, once the 2 cm plaster covering is passed, residual temperature entering the brick is quickly absorbed and there is no other possible exchange.



Those graphs demonstrate that the thickness of the insulation has no influence on the conservation of temperature level produced by the fire. Each layer composing the wall being at 20°C (equilibrium temperature before fire), they will only play their part in temperature conservation once they will reach their new equilibrium temperature. To keep a high temperature inside the room, the wall would have to be at that same temperature. This is possible almost 10 minutes after the fire begins, the temperature find its equilibrium around 100°C in the worst case. Density of the inside face of the wall is acting like an energy "pit" which allow to reduce hot fumes temperature level kept inside the building.

Conclusion:

From a thermal efficient housing point of view, past and coming evolutions are a real improvement for energetic resources management. They are subject to a lot of interrogations concerning fire safety, especially for closed room fire. Results obtained in this study do not show obviously that the orientation taken in the Thermal Regulation will increase Backdraft phenomenon occurrence.

However this phenomenon, which should remain unusual, is not a myth and it’s important for rescue teams to keep it in mind. Triggering a Backdraft is almost always resulting from an inappropriate operational procedure.

Conclusions that could be drawn from this study are bolstered by feedbacks from our North European counterparts, pioneer in the field of thermal efficient housing. They have not seen an increase in the number of backdraft for the last decades, as the eminent Dr Stefan Svensson can attest it. Dr Svensson has been working for some years on fire behavior issues in collaboration with the Swedish national civil defense.