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1 **Experimental study of the large scale flammability of wood cladding at the**
2 **wildland-urban interface**

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10 **Highlights:**

- 11 • Ignitability of wood cladding at the Wildland-Urban Interface
- 12 • Fire spread from a vegetation hedge to a building material
- 13 • Comparison of the critical heat flux for ignition at material and large scale

14 **Abstract:**

15 The aim of this work is to improve the understanding of the fire behaviour of building
16 materials used in the wildland urban interface at a large scale. To this end, wood cladding
17 was exposed to the heat flux from the burning of a cistus hedge ignited by a spreading fire
18 front in a fuel bed of excelsior litter. Six experiments were performed with different
19 configurations: hedge/cladding distance, cistus bulk density, hedge length. During the
20 experiments, the assessment of the cladding ignition was observed by camera. Wind
21 direction and velocity were measured continuously since the tests were conducted outdoors
22 and wind is a significant driver of flame spread. Heat fluxes and temperatures were also
23 measured in order to compare the intensity of the thermal aggression on the cladding
24 coming from the burning hedge. When the distance between the hedge and the cladding
25 was 3 m, the wood did not ignite even when the wind was in the direction of propagation
26 towards the cladding. In these cases, the maximum heat flux was $18 \text{ kW}\cdot\text{m}^{-2}$. This value
27 did not allow the ignition of the wood cladding. When the distance was reduced, the
28 ignition of the cladding depended on the wind direction. When the cladding was ignited,
29 the heat fluxes from the burning hedge could exceed $100 \text{ kW}\cdot\text{m}^{-2}$.

30 **Keywords:** WUI fire; wood cladding; fire spread; safety distance

31 **1. Introduction**

32 Wildland-Urban Interface (WUI) fires are a recurring issue around the world due to the
33 high number of destroyed dwellings [1, 2]. A statistical study shows that the best way for
34 homeowners to reduce the risk of these fires is through preparation and active defence. In

35 fact, an unprepared home is 10 times more likely to be affected by a fire [3]. As a result,
36 Australia and the United States have established recommendations on the vulnerability of
37 building materials to wildfire, such as minimum water supply, or defensible space around
38 dwellings [4]. These guidelines were determined through post-fire investigations in which
39 houses were exposed to wildfires [5, 6]. In Australia, regulations for fire prevention in the
40 WUI are set out in AS 3959-2018 which sets Bushfire Attack Levels (BAL) based on
41 vegetation and ground topography [7]. In the United States, recommendations concerning
42 the distance between the house and the vegetation vary from state to state, with a
43 minimum distance of 1.5 m in California (and now expanding to other regions) [1]. This
44 distance is still under discussion with stakeholders. As for the other recommendations for
45 distances beyond 1.5 m, these are rather vague. On the other hand, in Europe, regulations
46 are limited despite the large number of fires that occur there [8, 9] and the presence of
47 materials that can be damaged by a wildfire in the WUI [10, 11]. Some countries have their
48 own rules about the distance between hedges and house walls. It can be 2 m in Portugal or
49 Italy, or three times the height of the vegetation in France, with a minimum distance of 3
50 m. These different distances observed around the world therefore show that there is no
51 consensus on the minimum safety distances to be specified in the forest fire / bushfire
52 prone areas.

53 The Mediterranean, Australian and Californian are regions where forest fires are significant
54 and destroy homes every year. These fires can in some cases be caused by the spread of fire
55 from one house to a second [12, 13] or one material to another. Among the materials that
56 can be a vector for the fire spread, cladding, is a key element as it can propagate a surface
57 fire to the most vulnerable points of a building, including openings, roofs or vents. With
58 the popularity of bio-based materials in buildings, wood has become a commonly used
59 material for walls, whether in new construction or renovation. It is therefore important to
60 study how wood reacts to the effects of vegetation fire, as this material can spread fire to
61 weak points such as the under-eave or windows, vents, etc. Studies of the fire behavior of
62 cladding are varied, ranging from the material scale with cone calorimeter tests [14, 15] to
63 the large scale with a fire escaping from a compartment vent [16]. Nevertheless, these types
64 of experiments are different from the conditions that may be encountered during a WUI
65 fire. With regard to the coupling between wildland fires and building materials, studies are
66 limited and the most widely used study of wooden walls subjected to a representative fire
67 ignition in a WUI is that of Cohen et al. [17]. Cohen et al. observed that the walls ignited
68 but were self-extinguished at the same time as the crown fire for the distances tested
69 between the walls and the forest. Grishin et al. [18] observed through field experiments
70 that a wooden structure did not ignite during a wildfire when the distance of the fire from
71 the structure was 5 m, as the temperature and heat flux data remained low. The radiation
72 threshold for ignition of external building elements containing wood such as cladding is
73 estimated at 12.5 kW.m^{-2} according to [19].

74 To the best of our knowledge, there are no other large scale outdoor experiments that have
75 studied the effect of a vegetation fire on a wood cladding.

76 The aim of this work is to study the fire behaviour of a large scale wood cladding exposed

77 to the combustion of a hedge in order to contribute to the knowledge base of the distance
78 between the vegetation and the constructions. For this, six experiments were carried out
79 with burning hedges to investigate the impact of the fire on the cladding by assessing the
80 influence of the wind and that of the distance between the hedge and the cladding.

81 **2. Materials and methods**

82 The aim of this work is to investigate the fire reaction of wood cladding following the
83 burning of a large scale *cistus monspeliensis* hedge. This Mediterranean species is present
84 in a large part of the scrubland and garrigue, but is also used as an ornamental species.
85 Prior to this, 40 tests were performed using a cone calorimeter in order to assess the
86 conditions leading to the ignition of the wood cladding in front of a controlled heat flux.

87 **2.1 Wood cladding**

88 The cladding used for the experiments was made of scotch pine with an average density of
89 $350 \text{ kg}\cdot\text{m}^{-3}$. The wooden slats purchased were 4 m long, 13 cm wide and 1.8 cm thick
90 horizontal tongue and groove lap siding product.

91 **2.2 Cone calorimeter experiments**

92 A preliminary study was carried out using a cone calorimeter in order to determine the
93 ignition conditions of wood cladding in terms of exposure time and heat flux. The wood
94 samples used were pine, oven-dried at $105 \text{ }^\circ\text{C}$ for 24 hours. They were taken from the
95 cladding boards and cut to a size of $10 \times 10 \text{ cm}^2$. For each test, the sample was wrapped in
96 a double layer of aluminium and placed in a steel sample holder. The rear unexposed side
97 was insulated with a ceramic wool and then with a ceramic plate, all held in place by the
98 locking system. The samples were exposed to heat fluxes ranging from 15 to $45 \text{ kW}\cdot\text{m}^{-2}$ in
99 a vertical orientation until ignition occurred or up to 25 min. The distance between the
100 cone heater and the sample was 25 mm and a spark was used for pilot ignition. Shields et
101 al. [20] showed that the ignition times were similar for flame and spark ignition using a
102 vertical configuration of the cone calorimeter.

103 **2.3 Large scale experiments**

104 Six large scale tests were conducted outdoors in a flat, open area. The cistus hedge was
105 ignited by flame propagation in a fuel bed of excelsior used as a surrogate for a herbaceous
106 strata. This type of fuel bed is often used in laboratory experiments because it burns easily
107 and without residue. In addition, the flame front produced when the excelsior wood wool is
108 ignited is more homogeneous than with natural vegetation and is only intended to ignite
109 the hedge. In the Mediterranean region, the cistus is a native species that is common on
110 acidic soils in southern Europe. It is very specific in terms of its flammability, as it can
111 have a very low moisture content in summer, which makes this species very deleterious if it

112 is close to buildings in the WUI. This is the reason for the focus on this species. *Cistus* has
 113 been characterised on numerous occasions with laboratory scale tests [21, 22]. Figure 1
 114 shows the detailed configuration of the experimental setup.

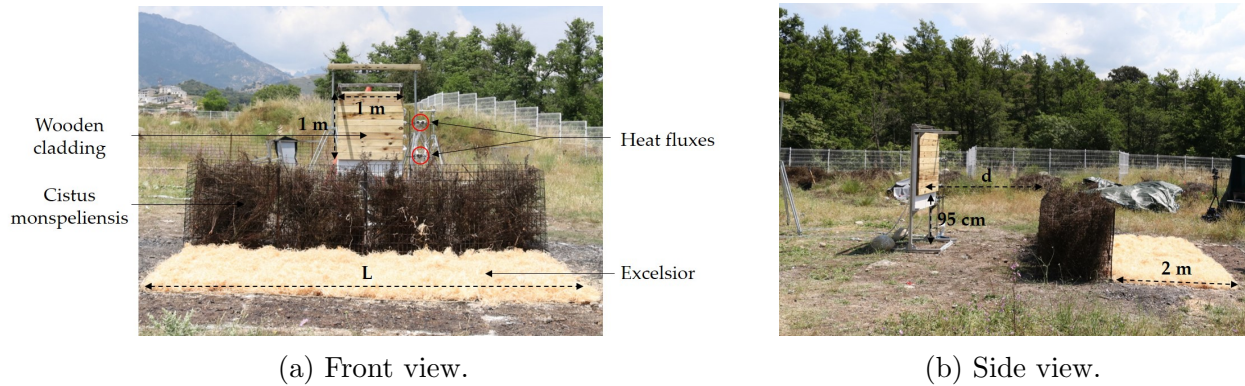


Fig. 1. Experimental setup.

115 The length L (Figure 1a) was related to that of the excelsior litter and the *cistus* hedge and
 116 varied from 2 to 4 m depending on the experiment (Table 1). The width of the litter was 2
 117 m and the pine excelsior litter had a fuel load of $1 \text{ kg}\cdot\text{m}^{-2}$ and a moisture content around 5
 118 % for all experiments. A *cistus* hedge was reconstructed with branches homogeneously
 119 placed in a welded mesh cages of 1 m^3 . The bulk density of the *cistus* was varied from 8 to
 120 $12 \text{ kg}\cdot\text{m}^{-3}$ in order to observe the influence on the ignitability of the cladding. For each
 121 experiment, the fuel bed of wooden wool was ignited along its entire length L using a
 122 butane burner.

123 The wood cladding was made of pine and was fixed to the cellular concrete with 28 mm
 124 thick pine cleats. Each plank was 10 cm high and 20 mm thick. The cladding was cut to
 125 obtain a section measuring into $100 \text{ cm} \times 100 \text{ cm}$ sections, i.e. 10 boards stacked vertically.
 126 The cladding and the cellular concrete were mounted on a support in order to achieve a
 127 height of 95 cm for the lower part of the cladding. The cladding was centered on the hedge
 128 and the distance, d , between the hedge and the cladding was fixed at 2 or 3 m, depending
 129 on the experiment. The six tests were carried out on the same day in June, with the
 130 ambient temperature varying between $35 \text{ }^\circ\text{C}$ for test 1 to $40 \text{ }^\circ\text{C}$ for test 6. These
 131 temperature conditions were representative of the temperatures encountered in vegetation
 132 fires.

133 As the tests were conducted outdoors, the wind was uncontrolled and was a determining
 134 factor in the spread of the fire and therefore the likelihood of the wood cladding ignition.
 135 Therefore, a standing anemometer was placed 15 m behind the cladding to continuously
 136 measure the direction and velocity of the wind. If the wind direction is 0° , then it is
 137 assumed that the wind is in the direction of propagation and perpendicular to the
 138 cladding. It is in this direction that the conditions are most favourable for the flame front
 139 to be tilted towards the cladding. It is also assumed that if the angle is greater than $\pm 45^\circ$,

Table 1: Variation of the experimental parameters for each test (cistus/cladding distance (d), cistus bulk density (ρ_b), hedge length (L), hedge mass (m_h), excelsior mass (m_e)).

Tests	d (m)	ρ_b (kg.m ⁻³)	L (m)	m_h (kg)	m_e (kg)
1	3	8	2	16	4
2	3	8	4	32	8
3	2	8	4	32	8
4	2	8	4	32	8
5	2	8	4	32	8
6	2	12	4	48	8

140 the wind direction is still in the propagation direction, but shifted to the right or to the
141 left. Finally, if the wind direction is greater than $\pm 90^\circ$, it is in the opposite direction of
142 fire spread. In this condition, it is very unlikely that the flame will hit the cladding.
143 For each test, temperatures and heat fluxes received by the cladding were measured. As
144 shown in figure 1a, all the measurements were located to the right of the cladding. Eight
145 K-type thermocouples were stapled on the cladding. Four were attached to the front side
146 and four to the rear side at 15, 35, 55 and 65 cm from the base of the cladding and 10 cm
147 to the right side. Grooves were made in the surface of the wood to match the diameter of
148 the thermocouple (1 mm) so that they could be placed and stapled in place, ensuring
149 contact between the tip of the thermocouple and the wood. Two pairs of heat flux gauges
150 (by Medtherm) were placed at 1 and 1.5 m from the ground and 20 cm from the cladding.
151 For each pair, one measured the radiant heat flux (range [0-100] kW.m⁻²) and the other
152 measured the total heat flux (range [0-200] kW.m⁻²). The water used to cool the
153 fluxmeters was stored in a water chiller in order to maintain a constant temperature all day
154 outdoor during the tests. Finally, two cameras were used to record the experiments: one
155 from the side of and one from the front behind the pine wool. All the measurements were
156 triggered simultaneously with a sampling rate of 1 Hz.

157 3. Results and discussion

158 3.1 Tests at material scale (using the cone calorimeter)

159 Table 2 shows the average ignition times calculated from three tests and the standard
160 deviations as a function of heat flux.

Table 2: Time-to-ignition (t_{ig}) according to the imposed heat flux.

Heat flux (kW.m ⁻²)	10	15	20	25	30	35	40	45
Mean t_{ig} (s)	1540	398	152	49	28	25	19	16
Std t_{ig} (s)	289	28	68	5	6	3	5	4

161 Times-to-ignition decreased with increasing heat flux. The standard deviation is higher for

162 fluxes close to the critical heat flux. This is consistent with the literature [23, 24, 25]. This
163 is due to the fact that close to the critical heat flux, ignition can be either caused by the
164 embers on the surface of the wood or by the pilot. This resulted in considerable variability
165 in ignition times. To achieve an ignition in less than one minute, the cladding had to be
166 exposed to a heat flux higher than 25 kW.m^{-2} . Additional tests were carried out without a
167 pilot to determine the critical heat flux for an auto-ignition. The cladding only
168 spontaneously ignites at 45 kW.m^{-2} for times greater than 840 s. Ignition did not happen
169 for each test at 45 kW.m^{-2} and never occurred at lower heat fluxes. These results are in
170 good agreement with work investigating spontaneous ignition of wood in a vertical
171 orientation [26, 27]. For auto-ignition to occur in less than 1 minute, the imposed heat flux
172 must to be at least 55 kW.m^{-2} in vertical orientation [26].

173 **3.2 Tests at large scale**

174 In each experiment, the flame spread in the wooden wool and then ignited the cistus hedge.
175 The fire then spread throughout the hedge, thermally attacking the wood cladding at
176 different rates and intensities depending on the experimental conditions and the wind.
177 Figure 2 shows pictures of two tests corresponding to both hedge lengths of 2 and 4 m from
178 the time of hedge ignition (t_{igh}). The wind direction and velocity are provided in each figure
179 with an additional compass rose. Figure 2 shows the photographs of the different stages of
180 combustion for tests 1 and 2, where the cistus bulk density and the distance from the
181 cladding d were the same. Figure 3 shows the wind velocity and direction during the tests
182 from the ignition of the cistus hedge. For each figure, the zone between the green dotted
183 lines ($\pm 45^\circ$) represents the wind direction that will be in the direction of fire propagation
184 towards the cladding. Between the green and red dotted lines, the wind will still be in the
185 direction of spread, but will be shifted to the right or to the left of the cladding.




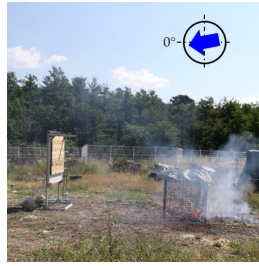

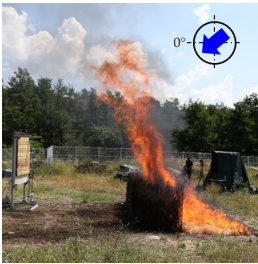

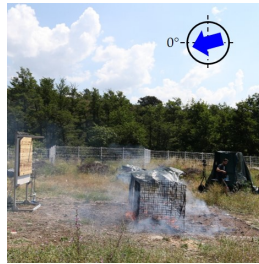
Tests	Hedge ignition (t_{igh})	$t_{igh} + 9$ s	$t_{igh} + 25$ s	$t_{igh} + 94$ s
1	WV: 1.7 m.s^{-1} WD: -5.6°	WV: 1.2 m.s^{-1} WD: -30°	WV: 1.6 m.s^{-1} WD: 2.8°	WV: 2.2 m.s^{-1} WD: 2.8°
$L = 2$ m				
2	WV: 1.9 m.s^{-1} WD: 31°	WV: 1.6 m.s^{-1} WD: 29°	WV: 1.5 m.s^{-1} WD: 35°	WV: 1.5 m.s^{-1} WD: 6°
$L = 4$ m				

Fig. 2. Pictures of the tests 1 and 2 with $d = 3$ m, $\rho_b = 8 \text{ kg.m}^{-3}$ (WV: Wind Velocity, WD: Wind Direction).

186 The important variations in wind direction and velocity show the difficulty of conducting
187 outdoor tests. The flame spread in the hedge for test 1 was very fast, with almost all of the
188 cistus having burned 25 s after ignition. The shape of the flame front at $t_{igh} + 9$ s and
189 $t_{igh} + 25$ s was inclined towards the wood cladding. This was mainly due to the wind
190 direction during the test, which was close to the axis of propagation: on average $\pm 0^\circ$ with
191 an average velocity of 1.8 m.s^{-1} during the first 30 seconds after ignition, when the flame
192 front was most prominent. In test 2, the flame spread was slower, both because the wind
193 was away from the axis of spread and because the average wind direction during the
194 burning of the hedge in test 2 was $\pm 54^\circ$ at a speed of 1.9 m.s^{-1} . The time of flame
195 residence in the hedge was 76 s and 96 s for tests 1 and 2 respectively. This difference is
196 mainly due to the smaller size of the hedge in test 1.

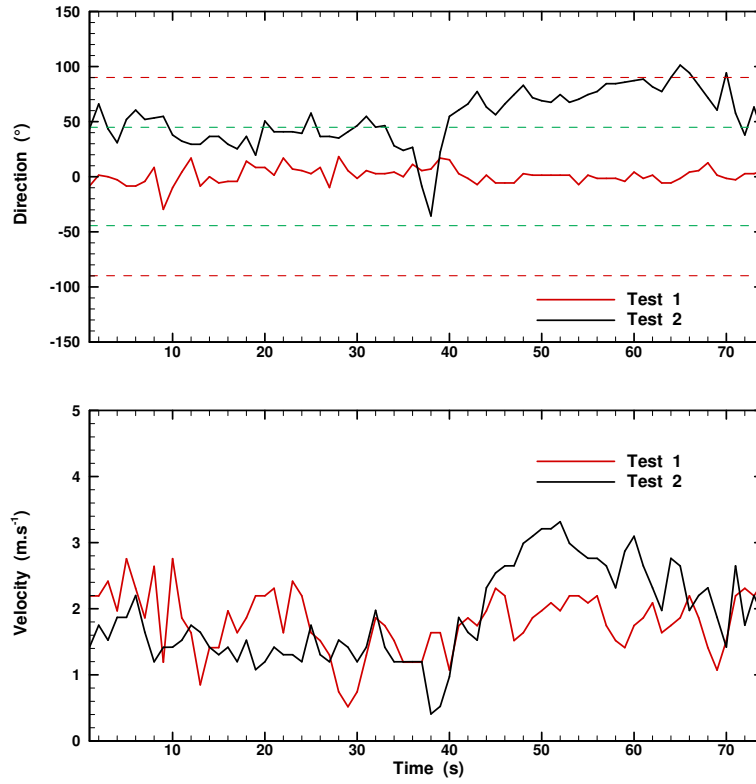


Fig. 3. Direction and velocity of wind during the tests 1 and 2.

197 Figure 4 compares the heat fluxes and the mean temperatures at the front face of the
 198 cladding for the tests 1 and 2. The temperatures measured at the rear of the cladding for
 199 tests 1 and 2 were constant and did not exceed 35 °C.

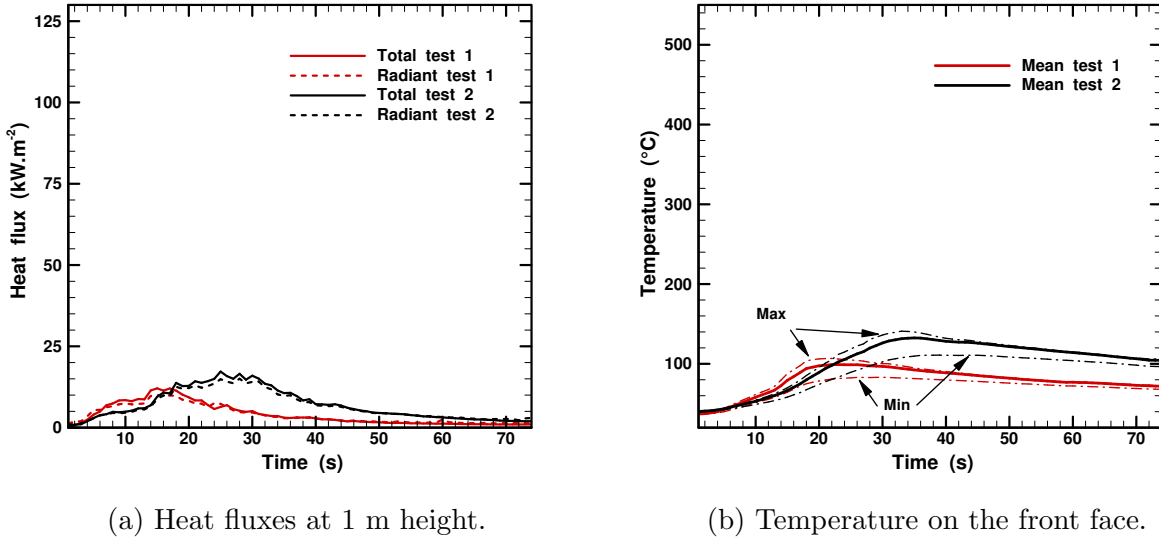


Fig. 4. Heat flux and temperature measured for tests 1 and 2 after the cistus hedge ignition.

200 In general, the heat flux and temperature of the front face increase rapidly as the cistus
 201 ignites, reaching a peak value when the fire is fully developed. After the peak, heat flux
 202 and temperature decrease rapidly as the fire intensity decreased. In both tests, the
 203 radiative heat flux was very close to the total heat flux, showing that radiation was the
 204 dominant heat transfer and that the flame, did not reach the device. For test 1 with a 2 m
 205 long hedge, the maximum total heat flux was 12 kW.m⁻². For test 2 with a 4 m long
 206 hedge, the heat flux reached 17 kW.m⁻². Despite the less favourable wind direction for test
 207 2, the heat flux received by the cladding was higher due to the length of the hedge and
 208 therefore a higher heat released. For both tests, the measured heat flux was in the range
 209 that allows the cladding to ignite on the cone calorimeter scale but the time was too short
 210 (less than 30 s) to allow the release of flammable gases. In fact, it has been shown on a
 211 laboratory scale that ignition was possible if the exposure to 15 kW.m⁻² time was at least
 212 370 s. On the other hand, for test 2, the heat fluxes and the temperatures increased with a
 213 time delay of 10 s compared to test 1. This difference may be due to the wind direction,
 214 which increased the propagation time. As for the heat fluxes, the maximum temperatures
 215 recorded during test 2 were higher than those of test 1: 140 and 110 °C respectively.
 216 According to the two tests carried out, the distance of 3 m between the wood cladding and
 217 the hedge prevents the building material from igniting in such wind conditions. The
 218 cladding was always centered in relation to the hedge. The flame did not reach the
 219 cladding and the heat flux conditions did not allow the wood to ignite. On the other hand,
 220 the risk of ignition may increase if the exposure time is extended by a denser hedge that
 221 would burn for a longer period.
 222 Figure 5 shows pictures for tests 3, 4 and 5. The configuration of these three tests was the
 223 same, with d reduced to 2 m, compared to the previous experiments presented in Fig. 2.













Tests	Hedge ignition (t_{igh})	$t_{igh} + 9$ s	$t_{igh} + 25$ s	$t_{igh} + 94$ s
3	WV: 1.2 m.s^{-1} WD: 41° 	WV: 0.6 m.s^{-1} WD: -8° 	WV: 2 m.s^{-1} WD: -85° 	WV: 1.2 m.s^{-1} WD: -110° 
4	WV: 0.2 m.s^{-1} WD: 115° 	WV: 2.8 m.s^{-1} WD: 4° 	WV: 1.8 m.s^{-1} WD: 58° 	WV: 1.1 m.s^{-1} WD: -14° 
5	WV: 2.1 m.s^{-1} WD: -41° 	WV: 1.7 m.s^{-1} WD: -58° 	WV: 1.7 m.s^{-1} WD: -94° 	WV: 2.3 m.s^{-1} WD: -15° 

Fig. 5. Pictures of the tests 3, 4 and 5 with $d = 2$ m, $\rho_b = 8 \text{ kg.m}^{-3}$, $L = 4$ m (WV: Wind Velocity, WD: Wind Direction).

224 The general description of the steps is similar to that given above. However, the pictures
225 show that the spread of the fire and the thermal aggression on the cladding are different for
226 each test. Ignition occurred only in test 3 because the flames reached the cladding. Figure
227 6 shows the wind direction and velocity during these tests. The wind direction during the
228 first 20 s after ignition of the hedge is indeed close to 0° , resulting an inclination of the fire
229 front towards the cladding. The cladding degraded, as indicated by the change in color and
230 finally ignited (Fig. 7). However, the flame self-extinguished immediately as soon as the
231 rate of burning of the hedge decreased. In tests 4 and 5, the flame front was slightly
232 inclined towards the cladding or was vertical. This was due to the direction of the wind,
233 which was between 45 and 90° during the first 30 s after the hedge was ignited. As a result,

234 the flames did not reach the wood cladding. No ignition was observed and the cladding did
 235 not scorch, indicating that it did not undergo thermal degradation. These experiments
 236 show that under the same conditions, ignition of the cladding is possible as long as the
 237 average wind velocity is 1.3 m.s^{-1} and the direction is less than -20° to the cladding. On
 238 the other hand, even if the average wind velocity increases (1.8 m.s^{-1} for test 4 and 2.5
 239 m.s^{-1} for test 5) but the direction is on average 50° to the axis of the cladding, then it will
 240 not ignite. The characteristics of the wind (velocity and direction) will therefore have a
 241 significant effect on the ignition of the cladding. However, these results should be treated
 242 with caution as these experiments only considered part of the cladding. The presence of a
 243 building can indeed induce air recirculation for strong winds, as shown by Hedayati *et al.*
 244 and therefore influence the inclination of the flame and the ignition of the cladding [28].
 245 Figure 8 shows the average cladding temperatures measured from the four thermocouples
 246 placed on the front side and the heat fluxes at 1 m height.

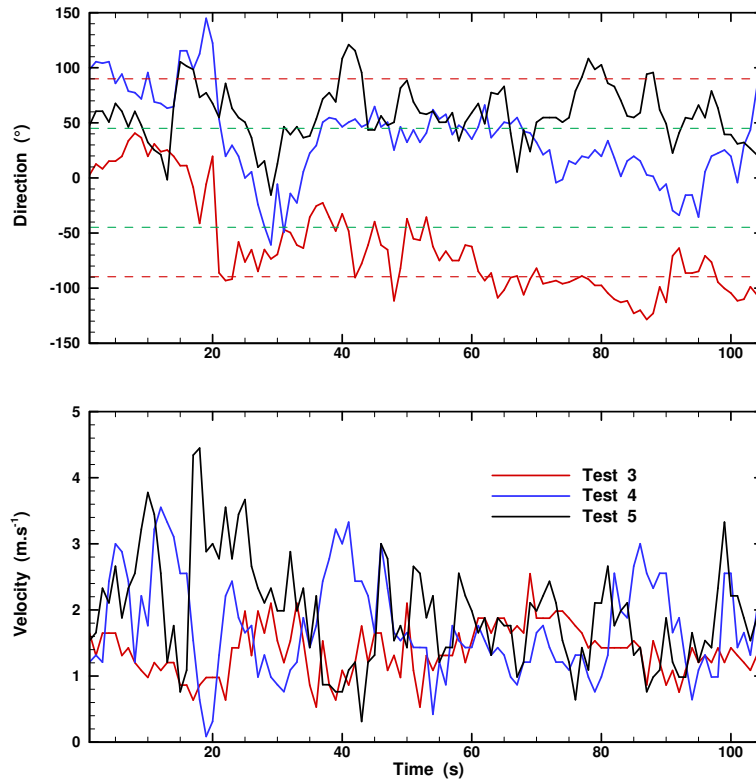


Fig. 6. Direction and velocity of wind during the tests.



Fig. 7. Wood cladding after the test 3.

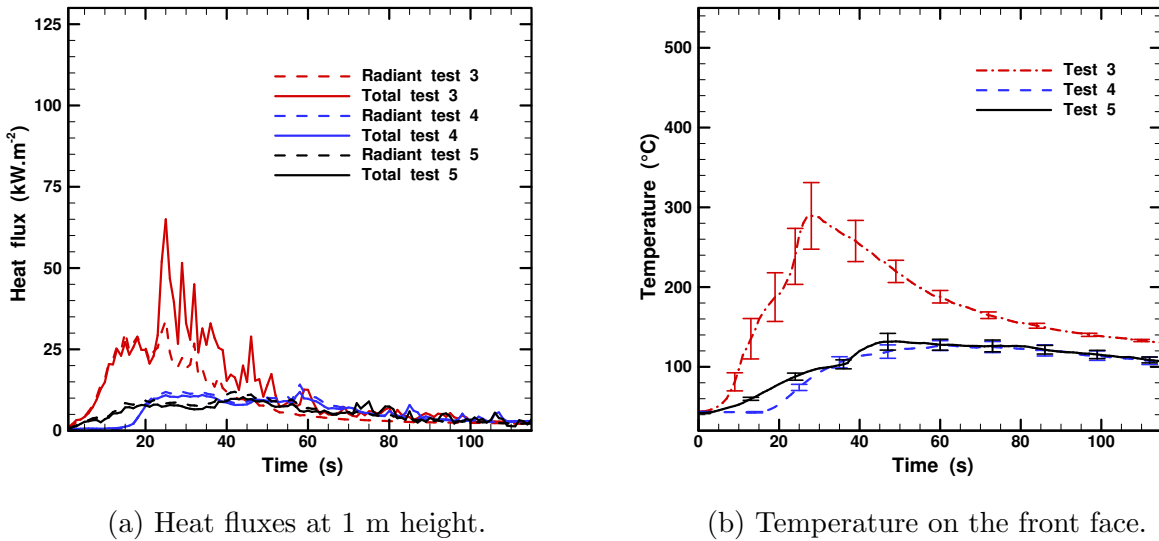


Fig. 8. Heat flux and temperature measured for tests 3, 4 and 5 after the cistus hedge ignition.

247 For tests 4 and 5, the heat fluxes did not exceed $12 \text{ kW}\cdot\text{m}^{-2}$. For these tests, the total and
 248 radiant heat fluxes were close. The cladding therefore received mainly radiation, as the
 249 flames were slightly inclined towards the cladding. The heat flux received by the cladding
 250 was not sufficient to cause ignition during the burning time of the hedge. According to the
 251 cone calorimeter experiments, the heat flux on the cladding would have been twice as high
 252 for ignition with an exposure time of less than 100 s. This is also visible from the

253 temperature curves. For tests 4 and 5, the maximum temperature recorded is around 130
 254 °C, which is not sufficient to degrade the wood [29]. The temperature would need to exceed
 255 200 °C for the pyrolysis process to start [30]. For test 3, the heat fluxes varied more
 256 significantly, especially after 20 s and were much higher than in tests 4 and 5, with values
 257 up to 35 kW.m⁻² for the radiant flux and 68 kW.m⁻² for the total heat flux. This
 258 difference is due to the flame burning close to the heat flux meters as the flame front is
 259 more inclined. This leads to an increase in the total heat flux as the hot gases released by
 260 the flame reach the sensor. An increase in the variability of the heat flux due to the
 261 flapping of the flame was observed. In test 3, ignition of the cladding occurs. This is
 262 consistent with the cone calorimeter results. At the large scale, the total heat flux actually
 263 reached 31 kW.m⁻² for a time of 30 s, which is sufficient to ignite the cladding according to
 264 Table 2. In terms of temperature, the heat fluxes received by the cladding allow it to reach
 265 temperatures in excess 300 °C. On the other hand, the surface temperature and the heat
 266 flux generated by the cladding flame did not allow the self-sustained combustion.
 267 Finally, figure 9 presents the results of the last test where the cistus bulk density is
 268 increased to 12 kg.m⁻³.




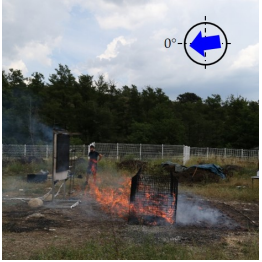
Test	Hedge ignition (t_{igh})	$t_{igh} + 9$ s	$t_{igh} + 25$ s	$t_{igh} + 94$ s
6	WV: 1 m.s ⁻¹ WD: -15° 	WV: 1.2 m.s ⁻¹ WD: 13° 	WV: 3.2 m.s ⁻¹ WD: 26° 	WV: 3.3 m.s ⁻¹ WD: 4.6° 

Fig. 9. Pictures of the test 6 with $d = 2$ m, $\rho_b = 12$ kg.m⁻³, $L = 4$ m (WV: Wind Velocity, WD: Wind Direction).

269 In this test, the fire spread quickly, mainly because the wind direction was close to 0° and
 270 the wind velocity was slightly higher (about 2.5 m.s⁻¹) than in the other tests. In addition,
 271 the increase in the bulk density of the vegetation contributed to the increase in fire
 272 dynamics compared to the other tests. As a result, the flame front reached and ignited the
 273 cladding. However, the burning of the cladding was not self-sustained as it extinguished as
 274 soon as the heat flux from the hedge decreases. Figure 10 shows the evolution of the wind
 275 direction and velocity during the test.

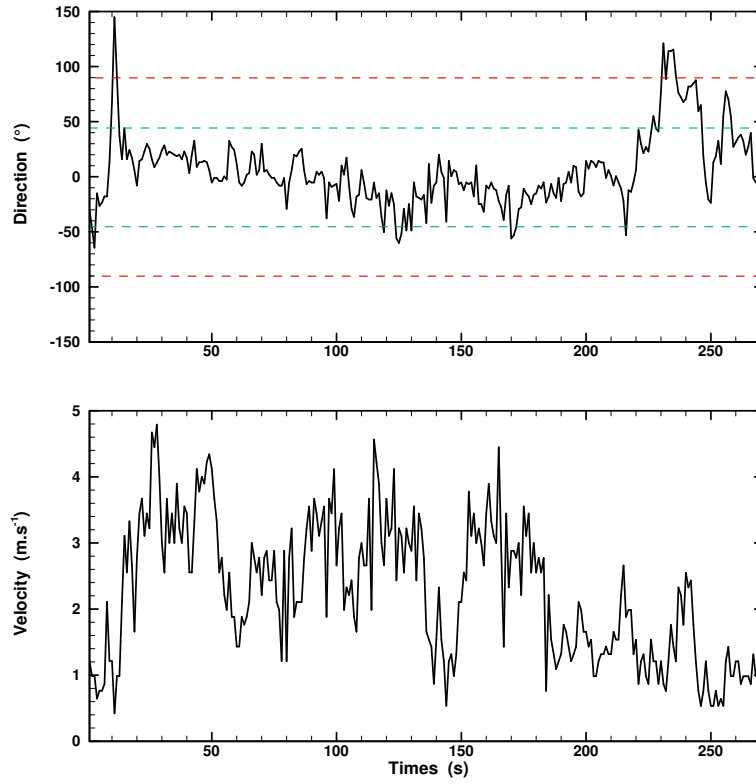
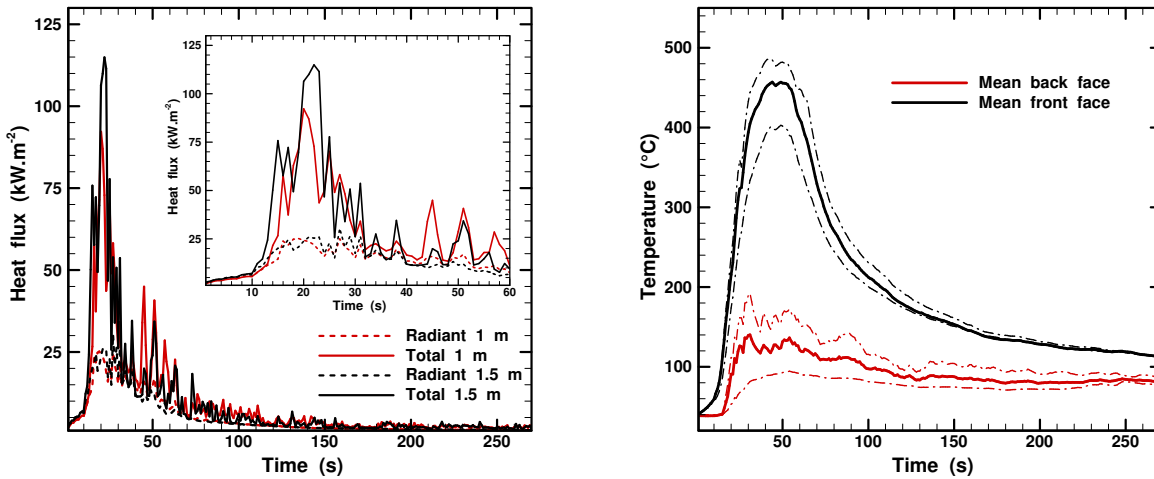


Fig. 10. Direction and velocity of wind during the test.

276 Figure 11 shows the heat fluxes at a height of 1 m and 1.5 m as well as the average
277 temperatures measured at the front and back face of the cladding.



(a) Heat fluxes at 1 m and 1.5 m heights.

(b) Temperatures on front and back faces.

Fig. 11. Heat fluxes and temperatures measured for test 6 after the cistus hedge ignition.

278 For test 6, the cladding burning time was approximately 43 s. Heat fluxes reach up to 25
 279 $\text{kW}\cdot\text{m}^{-2}$ for the radiative heat flux and $120 \text{ kW}\cdot\text{m}^{-2}$ for the total heat flux. By increasing
 280 the bulk density by 50 % (from 8 to $12 \text{ kg}\cdot\text{m}^{-3}$), there was little variation in the radiative
 281 heat flux or flame residence time compared to test 3 where the cladding was ignited. On
 282 the other hand, the total maximum heat flux increased by more than 70 % due to an
 283 increase in vegetation load and a more favorable wind direction. In terms of temperature,
 284 the exposed face reached $480 \text{ }^\circ\text{C}$ and remains almost constant for 30 s before decreasing
 285 rapidly to $110 \text{ }^\circ\text{C}$ as the hedge begins to extinguish. The temperature measured on the rear
 286 face also increased during the burning of the cladding with a maximum temperature of up
 287 to $180 \text{ }^\circ\text{C}$. Once the hedge was extinguished, the measured heat fluxes decreased rapidly to
 288 a value of less than $5 \text{ kW}\cdot\text{m}^{-2}$, while the temperature remained around $100 \text{ }^\circ\text{C}$ after the
 289 cladding had burned. The flame exposure should be longer to allow the flame to propagate
 290 through the back of the cladding in order to allow its self-sustained burning.

291 4. Conclusion

292 In order to better understand the fire risk in the WUI, large scale tests were carried out to
 293 assess the fire behaviour of wood cladding when exposed to the burning of a cistus hedge.
 294 Firstly, material scale experiments were carried out on the wood cladding to quantify the
 295 time required to ignite the samples as a function of the applied heat flux. Secondly, a total
 296 of six tests were conducted by varying the distance hedge/cladding, bulk density of the
 297 cistus and the length of the hedge. Ignition of the cladding was only possible when the
 298 flame front touched the cladding. However, the configurations tested did not result in
 299 self-sustained burning of the cladding. At a distance of 3 m between the hedge and the

300 cladding, no ignition of the cladding was observed. When the distance between the hedge
301 and the cladding is reduced to 2 m, the cladding can be ignited but not systematically.
302 The direction of the wind will affect the flame front and therefore the intensity to which
303 the cladding is exposed. However, if the wind direction is not towards the cladding, this
304 latter will not ignite. When the cistus bulk density increases and the wind is in the
305 propagation direction with a slightly higher velocity, cladding ignition is certain with total
306 heat fluxes exceeding 100 kW.m^{-2} . It has been observed that the cladding extinguishes
307 almost instantaneously as soon as the burning of the hedge decreases. The heat flux
308 generated by the flame on the surface of the wood and the temperatures on the back side
309 are not high enough to allow a self-sustaining combustion. Based on these results, it seems
310 necessary to require a distance of more than 2 m between facades with wood cladding and
311 a hedge of 1 m high. It is also important to ensure that no secondary fuel is present
312 between the cladding and the hedge, as this could increase the burning duration of the
313 cladding, leading to its self-sustaining combustion. In further works, it will be possible to
314 vary the slope between the vegetation and the cladding and to add additional elements
315 such as windows. A load cell will also be installed under the cistus hedge to measure the
316 mass loss during the combustion.

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408 **Figure captions**

409 Fig. 1 Experimental setup.

410 Fig. 2 Pictures of the tests 3, 4 and 5 with $d = 3$ m, $\rho_b = 8$ kg.m⁻³ (WV: Wind Velocity,
411 WD: Wind Direction).

412 Fig. 3 Direction and velocity of wind during the tests 1 and 2.

413 Fig. 4 Heat flux and temperature measured for tests 1 and 2 after the cistus hedge ignition.

414 Fig. 5 Pictures of the tests 3, 4 and 5 with $d = 2$ m, $\rho_b = 8$ kg.m⁻³, $L = 4$ m (WV: Wind
415 Velocity, WD: Wind Direction).

416 Fig. 7 Wood cladding after the test 3.

417 Fig. 6 Direction and velocity of wind during the tests.

418 Fig. 8 Heat flux and temperature measured for tests 3, 4 and 5 after the cistus hedge
419 ignition.

420 Fig. 9 Pictures of the test 6 with $d = 2$ m, $\rho_b = 12$ kg.m⁻³, $L = 4$ m (WV: Wind Velocity,
421 WD: Wind Direction).

422 Fig. 10 Direction and velocity of wind during the test.

423 Fig. 11 Heat flux and temperature measured for tests 1 and 2 after the cistus hedge
424 ignition.