PROGRAMME DE COOPÉRATION TRANSFRONTALIÈRE
GRENSOVERSCHRIJDEND SAMENWERKINGSPROGRAMMA

Interreg
France-Wallonie-Vlaanderen
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GRASS

Gazons a**R**tificiels **A**nti-feu **S**ûrs et durable**S**
Vlamwerende kunstgrasmatten: veilig en duurzaam

Final event

16/06/2022
UGent

AVEC LE SOUTIEN DU FONDS EUROPÉEN DE DÉVELOPPEMENT RÉGIONAL
MET STEUN VAN HET EUROPEES FONDS VOOR REGIONALE ONTWIKKELING

Agenda

- Introduction of GRASS
  Geert De Clercq (UGent)
- Legislation on the use of artificial turf
  Nicolas Martin (EuraMaterials)
- Technical results of the project
  Mathilde Casetta (Ulille)
  Stijn Rambour (UGent)
- LCA for eco designing GRASS innovation
  Olivier Talon (Materia Nova)
- Discussion
- Networking

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GRASS
A small introduction

ir Geert De Clercq

Final event GRASS
16th June 2022 , UGent

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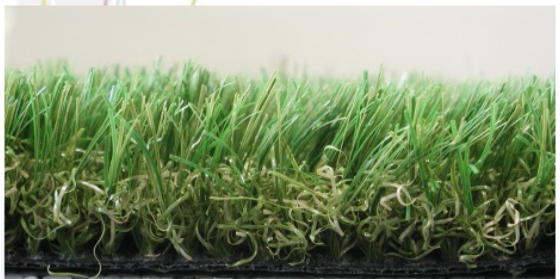
Project Raison (Why did we do it?)

- Existing situation:
  - Wrong idea:
    properties of artificial turf = properties of natural turf
  - Artificial turf has other fireproofing properties
  - Actual solutions not eco-friendly
  - Hence:
    - Public unaware of difference
    - Fields with insufficient FR properties

Which types of artificial turf exist?



Landscaping grass	Hockey grass	Sports grass
Generally no infill, recreational	No infill, use of water	Filled in with sand and rubber
Europe: $10x10^6$ m² (+ 10%/year)	Europe: $30x10^6 m^2$	

Current RISKS with artificial turf

USE	Outdoor recreational and private: garden, terrace, park,...	Indoor: theme parks, event halls, markets	Sport fields.
Artificial turf system	Carpet without infill materials	Carpet without infill materials	Carpet with sand and rubber.
Risk	BBQ, cigarettes, camp fire, fire works...	Normal indoor risks, such as cigarettes, cooking plates, candles, electrical short-circuit, ...	Fire works, use of stadium for other events, grass can't be used as evacuation area
Current Solution	Add sand	Add sand	Use special fire retardant rubber
Reality	Almost always used without sand	Fire report with sand, installed without sand	Over 90% with rubber from recycled tyres.

Lack of awareness

Stakeholders	Producers	Owners, Installers, public authorities	Fire brigades, police, law enforcers	End-users
Problem	Price pressure, environmental risks with anti-fire agents	No awareness on importance of sand. No fire legislation for outdoor area's	Lack of information, studies, fire propagation scenario's	Don't realise the difference with natural grass
Risk	*Prevention*: Costs, environment, *Accident*: Collapse of business	Liability in case of accidents Damage to people and infrastructure	Acceptance of unsafe installation Wrong judgement of risk crowd management problems	Personal injuries, burning wounds, inhalation of smoke, or even death
Information need	New Flame retardants, LCA, fire tests,…	Legislation (needs), risks, solutions, environmental aspects,..	Fire propagation, evaluation of risks, interpretation of tests,…	Correct use, Risks, Prevention,…

Project Objectives

- Make the stake holders aware of difference
  - Communications,
  - Workshops,
  - …

- Improve the fireproofing of artificial turf
  - Develop better solutions,
  - Taking into account the durability and ecologic aspects
  - Taking into account the industrial feasibilty

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Fire regulation of floorings for indoor applications in public building – The case of France and Belgium

Nicolas Martin, EuraMaterials

EuraMaterials

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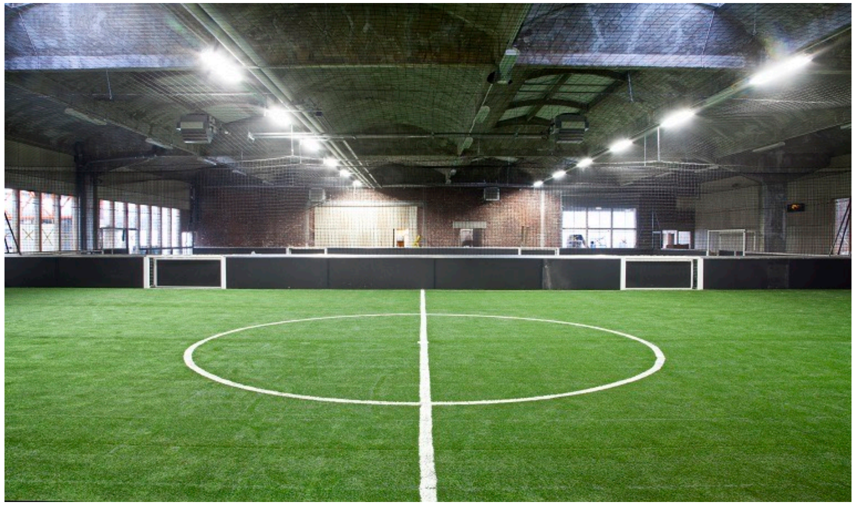
Objectives:

- Identify if specific regulation exists regarding artificial turf
- Define a target performance for materials developed in the project
- Define the level of performance needed for artificial turf regarding existing regulation
- Compare existing regulation between France and Belgium

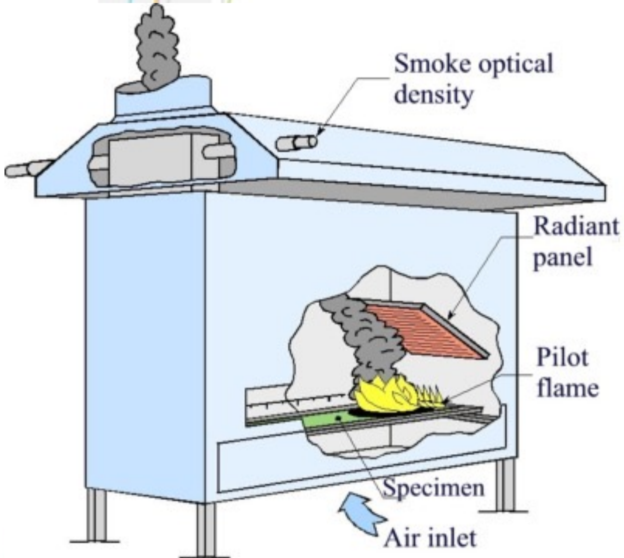


European regulation for fire reaction of flooring: Test methods

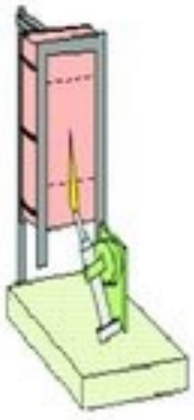
→Based on EN 13501-1 Standard: Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests

Evaluation of the fire behaviour of floorings:

1. ***Radiant panel test EN ISO 9239-1***



2. ***Single-flame source test EN ISO 11925-2***



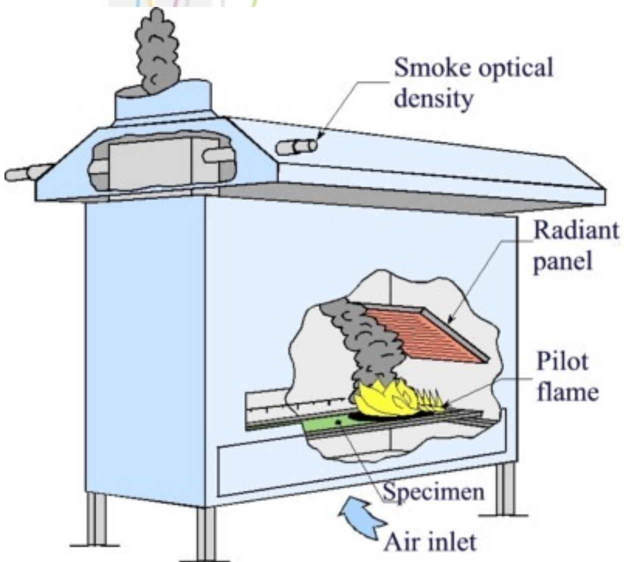
- Vertically positioned sample
- Determination of the flame height

European regulation for fire reaction of flooring: Test methods

→Based on EN 13501-1 Standard: Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests

Evaluation of the fire behaviour of floorings:

1. ***Radiant panel test EN ISO 9239-1***



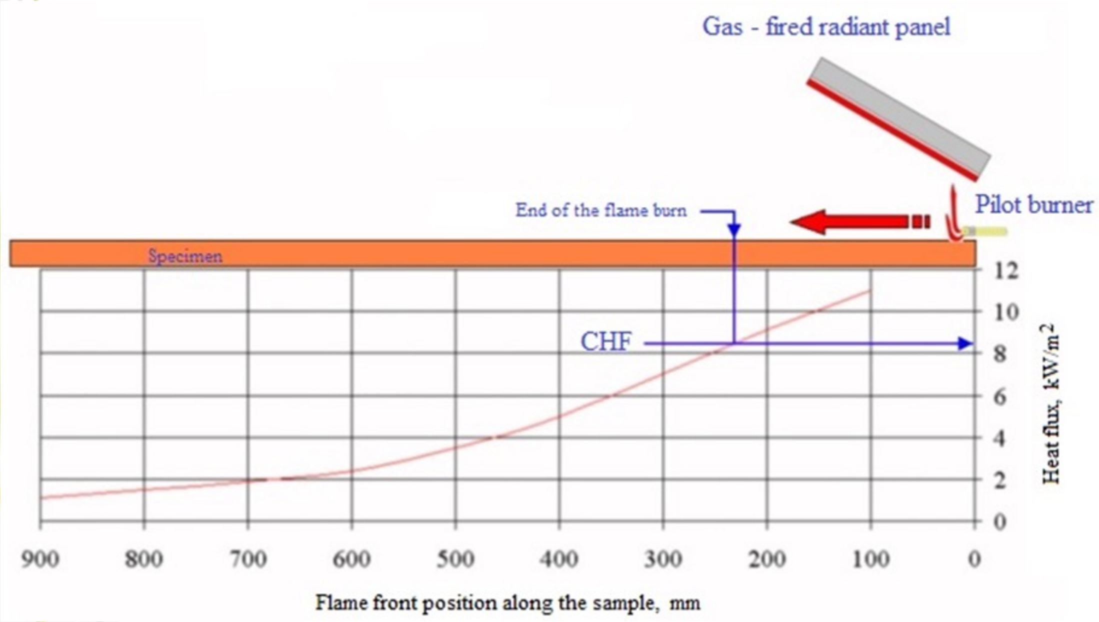
- **Energy heat flux gradient**
- **Flame propagation** (burnt length)
- Test duration: **30 min maximum**
- Specimen size : (1050 x 230) mm²
- Smoke density (additional requirement)

European regulation for fire reaction of flooring: Test methods

→Radiant panel test EN ISO 9239–1

Determination of the **critical heat flux (CHF):**

- Point where the flame stops advancing (specimen extinguishment)
- Position of the front flame after 30 min of test (no self-extinguishment)



Heat flux distribution

European regulation for fire reaction of flooring: Classification

→Based on EN 13501-1 Standard: Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests

Class of reaction to fire performance for floorings:

Class	Radiant panel test *EN ISO 9239 – 1*	Single – flame source test *EN ISO 11925 – 2**	Additional requirements
B_{FL}	CHF ≥ 8 kW/m²	Fs ≤ 150 mm within 20 s	Smoke ≤ 750%.min (s1)
C_{FL}	CHF ≥ 4.5 kW/m²	Fs ≤ 150 mm within 20 s	Smoke ≤ 750%.min (s1)
D_{FL}	CHF ≥ 3 kW/m²	Fs ≤ 150 mm within 20 s	Smoke ≤ 750%.min (s1)
E_{FL}	No requirements	Fs ≤ 150 mm within 20 s	No requirements
F_{FL}		No requirements	

**Ignition time: 15 s*

<u>For indoor applications:</u>

Minimum C_{FL} : CHF ≥ 4.5 kW/m²

→Burnt length about 420 mm max

→Smoke rate S1 ≤ 750 %.min

Regulation in France: provisions

- The rules to be applied are defined in the modified version of the decree of June 25, 1980 approving the general provisions of the safety regulations against the risk of fire and panic in establishments open to the public (ERP).

- Several categories of places exist. For artificial turf, the places typically concerned are in category X Indoor sports buildings, or PA Outdoor sports.

- Chapter 3 Interior fittings, decoration and furniture defines the classes of materials accepted according to their reaction to fire classification according to the Euroclasses scale, for all establishments open to the public.

Regulation in France: requirements

Type of flooring	Euroclasses
Floors in unprotected corridors and rooms	D_{FL}-s2 or M4
Rest landings and steps of protected staircases*.	C_{FL}-s1 or M 3
Floors of protected horizontal corridors**.	D_{FL}-s2 or M 4

(*) A protected staircase is one in which the public is protected from fire and smoke.
(**) A protected circulation is a circulation in which the public is protected from flames and smoke.

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Regulation in Belgium: provisions

- The rules to be applied are defined in the last version royal decree of 7 July 1994 setting the basic standards for fire and explosion prevention, to which new buildings and their components must satisfy.

- The fire class depends on the height of the building, the use and the type of occupants

<u>Type of occupants:</u>
Type1: non-autonomous occupants
Type 2: autonomous and sleeping occupants
Type 3: autonomous and vigilant occupants

<u>Height of building:</u>
High buildings: $h>25$ m
Mid size buildings: $10 \leq h \leq 25$ m
Small size: $h<10$ m

Regulation in Belgium: requirements

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Use of the premises		High buildings (h>25m)	Medium sized buildings (10 ≤ h ≤ 25 m)	Small buildings (h<10m)
Premises	**Occupants**			
Technical premises, car parks, machine rooms machine rooms, technical ducts	**All types**	$A2_{FL}$-s2		
Elevators	**All types**	C_{FL} -s2		E_{FL}
Kitchens	**All types**	B_{FL}-s2		
Rooms	**Type 1**	B_{FL}-s1		
	Type 2 and 3	C_{FL} -s2		
Other premises	**Type 1**	C_{FL} -s1		
	Type 2 and 3	D_{FL}-s2	E_{FL}	
Evacuation routes	**Type 1**	$A2_{FL}$-s1		
	Type 2	B_{FL}-s1		C_{FL} -s1
	Type 3	B_{FL}-s1	C_{FL} -s1	D_{FL}-s2
Staicases	**Type 1**	$A2_{FL}$-s1		
	Type 2	B_{FL}-s1		
	Type 3	B_{FL}-s1		C_{F}

Conclusion

- No specific regulation regarding artificial turf and fire safety

→ Flooring regulations need to be applied

- Difference between Belgium and France for fire reaction requirements, e.g. for rooms

France	Belgium
D_{FL}-s2	C_{FL}-s2

→ There is a need for harmonisation of regulations at European level

→ For indoor applications, we recommend to consider C_{FL}-s1 as a reasonable fire reaction (limited contribution to fire and low smoke emission) for artificial turf

→CHF ≥ 4.5 kW/m²
→Burnt length about 420 mm max
→Smoke rate S1 ≤ 750 %.min

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Comportement du gazon artificiel existant

Brandgedrag van bestaand kunstgras

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Stijn Rambour

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Comportement au feu

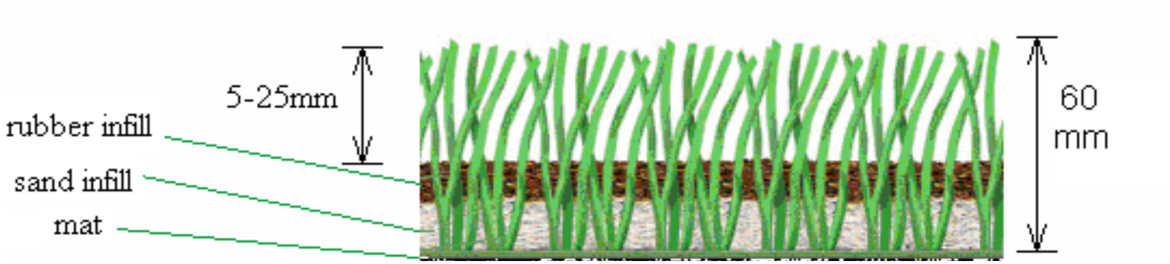
- ✓ Influence de l'hauteur des piles
- ✓ Influence de la matière d'infill
- ✓ Influence du backing primaire
- ✓ Influence du sous-couche
- ✓ Comportement des materiaux d'infill

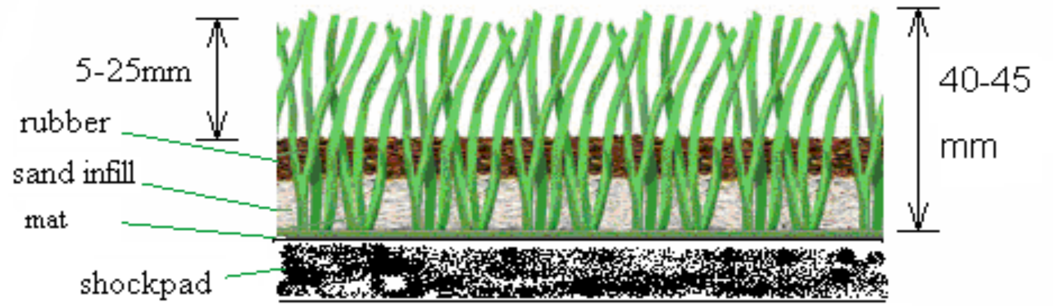
Brandgedrag

- ✓ Invloed van poolhoogte
- ✓ Invloed van soort infill
- ✓ Invloed van primaire backing
- ✓ Invloed van shockpad
- ✓ Brandgedrag van materiaal zelf

- ✓ Influence de l’hauteur des touffes: petite influence

- ✓ Invloed van poolhoogte: kleine invloed

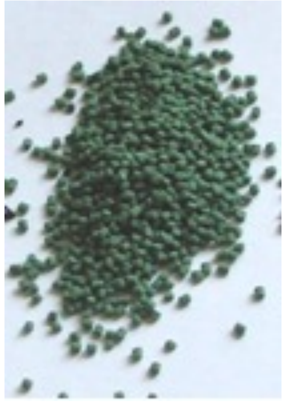




- ✓ Influence de la materière d'infill: 40mm tapis+sable+infill
une grande différence en comportement

- ✓ Invloed van soort infill: 40mm tapijt+zand+ infill
heel groot verschil in gedrag: volgorde zoals hieronder

SBR



TPE

cork

EPDM

←

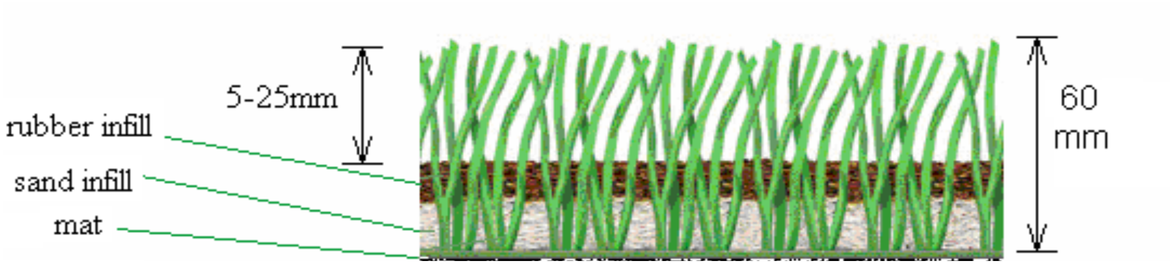
Brand/feu

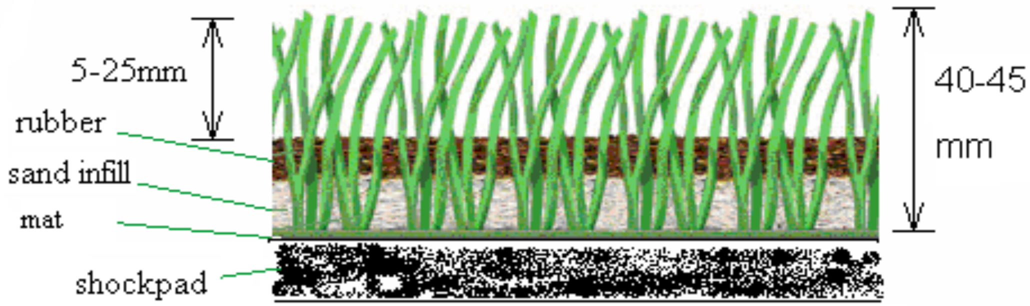
✓ Influence du backing primaire: petite influence

✓ Invloed van primaire backing: kleine invloed

- ✓ Influence du sous-couche: petite influence

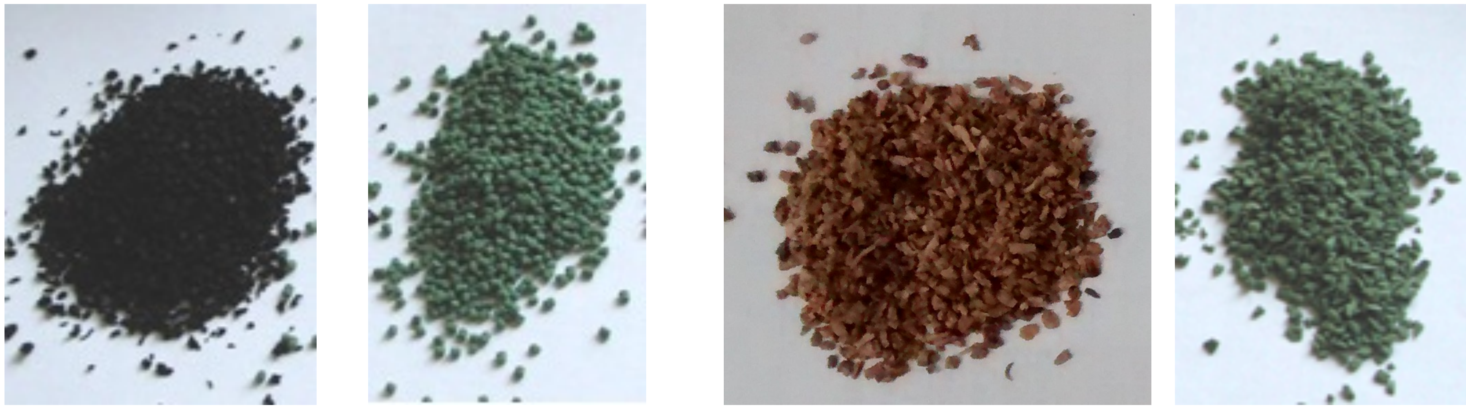
- ✓ Invloed van shockpad: kleine invloed





✓ Comportement des materiaux d’infill: même comportement comme test dans le système

✓ Brandgedrag van materiaal zelf: zelfde gedrag als in systeem



SBR TPE cork EPDM

← Brand/feu

Sport

✓ Influence de l'enduction/coating (SBR/SBR FR): petite influence dans des systèmes de sport

Sport

✓ Invloed van latex (SBR- SBR FR): kleine invloed in sportsystemen

Gazon paysager (landscaping)
✓ Influence de l’enduction/coating (SBR/SBR FR):
grande influence pour des tapis court (10mm)
Petite influence pour des tapis plus long (+25mm)

Landscaping
✓ Invloed van latex (SBR- SBR FR):
Grote invloed bij laagpolige tapijten (10mm)
kleine invloed in tapijten met lange pool (meer dan 25mm)

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Développement de solutions techniques pour l'ignifugation du gazon artificiel à partir du test à échelle réduite

Ontwikkeling van technische oplossingen voor het brandvertragend maken van kunstgras op basis van de test op kleine schaal

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FIRE PERFORMANCE OF ARTIFICIAL TURF STRUCTURES

Small-scale testing and development of fireproofing strategies

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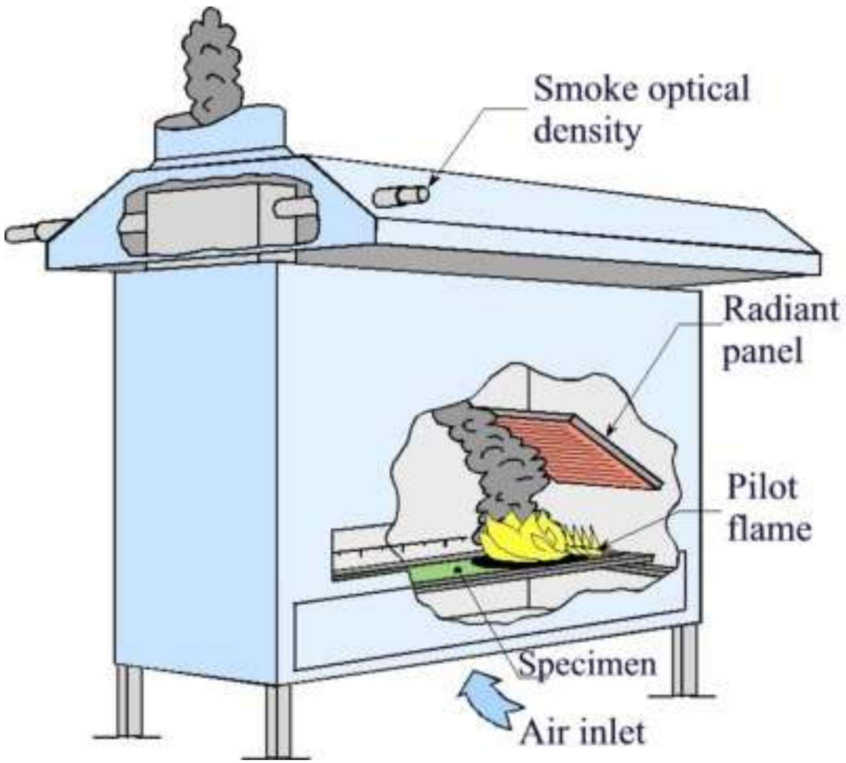
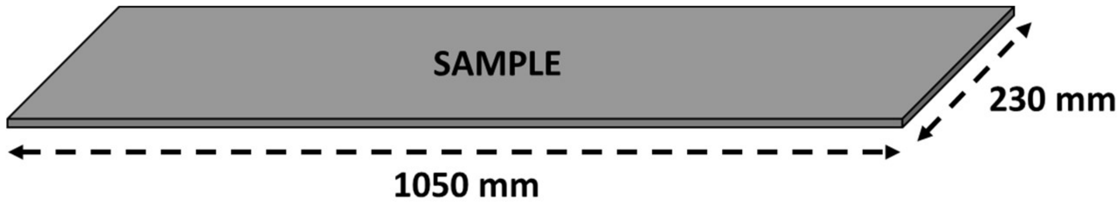
CHARACTERIZATION OF THE FIRE PROPERTIES OF ARTIFICIAL TURF STRUCTURES

EN ISO 9239-1 radiant panel test:



→ 6 replicates per tested structure

→ **Huge amount of material required to perform the tests**



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CHARACTERIZATION OF THE FIRE PROPERTIES OF ARTIFICIAL TURF STRUCTURES

Development of the EN ISO 9239-1 radiant panel test at lab scale:

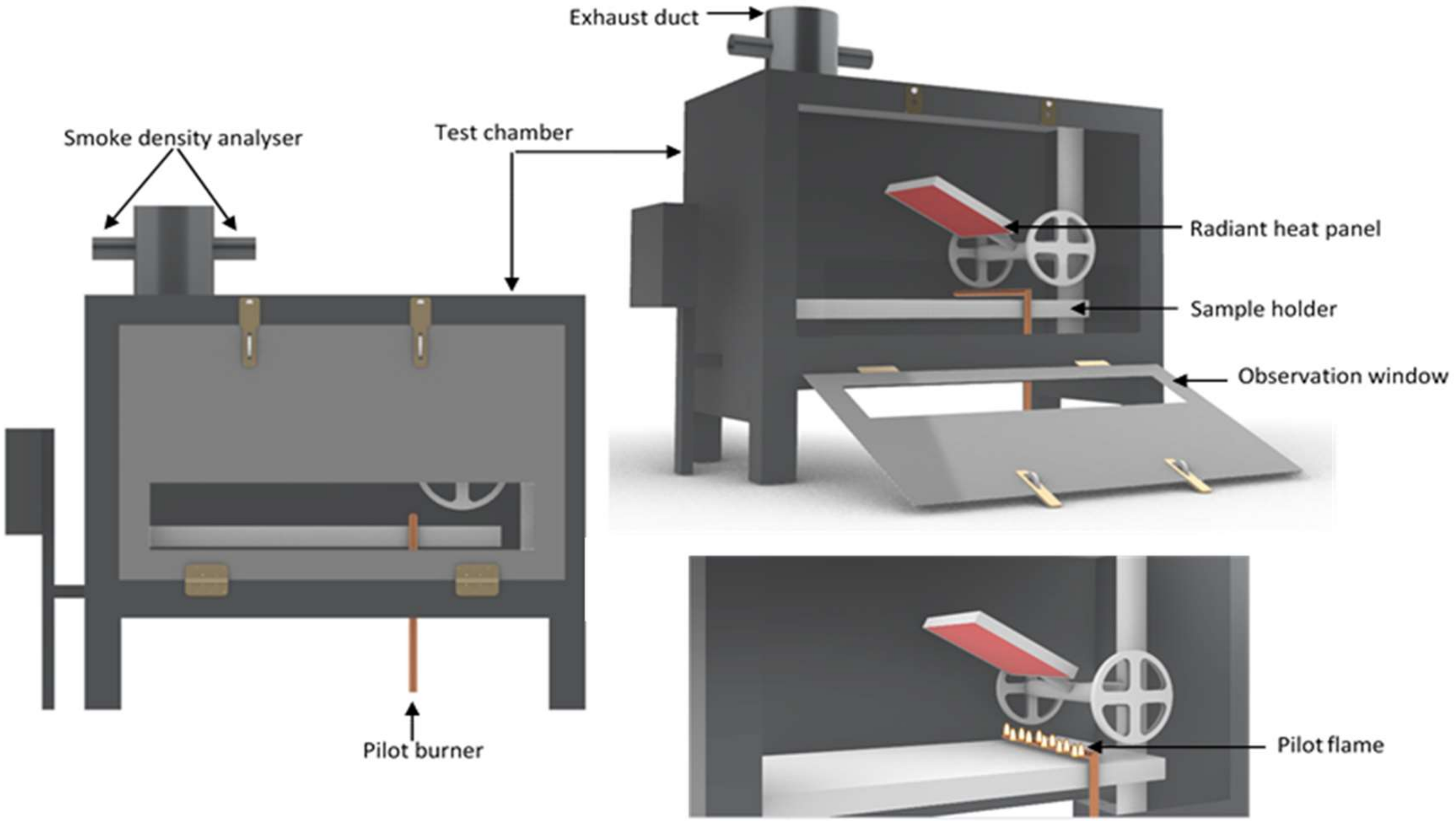
Reproduced at $^{1}/_{3}$ scale:

→ Faster and cheaper experiment

→ **Smaller sample size: (350 x 77) mm²**

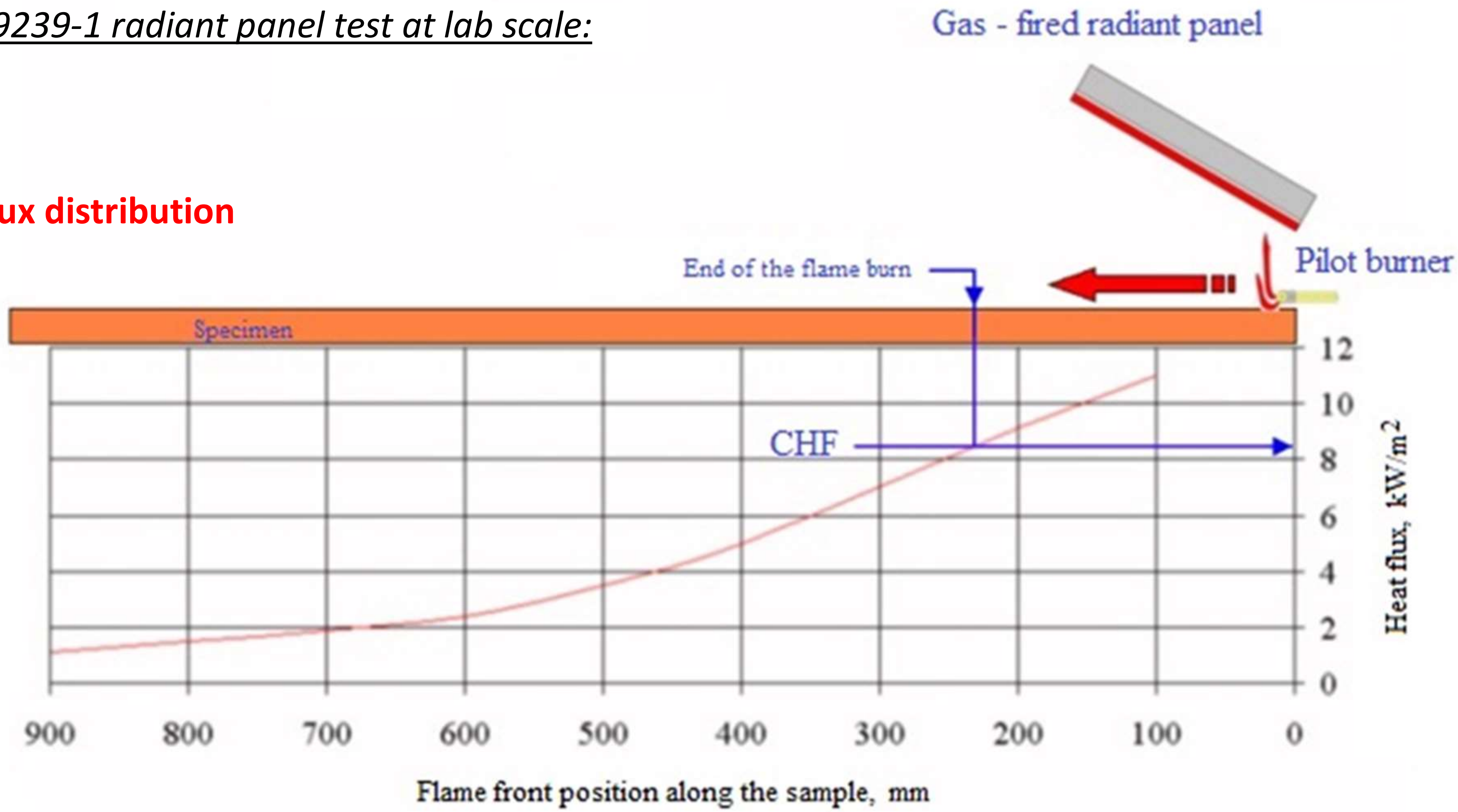
→ Flame propagation (burnt length)

→ Test duration: **30 min maximum**

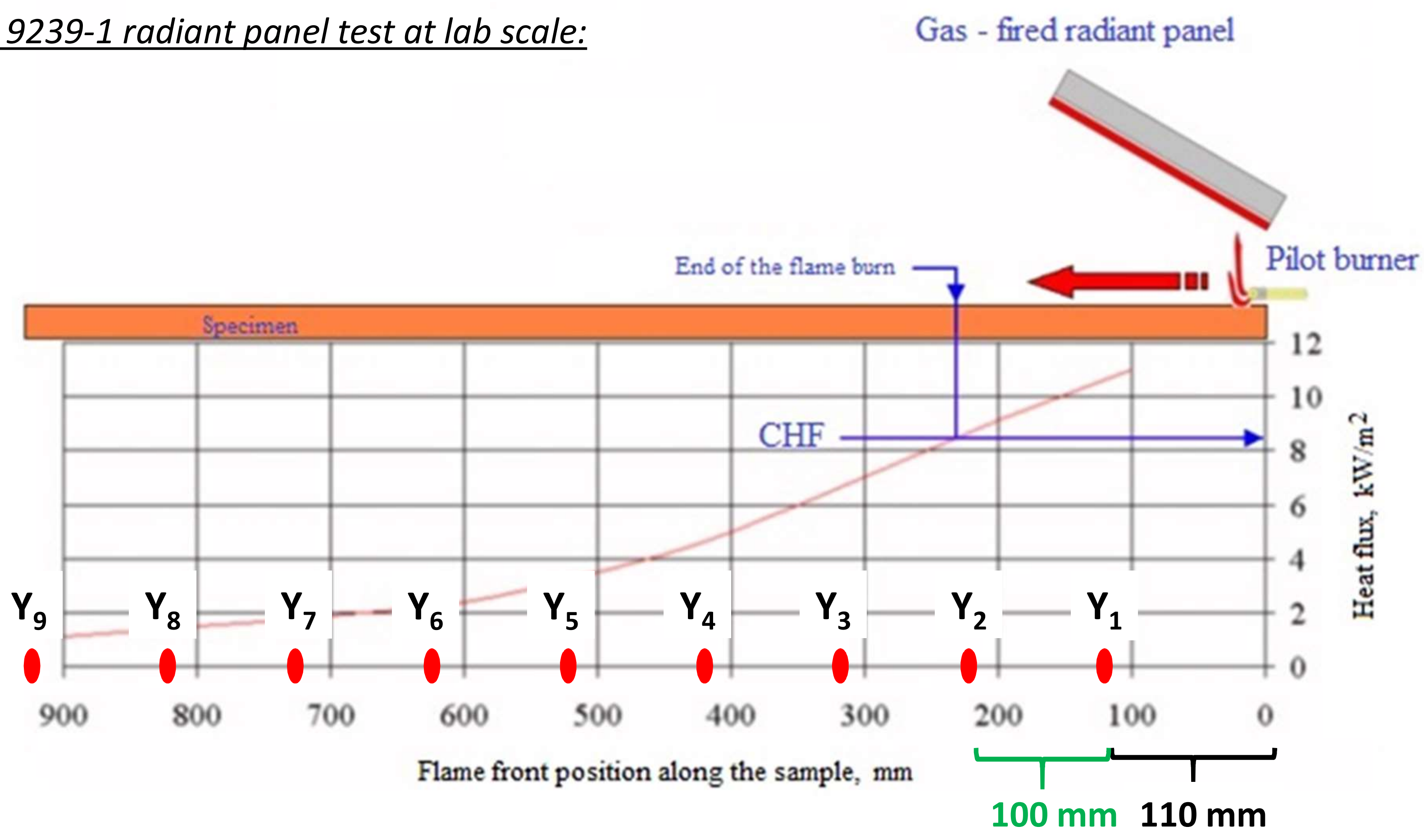


Development of the EN ISO 9239-1 radiant panel test at lab scale:

Standardized heat flux distribution



Development of the EN ISO 9239-1 radiant panel test at lab scale:



9 distances: 9 fluxes

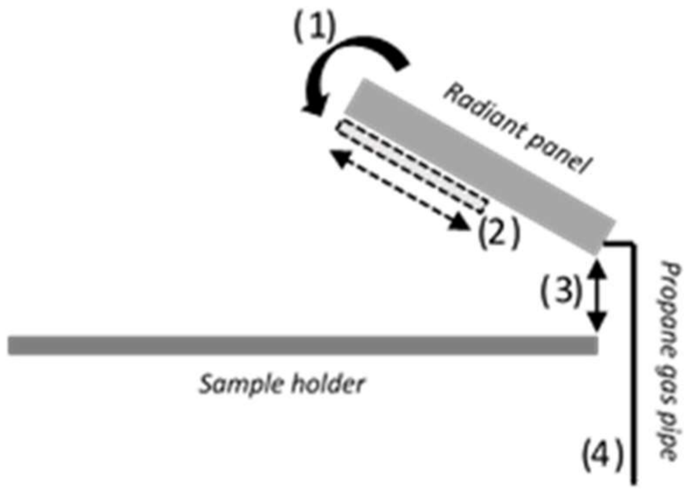
→Three times smaller

CHARACTERIZATION OF THE FIRE PROPERTIES OF ARTIFICIAL TURF STRUCTURES

Design of the small-scale test:

Experimental design:

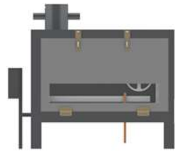
→ Consisting of **27 experiments** performed randomly



1) Angle of the radiative source (from 10 to 50°)
2) Surface of the radiative source (from 0 to 60 %)
3) Distance between radiative source / upper surface of the tested sample (from 75 to 175 mm)
4) Propane flow rate (from 200 to 500 L/h)

Optimal conditions:

U1 (°)	U2 (%)	U3 (mm)	U4 (L/h)
10	0	110	165

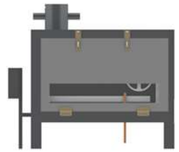


Design of the small-scale test:

Response variables	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
Distance from zero point of specimen on large scale (mm)	37	70	103	137	170	203	237	270	303
Expected heat flux (kW/m²)	10.9 ± 0.4	9.2 ± 0.4	7.1 ± 0.4	5.1 ± 0.2	3.5 ± 0.2	2.5 ± 0.2	1.8 ± 0.2	1.4 ± 0.2	1.1 ± 0.2

→ **1/3 scale**

CHARACTERIZATION OF THE FIRE PROPERTIES OF ARTIFICIAL TURF STRUCTURES



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Distance from zero point of specimen on large scale (mm)	37	70	103	137	170	203	237	270	303
Expected heat flux (kW/m²)	10.9 ± 0.4	9.2 ± 0.4	7.1 ± 0.4	5.1 ± 0.2	3.5 ± 0.2	2.5 ± 0.2	1.8 ± 0.2	1.4 ± 0.2	1.1 ± 0.2
Recorded heat flux at lab scale (kW/m²)	**11.6 ±0.4**	**9.4 ±0.2**	**6.8 ±0.1**	**5.0 ±0.1**	**3.5 ±0.1**	**2.6 ±0.1**	**2.0 ±0.1**	**1.6 ±0.1**	**1.3 ±0.1**

→ **1/3 scale**

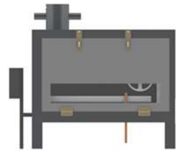
Optimal conditions:

U1 (°)	U2 (%)	U3 (mm)	U4 (L/h)
10	**0**	**110**	**165**

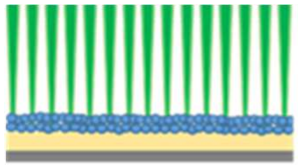
* A. Paturel, M. Casetta, S. Rambour, L. Janus, S. Duquesne, ***Journal of Fire Sciences*** *2022, Vol. 40(2), 97-114, DOI: 10.1177/07349041211062046*

CHARACTERIZATION OF THE FIRE PROPERTIES OF ARTIFICIAL TURF STRUCTURES

Large-scale test (UGent):



Structures / Parameters	S – SBR	S – EPDM	S – TPE	S – Cork	S – FR EPDM
Percentage of burnt length (%)	100	49	57	77	15
Rating	E_{FL}	D_{FL}	E_{FL}	E_{FL}	B_{FL}
Smoke rate	s2	s1	s1	s1	s1



Indoor applications

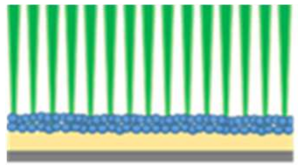
CHARACTERIZATION OF THE FIRE PROPERTIES OF ARTIFICIAL TURF STRUCTURES

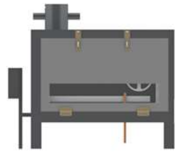
Large-scale test (UGent):

Parameters \ Structures	S – SBR	S – EPDM	S – TPE	S – Cork	S – FR EPDM
Percentage of burnt length (%)	100	49	57	77	15
Rating	E_{FL}	D_{FL}	E_{FL}	E_{FL}	B_{FL}
Smoke rate	s2	s1	s1	s1	s1

Small-scale test (ULille):

Parameters \ Structures	S – SBR	S – EPDM	S – TPE	S – Cork	S – FR EPDM
Percentage of burnt length (%)	100	53	65	44	21
Rating	E_{FL}	D_{FL}	E_{FL}	D_{FL}	B_{FL}
Smoke rate	s2	s1	s1	s1	s1





Same classifications except for S – Cork structure:

→ Natural infill with a high degree of variability in composition and structure.

→ Potential influence on the classification.

UNDERSTANDING OF THE FIRE BEHAVIOUR OF ARTIFICIAL TURF STRUCTURES

GRASS

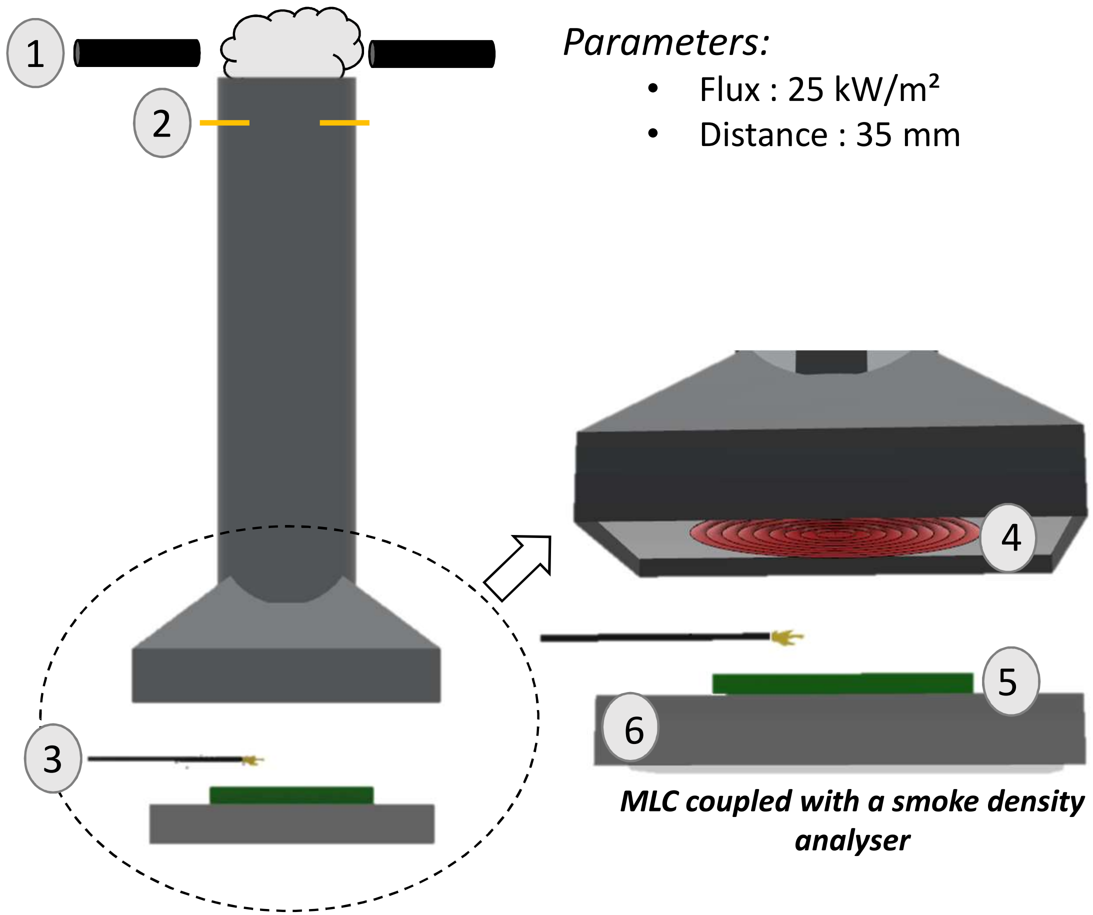
<u>*Fire testing:*</u> *Mass Loss Cone (MLC) test*

Parameters:

- Flux : 25 kW/m²
- Distance : 35 mm

Bench-scale reaction-to-fire test

- Forced-flaming combustion scenario
- External radiative heat flux

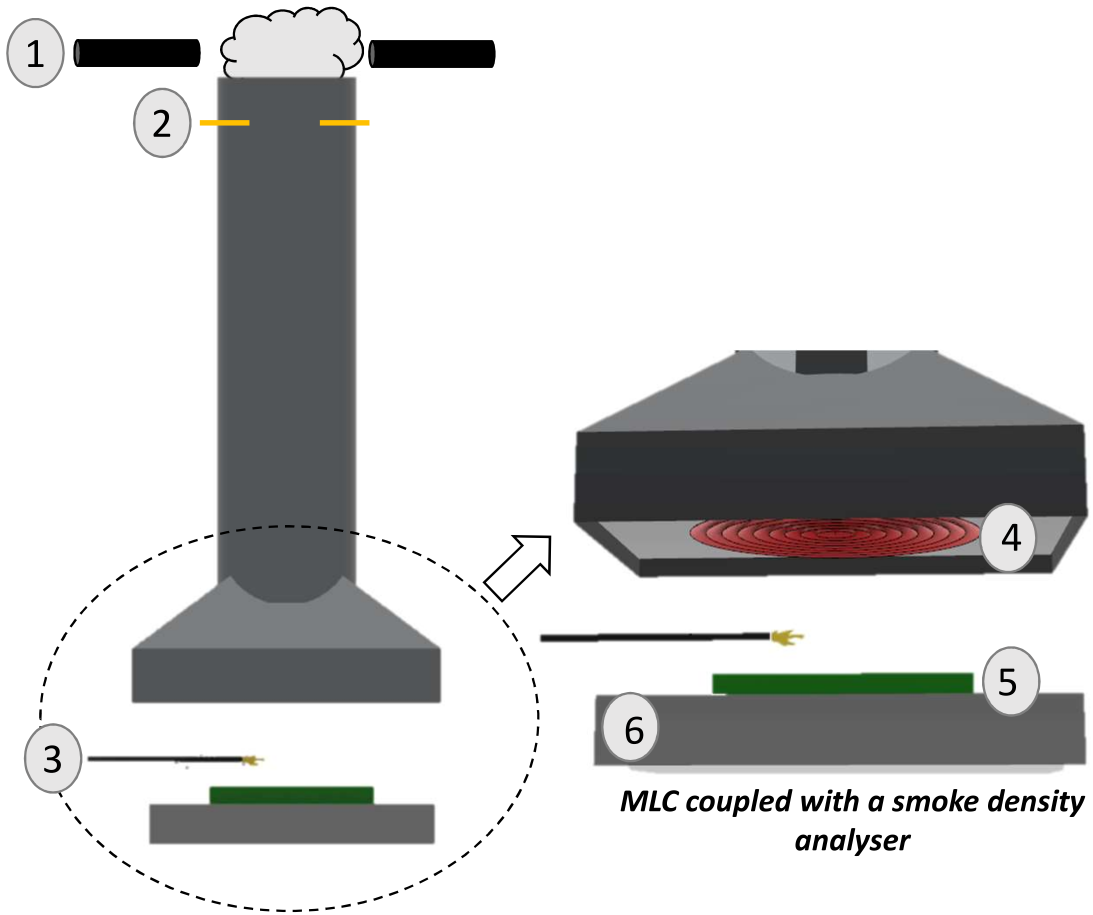


MLC coupled with a smoke density analyser

1. Smoke density analyser
2. Thermopile
3. Igniter (electric arc)
4. External radiative heat flux
5. Sample
6. Sample holder

UNDERSTANDING OF THE FIRE BEHAVIOUR OF ARTIFICIAL TURF STRUCTURES

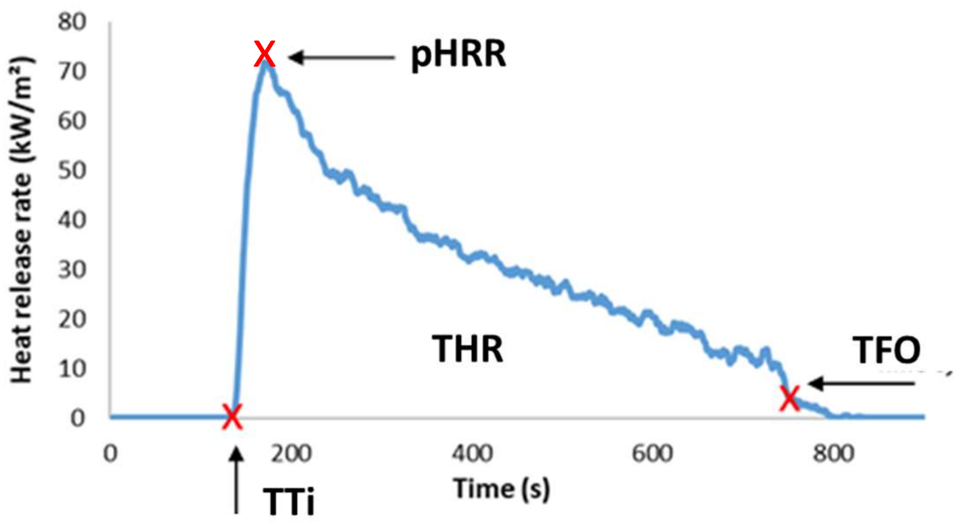
Fire testing: *Mass Loss Cone (MLC) test*



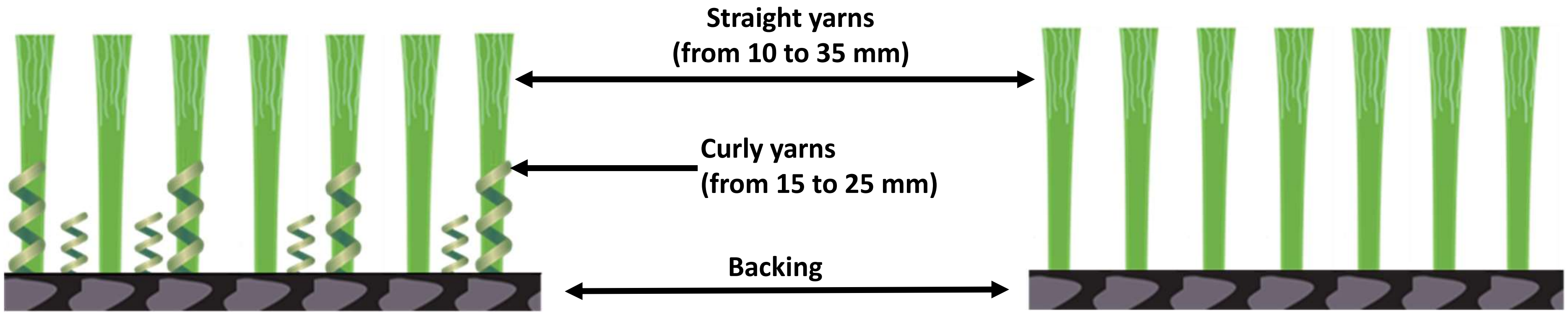
MLC coupled with a smoke density analyser

Measured values:

- Peak of heat release rate (pHRR)
- Total heat release (THR)
- Time to ignition (TTi)
- Time of Flame Out (TFO)



ARTIFICIAL TURF STRUCTURES FOR LANDSCAPING



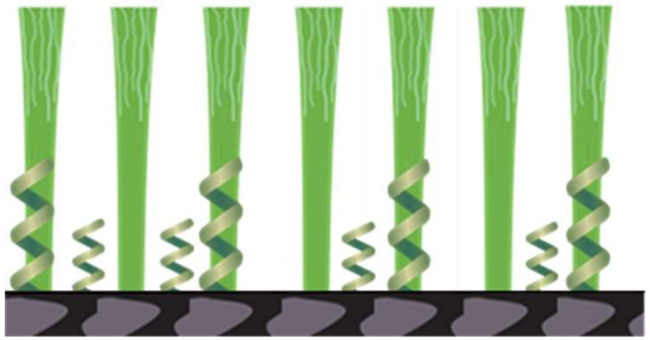
Influence of the pile length
3 structures

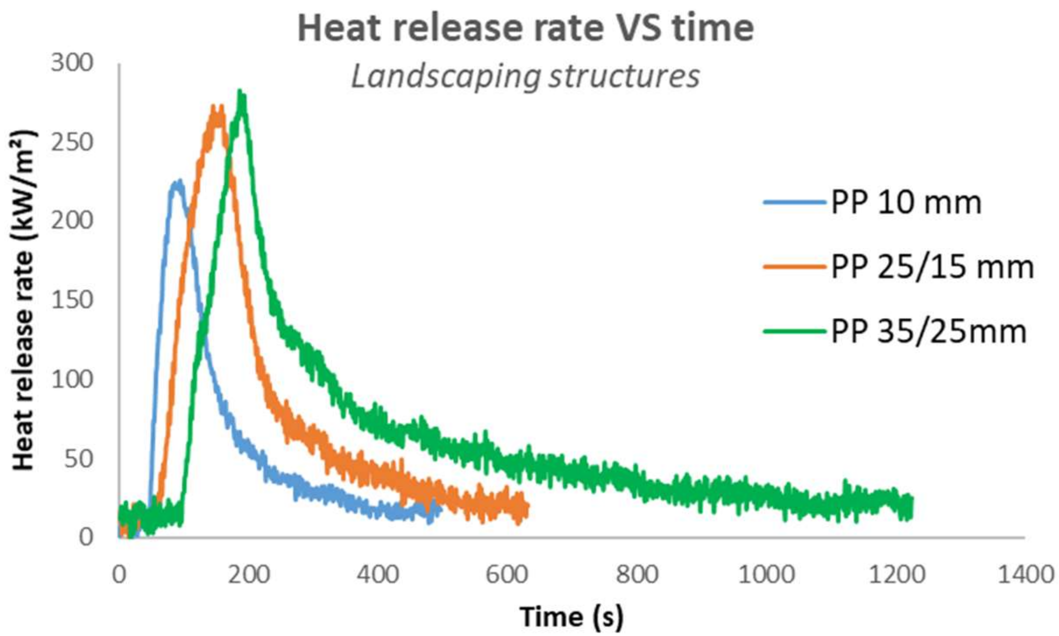
Influence of the backing and the pile
2 backings without pile

Presence of flame retardants (FR)
2 FR structures

UNDERSTANDING OF THE FIRE BEHAVIOUR OF ARTIFICIAL TURF STRUCTURES

ARTIFICIAL TURF STRUCTURES FOR LANDSCAPING





Influence of the pile length
3 structures

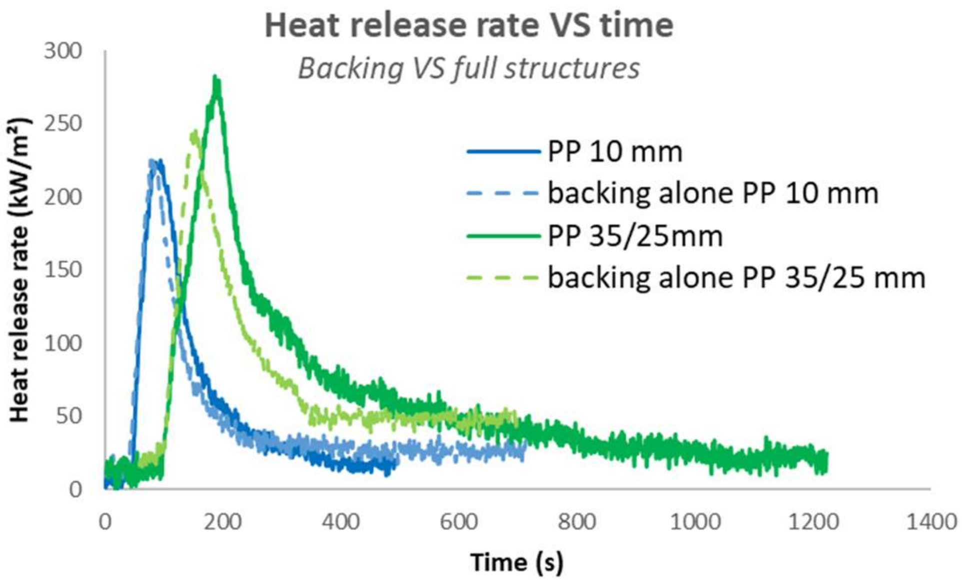
S1 (SY 25/ CY 15 mm)
S2 (SY 35/ CY 25 mm)
S3 (SY 10 mm)

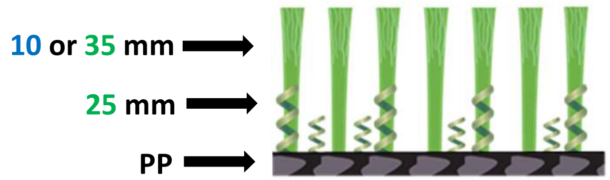
The higher the length of the pile, the higher the THR

UNDERSTANDING OF THE FIRE BEHAVIOUR OF ARTIFICIAL TURF STRUCTURES

ARTIFICIAL TURF STRUCTURES FOR LANDSCAPING

Influence of backing and pile





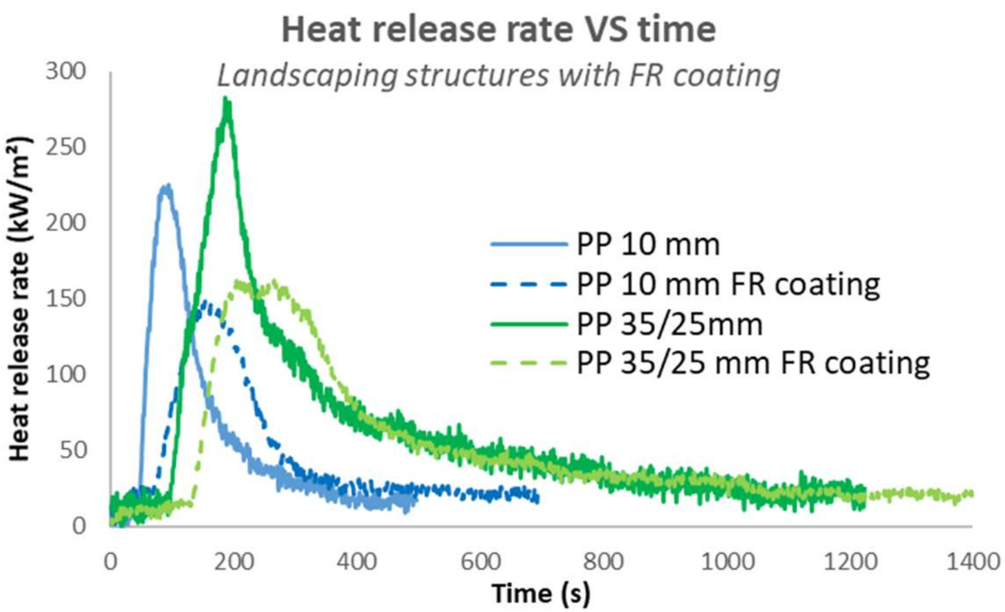
Structures	TTI (s)	pHRR (kW/m²)	THR (MJ/m²)
PP 35/25 mm	93	283	71
Backing without pile (35/25 mm)	40	245	49
PP 10 mm	43	225	27
Backing without pile (10 mm)	42	225	32

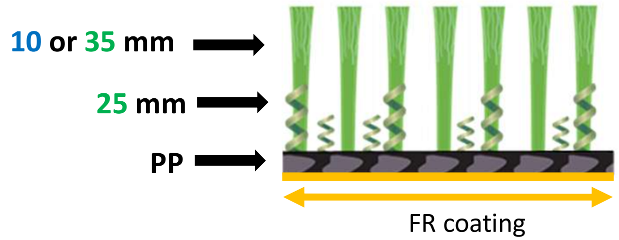
Major contribution of the backing to the fire behaviour: at least 70% of the THR

UNDERSTANDING OF THE FIRE BEHAVIOUR OF ARTIFICIAL TURF STRUCTURES

ARTIFICIAL TURF STRUCTURES FOR LANDSCAPING

Influence of a FR coating on the backing



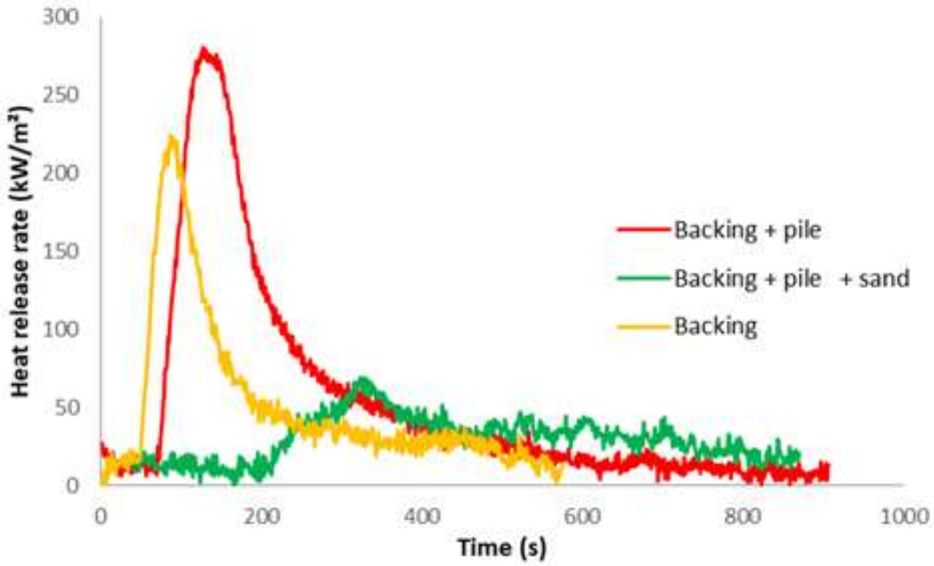


Structures	TTI (s)	pHRR (kW/m²)	THR (MJ/m²)
PP 35/25 mm	93	283	71
PP 35/25 mm FR coating	128	162	68
PP 10 mm	43	225	27
PP 10 mm FR coating	68	149	32

Important decrease of the pHRR but no modification of the THR

ARTIFICIAL TURF STRUCTURES FOR LANDSCAPING

Influence of sand



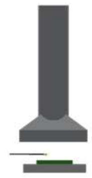
→ Increase of the TTI

→ Strong reduction of the pHRR (75%)

→ Strong reduction of the THR (48%)

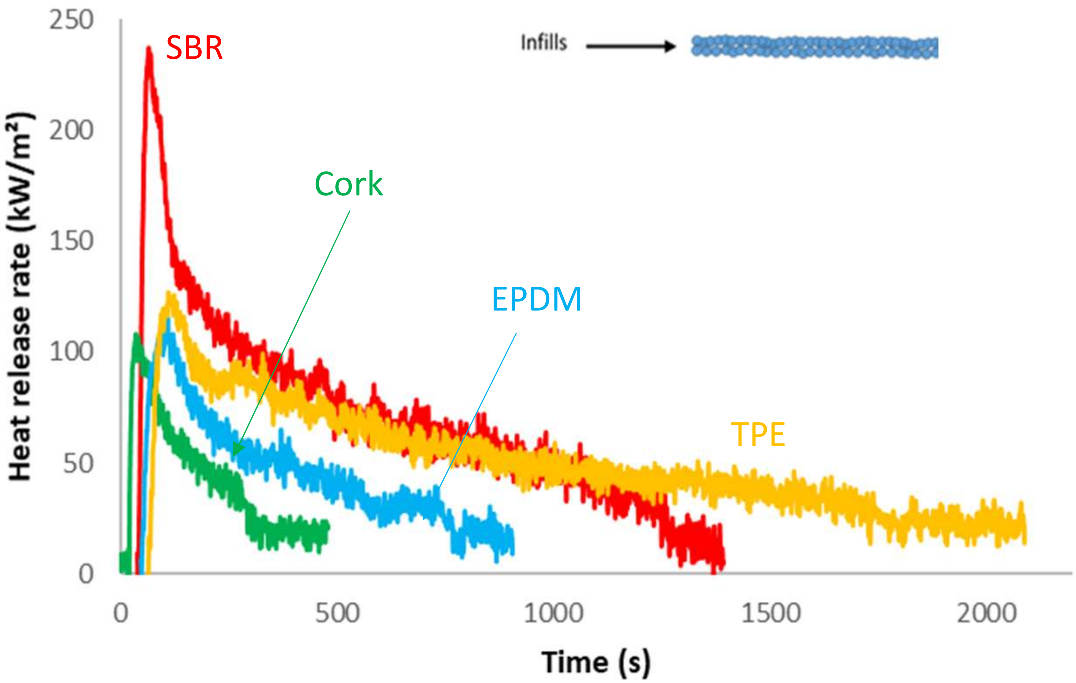
'Protective' role of sand (inert material)

UNDERSTANDING OF THE FIRE BEHAVIOR OF ARTIFICIAL TURF STRUCTURES



ARTIFICIAL TURF STRUCTURES FOR SPORTS

Fire behaviour of infill materials



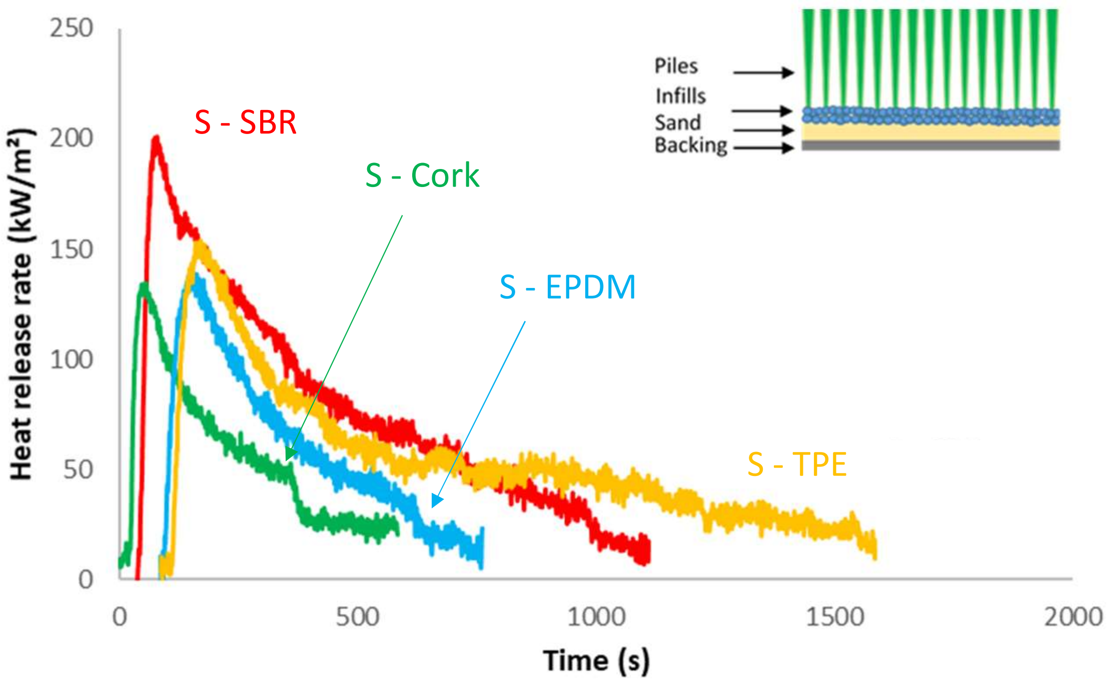
Infills	TTI (s)	pHRR (kW/m²)	THR (MJ/m²)	TFO (s)
SBR	39 ± 2	237 ± 24	81 ± 8	1267 ± 204
Cork	19 ± 3	108 ± 1	20 ± 1	284 ± 4
EPDM	47 ± 3	115 ± 2	39 ± 2	782 ± 62
TPE	66 ± 4	127 ± 3	86 ± 7	1895 ± 236

UNDERSTANDING OF THE FIRE BEHAVIOR OF ARTIFICIAL TURF STRUCTURES

ARTIFICIAL TURF STRUCTURES FOR SPORTS

Fire behaviour of the complete structures

Structures	TTI (s)	pHRR (kW/m²)	THR (MJ/m²)	TFO (s)
S – SBR	40 ± 4	201 ± 21	82 ± 2	981 ± 30
S – Cork	22 ± 1	143 ± 6	34 ± 1	272 ± 22
S – EPDM	86 ± 1	143 ± 4	41 ± 3	617 ± 75
S – TPE	86 ± 14	154 ± 1	82 ± 4	1739 ± 30



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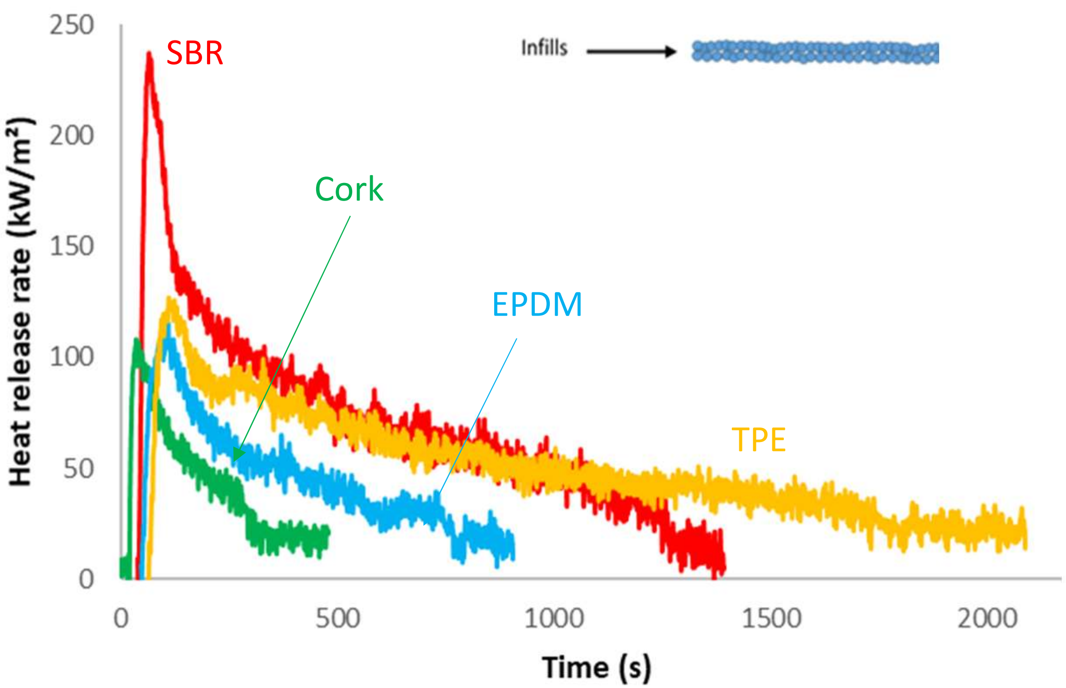
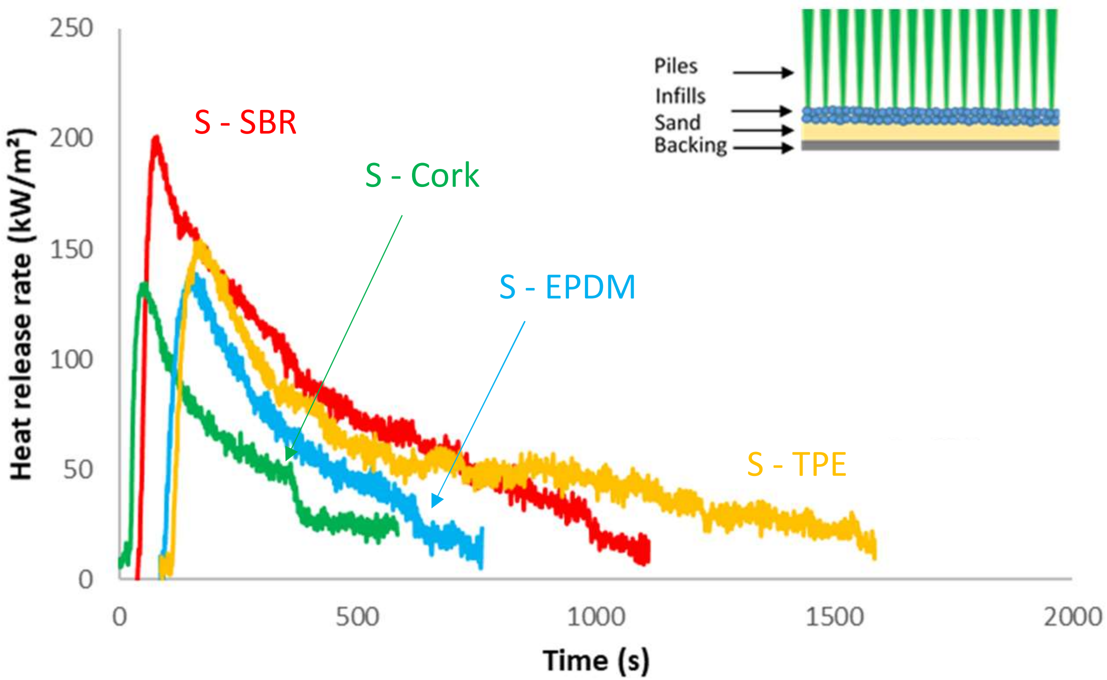
UNDERSTANDING OF THE FIRE BEHAVIOR OF ARTIFICIAL TURF STRUCTURES

ARTIFICIAL TURF STRUCTURES FOR SPORTS

Fire behaviour of infill materials



Fire behaviour of the complete structures



Fire performance of the whole turf structure driven by infill materials

FIREPROOFING STRATEGY

LANDSCAPING

→ **Strong contribution of the backing**

→ No modification of the THR with a FR coating

FIREPROOFING STRATEGY:

→ Formation of a protective layer on the surface of the backing to prevent its degradation

→ **Incorporation of FR additives during extrusion of filaments**

FIREPROOFING STRATEGY

LANDSCAPING

- → **Strong contribution of the backing**
- → No modification of the THR with a FR coating

FIREPROOFING STRATEGY:

- → Formation of a protective layer on the surface of the backing to prevent its degradation
- → **Incorporation of FR additives during extrusion of filaments**

SPORTS

- → **Fire behaviour driven by infill material**
- → **Best behaviour with cork** in terms of pHRR and THR
- → ECHA: Ban of microplastics under debate

FIREPROOFING STRATEGY:

Improvement of the fire behaviour of cork to meet the fire safety regulation for indoor use.

FIREPROOFING STRATEGY FOR CORK

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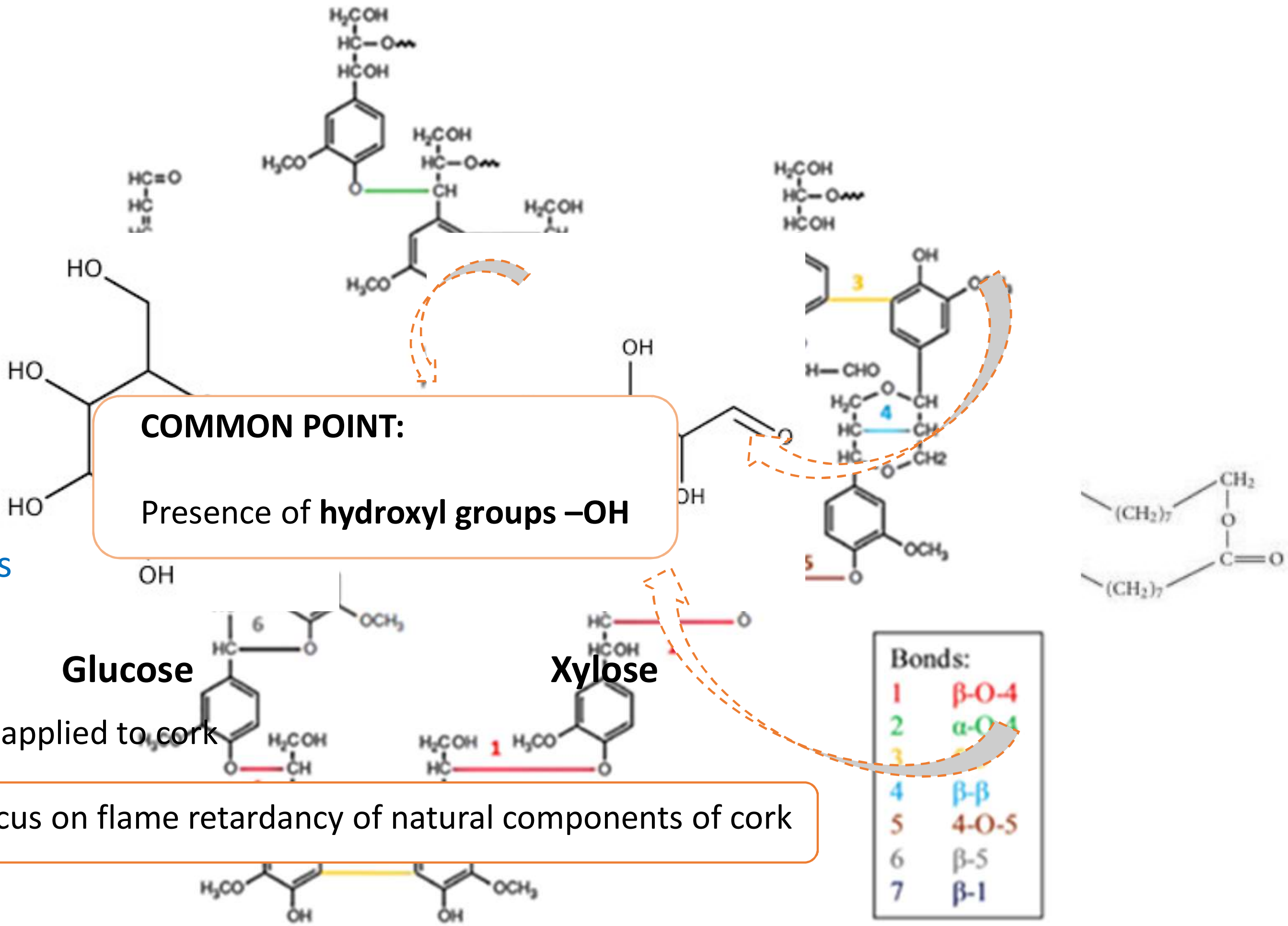
Literature review on cork:

Chemical composition[1]

- → **Suberin: 42%**
- → **Lignin: 22%**
- → **Polysaccharides: 15%**
- → Extractives: 14%
- → Ash: 2%



COMMON POINT:

Presence of **hydroxyl groups –OH**

Cork fireproofing methods

No literature on the:

- → Fire behaviour of cork
- → Fire proofing methods applied to cork

Focus on flame retardancy of natural components of cork

[1] *Average values*

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FIREPROOFING STRATEGY FOR CORK

<u>Literature review on cork:</u> Flame retardancy of natural compounds

Surface treatments applicable to cork:

→ Laser, plasma or cold plasma technologies
→ Layer-by-layer technique[1]

Risk of leaching and poor durability

→ Release of chemicals
→ Loss of fire properties over time

Grafting methods applicable to cork :

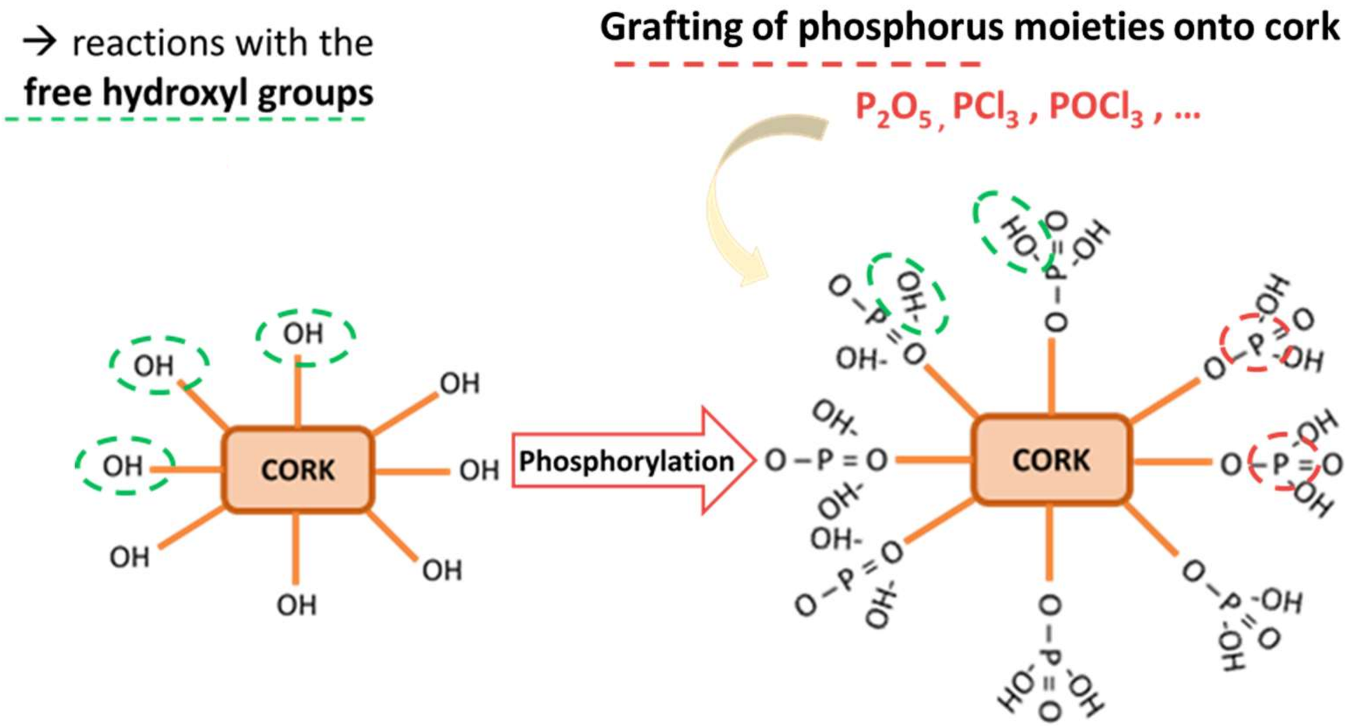
→ Derivatisation
→ Amination
→ Phosphorylation

Better durability

→ Significant improvements in thermal stability and fire performance for lignin[2] and cellulose[3]
→ Suberin, a polymer with a cellulose-like structure containing hydroxyl groups

[1]*Malucelli (2016), DOI: 10.1016/j.matlet.2015.12.103*
[2]*Prieur et al (2017), DOI: 10.1039/C7RA00295E*
[3]*Niu et al (2020), DOI: 10.1016/j.carbpol.2020.116422*

FIREPROOFING STRATEGY THROUGH CORK PHOSPHORYLATION



1. **Grafting of phosphorus moieties through covalent bonding** onto the reactive -OH groups, usually located at chain ends of natural compounds
2. **Esterification** of hydroxyl groups to graft **phosphate, phosphite or phosphonic acid functions** onto the polymeric chain

FIREPROOFING STRATEGY THROUGH CORK PHOSPHORYLATION

Phosphorylation process:

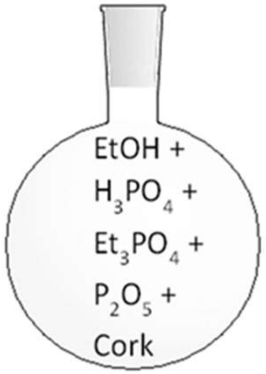
Objectives:

- → Enhance the fire behaviour of cork granules
- → Increase the charring phenomenon of cork

Limitation:

- Avoid toxic compounds, especially halogenated flame retardants

Selected protocol[1] after preliminary experiments:



- → Ethanol (EtOH)
- → Phosphoric acid (H_3PO_4)
- → Triethyl phosphate (Et_3PO_4)
- → Phosphorus pentoxide (P_2O_5)

Criteria for optimization:

- → Highest carbonization rate
- → Yield of reaction
- → Phosphorus grafting through
  - → Microscopic analysis
  - → Infrared analysis

[1] *Granja et al (2001), DOI: 10.1002/app.2193*

FIREPROOFING STRATEGY THROUGH CORK PHOSPHORYLATION

P – Cork:
→ $m_{cork\ granules}$ = **12 g**
→ $V_{EtOH} = V_{H_3PO_4} =$ 60 mL
→ $V_{Et_3PO_4} =$ 40 mL
→ $m_{P_2O_5} =$ 1.3 g
→ Mixture kept at 45 °C for 24 h.

Upscaling of the phosphorylation protocol through **dimensional analysis**:
→ **High amount of P-cork needed** for MLC and radiant panel tests

Selected optimised phosphorylation conditions

LS P – Cork*:
→ $m_{cork\ granules}$ = **80 g**
→ $V_{EtOH} = V_{H_3PO_4} =$ 400 mL
→ $V_{Et_3PO_4} =$ 270 mL
→ $m_{P_2O_5} =$ 8.8 g
→ Mixture kept at 45 °C for 24 h.

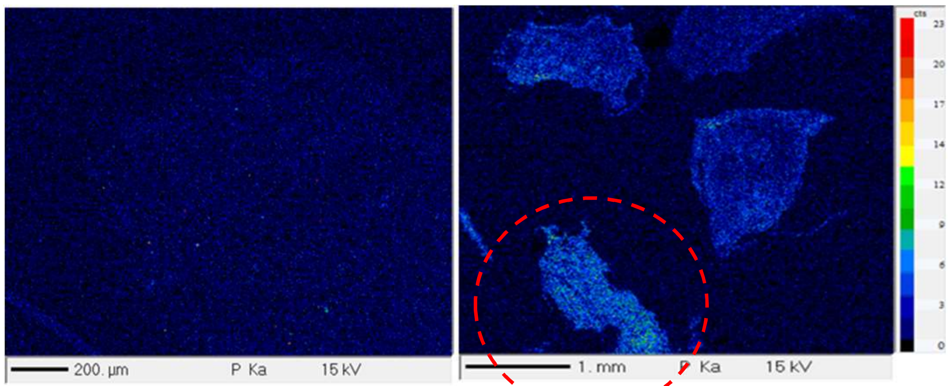
Characterizations:
→ Carbonization rate
→ Yield of reaction
→ Infrared spectroscopy analysis
→ Microscopic analyses
→ Nuclear magnetic resonance spectroscopy analyses
→ Phosphorus content determination

**Large-scale phosphorylated cork*

FIREPROOFING STRATEGY THROUGH CORK PHOSPHORYLATION

<u>Characterizations of LS P – Cork</u>: Microscopic analyses

EPMA mappings

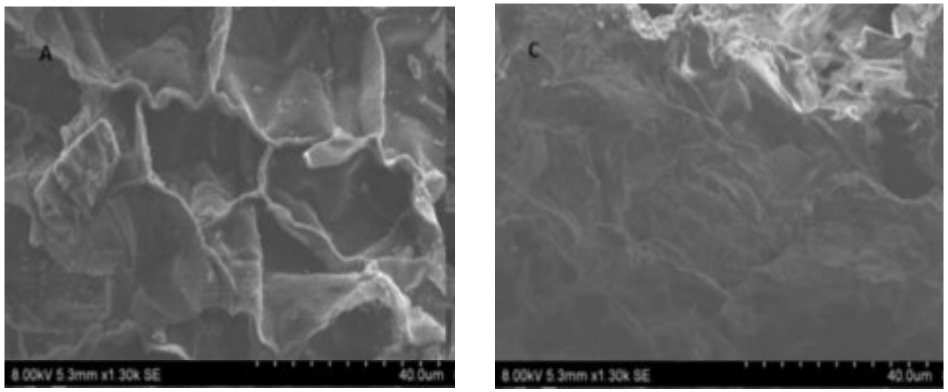


Virgin cork ***LS P-Cork***

Phosphorus distribution

- → Rather uniform throughout the entire thickness of granules
- → Cork variability (natural origin) affects the phosphorus content

SEM images:



Virgin cork ***LS P-Cork***

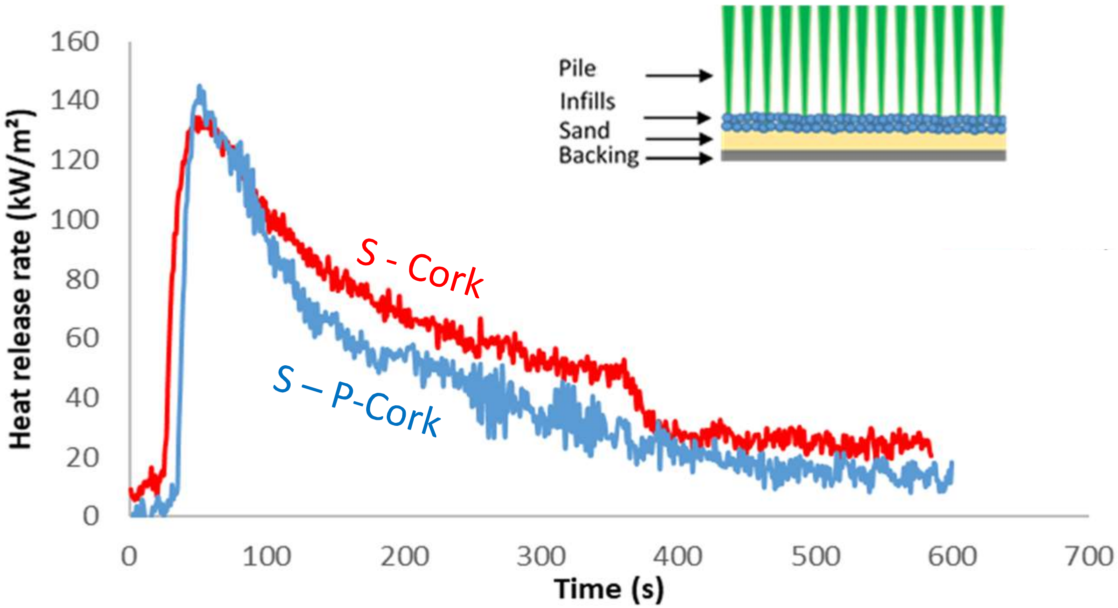
LS P-cork:

- → Structure and surface damaged by the reaction
- → Rather flat surface, cavities no longer visible
- → Potential influence on the required properties for sports applications

FIREPROOFING STRATEGY THROUGH CORK PHOSPHORYLATION

Fire behaviour of LS P – Cork:

Fire behaviour of phosphorylated cork through MLC test



Structures	TTi (s)	pHRR (kW/m²)	THR (MJ/m²)	TFO (s)
S – Cork	22 ± 1	143 ± 6	34 ± 1	272 ± 22
S – P-cork	34 ± 4	145 ± 6	27 ± 1	376 ± 18

Higher TTi: + 12 s

Lower THR value: -21%

FIREPROOFING STRATEGY THROUGH CORK PHOSPHORYLATION

Fire behaviour of LS P – Cork:

Fire behaviour of phosphorylated cork through MLC test

Virgin cork

LS P-Cork

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FIREPROOFING STRATEGY THROUGH CORK PHOSPHORYLATION

Characteristics of **phosphorylated cork**:

→ 7-fold increase of the phosphorus content

→ Carbonization rate of about 9 % (HTT = 600°C)

→ Uniform grafting of phosphorus

→ Bonds characteristic of phosphates and phosphonates

Phosphorylation drawbacks:

→ Extraction of structural compounds

→ Degradation of cork structure

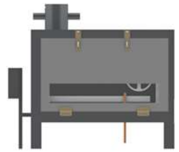
→ **Slight improvement of the THR at MLC test**

VALIDATION OF DEVELOPED MATERIALS:

→ Investigation of the fire behaviour of the structures including LS P-cork according to the standard (radiant panel test)

VALIDATION OF DEVELOPED MATERIALS: FIRE BEHAVIOUR

Fire behaviour of the phosphorylated cork structure at small scale:



Parameters \ Structures	S – Cork	S – P-Cork
Percentage of burnt length (%)	**44**	**30**
Burning time (s)	668	623
CHF (kW/m²)	4.3	7.0
Rating	**D_{FL}**	**C_{FL}**
Smoke rate	s1	s1

→ **Cork phosphorylation: significant reduction (33% decrease) of the burnt length**

→ Improvement of the fire properties: **C_{FL} rating, meeting the EN ISO 13501-1 regulation for indoor applications**

Observations:

→ Strong carbonization of granules
→ Dense and thick infill
→ **Enhanced charring phenomenon**

PROGRAMME DE COOPÉRATION TRANSFRONTALIÈRE
GRENSOVERSCHRIJDEND SAMENWERKINGSPROGRAMMA

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Validation des propriétés fonctionnelles à l'échelle pilote

Validatie van de functionele eigenschappen op proefschaal

Stijn Rambour

AVEC LE SOUTIEN DU FONDS EUROPÉEN DE DÉVELOPPEMENT RÉGIONAL
MET STEUN VAN HET EUROPEES FONDS VOOR REGIONALE ONTWIKKELING

Production des prototypes: 2 routes

- Phosphorylation de liège
- Additives dans le polymère des fibres

Productie van prototypes: 2 routes

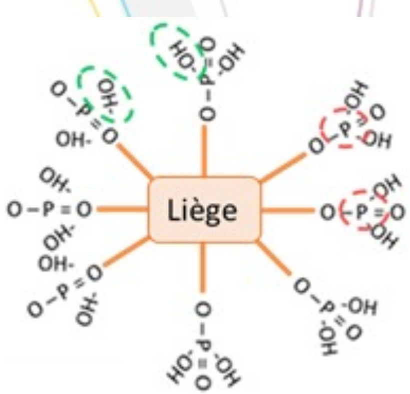
- Fosforylering van kurk
- Additieven in het vezelpolymeer

Phosphorylation de liège: Adaptation du protocole de ULille pour être utilisable avec des quantités plus grandes dans une machine à teindre

Fosforylering van kurk: Aanpassing van protocol van ULille om op te schalen naar grotere hoeveelheden met verftoestel

Usure de liège traité/ Slijtage van behandeld kurk

Échantillon/ staal	Unité/ eenheid	Résultat/ resultaat
Liège original Onbehandelde kurk	%	70
Liège traité Behandelde kurk	%	88



Test au feu du liège traité/ brandtest van behandeld kurk

Échantillon/ staal	Unité/ eenheid	Résultat/ resultaat	Classe/ klasse
Liège original Onbehandelde kurk	kW	2.4	Dfl s1
Liège traité Behandelde kurk	kW	8.2	Bfl s1
Liège mouillé et conditionné Nat gemaakt en geconditioneerde kurk	kW	8.6	Bfl s1

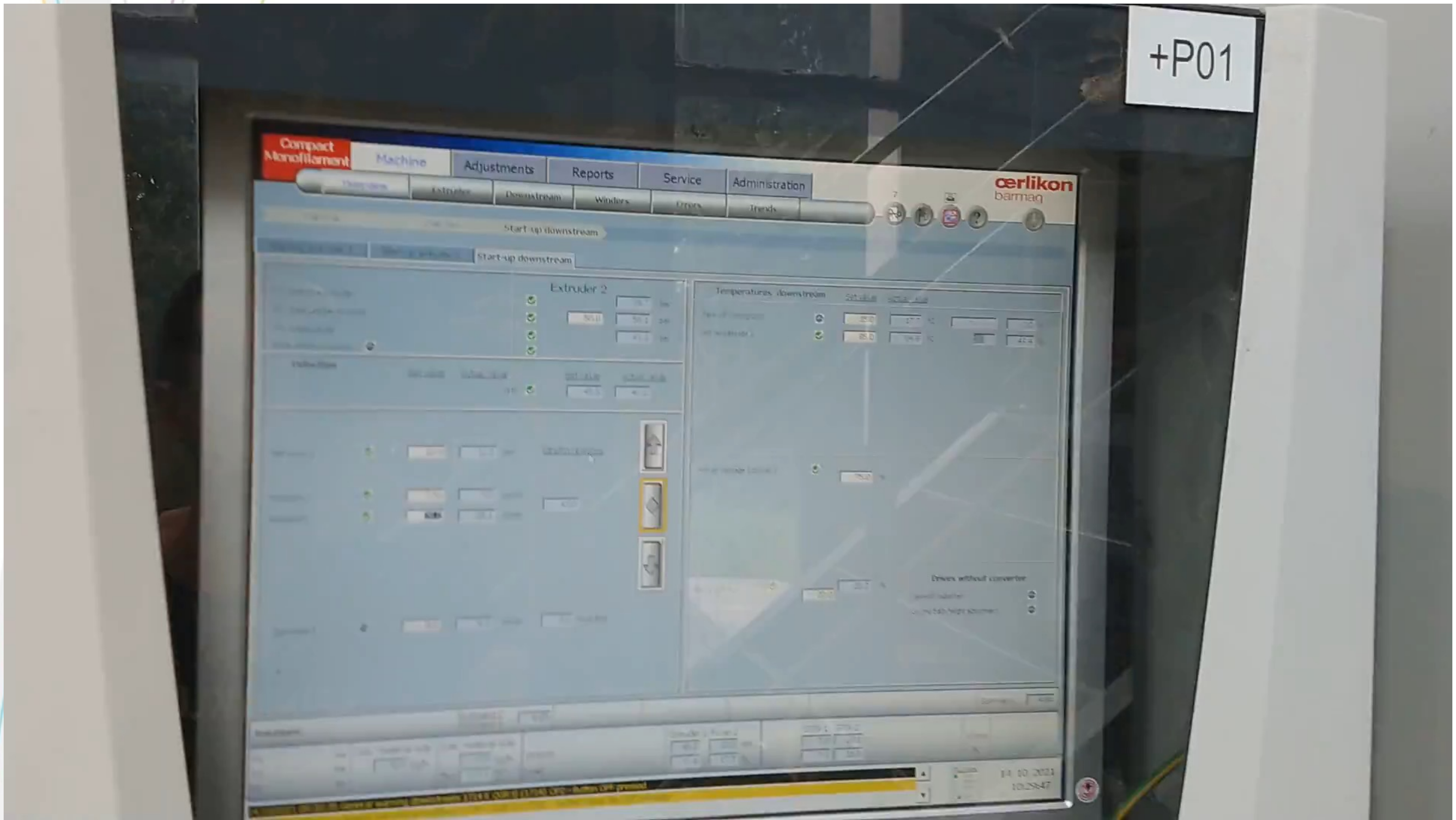
Usure de liège traité/ slijtage van behandeld kurk

Conclusion:
L'adaption du protocol améliore l'usure de liège et le comportement au feu.

Conclusie:
De aanpassing aan het protocol verbetert de slijtage en het brandgedrag van kurk.

Extrusion gazon paysager/ Extrusie landscape grass

Extrusion gazon paysager/ Extrusie landscape grass



Extrusion gazon paysager/ Extrusie landscape grass

Fibres extrudé pur (sans FR)/
Vezels met enkel polymeer /
(zonder brandvertragers)

Number of	average	stdev
cycles	F (cN)	F (cN)
1	2.1	0.4
100	0.8	0.1
300	0.7	0.1
Number of	average	stdev
cycles	F (%)	F (%)
100	36.4	4.0
300	31.6	3.9

Fibres extrudé avec FR
Vezels met brandvertragers

Number of	average	stdev
cycles	F (cN)	F (cN)
1	3.6	0.4
100	1.7	0.3
300	1.5	0.3
Number of	average	stdev
cycles	F (%)	F (%)
100	46.8	5.2
300	42.9	5.0

Conclusion/conclusie :
L'addition des produits FR améliore la résilience des fibres.
De toevoeging van de brandvertrager zorgt voor een verbetering in resiliëntie.

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Extrusion gazon paysager/ Extrusie landscape grass

Fibres extrudé pur (sans FR)/
Vezels met enkel polymeer /
(zonder brandvertragers)

Test No	Force @ Peak (N)	Elong. @ Peak (mm)	Strain @ Peak (%)
Min	32.010	246.267	97.700
Mean	35.070	272.427	108.185
Max	38.904	294.428	117.019
S.D.	2.422	16.148	6.481
C. of V.	6.905	5.928	5.991
L.C.L.	33.337	260.875	103.549
U.C.L.	36.802	283.979	112.821

Fibres extrudé avec FR
Vezels met brandvertragers

Test No	Force @ Peak (N)	Elong. @ Peak (mm)	Strain @ Peak (%)
Min	31.789	216.664	85.890
Mean	36.540	296.268	117.376
Max	41.704	364.692	144.332
S.D.	3.953	54.811	21.668
C. of V.	10.820	18.500	18.460
L.C.L.	33.711	257.058	101.875
U.C.L.	39.368	335.478	132.877

Conclusion/conclusie :
Il n'y a pas une grande différence entre les fibres avec et sans FR en force et élongation.
Er is weinig verschil tussen de vezels met en zonder brandvertagers in kracht in verlenging.

Test au feu du tapis sans remplissage/ brandtest van niet gevuld tapijt

Les 2 tapis brûlent complètement. Il n’y a donc pas de différence en classe de feu. La vitesse de propagation de flamme est totalement différente. Le gazon artificiel sans RF brûle complètement en 15 minutes, le gazon artificiel avec RF brûle complètement après 28 minutes. Il y a alors plus de temps pour évacuer l’endroit.

Beide tapijten branden volledig op. Er is dus geen verschil in brandklasse. De snelheid van branden is echter veel lager. Origineel tapijt brandt op in 15 minuten, terwijl behandeld tapijt 28 minuten nodig heeft om volledig op te branden.
Er is dus veel meer tijd om de plaats te evacueren.

Environmental Life Cycle Assessment in GRASS project

Olivier Talon

Final Event Interreg FWVL GRASS

16/06/2022 - Ghent

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What is LCA?

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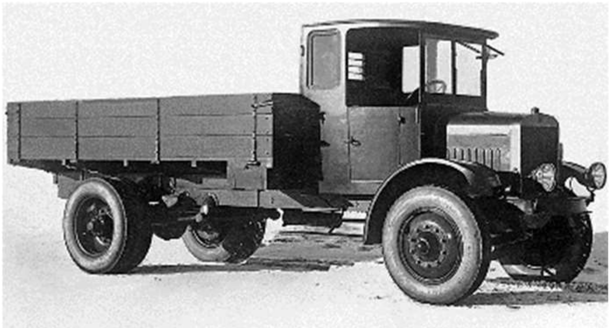
LCA identifies all steps of the life cycle of the studied system

end of life treatment

transports

manufacture of the product

raw materials extraction



use phase

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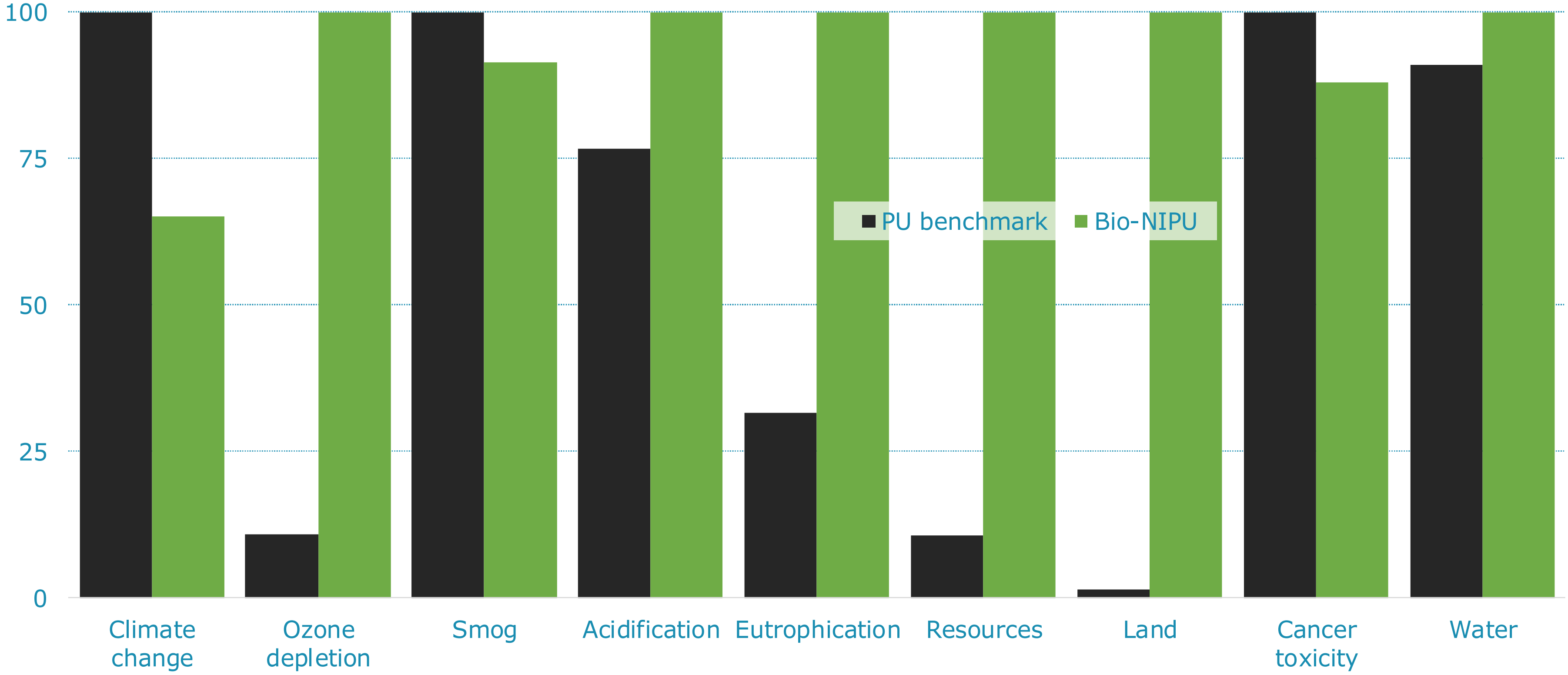
LCA quantifies exchanges between the system and the environment

LCA makes links between these exchanges and multiple environmental impact categories

LCA translates these flows into environmental impacts



Results of the CO2Green project financed by Région Wallonne

Wallonie

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LCA compares systems based on the same functionality

1 kg paint A vs. 1 kg paint B

cover 1 m² wall with paint A or B for 3 years

(includes lifetime, amount of paint, painting step...)

FUNCTIONAL UNIT

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What do we use LCA for in GRASS?

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MATERIA NOVA

- identify the main contributors to the environmental impacts of artificial turf
- evaluate the envrionmental consequences of a potential fire of artificial turf
- evaluate the environmental benefits of fireproofing artificial turf
- identify potential environmental hotsposts of the fireproofing strategy (and provide ecodesign advice for optimization)

What do we **not** use LCA for in GRASS?

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MATERIA NOVA

- compare artificial turf with other systems for similar applications

This enables us to simplify study and reduce the system boundaries

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LCA in GRASS

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Model of the reference system

Global turf structure

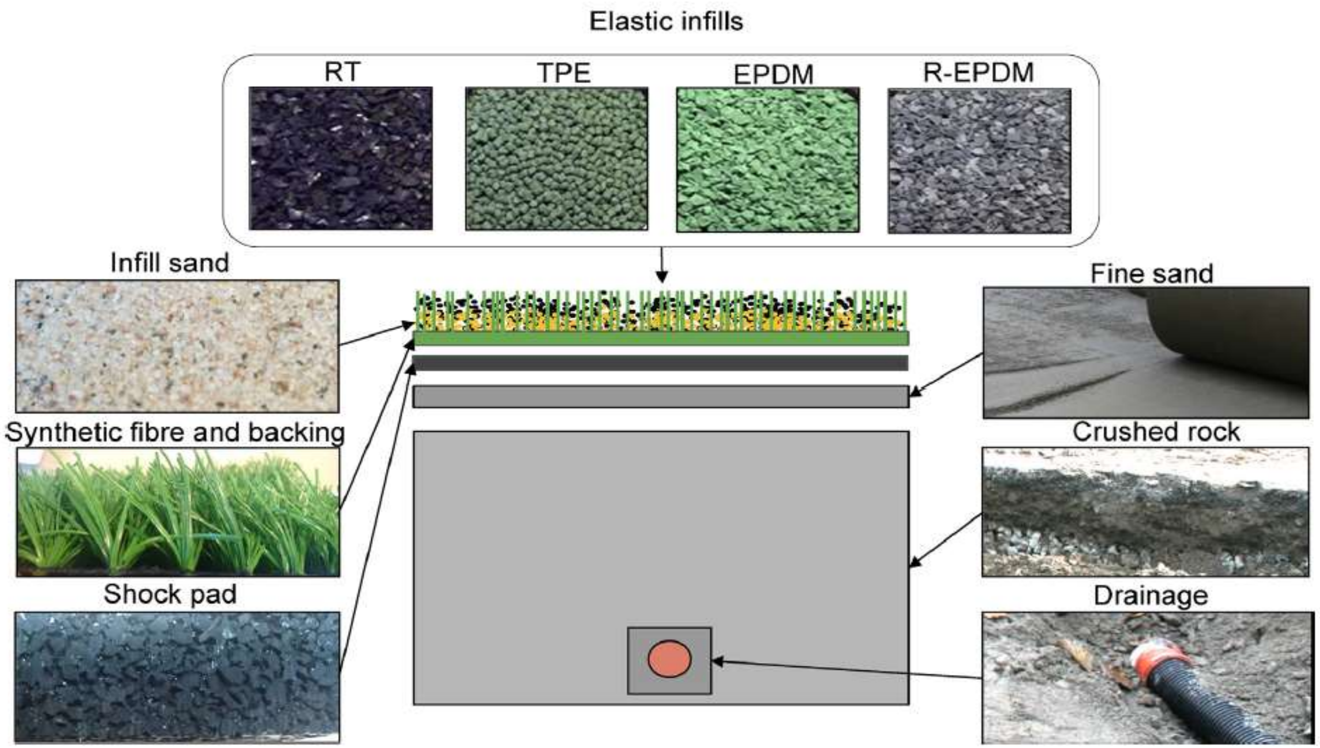

Fig. 1. Design of artificial turf fields. Pictures produced by the article authors. Illustration based on Simpson et al. (2013).

Source Magnusson 2017

Model of the reference system

Reduction of system boundaries

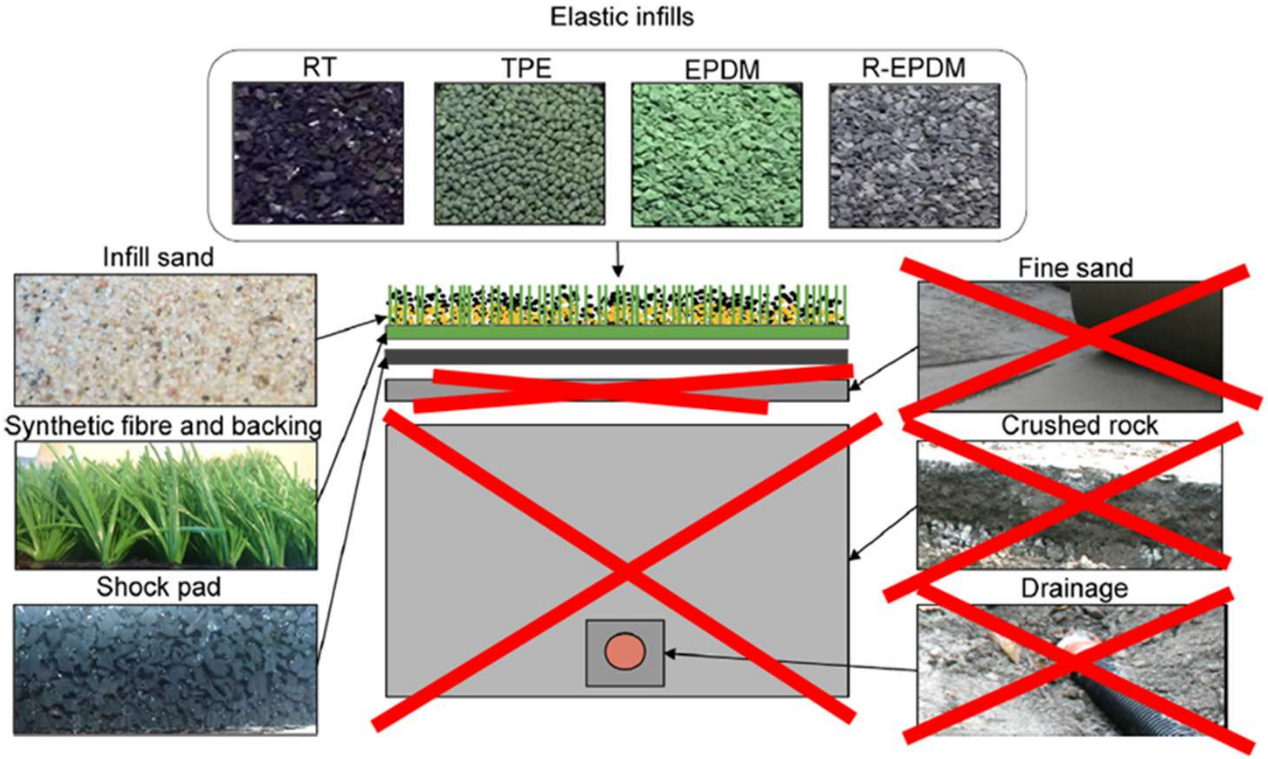

Fig. 1. Design of artificial turf fields. Pictures produced by the article authors. Illustration based on Simpson et al. (2013).

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Modelling life cycle inventories

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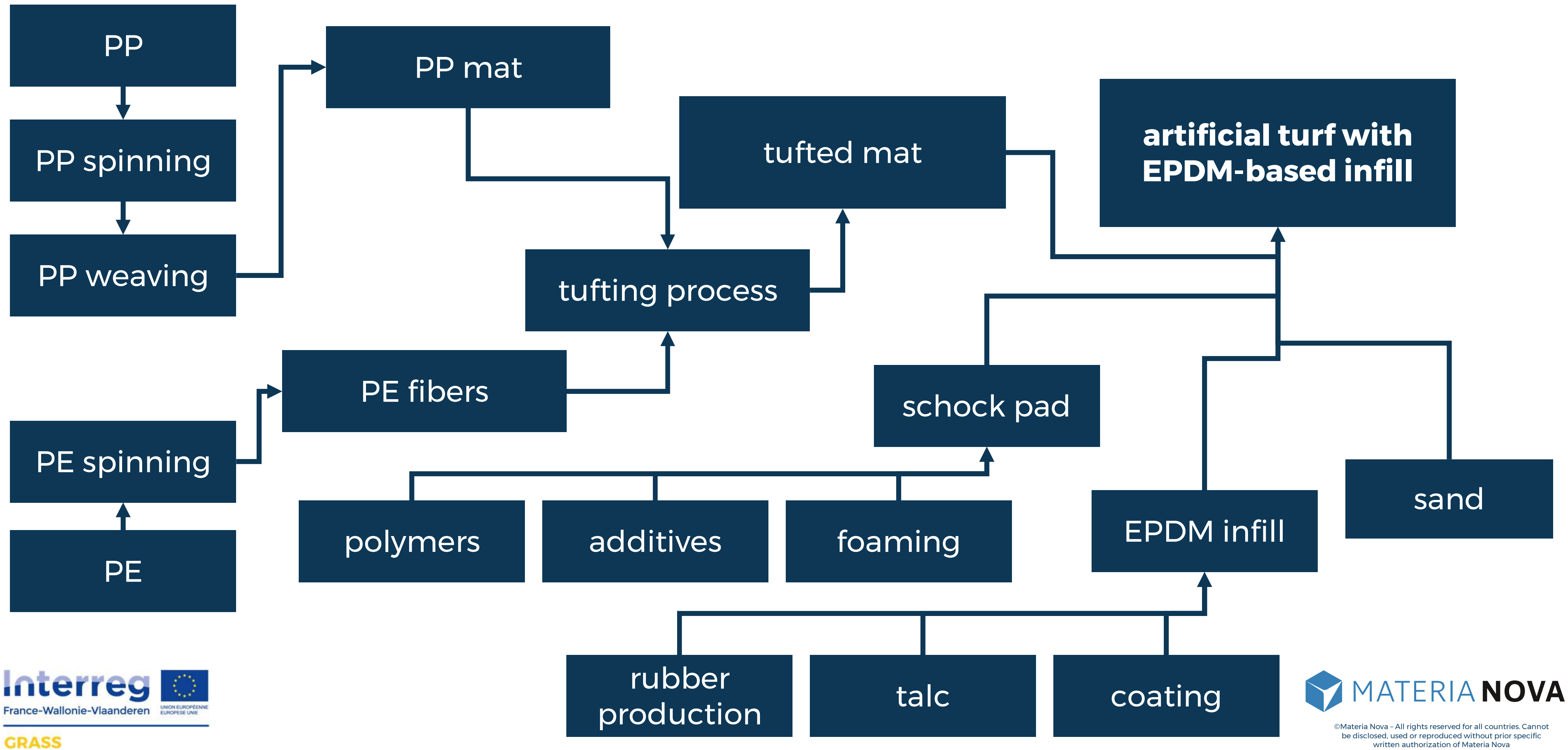
Process tree – reference turf for outdoor use



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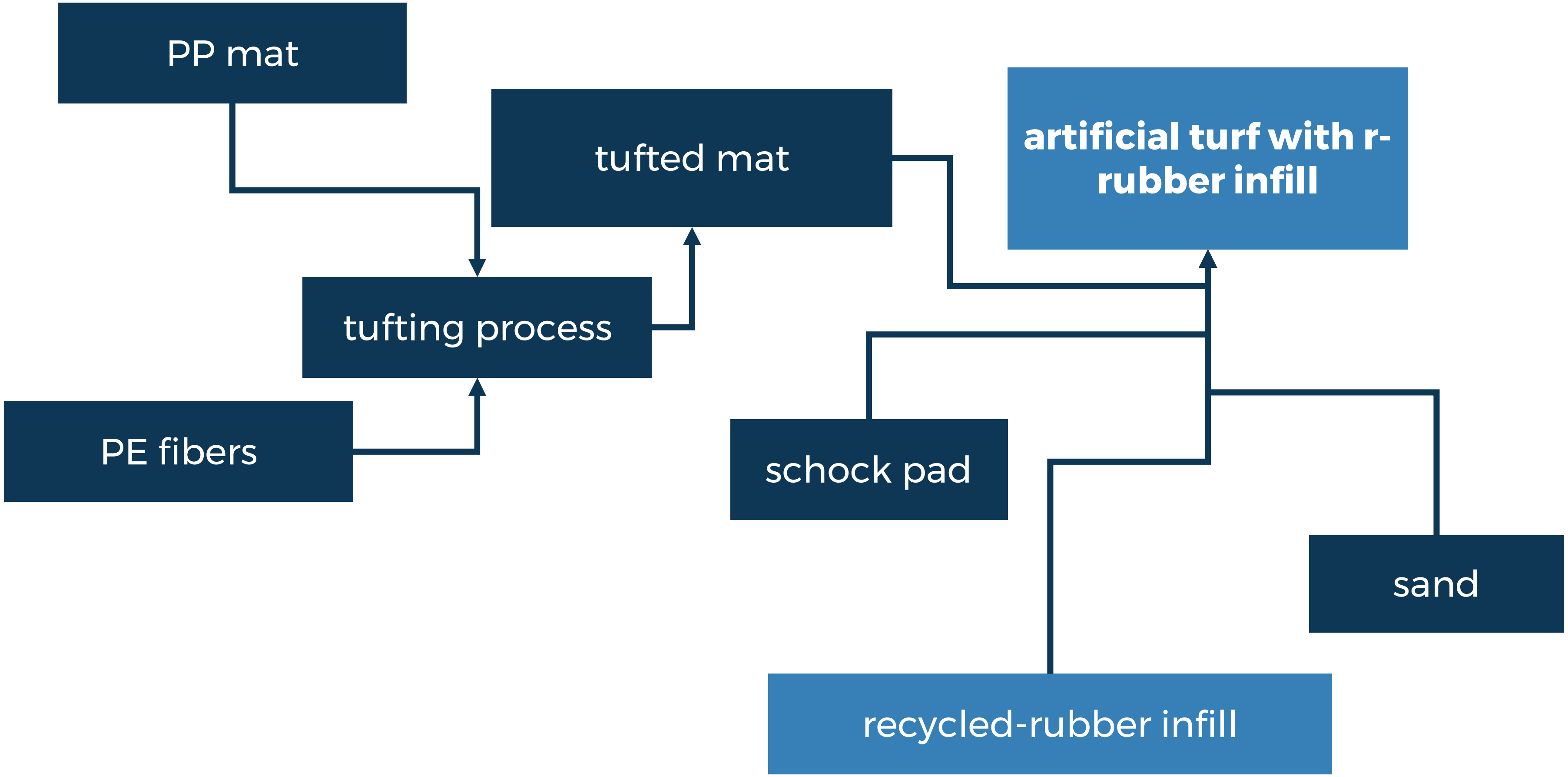
Alternative systems



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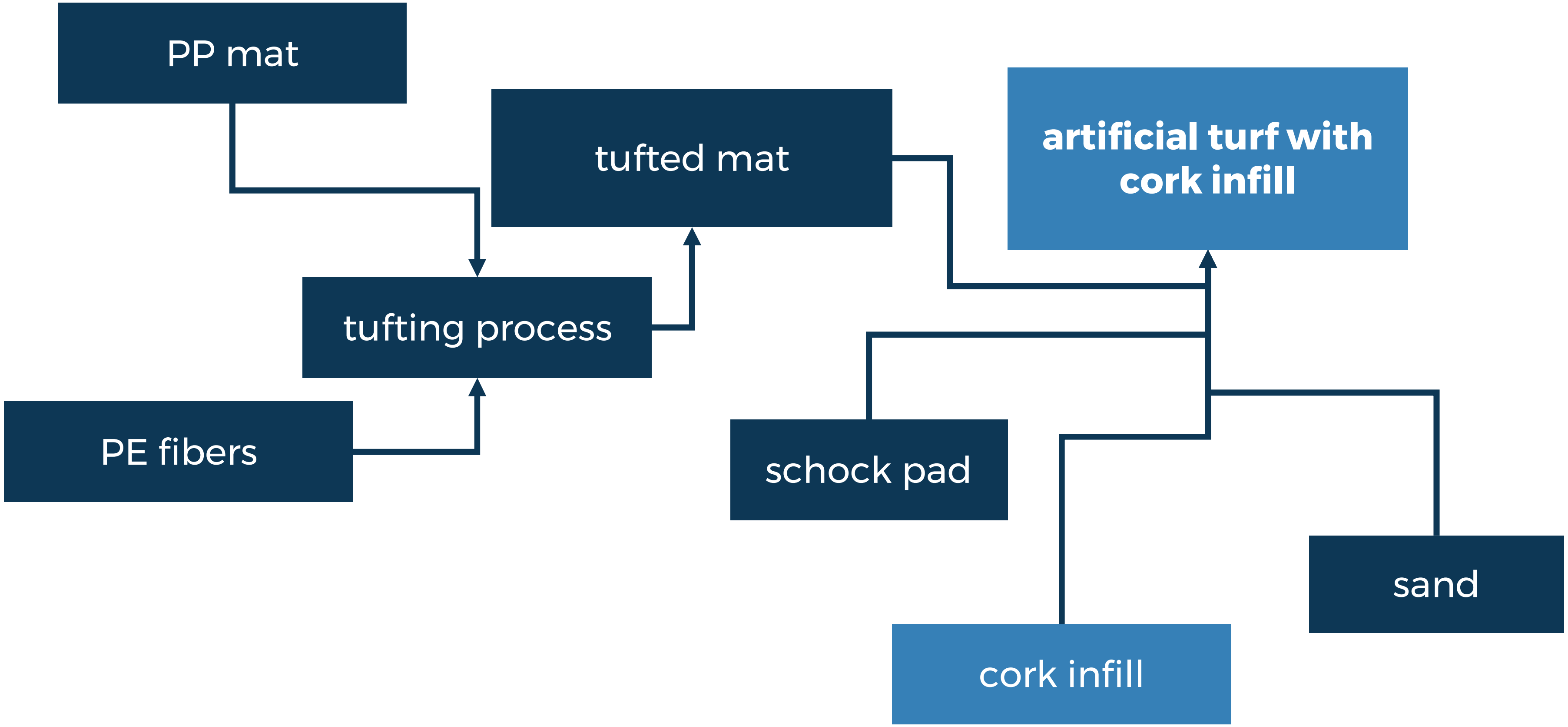
Alternative systems



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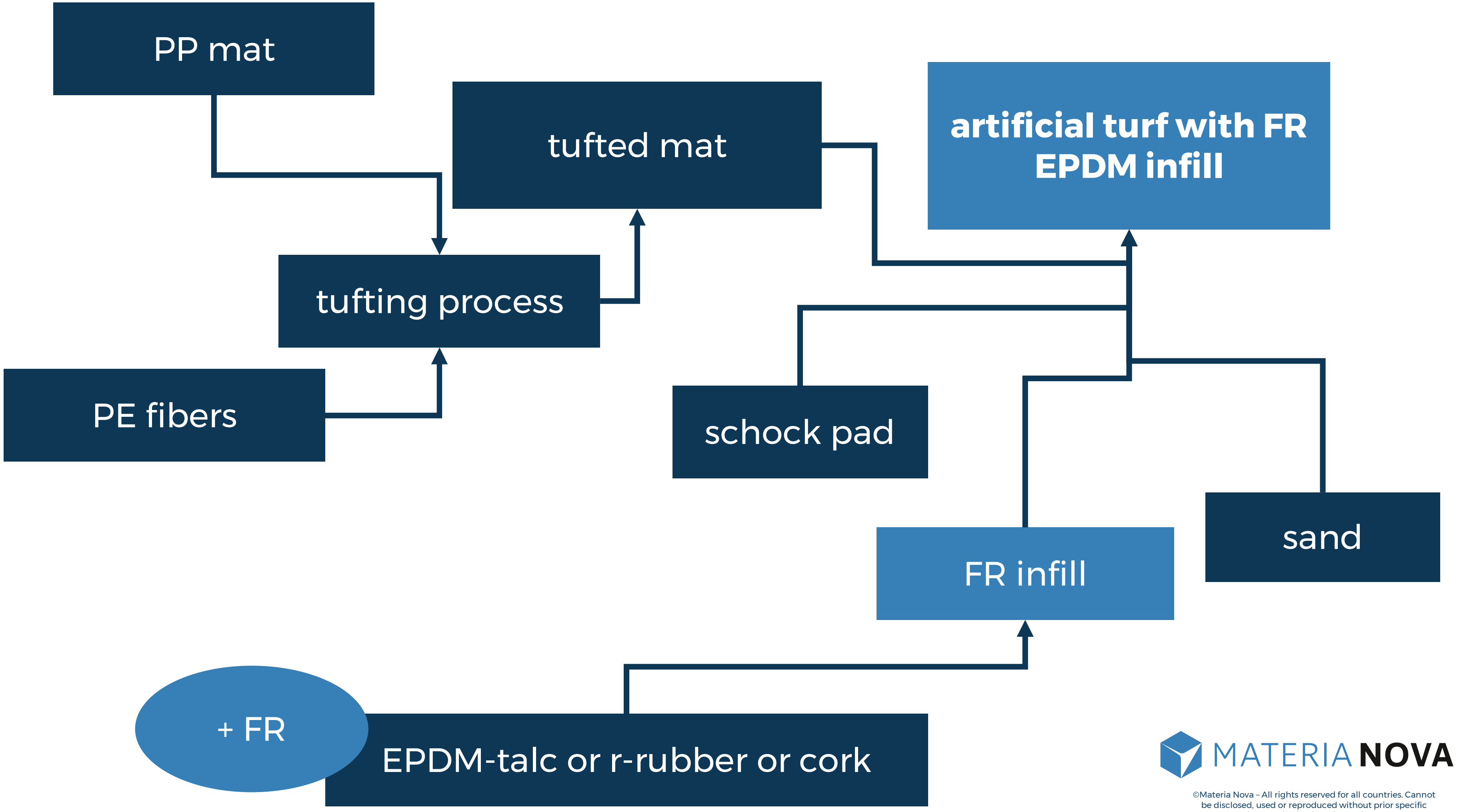
Alternative systems



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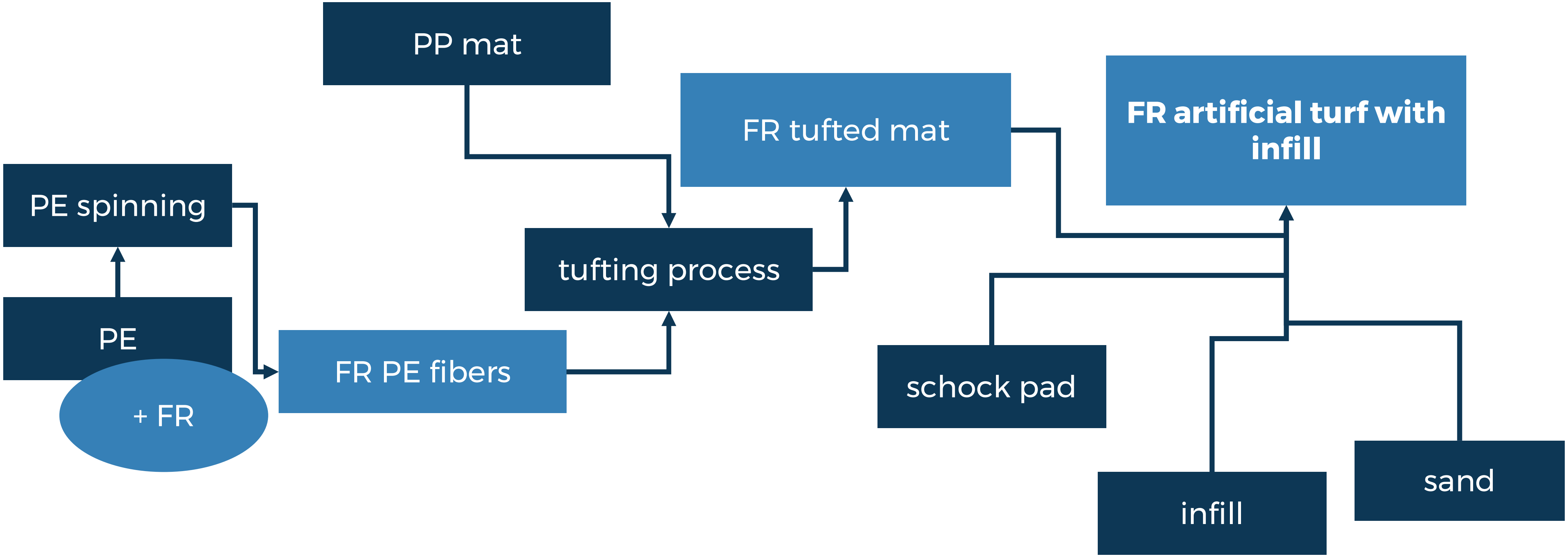
Alternative systems



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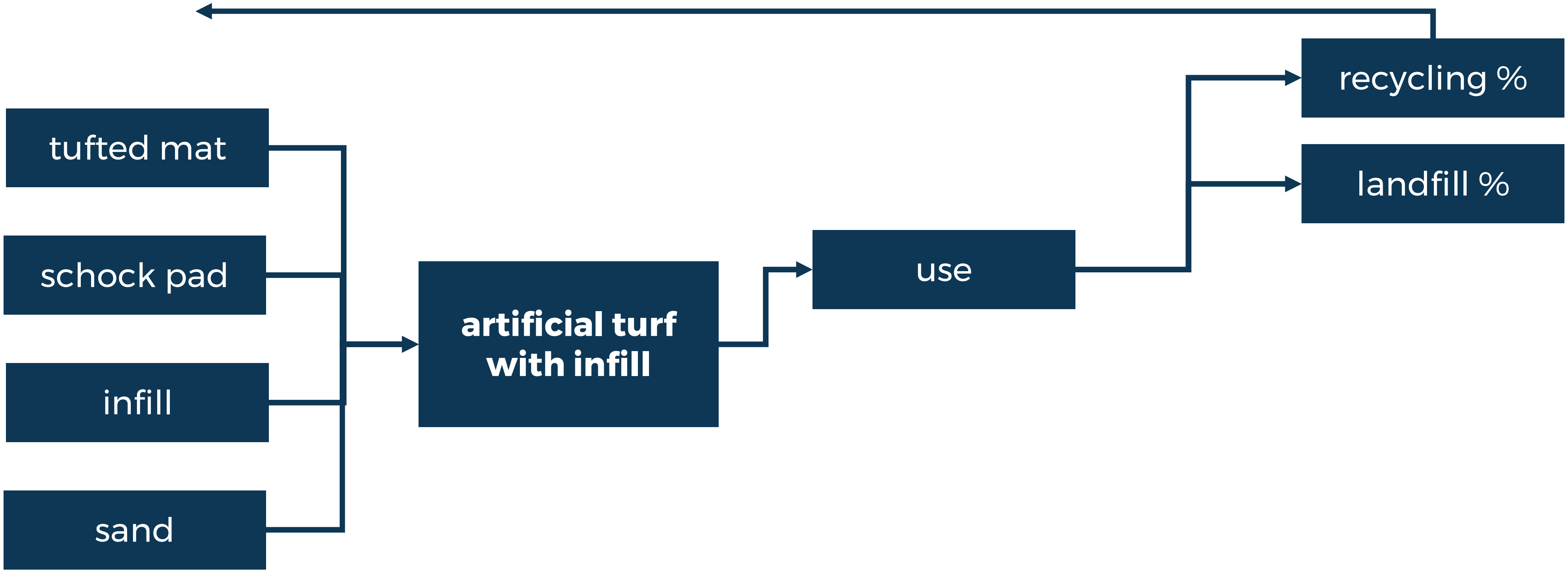
Full life cycle (for intended lifetime)



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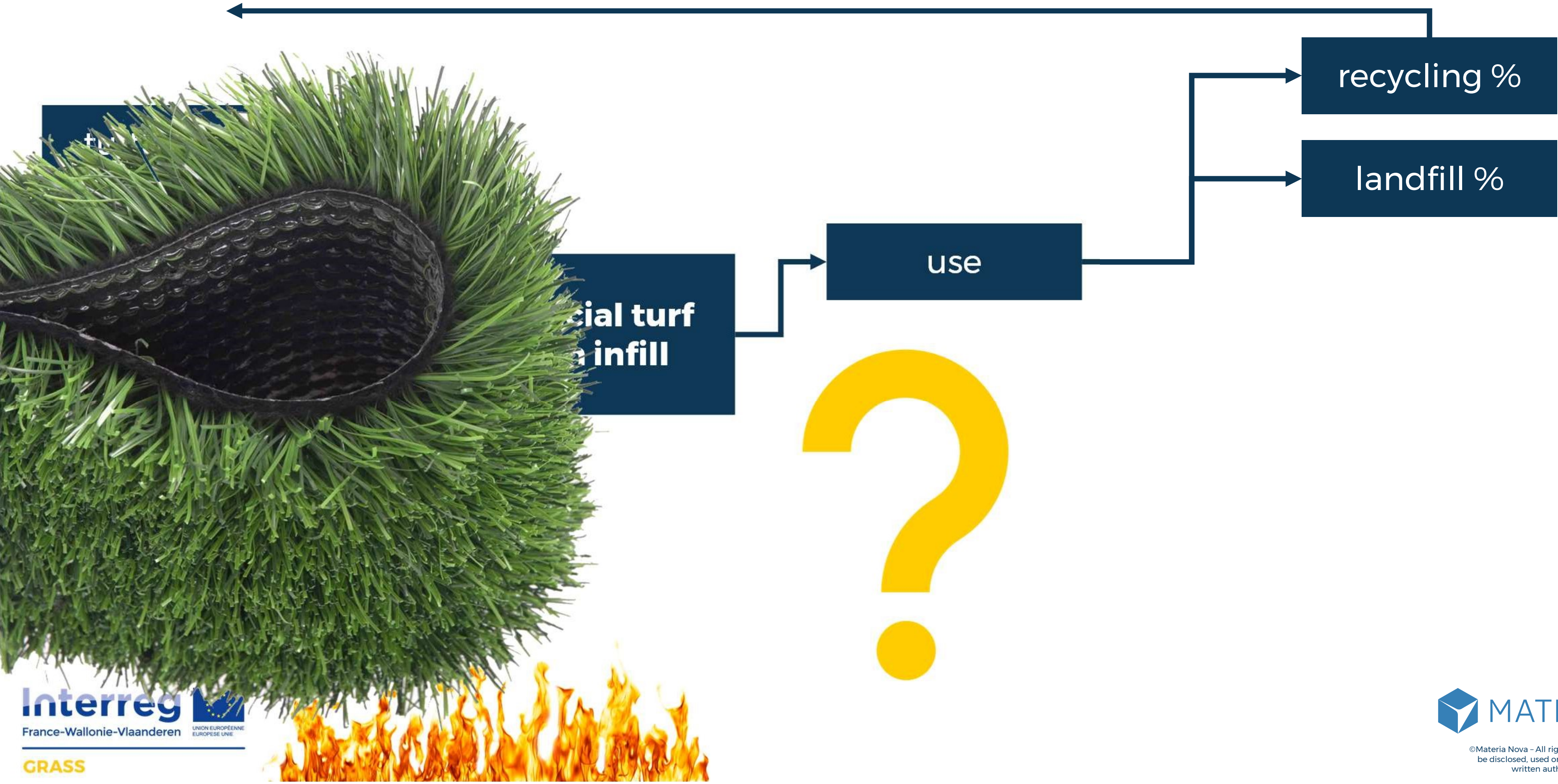
Full life cycle (for intended lifetime)



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Accounting for fire accidents in LCA

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LCA is based on (very) simple mathematics

$$EI(A+B) = EI(A) + EI(B)$$

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LC step 1

emission of 1 kg X

→ $IC_1(X) = x_1$

→ $IC_2(X) = x_2$

→ $IC_3(X) = 0$

LC step 2

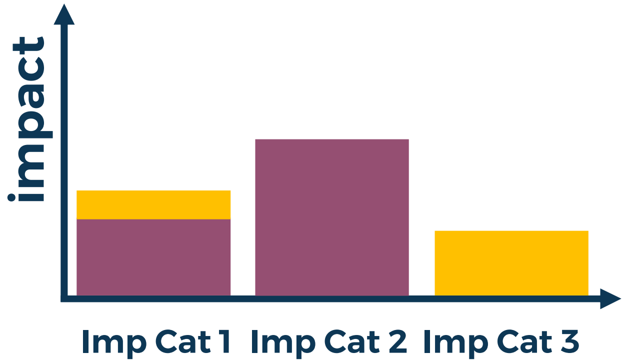
emission of 1 kg Y

→ $IC_1(Y) = y_1$

→ $IC_2(Y) = 0$

→ $IC_3(Y) = y_3$

Overall Life Cycle Impacts



Any system

$$EI(system) = EI(production) + EI(use) + EI(end\ of\ life)$$

Non-fire retarded system

$$EI(\overline{FR}) = EI(prod_{\overline{FR}}) + EI(use_{\overline{FR}}) + EI(eol_{\overline{FR}})$$

Fire retarded system

$$EI(FR) = EI(prod_{FR}) + EI(use_{FR}) + EI(eol_{FR})$$

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FR vs. $\overline{FR}$
What do we compare?

In LCA, everything is related to the function of the system

What is the common function of FR and $\overline{FR}$?

Not to burn? No.
To be used.

FR vs. $\overline{FR}$

Therefore, if $FR = \overline{FR} + fr$

$$EI(FR) = EI(\overline{FR}) + EI(fr)$$

$$EI(FR) > EI(\overline{FR})$$

because, obviously, $EI(prod_{fr}) + EI(use_{fr}) + EI(eol_{fr}) > 0$

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But...

Such systems should not be considered by LCA as if they would never burn. Because they may burn. Each of them.

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How can we do that?

By including fire statistics and environmental consequences of fire events in the comparative LCA study

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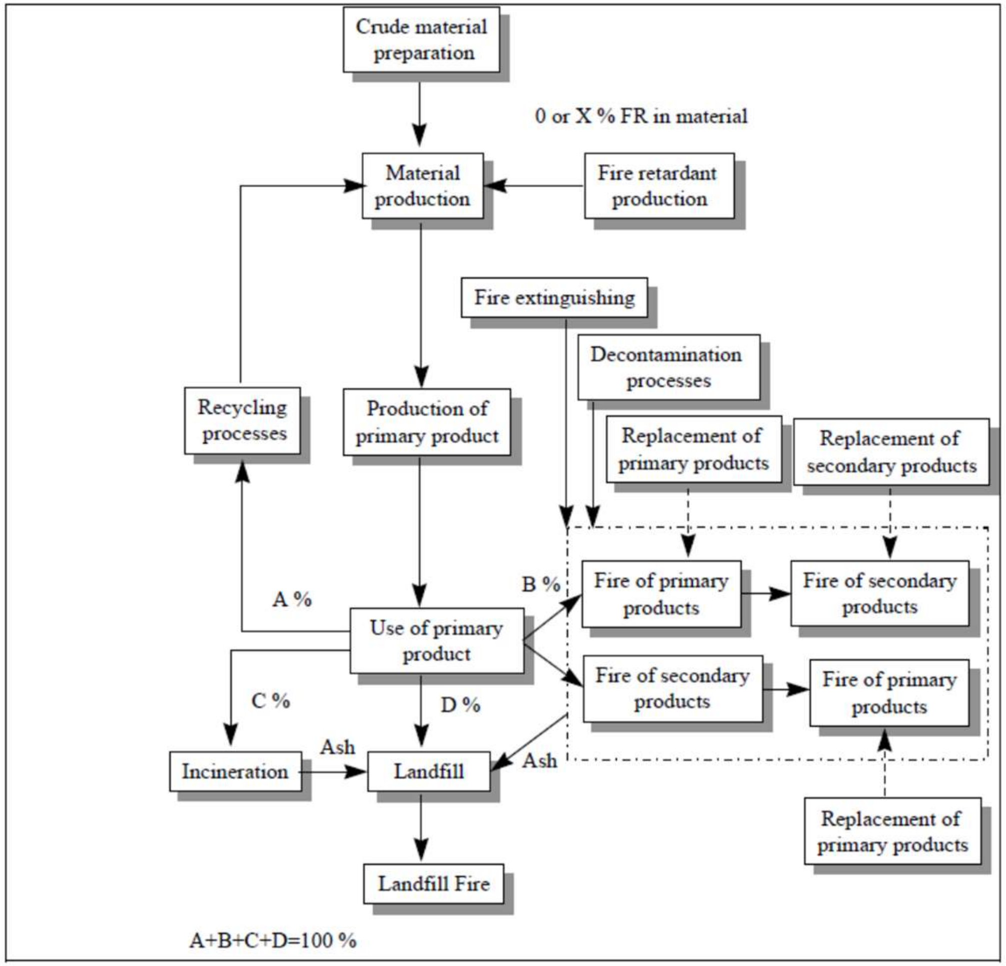

Figure 1: Schematic representation of the Fire-LCA model.

Source: Simonson, 2000

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What if $\overline{\text{FR}}$ burns?

Consequences of the fire event

System has to be replaced, even partly
People may have to be healed
Room may have to be cleaned
Walls may have to be painted
Building may have to be rebuilt
Burnt system has to be discarded / treated
CO_2, particles, dioxins etc. are emitted
...

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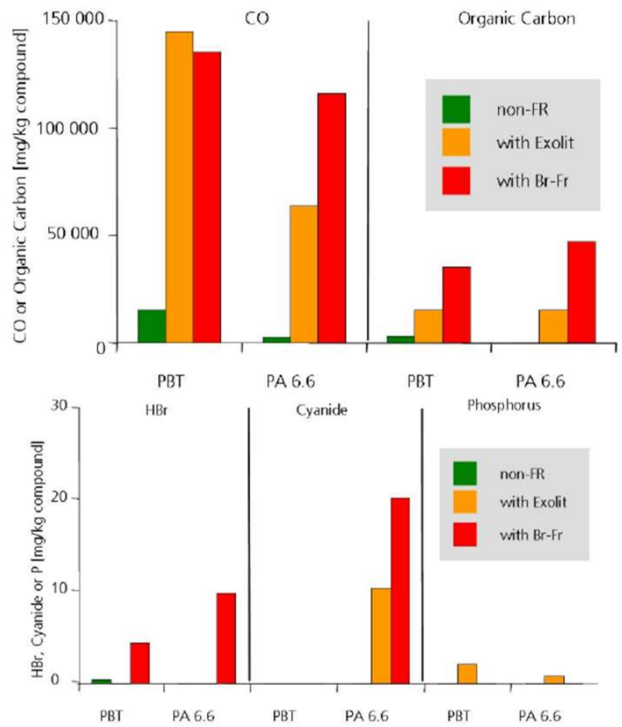
What if FR burns?

Consequences of the fire event

Similar consequences.
Maybe even worse consequences in terms of emissions.

Marzi, 2006
Toxic combustion products
green: $\overline{FR}$; orange & red: FR

Figure 5: Combustion products with acute toxicity as measured with the DIN oven.



Impacts of the two systems

$\overline{\text{FR}}$	FR
p(fire)*EI(consequences) + (1-p(fire))*normal EI($\overline{\text{FR}}$)	p'(fire)*EI'(consequences) + (1-p'(fire))*normal EI(FR)

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Full life cycle (for intended lifetime)

recycling %

landfill %

use

…cial turf
…n infill

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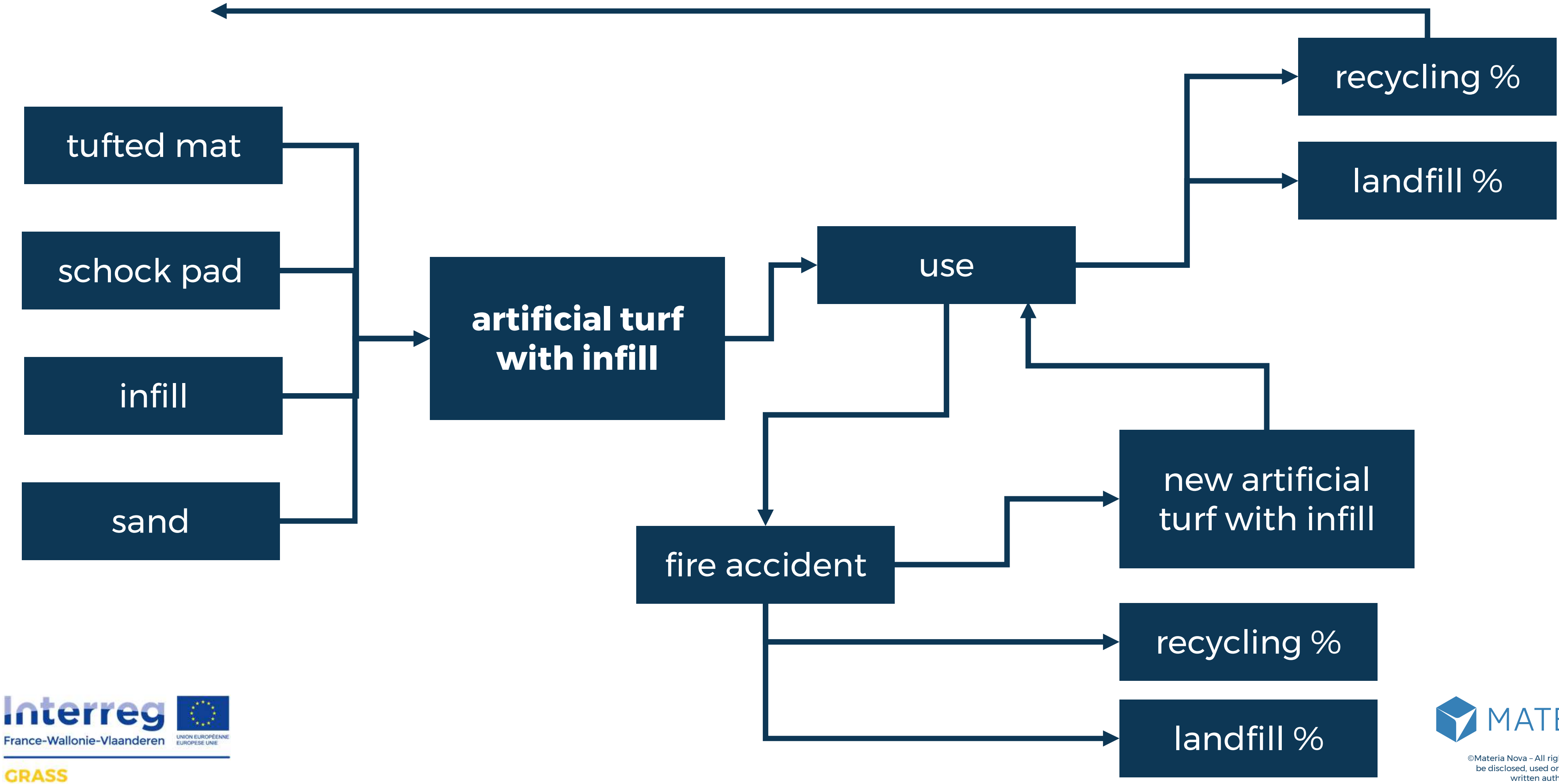
Full life cycle (for intended lifetime)



Data were therefore to be found about:

- impacts of fr production
- impacts of FR system production
- impacts of “normal” use phase
- impacts of disposal / treatment after “normal” use
- probability of fire events
- emissions directly linked to fr in case of fire
- other fire consequences
- impacts of disposal / treatment of burnt system

…

Results

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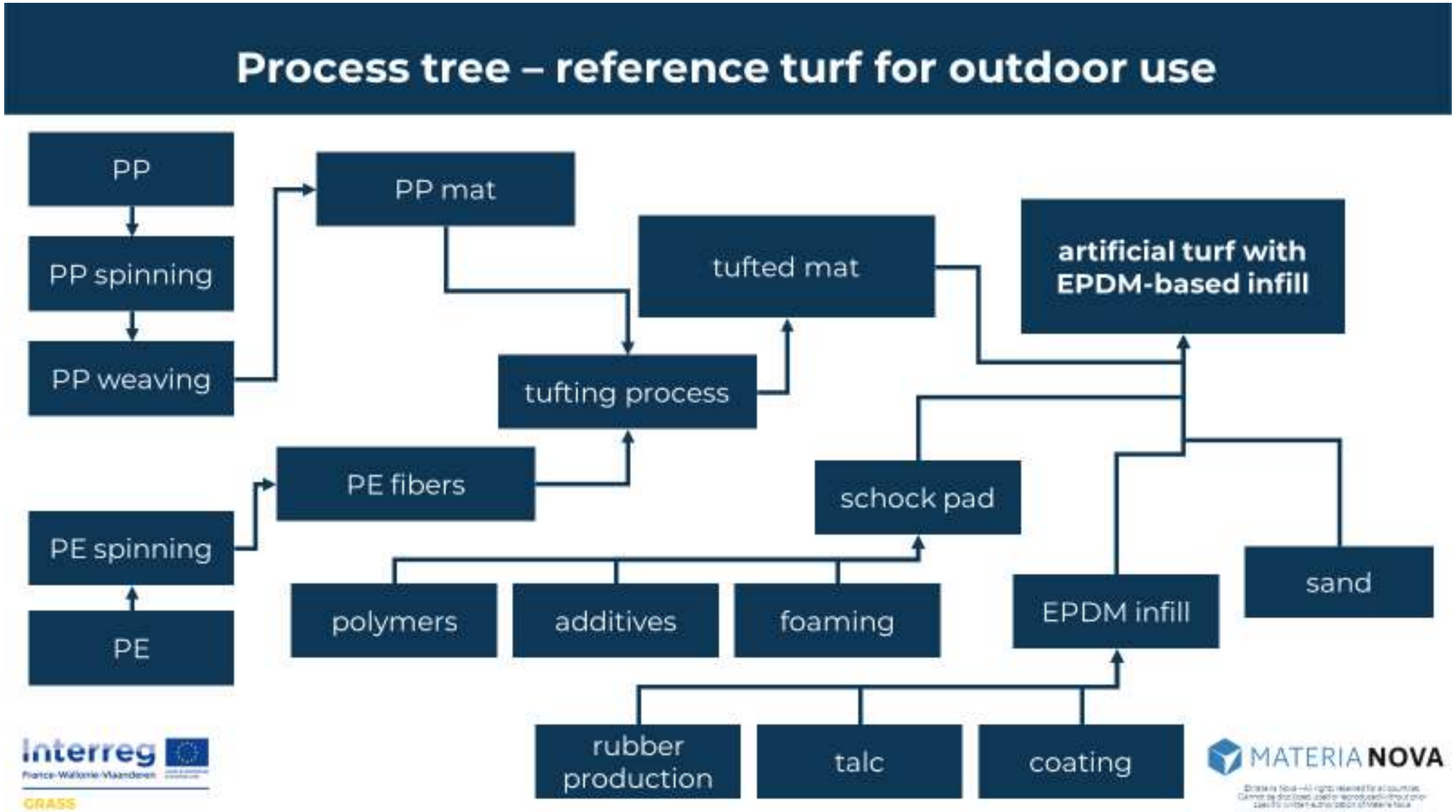
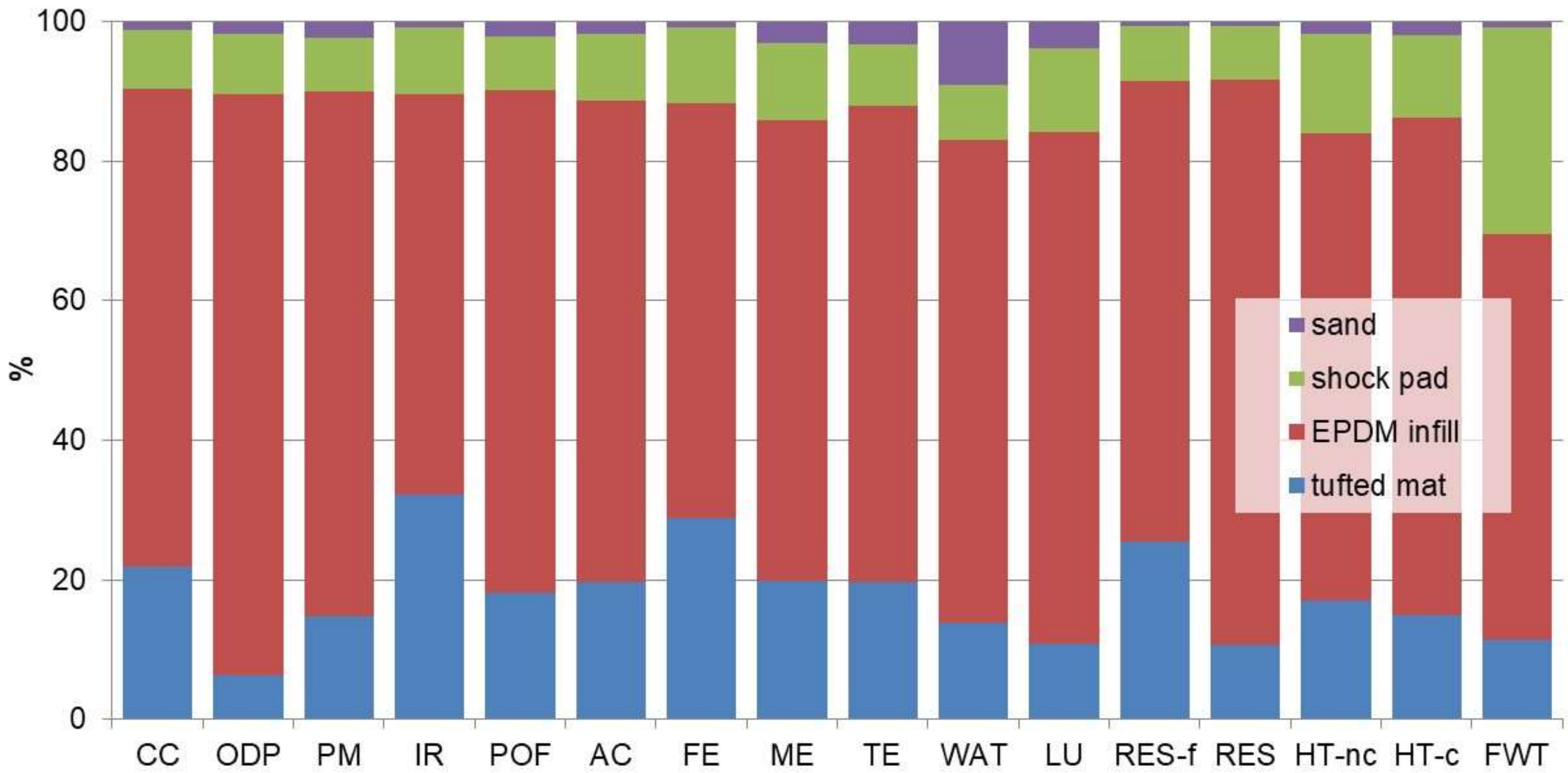
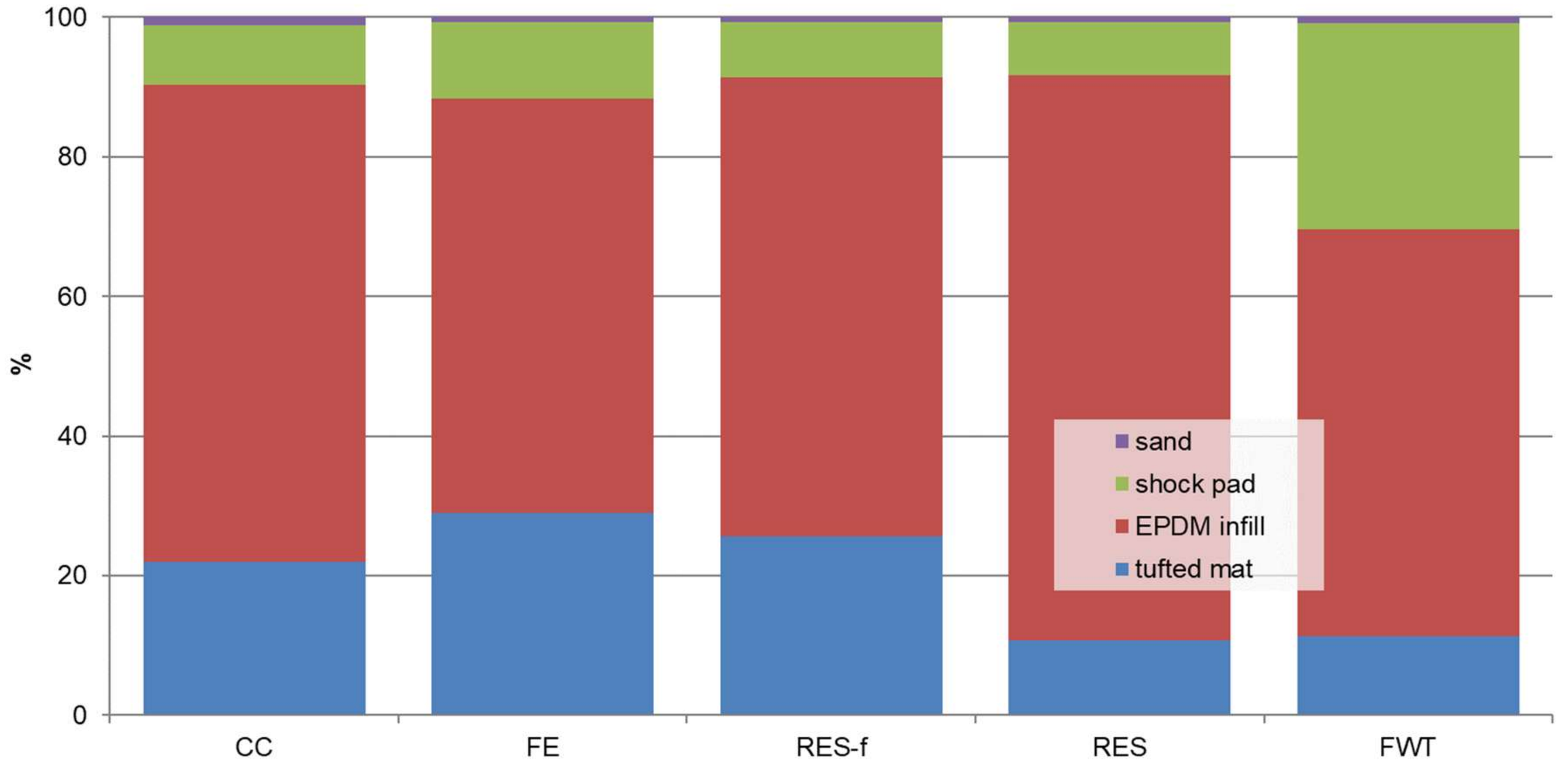
Contribution analysis / reference system



Contribution analysis / reference system



Contribution analysis / reference system / selected imapcts



High contribution of infill to the environmental impacts

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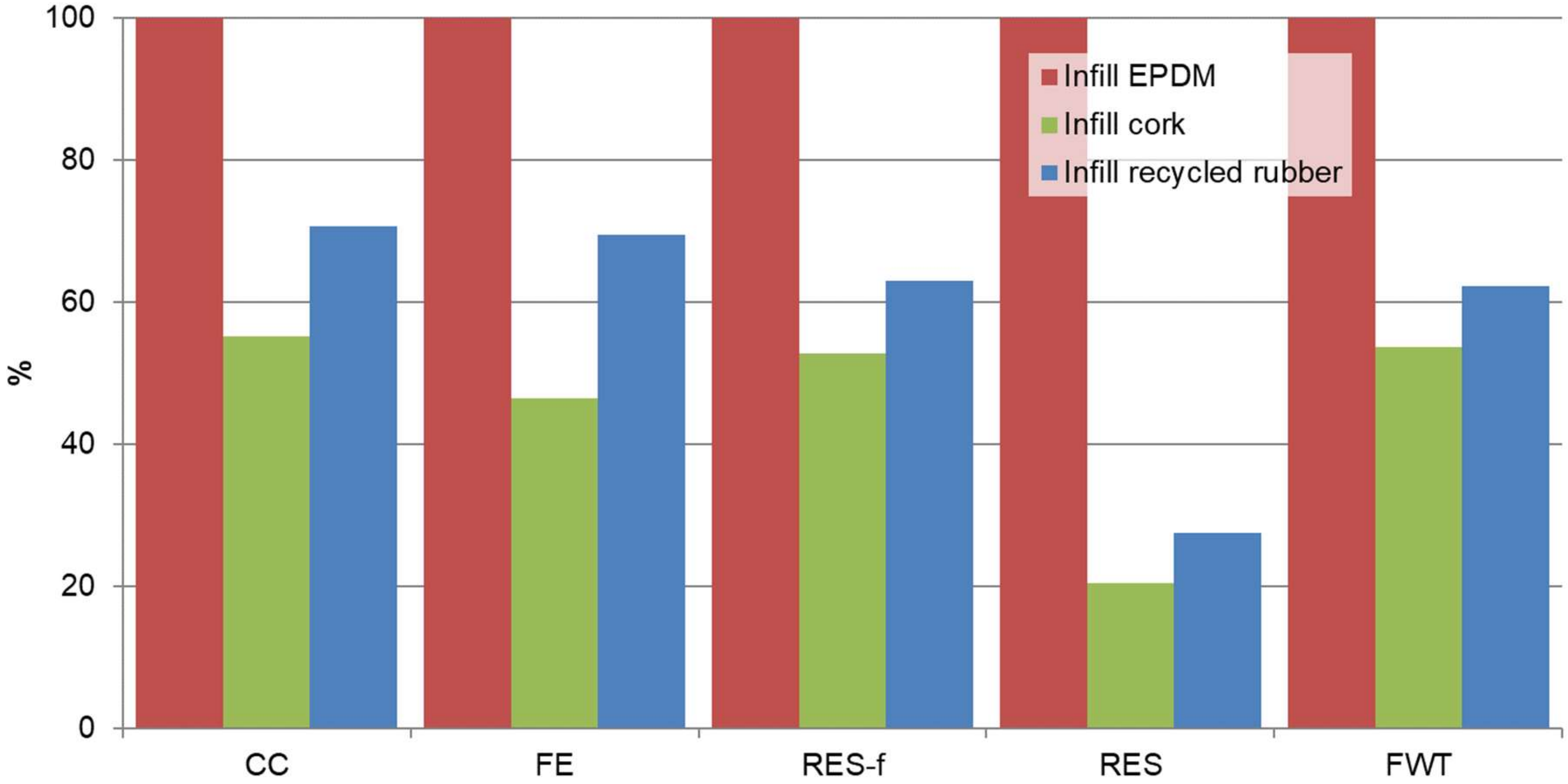
Compared impacts / alternative infills



Lower impacts for cork infill

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Full Life Cycle – reference system (no FR, EPDM infill)

Contributions to the single score impact of the life cycle of non-FR artificial turf with EPDM infill

End of life scenarios

landfill	85,68%
recycling	14,29%
fire	0,03%

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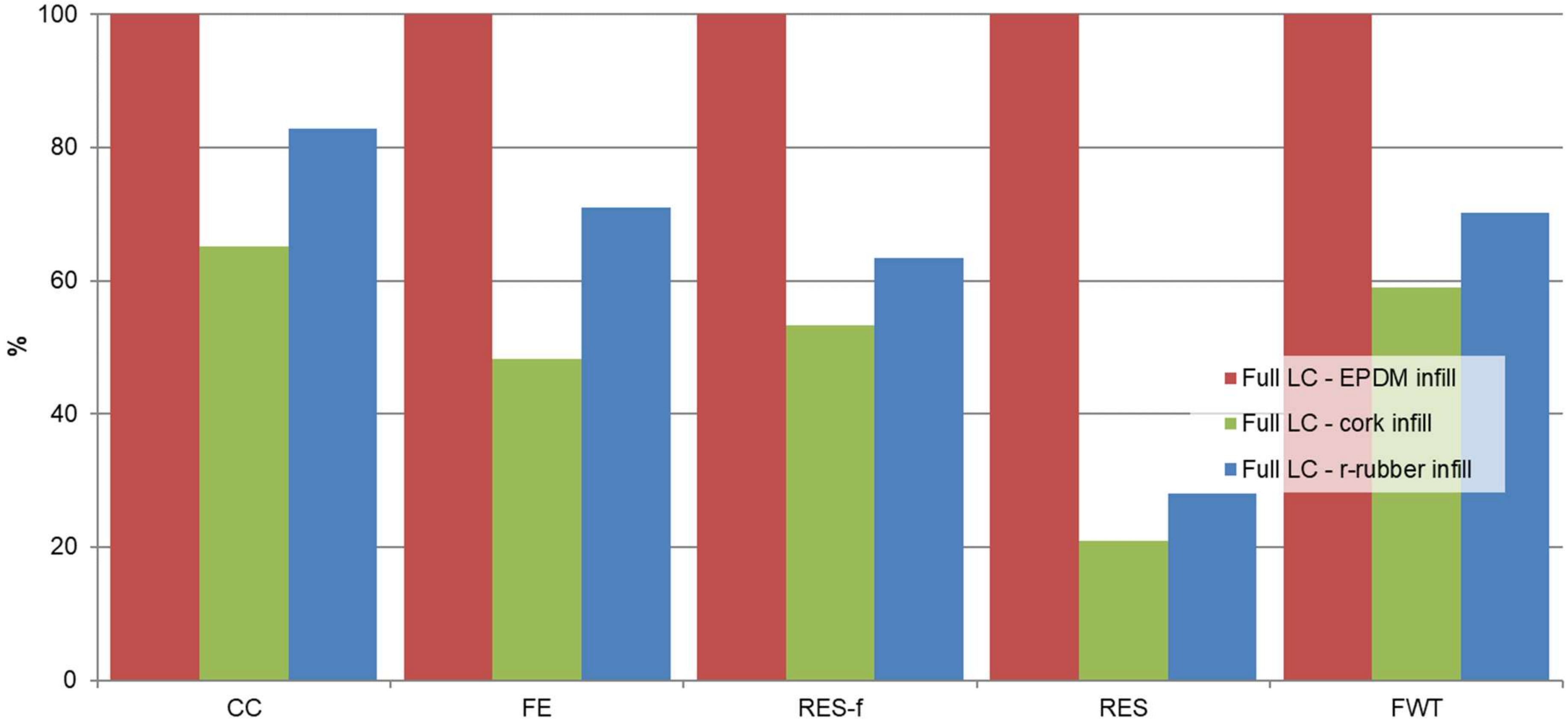
Full Life Cycle – alternative infills



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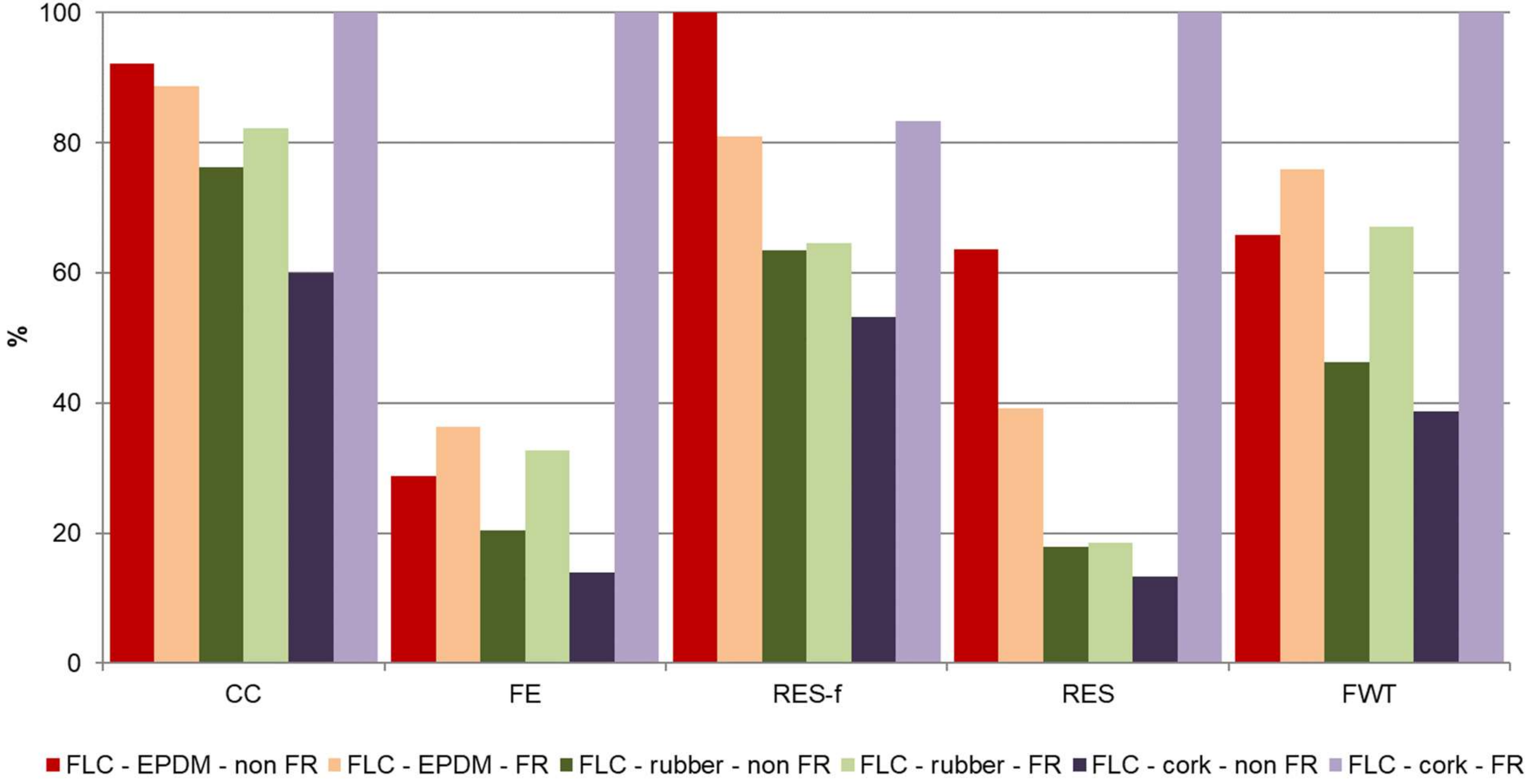
Full Life Cycle – effect of FR



Some impacts higher for FR systems!

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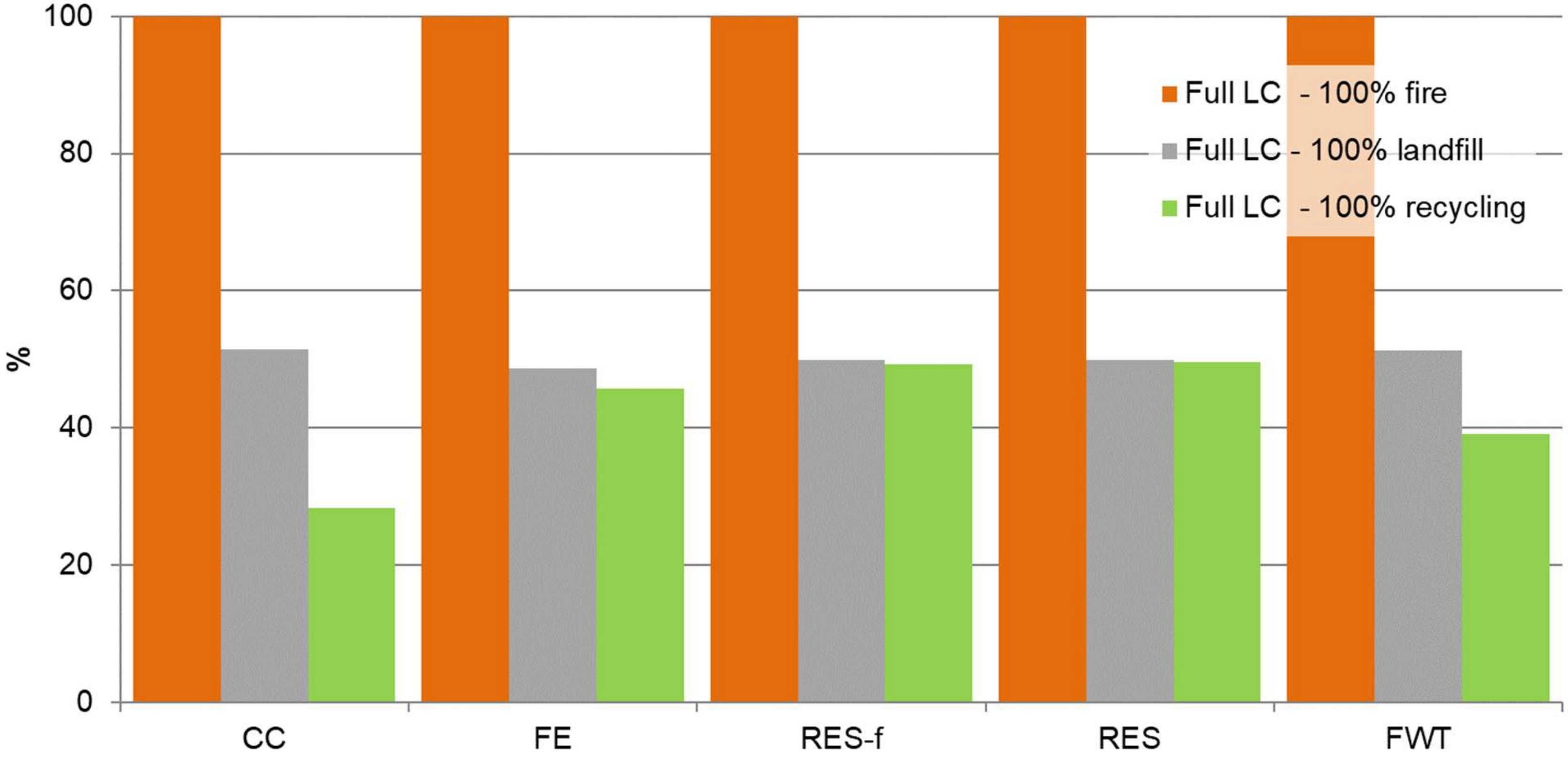
Full Life Cycle – comparison of EOL scenarios



Full life cycle, reference system with EPDM infill – non FR

Yet, fire is as expected the most impacting end-of-life...

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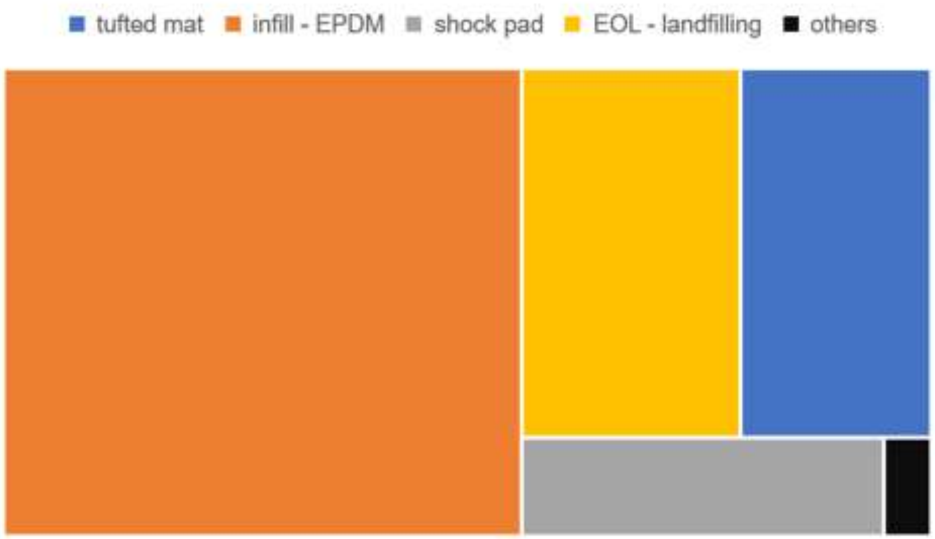
Full Life Cycle – contribution of EOL

Full Life Cycle – reference system (no FR, EPDM infill)



Contributions to the single score impact of the life cycle of non-FR artificial turf with EPDM infill

End of life scenarios

landfill	85,68%
recycling	14,29%
fire	0,03%

… but even without FR, the probability of fire is very low.

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Conclusions

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- infill is identified as the main contributor to artificial turf impacts
- turf with cork infill may be less impacting than with synthetic infills
- adding flame retardancy properties may induce higher impacts
- however, this LCA does not account for potential life saving by preventing heavy fire events… and non-FR system will not pass safety requirements
- eco-designing fireproofing solutions may lead to significant impact reductions

Environmental Life Cycle Assessment in GRASS project

Olivier Talon

Final Event Interreg FWVL GRASS

16/06/2022 - Ghent

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