

PLATFORM MEETING

L'esperienza dei Progetti LIFE per la sostenibilità ambientale
dell'industria Ceramica e dei Laterizi



Recycling of thermal spray waste in sintered products

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LIFE+12 ENV/IT/678

Sassuolo – 11 aprile 2017



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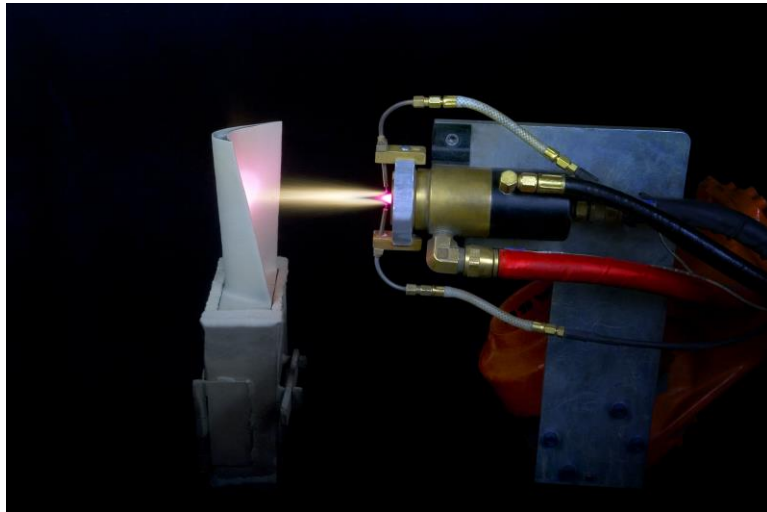
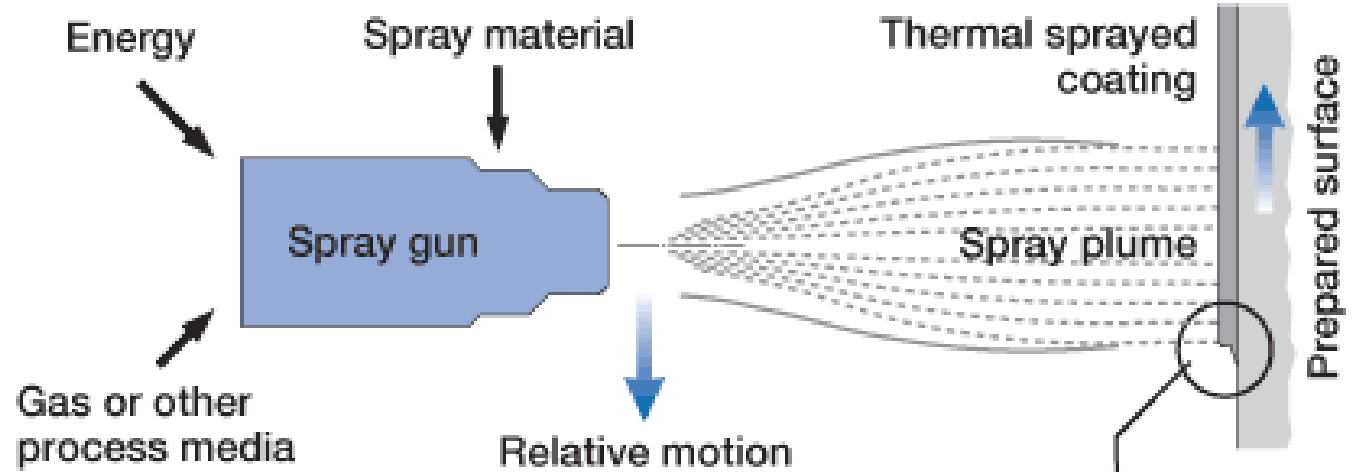
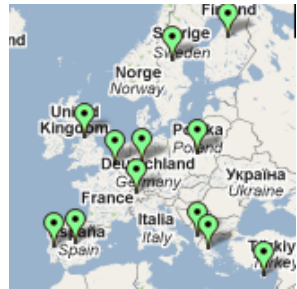
Aim of work

- ✓ Demonstrate the feasibility of valorizing and recycling thermal spray waste of different nature: mainly zirconia, NiCoCrAlY and other powders (i.e. alumina)
- ✓ To realize demonstrative products like frits, glazes, glazed sintered tiles and sintered samples containing up to 100% of spent thermal spray powders.
- ✓ Development of demonstrative pilot line for new frits and glaze

Melting → glasses, frits and glazes

Sintering → ceramic substrates, engobes

Thermal spray process



**75 Weight %
Overspray!!!**



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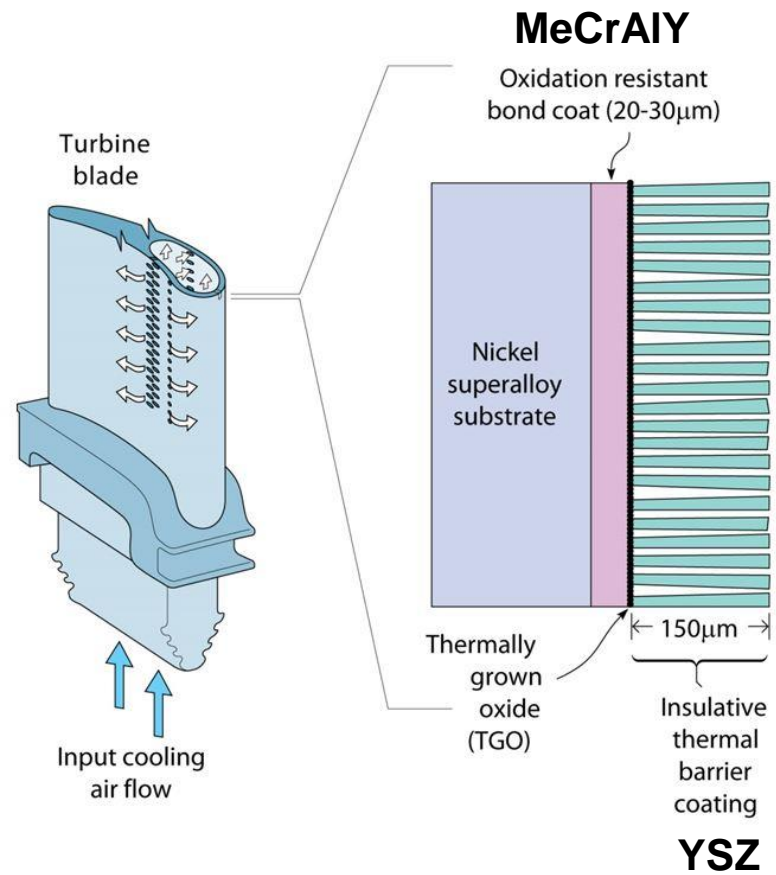
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Waste Powders



APS5
APS5SW
APS6
APS6SW



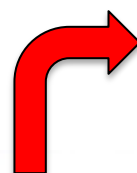
CORINDONE
CORINDONE-W



HVOF - INT
HVOF - EST
LVPS - EST



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Final Products





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HVOF-INT



HVOF-EST



LVPS-EST



CORINDONE



CORINDONE-W



APS5



APS5SW



APS6SW



APS6



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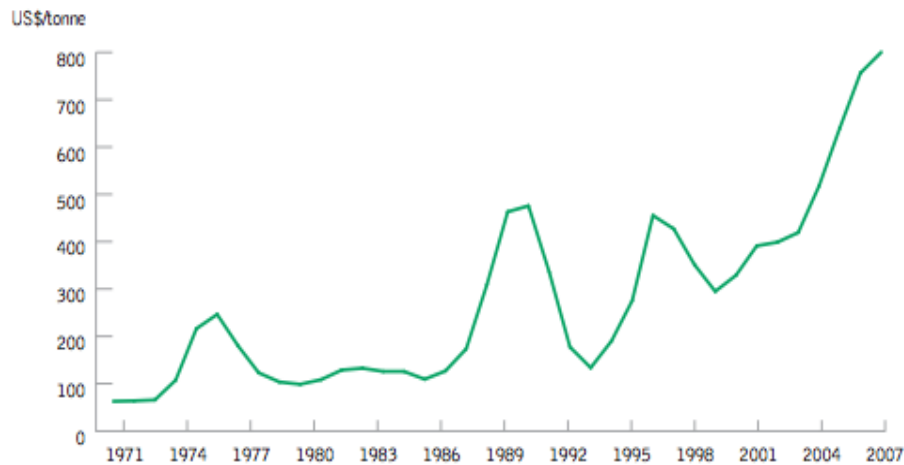


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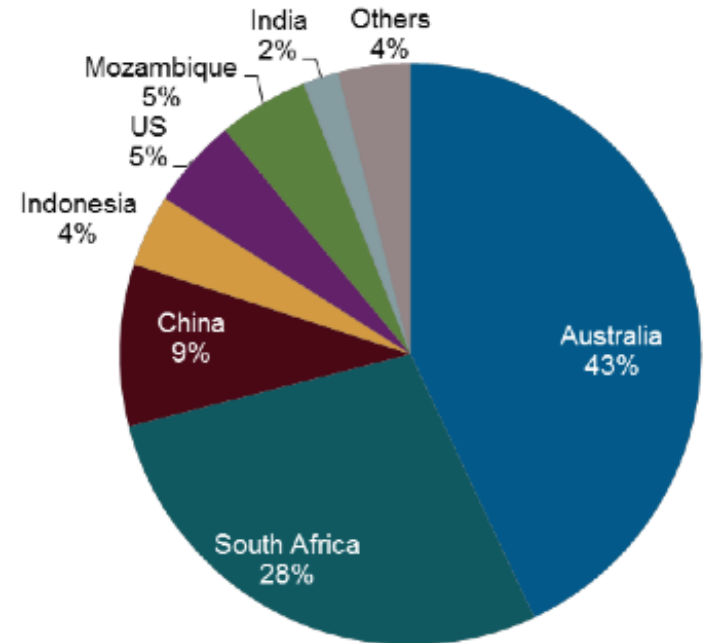
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Zr sand price Historical trend



Source: TZMI (TZ Minerals International Pty Ltd)

Zr sand production by region (2014 - 1.1mt)



Source: Iluka



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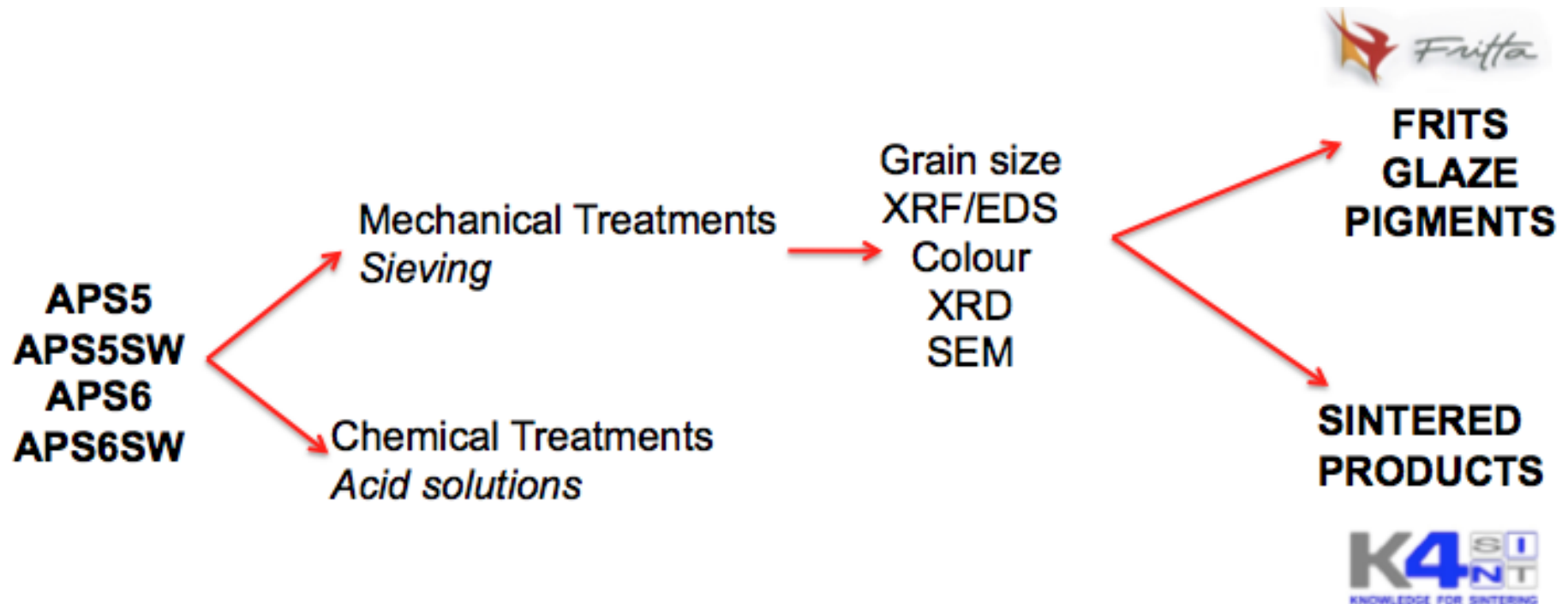
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Industrial GLAZE



100%
substitution

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Dipartimento di
Ingegneria "Enzo Ferrari"



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Industrial PIGMENTS



100%
substitution

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AP6 suitable for coloured bodies
CORINDONE-W suitable for coloured bodies

Standard	Standard	Standard	Standard	Standard	Standard
APS6	APS6	APS6	APS6	APS6	APS6
$\Delta E=3,35\pm 0,08$	$\Delta E=1,28\pm 0,27$	$\Delta E=0,38\pm 0,38$	$\Delta E=0,30\pm 0,10$	$\Delta E=1,13\pm 0,24$	$\Delta E=1,01\pm 0,44$



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NiCoCrAlY

Recycled Powder	1wt%	0,1 wt%
HVOF-EST		



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NiCoCrAlY

Recycled Powder	1wt%	0,1 wt%
HVOF-INT		



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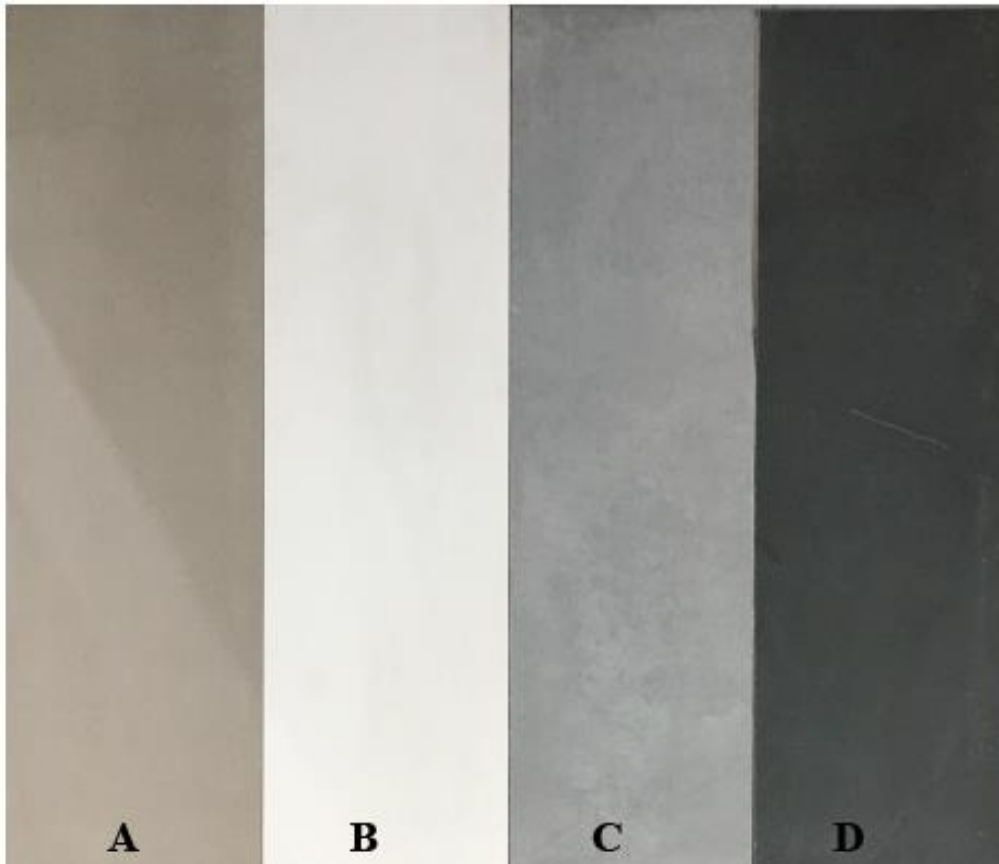


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Final Products



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- A → Coloured body
- B → White Engobe
- C → Final product grey
- D → Final product black

$A+B+Decoration=C$ or D



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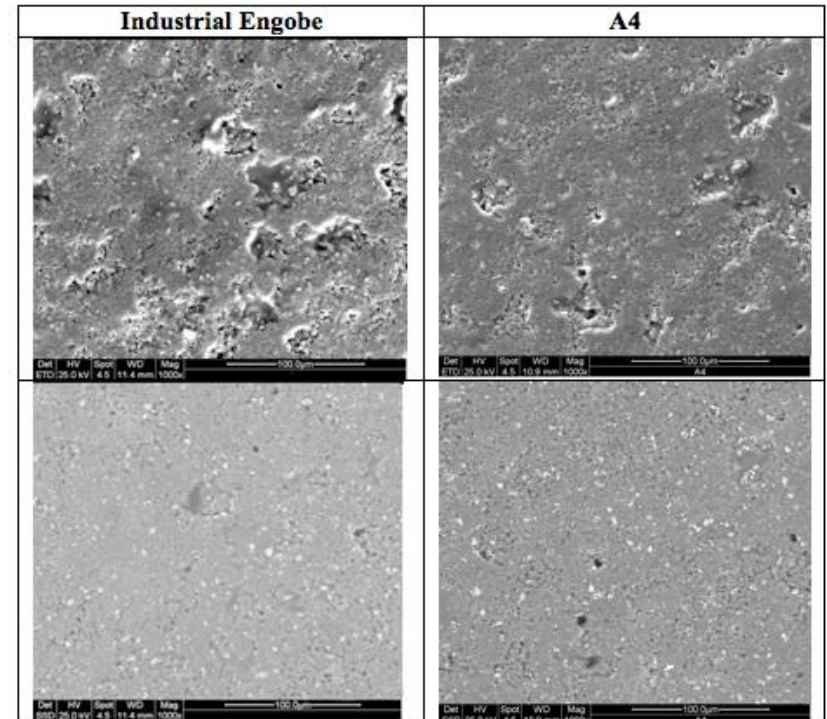
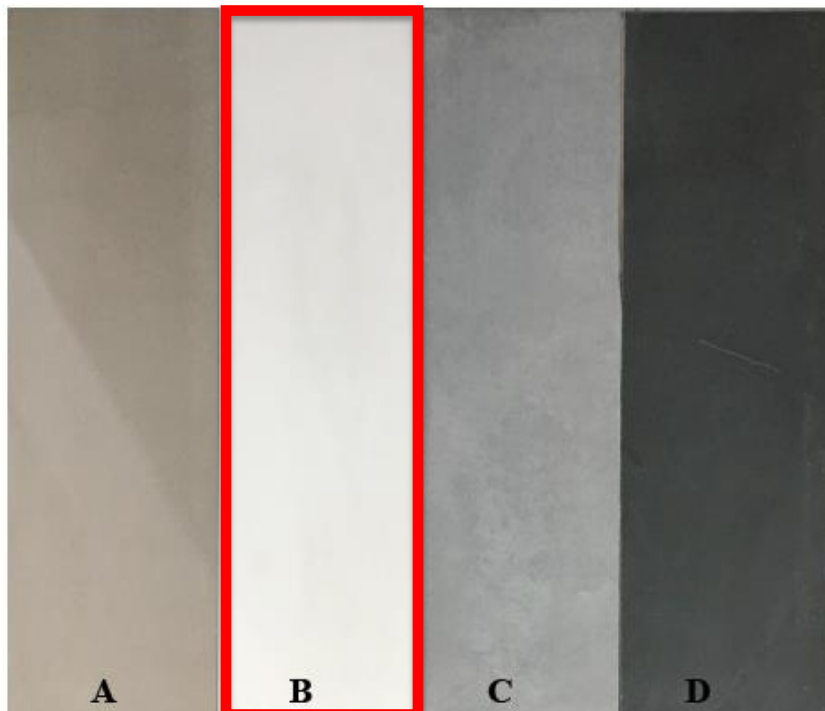
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Engobe	L*	a*	b*	ΔE
A4	87,73±0,23	-0,53±0,03	3,99±0,08	--
Industrial Engobe	88,21±0,38	-0,58±0,03	4,13±0,05	0,69±0,16



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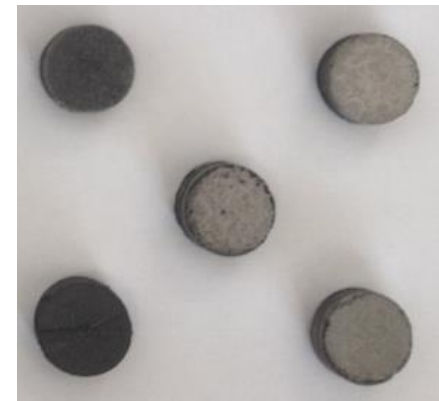
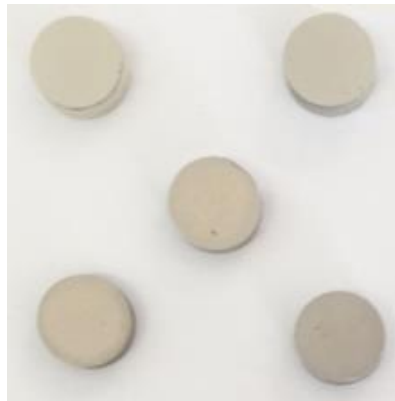
APS5A

APS5B

APS6A

APS6B

1450°
C
1550°
C
1650°
C



30 45 60

30 45 60

30 45 60

30 45 60

MPa



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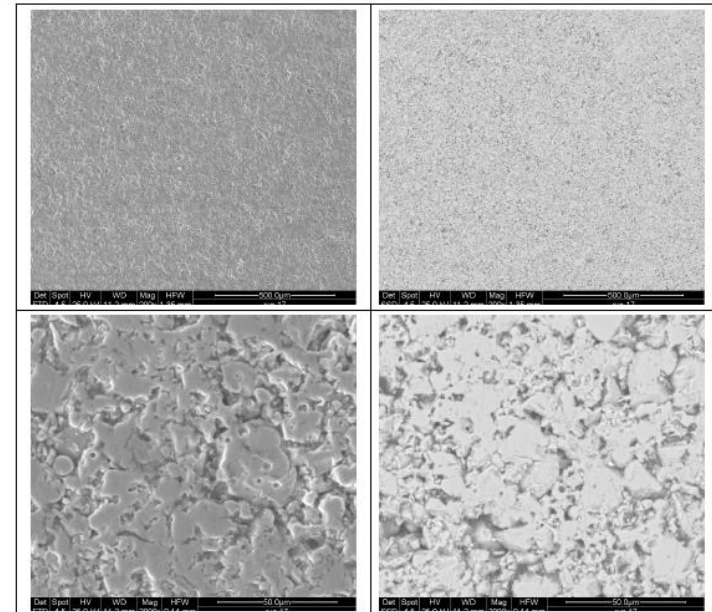


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RUN	Density	Porosity	XRD	Young Modulus	Hardness	Chemical Resistance	Colour
1	Green	Yellow	Green	Yellow	Green	Red	Green
2	Green	Red	Yellow	Green	Green	Red	Red
3	Red	Red	Green	Yellow	Yellow	Green	Red
4	Red	Green	Yellow	Green	Green	Red	Yellow
5	Green	Red	Green	Red	Green	Green	Green
6	Yellow	Red	Yellow	Green	Red	Green	Red
7	Green	Yellow	Yellow	Green	Red	Red	Yellow
8	Green	Red	Yellow	Yellow	Green	Red	Yellow
9	Red	Red	Green	Green	Red	Red	Yellow
10	Red	Red	Yellow	Yellow	Yellow	Red	Red
11	Green	Yellow	Yellow	Yellow	Green	Red	Yellow
12	Green	Green	Green	Yellow	Green	Red	Green
13	Yellow	Red	Red	Green	Yellow	Green	Green
14	Red	Red	Green	Red	Yellow	Green	Red
15	Yellow	Red	Red	Green	Red	Green	Red
16	Red	Red	Yellow	Green	Red	Green	Red
17	Green	Yellow	Yellow	Red	Green	Red	Yellow
18	Red	Red	Red	Green	Green	Green	Yellow
19	Yellow	Red	Yellow	Yellow	Red	Red	Yellow
20	Green	Red	Green	Red	Red	Red	Green
21	Yellow	Yellow	Green	Yellow	Red	Red	Green
22	Green	Red	Red	Red	Green	Green	Green
23	Green	Red	Red	Green	Green	Green	Yellow
24	Yellow	Yellow	Yellow	Yellow	Red	Red	Yellow

GOOD AGREEMENT WITH STANDARD
ACCEPTABLE AGREEMENT WITH STANDARD
BAD AGREEMENT WITH STANDARD

Morphology (SEM)





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LCA

The purpose of this action is to assess the environmental impact of the use of spent feedstock powders recovered at the end of various thermal spray processes as secondary raw materials for the production ceramic glazes.

In particular it has been considered that the recovered and pre-treated powders are added to the raw materials mixture for the production of quenched glass (“frit”) normally added to the raw materials mixture of a ceramic glaze.

Analysis has been conducted with the Life Cycle Assessment methodology (LCA), in order to consider the whole life cycle of the products, from the raw materials extraction, to the end of life phase, obtaining a “cradle to grave” overview.



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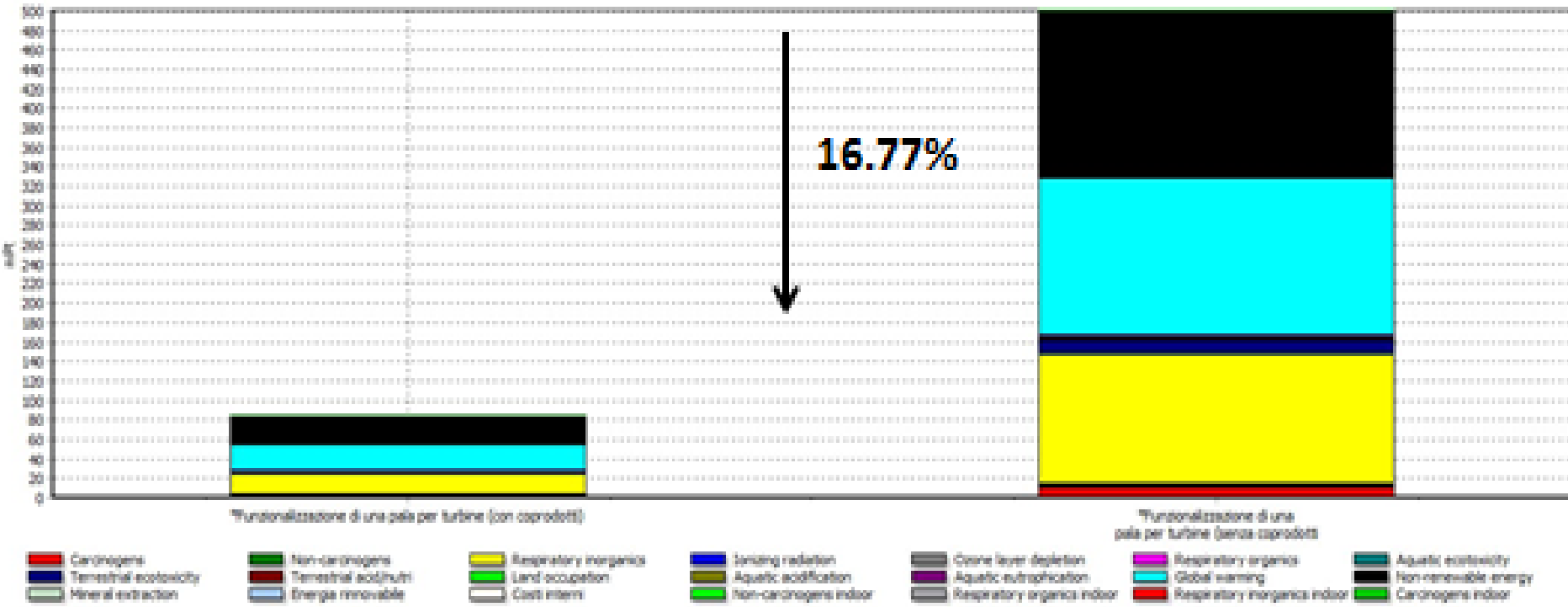


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LCA

Thermal spraying: Internal Sieving

Thermal spraying: External Sieving



Comparing 17000 g "Funzionalizzazione di una pala per turbine (con coprodotti)" with 17000 g "Funzionalizzazione di una pala per turbine (senza coprodotti)"
 Method: IMPACT 2002+2002(1) 150(1) indoor (2,12) / IMPACT 2002+ / Single score



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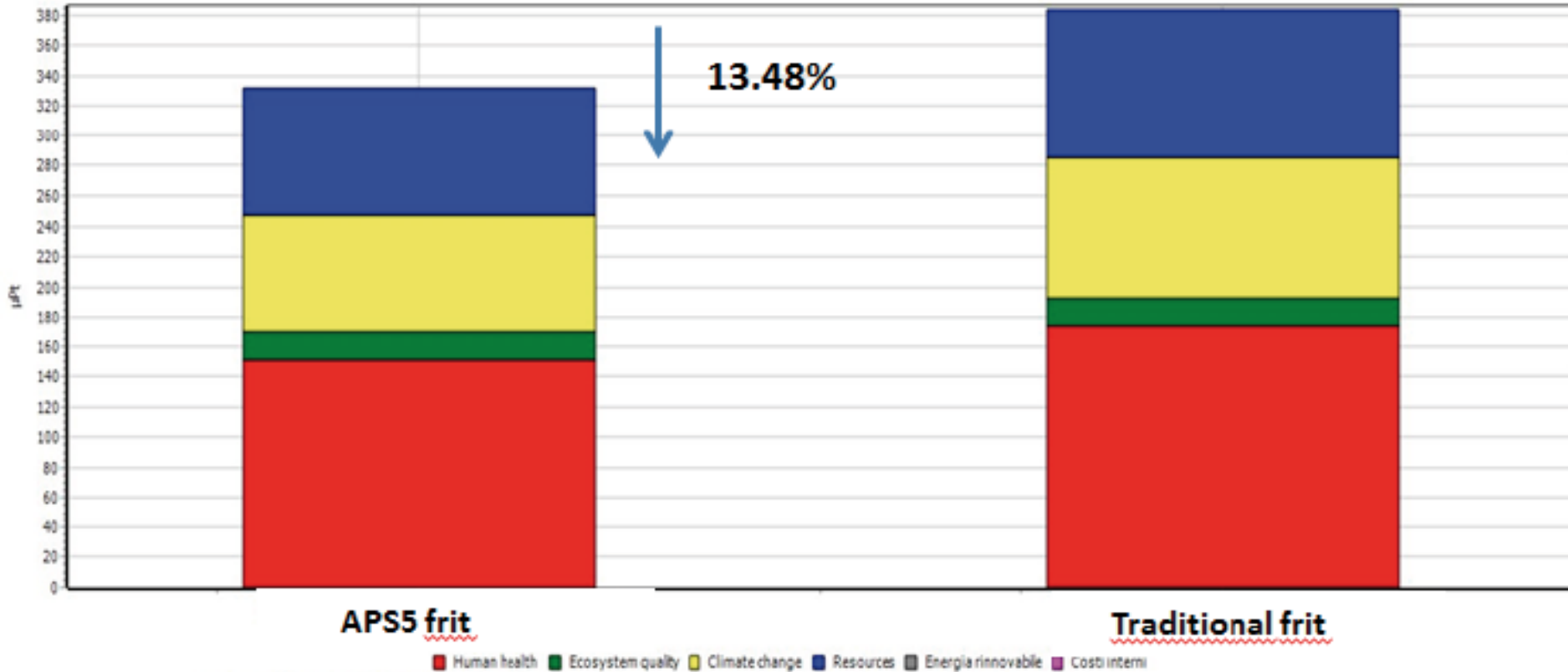


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LCA





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LCC

The reduction of **energy consumption** in the manufacturing phase of APS5 is **73.7%**.

The reduction in the **energy cost** associated to APS5 frit is **60.5%**

The reduction of **raw material cost** is therefore **24.16 %**.

The reduction of **manufacturing costs** per unit of product is **80.22%**.

The improvements about **workers' health and safety** amounts to **17.45%**



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Conclusion

- YSZ thermal spraying waste cannot be re-used for thermal spraying process because of morphology and particle aggregation;
- APS5 YSZ thermal spraying waste sieved can replace zircon raw material in variable percentages up to 100 wt.% for white tile production and for sintered products (K4SINT);
- APS6 YSZ and CORINDONE-W thermal spraying waste sieved can replace zircon raw material in variable percentages up to 100 wt.% for coloured products;
- NiCoCrAlY thermal spraying waste cannot be employed due to the presence of chromophore ions that lead to colour the glazes;



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DISSEMINATION

2014

M.Alessi, E. Cedillo Gonzales, C. Siligardi, Riutilizzo di polveri di zirconia provenienti da scarti del processo di termospruzzatura per l'ottenimento di smalti ceramici, Tesi di Laurea Triennale, UNIMORE, 2014

S. Barbi, C. Siligardi, Recycling of yttria-stabilized ZrO₂ (YSZ) thermal spray waste in tile ceramic glazes, Italian Speech Contest, Parma, ICERS, 16/12/2014

2015

S. Barbi, L.Lusvarghi, R. Casini, E. Ghidini, C. Siligardi, Recycling of yttria-stabilized ZrO₂ (YSZ) thermal spray waste in tile ceramic glazes, 14th conference of the European Ceramic society, Toledo, ECERS, 25/06/2015

S. Barbi, G. Bevini, R. Casini, C. Siligardi, T. Manfredini, Recycling of yttria-stabilized ZrO₂ (YSZ) for ceramic tile glazes and pigments, X National conference on materials science and technology, Favignana, INSTM, 01/07/2015

S. Barbi, R. Casini, C. Siligardi, T. Manfredini, Formulazione di smalti bianchi e pigmenti da impasto contenenti polveri di scarto, Ceramic World Review, SALA edizioni, 2015

F. Braglia, P. Neri, A. M. Ferrari, S. Barbi, C. Siligardi, Analisi LCA del recupero di zirconia da un processo di termospruzzatura, ECOMONDO, Rimini, 5/11/2015



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DISSEMINATION

2016

S. Barbi, C. Siligardi, Recycling of yttria-stabilized ZrO₂ (YSZ) thermal spray waste in tile ceramic glazes, Welcome to the life programme, Padova, 28/05/2016

S. Barbi, C. Siligardi, LIFE12 ReTSW-SINT, Firenzuola, 30/06/2016

S. Barbi, G. Bevini, R. Casini, C. Siligardi, T. Manfredini, Recycling of yttria-stabilized ZrO₂ (YSZ) for ceramic tile glazes and pigments, X National conference on materials science and technology, Journal of applied biomaterials and functional Materials, 2016, 14, E108.

2017

C. Siligardi, S. Barbi, R. Casini, L. Tagliaferri, V. Remigio, Recycling of thermal spray waste powders in glazes suitable for ceramic tiles, International Journal of ceramic technology, in proof



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Coordinator

Ceramica Fondovalle - Vito Remigio

Partners

Turbocoating - Luca Tagliaferri

Fritta - Roberto Casini

K4Sint - Luca Girardini

UNIMORE - Cristina Siligardi

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<http://ec.europa.eu/environment/life/index.htm>

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<http://www.elle3.it>



GRAZIE PER L'ATTENZIONE

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