Evento finale del progetto FAV4CER – Fibre vetrose di lana minerale per ceramici green

20 Luglio 2026 – Dipartimento di Scienze Chimiche e Geologiche UNIMORE, Aula U.02

Progetto cofinanziato da:

Da rifiuto di lana di roccia a materia prima seconda per l'industria ceramica: analisi Life Cycle Assessment dei potenziali impatti ambientali

Speaker: Alessandro Francini

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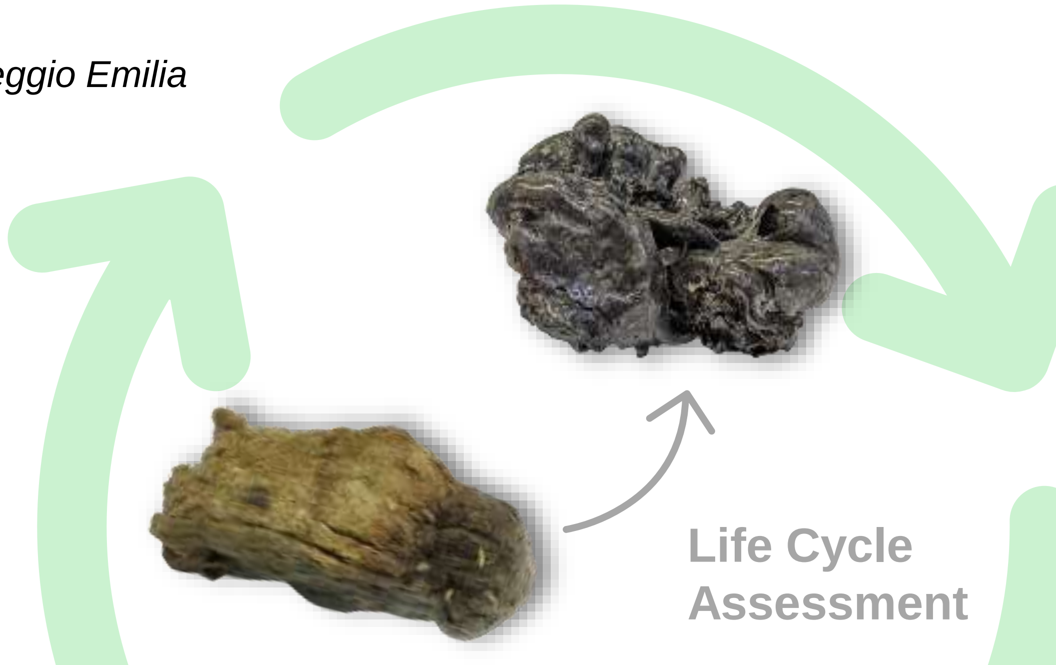


Management of mineral wool waste

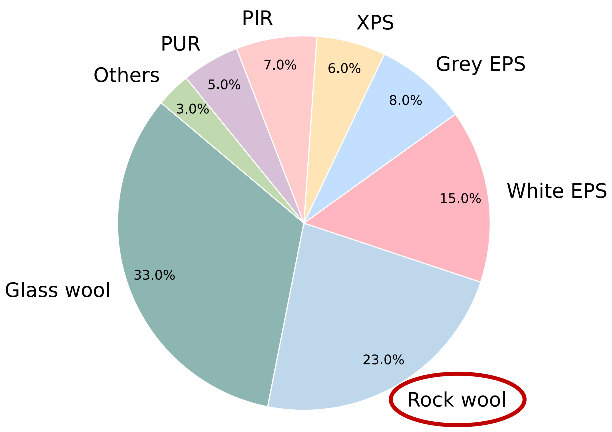
Man-Made Vitreous Fibers (MMVF)

- Rock wool
- Glass wool
- Slag wool
- …

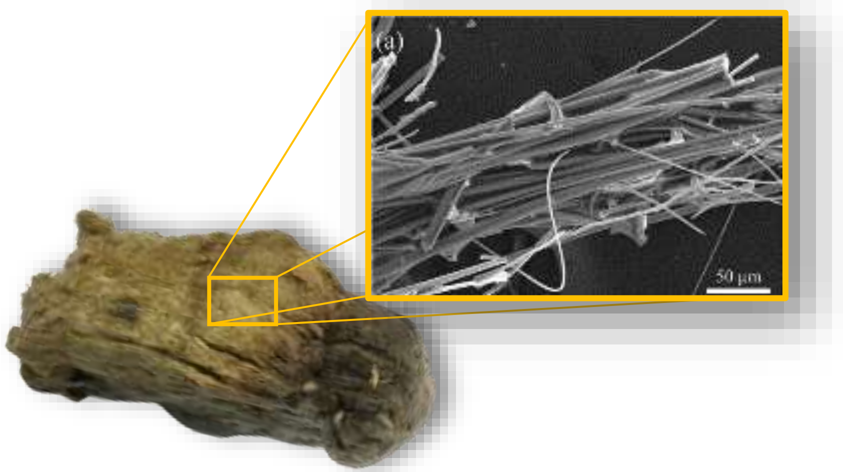
$\sum (Na_2O, K_2O, CaO, MgO, BaO) > 18$ wt%

↓

MINERAL WOOL



European thermal insulation market by product, 2022
(IAL Consultants, 2023)



Arletti, R. et al., Waste and Biomass Valorization, **2022**, 14, 1721–1736.

“Old” mineral wool waste is often classified as **hazardous**

Before 2002

- Higher biopersistance
- **Possibly carcinogenic - 2B Group** (IARC classification, 1988)

European waste codes

EWC 17.06.03* (hazardous waste)
EWC 17.06.04 (non-hazardous waste)

Management of mineral wool waste

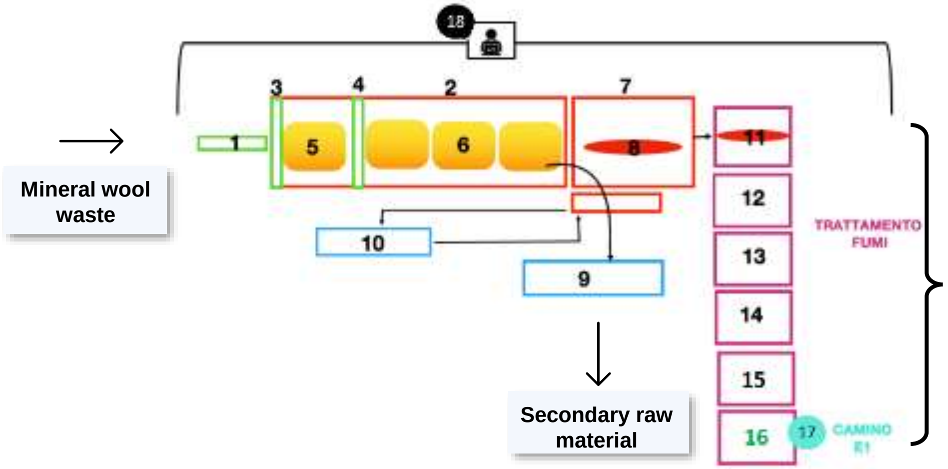
Precautionary approach when collecting and disposing exhaust mineral wool.
All is considered **hazardous**

Image: Zetadi Srl - storage site

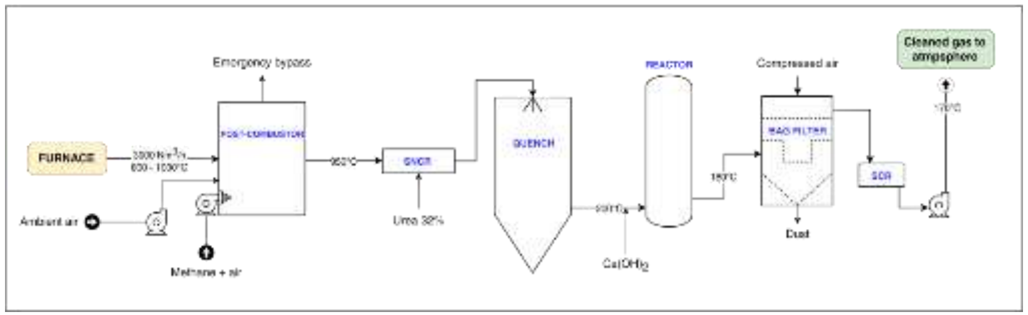
*Source: Z. S. Yap et al., Materials **2021**, 14, 5777.

Most of it will end up in landfills…

Innovative treatment for mineral wool waste recovery



Best Available Techniques (BAT) to treat exhaust gas



European Patent EP 22153845.7 - Filing date March 18, 2022.

Italian Patent N. 102021000002246 - Filing date February 2, 2021.

“Re.Wo”

Glass-like, inert material

Feldspar substitute in unglazed porcelain stoneware tiles (TRL 6)

Formulations of the batches.

Raw material	BNK	REWO2	REWO4	REWO6
Clay 1	20	20	20	20
Clay 2	18	18	18	18
Bentonite	2	2	2	2
Feldspar	50	48	46	44
Quartz sand	10	10	10	10
Re.Wo	-	2	4	6
Total	100	100	100	100

Conte *et al.*, Results in Engineering **2026**, 31, 111529.

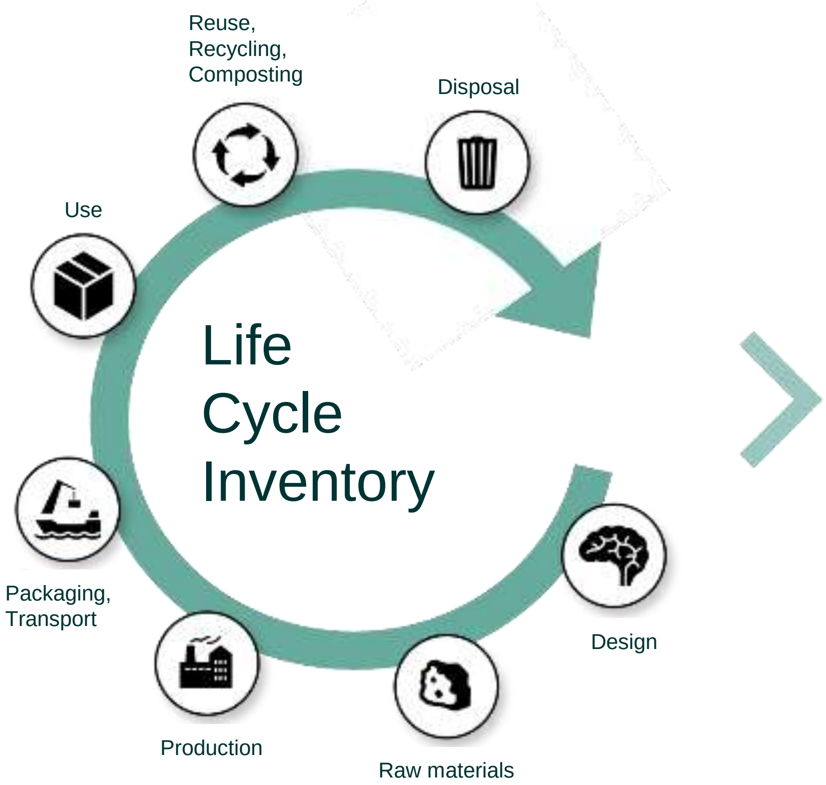
Frit for glazes in ceramic tiles

Formulation of the glazes tested in this study.

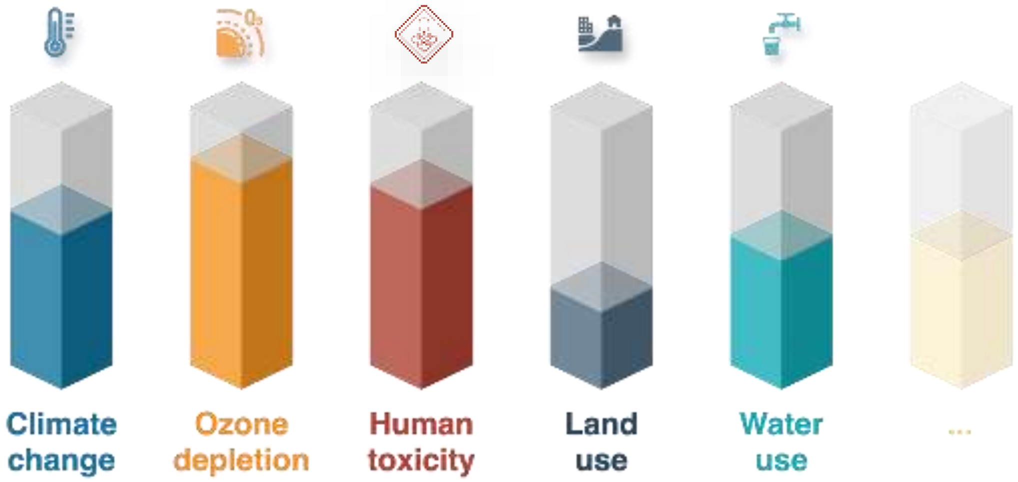
	Re.Wo (wt %)	Boric glass (wt %)	K-feldspar (wt %)	Albite (wt %)	Kaolin (wt %)	Rutile (wt %)	Cassiterite (wt %)	Hematite (wt %)
F1	50	25	15	–	5	3	2	–
F2	50	18	22	–	5	3	2	–
F3	50	15	28	–	3	3	1	–
F4	45	15	28	–	3	3	1	5
F5	44	15	28	–	3	–	–	10
F6	39	15	28	–	3	–	–	15
F7	44	15	–	28	3	–	–	10
F8	44	10	–	33	3	–	–	10

Sisti *et al.*, Ceramics International **2025**, 51, 4195.

Life Cycle Assessment



Life Cycle Impact Assessment



Environmental impact categories

Life Cycle Assessment

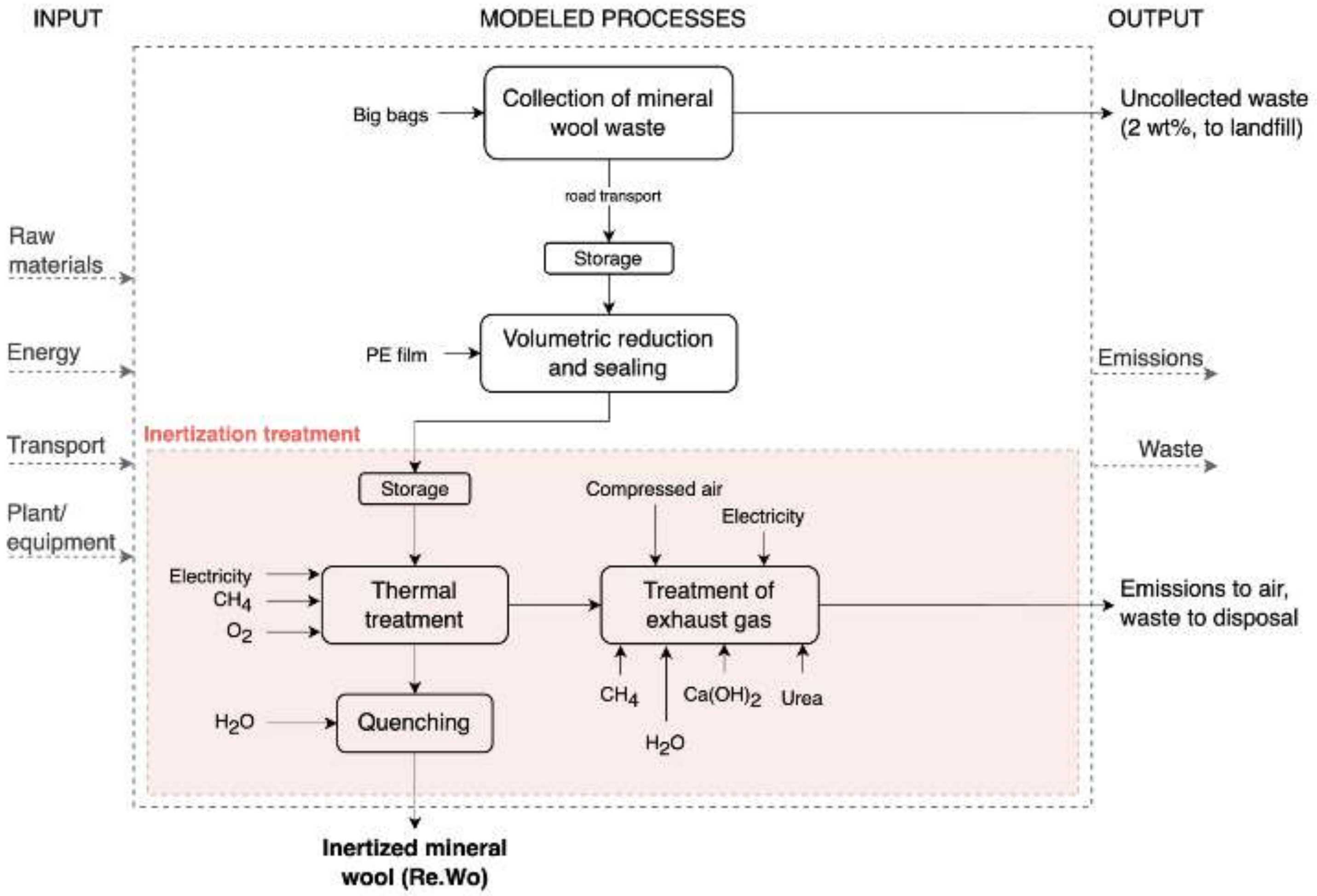
ISO 14040 and 14044

Secondary raw material (Re.Wo) in porcelain stoneware tiles and ceramic glazes. How does the environmental burden change? A prospective approach

Identify the **environmental hot spots** associated with the mineral wool waste inertization treatment

Highlight potential trade-offs across impact categories and propose possible solutions for impact reduction

System boundaries and functional units



Treatment of mineral wool waste through inertization

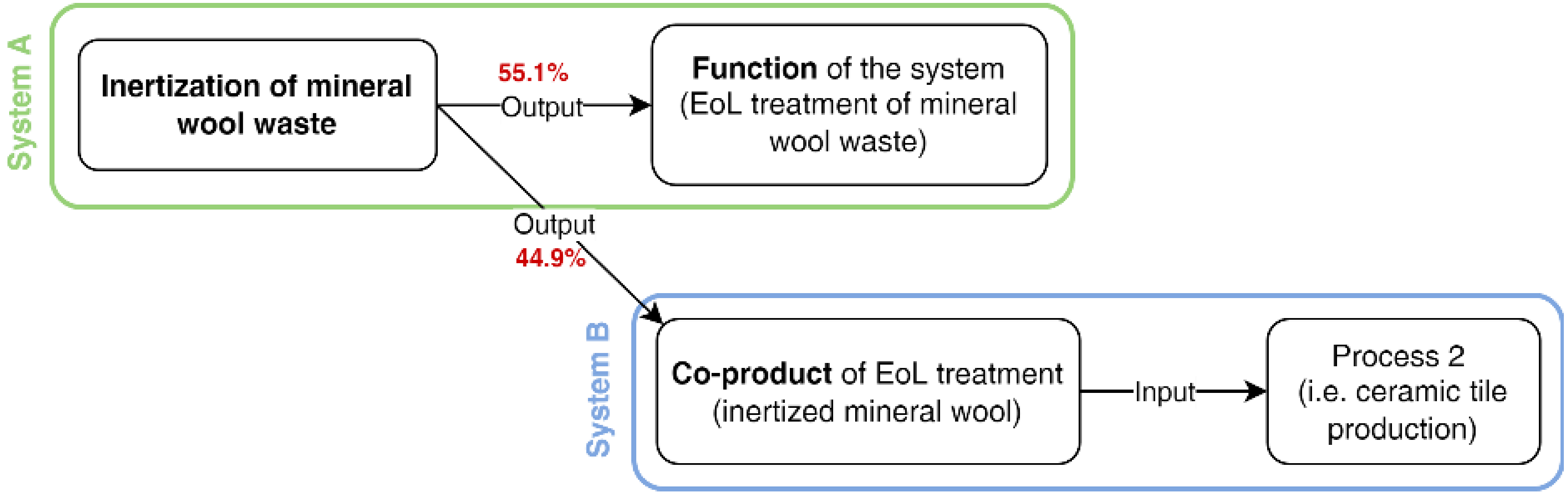
Functional unit:

Treatment of 1 kg of mineral wool waste in the inertization plant (8760 t/year).

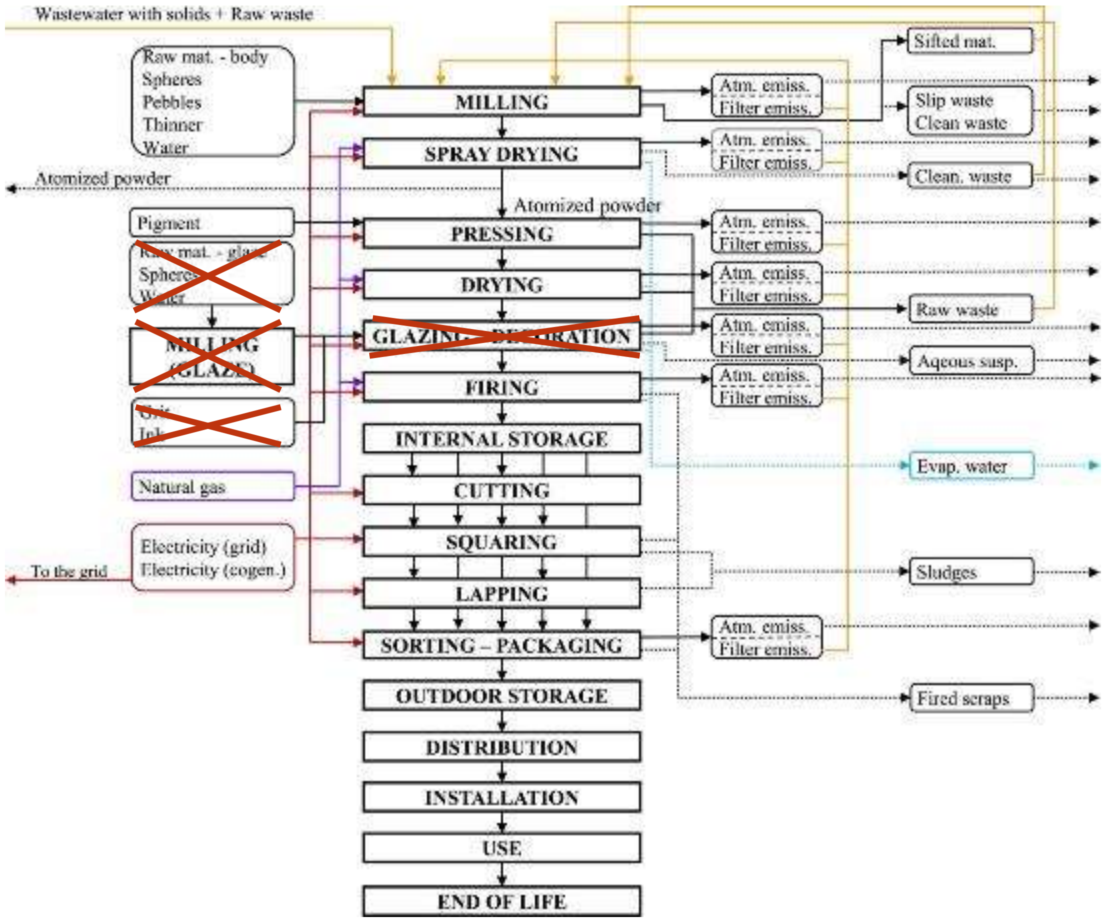
Multi-output system: allocation approach

Environmental burdens are shared between the function of the system and the recycled material (Re.Wo)

→ **Physical allocation** based on annual amounts and mass yield of the thermal treatment



System boundaries and functional units



Flowchart adapted from Ferrari *et al.*, Journal of Cleaner Production **2021**, 286, 125314

Cradle-to-grave

Life-cycle of unglazed ceramic tiles containing Re.Wo (0-4 wt.%)

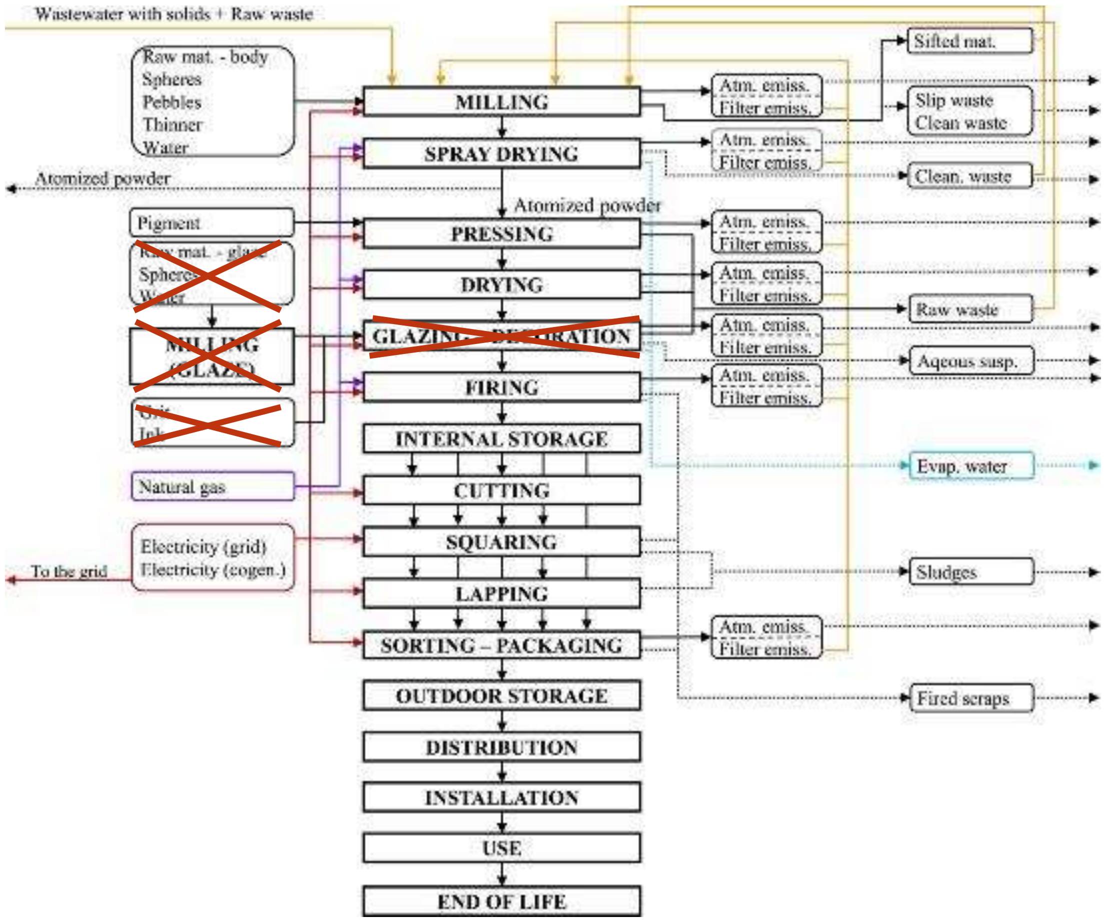
Industrial scale plant manufacturing (11.8 mln m^2 tiles/year) adapted from Ferrari *et al.*, Journal of Cleaner Production **2021**, 286, 125314.

Functional unit:

1 m^2 of unglazed ceramic tile with:

- average thickness of 7.3 mm
- average mass of 17.4 kg/m^2
- service lifetime of 50 years

System boundaries and functional units



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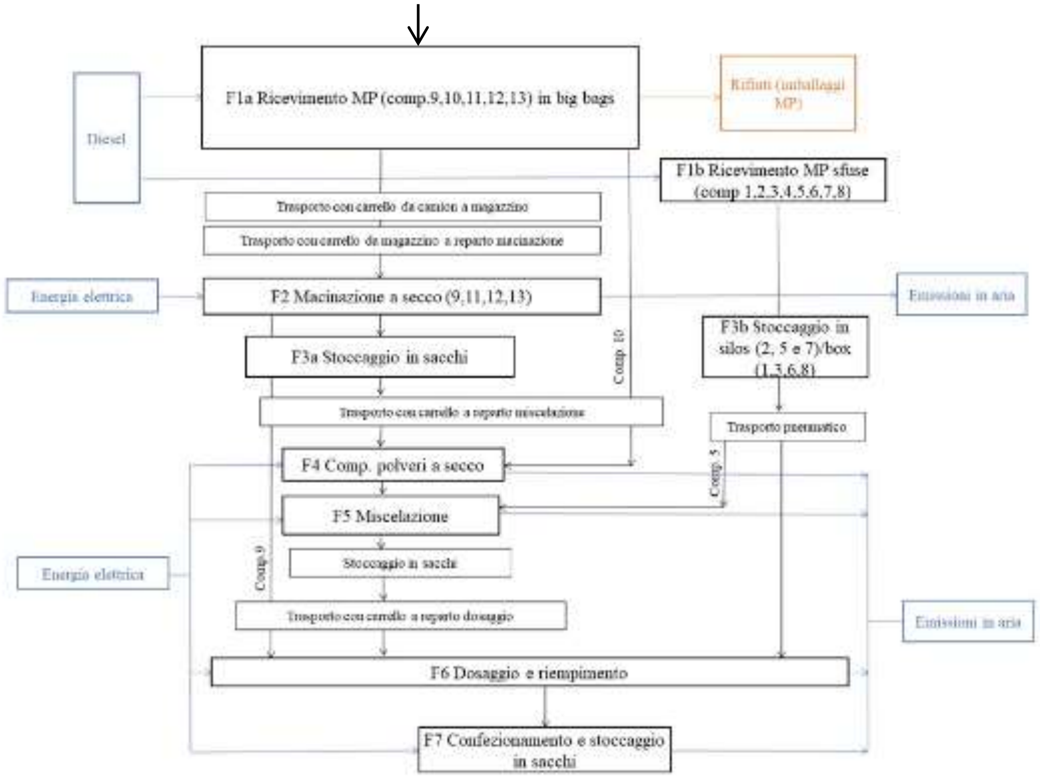
Raw material	Origin	Formulation (wt.%)				Transport distance (km)		
		BNK_SU_NL	BNK_SU	REWO2_SU	REWO4_SU	Road	Train	Barge
Clay 1	Germany	0	9.6	9.6	9.6	22	1000	-
Clay 1	Piedmont (Italy)	0	10.4	10.4	10.4	260	-	-
Clay 1	Ukraine	20	0	0	0	268	-	3111.4
Clay 2	Germany	18	18	18	18	22	1000	-
Bentonite	Sardinia (Italy)	2	2	2	2	323	-	650.1
Feldspar	Turkey	50	50	48	46	191	-	2222.4
Sand	Sardinia (Italy)	10	10	10	10	323	-	650.1
Re.Wo	Lombardy (Italy)	0	0	2	4	210	-	-

Non-local raw materials

System boundaries and functional units

Re.Wo (or traditional frit from primary raw mat.)



Flowchart from LCA study on glaze production in a facility based in Emilia-Romagna (LCA Working Group UNIMORE, 2024).

Cradle-to-gate

Manufacturing of ceramic glazes containing Re.Wo (44 wt.% - F8)

Industrial scale plant manufacturing (4.7 mln kg/year) adapted from a previous study on glaze manufacturing (LCA Working Group UNIMORE, 2024).

Functional unit:

1 kg of glaze (w/ Re.Wo vs w/o Re.Wo)

Traditional frit with a comparable composition to Re.Wo:

Oxide	Frit theoretical composition (wt. %)	Required raw material	$kg_{raw\ mat}/kg_{frit}$
Na_2O	3.60	Na_2CO_3 (soda ash)	6.10E-02
MgO	10.32	$MgCO_3$ (magnesium carbonate)	2.39E-01
Al_2O_3	13.05	Al_2O_3 (aluminium oxide)	1.30E-01
SiO_2	45.72	Silica sand	4.61E-01
CaO	16.28	$CaCO_3$ (calcite)	2.96E-01
TiO_2	1.25	TiO_2 (titanium dioxide)	1.20E-02
Fe_2O_3	9.78	Fe_2O_3 (hematite)	9.80E-02

Methods and quality of the data

Primary data from involved partners
Secondary data from literature or similar studies

FOREGROUND PROCESSES

ecoinvent database (v3.10) → BACKGROUND PROCESSES
LCA Software SimaPro (v9.6.0.1)

Calculation Method: Environmental Footprint 3.1 (EF3.1)

- 16 environmental impact categories
- Developed by the European Commission
- Reference for EN15804+A2:2019

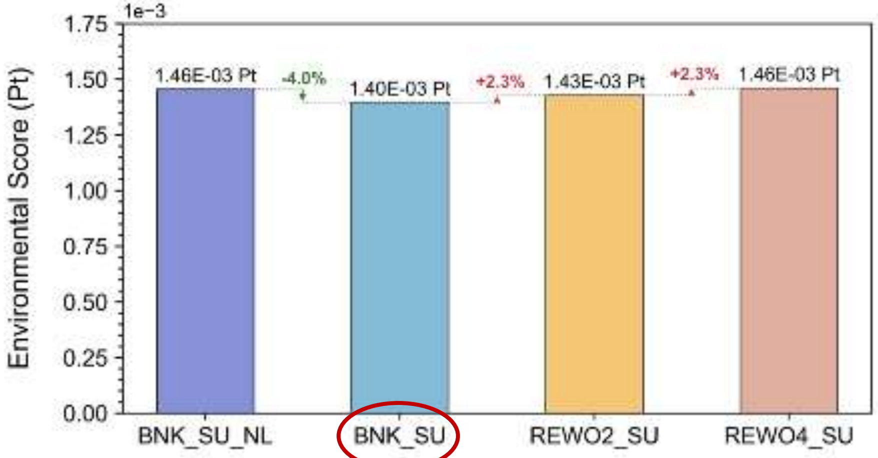
Inertized mineral wool: a secondary raw material for ceramic tiles

Impact category	Unit	BNK_SU_NL	BNK_SU	REWO2_SU	REWO4_SU	% variation (BNK_SU_NL-BNK_SU)	% variation (REWO2_SU-BNK_SU)	% variation (REWO4_SU-BNK_SU)
Acidification	mol H+ eq	7.80E-02	7.33E-02	7.40E-02	7.47E-02	-6.1%	+0.9%	+1.9%
Climate change	kg CO2 eq	1.45E+01	1.39E+01	1.44E+01	1.48E+01	-4.3%	+3.2%	+6.4%
Ecotoxicity, freshwater	CTUe	5.77E+01	5.60E+01	5.69E+01	5.78E+01	-3.0%	+1.6%	+3.3%
Particulate matter	disease inc.	8.69E-07	8.60E-07	8.67E-07	8.74E-07	-1.0%	+0.8%	+1.6%
Eutrophication, marine	kg N eq	2.49E-02	2.28E-02	2.29E-02	2.31E-02	-8.5%	+0.6%	+1.2%
Eutrophication, freshwater	kg P eq	1.85E-03	1.80E-03	1.92E-03	2.04E-03	-2.7%	+6.5%	+13.3%
Eutrophication, terrestrial	mol N eq	2.40E-01	2.17E-01	2.18E-01	2.19E-01	-9.6%	+0.5%	+0.9%
Human toxicity, cancer	CTUh	7.21E-08	6.83E-08	6.94E-08	7.04E-08	-5.3%	+1.5%	+3.0%
Human toxicity, non-cancer	CTUh	1.11E-07	1.08E-07	1.10E-07	1.12E-07	-2.0%	+1.5%	+3.1%
Ionising radiation	kBq U-235 eq	4.63E-01	4.42E-01	5.16E-01	5.93E-01	-4.7%	+16.8%	+34.3%
Land use	Pt	1.23E+02	1.17E+02	1.18E+02	1.19E+02	-4.4%	+0.7%	+1.4%
Ozone depletion	kg CFC11 eq	8.72E-07	8.61E-07	8.71E-07	8.80E-07	-1.2%	+1.1%	+2.2%
Photochemical ozone formation	kg NMVOC eq	8.01E-02	7.34E-02	7.42E-02	7.49E-02	-8.3%	+1.0%	+2.0%
Resource use, fossils	MJ	2.08E+02	2.00E+02	2.07E+02	2.13E+02	-3.7%	+3.3%	+6.7%
Resource use, minerals and metals	kg Sb eq	4.49E-05	4.41E-05	4.48E-05	4.55E-05	-1.8%	+1.5%	+3.1%
Water use	m3 depriv.	2.10E+01	2.10E+01	2.13E+01	2.17E+01	-0.2%	+1.6%	+3.2%

1 m^2 of unglazed ceramic tile (cradle-to-grave)

Midpoint level environmental impacts (EF 3.1)

Inertized mineral wool: a secondary raw material for ceramic tiles

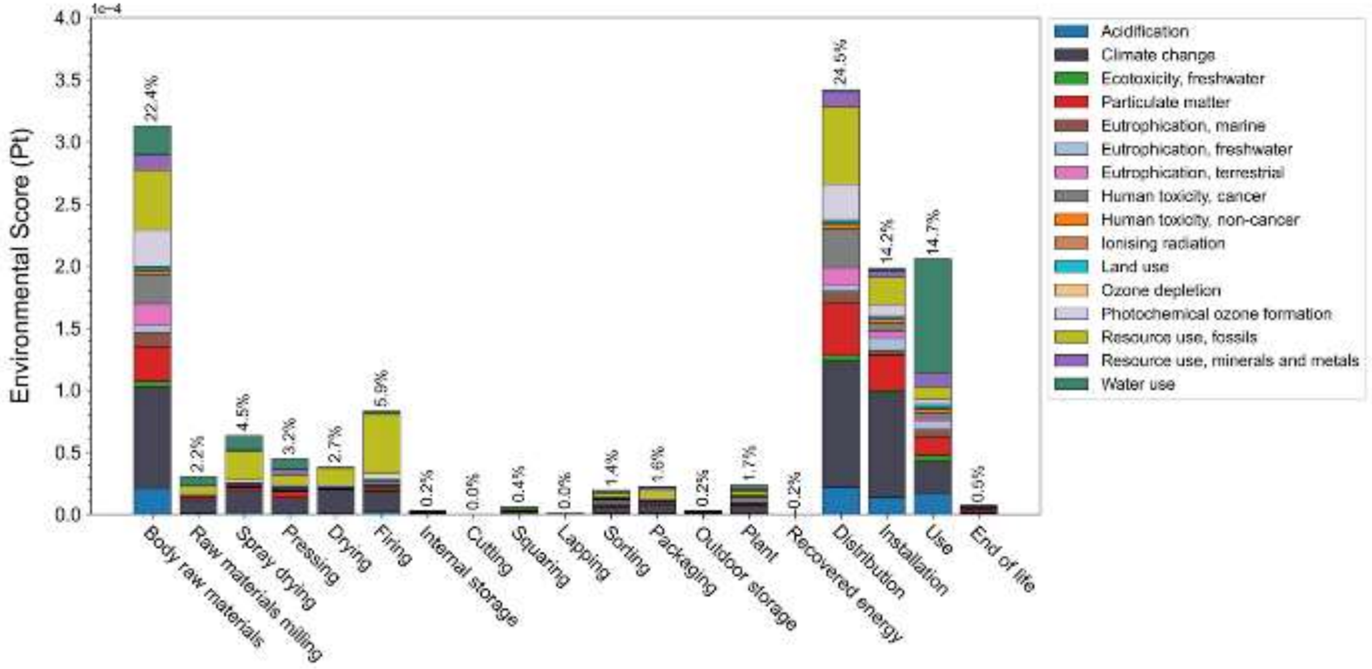


Non-local raw materials

1 m^2 of unglazed ceramic tile (cradle-to-grave)

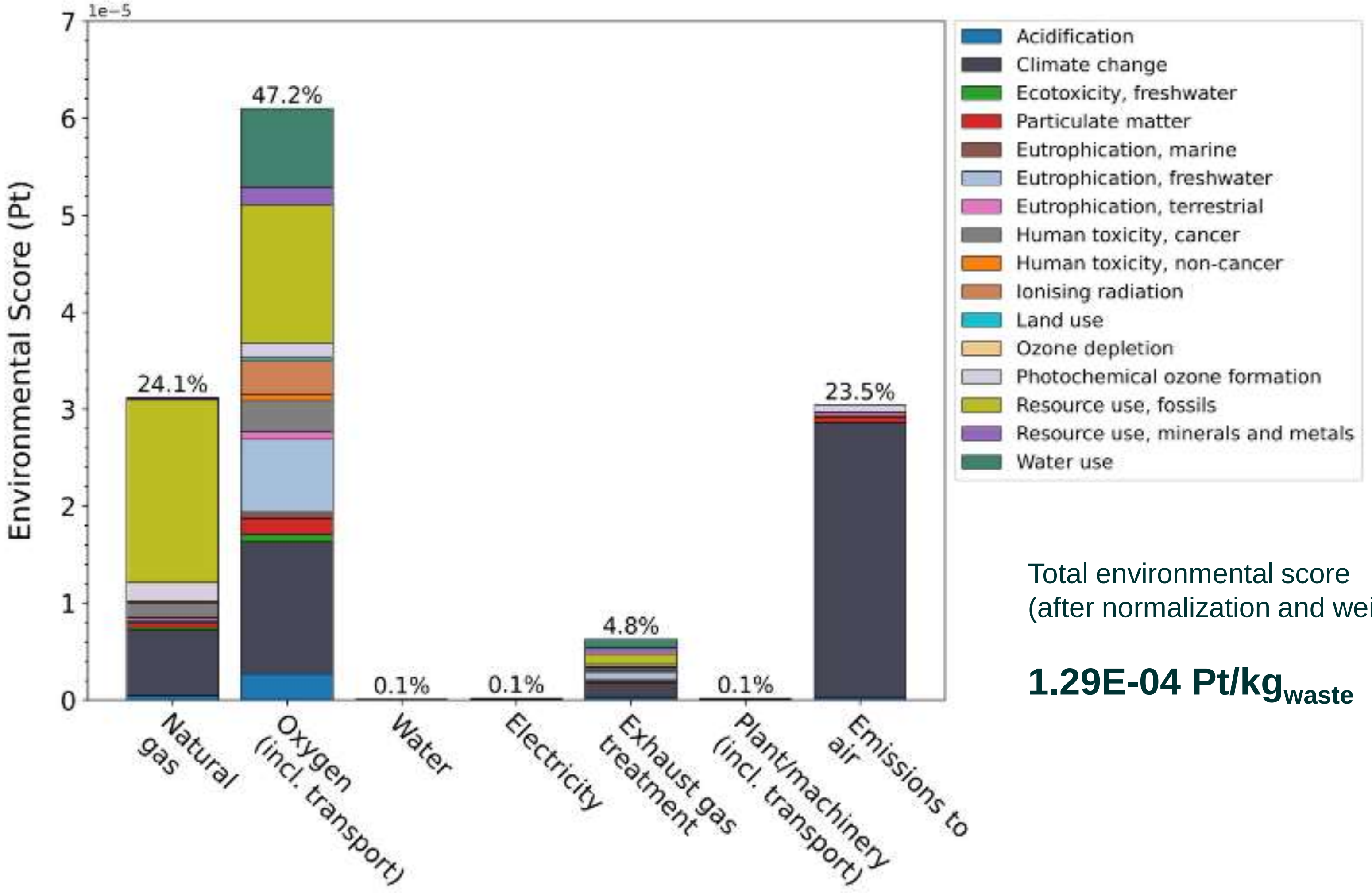
Midpoint level environmental score (EF 3.1)

Relative contributions to life-cycle environmental impacts



Conte *et al.*, Results in Engineering **2026**, 31, 111529.

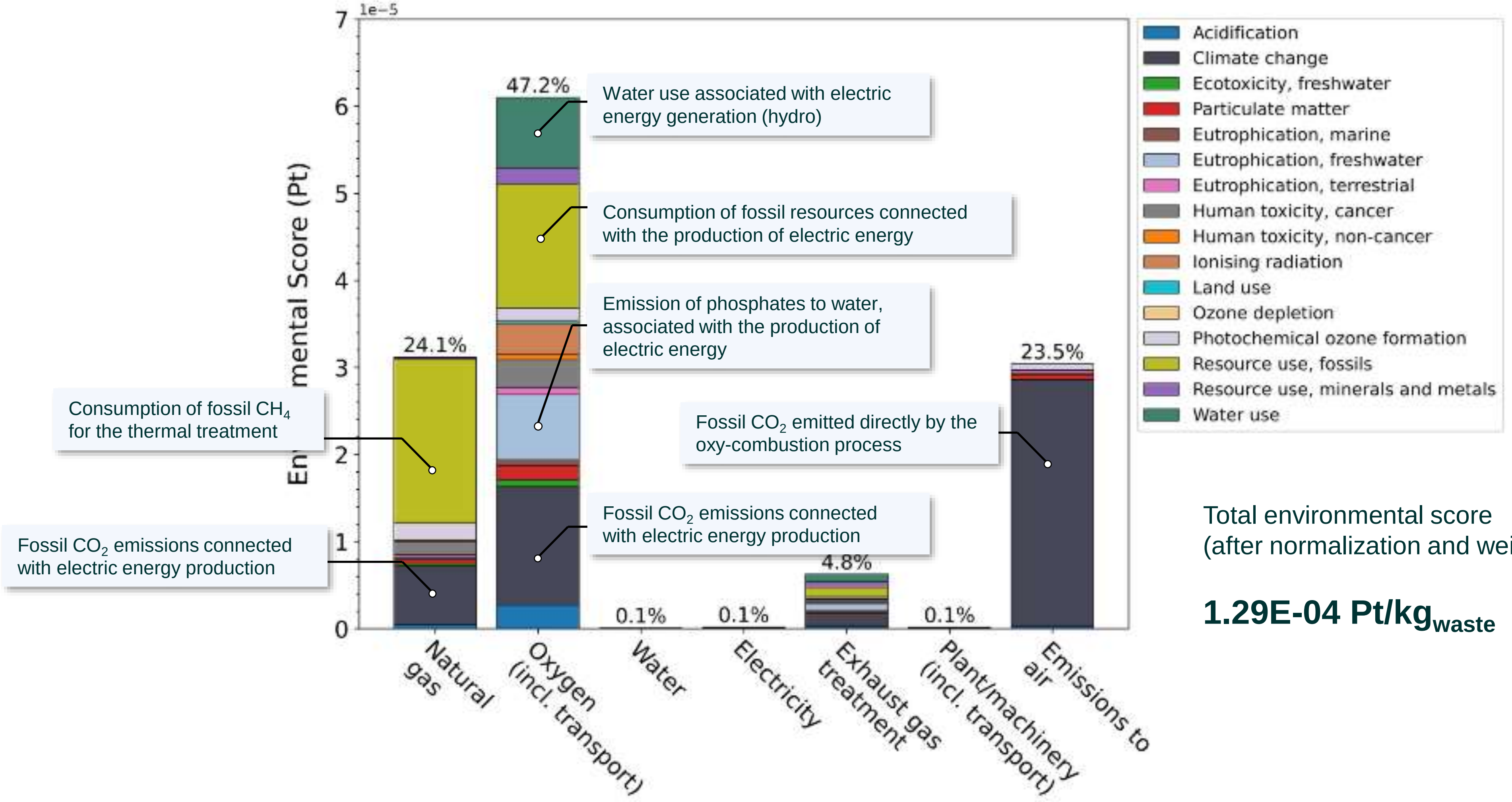
Inertization treatment: hotspot analysis



Total environmental score
(after normalization and weighting:

1.29E-04 Pt/kg$_{\text{waste}}$

Inertization treatment: hotspot analysis



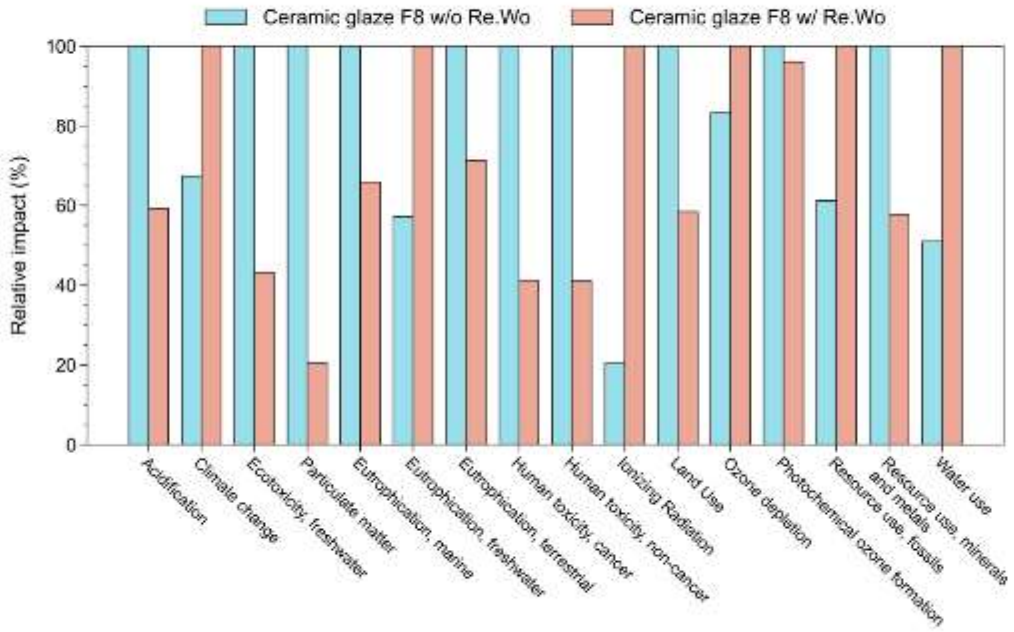
Total environmental score
(after normalization and weighting:

1.29E-04 Pt/kg$_{waste}$

Inertized mineral wool: a secondary raw material for ceramic glazes

1 kg of ceramic glaze (cradle-to-gate)

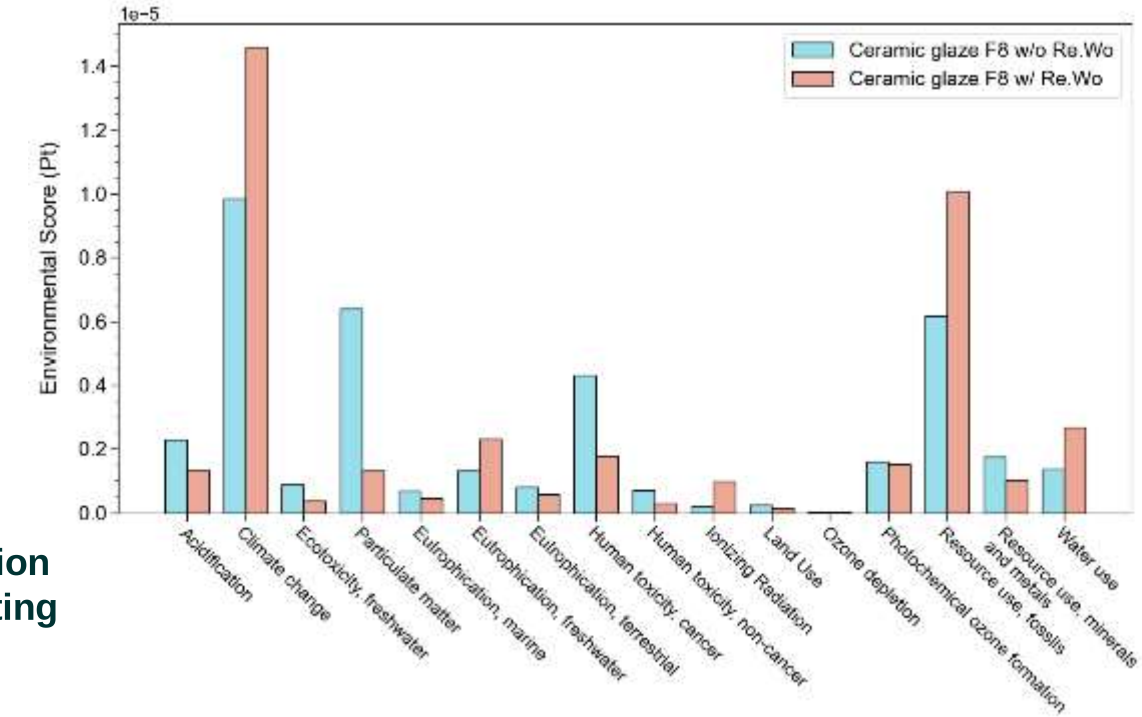
Midpoint level results (EF 3.1)



After normalization and weighting

Total environmental scores:

Ceramic glaze F8 w/o Re.Wo: 3.86E-5 Pt/kg
Ceramic glaze F8 w/ Re.Wo: 3.95E-5 Pt/kg



Conclusions

MAIN FINDINGS

- The use of **oxygen, CH_4** and **the direct emissions of CO_2** contribute significantly to the total environmental burden of the inertization process.
- The slight increase in environmental impact observed for the **incorporation of Re.Wo at 4 wt.% in unglazed ceramic tiles can be regarded as limited** in light of the overall uncertainties of the LCA model.
- The incorporation of **Re.Wo in ceramic glaze** led to **environmental trade-offs in several categories**, when compared with conventional glaze from primary raw materials.

POTENTIAL ADVANCEMENTS

- Adopt a different LCA modeling approach to account for avoided disposal of mineral wool waste or sodic feldspar.
- Monitor implementation and process improvements in the inertization process to further reduce environmental impacts.

Acknowledgments

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