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# Life Cycle Assessment of Novel Ceramic Pastes Incorporating Secondary Raw Materials


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# Agenda

1. Introduction

2. Objectives

3. Methodology

4. Results and Discussion

5. Conclusions

# Introduction



## Background

**Ceramic** is a vital economic sector in EU (PT, ES, IT) with multiple products:

**1,654 million m² of ceramic tiles** (EU, 2023) = **10.4% of global production** in this sector.

The **European sanitaryware** market plays a significant role globally, contributing to approximately **20% of worldwide production**.

**Portuguese ceramic tableware** is internationally recognized for its **high-quality standards** and distinctive design, holding a **strong position in the export market**.

- Made mostly of natural raw materials (clay, kaolin ; feldspar and sand)
- Energy intensive sector (due to firing requirements), energy = 30% of costs
- Associated $CO_2$ emissions

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# Introduction

**EU Ceramic** sector is committed to its path towards decarbonization and zero-pollution and circular economy

## Key issues to address

- High energy consumption
- Intensive extraction of raw materials
- Emissions and waste generation, have been identified as critical hot spots in previous LCAs[1]

## Current Waste Management

- Ceramic waste frequently disposed in landfills or used as low-value fill material.
- Recycling mainly limited to crushing coarse scraps for low-grade reuse
- Wastewater treated, with limited water recycling.


Journal of Cleaner Production

Integrated environmental and economic life cycle assessment of improvement strategies for a ceramic industry

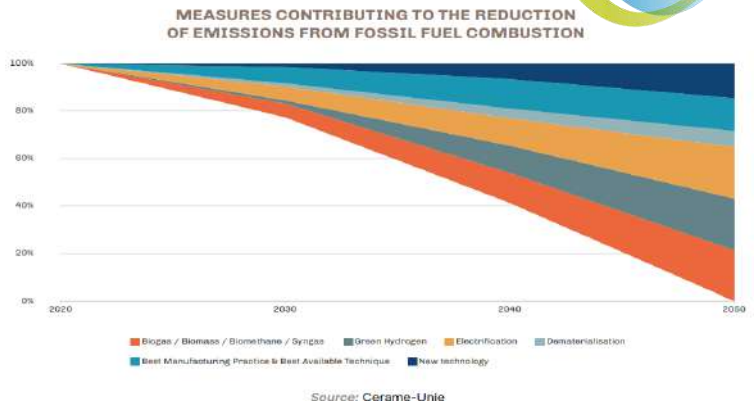
(1) https://doi.org/10.1016/j.jclepro.2022.131173

# Introduction

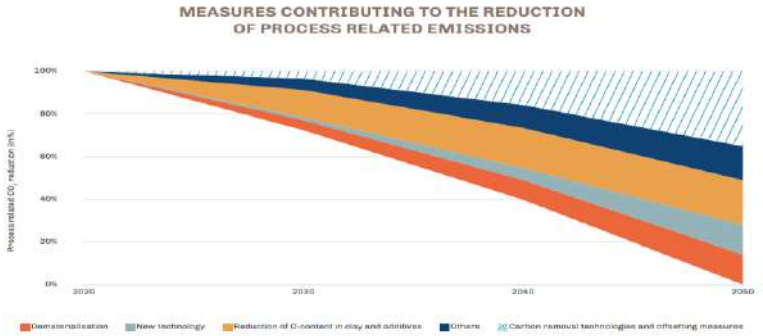
**Ceramic** sector is committed to its path towards decarbonization, zero-pollution and circular economy.

## Potential for Improvement

- Energy efficiency, waste heat recovery
- Low carbon fuels (Biofuels, green H2, eletric.)
- Waste Reduction and Recycling
- Use of Secondary Raw Materials
- New ceramics with to lower sintering temperatures
- Emissions Reduction
- Water Recycling




*Source:* Cerame-Unie

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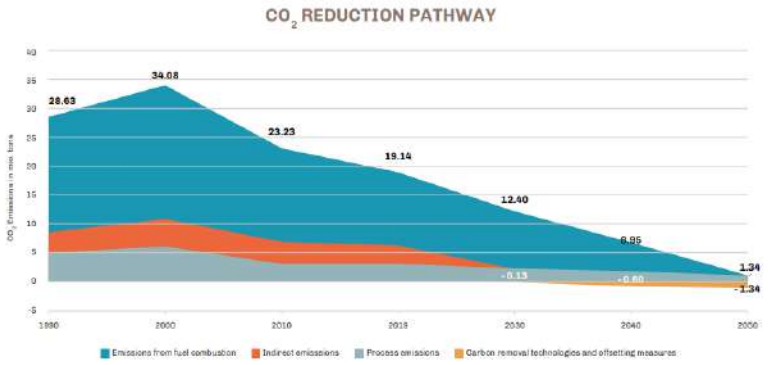


*Source:* Cerame-Unie

# Introduction

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## Mobilizing Agenda - EcoCeramics and Cristal from Portugal

Aims to drive the ecological and digital transformation. enhance the sector's competitiveness and efficiency, aligning it with the goals of circular economy and carbon neutrality. Pillars:

- Process decarbonization,
- Circular economy,
- Digital innovation,
- Skills and capacity building

https://agendaecp.pt/en

Develop sustainable ceramic pastes, low-impact firing technologies

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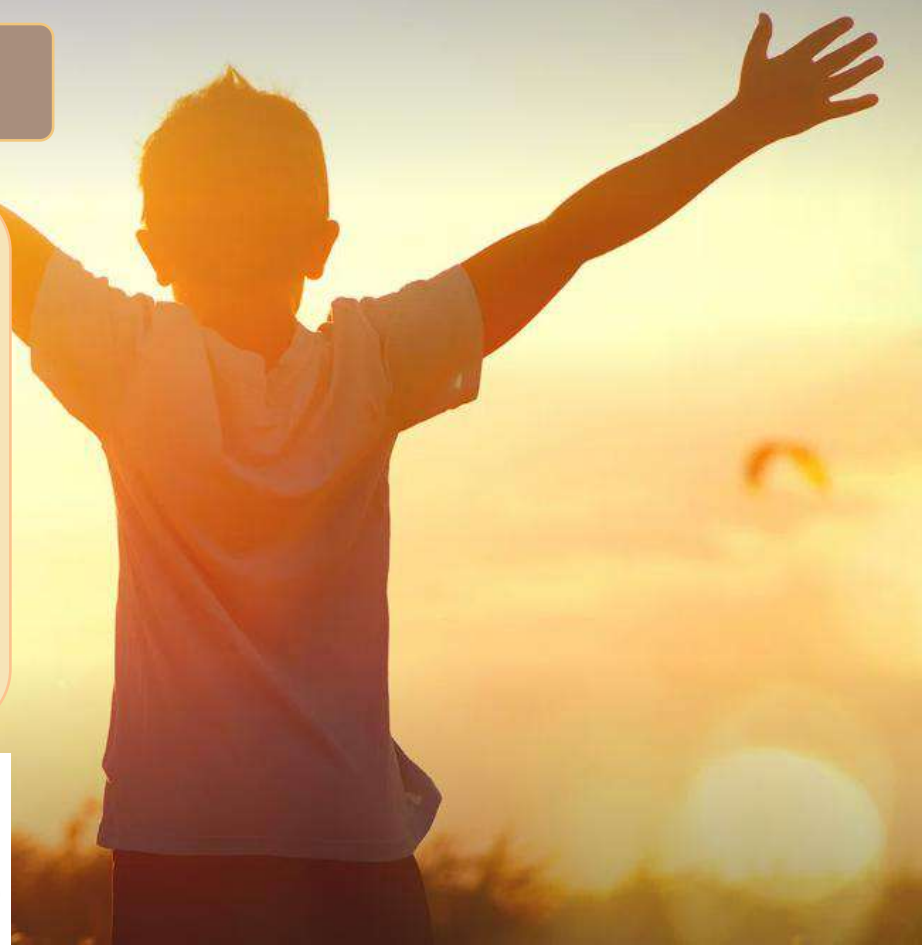
# Introduction



## Mobilizing Agenda - EcoCeramics and Cristal from Portugal

Develop sustainable ceramic pastes/blend incorporating industrial residues:

- ECOBLEND GP: new eco-Sustainable blend for – Floor tiles
- REVVER: new eco-Sustainable paste – Wall tiles
- GRESVER: new eco-Sustainable paste – Tableware stoneware
- ECOSAN: new eco-Sustainable paste – sanitaryware (sewage sludge and ceramic shards)



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# Introduction

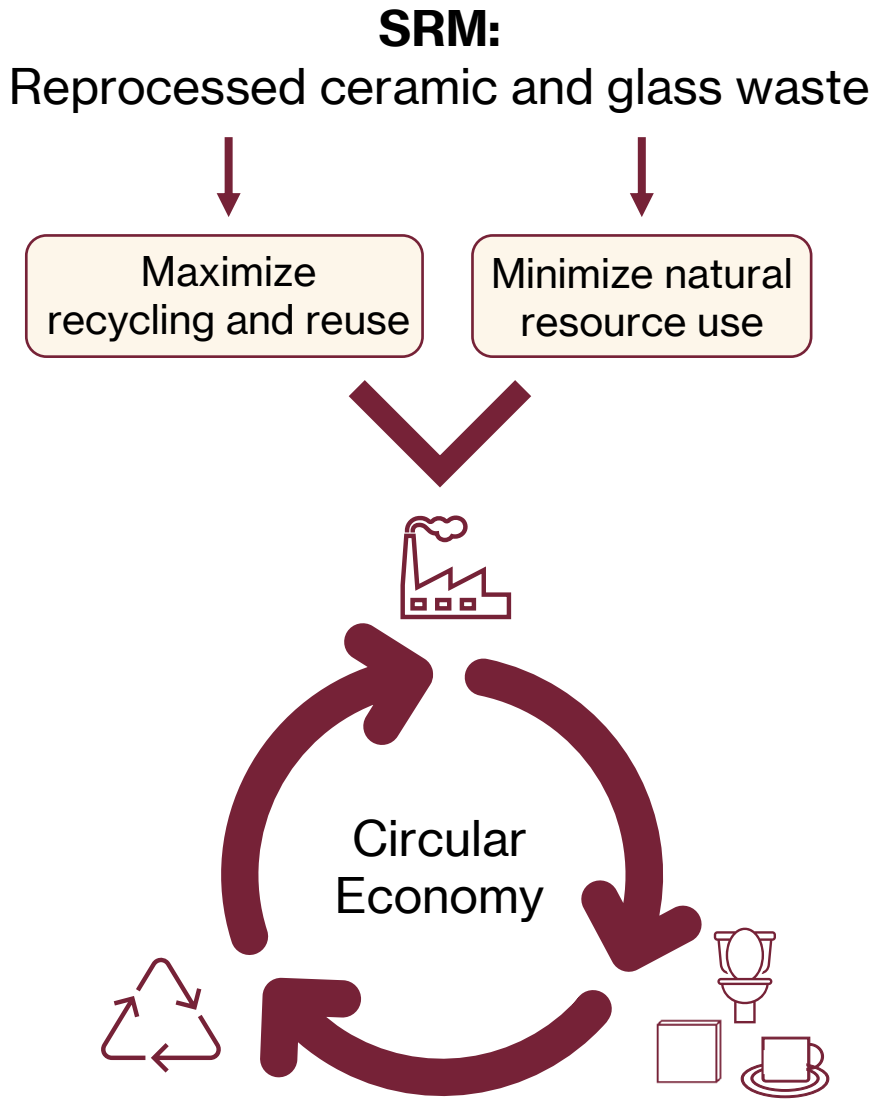
## Motivation

Global ceramic production contributes significantly to energy consumption, $CO_2$ emissions and the depletion of mineral resources

Need to enhance decarbonization and circularity by reducing primary raw material use and increasing material re-utilization

Interest in circular economy & secondary raw materials

Environmental performance not yet fully assessed



# Objectives

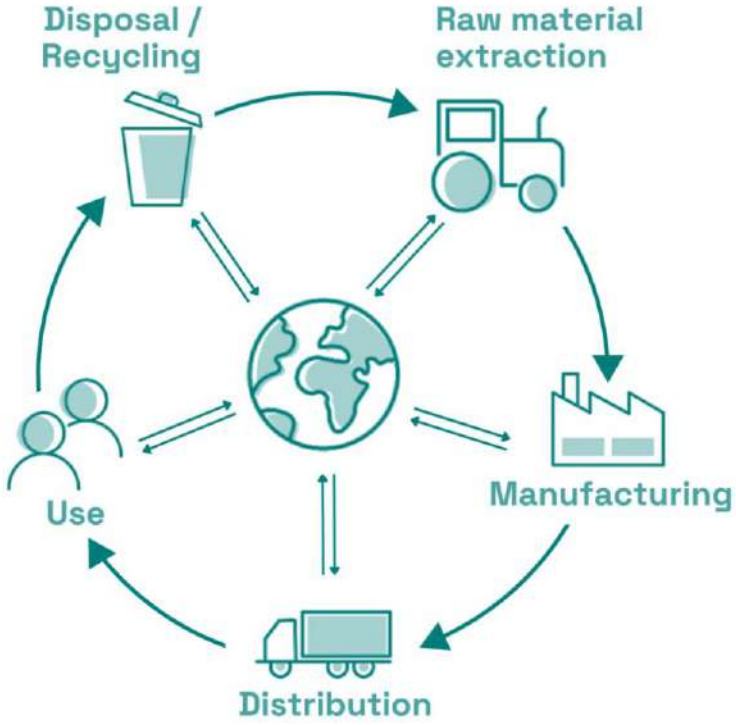
- Evaluate environmental impact of new ceramic paste compositions (Improve circularity + Lower environmental impact)
- Compare life cycle performance with conventional materials
- Assess viability of incorporating industrial waste streams

How to achieve these objectives ?

# Methodology: Life cycle Assessment



- Estimate potential environmental impact of a product throughout its life cycle from cradle (raw material extraction) to grave.
- Standards ISO 14040 and ISO 14044 guide LCA methodology.
- Identify critical environmental hotspots.
- Support decision and further improvements.
- Compare life cycle performance with conventional materials.




# Methodology: Life cycle Assessment

**Standards:**

ISO 14040 and ISO 14044: LCA has 4 iterative steps

**Definition of scope:**

Cradle-to-cradle: A1-A3 (C2G), C1-C4 (EoL), D (future benefits: reuse, recycling, energy recovery)

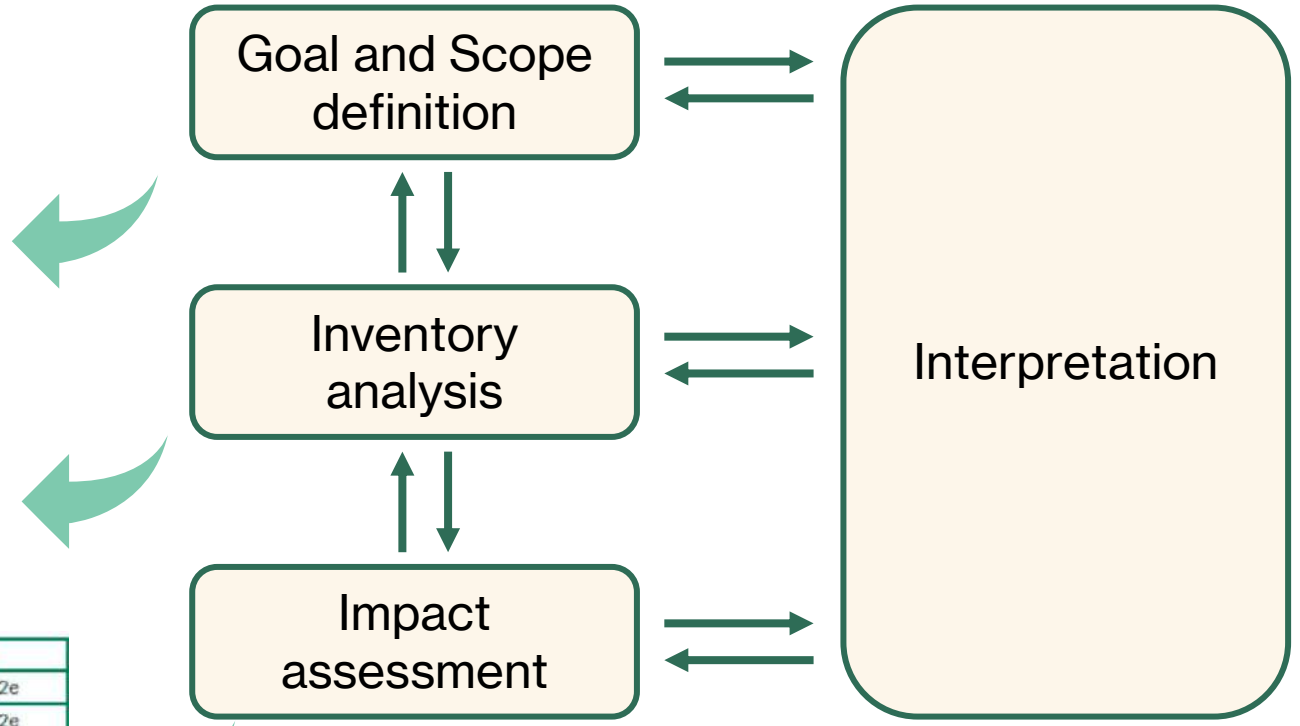
**Life Cycle Inventory:**

Primary data from industry partners, background data: Ecoinvent 3.11 , literature, EPDs

**Definition of impact method:**

EN15804+A2 - supporting EDPs in construction sector

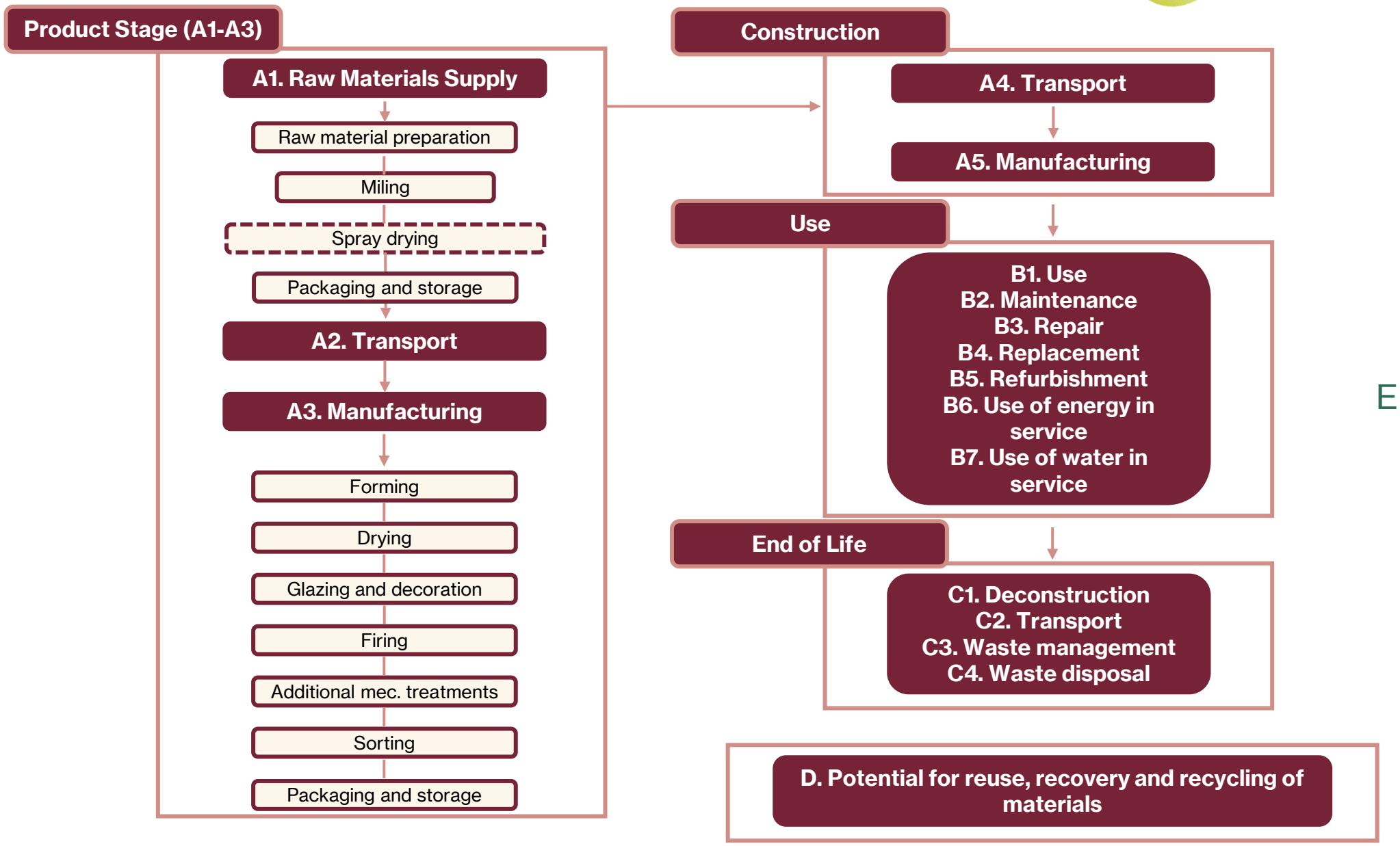
13 impact categories




| Impact category | Unit |
|---|---|
| Climate change – total | kg CO2e |
| Climate change – fossil | kg CO2e |
| Climate change – biogenic | kg CO2e |
| Climate change – LULUC | kg CO2e |
| Ozone depletion | kg CFC11e |
| Acidification | mol H+e |
| Eutrophication, aquatic freshwater | kg PO4e |
| Eutrophication, aquatic marine | kg Ne |
| Eutrophication, terrestrial | mol Ne |
| Photochemical ozone formation | kg NMVOCe |
| Abiotic depletion, minerals & metals | kg Sbe |
| Abiotic depletion of fossil resources | MJ |
| Water use | m3e depr. |

# Methodology (system diagram)






EN15804+A2

# Preliminary Results

Four Ceramic pastes are being developed in ECP project.

LCI primary data collection is under way: energy, material inputs, and outputs (emissions, residues, wastes, products):

- From ceramic paste producer.
- From ceramic industries.

| | | Functional Unit |
|---|---|---|
| ECOBLEND GP | Floor porcelain tiles | 1 $m^2$ |
| REVVER | Wall tiles | 1 $m^2$ |
| GRESVER | Tableware | 1 kg |
| ECOSAN | Sanitaryware | 1 kg |

Incoporating secondary raw materials (i.e: ceramic shards or wastewater sludge), generated internally, and wastes or by-products (e.g. glass cullet) from other industrial sectors.


- Preliminary LCA of benchmark pastes have been initially compiled based on available EPDs.
- LCAs for ECP pastes are under way, with results expected by the end of the year.

# Preliminary Results

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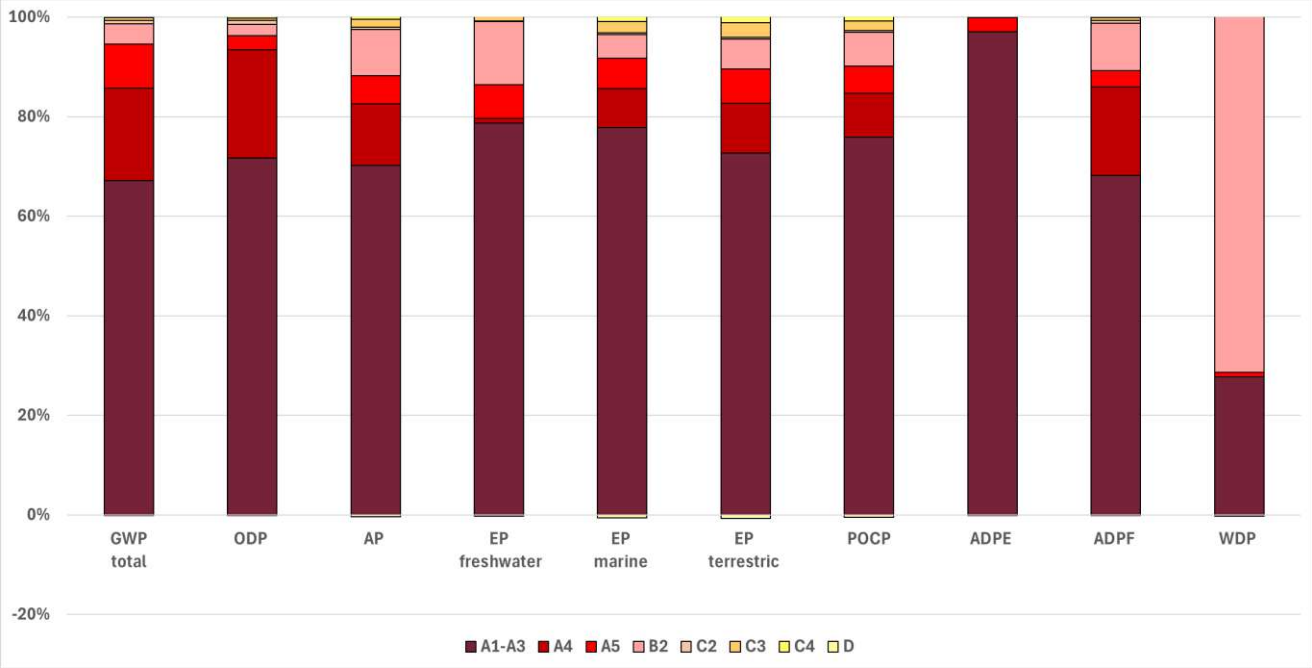
## Benchmarks

Based on Environmental Product Declaration (EPD) and literature

### Ceramic Tiles

Environmental Product Declaration (EPD) for porcelain tiles from Revigrés
(glazed and unglazed porcelain tiles, indoor and outdoor, wall and floor applications)




Caption: GWP - total = global warming potential; ODP = ozone depletion; AP = acidification terrestrial and freshwater; EP - freshwater = eutrophication potential (freshwater); EP - marine = eutrophication potential (marine); EP- terrestric = eutrophication potential (terrestrial); POCP = photochemical ozone formation; ADPE = abiotic depletion potential (element), ADPF = abiotic depletion potential (fossil) WDP = water scarcity. Source: based on Revigrés EPD, M. Almeida/CTCV, Revigrés

### Ceramic Tiles

**Hot spots**

•Most impacts are associated to the production stages (A1-A3) for all impact categories, except WDP (B2).

**Hot spots:**

- Energy requirements:
  - Natural gas used in firing, drying, and spray drying),
  - Electricity used throughout A1 and A3
- Ceramic paste is the third hotspot, in most categories.

(5) M. Almeida/CTCV, Revigrés

### Sanitaryware

**Hot spots**

- Energy requirements:
  - Fuel: natural gas
  - Electricity
- Ceramic paste, (Kaulin, Feldspar, ...)
- Glazing

(1) https://doi.org/10.1016/j.jclepro.2022.131173

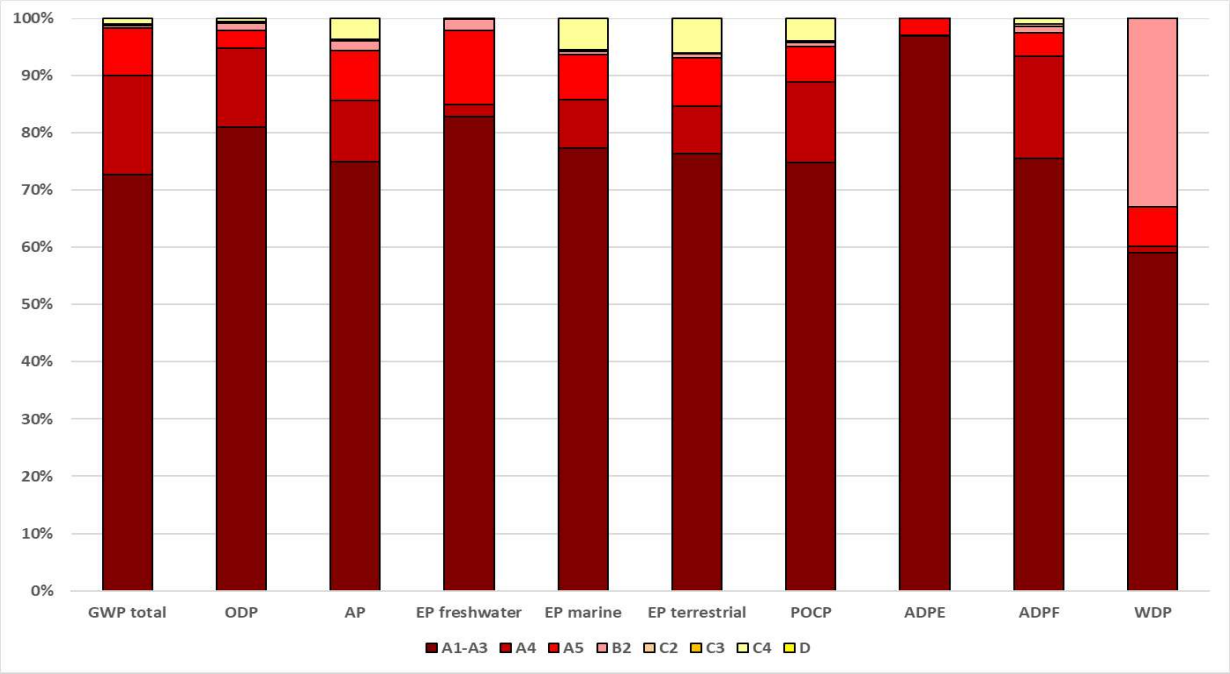
# Preliminary Results

## Benchmarks

Based on Environmental Product Declaration (EPD) and literature

### Ceramic Tiles

Environmental Product Declaration (EPD) for porcelain tiles from Primus Ceramics (Ceramic tiles (BIII group), indoor, wall and floor applications)

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(5) M. Almeida/CTCV, PRIMUS

# Conclusions

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- Integrating different wastes into ceramic products is a relevant and impactful approach expected to promote resource efficiency, advance circular economy, and enhance sustainability. the sector environmental performance.
- New ceramic Eco-sustainable pastes are being developed in ECP.

- LCA is being used to support project developments and address key environmental challenges.
- Benchmark analysis show that A1-A3 Production stages are by far the most relevant.

- Energy requirements are critical (Nat. Gas, electricity)
  - Prospective scenarios combining low carbon energy sources (biomethane, green H2, green electricity) are foreseen to reduce environmental impacts.
  - Ceramic pastes contributing to low firing/sintering temperature will also be addressed on ECP.
- Ceramic Eco Sustainable products under development are expected  present commercial solutions that further improve the sector environmental performance.

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# Thank you!

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(1) Instituto de Soldadura e Qualidade, Portugal; (2) MCS Portugal; (3) Vista Alegre Atlantis, Portugal; (4) Sanindusa, (5) Primus ceramics, Portugal; (6) CTCV- Centro Tecnológico da Cerâmica e do Vidro, Portugal.

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