Institute of science and technology for a circular low-carbon energy economy

Eco-Glass-Fabrication from the assembly of secondary precursors

EcoGlassFab

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Management of radioactive waste from the reprocessing of spent nuclear fuel and from dismantling

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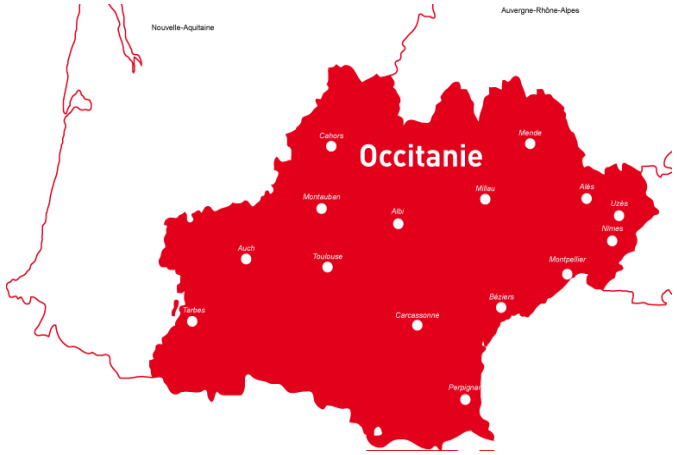
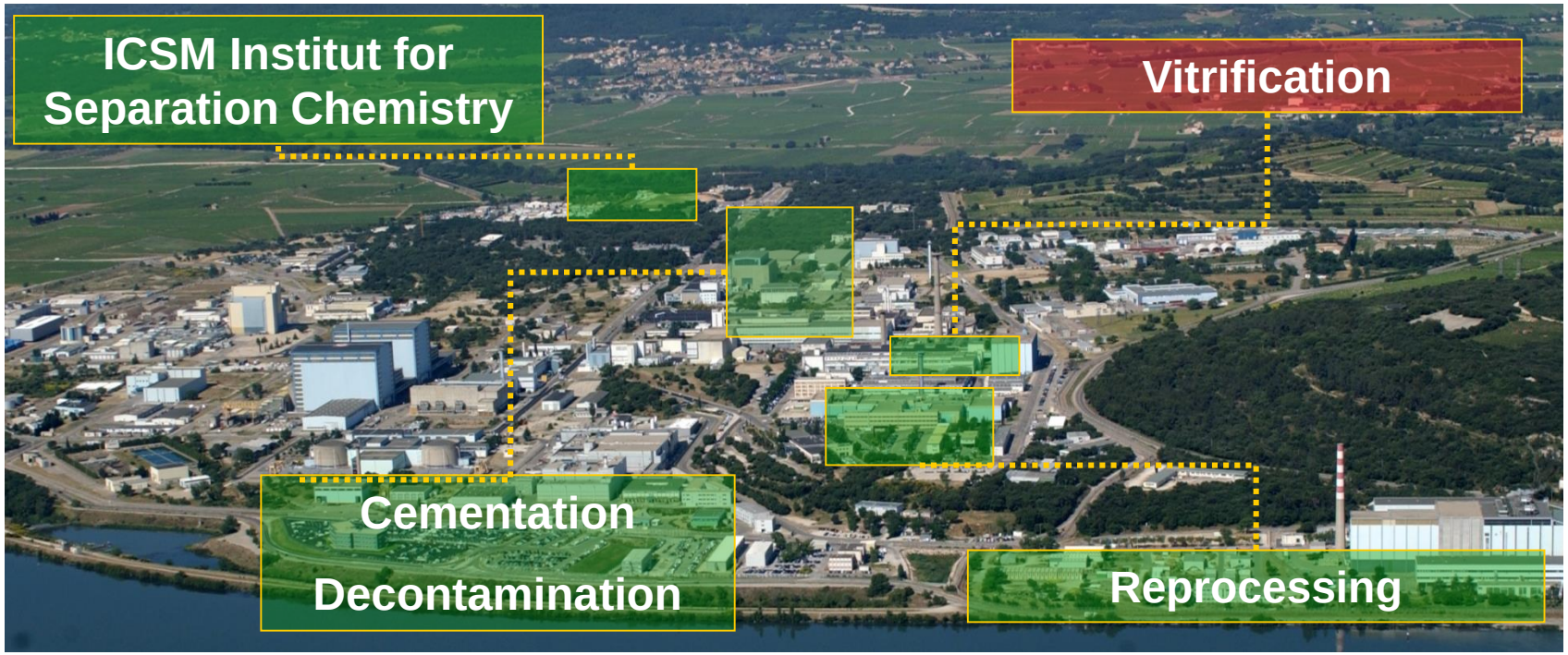


Marcoule center



CEA ISEC gather all historical R&D activities and also use its expertise to contribute to national **strategic independence on naturals resources and materials**

Glass industry in France

- Produces around 5 million ton of glass a year
- Generates 25,000 jobs at some 50 industrial sites in France
- Holds second place in Europe
- Manufactures multi-purpose glass

Energy consumption: 10 Gj/ton of glass

Primary resource consumption: ~1.4 t/ton of glass

CO_2 emissions: 500 kg/ton of glass (20% associated with raw materials)

Fédération du verre - France

- ***Packaging glass***
- ***Laboratory glassware***
- ***Window glass***
- ***Optical fiber, insulation fiber, reinforcement fiber***
- ***Glass frit for multiple applications***

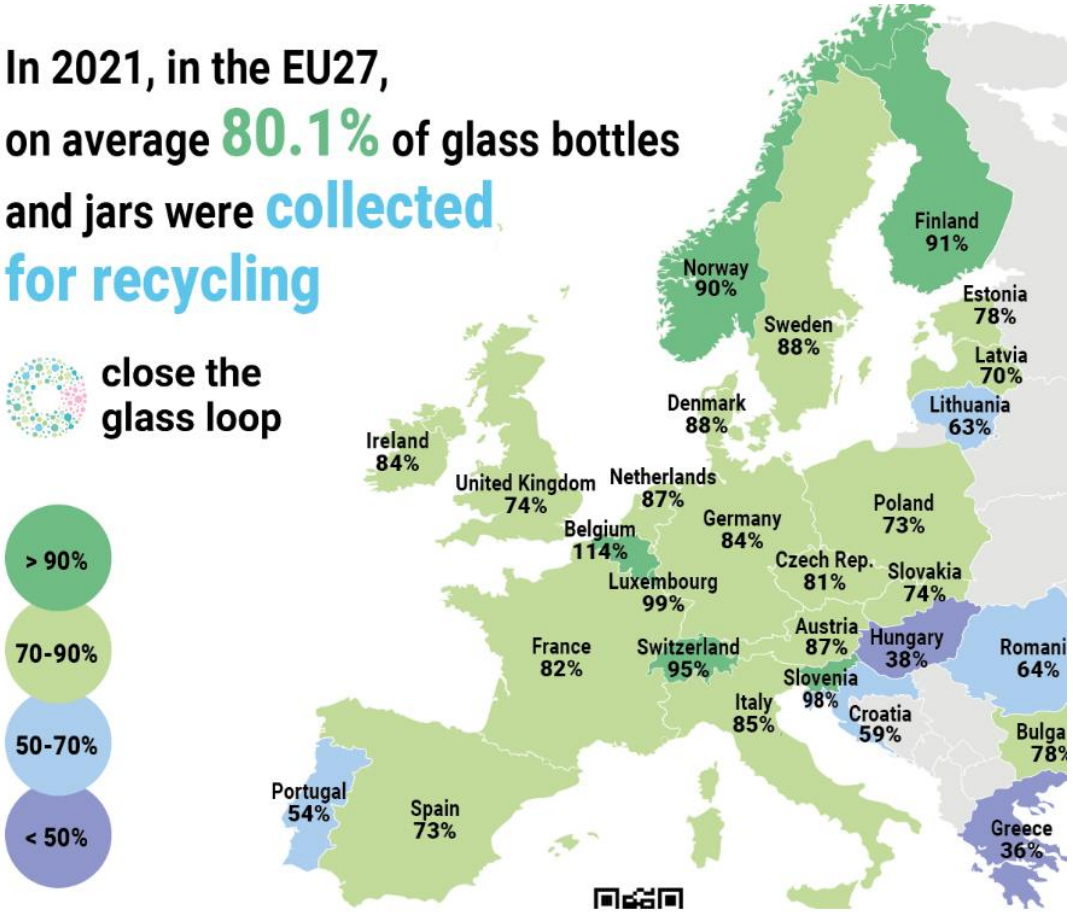
Glass industry in France

This industry is committed to a virtuous circular economy

The French glass industry is subject to Extended Responsibility Producer since 1993

Close the glass Loop program

In 2021 the French glass industry share a common European ambition to collect more glass packaging and recycle
70 to 90 % by 2023



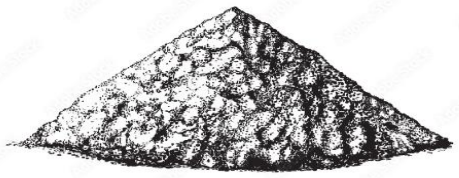
Conventional glass manufacturing in France

~77 %

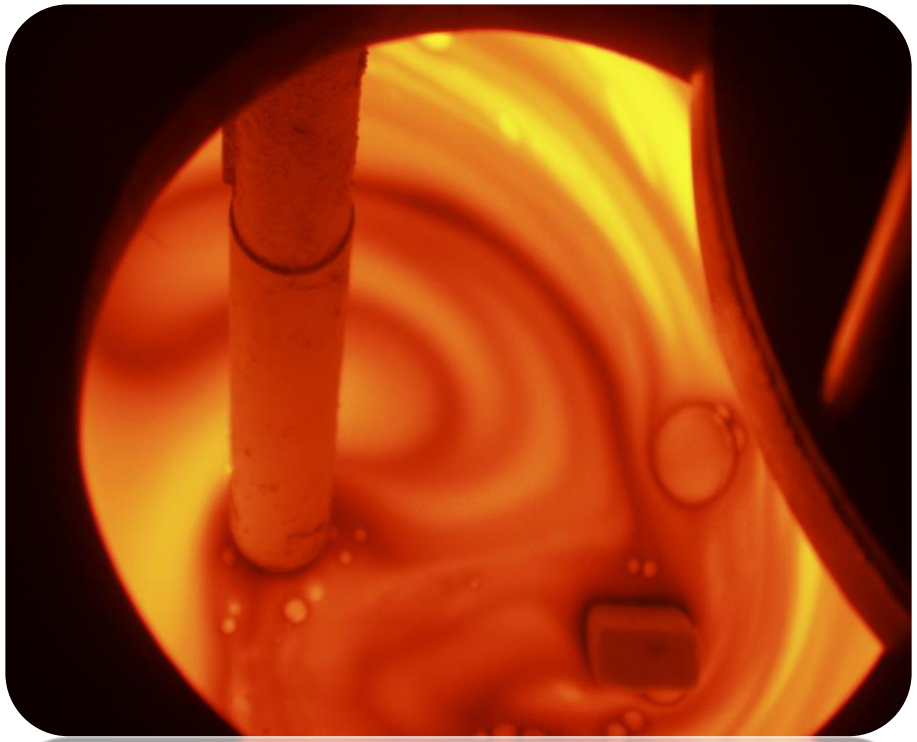
Cullet – Glass from collection and manufacturing scrap

EcoGlassFab - Replacing raw materials with secondary materials

~23%



Primary mineral raw materials (mining)



Glass compositions

Major elements (oxides)

- Silicon oxide (SiO_2) – Sand
- Sodium oxide (Na_2CO_3)
- Calcium oxide ($CaCO_3$) - Limestone

Specific elements (Li, B, Al, Zn, Pb, F)

Transition elements (Cr, Mn, Fe, Co, Ni, Cu,…)

EcoGlassFab : What are the sources of secondary raw material?

Mineral materials with low organic compounds

- Glass industry: specific cullet → pharmaceutical bottle, glass fiber (Si, B, Na), opal glass (F)
- Metallurgy industry: → silica fumes (Si), rinsing effluents (transition metals, Co, Ni, Cu, Mn, Cr, Fe)
- Mining industry: mining by-products → sand, (Si, Ca, Al) slag (Si, Fe,..), …
- Dismantling: Photovoltaic panel glass (Si, Na, Ca)
- Bio-sourced materials: shellfish (Ca)
- Recycling industry: battery recycling by-products (Co, Ni, Li)
- Soil remediation: recovery transition elements from contaminated soils (Cu)

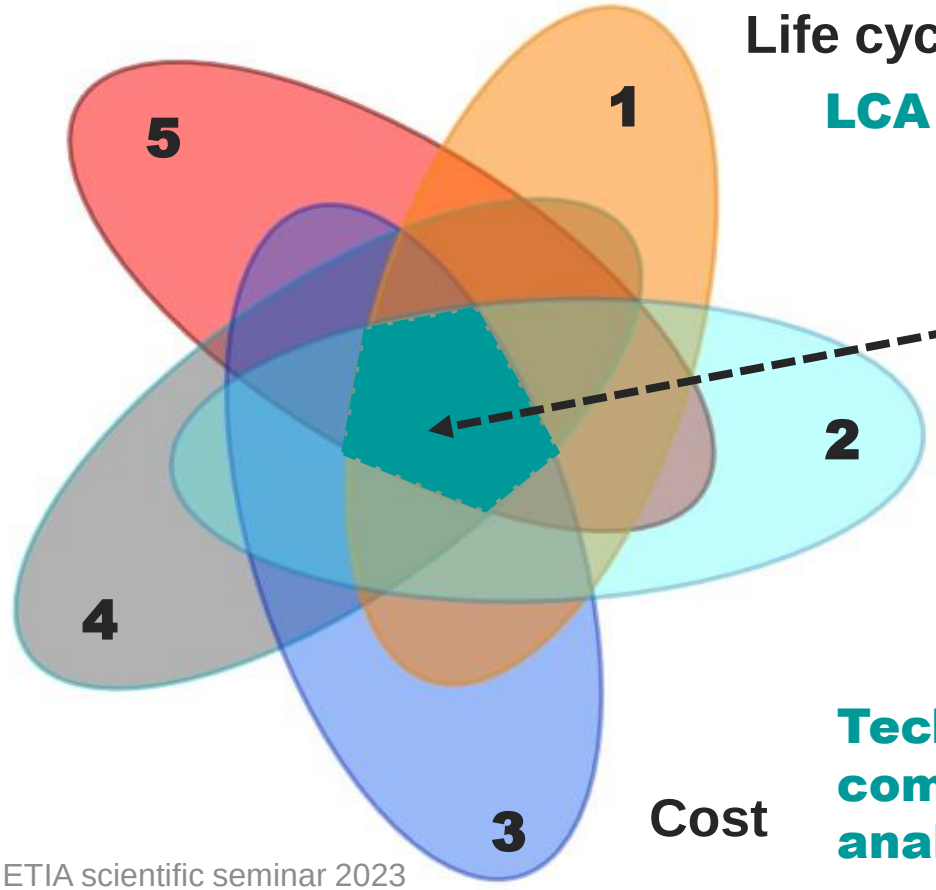
→ Secondary blended raw materials can be diluted in glass compositions

EcoGlassFab : Method and benefit?

Methodology of EcoGlassFab will lead to combine

- Inputs data on the available secondary raw materials
- Technical specifications of the glass industry

➔ Calculate the best assemblies for the production of eco-designed glass



Glass quality

Chemical reactivity at high temperature

Life cycle

LCA

Carbon footprint

Cost

Technical-commercial analysis

Energy balance

Measurement or calculation

Best assembly of optimized secondary materials

➔*accelerate the development of eco-designed glasses*

➔Application to a glass frit used in the nuclear industry

Nuclear glass frit

Primary raw material for conventional glass synthesis

Nom	Quantité	Unit
Lithium Carbonate	80	kg
Dehydrated Borax	250	kg
Calcium carbonate	100	kg
Zinc Oxide	50	kg
Cobalt Oxide	1	kg
Nickel Oxide	1	kg
Alumina	80	kg
Boric Acid	80	kg
Iron oxyde	10	kg
Quartz	700	kg
Zircon Oxide	10	kg
Carbon	20	kg

1st question : Which materials play a key role in life-cycle analysis?

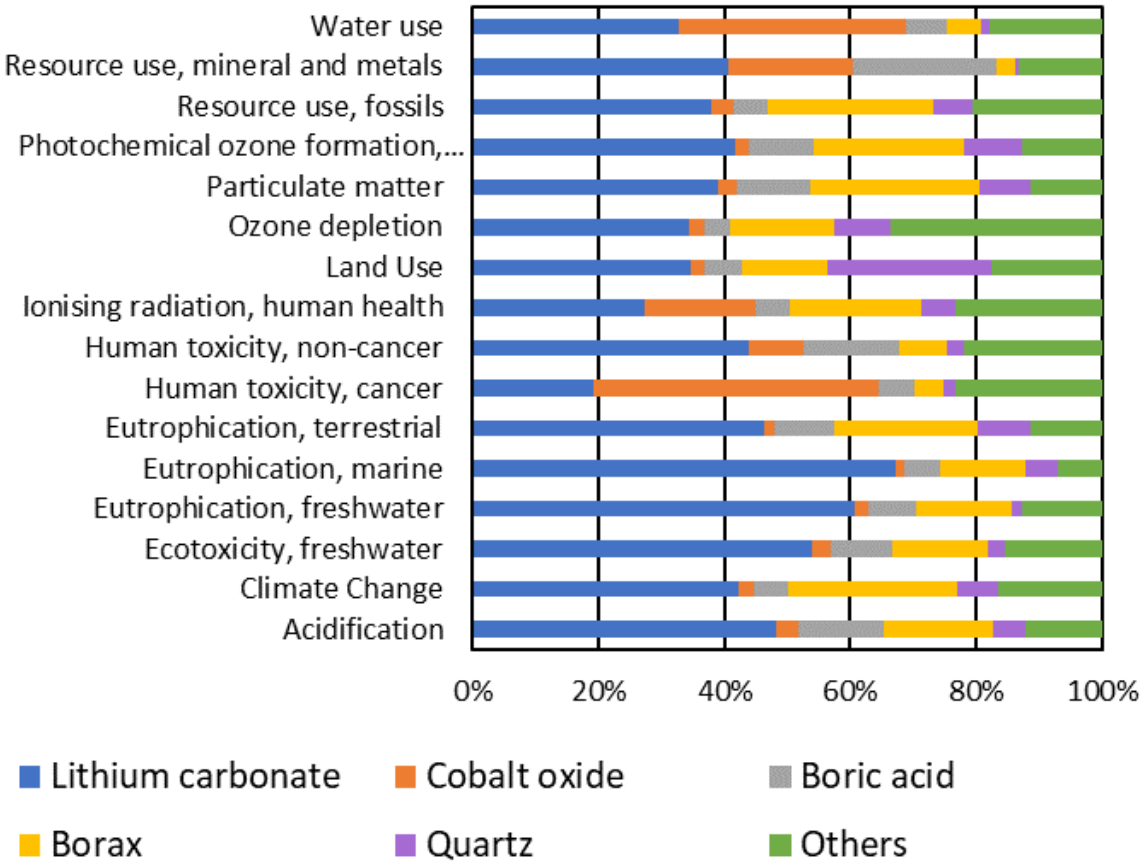
Preliminary Life-Cycle Analysis

M.L. Brusseau 2019

Identification of penalizing raw materials

16 impact classes

Gabi 6 TS (10.6.2.9) and Data base Ecoinvent3.8



- **Lithium carbonate = 42%** (max. = 67 %, min. = 19%)
- **Borax = 19%** (max. = 27%, au min. = 3%)
- **Cobalt oxide = 10%** (max. = 45%, au min. =2%)
- **Boric acid = 9%** (max. = 23%, au min.=4%)
- **Quartz = 6%** (max. = 16%, au min.=1%)
- **Others = 17%** (max. = 34%, au min. 7%)

The most impacting precursors in relative are Lithium carbonate, Borax, Cobalt oxide, Boric acid and quartz

Eco Glass frit Fabrication

25% of primary raw materials replaced by secondary materials

Database of secondary precursors

Conventional

Compounds	Quantity	Unit
Lithium Carbonate	80	kg
Dehydrated Borax	250	kg
Calcium carbonate	100	kg
Zinc Oxide	50	kg
Cobalt Oxide	1	kg
Nickel Oxide	1	kg
Alumina	80	kg
Boric Acid	80	kg
Iron oxyde	40	kg
Quartz	700	kg
Zircon Oxide	10	kg
Carbone	20	kg

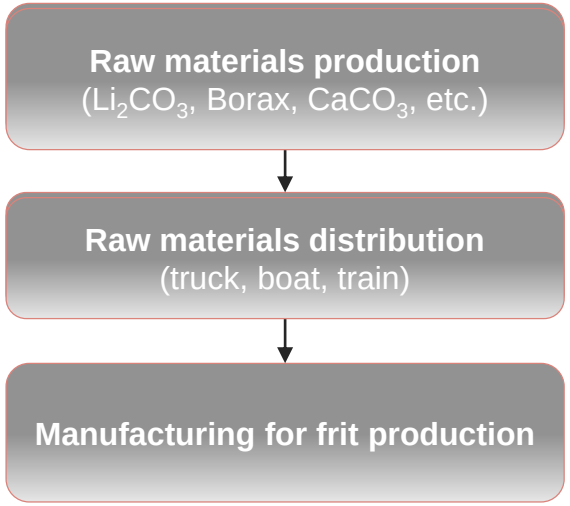
EcoGlassFab

Compounds	Quantity	Unit
Silica fume (Si, O)	150	kg
Borosilicate glass (Si, B, Na, O)	130	kg
Spodumene (Si, Al, Li, O)	100	kg
Black mass (Co, Ni,…)	5	kg
Recycled PV Glass (Si, Na, Ca)	25	kg
Lithium Carbonate	60	kg
Dehydrated Borax	230	kg
Calcium carbonate	100	kg
Zinc Oxide	50	kg
Cobalt Oxide	0	kg
Nickel Oxide	0,5	kg
Alumina	0	kg
Boric Acid	100	kg
Iron oxyde	40	kg
Quartz	400	kg
Zircon Oxide	10	kg
Carbone	15	kg

What is the environnemental impact ?

Comparative LCA modeling : System and fonctions

Conventional glass fabrication



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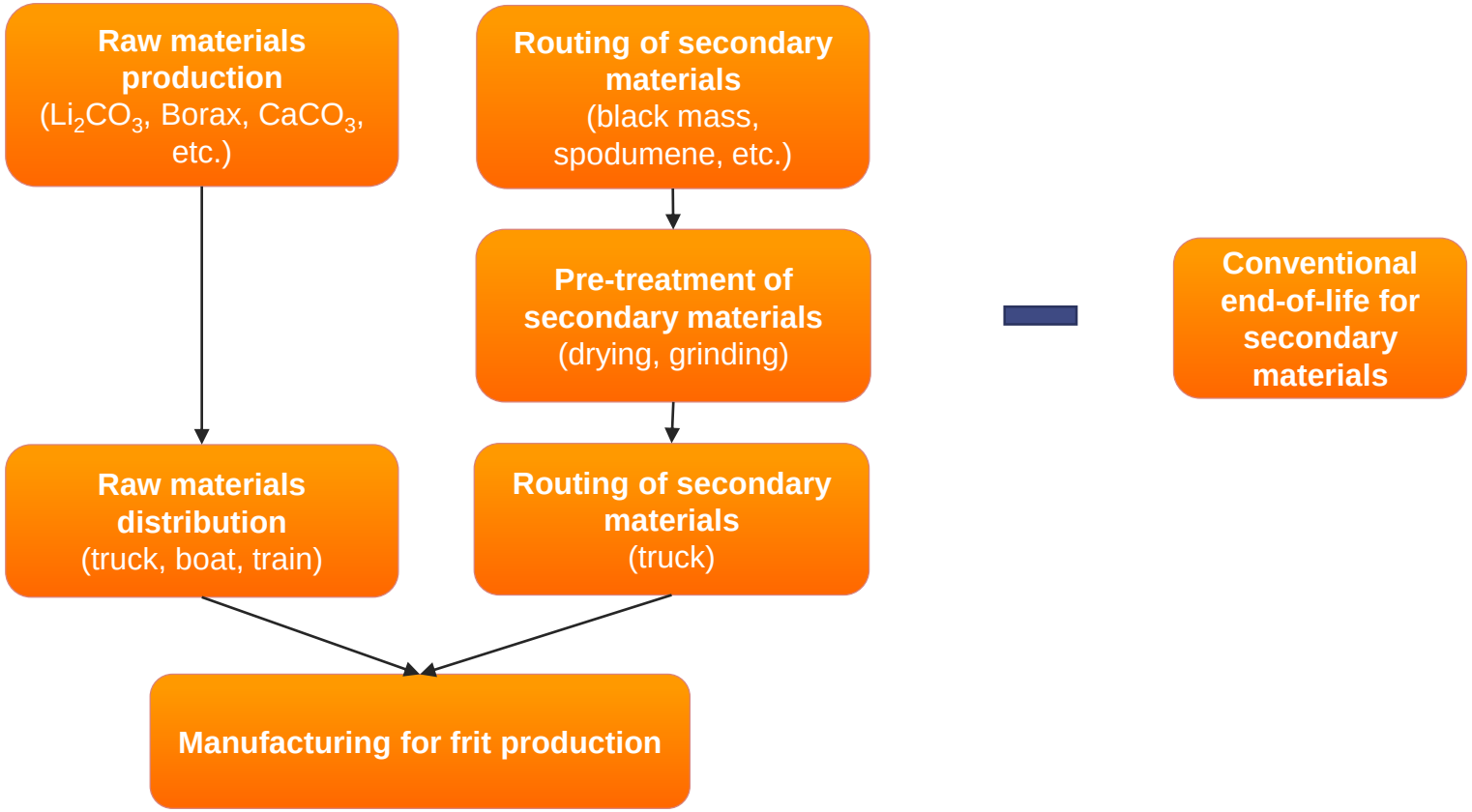
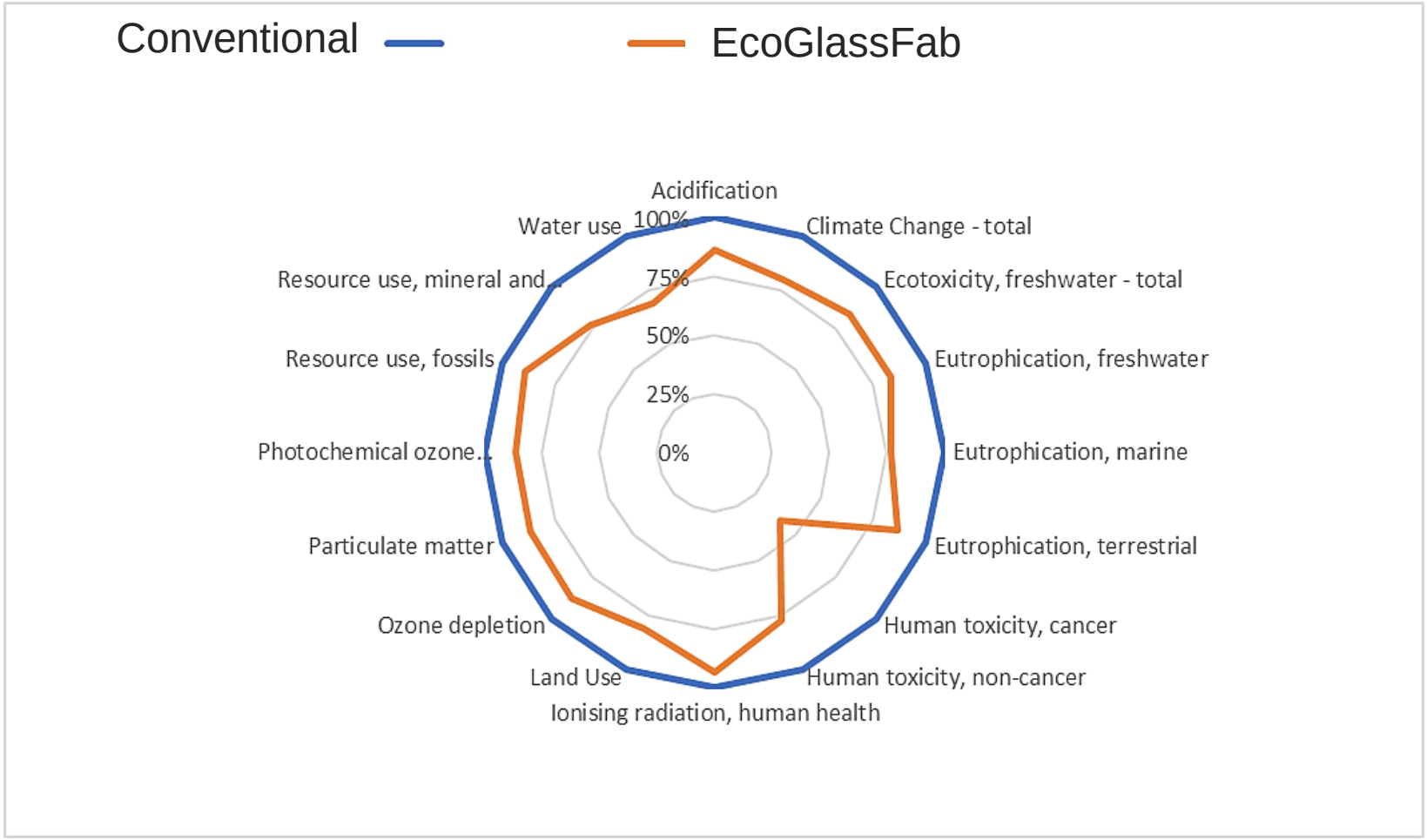


Comparative ACV modeling: Results

Considering a substitution of 25% of primary raw material

- Significant reduction impact in the human toxicity category compared to glass manufactured by conventional means
- Reduction of the environmental impacts by about -15% on all the 16 classes of the life cycle analysis (unique impact score by equivalent person)



Conclusion

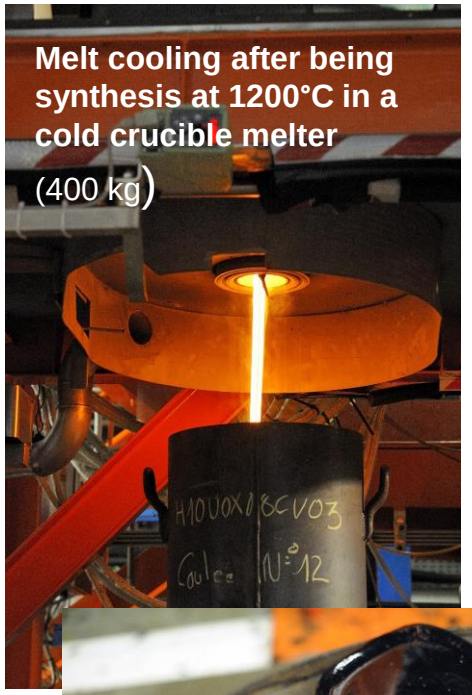
- EcoGlassFab: Methodology under development to accelerate the manufacture of Eco-glass fabrication

- In the long term, it could become a scientific tool and a computer application merging all functionalities and parameters:
  - Database on secondary resources
  - Database on industrial glass specifications
  - LCA
  - Technical-economic analyses
  - Calculation of energy efficiency
  - Chemical reactivity tests

- Develop a regional, national or European association to create a platform for bringing together manufacturers with non valorized resources and glassmakers

R&D on vitrification for nuclear and non nuclear industries

Nuclear glass fabrication in full-scale prototype to qualified the material and the process



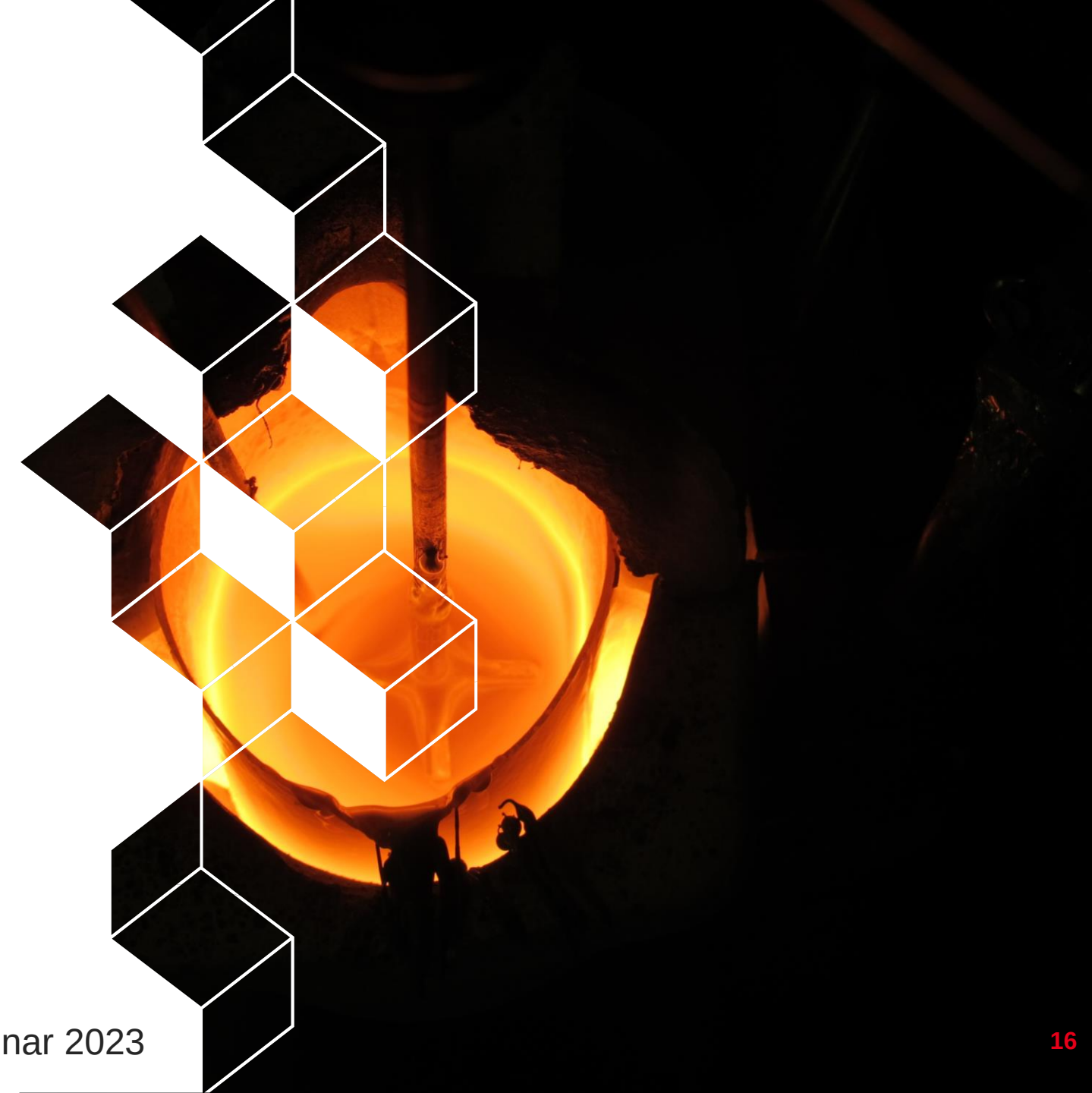
Recycling Cathode Ray Tube glasses

Glass sample after being melting at 1200°C in a cold crucible melter
(200 kg)

Perspectives: Proof of concept EcoGlassFab

At lab scale – (800 g)

In a cold crucible (400 kg)



Thank you for your attention

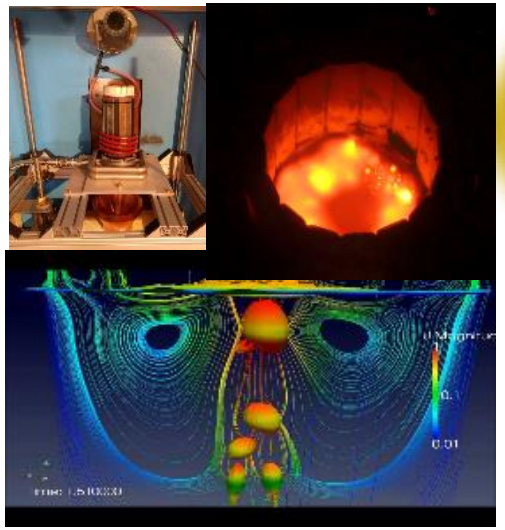
R&D from lab scale to industrial support

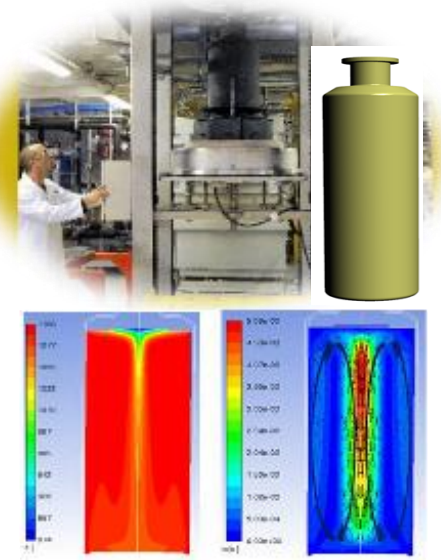
Vitrification and High Temperatures Processes Unit (CEA ISEC - Marcoule)

Lab scale | Mock up and modelling | Full scale prototype | Industrial support

1 2 3 4 5 6 7 8 9

Technology Readiness Level





Optimization of nuclear glasses and industrial vitrification technologies