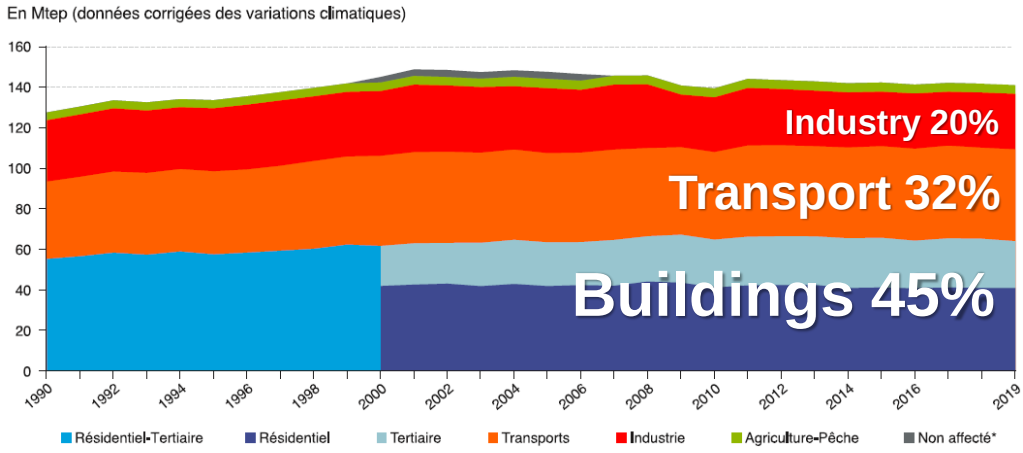
1

REDUCING ENERGY USES IN BUILDINGS AS A PRIMARY TARGET

Overall energy consumption in France



Source: Bilan énergétique de la France pour 2019 – jan. 2021 – Statistique Publique

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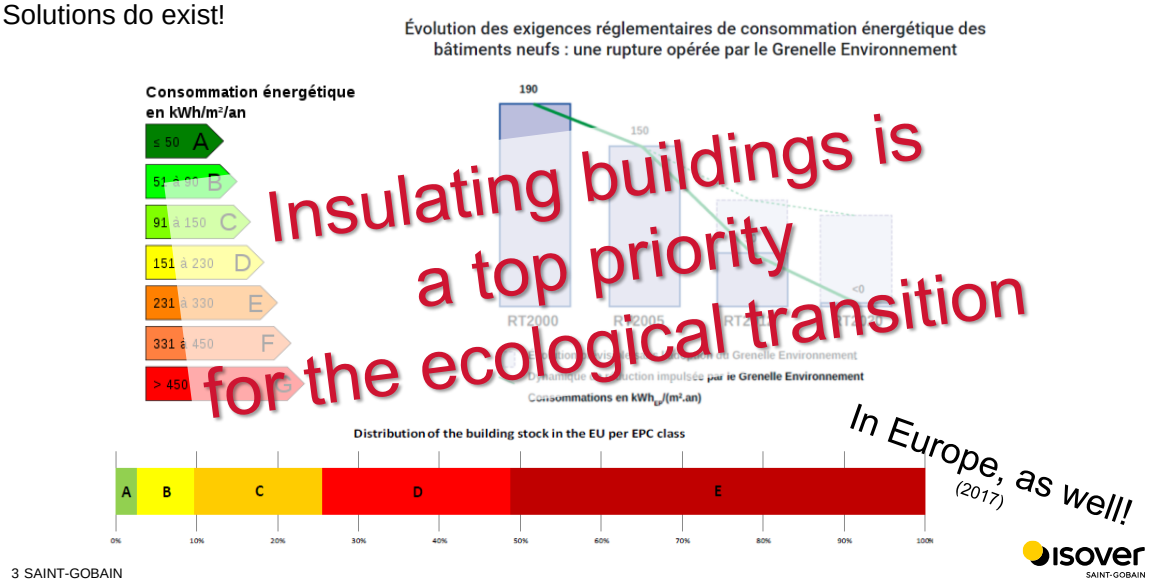
2

REDUCING ENERGY USES IN BUILDINGS AS A PRIMARY TARGET

Solutions do exist!



3

MAKING THE WORLD A BETTER HOME

SAINT-GOBAIN

4

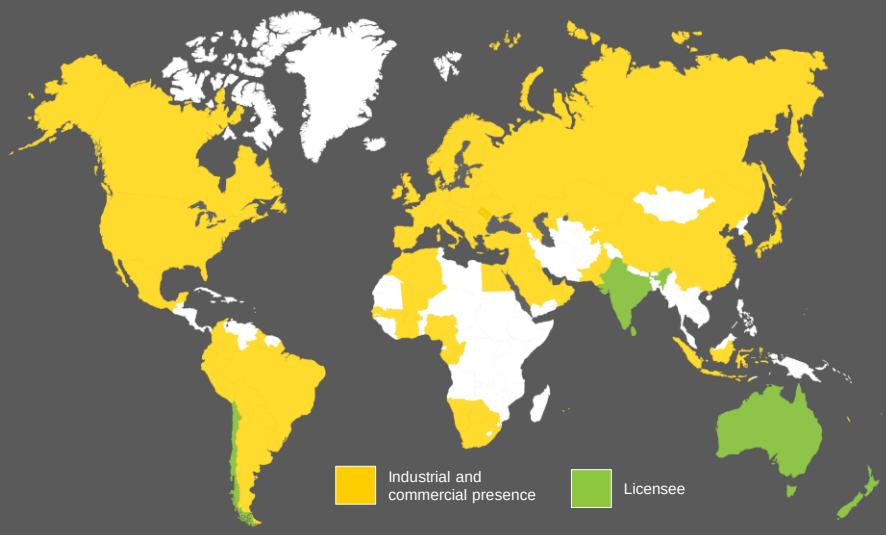
5

ISOVER manufactures and supplies high performing **insulation solutions** to address a variety of markets in buildings, transportation and industrial applications.

ISOVER provides **wellbeing, energy performance and fire safety** while helping to protect the environment.

6

A STRONG LOCAL FOOTPRINT WITH AN INTERNATIONAL NETWORK



107
countries
(excluding licensees)

More than 10 000
employees

63
industrial sites
(excluding licensees)

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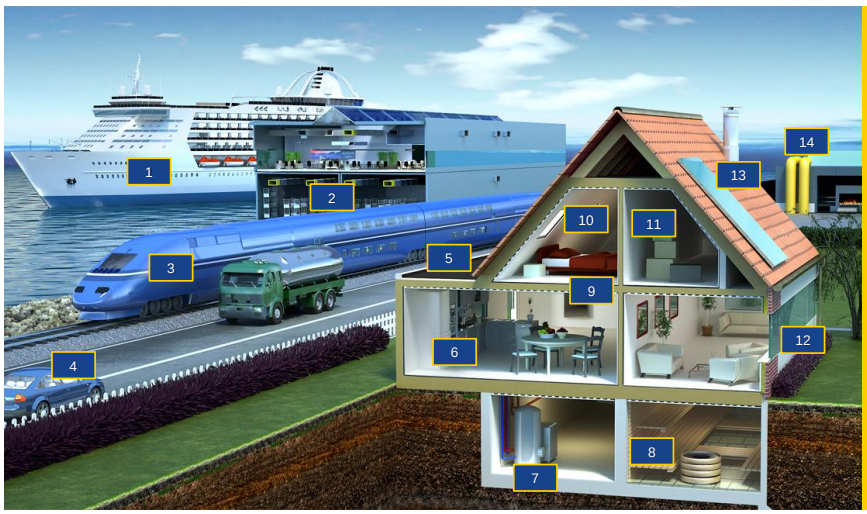
7

A MULTI-APPLICATIONS OFFER



1. Marine and offshore
2. HVAC - Heating, Ventilation & Air Conditioning
3. Trains
4. Automotive
5. Flat roofs insulation and waterproofing
6. Appliances (cooking ovens, washing machines…)
7. Basements
8. Saunas
9. Floors and ceilings
10. Sarking, pitched roofs
11. Internal insulation, partition walls
12. ETICS (External Thermal Insulation Composite Systems), ventilated facade, cavity walls
13. Thermal solar collectors
14. Industry

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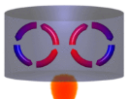
8

HOW TO DESIGN AN INSULATING MATERIAL?

Basics of heat transfer

Conduction

Convection



Radiation

Total heat flux

=

Conductive flux λ_{cond}

+

Convective flux λ_{conv}

+

Radiative flux λ_{rad}

$$\varphi = -\lambda \nabla T$$

Minimize

$$\lambda = \lambda_{cond} + \lambda_{conv} + \lambda_{rad}$$

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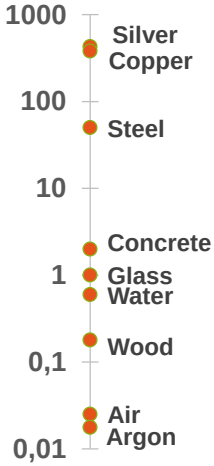
9

9

HOW TO DESIGN AN INSULATING MATERIAL?

…with common materials

λ [W.m^{-1}.K^{-1}] at 10°C



- Create **tiny pockets** of **motion-less air** in a **sparse structure** of **low heat-conducting solid**.

10

10

A MULTI-MATERIAL OFFER

CORE OFFER

GLASS MINERAL WOOL

Rolls, panels, pipe sections, blowing wool…

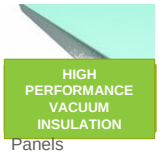
STONE MINERAL WOOL

Panels, rolls, wired mats, pipe sections

COMPLEMENTARY OFFER

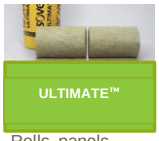
ELASTOMERIC FOAMS

Pipe sections, sheets



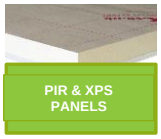
HIGH PERFORMANCE VACUUM INSULATION

Panels

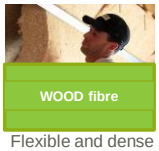


ULTIMATE™

Rolls, panels, wired mat, pipe sections

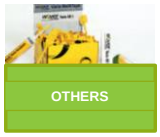


PIR & XPS PANELS



WOOD fibre

Flexible and dense panels



OTHERS

Accessories, vapor and wind barriers

11

ULTIMATE™: Unique insulation solution lighter than standard stone wool with similar fire performance

11

IN A NUTSHELL, GLASS WOOL IS MADE OF…

98% air in volume

95% glass fibres in mass

5% binder

others as traces

12

12

THE BINDER

Organic material that gives glasswool its mechanical properties

13

13

INSULATION GLASSES AMONG INDUSTRIAL GLASSES

Certificate for biosolubility

Main Oxides	Flat glass	Container glass	Glass wool	Stone wool	E Glass
SiO_2	72	70	65	43	55
Na_2O+K_2O	14.5	14	16.5		
CaO	10	10	7	39	21
MgO	4	2	3	4	1
B_2O_3			4.5		7
Al_2O_3	0.5	2	3	12	15
Others	Fe_2O_3	Fe_2O_3 Cr_2O_3, MnO…			

14

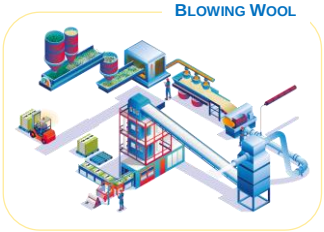
14

PROCESSES IN INSULATION

GLASS WOOL

STONE WOOL

BLOWING WOOL

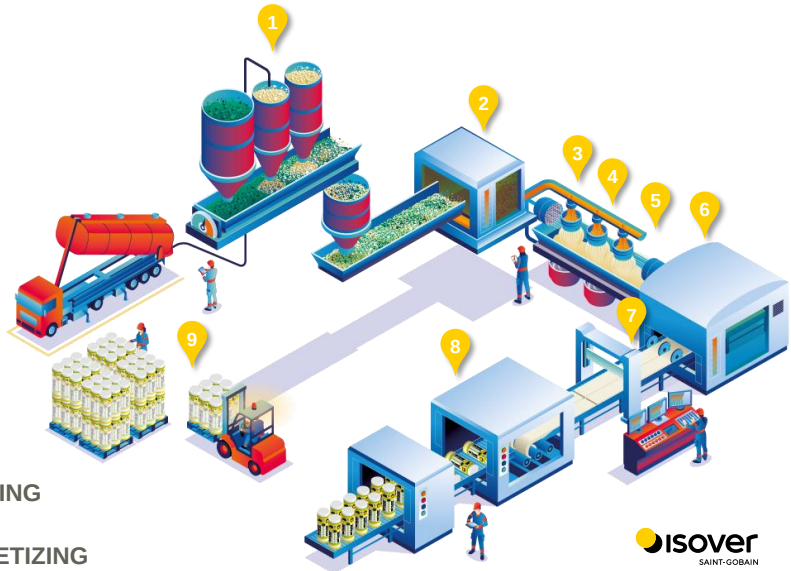


15

15

GLASS WOOL PRODUCTION PROCESS

1. BATCH
2. MELTING
3. FIBERIZING
4. BINDER SPRAYING
5. MAT CREATION
6. CURING
7. CUTTING
8. PACKAGING
9. PALLETIZING



16

16

Candy floss at 1000°C, 2000 rpm, 30 tpd !

17

17

SCIENTIFIC CHALLENGES RELATED TO GLASS WOOL

A glass-savvy selection

- Glass wool is a remarkable material **but / because it's a glass…**
  - Energy intensive
  - Brittle
  - Low reactivity at room temperature, highly corrosive at melting temperature
  - Infinitely recyclable
- Science is necessary to enhance applications
  - Improve performance in use: **thermal in the infrared**
  - Improve comfort during installation: **reduce dust**
  - Improve sustainability: **predict biosolubility, facilitate recyclability, increase spinner lifetime**

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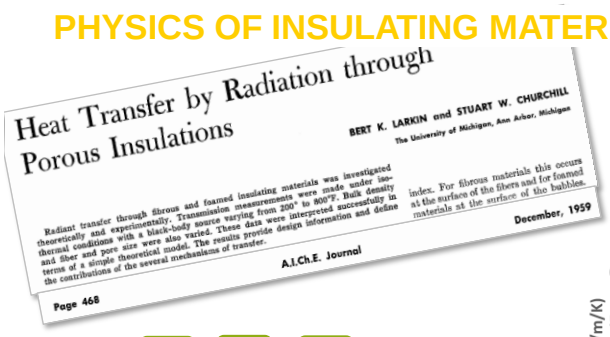
18

PHYSICS OF INSULATING MATERIALS



Heat Transfer by Radiation through Porous Insulations

BERT K. LARKIN and STUART W. CHURCHILL
The University of Michigan, Ann Arbor, Michigan

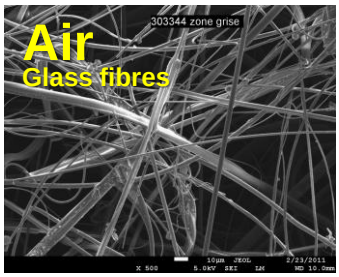
Radiant transfer through fibrous and foamed insulating materials was investigated theoretically and experimentally. Transmission measurements were made under isothermal conditions with a black-body source varying from 200° to 800°F. Bulk density and fiber and pore size were also varied. These data were interpreted successfully in terms of a simple theoretical model. The results provide design information and define the contributions of the several mechanisms of transfer.

index. For fibrous materials this occurs at the surface of the fibers and for foamed materials at the surface of the bubbles.

A.I.Ch.E. Journal

December, 1959

Page 468

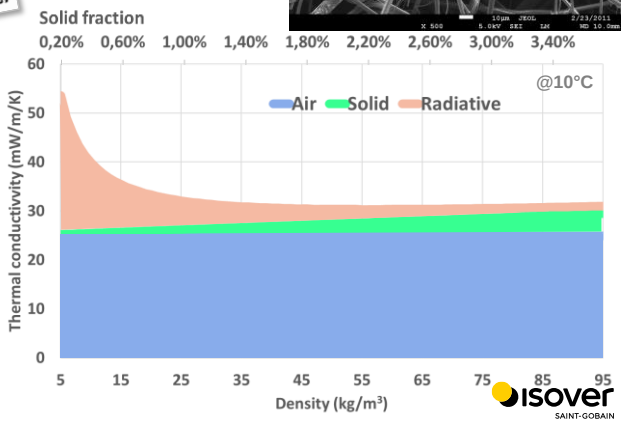


$$\lambda_{eff} = \lambda_a + \lambda_s + \lambda_r$$

$\lambda_a(T) \propto T^{\alpha \approx 1}$
conduction in air

$\lambda_s(\rho) \propto \rho(T)$
conduction in solid

$\lambda_r(\rho, T, e, \dots) = \frac{4\sigma T^3 e}{\frac{2}{\varepsilon} - 1 + N(\rho, \dots)e}$
radiation



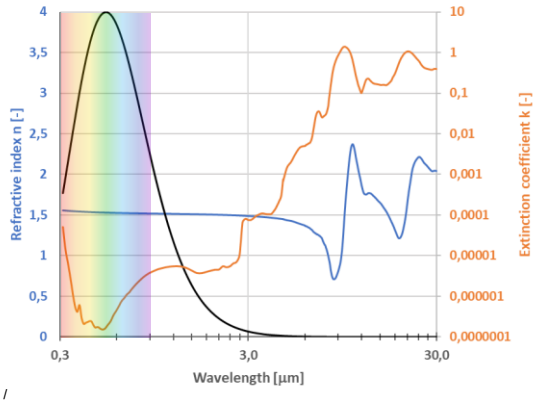
SCIENTIFIC CHALLENGES TO IMPROVE PERFORMANCE

Optics in the infrared

- Glass purely refractive in the visible

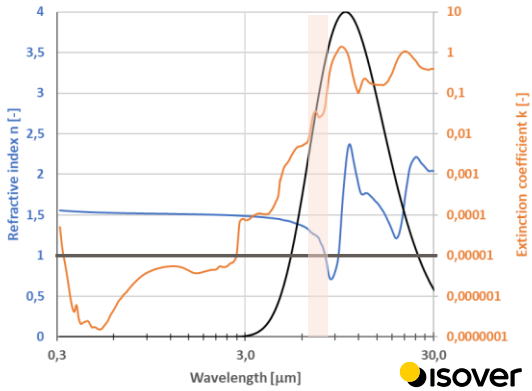
  Wien's displacement law: $\lambda_{max}\ T = 2\,898\ \mu m\ K$

T = 5250° C ➔ λ_{max} = 0.525 μm



- The unlucky Christiansen window

T = 10° C ➔ λ_{max} = 10.2 μm



SCIENTIFIC CHALLENGES TO IMPROVE PERFORMANCE

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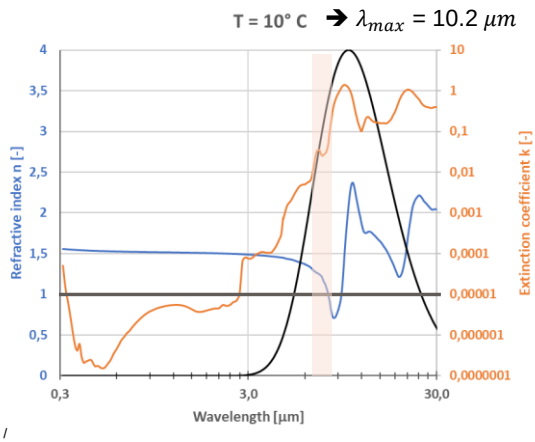

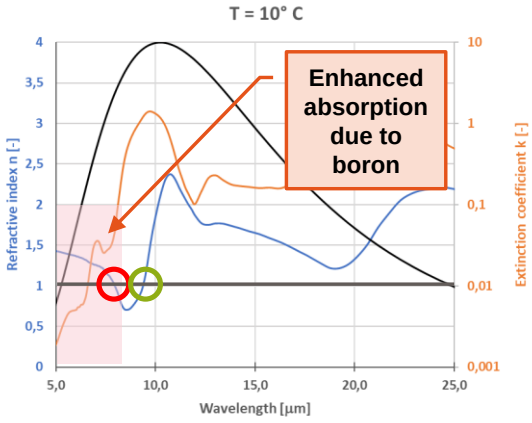

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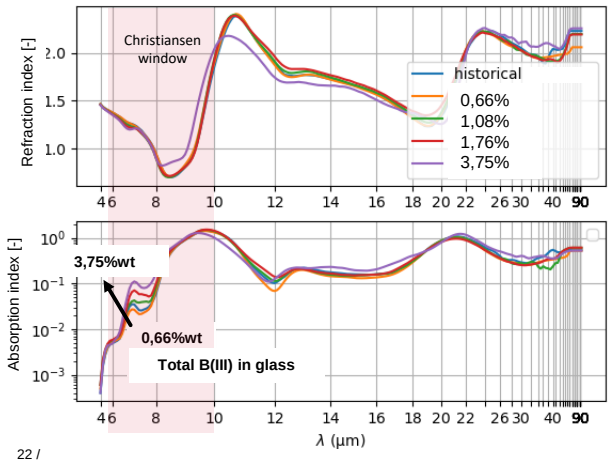
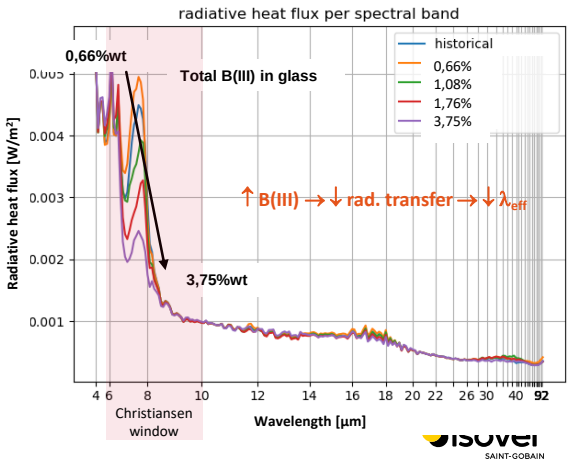
21

THE ROLE OF B(III) IN GLASS WOOL CONDUCTIVITY

- Only absorption in Christiansen window matters, and only B(III) only
  ➔Why? How to improve? Substitute?





22 /

22

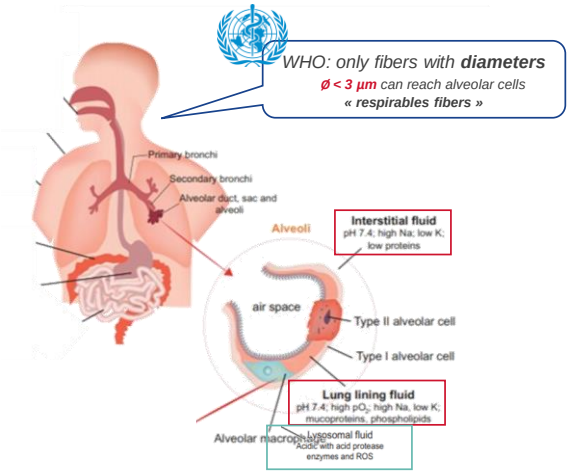
SCIENTIFIC CHALLENGES TO IMPROVE COMFORT

The mechanics of glass wool: how to avoid brittleness and control the creation of dust

- Intense compression
  → some fibres fracture
- What is the mechanics behind?
  - How many do fracture?
  - How to avoid/reduce?
    - Lubrication? Glass surface?
    - Process?
    - Glass composition?

SCIENTIFIC CHALLENGES TO PREDICT BIOSOLUBILITY

A short reminder on biosolubility



Only thinner fibers can reach deep lung alveolar cells

- **Dissolution :** glass hydrolysis by water
- **Biosolubility :** dissolution modified by proteins, complexing agents
- **Two types of mechanisms:**
  - **Dissolution** inside pulmonary fluids pH 7,4
    → glasswools fibers
  - **Phagocytose** of fibers with alveolary macrophages pH 4,5
    → stonewools and Ultimate fibers

THE CLP REGULATION

A legal framework for commercialising fibres in EU

- European **C**lassification, **L**abelling and **P**ackaging of chemical substances and mixtures
- For mineral fibres
  - Cat.1A : known to have carcinogenic potential for humans (asbestos)
  - Cat. 1B : presumed to have carcinogenic potential for humans (refractory ceramic fibers)
  - **Cat. 2 : suspected to have carcinogenic potential for humans: glasswool & stonewool**

Exemption of Cat. 2 if validated by certified in-vivo test
Compulsory for all fibres produced in Europe since 1997

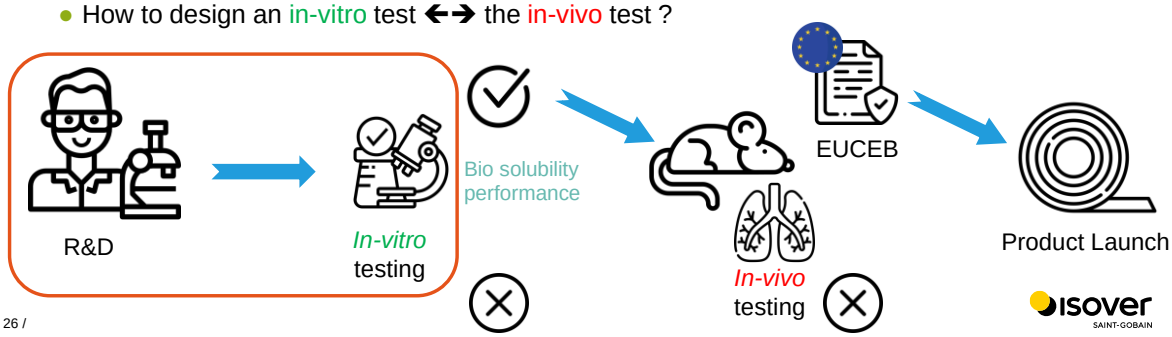
All fibres sold in EU since 1997 have been validated
… a "tour de force" in formulation

EUCEB

TESTING BIOSOLUBILITY: IS IT POSSIBLE TO DO BETTER?

An alternative to killing rats?

- For 3 months, rats breath fibres, sacrified, lungs analyzed..
  - Measure #fibres, determine $T_{1/2}$; test passed if $T_{1/2} \leq 40$ days
- How to formulate a glass which fibres would pass the in-vivo test?
  - How to design an in-vitro test ←→ the in-vivo test ?



SCIENTIFIC CHALLENGES TO IMPROVE SUSTAINABILITY

Recycling glass wool is necessary

- Scarcity will arise
  - In 2017, 76% of bottle glass in EU recycled to make bottles.
    2030 target: ~ 90%
  - Today ~10% ext. cullet in flat glass.
    2030 target: ~25%
- Adapt glass recipe (CaO)
- Recycle glass wool

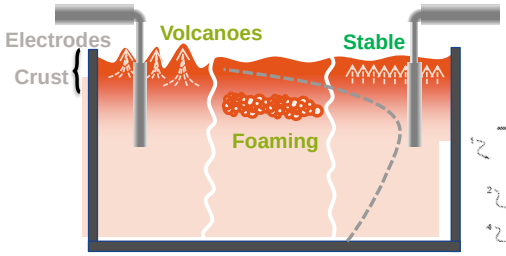
WHAT DO DECONSTRUCTION WASTES LOOK LIKE?

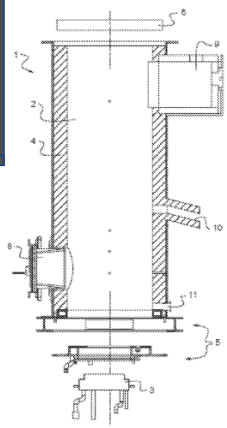
Not exactly a glass maker raw material

- Pollutants galore!
  - **Ceramics / Stones / Porcelain**
    ➔ Measure amount?
    ➔ Predict digestion?
  - **Iron & other heavy metals**
    // Poorly melt
    ➔ Extract ? Melt ?
  - **Aluminium**
    // + SiO_2 ➔ Al_2O_3 + Si (m)
    ➔ oxidisers?
  - **Sulfate**
  - **Organic materials – C**
    ➔ efficient & effective oxidation ?

SCIENTIFIC CHALLENGES TO IMPROVE SUSTAINABILITY

Fundamental limitations in the recycling of glass wool





- Which efficient melting furnace
- Electric furnace?
  - Foaming…
  - Electrode wear…
  - Residence time…
- Submerged Burner Melter?
  - Decarbonize…
  - Control redox…

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SCIENTIFIC CHALLENGES AT FIBERIZING

…it is eventually a material problem

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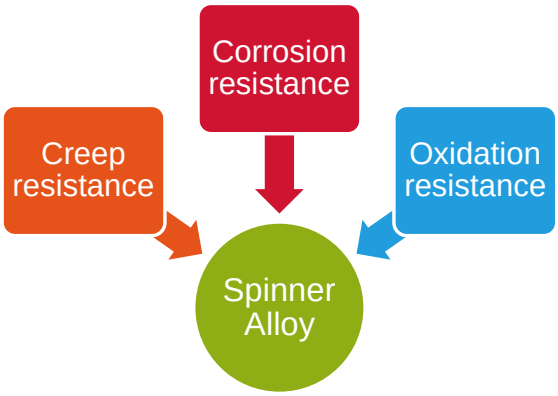
WHICH METALLURGY TESTS TO PROBE SUPER ALLOYS…

…in contact with molten glass?



*in **rotation** with **liquid glass** at **1000°C – 1200°C***

- In the lab
  ∄ correlation corrosion – creep
- In the plant
  ∃ correlation corrosion – creep

  ➔ very difficult to develop new alloys
- On going work
  - Mechanism at play between glass / alloy / alloy structure
  - Design new test / bench test

GLASSWOOL IS NOT THAT SIMPLE

Many open technical questions linked to real scientific problems

- Improve **performance**
  - How to enhance and achieve **absorption in the infrared?**
  - How to control **brittleness**?
- Anticipate **reactivity**
  - How to test and predict **biosolubility…**
  - …while **maintaining hydrolytic** resistance for decades?
- Develop **sustainability**
  - How to facilitate **recyclability?**
  - Design materials that sustain contact with **molten glass**

Thanks to
G Barba Rossa
A Rony
M Jacquet
Q Hérault
V Grigorova-Moutiers
S Gandon
…