Buildings Thermal management
Materials Efficiency, Electrification, Decarbonation

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With contributions from JM.Combes, E.Gouillart, E.Normant
Prelude: The Big Picture
The “Big Picture” (1)

- **Energy sources**
  - Solar
  - Wind
  - Mechanical
  - Hydro
  - Coal
  - Gaz
  - Nuclear

- **Energy vectors**
  - Electricity
  - Hydrogen
  - Heat

- **Energy usage**
  - Industry
  - **Housing**
  - Transport
The “Big Picture” (2)

• In order to produce, transport, and use energy we have to “make stuff”
  • Energy production
  • Cables, pipes
  • Storage devices
  • Manufactured goods
  • Building and insulation materials

• In order to “make stuff,” you need:
  • space,
  • energy
  • raw materials

• In order to “make stuff,” in a sustainable way
  • Sustainability of resources
  • Impact on the environment
  • Contribution to global warming
Decarbonize the heat source

Monitor the heat source

Minimize the heat losses

Minimize the carbon footprint of the « hole fillers »
Decarbonize the heat source

Electrification of heating, decarbonization of electricity production

Monitor the heat source

Digitalisation of energy use

Thermally efficient buildings/ Renovation

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CO2 efficient processes
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CO2 efficient processes

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Thermally efficient buildings/ Renovation

- In France, Building represents 44% of energy. One can decrease by 80% energy loss in buildings by a proper heat management (thermal insulation and windows).

- If one decreases by 10% the energy consumption, it is equivalent to 7 Nuclear powerplants...it can be done in 10 years, with existing technologies and materials which are locally produced and implemented.

- The production of glass, plasterboard, insulation materials, can be at least partially electrified and decarbonized in the coming years.
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OUTLINE

• Minimizing Heat losses
• Decarbonizing Processes
• Developing process electrification
• Conclusions
Minimize Heat losses
Thermal insulation for energy savings

Source: FILMM
Quantitative diagnosis of building performance

Faster / better in situ diagnosis? Also for acoustics, humidity

https://doi.org/10.1016/j.enbuild.2020.110540
Principle of thermal insulation: air (or gas) trapping

\[ \lambda \approx 30-35 \text{ mW.m}^{-1}.\text{K}^{-1} \]

\[ \lambda \left[ \text{mW.m}^{-1}.\text{K}^{-1} \right] \text{ at } 10^\circ\text{C} \]

<table>
<thead>
<tr>
<th>Material</th>
<th>[ \lambda ] [mW.m⁻¹.K⁻¹]</th>
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<tbody>
<tr>
<td>Silver</td>
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<td>220 000</td>
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<td>50 000</td>
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<td>2 100</td>
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<td>Krypton</td>
<td>9</td>
</tr>
<tr>
<td>Xenon</td>
<td>5</td>
</tr>
</tbody>
</table>
Super insulating materials at affordable cost?

Coll. N. Denkov

Cheng et al., ACS Nano 2011
https://doi.org/10.1021/nn204072n
How to describe multiscale materials?

Thermal transfers, acoustics, mechanics
Link with microstructure and process

Kallel et al. 2019
https://doi.org/10.1016/j.jqsrt.2019.106598

Corpart et al. EPL 2022

Meftah et al. Mat. Char. 2019
Sauret et al. EPJE 2015
THIN FILMS FOR THERMAL INSULATION

Radiative exchanged through glazing
Decarbonizing products
High-temperature processes

- 0.9 kg CO2 / kg cement
- 1.8 kg CO2 / kg steel
- 0.6 kg CO2 / kg glass

SAINT-GOBAIN
GLASS
FLOAT GLASS
Can we replace carbonates?

Can we heat in a decarbonated manner?

Can we use recycled glass?

Chemical Reaction: corrosion of the sand grains / melted carbonates

70% Sand + Carbonates → Silicate + CO2

1700°C → 800-900°C
Decarbonated heating

BIO-GAZ
Availability and cost

HYDROGENE
Availability and cost
Technical issues with combustion flame and cladding materials

ELECTRIFICATION
Technical issues and glass quality
Minimizing waste heat

Air
1250-1300°C

Q Loss

Q Fuel

Q Exhaust

Glass Melting Tank

Fume losses
600°C

Air
50 °C

Fumes
1500°C
Alternative raw materials


Thermodynamics, Atomistic simulations, Materials informatics, Characterization
Float glass furnaces: from gas to electricity

10.2320/matertrans.M2019044
10.1111/ijag.12286

Multiphysics: combustion, fluid mechanics, chemical reactions, ...
Multiscale: bubble size to furnace size

How to accelerate simulations?
How to make accurate predictions from approximate models?
Electrification of processes
EVOLUTION VERS DES FOURS BAS-CARBONE

Fours électriques
Nécessité d'une électricité verte
Emission résiduelle par la composition : hausse du calcin

Points majeurs
• À terme, 100% des fours à électrodes plongeantes (EHS)
• Durée de vie très sensible à la tirée spécifique et au % calcin

CO₂ emission factors of electricity per country (t CO₂ / MWh)

2015 IEA (2017 edition)

Fours électriques
- Fours flexibles (Intech/ZiTech)

Objectif standardisation 8 ans mini
CAVEAT!!!

• Glass furnaces are Continuous processes h24
• Power breakdown is a major threat
  => Above a few hours, heating via a safety burner is no longer efficient
• Emergency provision lines will be a problem: availability? Dimensioning?
• Electrification may makes sense if
  • Electricity is decarbonated
  • Electricity provision is stable
Conclusions
Thermal management of buildings is a major contributor to economy decarbonation.

No matter the way one produces energy, or the cleverness with which it is used, a prerequisite is NOT TO WASTE IT.

Building thermal management efficiency is possible with technologies already available, and always progressing, which can be produced by national industry. Contribution to Reindustrialisation.

The emphasis should be on renovation.

Production of glass, plaster, insulation materials, can be at least partially electrified and decarbonized in the coming years.

DECARBONISED AND STABLE ELECTRICITY IS A PREREQUISITE FOR INDUSTRIAL ELECTRIFICATION.