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Electric Melters: Principle, design, and limitations

ICG Spring School – Glass for a sustainable future

A.J. Santosh, 30th April 2024

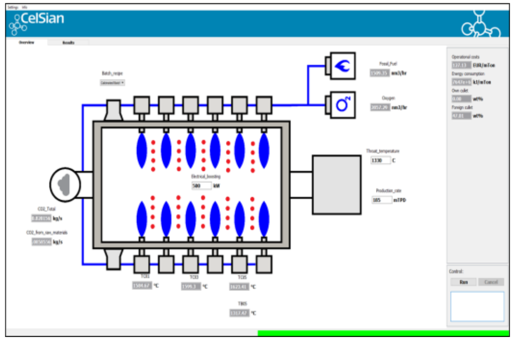
We are CelSian

- Engineering consultancy based in the Netherlands and the USA
- Fast, experienced and highly educated
- Dedicated to glass and supporting the glass industry

Four main services:

On-Site support

Process Optimization

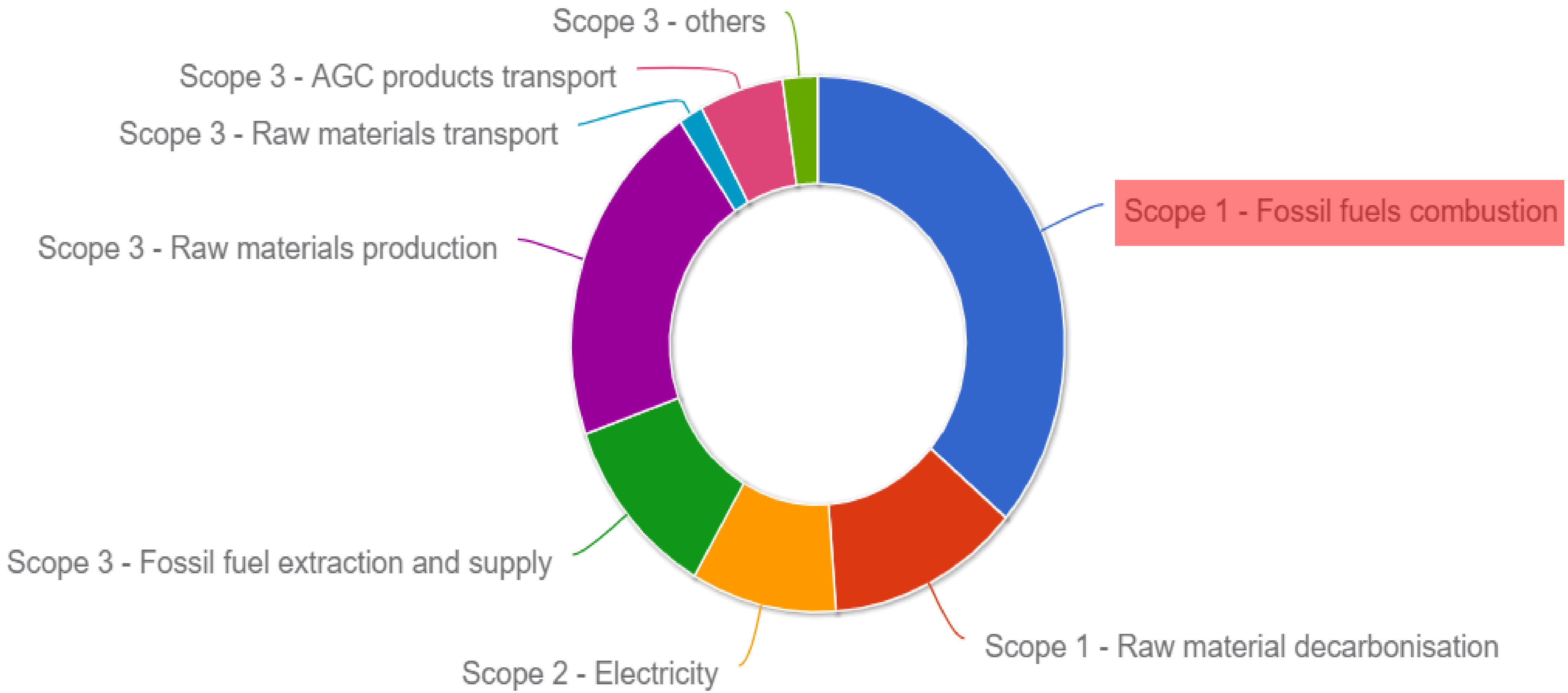


R&D and Lab support

Training academy

Why?

Carbon footprint breakdown



https://www.agc-glass.eu/en/sustainability/environmental-footprint/carbon-footprint

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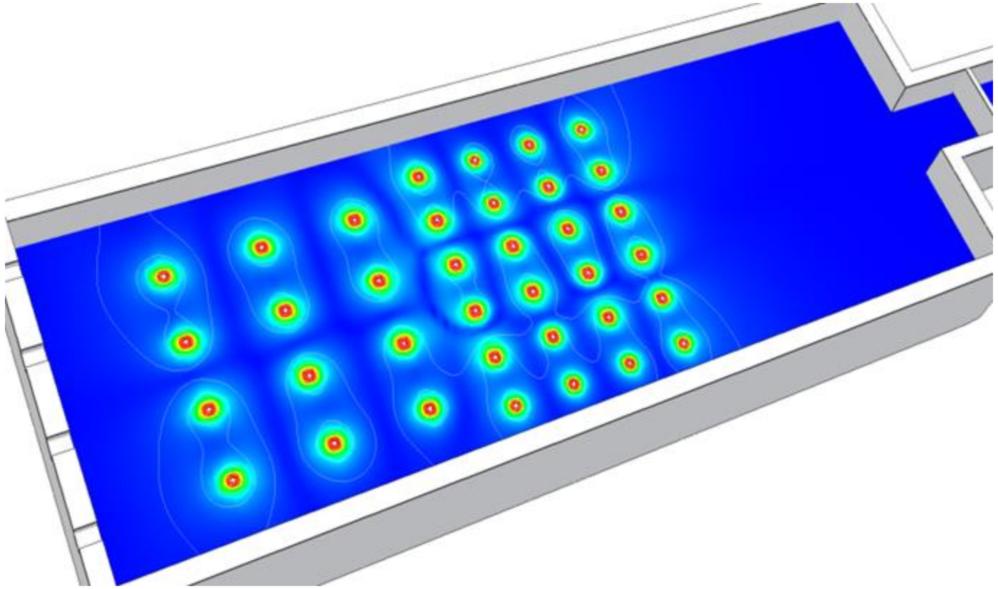
Transition to Electric furnaces

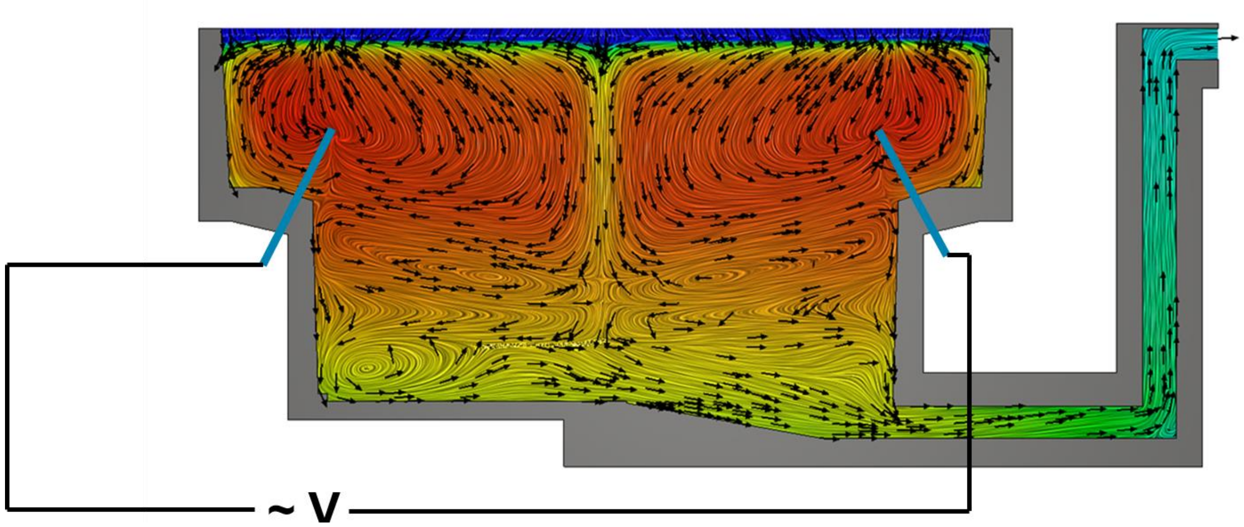
Hybrid Furnaces

60% energy supplied via boosting



Full electric (Cold Top)

100% energy supplied via boosting

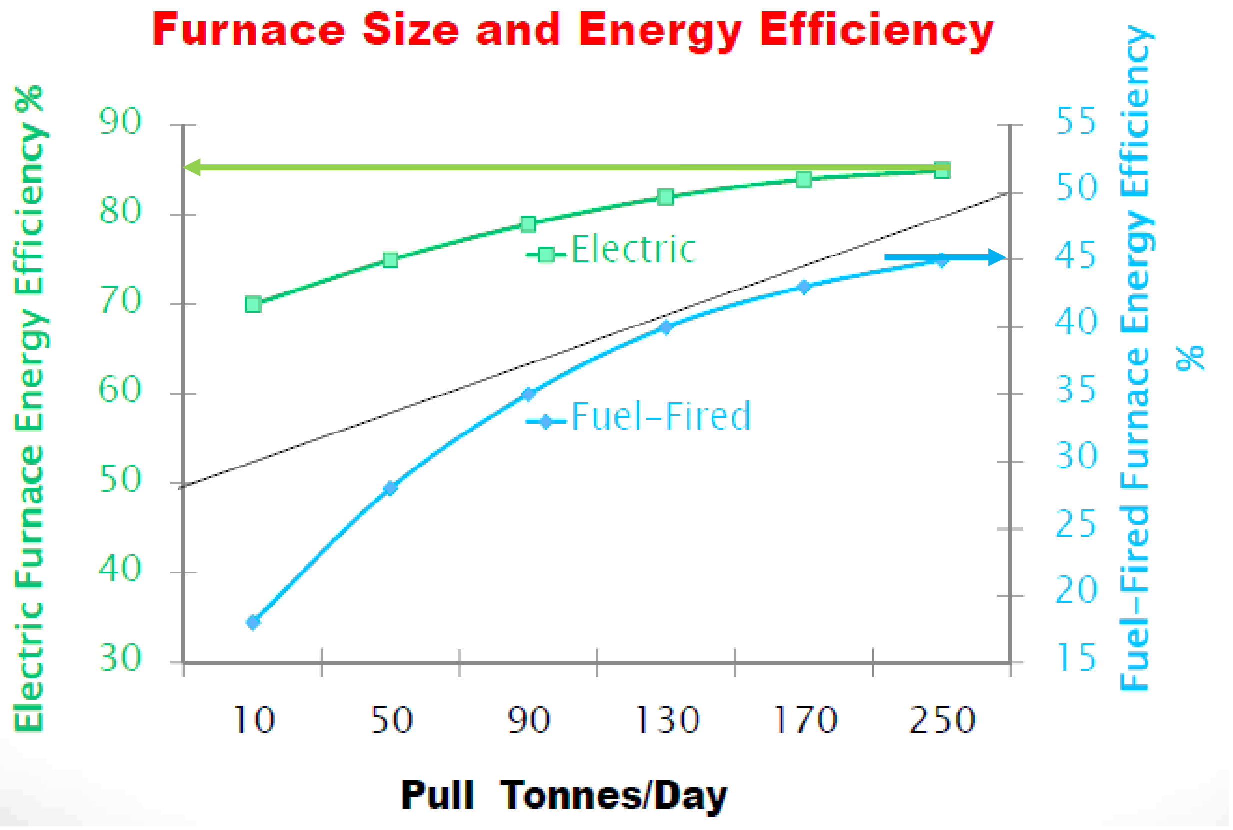


Energy efficiency of Fuel-fired against Electrical Heating

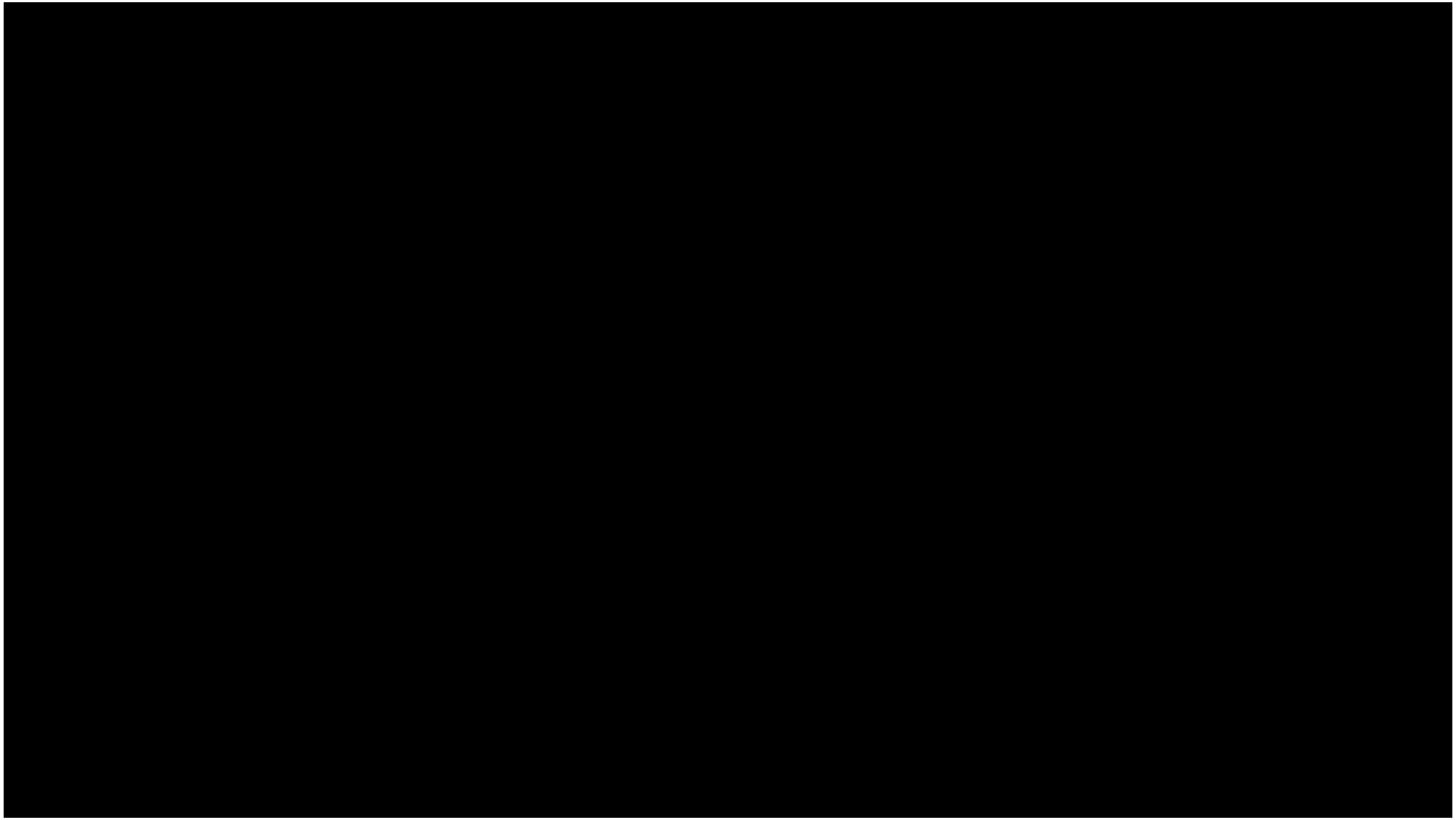
- Fossil fuel fired furnaces efficiency ≈ 45%
- Electric Furnace up to 85% of efficiency

State-of-the-art electric melters operate at 2.88GJ/ton of molten glass.

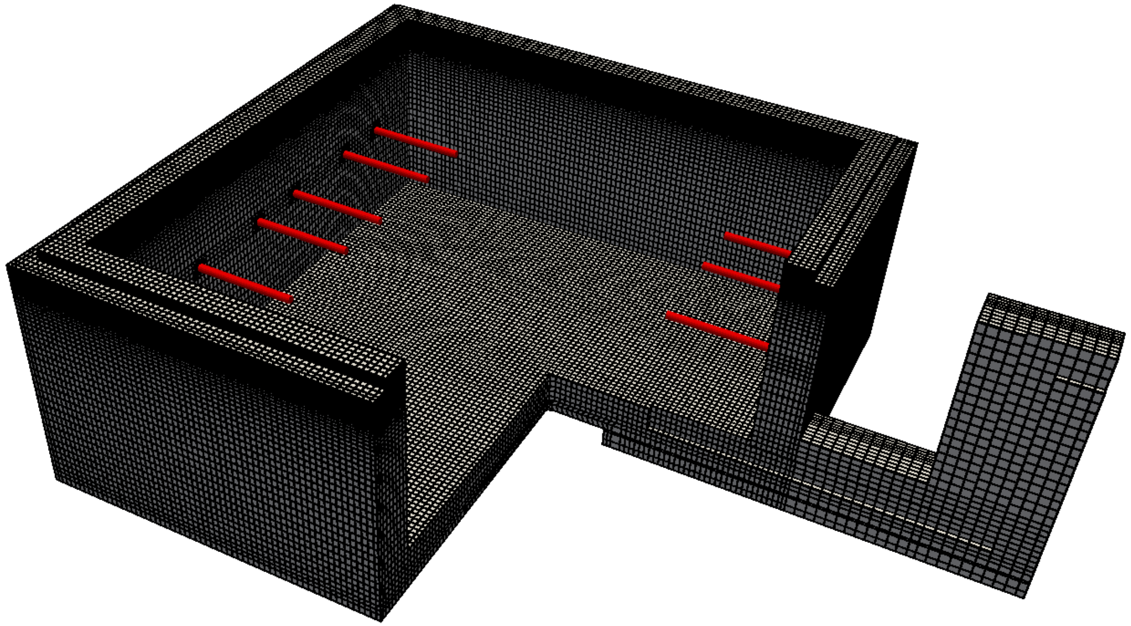
https://www.osti.gov/servlets/purl/927883

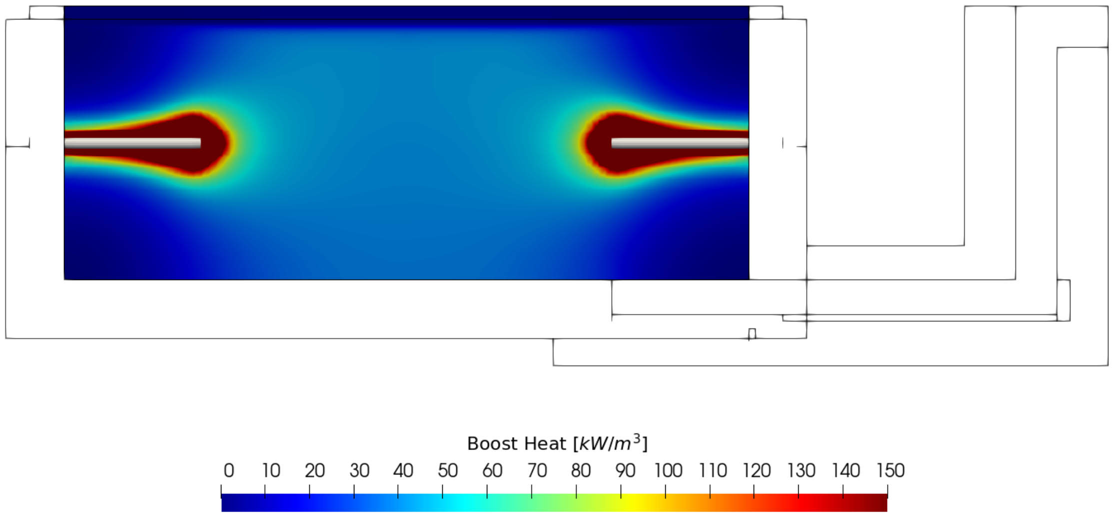


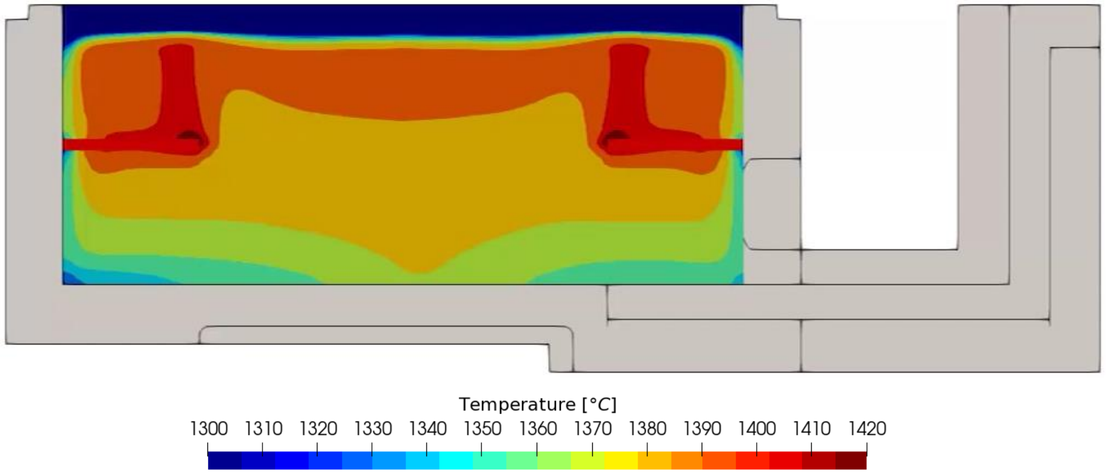
Principle of Electric Melters



Electrodes and modeling of the Joule effect







- Electric melters, make use of electric heating elements

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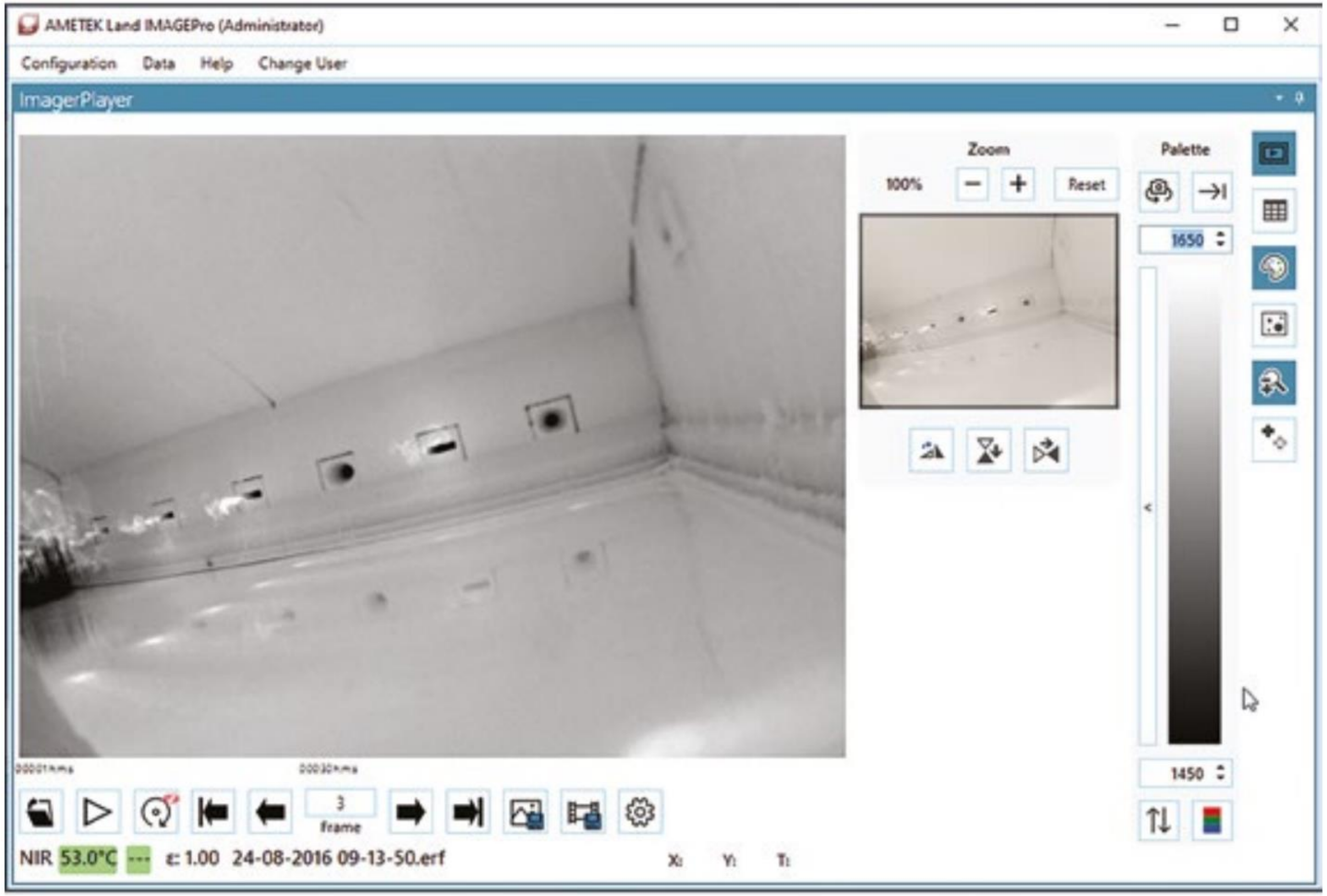
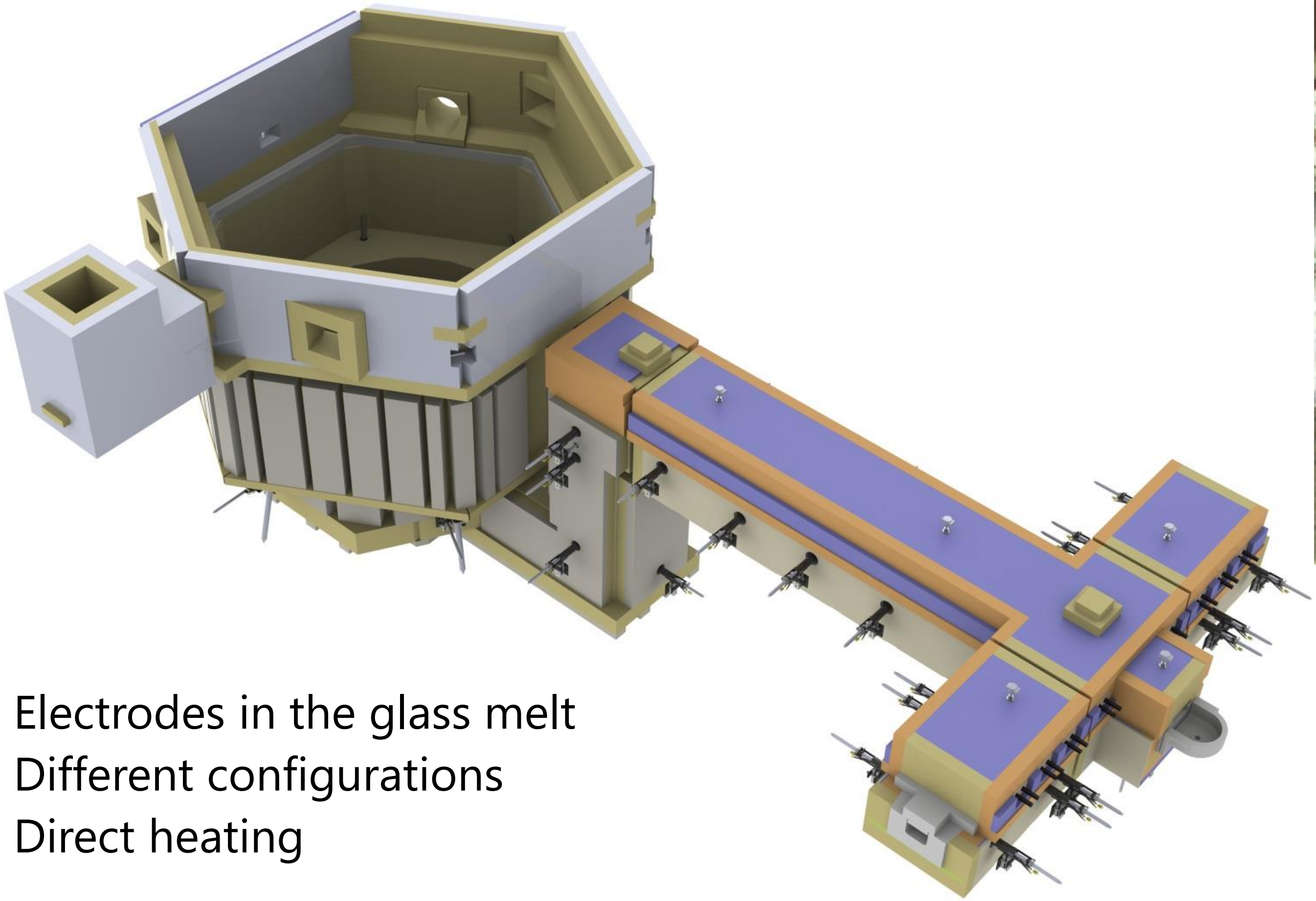
Observation of the Joule Effect

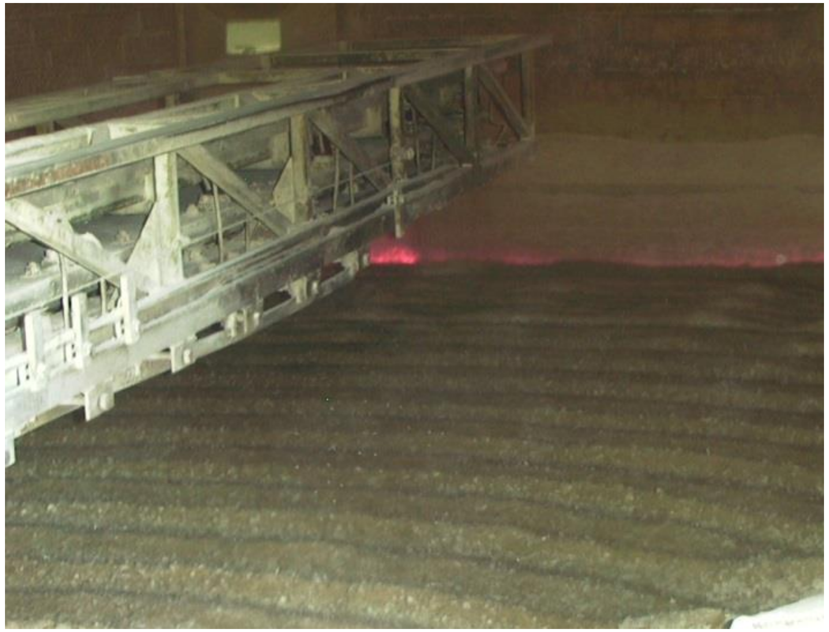


Survey mode with transportable NIR-B via an existing peephole.

Cold-top furnace

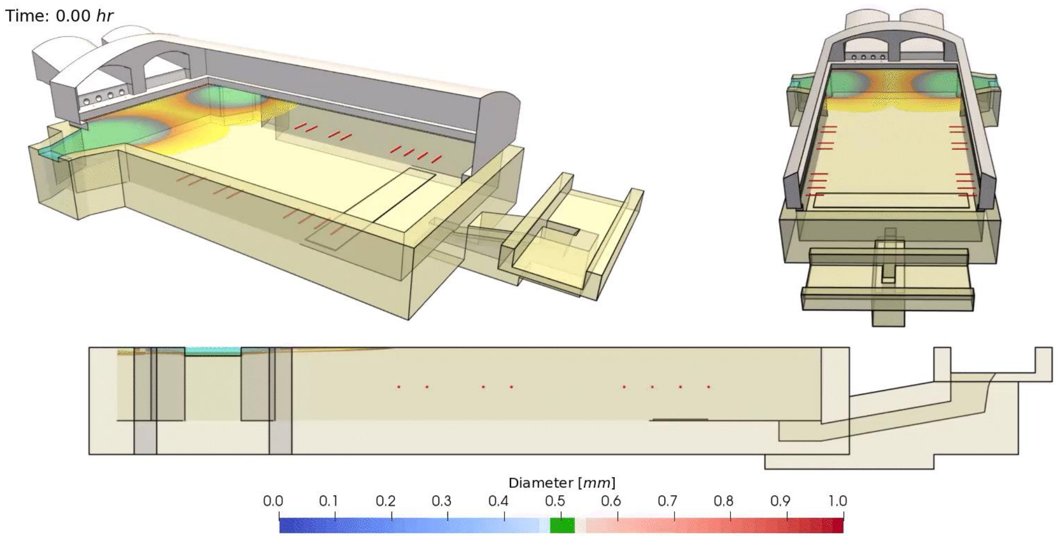


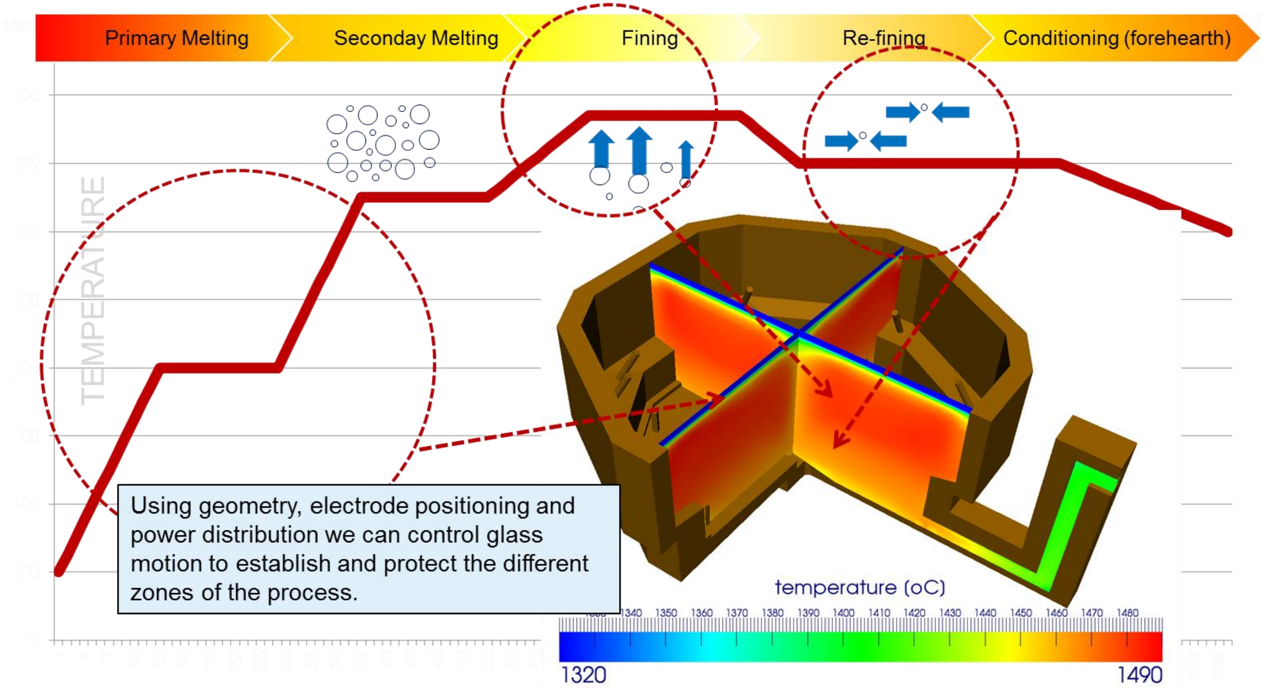
Electrodes in the glass melt
Different configurations
Direct heating



Batch charging from top
Insulating cold top
No hot flue gas

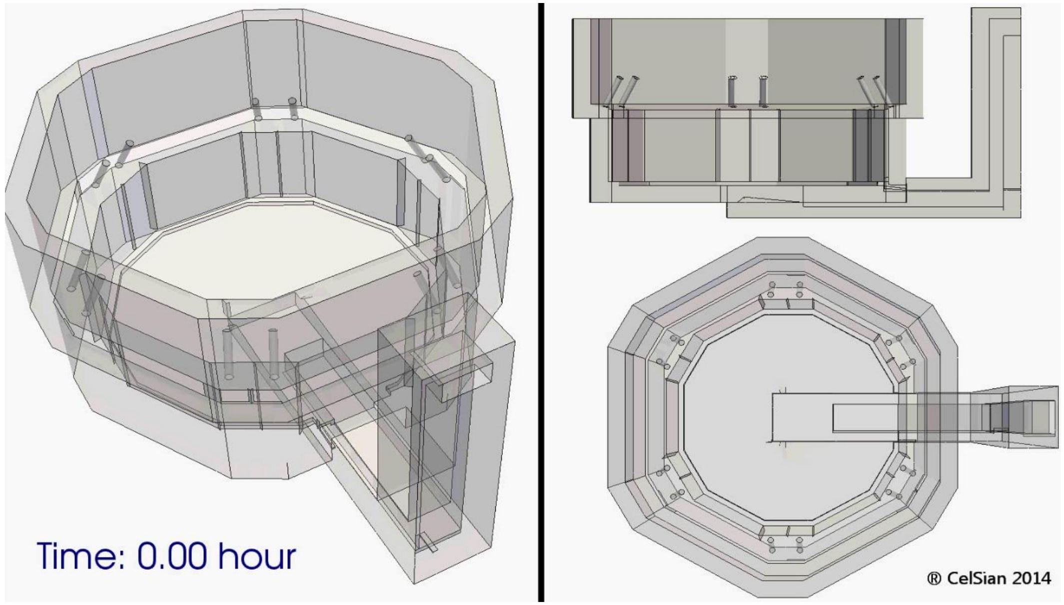
Vertical melter

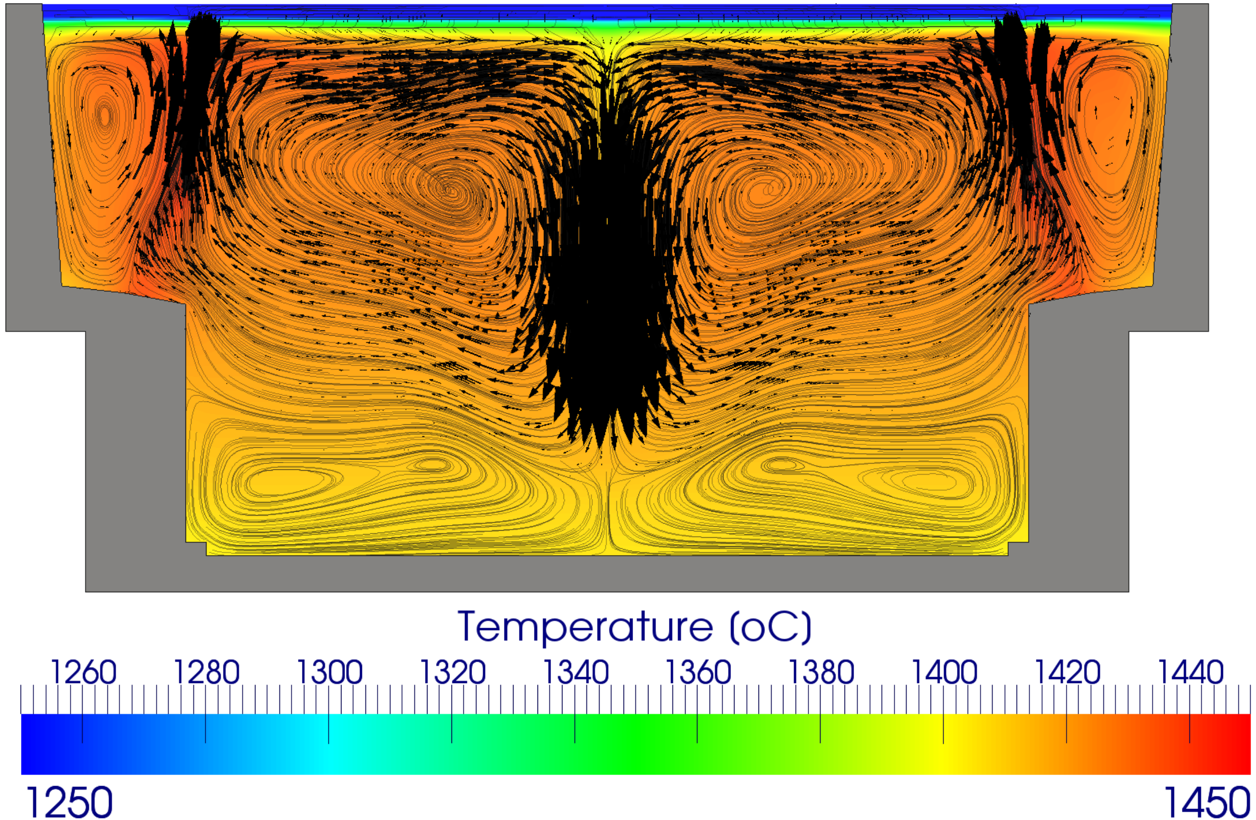




Heat transfer in full electric furnaces - Convection

Thermal profile driven by current density, local heat release





HTMOS - Cold Top configuration

Confidential set-up

Study the interaction hot melt & cold top → radiative transfer

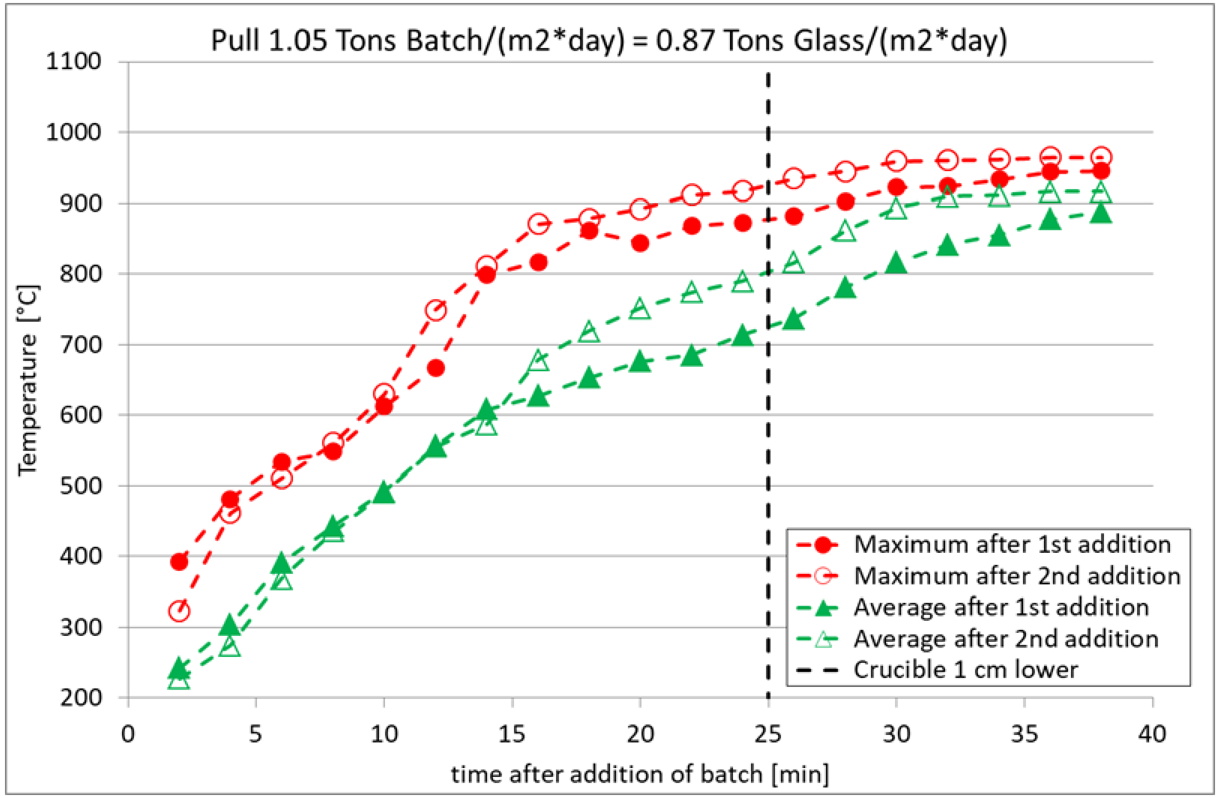
Specific pullrate = industrial scale

Features:

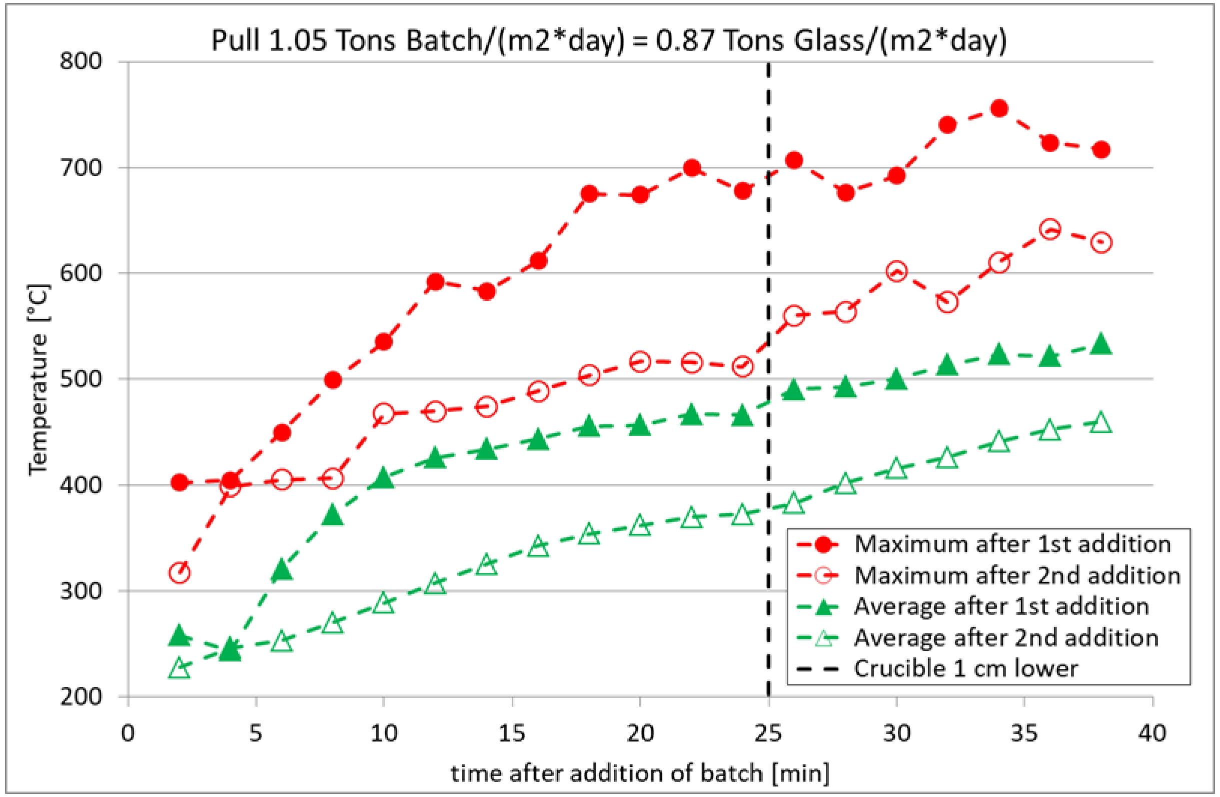
- Video recording “Side view”: Glass-batch interface
- Video recording “Top view”: Batch Surface
- IR measurement: Batch surface temperature f(time)

Melting behaviour amber vs. flint glass batch in cold top set-up

Batch surface temperatures



Batch surface temperatures flint batch



Batch surface temperatures amber batch

Batch model

Batch model

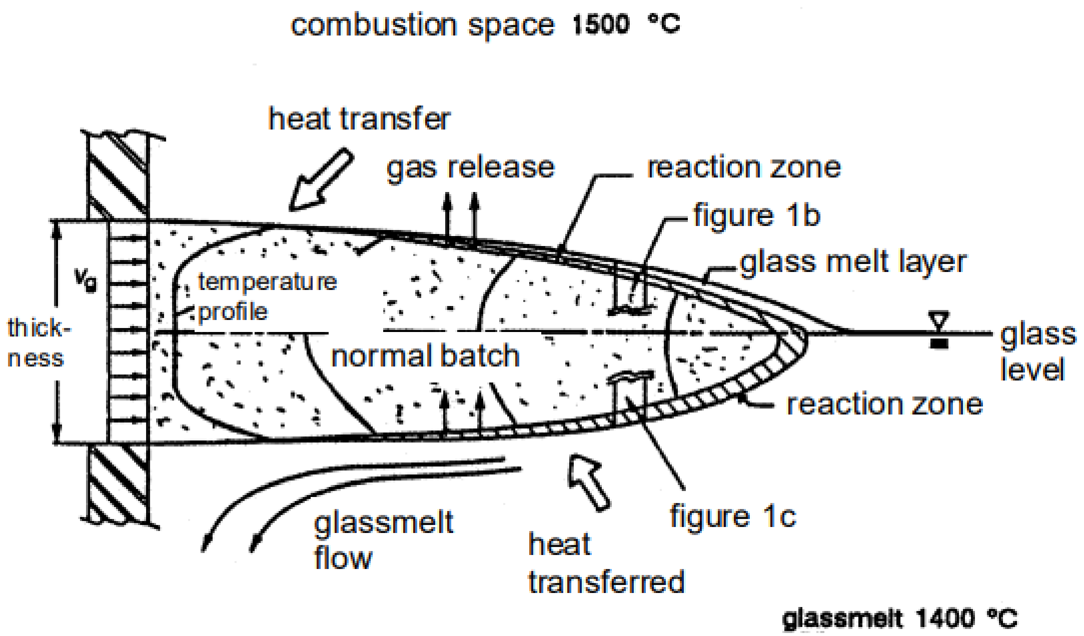


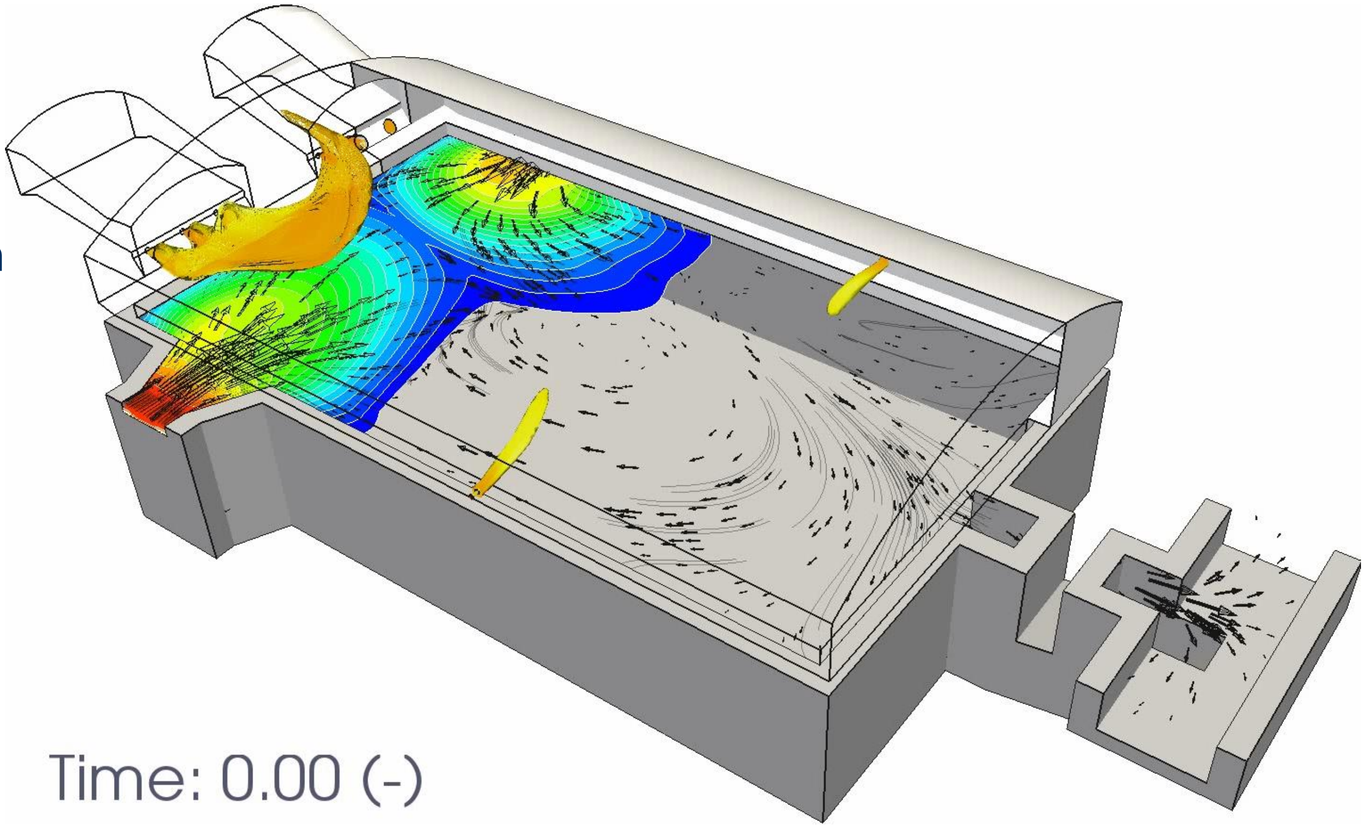
Figure 4-1. Schematic overview of the melting process of a batch blanket in a glass furnace, batch charging velocity vg (m/s)

Batch blanket model – 3 experimental inputs

- Melting onset temperature
    - HTMOS (High Temperature Melting Observation Setup) trials
- Batch to melt conversion rate
    - Interrupted melting rate trials
- Melting energy of raw materials
    - Chemical energy demand trials

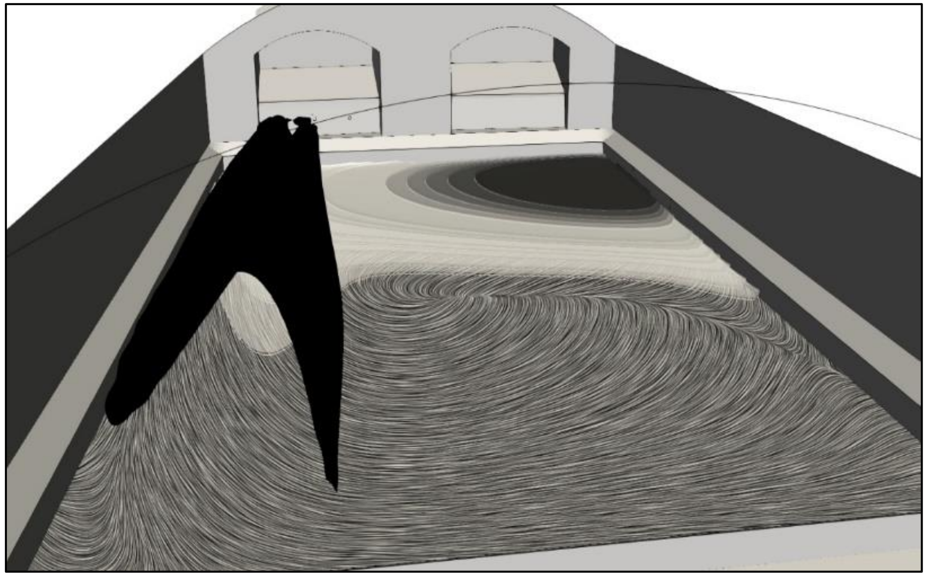
Batch blanket model

- Modeled as a batch mass fraction
- Uses a transient convection-diffusion equation



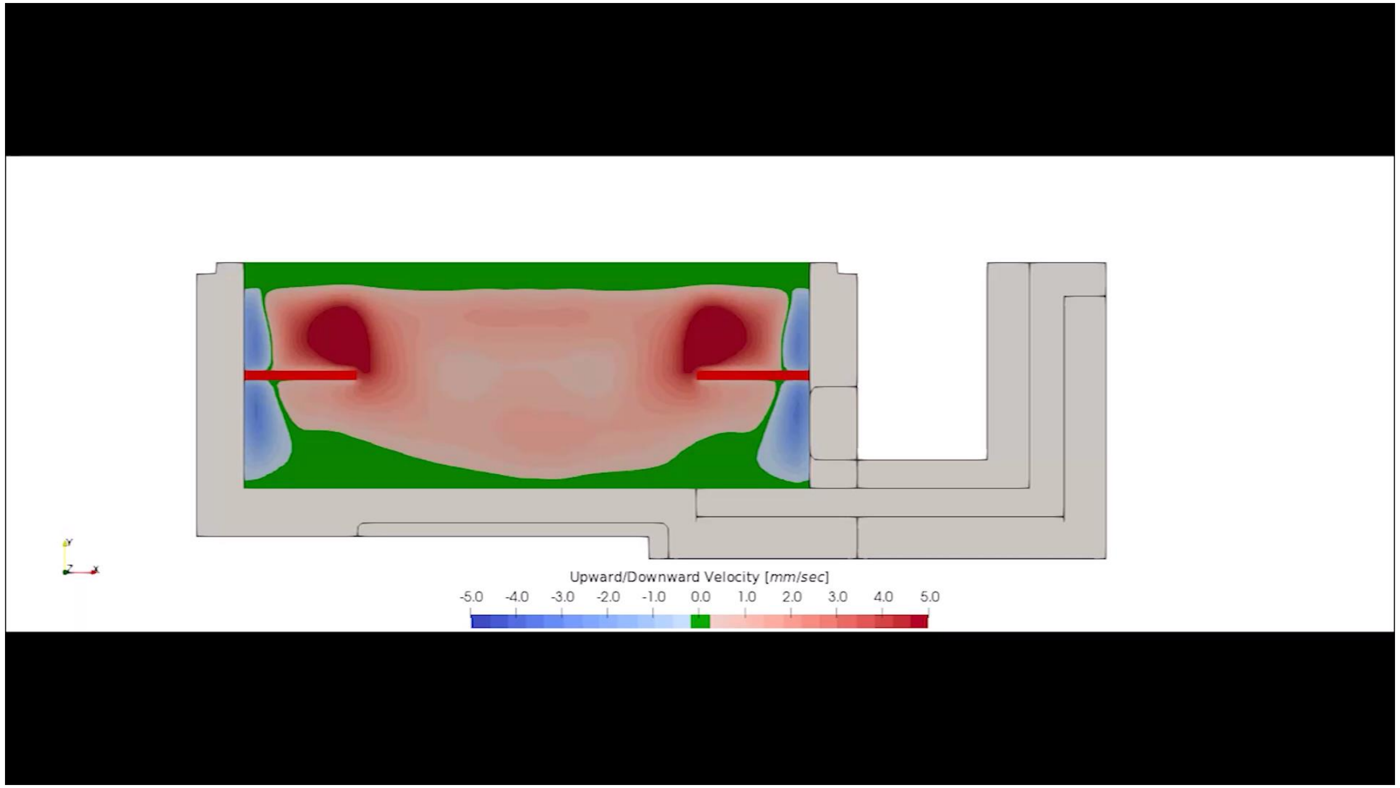
Batch blanket model

- Calculates the position of the batch blanket
- Calculates the shape of the batch blanket
- Calculates the thickness of the batch blanket
- Calculates the dissolution of raw materials in the glass melt



Batch blanket model

- CelSian's dedicated batch model can simulate changes in the batch blanket thickness with changes in process conditions.



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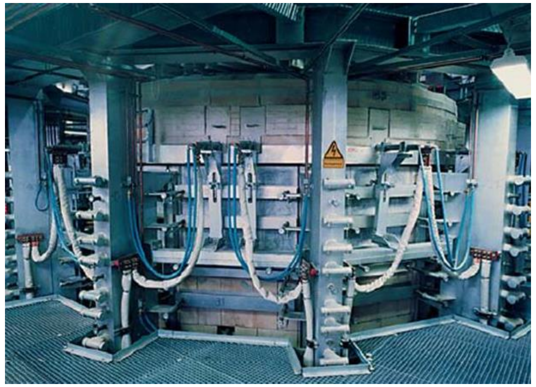
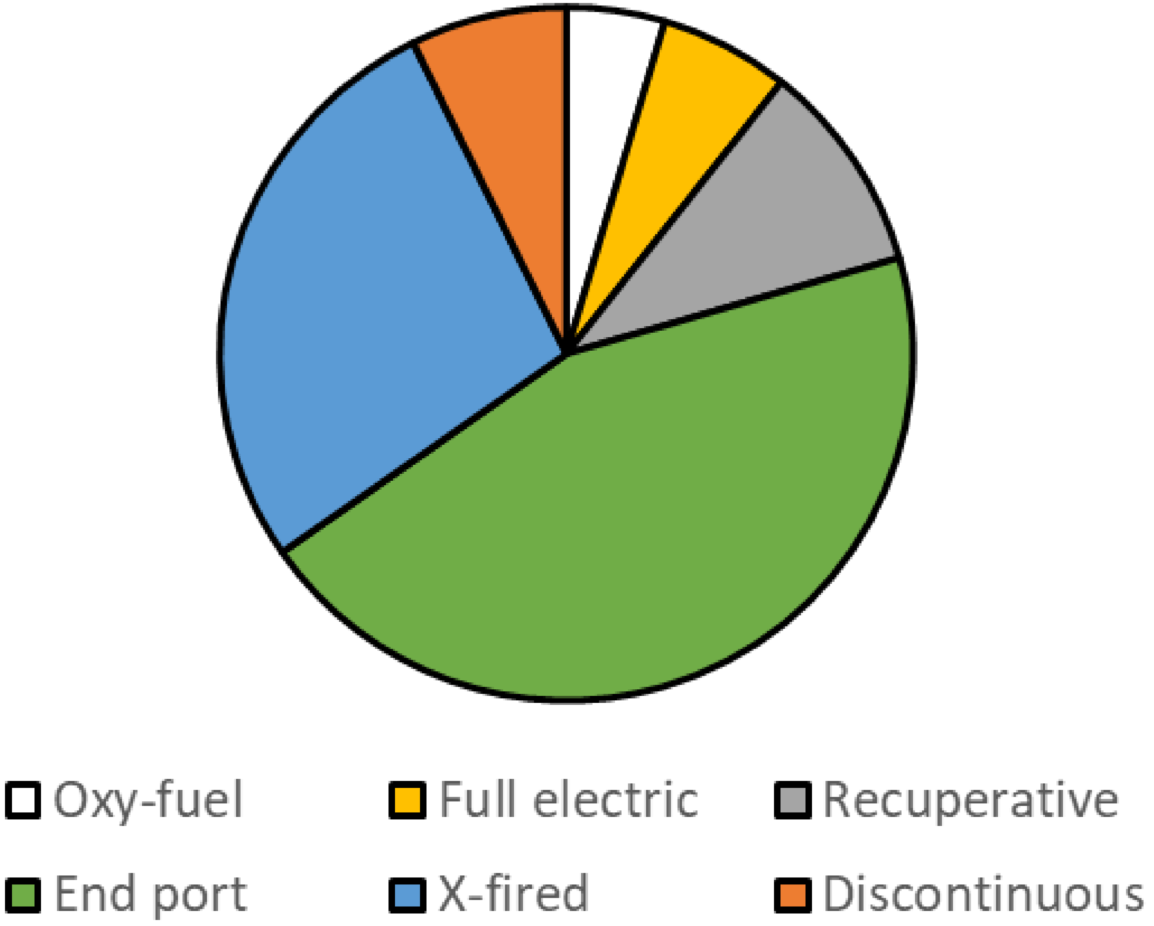
Full-electric melting advantages



- Lack of a combustion space:
  - Minimal CO_2 emissions from melter
  - Almost no NO_x emissions
  - Reduced evaporation of (volatile) raw materials
- Best available technology on Energy efficiency
- Reduced Capex : no regenerators, no burner skids and no expensive crown refractories
- From an innovation point of view a shorter lifetime is not a disadvantage

2484 glass furnaces worldwide

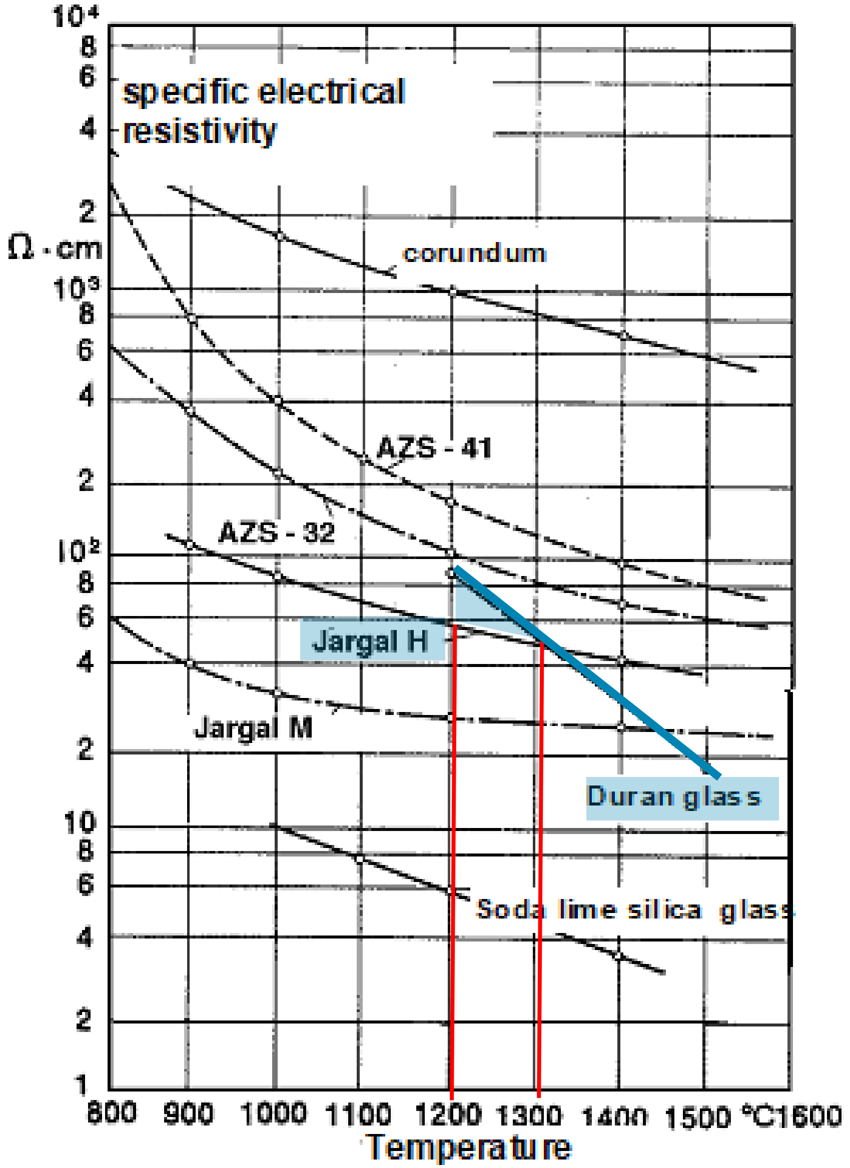
- Despite advantages, full-electric melters only account for 10% of all furnaces in operation



Source: Glass global database (Dec. 2021)

Full-electric melting challenges

- Limited in capacity
- Dark colors
- High cullet
- Less flexible in operating temperatures and pull
- Low pull
- Relative short lifetime
- Selection of refractory material



CO_2 emission electricity (indirect)

Emission factor depends on

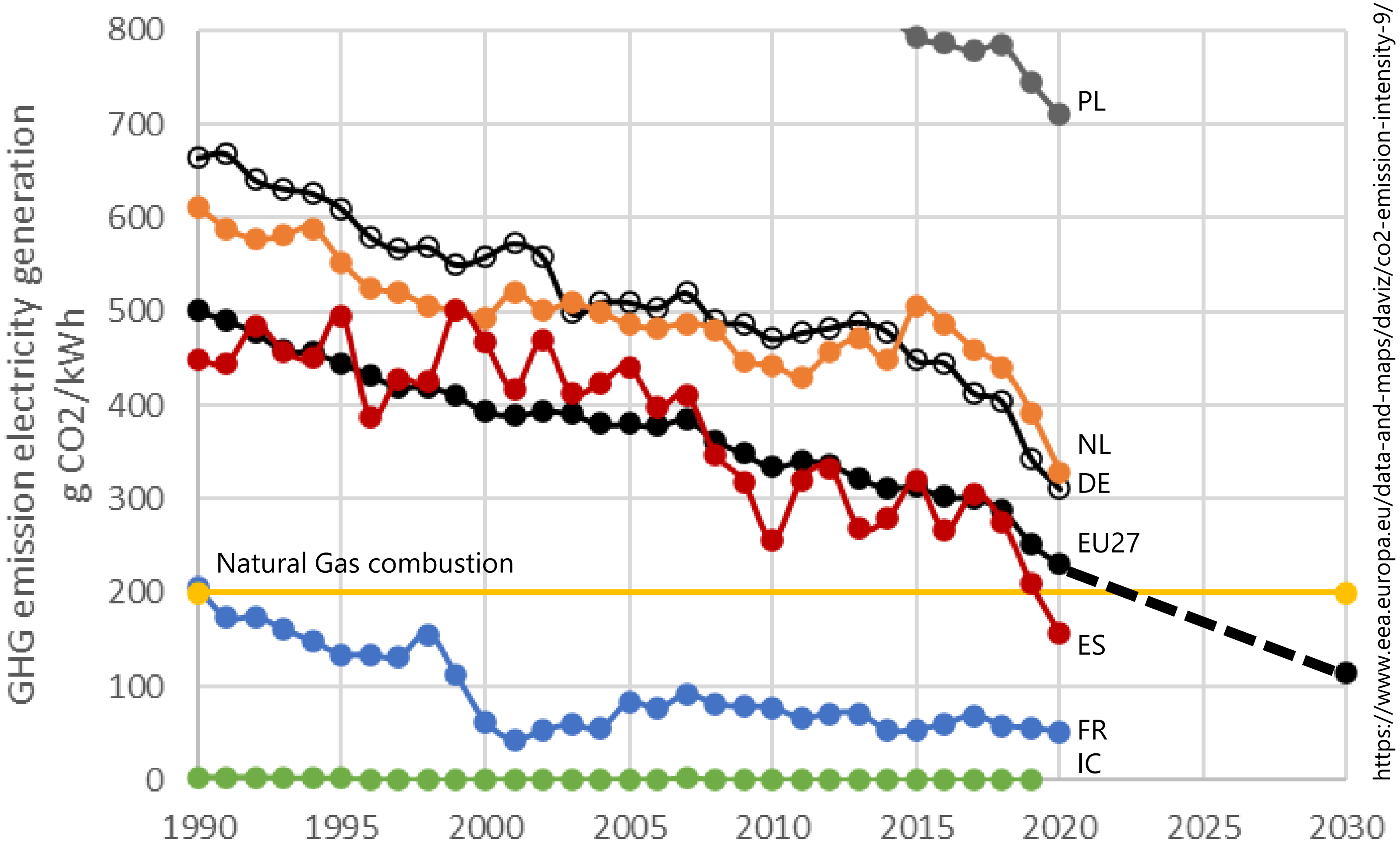
- Mix fossil & renewable
- Technology

Coal power plant:

≈ 700 g/kWh$_e$ (=0.200 kg CO_2/MJ)

Combined cycle power plant:

≈ 360 g/kWh$_e$ (=0.100 kg CO_2/MJ)



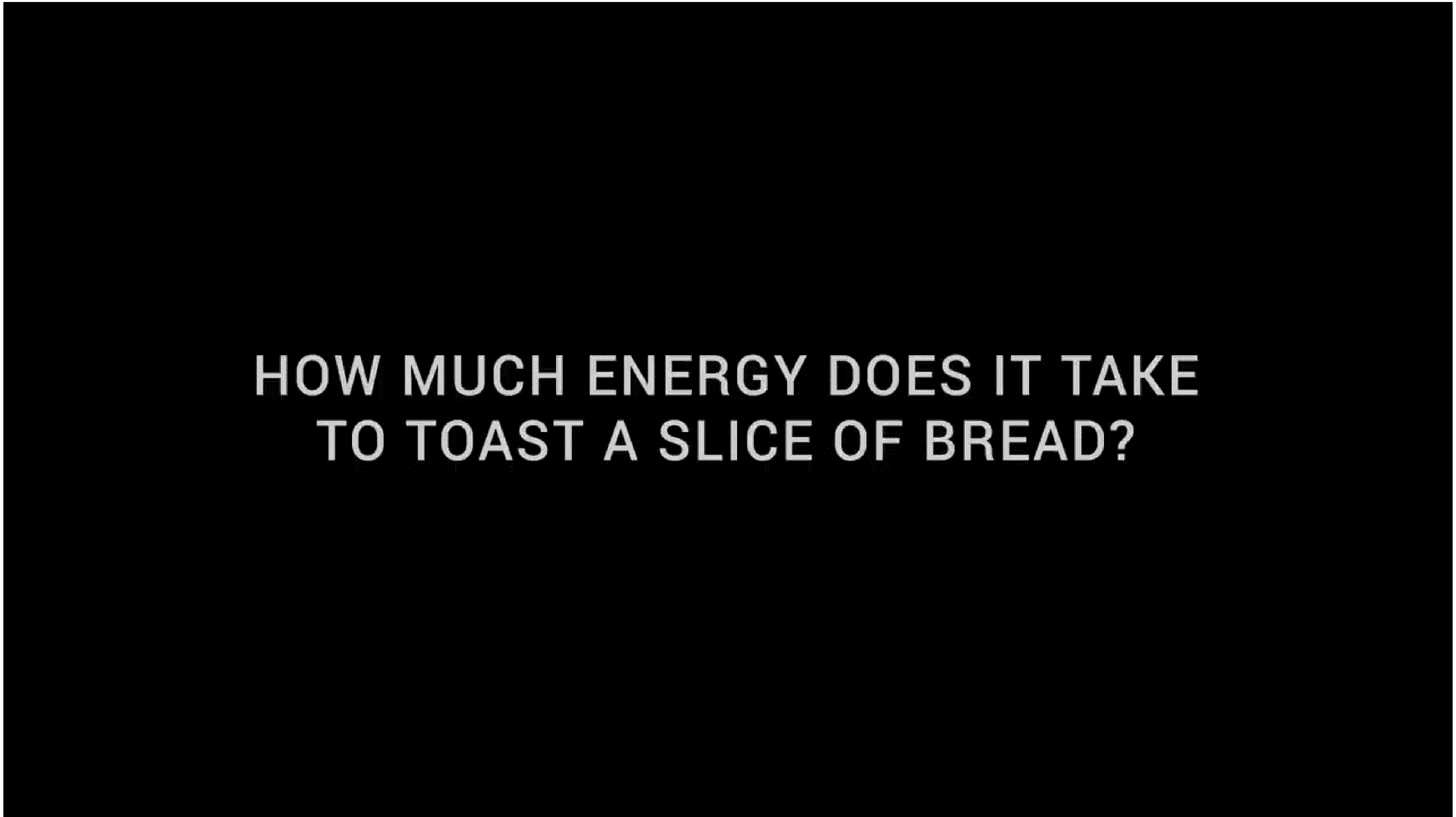
https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-9/

Conclusions

- Working principle of electric melters
  - Current density
  - Joule heating
  - Heat transfer via convection
  - Radiative heat transfer

- Advantages and current limitations

- Use of CelSian’s dedicated Batch blanket model


HOW MUCH ENERGY DOES IT TAKE
TO TOAST A SLICE OF BREAD?

Robert and glass

0,021 kWh = 21 Wh = 75,5 kJ

How much energy do you need to melt 1 ton (1000 kg) of your glass?

3 GJ = 833 kWh ≈ 38k Roberts

4 GJ = 1111 kWh ≈ 52k Roberts

Thank you for your attention