ZeroCO_2 glass advancing the path to carbon-neutral container manufacturing

IPGR

86TH GLASS PROBLEMS CONFERENCE

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How-to?

Motivation – Transforming the industry to a carbon neutrality

…in the lab

Glass characterization
Combustion trials
Forming almost impossible

…in the plant

Customer interests
Controlled conditions?
Scale of operation

→ Formation of a consortium
→ Funding application

→ Creation of a pilot facility
→ Benefits of flexibility and consistency for trials in respect of
  - batch composition,
  - type of combustion,
  - electrical boosting and
  - forming trials

ZeroCO2-Glass Project

Consortium and project partners

Technology partner

- Research institute in the field of packaging glass with worldwide networking
- Project consortium coordinator

R&D partner

- High research expertise in the field of glass and melting technology
- Close connection between basic research and industrial application

- High research and industry expertise in furnace engineering and heat transfer
- Simulation and modelling

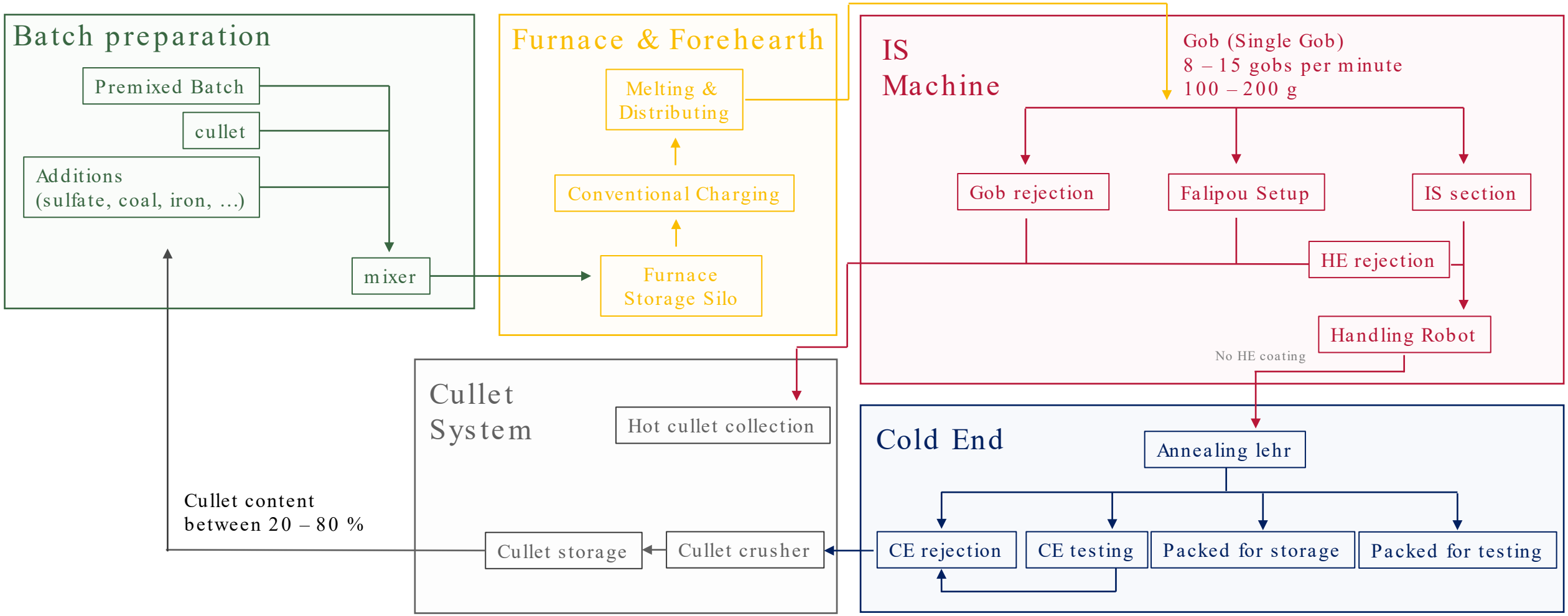
Industry partner

- One of the world's leading large-scale furnace manufacturers in all areas of the glass industry
- Technology carrier in the project

- One of the largest glass packaging manufacturers in Germany, > 2.9 billion bottles per year
- End user of the technology

ZeroCO_2-Glass

Plant Organisation



ZeroCO_2-Glass

Pilot plant

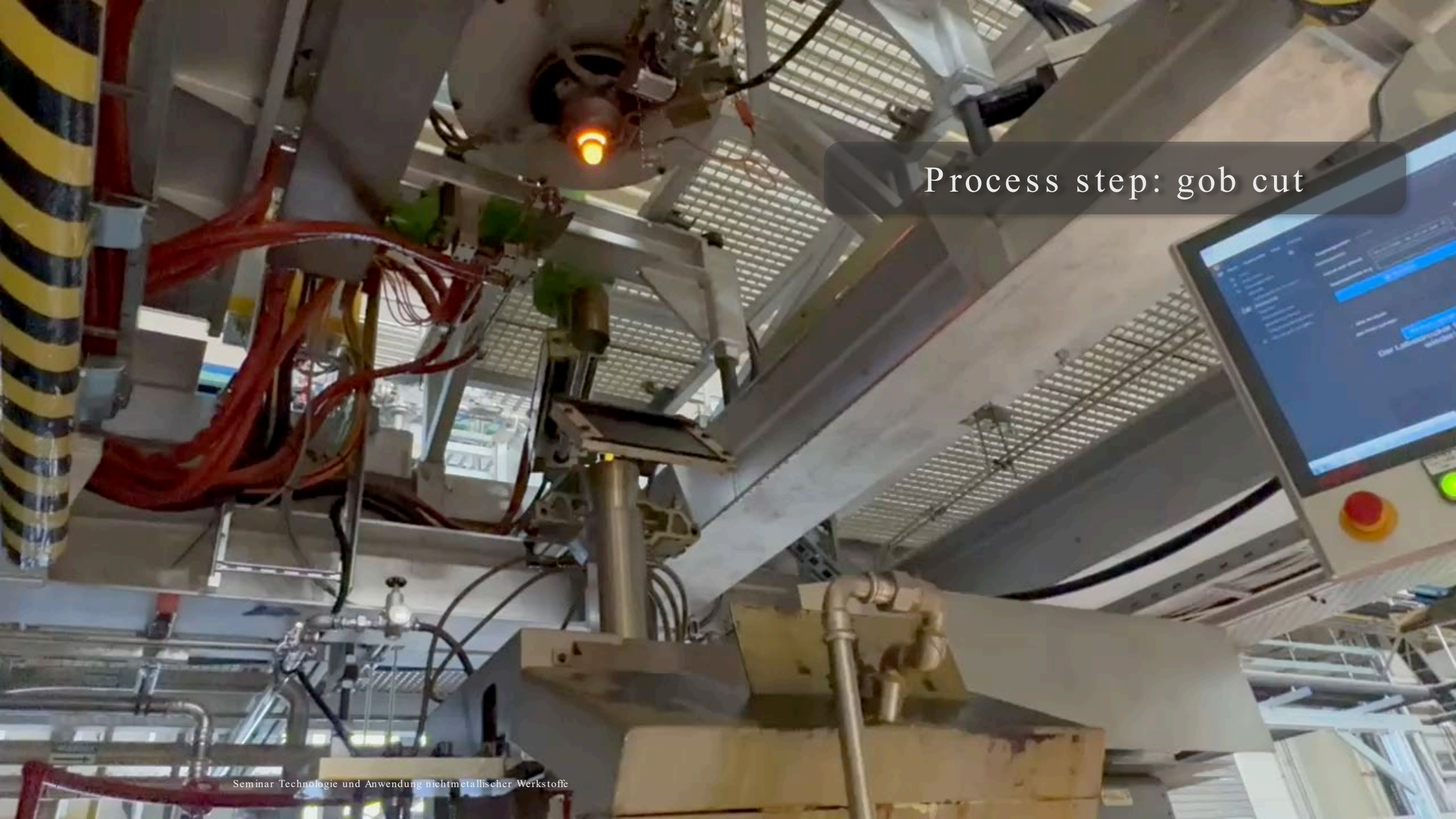
Furnace:

- 3,5 m^2 melting area, 2.4 tpd
- 12 electrodes in the melting area
- Flexible electric boosting between 20 % and >50 %
- Oxyfuel and H_2-O_2 heating
- Batch mixing tower

Forming:

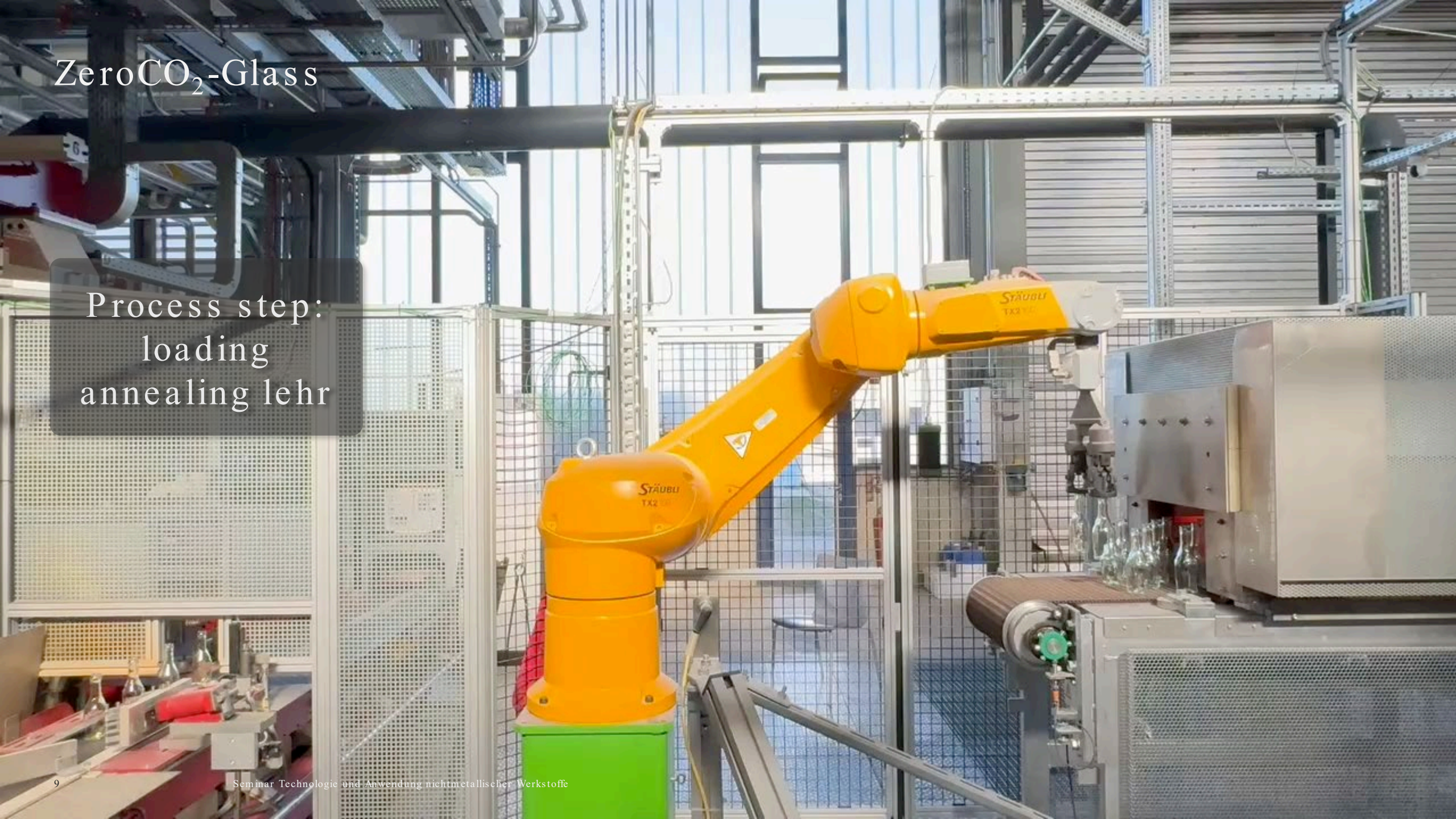
- AIS Machine
- Pick-and-place robot
- Full-electric annealing lehr
- Measurements
  - Gob camera
  - High speed thermal camera
  - 3D wall thickness measurement

Process step: gob cut



Process step: Bottle forming

ZeroCO_2-Glass



ZeroCO_2-Glass

Process step: sorting and crushing

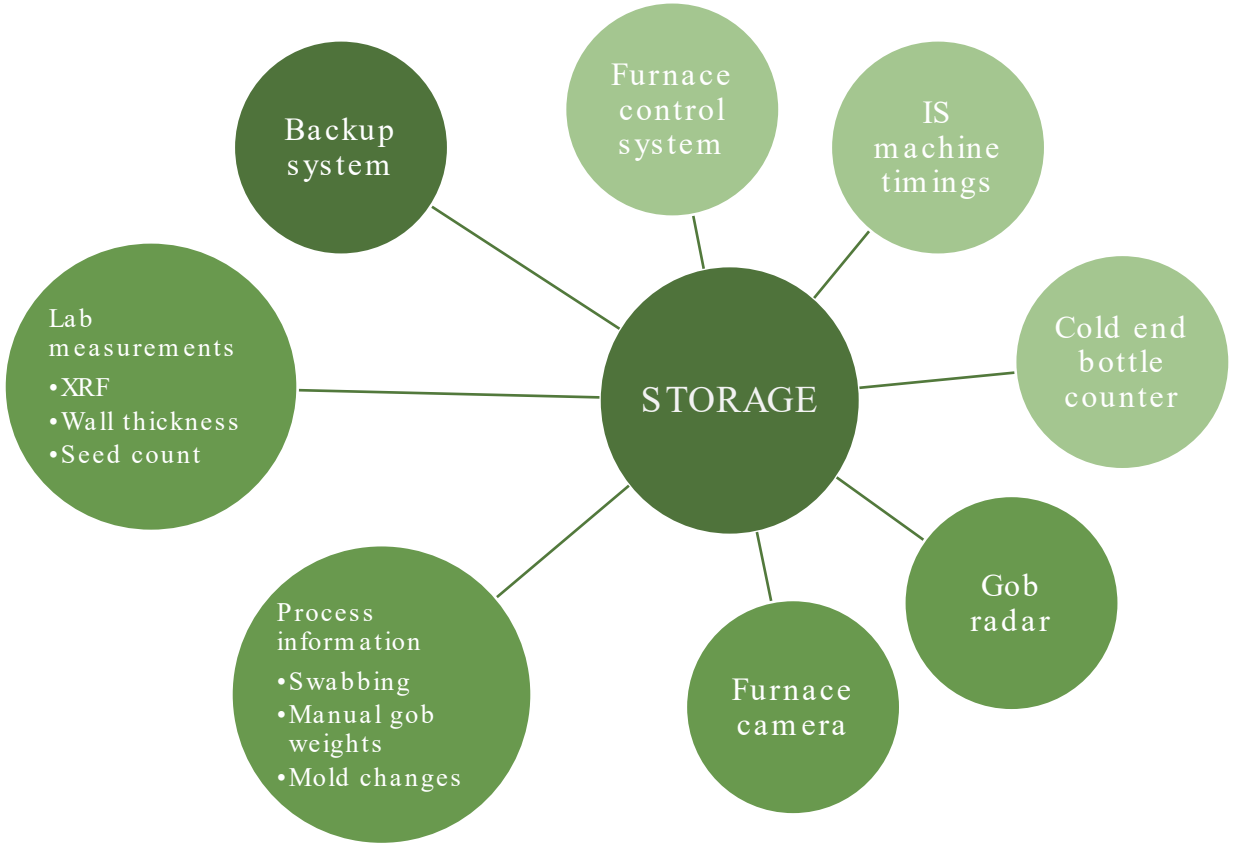
ZeroCO$_2$ Glass – Pilot Plant Operation

Data lake

- Incorporation of all available equipment data and process information from hot end, cold end and quality control

→ Central data lake

- Implementation of different algorithms for data evaluation
  - For example seed count
  - Glass temperature from IR pictures
- Visualization with Grafana Dashboards



ZeroCO$_2$ Glass – Pilot Plant Operation

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ZeroCO$_2$ Glass – Trial Plan

Electrical energy intake

- Increase of the boosting from 20 % to 50 % and >70 %

Hydrogen/ oxygen combustion

- Switch from oxyfuel combustion to a hydrogen-oxygen combustion

CO2 free batch compositions

- Test of soda and carbonate free compositions for melting and forming performance

Evaluation of a forming model

- Create a viscosity-driven forming model

ZeroCO_2 Glass – Trial Plan

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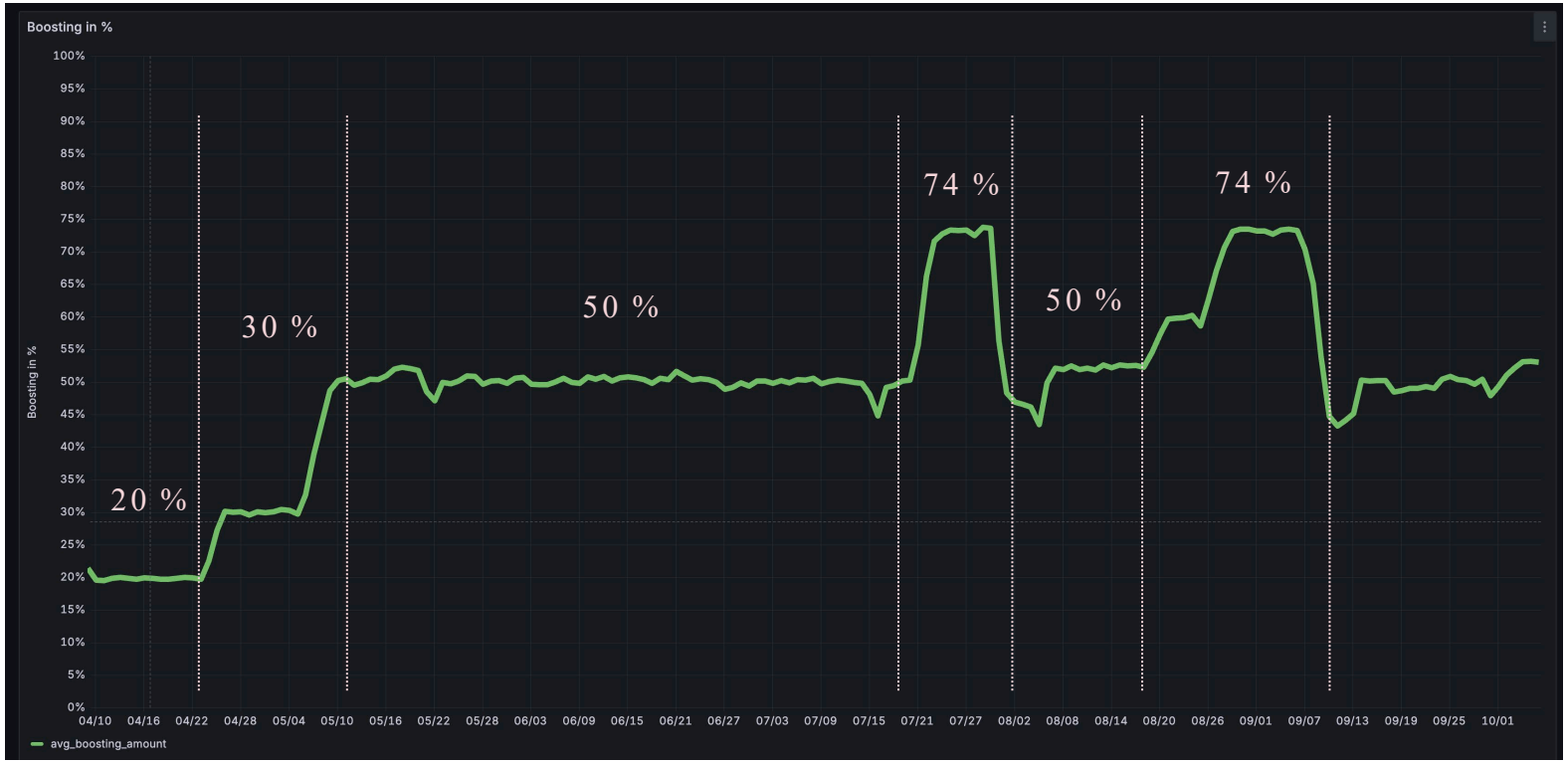
$ZeroCO_2$ Glass – Project

Trial: Boosting Increase from 20 % to 70 %

- Achievement of 50 % electrical boosting since May 9th
- Achievement of >75 % boosting in July



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ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

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Chair of Glass and Glass-Ceramic

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Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
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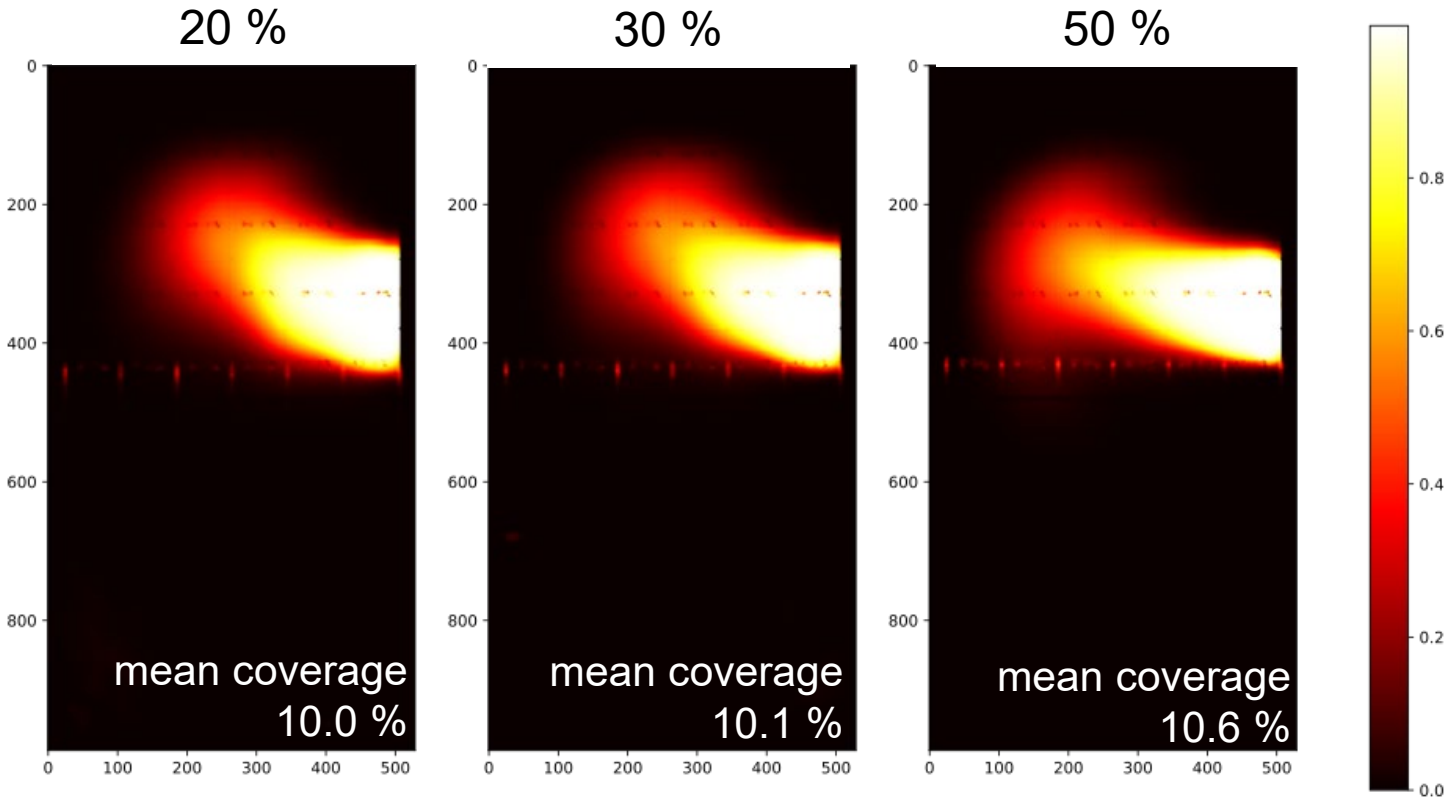
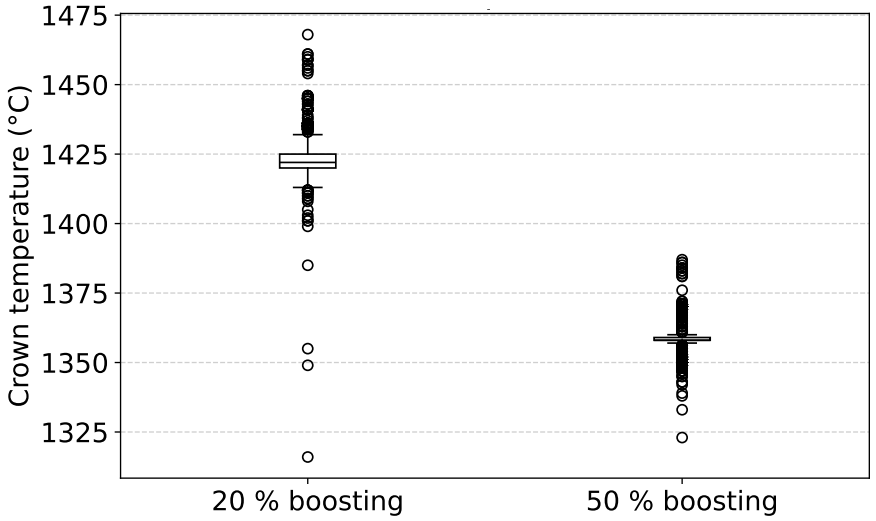
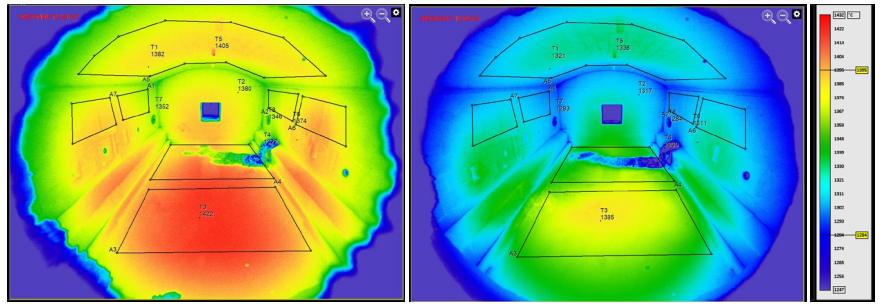
Evaluation of electrical boosting increase

ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Electrical Boosting increase – Batch coverage



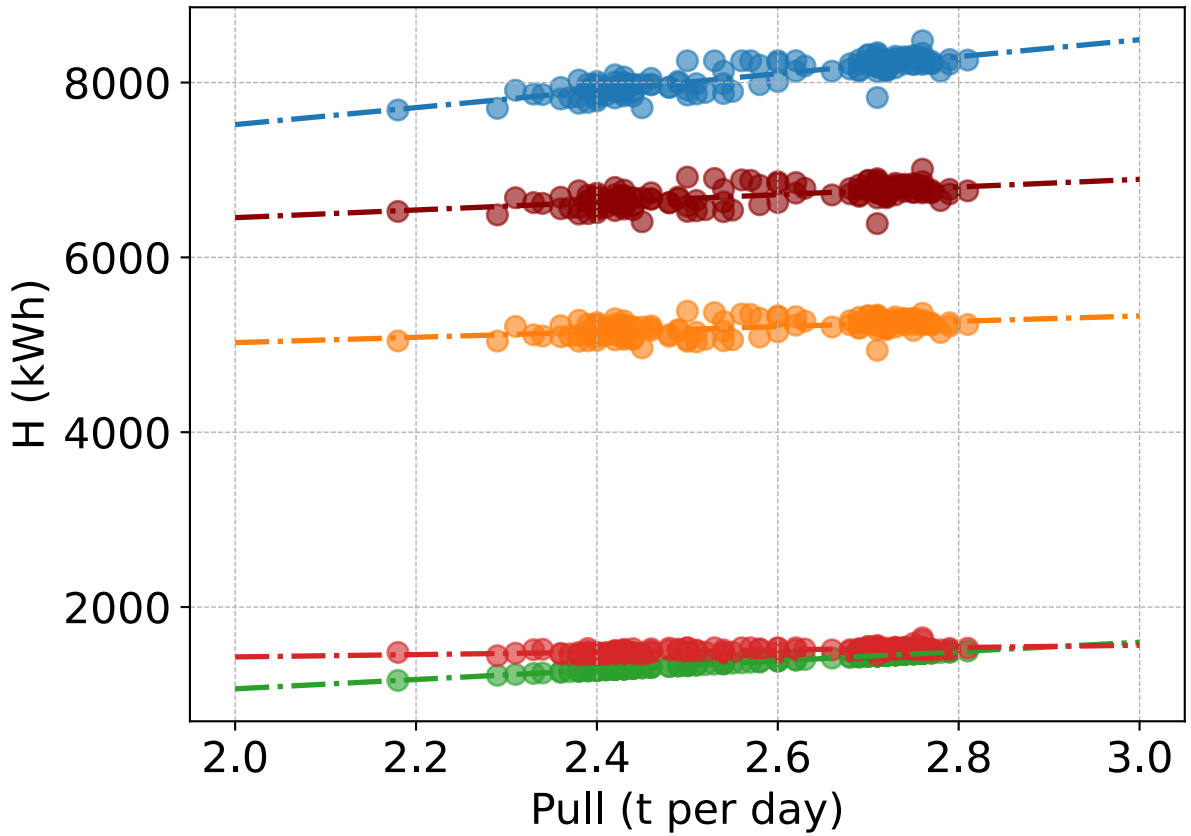




ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Electrical Boosting increase – Furnace Performance

Reference Case



= gas + boosting input

= batch reaction + heatup energy

= H_{in} - H_{ex}

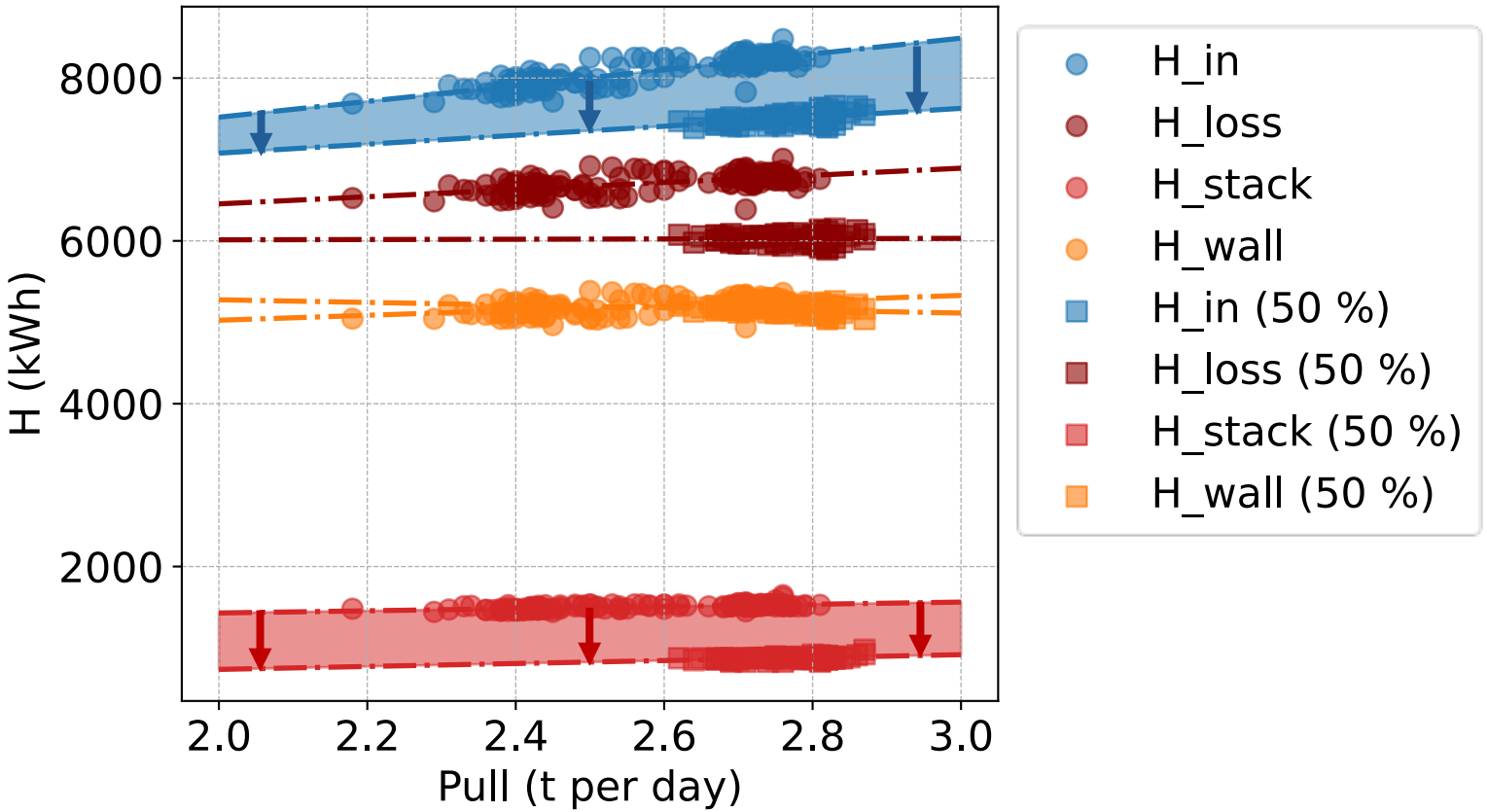
= energy loss through chimney

= H_{loss} - H_{stack} energy loss over walls/structure/cooling etc.

ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Electrical Boosting increase – Furnace Performance

Reference Case vs. 50 % boosting



Energy consumption decrease by >10%

Wall losses stable ->
Relative energy consumption decrease even higher on larger furnace due to lower proportion of wall losses

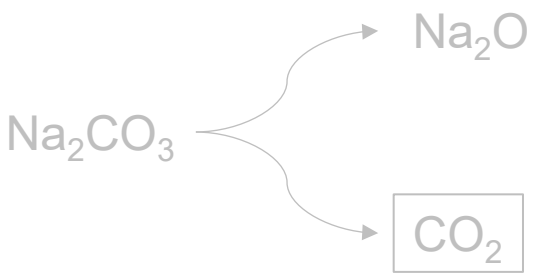
Energy loss through waste gas cut by half!

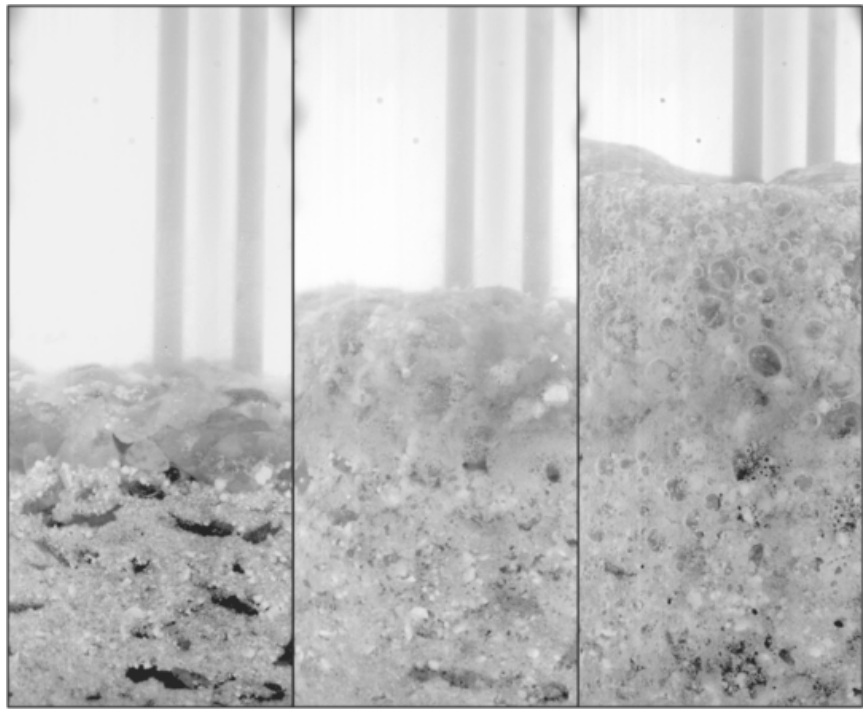
Alternative glass chemistry

ZeroCO_2-Glass – Investigations on Meltability of CO_2-free Glasses

Motivation – Alternative Glass Chemistry

- Why to remove soda from batch?
  - **synthetic** raw material
  - **most expensive** raw material
  - soda **releases CO_2** during decomposition in the melting tank

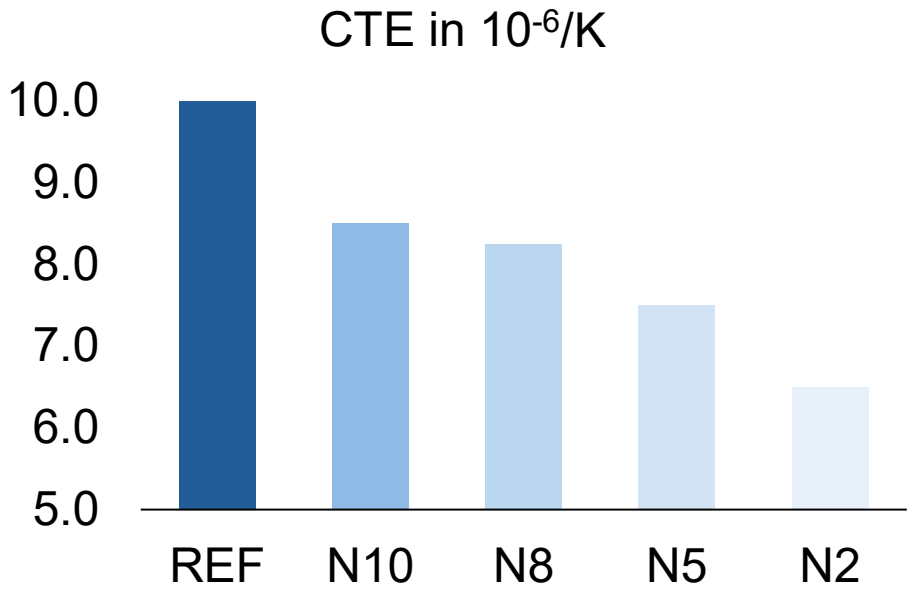


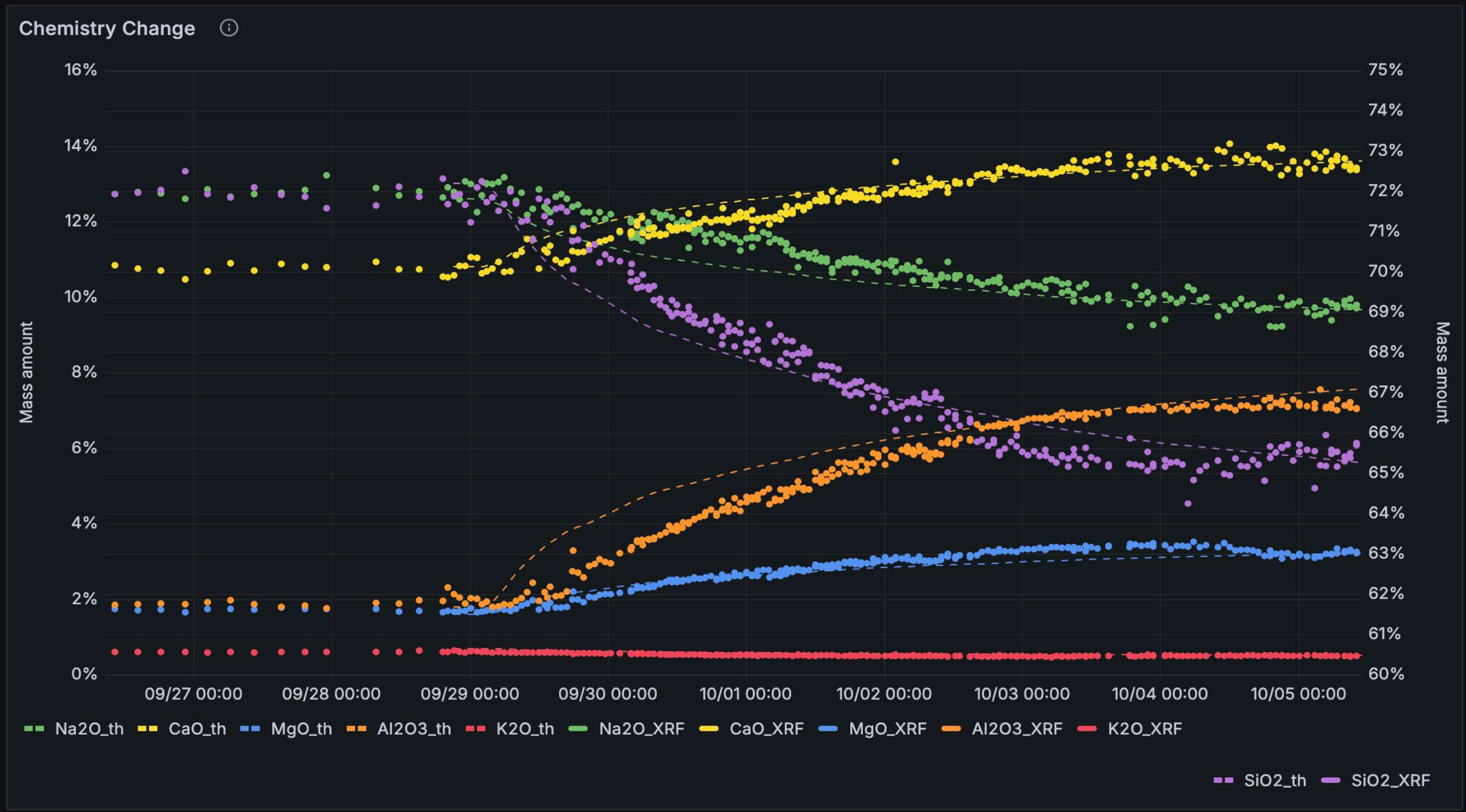


ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Motivation – Alternative Chemistry and Melting

- Why to reduce Na_2O content of glass?
  - Na_2O "weakens" the glass structure
  - reducing Na_2O can improve glass properties:
    - **strength**
    - **hydrolytic stability**
    - lower **coefficient of thermal expansion (CTE)**
    - **shown in lab trials**

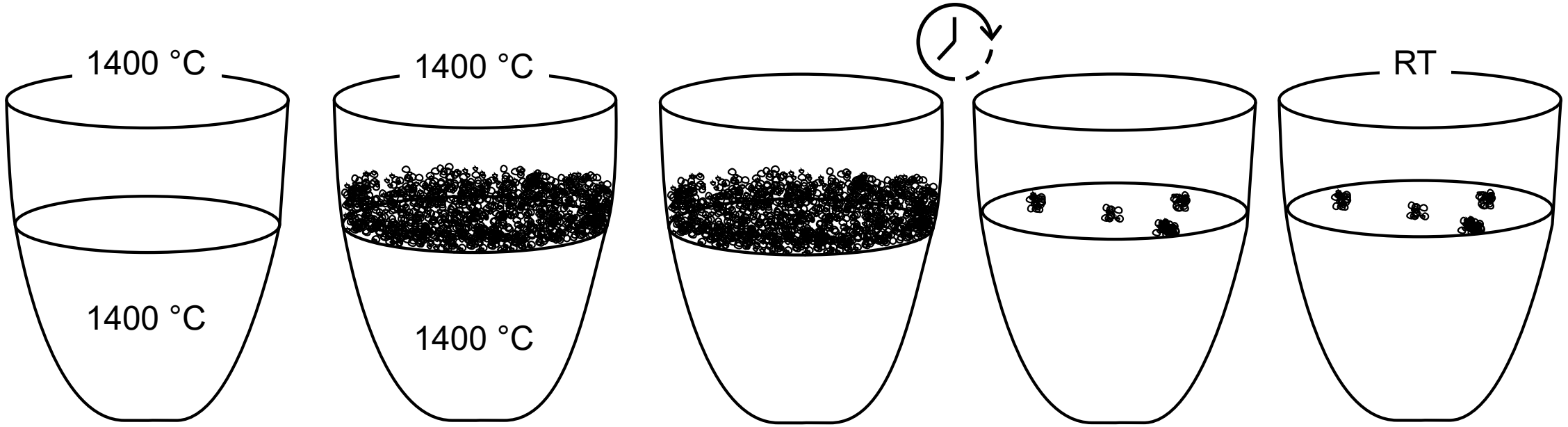



Chemistry Change
16%
14%
12%
10%
8%
6%
4%
2%
0%
Mass amount
75%
74%
73%
72%
71%
70%
69%
68%
67%
66%
65%
64%
63%
62%
61%
60%
Mass amount
09/27 00:00
09/28 00:00
09/29 00:00
09/30 00:00
10/01 00:00
10/02 00:00
10/03 00:00
10/04 00:00
10/05 00:00
Na2O_th
CaO_th
MgO_th
Al2O3_th
K2O_th
Na2O_XRF
CaO_XRF
MgO_XRF
Al2O3_XRF
K2O_XRF
SiO2_th
SiO2_XRF

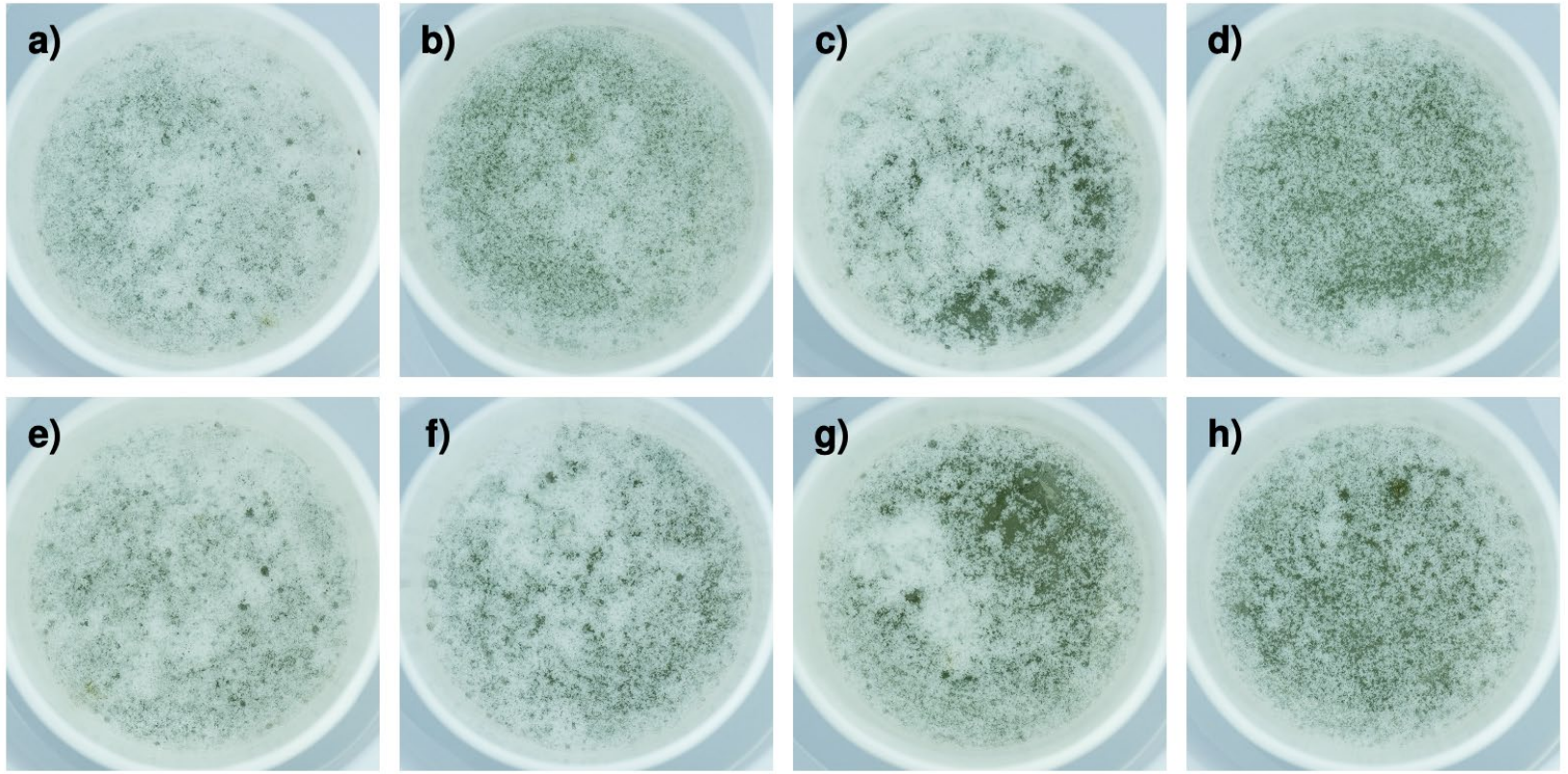
ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Evaluation of batch melting

- 50 g batch charged on 250 g of melt at 1400 °C **inside furnace** to avoid cooling of melt reservoir
- fixed dwell time
- **air-quenched to RT** to prevent further batch reactions



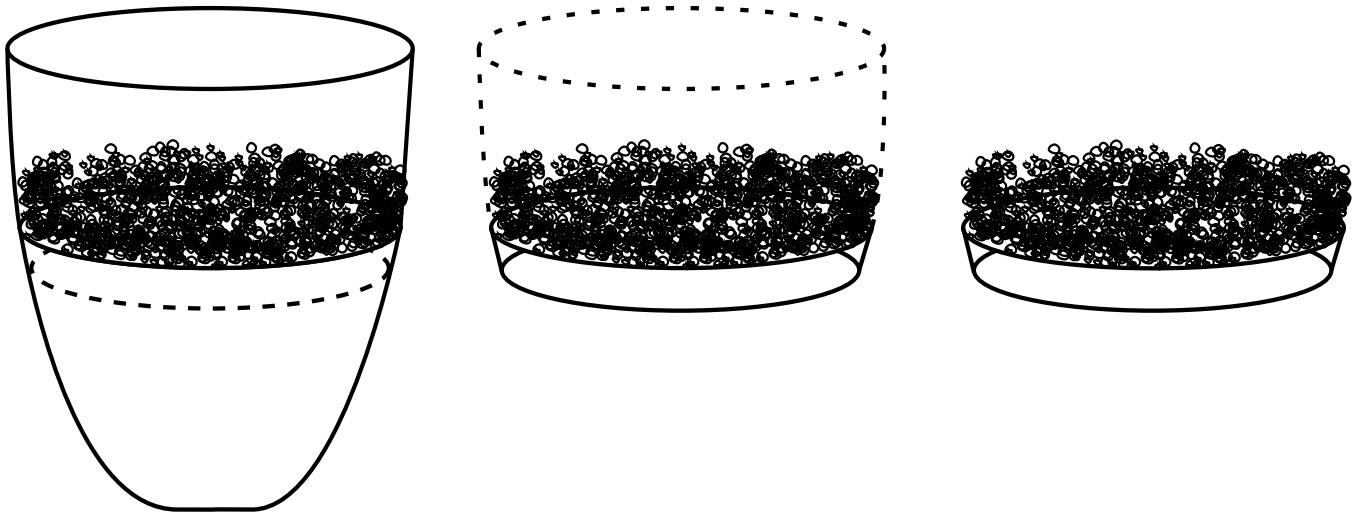
Evaluation of batch melting – SLS Reference



ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Evaluation of batch melting

- Separate batch blanket
- Milling <125 µm
- XRD Rietfeld analysis with K-factor method to determine quantity and type of unmelted batch



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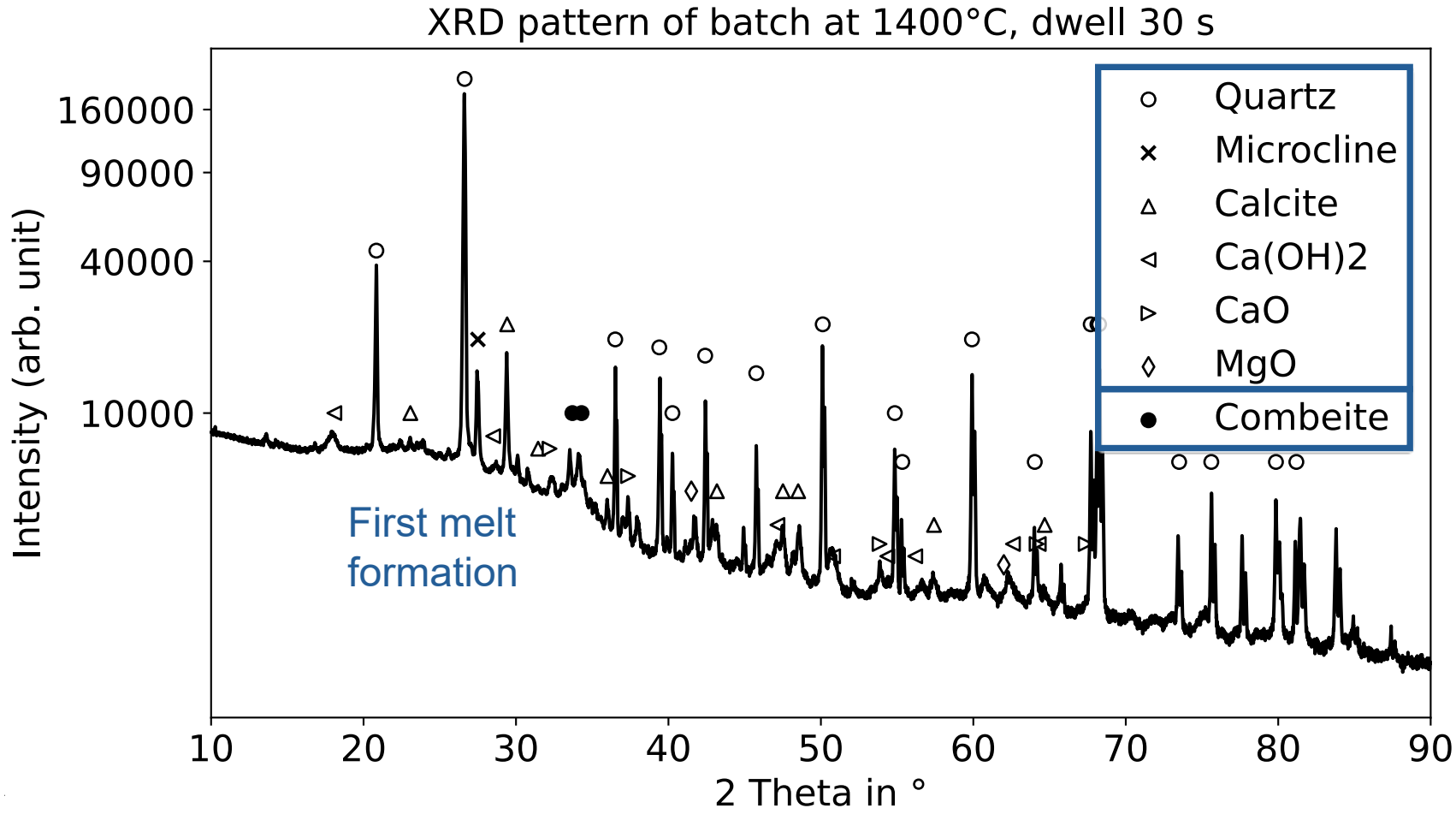
Evaluation of batch melting

ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Evaluation of batch melting – Rietveld refinement

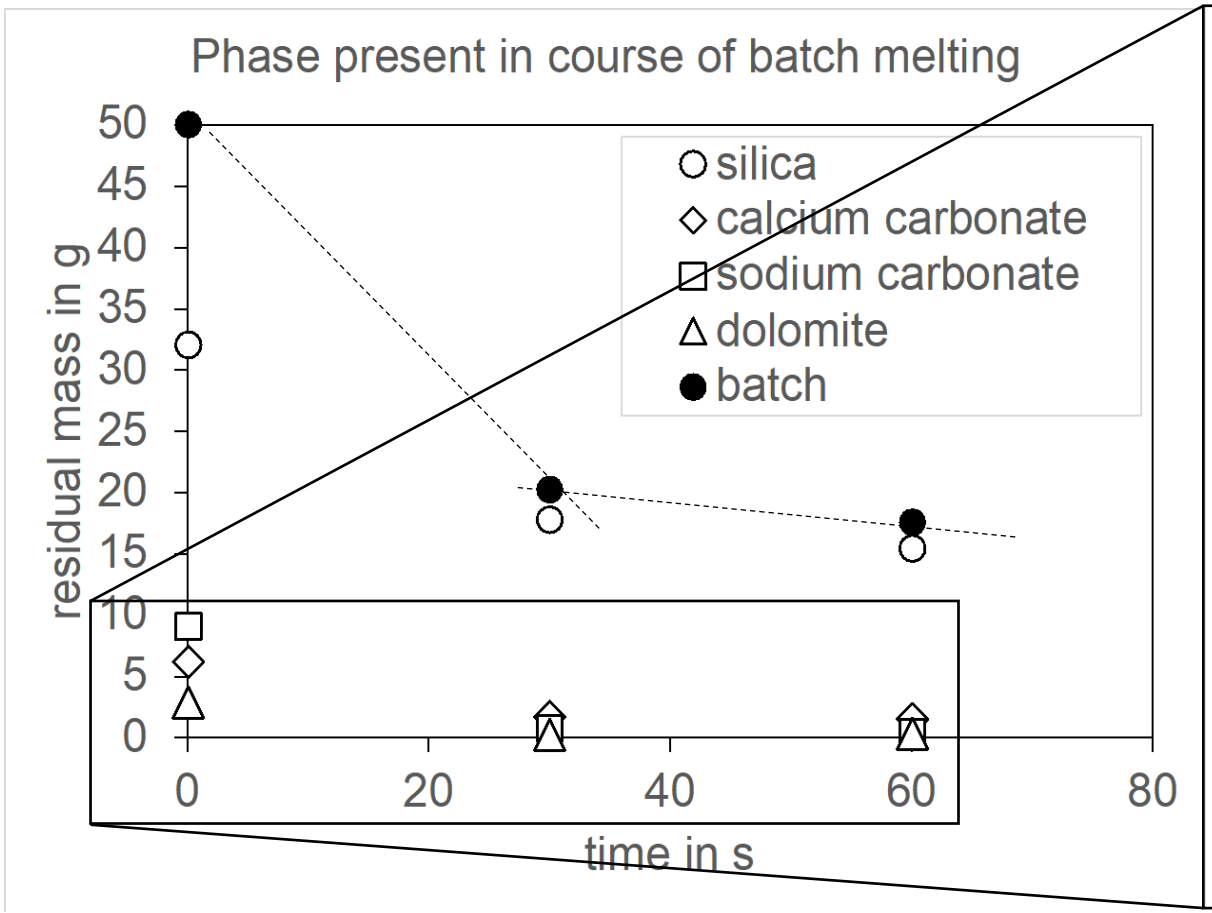


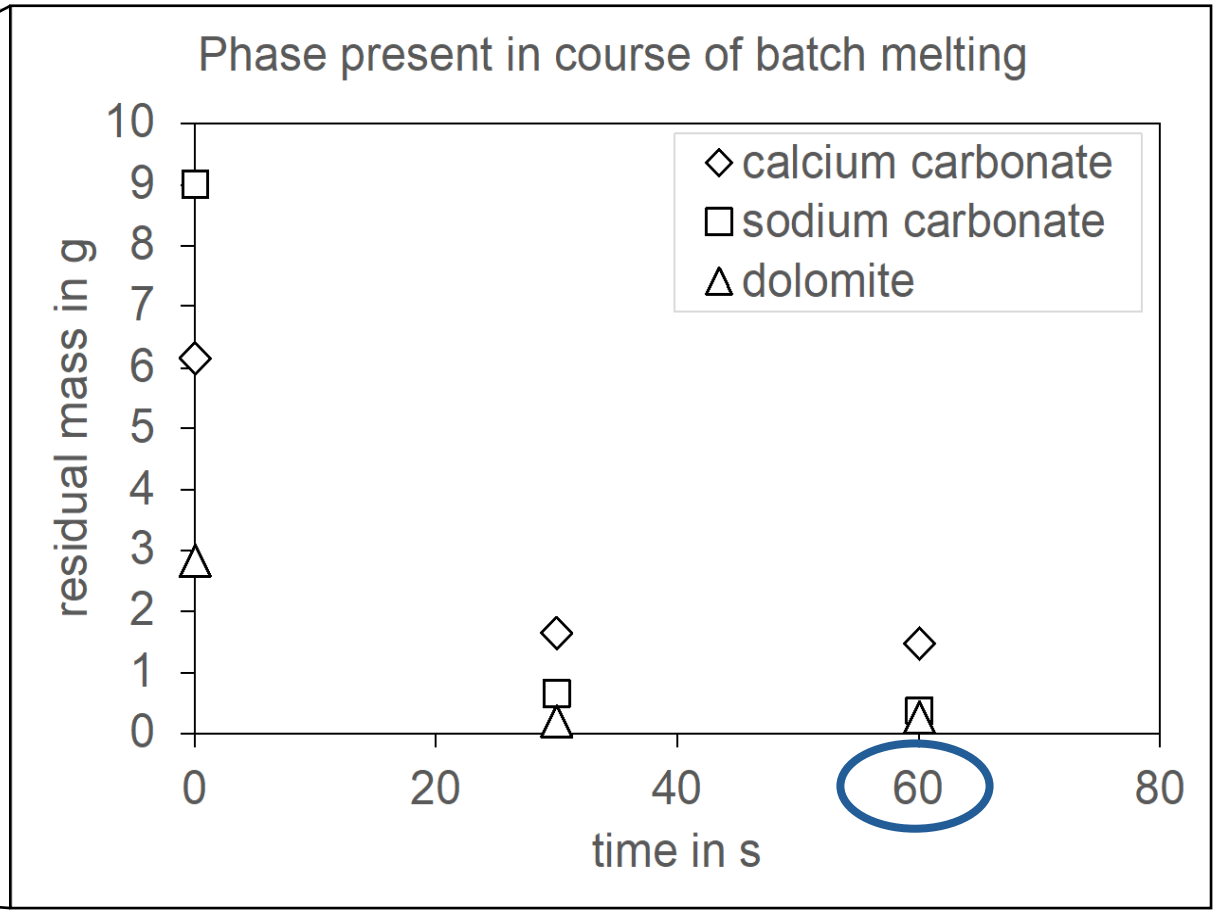
Sand
Limestone
Dolomite
Soda
} Raw Materials

$Na_4CaSi_3O_9$
$Na_2Ca_2Si_3O_9$
Solid state reactions

ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Evaluation of batch melting – SLS Reference





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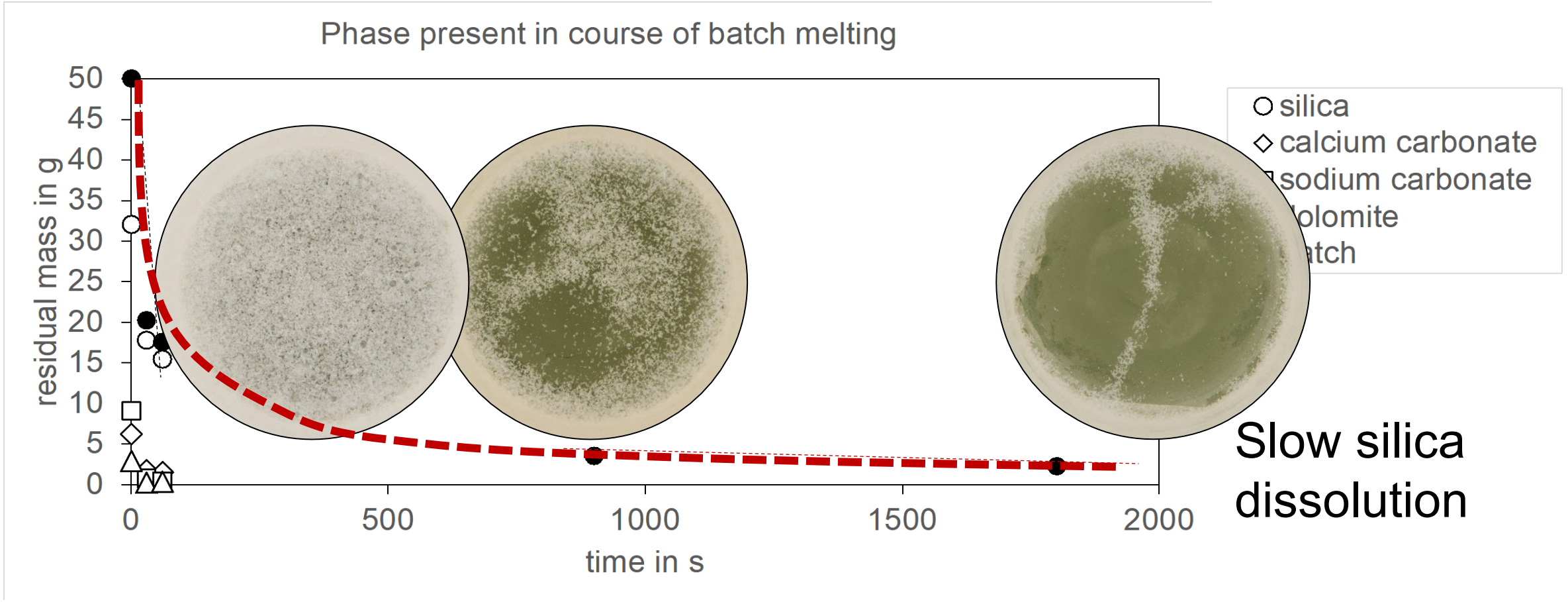
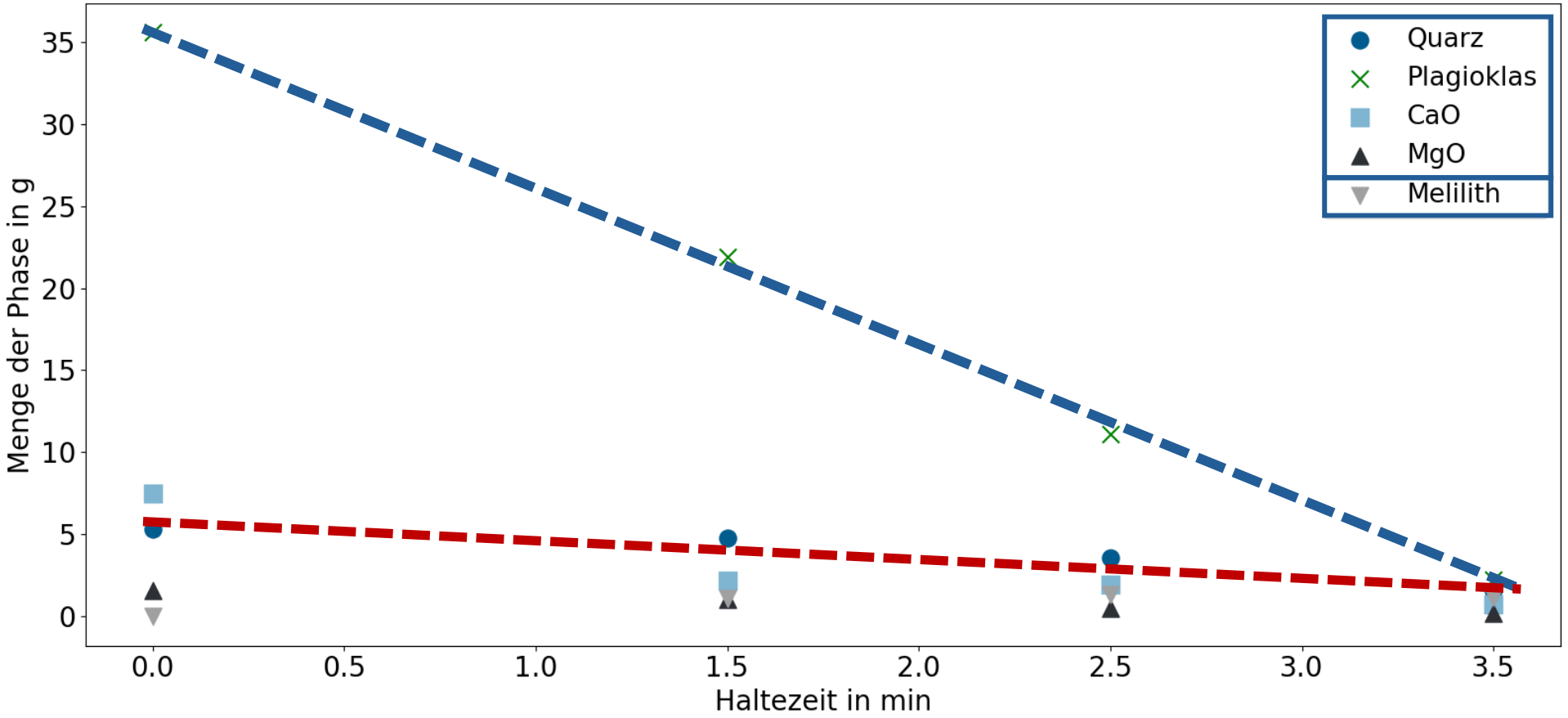
Evaluation of batch melting – SLS Reference



ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Evaluation of batch melting – CO$_2$-free batch 8 % Na2O



Raw Material

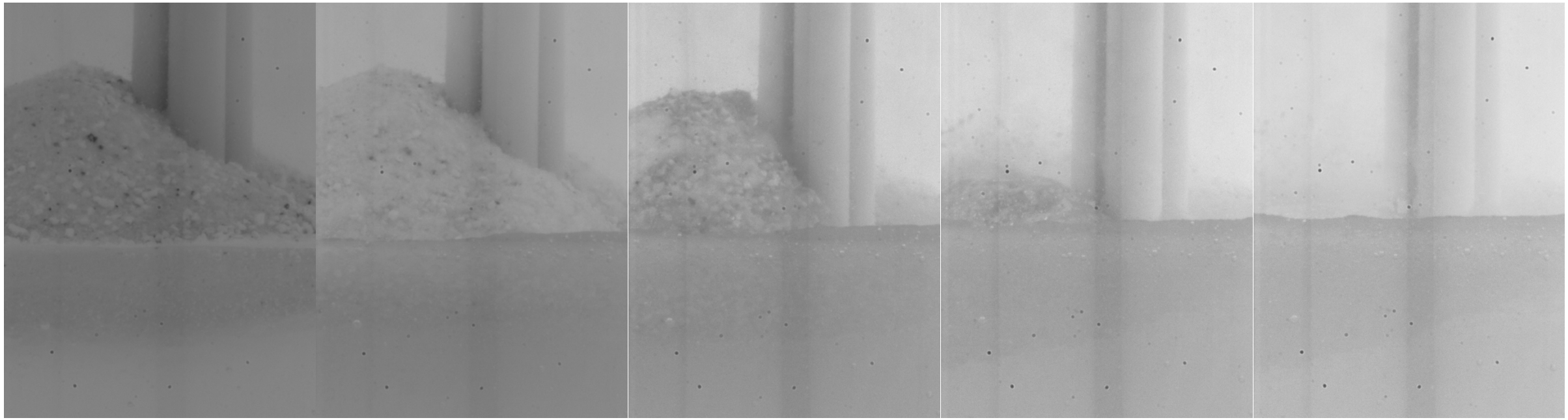
Melilite formation uncritical due to liquidus lower than melt temperature

Avoiding sand/silica accelerates melting-in

Silica from impurities remains problematic

ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

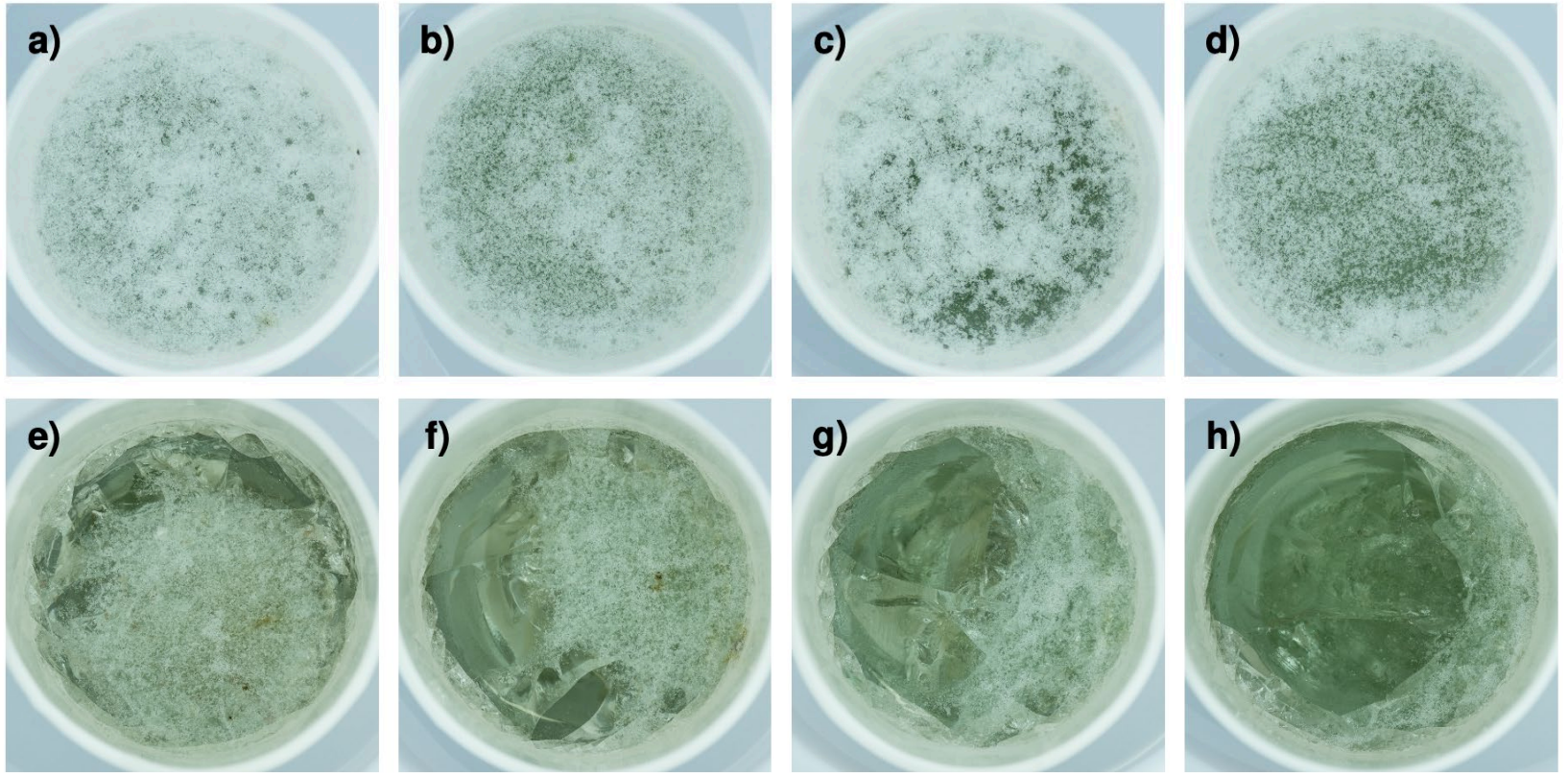
Evaluation of batch melting – CO$_2$-free batch 8 % Na2O



0 s | 90 s | 150 s | 210 s | 250 s

ZeroCO$_2$-Glass – Investigations on Meltability of CO$_2$-free Glasses

Evaluation of batch melting – CO$_2$-free batch 5 % Na2O

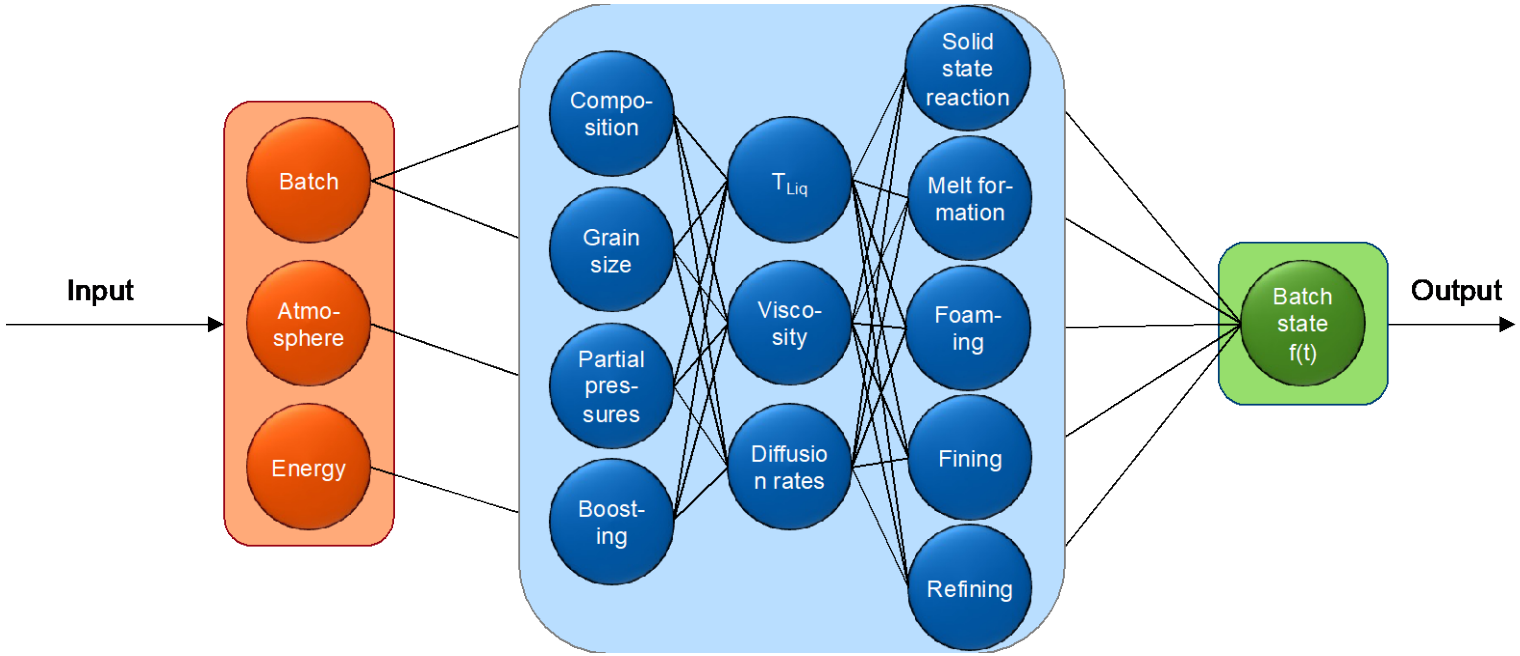


SLS reference batch

soda-ash and CO$_2$-free batch 5 % Na$_2$O by weight

Outlook — Understanding the batch melting

- Use furnace camera and batch monitoring system to evaluate batch melting in 2.5 tpd pilot plant
- Gain a **profound understanding** of the **melting and fining behaviour** based on **batch and glass properties** in **interaction with the energy input and furnace atmosphere**.



$ZeroCO_2$ Glass – Trial Plan

Acknowledgement

ENERGIE- UND CO2-EINSPAREN MIT ZEROCO2GLAS

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aufgrund eines Beschlusses des Deutschen Bundestages

Thank you to all contributors to this project!

- IPGR Members
- $ZeroCO_2$ consortium
  - Chair of Glass and Glass Ceramics – Institute of Mineral Engineering (Prof. Roos)
  - Department for Industrial Furnaces and Heat Engineering (Prof. Wuppermann)
  - Horn Glass Industries
  - Wiegand-Glas
- Prof. Conradt

Thank you for your attention

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