

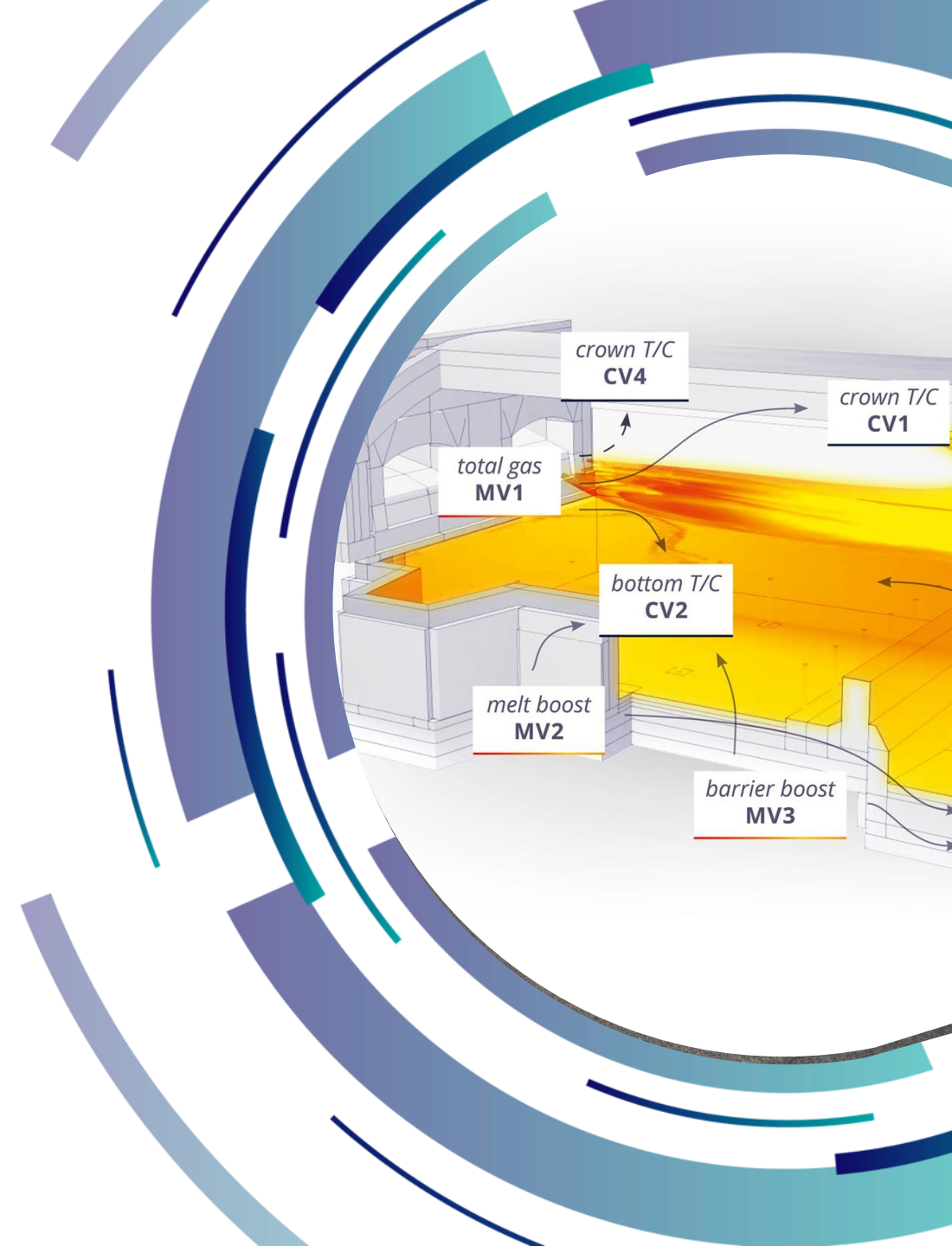
Tapping into Life Cycle Assessment (LCA) Insights for Cost Saving and Greenhouse Gases (GHG) Reduction in Glass Industry



Sarah Torkamani

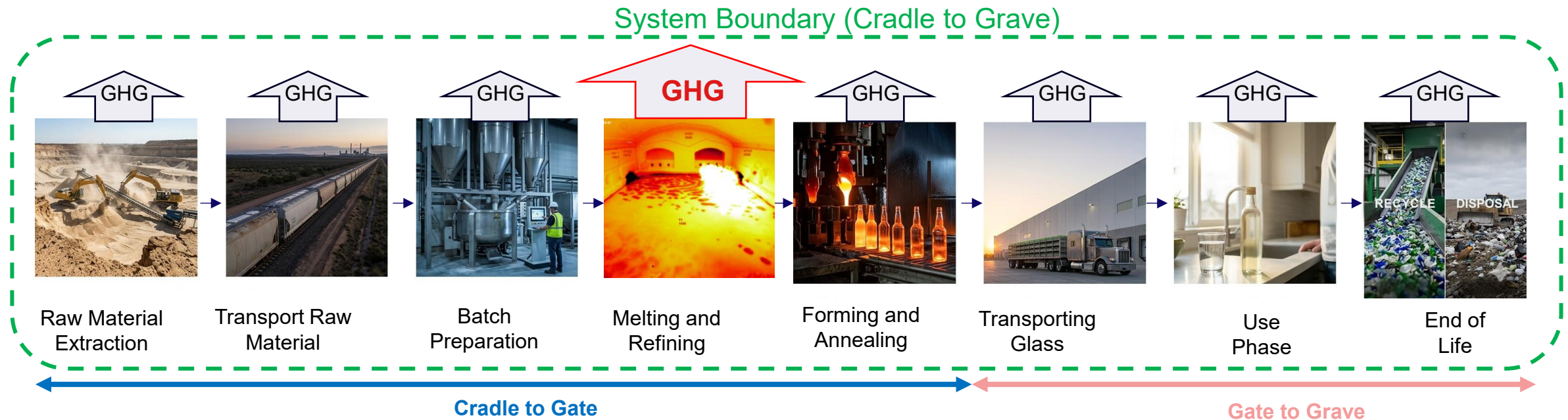
September 2026

Glass Service, a.s.
www.gsl.cz

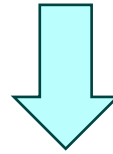


Life Cycle Assessment (LCA) to identify hotspots where coordinated actions deliver the highest impact

- What is Life Cycle Assessment (LCA)? LCA calculates the environmental impact of products or services throughout their entire lifecycle.
- Fundamentals of LCA are:
 - Functional unit describes a quantity of a product on the basis of the performance it delivers in its end-use application (e.g. tonne of saleable glass)
 - System boundary defines what is included in your assessment (e.g., cradle to grave, cradle to gate, gate to grave)
- Published LCA results show **melting** is the dominant GHG emitter and that cannot be fixed by one technology alone
- What are Greenhouse Gases (GHG)? GHGs absorb and re-emit infrared heat, slowing the loss of heat to space. Example are CO₂, CH₄, and N₂O.



$$\text{Life Cycle GHG Emissions} = \frac{\text{Total GHG Emissions}}{\text{Total Saleable Glass Produced}}$$

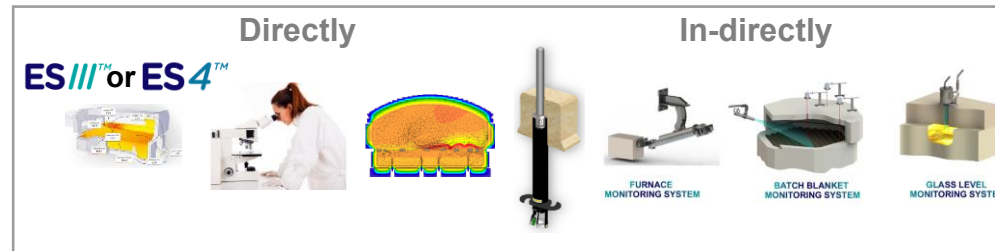


Life-cycle GHG & Cost Reduction Solutions

Increase Melting Efficiency



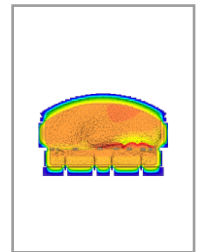
Reduce Glass Defects



Switch Fuels



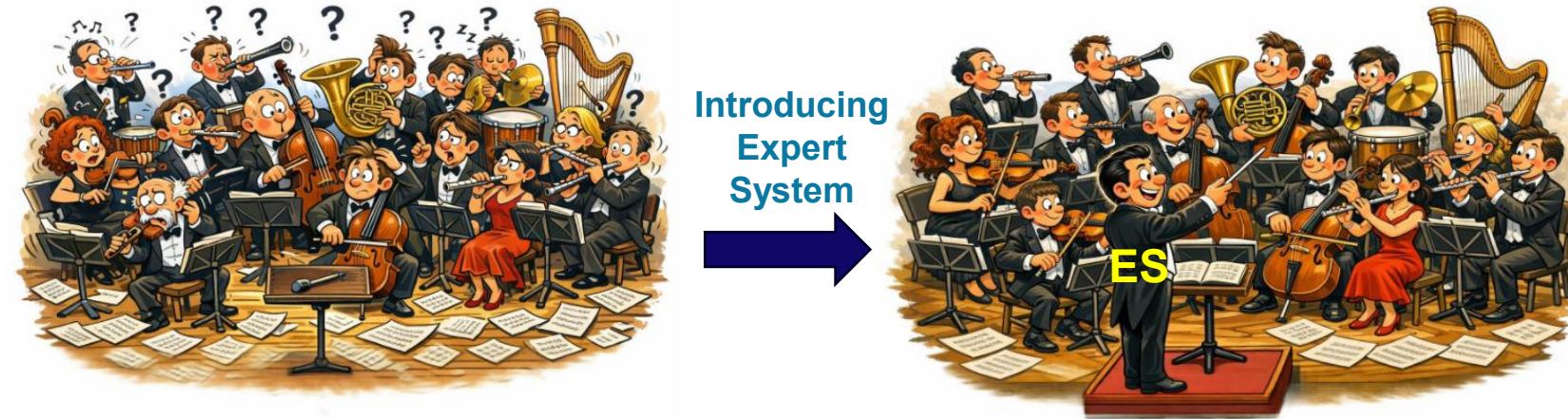
Recycle Glass



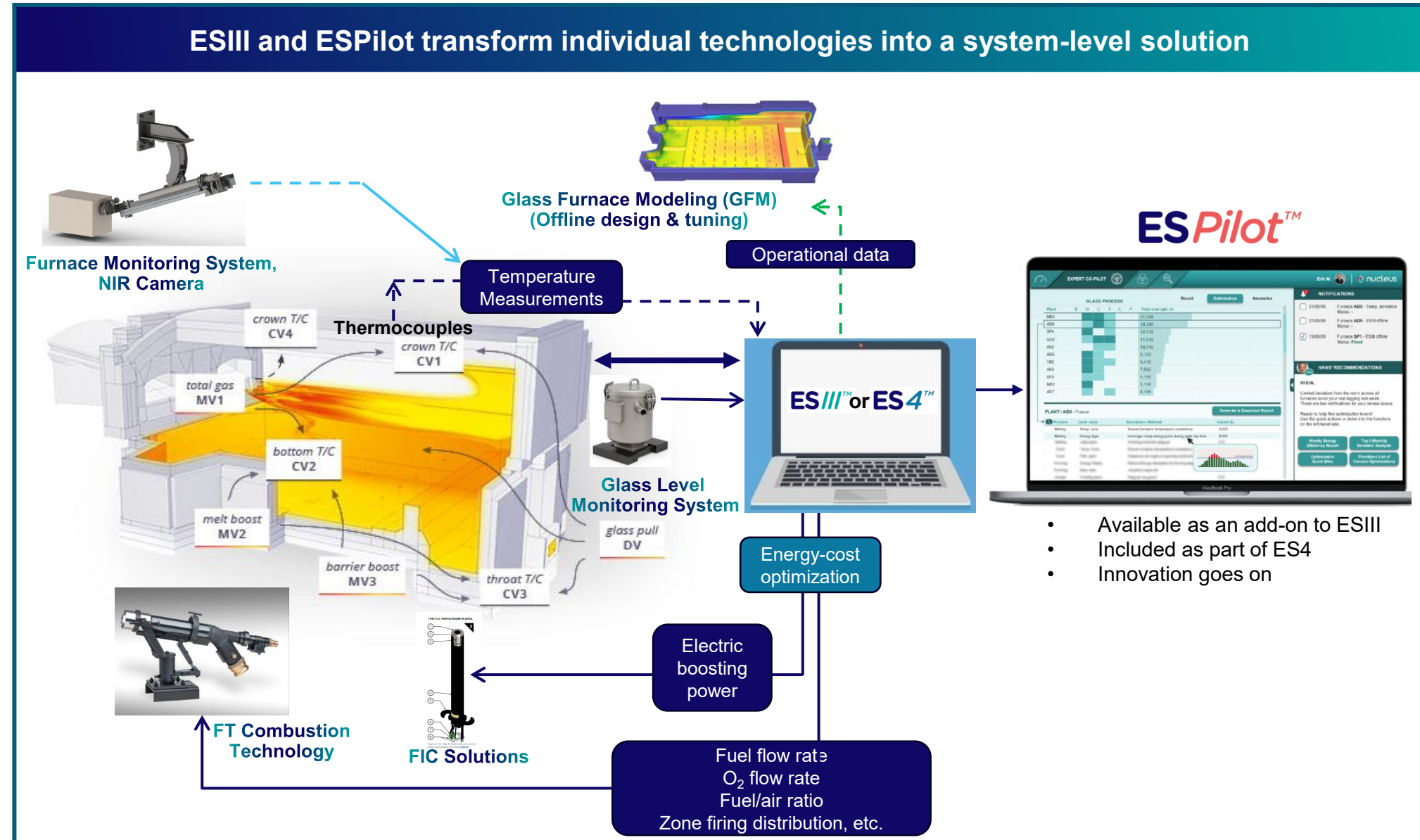
Modeling → Combustion → Sensors → Advanced Control → Automation & Optimization

Expert System is a GS furnace control software that acts like a conductor. It ensures all GHG & energy saving technologies work well together.

- GS Group technologies enable cost savings and GHG reduction.
- Expert System ensures all these furnace technologies work together in coordination:
 - Furnace control software at supervisory level
 - Worldwide installations > 440
 - Model-based Predictive Control (MPC)
 - Return in investment < 1 year
 - ESPilot provides benchmarking insights
- **Our newly-designed ES4 is not just for control. It's a performance platform.**



Expert System is the digital backbone enabling coordinated operation of multiple energy saving/decarbonization technologies



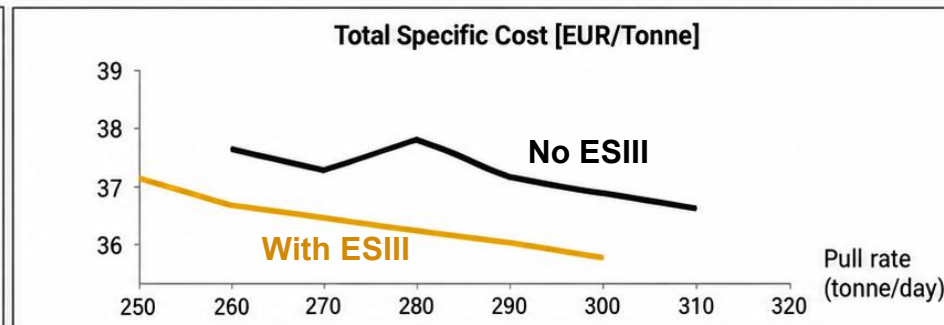
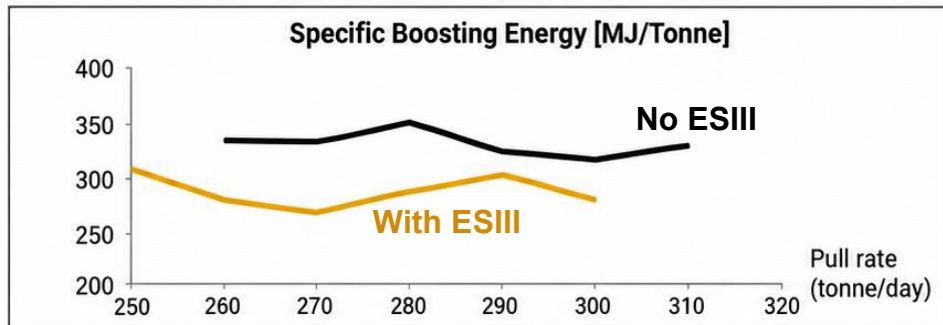
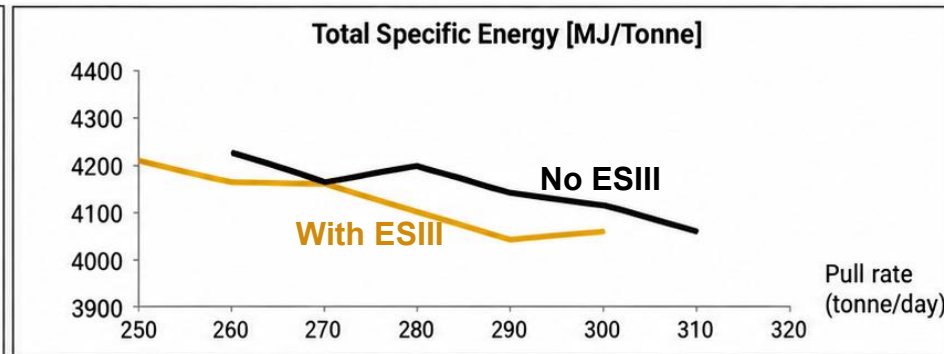
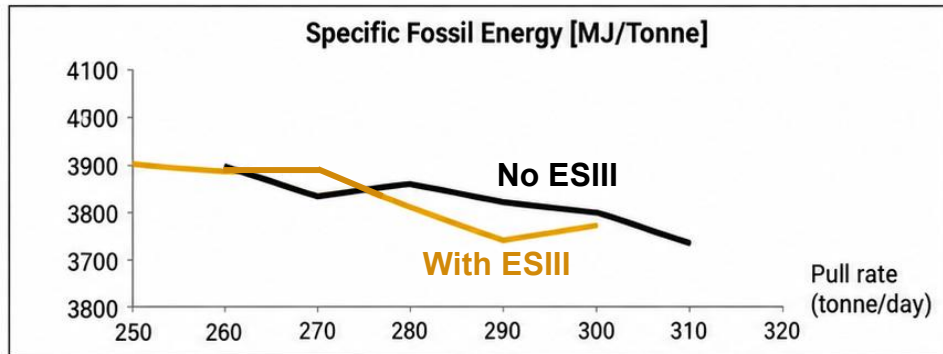
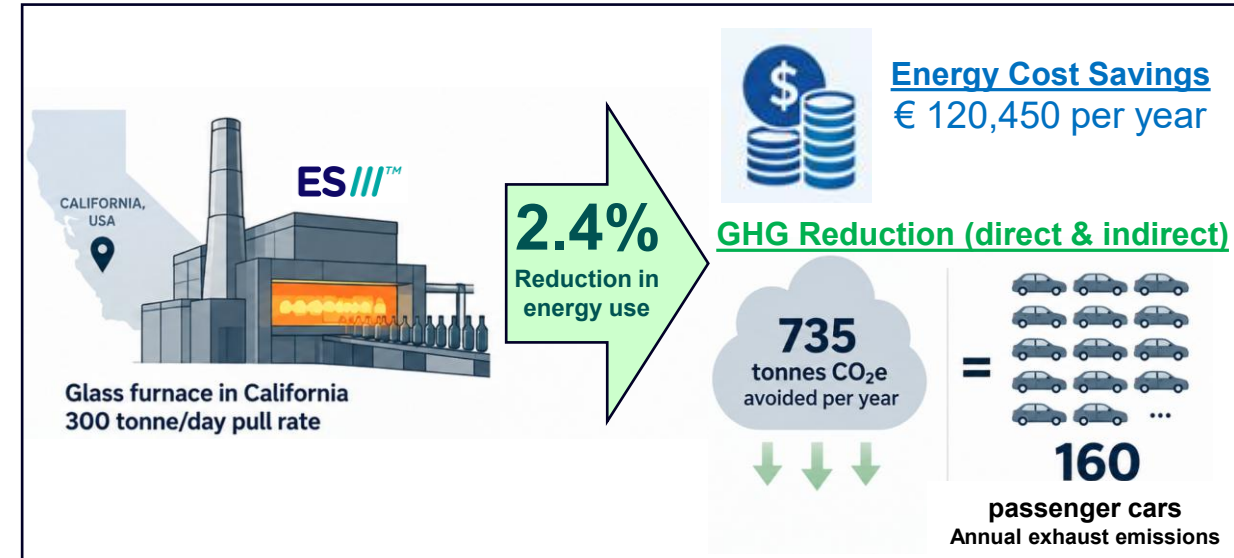
Expert System Reduces Energy Cost and GHG Emissions

EUROPEAN FURNACE — measured / calculated from operating data

- On a 300-tonne/day furnace, ESIII reduced energy use by up to 3.8%.
- 2.4% energy saving would reduce cost by ~€1.1 per ton, or € 120,450 annually.

CALIFORNIA SCENARIO — estimated environmental impact

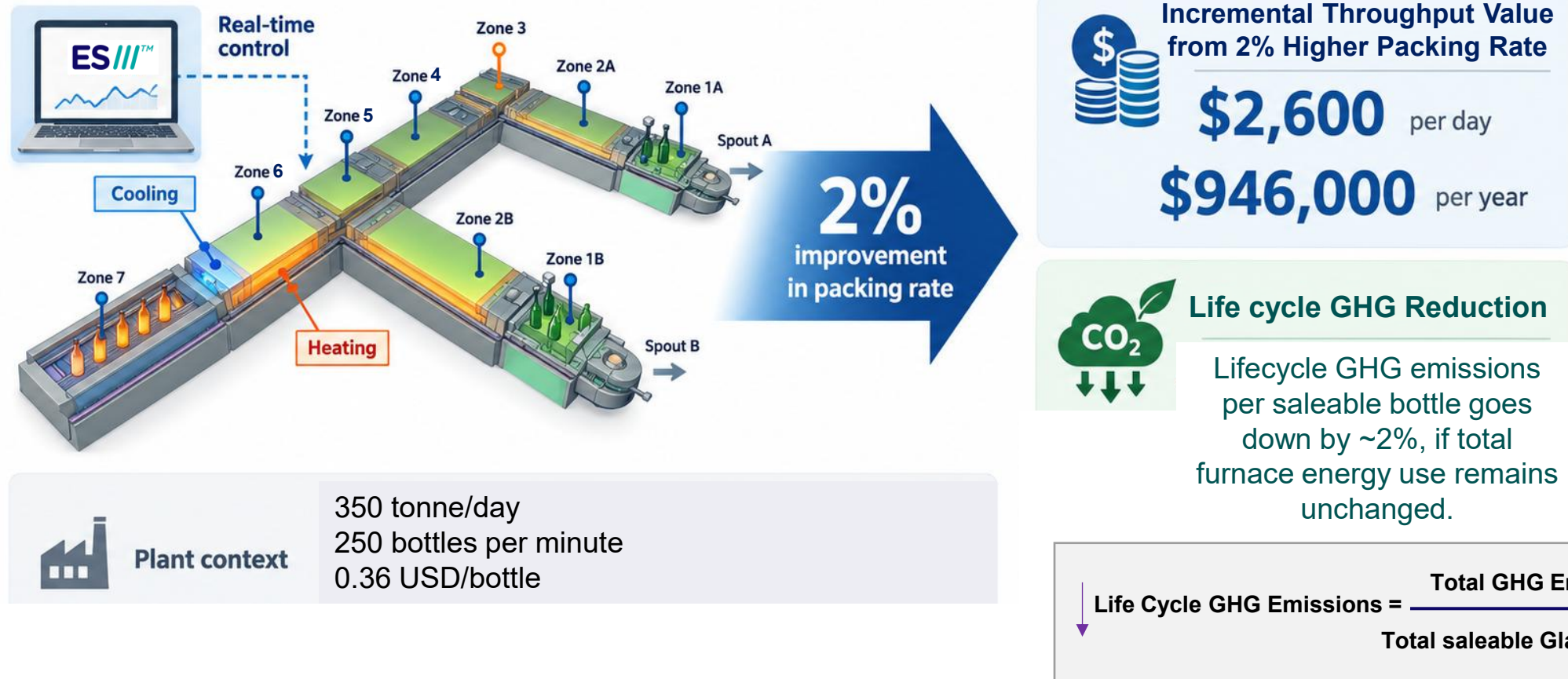
- GHG reductions vary with the fuel's carbon intensity.
- For a 300-tonn/day natural-gas furnace with ~8% electric boosting in California, a 2.4% energy saving could avoid ~ 735 tonnes CO₂ eq per year, equal to emissions of 160 cars.



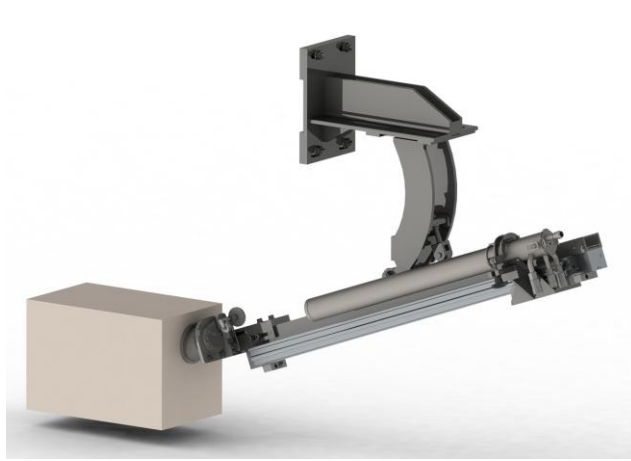
Note: Energy and cost results are based on a European furnace. GHG reduction is an illustrative California scenario using California fuel/electricity emission factors.

Optimized thermal control of forehearth via Expert System improves packing performance

- ESIII may improve production efficiency by 1% to more than 3% (depending on the operational condition).
- Real-time zone control increases packing rates, while lowers cost and reduces life cycle GHG emissions.

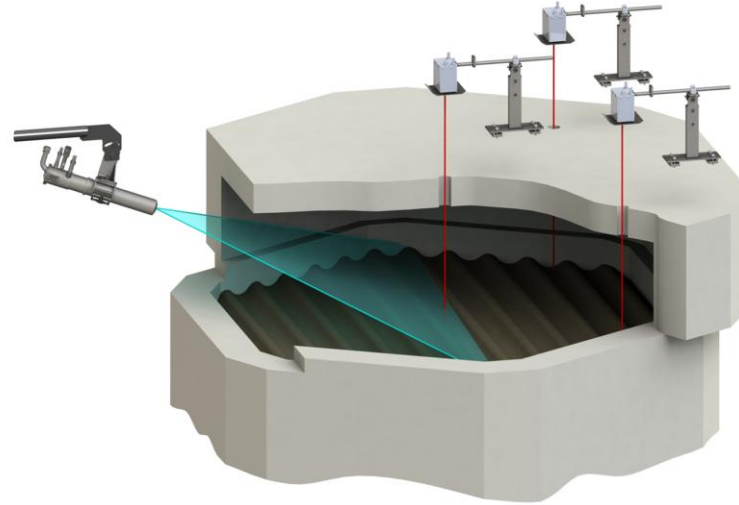


GS Advanced Sensors to Monitor Melting Process & NOx Trends



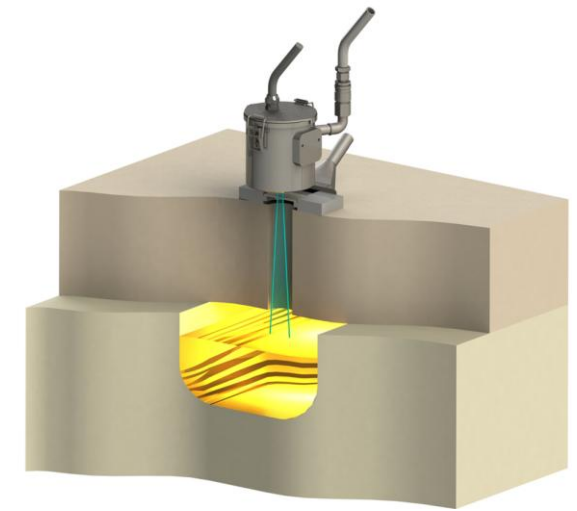
FURNACE MONITORING SYSTEM

(Temperature monitoring can enable taking on-time informed corrective actions to control NOx)



BATCH BLANKET MONITORING SYSTEM

(for cold top furnaces)



GLASS LEVEL MONITORING SYSTEM

2 to 8% fuel savings with optimized combustion system

Proper injectors / burners

- Increase fuel efficiency & reduce emissions
- Increase refractory's lifespan

How?

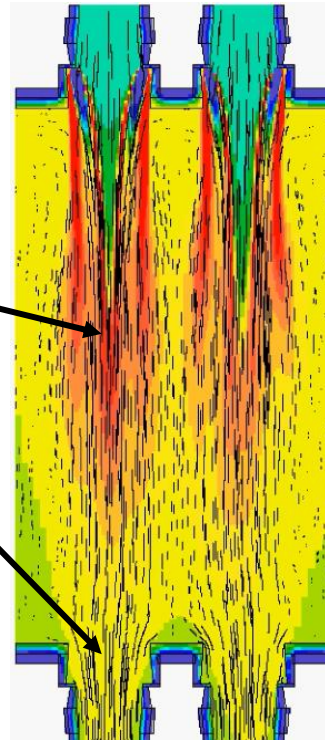
- Optimizing flame shape and glass melt coverage
- Maximizing flame's radiative properties
- Sealing contact between burners and burner blocks

Benefits

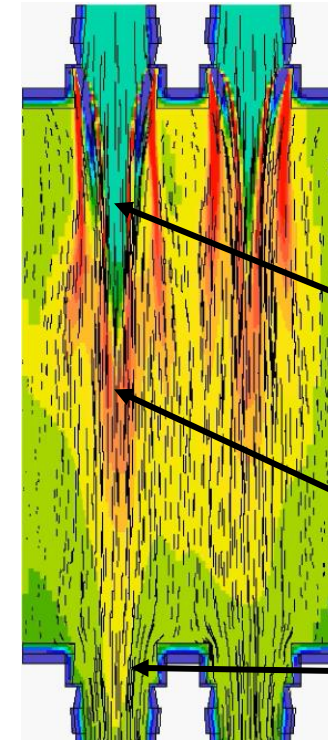
- 2-8% fuel savings depending on operational conditions

GFM CFD Study of a Furnace before and after Combustion Optimization with FlammaTec FLEX System

Before optimization

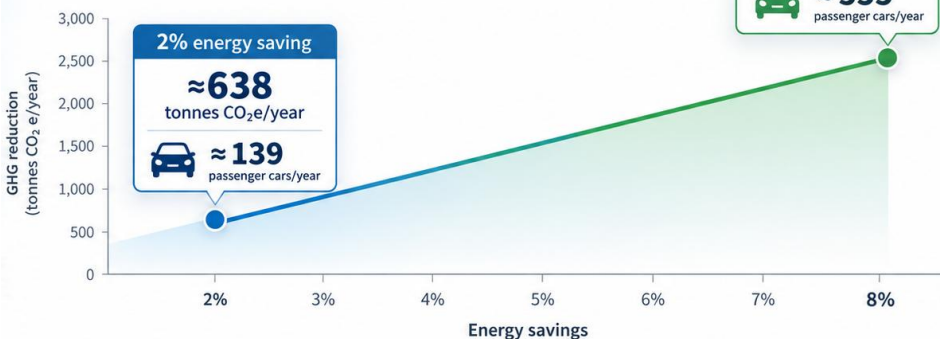


Optimized flame



FT FLEX

Estimated annual GHG reduction
(tonnes CO₂e per year)



Note: GHG reduction is an illustrative California scenario using California fuel/electricity emission factors for a 300-tonne/day furnace using natural gas.

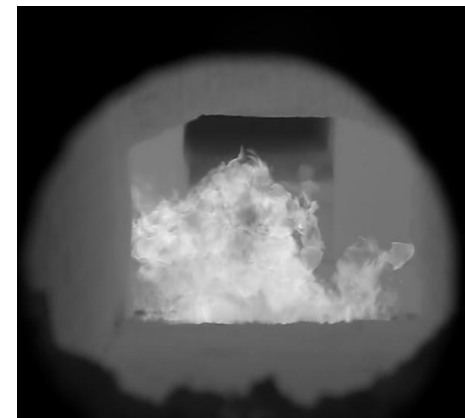
Libbey's Furnace Hot-Conversion by FlammaTec (FT) shows Fuel Savings > 2.5% MMbtu/ton



FLAMMATEC
Combustion Technologies

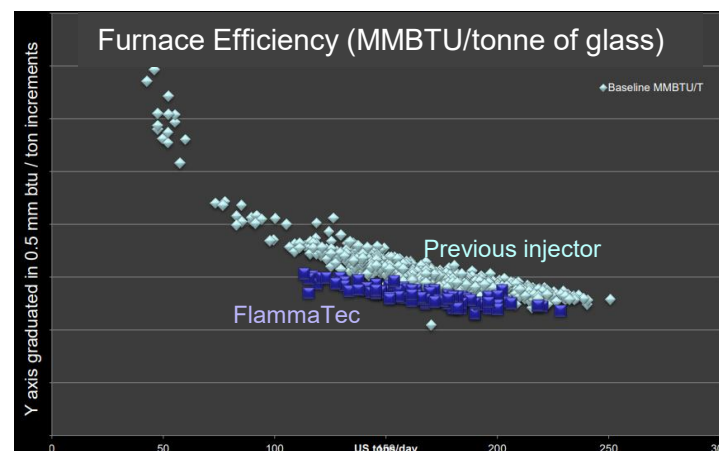
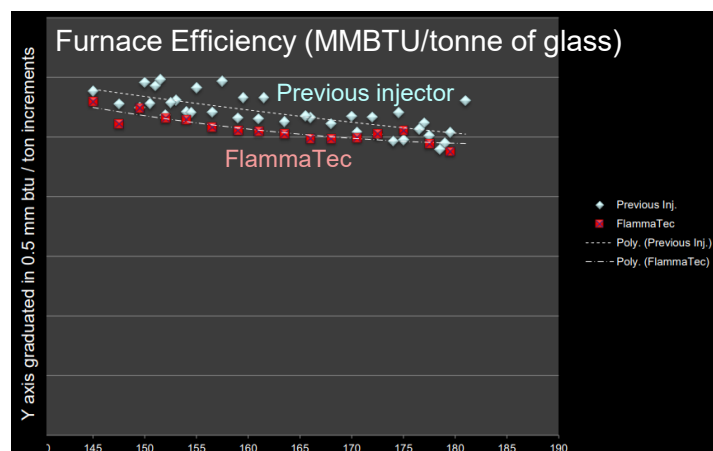


- FT installed low-NOx flexible dual gas injectors for two furnaces at a Tableware plant at Libbey, Inc.
- Flame improvement, excess air control, stabilization and a slight positive shift in redox were observed.
- Independent flow control through primary and secondary fuel streams

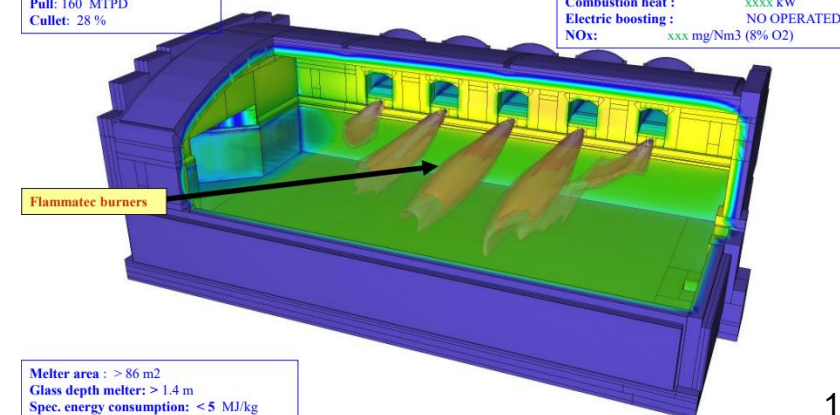


FT Installation

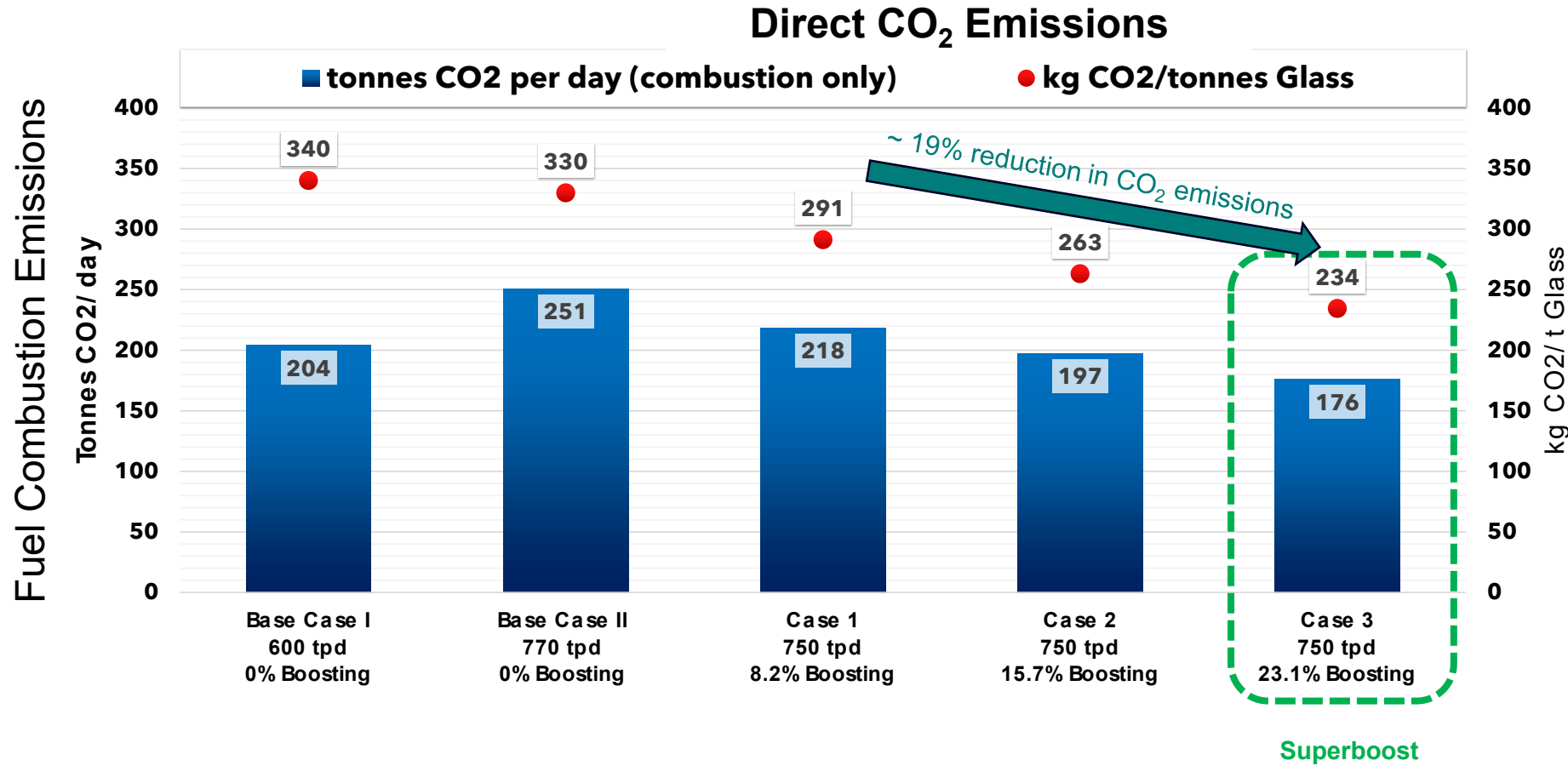
Furnace Operation Comparison (energy per ton of glass produced)



Furnace type : cross fired
Glass type : soda lime
Pull: 160 MTPD
Cullet: 28 %



Super-boosting reduces GHG emissions from combustion if clean power is used



Note: CO₂ values shown are combustion-only and exclude indirect emissions

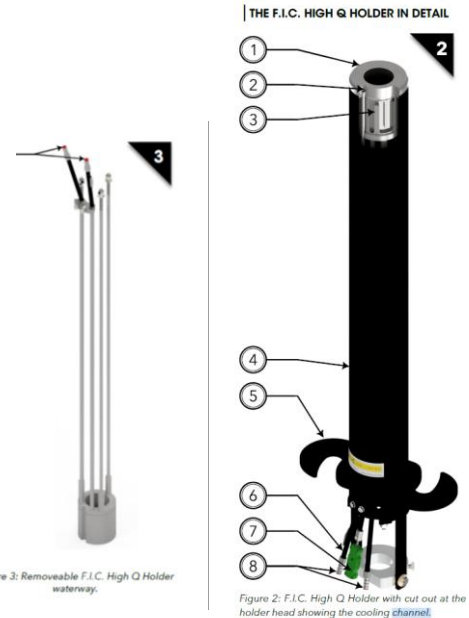
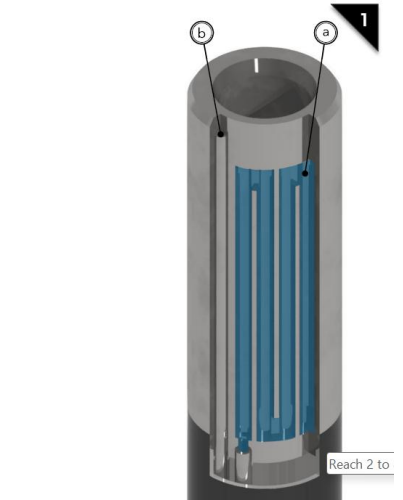
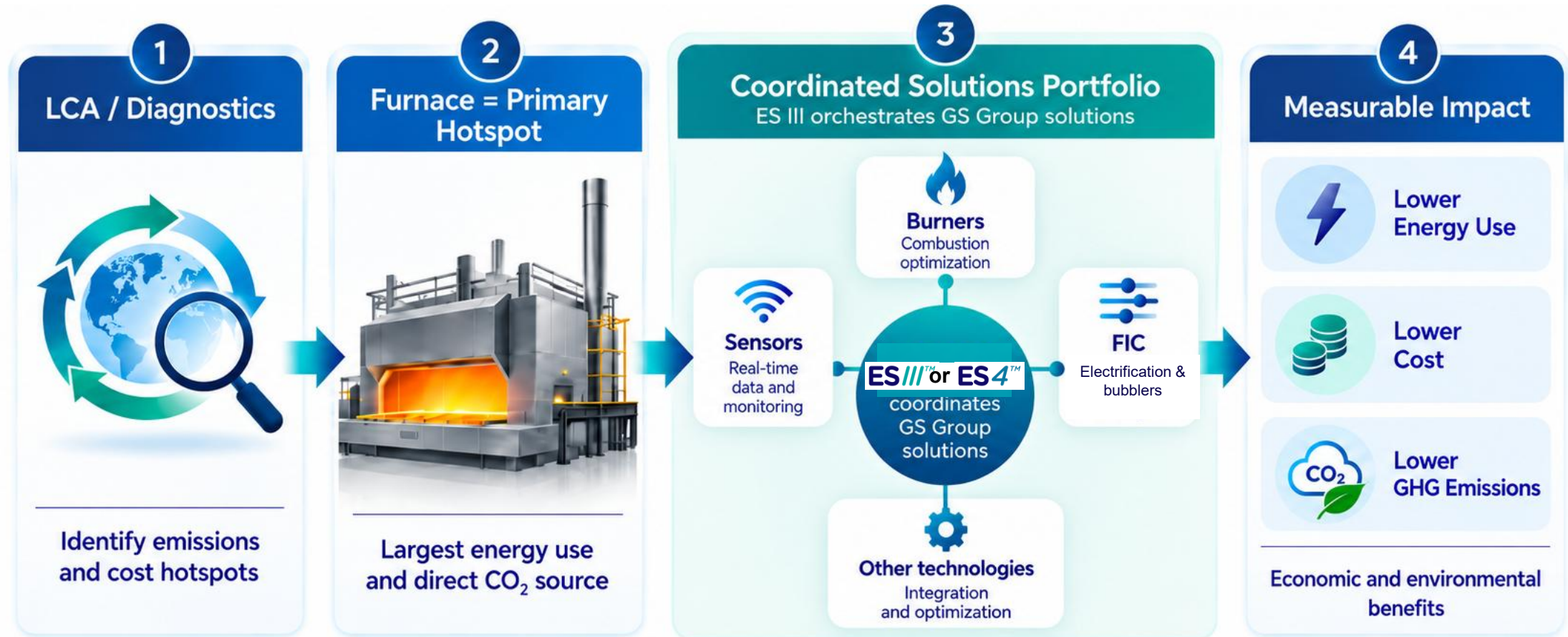


Figure 3: Removeable F.I.C. High Q Holder waterway.

Figure 2: F.I.C. High Q Holder with cut out at the holder head showing the cooling channel.

Summary: From LCA Insights to Operational Impact



Impact depends on furnace location, energy mix, and operating conditions.

| Thank you!

GS Group

<https://www.gsl.cz>

<https://www.fic-uk.com>

<https://flammatec.com>

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Published LCA results show melting is the dominant hotspot and cannot be fixed by one technology alone

Life Cycle Assessment of Glass bottle

March 2020

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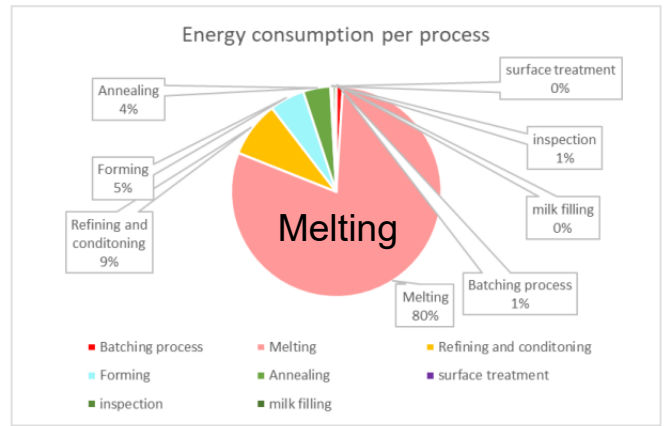


Figure 3: Total energy consumed in each process for packing milk in 1 million 1 litre glass bottles

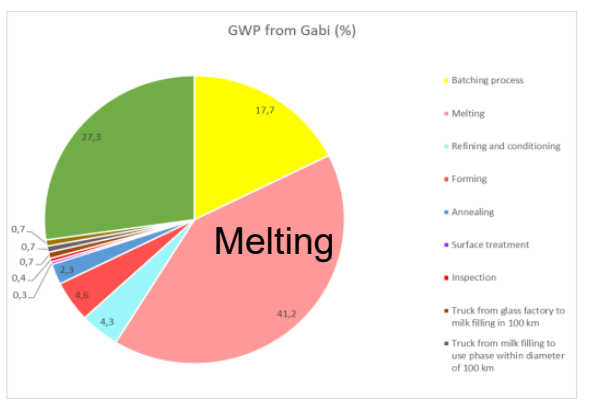


Figure 4: Pie chart of CO₂-eq percentage per process calculated by Gabi Education system

https://www.researchgate.net/profile/Aashwini-Uthayakumar/publication/344552941_Life_Cycle_Assessment_of_Glass_bottle/links/5f7fe990299bf1b53e18453f/Life-Cycle-Assessment-of-Glass-bottle.pdf

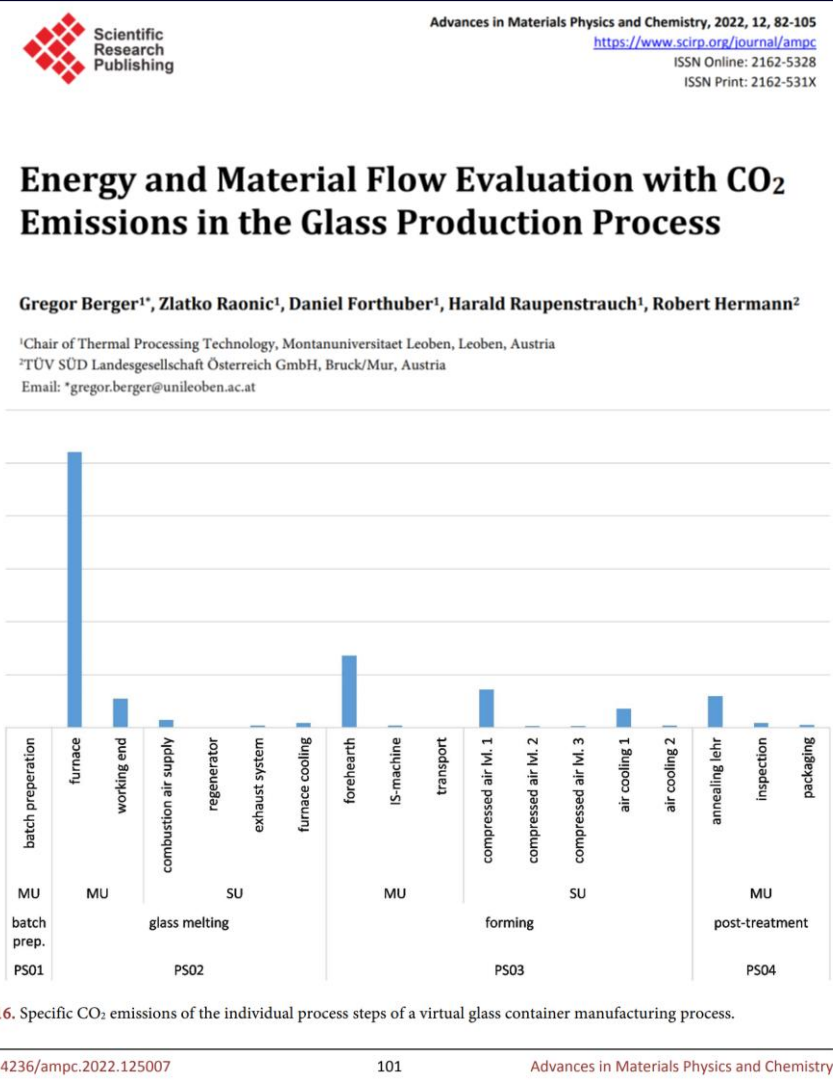


Figure 16. Specific CO₂ emissions of the individual process steps of a virtual glass container manufacturing process.

Emerging energy efficiency and carbon dioxide emissions-reduction technologies for the glass industry

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4. Conclusion

This paper describes 16 emerging energy efficiency and CO₂ emissions reduction technologies or processes for the glass industry. The information presented for each technology was collected from various publicly available sources. It is likely that no single technology will be the best or only solution for a more energy efficient glass industry – instead, a portfolio of commercial and emerging technologies should be deployed to address the increasing energy use and CO₂ emissions of the glass industry. The following table summarizes point estimates (in varying units) for energy and cost savings for the technologies that had such information.