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Title: Decarbonization the Glass Industry: Pathways, Challenges and Solutions

Large parts of the world are targeting a reduction in CO_2 emissions of approximately 55% over the next 30 years. It is evident that such ambitious targets cannot be achieved using current glass furnace designs. Although these regulations are currently most prominent in the EU, CO_2 reduction is rapidly becoming a global priority across other regions as well.

We are living in the *Glass Age*, where glass has become indispensable in our daily lives. From food packaging, drinking glasses, and pharmaceutical containers to window glass, automotive components, and communication fibres, glass is ubiquitous. More recently, its applications have expanded to include data storage and photonic glass-based CPUs. In addition, glass plays a critical role in renewable energy generation, particularly in wind turbines and solar panels.

The International Commission on Glass (ICG) plays a pivotal role in fostering collaboration and knowledge exchange across regions by organizing conferences focused on sustainability.

To achieve meaningful reductions in carbon emissions, new furnace designs and innovative technologies must be developed. Such advancements require the use of validated Computational Fluid Dynamics (CFD) tools, such as the GS Glass Furnace Model (GS GFM). No glass producer would risk constructing a new furnace concept capable of melting over 100 tons per day without rigorous analysis, detailed calculations, and CFD modelling. Recent trends show increasing interest in reducing carbon emissions through greater use of electric melting and hydrogen, similar to the widespread adoption of CFD modelling during the transition to oxy-fuel technologies. With the emergence of the next generation of large hybrid furnaces (with over 50% electric boosting) and fully electric melters, the demand for advanced CFD modelling is rising once again.

These complex furnaces, which incorporate multiple heat inputs, also require advanced control systems, such as model-based predictive control, to optimise the balance between electricity and natural gas consumption. This approach considers fluctuating energy costs and aims to maximise carbon reduction. To help to find the optimal approach GS/SEFPRO can start with a furnace audit and benchmark study.

The increasing use of electric boosting and melting is leading to higher glass melting temperatures, which in turn accelerates refractory corrosion. To address these more demanding conditions, SEFPRO has developed specialized refractory materials designed to reduce corrosion rates and associated risks. Furthermore, SEFPRO has successfully introduced Xeboost, Cruciforms, Tuckpro & SEFPRO Guard, an online monitoring system for refractory corrosion. The data generated by these sensors can be integrated into ESIII model-based control systems to optimise not only furnace operating costs and carbon emissions, but also furnace lifetime.

This presentation will address the following key topics:

1. Introduction: The role of the ICG and the significance of glass in modern applications – the *Glass Age*.
2. Renewable Resources: The importance of clean electricity for reducing carbon emissions and updates on global developments in renewable energy.
3. History of Electric Melting: A brief overview of the evolution of electric glass melting technologies.
4. Segment-Specific Technologies: Exploration of the most viable decarbonization technologies for various segments, such as crystal and tableware, container glass, borosilicate, fiberglass, and flat glass.
5. Case Studies: Examples of large-scale all-electric and hybrid melters currently in operation, with a focus on the performance of a large hybrid melter.

6. Forehearth Electrification: Insights into the potential for 70–90% energy and carbon emission reductions through electrifying forehearths.
7. Refractory materials & solutions: for high electric boosted furnaces, Xeboost, Cruciforms, Tuckpro and SEFPRO Guard
8. Product Life Cycle: Emphasizing the importance of considering the product life cycle, including glass cullet recycling, alternative decarbonized raw materials, both within and beyond the production loop.

Keywords:
Decarbonization, hybrid furnace, electric boosting, all-electric melting, CO_2 reduction, furnace design, forehearth design, energy audit, modeling, renewable energy. SEFPRO, Glass Service, FIC UK, FlammaTec, ICG.