# Evaluating low-carbon raw materials in glass production with GlassTrend

**In quantifying how batch materials shape the carbon footprint of glass melting and exploring alternative raw materials for soda-lime-silicate compositions, GlassTrend's step-by-step approach linked lab assessment, energy demand, and integrated costs to show how decarbonised sodium and calcium carriers can cut emissions significantly.**

**FOUNDATIONS** GlassTrend begins from a fundamental question: which decarbonised raw materials can truly drive sustainability in glass manufacturing? The answer demands a fully quantified examination of batch chemistry, furnace energy demand, $CO_2$ pricing, and the integrated cost of production, centred on soda-lime-silicate glass. Supported by eleven industrial sponsors, the partners show that raw materials are not secondary variables in decarbonisation but a central lever in meeting climate pledges toward 2030. Their work isolates the behaviour and impact of alternative sodium and calcium carriers, assessing their influence on both direct and indirect emissions as well as on overall energy intensity. The study begins with a reference case: a furnace operating with 60 percent cullet, converting a 1080 kg batch at 25°C into 1000 kg of melt at 1300°C. In this scenario, direct emissions from the batch reach 80 kg $CO_2$ per tonne of glass, while combustion of methane adds 240 kg $CO_2$ per tonne, bringing total direct emissions to 320 kg $CO_2$/t. This means that batch materials account for about one quarter of direct $CO_2$ emissions. With methane's lower heating value at 50 MJ/kg, the reference furnace requires 87.3 kg of methane per tonne of glass, or 4365 MJ/t. Raw materials, therefore, contribute to emissions not only through calcination but also by influencing the furnace's energy demand. Float glass data show that raw materials represent around 30 percent of the total $CO_2$ footprint, with contributions split between Scope 1 and Scope 3. As furnaces become more efficient,

the proportion of emissions coming from raw materials naturally increases, strengthening the case for targeted batch optimisation.

## ECONOMICS

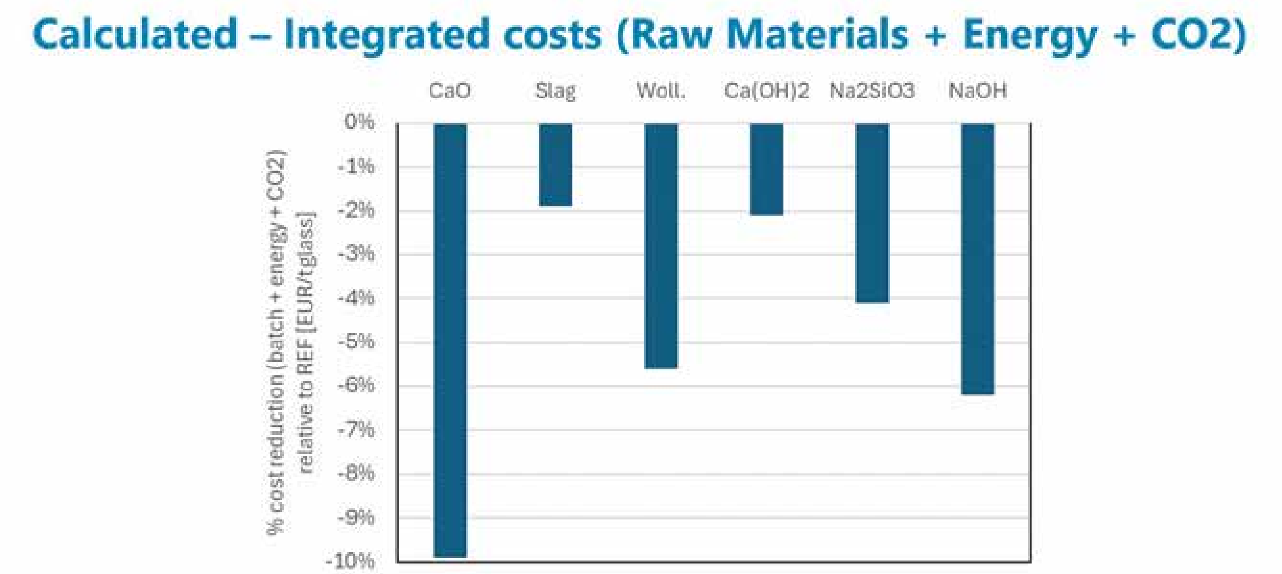
The economic side of the analysis is equally important. Over the course of the study, the $CO_2$ price rose from 37.5 EUR/t at kickoff to 86.7 EUR/t at project closure -an increase by a factor of 2.3- with projections pointing toward 50 EUR/t by 2030. Because raw materials affect both emissions and furnace energy demand, their selection directly shapes integrated cost. GlassTrend combines raw material prices, energy consumption and $CO_2$ cost into a single evaluative framework, quantifying how various substitution strategies shift the economic and environmental balance simultaneously.

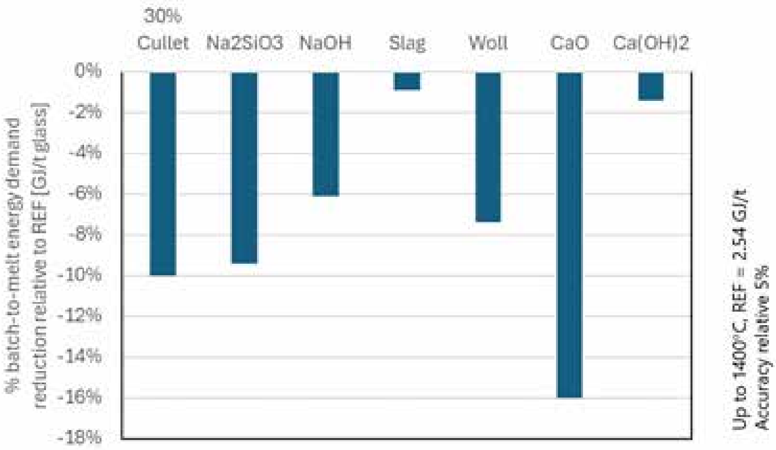
## SUBSTITUTION

To identify viable decarbonised raw materials, GlassTrend undertook a structured programme in partnership with its industrial project sponsors. They began by identifying alternative raw materials for soda-lime-silicate glass and assessing them at a laboratory scale. They then evaluated melting behaviour, examining foam, scum, emissions, and glass formation. Next, they quantified batch-to-melt energy demand up to 1400°C and translated these experimental outcomes into furnace-scale models describing energy use, emissions, and costs. This systematic approach ensures that any proposed raw material is judged according to industrial feasibility, not theoretical attractiveness.

## PERFORMANCE

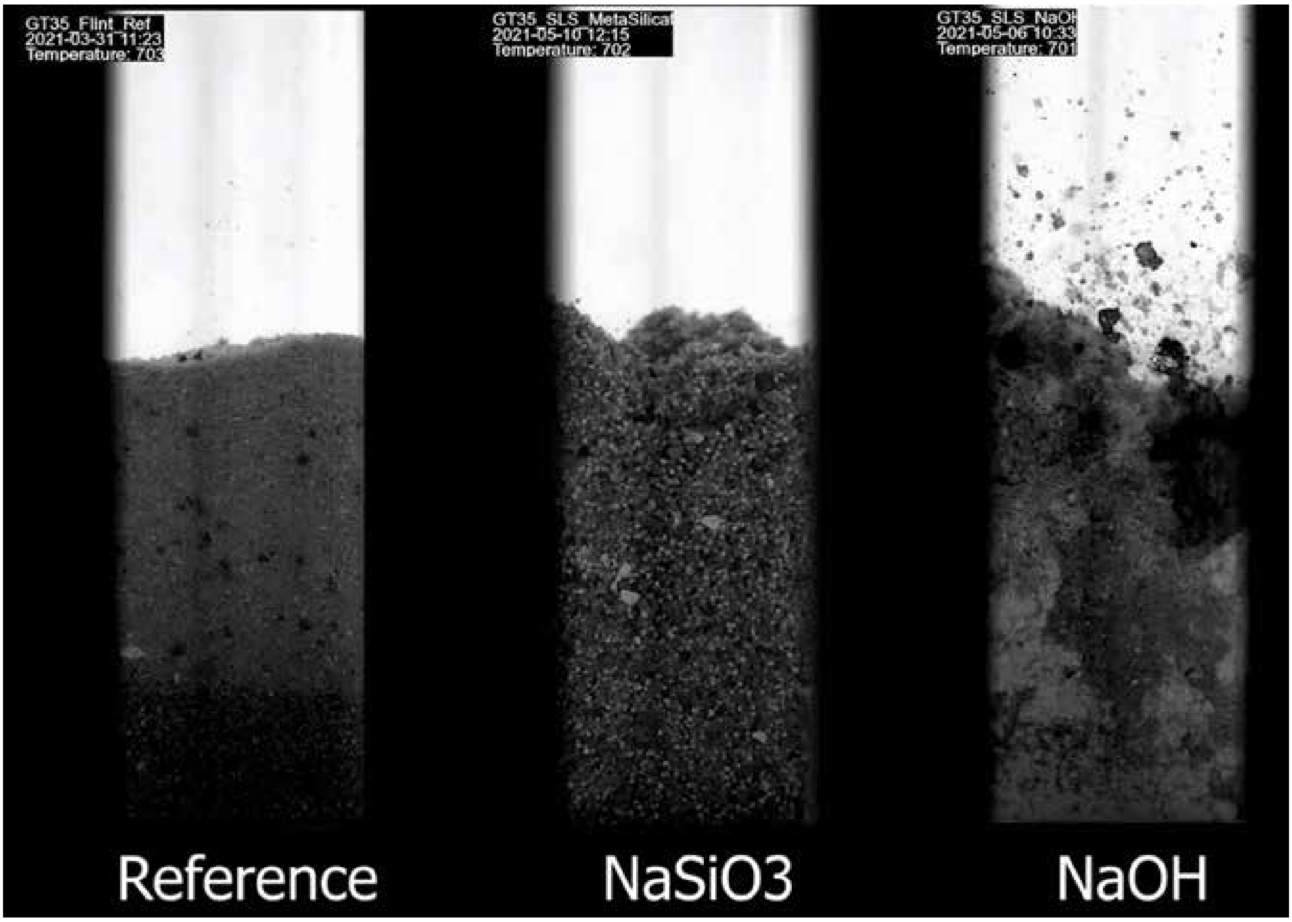
One of the study's central metrics is the batch-to-melt energy demand. For the reference soda-lime-silicate batch, GlassTrend measures an energy requirement of 2.54 GJ/t with a relative accuracy of 5 percent. When recalculated for alternative raw materials, the data reveal how different sodium and calcium carriers modify the thermal load of the melt. Reductions in batch-to-melt energy immediately translate into lower fuel consumption and thus reduced combustion-related $CO_2$. The picture grows clearer when direct and Scope 3 emissions are considered together. For a formulation with 50 percent cullet, direct emissions from batch plus combustion reach 239 kg $CO_2$/t and when Scope 3 contributions from raw materials are included, the combined total reaches 385 kg $CO_2$/t. These values confirm that raw materials exert influence far beyond their share of direct process emissions and that reducing their footprint can yield substantial overall savings. On the sodium side, the benchmark remains soda ash ($Na_2CO_3$), but GlassTrend evaluates alternatives including dry sodium silicate and electrically produced NaOH, as well as potential reductions in total soda content, now the focus of a new GlassTrend project. A key development comes from a Solvay pilot in Dombasle, where soda ash demonstrates a 50 percent lower $CO_2$ footprint than the standard material, excluding transportation. This reduced-footprint soda ash competes directly with natural soda, offering glass producers a practical means of lowering Scope 3 emissions without redesigning their formulation. Spray-dried sodium silicate, meanwhile, presents a different profile whose benefits and drawbacks must be assessed in relation to the energy and emissions required for drying. Through its integrated-cost approach, GlassTrend reveals how varied sodium carriers can shift both the environmental and economic calculus of glassmaking. Calcium carriers show similarly diverse impacts. The traditional limestone ($CaCO_3$) is compared with burnt lime, wollastonite, and calcium-rich slags. Burnt lime stands out for delivering a strong positive effect on energy savings-marked as having '+++ impact on energy savings'-while showing no change in the total $CO_2$ footprint under today's conditions. This makes it an attractive lever for improving furnace efficiency even when its net emissions performance remains comparable. Wollastonite and calcium-rich slags, especially in coloured glasses, pose more complex challenges. Their sulfur and iron content, tendency toward persistent amber colouration, and dependence on strict redox control limit their use. In addition, these materials are not easy to source, reducing their immediate applicability despite their theoretical advantages. Further considerations arise when examining sulfates and chlorides. These components, while sometimes proposed as substitutes, have the potential to create foam, generate emissions, cause scum formation and even prevent proper glass formation. GlassTrend underscores that decarbonisation measures cannot compromise basic production stability; therefore alternatives must be evaluated not only for their $CO_2$ reduction potential but also for operational robustness. A distinctive strength of GlassTrend's work is its integrated cost calculation, which incorporates raw material prices, furnace energy consumption and $CO_2$ costs. Glass producers may adapt the inputs-such as local raw material prices, gas costs, furnace efficiencies and $CO_2$ pricing - to align the model with their own operational context. This makes the methodology transferable across regions and market conditions while preserving consistent comparisons among raw material options. As carbon pricing intensifies and energy markets shift, some alternatives that once appeared marginal may become economically favourable. By integrating these variables into one




| REF | $Na_2SiO_3$ Dry | $Na_2SiO_3$ 5 $H_2O$ |
|---|---|---|
| 2.54 | -9.4% | +48.7% |

MJ/kg glass - Up to 1400°C
Accuracy - 5% relative




model, GlassTrend equips producers to anticipate such turning points. The analytical work is positioned within the broader context of global climate objectives. Direct $CO_2$-equivalent emissions in float glass production represent about 30 percent of the total footprint, while container glass data from 2005 show direct emissions of roughly 61 percent. Raw materials contribute 20-30 percent of these direct values and their optimisation can yield meaningful energy improvements. One striking combined scenario involving CaO and NaOH shows a reduction of around 35 percent in direct emissions, illustrating the potential scale of savings when sodium and calcium carriers are re-engineered together. With 2030 described as being 'right around the corner,' GlassTrend emphasizes the urgency of addressing raw materials now, rather than treating them as minor adjustments at the end of process development.

## OUTLOOK

Taken as a whole, the programme conducted by GlassTrend demonstrates that decarbonised raw materials form a practical and quantifiable pathway toward sustainability in glass manufacturing. Batch materials represent roughly one quarter of direct $CO_2$ emissions in key reference cases and their selection affects both melting energy and Scope 3 contributions. Sodium and calcium carriers with significantly reduced footprints or improved thermal performance can shift furnace behaviour, emissions and cost simultaneously. By merging raw material science with energy modelling, emissions accounting and integrated cost evaluation, the consortium provides manufacturers with a realistic roadmap for redesigning their batch in line with carbon, energy and economic constraints. In the end, decarbonised raw materials are not a single solution but a portfolio of carefully assessed options, grounded in measurable data and directly aligned with 2030 climate pledges. For GlassTrend and their sponsors, this work establishes how glass producers can meaningfully cut raw material-related emissions by 20-30 percent, improve energy performance and position themselves securely within a carbon-constrained industrial future - one tonne of glass at a time. ■

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