Decarbonization potential of the glass melting process via energy efficiency measures and fuel switching

(5) Dekarbonisierung: Industriesektor

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Motivation and central research question

The production of glass is energy-intensive, with around 80 % of the energy required for the melting process. Hydrogen can be used as an alternative fuel to decarbonize the melting process. However, the specific energy demand for the melting process fueled by hydrogen is unknown. Therefore, benchmarking the energy demand of the process is important. For this purpose, we model the glass melting process with natural gas and hydrogen combustion based on ideal thermodynamics. Based on the process model, we derive the specific energy consumption, the direct CO_2 emissions, and the waste heat recovery potential for the production of glass.

Methodical approach

We model the glass melting process based on ideal thermodynamic energy and mass balances. As shown in Figure 1, the system boundary for the glass furnace model contains the fuel combustion, and the melting process. The model considers natural gas or hydrogen as fuel, and air or oxygen for combustion. We apply four energy efficiency measures to reduce the fuel demand: waste heat recovery, electric boosting, usage of cullet, and oxyfuel combustion. Waste heat recovery preheats the air for combustion and decreases energy losses in the exhaust gas [2, 4]. Electric boosting decreases the fuel demand by heating the glass with submerged electrodes but is limited to low electric power of the heater [3]. Cullet is recycled glass and decreases the fuel demand by avoiding the energy required for the chemical glass reaction and the sensible heat of the CO_2 from the melting reaction [2, 4]. Oxyfuel combustion utilizes oxygen instead of air for the combustion to reduce the amount of inert gases in the combustion space [1].

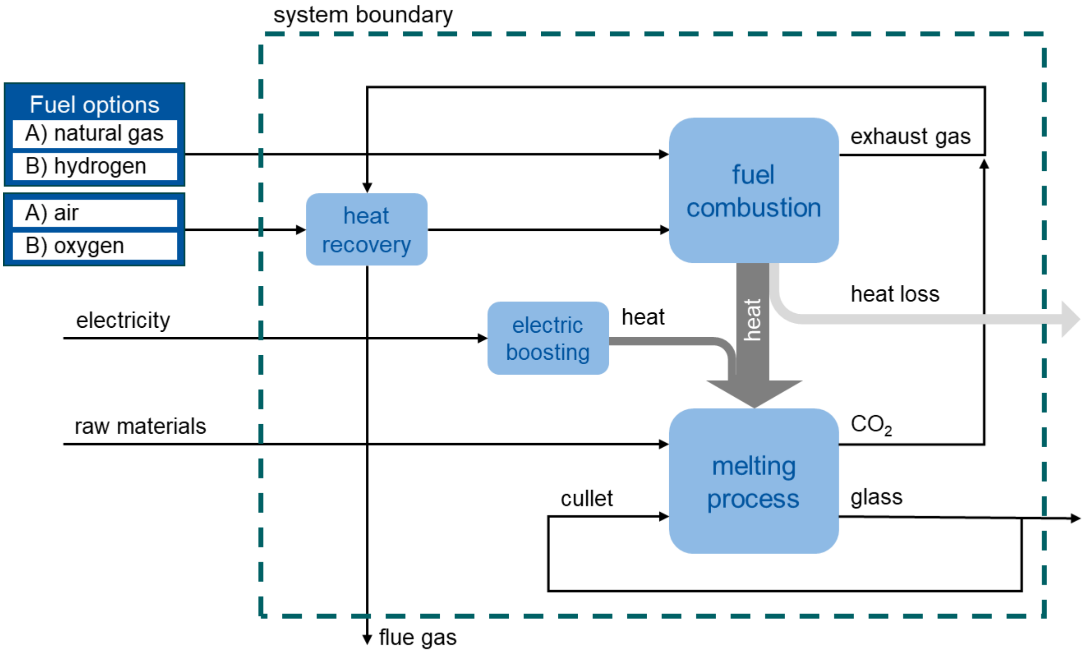

Figure 1: Schematic overview of the glass furnace model, including the heat supply by fuel combustion, the melting process, and energy efficiency measures.

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Using process conditions from the literature, we calculate the specific fuel demand, the direct CO_2 emissions, and the exergy of the flue gas. The exergy analysis allows a comparison of the waste heat at different flue gas temperatures.

Results and conclusions

Our benchmark process is the commercially used process nowadays, i.e., the melting process with natural gas combustion including waste heat recovery, electric boosting, and usage of cullet. The model for the benchmark process derives a fuel demand of 1.04 MWh natural gas and 459 kg CO_2 emissions per ton of glass.

Implementing oxyfuel combustion reduces the fuel demand by 18.3 % and lowers the emissions by 11.4 %. Considering the fuel switch to hydrogen and oxyfuel combustion reduces the fuel demand by 16 % and direct CO_2 emissions by 62.6 % to 171.7 kg $CO_2/tonne_{glass}$ compared to the benchmark. With hydrogen combustion, the remaining CO_2 emissions represent the process emissions from the melting reaction.

The exergy of the waste heat after the implemented waste heat recovery decreases by 11 % for oxyfuel combustion and increases by 1 % for combined hydrogen and oxyfuel combustion. Since the flue gas temperature increases in both assessed cases, further research regarding waste heat utilization is desirable.

To conclude, hydrogen and oxyfuel combustion are promising options for decarbonizing the glass melting process, whichcan reduce the fuel demand by up to 18.3 % and direct CO_2 emisions by up to 62.6 %.

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