IN4 CLIMATE .NRW

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Gas- und Wärme-Institut Essen e.V. gwi

Investigations into the use of natural gas / hydrogen blends and hydrogen for decarbonization in the glass industry

Floene Conference "Roadmap for the Introduction of Renewable Gases in the Industrial Sector"

HYGLASS H_2

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December 12, 2022

The challenge of decarbonized process heat

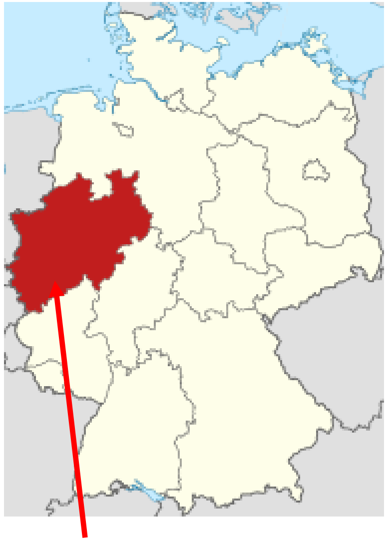
- In 2019, the industrial sector accounted for about **28 %** of the **final energy consumption** in Germany, and about **19 %** of the country‘s **GHG emissions**.
  (High-temperature) process heat is a major contributing factor, in many industries.
  In the glass industry, the melting process alone is responsible for about 75 % of the total energy consumption.
- There are various options to produce carbon-free or carbon neutral process heat, e. g. electrification with green power, CCUS, biogas/biomethane or **hydrogen**.
  Hydrogen has recently gained a lot of momentum, with many nations publishing national hydrogen strategies.
  At the same time, the European **gas industry** is moving forward with plans to **inject hydrogen directly into natural gas grids** as well as establishing **dedicated H_2 pipelines**.
- The glass industry will have to think about how their sensitive processes respond to natural gas/hydrogen blends or even pure hydrogen.

Quelle: GWI, 2020

The HyGlass project

Objective: Hydrogen in the glass industry – impact on glass manufacturing, development of solutions and potentials in NRW

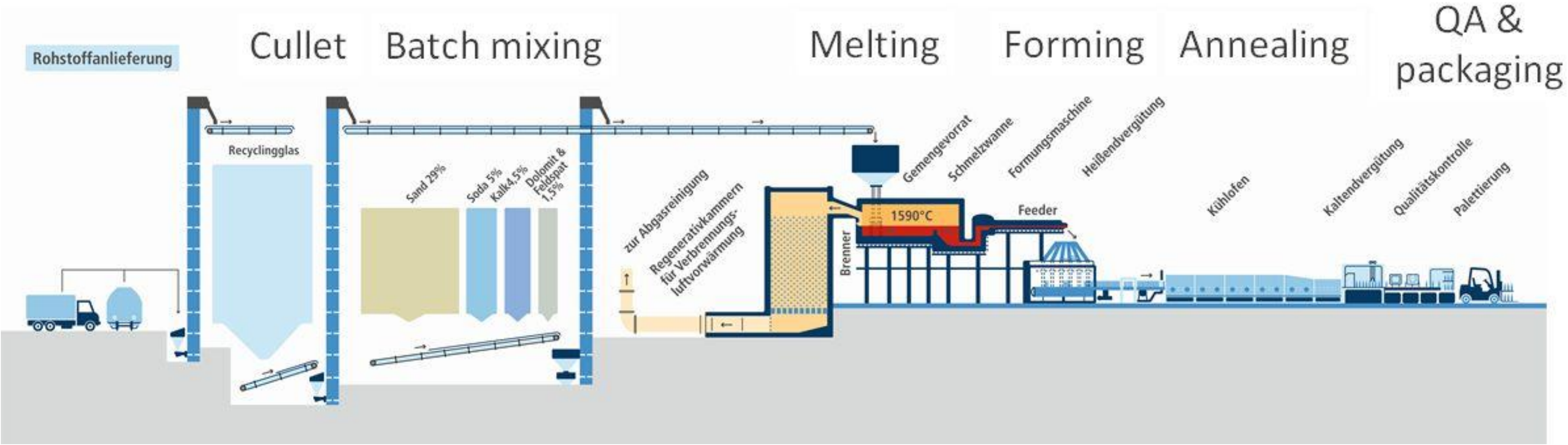
- Investigation of the impact of different levels of hydrogen admixture (up to **100 % H_2**) on the different combustion processes in glass manufacturing in terms of efficiency, heat transfer, pollutants, temperatures, CO_2 emissions, economic considerations, safety aspects, on product quality, lifetime, plant operation. …
- **Transfer** of the results **to real-life plants** using **CFD simulation** and **semi-industrial test rig experiments**
- **GIS analyses** and **gas grid simulations** for various scenarios of hydrogen admixture with spatial and temporal resolutions for glass production sites in NRW.



about 20 % of the turnover of the German glass industry is generated in NRW.

Quelle: GWI, 2020

The container glass manufacturing process



Quelle: GWI, 2020

Fuel properties: CH_4 vs. H_2

	Unit	100 % CH_4	80 % CH_4 / 20 % H_2*	100 % H_2
W_S	MJ/m_N^3	53.37	50.76	48.24
$H_{i,vol}$	MJ/m_N^3	35.89	30.87	10.79
$H_{i,m}$	MJ/kg	50.03	58.13	120.01
d	-	0.5571	0.4596	0.0698
Air_{min}	m_N^3/m_N^3	9.524	8.095	2.381
T_{ad} (λ = 1)	°C	1,951	1,960	2,106
s_L (λ = 1)	cm/s	38.57	45.22	209
$V_{flue, wet}$ (λ = 1)	m_N^3/MWh	1,055	1,049	961
Specific CO_2 emission**	g CO_2/MJ	55	51	0

Reference system: 25 °C / 0 °C

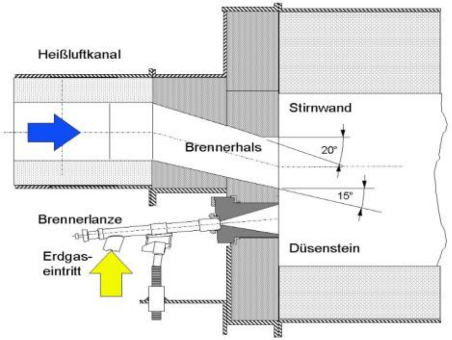
*: vol.-%

**: only CO_2 emissions due to combustion are considered

Quelle: GWI, 2020

1st measurement campaign, December 2020

Impact on the combustion process



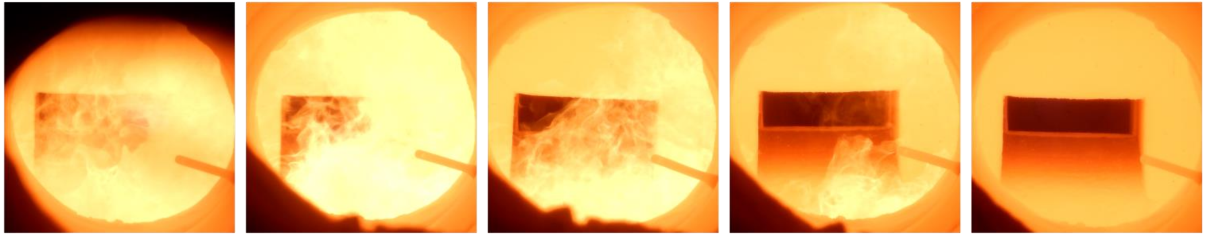
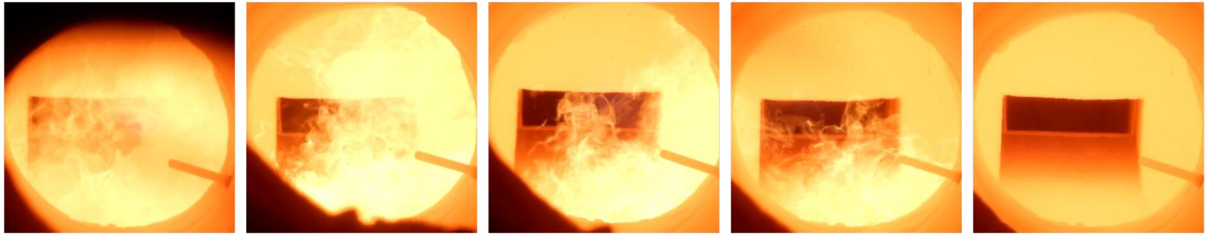
Measurement campaign:

- Underport configuration, variable-momentum lance
- 0 - 100 vol.-% H_2 admixture (0, 10, 30, 50 and 100 vol.-%)
- 2D field measurements (CO, CO_2, NO_x, $O_{2.}$ temperature)
- Different control scenarios
- $P \approx 500$ kW, $\lambda \approx 1.1$, $T_{air} = 1{,}150$ °C

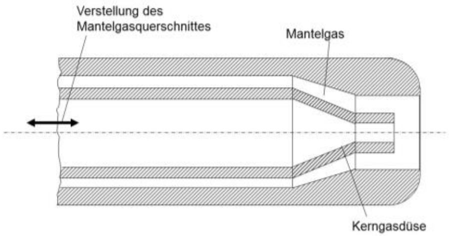
Quelle: GWI, 2020

Impressions from the GWI high-temperature test rig

H_2 - Anteil im Brenngas (volumetrisch)

	Brenngasverteilung	0 %	10%	30 %	50 %	100 %
Center flow 40 % of total fuel flow for NG	**nicht optimiert:** Verteilung von Kern- und Mantelgas wurde nicht angepasst.					
Center flow **always** 40 % of total fuel flow	**optimiert:** der Kerngasvolumenstrom wurde auf 40 % der Brenngasmenge (gesamt) eingestellt.					

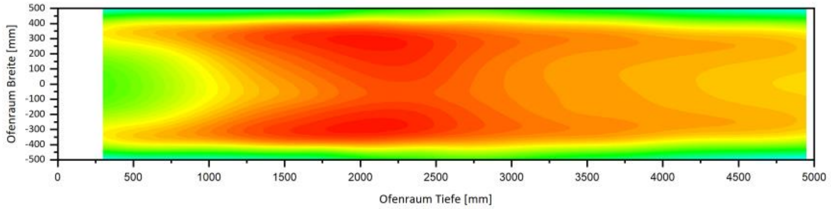
Variable momentum lance:



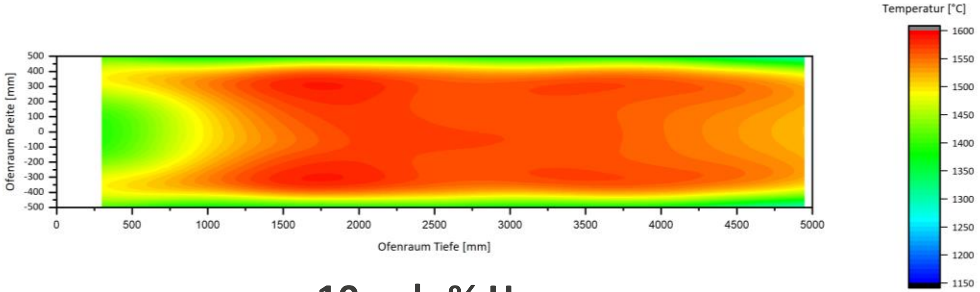
Quelle: GWI, 2020

Test rig experiments: temperature distributions

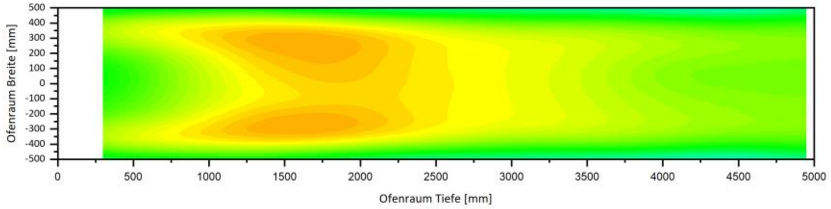
Impact of H_2 admixture on the temperature distribution (horizontal burner plane)



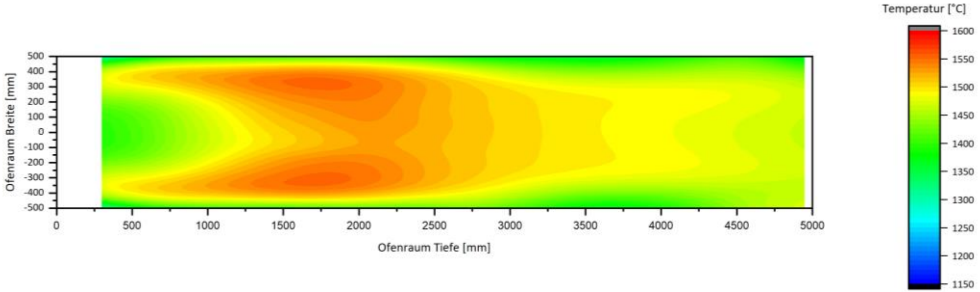
0 vol.-% H_2



10 vol.-% H_2



50 vol.-% H_2



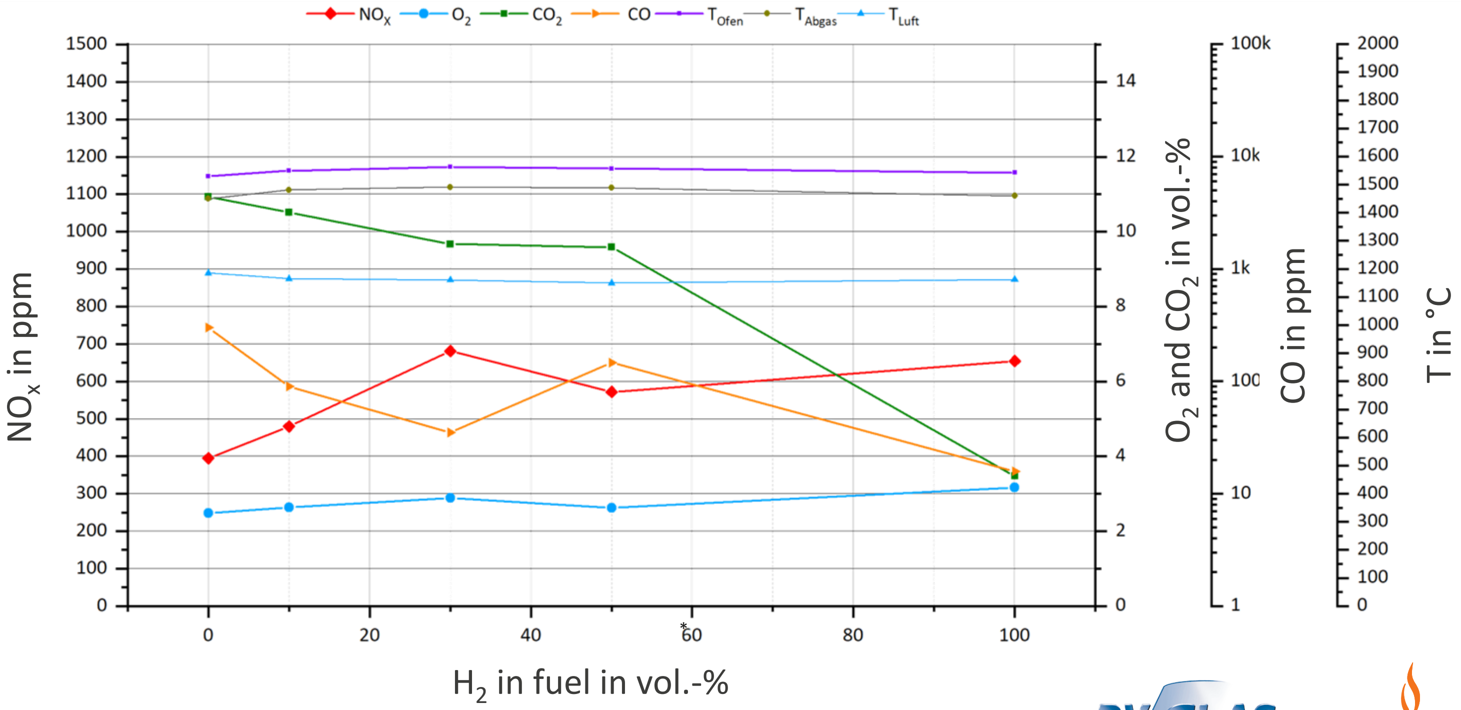
100 vol.-% H_2

Quelle: GWI, 2020

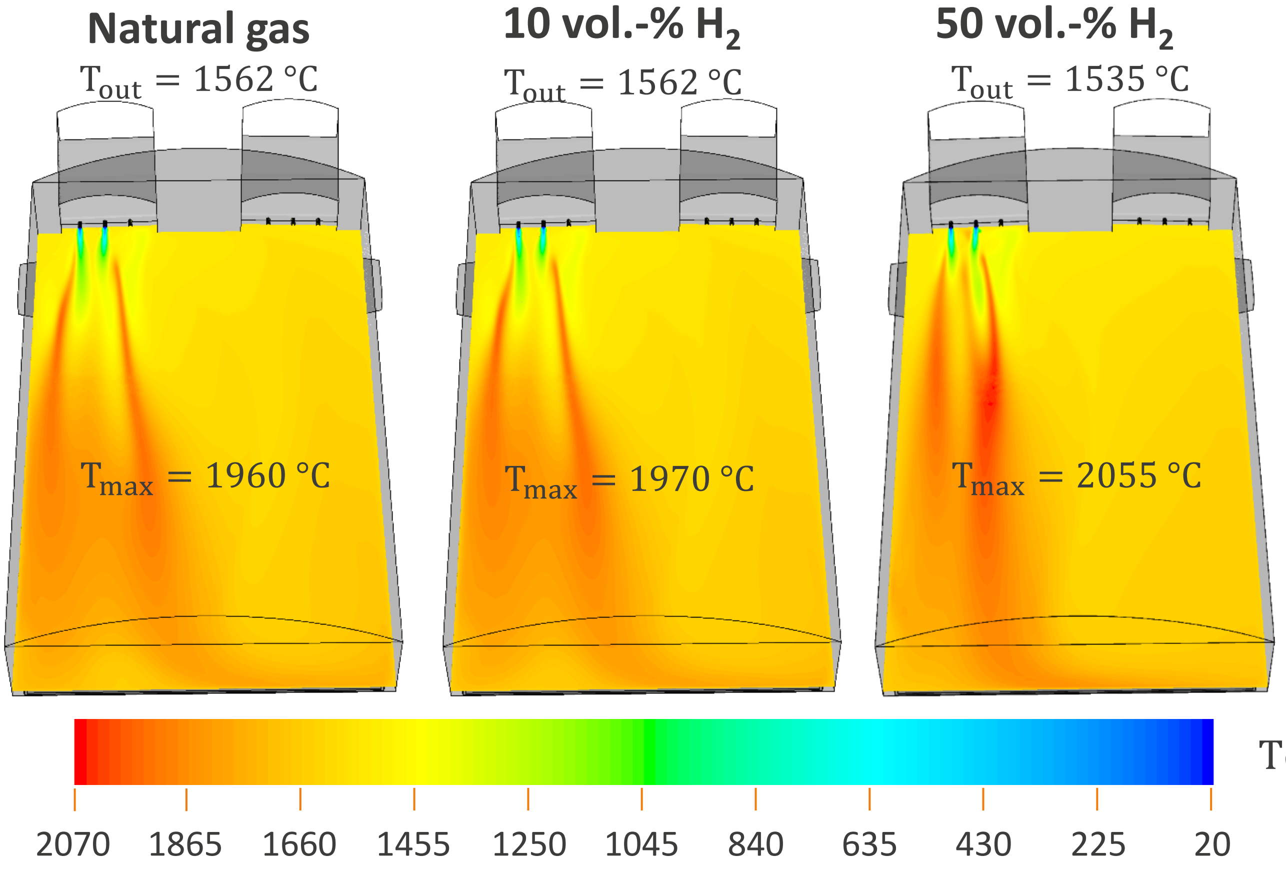
Measurements at the GWI test rig

Impact of the H_2 admixture on flue gas temperature and composition

Firing rate: ≈ 500 kW
Air excess ratio: ≈ 1.1
T_{air}: ≈ 1,150 °C



CFD simulations: Impact of H_2 on a regenerative glass melting furnace (P, λ und T_{air} constant)

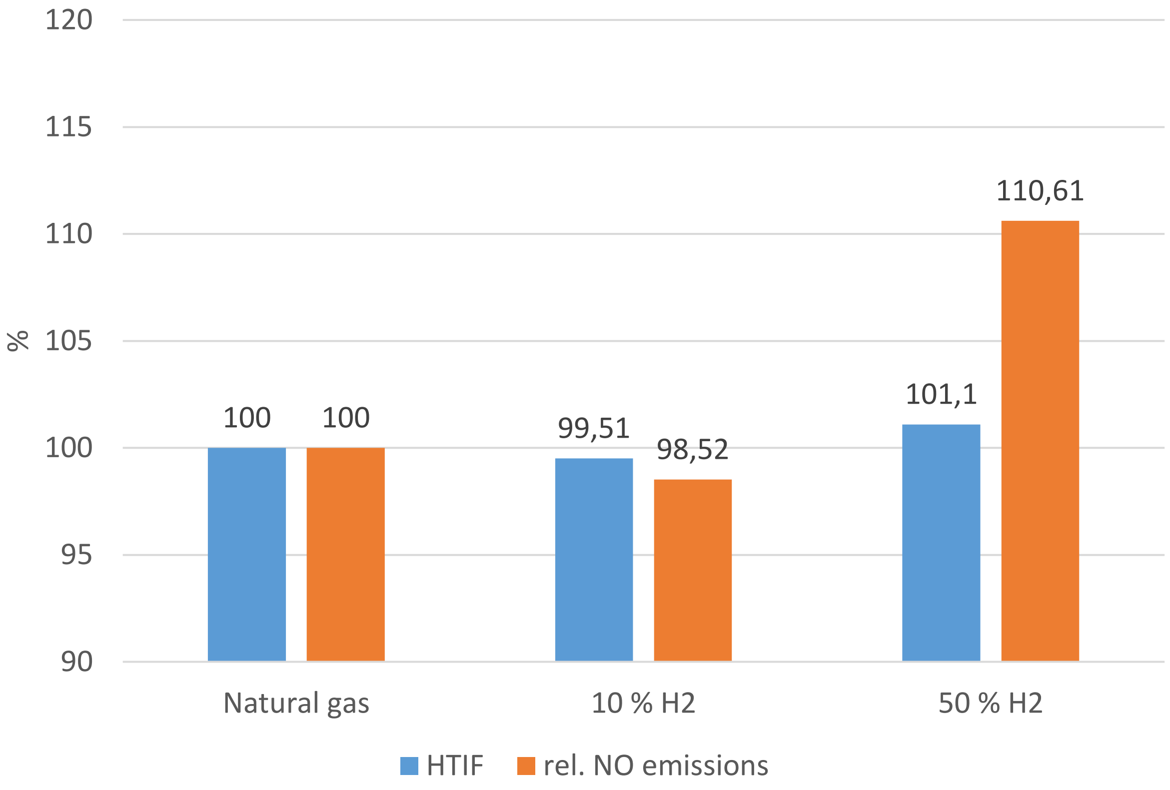


Operational parameters

$P = 12$ MW
$\lambda = 1.05$
$T_{air} = 1.400\ °C$

 Quelle: GWI, 2020

CFD simulations: Heat transfer and NO_X in a regenerative furnace (P, λ und T_{air} constant)



Heat Transfer Impact Factor:

$$HTIF[\%] = \frac{\dot{Q}_{Glas}}{\dot{Q}_{Glas.Reference}} \cdot 100$$

Relative NO emissions:

$$\Delta NO[\%] = \frac{X_{NO}}{X_{NO.Reference}} \cdot 100$$

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 Quelle: GWI, 2020

2^{nd} measurement campaign, 2^{nd} quarter 2021

Impact on glass quality

Charging and discharging batch crucibles during burner operation

Mobile test rig:

Melting of industrial batches (green, amber, flint, float) with different operating parameters and H_2 admixture rates.

Investigation of the effects on **glass quality** (HVG)

Quelle: GWI, 2020

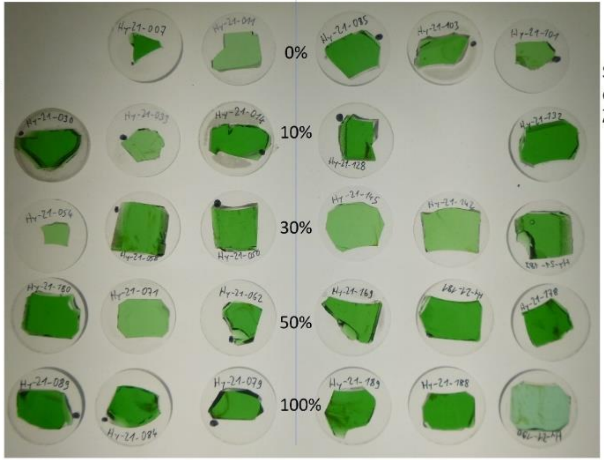
Glass quality investigations

green glass

green glass melting temperature ≈ 1450°C

4h | 2 + 2h | 2h | 2h | 2 + 2h | 4h

Hyperstoichiometric combustion λ=1,05



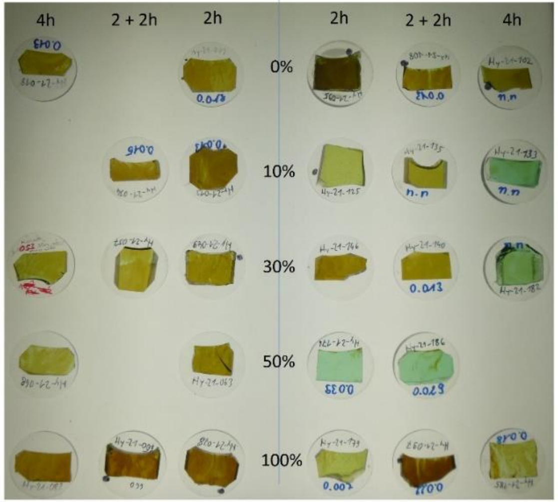
Substoichiometric combustion λ =0,97

Vol.-fraction of hydrogen in burnable gas

amber glass

Amber glass melting temperature ≈ 1450°C

Hyperstoichiometric combustion λ=1,05



Substoichiometric combustion λ =0,97

Vol.-fraction of hydrogen in burnable gas

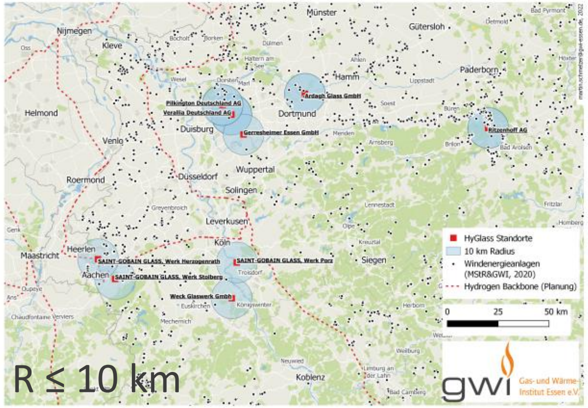
In some operational points, **soot formation** was detected both in the samples and at the crucibles with higher levels of hydrogen admixture.

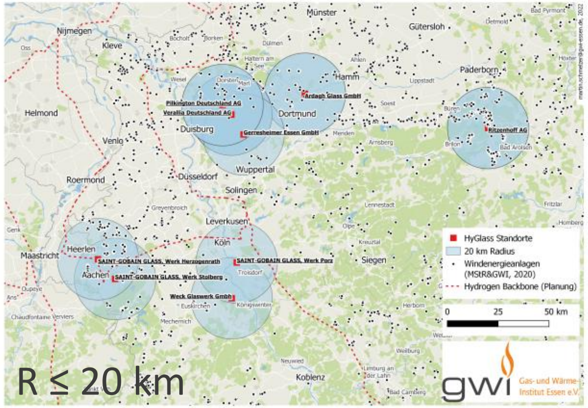
Preferential diffusion effects?

Quelle: GWI, 2020

Project „HyGlass“: GIS analysis of decarbonization potentials with local „green“ H_2 production

- **GIS analysis** (GIS: **G**eographic **I**nformation **S**ystem) was used to determine whether wind turbines and PV panels in the vicinity of glass production sites (maximum distances 10 and 20 km) can **potentially** generate sufficient „green“ electricity to produce the required H_2.
- Even with the **very optimistic assumption** that local wind turbines **exclusively serve the glass manufacturing sites**, **only 1 site** (out of 9 in NRW) could be supplied with sufficient H_2 in a 10 km radius.
  If the radius is extended to 20 km, **3 sites** could potentially be sufficiently supplied.
  For PV, no site even comes close.
- Full decarbonization via hydrogen will usually require either a **completely green power grid** with **local electrolysis** or a **dedicated H_2 grid.**





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Conclusion

- Decarbonizing (high-temperature) process heat is a major challenge for many energy-intensive industries. Partially or completely substituting natural gas with hydrogen is one option to reduce GHG emissions.
  At the same time, the gas industry is discussing both hydrogen admixture into existing natural gas grids and creating dedicated H_2 infrastructures.
  One way or the other, the glass industry has to think about hydrogen.

- Investigations so far indicate that natural gas / hydrogen blends and H_2 can be viable options to produce process heat. There is, however, still a lot of R & D to be done. There are concerns about product quality and NO_X, but **appropriate measurement** and **control technologies** seem to be able to mitigate many issues.

- The **origin of hydrogen** is crucial in the context of decarbonization. Procuring huge amounts of „green“ or at least „blue“ hydrogen is likely to be **the real challenge**.

Thank you for your attention

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