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INVESTIGATION OF THE EFFECTS OF CHANGING GAS QUALITIES ON INDUSTRIAL COMBUSTION PROCESSES

Dr.-Ing. Jörg Leicher
Gas- und Wärme-Institut Essen e.V.

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Authors and Acknowledgments

- Jörg Leicher*, Anne Giese, Klaus Görner, Gas- und Wärme-Institut Essen e.V., Essen (GWI), Germany
- Matthias Werschy, Steffen Franke, Hartmut Krause, DBI- Gas- und Umwelttechnik GmbH, Leipzig (DBI-GUT), Germany
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*corresponding author

DBI GUT
Gas- und Umwelttechnik GmbH

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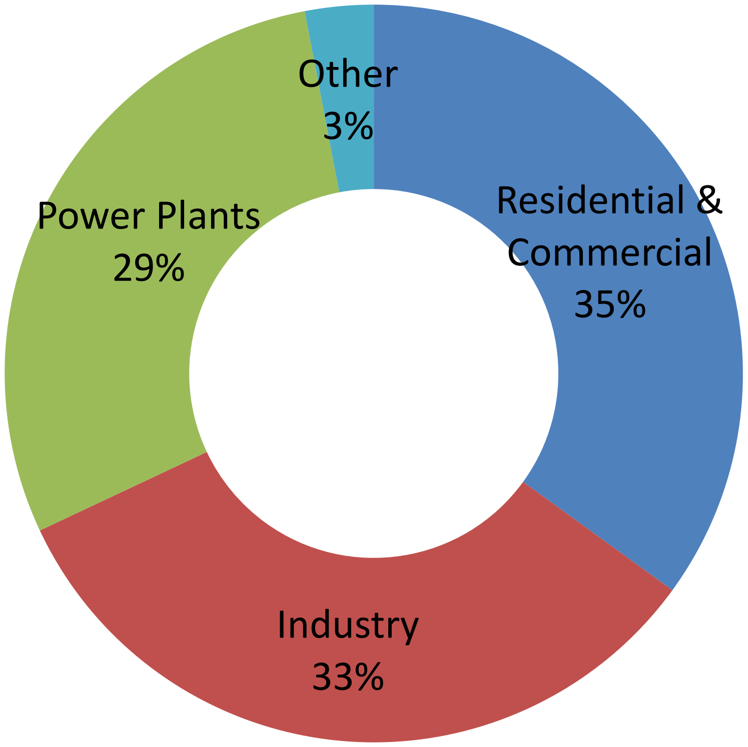
gwi Gas- und Wärme-Institut Essen e.V.

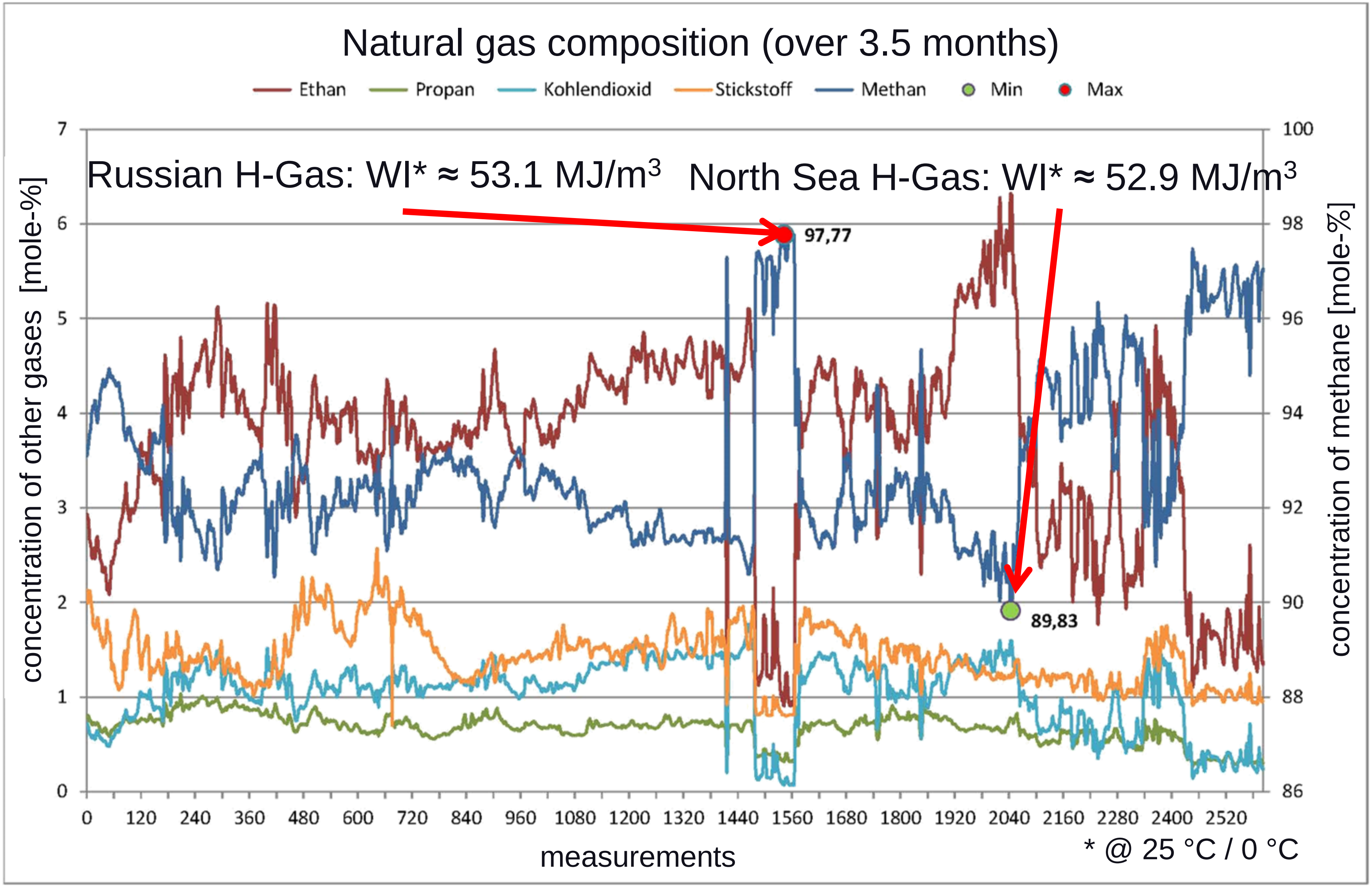
Natural Gas in Industrial Applications

- **Industrial applications** account for about **1/3** of Europe‘s consumption of natural gas.
- Natural gas is used to provide **process heat** in many industries, from the food industry to high temperature processes in glass, ceramics and metals manufacturing. The chemical industry uses gas not only as fuel, but also as a **feedstock**.
- About **85 % of process heat** in Germany are produced by natural gas.
- Manufacturing processes have **very high demands** for **efficiency**, **process stability**, **pollutant emissions** and of course **product quality**. They often require a **tight control of furnace conditions**. Constant local gas qualities are a distinct **locational advantage**.
- The markets are **changing** : EU H-Gas harmonization, LNG, renewables…



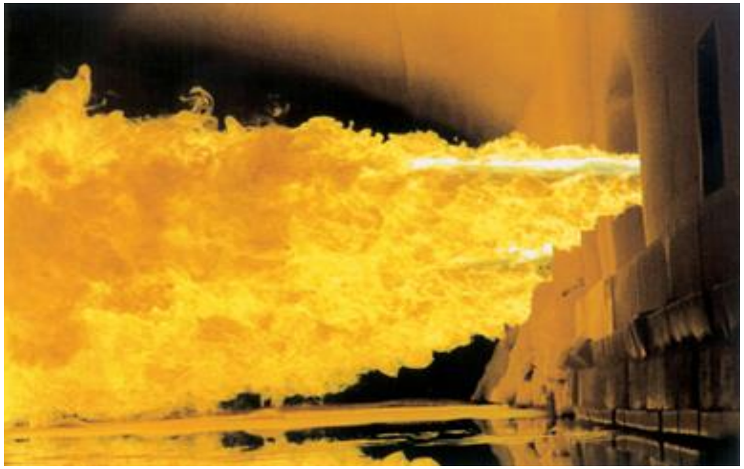
Source: EUROGAS

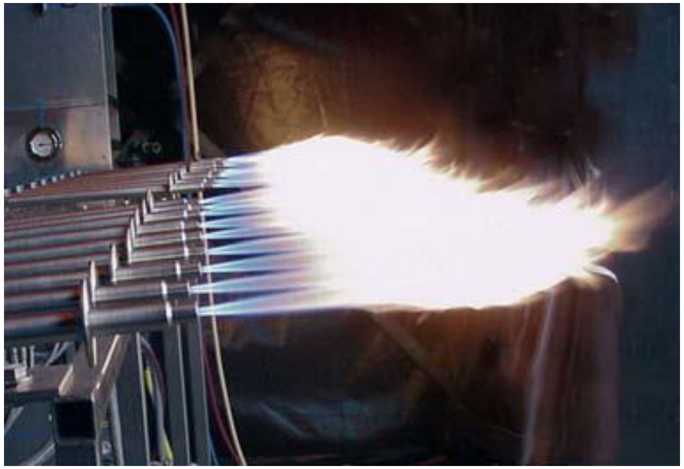
Measurements at Industrial Furnace near Leipzig, 2011



Industrial Experience: Glass Industry

- The glass industry is generally considered to be **very sensitive** to **gas quality fluctuations**. Gas is used in **many different production steps**: melting, feeders, shaping, annealing, …
- A poll carried out by the Research Association of the German Glass Industry (HVG) in 2011 shows that about **75% of the participants** (**90% of German glass manufacturing capacity**) have **already** encountered problems due to **fluctuating gas qualities**.
- Issues range from **loss of efficiency** and **reduced product quality** to **increased pollutant emissions** and **reduced process stability**.



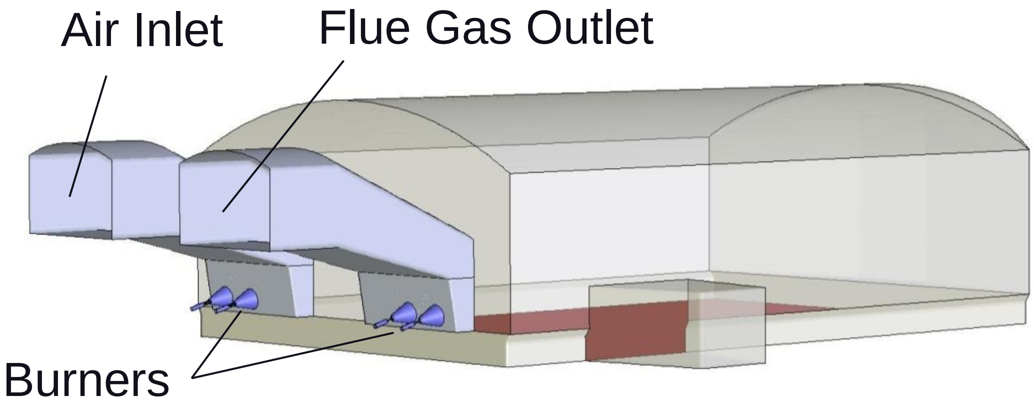


Source: HVG

CFD Case Study: Glass Melting Furnace

Operating Parameters (Reference Case):

- Load Burner 1: 2000 kW
- Load Burner 2: 2000 kW
- Air Ratio: 1.05
- Gas Temperature: 20 °C
- Air Temperature: 1300 °C

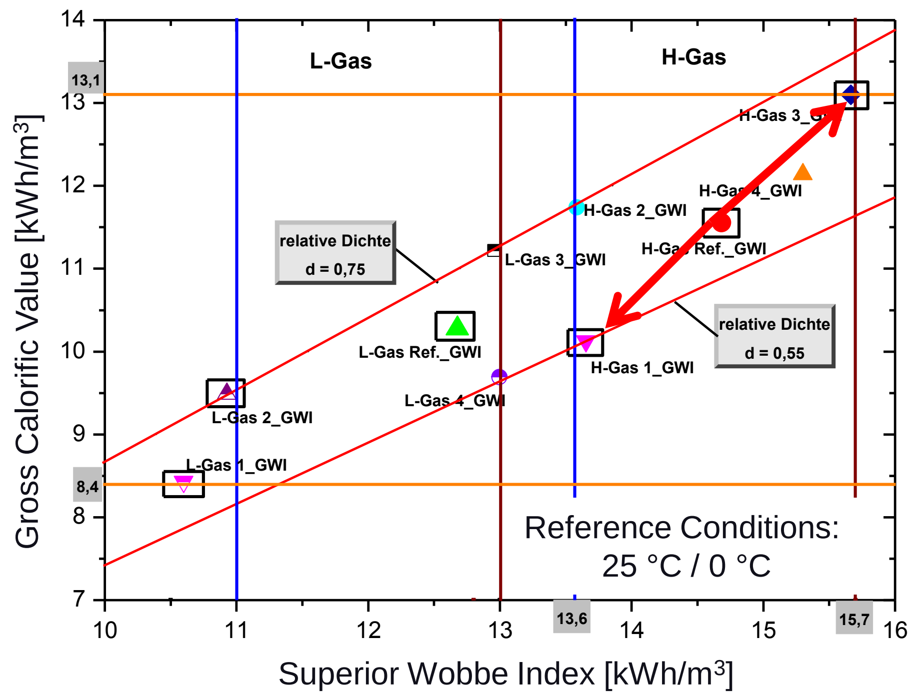


Approach:

- Test gases at the extremes of German gas quality code DVGW G 260 were defined
- Process was adjusted for reference gas and then supplied with another test gas
- Steady CFD simulations were used to examine the impact of a gas quality change
- Various furnace control strategies were investigated

Scenario I

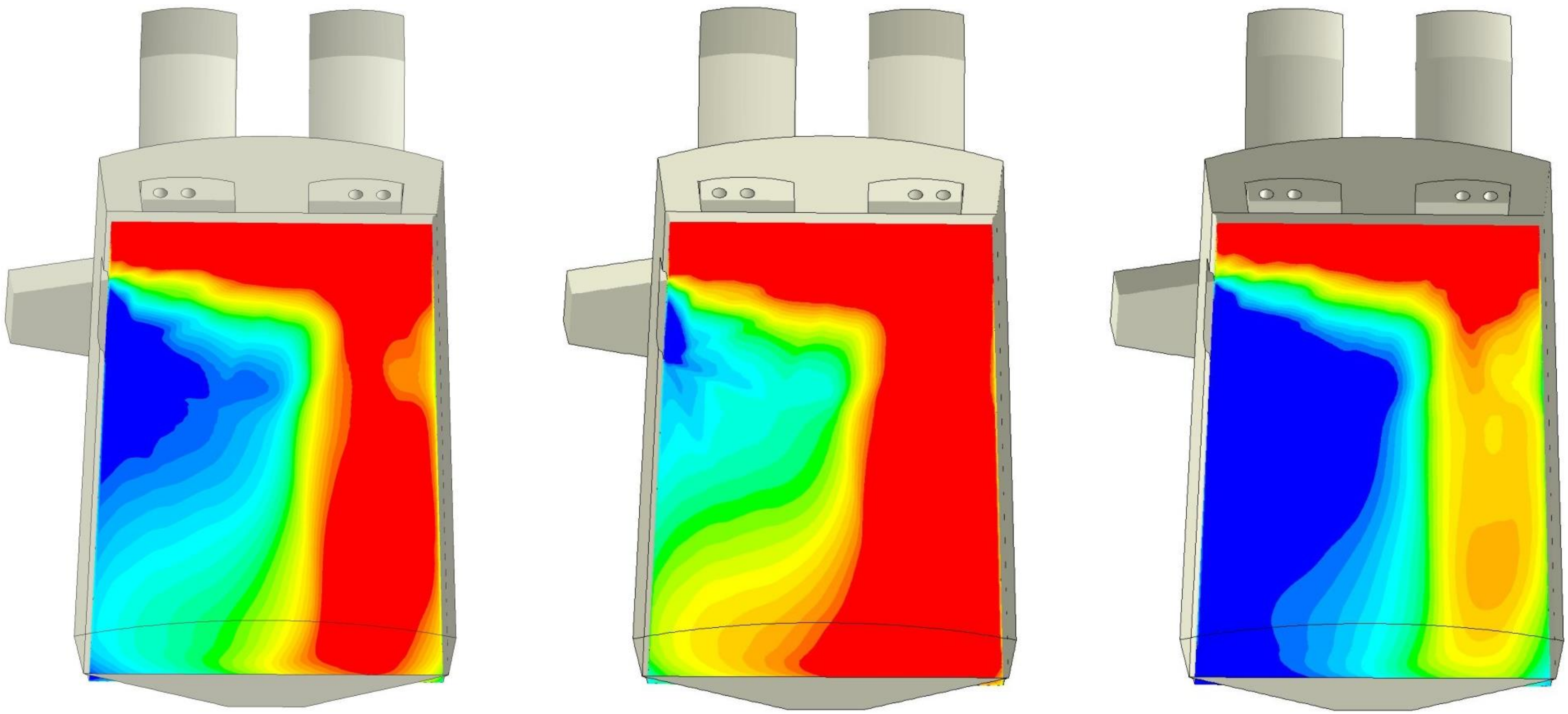
- Fuel gas composition changes from H-Gas Ref._GWI to H-Gas 1_GWI or H-Gas 3_GWI… an **oxygen sensor** detects the change.
- Volume flow of air is adapted for **constant λ**.
- But: volume flow of fuel remains constant !



Gas Type	$H_{i.n}$ [kWh/m³]	Q_{Burner} [kW]	$\rho_{n.Gas}$ [kg/m³]	$V_{n,Gas}$ [m³/h]	Air_{min} [m^3_{Air}/m^3_{Fuel}]	λ [-]	$V_{n,Air}$ [m³/h]
H-Gas Ref._GWI	10.436	4000	0.8004	383.3	9.99	1.05	4021
H-Gas 3_GWI	11.884	4554	0.9043	383.3	11.27	1.05	4536
H-Gas 1_GWI	9.114	3494	0.7110	383.3	8.65	1.05	3482

Scenario I: Total Heat Fluxes

H-Gas Ref._GWI | H-Gas 3_GWI | H-Gas 1_GWI

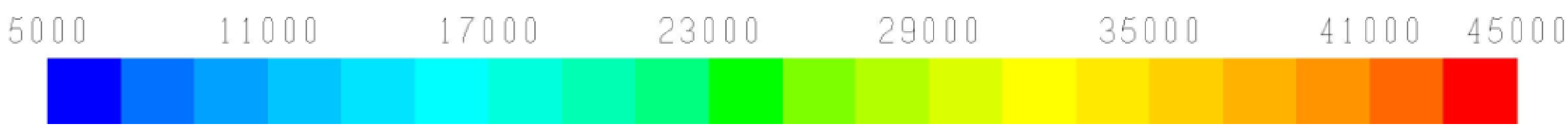


Q= 1096 kW

Q= 1455 kW
Δ=32.6 %

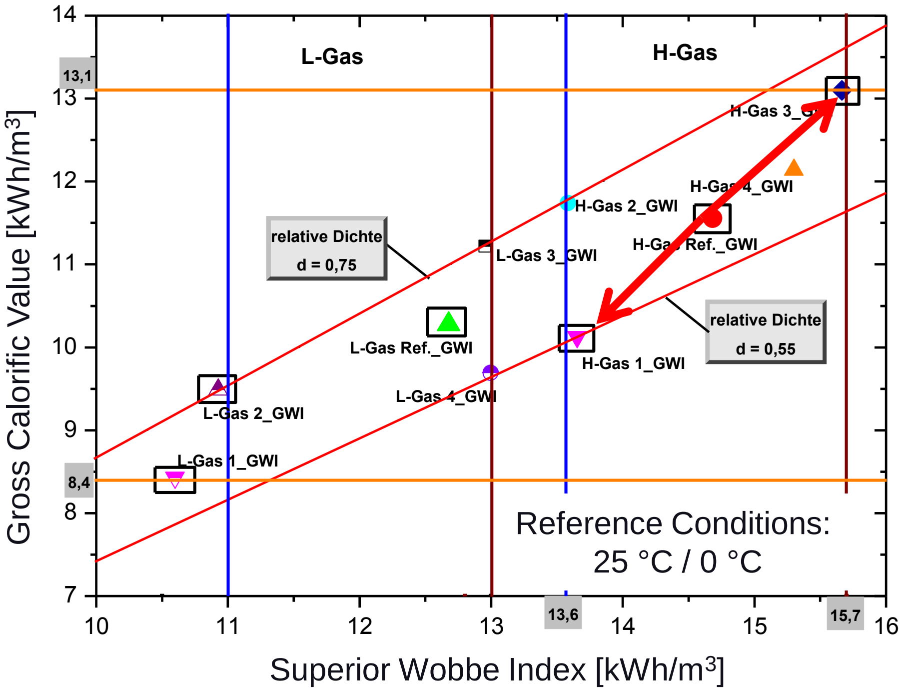
Q= 741 kW
Δ=-32.4 %

q [W/m²]



Scenario II: Worst Case

- Fuel gas composition changes from H-Gas Ref._GWI to H-Gas 1_GWI or H-Gas 3_GWI… **and no one notices** !
- Volume flows of **both** fuel and oxidizer remain constant.
- Definitely a **worst case scenario** !



Gas Type	$H_{i,n}$ [kWh/m³]	Q_{Burner} [kW]	$P_{n,Gas}$ [kg/m³]	$V_{n,Gas}$ [m³/h]	Air_{min} [m^3_{Air}/m^3_{Fuel}]	λ [-]	$V_{n,Air}$ [m³/h]
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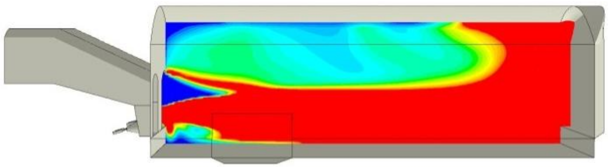
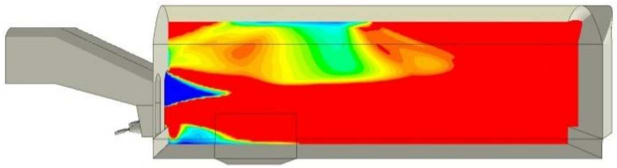
H-Gas 3_GWI	11.884	4554	0.9043	383.3	11.27	0.93	4021
H-Gas 1_GWI	9.114	3494	0.7110	383.3	8.65	1.21	4021

Scenario II: Flue Gas Compositions

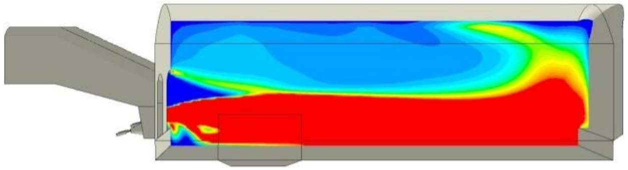
H-Gas Ref._GWI



H-Gas 3_GWI



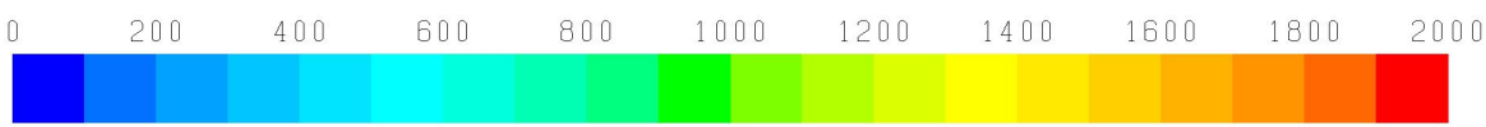
H-Gas 1_GWI



Total Load	kW	4000
Air Ratio	-	1.05
CO_2	Mole-%	11.38
N_2	Mole-%	87.39
O_2	Mole-%	1.23
H_2	Mole-%	0.00
CO	ppm	11
NO_x @ 3 % O_2	ppm	3460

Total Load	kW	4554
Air Ratio	-	0.93
CO_2	Mole-%	11.11
N_2	Mole-%	85.86
O_2	Mole-%	0.00
H_2	Mole-%	1.18
CO	ppm	18526
NO_x @ 3 % O_2	ppm	1670

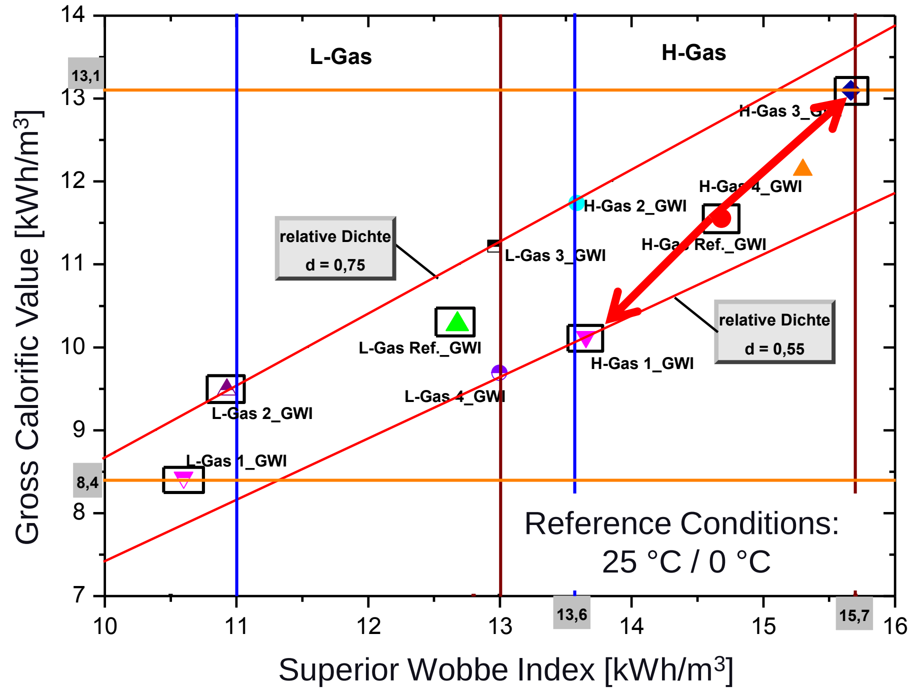
Total Load	kW	3494
Air Ratio	-	1.21
CO_2	Mole-%	9.50
N_2	Mole-%	86.34
O_2	Mole-%	4.16
H_2	Mole-%	0.00
CO	ppm	3
NO_x @ 3 % O_2	ppm	2850



CO_{dry} [ppm]

Scenario III: Best Case

- Fuel gas composition changes from H-Gas Ref._GWI to H-Gas 1_GWI or H-Gas 3_GWI… fuel composition is **constantly monitored** (PGC).
- Volume flows of air and fuel are adapted for constant λ and burner load.
- Technologically, the most sophisticated solution … but expensive!



Gas Type	$H_{i,n}$ [kWh/m³]	Q_{Burner} [kW]	$\rho_{n,Gas}$ [kg/m³]	$V_{n,Gas}$ [m³/h]	Air_{min} [m^3_{Air}/m^3_{Fuel}]	λ [-]	$V_{n,Air}$ [m³/h]
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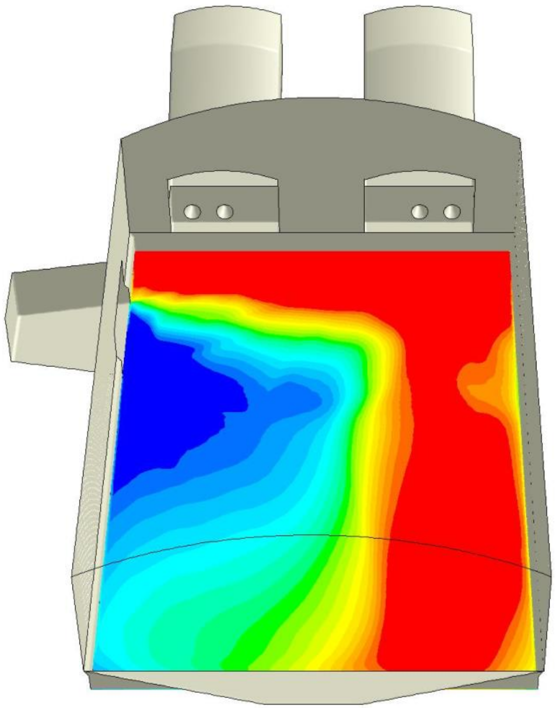
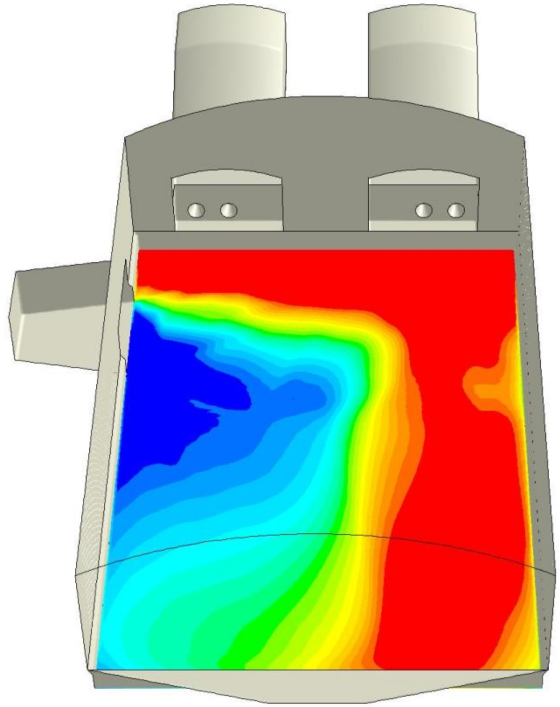
Scenario III: Total Heat Fluxes

H-Gas Ref._GWI



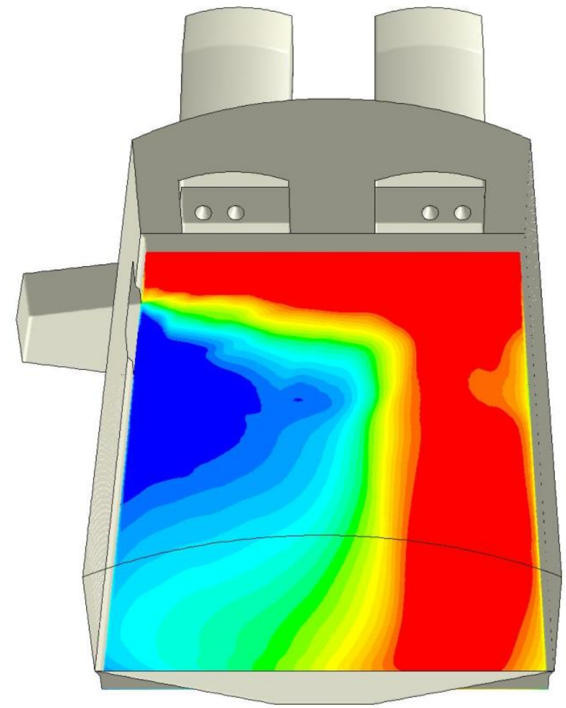
Q= 1096 kW

H-Gas 3_GWI



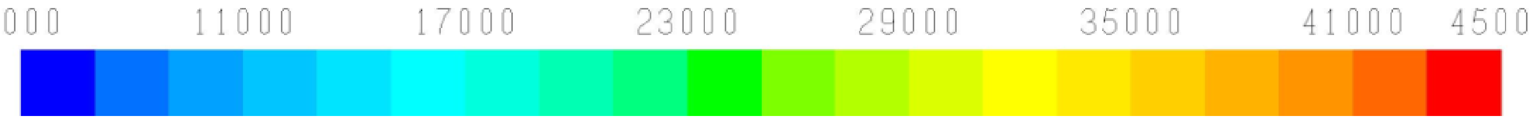
Q= 1102 kW
Δ=0.6 %

H-Gas 1_GWI

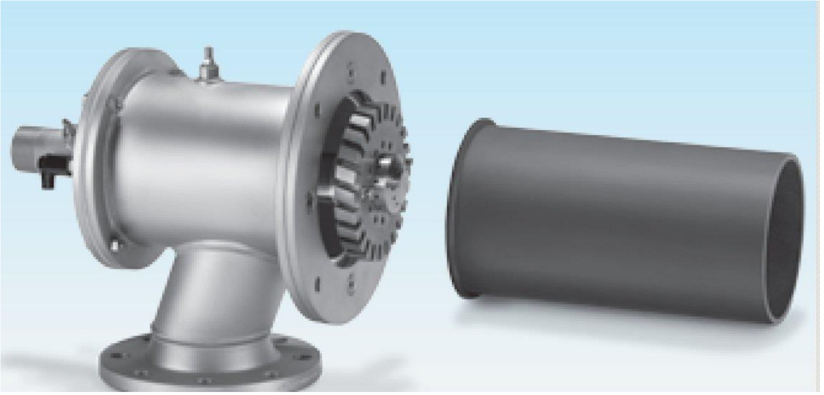


Q= 1076 kW
Δ= -1.8 %

q [W/m²]



GWI Semi-Industrial Burner Test Rig Experiments

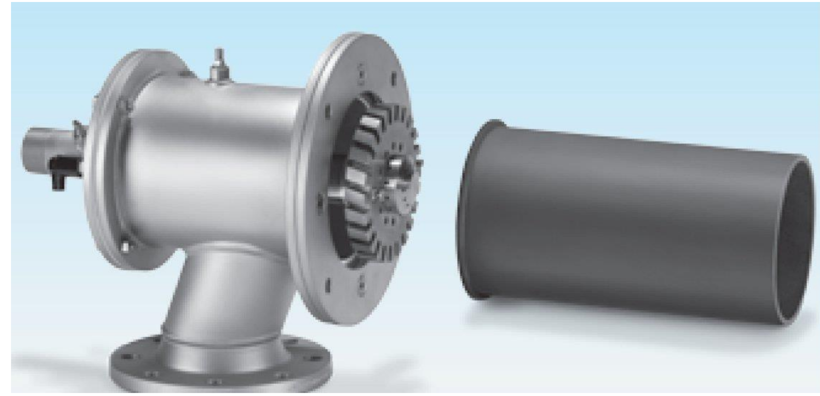


Operating Conditions:

- Burner Load:	200 kW
- Fuel:	Natural Gas H and L
- Air Ratio:	1.15
- Gas Temperature:	25 °C
- Air Temperature:	200 °C

Burner Load and **Air Ratio** remained constant for all experiments !

GWI Semi-Industrial Burner Test Rig Experiments



This is **NOT** industrial standard!
See CFD case study in Final Contribution for further information!

ing Conditions:

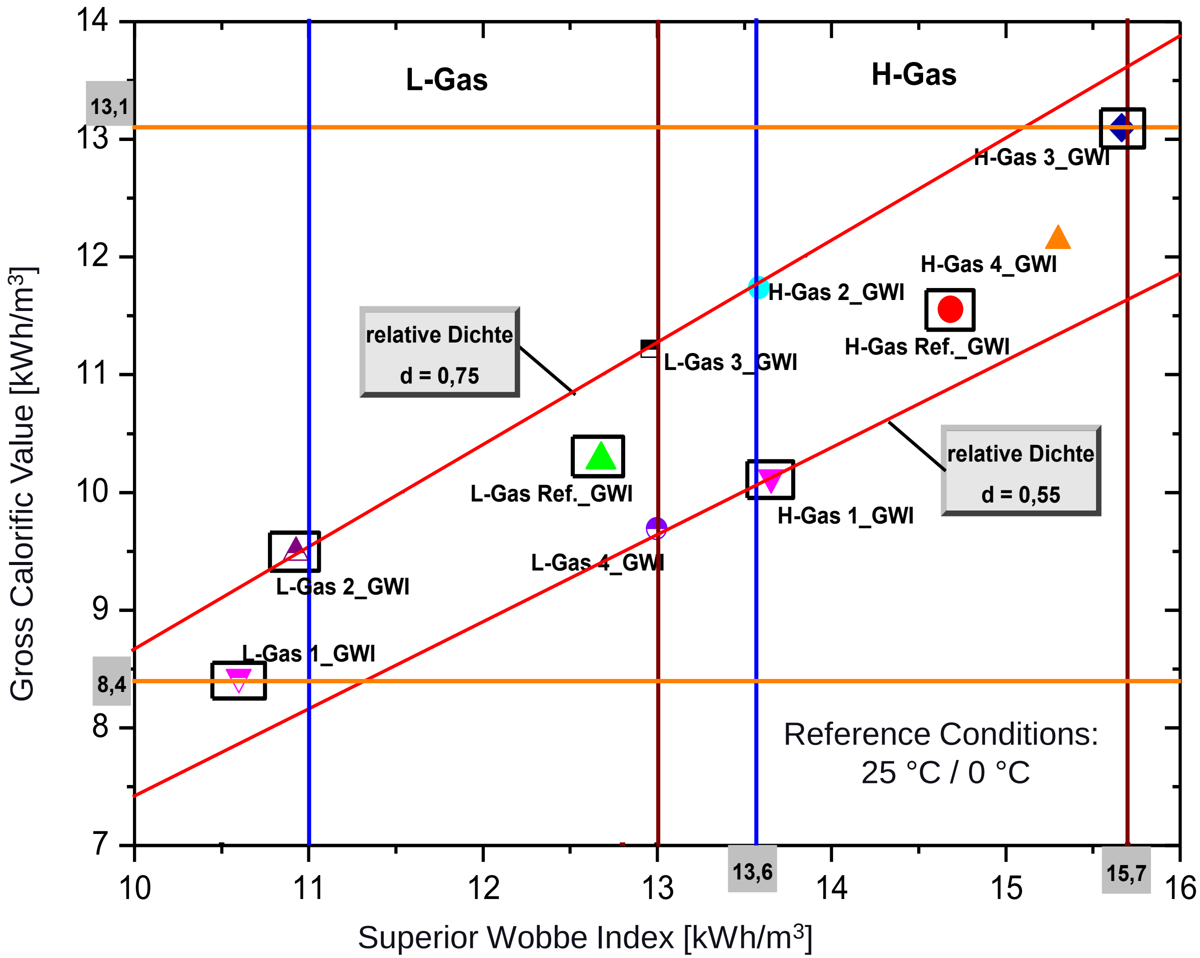
r Load: 200 kW

Natural Gas H and L

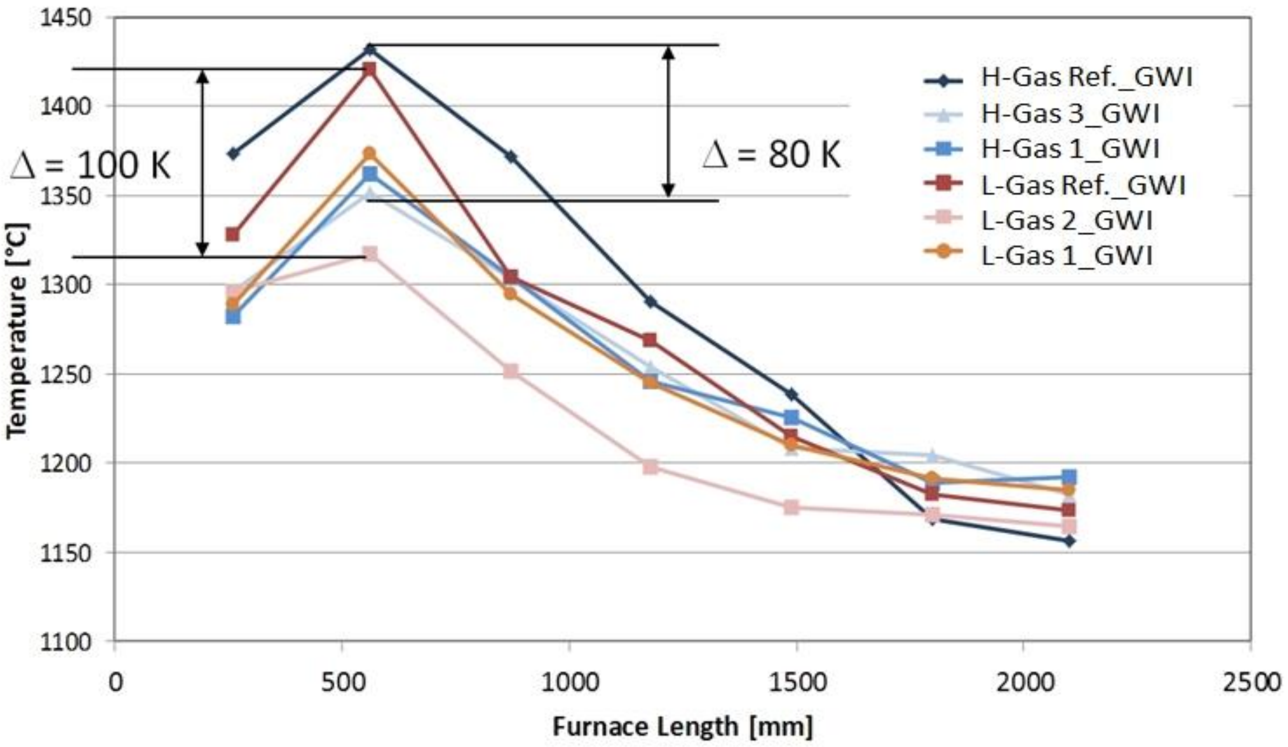
- Air Ratio: 1.15
- Gas Temperature: 25 °C
- Air Temperature: 200 °C

Burner Load and **Air Ratio** remained constant for all experiments !

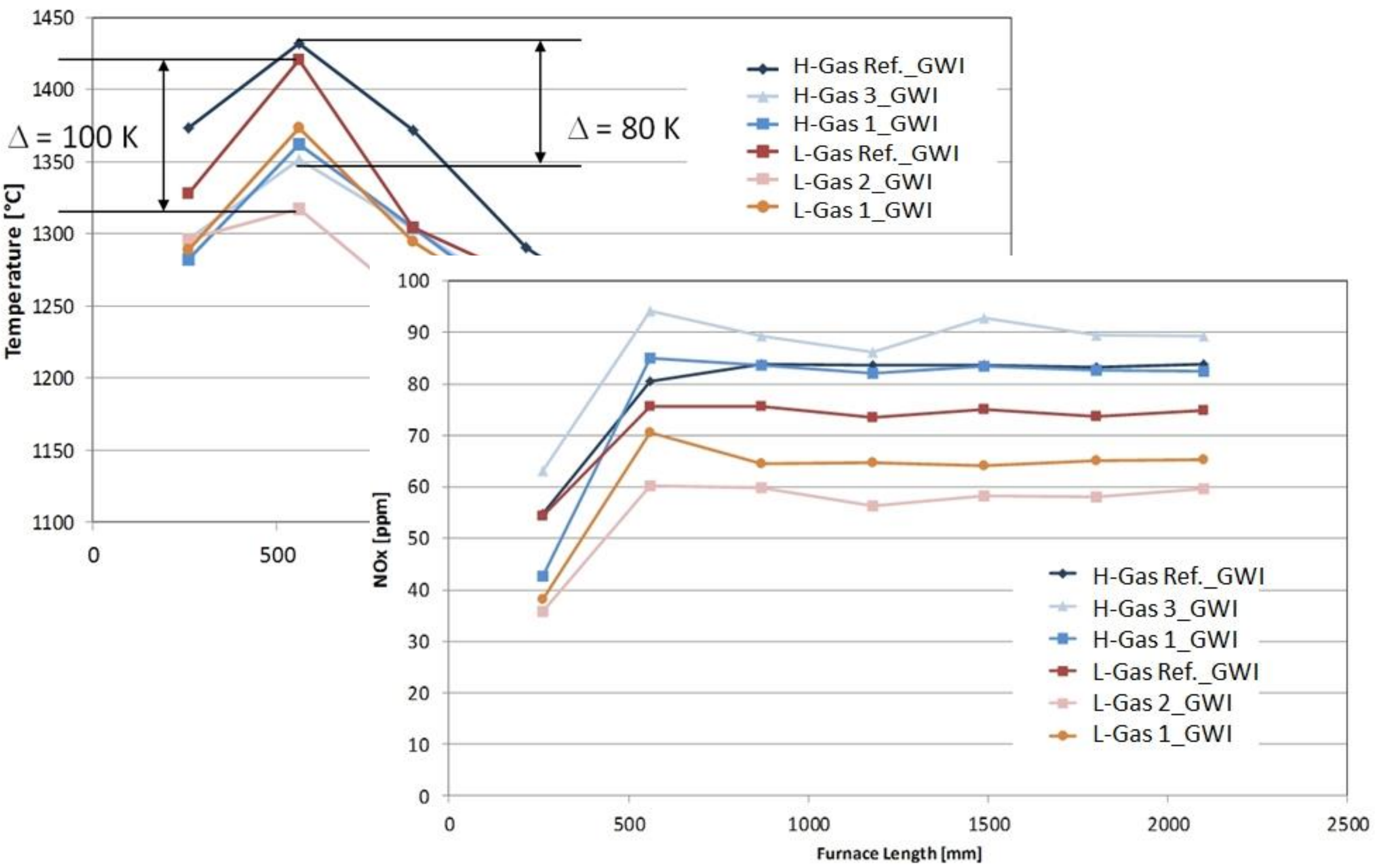
Test Gases in DVGW G260 Range



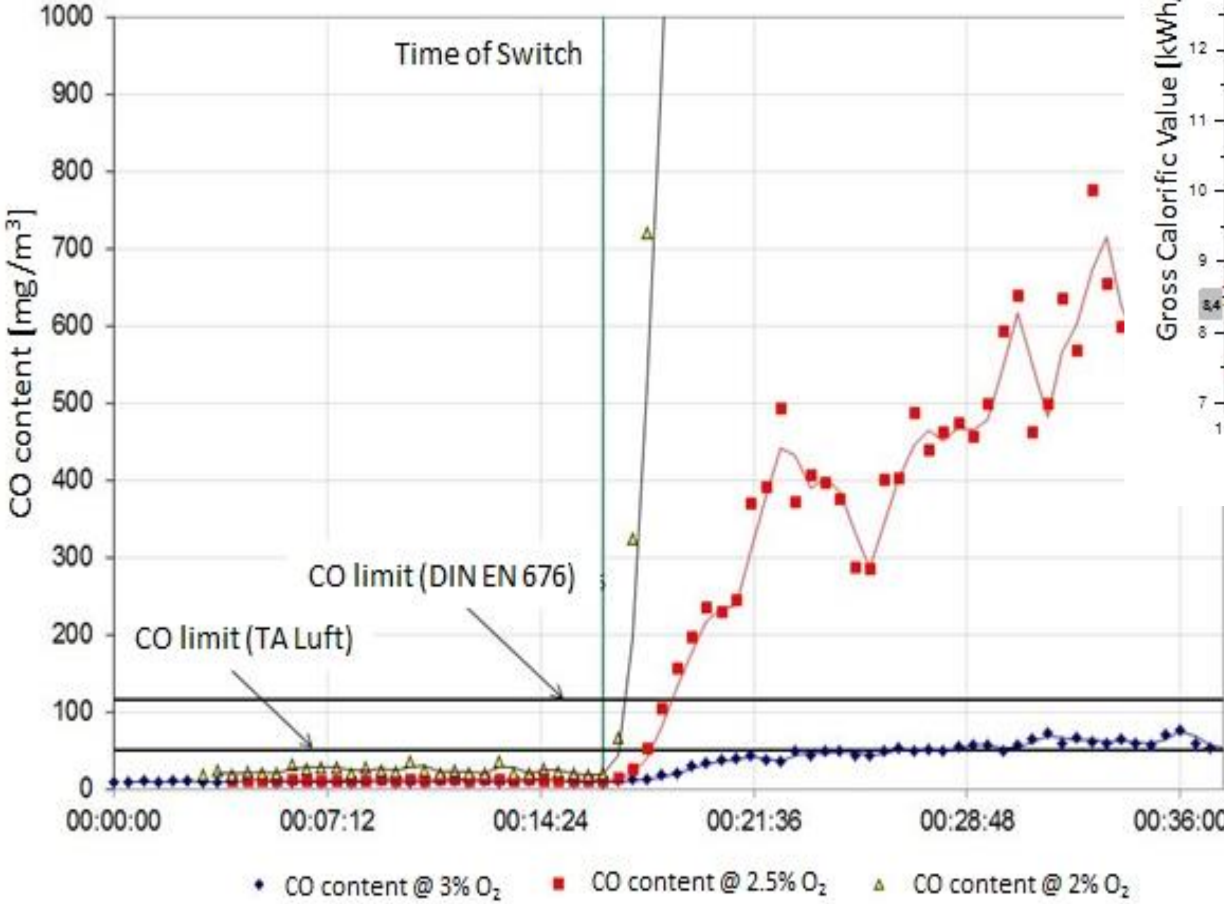
GWI Test Rig Results

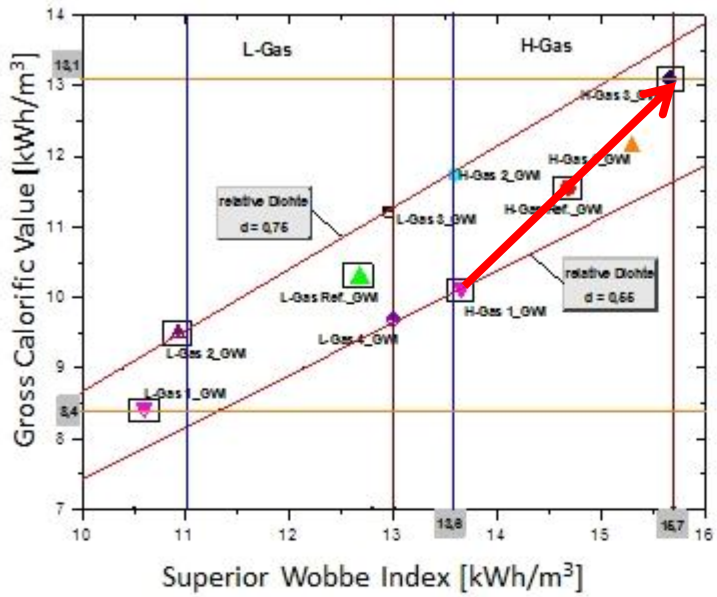


GWI Test Rig Results



DBI Experiment: Influence of Local Adjustment





Industrial processes are usually adjusted based on **excess O_2** in the flue gas, **without knowing the current gas quality**! Air ratios tend to be **close to λ = 1** for emissions and efficiency reasons.

Sensitivity Assessment (DVGW Study)

Industry	Process	Efficiency	Safety (Emissions and/or Thermal Overload)	Product Quality
When switching from lower to higher Wobbe Index (maximum possible range according to DVGW G 260)				
Heat	boilers	yellow	red	green
	luminous radiant heaters	yellow	red	green
	direct and indirect drying	yellow	yellow	yellow
Metallurgy	pre-heating (metals)	yellow	red	yellow
	thermochem. heat treatment	yellow	yellow	green
	zinc coating	yellow	green	red
	melting (non-ferrous metals)	red	red	red
Ceramics	calcination	yellow	yellow	yellow
	brick & tiles manufacturing	yellow	red	red
	porcelain firing	yellow	red	red
Glass	glass melting (float)	red	red	red
	glass melting (container), feeder	red	red	red
	glass finishing treatment	red	red	red
Other	chemical engineering, plastics	red	red	red

- green: no intervention required
- yellow: intervention possibly required
- red: intervention required

Conclusions

- Natural gas is a very **versatile fuel**, used in **many different industrial processes** for very different purposes. About **2/3** of the EU gas consumption do **not** go into domestic applications… **yet gas quality discussions tend to focus on this sector!**
- The gas quality criteria used in the gas industry are often not suitable for thermal processing applications. The relevant combustion characteristics **cannot be described by one property alone**!
- Industrial furnaces and plants usually operate in a **very small window of optimum performance** with regards to **product quality**, **efficiency** and **pollutant emissions**. **Fluctuating** fuel qualities can have **severe consequences**.
- Contrary to household appliances, industrial systems are generally designed for a **specified local (average) gas composition** and operate with **very little excess air**, depending on the process. They were never designed with **fluctuating gas qualities** in mind.
- There is **no single way** to prepare a thermal processing plant to fluctuating gas qualities. Each process is different and requires its own **tailor-made solution**.

Contact Info

Thank you for your attention!

Dr.-Ing. Jörg Leicher

Tel.: +49 201 36 18 278

Mail: leicher@gwi-essen.de

The final report (in German) of this DVGW research project is available at the GWI website:

www.gwi-essen.de