Gas- und Wärme-
Institut Essen e.V.

Gas Quality and Hydrogen from the Perspective of Industrial End Users

Swedish Gas Days 2019, Bastad

Jörg Leicher

GWI in a nutshell

Gas- und Wärme-Institut (GWI) is an institute dedicated to applied research
The Energy Institute in Essen

- Founded in **1937** by the German gas industry as a non-profit association to **bundle R&D activities**

- **Members from different parts of the gas-value-chain:**

  gas suppliers, TSOs & DSOs, equipment manufacturers, associations, municipal utilities

- **About 70 employees** in
  - research and development,
  - testing laboratory,
  - training and consulting center,
  - administration,
  - managing board.

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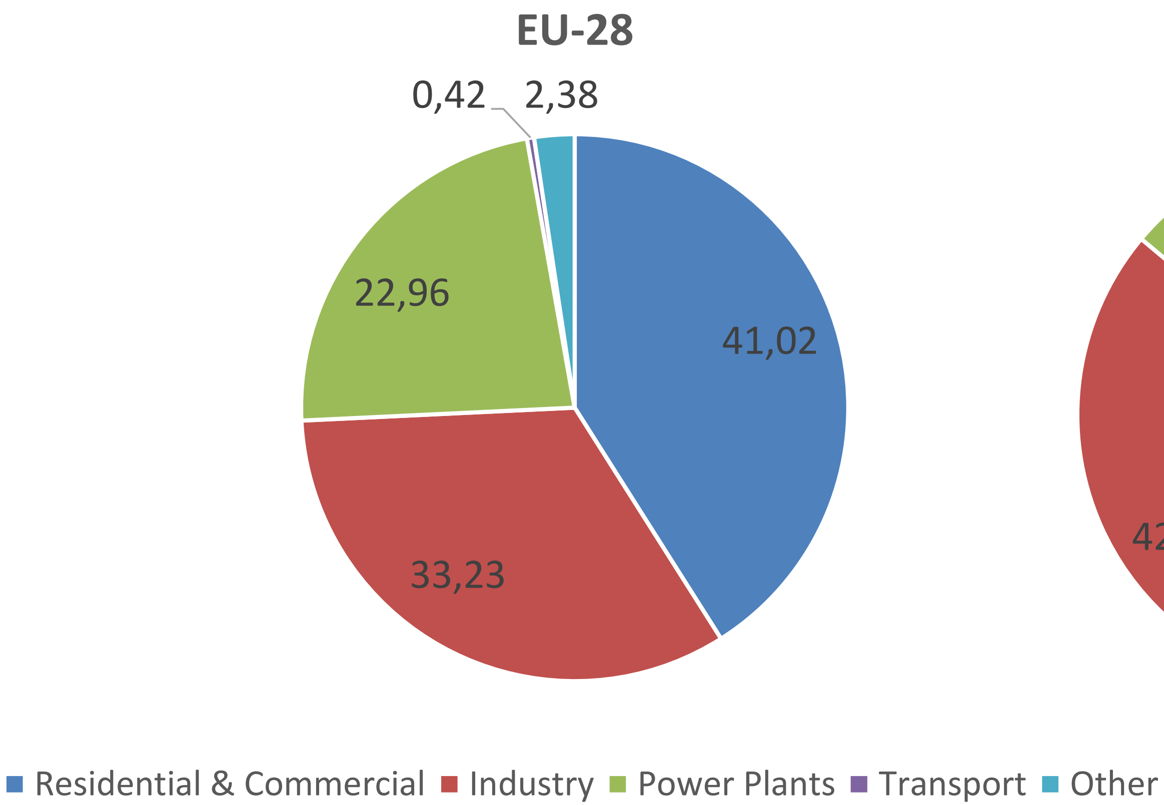
1937 - 2017
80 Jahre GWI

Mitglied

Natural gas consumption [%] in the EU and in Germany (2015)

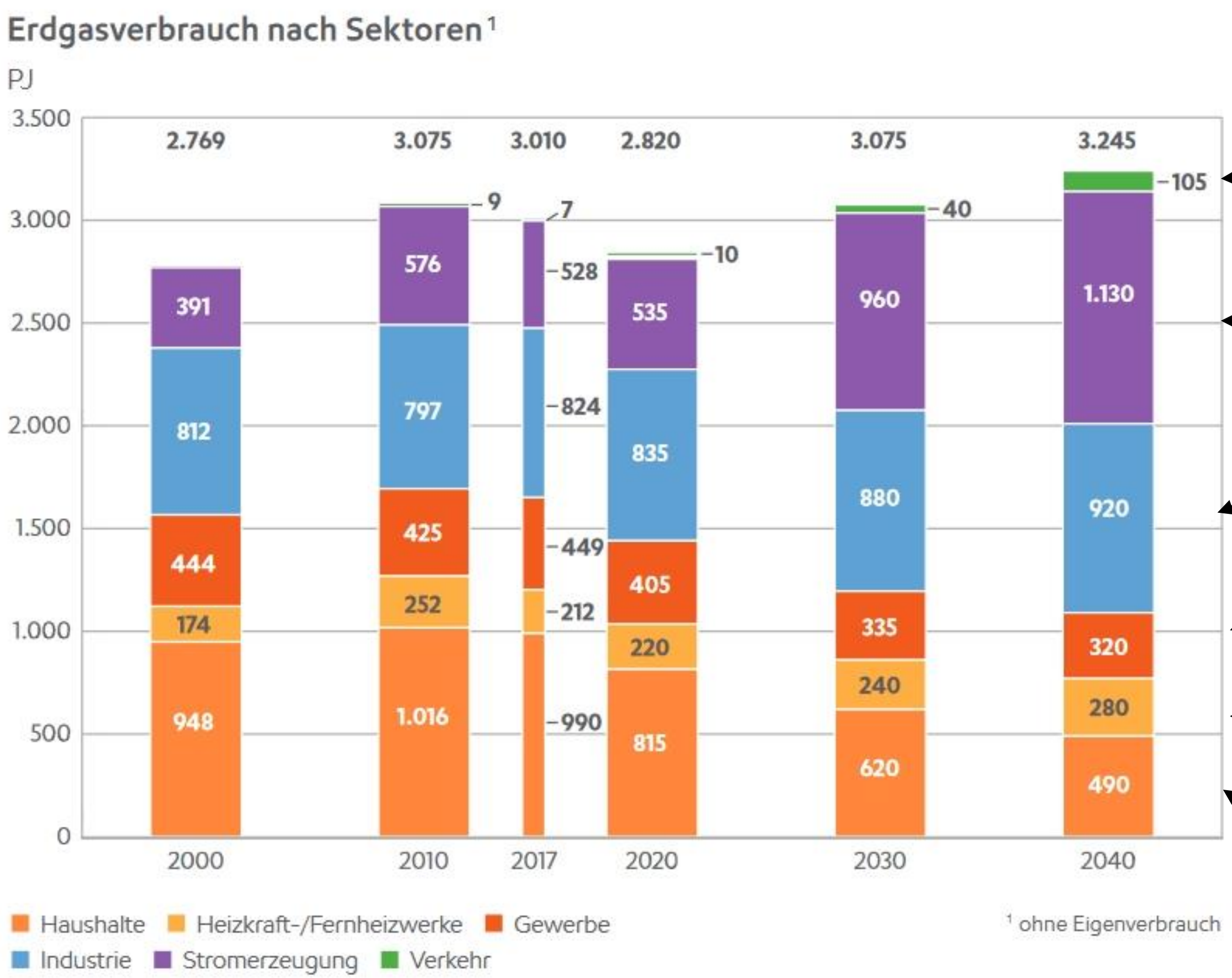


Total consumption: 4427 TWh **824 TWh**

More than 50 % of the gas consumption is accounted for by **industry** and **power generation**, both in the EU and in Germany.

Data: EUROGAS Statistical Report 2015

Forecast for natural gas consumption by sector in Germany



mobility (+1500 %)

power generation (+214 %)

industry (+12 %)

commercial (-29 %)

(district) heating (+32 %)

residential (-40 %)

Source: Energieprognose Deutschland 2018 – 2040, ExxonMobil, 2018

Alle percentages referenced to 2017 values

Current market developments and gas quality concerns

- The European gas markets are changing for a number of reasons:
  - liberalization & unbundling
  - increasing international trading of gas
  - increasing importance of LNG (especially in southern Europe)
  - „greening of gas“: injection of biomethane, SNG & hydrogen from „power-to-gas“

- One consequence of these developments is that **local gas quality variations** are expected to increase **both** in **frequency** and **strength** in many parts of Europe. Some end-use sectors are concerned that strong and frequent changes of **local gas quality** may have a **negative impact** on their applications. This is particularly relevant for **industrial end users**. Some cases have already been **documented**.

- At the same time, there is a European effort to **harmonize the different national gas quality regulations (EN 16726)**. A first version of the standard was published in 2016, but **lacks important aspects**, e.g. a **specified Wobbe Index range**.

Different perspectives

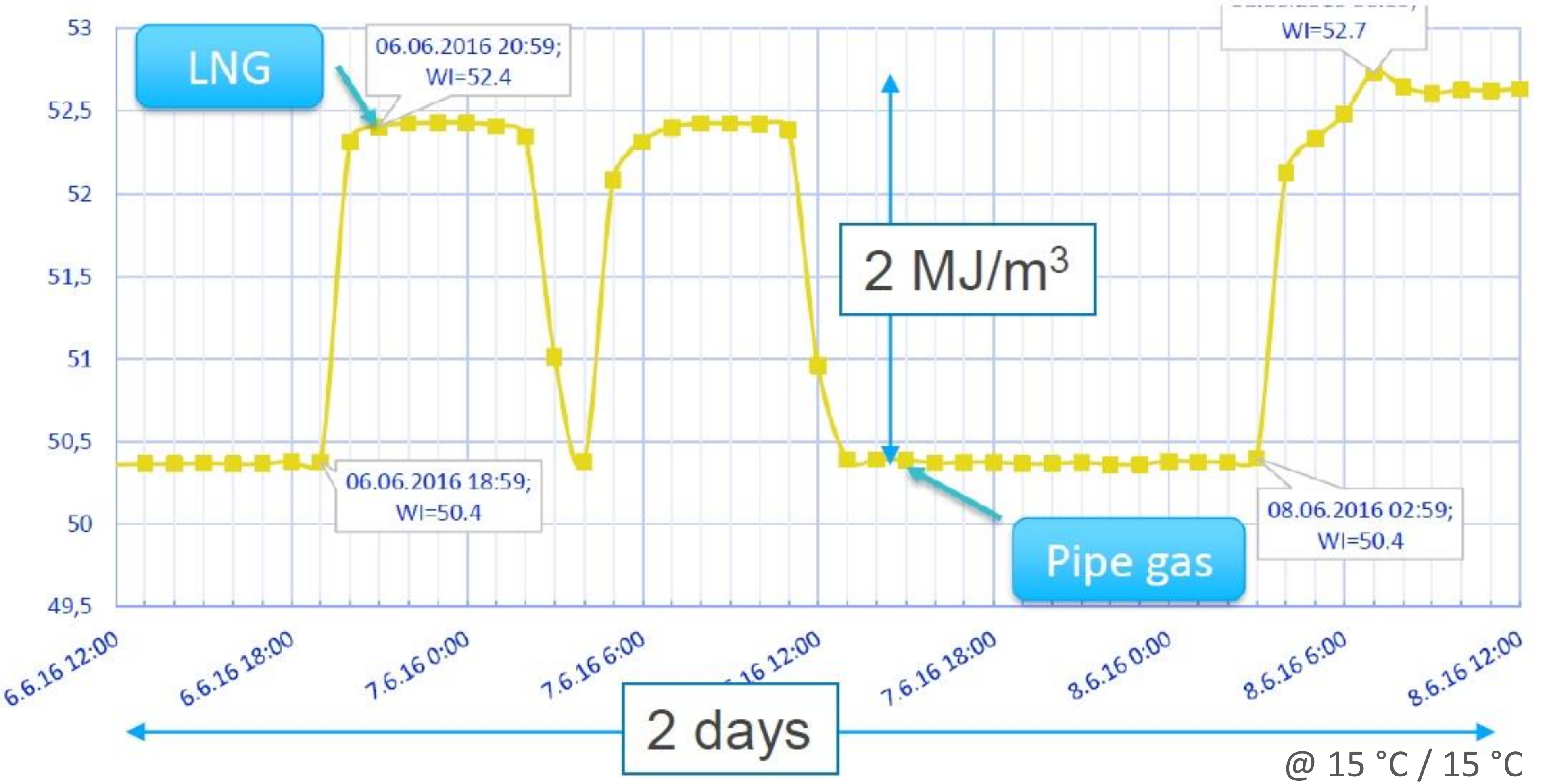
- The gas industry usually considers gas quality in **absolute** and **global** terms: minimum and maximum permitted values (density, Wobbe Index, GCV, ...) **within a grid** or the **scope of a national regulation**.

- End users in **industry** (and **power generation**) tend to see gas quality in **relative** and **local** terms: how much does the **current** gas quality **on-site** differ from the gas that the equipment/process was **originally designed and adjusted for**? Industrial equipment and processes can usually be designed and adjusted for a wide range of gas qualities, but **once adjusted**, are often **very sensitive to local changes**.

- The main gas interchangeability criterion in many regulations and codes, the **Wobbe Index**, is **not** considered to be particularly **meaningful for many industrial applications**. The **calorific value** is usually seen to be much **more relevant.**

- The gas industry is traditionally **focused** on **residential appliances**.

Local gas quality fluctuations in France (2016)



Source: Ourliac, M., „Deal with gas quality variations and melt glass with syngas from gasification", IFRF/GWI TOTeM 44 "Gaseous Fuels in Industry and Power Generation: Challenges and Opportunities", Essen, Germany, 2017

Gas quality and industrial gas utilization

gwi

- In recent years, natural gas quality has become a topic of discussion between the gas industry on the one hand and end-users and equipment manufacturers across all sectors on the other hand.

- The situation is complicated: the gas industry pushes for a **widening** of permissible gas quality ranges while end users generally are in favor of a **narrow range**. A potential future **large-scale injection of hydrogen** into the gas grid (“power-to-gas”) may further acerbate the issue.

- GWI has been involved in various **gas quality** and **hydrogen**-related research projects in recent years, often in the context of **industrial gas utilization**:
  - “Gasbeschaffenheit Industrie“ (DVGW) Link
  - “Hauptstudie Gasbeschaffenheit Phase 1 + 2“ (DVGW) Link
  - “GasQualitaetGlas“ (BMWi) Link
  - “H2-Substitution” (AiF) Link

French sensitivity assessment (ENGIE, 2017)

Thermal process	Variations in GCV or Wobbe index		
	< 3%	3 to 5%	5 to 10%
Shell boilers	Not sensitive	Not sensitive	Not sensitive
Air drying or drying oven	Not sensitive	Not sensitive	Not sensitive
Water-tube boilers	Not sensitive	Not sensitive	Little sensitive
Non ferrous metal melting	Not sensitive	Not sensitive	Little sensitive
Metals reheating	Not sensitive	Not sensitive	Little sensitive
Glass heating, decorating	Not sensitive	Not sensitive	Little sensitive
Tiles and bricks firing	Not sensitive	Not sensitive	Little sensitive
Gas turbines (premix burners)	Not sensitive	Little sensitive	Sensitive
Metals heat treatments	Not sensitive	Little sensitive	Sensitive
Lime or alumina calcining	Little sensitive	Sensitive	Sensitive
Finest ceramics firing (china)	Little sensitive	Sensitive	Sensitive
Glass flame working (bulbs)	Sensitive	Sensitive	Sensitive
Glass melting and feeders	Sensitive	Sensitive	Sensitive

Not sensitive | Little sensitive | Sensitive

Source: Ourliac, M., „Deal with gas quality variations and melt glass with syngas from gasification", IFRF/GWI TOTeM 44 "Gaseous Fuels in Industry and Power Generation: Challenges and Opportunities", Essen, 2017

German sensitivity assessment (DVGW 2018)

Industry		Process / Application		Efficiency				Safety (Emissions + Thermal Overload)				Product Quality			
				Variation of Wobbe Index or calorific value compared to the adjustment value of the process											
				±2 %	±4 %	±5.5 %	±7.5 %	±2 %	±4 %	±5.5 %	±7.5 %	±2 %	±4 %	±5.5 %	±7.5 %
Heat	Space heating	luminous radiant heaters*		green	green	yellow	red	green	green	yellow	red	green	green	yellow	yellow
Heat	Space heating	infrared radiant heaters*		green	green	yellow	red	green	green	yellow	red	green	green	yellow	yellow
Heat	Space heating	air heaters*		green	yellow	red	red	green	yellow	red	red	green	yellow	yellow	red
Heat	Process heating	boilers / steam generators		green	yellow	yellow	yellow	green	yellow	yellow	red	green	yellow	yellow	red
Heat	Process heating	direct and indirect drying		green	yellow	yellow	yellow	green	yellow	yellow	red	green	yellow	yellow	red
Power Generation		gas turbines	Diffusion Mode	green	green	yellow	red	green	green	yellow	red	green	yellow	yellow	red
Power Generation		gas turbines	DLE Mode	green	green	yellow	red	green	red	red	red	green	yellow	yellow	red
Power Generation		gas engines		green	yellow	red	red	green	red	red	red	green	yellow	yellow	red
Metals		preheating (metals)		green	green	green	yellow	green	yellow	yellow	red	green	green	green	yellow
Metals		thermo-chemical heat treatment		green	yellow	yellow	yellow	green	green	green	yellow	yellow	red	red	red
Metals		endothermic gas generation		yellow	red	red	red	green	green	green	yellow	yellow	red	red	red
Metals		galvanization processes		green	yellow	red	red	green	green	green	green	yellow	red	red	red
Metals		melting processes (non-ferrous metals)		green	yellow	yellow	red	green	yellow	yellow	red	yellow	yellow	yellow	red
Ceramics		calcination		green	green	green	yellow	green	green	green	yellow	green	green	green	yellow
Ceramics		bricks and tiles manufacturing		green	green	yellow	yellow	green	yellow	yellow	red	yellow	red	red	red
Ceramics		porcelain firing		green	yellow	yellow	yellow	green	yellow	yellow	red	yellow	red	red	red
Glass		glass melting (container glass)		green	yellow	yellow	red	green	yellow	yellow	red	green	yellow	yellow	red
Glass		glass melting (float glass)		green	yellow	yellow	red	green	yellow	yellow	red	yellow	yellow	yellow	red
Glass		glass melting (special-purpose glass)		yellow	red	red	red	green	yellow	yellow	red	yellow	red	red	red
Glass		feeders and lehrs (annealing)		yellow	yellow	yellow	red	green	yellow	yellow	red	yellow	yellow	yellow	red
Chemical		chemical engineering, plastics		green	yellow	yellow	red	green	yellow	yellow	red	green	yellow	yellow	red

Assumption: no control system

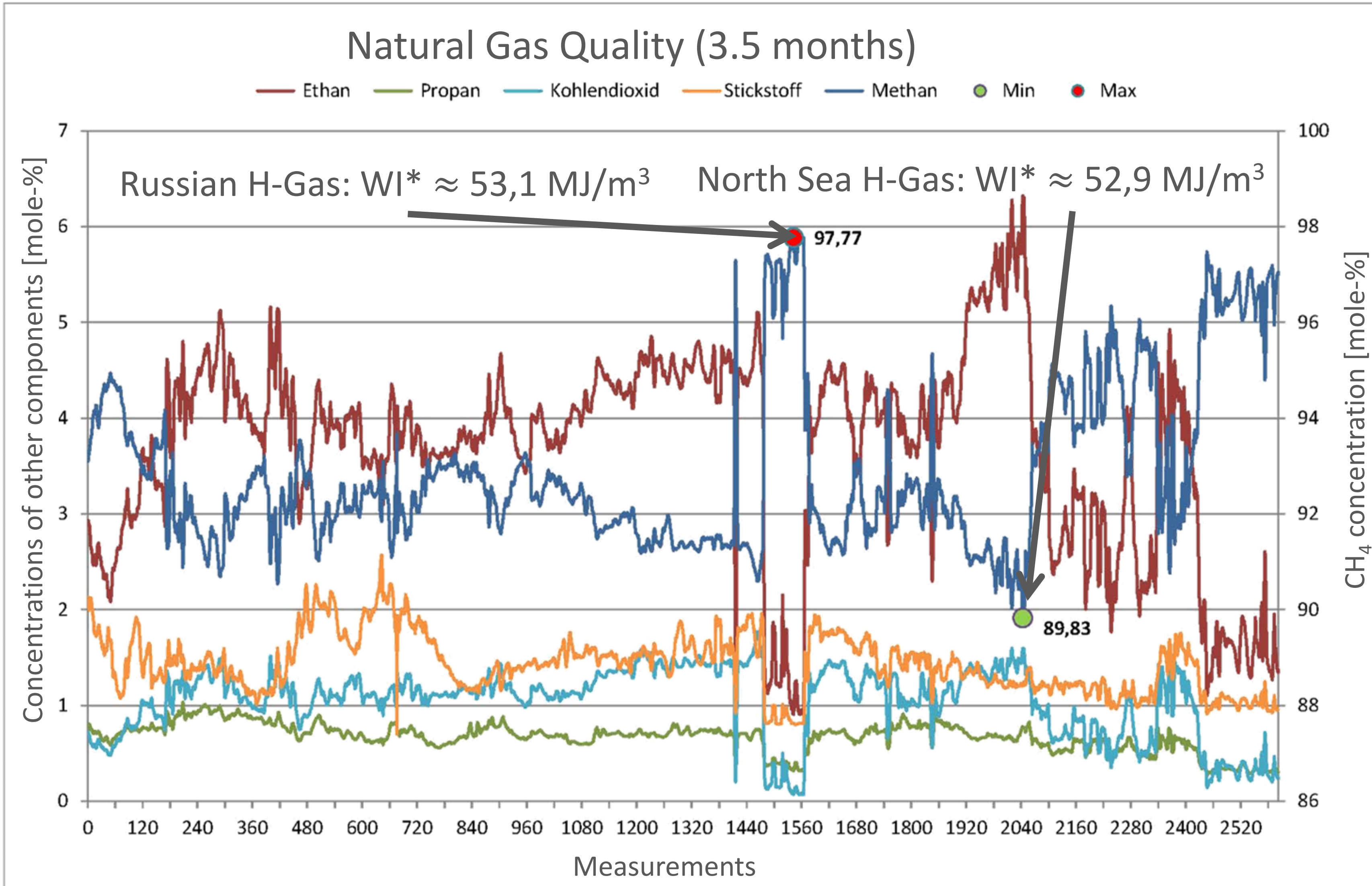
*For radiant heaters and air heaters: product quality means space heating quality

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

Source: „Hauptstudie Gasbeschaffenheit – Phase II", DVGW-Projekt G1-01-15, DVGW, 2018

Fluctuating natural gas qualities and their impact on combustion processes

Gas quality fluctuations in eastern Germany (Leipzig 2011)



* @ 25 °C / 0 °C

Impact on a generic pipe-in-pipe burner

Reference case:

Russian H-Gas
(P = 200 kW, λ = 1.1)

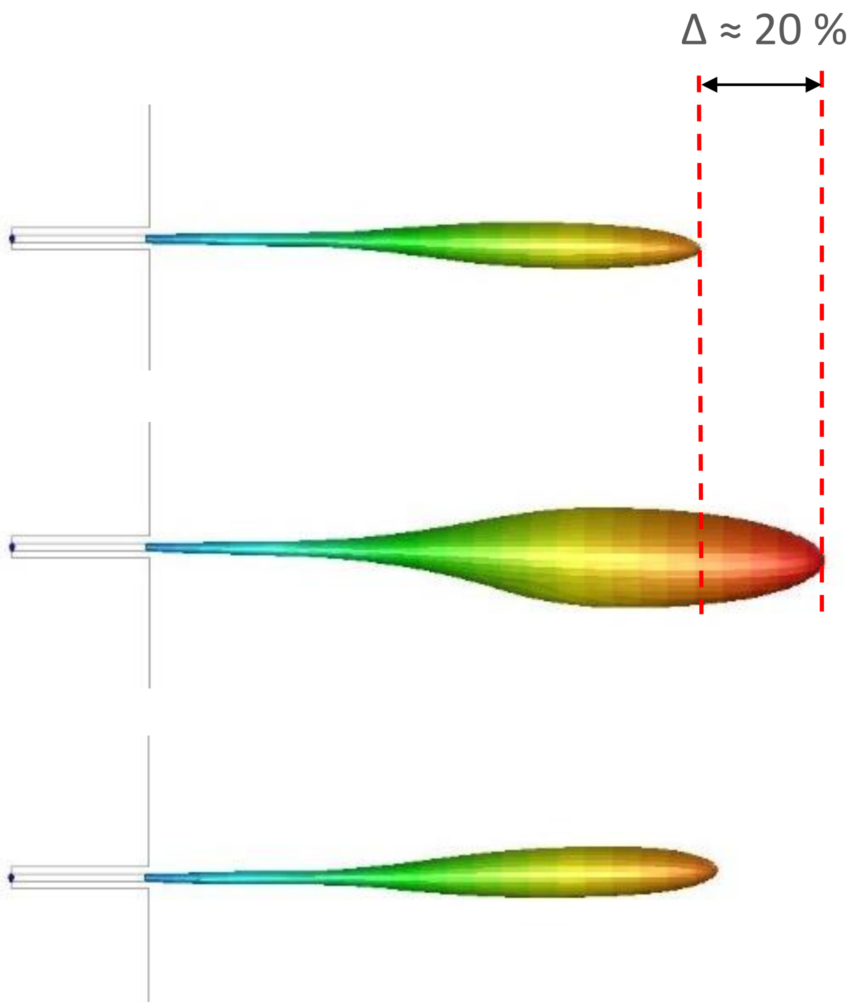
$\Delta W_S = 0.4\ \%$
$\Delta H_i = 4\ \%$

No control (Scenario 1):

North Sea H-Gas
Volume flows constant
(P = **208 kW**, λ = **1.056**)
↑ 4 % ↓ 4 %

Control of firing load and air excess ratio (Scenario 2):

North Sea H-Gas
(P = **200 kW**, λ = **1.1**)
Air and fuel volume flows adjusted,
Requirement: on-site gas quality measurement in combination with control capabilities.



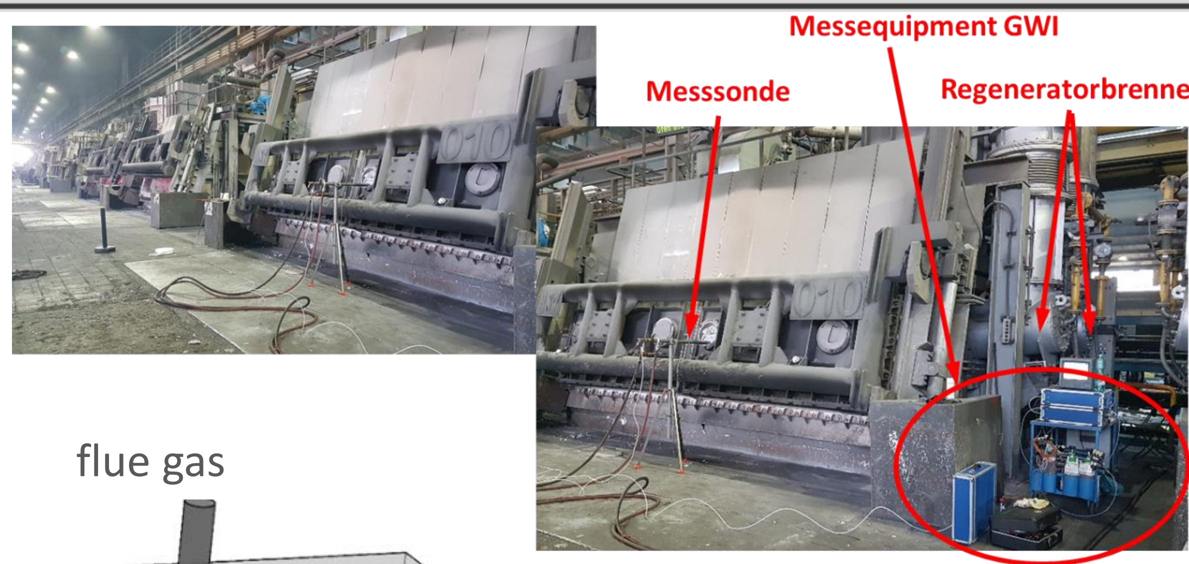
Test burner (non-premixed)

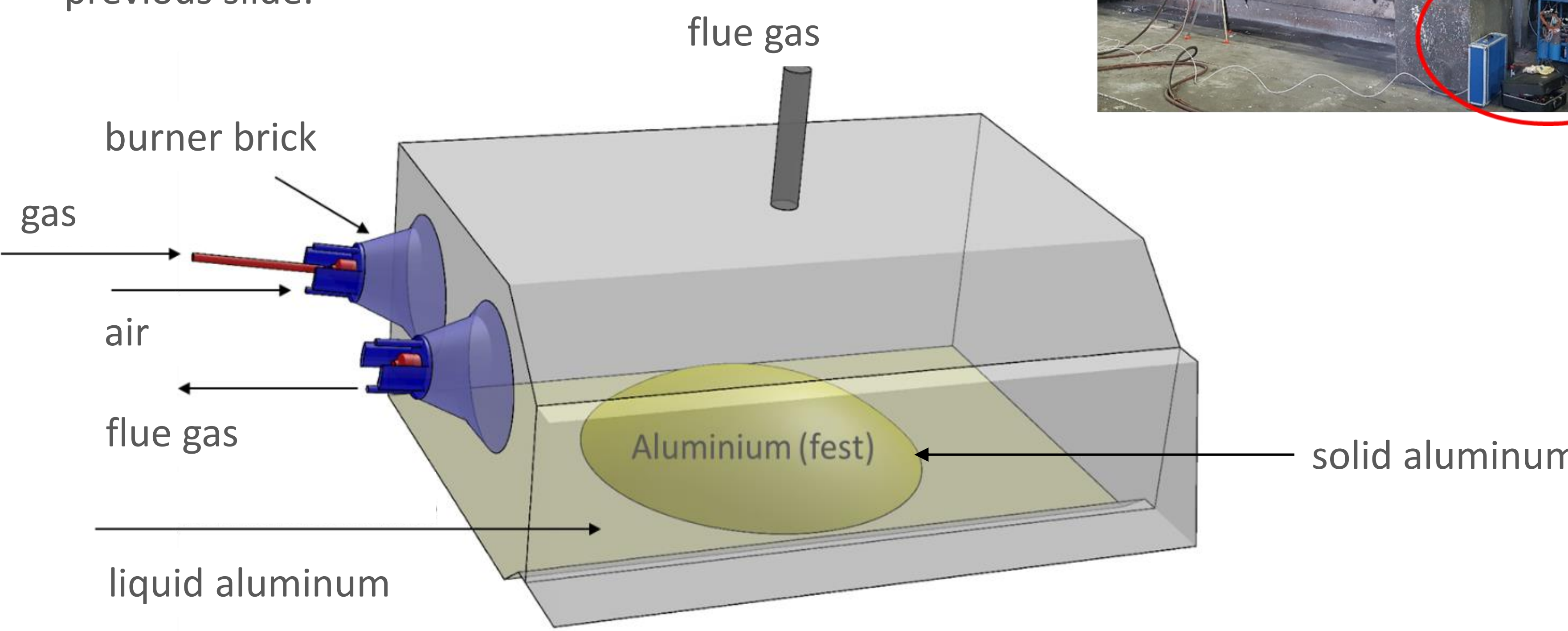
Source: „Hauptstudie Gasbeschaffenheit – Phase II", DVGW-Projekt G1-01-15, DVGW, 2018

Case study: secondary aluminum melting

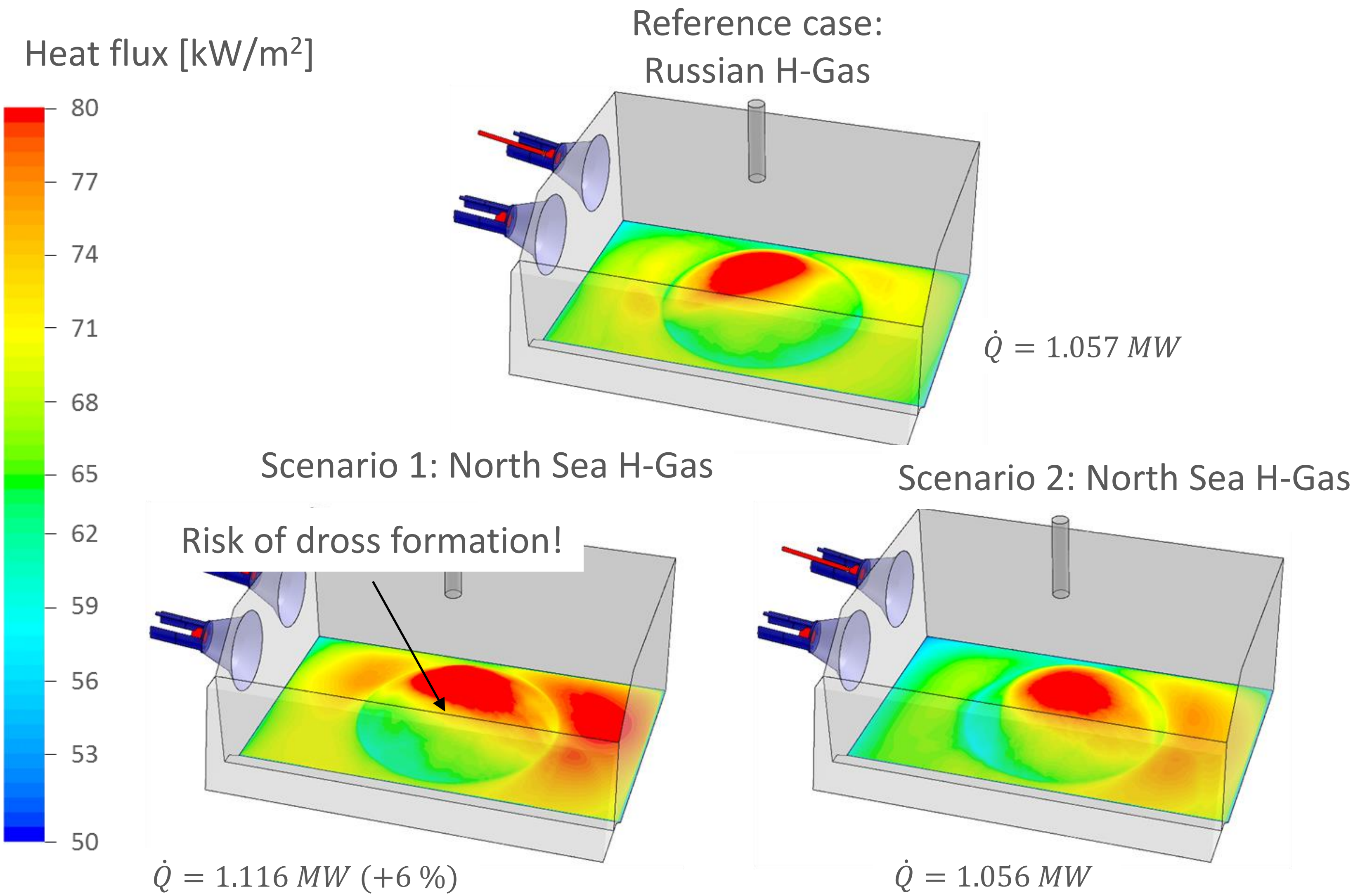
Firing rate: 1.8 MW
Air excess ratio: 1.13
Air preheating: 550 °C

Scenarios as defined on previous slide.





Impact on the heat flux in an aluminum melter



Source: „Hauptstudie Gasbeschaffenheit – Phase II“, DVGW-Projekt G1-01-15, DVGW, 2018

Hydrogen

- **Hydrogen injection** into the natural gas grid is being discussed as a means to **store surplus electricity from renewables**. Gas grids could serve as a **key component** in a future **integrated energy system**, coupling power and gas infrastructures.

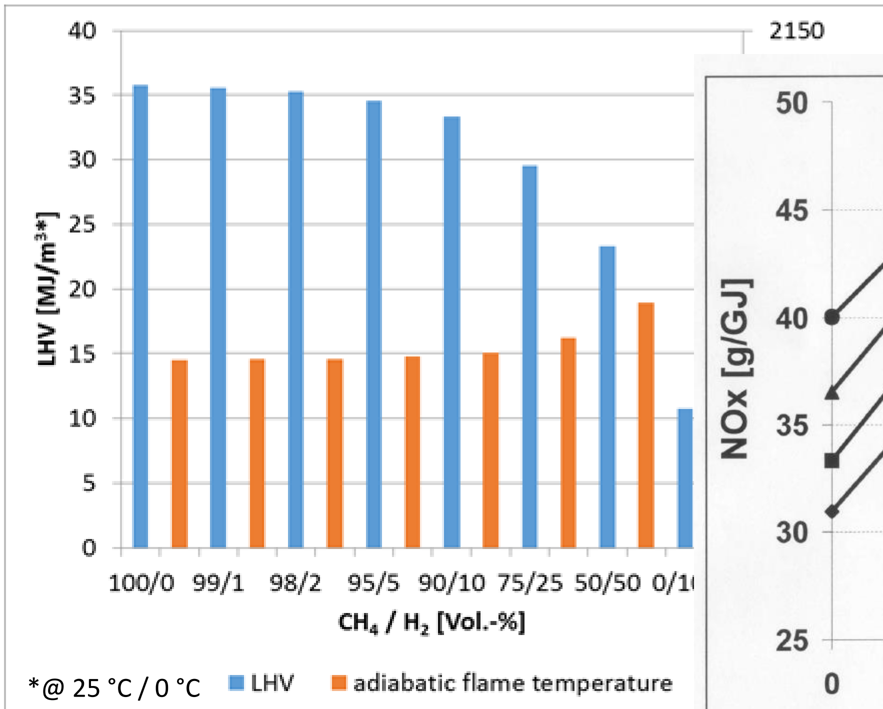
- From an **end user‘s perspective**, hydrogen in natural gas is basically a **gas quality problem**: due to an event upstream, the **local** gas quality and composition changes, and the end user has to deal with it.

- Hydrogen and natural gas have **very different combustion characteristics**. The impact on various end users **across all sectors** has to be considered when injecting hydrogen into the gas grid.

- The investigation of how **common industrial end-use applications** respond to high levels of hydrogen (**up to 50 vol.-%**) in natural gas was the focus of GWI‘s research project „H2-Substitution“.

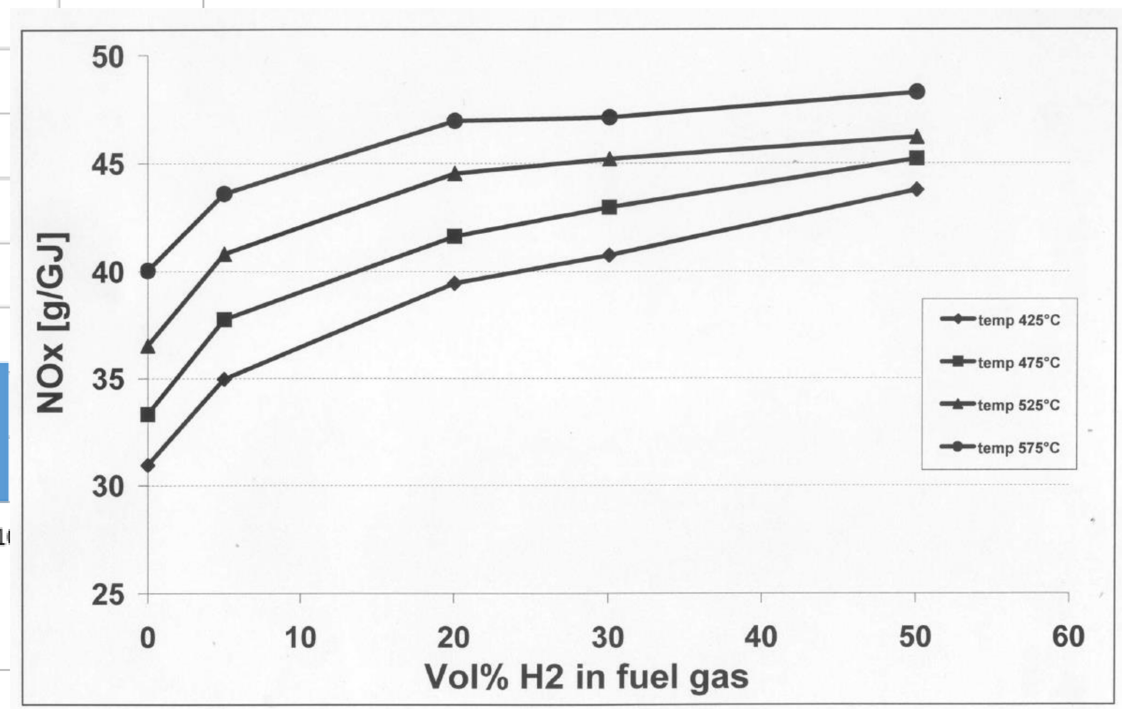
Impact of hydrogen in natural gas…

… on **combustion characteristics**?



Source: GWI

… on **pollutant emissions**?



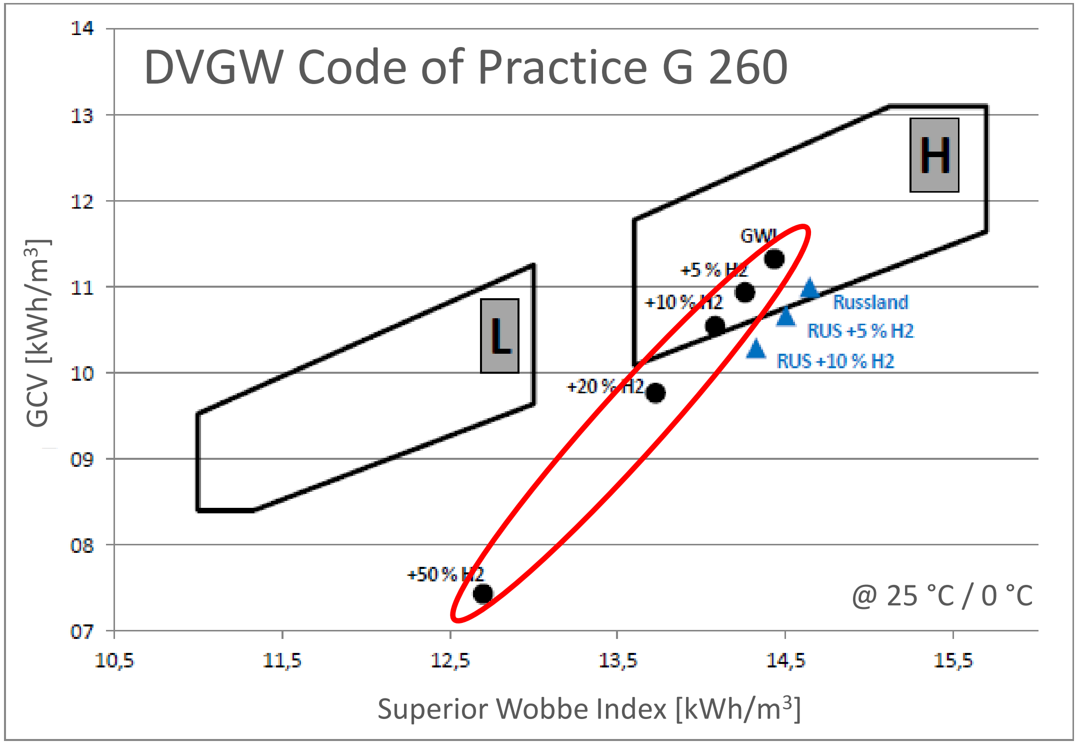
Source: Slim, B.K., Darmeveil, H., van Dijk, G.H.J., Last, D., Pieters, G.T., Rotink, M.H., Overdiep, J.J., Levinsky, H.B., "Should we add hydrogen to the natural gas grid to reduce CO2 emissions (Consequences for gas utilization equipment)", 23rd World Gas Conference, Amsterdam, The Netherlands, 2006

Campaign setup and boundary conditions

- Three commercially available industrial burners were investigated in detail:
  - Burner I: a modular**, non-premixed** burner
  - Burner II: a **forced-draught** burner
  - Burner III: a **flameless oxidation** burner

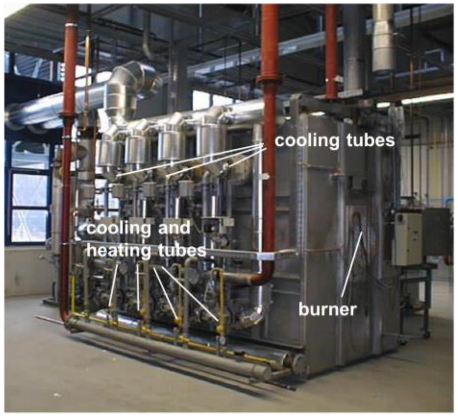
- Different blends of H_2 and a natural gas (GWI-Gas) were used. Many of the investigated fuel blends **do not comply** with German gas quality regulations.

- **Reference case (100 % NG):**
  P = 120 kW
  λ = 1.05
  no air preheating

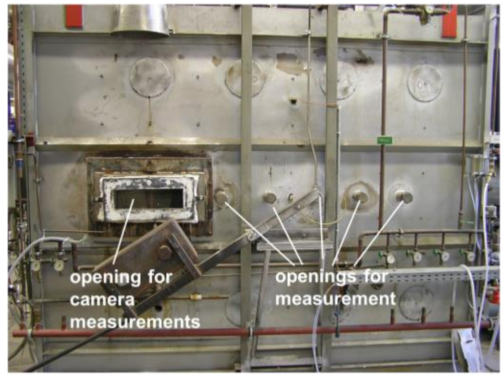


GWI 300 kW$_{th}$ semi-industrial test rig

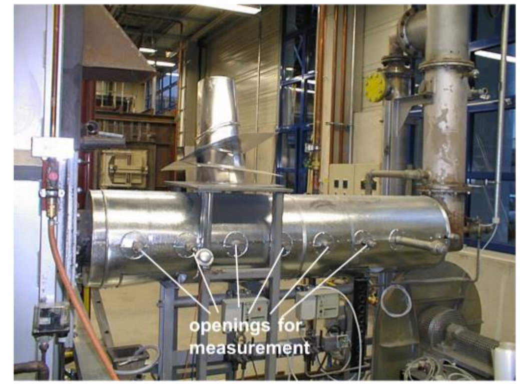
Left hand view

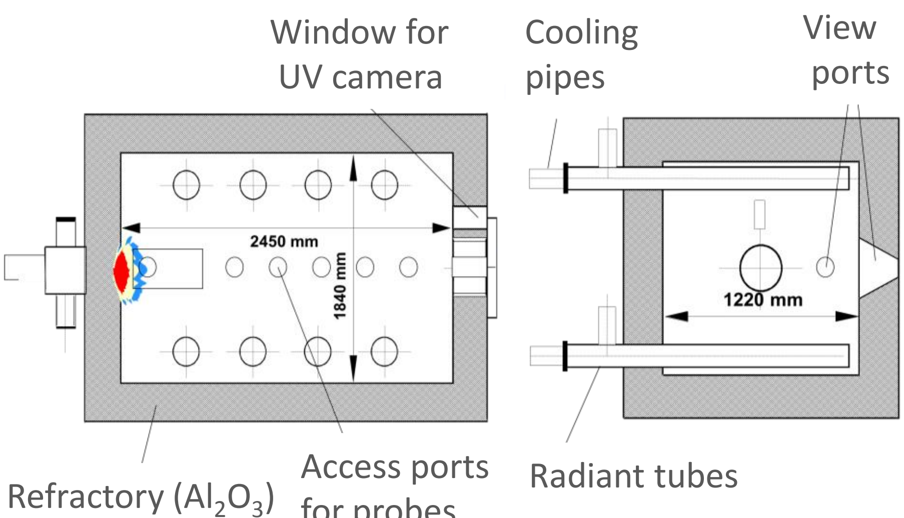


Right hand view

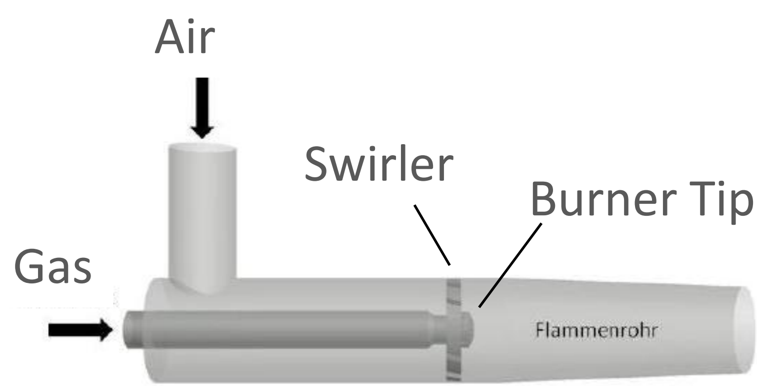


Flue gas duct





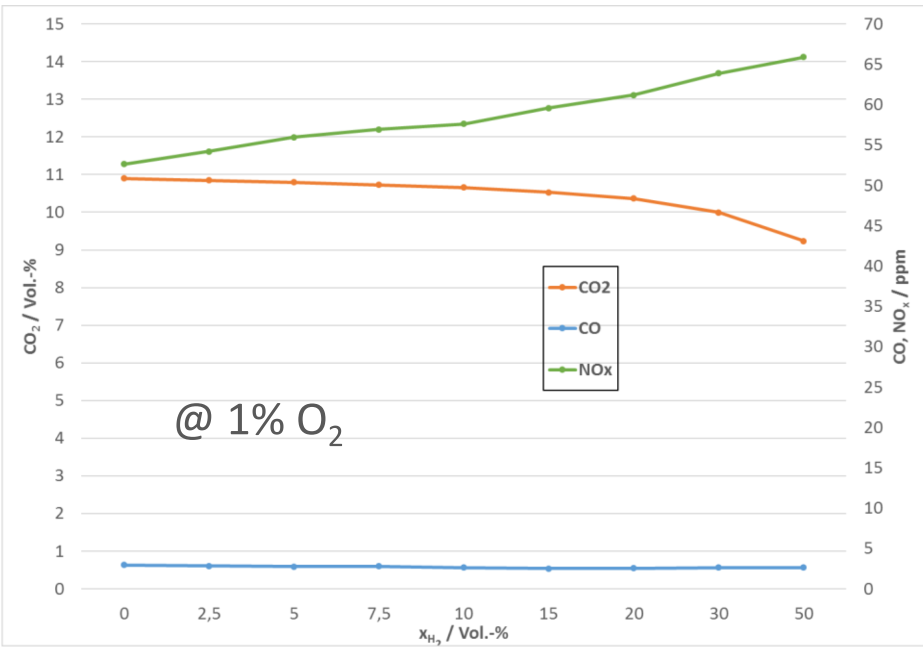
One of the investigated burners (Burner I)

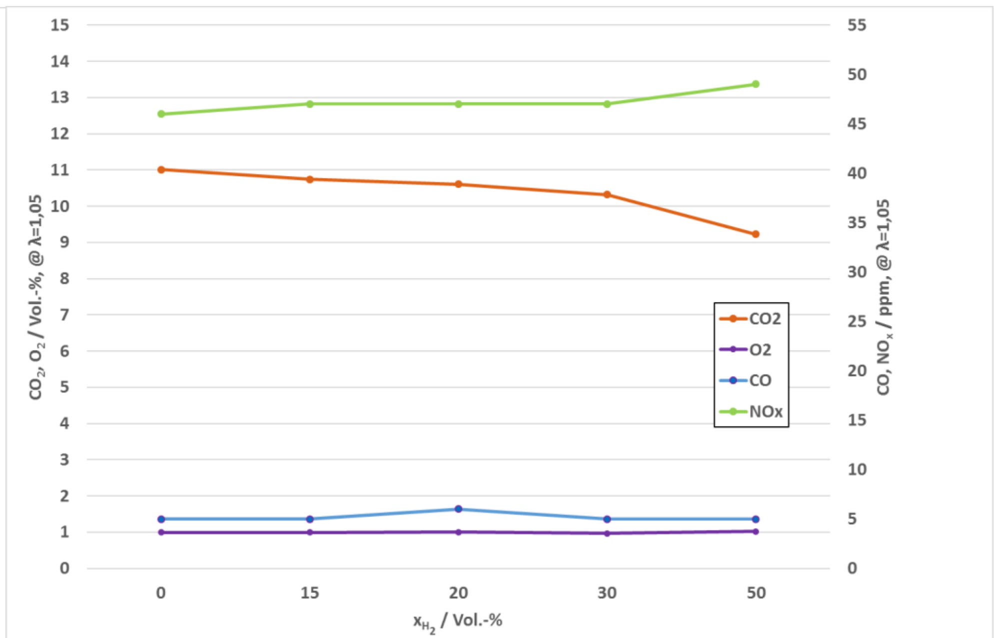


Burner I (non-premixed burner): emissions measurements

Scenario I: V_{gas} = constant
V_{air} = constant

Scenario III: P = constant
λ = constant

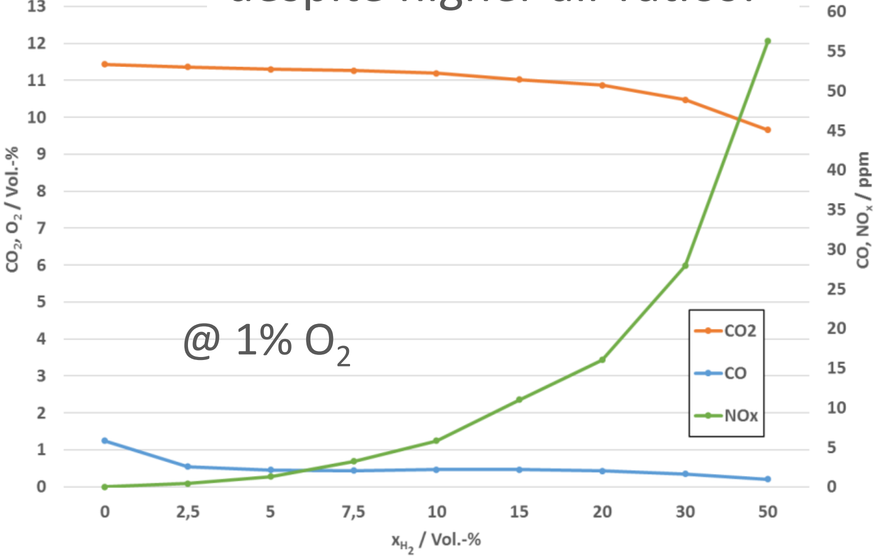




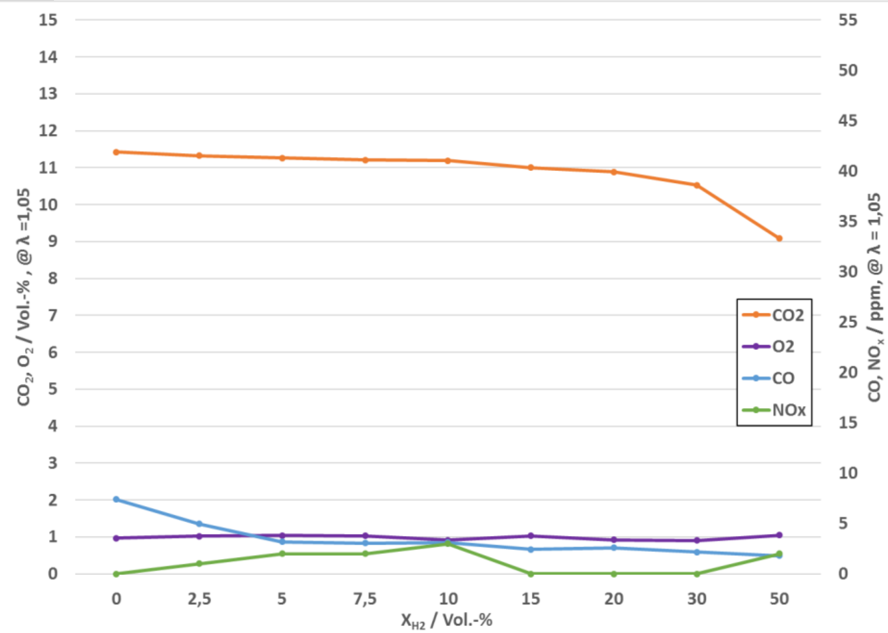
Burner III (flameless oxidation): emissions measurements

Scenario I: V_{gas} = constant
V_{air} = constant

Increased NO_X formation despite higher air ratios!



Scenario III: P = constant
λ = constant



- The burner systems respond **quite differently** to higher H_2 concentrations, especially in Scenario I where volume flows are **not adjusted** to compensate.
- In both cases, however, **advanced combustion control** in combination with **local gas quality measurement** maintain process performance despite significant changes in the fuel.

Conclusions

- Gas utilization in **manufacturing industries** and **power generation** is becoming increasingly more important for the European gas market. Compared to the residential sector, equipment and processes are **much more heterogeneous** and **sophisticated**, with high requirements in terms of **product quality**, **efficiency** and **pollutant emissions** (NO_X).

- At the same time, **local natural gas qualities** in Germany (and Europe) will **vary** to a much greater degree than what many end users are historically used to. **Industrial end users** in particular are often **sensitive** to these fluctuations, with consequences for **product quality**, **process efficiency** and **pollutant emissions**.

- There is still a **lack of awareness** both on the side of the gas industry, but also among the end users themselves.

Conclusions

- Gas quality fluctuations are likely to increase in **both frequency** and **strength**. If significant amounts of **hydrogen** are injected into the gas grid in the future, this is basically also a **gas quality issue** from an **end user's perspective**.

- GWI investigated the **impact** of such fluctuations on typical **industrial combustion processes** in the course of several German research projects as well as **mitigation strategies**.

- **Local gas quality measurements** in combination with **advanced combustion control technologies** were shown to be a powerful tool to deal even with severe gas quality fluctuations (with or without H_2) **without compromising** on process performance.

- This equipment is not yet commonly found in industrial plants, however.

Acknowledgments

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We would also like to thank all partners involved in these projects for the fruitful collaboration.

Gas- und Wärme-
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Thank you for your attention

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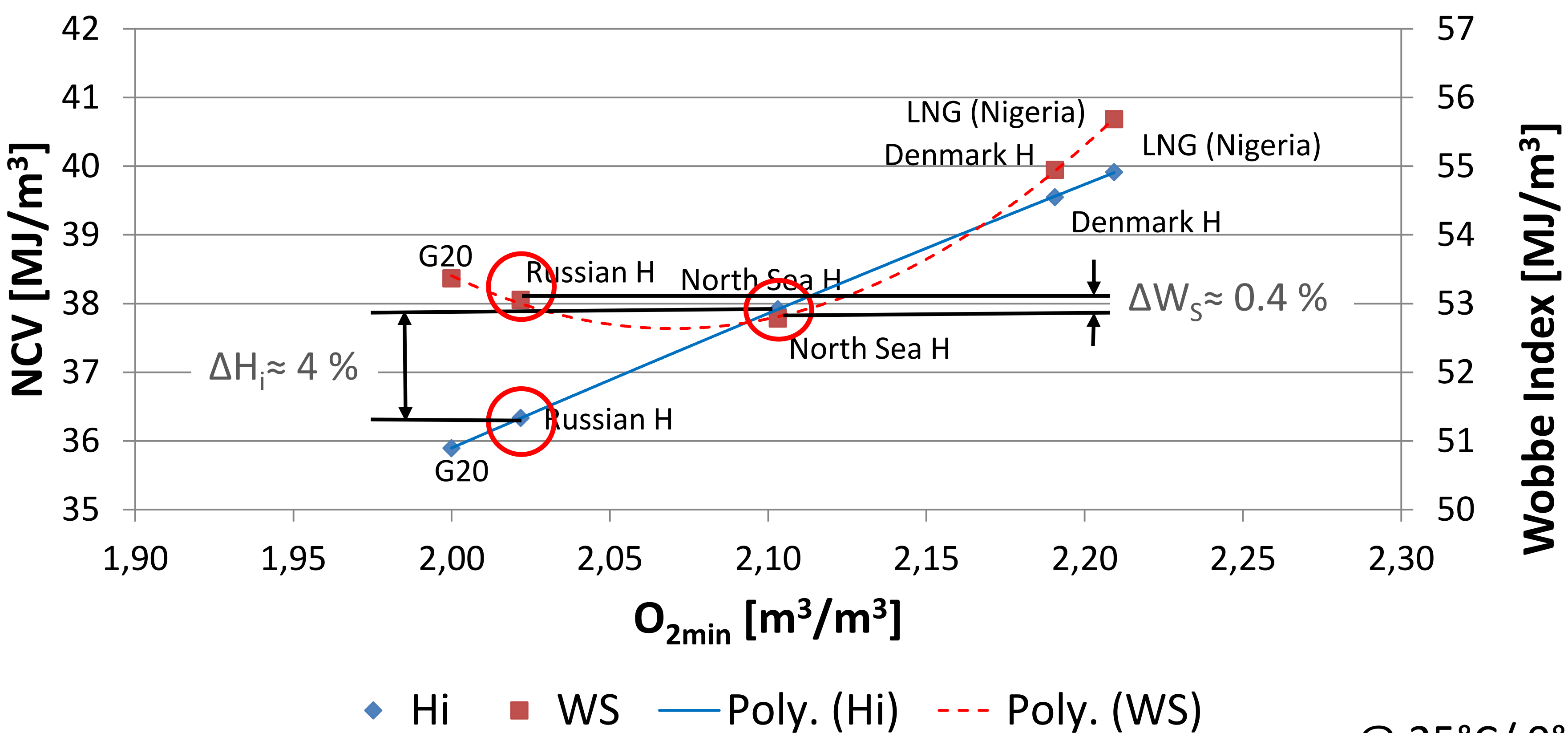
Wobbe Index vs. NCV/GCV vs. O_{2min}



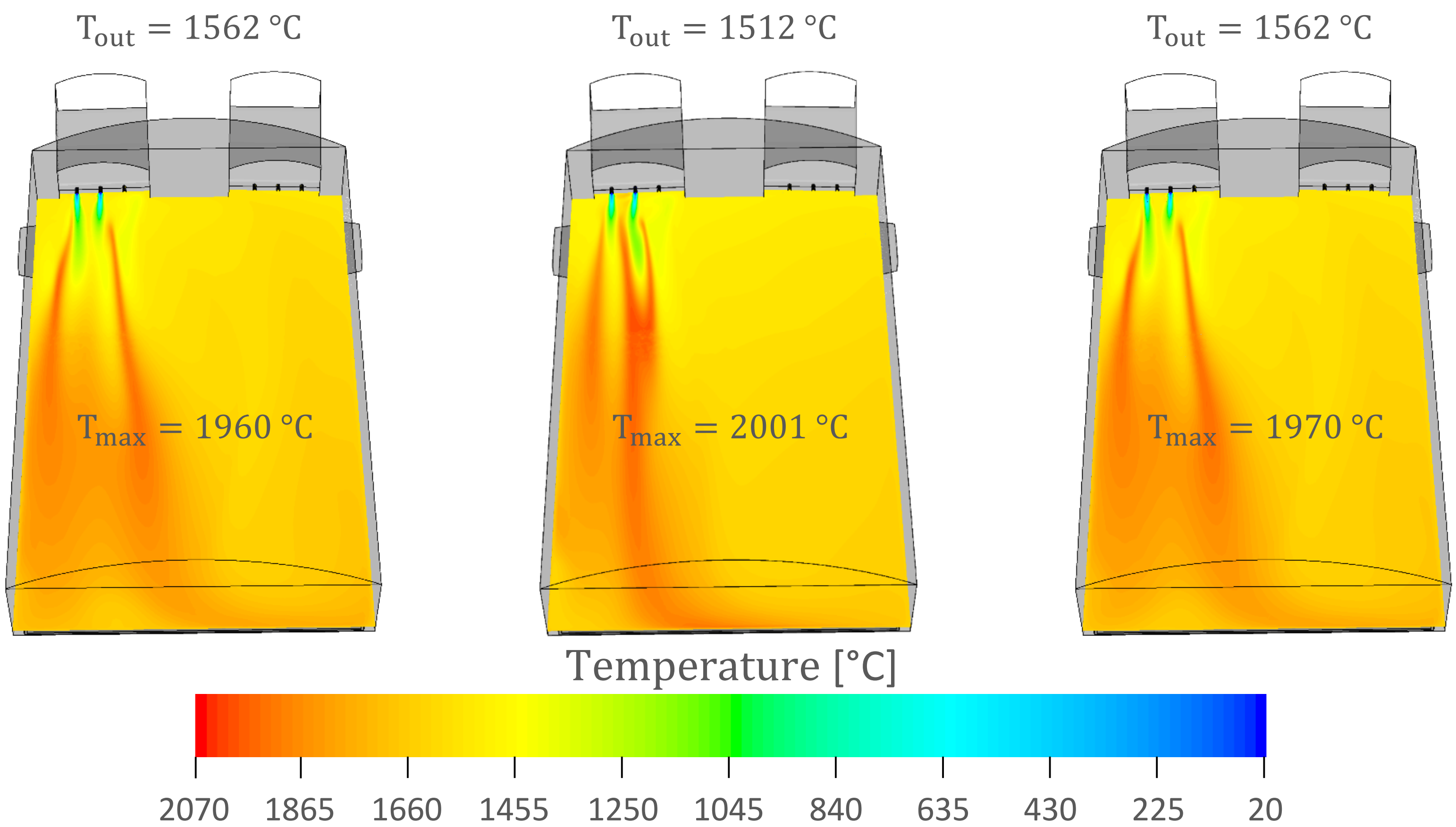
@ 25°C/ 0°

There is an **excellent correlation between NCV and oxygen requirements** of different fuel gases. The correlation between Wobbe Index and O_{2min}, on the other hand, is **ambiguous** and also far less pronounced.

CFD Study of H2/NG Blends in a Regenerative Glass Melting Furnace

Regenerative glass melting furnace: 10 vol.-% H_2 in NG

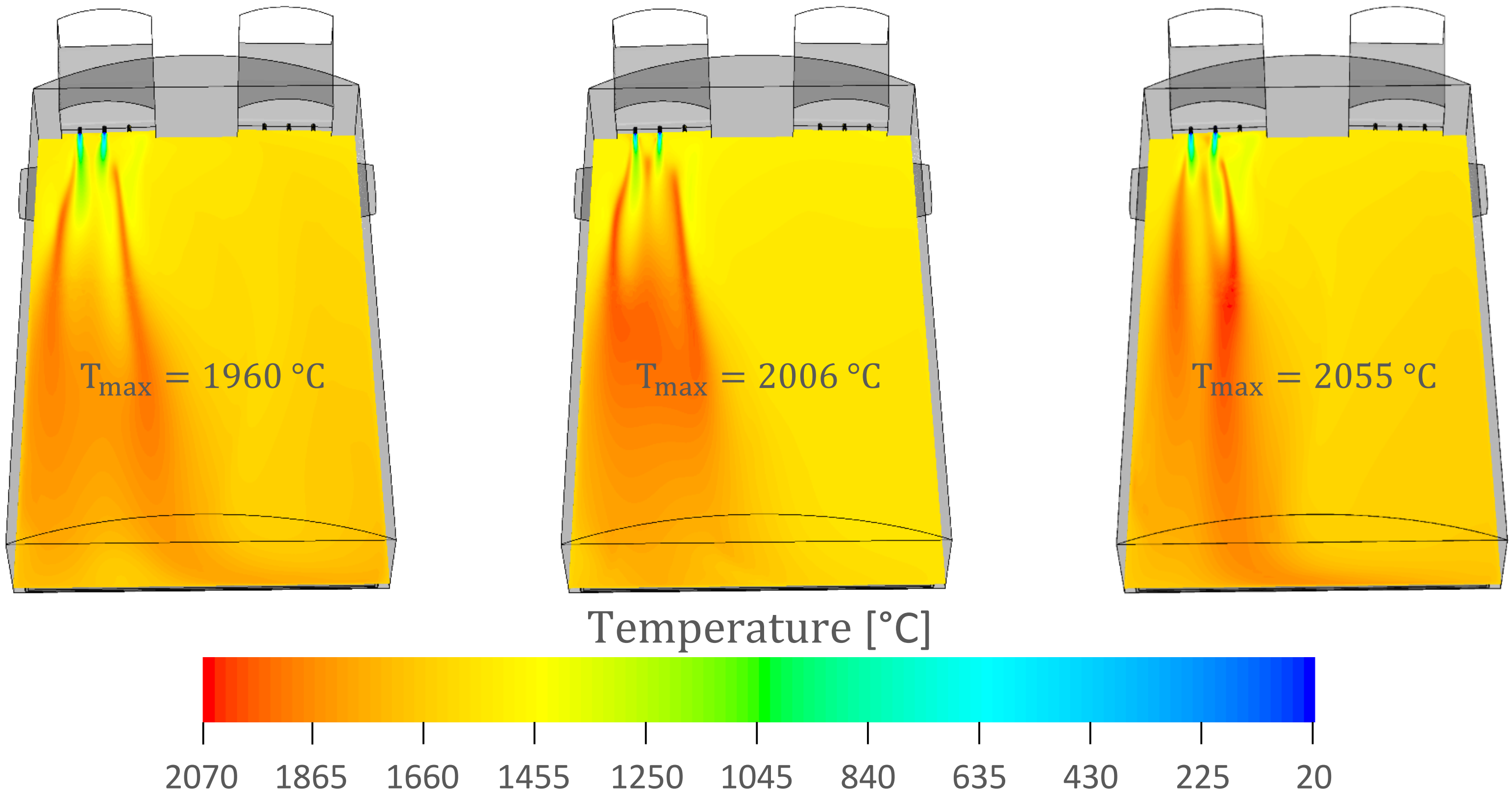
100 % natural gas	Scenario 1	Scenario 3



Operating Conditions (Reference Case): P = 12 MW; λ 1.05; T_{air} = 1,400 °C

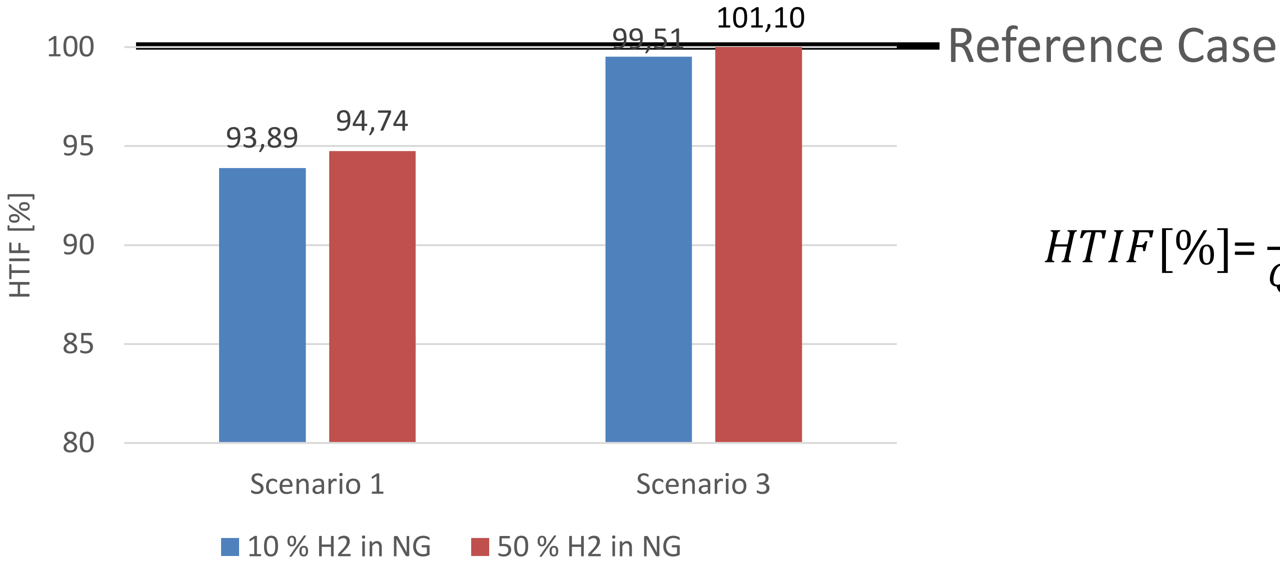
Regenerative glass melting furnace: 50 vol.-% H_2 in NG

100 % natural gas	Scenario 1	Scenario 3
$T_{out} = 1562\,°C$	$T_{out} = 1486\,°C$	$T_{out} = 1535\,°C$



Operating Conditions (Reference Case): P = 12 MW; λ 1.05; T_{air} = 1,400 °C

Impact of H_2 and control scenarios on heat transfer and NO



$$HTIF[\%] = \frac{\dot{Q}_{glass}}{\dot{Q}_{glass,reference}} \cdot 100$$

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