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Natural gas quality fluctuations – surveys and statistics on the situation in Germany

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Abstract

In recent years, natural gas quality has become a contested topic for market partners along the gas value chain, especially in the context of the European gas quality harmonization process. While a consensus could be achieved on many aspects of gas quality regulation, leading to a first European standard for H-gas quality (EN 16726), this standard lacks any regulation of combustion-related properties except for a minimum Methane Number.

There is also significant uncertainty to what extent gas quality variations actually occur in German gas grids today and how they may affect gas-fired applications. This was the focus of two surveys carried out by a group of German gas-related research organizations in which gas quality measurements over long periods of time were compiled for various regions in Germany to highlight frequency and severity of local gas quality and composition changes. While one of these studies concentrated on the glass industry and also looked at possible measures to compensate for gas quality fluctuations, the other took a broader view, investigating common adjustment practices, awareness of gas quality issues among operators of gas-fired equipment and typical countermeasures by a statistical analysis of all sectors of German gas utilization (domestic, chemical and thermal processing industries, power generation). It appears likely that these findings can be transferred to other countries to a certain extent.

The results of these studies as well as background information on the European gas quality harmonization process will be the focus of this contribution.

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1. Introduction

The European gas markets have been in a state of flux for a number of reasons for the last few years. The supply situation is changing (for example, the Netherlands are expected to cease their gas exports by 2030) while at the same time, the markets were liberalized. Integrated gas suppliers had to split up into different companies dealing with different aspects of the gas market such as trading, transport and distribution grid operation or the operation of underground storage facilities. Feed-in of renewable gases such as biomethane or possibly even hydrogen from power-to-gas applications in the future is on the rise, and on the political level, the European Union strongly supports the development of a common European standard for the quality of H-Gas within the internal market. The national gas quality standards currently in place are considered to be an obstacle to the free trade of the commodity "natural gas" in the internal market since they differ greatly [1]. A first European gas quality standard, EN 16726:2016-04, was published at the beginning of 2016. While there are still many open questions with regards to this document (e. g., at the moment the only combustion-related criterion given is a minimum Methane Number of 65), it is certainly a major step towards a unified European treatment of the issue of natural gas quality in the internal market.

There are opposing views how future permissible gas qualities in the EU should be defined: gas suppliers and grid operators propose a wide quality range in order to reduce costs and ensure security of supply by being able to access a wide range of different sources, including regenerative gases (biogas, possibly hydrogen) and liquefied natural gas (LNG). Operators and manufacturers of industrial combustion equipment as well as the chemical industry, on the other hand, voice concerns that a wider gas quality range would result in strongly fluctuating local gas qualities and compositions, with negative impacts on gas-fired processes in the thermal processing and power plant sectors, especially with regards to efficiency, pollutant emissions and product qualities. Manufacturers of domestic gas appliances are concerned how their products react when confronted with gas qualities they were never designed for.

One consequence of the developments on the European markets is that fluctuations of local natural gas qualities and compositions are likely to increase both in amplitude and frequency within the European grids [2]. For many regions, this may be a new experience and it is difficult to predict how a very diverse market such as the market for natural gas (cf. Figure 1) with its very heterogeneous end use applications will respond to increasing gas quality fluctuations.

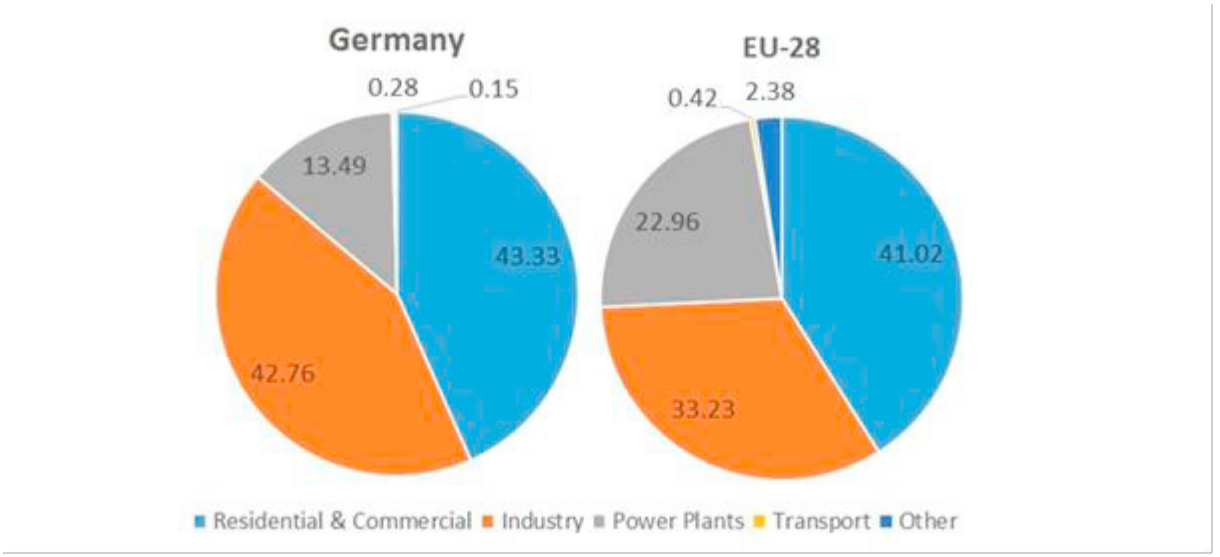

Figure 1: Natural Gas Consumption by Sector [%] in Germany and the EU in the Year 2014 [3]

It is evident that the different market sectors have very different structures. While the residential sector for example is made up of large numbers of small appliances (it is estimated that there are about 167 million gas-fired residential appliances installed in the EU [2]), the number of installations in the industrial sector is by orders of magnitude lower than in the residential sector. The firing rates per unit, however, tend to be much higher. Thus, the industrial and the residential sectors account for roughly the same share in both the German and European gas consumption. Gas-fired power generation in gas turbines and gas engines also plays an important role, though in Germany less than in Europe as a whole. In German industry, about 60% of process heat is provided by means of natural gas [4], a figure which underlines the importance of natural gas for this sector.

Compared to residential appliances, the requirements for industrial gas-fired equipment tend to be much more demanding with regards to efficiency, process stability and pollutant emissions. Of course, product quality and safety are of paramount importance for the operation of this kind of equipment. This has led to a much greater degree of specialization, diversity and optimization in the industrial sector as is demonstrated by Figure 2 which shows process heat requirements (in Germany) and typical process temperatures for various thermal processing industries. It is to be expected that, given the wide range of specialized and optimized technologies found in the various industrial gas-fired applications, some systems will be more susceptible to fluctuating gas qualities and compositions than others. A few such cases have already been reported where changes of local gas characteristics had a negative impact on the operation of industrial equipment and processes (e. g. [6], [7], [8]).

More generalized studies and reviews of this issue were carried out in Germany [9], [10], the Netherlands [11], [12] and France [13], but also in the U.S. [14], [15], [16], albeit for different reasons. The consensus is that there is a number of industrial processes, especially in glass, ceramics and metals manufacturing, which may be significantly affected by local gas quality fluctuations while others are expected to be more resilient. There are also concerns that varying gas compositions may negatively have on equipment like gas turbines and engines in the power plant sector [6], [11], [17], [18].

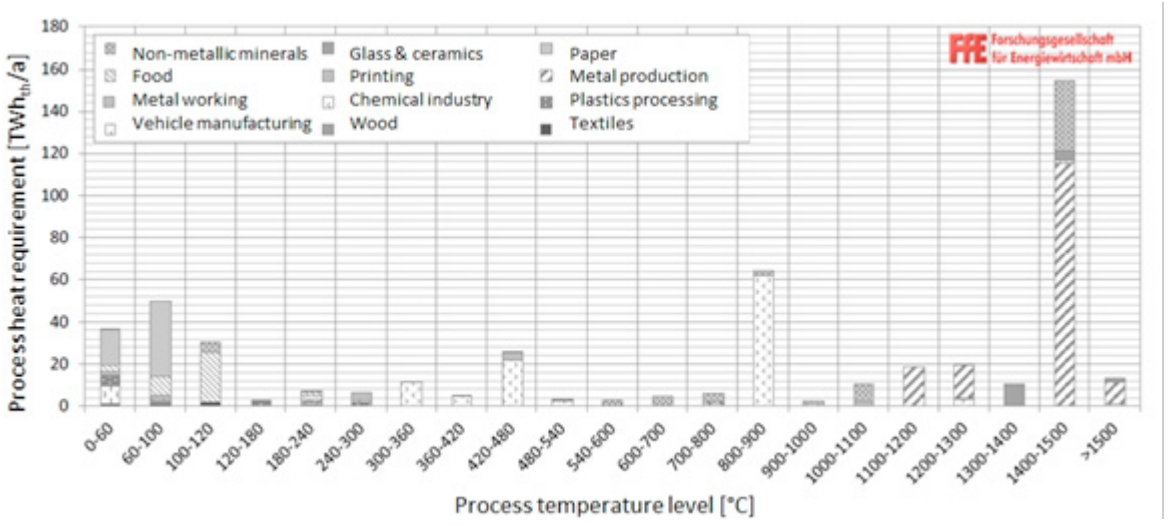

Figure 2: Process Heat Requirements and Typical Process Temperatures for Different Thermal Processes [5]

2. Industrial utilization of natural gas in Germany

In order to evaluate and cost different possible strategies for how to best address the issue of fluctuating local gas qualities and compositions in the future, it is important to have detailed and reliable data about the current situation in the different sectors of the gas market. Therefore, DVGW (the German Technical and Scientific Association of Gas and Water) initiated and funded a nationwide, statistically supported survey called “Hauptstudie Gasbeschaffenheit Phase 1” [19] where three German gas-related research institutes (DBI, GWI and EBI), with the active support of

various associations representing all major market partners (residential and industrial gas utilization, power generation and gas vehicles as well as transport and distribution gas grid operators), compiled and analyzed the results of questionnaires that had been sent to representative samples of the different end-user groups. While the findings of this survey only describe the current situation in Germany and its stock of installed appliances and equipment, it can be expected that there are many similarities to the status quo in other European countries. Phase I focused on compiling data to describe the current state of affairs in the different sectors of the gas market using questionnaires, surveys and statistical analysis. Phase II will concentrate on determining overall economic costs for different strategies on how to deal with fluctuating gas qualities, be it by measures on the grid level to reduce the quality fluctuations that end users will experience (e. g. grid-level conditioning of natural gas) or by making the various end-use applications more flexible towards such fluctuations without compromising on efficiency or pollutant emissions. The main results of the investigation into the industrial gas utilization in Germany will be presented in the following.

2.1. Structure and Sample Size of the Industrial End-Use Surveys

The findings of the DVGW survey concerning industrial gas utilization are based on the results of two questionnaires, one addressed to the operators of industrial gas-fired equipment, the other (distributed and analyzed by VDMA, the German Mechanical Engineering Industry Association) to the manufacturers of such equipment and components. 56 replies were received from operators, while 32 manufacturers also participated. Replies for both questionnaires covered many industries such as metals (steel as well as non-ferrous metals), glass, ceramics and the chemical industry, providing a comprehensive overview of many energy-intensive industries in Germany. The DVGW survey was predominantly answered by representatives of the chemical (43 %), glass (29 %), steel (9 %) and ceramics (7 %) industries in the western and southern parts of Germany (where many heavy industries are concentrated), while the VDMA questionnaire was mostly answered by equipment manufacturers for the metals industries. This may explain some of the minor discrepancies that were found during the analysis of the results though the overall conclusions of both surveys are very similar. While the respective sample sizes of both surveys are too small for a proper statistical analysis (in contrast to the analysis of residential gas utilization in the survey, where more than 1,200 residential HVAC installers (HVAC: heating, ventilation and air conditioning) participated, allowing for a more thorough statistical approach), they give an clear indication of how gas quality is perceived by industrial end users and how current practices and procedures regarding design, adjustment and operation of industrial gas-fired processes may have an impact on the susceptibility of industrial equipment to gas quality fluctuations.

Of the equipment operators, 80 % use gas for process heating, 13 % for chemical conversion processes and 7 % for both. About 60 % of the thermal processes and plants covered by the survey have firing rates between 1 and 50 MW, 8 % state that the firing rates in their applications exceed 100 MW. 90 % of the thermal processes run continuously, process temperatures range from 200 °C to more than 1600 °C.

2.2. Awareness of Gas-Quality Related Isssues

Figure 3 illustrates to what extent equipment operators are actually aware of the quality of the gas that they have on-site at any given moment. Of all participants, roughly 21 % state that they have no information whatsoever about gas quality while another 55 % replied that have access to gas quality data based on monthly, weekly or daily averages. In all likelihood, the answers in this group mostly refer to the monthly averaged gas composition or quality reports that are often issued by grid operators and/or gas suppliers at the end of a billing period (for industrial customers usually one month). This group also included answers such as “once a quarter” or “upon request”.

Only to 23 % of all participants, gas quality data is available based on “real-time” measurements with reasonably short intervals between measurements (hourly, each 15 minutes or even continuous measurement). Only this last group would be able to detect and respond to a sudden gas quality change. Based on all answers, only 16 % monitor gas quality themselves, most rely on information from grid operators or gas suppliers. Interestingly, the survey of the manufacturers shows an even more one-sided picture: according to their data, the vast majority (94 %) of manufacturers state that in their products, the current gas quality is not monitored at all. This discrepancy is probably

to some extent due to the composition of the sample of the manufacturers' survey which also included manufacturers of burners and other components which would not be able to monitor gas quality anyway.

Interestingly, although only 23 % of all participants state that they have access to gas quality measurements with sufficiently high sampling rates, 38 % claim that they do monitor current gas qualities in some form, be it by calorific value, Wobbe Index or actual composition. When asked in which form the local gas quality was monitored, most of these plant operators replied with calorific values, density or the actual composition. Only 38 % answered that they were aware of or even interested in the Wobbe Index of the available gas on-site. This is corroborated by the survey of equipment manufacturers where the trends are very similar. Gas quality is of course taken into account during the design process of equipment and components, but again, usually in the form of calorific values, a representative chemical composition and/or density. Only 28 % of the manufacturers consider the Wobbe Index (either in the inferior or superior form) to be relevant for their products.

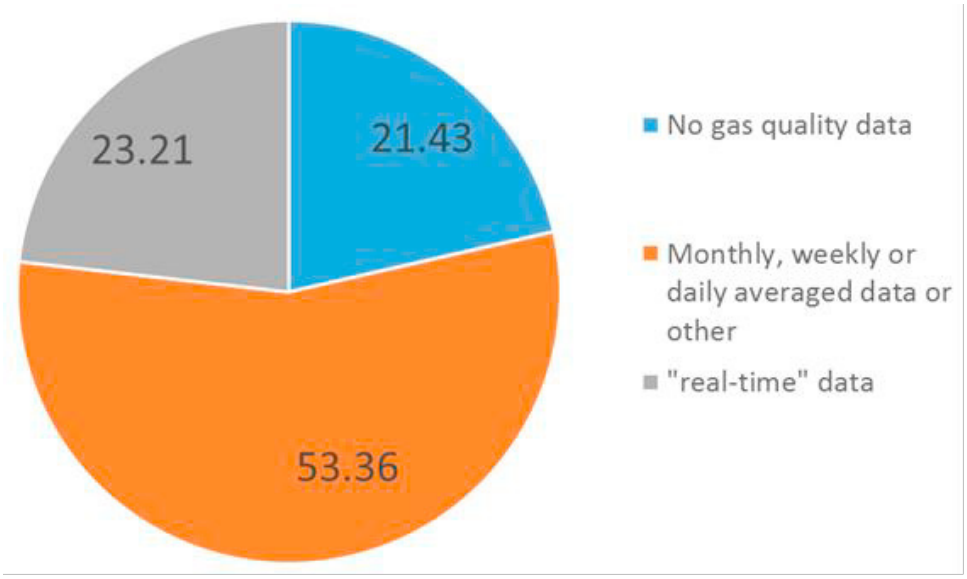

Figure 3: Awareness of operators of industrial equipment about the "currently available" gas quality

2.3. Adjustment and Maintenance

During plant commissioning or after maintenance, only very few manufacturers state that they use the current Wobbe Index for adjustment. For the most part, adjustment is carried out based on calorific values, or, more likely, based on process or flue gas criteria such as temperatures, oxygen content or pollutant emissions (CO, NO_X). In many cases, the shape of the flame also factors into the adjustment process. Adjustment is always based on the locally available gas at the time of the commissioning or maintenance; the quality or composition of the adjustment gas may or may not be known (30 %). The survey of the residential sector shows a surprisingly similar picture: although residential appliances are supposed to be adjusted based on a well-defined reference gas defined in EN 437 (for H-Gases G20, which is 100 % CH_4), even here a significant majority (83 %) of installers state that they adjust either always or at least sometimes to the local unknown gas. After maintenance, virtually all HVAC technicians re-adjust to the local gas. These findings are supported by a similar but significantly smaller survey from France [20].

The results from these industrial surveys underline the relative unimportance of the Wobbe Index for many process heating or chemical purposes. 64 % of equipment operators state that the Wobbe Index is not a meaningful fuel gas property for their application. In some industries like for example the chemical industry, the single biggest gas consumer in Germany [21], the number is even higher (75 %). In general, other gas quality criteria like calorific values, minimum air requirements or the actual compositions are considered much more relevant by industrial end users.

However, most national gas quality codes use the Wobbe Index as the sole criterion for fuel gas interchangeability, in some countries (e. g. Denmark) it is actually the only combustion-related criterion at the moment. Even the current discussion about the upcoming revision of EN 16726 tends to focus on the definition of an acceptable Wobbe Index range. Since the industrial sector accounts for more than 42 % of the gas consumption in Germany and about 33 % of the European consumption [3], this difference between regulatory efforts on the one hand and industrial practice on the other hand is likely to cause problems. In the past, this issue did not really occur because industrial processes are designed and adjusted for the locally available gas, based on the assumption that the local gas quality (or composition) at a specific location in the gas grid will not significantly change over time. This is assumption appears to be no longer valid though, given the current developments in the European gas markets. Also, the constant evolution of industrial combustion systems with regards to efficiency and low pollutant emissions often makes these sophisticated systems less flexible with regards to changing boundary conditions such as a gas quality change.

A case in point in this context is the adjustment to very low air excess ratios that is common practice for most industrial combustion processes. The survey of the operators of thermal processing equipment shows that about 72 % adjust their processes to air ratios of 1.1 or below. Processes that are intentionally operated at sub-stoichiometric conditions (e. g. galvanizing processes) are not included in this figure. In a similar vein, 41 % of the manufacturers of industrial combustion equipment state that they design their products for operating air ratios of 1.1 or below. 72 % of the manufacturers design for air ratios below 1.15.

2.4. Operator Experience with Gas Quality Changes and Response Strategies

When asked whether they had experienced a significant gas quality fluctuation (expressed as a change of more than ± 3 % of a relevant gas quality criterion for their application) in the last few years and what the impact had been on their production process, about 48 % replied that they had. Frequencies of these fluctuations ranged from “daily” (4 %) to “less than once a month” (74 %). As consequences of such fluctuations, unintended changes in process parameters (19 %), changes in product quality (15 %), problems with fluctuating process temperatures (11 %) and increased effort for manual re-adjustment of burners (7 %) were mentioned while 11 % stated that they had not noticed any consequences at all. These findings agree rather well with an older study carried out in the German glass industry which reported similar results for glass manufacturers [22], albeit with a higher number of participants reporting gas quality related issues (77 %).

About half of all participants stated that they had been informed about a gas quality fluctuation though it is unclear if this figure refers to an advance warning or a notification after the fluctuation had already occurred.

Obviously, the installed measurement and control equipment used to supervise the operation of a thermal processing plants plays an important part in how operators can actually detect and respond to fluctuating gas qualities. Among those that had previous experience with significant gas quality changes, 31 % stated in the DVGW survey that they react to changing fuel gas compositions by manually readjusting their process, while 50 % responded that they have some kind of automated control feature. This could be something like a probe monitoring excess oxygen in the flue gas which could be used to respond to a fuel gas change in a limited way, or a more sophisticated solution like a gas chromatograph in combination with an advanced furnace control system. Previous studies [7] underline how important a suitable control scheme can be in this context, especially for sensitive manufacturing processes. 19 % of the participants claimed nevertheless that they have no way whatsoever to compensate for a gas quality fluctuation.

No one in this survey mentioned local fuel gas conditioning, i. e. the mixing of natural gas with air, nitrogen or LPG in order to maintain certain fuel quality criteria like Wobbe Indices, net calorific values or minimum air requirements constant. This is probably due to the limited sample size of the survey as some such applications are known to exist in Germany [23]. Since they tend to incur higher operational costs though, the economic viability of local fuel gas conditioning is limited to manufacturing processes for high-value products such as special-purpose glass.

The DVGW survey also shows that, based on data provided by transport grid operators, the gas quality situation in Germany is not uniform but shows distinct regional differences. Regions in East Germany show relatively stable gas qualities, while the H-Gas region in the western parts of Germany exhibits more pronounced fluctuations in regional Wobbe Indices or gross calorific values.

2.5. Consequences of the Survey Findings

Due to its broad scope, the DVGW survey can only provide a relatively high-level impression of the current situation with regards to gas qualities in Germany and their relevance for the various end-use sectors. It points out however, that in many cases, thermal processing operators are ill-equipped to handle significant gas quality fluctuations and still rely on the relative stability of the local gas composition. Although about half of the participants state that they have experienced gas-quality-related issues in the last few years, only a distinct minority operates their own gas quality measurement equipment. Automated response strategies are not standard. All this could be interpreted in different ways: either the issue of gas quality fluctuations is relatively recent in Germany or the problems arising from gas quality are, for the moment, not yet considered painful enough to warrant investments into advanced measurement and control technologies. A lack of awareness may also be an issue in some industries.

The study also points to another potential problem: the primary gas interchangeability criterion used in most national and international gas quality codes, the superior Wobbe Index, is only of limited relevance for many industrial purposes. Despite this, however, international discussions about gas quality in the gas industry tend to focus almost exclusively on this property which means that current discussions and harmonization activities run the risk to exclude a significant part of the natural gas market, potentially even the most sensitive sector.

Given the great degree of heterogeneity in thermal processing and chemical industries, the impact of fluctuating gas qualities varies from end-user to end-user and from application to application. One industry that has frequently been identified as very susceptible to gas quality fluctuations is the glass industry [8], [9], [13]. In the currently ongoing research project “GasQualitaetGlas” [24], [25], funded by the German Federal Ministry of Economic Affairs and Energy, a consortium of research organizations and industrial partners is currently compiling long-term gas quality and composition measurements from various locations in Germany, evaluating different measurement technologies for their applicability under the conditions found in glass factories and adapting furnace control loops to better take gas quality fluctuations into account and mitigate their impact on manufacturing processes. As glass factories are often supplied via the low-pressure gas distribution grids, these measurements will help shape a more comprehensive picture about the current situation in Germany, since the feed-in of biomethane, for example, into the gas grids usually occurs on this level of the gas infrastructure.

3. Conclusions

The German and European gas markets are changing for a number of reasons, with consequences not only for the gas industry, but also for the many applications and appliances that use natural gas in one way or the other. The current discussions about gas quality highlight the complexity of this issue due to the very heterogeneity of the markets, with many different end use applications in the residential, industrial and power generation sectors, often with very different operational profiles and requirements to the resource “natural gas”.

In order to respond to these challenges, it is vital to have solid data on the various fleets of end-use appliances and equipment in the field, typical operational parameters and procedures and their respective requirements towards natural gas and their sensitivities to changes in gas quality or composition. The DVGW study briefly presented in this article offers, among other things, a detailed look into the status quo of industrial utilization of natural gas in Germany and provides valuable input to the European gas quality harmonization process. At the same time, the project “GasQualitaetGlas” promises to give a more detailed insight into one of the industries considered most vulnerable to gas quality changes as well as approaches towards technological solutions for these challenges.

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