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Gas Innovations Inspiring Clean Energy

Experience with the Injection of Hydrogen into a Historically Grown Natural Gas Distribution Grid

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Hygrid: Hydrogen Injection in a Distribution Grid

Project objective:

To investigate the impact of hydrogen injection in a historically grown residential area on gas appliances and grid components

Project scope:

existing gas grid with more than 100 customers
broad range of existing natural gas appliances
mainly domestic applications

Project goal:

To prove the feasibility of hydrogen injection up to 10% into an existing grid with mainly domestic customers
To support the development of the Power to Gas Concept

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Hygrid: Project Partners and Timeline

Preparation Phase:

September 2012 to May 2014

Executing Phase:

May 2014 to May 2015

Reporting Phase

May 2015 to June 2015

Preparation Phase (September 2012 – May 2014)

Distribution Grid

Tasks and Responsibilities

Schleswig-Holstein Netz AG

TÜV SÜD CE

Communication & Cooperation

Measurement and Billing

Appliance Inquiry

Build up and Approval

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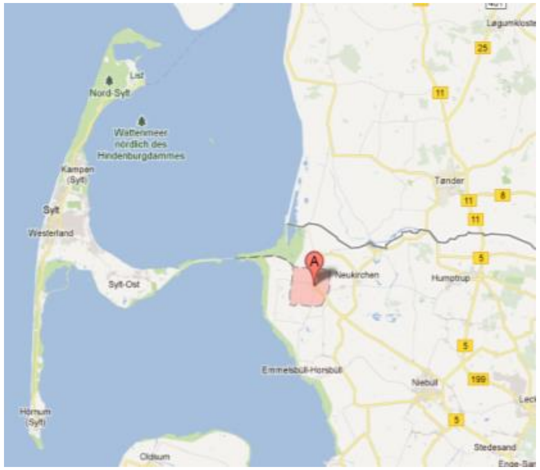
Characteristics of the Distribution Grid



- Gas distribution grid of Klanxbüll/Neukirchen
- Approx. 2000 residents and 170 grid clients
- Mainly domestic appliances / no filling station
- One gas entry point
- Pressure regulation site with two-train gas pressure control system 40-60 bar / 500 mbar
- Gas consumption max. ca. 170 m³/h (NTP)
- Changing gas qualities

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Responsibilities and Tasks - Technical guidelines

Design, Build up and Operation of the injection unit

- Design and Build up due to DVGW guidelines and Pressure Vessel Directive
- Approval by the TÜV and operated by Schleswig Holstein Netz AG, remote control
- Set Point of hydrogen injection by the project team

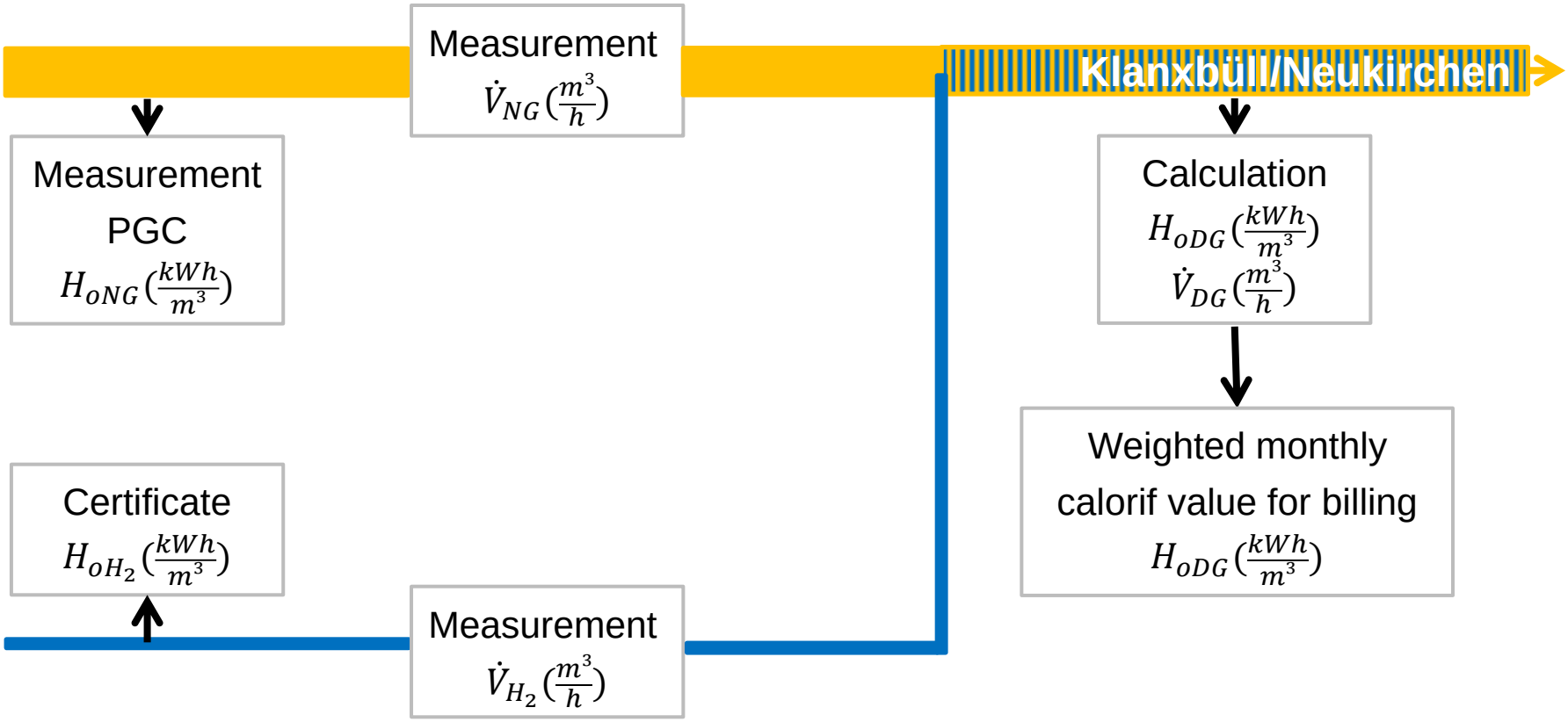
Distribution Grid and Gas Service Connection

- Distributed Gas within the DVGW G 260 (declaration by the DVGW EBI), additionally
- Inspection of the Grid 2013: no leakages
- Inspection of all gas services connections due to DVGW G 465
- Monitoring of the Odoration

Gas Utilisation

- Inquiry of all installed appliances and measurement of CO
- All appliances are approved due to standards, including test gas G222: 23% H_2
- Lab tests experiences indicated no severe dysfunction
- 24/7 hotline for all customers

Obligations of the Calibration Authority



Hydrogen Supply

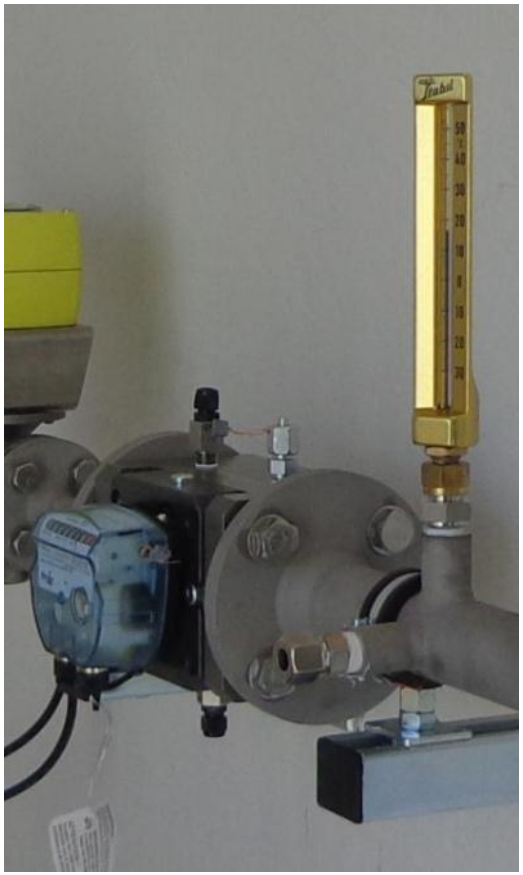
Installation on the pressure regulation site of Klanxbüll/Neukirchen

Hydrogen Delivery in cylinder bundles for independent measuring program

Injection of hydrogen for a period of two weeks with increasing rate 2%, 4%, … < 10%

Follow-up measurement of representative appliances

Hydrogen Measurement



Requirements:

Volume flow natural gas	6 – 170	m³/h*
Volume flow hydrogen (ca. 2–10%)	0.15 – 15	m³/h*

Pressure range up to 1 bar

Approval of calibration authority

Approval for explosion-proof Zone 2 for H_2 (ATEX 2C)

High frequent signal delivery

Suitable for E.ON Kundenservice *(NTP)

Rotary flow meter DN 40
Typ: ITRON Delta Compact Aluminium
Qmax = 25 m3/h (37.5 m3/h (NTP))
Qmin = 0.25 m3/h (0.375 m3/h (NTP))

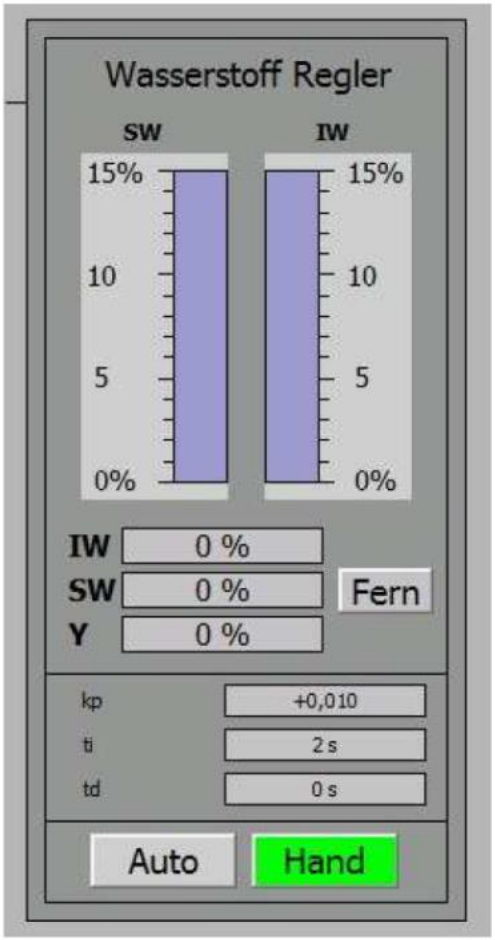
Hydrogen Limits and Control

Injection limits due to DVGW G 260
Hydrogen content < 10 vol.%
Wobbe number > 13.6 kWh/m³ * (46.4 MJ/m³ **)
Relative density > 0.55

Input value:
- $\dot{V}_{Natural\ Gas}$
- Set value % H_2

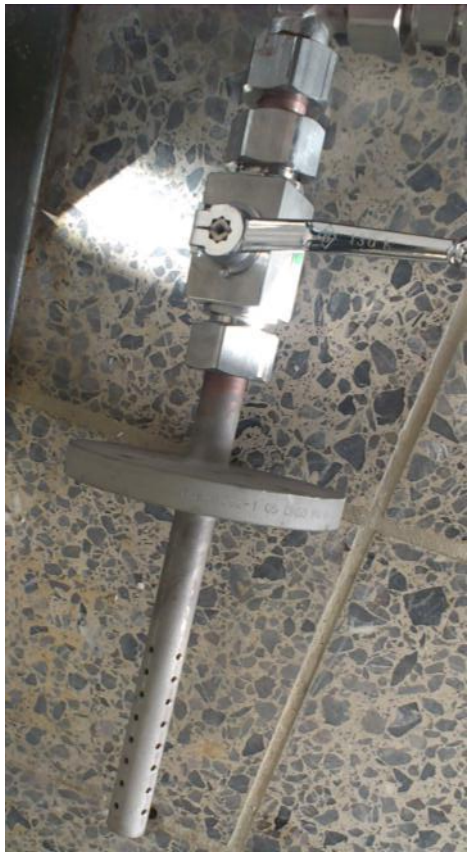
Output value:
- Actual value % H_2
  calcul. from $\dot{V}_{Natural\ Gas}$ and $\dot{V}_{H_2}$

Independent monitoring:
- measurement of the H_2 -rate in the output line



*(0°C/25°C,1013.25 mbar; **15°C/15°C, 1013.25mbar)

Construction of Components



Lance for hydrogen injection

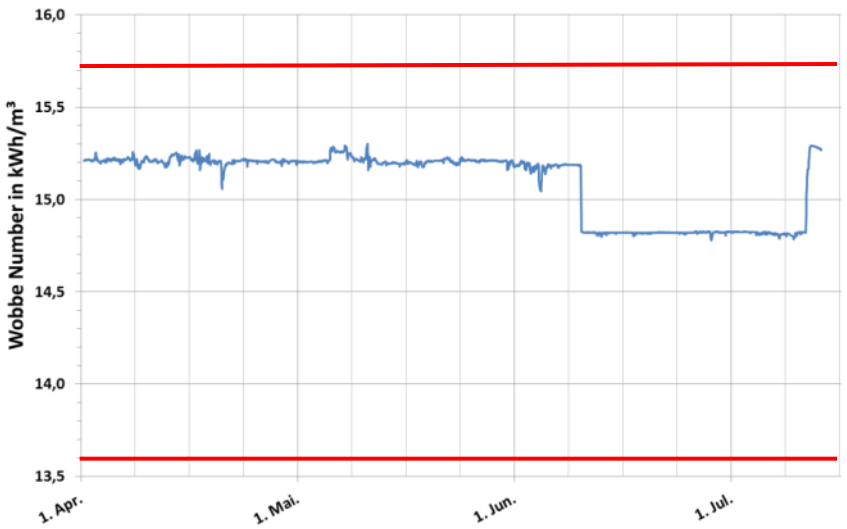
Gas sampling device

Design and Build up of the Injection Unit

Executing Phase: Mai 2014 to May 2015

- Analysis of gas qualities
- Analysis of natural gas volume flow
- Verification of the injection control and measurement
- Injection of hydrogen up to 4%
- Inquiry and analysis of the installed gas appliances
- Information and questionnaire for local installers

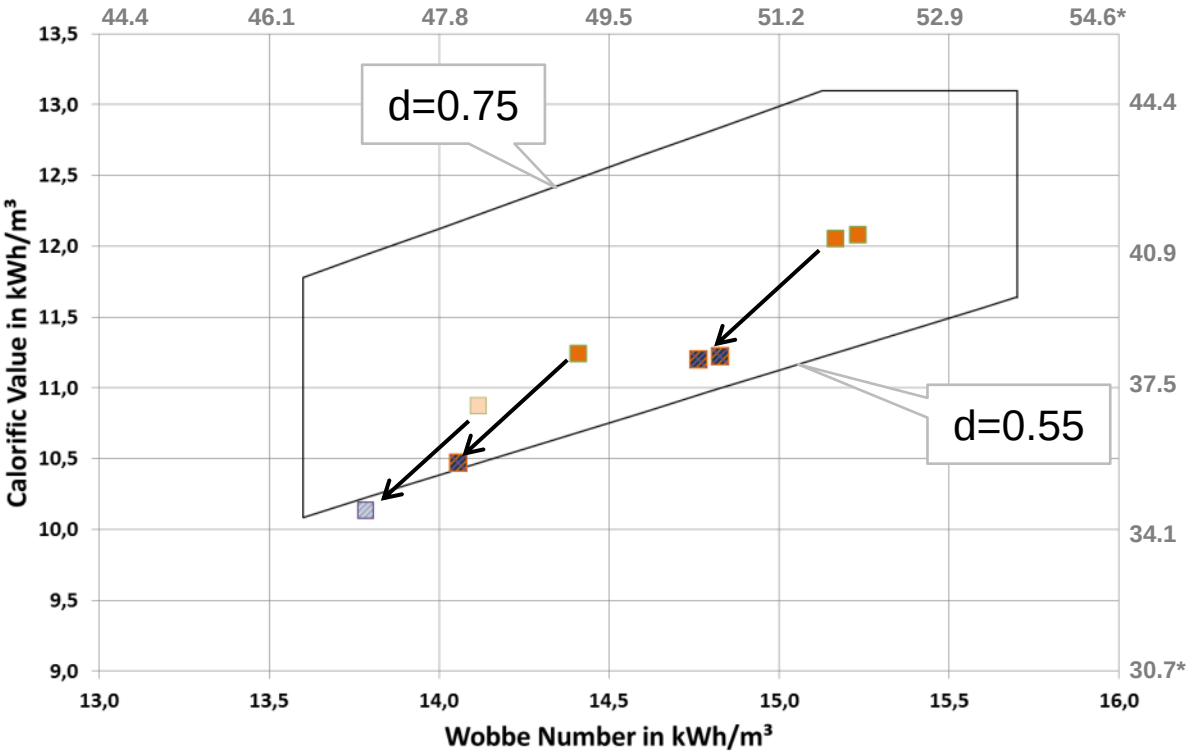
Anaylsis of the Gas Quality in Klanxbüll/Neukirchen – Hourly Mean Values of Wobbe Number



- Gas quality is highly fluctuating within the limits of DVGW G260
- Max. deviation of +2% and -6% from nominal value of 15,0 kWh/m³*
- During project time max. dev. of +2% and -2%

(0°C/25°C, 1013.25 mbar)

Analysis of the Gas Quality with Hydrogen Admixture in the Limits of the DVGW G 260



Calculated values for natural gas in Klanxbüll/Neukirchen with 10% Hydrogen admixture:

Decreases in

- calorific value
- Wobbe number
- relative density

The characteristic values of the distributed gas stay within the limits of DVGW G 260. For very low gases the relative density may fall slightly under the limit.

(0°C/25°C, 1013.25 mbar
*15°C/15°C, 1013 mbar)

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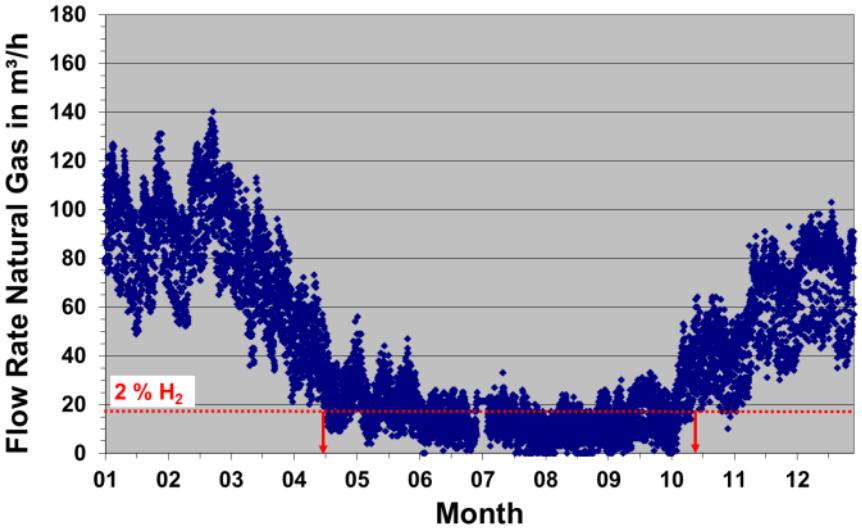
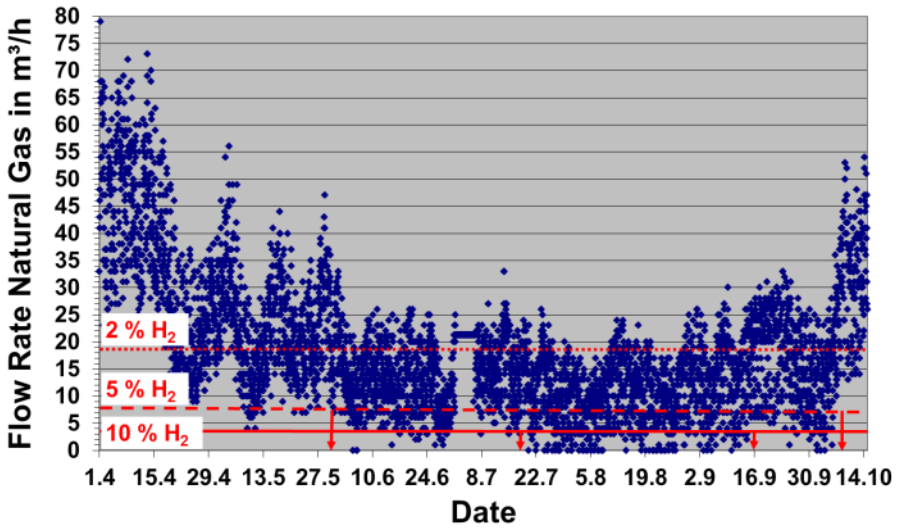
Analysis of Natural Gas Volume Flow and Limits of Injection





Minimum volume flow hydrogen due to gas meter is 0,375 m³/h.

A given injection rate of hydrogen requests a minimum volume flow of natural gas.

2%	18,8 m³/h
5%	7,5 m³/h
10%	3,8 m³/h

- Adaptation of the measuring program
- Integration of an automatic hydrogen shut off

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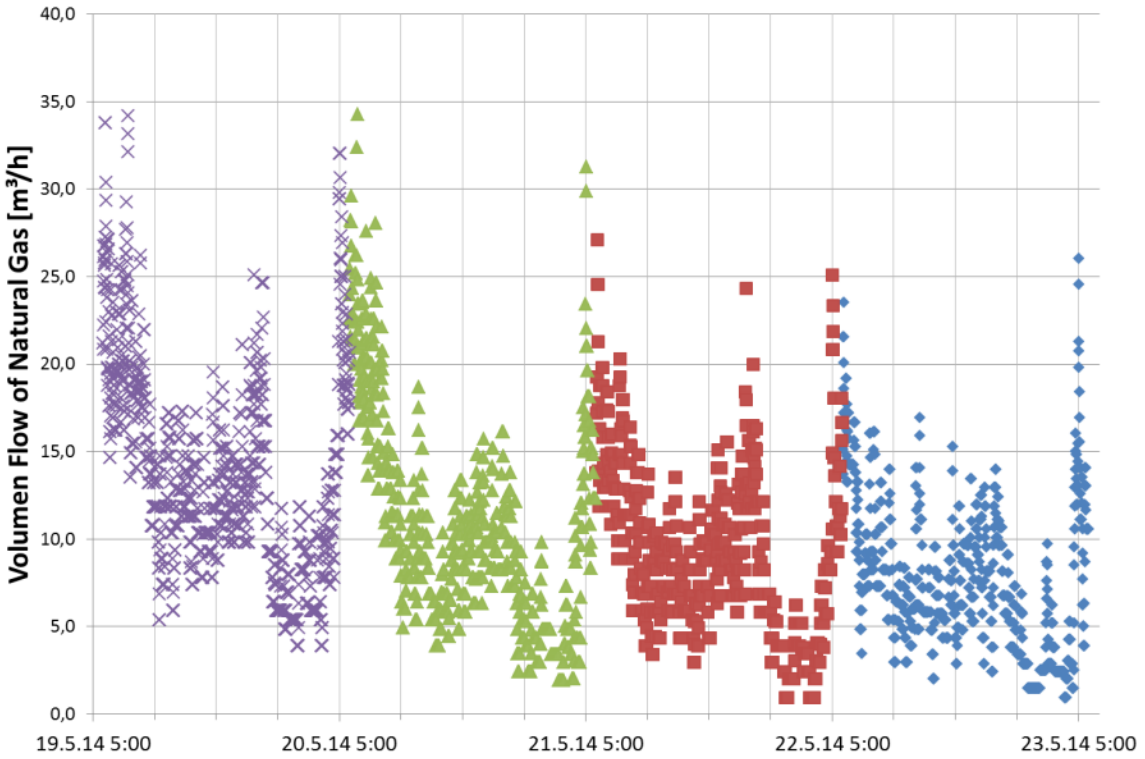
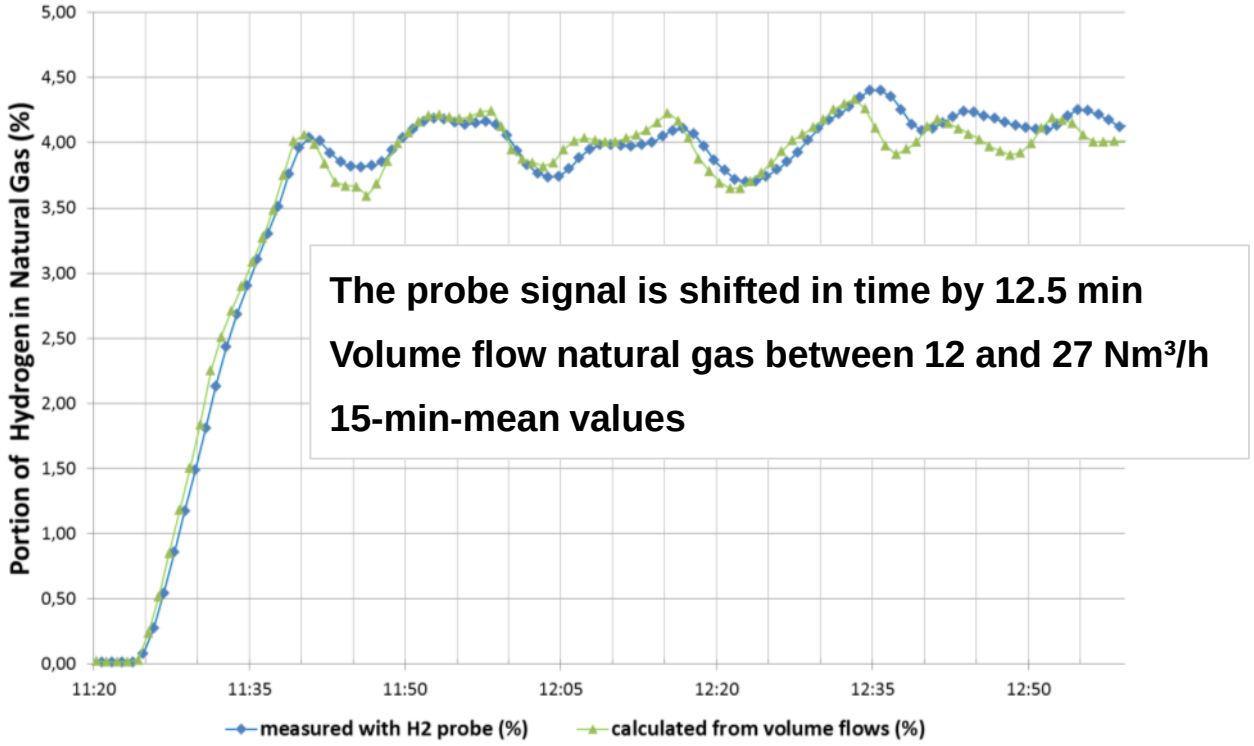
Analysis of the Fluctuations Natural Gas Volume Flow



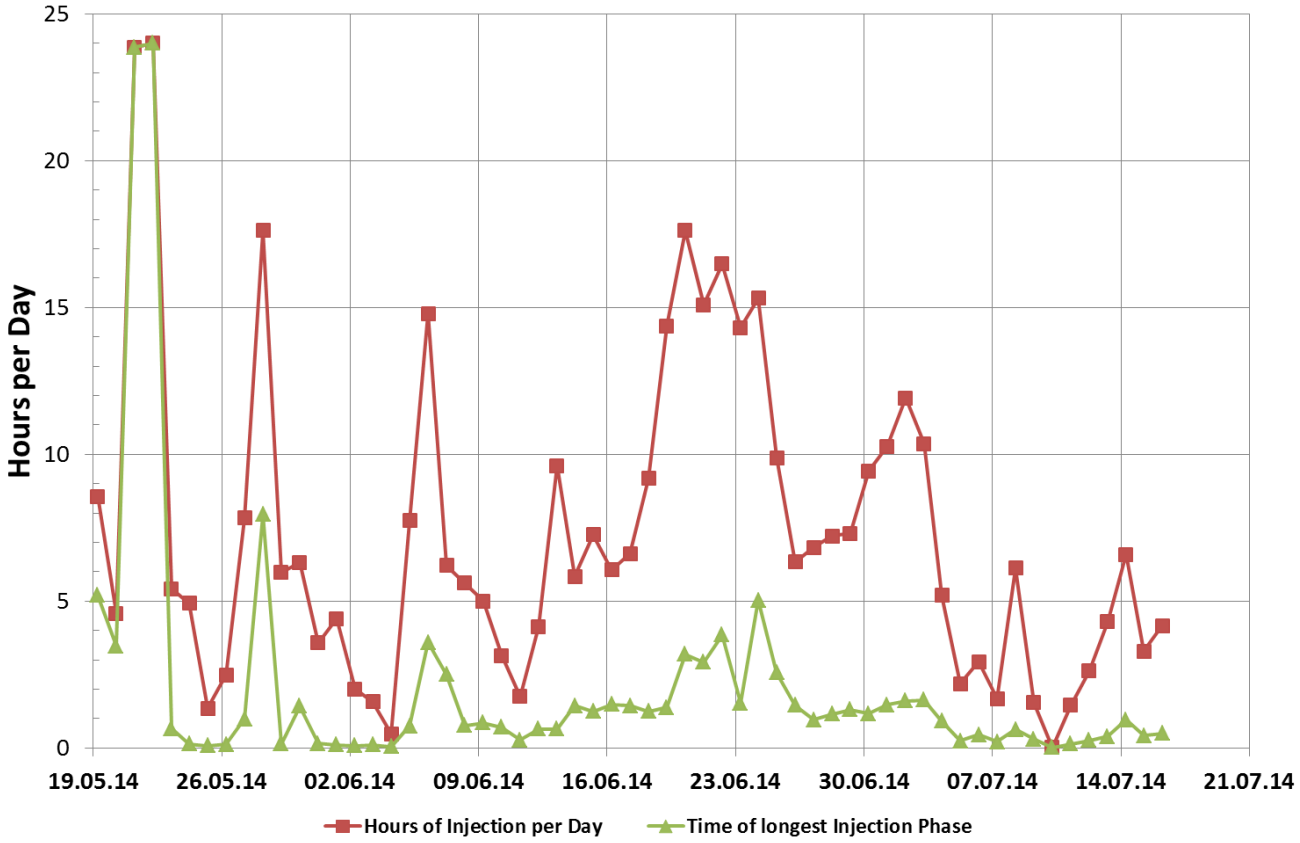
- Natural gas volume flow is highly fluctuation during 24 hours.
- The volume flow is decreasing due to increasing outside temperatures
- Hydrogen control has to follow the fluctuations

Resulting hydrogen rate in the distributed gas



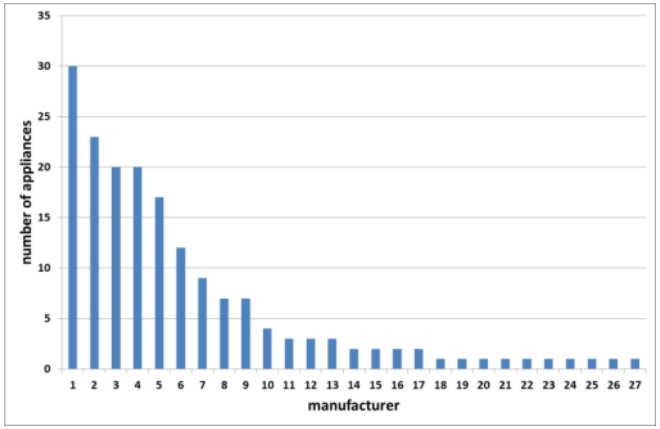
- Less than +/- 0.5% from the adjusted value of 4%
- Good accordance between both determined values

Overview of the injection phases from May to July

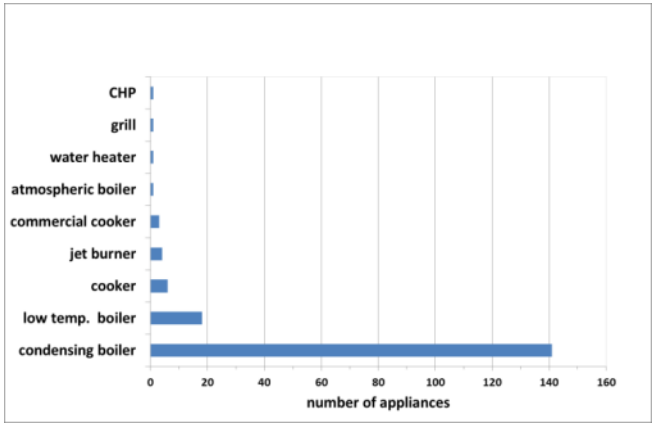


Daily time of injection and time of the longest continuous injection phase per day.

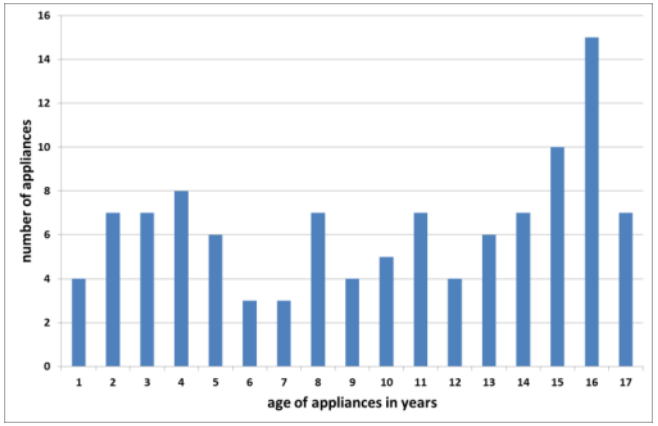
Analysis of the appliance park Inquiry by DVGW-EBI



- 27 different manufacturers
- 6 different manufacturers with more then 10 appliances



- 9 different technologies
- Mainly condensing boilers
- Nearly 20 low temperature boilers
- Commercial and domestic cookers
- 1 private CHP

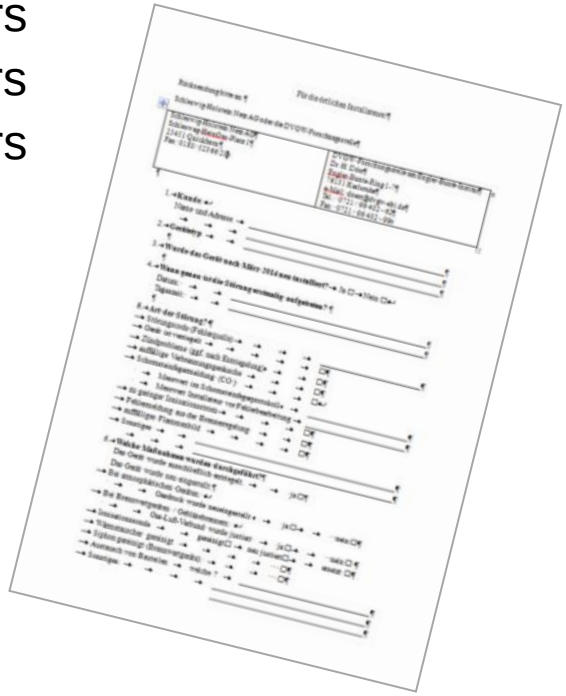


- Wide spread age of appliances up to 17 years
- Peak of 15-16 due to year of grid construction 1997

Observation of appliances behaviour

First injection phases from April to July

hydrogen portions of	2%, 3% and 4%
Injection time	433 hours
Average length of single injection phases	2 hours
Longest injection phase with 2 %	48 hours
Longest injection phase with 4 %	15 hours



Appliance observation:

No customer call back on the 24/7 hotline
No questionnaire coming back from installers
No reports of any malfunctioning of appliances

Measurements on representative appliances will be carried out when temperatures fall and the length of the injection periods begins to increase.

Summary

Preparation Phase of the project is completed:

- Good cooperation and agreement with the grid operator
- Agreement with the calibration authority
- Build up of the injection unit
- Appliance inquiry

Solutions found may serve as an example for following projects.

Executing Phase started successfully:

- Analysis of natural gas qualities
- Analysis volume flow rates
- Injection up to 4% hydrogen into natural gas with W_o between 14.7 -15.3 kWh/m³
- No reports of any malfunctioning of appliances

Outlook

Executing Phase (continuation):

- Continuation of the injection of hydrogen through the heating period 2014/2015
- Increasing the injection rate incrementally
- Achievement of long injection phases
- Measurement of representative appliances for
  - different operation modes (autumn, winter, spring, summer)
  - different natural gases (Danish gas, German mixed gas)
- Investigation of disturbances of appliances if applicable
- Analysis and evaluation of the appliances investigation

Reporting Phase