Research Project ME DSO Has Been Completed –

Significantly Lower Methane Emissions from the German Gas Distribution Network Than Previously Published

The purpose of research project ME DSO was not only to take stock of all available data on the estimated methane emissions in the German distribution network but also to develop and execute a measuring programme to collect the necessary data. The results show that the recorded emission factors [EF] for buried pipelines and gas pressure regulating and metering stations [PRMS] is roughly a factor of ten below the most recently published emission factors. Additionally, a concept for structuring measurements and measuring protocols was developed which will be used in future measuring campaigns to support a standardised execution of measuring operations and standardisation plans in general.

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The increased entry of greenhouse gases into earth's atmosphere and their effect on global warming has put a spotlight on methane emissions. After carbon dioxide, methane is the second largest factor in the anthropogenic influence on climate change [1]. In October 2020, the European Commission has addressed this issue by publishing the EU Methane Strategy [2] which in turn has led to the proposal of a regulation on methane emissions in December 2021. Based on these papers, the Commission sees significant potential in the energy sector, amongst others, for the cost-efficient reduction of methane emissions. The proposal for the regulation does not include only obligations for measuring, reporting, and evaluating methane emissions but also requirements for maintenance and repair measures. The document in general is strongly based on the requirements of the Oil and Gas Methane Partnership (OGMP) [3]. During the climate conference COP26 in Glasgow in 2021, the Global Methane Pledge has been introduced as an additional measure and signed by 111 countries, among them the EU member states and the US [3]. In this pledge, the signatories commit themselves to reduce the global methane emissions by at least 30 % from 2020 levels by 2030 as to help limit global warming to 1.5 °C [4].

The current proposal for an EU methane regulation also stipulates that gas infrastructure operators must report the methane emissions of relevant assets using generic but source-specific emissions factors [EF] within twelve months after the regulation has entered into force. The German Environment Agency ("Umweltbundesamt" – UBA) annually submits Germany's methane emissions under the United Nations Framework Convention on Climate Change (UNFCCC). The EF for buried pipelines and gas regulating and metering stations used in that report are, to date, the best available data for the German gas distribution network. However, they are based on emission rates from 1997 which were published as part of a study in 2000 [2], as well as on damage information from the period of 2003 to 2008 which have been published in a study in 2012 [1]. In recent years, more and more polyethylene pipelines have been tied into the German network which exhibit fewer leakage incidents compared to pipelines made from other materials. Consequently, the UBA's EF are expected to no longer represent the current situation. In addition, these EF are source-specific but do not differentiate between different types of emissions as defined by the OGMP. In short: The EU methane regulation requirements for the operator's first report would likely not be met by using the EF published by the UBA.

Objective

The ME DSO research project had the purpose to compare the current data situation with the data requirements for a transparent, consistent, and sufficiently precise evaluation of methane emissions from the gas distribution network. The precise nature of the data requirements is specified by OGMP regulations [7], the EU methane regulation proposal [8], and a CEN Technical Specification draft [9].

The project has applied the definitions and terms used in these documents.

Furthermore, the project also had the objective to determine the current national EF of the German gas distribution network. To gather missing emission rate, a suitable measuring programme was developed to make targeted measuring campaigns at selected assets possible. During this process, the development of measuring protocols as a blueprint for future application was also part of the objective. The project focused on buried pipelines, service lines, supply mains and gas pressure regulating and metering stations. These assets were identified as the main sources of emissions by the UBA's previous emission reports.

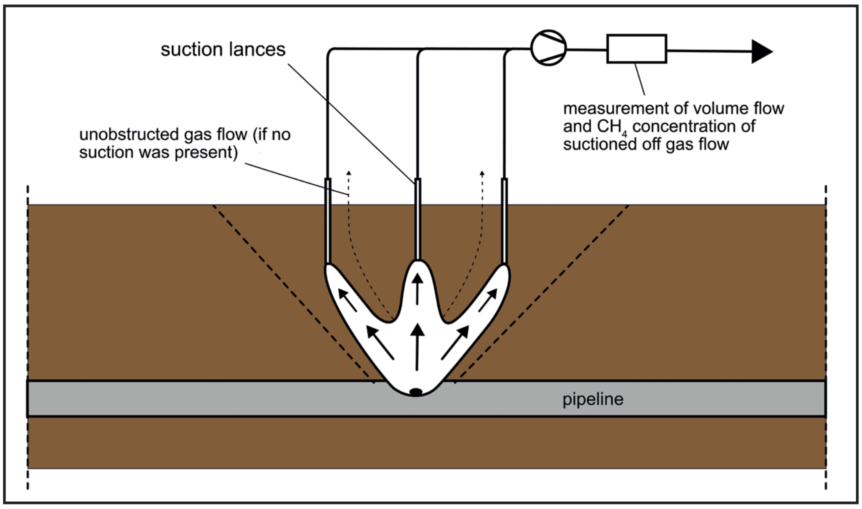


Figure 1: *Suction Method: Schematic Representation of Measuring and Suction of Ground Air at Buried Pipelines*

Measurements at Buried Pipelines

To detect emissions stemming from leakages at buried pipelines, the so-called suction method has been developed (**Figures 1 & 2**). This method uses high volume flows to suck sample volumes from the soil just above the pipeline leak. The gas flow leaking from the gas pipelines is extracted via suction pipes and subsequently measured for its methane concentration.

Figure 2: *Measurement Using the Suction Method at a Buried Pipeline*

Leakages found during inspection represent potential measuring points. Since these leakages must be repaired within short in accordance with DVGW Code of Practice G 465-3, there is no "pool" of leakages which can be used for randomly selecting points of measurement [13]. Measuring had to be coordinated with the network operator and be carried out between inspection and repair. The leakages were selected by the network operators willing to finance and allow measurements at leakage points in their network. Whether leakages were suitable for measuring operations was mainly determined by organisational and safety-related aspects. Consequently, leakages all over Germany were measured to create a representation as comprehensive as possible and to account for different soil and environmental conditions. In addition, measurements were carried out for all relevant pipe materials and pressure classes. Uncertainties were evaluated using the classical propagation of error and simulation methods (bootstrap and Monte Carlo).

Measurements at Gas Pressure Regulating and Metering Stations

The suction method has also been used to measure methane emissions at plants (especially gas pressure regulating and metering stations), both at the system level and at the component level (vent) (**Figure 3**). In this process, the complete system is flooded with a high volume flow of ambient air. Methane emissions are swept up by the directed volume flow and measured at the outlet of the air flow from the system.

To select representative stations for measurement, the individual stations were selected according to the specifications of the mathematical sampling theory. The measurement samples should be representative for both the asset inventory of the participating distribution network operators (DNO) and the plant characteristics of the operator at which the measurement was carried out. For every participating operator, an isolated sample was defined stacked according to the criteria "year of construction" ("before 1990" and "after 1990") and plant size (small/medium: $MOP_u \cdot Q_n \leq 20.000$, or large/citygate: $MOP_u \cdot Q_n > 20.000$).

Measuring Results at Buried Pipelines

Using the suction method at 28 DNOs, 126 measurements were taken at leakage points of buried pipelines within the German distribution network during the data collection period 14 May 2019 to 22 October 2021. **Figure 4** shows that the measurements were taken over the entirety of the German federal territory. For every measuring point, more than 40 parameters (e.g., operating pressure, the pipeline's year of construction, soil cover etc.) were collected. Below, only the influence of the most important parameters will be described.

The gathered values result in an arithmetic mean of 30 ± 5 l/h[1]. This value is significantly below the value of 140 ± 40 l/h per leakage [2] which the UBA has used for buried pipelines so far. In detail, 24 measurements were carried out at service lines and 102 at supply mains. Leakages at service lines exhibit a significantly lower rate of methane emissions (mean: 14,7 l/h)[2] than leakages at supply mains (mean: 33,8 l/h)[3].

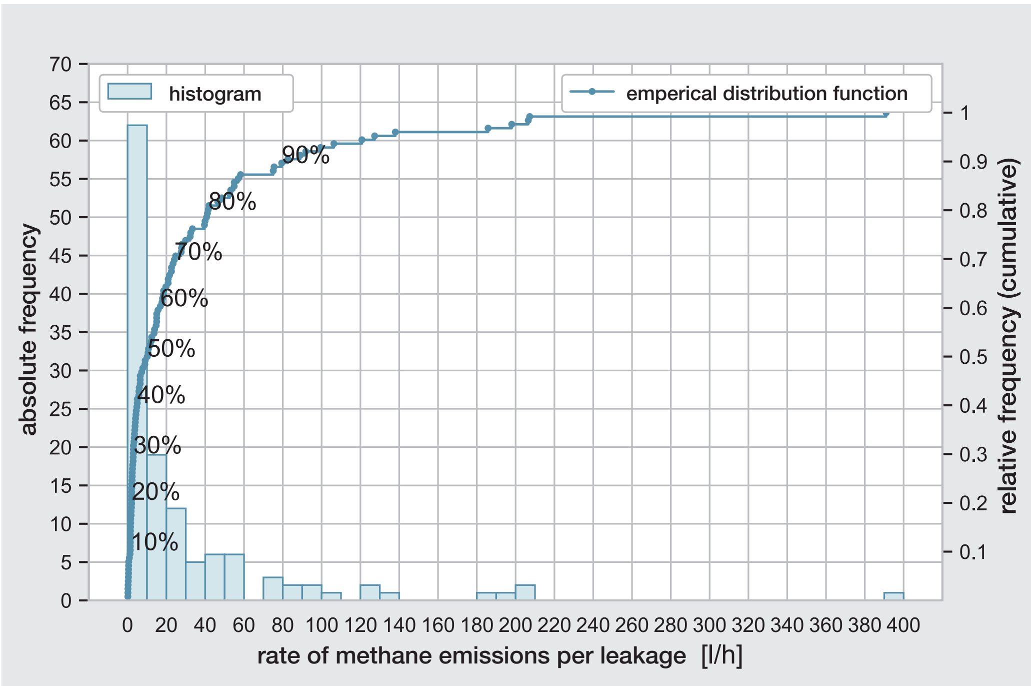
The data shows that although there are a few leakages with high methane emission rates, many leakages exhibit a relatively low rate of methane emissions. The majority (90 %) of

Source: A. Lennartz, KM Netz 2019

Source: DBI

Figure 3 (left): *Measurement Using the Suction Method at a Gas Pressure Regulating and Metering Station*

Figure 4 (right): *Geographic Distribution of Leakages Measured at Buried Pipelines.*



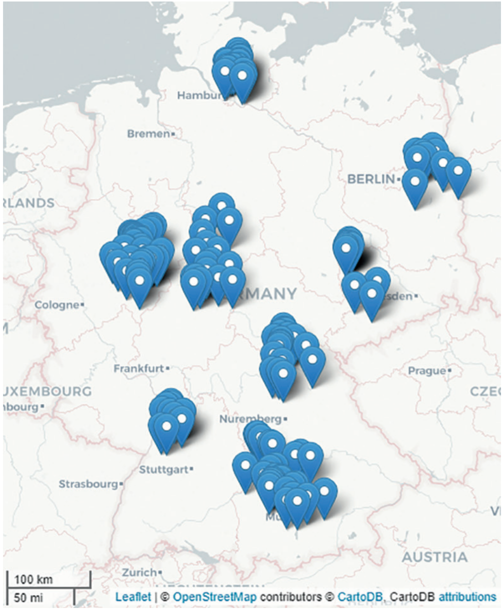
Source: DBI

Figure 5: *Histogram of Measured Methane Emission Rates at Pipeline Leakages (n = 126).*

values lie below 83 l/h. Half of all values (= median) are below 10 l/h. The most frequent rates were recorded within the subset 0 l/h to 10 l/h.

Whether the supply main's pressure class has an influence on the emission rate could not be proven. However, statistical testing[4] shows that the methane emission rate for steel pipe without CP is significantly higher (mean = 47,0 l/h)[5] than for other materials (17,6 l/h)[6].

The measurements were taken at pipelines constructed between 1905 and 2020. The data shows that there is no linear correlation between the year of pipeline construction and the level of the methane emission rate.



Source: DBI

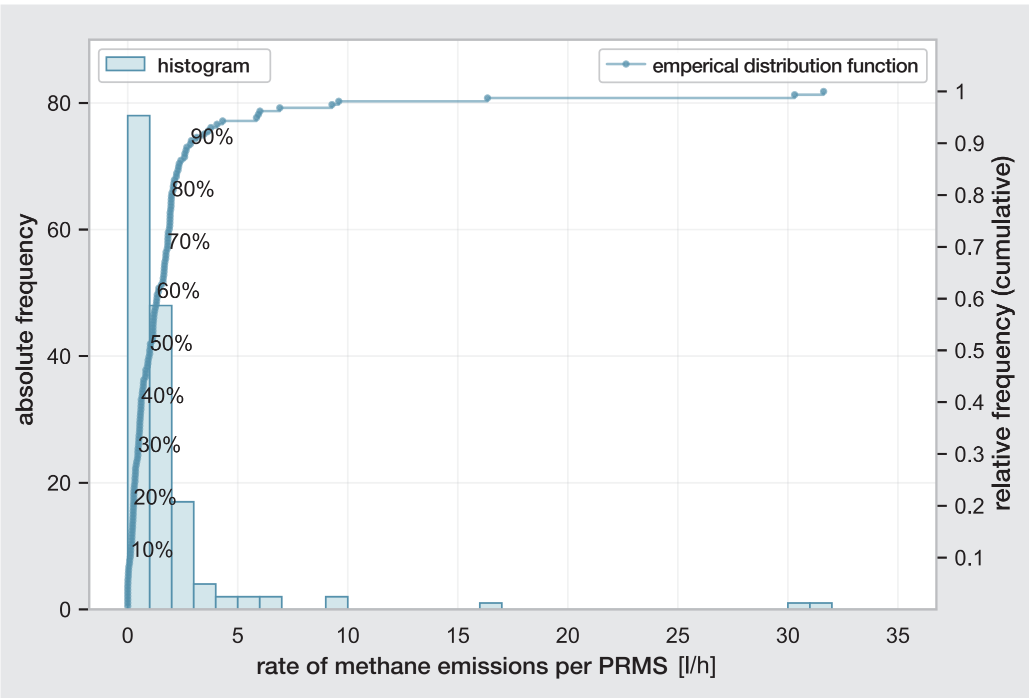
Figure 6: *Geographical Distribution of Measurements at PRMS*

Results for Gas Pressure Regulating and Metering Stations (PRMS)

Using the suction method, measurements at 159 PRMS, including 662 venting systems, were carried out during 10 DNO measuring campaigns for the data collection period from 1 September 2020 to 29 October 2021. **Figure 6** shows that the measurements were taken all over the German federal territory.

For every PRMS, more than 35 parameters (e.g., operating pressure, year of construction, number of control lines, were collected. Below, the influence of the most important parameters is described in detail.

For the PRMS, the arithmetic mean of the indications is 1.8 l/h. Two thirds of all measured rates are below 2 l/h. The observed differences between the size of the plant and its year of construction are minimal. Consequently, EF for PRMS are not subdivided according to size (pressure class / volume flow) or age.



Source: DBI

Figure 7: *Histogram of Measured Methane Emission Rates at PRMS (n = 159)*

[1] mean ± standard error of the mean (SEM)
[2] median = 2,9 l/h
[3] median = 13,8 l/h
[4] statement based on the Kruskal-Wallis test (χ^2= 15.5: p = 0.001) followed by a post hoc analysis
[5] mean from 56 measurements at steel pipelines without CP (all pressure classes); median = 23.0 l/h.
[6] mean from 46 measurements at pipelines from other materials (all pressure classes); median = 5.4 l/h.

Table 1: Emission Factors for Leakages at Supply Mains Found During Routine Inspection

Pressure Range [bar]e]	EF [kg CH_4/leakage]				
	Steel without CPa	Steel with CPb	PE + PVCb	other (ductile cast iron)	Median for all materials
≤ 1	664.7	359.5	359.5	248.9	555.3
> 1 to ≤ 5	369.3	248.9	248.9	138.3	285.5
> 5 to ≤ 16	_d	83.0	(83.0)e	83.0	83.0
> 16	_d	83.0	_d	_d	83.0

[a] The uncertainty for the given EF is -95%; +97% and largely derives from the uncertainty of leakage lifespans which in turn are based on the inspection periods of pipelines. In this case, a confidence interval of 95% has been used based on a Monte-Carlo simulation. Die underlying average emission rate is based on 56 indications at supply mains made from steel without CP from all pressure classes.

[b] The uncertainty for the given EF is -95%; +99% and largely derives from the uncertainty of leakage lifespans which in turn are based on the inspection periods of pipelines. In this case, a confidence interval of 95% has been used based on a Monte-Carlo simulation. Die underlying average emission rate is based on 46 indications at supply mains made from steel with CP, PC + PVC and ductile cast iron from all pressure classes.

[c] Derived from all of the 102 indications at supply mains for an average outflow duration for the different materials. Weighted in relation to the leakages occurring at pipelines from other materials

[d] This pressure class does not allow for the respective material, therefore no EF exists.

[e] According to [12], PE and PVC pipelines have a MOP of 10 bar. Therefore, the EF only applies up to 10 bar.

Source: DBI

Table 2: Emission Factors for Leakages at Service Lines Found During Routine Inspection

Pressure Range [bar]	EF [kg CH_4/leakage]		
	PE + PVCa	other (steel + ductile cast iron)a	Mean for all materialsb
≤ 1	300.3	207.9	243.4
> 1 to ≤ 5	207.9	115.5	141.9

[a] The uncertainty for the given EF is -96%; +72% and largely derives from the uncertainty of leakage lifespans which in turn are based on the inspection periods of pipelines. In this case, a confidence interval of 95% has been used based on a Monte-Carlo simulation. Die underlying average emission rate is based on 72 indications at service lines.

[b] Derived from all 24 indications at service lines for an average outflow duration for the different materials. Weighed in relation to the leakages occurring at pipelines from other materials

Source: DBI

Emission Factors

The comprehensive determination of the EF as well as the observation of uncertainties can be taken from the project report. As examples, only the EF for diffuse emissions (leakages) at supply mains, service lines, and PRMS are shown in **Tables 1, 2, and 3**. Concerning venting emissions, we recommend that the operators determine these values individually using the formulas specified in the project report. However, the report also provides median EF which could be seen as mean values for the complete German gas distribution network but use a more conservative choice of parameters and consequently might result in too high emission values. For determining the EF, the inspection periods detailed in DVGW Code of Practice G 465-1 (2019) have been used as the basis for the duration of gas emanation. Other outflow durations have not been recorded during the project but will be addressed in a follow-up project[7] since the implementation of the EU methane regulation will likely entail shorter inspection periods and consequently lower EF.

Determining the Main Sources for Emissions

During the project, methane emissions from buried pipelines (supply mains and service lines) and PRMS

[7] DVGW Project “Analysis of Methane Emission Reduction Through Adjustment of Inspection and Repair Periods at Buried Pipelines Within the Purview of Code of Practice G 465”; estimated completion: 31 December 2022.

Table 3: Emission Factors for Diffuse Emissions at Gas Pressure Regulating and Metering Stations		
Inlet Pressure[MOP] [bar]	EFa [kg CH_4 / (plant a)]	Uncertainty
≤ 70 bar	11.3	(-97 %, +44 %)

Source: DBI

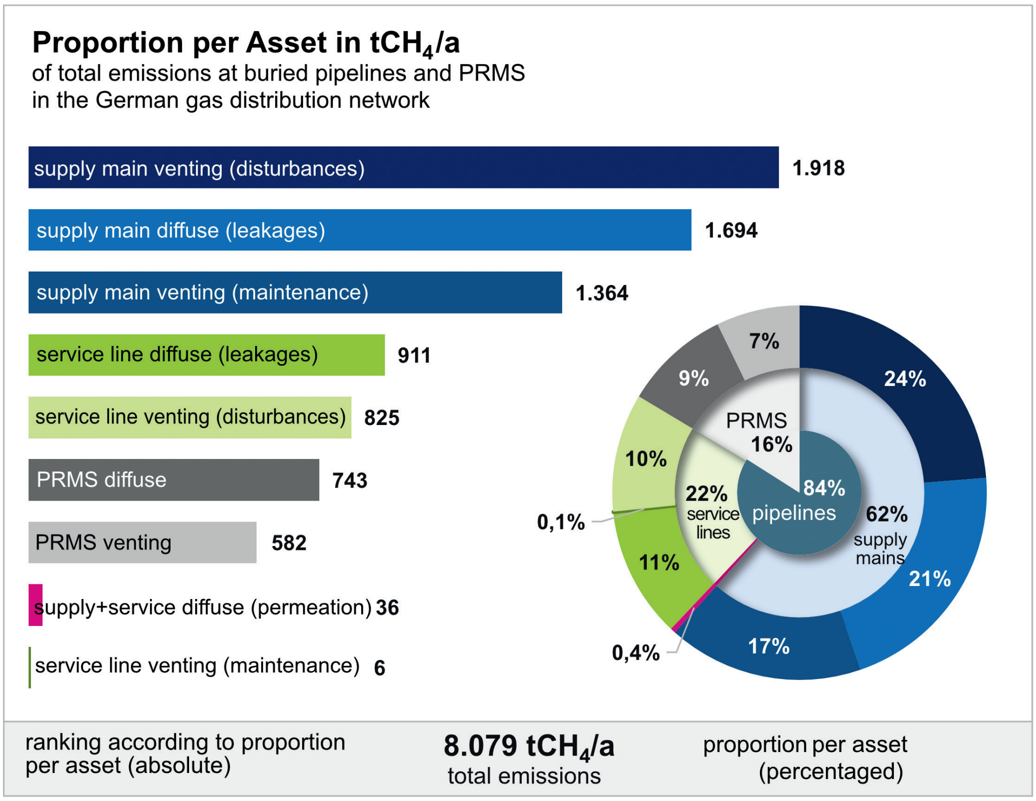
within the German gas distribution network worth 8.1 kt CH_4 have been recorded. These are divided among the assets as follows:

- 84 percent of emissions originate from buried pipelines (supply mains and service lines)
  - 34 percent from disturbances[8] (24 percent supply mains, 10 percent service lines)
  - 32 percent from leakages (21 percent supply mains, 10 percent service lines)
  - 17 percent from maintenance operations (17 percent supply mains, 0.1 percent ser vice lines)
  - permeation, with a percentage of < 1 can be disregarded
- 16 percent of emissions originate from PRMS
  - 9 percent from leakages
  - 7 percent from venting (disturbances and maintenance)

Consequently, PRMS are not one of the main sources of emissions. **Figure 8** is is a graphic representation of the absolute values (bars) and the percentages (circle).

Comparison with the Previously Published Values for the German Distribution Network

The German Environment Agency (UBA) annually submits Germany's methane emissions under the Framework Conventions on Climate Change of the United Nations (UNFCCC) [6]. The EF for buried pipelines and gas pressure regulating and metering stations used in that document have, so far, represented the best available data for the German gas distribution network. However, the data is based on emission rates from 1997, published in a study in 2000 [2], as well as on damage statistics from the years 2003 to 2008, published in 2012 [1]. It has become clear that the EF for buried pipelines (supply mains and service lines) and PRMS gathered throughout this project lie below the UBA's EF by a power



Source: DBI

Figure 8: *Methane Emissions at Buried Pipelines (Supply and Service Lines) and PRMS in the German Distribution Network Ranked According to Asset and Emission Type*

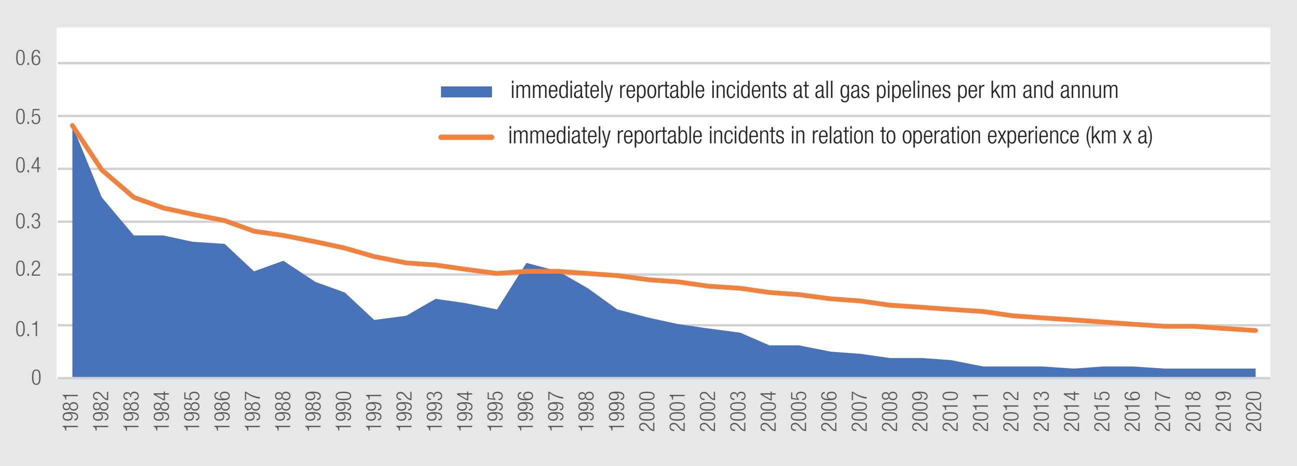
[8] e.g., third party damaging like incidents involving excavators or moling operations

Table 4: Comparison of Emission Factors Recorded by the UBA with the Emission Factors Found During This Project

	ME DSO					UBA	
Category	Emission [kg CH_4/a]	Activity Factor (AF)		Emission Factor (EF)		Emission Factor (EF)[1]	
Supply main	5.000.750	357.630	km	14	kg CH_4/km	112	kg CH_4/km
Service line	1.752.752	165.706	km	11	kg CH_4/km		
PRMS	1.325.560	51.468	no.	26	kg CH_4/plant	256	kg CH_4/plant
total	8.079.062						

[1] The EF was calculated by the DBI as an average using the values reported by the UBA. The detailed calculation can be found in the project report.

Source: DBI



Source: DVGW

Figure 9: *Development of Immediately Reportable Incidents at All Gas Pipelines Throughout the Years 1981 to 2020*

of ten (**Table 4**). The rate of damaging in the German gas distribution network is nowadays much lower (**Fig. 9**). Also, the EF determined by the UBA used a mean for the emission rate derived from a study from the year 2000 which was based on just 18 indications (buried pipelines) and 5 indications from PRMS [6][9]. For buried pipelines, the mean for the measurement per leakage was (140 ± 40) l/h and thus is consequently much higher than the mean (30 ± 5; averaged throughout all classes) l/h recorded in this study. For the gas plants, a mean of around 105 l/h (high pressure plants)[10] has been taken as a basis and consequently used to derive a value of 26 l/h for low pressure and medium pressure plants[11]. These values lie also far above the average of 1.8 l/h for all indications recorded during this project. Throughout this project, the number of measurements has been significantly increased which in turn helped to reduce the uncertainty of the mean. The uncertainty can be lowered further by increasing the number of measurements. As a rule of thumb: a quadruple sampling volume is needed to reduce the uncertainty by half.

Conclusion and Outlook

The ME DSO project significantly expanded and improved the data pool for diffuse emissions from buried pipelines and PRMS in Germany. To date, it has been the largest measuring programme (947 measurements) of DNOs in Germany. The execution of measurements in the infrastructure of the DNO has brought attention to the topic of methane emissions and also improved understanding of the matter. Measurements are helpful to determine realistic EF and highlight at which points emissions can reduced efficiently. Furthermore, DNOs can prepare for the new legal requirements which will be set in motion by the EU methane regulation.

It has also been shown that the implemented method of measuring (suction method) is comparably time-intensive (8 hours per pipeline leak, 4 to 8 hours at PRMS, plus additional travel time). Due to the fact that there currently just two specialised companies able to carry out such measurements in Germany, only 50 to 100 measurements of leakages at pipelines per year and an additional 50 to 100 measurements at PRMS per year are currently possible so that other companies would be able to offer such services. The service demand will result from the future requirements entailed in the EU methane regulation. More measuring programmes also en-

[9] For buried pipelines, this document only contains a value of 140 l/h. Uncertainties were calculated on the basis of individual indications by the DBI.
[10] In this study, only a value of 924 m³/a is given which has been converted to a value of 105 l/h assuming an outflow duration of 8.760 hours per year [6]
[11] In this study, only a value of 225 m³/a is given which has been converted to a value of 26 l/h assuming an outflow duration of 8.760 hours per year [6]

able further development of measuring systems as well as cost reduction and/ or reduction of measuring time.

During the realization of this project, still open issues surfaced – due to new additional OGMP and EU methane regulation requirements – that should be addressed in follow-up projects. The DVGW already initiated a second project (ME DSO 2.0) which aims to address bullet points 1 to 3. Points 4 to 6 require further projects that should be connected to ME DSO 2.0.

- Execution of additional measurements using the same measuring methods to increase the data pool and reduce uncertainty. Generally, a quadruple measuring volume is required to reduce uncertainties by half.
- Verification of indications by using measuring methods with comparable accuracy.
- Examination of the impact of increased injection of renewable gases (hydrogen and biogas) on the recorded emission rates and emission factors, especially against the backdrop of the national hydrogen strategy.
- Inspecting methane emissions during maintenance operations at PRMS: The derived EF are based on theoretical observations at individual plants and should be verified by measurements.
- Improving the data pool on methane emissions during disturbances. So far, these are the main source of emissions at buried pipelines which, however, could possibly be attributed to the usage of a simplified conservative calculation methodology for determining the emission values.
- Standardisation of the applied measuring methods to prepare and increase the efficiency of the many measurements which will be necessary in the future due to the EU methane regulation.

Distribution network operators who support the follow-up project ME DSO 2.0 will have the advantage of receiving indications for their own assets. Accordingly, they will be able to better fulfil the future requirements of the EU methane regulation for higher reporting standards.

The recorded methane emissions from gas distribution networks can be further reduced towards zero emissions by technological means. This, however, requires more research and further product development. The conversion to renewable gases will also lead to further reduction of methane emissions but requires that the infrastructure is tested for its compatibility and, if necessary, is retrofitted/modernised. Nevertheless, fugitive emissions should also be avoided in the future when renewable gases will be distributed. Meaning, an investment into methane reduction is also an investment into the future.

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