Management Summary

GERG Project Phase I "Analysing the Methods for Determination of Methane Emissions of the Gas Distribution Grid"

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Management Summary

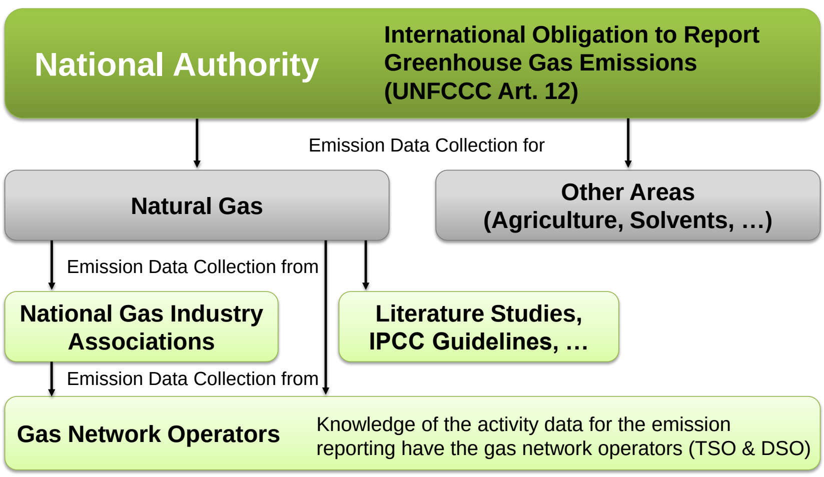
Analysing the Methods for Determination of Methane Emissions of the Gas Distribution Grid

The project “Analysing the Methods for Determination of Methane Emissions of the Gas Distribution Grid” was initiated by members of the project committee on gas distribution of the European Gas Research Group (GERG) in November 2014. Representatives from gas companies of seven European nations (Belgium, France, Germany, Italy, Netherlands, Spain and Switzerland) provided information from which a benchmark for existing methods of determining methane emissions could be achieved. The goal of the project was to identify best practices and optimisation potential as a first step to develop a uniform European method for methane emission estimation from the gas distribution grid that has the potential to be applied by all interested Member States of the European Union. Currently, many different methods are in place and may lead to inconsistent results for emission estimation in Europe. A consistent and transparent reporting scheme within the EU would facilitate the comparison of the total emissions of different countries and would enhance the reputation of the emission estimation.

Background and Motivation

Methane (CH_4), which is 25-times[1] more potent (100-year time horizon) as a greenhouse gas than CO_2, has become an increasingly important topic. According to Article 12 of the United Nations Framework Convention on Climate Change (UNFCCC), members are required to create “a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases” [1]. The same requirement exists in Article 5 of the Kyoto Protocol [2].

Figure 1: Example of Involvement of National Institutions, Associations and Grid Operators in Emission Reporting for Natural Gas



Source: own illustration DBI

Following the framework set out at the convention, the determination and publication of emissions is carried out via a National Inventory Report (NIR)[2]. Several institutions are involved in the creation of the NIR. Figure 1 shows an example how data is collected for emission reporting. It is notable that the institutions responsible for reporting to the UNFCCC often have no direct access to data and are, therefore, dependent

1 Parties of the UNFCCC shall utilise a GWP of 25 for methane (100-yr time horizon), which originates from the 4th Assessment Report of IPCC (AR4, 2007) [3]. However, according to the state of science (AR5, 2013), the GWP of methane has risen to 28 or 34 (including climate carbon feedback).

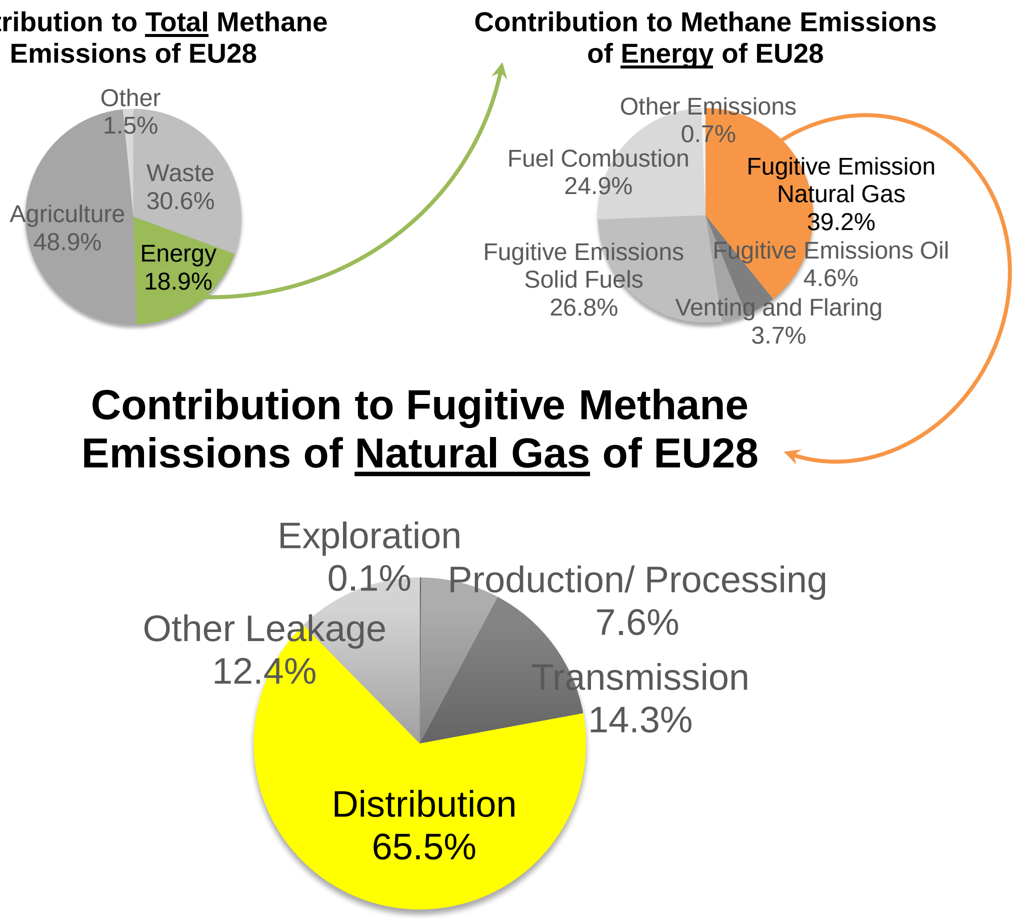
2 The preparation of National Inventory Reports is obligatory for Annex-I parties of the UNFCCC. For other members, the reporting can be done in a simplified form. [4]

on co-operation with other bodies (e.g. Associations of the Gas Industry), in order to fulfil their obligations. Although the framework for reporting is fixed by the UNFCCC, the method of emission estimation can differ from country to country, and even between several data providers within one country, as long as this method can be scientifically justified. As a result, inconsistencies in reported emissions between different countries can occur.

Looking to the total methane emissions caused by the members of the European Union (EU28) in 2012, the highest share of emissions is caused by the sectors ‘agriculture’ (48.9 %) and ‘waste’ (30.6 %) as Figure 2 shows. Figure 2 displays only national emissions as reported to the UNFCCC; emissions of production for example in Russia are not included. [5]

According to data submitted to the UNFCCC, the sector ‘energy’ caused 18.9 % of the methane emissions. Only 39.2 % of these emissions from the sector ‘energy' were fugitive methane emissions from natural gas. Thus, fugitive methane emissions from natural gas contributed only 7.4 % to the total methane emissions.[3] [5] This rather small part of methane emissions should nevertheless be estimated correctly to support the reputation of natural gas.

Figure 2: Contribution to National Methane Emissions of Members of the European Union (EU28) in 2012



Note: Illustration shows only national emissions. For instance, emissions of production in Russia are not included.

Source: own illustration DBI after UNFCCC [5]

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[3] All numbers are own calculations based on data submitted to the UNFCCC for the year 2012. Emissions were considered in the unit CO_2eq [5].

The GERG-Project focuses on gas distribution because, within the EU28, this element of the national natural gas supply causes the highest share of national methane emissions (Figure 2). Nevertheless, it should be kept in mind, that the emissions of distribution grids are comparatively small. According to the latest Marcogaz report, distribution grids show methane emissions of 0.4 % compared to the total mass [tons] of natural gas sales in Europe[4] [6, p. 3]. Further reasons for focusing in particular on the gas distribution grid are the length of the pipelines (the gas distribution grid forms a considerable part of the total length of the gas infrastructure), and the heterogeneity of the grid (the complexity with many different configurations and elements), which makes emission estimation particularly challenging.

Research Approach

The entire data for the project was gathered by comprehensive desk research and expert interviews. The existing methods for emission estimation of the gas distribution grid were in-depth analysed regarding to different aspects.

In order to evaluate the completeness of the methods, an analysis was made of possible technical sources of methane emissions in the gas distribution grid, and to what extent these sources had previously been considered. In this regard, the proportion of the sources of the total emissions was also assessed.

In the second step, the quality of the methods was evaluated with a detailed analysis of technical aspects. An evaluation matrix was developed based on evaluation criteria which were agreed upon by the project partners. Furthermore, the required effort of the methods was assessed with a simplified approach which relied on general criteria. Both results were combined in a benefit-effort analysis so that best practices could be identified.

The input data and assumptions within individual methods were also surveyed and evaluated. Some parameters are identified to be crucial for the emission estimation; others are still open and have to be evaluated in detail in the second phase of the project.

The following methods for estimating emissions of the gas distribution grid were examined in the GERG-Project:

- Method of Battelle 1989 [7] → applied by Belgium, (Italy)
- Method of Battelle 1994 [8] → applied by Switzerland
- Method of FH ISI 2000 [9] → applied by Germany, Netherlands, (Sweden)
- Method of Stoller-DBI 2012 [10] → applied by Germany
- Method of British Gas / National Grid [11] → applied by United Kingdom
- Method of GRDF/ENGIE[5] [12] → applied by France
- Method applied by Gas Natural Fenosa[6] [13] → applied by Spain
- Method of EPA [14] → applied by USA
- Method of IGU 2000 / IPCC Guidelines 2006 [15] → applied by Romania
- Method per Sale of Natural Gas [16] → applied by Poland
- Method of Marcogaz 2005 [17] → estimation at EU level

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[4] This calculation included the countries: Austria, Belgium, Czech Republic, Denmark, France, Finland, Germany, Greece, Italy, Ireland, The Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Switzerland, United Kingdom. [6, p. 3]

[5] “GRDF/ENGIE is the ENGIE Group research and operational expertise centre dedicated to gas, new energy sources and emerging technologies.” [18]

[6] GNF applies emission factors provided by Marcogaz and other studies. The only exception is for the polyethylene medium pressure networks, where emissions are estimated with emission factors determined by own measurements with pressure variation method (PVM). [13]

The word 'method' is hereby applied with different meanings. The methods of Battelle, ISI, National Grid, GRDF/ENGIE, EPA and the one applied by Gas Natural Fenosa develop emission factors. In contrast, the method of IGU and IPCC provides default emission factors. Within the method of Marcogaz, network operational data from its members are gathered to estimate methane emissions at EU level (bottom-up approach). Thus, (national) EFs (and further data) are not developed but collected from countries or companies to estimate national and European methane emissions. The data that are delivered to Marcogaz rely on different estimation methods (e.g. the studies of Battelle, ISI, etc.) and are not aligned this way.

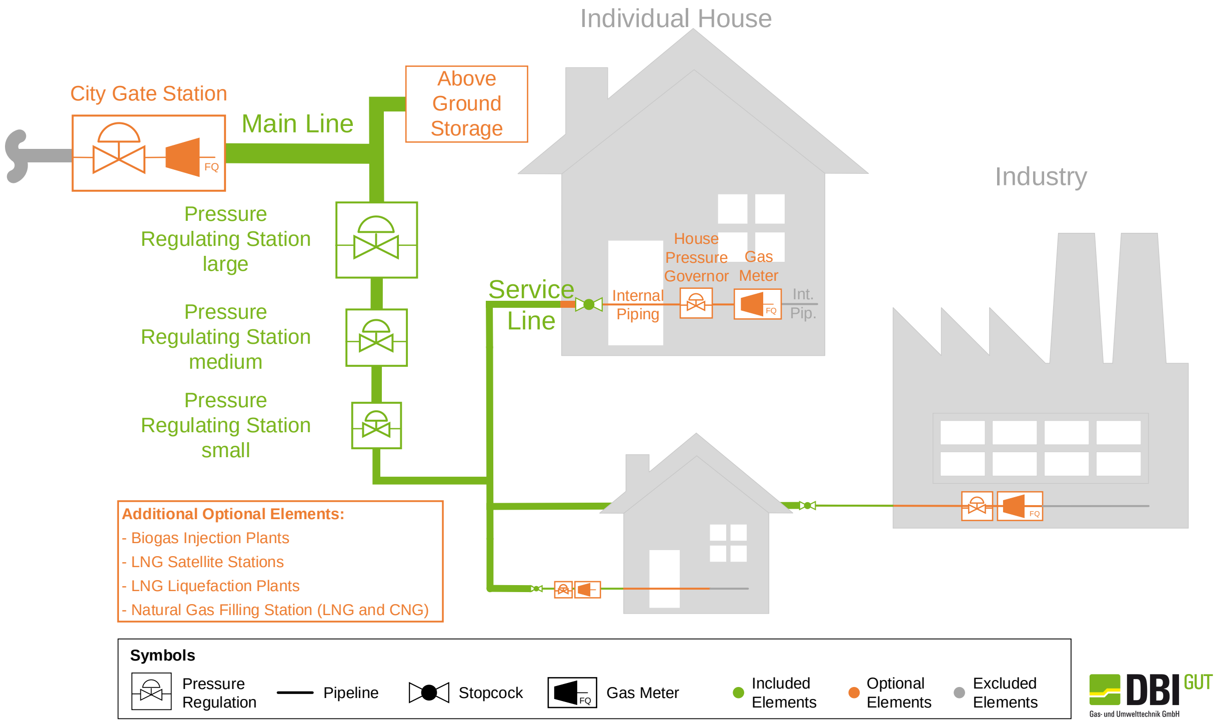
A pan-European approach for emission estimation (and for determining emission factors) would lead to aligned data, which can for example be included in the Marcogaz method in the future.

Results of the Present Report

Emission Sources and System Boundaries

In order to evaluate the completeness of the existing methods, an analysis was made of possible technical sources of methane emissions in the gas distribution grid, and to what extent these sources had previously been considered. In principle, methane can either be emitted from pipelines (main lines and service lines) or gas facilities (pressure regulating stations, above ground storages etc.). Under some existing methods, not all of these different sources are considered. One reason for this is that certain elements (such as biogas injection plants) did not exist at the time when some studies were written. Moreover, elements are sometimes disregarded due to their minor impact on total methane emissions. A further reason is the discrepancy between system boundaries (Figure 3) defining the scope of the gas distribution grid. For example, in some European countries city gate stations are regarded as part of the distribution grid, in others as part of the transmission grid. For the present work, the definition of a gas distribution grid will be flexible with certain elements classed as "included", "optional", or "excluded". "Included" elements are pipelines and pressure regulating (and meter) stations (with the exception of city gate stations and house pressure governors, which will be considered "optional"). "Optional" elements, for instance the city gate station, may belong either to the transmission grid or to the distribution grid. "Optional" shall secure that the city gate station is considered flexibly in either of the type of grids and will not be forgotten. Further "optional" elements include, for example, natural gas filling stations and LNG-facilities (satellite stations and LNG filling stations). "Excluded" elements are compressor stations and end-user appliances (e.g. gas boilers or ovens).

Figure 3: System Boundaries of the Gas Distribution Grid



Source: own illustration DBI

It has become apparent that existing emission estimation methods have focused on a detailed analysis of pipelines.

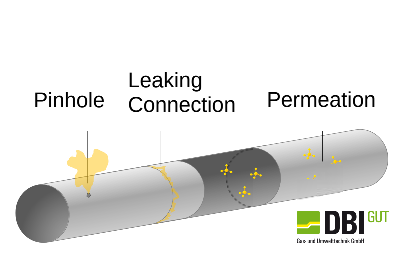
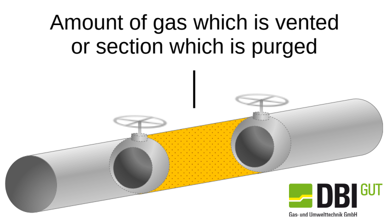
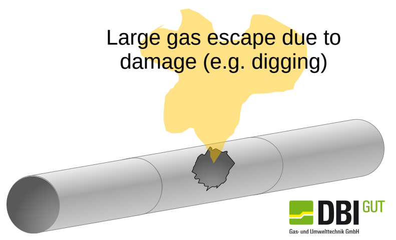
Emission Categories

In many studies the determination of emissions from pipelines is divided into different categories. Many different names exist for the same categories, which makes the comparison of different methods more complex. Thus, it was agreed by the partners in the GERG-Project to use three distinct categories with the following terms:

- "Intrinsic Emissions" (category A),
- "Operational Emissions" (category B), and
- "Incident Emissions" (category C),

from now on (Table 1). "Intrinsic Emissions" include all general leaks, permeation, as well as minor holes or cracks. "Operational Emissions" occur during commissioning and decommissioning, as well as during the renewal and maintenance of existing pipelines. "Incident Emissions" are the result of reduced integrity of the pipeline due to significant damage. A complete enumeration of all emissions falling under these definitions has not yet been produced, leaving uncertainties how to distinguish the two categories intrinsic and incident emissions. The creation of uniform exhaustive definitions should make it easier to compare emissions between different countries and different studies in the future and is also necessary to avoid double counting of emissions. The different categories of emissions from pipelines have differing degrees of relevance for emission estimation. According to the studies of Battelle and EPA, intrinsic emissions form the largest share of emissions from pipelines: approximately 90 %. The residual operational and incident emissions play a smaller role. However, the differentiation of intrinsic emissions and incident emissions is challenging. Due to different definitions (meaning what is included in a category), in some countries, incident emissions are perceived to be more important.

Table 1: Categories of Emissions

Category A: Intrinsic Emissions	Category B: Operational Emissions	Category C: Incident Emissions
		
Emissions arising from: pinholes, small cracks, leaking joints, permeation	Emissions arising from: venting and purging during commissioning, renewal, and decommissioning	Emissions arising from: incidents/ accidents occurring e.g. due to landslide or third party damage

Source: own illustration DBI

General Evaluation for Emission Estimation Methods

Emissions are in general determined by multiplying an emission factor (EF) with the respective activity data (AD, e.g. length of pipelines) as the following equation 1 shows:

$$E = EF \cdot AD \qquad (1)$$

E - Emission [m^3/a[7]]

EF - Emission Factor (e.g. [m^3/km·a] or [m^3/No.·a])

AD - Activity Data (e.g. [km] or [No.])

For the EFs either country-specific or default values can be applied. The application of default values is rather simple but often penalised by higher total emissions. Country-specific EFs are determined with different equations, which involve different levels of complexity. The EFs are based either on measurement, or on calculation, or on a combination of measurement and calculation.

The existing methods for estimating pipeline emissions need either highly detailed input data (e.g. the method of GRDF/ENGIE) or are less detailed and, as a result, less comprehensive (e.g. Battelle method). Some methods do not comprise all categories of emissions (e.g. FH ISI method). The most successful solution for the development of a pan-European method for determination of emissions from the gas distribution grid, therefore, would combine parts of different methods depending on their relevance to different emissions categories. For instance, according to the relevance of the categories in the studies of Battelle and EPA, detailed methods requiring the creation of a complex database could be considered for intrinsic emissions as they are the main contributor to the total methane emissions. For operational emissions, a

[7] The unit “a” means “anno” or “year”.

minor contributor to total emissions, a simplified method should be utilised requiring less data. For incident emissions a simplified method seems to be sufficient due to their limited relevance. However, more detailed methods would also be possible. In many countries the necessary activity data is already available because incidents in the pipeline are centrally recorded by the grid operator and reported to the regulator or a centralized association (for example, the German Association for Gas and Water (DVGW) in Germany). As mentioned before, combining of methods requires a clear definition of the emission categories.

Evaluation of Emission Estimation Methods for Pipelines

The project looked deeper into possible combinations of existing methods for emission estimation of **pipelines**. Eleven combinations were assessed for its technical suitability (benefit) and the required effort.

The technical suitability was evaluated for each of the three emission categories with a set of up to seven criteria per category. For each of the up to seven criteria, up to four options were given to evaluate the best option, second best, and so on. For instance, in category A (intrinsic emissions) one criterion is "How is the influence of pipeline pressure considered within the emission estimation?". There are several options to fulfil this criterion (e.g. application of emission factors for different pressure levels as low pressure or high pressure). The required effort was assessed with a simplified approach which relies on general, not specified, criteria, because there was only little information available. That means, one criterion in the effort analysis is for example "How difficult and time consuming is it to determine emission factors?". The criterion is assessed with the options "low", "medium", "high" or "very high".

Both results (technical suitability and required effort of the emission estimation) were combined in a benefit-effort analysis (Table 2). A scoring was necessary to keep the overview and to compare the eleven combinations. Please note therefore, that the introduced scoring should rather give directions (preferable approaches) to gain an impression and do not display reliable mathematical results.

Table 2: Benefit-Effort Analysis of Combinations for Emission Estimation for Pipelines

Category	**Combination of Emission Estimation Methods for Pipelines**										
Permeation (Cat. A)	Indirect Measurement[8]	Indirect Measurement	GRDF/ ENGIE	Indirect Measurement	GRDF/ ENGIE	Indirect Measurement	GRDF/ ENGIE	GRDF/ ENGIE	GRDF/ ENGIE	GRDF/ ENGIE	GRDF/ ENGIE
Other Intrinsic E. (Cat. A)	Indirect Measurement	Indirect Measurement	FH ISI	Indirect Measurement	FH ISI	Indirect Measurement	FH ISI	FH ISI	GRDF/ ENGIE	GRDF/ ENGIE	GRDF/ ENGIE
Operational E. (Cat. B)	Battelle	Battelle	Battelle	GRDF/ ENGIE	Battelle	GRDF/ ENGIE	GRDF/ENGIE	Battelle	Battelle	GRDF/ ENGIE	GRDF/ ENGIE
Incident E. (Cat. C)	GRDF/ ENGIE	Battelle	FH ISI	GRDF/ ENGIE	GRDF/ ENGIE	Battelle	FH ISI	Battelle	GRDF/ ENGIE	Battelle	GRDF/ ENGIE
Benefit/ Effort	1,62	1,59	1,59	1,57	1,56	1,54	1,54	1,53	1,47	1,46	1,44

Note: The "methods" which are assessed here in Table 2 are listed above on page 3. High scores indicate a preferable relation between benefit and effort.

Source: own illustration DBI

[8] There are different methods which use the indirect measurement for determining emissions (e.g. Battelle, Spain, United Kingdom).

All eleven compared combinations for pipelines differ only slightly in the benefit-effort analysis. Hence, an advanced evaluation (especially of the effort for emission estimation) is suggested and should be addressed in the second phase of the project.

Evaluation of Emission Estimation Methods for Facilities

The evaluation of the methods for estimating emissions of **facilities** in the gas distribution grid was carried out in a similar way as for the pipelines. The methods are less complex than for pipelines and do not differentiate different emission categories. The project evaluated ten methods with less criteria than for pipelines (three criteria and up to four fulfilling options), reflecting the reduced complexity of the methods.

The analysis results differ more significantly for facilities as shown in Table 3. However, the scoring is, here again, a first attempt that should be further (more detailed) developed.

Table 3: Benefit-Effort Analysis of Combinations for Emission Estimation for Facilities

	Emission Estimation Methods for Facilities									
	Belgium	GRDF/ ENGIE (France)	FH ISI 2000	Germany	Battelle 1989	U.K.	Battelle 1994	Switzer-land	Italy	Spain
Benefit/ Effort	1,87	1,33	1,00		0,97		-[9]		-[9]	

Note: The “methods” which are assessed here in Table 3 are listed above on page 3. High scores indicate a preferable relation between benefit and effort.

Source: own illustration DBI

The estimation of emissions from facilities seems to be sufficiently covered by a simplified method due to their small share of the total emissions (in the surveyed studies less than 7 %). Thus, it would be appropriate to determine EFs correctly by measurement in one country and to use these EFs in other countries (Belgian Variation of the Battelle-Method), if necessary by the use of correction factors (for example for different pressure levels). The described adaptation of country-specific EFs is limited to countries with comparable conditions of the distribution grid (facility type, state of maintenance, etc.).

However, since the emission estimation from facilities as well as its share of the total emissions has previously been based on limited research/literature and data volume, further analysis is suggested here.

Input Data and Assumptions for Emission Estimation

The input data and assumptions within individual methods are often different. For example, in some countries emission factors are not divided according to pressure levels and materials. However, this division is necessary as it directly influences the total amount of emissions. Due to the many differing influences on pipeline emissions from country to country (operational pressure, covering soil, maintenance condition of the network), it would be prudent to identify and utilise country-specific emission factors. In contrast, for facility emissions it is advisable to

9 For these methods the benefit-effort analysis could not be completed using the same approach as for the other methods (see report for details).

utilise a single emission factor across different countries. This is because facilities emissions are predominantly influenced by the technology, which is often comparable within different countries.

Conclusions and Outlook

Several methods for emission estimation of the gas distribution grid have been evaluated and the most promising methods that should contribute to a future pan-European approach for methane emission estimation, have been identified. The following conclusions can be drawn:

- Currently the emission estimation methods across Europe include different sources of emissions not necessarily consistently. This project therefore proposes a definition of system boundaries of the gas distribution grid.
- There are different emission categories, which have been elaborated in this project. Current emission estimation approaches do not always consider all of the emission categories completely.
- Every analysed approach for emission estimation shows strengths (e.g. consideration of many parameters that influence emission estimation) but also comprises weaknesses (e.g. complex database necessary) to various degrees.
- Combination of promising elements extracted from the existing methods is recommended and selected elements need to be further improved.
- A good balance of effort and benefits is important for the feasibility and acceptance of the method.

As important next steps the following activities have been identified:

- Performing a detailed effort-benefit analysis to support the selection of features for a future pan-European method
- Development of a pan-European method, including features that are currently missing, e.g. taking into account (in a rewarding way) emission reduction potential of measures that might be applied for example for safety or technical reasons (e.g. use of mobile compressors)
- Agreement on missing clear definitions (e.g. detailed distinction of categories)
- Defining the preferred detail of input data and agreeing on possible adjustment of methods if the necessary input data is not available in a specific country
- Discussing the approach with the authorities (together with respective national DSO and associations as MARCOGAZ and EUROGAS) to support the implementation of findings
- Proposal if and how the developed approach will be further implemented (e.g. as a CEN technical report).

These are the next challenges on the way to a pan-European method for the estimation of methane emissions from the gas distribution grid and will be in the scope of Project Phase II, which aims to start in summer 2016 and seeking the broad support of European gas network operators and gas industry associations.

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