

TFTEI

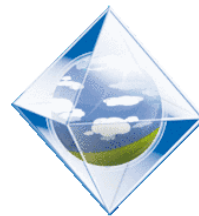


Under the Convention on Long Range Transboundary Air Pollution

Technical Work on CH₄ Emissions

Methane emissions in Europe from landfill gases, the natural gas supply system and biogas facilities

Simon Glöser-Chahoud (TFTEI Technical Secretariat)
French-German Institute for Environmental Research (DFIU/KIT)



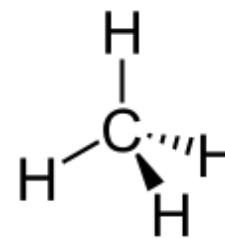
CITEPA



Agenda

- ❑ Methane as a new pollutant included in the mandate of TFTEI
- ❑ **Methane emissions from waste storage / landfills**
 - ❑ Measures and costs of emission reduction
- ❑ **Transport system of natural gas and emissions in Europe**
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Methane as a pollutant and GHG



❑ Why relevant?

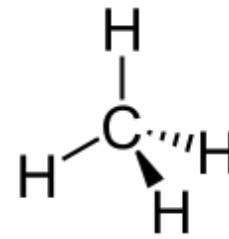
- ✓ Precursor for ground-level ozone (CH₄ as an air pollutant)
- ✓ CH₄ second most relevant greenhouse gas with a global warming potential (GWP) ~25 times higher than that of CO₂ (~80 times higher in the short-term)
- ✓ Natural gas plays an increasing role in energy supply (heat, electricity) due to comparatively low emissions / clean burning, flexibility of power plants
- ✓ Emitted by both natural and man-made sources → Difficult to clearly identify source of emissions once CH₄ accumulates in the atmosphere

GHG emissions in the EU28 (without Land Use, Land-Use Change and Forestry (LULUCF)):

GHG Emissions Mt CO ₂ eq.	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO ₂ emissions (without LULUCF)	4478	4225	4189	4315	4171	3833	3949	3804	3746	3658	3489	3522	3505	3523
CH ₄	740	679	618	557	523	511	501	491	487	476	469	469	465	466
N ₂ O	401	360	323	303	283	267	257	253	250	250	254	250	254	256
HFCs	29	44	55	77	97	98	104	106	109	111	114	110	107	105
PFCs	26	17	12	7	5	3	4	4	4	4	3	4	4	3
Total (without CO ₂ from LULUCF)	5691	5346	5210	5268	5087	4721	4822	4665	4603	4507	4335	4361	4343	4363

Source: Annual European Union greenhouse gas inventory 1990–2017 and inventory report 2019

Methane as a pollutant and GHG



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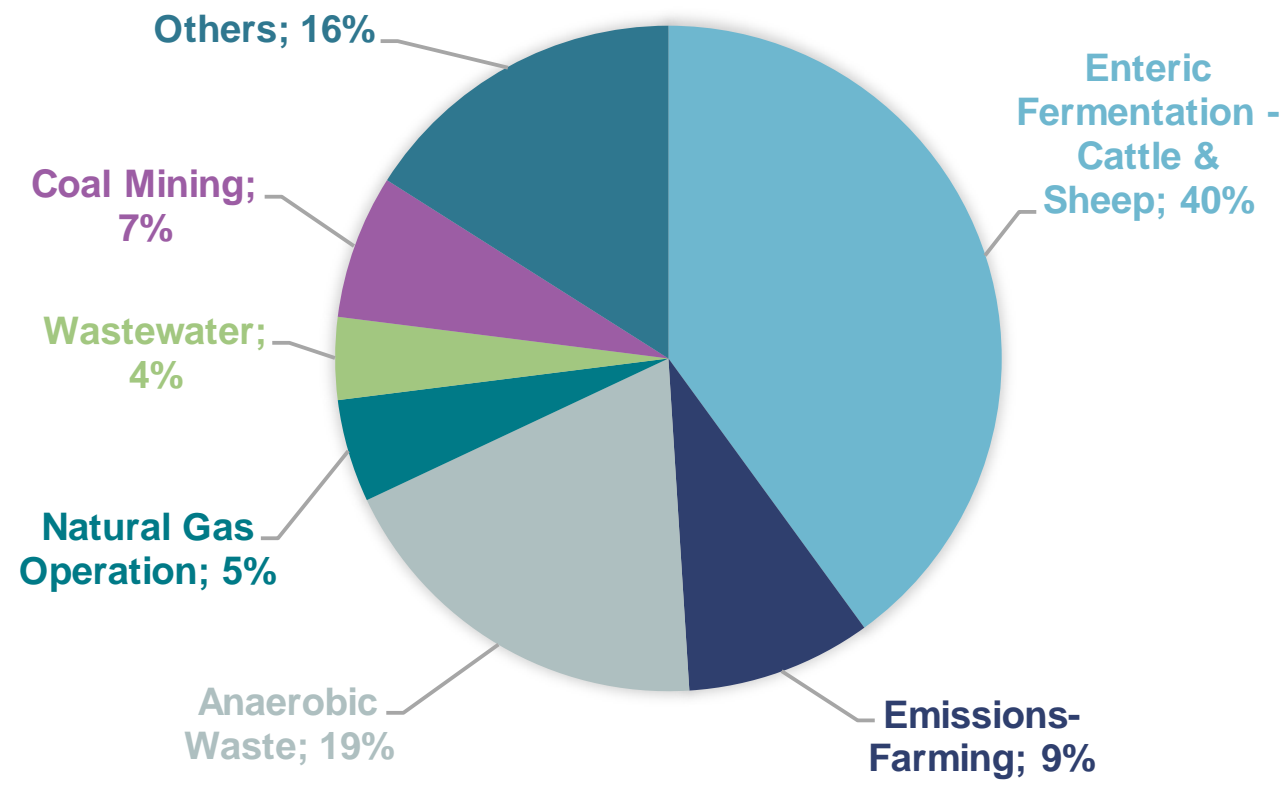
Since 2018 new pollutant included in the mandate of TFTEI and TFRN

- ✓ Focus of TFTEI activities at KIT in 2019/2020
- ✓ Work in progress → first draft report developed and sent to TFTEI experts
- ✓ Feedback received from various institutions

 **Goal: Finalization of a first report on methane emission until December 2020 (WGSR meeting)**

Sources of methane emissions in Europe

Emissions by source in 2017

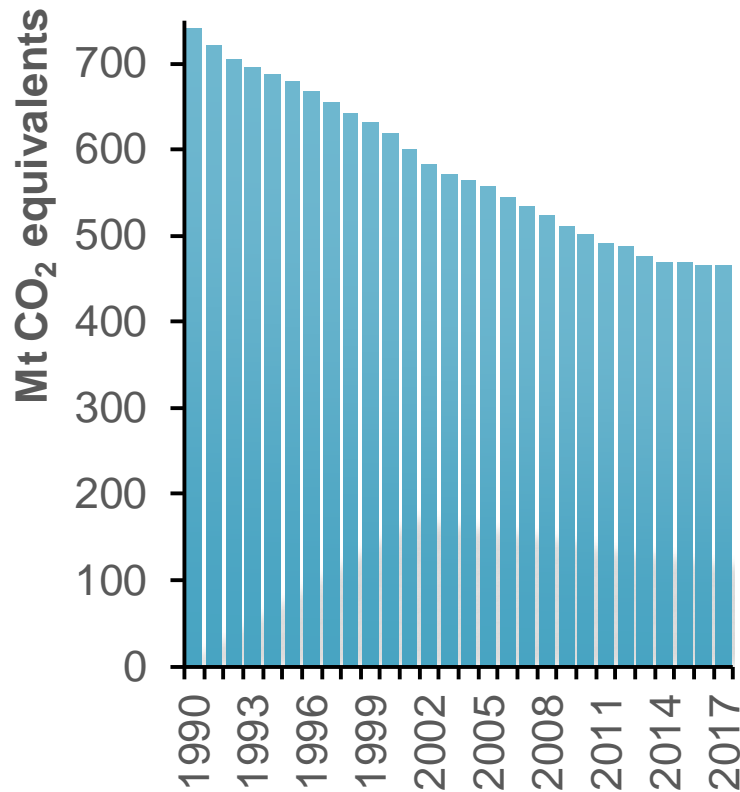


Source: Annual European Union greenhouse gas inventory 1990–2017 and inventory report 2019

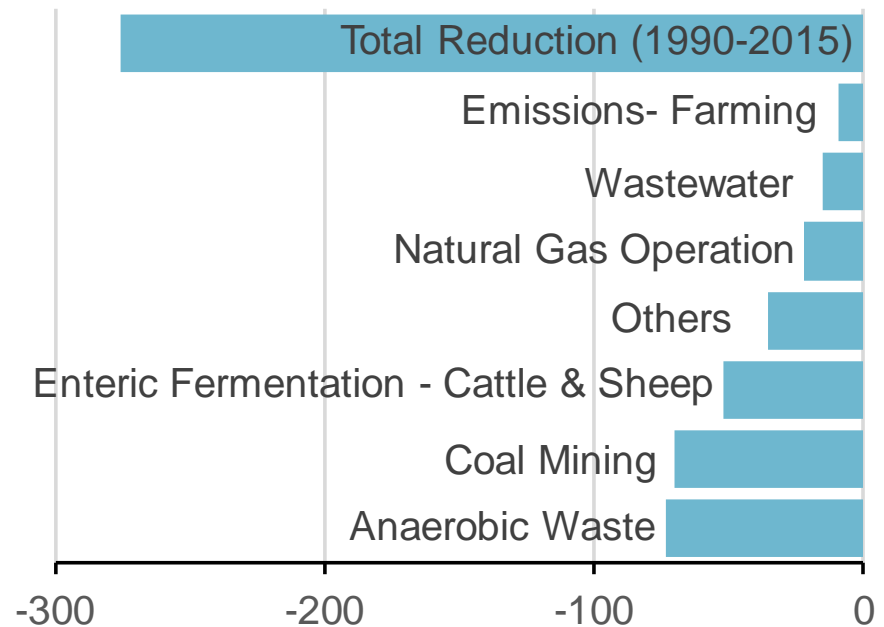
6th TFTEI Annual Meeting – Warsaw (online), October, 20, 2020

Methane emission reduction in Europe

Development of methane emissions in the EU



Reduction of CO₂ emissions by source in Mt CO₂ eq.

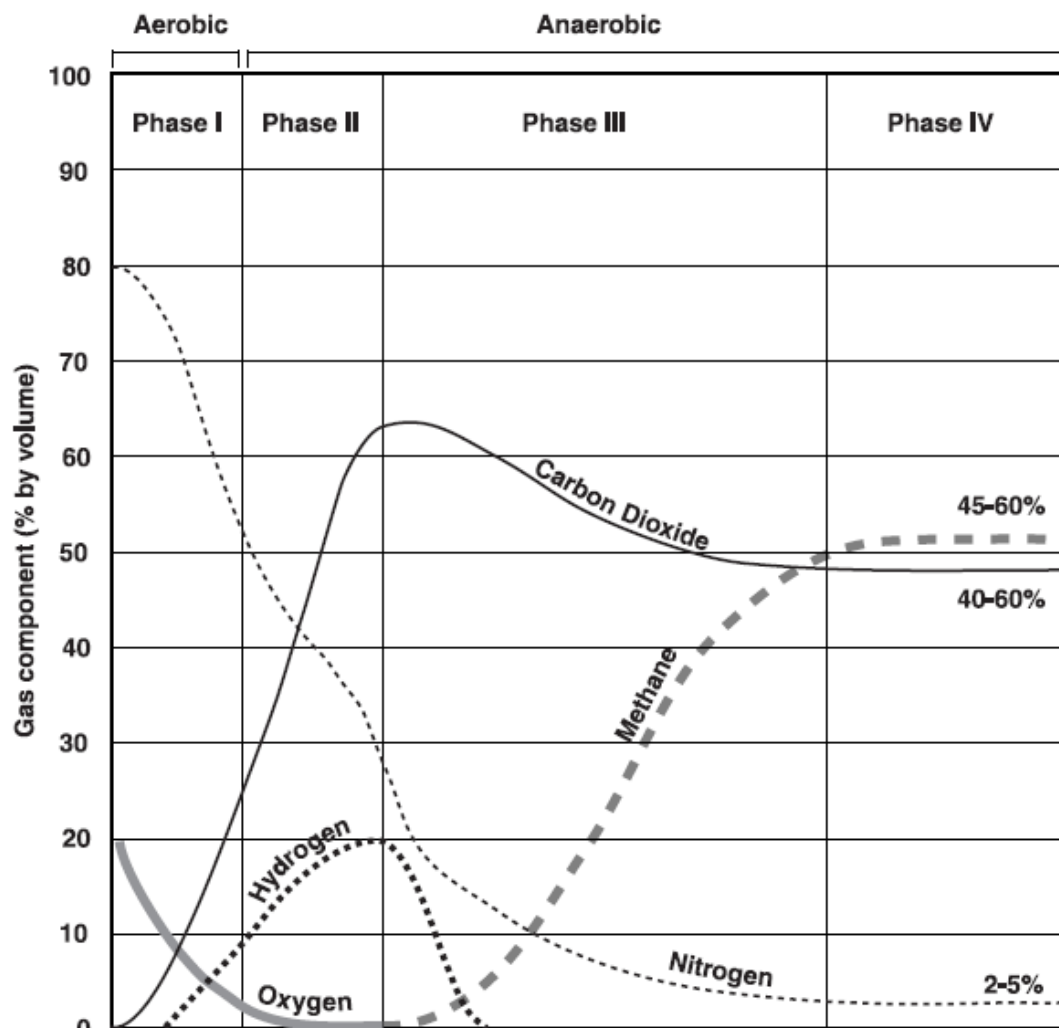


Source: Annual European Union greenhouse gas inventory 1990–2017 and inventory report 2019

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Landfill gas formation

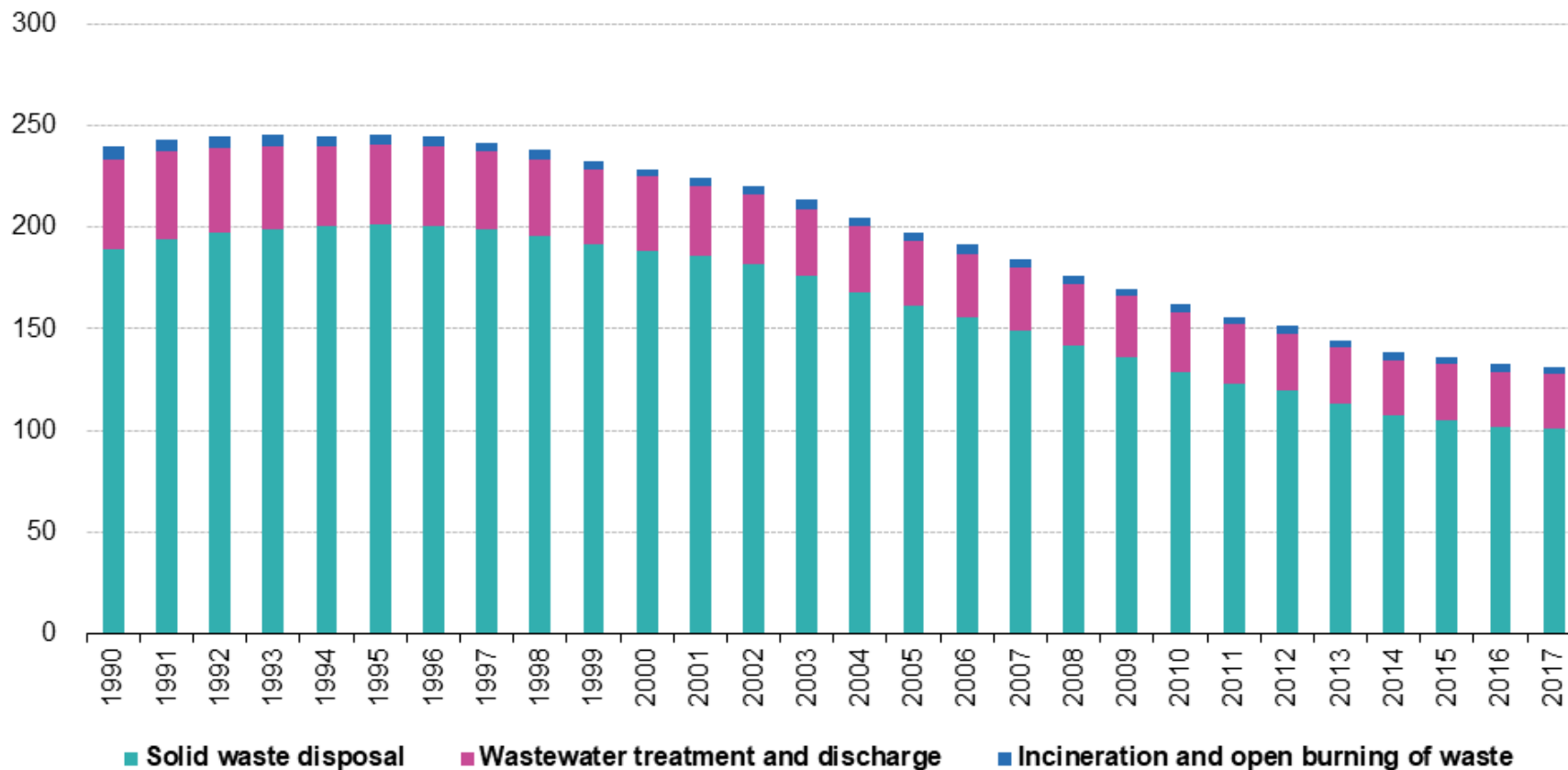


- ✓ Most landfill gas is produced by bacterial decomposition, which occurs when organic waste is broken down by bacteria that are naturally present in the waste and in the soil used to cover the landfill.
- ✓ Volatilization (vaporization) and chemical reactions also play minor roles
- ✓ Methane is produced in the anaerobic phase after several years
- ✓ Major source of anthropogenic methane emissions

Source: Landfill Gas Primer - An Overview for Environmental Health Professionals

Methane emissions from landfills in Europe

Greenhouse gas emissions of waste management, EU-28, 1990-2017
(million tonnes of CO₂ equivalent)

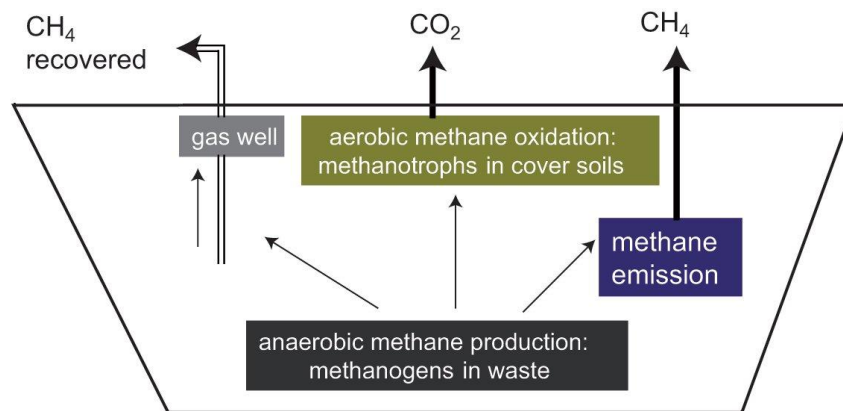
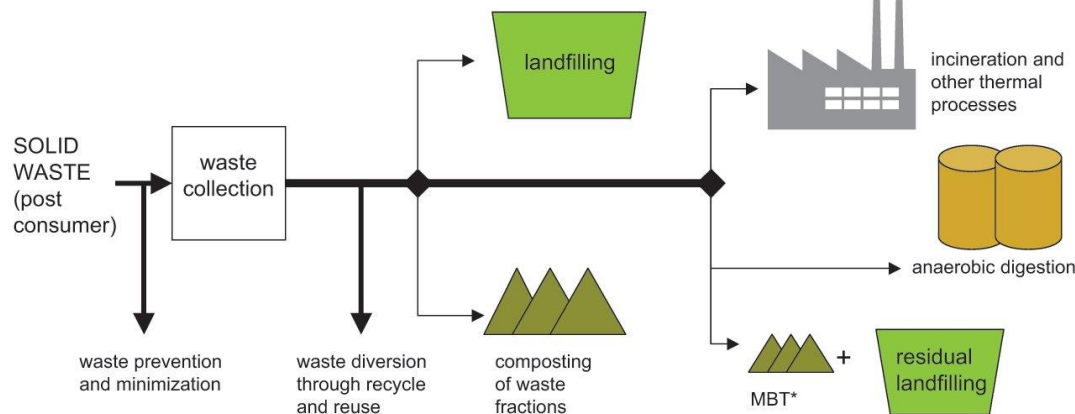


Source: Data based on Eurostat 2020

Mitigating CH₄ emissions from landfills

Main technologies for mitigating GHG emissions from landfills:

- ✓ Oxidation (biocovers / biofiltration)
- ✓ Landfill aeration
- ✓ Gas collection and utilization
 - ✓ Flaring
 - ✓ Electricity generation
 - ✓ Direct gas use for heat generation
 - ✓ Other uses (gas grid injection, fuel cells)

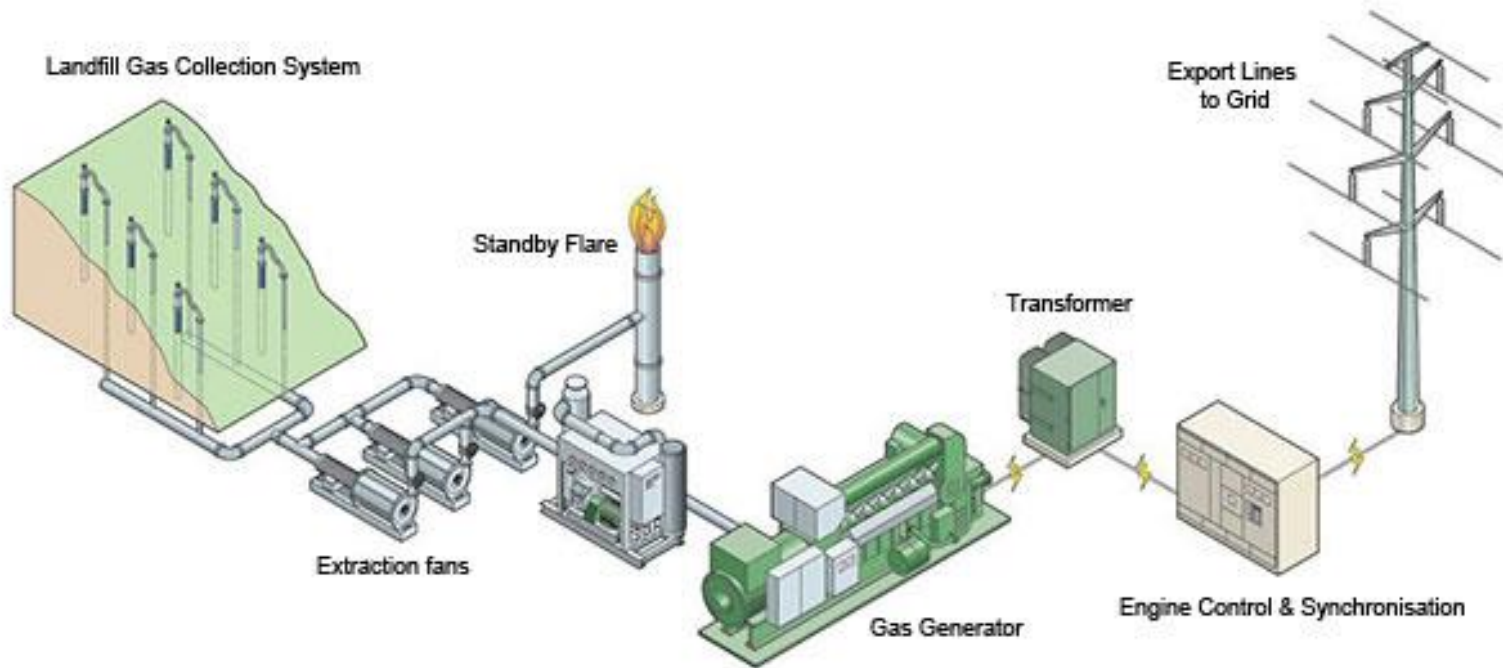


Simplified Landfill Methane Mass Balance

$$\text{Methane (CH}_4\text{) produced (mass/time)} = \Sigma(\text{CH}_4\text{ recovered} + \text{CH}_4\text{ emitted} + \text{CH}_4\text{ oxidized})$$

Source: Metz, Bert (Ed.) (2007): Climate change 2007. Cambridge: Cambridge University Press.

Landfill gas to energy solutions



- ✓ Landfill gas collected at the waste disposal site can be used for electricity generation.
- ✓ After pumping out, the gas usually must undergo pretreatment to remove CO₂ and yield CH₄.
- ✓ Energy production also requires a flare station to burn the excessive methane production

Source: Landfill gas. Edited by Yellow Power Power Plant Solutions. Available online at <http://www.yellowpower.com/solutions/landfill-gas>

Techno-economic aspects of different mitigation measures



		Biocover	In-situ aeration	Flaring	CH ₄ capture for power generation	CH ₄ capture for heat generation
Oxidation factor (fraction)		0.8	0.9	–	–	–
Fraction of recovered CH ₄		–	–	0.6 / 0.85	0.6 / 0.9	0.6 / 0.9
CH ₄ emission intensity of MSW (gCH ₄ / kg MSW)	min / max	8.5 / 21	4.2 / 11	6.4 / 43	4.2 / 43	4.2 / 43
CO ₂ eq emission intensity of MSW (tCO ₂ eq / t MSW)		0.12 / 0.19	0.058 / 0.10	0.087 / 0.35	0.058 / 0.35	0.058 / 0.35
Levelized cost of conserved carbon at 10 % WACC (USD/tCO ₂ eq)		99 / 100	99 / 130	5.0 / 58	37 / 66	– 70 / 89

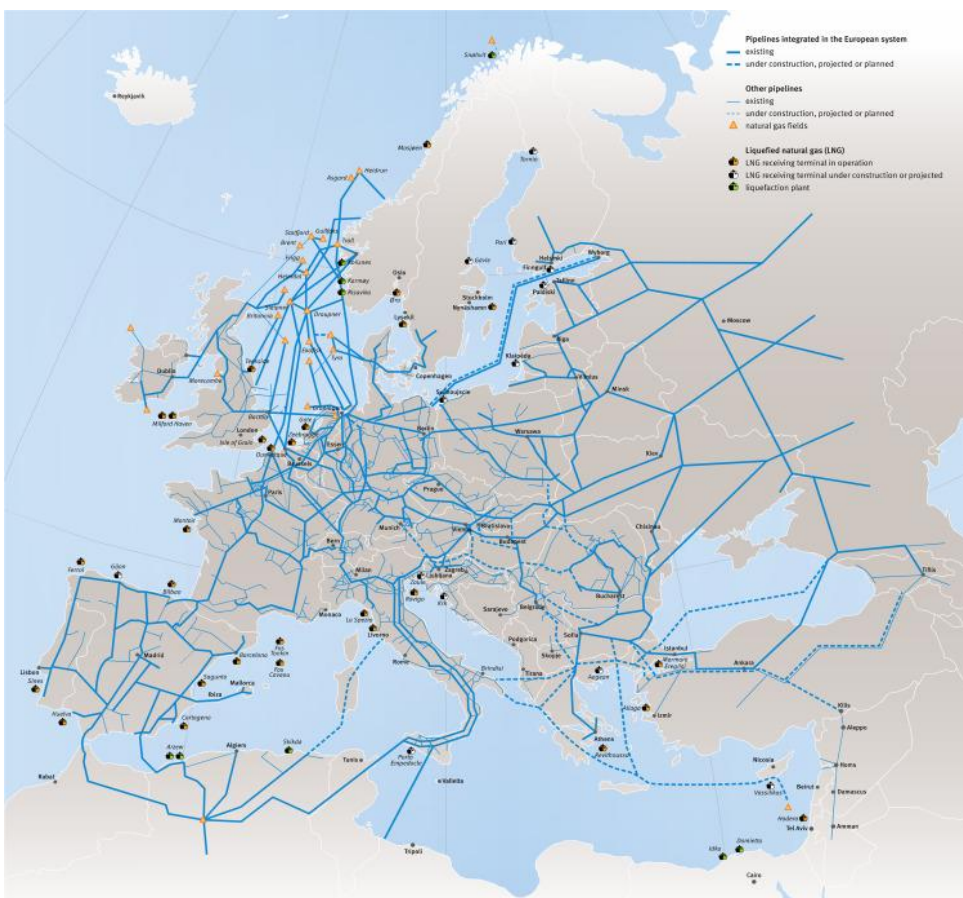
Emission reduction costs are very site specific, CH₄ use for heat and power generation generates revenues and is therefore usually economically favorable

Source: Schlömer et al. (2014): Annex III: Technology-specific cost and performance parameters. In Climate Change, pp. 1329–1356

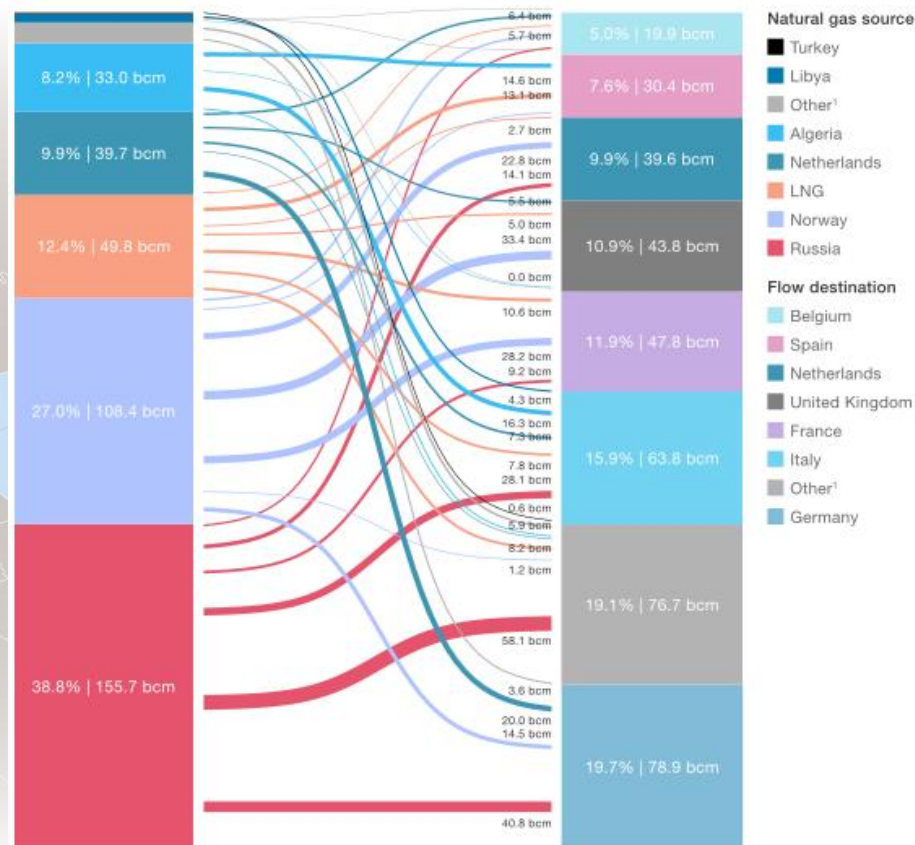
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Natural gas grid in Europe

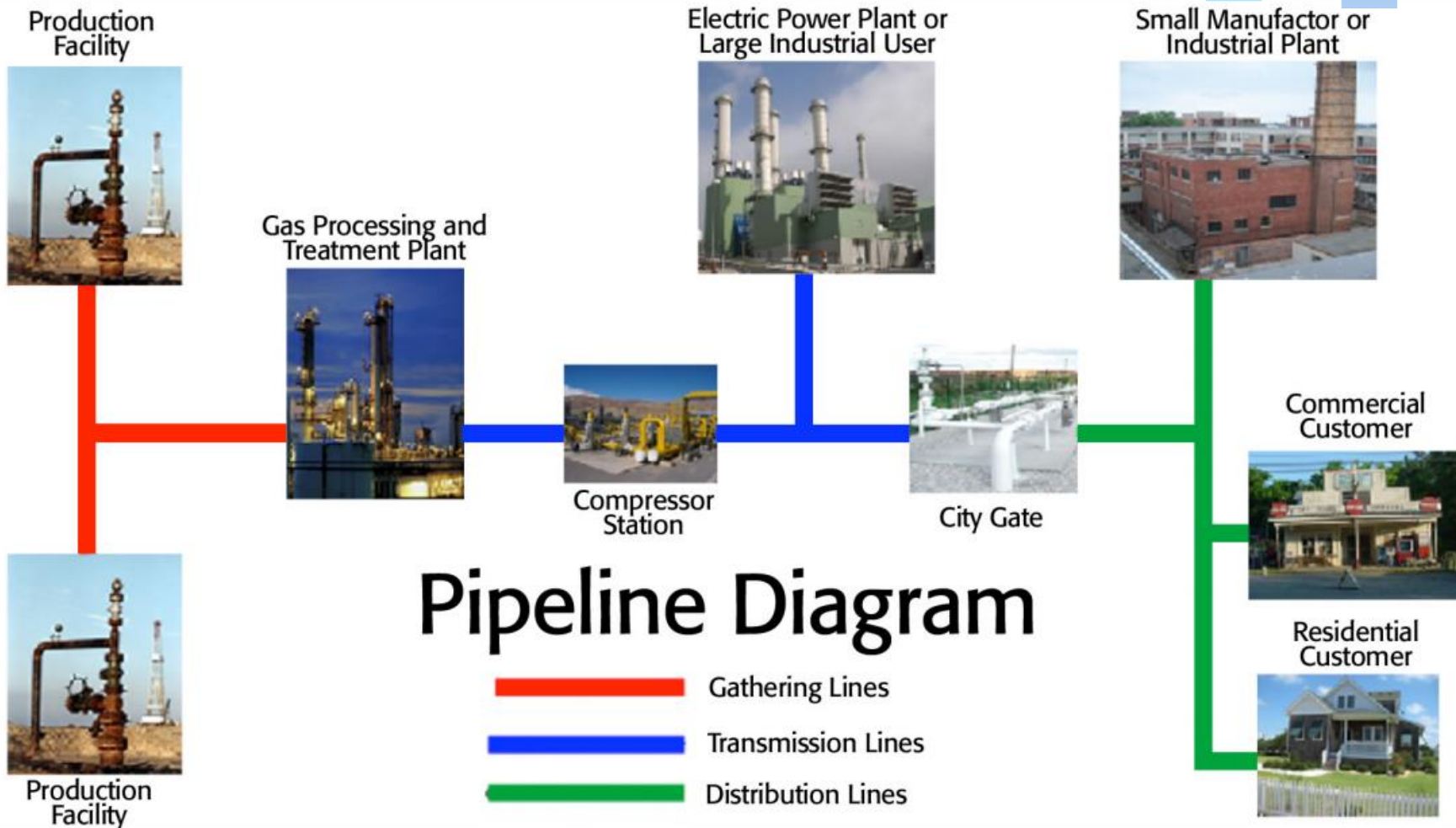


European natural gas flows, bcm



Source: McKinsey & Company: How did the European natural gas market evolve in 2018?

Key components of a natural gas grid

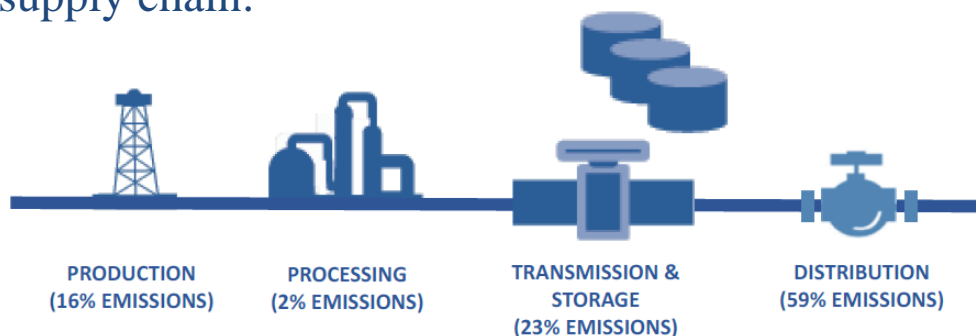


The gas pipeline transportation system from production to consumption

Source: Pipeline Safety Trust (2015): Pipeline Basics & Specifics About Natural Gas Pipelines

Emissions along the natural gas supply chain

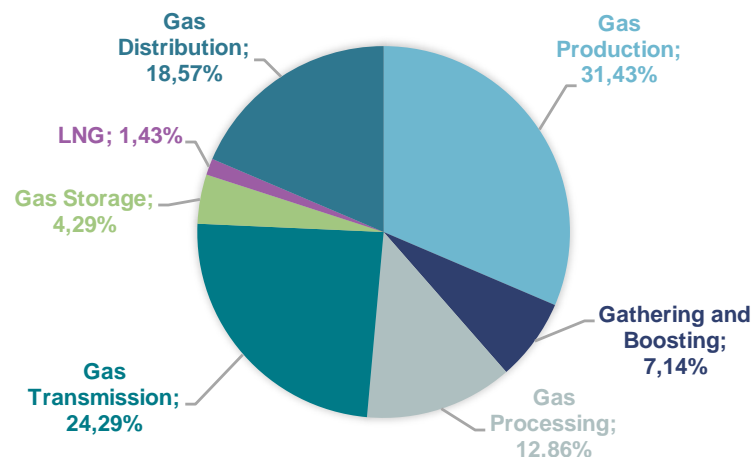
Emissions along the EU28 natural gas supply chain:



Distribution of emissions along the supply chain by country:

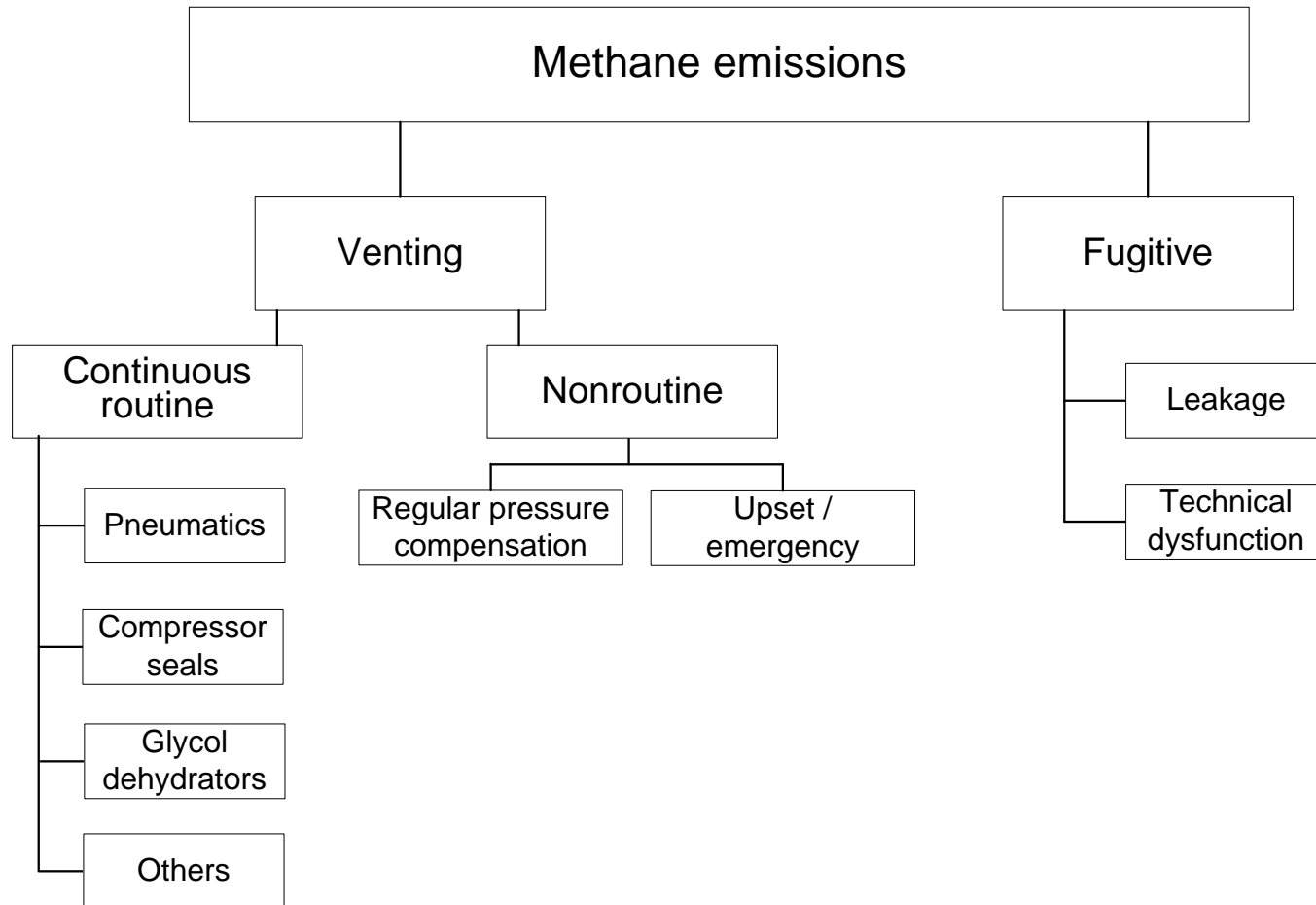
	E&P	Transmission	Distribution	Other	Total	Rate **
France	0	24	20	-	44	0.1%
Germany	1	76	89	27	193	0.2%
Italy	9	31	142	-	182	0.2%
Poland	16	6	13	-	35	0.1%
Russia	1164	3715	497	-	5376	0.6%
Ukraine*	75	54	433	575	1137	1.4%
USA	4709	1349	439	-	6497	0.5%
Canada	104	46	38	295	483	0.2%

Share of US emissions from the natural gas network by processing step:



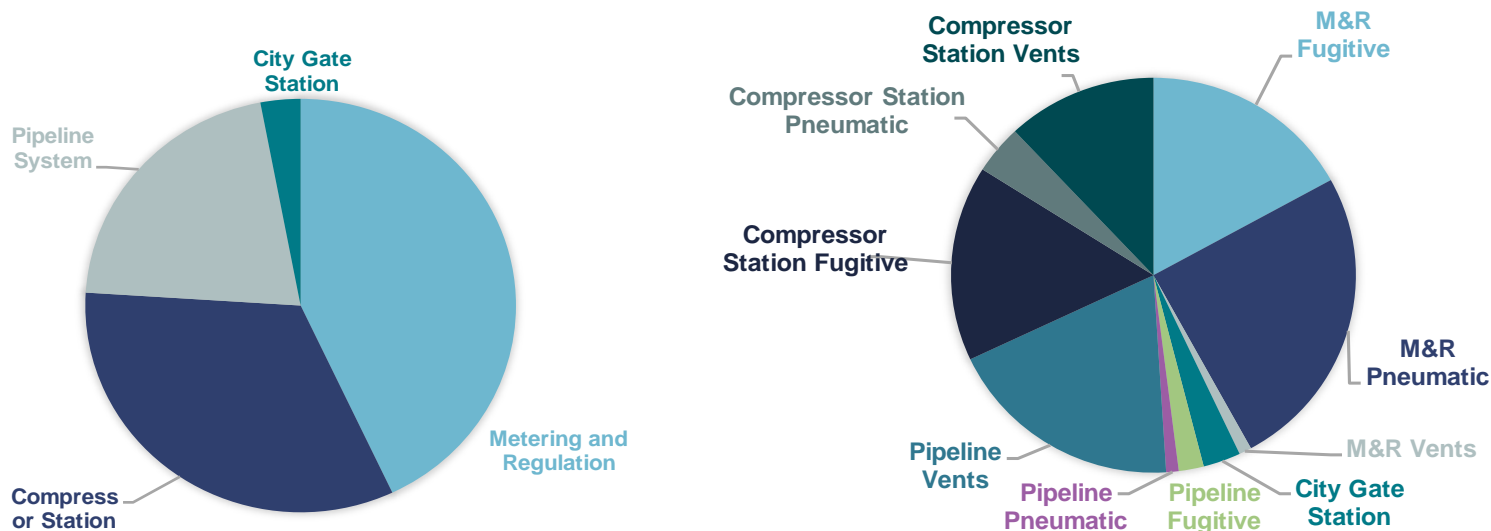
Sources: ICF International (2014), Marcogaz (2019), Oxford Institute for Energy Studies (2017)

Characterization of methane emission from the natural gas supply system



Source: Directive 60 of the Alberta Energy Regulator (AER 2018)

Sources of emission in the European natural gas supply system



- ✓ Fugitive emissions are all continuous leaks from flanges, pipe equipment, valves, joints or may occur due to dysfunction of respective devices.
- ✓ Vented emissions include intended vents for maintenance or operational reasons and vents from incidents, when the content of the gas equipment is released to the atmosphere.
- ✓ Pneumatic emissions are all emissions caused by gas operating valves and other devices, continuous as well as intermittent emissions.

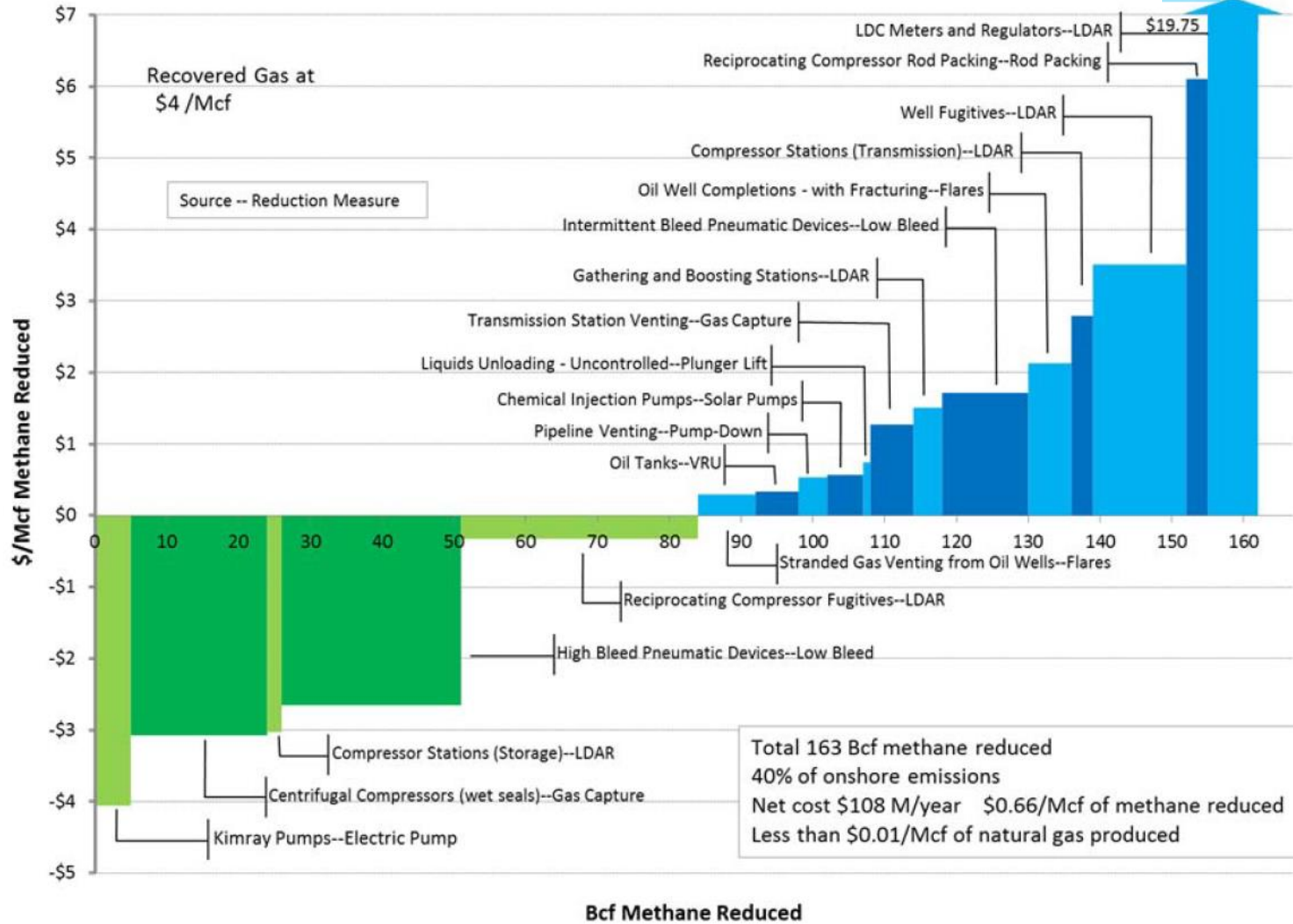
Source: E.ON Ruhrgas: REDUCTION OF METHANE EMISSIONS IN THE EU NATURAL GAS INDUSTRY (2010)

General measures to reduce emissions from the natural gas supply system



- ✓ **Reduction of operating emissions**
 - ✓ Use of low or zero emitting pneumatic and compressor systems with re-use of the gas instead of venting:
 - ✓ Replace centrifugal compressor seal oil systems (recover methane from seal oil)
 - ✓ Install low bleed pneumatic devices
- ✓ **Reduction of maintenance emissions**
 - ✓ Use of a mobile compressor to pump gas from a section to be vented into a neighboring sections
 - ✓ Use of a mobile flare unit to burn vented gas at pipeline maintenance works
- ✓ **Inspection and maintenance programs: Organizational measures to detect emissions earlier and stop them, also referred to as leak detection and repair (LDAR)**
 - ✓ Optimize compressor shutdown practices, minimize venting before pipeline maintenance
 - ✓ Perform periodic cost-effective leak inspections
 - ✓ Innovative leak detection (sensors, drones, machine vision, infrared cameras)

Techno-economic aspects of emission reduction



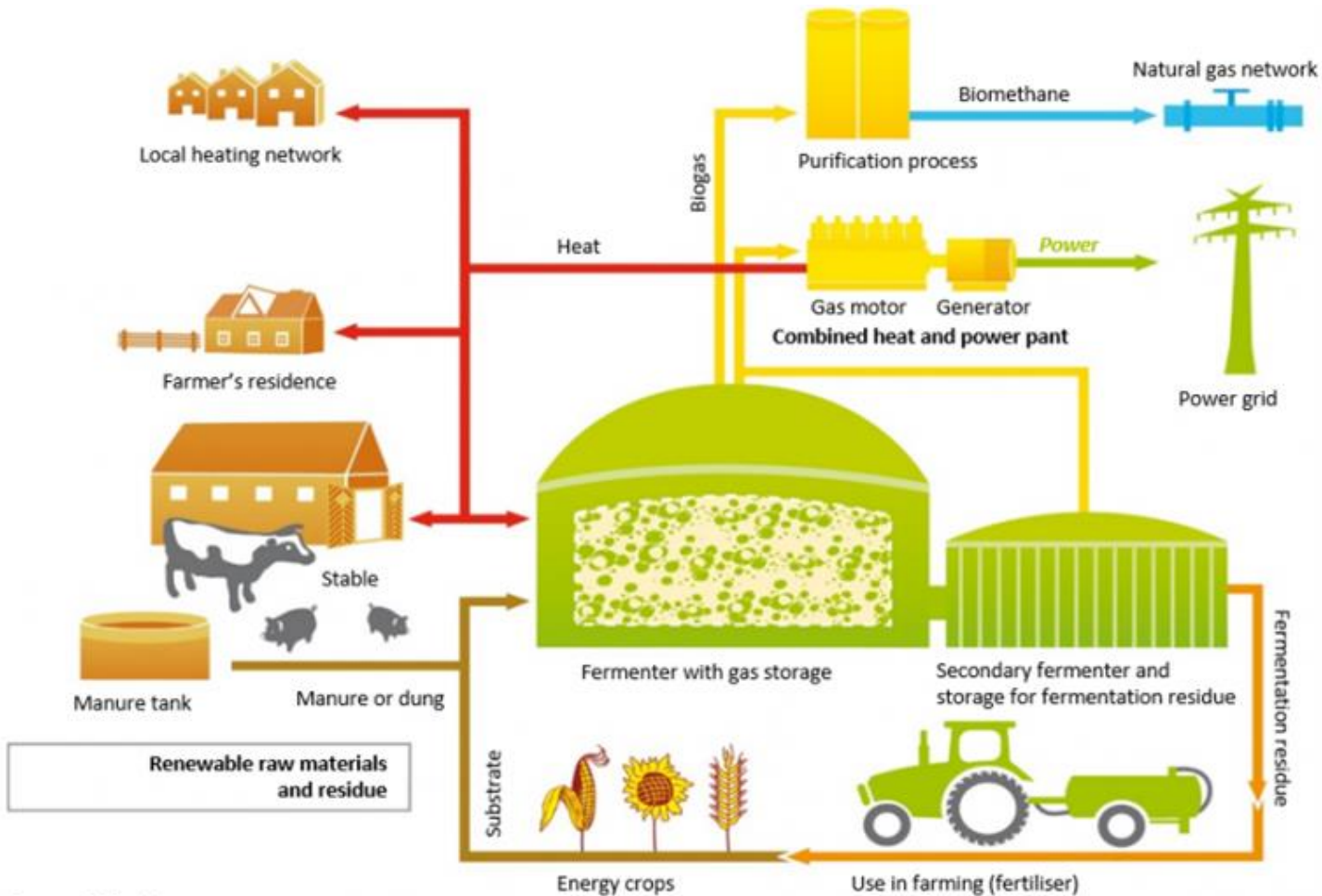
Total 163 Bcf methane reduced
 40% of onshore emissions
 Net cost \$108 M/year \$0.66/Mcf of methane reduced
 Less than \$0.01/Mcf of natural gas produced

ICF International: Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Gas Industries

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Methane emissions from biogas facilities

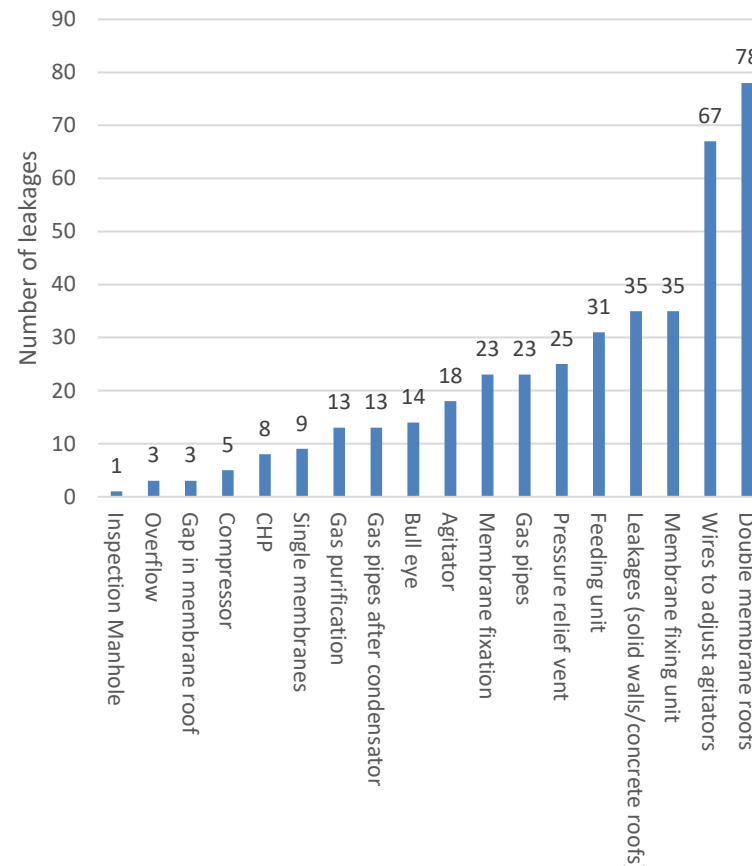


Source: FNR e.V.

Methane emissions from biogas facilities I



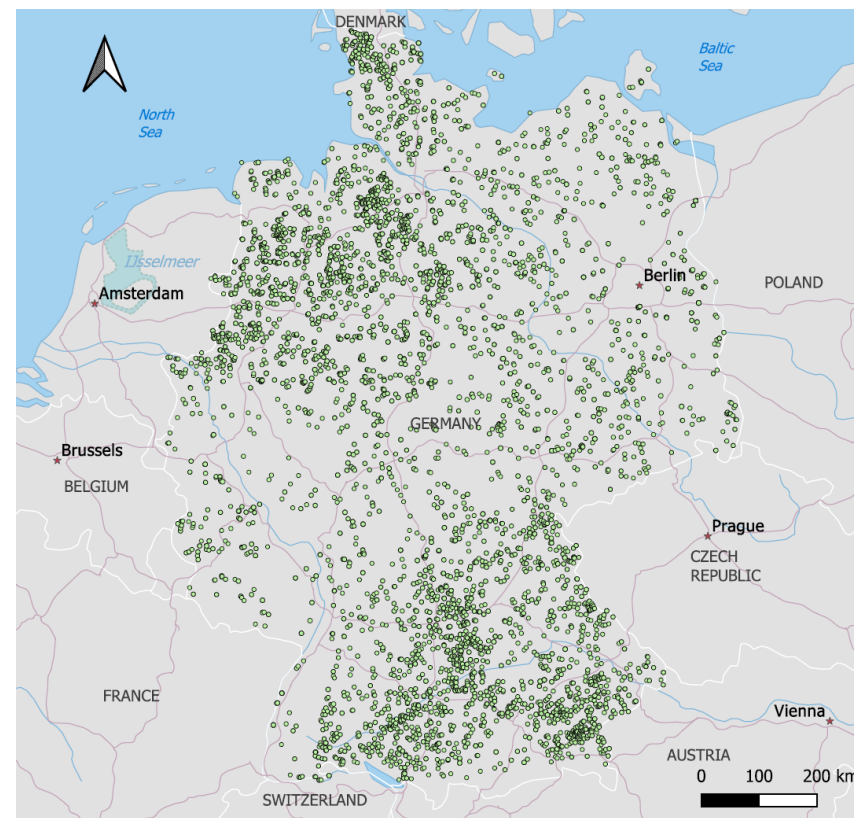
- ✓ Biogas emissions not negligible when regarding technical methane emission
- ✓ Biogas contains 40-60% methane, the rest is mainly CO₂
- ✓ Number of detected leakages not sufficient to quantify amount of methane emissions
- ✓ Beside leakages from the fermentation plant there are additional emission sources:
 - ✓ Incomplete combustion in the CHP
 - ✓ Substrate storage
 - ✓ Storage of residuals
 - ✓ ...
- ✓ Experts assume overall emissions of up to 5% of the CH₄ produced (UBA)



Identified leakages from biogas plants in Germany (data from Schreier (2011) and Clemens (2014) based on a overall number of 302 installations that have been determined)

Methane emissions from biogas facilities II

- ✓ 32.5 TWh of electricity produced from biogas plants (CHP) in Germany, another 29.5 TWh in the rest of Europe
- ✓ Considering a reasonable range of plant efficiencies and CH₄ emission levels from these plants, this results in overall methane emissions of 500-800 kt/a
- ✓ This is in a range of 3-4% of overall CH₄ emissions in Europe and should therefore not be neglected (5% of CH₄ emissions from natural gas operations)



Own illustration of biogas facilities in Germany (~10.000 small and medium biogas plants)

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Conclusions

Methane emissions are gaining increasing attention

- ✓ Methane is an important GHG (80 times higher GWP compared to CO₂ in the short term)
- ✓ Methane is an air pollutant and precursor of ground-level ozone
- ✓ EU Commission adopts EU Methane Strategy as part of European Green Deal:



Press release | 14 October 2020 | Brussels

Reducing greenhouse gas emissions: Commission adopts EU Methane Strategy as part of European Green Deal

- ✓ Improve measurement and reporting of methane emissions among member states
- ✓ The EU's Copernicus satellite programme will also improve surveillance and help to detect global super-emitters and identify major methane leaks.
- ✓ To reduce methane emissions in the energy sector, an **obligation to improve detection and repair of leaks in gas infrastructure** will be proposed and legislation to **prohibit routine flaring and venting practices** will be considered.
- ✓ In the waste sector, the Commission will consider further action to **improve the management of landfill gas, harnessing its potential for energy use while reducing emissions**, and will review the relevant legislation on landfill in 2024.

Conclusions

Landfill gases

- ✓ Most relevant source of methane emissions with around 20% of European emissions (even larger share at the global level)
- ✓ Reduction/banning of landfilled biodegradable waste is most important measure to reduce emissions in the long term
- ✓ Main technologies for mitigating GHG emissions from landfills:
 - ✓ Oxidation (biocovers / biofiltration)
 - ✓ Landfill aeration
 - ✓ Gas collection and utilization

Natural Gas Grid

- ✓ Methane emissions from natural gas network show high diversity (fugitive emissions, emissions from devices, venting)
- ✓ Reduction measures include technical (improvement / replacement of specific devices) and organizational components (maintenance / leak detection)

Biogas facilities

- ✓ Emissions from biogas facilities seem underestimated, especially in countries with subsidy

Next steps

- Feedback on the first draft**
- ✓ Document spread among TFTEI experts in September
- ✓ Feedback received from different institutions (experts commenting > 10)

- Next Steps**
- ✓ Implementation of feedback in the document, particularly regarding additional sources for Europe
- ✓ Establishment of an expert group for each topic (landfill / natural gas / biogas)
- ✓ Discussion in a web conference in November
- ✓ Finalization of the document for the next WGSR meetings December

- Please contact me in case you have not received the draft document yet or you wish to participate to the expert discussion:**

simon.gloeser-chahoud@kit.edu

**Methane Emissions
Background Document**
DRAFT INTERMEDIATE TFTEI Report 2019/2020

Background document on methane emissions in Europe from landfill gases, the natural gas supply system and biogas facilities

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Thank you very much
for your attention!
Questions?

TFTEI Technical Secretariat



Appendix / Backup

TFTEI Technical Secretariat



Landfill gas as an important source of methane emission

Table 2-1: Typical Landfill Gas Components

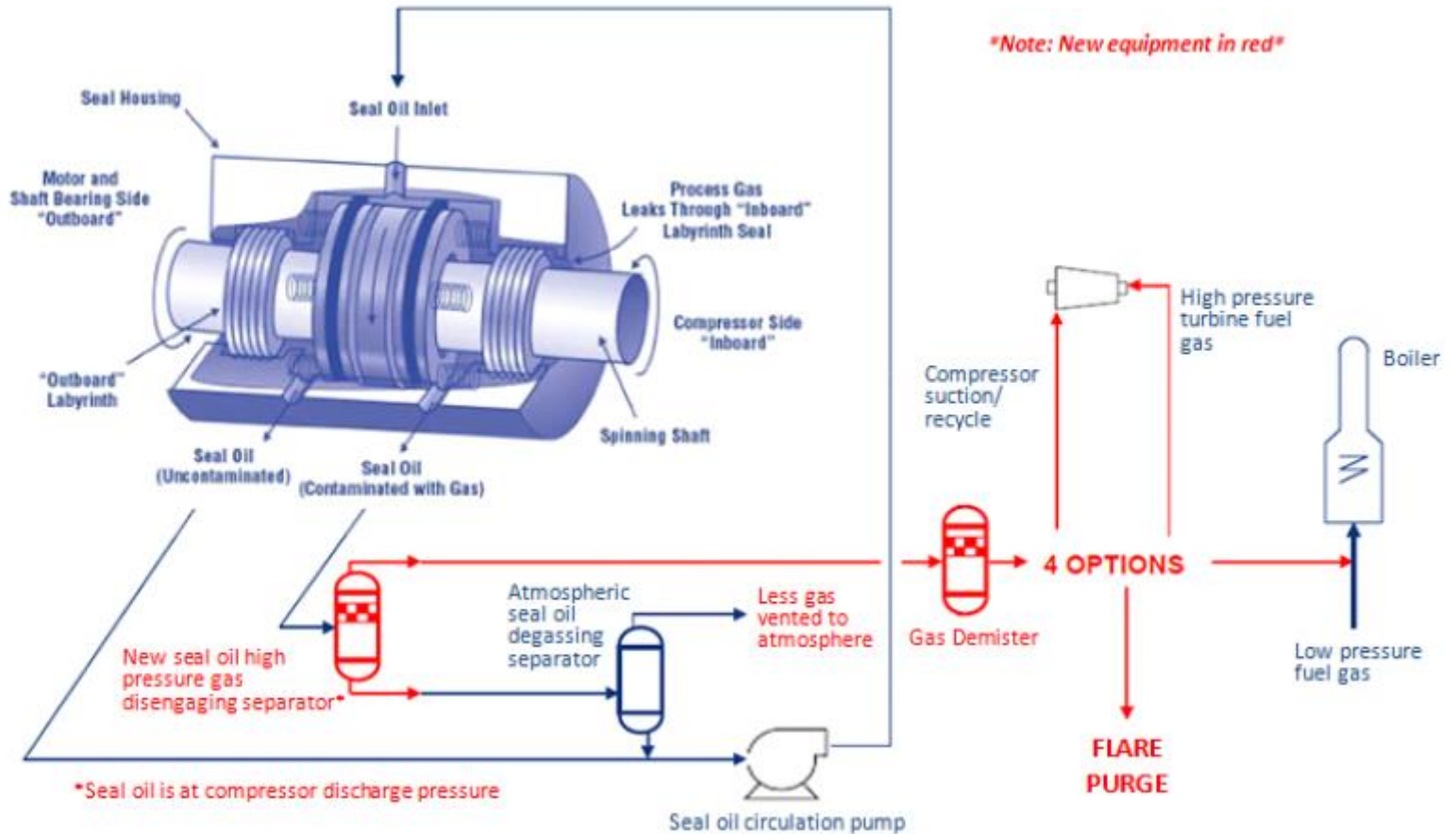
Component	Percent by Volume	Characteristics
methane	45–60	Methane is a naturally occurring gas. It is colorless and odorless. Landfills are the single largest source of U.S. man-made methane emissions.
carbon dioxide	40–60	Carbon dioxide is naturally found at small concentrations in the atmosphere (0.03%). It is colorless, odorless, and slightly acidic.
nitrogen	2–5	Nitrogen comprises approximately 79% of the atmosphere. It is odorless, tasteless, and colorless.
oxygen	0.1–1	Oxygen comprises approximately 21% of the atmosphere. It is odorless, tasteless, and colorless.
ammonia	0.1–1	Ammonia is a colorless gas with a pungent odor.
NMOCs (non-methane organic compounds)	0.01–0.6	NMOCs are organic compounds (i.e., compounds that contain carbon). (Methane is an organic compound but is not considered an NMOC.) NMOCs may occur naturally or be formed by synthetic chemical processes. NMOCs most commonly found in landfills include acrylonitrile, benzene, 1,1-dichloroethane, 1,2-cis dichloroethylene, dichloromethane, carbonyl sulfide, ethylbenzene, hexane, methyl ethyl ketone, tetrachloroethylene, toluene, trichloroethylene, vinyl chloride, and xylenes.
sulfides	0–1	Sulfides (e.g., hydrogen sulfide, dimethyl sulfide, mercaptans) are naturally occurring gases that give the landfill gas mixture its rotten-egg smell. Sulfides can cause unpleasant odors even at very low concentrations.
hydrogen	0–0.2	Hydrogen is an odorless, colorless gas.
carbon monoxide	0–0.2	Carbon monoxide is an odorless, colorless gas.

- ✓ Landfill gas is composed of a mixture of different gases.
- ✓ By volume, landfill gas typically contains 45% to 60% methane and 40% to 60% carbon dioxide.
- ✓ Landfill gas also includes small amounts of nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and non methane organic compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride.

Source: Landfill Gas Primer - An Overview for Environmental Health Professionals

Wet seal degassing recovery system for centrifugal compressors I

Wet seal degassing recovery system for centrifugal compressors - Source: U.S. EPA



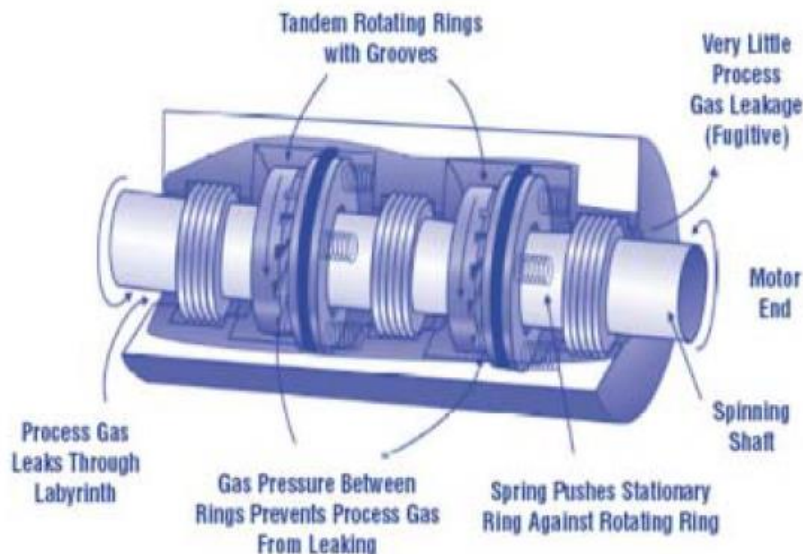
Wet seal degassing recovery system for centrifugal compressors II



Environmental Effectiveness and Key Factors: Wet Seal Recovery System for Centrifugal Compressors

Environmental Effectiveness	CO ₂	CH ₄	N ₂ O
Typical abatement efficiency for key GHGs (primary abatement metrics), %	Up to 100% (Assuming recovered gas is not flared)	Up to 99%	N/A
Factors affecting efficiency	Depending on the use of the recovered degassing emissions.	Depending on the use of the recovered degassing emissions.	
Limits of technical feasibility	"Knock-out" vessels to recover any seal oil mist from the recovered gas, if the gas is to be used as fuel. Piping capacity must exist to use recovered degassing emissions.		

Dry seals on centrifugal compressors

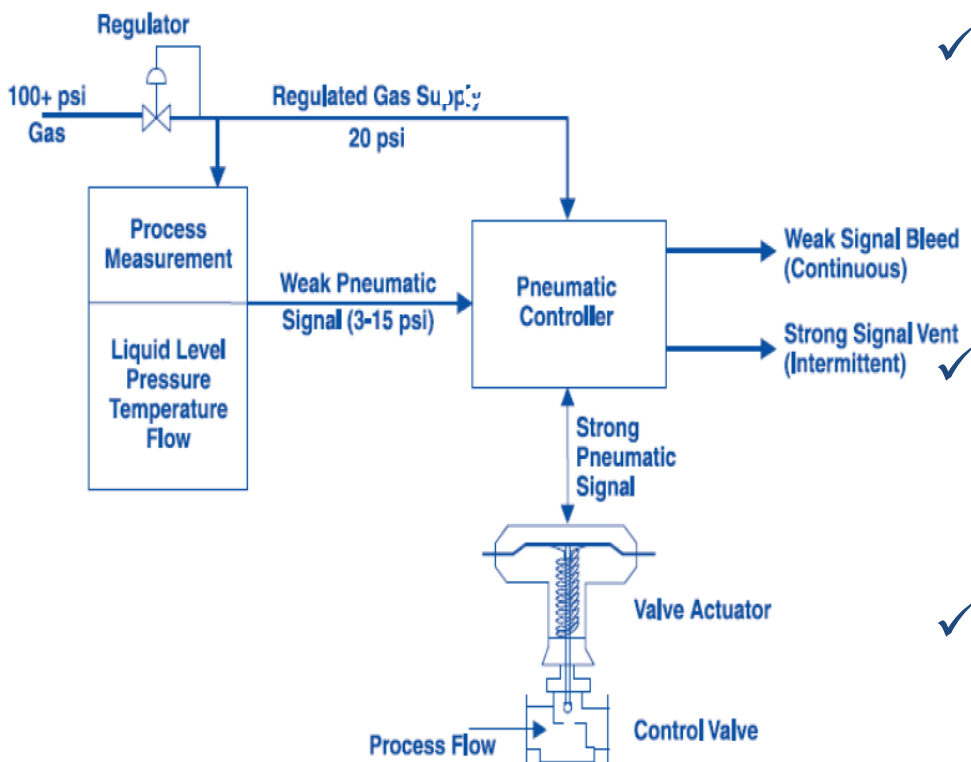


Environmental Effectiveness and Key Factors: Replacing Wet Seals with Dry Seals on Centrifugal Compressors

Environmental Effectiveness	CO ₂	CH ₄	N ₂ O
Typical abatement efficiency for key GHGs (primary abatement metrics), %	97%	97%	0%
Factors affecting efficiency	See below	See below	
Limits of technical feasibility	The compressor pressure must be below 3,000 psi and the temperature must be below 300° F. Furthermore; compressors should not be towards the end of their life.		

ICF International: Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Gas Industries

Modifications of pneumatic controllers and devices



- ✓ Pneumatic devices powered by pressurized natural gas are used widely in the natural gas industry as liquid level controllers, pressure regulators, and valve controllers.
- ✓ Pneumatic devices release or bleed natural gas to the atmosphere and, consequently, are a major source of methane emissions.
- ✓ The actual bleed rate or emission level largely depends on the design of the device.
- ✓ Significant emission reductions through replacement, retrofit, and maintenance of high-bleed pneumatics possible.

➔ Replacement of high bleed devices while maintaining safety regulation

US Environmental Protection Agency: Options For Reducing Methane Emissions From Pneumatic Devices In The Natural Gas Industry

Economic benefits of reducing pneumatic emissions

Exhibit 4: Economic Benefits of Reducing Pneumatic Device Emissions

Action	Cost ^a (\$)	Bleed Rate Reductions ^b (Mcf/yr/device)	Annual Savings ^c (\$/year)	Payback Period (months)	IRR ^d (%)
Replacement					
Level Controllers					
High-bleed to low-bleed	513	166	1,165	6	226
Pressure Controllers					
High-bleed to low-bleed	1,809	228	1,596	14	84
Airset metal to soft-seal	104	219	1,533	<1	>1,400
Retrofit					
Level Controllers					
Mizer	675	219	1,533	6	226
Large orifice to small	41	184	1,288	<1	>3,100
Large nozzle to small	189	131	917	3	>450
Pressure Controllers					
Large orifice to small	41	184	1,288	<1	>3,100
Maintenance					
All types					
Reduce supply pressure	207	175	1,225	3	>500
Repair leaks, retune	31	44	308	2	>900
Level Controllers					
Change gain setting	0	88	616	Immediate	---
Positioners					
Remove unnecessary	0	158	1,106	Immediate	---

^a Implementation costs represent average costs for Fisher brand pneumatic instruments installed.
^b Bleed rate reduction = change in bleed rate scf/hr x 8,760 hr/yr.
^c Savings based on \$7.00/Mcf cost of gas.
^d Internal rate of return (IRR) calculated over 5 years.

Source: US Environmental Protection Agency (2006): Options For Reducing Methane Emissions From Pneumatic Devices In The Natural Gas Industry