TFTEI

Under the Convention on Long Range Transboundary Air Pollution

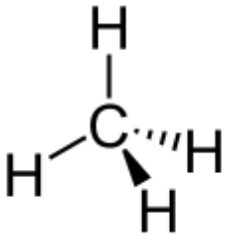
Methane emissions and related abatement technologies from waste landfills and the natural gas grid in Europe

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

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**
  - Measures and costs of emission reduction
- Conclusions and ongoing work on CH_4

Methane as a pollutant and GHG



❑ Why relevant?

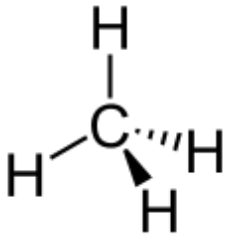
- ✓ Precursor for ground-level ozone (CH_4 as an air pollutant)
- ✓ CH_4 second most relevant greenhouse gas with a global warming potential (GWP) ~25 times higher than that of CO_2 (~80 times higher in the short-term)
- ✓ Natural gas plays an increasing role in energy supply (heat, electricity) due 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 CH_4 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_2O	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 CO2 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**

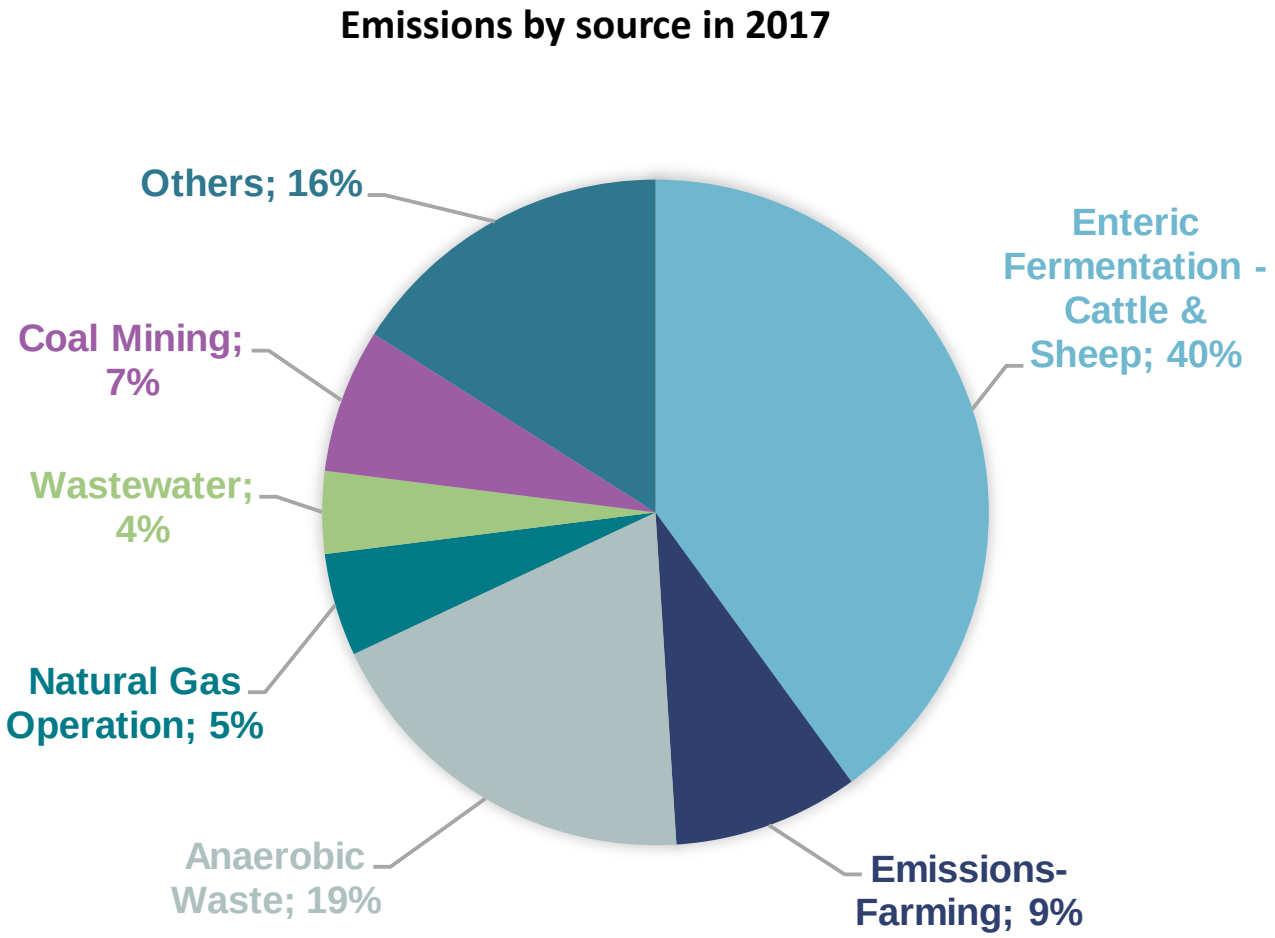
✓ Focus of TFTEI activities at KIT in 2019/2020

✓ 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)**

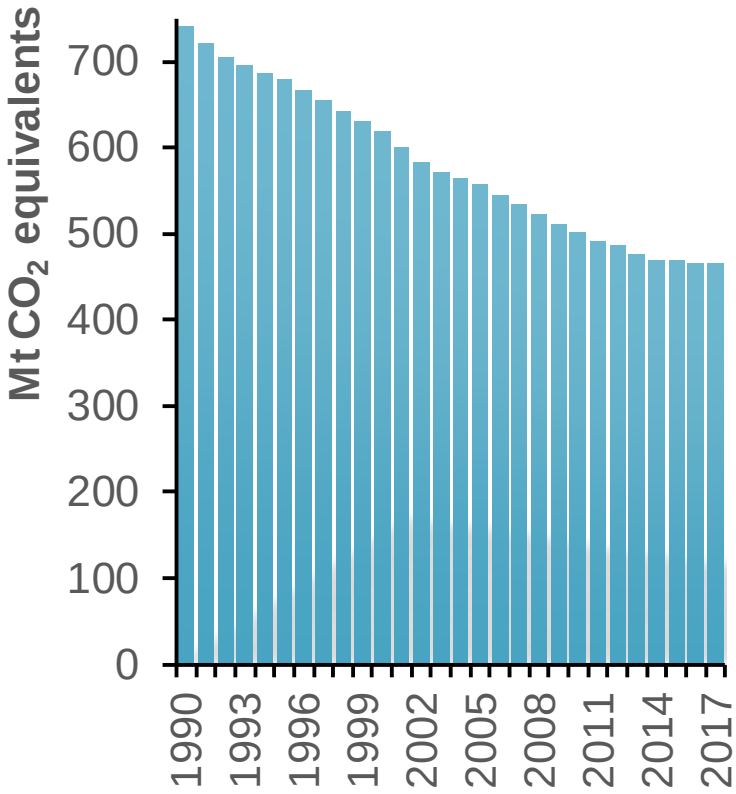
Sources of methane emissions in Europe



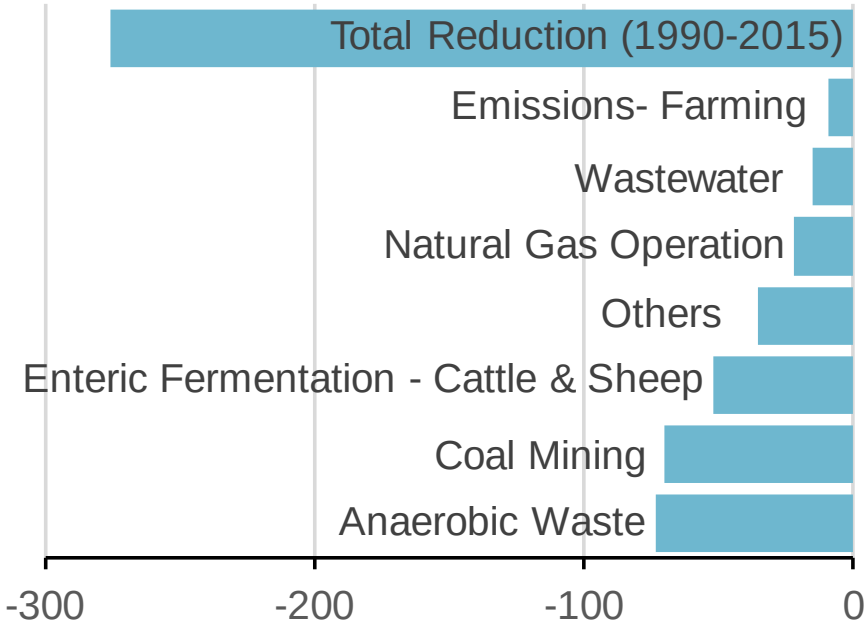
Source: Annual European Union greenhouse gas inventory 1990–2017 and inventory report 2019

Methane emission reduction in Europe

Development of methane emissions in the EU



Reduction of CO2 emissions by source in Mt CO_2 eq.



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

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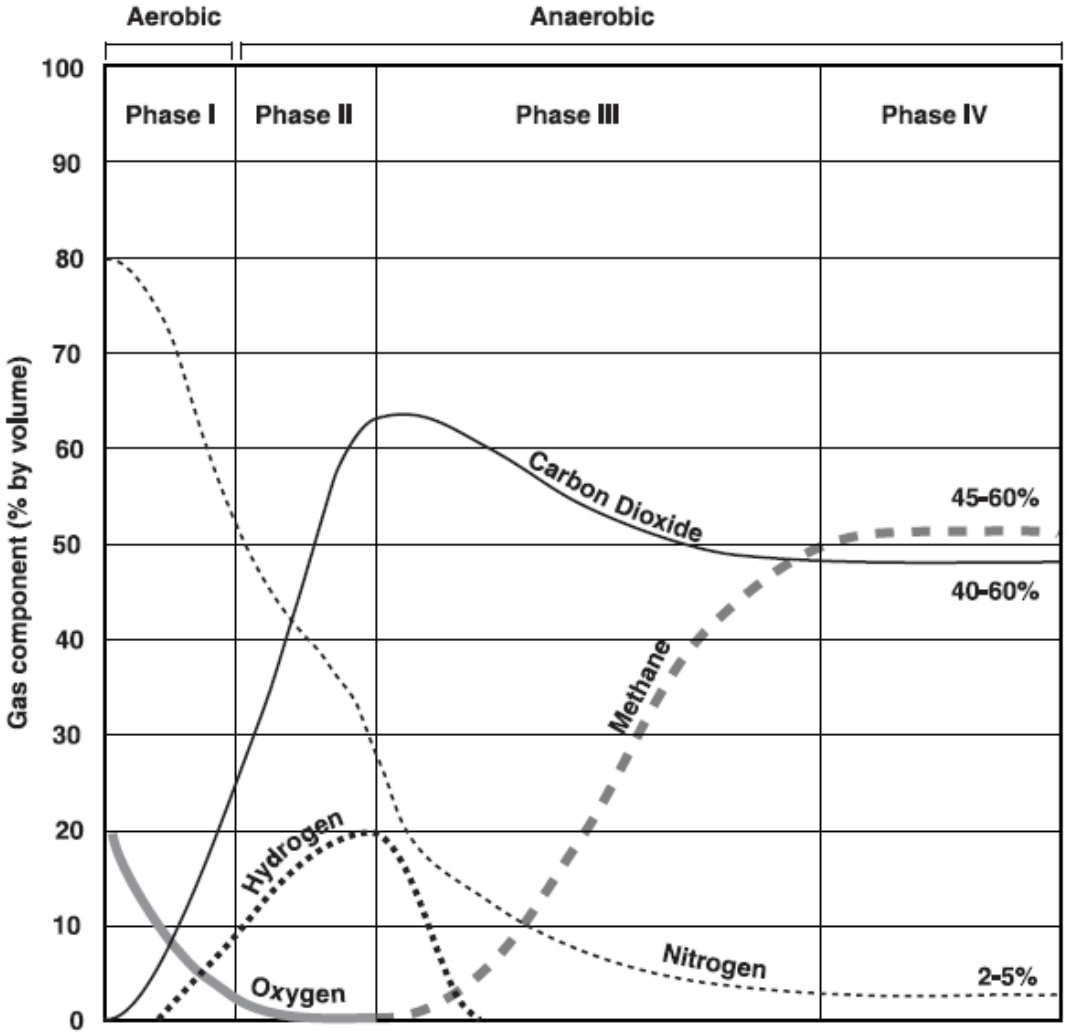
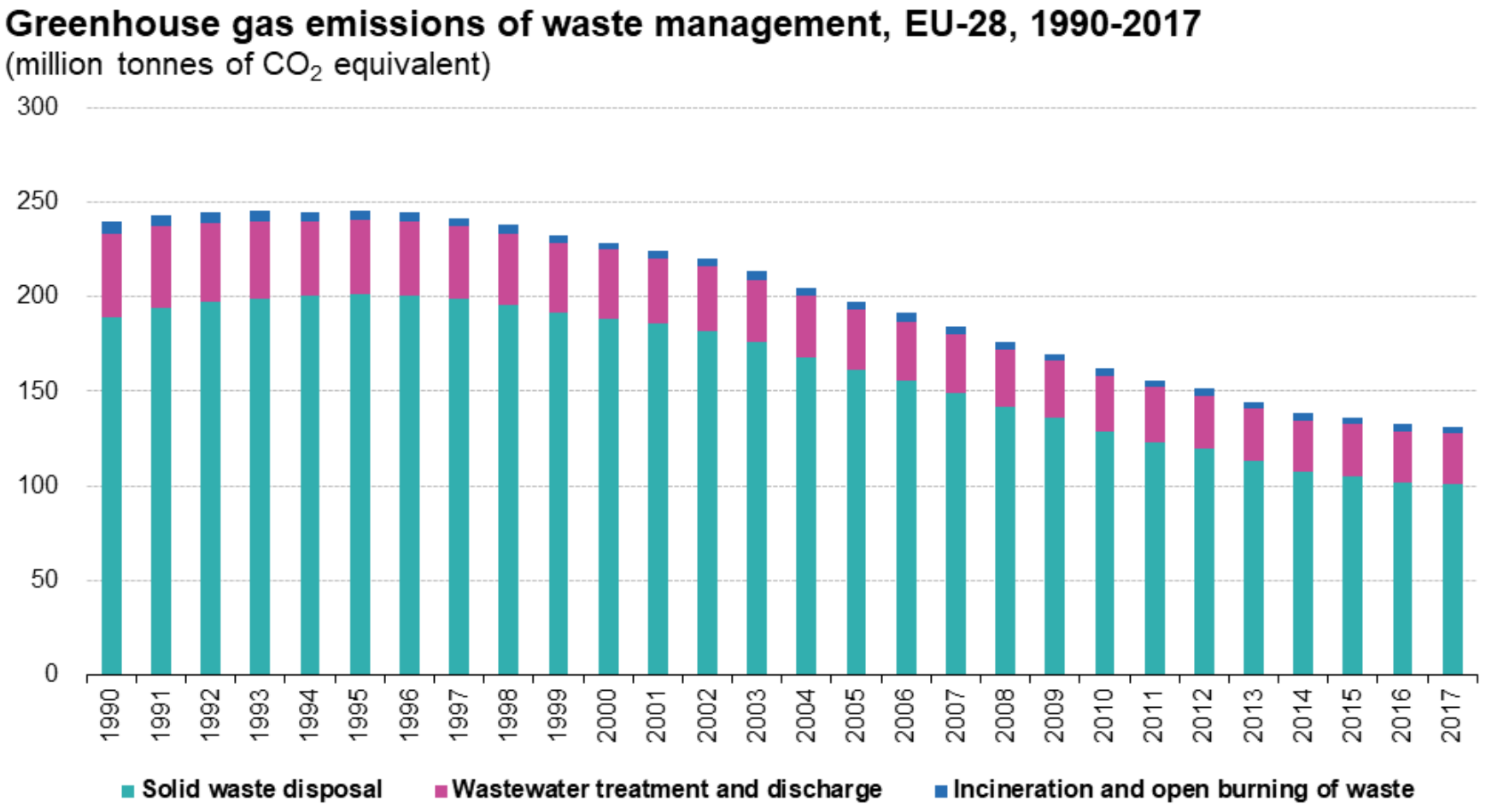
Landfill gas formation



- ✓ 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 anearobic 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

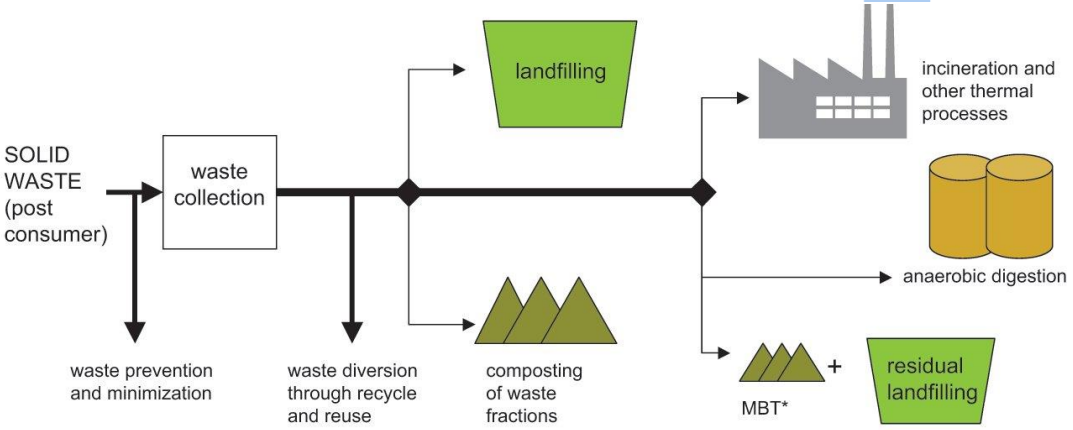


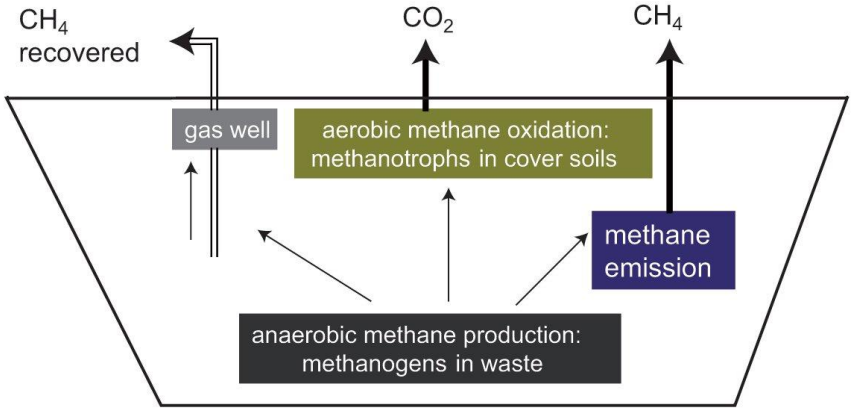
Source: Data based on Eurostat 2020

Mitigating CH_4 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

Methane (CH_4) produced (mass/time) = Σ(CH_4 recovered + CH_4 emitted + CH_4 oxidized)

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

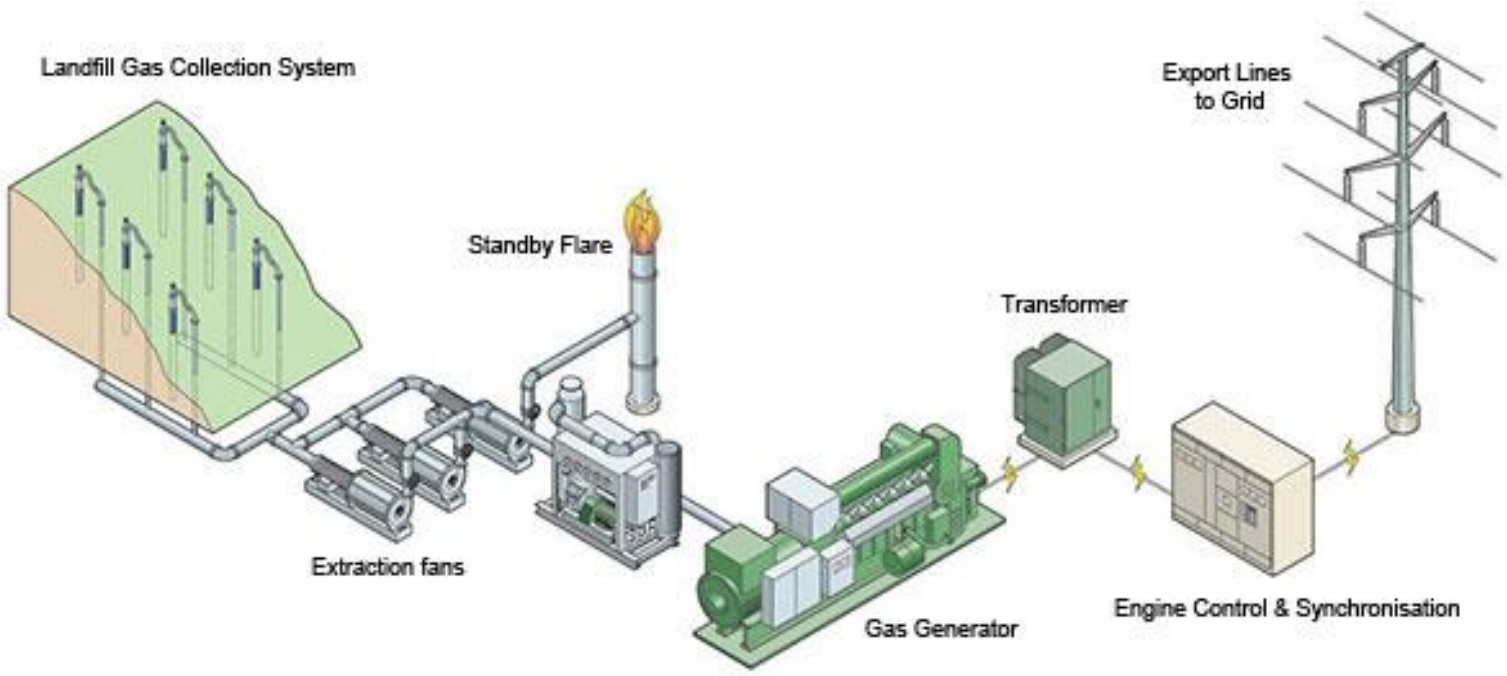
Techno-economic aspects of different mitigation measures

		Biocover	In-situ aeration	Flaring	CH_4 capture for power generation	CH_4 capture for heat generation
Oxidation factor (fraction)	min / max	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)		8.5 / 21	4.2 / 11	6.4 / 43	4.2 / 43	4.2 / 43
CO_2eq emission intensity of MSW (tCO_2eq / 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_2eq)		99 / 100	99 / 130	5 / 58	37 / 66	– 70 / 89

Emission reduction costs are very site specific, CH_4 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

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 CO_2 and yield CH_4.
- ✓ 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

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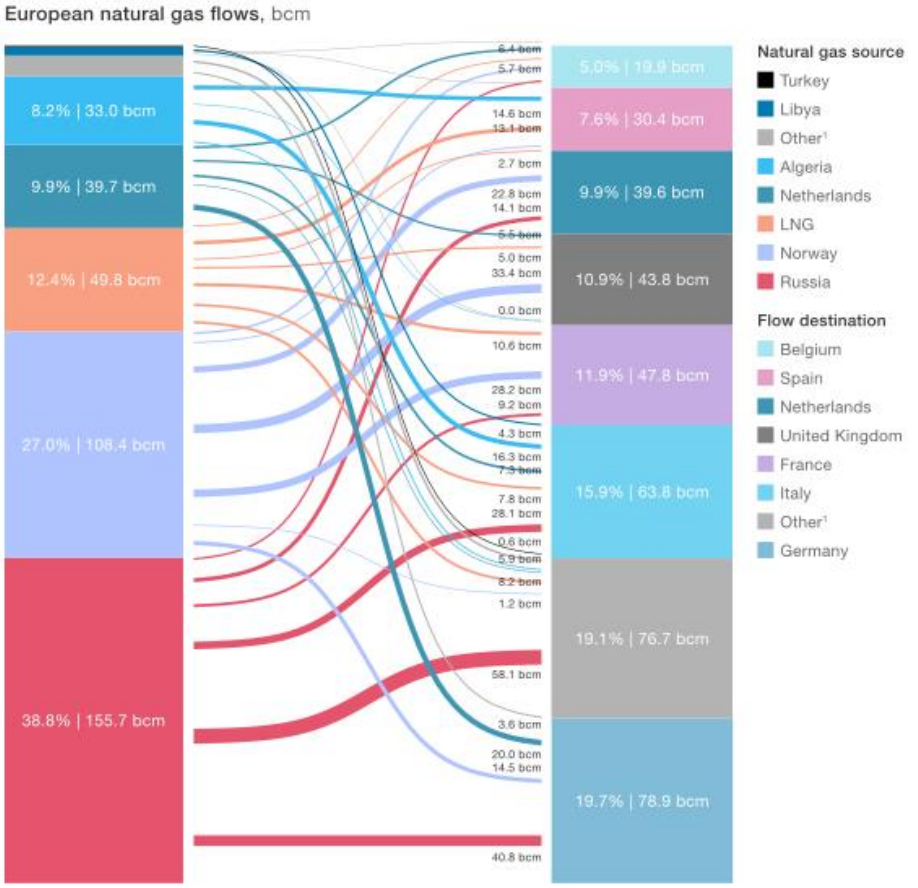
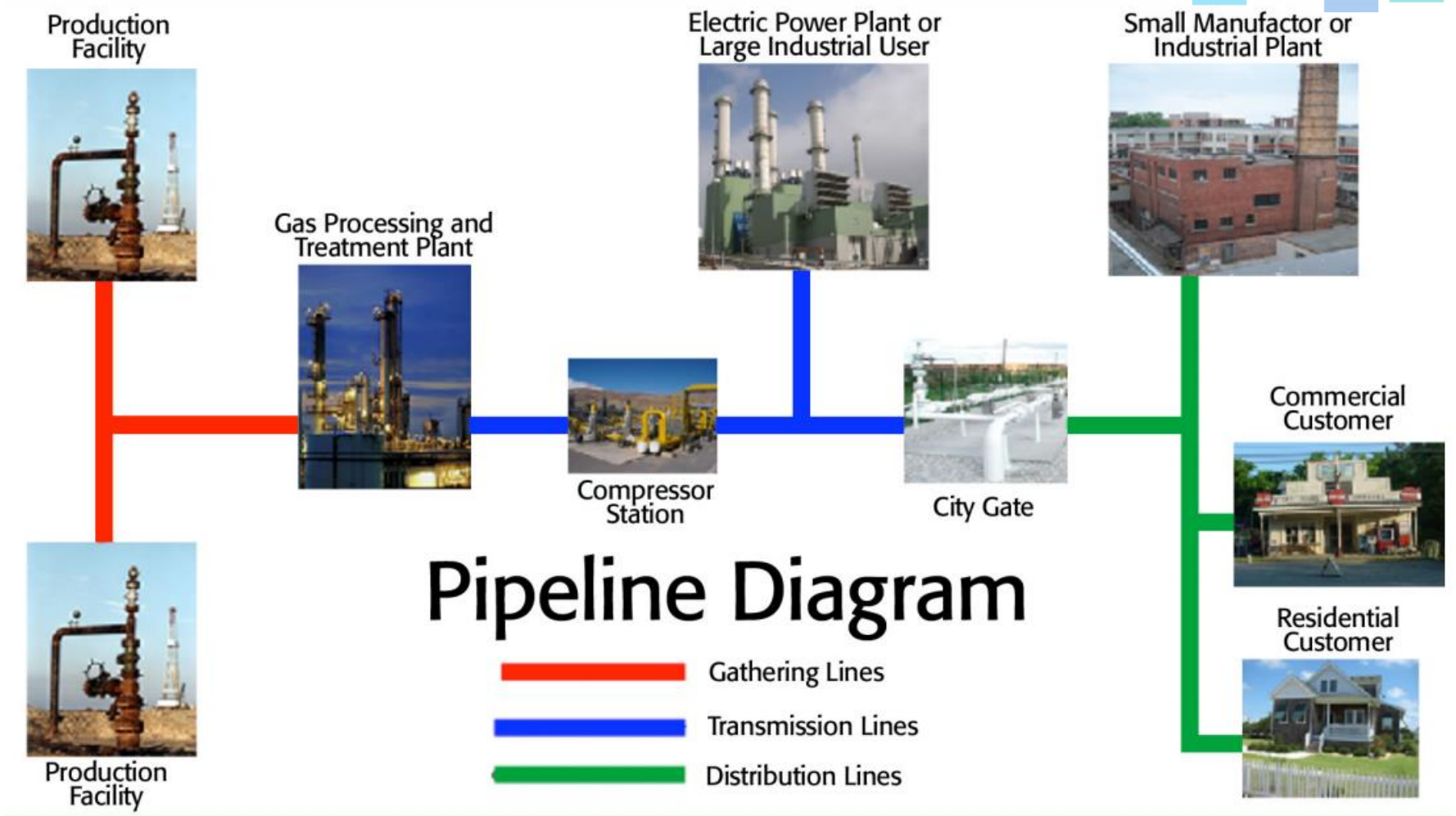
Natural gas grid in Europe



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

Key components of a natural gas grid

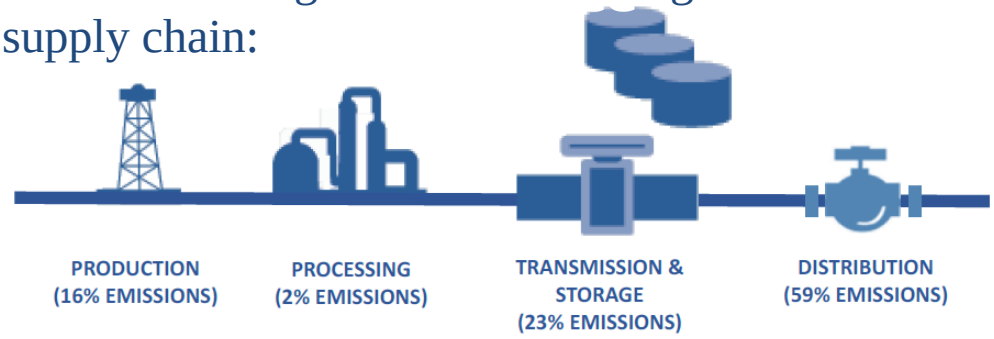


The gas pipeline transportation system from production to consumption

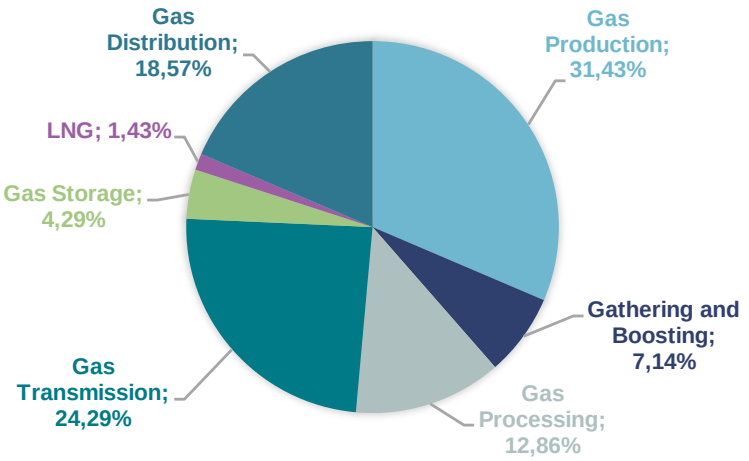
Source: Pipeline Safety Trust (2015): Pipeline Basics & Specifics About Natural Gas Pipelines

Emissions along the natural gas supply chain

Emissions along the EU28 natural gas supply chain:



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

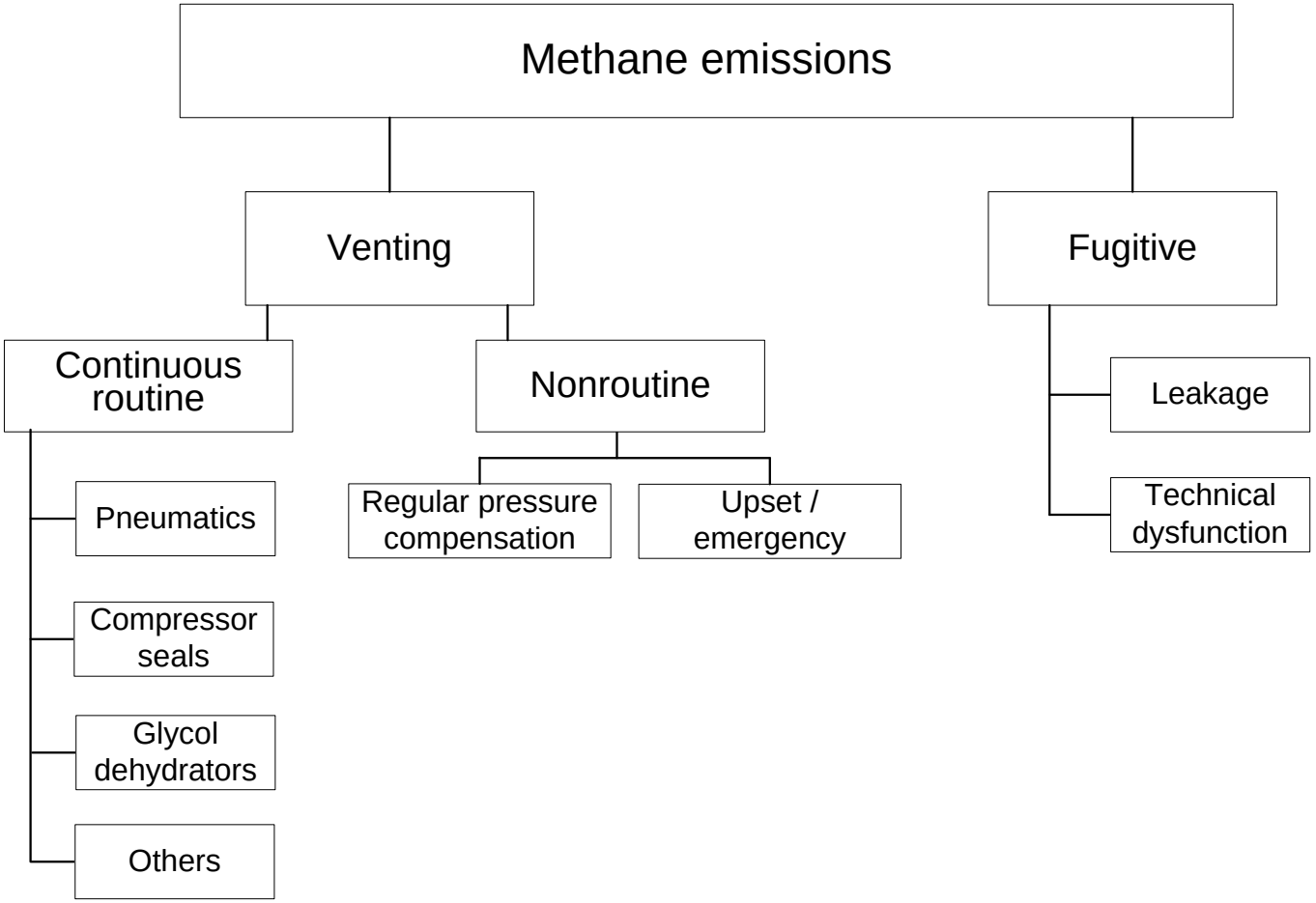


Distribution of emissions along the supply chain by country (kt/a). The rate refers to emissions as percentage of a country's production or consumption of natural gas :

	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%

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

Characterization of methane emission from the natural gas supply system

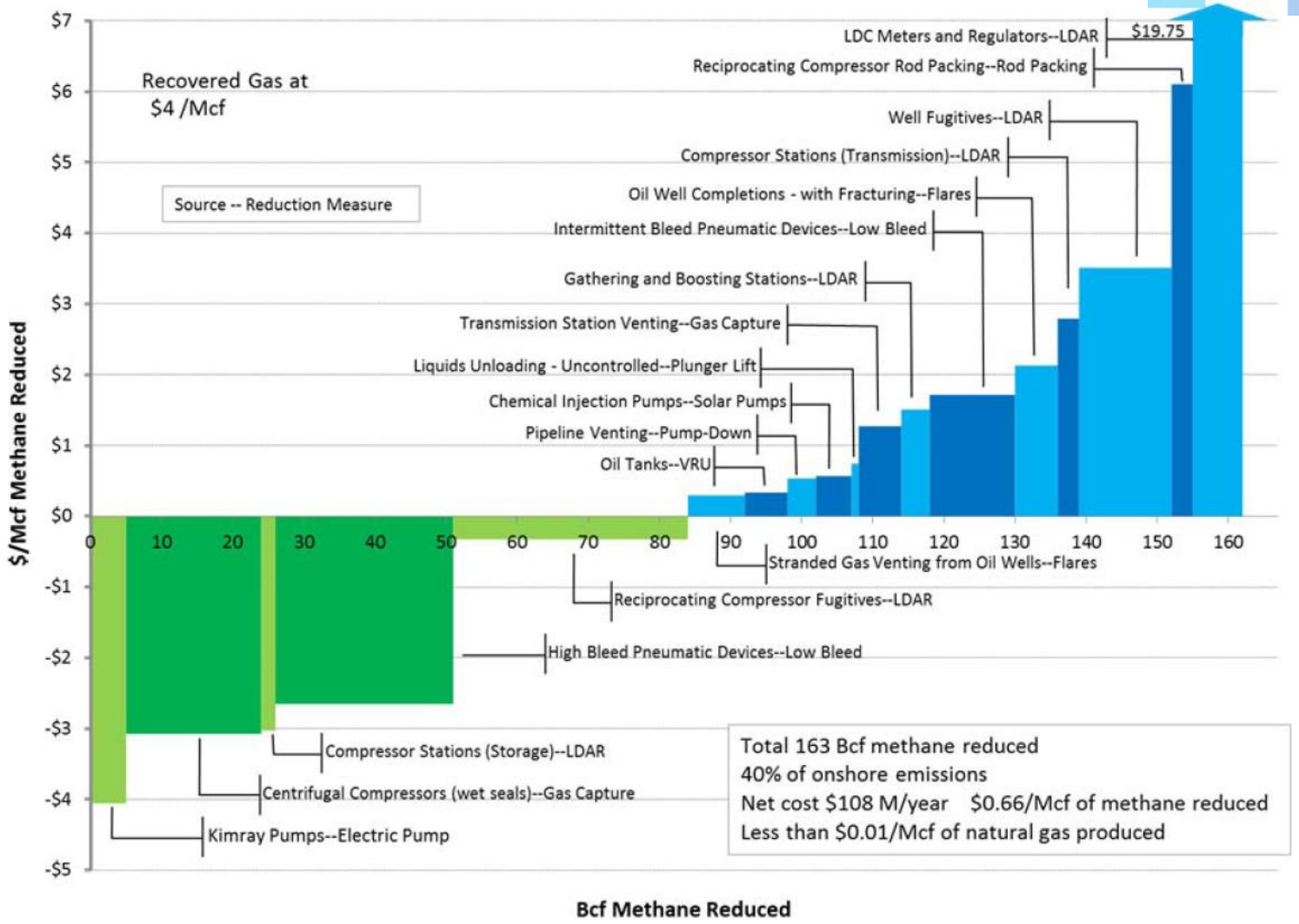


Source: Directive 60 of the Alberta Energy Regulator (AER 2018)

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



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

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Conclusions

Methane emissions are gaining increasing attention

- ✓ Methane is an important GHG (80 times higher GWP compared to CO_2 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 (2020):

  - ✓ 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**

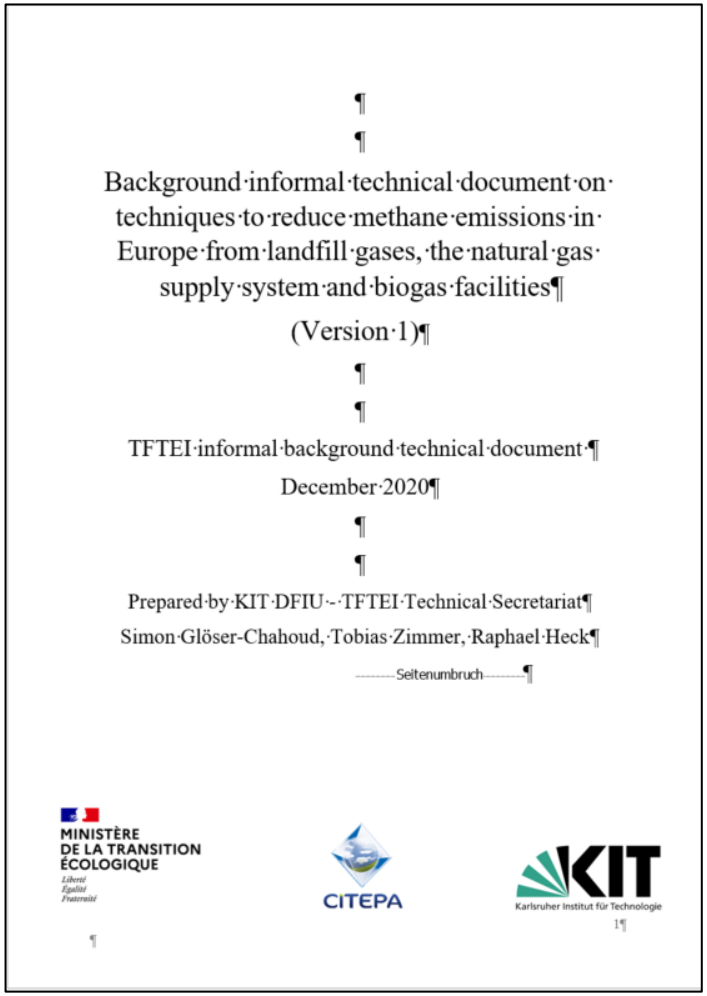
- ✓ Methane emissions from natural gas network show high diversity (fugitive emissions, emissions from devices, venting)
- ✓ Reduction measures include technical (improvement / replacement of specific devices) and organizational components (maintenance / leak detection)
- ✓ The entire processing chain of natural gas needs to be taken into account when regarding measures for reduction (production, compression, transmission, distribution)

Technical background document

- **Informal technical document about methane emission prepared in 2020**
  - **A document about emissions from landfills and the natural gas supply system in Europe has been prepared by TFTEI Technical Secretariat in 2020**
  - **The background document was made available to the parties' experts at the WGSR_58 meeting in December 2020**
  - **Further work on methane emissions is planned in the coming years**

- **Please contact me in case you are interested in the TFTEI background document:**

simon.gloeser-chahoud@kit.edu



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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

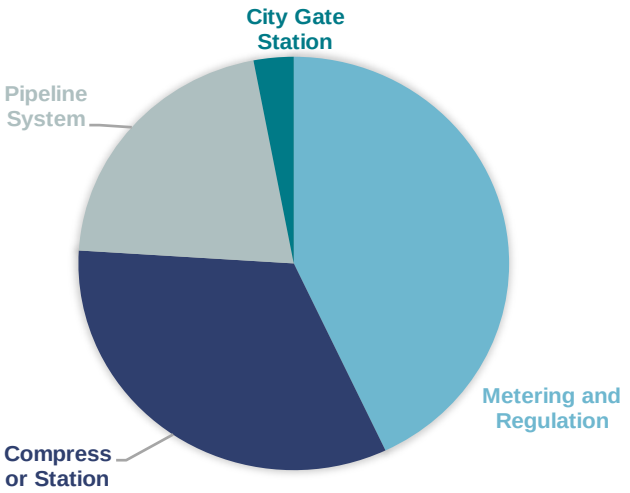
Table 2-1: Typical Landfill Gas Components

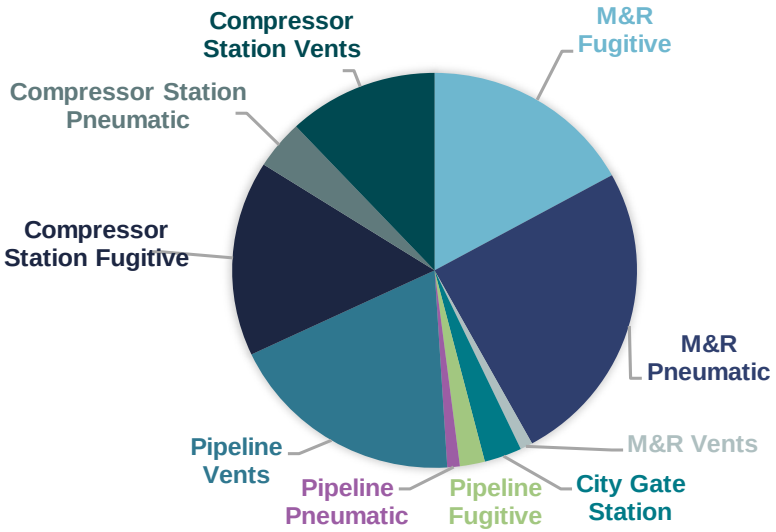
Component	Percent by Volume	Characteristics
methane	45–60	Methane is a naturally occurring gas. It is colorless and odorless. Landfills are the single largest source of U.S. man-made methane emissions.
carbon dioxide	40–60	Carbon dioxide is naturally found at small concentrations in the atmosphere (0.03%). 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

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)