MITIGATING BIOMETHANE LOSSES IN EUROPEAN BIOGAS PLANTS: A TECHNO-ECONOMIC ASSESSMENT

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DBFZ/IEA T37 event
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European legislative framework

- The **European Green Deal** set the path in 2019 to a green transition, towards climate neutrality by 2050.
- EC released in 2021 the **'fit for 55'** package, updating the EU target for GHG emissions reduction at 55% by 2030
- **REPowerEU** set in 2022 more ambitious RES target and **35 bcm biomethane** by 2030 (not binding)
- The proposed revision of the Renewable Energy Directive 2018/2001 (**RED III**) set a target **of 42.5% RES** by 2030:
  - for transports **14.5% GHG intensity reduction** (compared to the FFC baseline) or binding 29% RES (**biomethane injected into national grid is included**);
  - sub-target of 5.5% for **advanced biofuels/biogas for transport** & **renewable fuels of non-biological origin** (minimum requirement of 1% **RFNBO)** (with a 2x multiplier);
  - Revised sustainability requirements for bioenergy and biogas (plants capacity), strengthened requirements for biomass supply.
  - GHG reduction thresholds as in RED II: **50-65% for biofuels**, depending on date of facility construction, **70% for RFNBOs & RCFs**.

Sustainability criteria

What's the minimum size to avoid GHG emissions calculation? **Mid-size plant**

From RED III:

Biomass fuels shall fulfil the sustainability and greenhouse gas emissions saving criteria depending on their size. In the case of installations producing gaseous biomass fuels with the following average biomethane flow rate:

- (i) **above 200 m^3 methane equivalent per hour** measured at standard conditions of temperature and pressure, namely 0 °C and 1 bar atmospheric pressure;
- (ii) if biogas is composed of a mixture of methane and non-combustible other gas, for the methane flow rate, the threshold set out in point (i), recalculated proportionally to the volumetric share of methane in the mixture.

Member States may apply the sustainability and greenhouse gas emissions saving criteria to installations with **lower total rated thermal input or biomethane flow rate.**

RED II: GHG accounting methodology

- **GHG emissions calculation** are available in the **Annex V & VI (part C) in RED II** (developed by JRC).
- The calculation model considers also **savings and credits** generated by some cultivation practices and/or initial feedstock (e.g. use of manure)
- Operators can use **default values** listed in Annex V and VI (only if Land Use change emissions = 0) to simplify calculation... or declare their **actual values**
- **Default values** include a "safety" factor of **40% increase** in emissions from processing compared to typical values
- **Disaggregated** default values are specified:
  - cultivation (with or without N_2O); processing; transport and distribution, total emissions
  - a combination of default for some production steps + actual for others can be used

JRC' calculations are available at:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

where

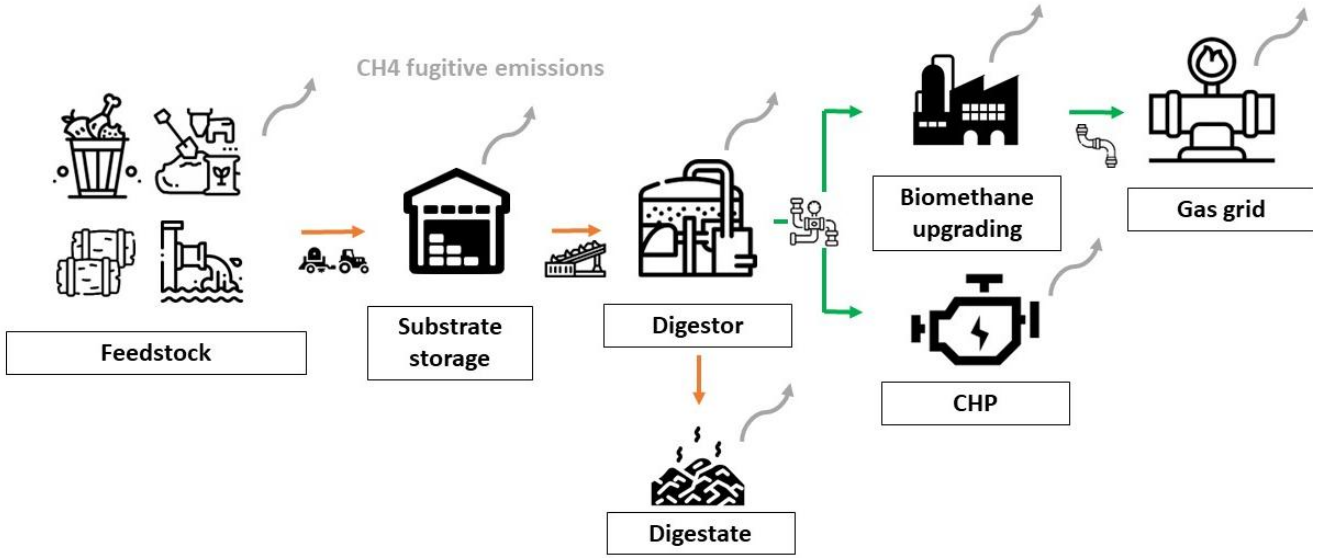
E	=	total emissions from the use of the fuel;
e_{ec}	=	emissions from the extraction or cultivation of raw materials;
e_l	=	annualised emissions from carbon stock changes caused by land-use change;
e_p	=	emissions from processing;
e_{td}	=	emissions from transport and distribution;
e_u	=	emissions from the fuel in use;
e_{sca}	=	emission savings from soil carbon accumulation via improved agricultural management;
e_{ccs}	=	emission savings from CO_2 capture and geological storage; and
e_{ccr}	=	emission savings from CO_2 capture and replacement.

Emissions from the manufacture of machinery and equipment shall not be taken into account.

- ANNEX V - http://data.europa.eu/89h/e51f4304-7023-4fca-8900-7d206f89b914
- ANNEX VI - https://data.jrc.ec.europa.eu/dataset/jrc-alf-bio-bioenergy_jrc_annexvi_com2016-767_v1_july17

Fugitive emissions in the GHG emissions calculations

- Biomethane fugitive emissions have a **high GWP**
- They can be:
  - **structural (the technologies deployed);**
  - **operational (plant management).**
- The most important sources: **open manure storage, open storage of the digestate**; the combined heat and power **(CHP) engine**; **leaks**; the Pressure Release Valve (**PRV**), etc.



Liebetrau J, Reinelt T, Agostini A, Linke B, Murphy JD, IEA Bioenergy Task 37. Methane emissions from biogas plants : methods for measurement, results and effect on greenhouse gas balance of electricity produced. 2017.

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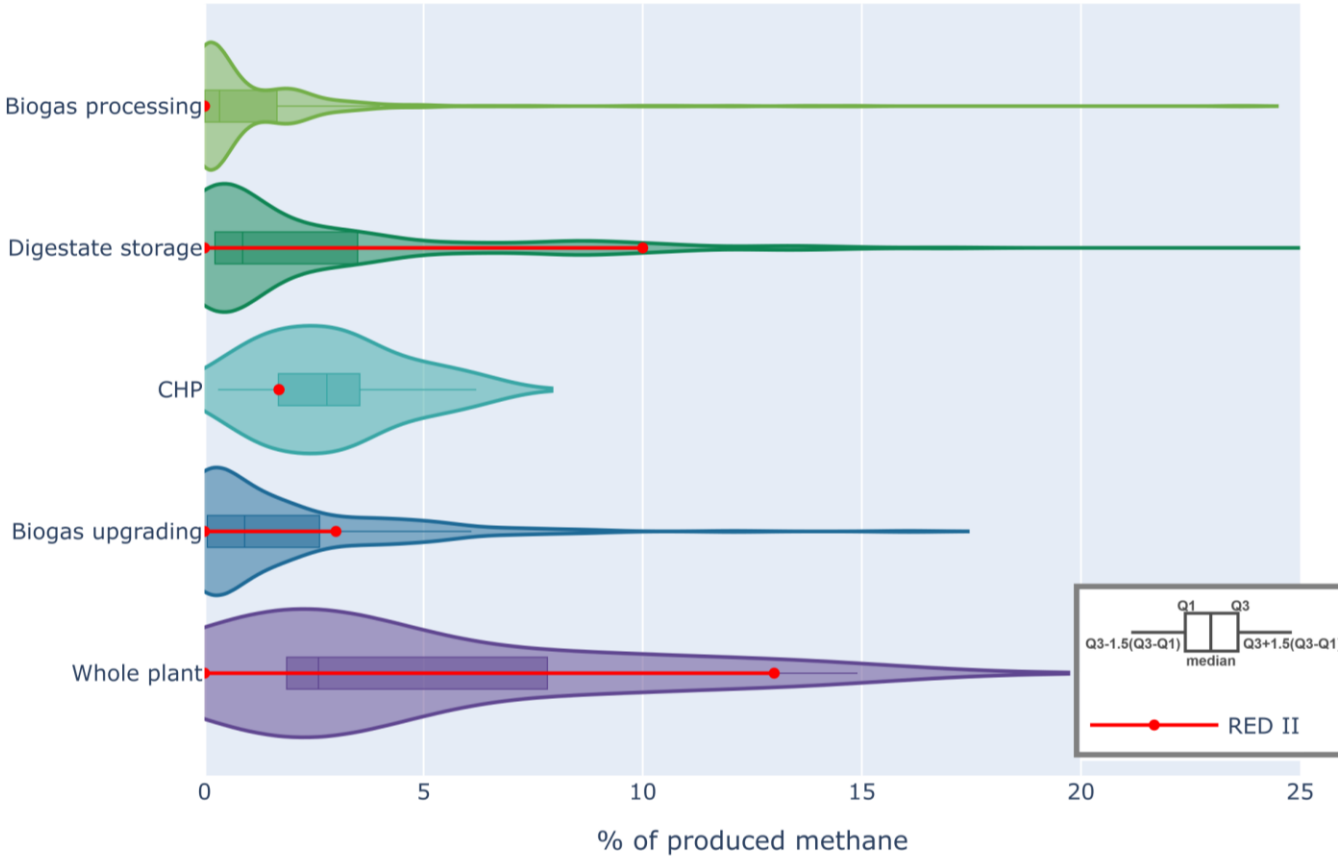
Biogas: Measured methane emissions



- Impossible to predict
- Wide range
- Some depend on technology
- Some on operation

Sources: JRC elaboration based on https://www.ineris.fr/sites/ineris.fr/files/contribution/Documents/Rapport-Ineris-20-167265-2515796_MethanEmis-version-finale-v1.pdf. https://doi.org/10.1016/j.oneear.2022.05.012. https://www.dbfz.de/index.php?id=837. https://doi.org/10.1016/j.agee.2005.08.016. https://backend.orbit.dtu.dk/ws/portalfiles/portal/137677923/153.pdf. https://doi.org/10.1533/9780857097415.2.248. http://task37.ieabioenergy.com/files/member-upload/Sax_report_Switzerland_2013.pdf. https://doi.org/10.5713/ajas.14.0683. Wechselberger, V. (2021) 'Performance of biogas plants towards methane emissions', in *European Biogas Conference*. https://doi.org/10.1016/j.wasman.2022.12.012.

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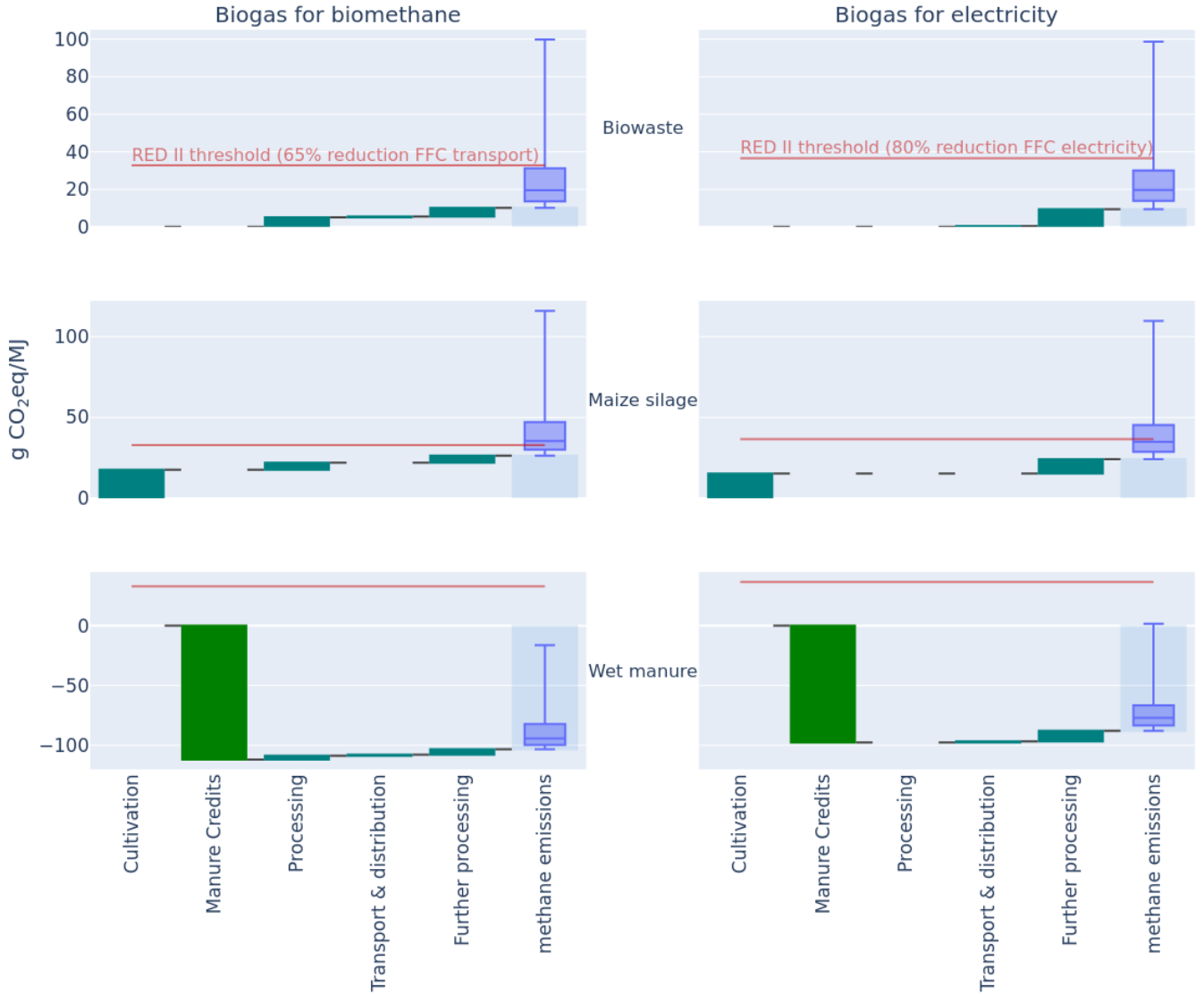
Impact of fugitive emissions into GHG calculations

- Considerable impact on biogas from maize silage and biowastes
- No impact on manure-based biogas



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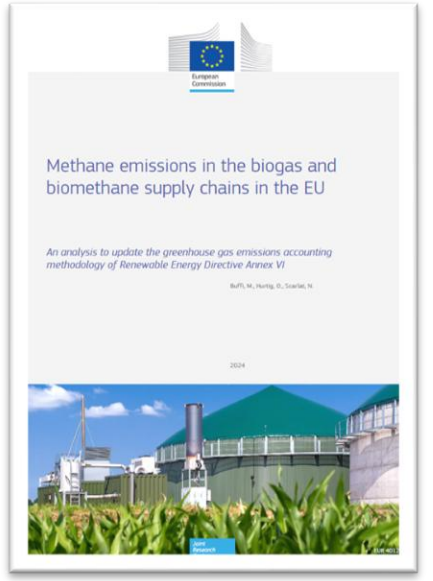
Updated emissions factors

Plant part	Type	Best practice [%]	Standard practice [%]	Emissions for standard practice [g CO_2eq/MJ]
biogas processing	piping, maintenance, overpressure events, leaks	0.5	5.0 (0.0)	24.3
digestate management	digestate composting or storage [silage]	0.1 (0.0)	2.2	11.3
	[biowastes]		2.5	13.0
	[manure]		10.0	53.5
	storage with RMP measurement below the proposed default emission factor for (open) digestate storage	X = RMP * 0.25	X= RMP * 0.75	(X - 0.1) * 5.4
Biogas upgrading to biomethane	Any technology	0.0	3.0	16.2
	Technologies certified or measured to have < 0.2% of produced methane in the off-gas	0.2		15.1
	Technologies certified or measured to have < 1% of produced methane in the off-gas	1.0		10.8
Biogas use in CHP	Slippage of methane in the exhaust gas	1.7		



Colours: Same as in current RED II

Newly proposed value in this study

(Current RED II value)

*** AR6 refers to the IPCC Assessment reports and the respective GWP values for biogenic methane of 27 g CO_2eq/g CH_4**

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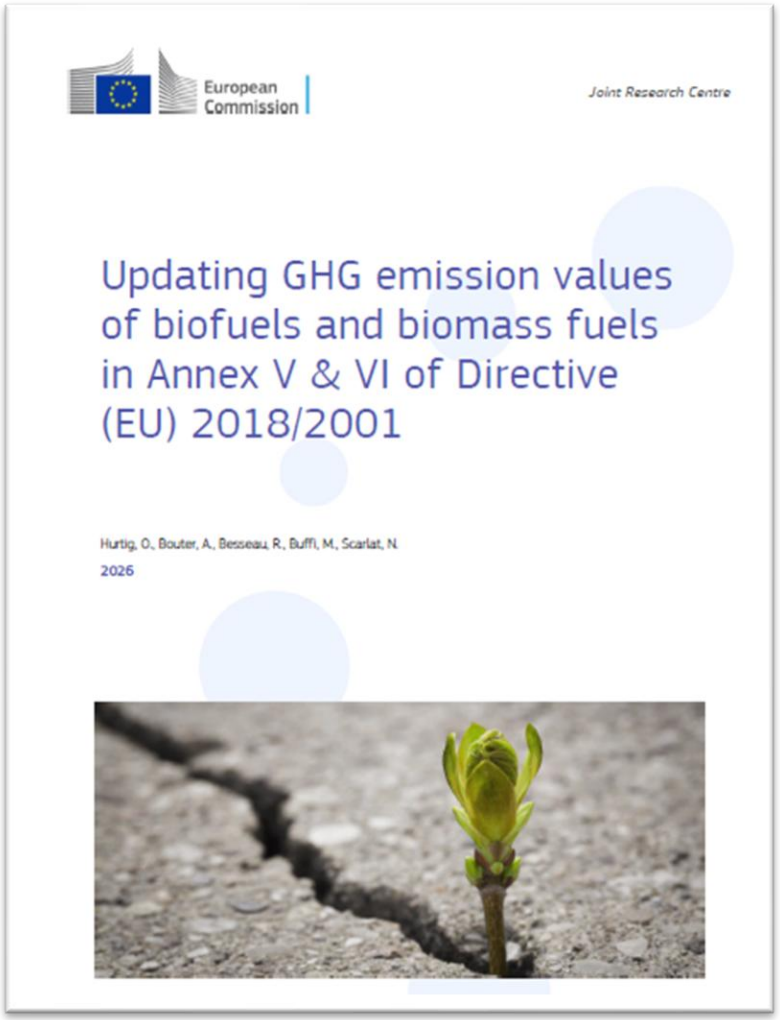
Towards updating RED Annex VI

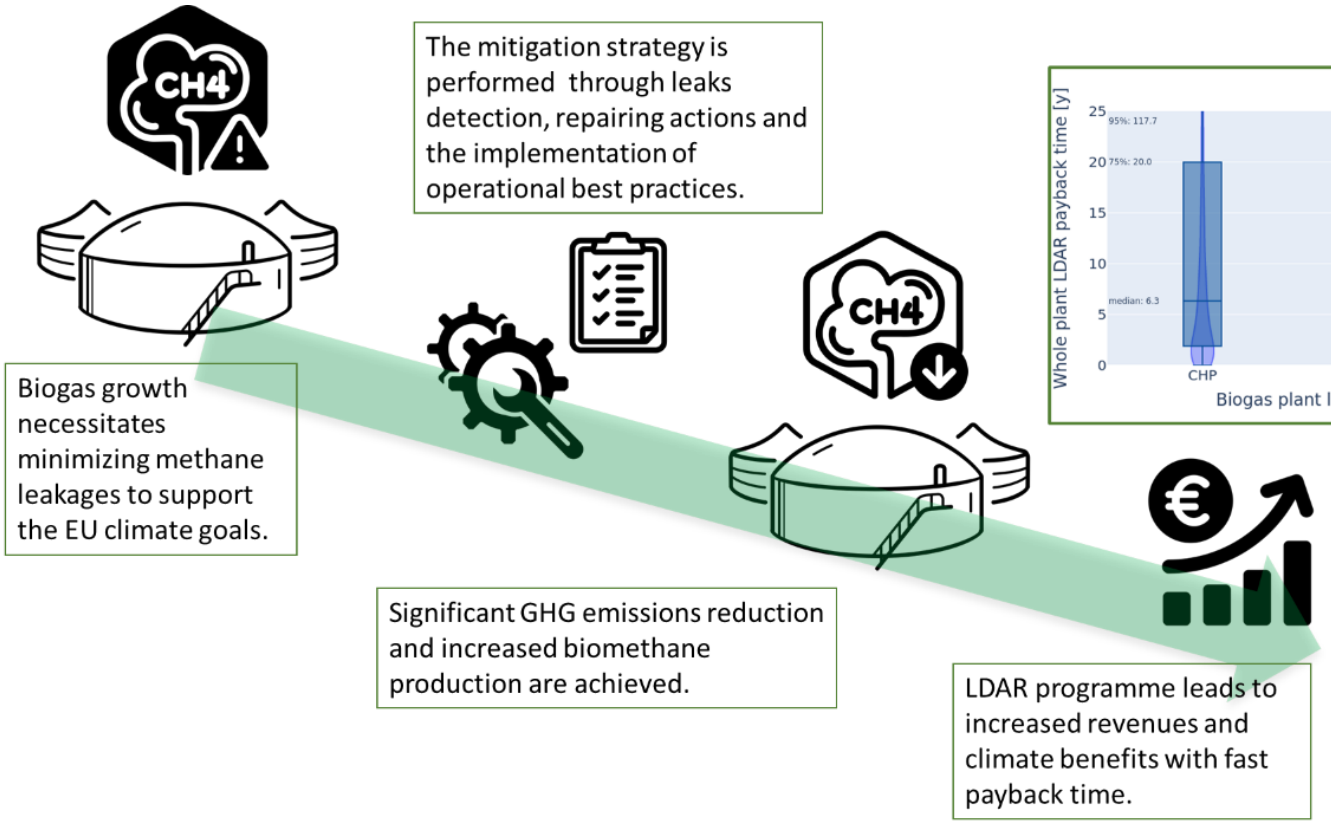


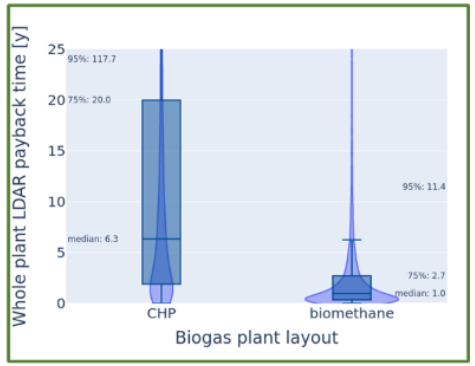
The methodology for assessing biomethane fugitive emissions is now integrated into the RED Annex VI update

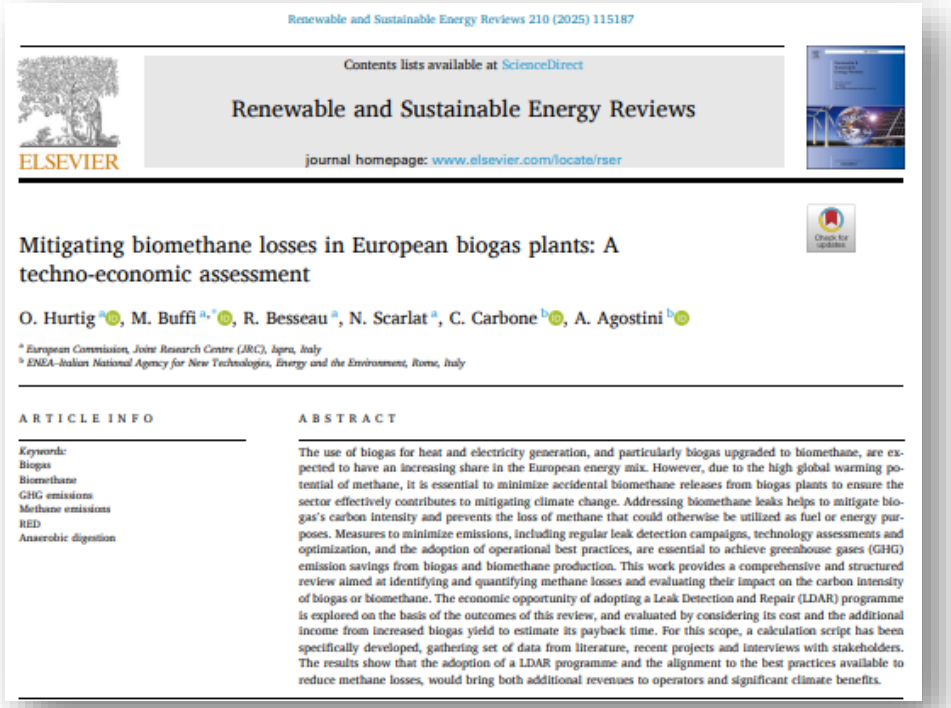
Biogas and biomethane		Typical values (g CO_2eq / MJ final fuel)				
		Emissions saved from raw manure management	Cultivation	Processing	Transport & distribution	Total
Biomethane, all standard practices						
OWCG1	Biomethane from biowastes	0.0	0.0	62.4	2.3	64.7
OWCG2	Biomethane from manure	-117.4	0.0	102.1	2.7	-12.6
OWCG3	Biomethane from sewage sludge	0.0	0.0	76.4	1.9	78.3
FMCG1	Biomethane from crop silage	0.0	19.8	60.6	2.3	82.7
WFCG2	Biomethane from gasification of farmed wood and methanation, 1 to 500 km)	0.0	0.0	10.5	10.7	21.2
WWCG2	Biomethane from gasification of forest residues & methanation, 500 km to 2500 km	0.0	5.3	10.5	6.3	22.1
Biomethane, all best practices						
OWCG1	Biomethane from biowastes		0.0	8.9	2.3	11.2
OWCG2	Biomethane from manure	-117.4	0.0	8.1	2.7	-106.6
OWCG3	Biomethane from sewage sludge		0.0	22.9	1.9	24.8
FMCG1	Biomethane from crop silage		19.8	8.8	2.3	30.9
WFCG2	Biomethane from gasification of farmed wood and methanation, 1 to 500 km)		0.0	10.5	10.7	21.2
WWCG2	Biomethane from gasification of forest residues & methanation, 500 km to 2500 km		5.3	10.5	6.3	22.1
Biogas for heat and power, all standard practices						
OWHP1	Biogas for electricity and heat from biowastes	0.0	0.0	50.1	0.3	50.4
OWHP2	Biogas for electricity and heat from manure	-102.2	0.0	90.6	0.7	-10.9
OWHP3	Biogas for electricity and heat from sewage sludge	0.0	0.0	50.0	0.0	50.0
FMHP1	Biogas for electricity and heat from crop silage	0.0	17.1	48.4	0.4	65.9
Biogas for heat and power, all best practices						
OWHP1	Biogas for electricity and heat from biowastes		0.0	12.8	0.3	13.1
OWHP2	Biogas for electricity and heat from manure	-102.2	0.0	12.8	0.7	-88.7
OWHP3	Biogas for electricity and heat from sewage sludge		0.0	12.7	0.0	12.7
FMHP1	Biogas for electricity and heat from crop silage		17.1	12.8	0.4	30.3

Source: JRC analysis

Less bio-CH_4 leaks, more money!







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Mitigating biomethane losses in European biogas plants: A techno-economic assessment

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ABSTRACT

The use of biogas for heat and electricity generation, and particularly biogas upgraded to biomethane, are expected to have an increasing share in the European energy mix. However, due to the high global warming potential of methane, it is essential to minimize accidental biomethane releases from biogas plants to ensure the sector effectively contributes to mitigating climate change. Addressing biomethane leaks helps to mitigate biogas's carbon intensity and prevents the loss of methane that could otherwise be utilized as fuel or energy purposes. Measures to minimize emissions, including regular leak detection campaigns, technology assessments and optimization, and the adoption of operational best practices, are essential to achieve greenhouse gases (GHG) emission savings from biogas and biomethane production. This work provides a comprehensive and structured review aimed at identifying and quantifying methane losses and evaluating their impact on the carbon intensity of biogas or biomethane. The economic opportunity of adopting a Leak Detection and Repair (LDAR) programme is explored on the basis of the outcomes of this review, and evaluated by considering its cost and the additional income from increased biogas yield to estimate its payback time. For this scope, a calculation script has been specifically developed, gathering set of data from literature, recent projects and interviews with stakeholders. The results show that the adoption of a LDAR programme and the alignment to the best practices available to reduce methane losses, would bring both additional revenues to operators and significant climate benefits.

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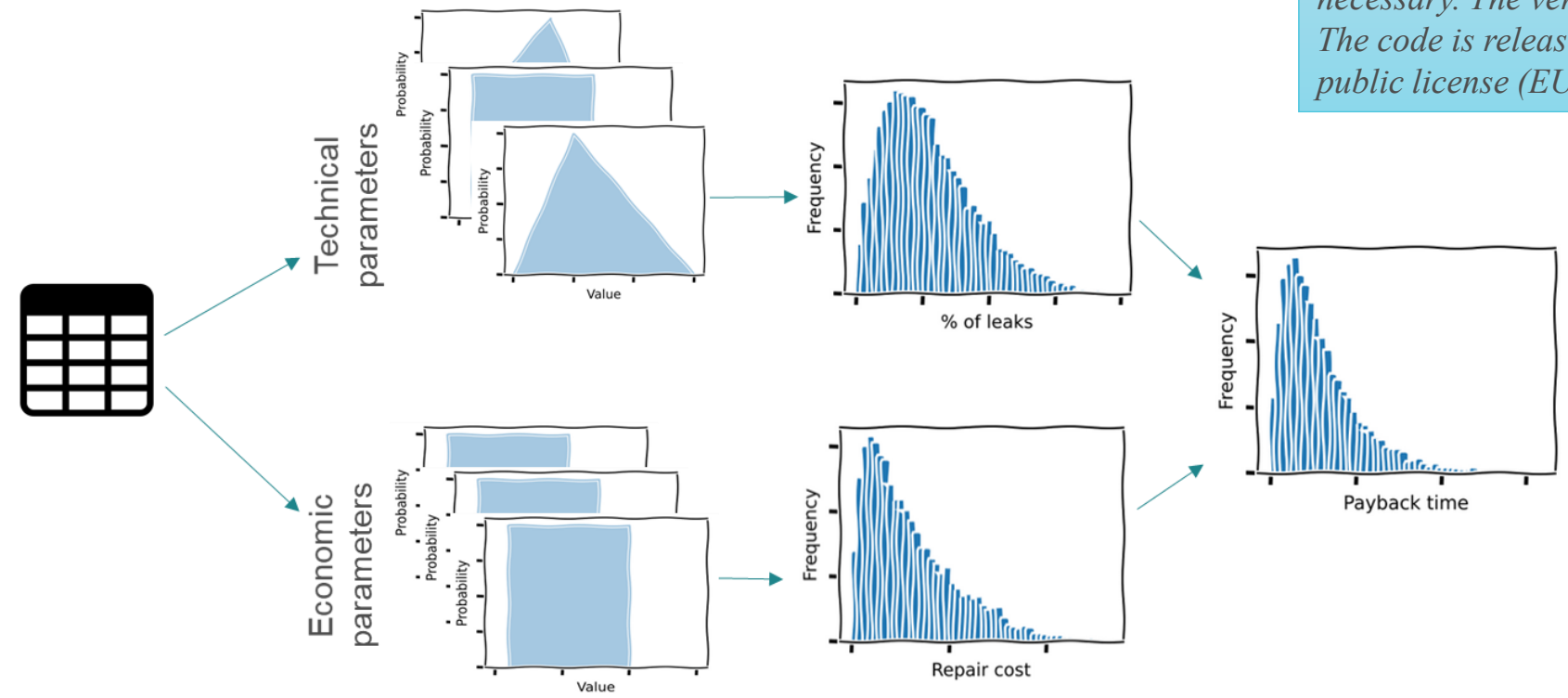
JRC calculation tool

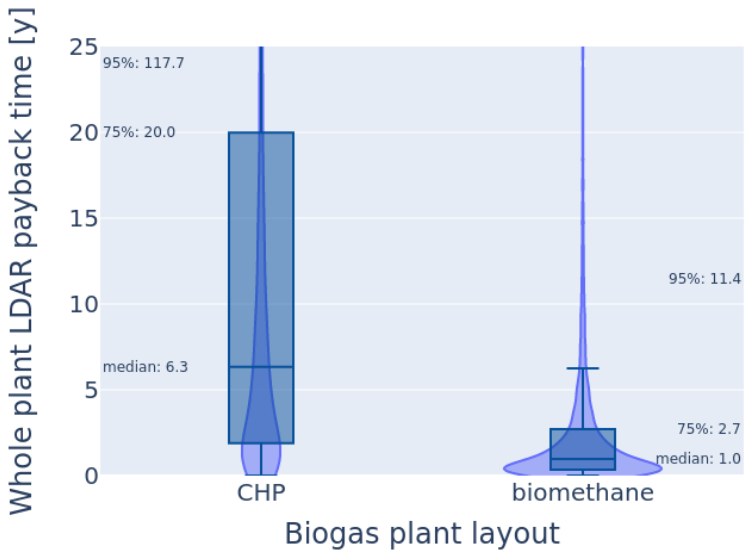
The tool consists of a Jupyter Notebook and a main input file gathering all the input data necessary. The version 3.11 of Python was used. The code is released under the European Union public license (EUPL).



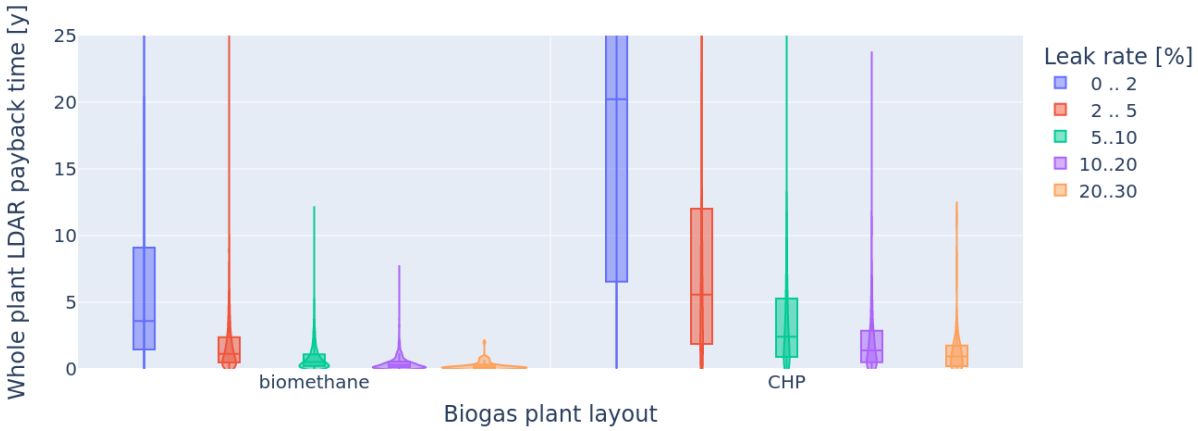
Results

- **Payback time offsets LDAR costs via electricity/biomethane revenue.**
- No discount factor applied for simplicity.
- Violin and box plots show payback time distribution.
- Median, 75%, and 95% payback times noted for CHP and biomethane plants.
- 75% of CHP plants repay in under 20.4 years; upgrading plants in under 2.7 years.
- Upgrading plants recover costs faster due to higher biomethane prices and lower repair costs.

Payback time for an LDAR programme considering detection and repair costs vs increased production revenues



Leakage rates vs payback time for LDAR programme



- **Higher leakage rates reduce payback time.**
- Median CHP payback drops from ~23 years (<2% loss) to under 1 year (20-30% loss).
- Upgrading plants' median payback drops from ~4 years to under 1 year.
- Denmark's 2.5% leak rate suggests quick LDAR repayment.
- Leak rates above 15% are rare, with few plants exceeding 20%.

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Recommendations

- **Biomethane sustainability** must be ensured with the **RED II calculation methodology,** where uncontrolled biomethane emissions could threaten the sustainability of the biogas sector
- Developing and demonstrating **LDAR programmes** within **biogas plants**, helps to reduce biomethane fugitive emissions
- **Significant variability** in emissions found, with most plants losing between 0.5% and 6% of produced methane (mean close to 5%).
- Methane loss rates vary by technology, with newer technologies being more efficient. **Regular maintenance and LDAR** can minimize emissions effectively.
- Majority of methane emission repairs can be financially justified within **10 years** through **increased biomethane recovery** alone, not counting GHG emission avoidance value.
- Cost for leak detection is **relatively low**, making regular checks and targeted repairs feasible. Statistical approach used in the study is best for estimating cost-effectiveness of LDAR due to varied data on leakages and repair costs.

Thank you!

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