

BIOMETHANE

Setting a target that is fit for food and the climate

An analysis of biomethane feedstocks to help fast forward sustainable energy and food system transition



AT A GLANCE

- Biomethane is a type of gas produced by anaerobic digestion (AD). The process of AD works by breaking down organic 'feedstocks', such as maize, food waste and manure, using micro-organisms in the absence of air, producing biogas. Biogas can then be purified to biomethane which can directly substitute fossil gas.
- In 2021, the EU produced 3.5 billion cubic meters (bcm) of biomethane. With RePowerEU, the European Commission proposes to increase this to 35bcm by 2030.
- The only detailed analysis of the feedstocks needed to produce 35bcm of biomethane was carried out by the gas industry. In contrast, a 2021 assessment commissioned by the EC concluded that around 24bcm of biomethane could be produced sustainably by 2030. Independent energy expert modelling has found that we can achieve climate neutrality and energy independence objectives with 20bcm.
- An interdisciplinary team of experts, including sustainable food system experts, needs to be convened to determine a sustainable biomethane target from the feedstock perspective. This report offers a detailed overview of many of the considerations and existing evidence to give such an expert team a head-start in their analysis and target setting.
- With current average methane leakage rates, biomethane emits more of the potent greenhouse gas methane into the atmosphere per unit of gas than conventional fossil gas. Untreated waste feedstocks such as sewage sludge emit methane, thus treating them via AD helps to reduce methane emissions. However, AD of energy crops or sequential crops (cover crops used as AD feedstock) intentionally creates more methane, in which case, even the smallest methane leakage rates result in additional methane emissions. Therefore, crop-fed biomethane may not always achieve emission reductions against the fossil fuel comparator, as set out in the Renewable Energy Directive. Moreover, by only including biomethane distribution whilst excluding biogas and biomethane production, the proposed EU Methane Emissions Regulation fails to prevent biogas and biomethane from being potential net contributors to climate change.
- Manure volumes in all projections ignore the broad scientific consensus and the Chief Scientific Advisors to the EC who stated that "*Reduction of excess meat consumption is amongst the most effective measures to mitigate greenhouse gas emissions, with a high potential for environment, health, food security, biodiversity and animal welfare co-benefits*".¹ While AD of significantly reduced volumes of manure can bring environmental benefits, at projected volumes manure-fed AD undermines overall climate mitigation, nitrogen waste and population health objectives. Because the livestock sector emits more methane than the energy sector, not reducing livestock production is also inconsistent with the proposed EU Methane Emissions Regulation.
- Without much clearer policies and industry commitment to prevent waste at source, at projected volumes, food waste and other waste-based feedstock targets risk creating harmful knock-on effects. To meet the 35bcm target, food waste volumes will need to remain the same as they are today, undermining ongoing efforts for food waste prevention. We could end up generating energy from food that did not need to be grown, harvested, transported, processed and packaged in the first place.
- Careful analysis by independent energy experts demonstrates that we do not need gas, be it fossil or renewable, for the heating of buildings or terrestrial transport. The small amounts of biomethane that we can produce sustainably will need to be reserved for aviation, maritime transport and other hard-to-abate sectors subject to an overall "reduce-demand-and-increase-efficiency-first" approach.

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SUMMARY FOR POLICY MAKERS



Biogas Plant • Credit: LianeM, Shutterstock

In 2021, the EU produced 3.5bcm of biomethane and 14.9bcm of biogas. A European Parliament amendment to the proposed EU Gas Regulation lays down that Member States shall ensure that by 2030 at least 35 bcm of sustainable biomethane is produced and injected into the natural gas system, with the aim of safeguarding the security of the EU's gas supply and decreasing dependence on fossil fuel gas imports.

A detailed analysis of the feedstock assumptions underlying the 35 billion cubic meter (bcm) biomethane target shows that at best it will be simply impossible to reach this target. At worst, strong policy support for the target will lock in dangerously unsustainable agricultural, land use and energy practices. We acknowledge that there is a niche role for anaerobic digestion of unavoidable organic waste streams, but the volume of biomethane produced will need to be much smaller than envisaged by the gas industry to avoid negative impacts on food security, the environment and the climate.

As evidence base for this target, the proposed EU Gas Regulation refers to a 2021 study *“Assistance to assessing options improving market conditions for biomethane and gas market rules”* by energy experts and the European Commission's Joint Research Centre (JRC). This EC

Assessment concluded that around 24 bcm (259 TWh) of biomethane could be produced sustainably by 2030. The proposed Gas Regulation relies on the assumption that the gas infrastructure and gas market development measures set out in the RepowerEU action plan will smooth the way to increase this figure to 35bcm. However, it appears that the only detailed feedstock analysis behind the 35bcm figure was carried out by the gas industry group “Gas for Climate” in its “Feasibility of RePowerEU” report. The EC's RePowerEU action plan lists a set of criteria aimed at avoiding negative impacts on food security or land use but does not detail any evidence regarding feedstock volumes which would substantiate the 35bcm goal. EU member state governments were also briefed by the biogas and oil and gas industry experts on the target at a workshop organized by the International Energy Agency^a, but as far as we were able to ascertain there were no sustainable food system or agriculture experts presenting at this event.

This report shows that from a sustainability and feasibility perspective, much less biomethane may be available than was hoped for by European policy makers. What does this mean for the EU's climate targets and ambition to reduce dependence on (imported) fossil fuels? How will we cope without the “biomethane magic bullet”? The good news is: we don't need to. Independent experts designed a

^a The agenda for the IEA workshop for EU policy makers lists speakers from IEA, EC, European Biogas Association (EBA), Nature Energy, TotalEnergies, Shell, European Renewable Gas Registry, Isinnova, Guidehouse (consultants to the gas industry), Biogasdoneright, SWEN Capital, Energinet, Enagas. https://iea.blob.core.windows.net/assets/abca6697-2903-4c5e-b122-e76a3ce1e4db/IEAWorkshop_Scalingupbiomethane_AgendaFinal.pdf

structural transition pathway away from fossil gas use by 2050 based on detailed sectoral modelling of the energy, buildings and industry sectors, as an alternative to RePowerEU. This alternative to RePowerEU is called the “*EU Gas Exit Pathway*”² and shows that Europe can structurally reduce the consumption of fossil gas by 2027 by an amount equivalent to gas imports from Russia before the war in Ukraine. **In the “*EU Gas Exit Pathway*”, biogas and biomethane consumption is expected to be around 20bcm.** Overall, the EU Gas Exit Pathway foresees lower demand for fossil gas, biomethane, hydrogen and hydrogen derivatives than other long-term scenarios projected by the European Commission. Even with this lower dependency on renewable and fossil gas, **energy import dependency in the EU Gas Exit Pathway quickly declines from 79% today to 29% in 2040.** The gas industry study³ analysed in detail in this report, and other projections prepared by gas grid operators foresee large investments into fossil gas infrastructure (for example to connect new AD plants to the grid), which would lead to significantly higher system costs and grid tariffs in future years and raises the risk of stranded assets. In contrast, the *EU Gas Exit Pathway* suggests the need to prepare for a managed downsizing of fossil gas infrastructure to contain energy-system costs and tariffs.

Similar to Feedback’s analysis, the *EU Gas Exit Pathway* research suggests that **targets in REPowerEU were set in a rush under enormous political pressure without proper impact assessment and that these should be critically reviewed.** Feedback’s analysis adds further critical elements into the mix for policy makers to urgently consider:

1. **Methane leakage:** At current rates, leakage of the extremely powerful greenhouse gas methane from the biomethane supply chain results in potentially higher emissions of methane per unit of gas than is the case for fossil gas. As opposed to certain waste streams such as sewage sludge which would emit methane if left untreated, the AD of purpose grown crops (whether grown as primary or sequential/cover crop) results in the intentional creation of more methane. If even a small amount of this additional methane leaks into the atmosphere, crop-based biomethane may not meet the fossil fuel comparator limit established in the Renewable Energy Directive. The proposed EU Methane Emissions Regulation applies to emissions from biomethane from the moment that it is injected into the gas grid, distributed as liquid natural gas (LNG) or stored underground. However, there is a dangerous gap in the proposed EU Methane Emissions Regulation because it does not apply to any methane emissions from the production of biogas and biomethane, feedstock handling or digestate handling.
2. **Spatial analysis of agricultural feedstock availability and digestate production at the local/regional level:** the gas industry has estimated potential volumes for each feedstock on an individual basis even though in practice nearly all rural AD plants combine different feedstocks to ensure year-round availability and avoid technical challenges resulting from the mono-digestion of certain feedstocks. For example, the gas industry study providing the detailed feedstock projections behind the 35bcm target, estimates that the 2050 annual biomethane potential from agricultural biomass for France is 152.4 TWh. In contrast, the French government’s Environment and Energy Management Agency (ADEME) and the French government’s Agriculture, Food and Environment Research Institute (INRAE) estimated that only 108.7TWh per year could be produced because an overuse of crop residues in certain regions would lead to excessively dry substrate mixtures unsuitable for anaerobic digestion. In other words, gas industry feedstock estimates need to be adjusted to reflect these types of discrepancies between theoretical feedstock volumes and adequate year-round availability at a local scale.
3. The shocking **disregard of the scientific consensus on the** inescapable fact that for climate *and* health reasons we **need to reduce animal farming and meat, egg and dairy consumption**, as recently underlined by the Group of Chief Scientific Advisors to the EC⁴. This disregard is extremely relevant given that one third of the biomethane target rests on manure as a feedstock. If too high a binding target is set, we may not only lock in current unsustainable livestock production volumes, but risk creating “energy pigs”, “energy cows” or “energy chickens” as their manure takes on an economic value within intensive livestock farming operations. Moreover, because the livestock sector emits more methane than the energy sector, not reducing livestock production is also inconsistent with the proposed EU Methane Emissions Regulation.
4. **Volume:** One cannot assume that feedstocks used in AD which have a positive impact when used in limited volumes, will remain environmentally beneficial when volumes increase.

Yes to these AD feedstocks	No to these AD feedstocks
Unavoidable food waste and food & drink industry wastewaters no longer fit for food or feed	AD of large volumes of food waste and waste waters procured indiscriminately.
Crop residues removed without affecting soil health and available after re-use needs have been satisfied (animal bedding, horticulture mulching, sustainable building materials, and others)	Crop residues removed without considering long-term soil health or demand from other sectors
Manure from animals kept in high welfare agro-ecological systems, in much smaller, more sustainable numbers in line with the scientific consensus (incl. Chief Scientific Advisors to the EC)	Current volumes of manure from intensive animal farming systems where unsustainably high livestock numbers make animal farming the most important food system driver of climate change by far
Biodiesel wastewaters from used cooking oil	Large volumes of wastewaters from biodiesel made from human-edible cooking oil
Roadside verge grass from once/twice yearly mowings (optimum frequency for biodiversity) that does not need long transportation to the AD plant	Large volumes of roadside verge grass from regular mowings and transported over long distances
Digestate applied carefully in the right quantities without requiring either energy intensive processing or long transportation	Excessive volumes of digestate with heavy metals and antibiotic resistant genes in intensive livestock production areas

**This table illustrates only some of the nuances around AD feedstock volumes. The report sets out many more issues and challenges related to each of the feedstock projections behind the 35bcm biomethane goal.*

We do not suggest that the descriptions of AD feedstock procurement in the right hand column are currently the norm. Rather, our research shows that it will be impossible to scale up biomethane production to 35bcm without these detrimental knock-on and lock-in effects. A further risk is that with such an unrealistically high target, it may well be impossible to phase out energy crops, despite the European Biogas Association’s assertions that this is the plan. This report also highlighted serious risks around soil health and food and feed crop yields resulting from the combined impacts of manure, sequential crop and agricultural residue feedstocks if produced in line with gas industry assumptions.

Based on these fundamental shortcomings combined with a wide range of additional feedstock-specific issues set out in this report, Feedback concludes that a 35bcm biomethane target and lack of strong legal safeguards

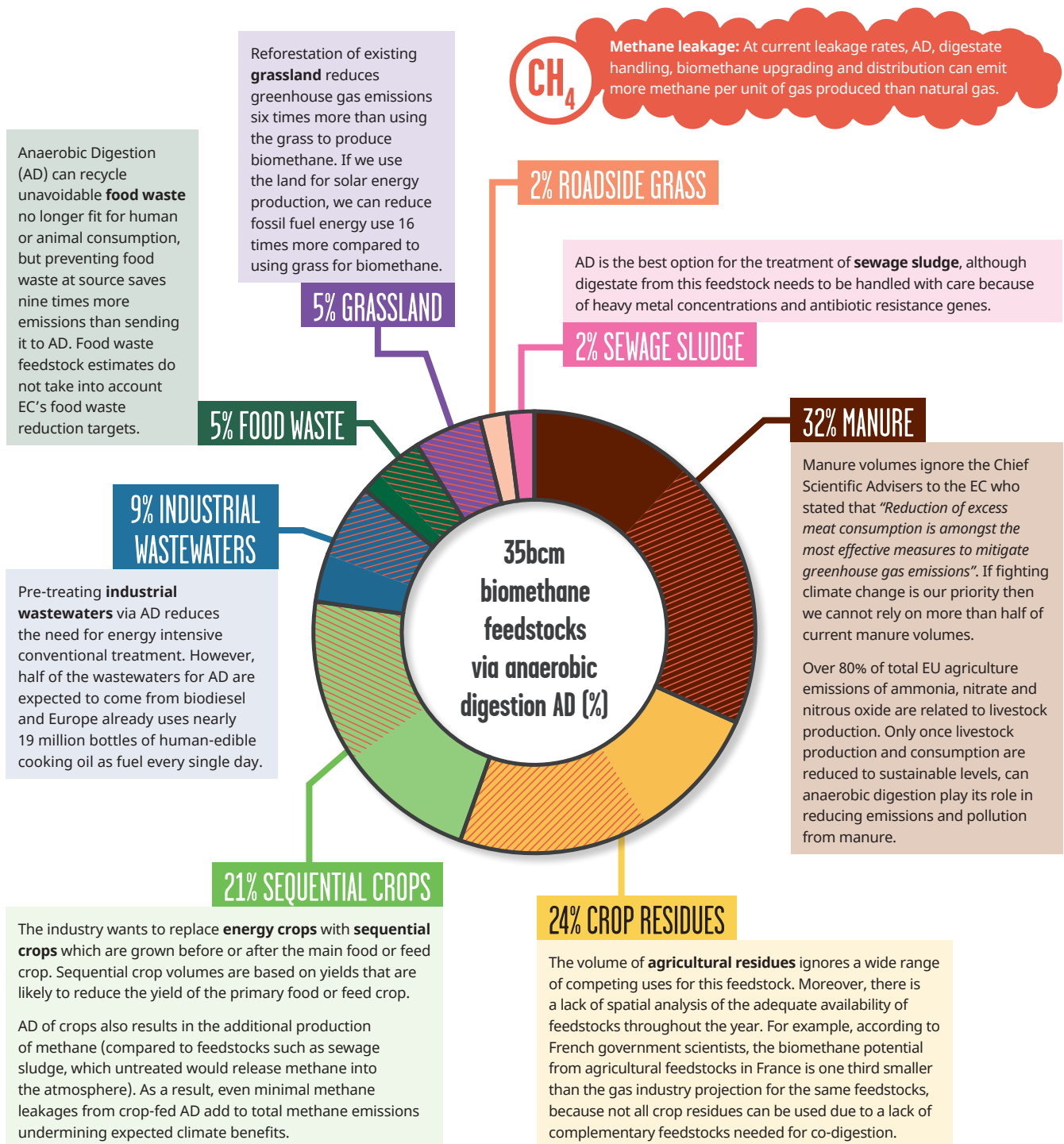
regarding unsustainable feedstocks (energy crops, energy livestock) is not only completely unrealistic, but, if made binding, will lead to a “scramble for feedstocks” causing a range of unintended knock-on and lock-in effects. If, in addition we account for the impact of methane leakage more accurately, measured over a 20-year timespan as opposed to the standard 100-years, we truly have a recipe for disaster. In contrast, a more conservative target, set in conjunction with independent sustainable food system experts – starting with the EC’s own Chief Scientific Advisers – could allow biomethane to play its role in decarbonizing some of the most energy-intensive sectors. Biomethane will be a scarce resource, usage of which will need careful prioritization starting with chemical feedstock, maritime shipping and aviation but only after applying efficiency and demand reduction measures. If we want to prevent climate disaster, piping biomethane to heat our homes or to fuel our cars will simply not be possible.

THERE ARE NOT ENOUGH SUSTAINABLE FEEDSTOCKS TO MEET THE 35BCM BIOMETHANE TARGET

Percentages show the gas industry's projected feedstock distribution for biomethane by 2030. The sections shaded with diagonal lines indicate the share of each feedstock which cannot be produced sustainably based on our analysis. It is important to note that this is a visual representation showing approximate volumes. Precise figures need to be determined in a participatory target setting process under the oversight of the Chief Scientific Advisers as described in our policy recommendations. on p.8 of this report.



Unsustainable



POLICY RECOMMENDATIONS

- 1. A decision on the 35bcm biomethane target must be put on hold until a full impact review and feasibility assessment has been carried out in conjunction with sustainable food system experts so that it can meet the RePowerEU ambition of avoiding impact on food security and unsustainable land use and compliance with REDII fossil fuel comparator limits.**
- 2. Methane leakage:** include biogas and biomethane production, feedstock and digestate handling in the proposed EU Regulation on methane emissions in the energy sector (amending EU Reg 2019/942) (which currently only covers biomethane from the point of distribution).
- 3. The impact review must consider the following aspects and make detailed recommendations in relation to the following:**
 - Explicitly **prohibit** the use of primary **energy crops**
 - Put a **moratorium on the expansion of sequential crops** until their climate and food security impacts are assessed as follows:
 - Independent agricultural and food system expert assessment to determine at which yields and in which climatic, soil and other relevant local circumstances sequential crops can be produced without directly, or indirectly, impacting the primary food or feed crop, water availability or land use.
 - Independent life cycle assessment (LCA) to establish the sequential crop yields, cultivation parameters (tractor fuel, potential fertiliser or pesticide use, etc.) and AD methane leakage rates that would ensure compliance with the fossil fuel comparator limit as established in the Renewable Energy Directive. In addition, given the extremely powerful climate impact of methane in the short-term, such an LCA should calculate Global Warming Potential over a 20-year timespan.
- **Animal farming related feedstocks:** Significantly reduce any animal farming related feedstock targets (manure, meat and dairy industry by-products and waste waters) so that biomethane feedstock demand for manure does not create perverse incentives to sustain or expand livestock numbers, and thus undermine overall climate mitigation, nitrogen waste and population health objectives. Sustainable manure volumes can be set building on the recent opinion by the Chief Scientific Advisors to the European Commission.
 - **Food, agricultural and wood residues, and industrial wastewaters:**
 - Prioritise the completion of the biomass balance sheet harmonising data on the supply and food, feed, fuel, fiber, and other demands of all biomass streams in the EU. Like the food recovery hierarchy, an interdisciplinary science-based biomass use hierarchy should be established. After prioritizing waste prevention at source, such a hierarchy should allocate available supplies according to human and animal well-being, climate, and environmental goals.
 - Ensure that demand for food waste feedstock does not undermine the EC food waste reduction targets, or the Sustainable Development Goal of 50% food waste reduction by 2030, by ensuring that food waste reduction at source is prioritized in policy and financial incentives. Ensure that incentives for biogas and biomethane do not indirectly or directly reduce food waste reduction efforts.
- 4. Once the review and impact assessment are completed, carry out a participatory and transparent target setting process under critical oversight by the Group of Chief Scientific Advisors and interdisciplinary experts from the Joint Research Centre. Data transparency** should be part of the target setting and ongoing sustainability monitoring process by making complete, fully disaggregated, and transparent data sharing compulsory for the biogas and gas industries – possibly via Eurostat – so that policy makers, scientists and civil society actors can monitor the industry’s environmental impacts, both positive and negative.

GLOSSARY

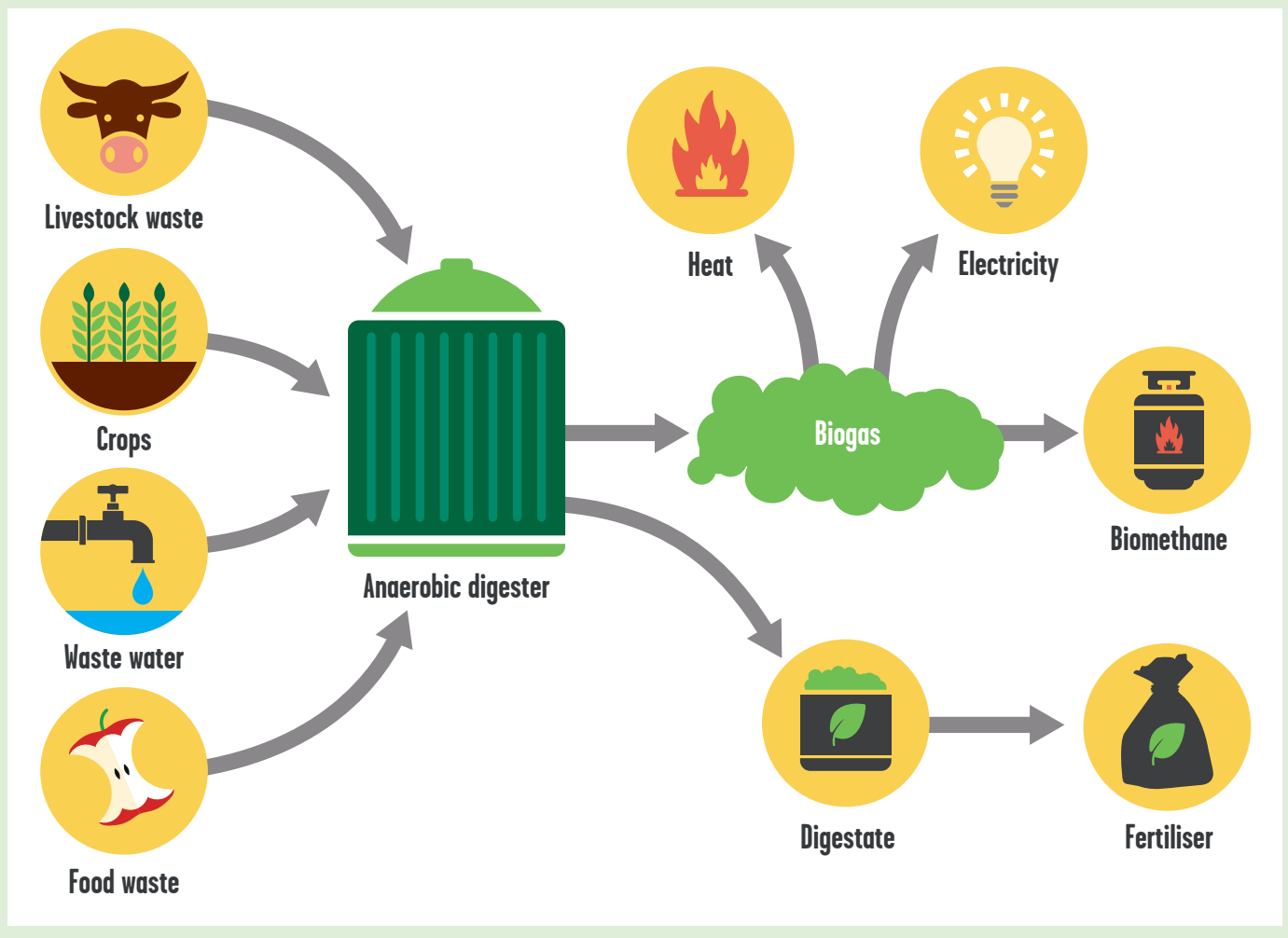
AD	Anaerobic digestion
Bcm	Billion cubic meters
EC biomethane assessment	Assessment commissioned by the European Commission (EC) and published in 2021 with the title “Assistance to Assessing Options Improving Market Conditions for Bio-Methane and Gas Market Rules”.. This assessment was carried out by three energy expert consultancies (detailed in Annex A) and the EC’s Joint Research Centre https://data.europa.eu/doi/10.2833/912333
Energy crops	Crops grown as primary crop specifically for producing bioenergy, and using arable land suitable for food and feed crop production
EU Methane Emissions Regulation	Proposed EU Regulation on methane emissions in the energy sector and amending Regulation (EU) 2019/942 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A805%3AFIN&qid=1639665806476
Gas industry study	Study published in 2022 by the Gas for Climate group which is a group of eleven leading European gas transport companies and the European, German, and Italian biogas associations. This study entitled “Biomethane Production Potentials in the EU: Feasibility of REPowerEU 2030 Targets” sets out the feedstock projections and assumptions behind the 35bcm biomethane target. https://gasforclimate2050.eu/wp-content/uploads/2022/10/Guidehouse_GfC_report_design_final_v3.pdf
JRC manure study	Estimate of potential manure feedstock volumes carried out by researchers at the EC’s Joint Research Centre and published as follows: Scarlat et al., “A Spatial Analysis of Biogas Potential from Manure in Europe,” <i>Renewable and Sustainable Energy Reviews</i> 94 (2018): 915–30
JRC crop residue study	Estimate of potential crop residue feedstock volumes carried out by researchers at the EC’s Joint Research Centre and published as follows: Scarlat et al. “Integrated and spatially explicit assessment of sustainable crop residues potential in Europe.” <i>Biomass and Bioenergy</i> 122 (2019): 257-269.
JRC nitrogen waste study	Study on the measures needed to tackle nitrogen waste and pollution, led by a researcher of the EC’s Joint Research Centre, in collaboration with various European universities and published as follows: Leip, A. et al. “Halving nitrogen waste in the European Union food systems requires both dietary shifts and farm level actions.” <i>Global Food Security</i> 35 (2022): 100648.
Sequential crops	Also referred to as multi-cropping, double cropping or growing a “harvestable cover crop” where this crop is grown before or after the harvest of the main food or feed crop.

1. INTRODUCTION

In May 2022, the European Commission launched RePowerEU, which is “about rapidly reducing our dependence on Russian fossil fuels by fast forwarding the clean transition and joining forces to achieve a more resilient energy system and a true Energy Union”.⁵ One of the ways in which the EC proposes to achieve this is by significantly increasing biomethane production from 3.5 in 2022⁶ to 35 billion cubic meters (bcm) by 2030⁷. An amendment proposed by the European Parliament to the EU Gas Regulation⁸ aims to make this a binding target.

BOX 1: WHAT ARE ANAEROBIC DIGESTION, BIOGAS AND BIOMETHANE?

Biomethane is a type of gas which is most commonly produced by anaerobic digestion (AD). AD is the process of taking organic materials, known as ‘feedstocks’, both purpose-grown, like maize and other crops, and waste streams, like food waste and manure, and breaking them down using micro-organisms in the absence of air. This produces methane-rich biogas, which can be used to generate heat or electricity, and nutrient-rich digestate, which can be used as a fertiliser. After a purification process this gas can be injected into the gas grid or used as a fuel and is therefore presented by the industry as a viable replacement for fossil gas. See section 6 for information on the different uses of biomethane.



The EU's biomethane target is to be achieved sustainably by ensuring that production is *"waste-based, avoiding the use of food and feed feedstocks that would lead to land use change problem or "hamper food security"*⁹. The RePower EU Action Plan considers the following feedstocks to be waste-based and thus sustainable:

- agricultural and agro-industry waste and residues, including crop residues and manure
- forest and forest-industry waste and residues
- food industry waste
- energy and chemical industry biogenic CO₂ effluents and waste
- industrial wastewater
- domestic organic waste
- sequential or cover crops (not waste based, but when fulfilling certain criteria, considered by the EC not to compete for land with food or feed crops). See the section on sequential crops below.

BOX 2: ARE THE SUSTAINABILITY AMBITIONS OF REPOWER EU ENSHRINED IN ENFORCEABLE LEGISLATION?

Unfortunately, despite the ambition not to use food or feed crops, or agricultural biomass grown on food or feed cropland, the proposed EU Gas Regulation¹⁰ does not appear to enshrine this ambition in enforceable legislation. At the time of writing, the proposed Gas Regulation points to the feedstock sustainability criteria set out Article 29 of Renewable Energy Directive II (REDII)¹¹, which does not exclude food or feed crops as biogas feedstock. To ban the use of crops that hamper food security, the Gas Regulation should, at a minimum, explicitly state that only feedstocks listed in Annex IX of RED II can be used. **For an excellent, more detailed analysis of the issues related to using food or feed crops as biogas feedstock, see the life cycle analysis by the International Council on Clean Transport (ICCT)¹² and the analysis by IFEU¹³.**

2. OVERVIEW: WHERE IS THE SUSTAINABLE FOOD SYSTEM PERSPECTIVE?

KEY MESSAGE

The target of 35bcm biomethane by 2030 appears to be grounded in an analysis of feedstock sources commissioned by the gas industry. In contrast, a study commissioned by the EC estimated a significantly lower sustainable potential of 24bcm (259 TWh) biomethane. It is worth noting that this study was also carried out by energy system experts, as was a separate study by the International Energy Agency (IEA). We could not find any detailed independent analysis by sustainable food system, land use, crop agriculture, or soil health experts, leaving a gaping hole in the research behind the 35bcm target.

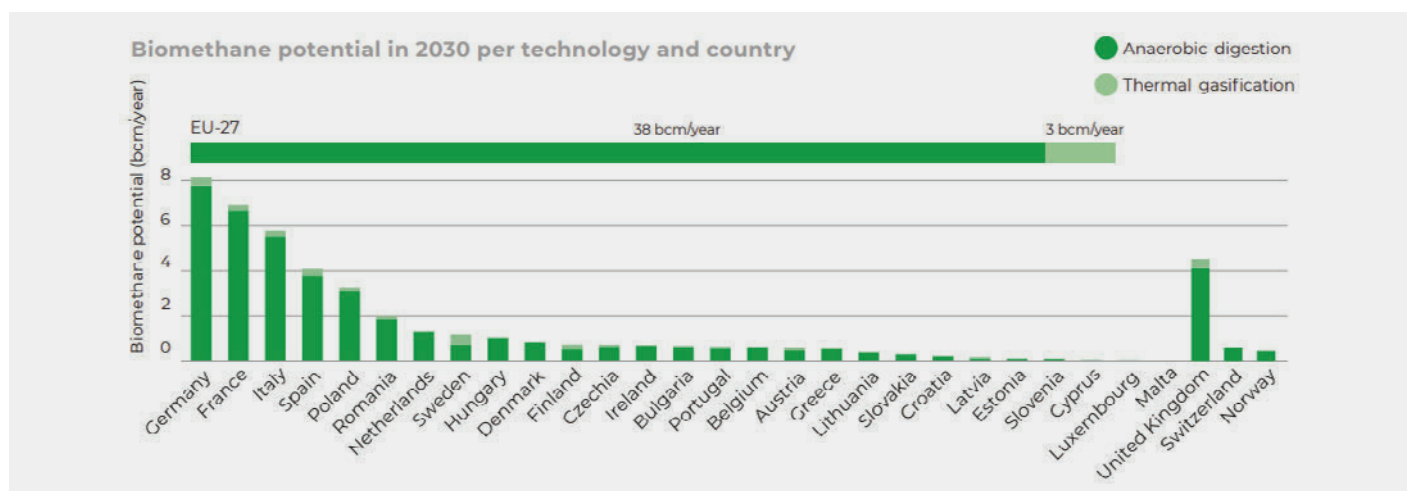
As far as we have been able to ascertain, the RePowerEU action plan does not provide any details regarding the nature, sourcing, or volume availability of biomethane feedstocks to achieve 35bcm by 2030. The proposed EU Gas Regulation refers to a 2021 study *“Assistance to assessing options improving market conditions for biomethane and gas market rules”*⁴. This study was commissioned by the EC and carried out by three energy consultancies^b and energy experts at the European Commission’s Joint Research Centre (JRC). We will henceforth refer to this study as the *“EC biomethane assessment”*. EU member state governments were also briefed by biogas and oil and gas industry experts on the target at a workshop organized by the IEA, but it appears that no sustainable food system or agriculture experts presented at this event^c. The IEA prepared a background paper *“Scaling up biomethane in the European Union”*¹⁵ based on an earlier report analysing biomass potentials for biomethane globally. The only feedstocks considered by the IEA are manure, crop residues and municipal waste; we will come back to the IEA findings below in the sections analysing these feedstocks in detail.

The most recent and detailed analysis behind the 35bcm goal is provided by the gas industry, represented at the European level by the *“Gas for Climate”* group^d. The Gas for Climate group set out their feedstock projections and policy recommendations for reaching the 35bcm via anaerobic digestion by 2030 in a report titled *“Biomethane production potentials in the EU: Feasibility of REPowerEU 2030 targets, production potentials in the Member States and outlook to 2050”*¹⁶. This study will henceforth be referred to as the *“gas industry study”*.

b See Annex A for details on the consultants and types of expertise involved

c The agenda for the IEA workshop for EU policy makers lists speakers from the following organisations or companies: IEA, EC, European Biogas Association (EBA), Nature Energy, TotalEnergies, Shell, European Renewable Gas Registry, Isinnova, Guidehouse (Author of the GfC report analysed in this briefing), Biogasdoneright, SWEN Capital, Energinet, Enagas. Moderators were from Columbia University (hydrogen and natural gas expert), German Biogas Research Centre, the Norwegian Institute for Sustainability Research (biogas expert) and the EBA. Judging by the agenda, there was not one speaker from the food or agricultural sector. The full agenda can be found here: https://iea.blob.core.windows.net/assets/abca6697-2903-4c5e-b122-e76a3ce1e4db/IEAWorkshop_Scalingupbiomethane_Agendafinal.pdf

d *“Gas for Climate”* is a group of eleven leading European gas transport companies (DESFA, Enagás, Energinet, Fluxys, Gasunie, GRTgaz, Nordion, ONTRAS, Open Grid Europe, Snam, and Teréga) and three renewable gas industry associations (Consorzio Italiano Biogas, European Biogas Association and German Biogas Association) <https://gasforclimate2050.eu/gas-for-climate/who-we-are/>.

Figure 1: 2030 biomethane potential for Europe as envisaged by the gas industry¹⁷**FURTHER RESEARCH NEEDED**

This report will only analyse the key feedstocks for biomethane from anaerobic digestion. Industry projections around feedstocks for thermal gasification, primarily different types of woody biomass to be deployed from 2030 onwards, require a separate analysis.

Table 1 shows the estimated volumes of biomethane each feedstock is expected to provide by 2030 and 2050 via anaerobic digestion (AD) and thermal gasification (TG). We assume that with the scale of increase that is proposed, the gas industry plans to fit most AD plants with biomethane upgrading technology, or replace old biogas plants with modern biomethane ones. The technical challenges related to such large-scale retrofitting or replacing have not been analysed in this report.

Table 1: Gas industry feedstock projections for biomethane via anaerobic digestion

	2020 ¹⁸	2030		2050	
	Actual feedstocks, biogas (15bcm) and biomethane (3bcm) combined	Projected feedstock distribution ¹⁹ for biomethane only in percentage and billion cubic meters (bcm)			
Manure	24%	32%	11.2	19%	17.29
Agricultural residues		24%	8.4	17%	15.47
Sequential cropping		21%	7.35	47%	42.77
Industrial wastewater	8%	9%	3.15	12%	10.92
Permanent grassland		5%	1.75	2%	1.82
Roadside verge grass		2%	0.7	1%	0.91
Sewage sludge	8%	2%	0.7	1%	0.91
Food waste (biowaste)	16%	5%	1.75	2%	1.82
Energy crops	42%	-	-	-	-
TOTAL bcm			35 ^e		91

^e Gas for Climate projects a slightly higher production of 38bcm by 2030, but to keep the analysis consistent with the RePowerEU target, we have applied the feedstock percentages set out in the Gas for Climate report to the 35bcm target

BOX 3: ENERGY CROPS: DOES THE BIOGAS INDUSTRY INTEND TO WALK THE TALK?

In theory, nearly all stakeholders, including industry and governments, agree that purpose-grown energy crops have a negative impact on the environment and food security. Excellent reviews of the energy crop issue can be found in previous reports by ICCT²⁰ and IFEU²¹. Hence, energy crops are not part of the industry's projected feedstock composition in 2030. However, energy crops currently provide 78% of the energy contained in biogas in Germany²². According to German government statistics, **cultivation of renewable raw materials^f in 2022 occupied almost 2.6 million hectares or about one-sixth of Germany's agricultural area, a proportion which has remained constant since 2014. Of this, 1.41 million hectares were taken up by energy crops for biogas plants²³.** Germany accounts for over half of total EU biogas production, and due to Germany's high share of energy crops for biogas, over 40% of biogas produced in the EU came from energy crops in 2020²⁴.

This means that **the industry has set itself a dual challenge of titanic proportions: converting 40% of its existing feedstock supply away from energy crops, while also increasing production of biomethane 10-fold by 2030.** To make matters worse, it appears that **national level biomethane feedstock projections of some of the key biogas producers continue to include energy crops.** For example, the French government's Environment and Energy Management Agency (ADEME) expects that in 2050 7% of biogas and biomethane will come from energy crops²⁵. And the German national level feedstock projection for 2030 cited in the gas industry study expects that at least 23% will come from energy crops. According to the EC's recent Union Bioenergy Sustainability Report²⁶, in some countries, land-use for energy crops is increasing. Denmark reported an increase in maize cultivation as biogas co-feedstock from 2,390 ha in 2012 to 17,433 ha in 2021. Poland reported an annual 4% increase of land for bioenergy cultivation in 2021 and Italy reported land-use change without further details.

IFEU²⁷ calculated the consequences of setting a binding 35bcm biomethane target in a scenario where the projected volumes of manure and agricultural residues by the gas industry do not meet expectations, and the use of primary energy crops is not explicitly prohibited and found that the area needed for biogas from maize would take up 5 % of the total arable land in the EU. If this land were used for food crops instead, 27.5 million tonnes of wheat could be produced corresponding to 20 % of the European wheat production and 83 % of Ukrainian wheat production in 2021, or 16.4 million tonnes of rapeseed corresponding to 108 % of European rapeseed production.



Maize stubble in a field in winter • Credit: Franke de Jong, Shutterstock

^f In German *Nachwachsende Rohstoffe* which can be defined as organic raw materials that come from agricultural, forestry and fisheries production and are used by humans for further application purposes outside food and feed.

3. METHANE LEAKAGE

KEY MESSAGE

At current rates, methane leakage during biogas production and digestate storage means that biomethane produced via anaerobic digestion can emit more greenhouse gases per unit of gas produced than natural gas. Methane is responsible for about a third of current global warming²⁸. The proposed EU Methane Emissions Regulation only applies to biomethane from the point that it is injected into the gas grid, leaving out critical methane leakages during anaerobic digestion, feedstock and digestate management.

3.1 METHANE LEAKAGE FROM ANAEROBIC DIGESTION IS UNDERESTIMATED

A recent study by researchers at Imperial College London²⁹ analysed 51 previously published studies on mobile methane measurements and site data taken from emission sources along the biomethane and biogas supply chain. The study shows that **methane emissions from biogas and biomethane production and supply chains could be more than two times greater than those estimated by the International Energy Agency in 2021**. Most methane emissions come from just a few super-emitters, mainly at the digestate handling stage. Furthermore, while overall methane emissions from biogas and biomethane are lower than those from oil and natural gas, **the amount of methane released from their supply chains relative to total gas production is much higher than for oil and gas**. In other words, on average one unit of biogas is more polluting than one unit of fossil gas, unless methane leakage is controlled more tightly.

These higher emission rates could be due to a variety of factors, including poorly managed production facilities; a lack of attention to the biomethane industry resulting in lower investments for modernization, operation, and monitoring; and lower employment of highly skilled plant operators. In addition, poor design and management of feedstock and digestate storage units as well as limited interest in infrastructure emissions may result in higher emission rates compared with the amount of gas produced. Because oil and fossil gas supply chains have been primarily operated by large companies for decades, they have invested more in leak detection and repair.³⁰

“We need better regulations, continuous emission measurements, and close collaboration with biogas plant operators in order to address methane emissions and meet Paris Agreement targets”³¹.

Dr Semra Bakkaloglu, Sustainable Gas Institute & Department of Chemical Engineering, Imperial College London

Another study looked at the issues of leakage in the context of wider energy system decarbonisation and found that “policy makers should consider that under reasonable leakage and demand assumptions, renewable natural gas [biomethane] could be climate intensive”³². In other words, **in a decarbonised energy system** where methane would be less likely to be replacing greenhouse gas (GHG)-intensive fuels, expected levels of methane leakage suggest that **biomethane is unlikely to be a low GHG energy resource relative to alternatives**.

A further consideration is whether anaerobic digestion plants and biomethane upgrading technology capture methane emissions that would have otherwise been emitted into the atmosphere, for example from untreated sewage. **When using crops as AD feedstock (whether grown as primary energy crops or sequential crops), we are intentionally producing additional methane. As a result, even minimal methane leakages from crop-fed AD add to total methane emissions.** Section 4.2.1 provides further detail on the concern around sequential crop cultivation in relation to methane leakage.

Finally, if biomethane is injected into the gas grid, we must also account for leakages in the fossil gas system. A recent study found that if global gas systems leak over 4.7% of their methane, they have life-cycle emissions intensities on a par with coal³³. Unfortunately, such leakage rates are all too common. One study identified over 3300 methane leaks in the urban gas distribution network of the city of Boston alone³⁴, emitting up to 4.7% of natural gas consumed³⁵. A separate study found that total emissions from US local gas distribution systems have been estimated at up to 7.6% of total US methane emissions³⁶.

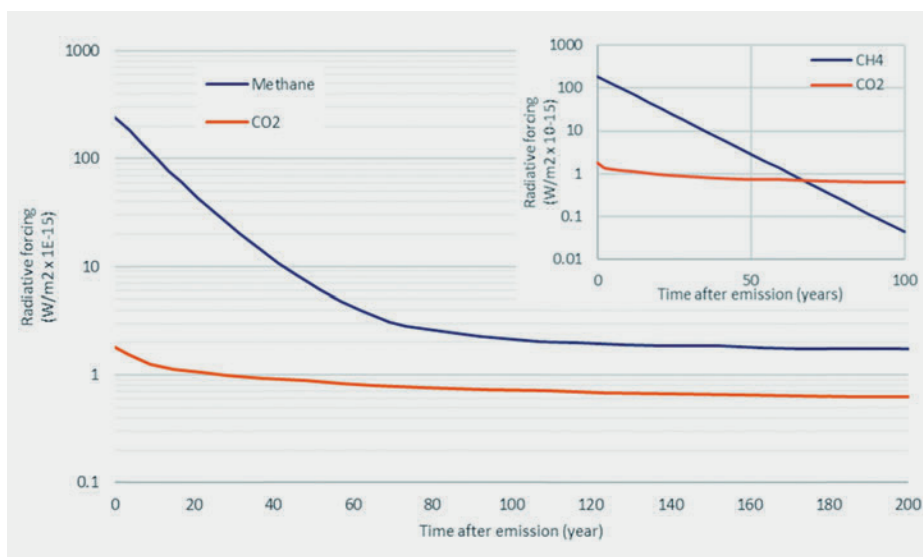
The proposed EU Methane Emissions Regulation applies to methane emissions from biomethane from the moment that it is injected into the gas grid, distributed as liquid natural gas (LNG) or stored underground³⁷. However, critically, the **proposed EU methane emissions regulation does not apply to any methane emissions from the production of biogas and biomethane, feedstock handling or digestate handling**. Given current average leakage rates, this is an alarming omission. It appears that the European Parliament has pushed for upstream methane emissions for imported fossil fuels to be included in the methane regulation, and that the EC has taken this on board³⁸. **It is imperative that the proposed EU Methane Regulation is further adjusted to ensure all upstream emissions from biomethane are also included.**

3.2 THE IMPACT OF METHANE ON CLIMATE CHANGE IS UNDERESTIMATED

Methane is 120 times more powerful than CO₂ immediately after it is emitted³⁹. On the other hand, methane only lasts a decade or two in the atmosphere, whereas CO₂ lasts much longer. Methane itself will eventually oxidise to form water and CO₂, so while methane will disappear quite quickly, 88% of it transforms into CO₂.

Figure 2⁴⁰ shows the total change in heat balance (radiative forcing) in the atmosphere from a 1kg emission of methane and carbon dioxide over time, including the eventual oxidation of methane into carbon dioxide. The graph inset is the radiative forcing of methane without the inclusion of methane oxidation into CO₂.

Figure 2: Climate impacts of CO₂ and methane over time



These differences in lifespan and behaviour in the atmosphere make comparisons between the impact of methane and CO₂ on the climate complicated. When attempting to understand the comparative impact of different greenhouse gases, scientists developed a metric called Global Warming Potential 100 or GWP100. This metric measures impact in CO₂ equivalents over a 100-year period principally because of the lasting and cumulative effects of CO₂. However, by using a 100-year period (which is essential to understand the impact of CO₂) and not accounting for methane's oxidation into CO₂, the impact of methane emissions is underestimated. What is more, to avert catastrophic climate change, we must bring our emissions down as rapidly as possible. Therefore, understanding the emissions of different technologies over a shorter period is imperative to ensure that we are focusing our efforts in the right areas.

Over a 100-year period, the Global Warming Potential of methane is 36 times that of an equivalent mass of CO₂. In contrast, over a 20-year period, the GWP of methane is 87 times that of an equivalent mass of CO₂.⁴¹ It is crucial that we keep calculating impacts of different technologies and energy pathways for a 100-year period, to not underestimate the impact of CO₂. However, simultaneously **calculating impacts for a 20-year period is equally critical to ensure we have a clear picture of the impact of methane emissions. In short, if we want the biogas industry to contribute to climate mitigation, we must analyse methane emissions in the short term.**

FURTHER RESEARCH NEEDED

It is crucial that independent life cycle assessments of biogas and biomethane are carried out. These LCAs must simultaneously compare (a) global warming potential over 100-year and 20-year periods and (b) average, best and worst practice methane leakage rates to give policy makers a much more complete understanding of the environmental impact of biogas and biomethane production.

Note that we have further recommendations regarding life cycle assessment specifically in relation to manure (section 4.1.3) and sequential crop-fed AD (section 4.2.1).



Aerial view of a cattle feedlot in the United States • Credit: Bim, iStock

4. SUSTAINABILITY ANALYSIS OF AGRICULTURAL FEEDSTOCKS

Together, manure, agricultural residues, and sequential crops make up 77% of AD feedstocks in the 2030 projection in the gas industry study. The IEA excludes sequential crops⁴², but the sum of manure and crop residues reach a similar proportion in the IEA 2050 projection⁹. In this section we look at the assumptions and data behind these projections alongside the EC biomethane assessment.

4.1. MANURE

KEY MESSAGE

Manure volumes in all projections ignore the broad scientific consensus that *“Reduction of excess meat consumption is amongst the most effective measures to mitigate greenhouse gas emissions, with a high potential for environment, health, food security, biodiversity and animal welfare co-benefits⁴³”*. Only once livestock production and consumption are reduced to sustainable levels can anaerobic digestion play its role in reducing the methane emissions from manure. Logistical and infrastructure limitations further reduce the amount of manure available as a biomethane feedstock.

At first glance, the use of manure as a feedstock for anaerobic digestion looks like a win-win, mitigating problems with conventional manure management, while producing energy⁴⁴. However, these perceived benefits need to be scrutinised from a systemic perspective, looking at the role of livestock production within the food system and its overall environmental impacts. In addition, as manure starts to become a valuable resource, there is a risk that perverse incentives arise, leading to its increased production of manure as a co-product, rather than a by-product, of meat production.

4.1.1. THE LOGISTICS AND ECONOMICS OF TURNING OVER 800 MILLION TONNES OF MANURE INTO BIOMETHANE

KEY MESSAGE

Due to its low energy content, it is economically and environmentally unviable to transport manure over anything but very short distances. As a result, the EC biomethane assessment assumes all manure goes to biogas – which is easier to produce at small-scale locally, given no biomethane upgrading technology is needed. In contrast, the gas industry study assumes that all collectible manure can be turned into biomethane, ignoring the infrastructure and logistical challenges related to using manure as a feedstock in areas with fewer farm animals.

g On p. 10 of their report “Scaling up Biomethane in the European Union: Background paper”, the IEA projects that 40bcm of biomethane in 2050 will come from manure, and 20bcm from crop residues. These amounts seem slightly larger than those shown in the graph on p. 9 of the report, where around 64 bcm is the total that comes from AD (assuming that forestry biomass will go to thermal gasification instead of AD, as set out in the gas industry report)

Infrastructure issues

The potential for manure feedstock identified in the gas industry study is based on a study published by the ECs Joint Research Centre⁴⁵ (henceforth referred to as *the JRC manure study*). Likewise, the EC biomethane assessment cites the JRC manure study as the basis for its manure projections. Via a thorough spatial analysis of farm animal numbers and manure volumes and their location, the JRC manure study estimates that at EU-level around 1200 million tonnes of manure are produced. Of this, around 860 million tonnes are estimated to be realistically “collectable” to be turned into over 16bcm of biomethane^h. The gas industry study expects that all the manure considered “realistically collectable” by the JRC manure study will be used for biomethane production by 2050. For the 2030 projected volume, it is assumed that 70% of the potential could be accessed⁴⁶.

The JRC manure study mainly looked at manure availability, but it did not consider energy infrastructure. Therefore, the authors recommend that as a next step it is necessary to *“explore the potential to integrate the biogas produced by AD plants into the natural gas grid and the supply of electricity production into the existing electricity grid. This will require more information on the energy infrastructure, such as the existing low voltage electricity grid and the low-pressure gas grid (distribution grids) that can be used by the biogas plants. This more detailed analysis would include a spatial multicriteria decision making approach based not only on distance to gas pipelines or power lines but also social, environmental, and economic constraints such as heat demand, land use/land cover restrictions, transportation costs, etc.”*⁴⁷

The 2022 gas industry study does not appear to address these infrastructure issues at least when it comes to the suitability of manure as a biomethane feedstock. The EU Gas Regulation proposal highlights this challenge as follows: *“For this scale-up to 35bcm to happen not only the market integration of renewable gas should be fostered but also the necessary infrastructure should be developed in due time. Specifically, this means developing a strategic approach, based on regional maps identifying the areas that have the highest potential for production of sustainable biogas and biomethane from biomass, to overcome existing technical barriers to boost sustainable biomethane within the Union and to fully integrate biomethane into the current gas system.”*⁴⁸

Grid connection, technical and infrastructure issues are analysed in detail in the EC biomethane assessment⁴⁹ which concluded that “manure potentials are assumed to be directly converted into electricity and heat on-site in small plants, as this substrate is not worthy of transport.”ⁱ In other words, the EC biomethane assessment which primarily analysed infrastructure and market challenges for biomethane upscaling concluded that most manure will be used for biogas and not biomethane.

h The 16bcm estimate is for EU-28. For Europe, the JRC manure study estimates that nearly 18bcm of methane can be produced. This is roughly in line with the methane volume for manure in the 2050 projection of the gas industry report. See Table 1 in Section 2.

i See p. 275 of the EC biomethane technical assessment. The EC assessment also clarifies that some manure will be used in biomethane, just as some of the other feedstocks (eg. crop residues or grass) will be too distant from biomethane plants. This means that they expect the totals to balance out in terms of the amount of feedstock to be used for biogas (usually in combined heat and power plants), and the amount of feedstock for bigger biomethane plants. Biomethane plants located too far from the grid can also produce bio-CNG (compressed natural gas) or bio-LNG (liquefied natural gas), but the viability at small scale is not clear.

Plant scale issues

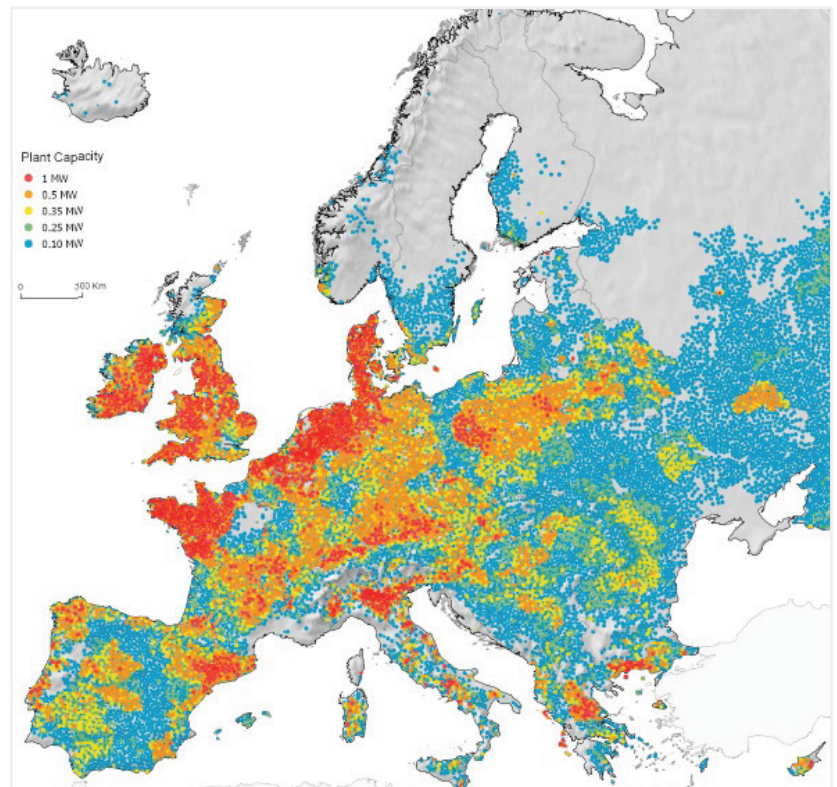
The JRC manure study optimized its calculations prioritizing larger plants as these are generally more cost-effective. In areas with lots of animal farming, very large plants could be built, but there are also many areas with fewer farm animals where only small plants can be built given the manure available within a realistic transport distance (the JRC manure study assumes a maximum collection distance of 10km). Manure is the least energy dense feedstock used in AD, with much larger volumes needed compared to crop or food waste feedstocks. The JRC manure study set a threshold of minimum capacity of biogas plants at 100kWe. Using a plant capacity calculator developed by the University of Surrey⁵⁰, we estimate that 100kWe is comparable to a plant that could produce 25 m³ of biomethane per hour.

Figure 3⁵¹ shows a suitability map for biogas plant location. The blue dots represent plants of 100kWe capacity, comparable to a production of 25 m³ of biomethane per hour.

However, according to the European Biogas Association plants with a size smaller than 50 m³/h are rarely built, except for demonstration purposes⁵². In other words, the projected production of biomethane from manure implies a significant increase in very small plants so that manure from areas with fewer farm animals can be used. Even though the sum of the capacity of these mini-plants is not that large compared to the mega-plants in area with high livestock density, this highlights an overly optimistic approach by the gas industry when choosing which scientific data to include in its estimates. A glance at the available research for example in Spain⁵³, Italy⁵⁴ and the UK⁵⁵ shows that economic viability is not guaranteed for small plants, even with substantial government subsidies.

The International Energy Agency⁵⁶ estimates the biomethane potential of manure at 40bcm which is more than twice the amount projected by the JRC manure study. We speculate that the IEA's estimate may be based on aggregated data of theoretical maximum volumes without any consideration for the collectability or spatial availability of this manure. The JRC manure study did carry out a detailed volume and spatial analysis, although not of infrastructure issues. We therefore conclude that the IEA manure volume estimate is unrealistic while the JRC manure estimate provides a more precise starting point.

Figure 3: Suitability map for biogas plant location



4.1.2. ACCOUNTING FOR DIETARY CHANGE IN MANURE VOLUME PROJECTIONS

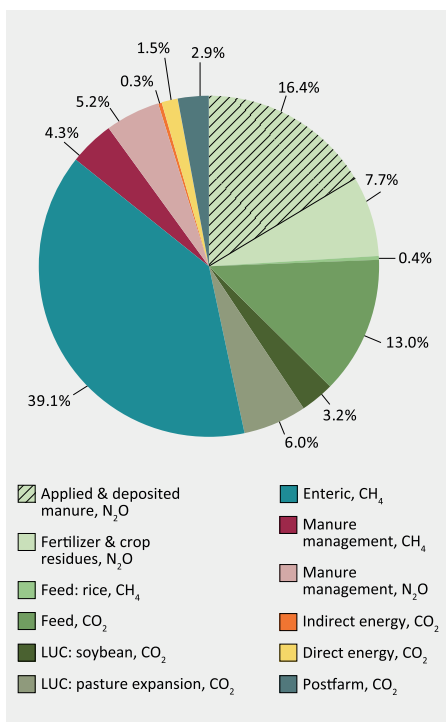
KEY MESSAGE

Using manure as a biogas or biomethane feedstock only marginally reduces the overall climate impact of livestock production. At current volumes, all projections are shockingly ignorant of the scientific consensus regarding dietary change, and the biogas and biomethane industry will lock in livestock production at a scale dangerous to the climate, environment and human health – providing perverse incentives to sustain or even expand livestock numbers. Anaerobic digestion can play a role in making manure management more sustainable, but only once livestock production has been reduced to sustainable levels.

To calculate the manure potential for 2030, **the gas industry study assumes that in 2030, there will be 7% fewer cows, 8% fewer pigs but 3% more goats and sheep and 4% more chickens.** As such, the gas industry’s projections on manure availability are in large part based on current meat and dairy consumption patterns. The gas industry believes that AD offers the principal way in which to solve the livestock industry’s carbon footprint:

“The anaerobic digestion of livestock effluents, whether shovelable or pumpable, is the most effective technology to [sic] limit – or even eliminate – GHG emissions from livestock farming [sic].”

Figure 4: Different contributors to total greenhouse gas emissions resulting from livestock production



There is no evidence to support this claim. In fact, reducing emissions via manure management whilst maintaining numbers of farm animals is not enough, partly because manure only makes up around a quarter of total livestock-related emissions – see Figure 4.

Figure 4⁵⁸ shows the different contributors to total greenhouse gas emissions resulting from livestock production. The red and pink sections show methane and nitrous oxide emissions arising directly from manure management, while the striped section shows emissions arising once manure has been applied to a field. The sum of these manure related emissions is 25.9%, compared to 39.1% from enteric fermentation (ruminant animal burping and farting) and 30% emissions from feed production.

Future availability of manure as projected by the gas industry goes against key findings of the Group of Chief Scientific Advisers to the EC, the Intergovernmental Panel on Climate Change (IPCC) and the European Court of Auditors, as well as innumerable scientific studies.

“Without reducing and cutting down on meat consumption and the associated high-intensity agriculture systems, we will not be able to keep global warming to 1.5 degrees”, in line with the Paris commitment⁵⁹”
 Prof Hans Pörtner, scientist and co-chair of the UN Intergovernmental Panel on Climate Change.

“Reduction of excess meat consumption is amongst the most effective measures to mitigate greenhouse gas emissions, with a high potential for environment, health, food security, biodiversity and animal welfare co-benefits. Scientists agree that more sustainable and healthier diets depend on higher consumption of plant-based food and, consequently, on a significant reduction in meat consumption, and particularly in processed meat. A global adoption of healthy, low-meat diets could dramatically reduce the environmental impact of the European food system and premature mortality⁶⁰”.

Group of Chief Scientific Advisers to the EC.

In addition to this, the European Court of Auditors found that without limiting or reducing the production of farm animals, which account for over half of emissions from food production, the €100 billion of Common Agricultural Policy funds attributed to climate action will have little impact on emissions from agriculture⁶¹.

BOX 4: THE NEED FOR DIETARY CHANGE CANNOT BE IGNORED

Livestock production is of particular concern because it accounts for 31% of global methane emissions^j, followed by oil & gas (26%), landfills (14%) and coalmining (11%)⁶². The livestock sector can only achieve an estimated 30% reduction through technical means, such as feed additives and improved manure management⁶³. In the case of the EU, livestock causes an estimated 81-86% of the EU’s total agricultural GHG emissions⁶⁴.

The production of beef emits, on average, over one hundred times more greenhouse gases (GHG) per 100g of protein compared to nuts or peas⁶⁵. 100g of protein from cheese emits 25 times more compared to nuts or peas. For pig meat the figure is 17, poultry and farmed fish 13 and eggs 10 times more GHG per 100g of protein. Meat, aquaculture, egg, and dairy production uses 83% of the world’s farmland, making it one of the biggest drivers of deforestation and biodiversity loss, despite providing only 37% of our protein and 18% of our calories⁶⁶. Not reducing ruminant farm animal numbers is a missed opportunity to buy time in the desperate race against the clock on climate mitigation. If fossil fuel production is reduced and the oil & gas sector applies methane reduction measures, **methane emissions from livestock are expected to contribute half of the remaining future methane emissions unless we reduce ruminant meat and dairy production and consumption⁶⁷.**

Finally, while they emit less methane, non-ruminant farmed animals such as pigs and poultry come with their own problems principally because their feed consists almost entirely of human edible crops such as wheat and soya. Demand for soya drives deforestation of the Amazon and other key biomes in South America^k. Of every 100g of protein fed to a chicken, only 37g ends up on our plate, for pork this figure is 21g⁶⁸. In contrast, a study by the University of Wageningen found that to eliminate reliance on soya imports whilst avoiding increases in EU feed cropland, Europe would have to reduce pork production by over 40% and poultry production by over 70%⁶⁹

A lack of significant reductions in farm animal numbers also ignores the danger of anti-microbial resistance, one of the biggest threats to public health⁷⁰. Globally, 73% of all antimicrobials sold on Earth are used in animals raised for food⁷¹. One-third of the global projected increase in antimicrobial drugs used for livestock by 2030 is attributable to a shift to more intensive animal farming systems⁷²⁻⁷³. These are the very systems which supply the biogas industry with most of its manure feedstock. Finally, ethical and animal welfare issues are usually exacerbated in farming systems with larger numbers of animals.

j Most GHG emissions from livestock come from enteric fermentation in the digestive systems of ruminant animals. Methane is produced as a by-product of this fermentation process, and exhaled, farted or belched by the animal.

k A summary of the latest key evidence regarding the role of animal feed soya in deforestation can be found in Luyckx, Karen et al. (2023) Soy no More: Breaking away from soy in UK pig and poultry farming. A report by the Landworkers’ Alliance, Pasture for Life, Sustain and Hodmedod. <https://landworkersalliance.org.uk/wp-content/uploads/2018/10/Digital-Soy-No-More-.pdf>

The current average per capita protein intake in the EU is about 70% higher than would be required according to the World Health Organization (WHO) recommendations and the current intake of saturated fats – the majority from meat – is 42% higher than the recommended maximum dietary intake, leading to increased risk of cardiovascular diseases⁷⁴. The Chief Scientific Advisors to the EC state that consumers will need to eat more legumes, fruits and vegetables, nuts and seeds; and less meat (mostly red and processed meat), based on the scientific targets for healthy diets and sustainable food production outlined by the Eat Lancet commission^l. Eat Lancet⁷⁵ recommends consuming no more than 98 grammes of red meat (pork, beef or lamb) and 203 grammes of poultry per week^m. However, current mean total meat intake by European adults ranges from 525g to over 1600g of meat per week⁷⁶. This means that reductions of around 7 to 8% in pork and beef – as foreseen in the gas industry study – are far from sufficient, not to mention the problematic projected increases in poultry, sheep and goat production.

To achieve reductions in meat consumption, the Chief Scientific Advisors to the EC have recommended that the EU should align CAP subsidies with dietary guidelines, and these guidelines should factor in sustainability criteria as the norm. The Advisors also said that:

“Sufficiently high taxes on red and processed meat and on products high in unhealthy fats, salt and sugar should be introduced. A tax on meat production could also be linked to associated greenhouse-gas emissions, thus building on existing emission reduction schemes such as the Emission Trading System (ETS) and the Carbon Border Adjustment Mechanism (CBAM)... To overcome opposition, policymakers need to define (through a dialogue with all stakeholders) the appropriate speed and progressivity of policy reforms, but they also must be mindful of the urgent need to transform food systems.”⁷⁷

Whilst such a tax on meat may sound far-reaching to some, the range of policies to limit access and availability of tobacco that are now mainstream set a clear precedent. Dietary change will not necessarily be bad for farmers. For example, one study found that if the EU shifted consumption in line with the Eat-Lancet diet, total EU farmer income could increase by 71% by 2050, although there would be losses in the shorter term in regions where livestock farming dominates⁷⁸.

l <https://eatforum.org/eat-lancet-commission/commissioners/>

m Although the planetary health diet, which is based on health considerations, is consistent with many traditional eating patterns, it does not imply that the global population should eat the same food, nor does it prescribe an exact diet. Instead, the planetary health diet outlines empirical food groups and ranges of food intakes, which combined in a diet, would optimize human health. Local interpretation and adaptation of the universally-applicable planetary health diet is necessary and should reflect the culture, geography and demography of the population and individuals. https://eatforum.org/content/uploads/2019/07/EAT-Lancet_Commission_Summary_Report.pdf

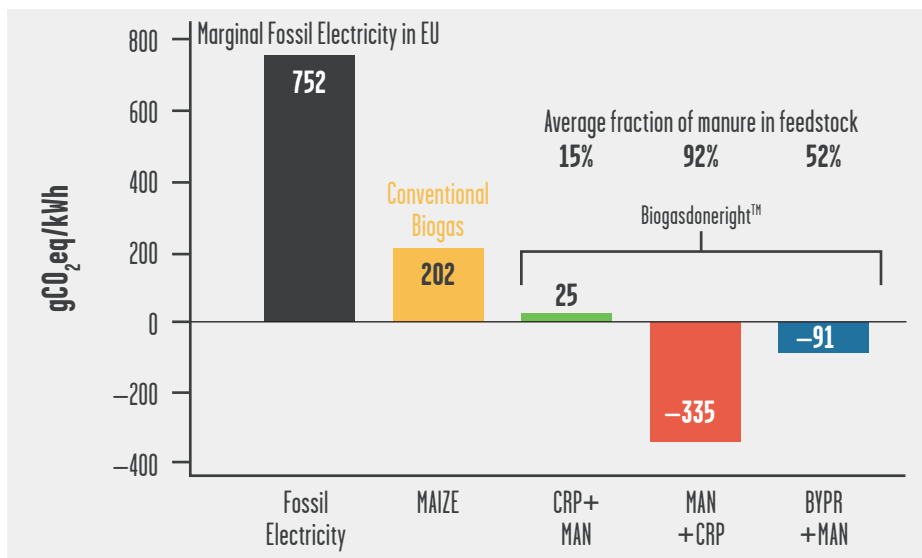
4.1.3. ACCOUNTING FOR THE ENVIRONMENTAL IMPACT OF BIOGAS AND DIGESTATE AS CO-PRODUCTS OF MEAT

KEY MESSAGE

Once livestock production is reduced to responsible levels, well-managed anaerobic digestion can help reduce the greenhouse gases that would have been released from untreated manure. However, because biogas and digestate increasingly contribute to the operational and financial viability of livestock farming, a proportion of the greenhouse gas emissions and other environmental impacts arising from the whole livestock production cycle should be attributed to biogas and digestate when studying their environmental impact.

Most life cycle assessments (LCAs)ⁿ of meat consider manure to be a residue or material output without any environmental burdens allocated to it, or a waste product which the holder is required to dispose of, in which case impacts from disposal are allocated between the main products (meat, dairy, eggs, etc)⁷⁹. Consequently, most LCAs of biogas assume that using a waste feedstock such as manure brings a positive impact as it helps avoid emissions generated by the manure management process. In figure 5, we can see that according to a typical LCA of biogas production, the larger the proportion of manure in the feedstock, the bigger the GHG savings:

Figure 5: Typical example of a biogas GHG LCA showing GHG emissions from electricity produced in four different biogas systems.



Source:⁸⁰

ⁿ Life-cycle assessment (LCA) is a process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities. It can be used to study the environmental impact of either a product or the function the product is designed to perform. LCA is commonly referred to as a “cradle-to-grave” analysis. LCA’s key elements are: (1) identify and quantify the environmental loads involved; e.g. the energy and raw materials consumed, the emissions and wastes generated; (2) evaluate the potential environmental impacts of these loads; and (3) assess the options available for reducing these environmental impacts. <https://www.eea.europa.eu/help/glossary/eea-glossary/life-cycle-assessment>

Put differently, although several other usable materials (e.g., inedible body parts and manure) are recovered from milk and beef production systems, they are usually not considered as products in life cycle assessments. Not considering these co-products in LCAs ignores the fact that a decrease in livestock production would also lead to a demand for alternative products to replace some of these materials⁸¹.

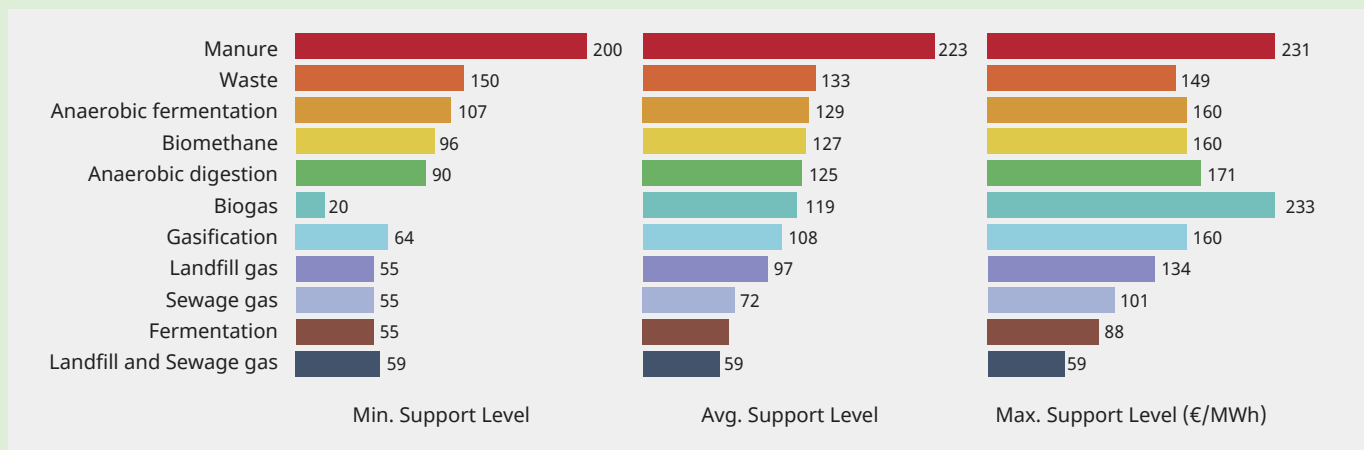
For example, a key LCA by the Food and Agriculture Organisation LEAP partnership⁸² in collaboration with the EC Joint Research Centre studied manure production and usage on two poultry farms and concluded that manure accounted for 6% and 18% of revenue depending on the farm⁸³. In a similar way, if digestate from an on-farm biogas plant is used on the same farm, the replacement value of conventional fertiliser could be allocated to the manure. Off-setting on-farm energy costs (electricity, diesel, LPG) and selling surplus energy to the grid can also be important for the farm business model⁸⁴ and thus should be accounted for in LCAs of all co-products resulting from livestock production. In one Italian case, farmer income per hectare increased by 40% as a combination of reduced fertilizer costs due to digestate application and the new income from biogas⁸⁵.

It is important that LCA experts further develop methodologies to valorise indirect revenue generation, savings and other ways in which manure for biogas contributes to a farm's economic viability. The value of manure for biogas is reported anecdotally in articles with titles such as *"How Dairy Farmers Are Turning Manure Into Money⁸⁶"* or *"What's Worth More: A Cow's Milk or its Poop?⁸⁷"*.

BOX 5: FEED-IN-TARIFFS FOR BIOGAS IN EUROPE

Feed-in-tariffs are national policy mechanisms that provide payments and long-term contracts to renewable electricity producers, proportional to the amount of power generated. The payments are often dependent upon the size of the plant in terms of installed electrical capacity, issuing higher subsidies to small and medium sized projects to reflect their higher operational costs⁸⁸. Moreover, as can be seen from Figure 6, in many countries, using manure further increases the chances of receiving these financial incentives. In other words, manure can generate a direct revenue for the biogas plant operator. Even for a farmer who does not run the biogas plant themselves, there are indirect revenue benefits through savings on manure disposal costs. Tax incentives can also be used⁸⁹.

Figure 6⁹⁰: Current incentives to support biogas for electricity in EU (minimum, average, maximum) from Feed-in-tariffs and tendering processes for new installations.



There are three mechanisms via which biomethane production can create perverse incentives to sustain and expand the livestock industry: 1) helping livestock facilities gain planning permission, 2) helping lower waste disposal costs and 3) locking in demand for manure for years, to pay off the upfront costs of building the biomethane plant. As discussed in section 4.1.1, viability of manure-based biogas facilities depend on economies of scale. Simply put the larger the herd nearby the AD plant and the more intensive the farming model, the more economically viable its operations⁹¹.

Disposal of litter and manure, within environmental legislation, is often a key constraint to the expansion of the intensive meat industry, because producers are faced with the challenge of what to do with the extra animal wastes in order to obtain permits. By providing an infrastructure for dealing with these wastes, AD may create perverse incentives to increase livestock production. As slurries and manure have a very low energy density, very large amounts of wastes are required to make it economically viable⁹², while also creating an increased demand for crop-based feedstocks to co-digest with the manure (for more information on co-digestion versus mono-digestion see Annex B). For example, when Broadley Copse Farm in the UK applied to significantly expand its operation to 50,000 bacon pigs a year, a biogas plant was key to gaining the permit⁹³. To pay off the £10 million this biogas plant cost to build, it must be supplied with 70 tonnes of pig manure per day, along with straw and some 20 tonnes of maize – locking in demand for the huge volumes of manure and harmful energy crops for decades. In Montauban-de-Bretagne, France, planning permission for a poultry farm with capacity for 144,000 chickens was granted immediately after a 1.2 MW AD plant was opened nearby⁹⁴. Here, the question arises, are these egg-laying chickens, broiler chickens or “energy chickens”?

Northern Ireland provides another example of how badly designed subsidies for biogas can create perverse incentives to sustain and expand the livestock industry. In 2013, Northern Ireland’s Going for Growth strategy was launched to drive a huge expansion of intensive pig and poultry production locally. By granting huge subsidies for AD plants⁹⁵, the government was able to provide an outlet for all the extra animal wastes, lower waste disposal costs and help farms to gain planning permission and bypass nitrate regulations⁹⁶. Instead of paying for their chicken litter to be disposed of, at about £90 per tonne, producers were now paid for their waste by the AD plants. For Moy Park farms, Northern Ireland’s biggest poultry producer, Feedback has calculated this would result in up to £12 million per year in savings. By 2019, Northern Ireland was producing 41% more pigs and 30% more chickens than in 2013, mainly in intensive farming facilities⁹⁷.

“Anaerobic digestion has become a popular diversification for [livestock] farmers as the extra income often subsidises other parts of the enterprise.”⁹⁸

We have not found any studies adding biogas into the co-product mix of livestock farming, but the importance of doing so is illustrated by an LCA on tallow-derived hydro-processed jet and diesel fuels⁹⁹. Tallow is derived from rendering edible or inedible portions of beef carcasses. This LCA compares two approaches to calculating the environmental impact of tallow-derived jet and diesel fuels. System 1 treats tallow as a waste of the meat production industry, and therefore is only concerned with emissions from the rendering process, fuel production and transportation steps. System 2 treats tallow as a co-product of meat production, and therefore also includes emissions from farming for feed production, methane and other emissions resulting from the cattle husbandry itself, and emissions from slaughtering. As can be seen in figure 7, it is instructive to analyse System 2 because it can be argued that a material should bear emissions from all processes that lead to its production once the material has an economic value.

Figure 7: Emissions of the tallow derived fuels

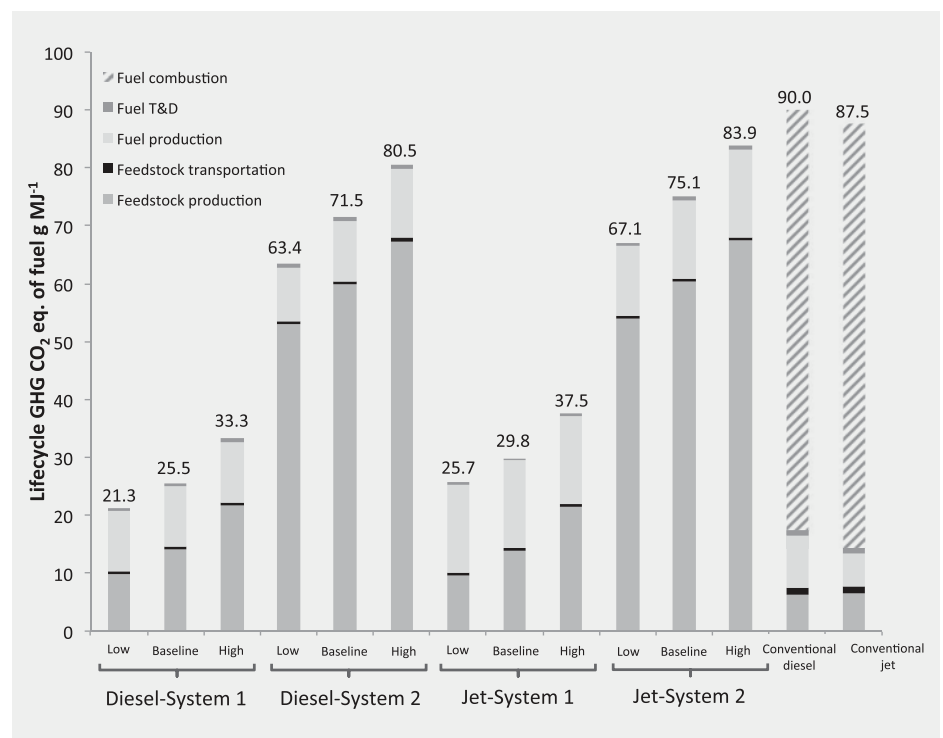


Figure 7¹⁰⁰ shows how the emissions of the tallow derived fuels are more than double when the emissions from farming for feed production and cattle husbandry are accounted for (system 2). The worst-case scenarios where the tallow production was least efficient (the “high” bars in system 2) generated nearly as much greenhouse gas emissions as conventional diesel and jet fuels.

In sum, as manure accrues economic value in the livestock farm, the emissions savings resulting from replacing conventional fossil energy and fertilisers will increasingly be cancelled out by the biogas and digestate co-product share of GHG emissions resulting from the whole livestock production system.

FURTHER RESEARCH NEEDED

A full review of the economic aspects of livestock farming and manure production needs to be carried out to elicit realistic examples of the true economic value of biogas and digestate alongside the production of meat, milk and eggs. Such a review should consider all sources of expenditure, income and savings for the livestock farmer in the form of reduced fertiliser costs or energy bills, feed-in tariffs if there is an AD plant on site, but also farm start-up costs and indirect benefits in the form of farm permits granted on the basis of the presence of an AD plant. Only a thorough analysis of the true value of manure within the farm business model – in current cases and different future biogas demand and incentive scenarios – will allow a complete understanding of the environmental benefits and costs.

4.1.4. DIGESTATE AND NITROGEN POLLUTION**KEY MESSAGE**

If well-managed with careful agronomical practices, it may be a good idea to treat manure via AD before applying it to cropland. However, there needs to be very careful monitoring to ensure that there is no overapplication of digestate to avoid pollution risks. Furthermore, digestate from manure and food waste can concentrate heavy metals. If the animals producing manure are receiving antibiotic treatment, crops could be exposed to antibiotic-resistance genes present in the digestate¹⁰¹. Even *if* digestate is handled to the highest standards, a narrow focus on digestate misses the complete picture of the nitrogen issue. Over 80% of the total EU agriculture emissions of ammonia, nitrate and nitrous oxide are related to livestock production¹⁰². Better manure management on its own is not sufficient to address the nitrogen issue and dietary change is a pre-condition for achieving the substantial reduction of nitrogen needed in EU agriculture¹⁰³.

Biogas industry reports suggest that digestate from co-digestion of manure, sequential crops and other residues can be a great substitute for chemical fertilizer (more information on co-digestion in section 4.2.3 and Annex B). In the French pilots discussed in section 4.2.3 below, synthetic nitrogen fertilizer use reduced by 20% because of adding digestate¹⁰⁴. And in the Italian case studies, about 65% of the nitrogen requirements of the crops are met with recycled digestate, and 100% of the potassium and phosphorus requirements¹⁰⁵.

BOX 6: DIGESTATE AND CLIMATE PERFORMANCE IN 30 FRENCH AD PLANTS

Based on a recent life cycle assessment of 30 French AD plants¹⁰⁶ with 73% of feedstock coming from manure, researchers from the French government's Environment and Energy Management Agency (ADEME) and the French government's Agriculture, Food and Environment Research Institute (INRAE) found that leaving cover crops and spreading raw manure on soils substituted more synthetic fertiliser and stored more carbon in the soil, compared to spreading digestate. In addition, while methane emissions from manure storage were strongly reduced by AD, three quarters of these reductions were offset by the emissions from digestate storage. Adding in emissions from feedstock and digestate transport, it was concluded that currently AD in France emits slightly more GHG compared to the baseline scenario of composting and applying raw feedstocks to the field. This result must be interpreted in the French energy context, where electricity generated by AD was measured against a grid with lots of nuclear electricity, but this still gives useful insights into the climate performance of AD in a more decarbonized scenario^o. The study used the standard GWP 100-year time horizon not reflecting the critical short-term impact of methane (see section 3.2) and only assumed a 1% methane leakage rate not reflecting realistic leakage rates in current AD production and supply chains (see sections 3.2 and 4.2.1), meaning that the overall climate impact may be higher than calculated in this study.

Digestate has become a bottleneck for biogas industry expansion because it often exceeds the capacity of surrounding croplands as fertilizer¹⁰⁷ and its use is legally limited by the Nitrates Directive (91/676/EEC) due to nutrient runoff and groundwater contamination risks¹⁰⁸. The handling of digestate can be associated with several difficulties, such as excessive requirements for storage capacity, high transport costs, the compaction of the soil because of the frequent application of digestate by agricultural machinery, or significant nitrogen losses during the storage of digestate and its application to soils¹⁰⁹. One systematic review concludes that "research on anaerobic digestion does not consider the long-term effects on local soil conditions and often ignores the potential risks of pollutants in digestates"¹¹⁰.

Ammonia emissions related to digestate handling induce significant problems related to the decreased nutritional value of digestate and environmental and health risks connected with ammonia toxicity¹¹¹. And as there is a high amount of ammonia in the digestates, manure should not be applied to alkaline soils without adequate pre-treatment to prevent ammonium (NH₄) emissions¹¹². Moreover, the AD process can concentrate heavy metals present in manure, with negative impacts on soil micro-organisms¹¹³. Finally, AD does not eliminate all antibiotic-resistance genes present in manure from animals that consumed antibiotics, with vegetables grown in soil with manure-based digestate at risk of exposure to manure-borne antibiotic-resistance genes¹¹⁴. Another study found that AD is a relatively inefficient method for antibiotic resistance gene removal from sewage sludge¹¹⁵. Pretreatment of sludge via thermal hydrolysis – which also improves methane yield – can reduce antibiotic resistant bacteria and genes to some extent. However, the increased prevalence of a particularly resistant *E. coli* strain in digested sludge "compared to raw sludge is direct evidence of the selection for a resistant potential pathogen within the digester and may have public health implications when this sludge is applied to agricultural land."¹¹⁶

^o Please note that Feedback does not advocate for the use of nuclear energy, given the myriad of critical safety and environmental problems associated with this technology.

The optimal time for digestate application presents a further challenge. “Autumn application of digestate, when crop uptake has slowed to a crawl, has been shown to substantially increase nitrogen volatilisation and nitrate leaching, both of which can be further exacerbated on sandy soils with low water retention capacity”¹¹⁷. In contrast, for summer crops, reliance on digestate with a higher organic load would cover the plant’s demands without jeopardizing the environment.

The pivotal role of nitrogen to transform our food system is recognized in an ambitious nitrogen waste reduction target in the European Commission’s Farm to Fork Strategy¹¹⁸. From the late 1960s to the present day, there has been an 800% increase in the use of nitrogen fertilizers globally, but the production of chemical nitrogen fertiliser is considered one of the most energy-consuming industrial processes on a global scale, responsible for 1.2% of the annual anthropogenic CO₂ emissions¹¹⁹. While nitrogen fertiliser is used in almost all conventional agriculture, nitrogen losses from agriculture result in significant water and air pollution. The EC has warned that more needs to be done against water pollution from nitrates¹²⁰.



Liquid cow manure in a storage pit • Credit: Lagui, Shutterstock

When it comes to digestate as a fertiliser, with precision application techniques¹²¹ such as digestate quality control, the use of catch crops, soil monitoring and other appropriate agronomic practices, the risk of nitrate leaching can be reduced in comparison to conventional fertilisers¹²². One of the papers cited in a recent European Biogas Association statement on digestate finds that a “highly stabilised digestate” can replace chemical fertiliser without the environmental risks¹²³. The EC Joint Research Centre has proposed that in strict conditions, the liquid part of digestate could be used as standard chemical fertilizer and thereby become exempt from the limitations set out in the Nitrates Directive¹²⁴.

Even *if* the biogas industry manages to produce digestate to these highest standards as a norm, a narrow focus on digestate misses the complete picture of the nitrogen issue. Around 81-87% of the total emissions related to EU agriculture of ammonia (NH₃), nitrate (NO₃) and of nitrous oxide (N₂O) – the third most important GHG after CO₂ and methane – are related to livestock production¹²⁵. A recent study by the EC Joint Research Centre and various European universities¹²⁶ has concluded that technological solutions at the farm level to reduce nitrogen losses and emissions from livestock housing and better manure management on their own are not sufficient to address the nitrogen issue and that **dietary change is a pre-condition for achieving substantial reduction of nitrogen needed in EU agriculture.**

In other words, **both changes in manure management (such as AD) and reduced consumption of animal products are essential.** From a consumption perspective, the current average nitrogen ‘footprint’ per person differs by a factor of 2 to 4 between European countries, mainly because of differences in average food consumption patterns. Countries with high intake of animal products (such as France and Denmark) in general have considerably larger nitrogen footprints than countries with a low intake of animal products (such as Bulgaria and Slovakia)¹²⁷.

4.2. SEQUENTIAL CROPPING

KEY MESSAGE

Sequential cropping is the cultivation of a second crop before or after the harvest of the main food or feed crop, relying primarily on digestate for fertiliser. The industry expects to replace energy crops with sequential crops¹²⁸, which by 2030 are expected to supply about one fifth of biomethane feedstocks. In contrast, the EC assessment excludes sequential crops from its most sustainable scenario citing uncertainties around the sustainability of the practice. The yields assumed in the gas industry calculations on sequential crop volumes risk affecting the yields of the primary crop. Of most concern is the fact that by using crops as feedstock (whether grown as primary energy crops or sequential crops), we are intentionally producing additional methane^p. As a result, even minimal methane leakages from crop-fed AD add to total methane emissions.

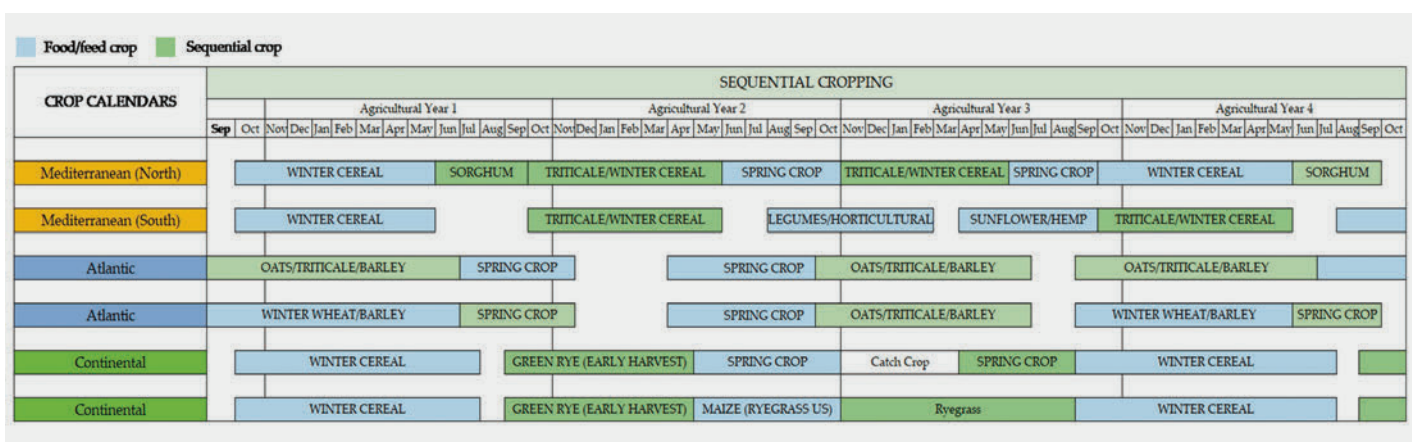
p As opposed to AD of certain waste-based feedstocks such as sewage sludge, where untreated sewage sludge would have emitted more methane into the atmosphere.

Sequential cropping is also referred to as multi-cropping, double cropping or growing a “harvestable cover crop”. In France, these crops are referred to as CIVE (*culture intermédiaire à vocation énergétique*). The difference with catch crops (mostly used to prevent nitrate leaching), cover crops (mostly used to prevent soil erosion) and green manures (often legumes used to fix nitrogen) is that sequential crops are harvested immaturity to be used as a feedstock for anaerobic digestion, rather than cut and left on the field. The resulting digestate is returned to the field in lieu of the catch or cover crop and can partially replace chemical fertiliser. Sequential crops are mostly lignocellulosic crops such as triticale, ryegrass, barley, oats and maize. The gas industry claims that “sequential cropping does not impact existing food or feed markets as no existing food or feed is used for biogas production. As the sequential crop is put whole into the anaerobic digestion plant, it does not necessarily require a fully matured crop to be grown. Therefore, given the right climatic conditions, it can be implemented in a way which does not impact the yield of the main crop.”¹²⁹

Projections for sequential crop feedstock are extremely ambitious. By 2030, the industry expects that one fifth of the feedstock used to meet the 35bcm goal will come from sequential or cover crops. By 2050, nearly half of the 91bcm goal is expected to come from sequential crops. These projections are based on a paper modelling the potential of sequential cropping by researchers from the University of Ghent^q and the European and Italian biogas associations¹³⁰. In this study, the total area of arable land was assumed to remain largely unchanged though certain land may become more suitable and other less because of climate change.

The arable land with potential for sequential cropping was assumed to be 20% in the Atlantic, Continental and Mediterranean regions of Europe. For the 2030 projections, given that in most of Europe’s key agricultural areas sequential cropping remains largely untested, it was assumed that in most countries only 10% of this theoretical potential (of 20% of the total arable area) could be achieved, except for Italy and France where farmers have more experience with sequential cropping and Germany, where farmers are actively seeking to change their mono-energy-crop farming models.¹³¹

Figure 8: Example sequential cropping calendars on which the gas industry projections are based.



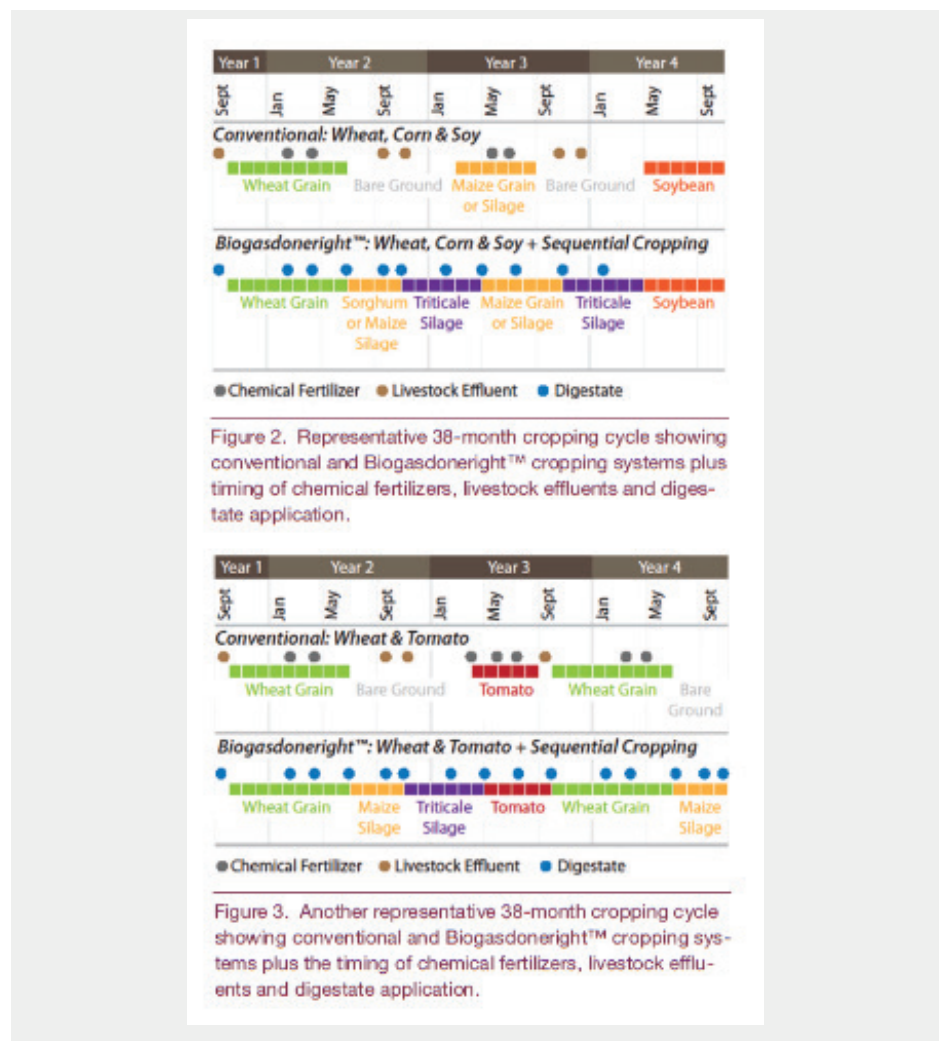
Source¹³²

q One of the senior Ghent University authors sits on the scientific advisory board of the European Biogas Association: <https://www.europeanbiogas.eu/team-organisation/prof-erik-meers/>

The Repower EU action plan is cautiously optimistic but reflects the fact that in most areas and situations the idea is unproven: “sustainably produced biomass from sequential crops and cover crops, the impact on the cultivation of e.g. green manure and the subsequent use of mineral fertilizer, should be considered. A case-by-case analysis of the economic, social and environmental factors for the use of a particular area for the production of sustainable feedstock should be undertaken as well.”¹³³.

Aside from various experiments in France, the biogas industry’s sequential cropping ambitions are principally based on the Italian experience, where around 600 farms apply sequential cropping under the Biogasdoneright™ (BDR™) model¹³⁴. **Unfortunately, the European Biogas Association’s statistical report 2022¹³⁵ does not provide data showing the overall volume or proportion of sequential crop feedstocks currently used in the EU or in the Italian and French biogas and biomethane industry.** For the 16 countries for which data is shown, only the United Kingdom, Serbia and Greece appear to use sequential crops. In Greece, sequential crops made up less than 5% of feedstock. Serbia does not currently produce biomethane and is one of the smallest biogas producers in the EU. Such lack of data is surprising given the importance of sequential crops in overall feedstock projections.

Figure 9: Sequential versus conventional cropping cycle examples in the Italian Biogasdoneright™ model¹³⁶



4.2.1. METHANE LEAKAGE AND SEQUENTIAL CROP FARMING EMISSIONS

KEY MESSAGE

Compared to certain waste-based feedstocks, such as sewage sludge, which in their untreated form emit methane into the atmosphere – and where well-managed AD can decrease these methane emissions, the anaerobic digestion of any purpose-grown crop, including sequential crops, results in the intentional creation of additional methane. This means that even minimal methane leakage from AD, digestate management and biomethane distribution results in the release of methane additional to that which would have existed if we did not grow these crops in the first place. Given the potency of methane as a greenhouse gas, this is of grave concern and puts any purported climate benefits of (sequential) crop-fed AD into question. Furthermore, biomethane made primarily from sequential crops may not be able to meet the fossil fuel comparator limits established in the Renewable Energy Directive.

A life cycle assessment (LCA) of the sequential crop cultivation process (such as tractor diesel, and fertiliser use additional to digestate) is urgently needed to establish whether sequential crop-fed AD can achieve legally required GHG emission savings under realistic methane leakage rates. Such an LCA is critical in light of an earlier LCA by the IEA¹³⁷ of electricity produced from maize-fed AD. Given that this LCA by the IEA did not consider any GHG emissions arising from indirect land use change, but only looked at emissions arising from crop cultivation, the results are sufficiently relevant to sequential crops to underscore the urgent need for an updated LCA on these crops specifically. A new LCA is also needed because the IEA LCA did not consider upgrading to biomethane – which comes with additional methane leakage risks.

The IEA found that if maize is digested alone, and the plant maximises heat export alongside electricity production, the legally established 30% fossil fuel comparator (FFC) limit^r can only be attained up to a maximum of 2 % methane leakage. If only electricity is produced, the additional emissions deriving from the cultivation process allow biogas from maize to have GHG emissions lower than 30 % of the FFC *only* with methane losses lower than 1%¹³⁸. From 2026 the FFC limit will be 20%. Currently, almost no biogas plants appear to achieve such low methane leakage rates. On top of this, greenhouse gas forcing over 100 years is used while it should be considered over 20 years, as explained in section 3.2.

^r The fossil fuel comparator used by the IEA is taken from the EC Staff Working Document SWD 259 (2014) and is equal to 186 g CO₂eq. per MJ of electricity (see https://lexparency.org/eu/32018L2001/ANX_VI/) and is based on the following power mix: 50 % natural gas fired CCGT plants (with gas sourced from a mixture of sources, from short/long distance as well as LNG), 25 % coal fired IGCC plants, and 25 % conventional coal.

The 70% reduction is set out in the (EU) 2018/2001 Renewable Energy Directive II where Article 29 states that “at least 70 % for electricity, heating and cooling production from biomass fuels used in installations starting operation from 1 January 2021 until 31 December 2025, and 80 % for installations starting operation from 1 January 2026. See https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG

The meta-analysis by Imperial College London discussed in section 3.1 above found that only the best 5% of biogas plants were able to keep unintended methane emissions to 1.7 to 2%, with the mean emission rates of 5.9%. Another recent study¹³⁹ investigating 33 biogas plants in Austria, Germany, Sweden and Switzerland – where cooler climates result in slower methane release from stored digestate compared to warmer climates – shows how challenging it is to keep the sum of unintended methane emissions from the AD plant and digestate storage below 2%. In sum, **unless methane leakage can consistently be limited to rates considerably lower than current practice, and/or sequential crops deliver better biogas yields than maize relative to the emissions arising from crop cultivation, sequential crop-fed AD will be unable to achieve the GHG emission reductions required by the Renewable Energy Directive.**

FURTHER RESEARCH NEEDED

An independent life cycle assessment urgently needs to be carried out to establish sequential crop yields (achieved without affecting soil health or primary crop yields), tractor fuel and all other cultivation parameters and methane leakage rates to ensure compliance with the 20% fossil fuel comparator limit (from 2026) as established in the Renewable Energy Directive. Such an LCA should also report Global Warming Potential for a 20-year timespan (see section 3.2).

4.2.2. CAN WE GUARANTEE SEQUENTIAL CROPPING WILL NOT AFFECT FOOD AND FEED PRODUCTION?

KEY MESSAGE

Some of the assumed sequential crop yields used to calculate feedstock volumes by the gas industry may in practice result in the yield of the primary food or feed crop being reduced. Significant increases in total biomass production resulting from a widespread introduction of sequential cropping may also result in an increase in water use. Although nearly all existing AD plants co-digest sequential (or energy) crops with manure, gas industry feedstock projections assume mono-digestion of sequential crops which rarely happens in practice because of technical challenges. Little research appears to have been carried out to determine whether manure-poor digestate can replace fertilisers and enhance soil sufficiently compared to the existing experience of manure-rich digestate.

According to the biogas industry, the principal benefit of sequential cropping is that, in contrast to conventional energy crops, it does not affect food or feed production and thus has no indirect land use change impacts. However, the calculations for the available volumes of sequential crops are based on potentially problematic assumptions.

First, the average crop yields at the basis of the gas industry calculations for sequential crop feedstocks are 7.1 dry tonnes per hectare in the Atlantic region, 7.3 dry t/ha in the Continental region and 13.5 dry t/ha in the Mediterranean region¹⁴⁰. However, according to a study by the French

government, the maximum sequential crop yield to avoid reducing primary crop yield is 7 dry t/ha¹⁴¹. A higher sequential crop yield can be achieved by a later harvest, but the yield of the primary food or feed crop that follows can be reduced by 10 to 15%. In 2030, around 40% of sequential crop feedstock is expected to come from Italy, due to Italy having more relevant experience. All of Italy's arable land sits within the Mediterranean area and thus yields are assumed to be nearly twice as large as the maximum sustainable yield calculated by the French government study.

If we accept that in warmer climates we may achieve higher crop yields in double-cropping systems, the question arises whether in fact double food- or feed cropping may be possible. One of the often-cited Italian Biogasdoneright case studies shares data on two of the farms using sequential crops as AD feedstock¹⁴². In one farm, two sequential maize crops from a total of 160 hectares yielded over 90% of the yield of the primary maize crop. In another farm, the sequential sorghum crop yielded 88% of the primary sorghum crop¹⁴³. Such small yield differences beg the question whether the sequential crop reduced the yield of the primary crop. Or, if that is not the case, then the question arises as to whether clever agronomical techniques (rotations, varieties, intercropping, etc) could result in food or feed crops being produced year-round as is done in double-cropping systems in Argentina for example¹⁴⁴. Indeed, "incorporating energy cover crops into rotations induces changes in cropping systems that can lead to certain excesses, where energy crop production is favoured to the detriment of food crop production"¹⁴⁵. For example, one study observed that the yield of spring crops declined by an average of 10% if seeding was delayed by more than 7 days, and another study observed a 7% yield loss after a 10 to 15-day delay of seeding. When the delay was even longer the next cash crop could not reach maturity and no longer feed humans but had to be used as animal feed or AD feedstock instead.

Furthermore, late harvesting of the sequential crop can reduce the water held in the soil, further affecting the following primary crop¹⁴⁶. While the water dynamics in relation to cover cropping are complicated, the depletion of water reserves in surface has often been seen in association with different types of cover crops, with a later harvest date of the cover crop resulting in increased water stress for the primary crop¹⁴⁷. There are also further uncertainties regarding the site-specific conditions that influence the extent to which these crops can reduce pesticide use¹⁴⁸.

A further potential issue is that of soil compaction which the EC recognizes as a major threat to soils¹⁴⁹. The use of heavy machinery often leads to soil compaction, in particular during field operations under unfavorable soil conditions, such as wet soils, with risks for long-term soil health and crop yields. A review of sequential cropping for AD found that field traffic can increase and that ensiling sequential crops and applying the digestate requires the use of heavier machinery, sometimes under sensitive conditions during early spring or autumn¹⁵⁰. In other words, sequential cropping may result in more frequent machinery usage on fields during wetter times of the year with long-term impacts on soil health.

4.2.3. THE INTERDEPENDENCE OF SEQUENTIAL CROP AND MANURE FEEDSTOCKS

KEY MESSAGE

To keep soils healthy, current sequential cropping experience is heavily dependent on manure-rich digestate. The proportions of manure used in these sequential cropping examples are much higher than those projected in the gas industry's overall feedstock composition. In addition, to avert the climate crisis, we need significant reductions in animal farming, and thus less manure relative to the volume of sequential crops and agricultural residues. It is unlikely that manure-poor digestate can sustain healthy soils with intensive double-cropping as is currently practiced in sequential cropping farms in France and Italy. Increasing legume production (and eating these legumes instead of meat to ensure our nutritional needs are met) alongside a reorganization of biomass flows can achieve adequate crop fertilization despite drastically reduced manure availability, while resulting in far-reaching reductions in GHG emissions and land use.

A further assumption is that the nutrient requirements of the sequential crops will be met through digestate application. The nutrient content of digestate is highly influenced by the characteristics of the feedstock being digested. One review looked at digestate from sequential crops and found that introducing sequential crops into crop cycles and utilizing the resulting digestate as fertilizer should help reduce erosion and promote soil stability but found that synthetic fertiliser use was also increased to allow for double cropping¹⁵¹. All the other studies we have seen on the fertilising qualities of digestate look at digestate resulting from the co-digestion of various feedstock types, always including manure. For example, the study at the basis of the European Biogas Association calculations on synthetic fertiliser replacement only considered digestate from co-digestion of manure with crops or biowaste¹⁵², as these combined digestates make them suitable candidates for RENURE^s materials.

In contrast, the study at the basis of the sequential crop feedstock estimates assumes the mono-digestion of these crops. On the one hand this may mean that, compared to the sequential crop study, better biomethane yields may be achievable when there is co-digestion with manure^t. On the other hand, if manure volumes reduce because of essential dietary change and infrastructure challenges, the nutrient qualities of digestate may not be as good as calculated by the industry.

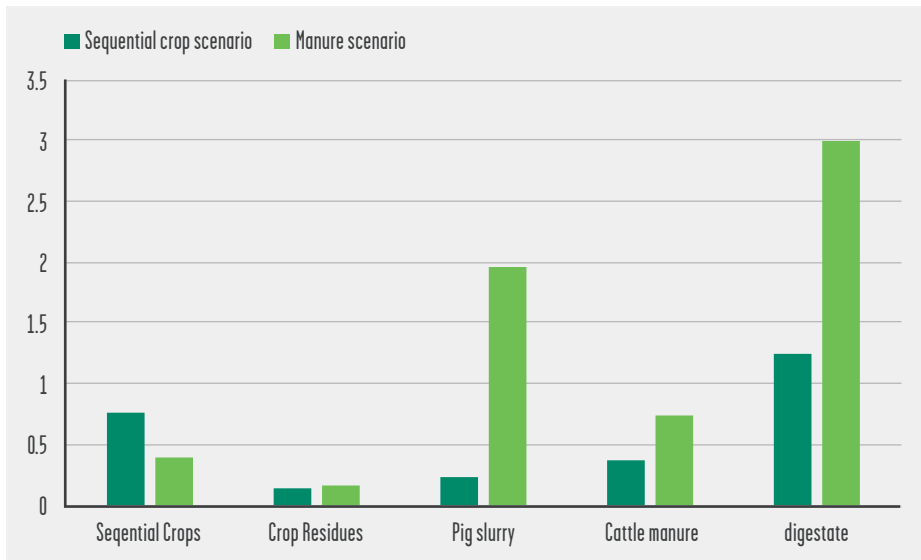
Figure 10 shows the amount of digestate and the different feedstocks used in a low-manure sequential crop scenario and a high-manure scenario studied in a life cycle assessment by the French government agricultural research institute¹⁵³. To produce the same amount of biomethane the manure scenario uses more than double the volume of feedstock, because crops are much

s RENURE^s stands for "recovered nitrogen from manure", and is defined as "any nitrogen containing substance fully or partially derived from livestock manure through processing that can be used in areas with water pollution by nitrogen following otherwise identical provisions applied to nitrogen containing chemical fertilisers as defined in the Nitrates Directive (91/676/EEC), while ensuring the achievement of the Nitrates Directive's objective and providing adequate agronomic benefits to enhance plant growth".

t See annex B for further information on mono and co-digestion of feedstocks.

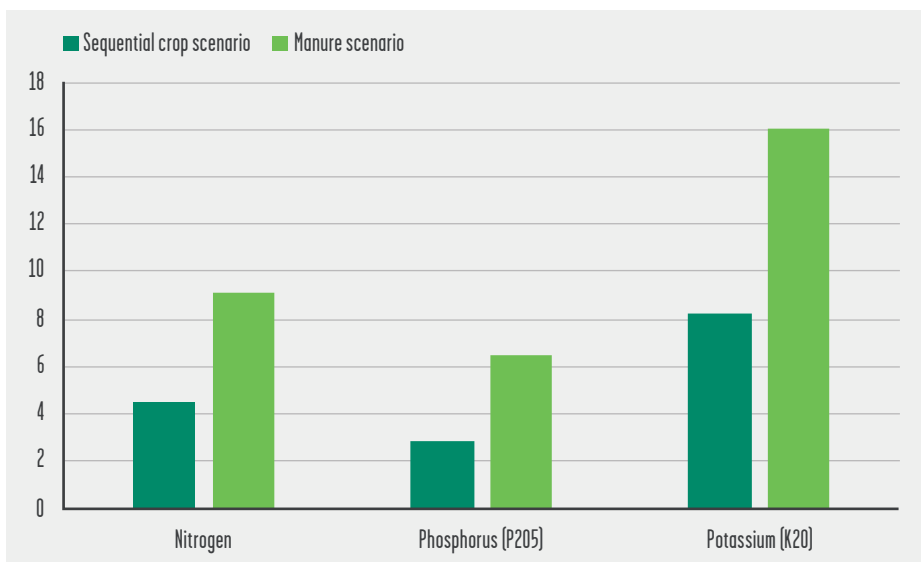
more energy dense. At the same time, the sequential crop scenario produces much less digestate compared to the manure scenario, and about half of the key fertilising nutrients (figure 11).

Figure 10: Feedstock inputs (kg) to produce 0,109 m³ of biomethane and resulting digestate



Source¹⁵⁴

Figure 11: Fertilising elements (g) in manure-poor or manure-rich digestate with same biomethane production



Source¹⁵⁵

Most of the documented examples of sequential crop-AD use manure in similar proportions to the manure scenario in figures 10 and 11. Moreover, manure delivers over half of all feedstock currently in AD in France, combined mainly with 5.5% energy crops, 13% sequential crops and 16% food industry by-products^{156 u}. This means that assumptions on the ability of digestate to maintain a healthy soil with adequate levels of nutrients and organic matter are based on digestate feedstock proportions very different to those projected in the long-term by the industry. And this is without accounting for the inevitable reduction in meat production as discussed in section 4.1.2. We have not been able to find current figures on the average proportion of manure feedstock in the BiogasDoneRight farms in Italy, but an earlier research document by the Italian biogas industry^{157 v} projected that in 2030 nearly one third of AD feedstock would come from manure^v.

In sum, existing examples of sequential crop feedstocks primarily appear to be based on livestock farms where the sequential crops are co-digested with manure compared to current manure feedstock proportions. This means that nutrients are imported into the farm system through manure – which is a vehicle for the nutrients first imported into the farm system via animal feed. In other words, the digestate includes nutrients that may have come from grass in the field next door, or from as far as South America through soya in the animal feed. At the scale of sequential cropping proposed in the gas industry feedstock projections, there will be less manure. In addition, to avert the climate crisis, we need significant reductions in animal farming which will lead to an inevitable reduction of such nutrients brought into the farm system, as there will be less manure relative to the volume of sequential crops and agricultural residues. It is difficult to see how in these changed circumstances, digestate can sustain healthy soils with intensive double-cropping as the current manure-reliant sequential cropping pilots in France and Italy.

If digestate with no or little manure does not substitute nitrogen fertiliser to the same extent as manure-rich digestate, then the question arises whether we should focus on cover cropping with nitrogen-fixing legumes to reduce reliance on chemical fertilisers and improve soils (in contrast, most of the crops considered in the biomethane feedstock calculations are lignocellulosic crops such as triticale, sorghum, oats, maize, barley, rye etc). The multiple benefits of legume cover cropping and intercropping are well-documented and in some cases legume biomass can also be sent to AD¹⁵⁸ though we could not find examples or data to show that this was a common practice.

u For France, the gas industry report states that “successful pilots have been undertaken funded by ADEME, which works with various French ministries, though no citation or further information is provided to determine exactly which pilots the report is referring to. A paper by Dale et al (2020 The Potential for Expanding Sustainable Biogas Production and Some Possible Impacts in Specific Countries,” Biofuels, Bioproducts and Biorefining 14) gives more detail on a pilot programme called Methalae which was funded by ADEME. According to the summary of results of the pilot, the 46 participating farms were categorized as follows: 19 dairy cattle farms, 10 beef cattle farms, 9 pig farms, 1 goat, 1 sheep and 2 poultry farms, and 4 cereal farms. ADEME, and Solagro. “La Méthanisation, Levier de l’agroécologie, Synthèse Des Résultats Du Programme MéthaLAE,” 2018. https://solagro.org/images/imagesCK/files/domaines-intervention/methanisation/2016/2019/methalae_10_pages_web.pdf.

v In 2016, the Consorzio Italiano document on Biogasdoneright projects that by 2030 34% biomethane will come from energy crops, 33% from sequential crops, and 33% from residual biomass. Of this residual biomass around 90% of which is projected to come from manure. See p. 10 and p. 16 in https://www.consorziobiogas.it/wp-content/uploads/2017/05/Potenzialit%C3%A0_biometano_Italia_FINALE-ENG.pdf

BOX 7: THE MAGIC OF LEGUMES AND LOW-MEAT CIRCULAR FOOD SYSTEMS (BASED ON¹⁵⁹ AND ¹⁶⁰)

There is a wealth of agronomic research showing how legumes can increase soil organic matter and add resilience to crop rotations, while increasing crop yields. For nutritionists, legumes represent healthy, high-protein and nutrient dense foodstuffs that can reduce the risk of heart disease and stroke, especially if consumed as meat-alternatives. The nitrogen fixing qualities of legumes can lessen the greenhouse gas emissions of arable production by lowering the need for mineral fertilisers, while decreasing local environmental impacts associated with diffuse water pollution and runoff. When eaten in place of meat and dairy, legumes can also significantly reduce pressure on agricultural land and resources. A recent paper in *Nature food* on circular food systems shows how optimizing the use of food and agri-biomass flows can achieve far-reaching reductions in GHG emissions and land use while ensuring our nutritional needs (protein, calories and micro-nutrients) are met. This study also demonstrates **how biomass flows can be redirected to achieve adequate crop fertilization in scenarios with drastically reduced manure availability.**

4.3. AGRICULTURAL RESIDUES

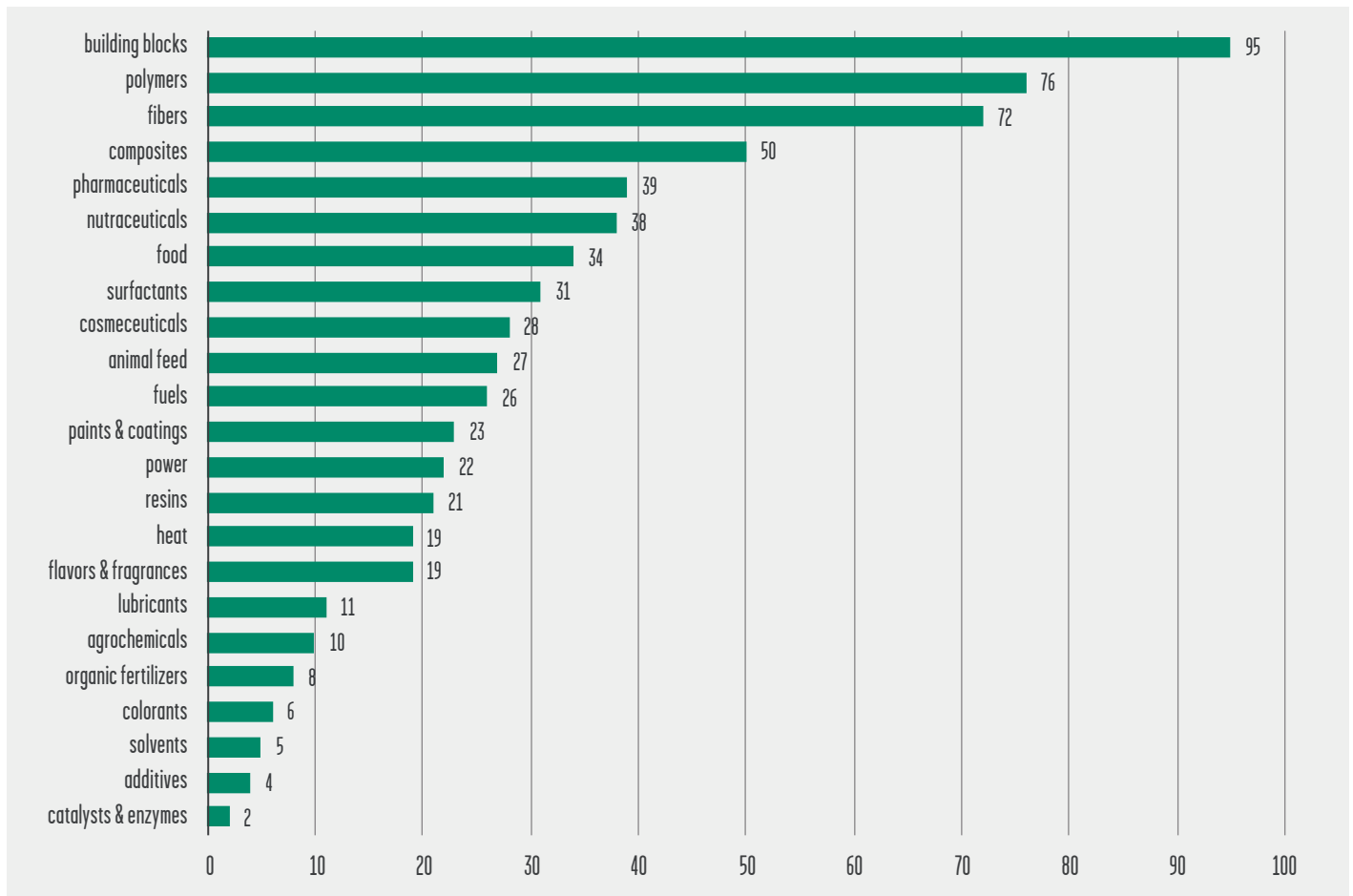
KEY MESSAGE

The gas industry estimate for agricultural residue feedstock is based on a 2019 study by the EC Joint Research Centre, but nearly twice as much as the later EC biomethane assessment. This discrepancy may in part stem from uncertainties around the sustainable removal rate of agricultural residues without affecting soil health, and from different ways of accounting for competing demands beyond animal bedding, for instance in the biorefinery sector, bioethanol, building materials, mulch in horticulture and vegetable cultivation, or as a growth substrate in mushroom production. Further uncertainty stems from annual variations in crop residue availability combined with a lack of understanding of spatial constraints (there is a limit to the transport distances for moving feedstocks around).

Agricultural residues (such as cereal straw) are defined as the materials that arise *in the field*, following the harvesting of the grain or seed. The latest gas industry calculations assume that 42% can be removed sustainably, and of this volume 25% is required for existing uses such as straw for animals¹⁶¹ with an estimated 9bcm biomethane to be produced from these residues by 2030. An earlier study by the gas industry put the figure at only 5 bcm of biomethane by 2050¹⁶². And in its most sustainable scenario, the EC biomethane assessment states that it expects less straw to be available than the earlier industry projection of 5bcm due to uncertainties around the impact of excessive straw removal on soil health¹⁶³. We have not been able to determine the exact detail of the difference in these estimates, but it appears to be related to the fact that the sustainable removal rate is difficult to quantify because it depends on cultivated crops, soil conditions (soil type, soil organic carbon, etc.), farming practices (crop rotation, fertiliser application) and climate (temperature, precipitations), which are all very location specific¹⁶⁴.

We do not have information on whether the gas industry study attempted to fully account for competing uses for agricultural residues beyond animal bedding, such as building materials¹⁶⁵, mulch in horticulture and vegetable cultivation, or as a growth substrate in mushroom production, among other uses. A further competing use is the biorefinery sector where the main feedstock is agricultural biomass. According to a database developed by the EC Joint Research Centre, there are 298 biorefineries in the EU – see figure 12.

Figure 12: EU biorefineries by product using a range of agricultural and forestry biomass, including residues¹⁶⁶.



Another significant competing use for crop residues is bioethanol. Bioethanol from crop residues such as wheat straw and maize stover does not necessarily have a smaller environmental footprint than conventional energy-crop-based ethanol¹⁶⁷. However, because bioethanol from crop residues counts as an advanced biofuel under Annex IX of the Renewable Energy Directive, the demand for crop residues from bioethanol is likely to be significant. A recent study concluded that at sustainable removal rates there is 65 million tonnes (dry weight) of wheat and maize crop residues for such advanced bioethanol production annually¹⁶⁸. This volume is around half of the estimate of all sustainable crop residues estimated in the JRC study on which the gas industry projections for agricultural residues is based. And even then, this volume of crop residues for bioethanol is insufficient to achieve the EU’s target of a minimum share of 3.5% of advanced biofuels in the transport sector by 2030. If we deduct the 25% of crop residues used for animal bedding and feed, plus demand from the biorefinery sector, there is not much left over to be used as biomethane feedstock.

Finally, a spatial analysis of co-availability of sustainable feedstocks appears to be missing. For example, the main gas industry study¹⁶⁹ analysed in this report estimates that the 2050 annual biomethane potential from agricultural biomass for France is 152.4 TWh^w, compared to 108.7TWh per year estimated by the French government's Environment and Energy Management Agency (ADEME) and the French government's Agriculture, Food and Environment Research Institute (INRAE) in a just published peer-reviewed study¹⁷⁰. In this very recent estimate by ADEME and INRAE, biomethane production was highly variable across the French regions and consequently, crop residues could only partly be used for anaerobic digestion – especially in arable regions – because if not enough other feedstocks, such as manure, are available for co-digestion, an overuse of crops residues leads to excessively dry substrate mixtures.

FURTHER RESEARCH NEEDED

An independent life cycle assessment and/or metareview of published LCAs needs to determine an order of preference for crop residue / cascading usage for all types of demand (soil, biodiversity, food, feed, fuel, materials and others) for this biomass.

Detailed spatial analyses need to be carried out to ensure estimated biomethane potentials consider sustainable crop residue removal rates in accordance with local conditions and year-round availability of feedstocks in adequate proportions for high-yielding co-digestion and without creating perverse incentives for unsustainable feedstocks, such as manure from excessive animal farming.

^w About 87% of the estimated total potential, the other 13% is assumed to come from mainly industrial wastewater, with small amounts from sewage sludge, food waste and roadside verge grass.

5. SUSTAINABILITY ANALYSIS OF FEEDSTOCKS NOT DIRECTLY RESULTING FROM AGRICULTURE

5.1. FOOD WASTE / BIOWASTE

KEY MESSAGE:

Although the gas industry study takes account of the Circular Economy Package recycling ambitions regarding municipal waste, there seems to be no mention of the EC's food waste reduction targets. The volumes of food waste assumed to be available as biomethane feedstock in the gas industry report are higher than the food waste currently generated. While AD can recycle unavoidable food waste no longer fit for human or animal consumption, preventing food waste at source saves nine times more emissions than sending it to AD and 40 times more if the land saved is used for reforestation¹⁷¹. Policy needs to ensure that food waste prevention followed by diversion to animal feed, are financially and logistically more attractive to those producing food waste. If not, incentivising food waste-based AD risks disincentivizing the prevention of food waste.

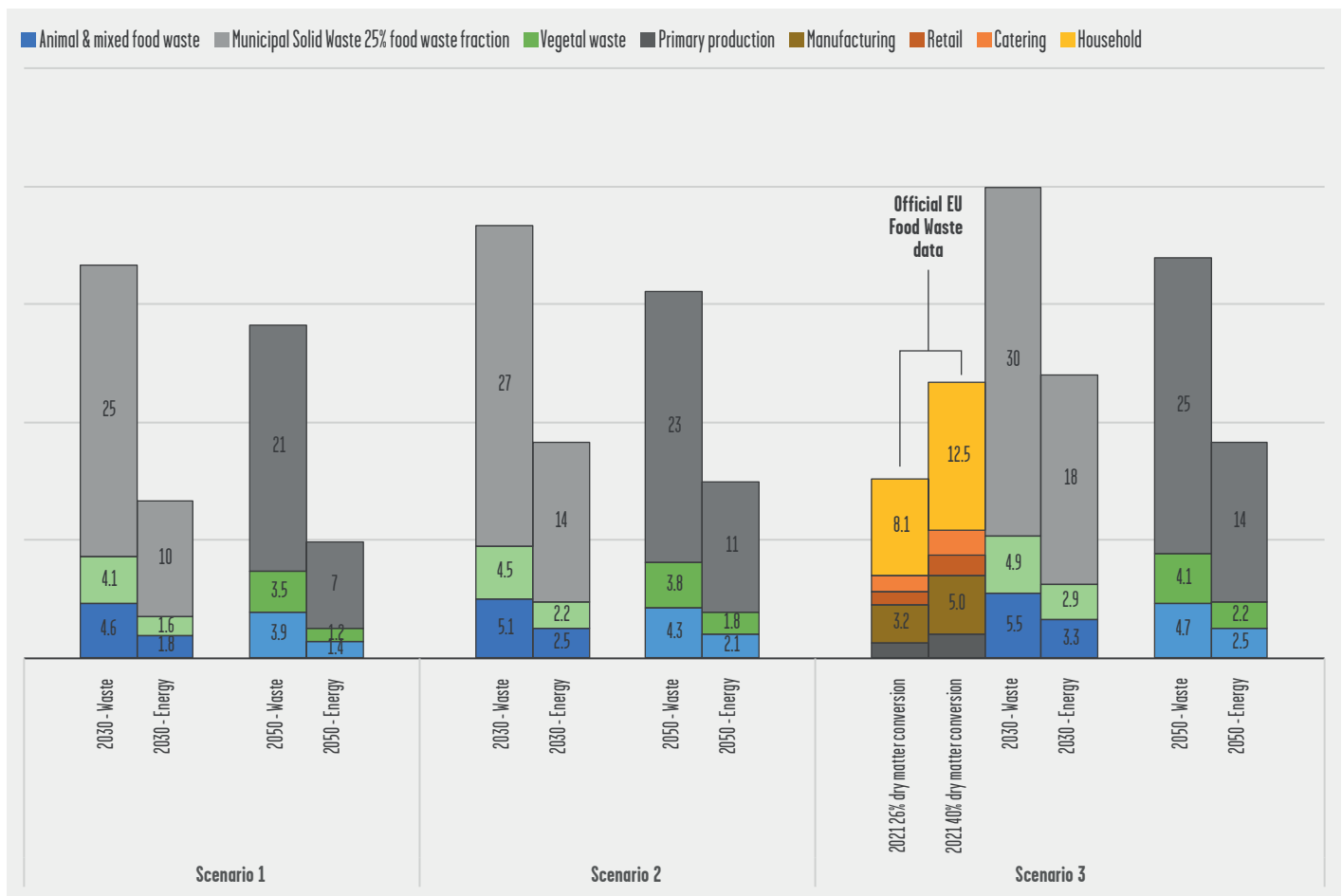
According to the gas industry report, the food waste fraction of biowaste that is not mixed with municipal solid waste is considered to be suitable feedstock for AD. The estimates are based on projected mixed food waste and vegetable waste volumes in a study by Imperial College London (ICL)¹⁷² commissioned by the oil and gas industry^x. This study only considers biowaste available after recycling ambitions of the Circular Economy Package are applied, and thus assumes that by 2030 60% of municipal waste will be recycled. Once these recycling targets are applied, the gas industry study proposes that 60% of the unrecycled municipal solid waste, including the food waste fraction, will be used as a feedstock for thermal gasification. Analysis of thermal gasification as a biomethane production technology is out of the scope of this report (even though independent analysis is urgently required).

Of the categories of mixed food waste and vegetal waste^y, it is then assumed that of the total waste collected separately, 60% would be available for AD in 2030 and 55% in 2050. Data in these calculations are in dry tonnes. As the ICL study was published in 2021 it seems it was not able to consider the specific food waste data that are now reported by the EC. According to the methodology explanation in the ICL study, current competing uses for biowaste (ie already going to recovery or treatment) were considered to be unavailable for AD. But any biowaste currently going to incineration (with or without energy recovery) or to landfill was considered available, after the 60% recycling ambition was applied. This means that any food waste suitable for human or animal consumption that is currently sent to incineration or landfill would go to AD instead.

x Study commissioned by Concawe whose members range from multi-national oil and gas Companies that operate in exploration and production, refining, and chemicals, to European regional and National Companies operating one or more refineries in the EU, UK, Norway or Switzerland. <https://www.concawe.eu/about-us/membership/>

y We believe 2018 or 2019 Eurostat data were used as the baseline

Figure 13: Comparison of EU food waste data with the data used by the gas industry to calculate food waste availability as biomethane feedstock in million tonnes dry matter.^z



Vegetal and mixed food wastes are assumed to be suitable for anaerobic digestion and municipal solid waste for thermal gasification^{aa}. The report commissioned by the gas industry on biomass availability envisages three different scenarios, with each scenario showing a decrease of overall waste production from 2030 and 2050. Scenario 1 assumes least ambition in terms of recycling and separate collection, while Scenario 3 assumes the most ambitious separate biowaste collection practices. The gas industry calculations for the 35bcm biomethane target are built on Scenario 3, thus assuming the most ambitious separate collection rates. The yellow-red bars represent current food waste data as reported by Eurostat. The bar “2021 26% dry matter conversion” converted EU food waste data from fresh to dry

^z Figure 13 elaborated by author based on supplementary data provided with Calliope Panoutsou and Kyriakos Maniatis, “Sustainable Biomass Availability in the EU” (Imperial College London, 2021) (available at <https://www.concawe.eu/wp-content/uploads/Concawe-Sustainable-biomass-availability-in-the-EU-final-version.xlsx>). Data for animal & mixed food waste, and vegetal waste were directly copied from this study. Data for municipal solid waste were converted by a factor of 0.25 to reflect the food waste fraction as recommended by the EC Joint Research Centre. See Caldeira, Carla, et al. “Grown and thrown: Exploring approaches to estimate food waste in EU countries.” Resources, Conservation and Recycling 168 (2021): 105426. The 2021 food waste data represent the totals as reported on Eurostat https://ec.europa.eu/eurostat/databrowser/view/env_wasfw/default/table?lang=en.

^{aa} On the whole, the projections for thermal gasification feedstock are outside the scope of this report. However, given that municipal waste contains food waste, we consider municipal waste here.

by a factor of 0.26 as reported in the scientific literature¹⁷³, whereas the “2021 40% dry matter conversion” used a factor of 0.4 as suggested by food waste measurement experts at JRC.

As shown by figure 13, **the volumes of food waste assumed to be available as biomethane feedstock in the gas industry report are higher than the total amount of food waste currently generated.** This reflects the fact that *neither the ICL study nor the gas industry study appears to mention the ECs food waste reduction policies and targets.* EU member states have signed up to halve food waste by 2030, in line with Sustainable Development Goal (SDG) 12.3. This goal should be interpreted as a 50% reduction in all food loss and waste from farm to fork, not just food waste at the retail/consumer-level according to guidance by Champions 12.3^{ab}. The Commission has proposed less ambitious targets to reduce food waste in processing and manufacturing by 10% per capita, and in retail, restaurants, food services and households by 30% per capita by 2030 against a 2020 baseline¹⁷⁴. The European Parliament and Council will now develop proposals for amendments before final targets are agreed by triologue negotiations.

The European Parliament has previously voted in favour of more ambitious targets to reduce food loss and waste, from farm to fork, by 50% by 2030¹⁷⁵ – and there is strong pressure from civil society to maintain this level of ambition so the EU meets its obligations under SDG 12.3¹⁷⁶. Whatever the level of legally binding targets eventually agreed, many member states will likely aim to maintain their ambition of meeting the SDG of a 50% reduction. This will limit the availability of food waste feedstocks for AD. In an earlier 2022 document on achieving the 35bcm goal, the European Biogas Association stated that they “expect to see increased supply of food waste”¹⁷⁷. We assume that the EBA does not mean an actual increase in food waste, but rather better separate collection. Even so, **it would be advisable that the biogas industry more explicitly highlights the food use hierarchy and how it will ensure that AD demand for food waste does not divert from efforts to prevent food waste occurring in the first place. To prevent a lock-in of avoidable food waste as biogas feedstock, new biogas industry projections should start from ambitious food waste prevention targets at source.**

BOX 8: MEAT INDUSTRY FOOD WASTE

A Swedish study found that “almost half of the edible byproducts in 2020 (such as offal, fat, blood, feet and tail) that had potential for human consumption, did not become food. This is mainly due to low demand and lack of export channels. Most of this goes instead to biogas/waste.”¹⁷⁸ Another study found that if German households substituted part of their prime meat cuts with quality edible offal, assumed to be 50% of all the offal which is currently used in animal feed, AD or thrown away, German meat supply chain GHG emissions could reduce by 14%¹⁷⁹. By way of comparison, halving current meat consumption (without a change in consumption of offal) reduces GHG emissions by 32%. This again confirms that there is no alternative or tech fix out of the essential need to reduce meat consumption, but it also highlights the missed opportunity in not consuming highly nutritious food currently wasted or going to AD.

ab Champions 12.3 is an international coalition of executives from governments, businesses, and civil society leading global food waste action. EU policymakers are currently debating the introduction of legally binding food waste reduction targets for EU member states. <https://champions123.org/>

Furthermore, there is evidence that a focus on disposal practices, such as recycling or composting, often undermines people's motivation for waste prevention¹⁸⁰. Recycling may even induce an increase in waste production by mitigating the guilt associated with wasteful consumption¹⁸¹. For example, it has been shown that the efficacy of attempts to reduce food waste in a cafeteria via an information campaign can be undermined when diners are told that their wasted food is composted to reduce methane emissions. This suggests a crowding out effect or informational rebound effect in which promoting policies that mitigate the environmental damages of food waste may unintentionally undermine policies meant to encourage individual consumer food waste reduction¹⁸². Therefore, **information campaigns to encourage food waste separation by explaining that food waste can be valorised into fertiliser and biogas**, such as the one in Paris, shown in figure 14, **may undermine food waste prevention efforts**.

In other words, the call for a "binding reduction target on the amount of bio-waste included in mixed/residual waste" as supported by the biogas industry¹⁸⁴, needs to be accompanied by very strong food waste prevention measures.

The bioeconomy, which can use food residue streams as a feedstock is projected to grow rapidly in the future, having generated 2.2 trillion euros in Europe with 18.6 million people employed in 2014¹⁸⁵. A study examining 149 examples from the scientific literature found that inedible, unavoidable waste from food processing activities was shown to have great potential for producing high-value chemicals ranging from platform chemicals like acids to bio-based materials like bioplastics¹⁸⁶. However, just like biogas, we need to approach these technologies cautiously because some of the production processes are energy-intensive and end up having larger environmental impact compared to the problem they purported to solve¹⁸⁷.

With regard to using unavoidable food residues no longer fit for human consumption as animal feed, ongoing research and development is happening in multi-stakeholder initiatives with livestock industry involvement in the Netherlands¹⁸⁸ and Australia¹⁸⁹. Existing experience in Japan shows how mixed food wastes can be heat-treated in specialist off-farm processing facilities to deliver safe feed for non-ruminant omnivorous livestock such as pigs and chickens. Around 40% of Japanese food waste is kept within the food system in this way. Various life cycle assessments demonstrate that the animal feed use of unavoidable food waste that can no longer be donated is environmentally preferable to using it in anaerobic digestion^{190 191}. Furthermore, feed made from specially processed unavoidable food waste together with significant reductions in livestock production could help halt imports of deforestation-risk soya¹⁹². Still, **while sending unavoidable surplus to animal feed is preferable to sending it to AD, prevention of food waste at source results in vastly superior greenhouse gas savings, land sparing and other environmental benefits**.

Badly designed support for biomethane can create perverse incentives undermining waste prevention. For instance, if waste collection costs (gate fees) charged by AD plants are too low – potentially enabled by excessive subsidies – then this lowers the cost of food waste disposal, disincentivising prevention. A potential solution to this is to heavily tax or ban sending food waste to landfill and incineration and set a mandatory minimum floor price

Figure 14: Cut-out of a Paris city infographic: "By disposing of our food waste separately, we can valorise [the waste] into natural fertiliser and into biogas to fuel buses"¹⁸³



which AD and composting plants charge for food waste collection – this would increase AD plant income, reduce reliance on subsidies, and incentivise food waste prevention.

BOX 9: ANIMAL FEED PRODUCERS SOUND THE ALARM ON AD COMPETITION FOR FEEDSTOCKS ^{193,194}

The European Feed Manufacturers' Association (FEFAC) has expressed concern that the supply stream of co-products traditionally used in animal feed is increasingly being diverted away from the feed industry and into the biomethane sector. This is happening because of financial incentives and policy boosting biomethane, which combined with rising energy prices affects animal feed co-product suppliers. For example, in France, producers claim it is no longer viable to dry sugar beet pulp and therefore "they are making noise about selling the pulp to biomethane players".

Similarly, the Italian animal feed producers' organization ASSALZOO has called on the Italian government to ensure that the food-feed-fuel hierarchy is respected and to not "endanger the animal feed sector by [...] incentives that reward the use of food industry by-products for energy purposes [...] causing a serious loss of resources necessary to guarantee the food safety of our country". Italian feed manufacturers underline the role they play in the circular economy by valorising about 9 million tons per year of products such as cereals bran, sugar molasses and beetroot pulp, and by-products of baked goods and pasta industry. While understanding the Government's urgent action on energy policy following the war in Ukraine, ASSALZOO firmly rejects the measure that promotes food by-product use as AD feedstock judging it to be a shot in the foot that will hit Italians in their pockets and their bellies.

In the words of FEFAC's secretary general "if the EU makes diverting co-products into the bioenergy sector economically more attractive than supplying animal feeding systems, then critical nutrient streams will be lost, and the EU feed circularity and sustainability agenda will be severely hindered". FEFAC is advocating for **the establishment of a clear hierarchy for nutrient-rich biomass usage, prioritizing the uptake of nutrients by the food chain over non-food users**. "We have engaged with the whole bioenergy sector on this, and we are all calling for a biomass balance sheet given that we are all currently navigating in the dark. We have requested DG Agri to provide an assessment of biomass flows as it is best placed to build on the existing EU cereals and protein balance sheets. We want it to **assess all organic matter, in terms of supply streams, and look at all users of such biomass, both non-food as well as food and feed sectors**. Looking at food waste, what the bioenergy sector considers agriculture residues, we consider co-products – thus, it is also a matter of getting the terminology right so that we are not talking at cross purposes when we discuss feedstocks".

5.2. INDUSTRIAL WASTEWATER

KEY MESSAGE

Pre-treating wastewaters heavily loaded with organic matter via anaerobic digestion reduces the need for energy intensive conventional treatment. However, half of the wastewaters for AD are expected to come from biodiesel production when Europe already burns nearly 19 million bottles of rapeseed and sunflower cooking oil every single day. Consumption of vegetable oil for biofuel production is expected to increase by 46% to 54 million tonnes by 2027. In other words, 4.5% of the 2030 biomethane feedstock is based on an industry which is a major driver of food-feed-fuel competition. For certain other food industry wastewaters, we need to consider other demands such as the animal feed sector.

According to the European Biogas Association (EBA), “Many industrial sectors such as beverage, food and paper companies produce wastewaters which are heavily loaded with organic matter. Therefore, before discharging a purification step is required. The currently widely applied activated sludge process ... has a high energy consumption... In an anaerobic pre-treatment step a major part of the organic load can be converted to biogas, reducing the waste load of the water while producing biogas and the need for the energy-intensive aeration as well.”¹⁹⁵

The gas industry report suggests that by 2030, 9% of biomethane will come from industrial wastewaters by accessing 30 to 40% of total available wastewaters as identified in Eurostat, depending on the country. By 2050, it is expected that all industrial wastewaters will be used in anaerobic digestion, making up 12% of biomethane production. Table 2 lists the food manufacturing processes from which wastewaters arise that can be used in anaerobic digestion, based on an EBA industrial wastewater working group report¹⁹⁶.

Table 2: Food and energy industries producing wastewaters suitable for AD^{ac}

Wastewater production process	Biogas potential (TWh/year)	
Dairy (cheese, milk, icecream)	3.8	3%
Beer, wine, spirits	7.1	5%
Ethanol	8.5	6%
Pulp	33.5	24%
Rendering meat (bovine, pig, sheep)	5.3	4%
Vegetable oils	11.9	8%
Biodiesel	68.3	48%
Other (juice, yeast, sugar, potato processing, ...)	3.4	2%
Total	141.8	100%

5.2.1. BIODIESEL AND ETHANOL WASTEWATERS

Nearly half of the biogas production potential from industrial wastewaters is projected to come from biodiesel. This means that wastewaters from biodiesel are expected to deliver 4.5% of the 2030 biomethane potential in the Gas for Climate report, and 6% of the 2050 biomethane potential.

However, according to the International Energy Agency (IEA), biodiesel producers are headed for a feedstock supply crunch during 2022-2027¹⁹⁷. The share of vegetable oil production for biofuel demand is expected to rise from 17% to 23%. In the United States, this increase in demand is already reducing

ac Aggregated from detailed table provided in EBA “The role of Biogas Production from Industrial Wastewaters”.

soybean oil export estimates, ultimately resulting in a reduced supply of vegetable oil globally. Used cooking oil and animal fats are unlikely to provide relief, as they are in even higher demand because they offer lower GHG emissions intensity and meet EU feedstock requirements. In fact, demand for used cooking oil and animal fats nearly outstrips all estimated supplies. **In the EU, this means more rapeseed oil for biodiesel¹⁹⁸, undermining the sustainability credentials of biomethane production reliant on the biodiesel industry** as a significant proportion of vegetable oil used as biodiesel is fit for human consumption¹⁹⁹. Each ton of biodiesel also produces 30,000 liters of wastewater²⁰⁰, adding further to the very heavy environmental footprint of biodiesel.

Based on the most recent 5-year average, Europe alone burns over 17,000 tonnes of rapeseed and sunflower oil every single day²⁰¹. Europe put 58% of all rapeseed oil and 9% of all sunflower oil consumed in its cars and trucks. Large volumes of soy and palm oil, major staple foods in other regions, are also diverted to powering road transport in Europe, 50% for palm and 32% for soy oil consumed in the EU²⁰². This has contributed to vegetable oils showing the highest price increases amongst all food products globally, even before the war in Ukraine²⁰³.

Potential ways forward discussed by the IEA seem to be highly problematic. For instance, corn ethanol from second-crop production in Brazil is proposed as a way forward, but as demonstrated by the ICCT, in Brazil these types of secondary crops are already well integrated into global food and feed markets; growing them for biogas would necessarily result in similar land use impacts as using primary crops for biofuel would. Similar issues arise with some European biofuel producers sourcing oilseeds grown on degraded terrain. If the oilseeds produce oil, then we have food-feed-fuel competition over land, regardless of the classification of the terrain. The mention of fish oil as an alternative biodiesel feedstock²⁰⁴ is alarming given all the issues of reduction fisheries and the very high demand for fish oil produced as a co-product of fish processing²⁰⁵. A similar issue arises for ethanol. As Russia was invading Ukraine and cereal supplies fell, Europe continued to turn 10,000 tonnes of wheat – the equivalent of 15 million loaves of bread (750gr) – into ethanol for use in cars²⁰⁶. The conflict between energy demand for cereals for ethanol production and food security has been demonstrated²⁰⁷. A briefing by Transport and Environment sets out the myriad of issues arising from the use of animal fats in biodiesel²⁰⁸.

5.2.2. FOOD INDUSTRY WASTEWATERS

For starters, volumes of dairy processing and animal rendering wastewaters would need adjusting to reflect reductions in consumption and production of farm animals, as discussed in section 4.1.2. Then we need to look at competing uses for these wastewaters. The biogas industry itself recommends that a wastewater hierarchy should be implemented to ensure optimal treatment and valorisation of wastewaters²⁰⁹. After producing as little wastewater as possible, nutrient recovery and reuse should be prioritised. It is predicted that by 2050, microbial protein, which can be made from wastewaters, could replace 10–19% of crop-based and animal-based protein²¹⁰. Researchers have also considered dairy wastewater as nutrient rich feedstock for the cultivation of algae biomass for use in animal and aquaculture feeds²¹¹. As with all such

high-tech solutions, thorough life cycle assessment and broad food system analyses need to be carried out to ensure that there are no unintended consequences. As such research develops it is important **to ensure that the biogas industry does not cause a lock-in of use of unavoidable wastewaters, especially if recovering them for food and feed generates more environmental benefits.**

It is not clear whether the volume projections on wastewaters from cheesemaking include whey. “The dairy industry produces large amounts of whey as a by- or co-product, which has led to considerable environmental problems due to its high organic matter content. Sustainable whey management is mostly oriented to biotechnological and food applications for the development of value-added products such as whey powders, whey proteins, functional food and beverages, edible films and coatings, lactic acid and other biochemicals, bioplastic, biofuels and similar valuable bioproducts²¹².” **No doubt the biogas industry can play a role in the treatment of unavoidable wastewaters of certain industrial processes, but the volumes may need to be revised downwards for biogas to truly fulfill its sustainability ambitions.**

5.3. PERMANENT GRASSLAND

KEY MESSAGE

From a climate perspective, biomethane from grass feedstock does not measure up to other uses of this land. Compared with grass-biomethane transport fuel, solar electricity generation can avoid 16 times more fossil energy and afforestation can mitigate 6 times more GHG per hectare of land occupied²¹³.

In general, grass cut from permanent grassland was not considered a key feedstock in gas industry estimates as “there could be competing uses for the land in some countries. However, in Germany, there is already a significant amount that is not needed for feeding animals and that is used for biogas (around 2bcm), so it was included in the potential estimate for Germany specifically. It is important to consider lost opportunity costs by not reforesting grassland or using it for solar electricity generation. A study in *Nature Sustainability*²¹⁴ for example found that shifts in global food production to plant-based diets and using the spared land to reforest alone could sequester CO₂, equivalent to 99–163% of the CO₂ emissions budget, vastly improving our chances of averting catastrophic climate change. Reforesting land currently devoted to pasture in the UK could result in the removal of CO₂ equal to offsetting 9 years of current UK CO₂ emissions²¹⁵.

5.4. ROADSIDE VERGE GRASS

Roadside verge grass is expected to deliver 2% of biomethane feedstock by 2030. Mowing grasslands just once or twice per year can optimise species richness²¹⁶, however, we were unable to ascertain the number of times grassland would be mown in the gas industry calculations.

FURTHER RESEARCH NEEDED

An independent life cycle assessment and/or metareview of published LCAs and broader socio-environmental considerations needs to determine an order of preference for roadside verge grass / cascading usage for all types of demand (soil, biodiversity, food, feed, fuel, materials and others) for this biomass.

Detailed spatial analyses need to be carried out to ensure estimated biomethane potentials consider optimum environmental roadside verge grass removal rates in combination with adequate availability of year-round feedstocks in adequate proportions for high-yielding co-digestion and without creating perverse incentives for unsustainable feedstocks, such as manure from excessive animal farming.

5.5. SEWAGE SLUDGE

Anaerobic digestion is the best option for the treatment of **sewage sludge**, although digestate from this feedstock needs to be handled with care because of heavy metal concentrations²¹⁷ and the fact that AD is a relatively inefficient method for antibiotic resistant gene removal from sewage sludge²¹⁸.

5.6. WOODY BIOMASS FOR THERMAL GASIFICATION

The gas industry report projects an enormous volume of biomethane produced through thermal gasification of woody biomass by 2050. Analysis of the calculations and assumptions surrounding the different types of woody feedstocks is out of the scope of this report.

FURTHER RESEARCH NEEDED

An independent analysis is needed to determine the volumes of sustainable woody biomass of all types, along with all potential demands and uses of such biomass (including the use of woody biomass for ecosystem restoration, mushroom farming, the production of sustainable building materials to mention just a few) to create a woody biomass balance sheet. The potential demands for woody biomass must be compared through life cycle assessment and other studies to ensure a full understanding of the ecosystem, energy, building, social, climate and other functions of this woody biomass before prioritizing usage.

6. USING A SCARCE RESOURCE WISELY

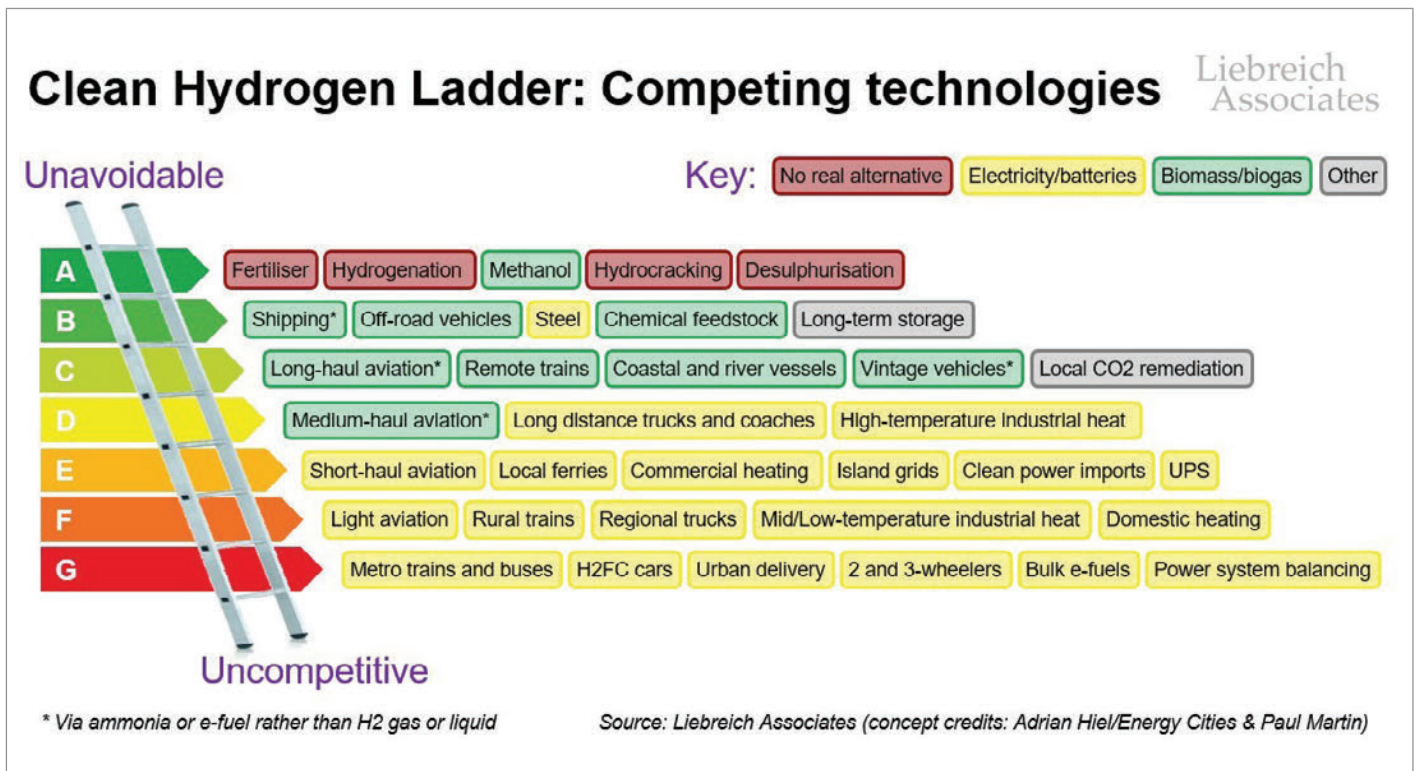
KEY MESSAGE

We must use the little biomethane that can be produced sustainably wisely. For starters, as in all energy planning, we must maximise energy savings and efficiency. That means the best possible insulation for buildings, drastically cutting down on plastic and travelling by bicycle, bus and train. However, piping biomethane into our homes instead of fossil gas or using it (as bio-CNG) to fuel passenger transport are probably some of the worst uses of a precious and scarce resource. Instead, biomethane will be required in (petro-) chemical production processes (eg. fertilisers, resins), and to help fuel maritime shipping and essential long-haul aviation, among other difficult-to-decarbonise sectors.

This report has shown that to be truly sustainable and genuinely contribute to mitigating climate change, volumes of biomethane will be much smaller than currently envisaged by the EC and the gas industry. This means that we need to carefully think about biomethane usage prioritization, and that reducing energy use must come first as set out in the EU's "energy efficiency first principle"²¹⁹.

While a specific usage hierarchy for biomethane must be developed, the clean hydrogen ladder shown in Figure 15 points us in the right direction.

Figure 15: The hydrogen ladder as a starting point for biomethane usage prioritization

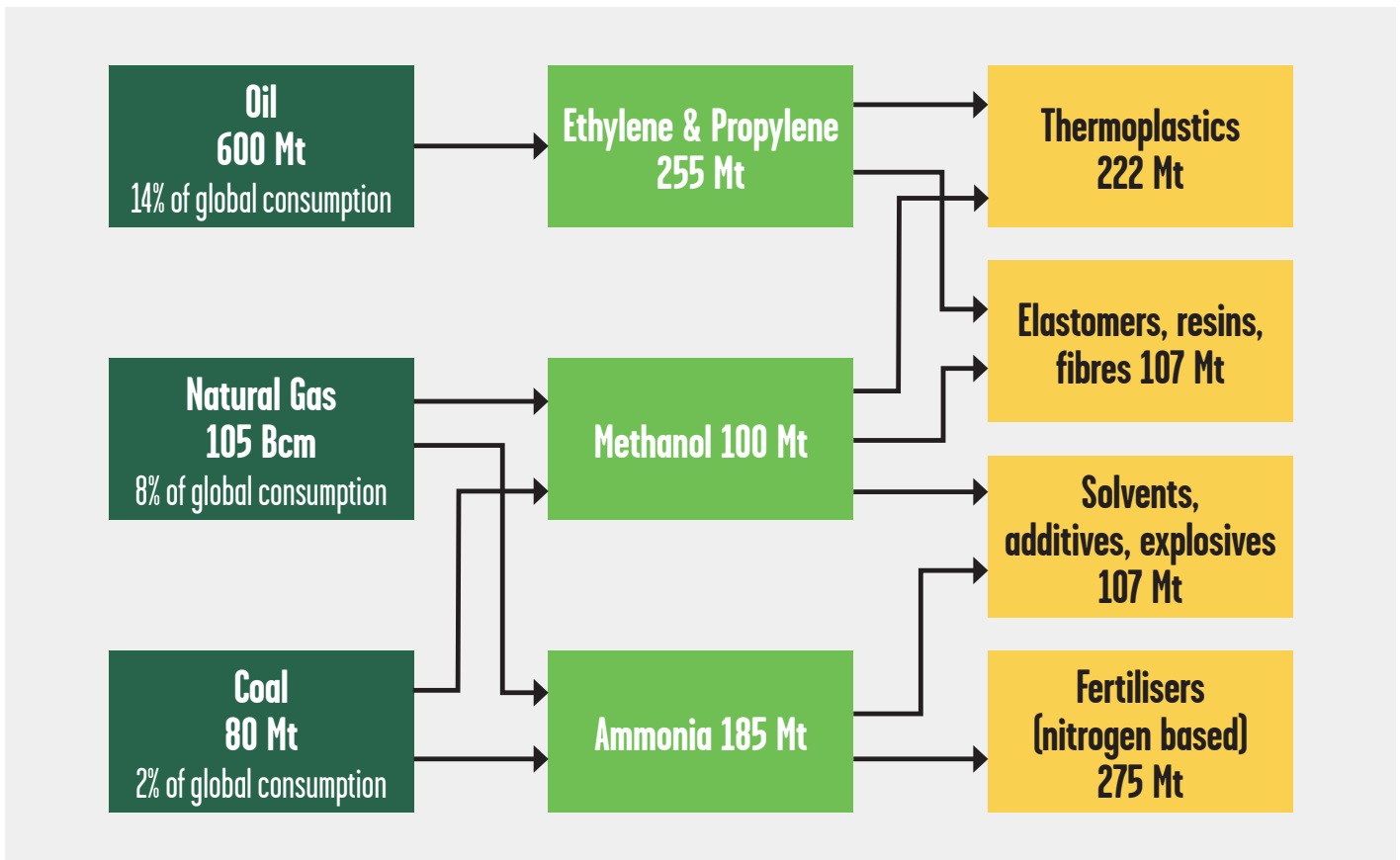


On the whole, the ladder is in line with the Group of Chief Scientific Advisors to the EC²²⁰ stating that “large-scale electrification as the most promising primary measure to improve efficiencies and radically reduce emissions for heating/cooling, transport and industry, whereas different approaches (e.g. hydrogen) will be limited to those sectors which are harder to decarbonise effectively such as agriculture, aviation, shipping and some heavy industries.” It is beyond Feedback’s expertise to provide a full analysis of all competing uses of biomethane, but a few highlights are useful to provide a reality check against the ambitions of the gas industry for biomethane to be injected into the gas grid to be used in domestic heating or for it to fuel passenger vehicles.

Chemical feedstock

Petrochemicals, which turn crude oil and natural gas into all sorts of daily products, are integral to modern societies and one of the “blind spots” in the global climate mitigation debate. The chemical industry is unique in its fossil fuels use²²¹. Fossil resources are used as raw material for a variety of widely used products like plastics, fertilisers, detergents or tyres. The chemical industry accounts for 14 per cent of the total primary demand for crude oil and 8 per cent for natural gas. Ammonia, methanol, ethylene, and propylene are the most important basic chemicals used as the starting materials for a large number of industrial downstream products. For example, nitrogen-based fertilisers are produced from ammonia, formaldehyde from methanol, and plastics using ethylene and propylene.²²² Although reductions in demand for plastics for example must be our priority, it is clear that petrochemicals currently using natural gas feedstock will require biomethane in order to decarbonize.

Figure 16: Fossil fuels, including natural gas as a chemical feedstock²²³



Maritime shipping



Credit: <https://www.bergebulk.com/berge-bulk-unveils-the-worlds-most-powerful-sailing-cargo-ship>

Green ammonia and green methanol (not derived from fossil gas), green hydrogen (using renewable electricity) and liquid biogas (from sustainable feedstocks) are options to decarbonize the maritime shipping industry because right now they seem more cost-effective, but electricity and batteries can still play their role with the right financial support²²⁴. In addition, we forget that a modern take on proven technologies can also play a role. As this report was being written, Berge Bulk, one of the world's leading dry bulk ship owners, launched its new cargo ship Berge Olympus "the world's most powerful sailing cargo ship"²²⁵ where high-tech sails will help the Berge Olympus save up to 20% of fuel on an average worldwide route. If we put our best minds to it, surely this technology can be developed to further reduce fuel consumption. LNG (liquefied natural gas) is not the solution for shipping; LNG engines are unable to meet the shipping industry's 50% reduction target without significant efficiency improvements and big reductions in methane emissions²²⁶. In the words of shipping giant Maersk's head of decarbonization: "I think it is borderline greenwashing to call LNG a transition fuel towards the decarbonization of shipping."²²⁷

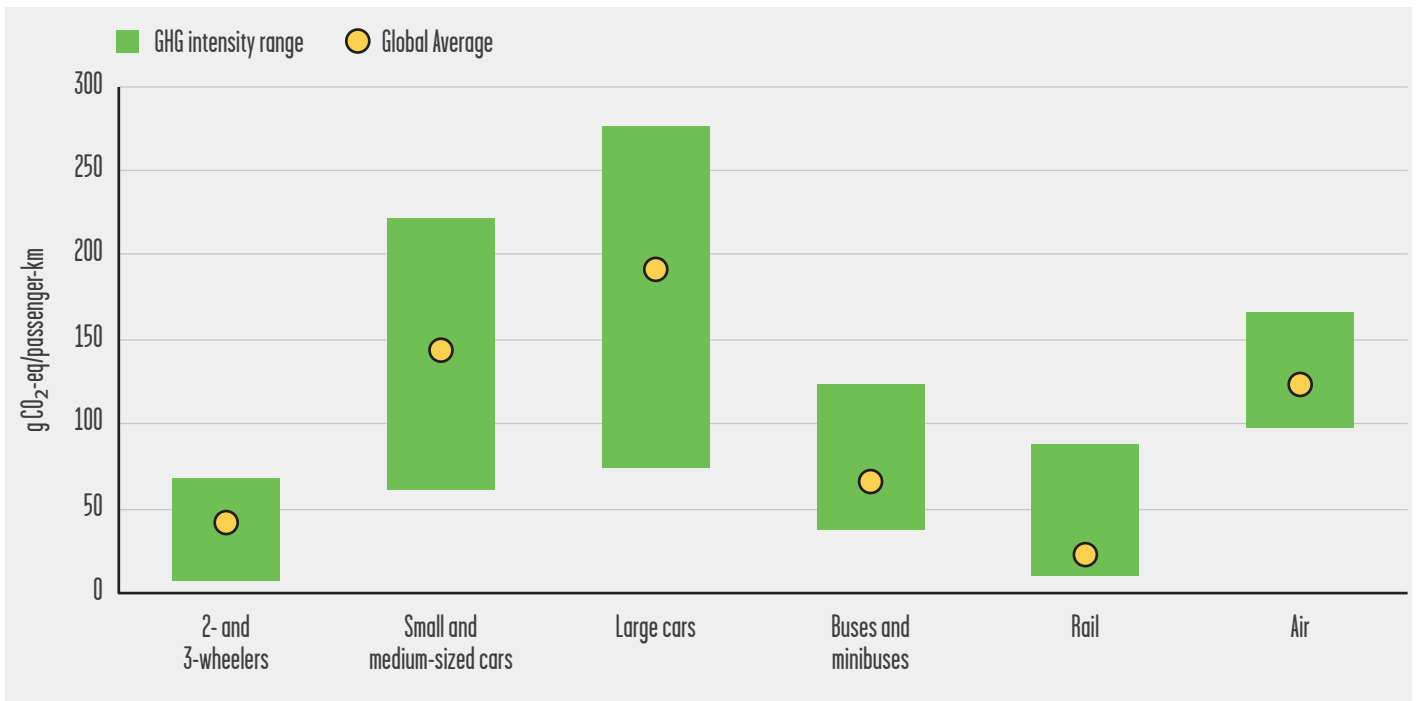
Power storage and peak demand management

"In the power sector numerous long duration storage technologies besides hydrogen are under development, including liquid air, compressed air, advanced geothermal, new battery chemistries, flow batteries and thermal storage, as well as balancing alternatives such as load shaping and interconnection. However, hydrogen may be more scalable than any other technology given its many applications outside the power sector."²²⁸ Nevertheless, it has been argued that we should not use renewable gases to deal with short-term grid imbalances, and that in many cases we should focus on smart software systems to balance supply and demand alongside batteries²²⁹. There may be a niche role that biomethane could play in terms of longer-term seasonal storage to balance supply and demand.

Public transport

We cannot discuss the use of biomethane as a transport fuel without first highlighting the need for hefty investment in public transport, this being the most obvious sector in which we can apply the “energy efficiency first principle”.

Figure 17: grams of CO₂ equivalent per passenger per kilometre. The bars represent the range of emission rates, the dots the global average²³⁰.



Please see Transport & Environment²³¹ for an excellent analysis of the challenges and policy recommendations to improve rail transport and mobility in cities²³².

BOX 10: TAXING EXTREME LUXURY TRAVEL²³³

The highest-polluting SUVs and luxury pick-up trucks emit up to 9 times more CO₂ than the average new car. Just 1% of people cause 50% of global aviation emissions. Private jets are up to 14 times more polluting than commercial planes. Long haul, mostly business travel, to places like New York or Singapore, accounts for over half of EU aviation emissions but is exempt from carbon pricing. One single yacht emits on average as much CO₂ as 366 cars a year. It is time to force super polluters to become part of the solution. Ban the circulation or docking of non-zero emission private jets and superyachts starting in 2030, and introduce weight and size limitations for cars to end the race to ever larger, heavier vehicles. Extend the EU Emissions Trading System to all EU flights, including flights going outside Europe.

Aviation

First, demand for short haul flying must be slashed through the massive deployment of quality, well-connected and affordable rail travel and a reduction in corporate travel – where the Covid pandemic showed the possibilities and new opportunities. Legislation must be introduced to minimize climate heating aviation contrails²³⁴. There is no justification for why airlines should be allowed to buy fossil jet fuel tax free, and why the majority of Europe’s aviation emissions should be exempt from the EU’s increasingly effective carbon

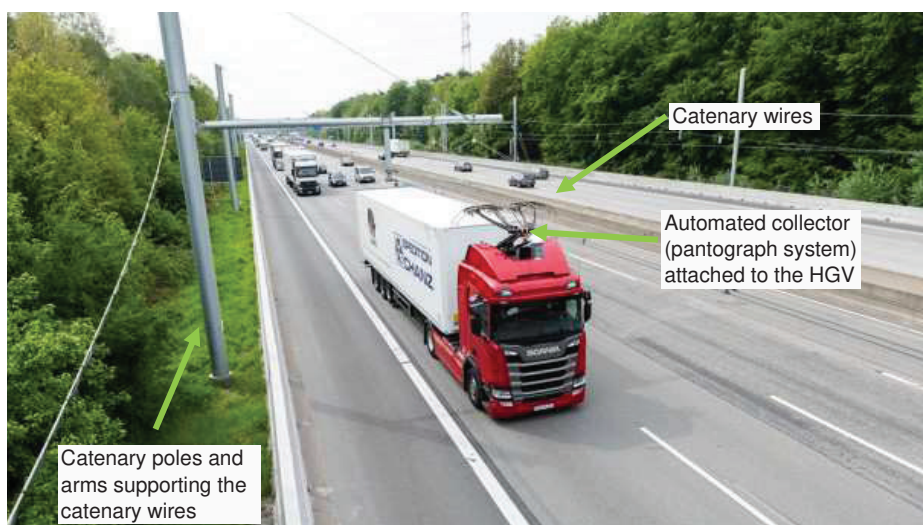
pricing mechanism²³⁵. Once all these demand-side issues are addressed we can consider the role biomethane could play as one of the feedstocks to produce sustainable aviation fuel. Careful life-cycle assessment needs to be done to ensure these fuels are truly part of the solution²³⁶. See section 4.1.3 for one such example of a life cycle assessment showing that aviation fuel made from animal-derived tallow does not deliver the expected climate benefits.

Cars

Even when deployment of affordable and user-friendly public transport has been maximized, people in certain personal or professional circumstances will need cars. The EU's Social Climate Fund should require countries to support social leasing of electric vehicles. Tax incentives should promote rightsized, resource efficient vehicles. The EU should introduce a new electric vehicle environmental standard that ends the race towards ever larger, heavier cars and encourages car makers to produce the compact, energy efficient, electric vehicles we need²³⁷. E-fuels, including bio-CNG make no sense for cars²³⁸. Battery vehicles are around 3.2 times more energy efficient than hydrogen fuel cell cars²³⁹.

Road freight

Shifting more goods to rail and waterborne transport, as well as optimising logistics processes can contribute to reducing freight emissions. Freight efficiency measures must come in addition to zero-emission vans and trucks moving goods on European roads. With technology quickly improving, cities demanding improved air quality and the recent announcements from European truck makers, zero-emission trucks will enter the EU market fast in the coming years. To speed up the switch, the deployment of an effective and comprehensive charging infrastructure network for battery electric trucks is key²⁴⁰. Transport & Environment provides more information on batteries and the environmental and economic performance of trucks²⁴¹. It takes about 3.3 times more electricity to power a hydrogen fuel cell truck than one running on an Electric Road System²⁴².



Photograph of a Scania HGV operating on a catenary lorry 'eHighway' demonstrator in Germany, from Siemens (2020) • Source.²⁴³

Not all systems would need to rely on batteries: a technoeconomic comparison between (a) fuel cell heavy good vehicles (HGVs) with public fuel stations supplying green hydrogen and (b) a system supplying electricity via overhead catenaries and compatible HGVs showed that the electric option is the more energy-efficient and cost-effective solution to decarbonise the UK's long-haul road freight network and would deliver competitive payback periods to both the infrastructure provider and fleet operators²⁴⁴. We must also bear in mind vans which now account for 13% of road transport carbon pollution in the EU. Emissions-free vans are ready, but due to weak CO₂ targets for van-makers, only 2% of the new vans sold in 2020 were electric – compared to 10% for cars. All new vans sold in the EU should be zero-emission at the latest by 2035²⁴⁵.

In sum, **land-based hydrogen and bio-LNG or CNG mobility will remain a niche application. Any low-pressure gas distribution grids that survive will be close to ports, where the refuelling and storage infrastructure could provide an impetus for the decarbonization of the maritime and aviation sectors**²⁴⁶.

Heating and cooling of buildings

The Group of Chief Scientific Advisors to the EC sees little role for hydrogen^{ad} or biomethane in the cooling or heating of buildings and instead points to efficiency improvements such as insulation and ventilation control, changes in building design (orientation, layout, passive systems such as natural ventilation and cooling, thermal mass, external shutters) with the resulting reduction in energy consumption combined with the use of heat pumps²⁴⁷. Even with today's electricity mix, heat pumps can reduce emissions in most of the world's regions²⁴⁸.

In sum, **gas distribution grids need to prepare for a disruptive end to their business model, because net-zero scenarios see very limited hydrogen²⁴⁹ and biomethane in buildings.**

ad For hydrogen, a meta-review concluded that “widespread use of hydrogen for heating is not supported by any of the 32 studies identified in this review”. Rosenow, Jan. “Is heating homes with hydrogen all but a pipe dream? An evidence review.” *Joule* (2022). <https://www.cell.com/joule/fulltext/S2542-4351%2822%2900416-0>

7. CONCLUSION

This report has shown that from a sustainability and feasibility perspective, much less biomethane may be available than was hoped for by European policy makers. Policy makers need to urgently broaden their scope of evidence and expertise to include a sustainable food system perspective and will need to carefully reduce targets for each feedstock so that targets consider critical issues such as dietary change and prioritization of waste prevention. Further reductions may be necessary in light of spatial analyses determining adequate availability of feedstocks for efficient year-round anaerobic digestion. This report has also highlighted competing demands (most of which are environmentally preferable) for various feedstocks and serious risks around soil health and food and feed crop yields resulting from the combined impacts of manure, sequential crop and agricultural residue feedstocks if produced in line with gas industry assumptions. Having said this, there is a niche role for the biogas and biomethane industry to play: smaller amounts of manure and industrial wastewater will benefit from AD treatment, as will sewage sludge, some agricultural residues and unavoidable food waste that cannot be used in animal feed.

What does this mean for the EU's climate targets and ambition to reduce dependence on (imported) fossil fuels? How will we cope without the "biomethane magic bullet"? The good news is: we don't need to. Independent experts²⁵⁰ designed a structural transition pathway away from fossil gas use by 2050 based on detailed sectoral modelling of the energy, buildings and industry sectors, as an alternative to RePowerEU. This alternative to RePowerEU is called the "*EU Gas Exit Pathway*"²⁵¹ and shows that Europe can structurally reduce the consumption of fossil gas by 2027 by an amount that is equivalent to gas imports from Russia before the war in Ukraine. Europe could eliminate its dependency on fossil gas from Russia even earlier if industry were to sustain efforts to save energy, similar to those seen in winter 2022-2023. **In the "*EU Gas Exit Pathway*", biogas and biomethane consumption is calculated to be around 20bcm.** Overall, the EU Gas Exit Pathway foresees lower demand for fossil gas, biomethane, hydrogen and hydrogen derivatives than other long-term scenarios by the European Commission. Thanks largely to increases in domestic renewables-based hydrogen production, **energy import dependency in the EU Gas Exit Pathway quickly declines from 79% today to 29% in 2040^{ae}.** The gas industry study²⁵² analysed in detail in this report, and other projections prepared by gas grid operators foresee large investments into fossil gas infrastructure (for example to connect new AD plants to the grid), which would lead to significantly higher system costs and grid tariffs in future years and raises the risk of stranded assets²⁵³. In contrast, the *EU Gas Exit Pathway* suggests the need to prepare for a managed downsizing of fossil gas infrastructure to contain energy-system costs and tariffs.

Similar to Feedback's analysis, the *EU Gas Exit Pathway* research suggests that **several targets in REPowerEU set in a rush under enormous political pressure without proper impact assessment should be critically reviewed.** Feedback's analysis adds further climate-critical elements into

ae The REPowerEU plan achieves higher fossil gas reductions by 2030 (-67% vs 2018 levels) than the EU Gas Exit Pathway (-47% vs 2018 levels). However, modelling for the REPowerEU plan shows that this somewhat faster fossil gas phase-down comes at the expense of oil and coal use that is higher than anticipated in the Fit for 55 package. This counter-acts most of the positive climate effects of the accelerated fossil gas phase-down. The EU Gas Exit Pathway, in contrast, achieves faster oil and coal reductions and thus also accelerated emission reductions compared to REPowerEU.

the mix for policy makers to urgently consider: First, the shocking disregard of the scientific consensus on the inescapable fact that for climate *and* health reasons we need to reduce animal farming and meat, egg and dairy consumption, as recently underlined by the Group of Chief Scientific Advisors to the EC²⁵⁴. This disregard is extremely relevant given that one third of the biomethane target rests on manure as a feedstock.

Second, the role of methane leakage in undermining any theoretical climate benefits from feedstocks that would otherwise not have emitted methane. For example, untreated sewage sludge will emit methane, so it is a good idea to capture it. In contrast, anaerobically digesting purpose-grown crops, whether they are primary or secondary crops, results in the intentional creation of additional methane to the extent that crop-based biomethane may not meet the Renewable Energy Directive Fossil Fuel Comparator limits. When we add in the constant underestimation of the horrific atmospheric impact of methane emissions in the early years after emission, the 35bcm biomethane target may well end up contributing to climate change as opposed to helping mitigate it. Let us set a new biomethane target, one that allows it to play its important, but niche role, in a truly decarbonized future within a sustainable, healthy and just food system.



Manure lagoon at Broadley Copse Farm, Funtington, Sussex • Credit: Farms Not Factories

SUMMARY OF FURTHER RESEARCH NEEDS

- a. Independent life cycle assessment to establish the sequential crop yields, cultivation parameters (tractor fuel, potential fertiliser or pesticide use, etc) and AD methane leakage rates that would ensure compliance with the fossil fuel comparator limit as established in the Renewable Energy Directive. In addition, given the extremely powerful climate impact of methane in the short-term, such an LCA should calculate Global Warming Potential for a 20-year timespan.
- b. Independent agricultural and food system expert assessment to determine at which yields and in which climatic, soil and other relevant local circumstances sequential crops can be produced without directly, or indirectly, impacting the primary food or feed crop, water availability or land use.
- c. Investigate the exact methane emission parameters adequate for biogas and biomethane that would need to be incorporated in the proposed EU Methane Emissions regulation.
- d. Compare member-state biomethane feedstock projections with EU-wide industry numbers.
- e. An independent analysis on the volumes of sustainable woody biomass of all types, along with all potential demands and uses of such biomass (including the use of woody biomass for ecosystem restoration, mushroom farming, the production of sustainable building materials to mention just a few) to create a woody biomass balance sheet. The potential demands for woody biomass must be compared through life cycle assessment and other studies to ensure a full understanding of the ecosystem, energy, building, social, climate and other functions of this woody biomass before prioritizing usage.
- f. Life Cycle Assessment of biogas and digestate as co-products of meat and dairy, with sensitivity analyses looking at manure taking on an increasing economic value within the farm business model, building on a research precedent set by the FAO and JRC which looked at manure-fertiliser as a co-product of livestock farming²⁵⁵.
- g. Completion of the biomass balance sheet harmonising data on the supply and food, feed, fuel, fiber and other demands of all biomass streams in the EU. Like the food recovery hierarchy, an interdisciplinary science-based biomass use hierarchy should be established. After prioritizing waste prevention at source, such a hierarchy should allocate available supply according to human and animal well-being, climate and environmental goals. Such a biomass use hierarchy should also be informed by:
 - an independent life cycle assessment and/or metareview of published LCAs to determine an order of preference / cascading usage for crop residue, roadside verge grass, woody biomass etc for all types of demand (soil, biodiversity, food, feed, fuel, materials and others) for this biomass.
 - Detailed spatial analyses to ensure estimated biomethane potentials consider sustainable crop residue removal rates in accordance with local conditions and year-round availability of feedstocks in adequate proportions for high-yielding co-digestion and without creating perverse incentives for unsustainable feedstocks, such as manure from excessive animal farming.

ANNEX A: BACKGROUND AND SPECIALISATION OF CONSULTANTS THAT DEVELOPED THE EUROPEAN COMMISSION'S ASSESSMENT

The 2021 study *“Assistance to assessing options improving market conditions for biomethane and gas market rules”* commissioned by the European Commission was carried out by the following consultants:

ARTELYS

www.artelys.com

Artelys is an independent company specialised in optimization, decision support and modeling. “Through a high-level expertise in quantitative techniques, our consultants design suitable solutions to the needs of their customers. They operate in diversified sectors such as energy, transportation and logistics.” It offers solutions in the following sectors:

- Optimization
- Data science
- Smart city
- Energy: Prospective studies
- Energy: Operational solutions
- Energy: Market clearing
- Oil & Gas
- Supply Chain & Scheduling
- Transportation & Mobility

TRINOMICS

trinomics.eu

Trinomics B.V. is a consultancy firm offering bespoke policy advice related to energy, environment and climate change issues. Trinomics “carries out independent research for international, European and national public sector bodies and NGOs, delivering high quality research to tackle some of the most pressing societal issues of our times. Our analytical approach takes place through an economic lens, providing our clients with a solid

foundation to base their strategies and policies upon. As such, we pride ourselves on delivering clear, concise and accessible reports to facilitate the transition to a sustainable future.”

The Trinomics experts who worked on the EC assessment were specialized in the following areas:

- governance of the energy transition, energy infrastructure regulation, energy & environmental taxation, energy technology innovation and supply chains, regulatory innovation, and energy systems modelling
- large experience in the Belgian electricity and gas sector
- energy transition, industrial decarbonization and broader climate policy, experience on policy analyses (evaluations, impact assessments), energy infrastructure (gas, electricity), renewable energy support schemes, carbon pricing and sectoral emission reduction pathways (e.g. in agriculture).

FRAUNHOFER

fraunhofer.de/en.html

The Fraunhofer-Gesellschaft, based in Germany, states that it is the world’s leading applied research organization. Fraunhofer has very wide research expertise, but from what we have been able to discern, the experts who worked on the EC assessment were specialized in

- wind energy
- energy system analysis
- energy process technology
- biogas

ANNEX B: CO-DIGESTION VERSUS MONO-DIGESTION

The academic studies underlying the gas industry projections on manure and sequential crops appear to have based their calculations on the assumed mono-digestion of each of these feedstocks. Drawbacks of mono-digestion are digester instability, limited year-round availability of some feedstock, presence of heavy metals and low biogas /methane yield²⁵⁶. Mono-digestion of manure is often not viable because of its very low energy density – which means large volumes are required. Mono-digestion of manure also often leads to ammonia toxicity but this can be prevented through co-digestion with carbon rich feedstocks. Moreover, while there are still many technological challenges, benefits of co-digestion include enhanced system stability and methane yield through better nutrient balance, a more diverse microbial community, dilution of toxic compounds, safe and better quality digestate for agricultural applications²⁵⁷.

The mono-digestion of crops which are proposed to be grown as sequential crops – sorghum, triticale, ryegrass, barley, oats²⁵⁸ and maize²⁵⁹ comes with challenges similar

to other lignocellulosic²⁶⁰ feedstocks, which are described as highly recalcitrant feedstocks due to their slow rate of hydrolysis²⁶¹. These feedstocks either require costly pre-treatments or co-digestion with other types of feedstocks. For instance, one recent paper highlights the need to co-digest maize with manure as the digester otherwise loses stability due to lack of trace elements²⁶². Similarly, another study looking at mono-digesting of sorghum reported poor performance without nutrient supplementation. Serious deficiencies in copper and sulfur were confirmed by nutrient analysis of dry sorghum and digestate. To maintain stable methane fermentation and achieve best yield potentials, suitable supplementations of copper and sulfur are recommended for anaerobic sorghum mono-digestion²⁶³. Research into the extent to which tech solutions to the problems of mono-digestion have been operationalized at commercial level is beyond the scope of this report, but in any case, more and more biogas plants intend to use multiple feedstocks to improve their digestion process performance²⁶⁴.

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All reasonable attempts have been made to verify the nature and status of the primary and secondary sources collected here in good faith and in the public interest. Any opinions expressed are honestly held and based on facts true at the time of publication.

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