



Biogases

Europe's overlooked path to energy independence?

Reassessing sustainable production potential

April 2026

 **Guidehouse**

Imprint

Copyright

© 2026 Guidehouse Europe Ltd.

Authors

Sacha Alberici, Gemma Toop,
Shanon Peeters and Jaap Peterse

Date

April 2026

Contact

Guidehouse
1 Angel Court, London EC2R 7HJ
United Kingdom
+44 20 3880 0800
guidehouse.com

Photo credits

Cover credits: borchee

Design

Annemiek Schellenbach | byannem.nl
and Guidehouse

Table of Contents

Executive Summary	1
1. Introduction	5
2. Production potential in Europe	6
2.1 Feedstock and technology selection	6
2.2 Biomethane potentials in 2030, 2040 and 2050	8
3. Calculation methodology	12
3.1 Methodology and data updates	12
3.2 Marginal and contaminated land.....	13
3.2.1 Methodology	13
3.2.2 Results.....	17
3.3 E-methane production from biogenic CO ₂	19
3.3.1 Methodology	21
3.3.2 Results.....	24
4. Feedstock mobilisation	25
4.1 Wastes and residues	27
4.2 Sustainable crops.....	29
4.2.1 Sequential crops	29
4.2.2 Marginal land, contaminated land and abandoned land	32
4.3 Biogenic CO ₂	36
5. Feedstock competition	38
5.1 Anaerobic digestion.....	38
5.1.1 Wet organic waste feedstocks	38
5.1.2 Agricultural residues	39
5.1.3 Sustainable crops	40
5.2 Thermal gasification	41
5.2.1 Woody biomass	41
5.2.2 Organic fraction of Municipal solid waste	42
5.3 Overall assessment.....	43
Appendix A. Biomethane production potentials in 2030, 2040 and 2050	A-1

Executive Summary

Biogases are a scalable energy vector contributing to Europe's energy independence.

Biogases will play an important role in the European Union's (EU) ambition to be resilient, competitive and to achieve a net zero future by 2050. In 2022, the European Commission established a political target in the REPowerEU plan to produce 35 billion cubic metres (bcm) of biomethane annually by 2030 in the EU¹. This objective aims to enhance energy security and support net zero goals by providing a renewable, domestically-produced source of gas that can directly substitute fossil natural gas across multiple sectors of the economy.

Despite progress since 2022, current developments show that the EU is not on track to meet this target. Although the underlying potential in Europe is sufficient to meet the target, further action is required to mobilise resources and scale this strategic domestic industry through 2030 and beyond, enabling it to reach its full potential by 2050.

In 2024, Europe produced 5 bcm of grid-quality biomethane and 17 bcm of biogas for combined heat and power.² Predecessor studies conducted in 2022³ and 2024⁴, assessed the biomethane production potential in Europe (EU-27, plus Norway, Switzerland and the United Kingdom). This updated study revisits the 2024 Guidehouse assessment, incorporating the latest data as well as current market and regulatory insights. The underlying methodology remains consistent with the earlier studies.

The core potential assessment focuses on feedstocks that are ideally suited for anaerobic digestion, many of which are **waste and residue** streams that already exist in significant volume across Europe. Additionally, this study quantifies the potential from feedstocks grown on **marginal and contaminated lands** and from **biogenic carbon dioxide (CO₂)**. Marginal and contaminated lands can be used in an agroecologically responsible manner to restore and revitalise these under-utilised lands and unlock additional biogases potential. Furthermore, biogenic CO₂ arising from either the production or use of biomethane provides a viable pathway for producing additional renewable gas through e-methane.

The **total potential of biomethane and e-methane** in 2030, assessed in this study, is **34-35 bcm/year (of which 31-32 bcm/year relates to the EU-27)**, and almost exclusively based on biomethane from anaerobic digestion (with a minor share of e-methane)⁵. Thermal gasification is no longer considered to be close enough to commercialisation to make a material contribution towards the potential in 2030.

However, both thermal gasification and e-methane are set to become relevant in the 2040 timeframe and beyond (see figure below). A steep increase in the total potential is anticipated after 2030, with an assessed range of **116-132 bcm/year in 2040** and **181-205 bcm/year in 2050 (of which 105-119 bcm/year and 163-184 bcm/year relates to the EU-27 in 2040 and 2050 respectively)**.

¹ European Commission, REPowerEU Plan, 2022. https://commission.europa.eu/topics/energy/repowerEU_en

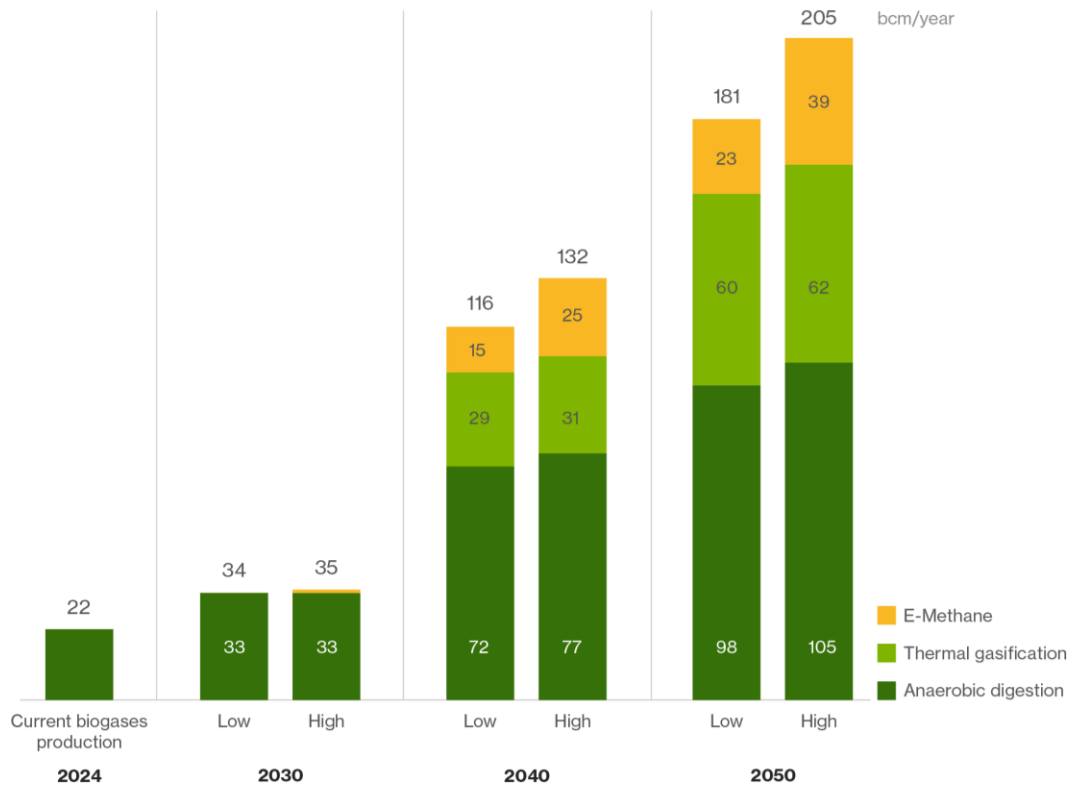
² European Biogas Association, Statistical Report 2025, Tracking biogas and biomethane deployment across Europe, 2025.

³ Gas for Climate, Biomethane production potentials in the EU, 2022. https://gasforclimate2050.eu/wp-content/uploads/2023/12/Guidehouse_GfC_report_design_final_v3.pdf

⁴ Guidehouse, Biogases towards 2040 and beyond, 2024. <https://www.europeanbiogas.eu/news/report-reveals-111-bcm-of-sustainable-biomethane-potential-for-2040/>

⁵ In contrast to the 2024 Guidehouse study, the potentials in this study are presented as a 'low' and 'high' range.

Anaerobic digestion is still expected to be the dominant technology, representing ~61% of the total in 2040 and ~53% of the total in 2050, as these complementary technologies further commercialise towards 2050 (with thermal gasification representing ~25% and ~32% of the totals in 2040 and 2050 respectively).



Actual 2024 biogases production in Europe and assessed biomethane and e-methane production potential in 2030, 2040 and 2050 per technology (low and high)⁶⁷

As highlighted in the 2024 study, **additional potential** could be unlocked from **novel feedstocks** such as seaweed and digestate, and **landfill gas** will further increase the potential in the short to medium term.

Faster feedstock mobilisation is critical to Europe meeting its biomethane potential.

This report presents an assessment of the sustainable potential for biogases production within Europe, reinforcing the conclusions of earlier assessments that biogases have an important role to play in the future defossilised energy system. However, the potential assessment for 2030 has been lowered compared to previous studies, which reflects not a change in the total sustainable potential, but a **lack of timely action to date to accelerate deployment of biogases and to mobilise available feedstocks.**

⁶ Note that the 'low' and 'high' potential ranges are specifically assessed for e-methane and biomethane from feedstocks cultivated on marginal and contaminated land.

⁷ Data is reported on a lower heating value (LHV) basis. Furthermore, all values have been rounded up/down to the nearest whole number.

The results of this study reiterate the conclusions from earlier assessments that there is a significant potential. More coherent policy recognition of the system-wide benefits that biomethane can bring is needed to provide the boost that the sector needs. Scale up of the European biogas industry needs more coherence and harmonisation across different policy areas and Europe, as well as faster permitting and faster feedstock mobilisation. Mobilising the sustainable feedstock potentials in this study, in particular, requires clear definitions, targets and targeted outreach to the farming, forestry and waste communities to stimulate collection of wastes and residues, and plant sustainable crops for the production of biogases.

There is a crucial difference between **waste and residue** feedstocks that exist and need collecting and sustainable crops that need to be cultivated. Countries should quantify and map feedstock potentials and then develop actions and strategies targeted at their corresponding feedstock potential and to their specific agricultural or forestry sectors. As biogas plants become larger, structures will need to be put in place to either pool the sources of feedstock into one plant or otherwise have smaller capacity biogas plants but pool the biogas into a central biomethane upgrading facility.

For **sequential crops**, clear definitions are needed, including integration into current policy and putting in place national production targets to help to scale up this sustainable method of cropping. Definitions should be consistent across different areas of policy including energy and agriculture. Long-term predictable support to farmers can help to stimulate uptake. This could be via policy support or from offtake contracts with biogas producers. Furthermore, coordinated outreach and training from biogas project developers can help to mobilise cultivation of sequential crops centred around a specific biogas plant.

For **marginal and contaminated land**, income via biogas production could help to turn the fate of these lands around, bringing also broader benefits including to nature and biodiversity by halting further degradation and soil erosion, restoring land after industrial uses and more specifically restoring the soil through phytoremediation in cases of contamination. Depending on the reasons for the land being under-utilised, there can be a substantial upfront investment needed to start cultivation on the land, especially if it is degraded (for example with low soil organic matter) or contaminated. Mobilisation will therefore require incentives for farmers and landowners. Incentives could be provided via the Common Agricultural Policy or via the Renewable Energy Directive or by a contractual guaranteed feedstock price from a biomethane producer.

Furthermore, a clear classification of these lands via policy will help to provide certainty to those investing, and provide a framework upon which a system of policy incentives could be based. Government can play a role in mapping of such lands to make it easier for the market to identify lands that can be brought back into productive use. There is also a clear role for municipalities to facilitate land use planning. Combining such maps with consideration of logistical access for agricultural infrastructure and machinery and proximity to the gas grid can also inform those areas where it would make sense to focus efforts in the first instance. There is also a role for larger landowners, such as former mining or industrial sites, which may have suitable land and an obligation to rehabilitate the land after use.

Feedstock competition across the bioeconomy will tighten towards 2050, however the expected impact is limited for many conventional biogas feedstocks.

The large-scale deployment of biomethane in Europe depends not only on the technical availability of sustainable biomass, but also on how feedstocks are allocated across competing uses in an increasingly integrated bioeconomy. Wet organic waste feedstocks, such as animal manure, biowaste, industrial wastewater and sewage sludge, are very well

suited to treatment via **anaerobic digestion**, and are not expected to face significant competition into the future as there are limited alternative options to utilise them for energy generation or across the wider bioeconomy. Additionally, the use of these feedstocks for anaerobic digestion delivers multiple environmental benefits, such as fugitive greenhouse gas emission avoidance, opportunities for nutrient recycling through the application of digestate and local pollution reduction. In contrast, significant competition for woody biomass feedstocks that are well suited for **thermal gasification** is expected over time, from continuing demand for conventional heat and power generation, as well as emerging demand for sustainable aviation fuels production, permanent carbon removals (carbon capture and storage and biochar), as well as demand as a bio-based material in sectors such as construction or bio-based chemicals.

This study is not a prediction of what will happen. Rather, it illustrates what is possible when concerted action is taken across Europe to mobilise sustainable feedstock streams towards producing biomethane. Realising the potentials assessed in this report will require coordinated efforts and a favourable and stable policy environment that gives certainty to stakeholders across the biomethane value chain. With the right conditions, Europe holds a significant sustainable potential to produce a domestic source of renewable energy that contributes significantly towards energy independence into the future.

1. Introduction

Biogases will play an important role in the European Union's (EU) ambition to be resilient, competitive and to achieve a net zero future by 2050. In 2022, the European Commission established a political target in the REPowerEU plan to produce 35 billion cubic metres (bcm) of biomethane annually by 2030 in the EU⁸. This objective is intended to enhance energy security and support net zero goals by providing a renewable, domestically-produced source of gas that can directly substitute fossil natural gas across multiple sectors of the economy.

Despite progress since 2022, current developments show that the EU is not on track to meet this target. Although the underlying potential in Europe is sufficient to meet the target, further action is required to mobilise resources and scale this strategic domestic industry through 2030 and beyond, enabling it to reach its full potential by 2050.

In 2024, Europe produced 5 bcm of grid-quality biomethane and 17 bcm of biogas for combined heat and power.⁹ Predecessor studies conducted in 2022¹⁰ and 2024¹¹, assessed the biomethane production potential in Europe (EU-27, plus Norway, Switzerland and the United Kingdom). The 2024 study assessed that the EU-27 could achieve 40 bcm/year of biomethane production in 2030, 101 bcm/year in 2040 and 150 bcm/year in 2050 assuming realisation of the sustainable potential¹².

This updated study revisits the 2024 Guidehouse assessment, incorporating the latest data as well as current market and regulatory insights. The underlying methodology remains consistent with the earlier studies. The core potential assessment focuses on feedstocks that are ideally suitable for anaerobic digestion, many of which are existing waste and residue streams. These waste and residue streams already exist in significant volume across Europe – the main challenges lie in their collection, and in expanding biomethane production capacity to process them.

Additionally, this study quantifies the potential from feedstocks grown on **marginal and contaminated lands** and from **biogenic carbon dioxide (CO₂)**. Marginal and contaminated lands can be used in an agroecologically responsible manner to restore and revitalise these under-utilised lands and unlock additional biogases potential. Furthermore, biogenic CO₂ arising from either the production or use of biomethane provides a viable pathway for producing additional renewable gas through e-methane.

This study is not a prediction of what will happen. Rather, it illustrates what is possible when concerted action is taken across Europe to mobilise sustainable feedstock streams towards producing biomethane. Realising the potentials assessed in this report will require coordinated efforts and a favourable and stable policy environment that gives certainty to stakeholders across the biomethane value chain.

⁸ European Commission, REPowerEU Plan, 2022, https://commission.europa.eu/topics/energy/repower.eu_en

⁹ European Biogas Association, Statistical Report 2025, Tracking biogas and biomethane deployment across Europe, 2025.

¹⁰ Gas for Climate, Biomethane production potentials in the EU, 2022. https://gasforclimate2050.eu/wp-content/uploads/2023/12/Guidehouse_GfC_report_design_final_v3.pdf

¹¹ Guidehouse, Biogases towards 2040 and beyond, 2024. <https://www.europeanbiogas.eu/news/report-reveals-111-bcm-of-sustainable-biomethane-potential-for-2040/>

¹² The assessed potentials for Europe were 44 bcm in 2030, 111 bcm in 2040 and 165 bcm in 2050.

2. Production potential in Europe

This chapter sets out the feedstock and technology scope, and the assessed biomethane and e-methane potentials in 2030, 2040 and 2050.

2.1 Feedstock and technology selection

Biomethane is produced from a diverse range of organic feedstocks. Two main biomethane production technologies exist: **anaerobic digestion** combined with upgrading the biogas, and **gasification**. Gasification includes **thermal gasification**, which converts dry woody or lignocellulosic biomass and solid waste, and **hydrothermal gasification**, which is particularly well suited to the treatment of water-based organic wastes and effluents.

Biomethane in Europe today is almost exclusively produced via anaerobic digestion. Thermal gasification with biomethane synthesis is currently at a demonstration to early commercial scale. Hydrothermal gasification is at demonstration stage, with initiatives underway in several European countries. The potential to scale up both technologies is large in the medium to long term (2040 and beyond).

The feedstock and technology selection applied in this study is set out in Table 1 below. Two additional feedstock pathways have been assessed compared to the 2024 Guidehouse study: **Biomass grown on marginal land** and **Biomass grown on contaminated land**.

Table 1. Feedstock and technology scope

Anaerobic digestion	Thermal gasification
Agricultural residues Materials that are left over in the field, following the harvesting of the main crop (e.g. cereal straw).	Biomass grown on Contaminated land [NEW] Industrial hemp, miscanthus, sorghum and switchgrass.
Animal manure Liquid and solid animal waste arising from livestock housed in stables or barns.	Forestry residues Primary residues from thinnings and final fellings, pre-commercial thinnings and logging residues.
Biomass grown on Marginal land [NEW] Cardoon, giant reed, miscanthus, reed canary grass, switchgrass and tall wheat grass	Landscape care wood Includes, for example, tree management operations performed along roadsides, railways and in private gardens.
Biowaste Food and vegetal waste produced by households or commercial enterprises.	Municipal solid waste (organic fraction only) Mixed municipal waste represents the waste material that has not been separately collected for recycling, composting or anaerobic digestion, and originates mainly from households but can also be generated by industries.
Industrial wastewater Wastewaters arising from industry sectors in which anaerobic digestion technology could be implemented as a pre-treatment method.	Prunings Woody residues produced after cutting, mulching and chipping activities of fruit trees, vineyards, olives and nut trees.
Permanent grassland [Germany only] Grass cut from grassland which does not compromise use of animal husbandry purposes.	Wood waste Secondary woody biomass, including wood processing, wood from paper and pulp production, construction and demolition waste, waste collected from households and industries.
Roadside verge grass Roadside verge grass is collected during maintenance operations in urban areas.	
Sequential crops Cultivation of a second crop before or after the harvest of the main food or feed crop on the same agricultural land during an otherwise fallow period.	
Sewage sludge Residual, semi-solid or liquid material that is produced as a by-product during sewage treatment of municipal wastewater.	

As can be seen in Table 1 above, with the exception of sequential crops and biomass grown on marginal or contaminated land, all of the feedstocks included in the main biomethane potential assessment are either wastes or residues. Energy crops (e.g. mono-cropping of maize) and stemwood¹³ (roundwood) are not considered in the potential assessment.

It should be noted that some of the feedstocks listed in Table 1 could be converted to biomethane through either technology. For example, agricultural residues are suitable for either anaerobic digestion or thermal gasification. Likewise, several of the anaerobic digestion feedstocks, such as animal manure, industrial wastewater and sewage sludge, could be converted to biomethane through hydrothermal gasification. However, in the context of this study, feedstocks have been assigned to one technology type only, as a simplification step to avoid double counting towards the potential assessment. Biomethane production from hydrothermal gasification was not explicitly included in this study given the potential overlap with anaerobic digestion, which is already commercially deployed at scale. However, in the future, hydrothermal gasification can further extend the scope of feedstocks suitable for biomethane production¹⁴. Likewise, different types of crops could be grown on marginal or contaminated lands and therefore they could be processed either via anaerobic digestion or thermal gasification. For simplification, we have assigned all crops produced on marginal land to anaerobic digestion as it is commercially available today, and all crops grown on contaminated land to thermal gasification due to the risk of difficulties disposing of digestate that may contain contaminants.

Importantly, for some of the assessed feedstocks, competition will emerge with other conversion pathways. For example, **agricultural residues and woody biomass feedstocks** could be used directly to generate heat and/or power. Alternatively, these feedstocks could be processed into advanced biofuels, such as cellulosic ethanol, renewable diesel, methanol or sustainable aviation fuels (particularly beyond 2030). **The assessed biomethane potential presented in this report considers that the feedstocks in scope are fully utilised for biomethane production.** Competition with other energy end uses is discussed further in chapter 5 of this report.

In addition to the biomethane potential assessments, an estimate of the European potential of **e-methane from biogenic CO₂** has been included in this study (note this is not broken down by country). Two main e-methane pathways exist: **biological e-methane** and **chemical e-methane** (see section 3.3 for further details). The assessments in this study are based on the amount of biogenic CO₂ available; the e-methane could be produced via either route.

The biomethane potential assessments derived in the context of this study are intended to provide a methodical assessment at a European level, as well as an estimation of the likely distribution per country, feedstock and technology. It is acknowledged that biomethane potential assessments that have been developed at the national level will invariably derive different outcomes, as the data and assumptions that are applied are likely to be available at a more granular level, more refined and better fit the national context (including a more comprehensive understanding of the feedstocks available, current deployment levels per feedstock and the policy framework for biomethane).

¹³ Stemwood is suitable for the production of sawn logs, panel products or pulp logs.

¹⁴ For further details, see Guidehouse, Biogases towards 2040 and beyond, 2024.

https://www.europeanbiogas.eu/wp-content/uploads/2025/06/Biogases-towards-2040-and-beyond_FINAL.pdf

2.2 Biomethane potentials in 2030, 2040 and 2050

In 2024, around 22 bcm of biogases were produced in Europe, of which 5 bcm is biomethane. Current production is almost exclusively via anaerobic digestion. The evolution of the **biomethane (anaerobic digestion and thermal gasification)** and **e-methane potential** from 2030 to 2050, as assessed in this study, is illustrated in Figure 1 (current biomethane production is also included for context).

The **total potential of biomethane and e-methane** in 2030, assessed in this study is **34-35 bcm/year**, and almost exclusively based on biomethane from anaerobic digestion (with a minor share of e-methane)¹⁵. A steep increase in the potential is anticipated after 2030, with both thermal gasification and e-methane set to become relevant as these technologies commercialise. The assessed production potential is **116-132 bcm/year in 2040** and **181-205 bcm/year in 2050**. Anaerobic digestion is expected to remain the dominant technology, representing ~58% of the total in 2040 and 51% in 2050 (with thermal gasification representing the next highest share with ~23% and ~30% of the totals in 2040 and 2050 respectively).

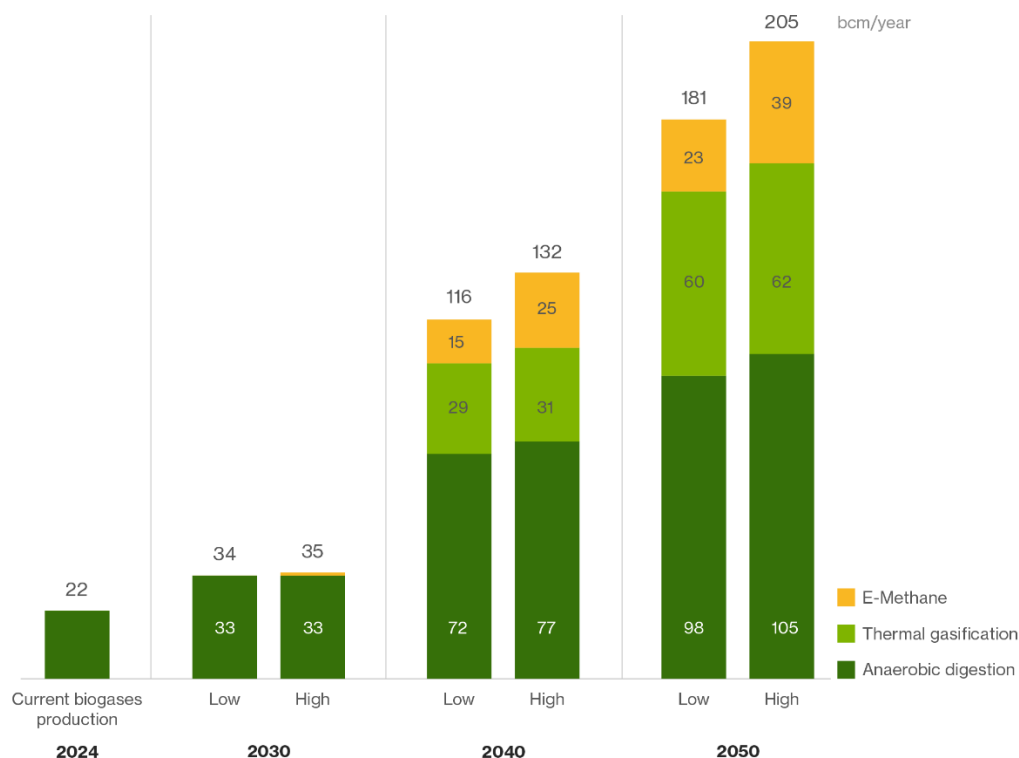


Figure 1. Actual 2024 biogases production in Europe in 2024 and assessed biomethane and e-methane production potentials in 2030, 2040 and 2050 per conversion technology (low and high)¹⁶¹⁷

An overview for each time horizon is provided below. Biomethane and e-methane are discussed separately to facilitate comparison with the 2024 study.

¹⁵ In contrast to the 2024 Guidehouse study, the potential estimates in this study are presented across a 'low' and 'high' range. See chapter 3 for further details.

¹⁶ Note that the 'low' and 'high' potential ranges are specifically assessed for e-methane and biomethane from feedstocks cultivated on marginal and contaminated land.

¹⁷ All potential values shown have been rounded up/down to the nearest whole number.

2030 potentials

A **biomethane potential of 33 bcm/year** is assessed for 2030 in Europe, of which **30 bcm/year** relates to the EU-27 (see Figure 2)¹⁸. This potential is exclusively based on biomethane produced via **anaerobic digestion**. Thermal gasification is no longer considered to be close enough to commercialisation to make a material contribution towards the potential in 2030. The top 5 countries with the highest potential in Europe are Germany, France, Italy, Poland and the United Kingdom. Collectively, these countries represent over 60% of the total biomethane potential in 2030. Key feedstocks in 2030 are agricultural residues (25%), animal manure (24%), sequential crops (19%) and industrial wastewater (15%). Collectively these feedstocks represent 81% of the total.

The assessed biomethane potential is ~11 bcm/year lower than in the 2024 study. This reflects the situation as it currently stands, rather than indicating any shift in the fundamental potential for biomethane production. The change is largely due to revised assumptions on the feasible ramp up for 2030 and therefore the accessible technical potential in 2030 for agricultural residues, animal manure and sequential cropping, which lowered the potential by 10 bcm in total. In addition, as mentioned above, thermal gasification is no longer considered for the 2030 timeframe in this study (3 bcm impact). This decrease is partly offset by a small increase of 1.5 bcm in the potential for industrial wastewater, and the inclusion of marginal land in this study (0.1-0.5 bcm).

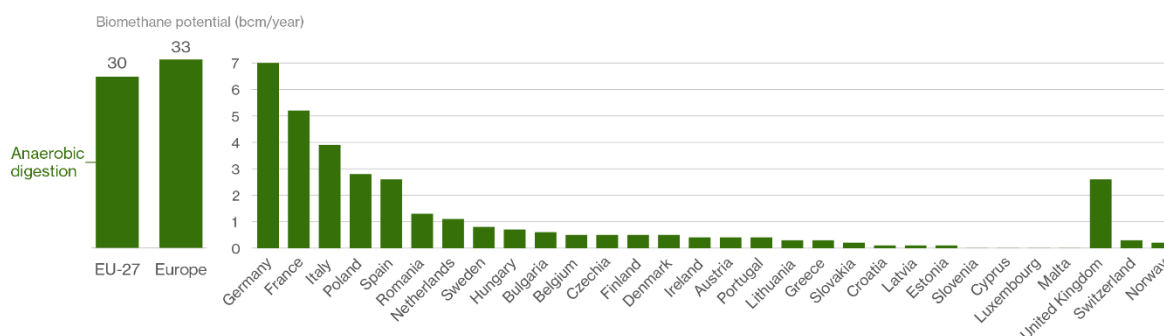


Figure 2. Biomethane ‘high’ potential (bcm/year) in 2030 per country and technology

In addition, an **e-methane potential of 0.8-1.4 bcm/year** in Europe is assessed in 2030 (of which 0.7-1.2 bcm/year relates to the EU-27), bringing the total potential to **34-35 bcm/year in Europe and 31-32 bcm/year in the EU-27**.

¹⁸ Note that the biomethane potentials represented in Figures 2, 3 and 4 specifically show the ‘high’ assessments for marginal land and contaminated land. Furthermore, all values have been rounded.

2040 potentials

A **biomethane potential of 101-107 bcm** is assessed for 2040 in Europe, of which **91-96 bcm** relates to the EU-27 (see Figure 3). In contrast to 2030, just over 70% of the potential is based on biomethane produced via **anaerobic digestion**, as it is expected that **thermal gasification** will start to commercialise from 2030 and be deployed at scale by 2040.

The assessed biomethane potential in 2040 is broadly comparable to the 2024 study, which assessed a potential of 111 bcm/year. However, a key difference is that a lower thermal gasification potential is assessed in this study. This is largely due to more conservative assumptions about the potential of woody biomass, stemming from stricter application of the cascading use principle (8 bcm impact). In addition, the anaerobic digestion potentials for both agricultural residues and sequential crops are 4.5 bcm lower in total, as a result of updated Eurostat datasets. This was partly offset by the inclusion of marginal and contaminated land in this study (4-10 bcm impact).

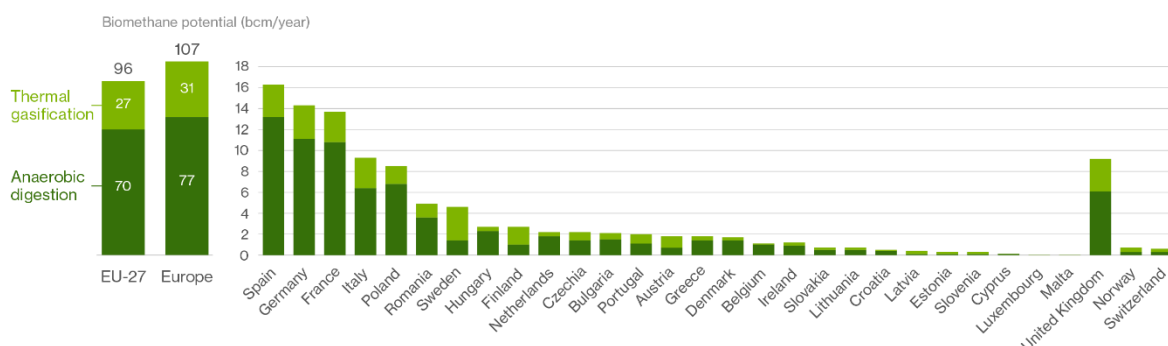


Figure 3. Biomethane ‘high’ potential (bcm/year) in 2040 per country and technology

A potential of **72-77 bcm/year** is assessed for **anaerobic digestion** in 2040, of which **66-70 bcm/year** relates to the EU-27. The top 5 countries with the highest potential are Spain (driven by the high potential from marginal land), Germany, France, Poland and Italy. Key feedstocks in 2040 are sequential crops (38%), as well as animal manure (19%) and agricultural residues (17%). Collectively these feedstocks represent 73% of the total. Industrial wastewater and marginal land each contribute 10% of the potential in 2040.

A potential of **29-31 bcm/year** is assessed for **thermal gasification** in 2040, of which **26-27 bcm** relates to the EU-27. The top 5 countries with the highest potential are Germany, Sweden, Spain, United Kingdom and France. Key feedstocks in 2040 are the organic fraction of municipal solid waste (30%), forestry residues (26%) and wood waste (21%). Collectively these feedstocks represent 78% of the total.

In addition, an **e-methane** potential of **15-25 bcm/year** in Europe is assessed in 2040 (of which 13-22 bcm/year relates to the EU-27), bringing the total potential to **116-132 bcm/year in Europe and 105-119 bcm/year in the EU-27**.

2050 potentials

A **biomethane potential of 158-166 bcm/year** is assessed for Europe in 2050, of which **142-149 bcm/year** relates to the EU-27 (see Figure 4) Figure 2. In 2050, biomethane from anaerobic digestion still dominates, but with a slightly lower share of 62% compared to 2040, as thermal gasification is expected to further scale-up over this period.

The assessed biomethane potential in 2050 is broadly comparable to the 2024 study, which assessed a potential of 166 bcm/year. However, as noted above a lower thermal gasification potential is assessed in this study (9 bcm impact). In addition, the anaerobic digestion potentials for both agricultural residues, animal manure and sequential crops are lower by almost 7 bcm in total (again resulting from updated Eurostat datasets). This was largely offset by the inclusion of marginal and contaminated land in this study (8-18 bcm impact).

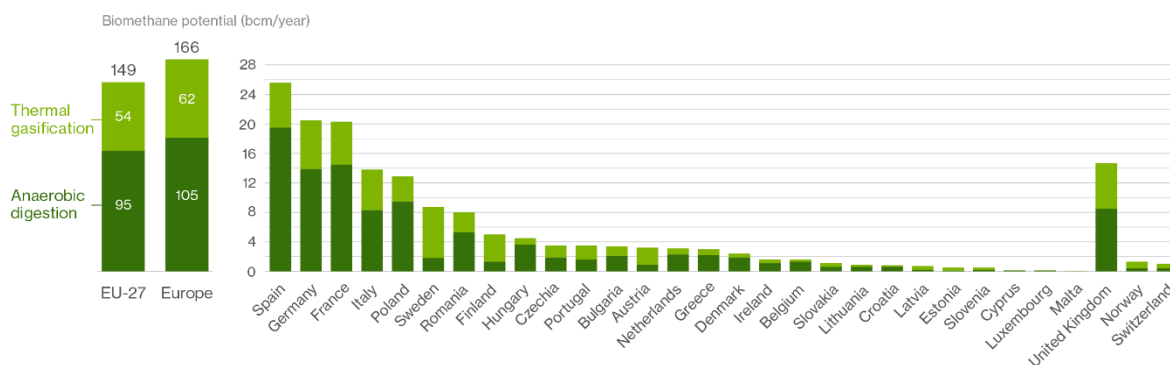


Figure 4. Biomethane 'high' potential (bcm/year) in 2050 per country and technology

A potential of **98-105 bcm/year** is assessed for **anaerobic digestion** in 2050, of which **90-95 bcm/year** relates to the EU-27. The top 5 countries with the highest potential are Spain (driven by the very high potential from marginal land), France, Germany, Poland and the United Kingdom. The key feedstocks in 2050 are again sequential crops (42%), animal manure and agricultural residues (15% each), as well as biomass from marginal land (12%). Collectively these feedstocks represent 84% of the total.

A potential of **60-62 bcm/year** is assessed for **thermal gasification** in 2050, of which **52-54 bcm/year** relates to the EU-27. The top 5 countries with the highest potential are Sweden, Germany, United Kingdom, Spain and France. Key feedstocks in 2040 are the organic fraction of municipal solid waste (27%), forestry residues (27%) and wood waste (25%). Collectively these feedstocks represent 78% of the total.

In addition, an **e-methane** potential of **23-39 bcm/year** is assessed for Europe in 2050 (of which 21-35 bcm/year relates to the EU-27), bringing the total potential to **181-205 bcm in Europe and 163-184 bcm/year in the EU-27**.

A detailed overview of the feedstock distribution per country and technology type in 2030, 2050 and 2050 is provided in the Appendix.

3. Calculation methodology

For the majority of feedstocks, this study replicates the calculation methodology used in the 2024 Guidehouse study, with some updates which are set out below in section 3.1. The methodologies applied to assess the biomethane potentials from **marginal and contaminated land**, and **e-methane from biogenic CO₂** are described in sections 3.2 and 3.3 respectively.

3.1 Methodology and data updates

The total biomethane potential per country was calculated by assessing the availability of each feedstock and its conversion yield to biomethane through the assigned biomethane conversion technology. For some feedstocks¹⁹, the feedstock potential was assessed using a 'bottom-up' method, based on the latest statistical data (European/national level) and projections up to 2050 (for example considering trends in population, land area/crop production, livestock numbers and production volumes of key commodities in selected sectors linked to the agricultural sector). For other feedstocks²⁰, the feedstock potential assessments are based on credible third-party reports, most notably a study conducted by Imperial College London²¹.

The feedstock potentials reflect **technical constraints** (e.g. share of the theoretical feedstock potential that can be realistically mobilised over time) and where relevant **environmental constraints** (e.g. soil preservation), to derive a **sustainable potential**. The sustainable potential has then been further reduced to take into account **existing non-energy uses**, to ensure that the use of the feedstock for biomethane production does not impact these existing uses and lead to indirect impacts. For **sequential crops**, the assessed potential for 2030 has been revised to better reflect the current deployment of this type of cropping for biomethane production in each Member State, informed by country level data provided by national biogas associations to the European Biogas Association. Similarly, the assumed shares of the technical potential accessible in 2030 for agricultural residues and animal manure have been adjusted downwards informed by discussions with industry experts²². Finally, for **thermal gasification**, as a further constraint, it was assumed that none of the feedstock potential would be utilised for biomethane production in 2030, given that this technology is not yet available at commercial scale. This assumption is also consistent with a recent report published by the European Commission on mobilising industrial capacity building for advanced biofuels²³. Notably, that report still sees a material long-term potential for thermal gasification. As such, this study has retained similar feedstock conversion assumptions assumed in the 2024 Guidehouse study for 2040 (50% feedstock deployment, revised down slightly from 55%) and for 2050 (100% feedstock deployment).

The feedstock potential assessments have **not** been adjusted to take into account the use of those feedstocks in **other energy sectors** (e.g. production of advanced biofuels, including sustainable aviation fuels, or heat and power generation). As such, the assessments derived in this study aim to provide a perspective on the total potential that could be realised if all of

¹⁹ Agricultural residues, animal manure, industrial wastewater, sequential crops and sewage sludge.

²⁰ Biowaste, forestry residues, landscape care wood, municipal solid waste, permanent grassland, prunings, roadside verge grass and wood waste.

²¹ Imperial College London, Sustainable biomass availability in the EU to 2050, 2021.

<https://www.concawe.eu/publication/sustainable-biomass-availability-in-the-eu-to-2050/>

²² The Agricultural residues share has been revised downwards from 60% to 50%, and the share for Animal manure revised downwards from 70% to 45%.

²³ European Commission, DG Research & Innovation, Mobilization of industrial capacity building for advanced biofuels, 2026. <https://op.europa.eu/en/publication-detail/-/publication/cc500efe-fe51-11f0-8da5-01aa75ed71a1/language-en>

the sustainable feedstock available for the energy sector is utilised for biomethane production (see also chapter 5 for further details).

Although the overall calculation methodologies applied for all feedstocks largely follows the same as approach as in the 2024 Guidehouse study, newly available data are included. For example, the most recent Eurostat/FAOSTAT country level statistics are included, as well as data from the updated EU Agricultural Outlook²⁴ which provides projections on how crop production and livestock numbers may develop to 2035. In this study, the EU Agricultural Outlook was also used to estimate the production volume trends of several agro-industrial commodities²⁵, to derive a more realistic view of the biomethane potential from industrial wastewater. In the 2024 Guidehouse study, the current production volumes for all commodities were fixed out to 2050.

The feedstock potential assessments for forestry residues and wood waste derived from the Imperial College London study were further reviewed in light of the strengthened sustainability criteria for woody biomass under the Directive 2023/2413 (amended Renewable Energy Directive (RED) II), effective from 21 May 2025. As context, the updates to the REDII include additional criteria to protect old growth forests, highly biodiverse forests and heathlands, the introduction of the '**cascading principle**' to ensure that Member States incentivise woody biomass to be 'used according to its highest economic and environmental added value', and not allowing financial support for energy from logs, industrial grade roundwood, roots and stumps. Although the 2024 study was judged to sufficiently address all of these aspects, a stricter approach was taken in this study. In discussion with the Imperial College London report lead author, the more conservative 'Scenario 1 – Low mobilisation scenario' datasets were applied, and a lower share of the total available feedstock volume for Wood waste allocated to biomethane production²⁶.

3.2 Marginal and contaminated land

This methodology assesses biomass availability from **marginal and contaminated land** in the EU-25²⁷ and the UK in 2030, 2040 and 2050, drawing on Horizon 2020²⁸ EU-funded research and supporting studies. The approach focuses on land that can support biomass production without competing with food or feed production, or existing ecological functions.

The additional potential that may be available from **abandoned land** is also discussed; however, that potential is not quantified.

3.2.1 Methodology

The methodologies to assess the potentials from marginal and contaminated land follow a broadly similar approach. The areas of land per category are combined with reduced yields fitting the land categories to determine the total potential amount of biomass available. The

²⁴ European Commission, EU Agricultural Outlook 2023-2035, 2025. https://agriculture.ec.europa.eu/data-and-analysis/markets/outlook/medium-term_en

²⁵ Namely: Biodiesel, bioethanol, butter, cheese, meat (cattle), meat (goats and sheep), meat (pigs), sugar, vegetable oils and wine. These feedstocks collectively contribute towards ~80% of the total industrial wastewater biomethane potential.

²⁶ Specifically, a reduction from 55% to 45% was applied.

²⁷ Note that Cyprus and Malta (in the EU), and Norway and Switzerland (non-EU) were not assessed, due to the absence of data.

²⁸ European Commission, Horizon 2020. https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en

reduced yields are taken from the BIKE project²⁹ for marginal land, and the GOLD project³⁰ for contaminated land. Biomass grown on marginal land was assumed to be processed using anaerobic digestion. However, biomass grown on contaminated land was assumed to be processed via thermal gasification. This is because if there are heavy metal contaminants present in the biomass, this could decrease the efficiency of the anaerobic digestion process and could under certain conditions be toxic in biochemical reactions, depending on their concentrations.^{31 32} In addition, any trace contaminants remaining in the digestate would likely pose a disposal problem. These factors could make anaerobic digestion a more challenging processing route for biomass from contaminated land, but that is not to say anaerobic digestion would not still be an option in some instances.

3.2.1.1 Marginal land

Marginal land availability is primarily derived from the Horizon project MIDAS³³ which updated the previous estimates from the Horizon project MAGIC³⁴. MIDAS used updated mapping techniques and changed some of the underlying assumptions. For example, the MIDAS project lowered the thresholds for the category 'low soil fertility' which increased the amount of land tagged under this category. MAGIC/MIDAS identify land affected by natural constraints such as adverse climate, soil conditions, moisture, terrain, and rooting limitations. The total marginal land identified in the MIDAS dataset amounts to approximately 73.2 million hectares. However, this figure reflects a broad definition of marginality³⁵.

For this study, **the assessments of marginal land availability are further refined to align more closely with the Renewable Energy Directive (RED) concept of severely degraded land.** As a result, for this study only land affected by **adverse chemical composition and low soil fertility** have been included. These two categories together represent around 18.2 million hectares, of which around 50% is located in Spain and 12% in the UK. Land constrained mainly by climate, excessive moisture, rocky soils, or steep slopes is excluded, as these constraints do not necessarily imply degradation.

Biomass yields on marginal land are calculated using average yield baselines for land with natural constraints included in the Horizon 2020 BIKE project³⁶. Yields are differentiated across Atlantic, Continental and Mediterranean regions. Feedstocks considered include tall wheat grass, miscanthus, switchgrass, cardoon, giant reed and reed canary grass. These yields reflect average biomass yields per climate region from field experiments which tested

²⁹ Elbersen B., Verzandvoort S., Panoutsou C., Alexopoulou E., Horizon 2020 project BIKE (Grant Agreement No. 952872) - Deliverable 2.2 - Options to grow crops on unused, abandoned and/or severely degraded lands, 2022. <https://www.bike-biofuels.eu/wp-content/uploads/2022/10/Deliverable-2.2-Final.pdf>

³⁰ GOLD. D1.4 Application of best performing phytoremediation practices on pilot small-field trials <https://www.gold-h2020.eu/wp-content/uploads/2025/03/D1.4-Application-of-phytoremediation-strategies-on-small-scale-trials.pdf>

³¹ [Biogas production as affected by heavy metals in the anaerobic digestion of sludge - ScienceDirect](#)

³² [Effects of heavy metals as stress factors on anaerobic digestion processes and biogas production from biomass - Astrophysics Data System](#)

³³ Horizon 202- project MIDAS: [Microsoft Word - MIDAS First version of MLDIS1.1 Clean.docx](#)

³⁴ Horizon 2020 project MAGIC: https://magic-h2020.eu/wp-content/uploads/2022/04/MAGIC_D2.6-Methodological-approaches.pdf

³⁵ Land categories included are: Adverse chemical composition, Adverse climate, Adverse rooting conditions, Adverse terrain, Excessive soil moisture and Low soil fertility.

³⁶ Elbersen B., Verzandvoort S., Panoutsou C., Alexopoulou E., Horizon 2020 project BIKE (Grant Agreement No. 952872) - Deliverable 2.2 - Options to grow crops on unused, abandoned and/or severely degraded lands, 2022. <https://www.bike-biofuels.eu/wp-content/uploads/2022/10/Deliverable-2.2-Final.pdf>

different environmental and management/rehabilitation conditions between the field experiments.

The MIDAS estimates of the marginal land areas per type are provided for both a 2020 and 2050 timeframe. In this study, the 2020 data was applied to derive the production potential assessments in both 2030 and 2040, while the 2050 data could be used directly to assess the 2050 production potential. For the **2030** assessment, a technical potential range of 0.5% to 2.5% was assumed as default for most countries due to the limited time remaining to use this land for biomass production by 2030, and the associated mobilisation challenge this would require. A lower technical potential range of 0.25% to 1.25% was applied for Spain, Finland and Sweden, specifically, given the significant area of marginal land available – either in absolute terms (Spain) or as a share of the current total arable land area (Finland and Sweden). For **2050**, a technical potential range of 26% to 50% was assumed as default, as not all land will be feasibly put to use for biomass production as the process can be cost- and labour-intensive, depending on the degree of degradation of the land and climatic conditions, and there will likely be competing uses for this land (e.g. urban development, rewilding). A lower technical potential range of 15% to 35% was applied for Spain and Sweden, specifically, consistent with the rationale applied in 2030³⁷. Finally, for **2040**, a technical potential range of 10% to 25% was applied for all countries.

3.2.1.2 Contaminated land

The assessment of biomethane potential from contaminated land in this study is based on spatial data from the Horizon 2020 GOLD project³⁸, which identifies potentially contaminated land sites across the EU suitable for phytoremediation³⁹. In the GOLD project, only areas with less than 40% impervious surface cover and land cover compatible with biomass cultivation are included, meaning that areas that have been sealed off for more than 60% were excluded as it is not suitable to grow biomass on sealed areas. Contaminated land that is densely built-up is excluded, as well as forest and other naturally vegetated land, as these areas are either sealed (built-up areas) or already serve ecological purposes (forest and naturally vegetated land).

The GOLD project analysis covers former military sites, industrial and brownfield sites, quarries, and landfills. Former military areas and landfills are assumed to require less conversion effort to grow biomass than the other categories. Quarries (mainly mineral extraction sites) represent the largest land category. Phytoremediation combined with biomass production is considered appropriate where contamination poses a potential risk to human health and where biomass cultivation can contribute to reducing that risk.

Biomass feedstocks considered suitable for these conditions include industrial hemp, sorghum, switchgrass and miscanthus. Specific biomass yield reduction factors that reflect the impact of contamination on biomass productivity are applied, derived from the GOLD project.

³⁷ Note that to ensure the estimated area is not unfeasible compared to the current arable land, a maximum threshold of 1% of the total arable area was set for marginal land conversion in 2030, which was increased to 30% for 2050.

³⁸ Horizon 2020 project GOLD: D3.1 Extent, location and contaminated land status potentially suitable for phytoremediation, 2022. https://www.gold-h2020.eu/wp-content/uploads/2024/05/D3.1_Extent_location_and_contaminated_land.pdf

³⁹ Phytoremediation is a technique that uses plants to remove contaminants from the soil. The plants take up the contaminants through their roots and store them in stems and leaves. After harvesting the plants, the contaminants stored in plants are thereby permanently removed from the soil.

The GOLD project estimates that there are 2 million hectares of contaminated land available and suitable for phytoremediation in the EU-25+UK. Germany and France have the largest availability of contaminated land at ~0.28 million hectares each (28% of the total each). Spain and the UK also have high contaminated land availability at ~0.19 million hectares each (18% of the total each).

The GOLD estimates of contaminated land are based on a 2020 baseline. These were applied to derive the production assessments in 2030, 2040 and 2050. For consistency, the biomethane potential assessment were based on the default technical potential ranges applied for marginal land (namely 0.5% to 2.5% for 2030, 10% to 25% for 2040 and 26% to 50% for 2050 as default).

3.2.1.3 Abandoned land

Abandoned land is another land category where biomass could be grown for biomethane production without increasing the overall demand for additional land. Land could become abandoned due to biophysical constraints, such as through the effects of climate change, or due to socioeconomic constraints such as aging population and rural to urban migration. The 2024 RALUC study from Wageningen Environmental Research, Guidehouse and MEDES on competition for land use and sustainable farming⁴⁰ assessed land abandonment trends under both business-as-usual and sustainable agriculture scenarios up to 2050. The **'business-as-usual' scenario** assumed that there would be no changes in rural or agricultural policies, the **'sustainable agriculture policy' scenario** assumed that rural and agricultural policies would be put in place to prevent land use change in rural and agricultural areas, such as sustainable agriculture policies to protect the soil, as well as policies to limit urbanisation.

The resulting values indicate a percentage of agricultural land in 2020 that could become abandoned due to socioeconomic or biophysical constraints by 2050. The RALUC study applied country-specific land abandonment rates to the current total arable land, as published by Eurostat, to determine additional land availability under each scenario, with higher availability assumed in the business-as-usual case. These results indicate the area of *additional* agricultural abandoned land that could become available under the business-as-usual or sustainable agricultural scenarios and excludes any land that is currently already abandoned.

In the **business-as-usual scenario** an additional 3,786 kha would become abandoned by 2050, which corresponds to a maximum biomethane potential of 3.4 bcm/year (with the assumption that 100% of this land would be utilised). Most abandoned land is assumed to be present in Poland (26.6% of the total), followed by Italy (14.6%), France (14.0%) and Germany (13.3%). In the **sustainable agricultural policy scenario**, there would be no additional abandoned land in 2050.

The abandoned land category is **not explicitly included** in the quantified assessment of total marginal land, as the available data only covers *additional* abandoned agricultural land, not *total* abandoned agricultural land available, and was only available for the year 2050.

⁴⁰ Wageningen Environmental Research, Guidehouse and MEDES Foundation, Study on competition for land use and sustainable farming, 2024. https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cmef/sustainability/study-competition-land-use-and-sustainable-farming_en

Furthermore, the European Commission definition⁴¹ of abandoned land – and therefore the abandoned land in these assessments – relates specifically to land that becomes abandoned due to biophysical or socioeconomic constraints. Land that is abandoned due to biophysical constraints, such as soil degradation or contamination, overlaps with the marginal land and contaminated land assessments in this study, therefore it is not possible with the current data available to credibly quantify abandoned land as a separate category on top of marginal and contaminated land.

3.2.2 Results

The total assessed biomethane potential in the EU-25+UK from marginal and contaminated land in 2030 is between 0.1 bcm/year and 0.5 bcm/year, increasing to between 3.7 bcm/year and 9.4 bcm/year in 2040 and between 7.7 bcm/year and 16.2 bcm/year in 2050. The country with the largest potential across all years is Spain (3 to 7 bcm/year in 2050), driven by the significant availability of marginal land.

For **marginal land**, the assessed potential increases from 0.1-0.5 bcm/year in 2030 to 3.0-7.6 bcm/year in 2040, reaching 5.9-12.7 bcm/year by 2050. Figure 5 provides an overview of the biomethane potential for marginal land across the assessed countries (note that potential values are only indicated for countries with a potential greater than 0.1 bcm/year).

⁴¹ Delegated Regulation 2019/807 defines abandoned land as “unused land, which was used in the past for the cultivation of food and feed crops but where the cultivation of food and feed crops was stopped due to biophysical or socioeconomic constraints”.

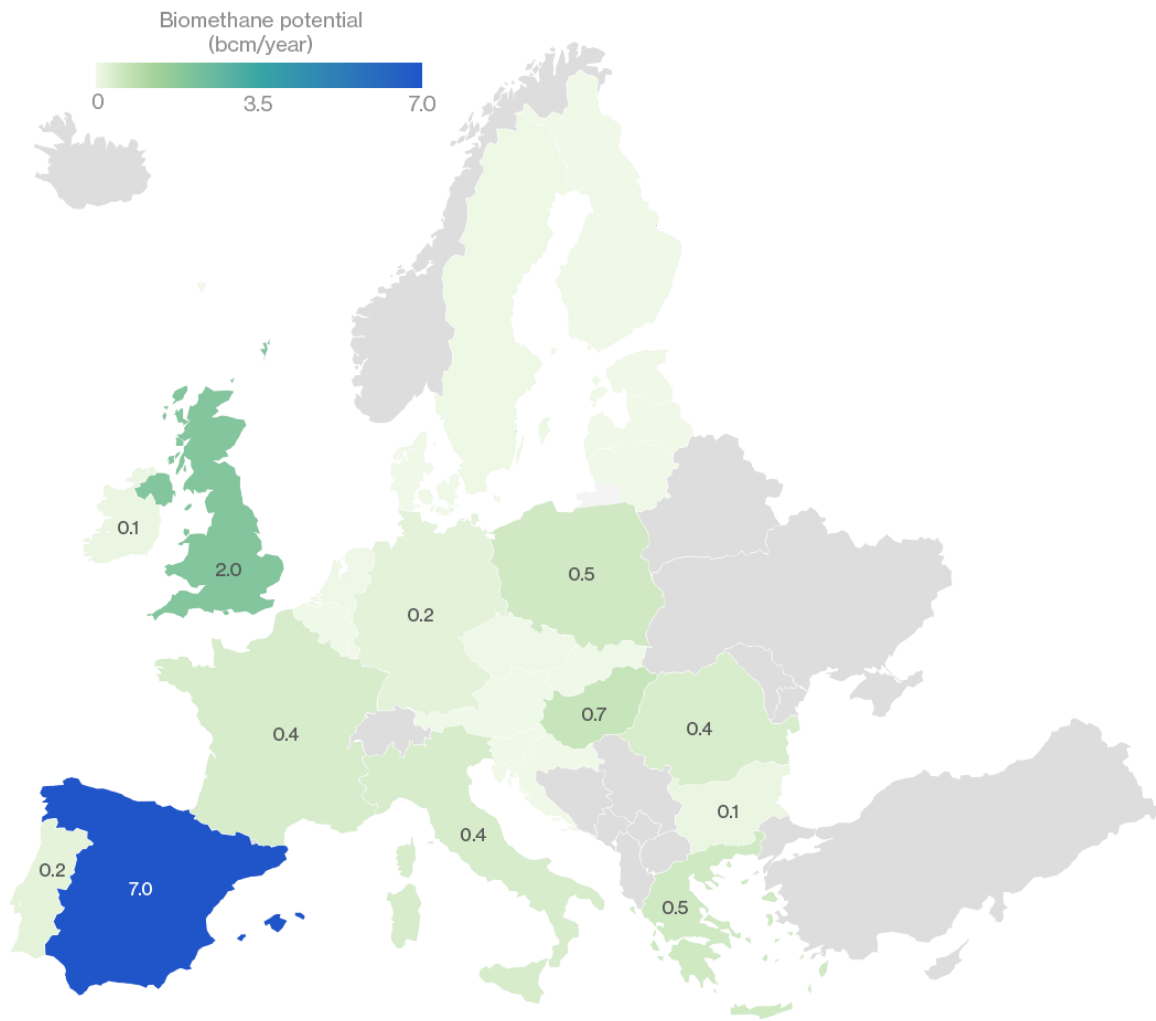


Figure 5. Biomethane potential (bcm/year) in EU-25 + UK in 2050 for marginal land (high scenario)

For **contaminated land**, the assessed potential in 2030 is assumed to be zero in-line with the assumption that there will be no significant thermal gasification roll out in 2030, as set out in section 3.1. In 2040, the assessed potential is 0.7-1.8 bcm/year, increasing to 1.8-3.5 bcm/year in 2050. Figure 6 provide an overview of the biomethane potential for marginal land and contaminated land across the assessed countries (note that potential values are only indicated for countries with a potential greater than 0.1 bcm/year).

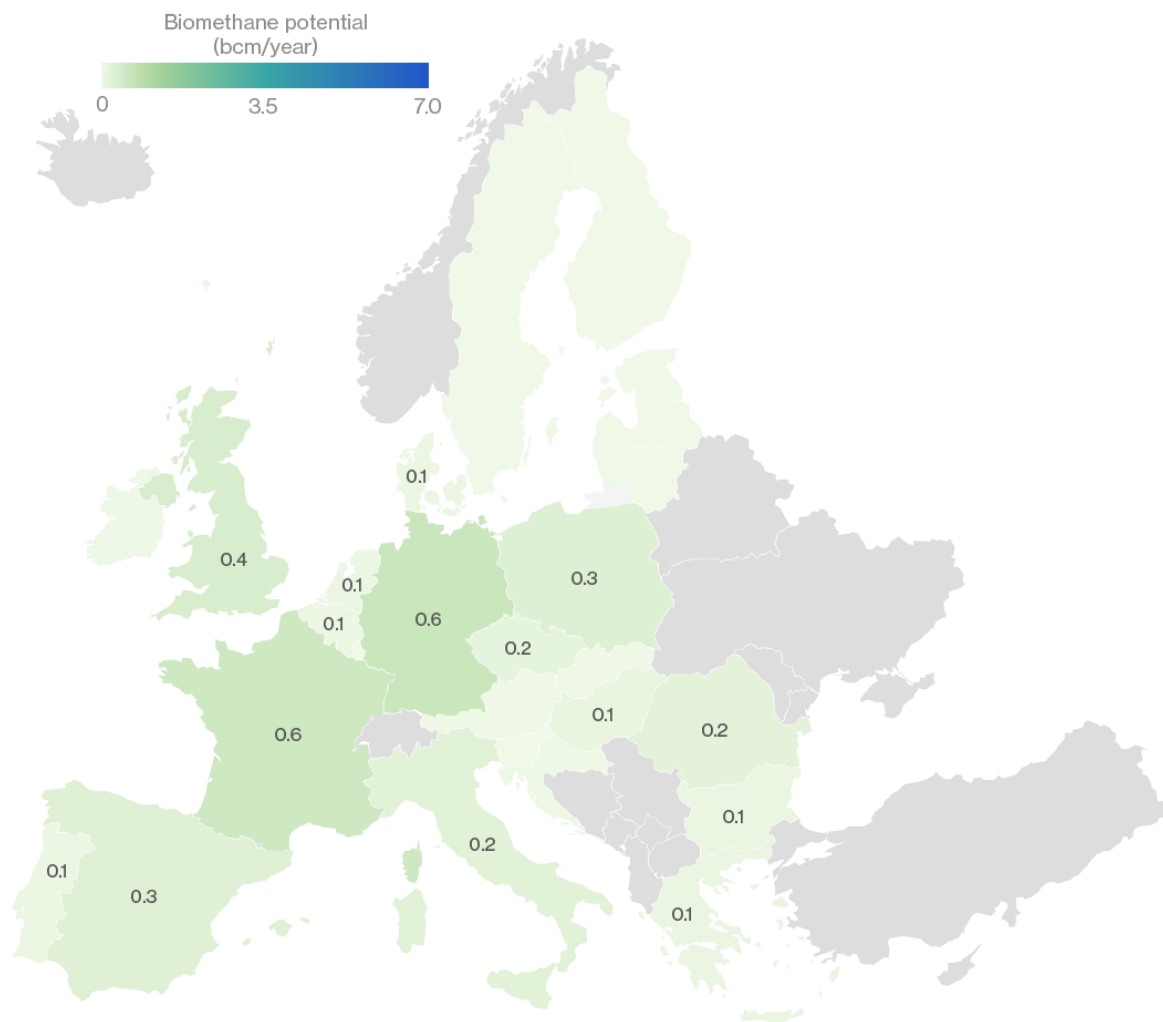


Figure 6. Biomethane potential (bcm/year) in EU-25 + UK in 2050 for contaminated land (high scenario)

3.3 E-methane production from biogenic CO₂

Achieving the EU's 2050 net zero climate goals will require a material acceleration of renewable gas production in Europe, including both biomethane and e-methane⁴². The European biomethane sector can play a key role in facilitating the scale up of e-methane production, given that these fuels require a source of carbon dioxide (CO₂) as well as a source of renewable hydrogen.

⁴² Note that in the context of EU policy, these fuels are specifically referred to as Renewable Fuels of non-biological origin or 'RFNBOs'.

Currently, the EU policy framework permits any CO₂ source to be used for e-methane production. However, non-biogenic carbon from electricity generation is only permitted until 2035 (as it assumed that these emissions should largely be abated by that date), but only if it is covered by an effective carbon pricing scheme. Non-biogenic carbon, such as process emissions, is only permitted to be used until 2040, and again only if covered by an effective carbon pricing scheme. Therefore, after this time only biogenic sources of CO₂ or CO₂ from direct air carbon capture (DACC) will be permitted to count towards the RED target.⁴³

Biogenic CO₂ can arise from either the production or use of biomethane. Specifically:

- **Biomethane production from Anaerobic digestion:** Biogas produced via anaerobic digestion contains around 55% to 65% biomethane by volume, the remainder being mainly biogenic CO₂. This CO₂ can be captured during the upgrading of biogas to biomethane at low cost.
- **Biomethane production from Thermal gasification:** The gasification of biomass feedstocks produces syngas, a mixture of methane (CH₄), carbon monoxide (CO), carbon dioxide (CO₂) and hydrogen (H₂). Following the conditioning of the syngas and subsequent water-shift reaction, the resulting biogenic CO₂ can be readily captured at relatively low additional cost as the CO₂ must already be separated in the production of biomethane.
- **Capture from biomethane post-combustion:** If biomethane is used as a fuel in industrial processes, or in combined heat and power plants, the resulting biogenic CO₂ can be captured from the flue gas. (Capture from biogas post-combustion is currently less viable as the flue gas stream contains a relatively low concentration of CO₂, of less than 10%.)

Other potential biogenic CO₂ sources include **bioethanol production**⁴⁴, **post-combustion of solid biomass**⁴⁵ and **DACC**⁴⁶. These have not been considered within the scope of this study.

Biogenic CO₂ from anaerobic digestion, thermal gasification and post-combustion capture represent a strategic, but ultimately limited, resource. While today most biogenic CO₂ is vented, meeting the EU's net-zero climate goals in 2050 will require that it is increasingly captured and either stored permanently (CCS), contributing to net-negative emissions, or utilised through carbon capture and utilisation (CCU) pathways, enabling the production of renewable fuels and materials or in direct utilisation. Figure 7 below provides an overview of the various CCS and CCU applications available for biogenic CO₂.

⁴³ The United Kingdom has no such rules on the use of non-biogenic carbon sources or waste fossil sources (as long as the resulting fuel can meet the greenhouse gas saving threshold).

⁴⁴ Biogenic CO₂ arises from the **fermentation of biomass** to alcohol. Volumes are relatively limited, and in the case of bioethanol for use as a transport fuel will reduce over time in Europe.

⁴⁵ Inclusion of **post-combustion of solid biomass** would constitute double counting as the solid biomass feedstocks are already assumed to be fully utilised for biomethane production in this study.

⁴⁶ **DACC** has not been included due to challenge of assessing the future CO₂ potential to 2050. Notably, this technology requires significant electricity consumption to operate due to the very low CO₂ concentration (~0.04%) in the atmosphere and is therefore by far the costliest capture technology.

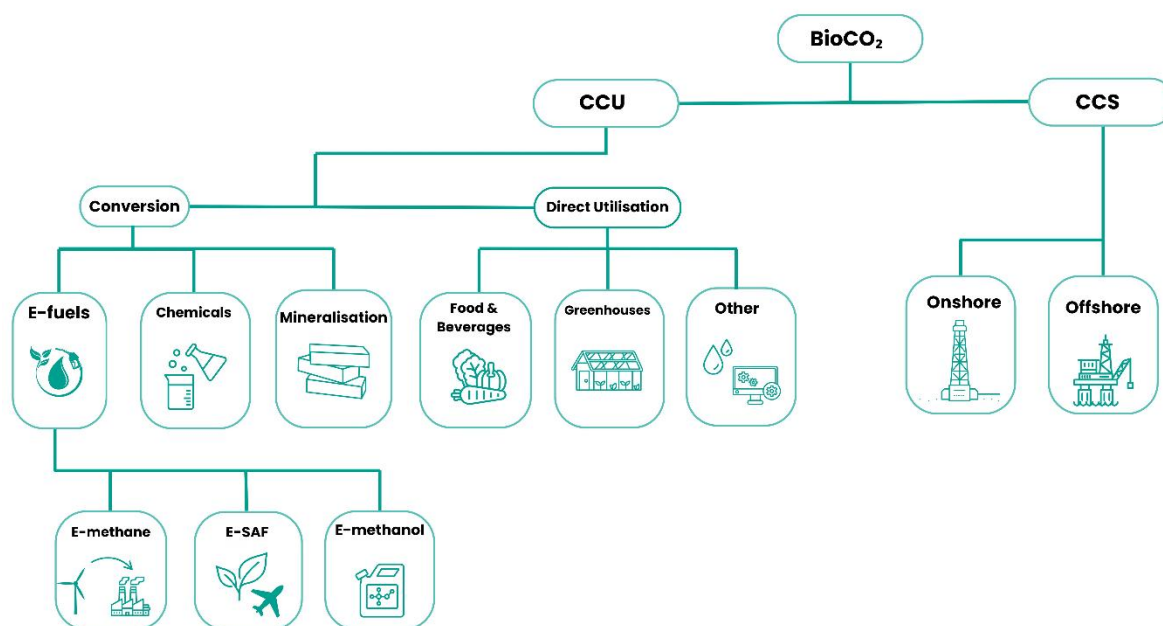


Figure 7. CCU and CCS applications for biogenic CO₂⁴⁷

E-methane production⁴⁸ is a high-value CCU option, providing a fully compatible molecule for Europe's existing gas infrastructure and end-user equipment. It can also support the defossilisation of hard-to-abate sectors that require high energy density fuel. However, the availability of biogenic CO₂ for e-methane production will be constrained by multiple competing demands. These include **e-SAF production** (driven by the ReFuelEU Aviation regulation and UK SAF Mandate – which both have specific targets for these fuels⁴⁹), **e-methanol production** for use in industry and maritime (driven by the FuelEU Maritime regulation), **mineralisation pathways** as well as demand for CCS (supported by the EU's Carbon Removals and Carbon Farming regulation⁵⁰). Additional CCU applications include use in existing markets, such as food and beverage production and greenhouses.

In this context, a low/high assessment of the availability of biogenic CO₂ in Europe (and EU-27) for e-methane production in 2030, 2040 and 2050 is made, and from these the resulting theoretical e-methane production potential is assessed.

3.3.1 Methodology

A four-step approach has been taken to assess the e-methane production potential from biogenic CO₂.

⁴⁷ European Biogas Association, Biogenic CO₂ from biomethane: The key to Europe's carbon strategy, 2025. <https://www.europeanbiogas.eu/news/biogenic-co2-from-biogases-key-to-europes-carbon-strategy/>

⁴⁸ Technologies include biological methanation (in-situ and ex-situ) and catalytic methanation. For a comprehensive overview, refer to: European Biogas Association, Mapping e-Methane plants and technologies, 2024. <https://www.europeanbiogas.eu/publication/mapping-e-methane-plants-and-technologies/>

⁴⁹ The ReFuelEU Aviation targets are set at 1.2% in 2030, rising to 10% in 2040 and 45% in 2050. The UK SAF Mandate targets are set at 0.5% in 2030, rising to 3.5% in 2040.

⁵⁰ European Commission, Carbon Removals and Carbon Farming. https://climate.ec.europa.eu/eu-action/carbon-removals-and-carbon-farming_en

1. Assess total biogenic CO₂ availability
2. Allocate shares of biogenic CO₂ used for CCS and CCU
3. Allocate share of biogenic CO₂ available for e-methane production
4. Calculate e-methane production potential

Step 1. Assess total biogenic CO₂ availability

For anaerobic digestion and thermal gasification, the biogenic CO₂ availability was based on the assessed production potential in this study, and the amount of biogenic CO₂ available per bcm of biomethane produced⁵¹. For **anaerobic digestion** specifically, an assumed split of biogas to biomethane production was made in 2030, 2040 and 2050 (of 35%, 85% and 97.5%), and CO₂ capture rates (of 50%, 90% and 100%⁵²). The biogenic CO₂ availability for **biomethane post-combustion** assumed that 10% of the total biomethane production in 2030 applies this technology, increasing to 20% in 2040 and 2050 (based on ENTSO-E and ENTSO-G Ten-Year Network Development Plan scenarios⁵³).

The total theoretical amount of biogenic CO₂ available in Europe and the EU-27 (included in brackets) is indicated in Table 2.

Table 2. Biogenic CO₂ available per source (Mt CO₂)

Source	2030	2040	2050
Biogenic CO ₂ from anaerobic digestion	7.6 (6.9)	69.5 (63.7)	118.2 (108.9)
Biogenic CO ₂ from thermal gasification	0.0 (0.0)	76.6 (66.7)	172.1 (150.6)
Biogenic CO ₂ from post-combustion	1.1 (1.0)	17.2 (15.5)	43.6 (39.4)
Total available biogenic CO₂	8.7 (7.9)	163.3 (146.0)	333.8 (298.8)

Step 2. Allocate shares of biogenic CO₂ used for CCS and CCU

In line with European-wide 2050 climate goals an increasing share of biogenic CO₂ is assumed to be used for CCS from 2030 to 2050. However, given the uneven geographical distribution of storage sites across Europe, this will not be a viable option for all producers. Furthermore, the feasibility of storage options for biomethane will largely depend on the pace of CO₂ infrastructure development⁵⁴. This study has assumed a share of 5% (2030)⁵⁵, 35% (2040) and 50% (2050) of the total biogenic CO₂ is allocated for CCS, with the balance available for all CCU applications (see Table 3).

⁵¹ Specifically, 1.3180 Mt CO₂/bcm biomethane for anaerobic digestion and 2.9655 Mt CO₂/bcm biomethane for thermal gasification.

⁵² According to the European Biogas Association, around 1.17 Mt CO₂ is captured from biomethane production today from 125 plants, equivalent to around 14% of Europe's merchant liquid and solid CO₂ demand.

⁵³ ENTSO-E and ENTSO-G, TYNDP // 2024, Scenarios Methodology Report 2024, 2025. https://2024.entsos-tyndp-scenarios.eu/?utm_source=chatgpt.com#download

⁵⁴ European Biogas Association, Biogenic CO₂ from biomethane: The key to Europe's carbon strategy, 2025. <https://www.europeanbiogas.eu/news/biogenic-co2-from-biogases-key-to-europes-carbon-strategy/>

⁵⁵ According to the European Biogas Association, the significant share of biogenic CO₂ today is used for CCU applications (primarily in the food and beverage sector and for e-fuels production). The share of CCS is expected to be around 9% by 2027, although this also includes mineralisation.

Table 3. Shares of biogenic CO₂ available for CCS and CCU (Mt CO₂)

Source	2030	2040	2050
CCS	0.4 (0.4)	57.2 (51.1)	166.9 (149.4)
CCU	8.3 (7.5)	106.2 (94.9)	166.9 (149.4)
Total available biogenic CO₂	8.7 (7.9)	163.3 (146.0)	333.8 (298.8)

Step 3. Allocate share of biogenic CO₂ available for e-methane production

As discussed above, there will be multiple competing CCU uses for biogenic CO₂ over time, particularly driven by demand in aviation from the mid-2030s. These are summarised in Table 4 below, along with the estimated demand per application (note that these data are not applied in our assessment but included for information purposes).

Table 4. Biogenic CO₂ demand for competing CCU applications (Mt CO₂) in EU-27^{56 57}

Application	2030	2040	2050
Chemicals ⁵⁸	3	17	51
Mineralisation (concrete curing)	1	12	23
Greenhouses	1	11	22
E-Methanol (as a fuel)	8	11	14
E-SAF ⁵⁹	2	24	96
Total biogenic CO₂ demand	15	75	206

In addition, according to the European Biogas Association, around 14 Mt CO₂ is currently used in existing conventional applications in Europe, like food and beverage production. Currently this is almost exclusively fossil based CO₂, however, it is expected that these applications will increasingly use biogenic CO₂.

For the purpose of this study, the share of biogenic CO₂ allocated for e-methane production has been based on an illustrative low/high range of 20% to 35% of the available CO₂ for CCU in 2030 (based on Table 2) and 30% to 50% in both 2040 and 2050 (representing potential 'realistic' ranges). The resulting volumes of biogenic CO₂ are shown in Table 4 below (note that the values included in brackets relate to the EU-27).

⁵⁶ Ricardo, prepared for Transport & Environment, European CO₂ availability from point-sources and Direct Air Capture, 2022. <https://uploads.transportenvironment.org/production/files/DAC-final-report.pdf>

⁵⁷ It is expected that a share of the demand in maritime and aviation will be met through imported fuels, and so the actual demand for biogenic CO₂ will be lower. The import dependency will depend on (geo)political goals, costs of production and related (EU and national level) policy measures.

⁵⁸ Specifically: methanol, benzene, toluene and xylene (BTX) and plastics (ethylene, propylene).

⁵⁹ NOW GmbH, ReFuelEU Aviation Regulation – How does it affect the aviation sector?, 2023. https://www.now-gmbh.de/wp-content/uploads/2023/11/NOW-Factsheet_ReFuelEU-Aviation-Regulation.pdf (assumes a CO₂ demand 3.9 kg CO₂/kg fuel)

Table 5. Biogenic CO₂ available for e-methane production Europe and EU-27 (Mt CO₂)

Source	2030	2040	2050
Low	1.7 (1.5)	31.8 (28.5)	50.1 (44.8)
High	2.9 (2.6)	53.1 (47.4)	83.5 (74.7)
Theoretical maximum	8.3 (7.5)	106.2 (94.9)	166.9 (149.4)

Step 4. Calculate e-methane production potential

Finally, the e-methane production potential is calculated by considering the methanation reaction stoichiometry and the energy content of methane. Note that importantly this assumes that the equivalent volumes of renewable hydrogen are available over the required timeframe (i.e. that biogenic CO₂ supply is leading).

3.3.2 Results

Following this approach, the assessed e-methane production in Europe and the EU-27 (included in brackets) is shown in Table 6.

Table 6. Assessed e-methane production potentials in Europe and EU-27 (bcm).

E-methane production	2030	2040	2050
Low	0.8 (0.7) ⁶⁰	14.9 (13.3)	23.4 (21.0)
High	1.4 (1.2)	24.8 (22.2)	39 (34.9)
Theoretical maximum	3.9 (3.5)	49.6 (44.4)	78 (69.8)

It should be noted that these assessments are highly sensitive to the underlying assumptions, including achieving the biomethane potentials from anaerobic digestion and thermal gasification assumed in this study, and that the required volume of renewable hydrogen is available. They do not account for the relative techno-economics of competing CCU applications (or the willingness to pay for biogenic CO₂), nor for the potential influence of future policy developments on technology choices.

⁶⁰ According to the European Biogas Association, current planned production capacity for e-methane production in Europe is expected to reach around 0.3 bcm per year by 2030. Over 80% of the projects are understood to be targeting the use of biogenic CO₂.

4. Feedstock mobilisation

This report presents an assessment of the sustainable potential for biogases production within Europe, reinforcing the conclusions of earlier assessments that biogases have an important role to play in the future defossilised energy system. However, the potential assessment for 2030 has been lowered compared to previous studies, which reflects not a change in the total sustainable potential, but a **lack of timely action to date to accelerate deployment of biogases and to mobilise available feedstocks**.

The results of this study reiterate the conclusions from earlier assessments that there is a significant potential. More coherent policy recognition of the system-wide benefits that biomethane can bring is needed to provide the boost that the sector needs. Scale up of the European biogas industry needs more coherence and harmonisation across different policy areas and Europe, as well as faster permitting and faster feedstock mobilisation. As the next sections will describe, mobilising the sustainable feedstock potentials in this study, in particular, requires clear definitions, targets and targeted outreach to the farming, forestry and waste communities to stimulate collection of wastes and residues, and plant sustainable crops for the production of biogases.

A 2022 'Manual for National Biomethane Strategies', produced by the Gas for Climate consortium, listed ten priority actions for countries to scale-up their biomethane production, three of which focused specifically on mobilising the biomethane sector.⁶¹ All these actions are still relevant today. The actions most necessary to mobilise sustainable feedstocks include **quantifying and mapping feedstock potential** to understand how much untapped potential feedstock is available and where it arises, **engaging stakeholders** to foster public acceptance, **initiating capacity building** activities to mobilise sustainable feedstocks, and building a reliable supply chain including providing relevant training.

Of the feedstocks included in the scope of this study, there is a crucial **difference between feedstocks that exist and need collecting and those that need to be cultivated**. Wastes and residue feedstocks like animal manure or straw are already produced but action is needed to collect the feedstocks and channel them towards production of biogases. On the other hand, sustainable crops (both sequential crops and feedstocks grown on marginal and contaminated lands) do not exist today and need to be cultivated. This study shows they can offer a significant potential for additional feedstock, but the potentials will only be achieved with targeted action to stimulate farmers and landowners to start cultivation. Furthermore, opportunities to harness biogenic CO₂ streams provide a viable pathway to produce additional renewable gas through e-methane production pathways and require different type of actions, for example, creating a single market and infrastructure for biogenic carbon across the EU.

Different actions are needed to mobilise the different types of feedstock. Countries should quantify and map feedstock potentials and then **develop actions and strategies targeted to their corresponding feedstock potentials** and to their specific agricultural or forestry sectors. For example, regions with strong livestock sectors will require actions focusing on collecting and aggregating different sources of animal manure, whereas regions with large areas of marginal land should focus on support schemes or capacity building for landowners, and regions with a mix of agriculture types – animal and arable farming – may require a different set of actions again.

⁶¹ Sections 8, 9 and 10: Gas for Climate, Manual for National Biomethane Strategies, 2022.
https://www.europeanbiogas.eu/wp-content/uploads/2022/09/2022-Manual-for-National-Biomethane-Strategies_Gas-for-Climate.pdf

In the **short term to 2030**, action should focus on mobilising feedstocks for anaerobic digestion whilst gasification moves closer to being commercialised in Europe. There is a trend towards larger anaerobic digestion plants for increased economies of scale, but these will require a greater source of feedstock and good proximity to the gas grid if targeting biomethane production. Project developers can consider whether it is preferable to either **pool (the same or different) sources of feedstock** into one plant or otherwise have smaller capacity biogas plants but **pool the biogas** into a central biomethane upgrading station. Pooling concepts are still in the early stages of development, but have been successfully trialled in Europe. A notable project was undertaken in Bitburg, Germany, where a new 45 km pipeline was built to aggregate the raw biogas supply of around 50 biogas plants to a central upgrading plant⁶².

Denmark has enjoyed considerable success with co-digestion based anaerobic digestion, anchored on using animal manure as the main feedstock⁶³, whereas in Germany there has also been a tendency to implement more single-feedstock mono-digestion systems. Mono-digestion reduces overall flexibility in terms of technical infrastructure and feedstock sourcing options, but importantly allows plant operators to more readily optimise performance on that feedstock. An advantage of co-digestion is that by using a mixture of multiple feedstocks it is then possible to optimise the feedstock shares depending on feedstock prices and availability. Both approaches can work, stressing the need to understand and leverage the available local feedstock resource.

Another key consideration is **public acceptance** and planning, in particular with respect to transport movements of both feedstocks and digestate. For example, that trucks avoid passing by schools, and through locations which are not readily able to accommodate large-scale truck movements.

Having a clear **route to valorise and use the digestate** is also important. One potential option to provide more options for an end market for the digestate is digestate treatment, for example, as practiced by Green Create in the Netherlands, who is drying and pelletising the digestate into a more readily transportable commodity⁶⁴.

In the **medium term**, actions should also focus on mobilising the feedstocks that are included in the thermal gasification potential. These are mainly forest and wood residues, which exist at scale today, but would need to be more systematically collected and diverted towards biomethane production. On top of that is the potential from contaminated land, which in this study is assumed to be processed via gasification due to the challenges of disposing of digestate that may contain contaminants. These actions will need to continue to keep ramping up the mobilisation of feedstocks to reach the higher shares assumed in 2040 and the full technical potential in 2050. A commercial scale gasification plant will be significantly larger scale than an anaerobic digestion plant, so plants will need to be carefully sited to ensure a significant and stable source of feedstock can be accessed.

The following sections describe more specific actions to mobilise the significant feedstock potential that exists in Europe, also considering any specific barriers that may need to be overcome.

⁶² Gas for Climate, Market state and trends in renewable and low-carbon gases in Europe, 2020.
<https://gasforclimate2050.eu/publications/>

⁶³ Bruno Sander Nielsen, Biogas - The Danish Model- Renewable gas based on circular economy, 2026.

⁶⁴ <https://www.green-create.com/locations/wijster/>

4.1 Wastes and residues

Wherever possible, countries should prioritise the mobilisation of the available volumes of waste and residue feedstocks including animal manure, agricultural residues, biowaste (food waste) and industrial waste (including industrial wastewater). Waste and residue feedstocks have no costs or greenhouse gas emissions associated with their production, so can be expected to be the cheapest and offer the highest greenhouse gas emission savings. These feedstocks exist today so these actions can be prioritised in the short-term.

Some waste feedstocks, such as **animal manure** and **biowaste**, present a challenge with respect to fugitive emissions (primarily methane) if left untreated in open storage systems. Therefore, diverting these feedstocks to biomethane production can play an important role to reduce these emissions (particularly in the agricultural sector), as well as producing valuable renewable energy and nutrient-rich digestate, and providing an important contribution to the control of pathogens.

Animal manure, in particular, is widely available but currently under-utilised for anaerobic digestion, compared to land spreading. Even if we transition more towards plant-based diets, there will still be significant potential from animal manure into the future⁶⁵. Some Member States recognise the long-term potential for biogas production from manure – for example, France has signalled intent to mobilise 80% of animal manure by 2050. Where livestock densities are high, either centralised and farm-scale digestion models can potentially be implemented, but importantly tailored to local constraints (logistics, nutrient regulations and grid access). A key challenge with manure-based anaerobic digestion systems is collecting and aggregating the manure to a sufficient scale and managing transportation logistics. Manure has a very high water content (of up to 95%) and as such is costly to transport, limiting transport distance to around 20 km on average. However, by dewatering the manure it can be possible to increase the transport distance to up to 200 km⁶⁶, enabling very large-scale dedicated manure-based biomethane plants to be built (such as the Nordfuel plant in Germany which is able to process one million tonnes of farm manure per year⁶⁷). Denmark has successfully built manure-based systems at scale, pooling manure from multiple farms, stressing the importance of optimised logistics – making sure the anaerobic digestion plants are sited in a way that minimises transport costs and ensuring trucks that are used to transport the manure to the plant are used to transport digestate back to the farmers who supplied it, so that they are full both ways. Danish biomethane producer, Agri Energy, has even successfully established a pipe system that connects ten farms to a biomethane plant to reduce the need for truck movements, as well as helping to reduce odour nuisance⁶⁸.

There are increasingly policy drivers to reduce methane emissions, such as those from untreated manure. The **Global Methane Pledge**⁶⁹ aims to reduce global methane emissions by at least 30% from 2020 levels by 2030. Member States are also taking their own actions to reduce such emissions. The Danish Parliament adopted a new carbon tax on agriculture to be introduced from 2030, to be paid for methane emissions from livestock. Potentially, treating methane via anaerobic digestion could reduce that tax for farmers. Some Member States are also implementing greenhouse gas emissions reduction-based quota systems under the RED, which can act as a strong driver for low carbon intensity biomethane

⁶⁵ European Commission, EU Agricultural Outlook 2023-2035, 2025. https://agriculture.ec.europa.eu/data-and-analysis/markets/outlook/medium-term_en

⁶⁶ Personal communication with Henning Dicks, Managing director and co-founder, Agriportance GmbH.

⁶⁷ <https://agrotel.eu/en/nordfuel-biomethananlage/>

⁶⁸ <https://vraa.agrienergy.dk/>

⁶⁹ European Commission, Launch by United States, the European Union, and Partners of the Global Methane Pledge to Keep 1.5C Within Reach, 2 November 2021. https://ec.europa.eu/commission/presscorner/detail/%20en/statement_21_5766

production from wastes. Germany was the first country to implement a greenhouse gas-intensity based quota system in 2021, which has made it more favourable to use manure in anaerobic digestion plants. Since then, several other countries, including the Netherlands and Czechia, have also implemented greenhouse gas-intensity based quota systems. In addition, the FuelEU Maritime Regulation is based on a greenhouse gas-intensity reduction system, incentivising the use of manure-based bio-LNG as a maritime fuel.

Agricultural residues (e.g. cereal straw and other field residues) are an important source of feedstock that can complement manure by increasing energy yield and expanding the geographic resource base. The feedstock potential assessment here takes into account sustainable removal rates to protect soil organic carbon and erosion control. Local guidelines – working in harmony with EU level legislation such as the new Soil Health Directive – should be provided to ensure soil health is maintained in practice. Agricultural residues also face higher competing uses compared to manure (e.g. animal bedding and feed). In the case of animal bedding, Denmark frequently uses the agricultural residues for anaerobic digestion after they have been used for animal bedding, thus combining straw with manure. Dedicated straw-to-biomethane plants are more technically challenging to operate, but the first examples in Europe are now emerging (including those developed by Verbio⁷⁰ in Germany and Green2X⁷¹ in Denmark).

A potential barrier to the scale-up of agricultural residues for bioenergy is highlighted in a recent report published by the European Commission. This indicates a lack of harmonisation between EU agricultural and energy regulation, specifically requirements under the Common Agricultural Policy (CAP) – GAEC 6 (minimum soil cover) and GAEC 5 (erosion) – and the RED. It is suggested that this may deter farmers from supplying residues for bioenergy.⁷²

Since 2024, landfilling or incineration of **biowaste** is no longer permitted in the EU.⁷³ Similarly, from 31 March 2025, local authorities in England were required to implement separate food waste collection services from businesses, which was extended to cover households from 31 March 2026. This is resulting in an increase in the biowaste material that is collected and that could be available for biomethane production. Municipalities should anticipate where new sources of organic waste will become available and work with waste management companies and biomethane project developers to channel this new source of feedstock to develop new biomethane projects. In some cases, biowaste will continue to be managed through composting, which provides valuable nutrients that can be returned to the soil. However, wherever the feedstock can be channelled to anaerobic digestion, renewable energy can be produced, whilst still providing digestate that can be used as a natural fertiliser. Anaerobic digestion can also be used as a complementary pre-treatment technology prior to composting. This has the benefit of reducing the substrate mass, and therefore the mass of material to be composted, which in turn reduces the overall cost of composting by an estimated 15%⁷⁴.

⁷⁰ <https://www.verbio.de/en/green-solutions/mobility/>

⁷¹ <https://green2x.com/>

⁷² European Commission, DG Research & Innovation, Mobilization of industrial capacity building for advanced biofuels, 2026. <https://op.europa.eu/en/publication-detail/-/publication/cc500efe-fe51-11f0-8da5-01aa75ed71a1/language-en>

⁷³ Revised Waste Framework Directive which requires a separate biowaste collection or recycling at the source by 31 December 2023 (Directive 2018/851/EU). All municipalities must plan and implement separate biowaste collection schemes.

⁷⁴ Guidehouse, Beyond energy monetising biomethane's whole-system benefits, 2023. <https://www.europeanbiogas.eu/publication/beyond-energy-monetising-biomethanes-whole-system-benefits/>

Similarly, for **industrial wastewater**, adding an anaerobic digestion pre-treatment stage prior to conventional activated sludge aerobic treatment significantly reduces organic load⁷⁵, and hence electricity consumption (which is the main cost driver for aerobic treatment). As a conservative estimate, biomethane production from industrial wastewater reduces the counterfactual cost by 75%, providing a compelling business case for its implementation⁷⁴. An additional benefit is a significant reduction in greenhouse gas emissions.

4.2 Sustainable crops

In addition to wastes and residues, there is a significant potential for sustainable crops that can be produced without displacing existing land uses, including both sequential crops and crops grown on under-utilised lands. Such crops can provide a source of energy-dense feedstock that does not face the same issues as the use of food and feed crops, and can provide broader benefits in terms of soil health, biodiversity and supporting rural economies.

4.2.1 Sequential crops

Sequential crops – also referred to as cover or catch crops or intermediate crops⁷⁶ – are cultivated **between two main crops** in otherwise fallow periods, to generate additional biomass while maintaining (food and feed) output from the main crop.

Sequential crops are treated as distinct from conventional energy crops because they offer a pathway to increase biomass supply from existing farms **without land expansion and without competition with food or feed production** when properly designed and verified. This logic aligns with broader EU sustainability framing that distinguishes intermediate crops from “food and feed crops” provided they do not trigger demand for additional land and maintain soil organic matter. The potential for sequential crops is large, and they can be implemented by existing farmers today, without any change in land ownership or designation. How they are implemented in practice, however, is highly **region-specific**. Different climates and soils in different regions influence existing crop rotations and therefore influence which crop varieties are suitable to be grown when the land is typically left fallow.

Whilst some countries are already reporting an increase in these types of crops, action is needed today to further scale-up this method of sustainable crop production to be able to see significant feedstock volumes by 2030 and beyond. As well as the time to mobilise, train and contract farmers, as these crops are integrated into crop rotations, optimal integration of sequential cropping into a farm's cropping system will require several cultivation seasons.

Clear definitions of sequential cropping and integration into current policy – including national production targets – can help to scale up this method of cropping. The recent inclusion of intermediate crops in **Annex IX** of the RED is expected to provide a significant boost to stimulate sustainable crop production. However, further guidance is needed to ensure the definition can be implemented clearly in practice, and it has been recommended that the cap on Part B of Annex IX is addressed to ensure there is sufficient room for this type of feedstock to grow⁷⁷. The Annex IX definition is very specific and designed to avoid

⁷⁵ In an anaerobic pre-treatment step a large share of the organic load can be converted to biogas.

⁷⁶ Note that since March 2024, Annex IX of the Renewable Energy Directive includes intermediate crops defined in a specific way: “such as catch crops and cover crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land and provided the soil organic matter content is maintained [...]” <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32024L1405>

⁷⁷ studio Gear Up, Benefits of intermediate crops, and bottlenecks to their development, 2025. https://www.studiogearup.com/wp-content/uploads/2025/09/2025_sGU_Benefits-of-intermediate-crops-and-bottlenecks-to-their-development_FINAL.pdf

any risk of triggering demand for additional land in any cropping system in any part of the world. However, a very strict implementation of this definition may result in missed opportunities for sequential cropping that could still bring benefits by diversifying crop rotations. Annex IX is designed for transport fuel feedstocks and policy makers focusing on biomethane could also consider supporting slightly broader approaches to sustainable cropping solutions that still apply strict regenerative agricultural practices, such as rotational cropping.

Rotational cropping⁷⁸ here describes the concept of a modified crop rotation, centred on a long and diverse crop rotation (e.g. up to 7 years) that can also include a crop that can be used for bioenergy. Whilst this would technically not meet the Annex IX definition of intermediate crop, it can bring environmental benefits of diversity in the crop rotation in a way that can be implemented in climates with a shorter vegetation period (for example, in northern Europe). Future Biogas, a leading biomethane producer in the UK, source from farms that practice rotational cropping. Growers are required to sign up to a Bioenergy Crop Charter⁷⁹ that commits them to grow crops in a way that ensures soil health, good nutrient management, pest control, water protection and biodiversity integration – going beyond the minimum regulatory sustainability criteria. In addition, a central component of the approach is the return of digestate back to the land.

France has implemented a definition of main crop as a crop that is on the land on 1 to 15 June and is covered by the CAP. By default, if a crop does not meet this definition, then it can be considered an intermediate crop. The definition is clear and operational and since its introduction, production of intermediate crops has grown. **National production targets** can clearly also help stimulate the uptake. France has set a national target in its National Energy and Climate Plan (NECP) of 100 TWh biogas production per year in 2050, of which 50% should come from intermediate crops. It is currently estimated that 3-4 TWh of biogas was produced via intermediate crops in 2025, of the 16 TWh total biomethane production in France⁸⁰. Integration of this concept of harvestable cover cropping into good agricultural practices under the CAP – and aligning definitions with those stimulated in the energy sector – would also provide a significant stimulus for the scale-up of such practices.

Providing long-term predictable support to farmers to grow intermediate crops will help to stimulate uptake. Growing intermediate crops does not necessarily have to mean a significant upfront investment for farmers beyond buying seeds, especially if they have access to appropriate sowing and harvesting machinery already. However, as the crop is by definition being grown at a poor time of year from a climate perspective, there is a higher risk of crop failure than with the main crop, for example if there is severe frost or flooding. Therefore, providing a predictable price to farmers for the intermediate crops that they grow can help to provide the certainty they need to invest in growing them. This could be via policy support or from offtake contracts with biogas producers, for example via a contractual guaranteed feedstock price per tonne from biogas producers, with prices benchmarked

⁷⁸ An Alder BioInsights report for the UK Green Gas Taskforce defines Rotational crops as “Alternating crops on a specific field (or fields) in a planned pattern or sequence in successive years. Rotations are typically 4 to 7 years. A long, diverse rotation can support the delivery of multiple environmental and agronomic benefits, including improved soil fertility, increased soil carbon, enhanced crop yields, ground cover and soil protection, pest and disease control, diversified income.” See: Alder BioInsights, A Green Gas Future: Outlining the Feedstock Potential for Biomethane Generation, 2025. <https://greengastaskforce.co.uk/wp-content/uploads/2025/09/GGT-Unlocking-the-Potential-of-Biomethane.pdf>

⁷⁹ <https://www.futurebiogas.com/farming/bioenergy-crop-charter/>

⁸⁰ A notable project is Secalia Châtillonna, developed by Shell Biogas (formerly Nature Energy) in 2023, with support from Dijon Céréales, a French farming cooperative. This utilises intermediate crops (fodder rye) sourced from 155 member farmers, along with cereal wastes, livestock effluents and industrial wastes, to produce 260 GWh of biomethane per green gas per year. See: <https://solarimpulse.com/solutions-explorer/implementation-stories/nature-energy-s-renewable-gas-green-fertilizer-plant-adopted-by-secalia-in-cerilly-france>

against what farmers could make from their winter cereals. Also from the biogas project developer perspective, long term feedstock contracts for sequential crops can reduce exposure to volatile feedstock markets, improving supply predictability and supporting investment in larger or centralised anaerobic digestion plants.

From a policy support perspective, a report published by the European Commission on mobilising industrial capacity building for advanced biofuels advocates for a **targeted EU-level financing plan that should prioritise provision of EU, or national-funded, feedstock price premiums to support farmers**⁸¹. Without such premiums, it is argued that farmers may not find it economically viable to switch or expand feedstock production for bioenergy. Beyond direct energy policy incentives, sequential crops could be actively mobilised through the CAP when implementation is aligned across Member States. Intermediate crops can contribute simultaneously to GAEC 6 (minimum soil cover), GAEC 7 (crop rotation/diversification) and, in some national frameworks, GAEC 8 (biodiversity features). When explicitly recognised in national CAP Strategic Plans, sequential crops can reduce compliance risk for farmers rather than adding complexity, thereby lowering the barrier to uptake.

Coordinated outreach and training from biogas project developers can help to mobilise cultivation of sequential crops centred around a specific biogas plant. From a feedstock mobilisation perspective, sequential crops for bioenergy will work better as part of an integrated supply chain model, rather than as a stand alone agronomic decision by an individual farmer. Mobilisation will be strongest where sequential crops are anchored to nearby anaerobic digestion plants or regional hubs that can provide guaranteed offtake contracts, training and technical support, and digestate return pathways.

Biogas project developers can employ a dedicated farm manager whose role it is to identify potential farms that could be suitable for sequential or rotational cropping, to reach out to such farms, provide training and support and manage the supply contracts. Such a role could also be provided by local farmer cooperatives or national biogas associations that work with farmers in the local area. Organisations, like local farmer cooperatives, can also provide support such as feedstock storage via central hubs or facilitating sharing of farm equipment, if different farm machinery is needed for the sequential crop, to lower the upfront investments needed from farmers.

Lastly, agricultural research into different kinds of seeds is useful, focusing on how to grow intermediate crops that require low inputs or have a faster growing period and thus do not impact the growth period of main crops.

Examples of best practice

In Italy, the **BiogasDoneRight™** concept was set up to encourage the use of sequential crops, crop rotation, minimum tillage, and integration of crop residues with livestock effluents sub-products and organic waste, instead of primary energy crops, in order to limit the competition between food and energy for land occupation (see Figure 8). The Italian Biogas Association (CIB) provides extensive outreach and training to farmers in different Italian agricultural areas on how to implement this concept and furthermore engages with local communities. The main activities include demonstration of machinery targeted at more sustainable farming solutions, as well as discussions around feedstock sustainability and biomethane market opportunities. The initiative's objective is to steer agricultural communities' interests and knowledge and raise awareness among citizens.

⁸¹ European Commission, DG Research & Innovation, Mobilization of industrial capacity building for advanced biofuels, 2026. <https://op.europa.eu/en/publication-detail/-/publication/cc500efe-fe51-11f0-8da5-01aa75ed71a1/language-en>

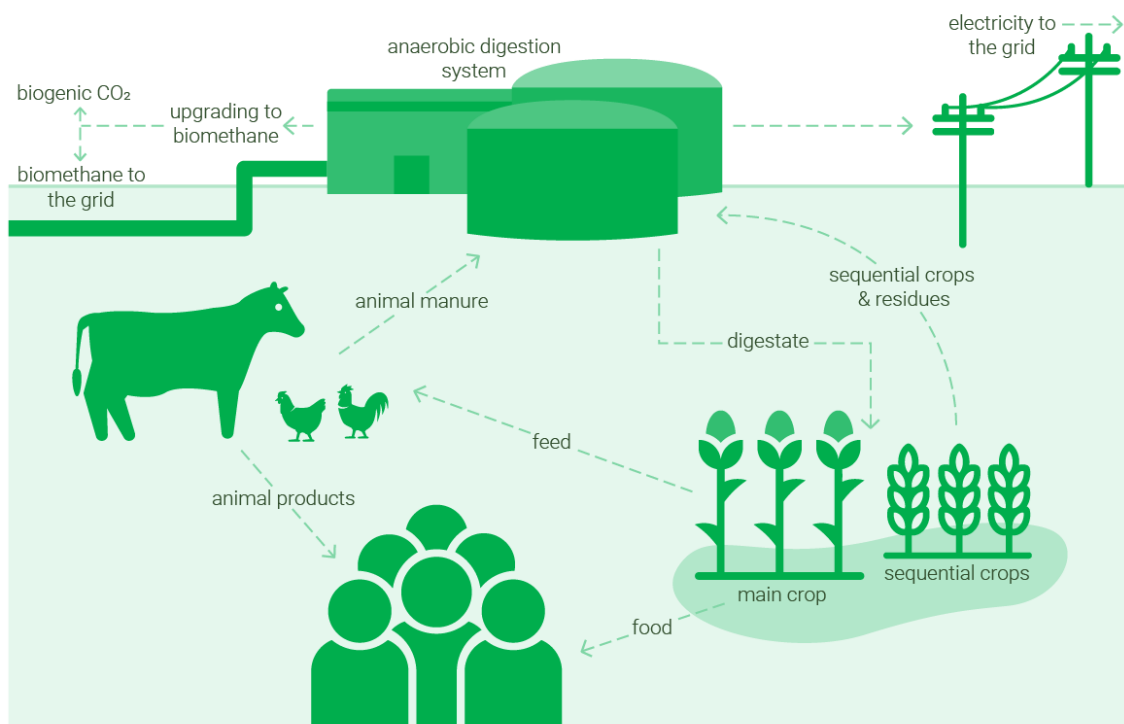


Figure 8. Graphical representation of the BiogasDoneRight (BDR™) concept

French government agency ADEME funded the 'RECITAL' research project, led by Arvalis Institut du Végétal. The objective was to provide guidelines on sequential cropping (Intermediate Crops for Energy – CIVE⁸²) for farmers in France in order to optimise its application in the different regions and with different crop rotations. The project started in 2020 and continued until 2023. Alongside Arvalis, the Association of Biogas Farmers of France (AAMF) and the Chambers of Agriculture and other French economic operators were also involved in the project.

4.2.2 Marginal land, contaminated land and abandoned land

As the data shows, there is a significant potential for currently **under-utilised lands** to produce crops for bioenergy. Planting crops for biomethane on so-called **marginal lands, or contaminated or abandoned land** could provide a new source of feedstock for biomethane production without contributing to an increase in land use change, or compromising existing food or feed production.

Marginal, contaminated or abandoned lands will produce lower yields per hectare compared to good quality agricultural land because of biophysical and climatic challenges, but can nonetheless still offer a significant feedstock potential due to the large amounts of land potentially available today. Increased areas of these lands are also projected to become available over time, as the effects of climate change and trends of land abandonment continue. Providing a source of income via biogas production could help to turn the fate of these lands around. Furthermore, bringing these types of land into productive use can also bring broader benefits including to nature and biodiversity by halting further degradation and

⁸² Cultures Intermédiaires à Vocation Énergétique.

soil erosion, restoring land after industrial uses and more specifically restoring the soil through phytoremediation in cases of contamination.

Depending on the reasons for the land being under-utilised, there can be a substantial **upfront investment needed** to start cultivation on the land, especially if it is degraded (for example with low soil organic matter) or contaminated⁸³. Mobilisation will therefore require **incentives** for farmers and landowners. Incentives could be provided via the CAP or via the RED or by a contractual guaranteed feedstock price from a biomethane producer.

Furthermore, a **clear classification of these lands** via policy and coherence across different policy areas will help to provide certainty to those investing, and provide a framework upon which a system of policy incentives could be based. These categories of land are not mutually exclusive (e.g. land could be abandoned because it is degraded), and the drivers for land being under-utilised are complex, but clear policy definitions will help to enable identification of lands that can be used and practical actions that improve the cultivation of these lands. Practical policies and definitions that focus on providing guidelines and encouraging sustainable actions that farmers or land owners would help to stimulate actions with low risk to land owners or policy makers, rather than definitions that rely heavily on costly soil testing or complex measurements and calculations, which put the burden of risk onto farmers or land owners that their land may not meet the definition. Governments could play a role in helping to spatially map these types of lands, and to categorise them according to the definitions, to make it easier for the market to identify lands that can be brought back into productive use. There is a clear role also for municipalities to help in the land planning side. Combining such maps with consideration of logistical access for agricultural infrastructure and machinery and proximity to the gas grid can also inform those areas where it would make sense to focus efforts in the first instance.

A further challenge is that these types of lands may be under different types of **ownership**. Some land will already be owned by farmers and in the short term, actions could focus on capacity building and mobilising those farmers to take steps to restore land and increase productivity on it. Other areas may not have a clear legal owner, so there could be an additional effort required by a project developer to locate the owners. In the longer term, actions could focus on stimulating larger land owners to bring areas into cultivation. Large actors such as industrial players or the military may own suitable land. For example, former mining⁸⁴ or industrial sites may be subject to obligations to rehabilitate the land after use, with fines for inaction. Growing feedstocks for bioenergy could be a significant opportunity for those lands, potentially also to help solve contamination issues. Combining feedstock cultivation on industrial sites with biomethane production could even provide a source of biomethane for the industrial end users.

Depending on the condition of the land and the reasons for it being under-utilised, it can take 3-5 years to restore the land to bring it back into cultivation, so significant mobilisation before 2030 is assumed to be limited. Nevertheless, there are several examples of projects in Europe today showing that it is possible to use these types of land (see case studies below).

⁸³ Note also that we have assumed that feedstocks grown on contaminated land would be processed via thermal gasification due to risk of contaminants in the digestate, and this would also increase the overall cost of biomethane production compared to anaerobic digestion.

⁸⁴ Just Transition Platform Knowledge Hub: https://just-transition-experts.ec.europa.eu/find-knowledge/approaches-biomass-projects_en

Case study 1: Restoring severely degraded land in Spain for biomass production

The Horizon 2020 funded BIO4A project^{85 86} conducted a pilot in **Castilla-La Mancha, central Spain**, to test whether severely degraded, semi-arid farmland, could be returned to productive use by combining soil restoration with a low-input, non-food energy crop. The land selected was severely degraded former agricultural land that had very high salinity levels (visible salt crusting in places) and very low organic matter (<1%) resulting from decades of intensive cereal cultivation and chronic drought conditions. The pilot started in January 2019 and ran until June 2021.

The oil seed, *Camelina sativa*, was selected for its ability to grow well with minimal input. The pilot site consisted of four micro test plots of 12.5 m by 1.2 m. Before planting, the project team applied soil amendments with the aim of rehabilitating the soil. The core amendment was COMBI compost (an experimental blend of compost, digestate from anaerobic digestion and biochar) developed by RE-CORD⁸⁷, an Italian research and demonstration company involved in the project. Biochar was incorporated into the COMBI compost to increase the soil carbon content, while the compost and digestate provided nitrogen, phosphorus and other nutrients. About 30 tonnes/ha of this rich organic compost mixture was incorporated into the top 20 cm of soil on each of the plots. The treatments including organic fertilizer (compost, COMBI) in the background fertilisation have shown the fastest development, followed by mineral fertilization treatments.

In the first season, *Camelina* established well, achieving ~60–70% ground cover at full harvest (vs. <20% on unamended soil). The yields across the plots ranged between 0.5 to 1.8 tonnes/ha, which is comparable to conventional yields from semi-arid farms in Spain. Importantly, in this pilot, farmers were successfully able to plant a second crop after the camelina, which increased the overall yield from the land after rehabilitation. These promising trials demonstrate the potential to restore marginal lands through the application of a novel blend of carbon rich compost.

⁸⁵ BIO4A, Cultivation of *Camelina* in semi-arid land with a high risk of desertification, 2023. https://www.bike-biofuels.eu/wp-content/uploads/2023/02/4-Bio4A_Cultivation-of-Camelina-in-semi-arid-land-with-a-high-risk-of-desertification_JPrieto.pdf

Cultivating *Camelina* for sustainable aviation fuels in EU med marginal, David Casini et al.: https://dc.engconfintl.org/biochar_ii/53/

BIO4A, Deliverable D2.3: Compost agronomic protocol optimization trial. https://www.bio4a.eu/wp-content/uploads/2023/08/D-2.3-Compost-agronomic-protocol-optimization-trial_PU.pdf

⁸⁶ The BIO4A project aimed to scale up the industrial production of sustainable aviation fuel from residual lipids grown on severely degraded land in the Mediterranean.

⁸⁷ <https://www.re-cord.org/#>

Case study 2: Remediating contaminated land in Greece for biomass production

This GOLD pilot project⁸⁸ took place in **Kozani, northern Greece**, on land previously used for lignite (coal) mining. Mining activities had left the soil severely contaminated with heavy metals such as nickel (Ni), zinc (Zn), copper (Cu) and chromium (Cr). In some areas, these metals were found at levels two to three times higher than normal levels, making it unsafe to grow food or feed crops.

To address this challenge, researchers from the Center For Renewable Energy Sources (CRES) tested whether non-food energy crops could instead be grown safely⁸⁹ while also helping to remediate the soil. A 0.5 ha experimental plot was selected on contaminated land that already had some natural vegetation. The approach combined the application of two environmentally friendly techniques:

- **Phytoextraction**, where plants absorb metals from the soil and store them in their stems and leaves, which are later harvested.
- **Bioaugmentation**, where beneficial microorganisms and natural plant stimulants are added to promote plant growth, support nutrient uptake and enable crops to better tolerate stress from polluted soils.

Three fast growing energy crops were tested: sorghum, switchgrass, and miscanthus. Different bioaugmentation treatments were applied, including combinations of fungi that live on plant roots (mycorrhiza), natural soil substances (humic and fulvic acids) and protein-based plant boosters.

Field trials ran over two growing seasons (2022–2023) and demonstrated successful outcomes. All three crops established well and achieved high biomass yields, especially in the second year. Sorghum showed strong growth in both years and achieved a yield of 34 tonnes of dry biomass per hectare in the second year. The perennial crops – miscanthus and switchgrass – showed much higher yields in the second year compared to the first year of establishment. Miscanthus yields increased more than fourfold to >33 t/ha while switchgrass yields doubled 7 t/ha to 14.5 t/ha.

Heavy metal can decrease the efficiency of the anaerobic digestion process. The GOLD study included various methods for contaminant separation prior to further processing, although the focus was pre-treatment for advanced biofuels production through gasification rather than for anaerobic digestion. These pre-treatment steps resulted in improvements to the energy density of the feedstock by reducing the moisture and oxygen content and increasing the carbon content. Pre-treatment using slow pyrolysis or torrefaction were both found to be more practically suitable for integration with gasification processes.

⁸⁸ [GOLD - Factsheets](#)

[D1.1 Site description and characterisation.pdf](#)

[D1.2 Comparison of phytoremediation practices for growing selected high-yielding energy crops.pdf](#)

[D1.4-Application-of-phytoremediation-strategies-on-small-scale-trials.pdf](#)

[D-2.3-Pre-treatment-options-and-contaminant-separation-as-well-as-concentrated-recovery.pdf](#)

⁸⁹ Safely in this context means that the tested feedstocks are not edible feedstocks and thus there is no risk that feedstocks grown on contaminated land would unintentionally end up on the food or feed market.

Case study 3: Bringing abandoned land back into agricultural production in Italy

In the region of **Reggio Calabria, southern Italy**, 103 hectares of abandoned land was acquired in 2012 for rehabilitation by the regional dairy cooperative *Fattoria della Piana*.⁹⁰ The land had suffered from low soil organic matter content and increasing desertification, and had been abandoned due to the low productivity of mixed hay cultivation. The cooperative spent 9 years progressively increasing the soil organic matter content, through the incorporation of digestate from anaerobic digestion. The formerly-abandoned area of land is now able to grow corn as a primary crop and various grains as a secondary crop.

As further context, Fattoria della Piana operates one of the largest biogas plants in southern Italy, and follows the BiogasDoneRight™ and the Farming for Future sustainable agriculture models to produce biogas. Input feedstocks include agricultural by-products, such as animal manure from cows, supplied by around 90 farmers in the local area as well as sequential crops. The digestate is continuously returned to the land, thereby improving the quality of the soil.

This case study illustrates how biogas production, combined with use of the digestate, can restore the fertility of soils and bring formerly abandoned land back into agricultural production, without causing land displacement.

4.3 Biogenic CO₂

It is evident from section 3.3 that biogenic CO₂ from biomethane production and use has the potential to play a key role in supporting Europe's 2050 net zero climate goals. With this in mind, several countries across Europe have implemented support schemes targeting the uptake of biogenic CO₂. For example, **Denmark** has awarded contracts to support three biomethane producers to collectively capture and store 160,350 tonnes of CO₂ annually from 2026 until 2032, through a recently run Negative Emissions via Carbon Capture and Storage (NECCS) tender process⁹¹. The **Netherlands** provides feed-in premium support for CCUS projects under the SDE++ scheme, however this is limited to use of the CO₂ in greenhouses to boost yields and up to 4,000 operating hours. Finally, in 2024, **Sweden** launched a €3 billion (SEK 36 billion) scheme to support projects removing biogenic CO₂ emissions through CCS⁹².

However, to fully unlock the potential of biogenic CO₂, concerted action is needed to address policy and infrastructure barriers. The European Biogas Association has set out the following policy actions to enable the scale-up of bioCCUS in Europe⁹³.

1. **Set an EU-wide target for biogenic carbon capture:** Setting an ambitious EU-wide target for biogenic carbon capture and explicitly prioritise utilisation and storage solutions based on biogenic carbon over fossil carbon.

⁹⁰ BIKE, Soil fertility and biogas production: a good practice from southern Italy, 2023. <https://www.bike-biofuels.eu/news/soil-fertility-and-biogas-production-a-good-practice-from-southern-italy/>

⁹¹ <https://ens.dk/presse/tre-nye-ccs-projekter-faar-tilsagn-om-stoette-til-fange-og-lagre-co2>

⁹² <https://www.energimyndigheten.se/en/news/2025/20-billion-to-capture-and-store-over-11-million-tons-of-biogenic-carbon-dioxide/>

⁹³ European Biogas Association, Mapping e-Methane plants and technologies, 2024. <https://www.europeanbiogas.eu/publication/mapping-e-methane-plants-and-technologies/> (the report provides a more detailed overview of recommended policy actions)

2. **Define carbon capture targets and a roadmap towards 2040 and 2050:** Engaging with the biomethane sector to understand how it can contribute towards CCUS scale-up towards 2050.
3. **Develop a regulatory framework that supports the business case for biomethane CCUS:** Implementing a suite of policy measures that support biomethane CCUS. For example:
 - a. Introducing a legal definition of biogenic carbon;
 - b. Establishing common criteria for biogenic carbon certification (to differentiate it from fossil-based CO₂);
 - c. Extending the EU Emissions Trading System to incorporate carbon credits generated by carbon removal certificates;
 - d. Setting targets for minimum biogenic carbon content to create and sustain demand for low-carbon products⁹⁴; and
 - e. Creating a single market and infrastructure for biogenic carbon across the EU.
4. **Create a single market and infrastructure for biogenic carbon across the EU:** Specific recommendations include:
 - a. Introducing targeted financial support instruments to address the currently low market value of biogenic CO₂;
 - b. Streamlining CCUS permitting procedures to reduce administrative burdens and accelerate deployment;
 - c. Promoting regional CO₂ hubs to aggregate volumes from decentralised producers and reduce transport costs; and
 - d. Ensuring integrated planning and governance of CO₂, biomethane and hydrogen infrastructure to maximise synergies across sectors.

⁹⁴ For example, under the Ecodesign for Sustainable Product Regulation (ESPR) and the Construction Products Regulation (CPR).

5. Feedstock competition

The large-scale deployment of biomethane in Europe depends not only on the technical availability of sustainable biomass, but also on how feedstocks are allocated across competing uses in an increasingly integrated bioeconomy. As the pressure to decarbonise and defossilise the economy increases, how policy steers the allocation of feedstocks can have a large impact on the potential for different biobased pathways, including biomethane.

This final chapter examines feedstock competition relevant to biomethane production, focusing on **competition with other energy uses** (including renewable fuels for hard-to-abate sectors, power or heat production), as well as **emerging uses** (such as the carbon removals sector – which can be competing or complementary – and material sectors such as chemicals). Existing non-energy uses (e.g. animal feed and bedding, soil preservation) are already taken into account in the assessment of the feedstock availability used to develop the biomethane potential assessments in this study.

The analysis covers the **2030 to 2050 timeframe**, recognising that competition dynamics are expected to evolve as climate ambition increases, policy frameworks mature and new conversion pathways scale up. The main feedstocks for anaerobic digestion and thermal gasification are covered separately.

5.1 Anaerobic digestion

5.1.1 Wet organic waste feedstocks

Competition risk - Low: Competition for these feedstocks outside of anaerobic digestion is expected to remain low across all modelled time horizons.

Wet organic waste feedstocks, including **animal manure, biowaste, industrial wastewater and sewage sludge** are very well suited to treatment via **anaerobic digestion** due to their high biodegradability. Likewise, their high water content makes them expensive to transport long distances for other types of industrial uses. Therefore, these already represent key feedstocks for biomethane production today⁹⁵. The recent report published by the European Commission on mobilising industrial capacity building for advanced biofuels⁹⁶ anticipates that anaerobic digestion will continue to be the dominant processing technology for these feedstocks in 2030 and towards 2050 (that report is prepared in the context of deployment in the road and maritime sectors).

Over time, hydrothermal gasification may further extend the scope of feedstocks suitable for biomethane production. However, as indicated in chapter 2, this technology was not explicitly included in this study given the overlap with anaerobic digestion feedstocks, which is already commercially deployed at scale. Hydrothermal gasification of wet feedstocks could otherwise be used to produce liquid fuels for transport, although the above European Commission report does not expect the mobilisation of significant production capacity using this technology over the timeframe to 2050 in Europe.

⁹⁵ European Biogas Association, Statistical Report 2025, Tracking biogas and biomethane deployment across Europe, 2025.

⁹⁶ European Commission, DG Research & Innovation, Mobilization of industrial capacity building for advanced biofuels, 2026. <https://op.europa.eu/en/publication-detail/-/publication/cc500efe-fe51-11f0-8da5-01aa75ed71a1/language-en>

The use of wet biomass feedstocks for **anaerobic digestion** additionally delivers multiple environmental benefits, such as fugitive greenhouse gas emission avoidance (see section 4.1), opportunities for nutrient recycling through the application of digestate and local pollution reduction^{97 98}.

5.1.2 Agricultural residues

Competition risk – Medium: Strong competition is expected beyond 2030 for agricultural residues, in particular as a feedstock for sustainable aviation fuels.

Agricultural residues, such as cereal straw, are another key feedstock used for biomethane production in Europe today. A large volume of agricultural residues is also deployed for power and heat generation, notably in Denmark, where an estimated 1.5 million tonnes per year is used (heat and electricity combined). Of this, close to 1 million tonnes per year are consumed in large scale plants, with the remainder used in on-farm boilers and district heating systems. Examples of large-scale use in other European countries are relatively limited, with the exception of the United Kingdom, which consumes around 1 million tonnes per year for power generation, supported under the Renewables Obligation scheme. This support mechanism is due to end in 2032, at which point many of the plants are expected to cease operation unless repurposed or re-supported under alternative frameworks⁹⁹.

In contrast to wet organic waste feedstocks, agricultural residues are expected to be subject to more pronounced competition as new conversion pathways scale-up, particularly beyond 2030. These feedstocks will be expected to be in competition to produce advanced biofuels, such as cellulosic ethanol, and in particular for SAF. The ReFuelEU Aviation Regulation, and SAF Mandate equivalent in the UK, serve as strong drivers. Both set long-term targets for the supply of SAF at European airports, which increase significantly after 2030, creating a very strong market pull towards aviation fuels¹⁰⁰. Mandatory targets for the supply of advanced biofuels under the RED will also serve as a driver towards transport fuels, as straw is listed in Part A of Annex IX (although noting that, unlike intermediate crops and crops grown on severely degraded land, for straw there is no Part A versus Part B distinction depending on the end use of the energy vector).

SAF production pathways that can use agricultural residues as a feedstock include Alcohol-to-jet (ATJ) and Thermal gasification + Fischer-Tropsch fuel synthesis (FT). According to analysis published by SkyNRG¹⁰¹, a scale up of SAF post-2030 will necessitate a transition away from Hydrotreated Esters and Fatty Acids (HEFA) – the dominant SAF production pathway today – toward a broader mix of alternative feedstocks and production technologies¹⁰². This implies that both ATJ and FT pathways will be needed, although these routes to produce SAF are currently significantly more expensive than the HEFA route. This is consistent with the European Commission's Impact Assessment for the ReFuelEU Aviation Regulation, published in 2021, which estimates high shares for both pathways in 2050 (each represent ~12-14% of the aviation fuel mix, compared to HEFA with a lower

⁹⁷ Guidehouse, Beyond energy monetising biomethane's whole-system benefits, 2023.

<https://www.europeanbiogas.eu/publication/beyond-energy-monetising-biomethanes-whole-system-benefits/>

⁹⁸ Similar benefits may arise from hydrothermal gasification.

⁹⁹ Alder BioInsights, A Green Gas Future: Outlining the Feedstock Potential for Biomethane Generation, 2025.

<https://greengastaskforce.co.uk/wp-content/uploads/2025/09/GGT-Unlocking-the-Potential-of-Biomethane.pdf>

¹⁰⁰ The target in 2030 is a minimum SAF supply of 6%. This increases to 20% in 2035, and to 70% in 2050.

¹⁰¹ SkyNRG and ICF, 2025 SAF Market Outlook, 2025. <https://skynrg.com/safmo25/>

¹⁰² This results from a constraint on the long-term scalability of HEFA, due to limitations on the availability of sustainable waste oils and fats.

share of ~4-5%). In addition, in the UK there is a cap on the share of HEFA fuel that can be used by fuel suppliers to comply with the mandate, which will decrease over time, steering future supply towards over SAF pathways.

Some future demand for agricultural residues may also arise from the EU's Carbon Removals and Carbon Farming regulation (CRCF)¹⁰³. This voluntary framework is expected to form the basis of a policy pull towards the use of biomass for **permanent removals**, either biogenic carbon capture and storage (BioCCS) (if used for heat or power generation with CCS), or biochar carbon removal (BCR)¹⁰⁴.

Additional competition is likely to arise from the chemicals sector over time; however, this would require dedicated policy support, which is currently lacking, and the extent to which conventional sugar and starch crops are allowed as feedstocks¹⁰⁵.

5.1.3 Sustainable crops

Competition risk – High: Competition is expected beyond 2030 especially from feedstocks for sustainable aviation fuels.

For both categories of sustainable crops – sequential crops and crops grown on marginal and contaminated land – different types of crops could be suitable to be grown, so the question of competition relates to other uses of the land as well as to other uses of the specific crops that are grown.

Annex IX of the RED now includes intermediate crops and crops (excluding food and feed crops) grown on severely degraded land¹⁰⁶. If fuels made from those crops are used for aviation, they can be counted in Part A of the Annex, which has a specific sub-target within the RED that is uncapped unlike Part B. Fuels produced from these crops importantly count towards the ReFuelEU Aviation targets, unlike conventional crops. Therefore, this is expected to provide a significant pull for these categories of land towards SAF. In some parts of Europe – especially in southern Europe – it may be possible to grow oil seeds such as camelina as an intermediate crop or on marginal land. Oil seeds are relatively low cost to convert to SAF via the HEFA route so will be attractive to grow. However, in other parts of Europe, the climate may be better suited for growing crops for anaerobic digestion. An advantage with anaerobic digestion is that it is possible to harvest and use crops before they reach full maturity, as the total biomass can be used in the biogas plant, rather than having to wait for the oil seed to mature to achieve an optimal oil yield. Therefore, crops could be grown as an intermediate crop between main crop harvests, or perhaps on lower quality soils, and still provide a useful yield for biogas production.

For marginal and contaminated land, there is a wide range of other potential uses for the land, from urbanisation to rewilding and anything in between. The use of the land will depend on the decision of the landowner, influenced by the balance of incentives in place and local circumstances.

¹⁰³ Regulation 2024/3012: <https://eur-lex.europa.eu/eli/reg/2024/3012/oj/eng>

¹⁰⁴ Biochar is typically produced via pyrolysis, and can be used to improve quality and carbon in soils.

¹⁰⁵ According to the industry association, CEFIC, around 5.5% of the carbon demand for the chemical and derived industries was covered by biomass in 2023. However, a large share of this is understood to be biomethane used as a feedstock.

¹⁰⁶ REDIII Annex V defines severely degraded land as “land that, for a significant period of time, has either been significantly salinated or presented significantly low organic matter content and has been severely eroded.”

5.2 Thermal gasification

5.2.1 Woody biomass

Competition risk – High: Significant competition is expected in 2040 and 2050 for woody biomass feedstocks.

As outlined in chapter 2, thermal gasification is not considered to be close enough to commercialisation to make a material contribution towards the potential in 2030. However, the potential to scale up this technology is large in the medium to long term (2040 and beyond), with **woody biomass (including forestry residues, wood waste, landscape care wood and prunings)** expected to be a key group of feedstocks.

However, woody biomass is set to face some of the strongest feedstock competition across the bioeconomy to 2050, with continuing demand for energy generation expected as well as demand from many other sectors under pressure to decarbonize and “defossilise”.

Woody biomass is already widely used as an energy feedstock in Europe, primarily for combustion to heat and power at both domestic and large scale. Combustion for heat and power is a very well-established conversion technology, and lower cost compared to alternative ways of using these feedstocks for energy, such as thermal gasification. In 2023, almost 70% of the total bioenergy consumption in the EU-27 consisted of solid biomass, of which woody biomass represented the main share. Germany, Sweden and Austria are key markets for the use of woody biomass for energy. Outside of the EU, the UK is a key market (however a significant share of the woody biomass used in the UK is currently sourced from outside of Europe – and so not directly competing with European feedstock supply).

A key driver for biomass use in heat and power is the EU ETS and the new EU ETS 2 – due to start in 2027 – which will cover heating emissions in buildings and small industrial sectors (as well as the transport sector). Sustainable biomass use is ‘zero-carbon rated’ under both versions of the ETS, which provides a financial incentive for its use over fossil fuels.

Woody biomass that meets the mandatory sustainability criteria can furthermore contribute towards the overall renewable energy target set in the RED of 45%. Similar to agricultural residues, a strong pull is also expected for feedstock for SAF production (via the FT pathway), driven by the EU and UK SAF mandates and the fact that ligno-cellulosic feedstocks are included in Part A of Annex IX. Although, again as with agricultural residues, this is expected to be a relatively expensive route to produce SAF.

The REDIII has introduced a requirement for Member States to take into account the “cascading principle” when designing support systems that could include woody biomass for energy. The aim is that energy used from biomass minimises the distortive effects on the raw material market by prioritising the biomass based on its highest economic and environmental added value – i.e. products, extending the life of products, re-use and recycling should be prioritised before bioenergy uses. This provides a steer to use woody biomass for non-energy uses, which would impact existing uses for heat and electricity as well as impacting woody biomass use to produce biogases. Note that this is already accounted for in this study's overall biomethane assessments, as more conservative assumptions have been applied on woody biomass availability for energy.

Woody biomass also has a key role in carbon removals. The CRCF Regulation, whilst voluntary, is expected to give a significant boost to the carbon removal sector in the EU. The CRCF provides an underlying basis to quantify the removals from carbon removal activities,

enabling a value to be put on carbon removed. The CRCF includes both permanent carbon removals, including bioCCS and biochar, and temporary removals via carbon farming activities such as afforestation. The Commission is considering whether permanent carbon removals could be allowed into the EU ETS in the future, as part of their 2026 review of the ETS Directive. This would create a further economic incentive for permanent biomass-related removals. All of these could provide a pull for woody biomass feedstocks.

The Land use, land-use change and forestry (LULUCF) Regulation sets a net carbon removal target of 310 million tonnes of CO₂ equivalent per year by 2030 from the LULUCF sector across the EU. In 2023, the LULUCF sector provided a net carbon sink of 198 million tonnes of CO₂ equivalent, so there is some way to go to achieve the 2030 target. The forestry sector is key to maintaining and increasing land-based carbon sinks, so policy pressure exists to avoid over-harvesting woody biomass.

The construction sector also provides a significant demand for woody biomass. Whilst this existing use is already covered in the assessments of potential, there are further EU policy drivers aiming to decarbonise the building sector into the future. This also includes the CRCF which will enable certification of carbon removals via carbon storage in products.¹⁰⁷ Bio-based materials represented 3% of the total mass of building material used in Europe in 2022¹⁰⁸ and this is expected to grow.

5.2.2 Organic fraction of Municipal solid waste

Competition risk – Medium: A shift away from incineration to higher-value uses, including biomethane or SAF production, is expected over time driven primarily by policy steering and societal constraints.

The organic fraction of residual municipal solid waste (OFMSW) is widely used as a feedstock for energy in Europe, predominantly through **waste incineration** for electricity (and heat) generation¹⁰⁹. Incineration remains a mature and cost-effective waste management option and plays a role in reducing landfill volumes, particularly in countries with limited landfill availability. In 2023, around 26% of the total bioenergy consumption in the EU-27 from solid biomass was based on the OFMSW, with Germany representing the highest share. A significant share of municipal solid waste in the UK is also incinerated.

Although incineration remains an established option, public acceptance challenges and concerns over lock-in of residual waste are increasingly influencing local and national decisions. Several Member States are tightening restrictions on new incineration capacity, while European waste and circular economy policy frameworks increasingly promote the use of biogenic waste streams in pathways that steer towards higher-value uses, which creates a pull away from combustion and towards biological treatment (e.g. biomethane production or composting through better waste separation) and fuel production routes, including in hard-to-abate sectors. In this regard, additional waste feedstock is expected to become available for biomethane production via thermal gasification, along with alternative gasification-based conversion pathways such as FT to produce SAF (and other advanced transport fuels).

¹⁰⁷ A CRCF credit is available for wood stored in buildings for 35 or more years.

¹⁰⁸ [ETC CM report 2022/01: Synergies, energy efficiency and circularity in the renovation wave. Bio-based products for the renovation wave.](#)

¹⁰⁹ For clarification, MSW is composed of both a fossil and organic fraction (that is co-mingled), but for the context of this study we only consider the organic fraction.

Overall, while OFMSW will remain an important energy feedstock, its role is expected to evolve from a disposal and incineration-oriented energy source toward higher-value bio-based applications.

5.3 Overall assessment

The large-scale deployment of biomethane in Europe depends not only on the technical availability of sustainable biomass, but also on how feedstocks are allocated across competing uses in an increasingly integrated bioeconomy.

Anaerobic digestion

Wet organic waste feedstocks, such as animal manure, biowaste, industrial wastewater and sewage sludge, are very well suited to treatment via anaerobic digestion, and are not expected to face significant competition into the future as there are limited alternative options to utilise them for energy generation or across the wider bioeconomy. Additionally, the use of these feedstocks for anaerobic digestion delivers multiple environmental benefits, such as fugitive greenhouse gas emission avoidance, opportunities for nutrient recycling through the application of digestate and local pollution reduction. However, greater competition is anticipated for agricultural residues, primarily driven by demand as a feedstock for SAF production.

Thermal gasification

Significant competition for woody biomass feedstocks that are well suited for **thermal gasification** is expected over time, from continuing demand for conventional heat and power generation, as well as emerging demand for SAF production, permanent carbon removals, as well as demand as a bio-based material in sectors such as construction or bio-based chemicals. However, an expected shift away from incineration of OFMSW to higher-value uses is expected over time, which may provide opportunities for biomethane production alongside use as a SAF feedstock.

Appendix A. Biomethane production potentials in 2030, 2040 and 2050

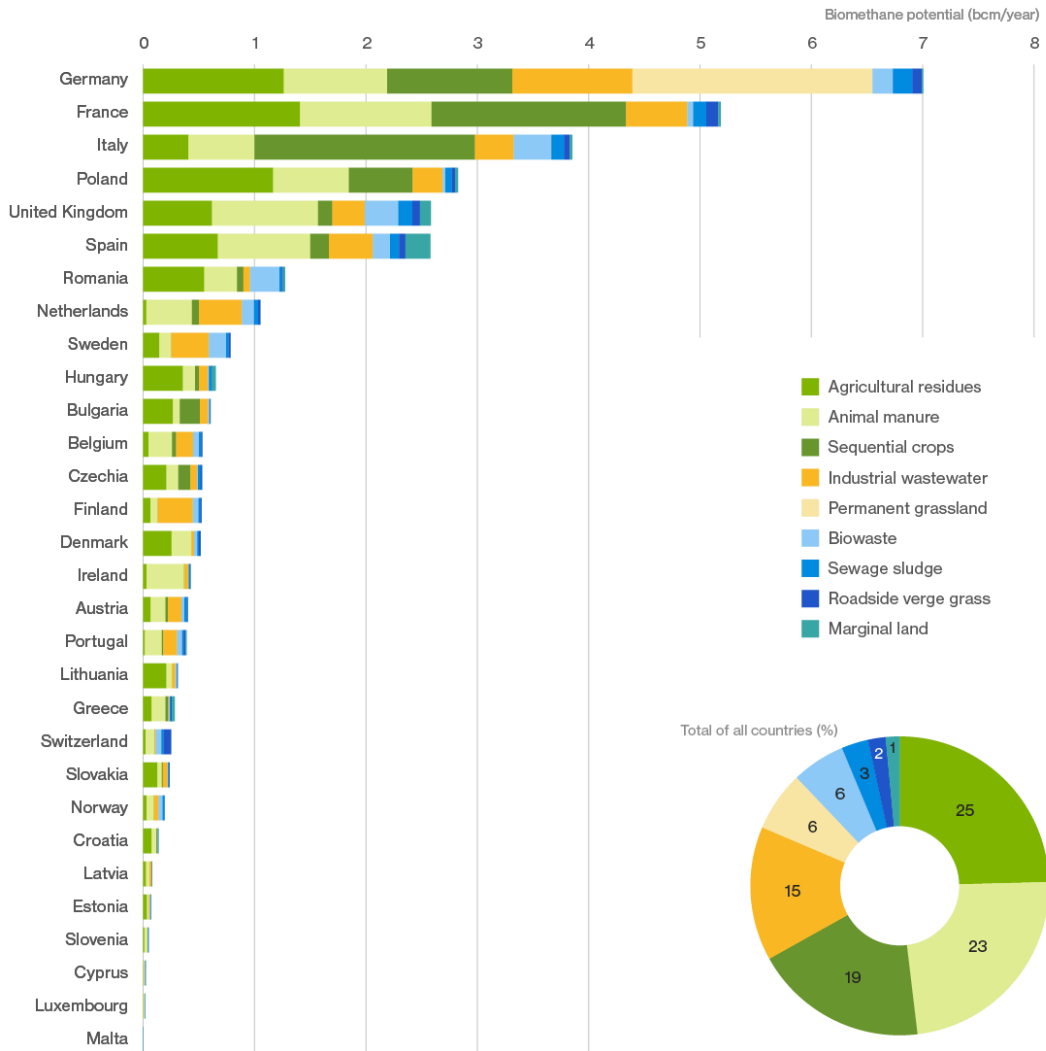


Figure 9. Biomethane potential (bcm/year) per country in 2030: anaerobic digestion

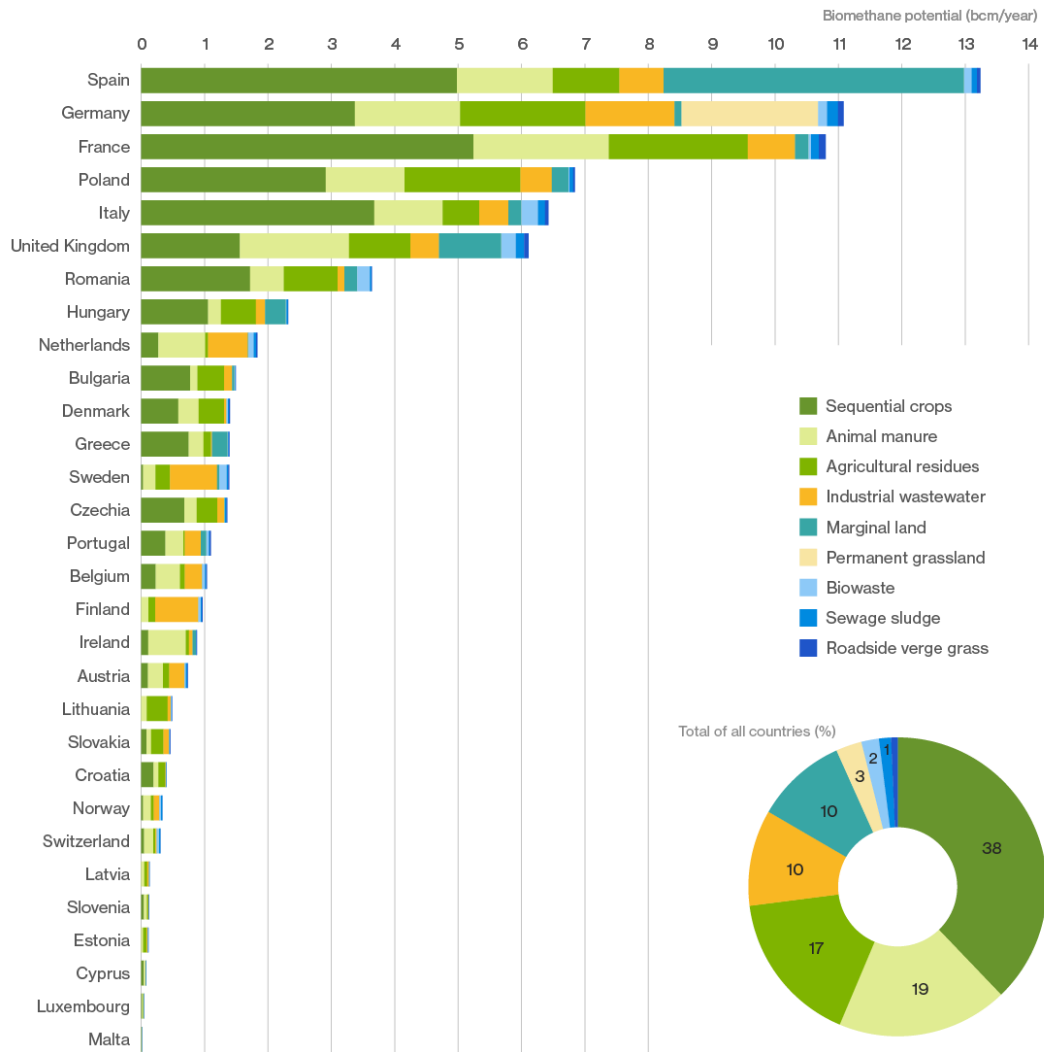


Figure 10. Biomethane potential (bcm/year) per country in 2040: anaerobic digestion

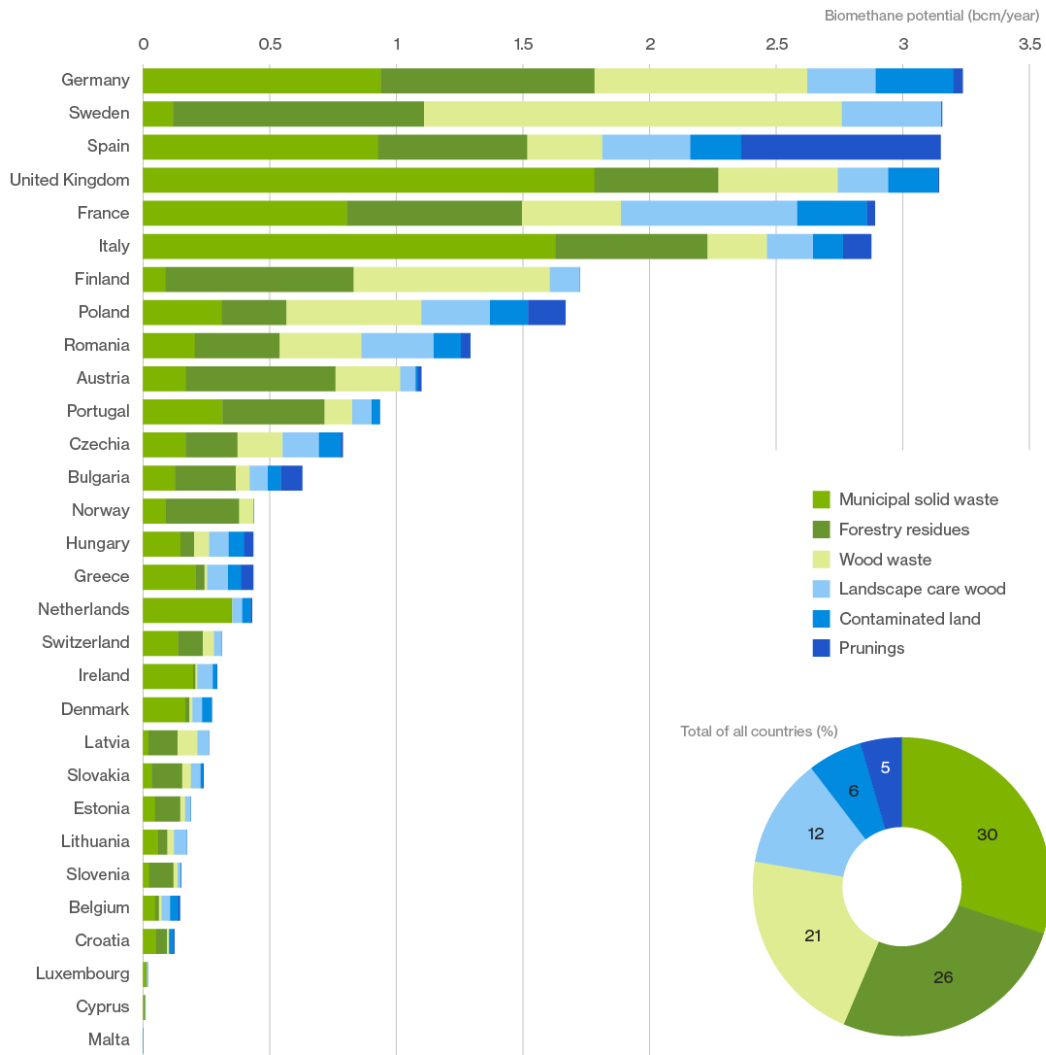


Figure 11. Biomethane potential (bcm/year) per country in 2040: thermal gasification

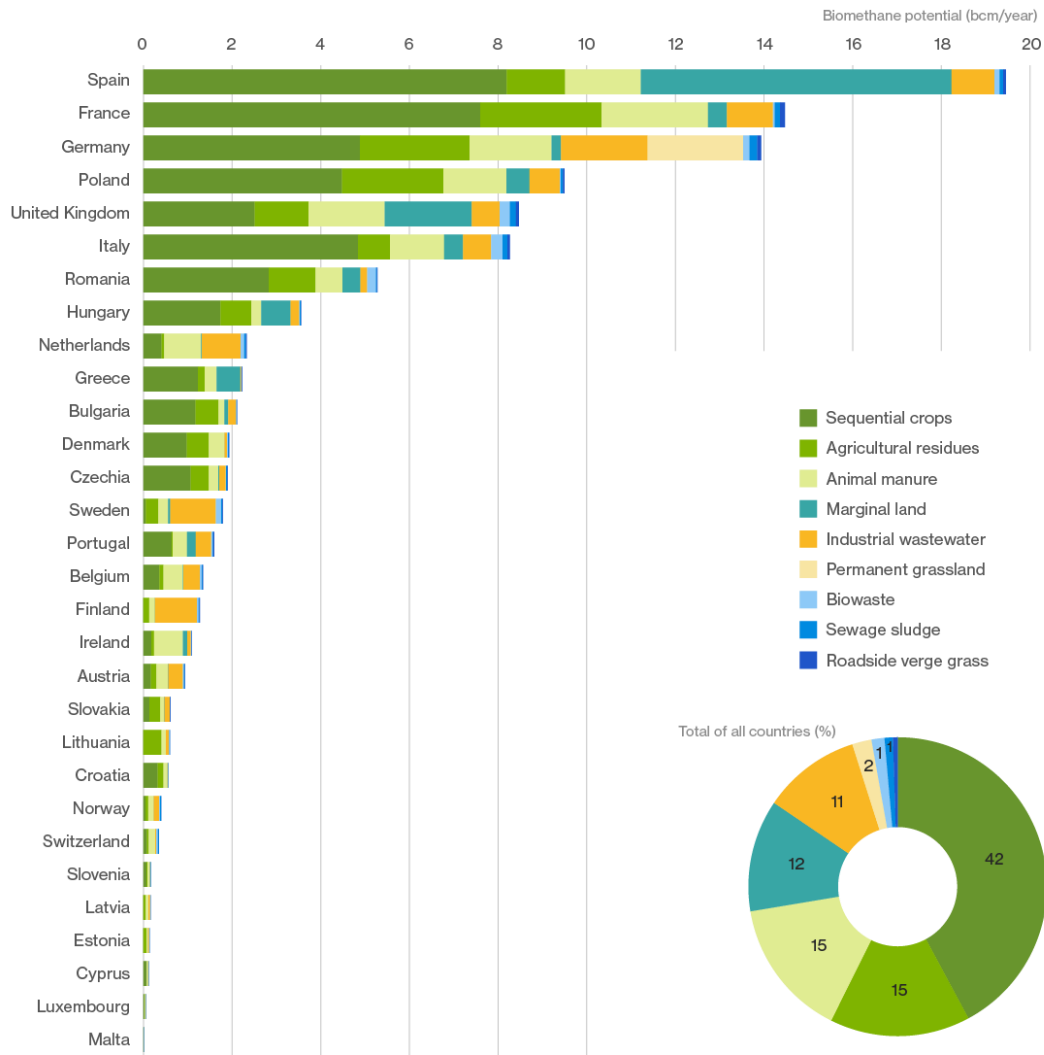


Figure 12. Biomethane potential (bcm/year) per country in 2050: anaerobic digestion

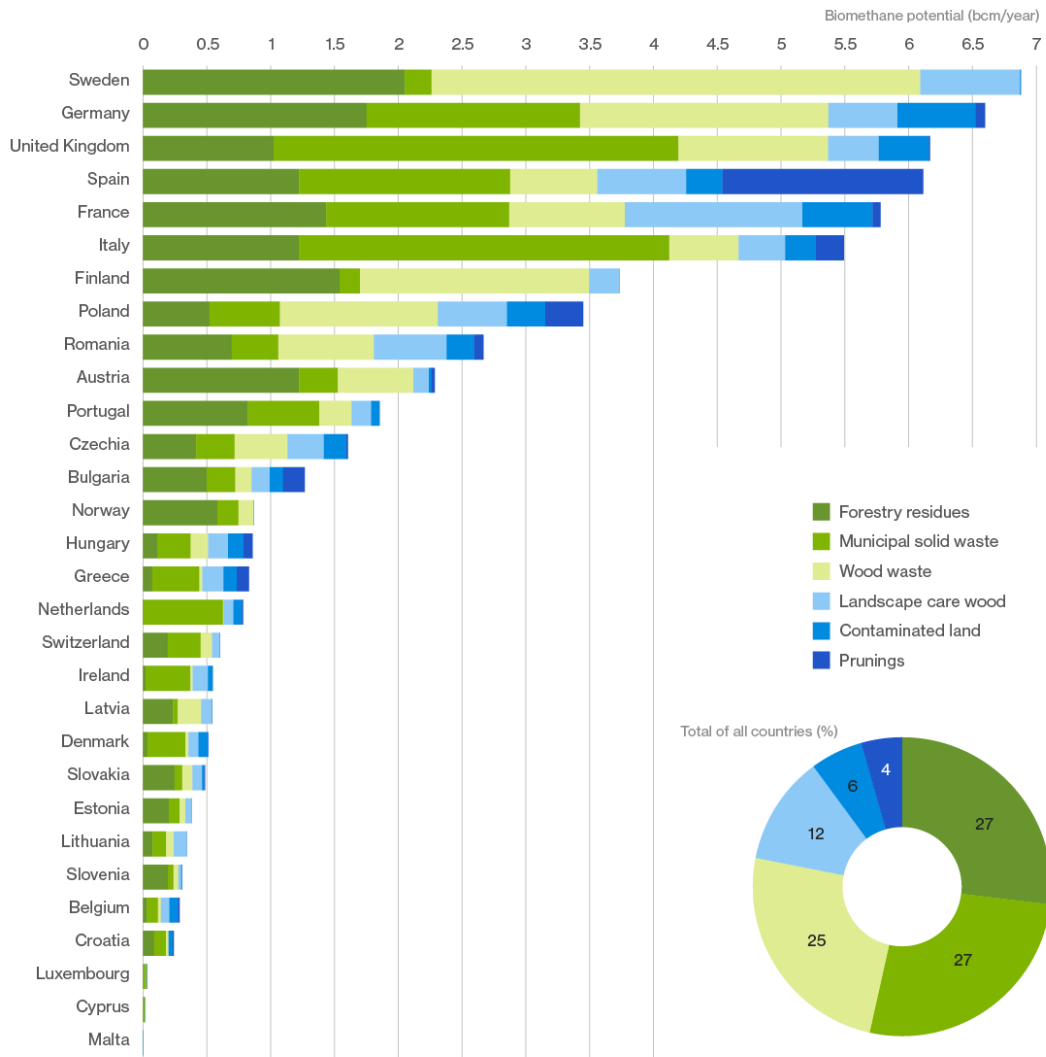


Figure 13. Biomethane potential (bcm/year) per country in 2050: thermal gasification

