GAS FOR CLIMATE
A path to 2050

Guidehouse

The future role of biomethane

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Contents

Executive Summary

Biomethane can make a significant contribution to climate action in the European Union (EU). To achieve the 2030 goals of the European Commission's Fit for 55 package, and the EU target to reach a net zero emissions economy by 2050, multiple climate solutions must be pursued in parallel.[1]

The future energy mix is predicted to be dominated by wind and solar power, both as generators of electricity and in the production of hydrogen. Yet biomethane also has a relevant role to play. Biomethane is the cheapest and easiest to scale form of renewable gas available today and can bring important energy system services tomorrow. This paper analyses the scale-up potential of biomethane in Europe based on a number of studies and compares these with the European Commission's own estimates. The paper also describes the energy system and climate benefits of biomethane and other relevant aspects, including rural employment. Strategies to scale-up biomethane and the role that policy can play in removing barriers are also discussed.

Biomethane can be scaled-up significantly. The European Commission estimates that 350 TWh, or 33 billion cubic meters[2] (bcm), of biomethane could be produced per year in 2030, which equals around 10% of the projected EU natural gas use. This quantity of biomethane would save about 110 Mtonne CO_2 equivalent emissions, or around 6% of the total required effort to achieve 55% GHG reduction.[3]

Biomethane has a very high greenhouse gas emission saving potential. Firstly, biomethane replaces fossil energy. Secondly, methane emissions from manure and traditional waste treatment are avoided if used as feedstocks, and thirdly, negative emissions can be achieved by combining biomethane production with carbon capture utilisation and storage and by storing carbon below-ground in agricultural soil. The latter can be achieved through improved agricultural systems, including integrating bioenergy crops as sequential crops, minimising soil disturbance and leaving plant roots to decompose in the soil to create a carbon sink (so called 'Biogasdoneright' concept).

Towards 2030, biomethane will be mainly produced via anaerobic digestion of waste and residual biomass from agriculture, the food industry and municipal waste. Beyond 2030, other pathways such as gasification of forestry residues will help to further increase the potential, to achieve over 1,000 TWh per year by 2050, which would be a substantial share of the future gas mix.[4,5]

Biomethane finds use across the economy, and has a particularly high energy system value in:

- industry (for high temperature heat that cannot easily be electrified, or for biogenic carbon feedstock);
- power (to balance the grid with storable and dispatchable energy);
- transport (for long distance heavy transport and maritime that cannot easily be electrified); and
- buildings (in existing buildings with gas connections through hybrid heat pumps).

Beyond energy system and climate benefits, the production of biomethane creates employment in rural areas, can enhance biodiversity, soil quality and can reduce erosion risks if sequential cropping (double cropping) is applied to produce biomethane feedstock, meaning that agricultural land is covered year-round.

Several strategies can support the scale-up of biomethane today. Firstly, the size of anaerobic digestion and upgrading facilities should be increased, leading to economies of scale and cost-efficiencies. Pooling of feedstock and/or biogas is one way to achieve this. In addition, supply needs to transition away from biogas providing local power or heat to biomethane production where it can

[1] European Green Deal. The EU's goal of climate neutrality by 2050. https://www.consilium.europa.eu/en/policies/green-deal/

[2] On basis of a methane Gross Heating Value of 37.7 MJ/m^3, or 10.5 kWh/m^3 [IEA 2004, Energy Statistics Manual].

[3] The 110 Mtonne CO_2eq emission reduction is explained in Chapter 3. Total savings required in the EU between 2020 and 2030 amount approximately 1,800 Mtonne [https://www.eea.europa.eu/ims/total-greenhouse-gas-emission-trends].

[4] European Commission (2018). In-depth analysis in support of the Commission Communication COM(2018) 773. A Clean Planet for all. A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy.

[5] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Natural_gas_supply_statistics

realise the greatest societal benefit. Implementing grid capacity solutions, such as in-grid compression of gas, can facilitate this by providing more flexibility for the gas system. In addition, technology innovation is needed to increase process efficiencies, and to further develop pre-treatment technologies to unlock new feedstocks for anaerobic digestion, such as straw. Finally, a scale-up of the promising sequential cropping concept (Biogasdoneright) requires research to establish to what extent it can be implemented in more temperate parts of Europe.

Anaerobic digestion and methanation technologies to scale-up biomethane are commercially proven. Additional scale-up of biomethane beyond 2030 requires further commercialisation of gasification technologies, syngas cleaning and methanation synthesis. These technological developments can take place if companies are prepared to invest in commercial scale projects. This will only be feasible under a long-term policy framework that offers the right incentive for biomethane gasification while simultaneously pushing for continuous cost reductions to minimise societal costs.

The ambition level of policies supporting gas decarbonisation should also be raised, both at a national and EU-level. A greater recognition and support for biomethane will help the EU to achieve a climate-neutral EU energy system at the lowest societal costs. Such recognition should also consider the multiple environmental benefits that biomethane can bring, such as the important role it can play in reducing fugitive methane emissions in the agricultural sector. The EU should furthermore prioritise sustainable energy sources that are available today and are therefore able to make a meaningful contribution to greenhouse gas emissions reduction. Finally, improving market liquidity and cross-border trading of biomethane is critical. The EU has already created well-functional trading conditions for renewable electricity. The gas sector needs similar mechanisms to trade volumes and guarantees of origin (GOs) of renewable gas across borders.

This is a Gas for Climate publication, prepared to support the work of the group of companies and organisations that support the Biomethane Declaration.[6] The Declaration was published on 7 December 2021 with an invitation to all stakeholders to engage in the scale-up of sustainable biomethane in Europe to accelerate the energy transition at the lowest possible overall societal costs.

[6] Our Vision for Biomethane, presented to European Commissioner for Energy Kadri Simson on 7 December 2021. https://gasforclimate2050.eu/wp-content/uploads/2021/12/Biomethane-Declaration-7-December-2021_final.pdf

1. Biomethane scale-up potential

At a European level, there is significant potential to scale up the production of sustainable biomethane in the coming decades. This can simultaneously offer substantial environmental and social co-benefits. In the view of the parties supporting the declaration on scaling-up biomethane, biomethane must meet strict sustainability criteria, not displace existing food and feed production nor lead to unwanted direct or indirect land-use change and should have a short carbon cycle.

1.1 Biomethane feedstocks and production technologies

The two main technologies to produce biomethane are **anaerobic digestion** and **gasification**. In addition, **renewable methane** (or power-to-methane), which is produced from renewable electricity and biogenic CO_2, can contribute to future supply but is not the focus of this report.

A diverse range of biogenic feedstocks can potentially be processed by **anaerobic digestion**. These include manure, sequential crops,[7] energy crops,[8] agricultural waste and residues, industrial food and beverage waste, sewage sludge and the organic fraction of municipal solid waste (e.g. food waste). Lignocellulosic feedstocks such as agricultural residues can also be processed, after pre-treatment. **Gasification** on the other hand can more readily process feedstocks with low anaerobic biodegradability, such as sustainable woody biomass (e.g. forestry residues, post-consumer waste wood), agricultural residues, municipal solid waste[9] and liquid organic waste streams (e.g. slurries).

1.1.1 Anaerobic digestion

Anaerobic digestion involves a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. The process initially produces biogas, which is rich in methane, and digestate, a nutrient-rich solid fraction commonly used as an organic fertiliser. Biogas contains around 55% methane, the rest being mainly biogenic CO_2 with a short carbon lifecycle.[10] Biogas can be upgraded to biomethane, by removing CO_2 and other gas impurities. This biomethane can then be injected into the gas grid to use as a natural gas substitute. The installation of upgrading technology is relatively easy, and injection can in principle be done at any gas grid location. The CO_2 could be captured and used in industry (e.g. food and beverage industry) so to avoid fossil-based CO_2 production, or could be used as a feedstock for renewable methane.

Biomethane production through anaerobic digestion is a proven and market-ready technology. Costs today range from 50 EUR/MWh to 90 EUR/MWh and largely depend on the feedstock used and plant scale (plants using manure are typically lowest cost).[11] There are almost 20,000 biogas plants operating in Europe today and almost 1,000 of them upgrade and inject biomethane into the natural gas grid. The combined biogas and biomethane production in 2020 was 191 TWh, of which the majority (159 TWh) was biogas used to produce local power or heat.[12]

[7] Sequential cropping is the cultivation of a second crop before or after the harvest of main food or feed crop on the same agricultural land during an otherwise fallow period. Sequential cropping does not impact existing food or feed markets as no existing food or feed is used for biogas.

[8] The deployment of energy crops should be prioritised on abandoned and degraded land.

[9] Municipal solid waste is first pre-processed into refuse derived fuel (RDF). Non-combustible materials such as glass and metals are removed from the waste, leaving biogenic material and plastics.

[10] The biogenic carbon was absorbed from the atmosphere during the growth of plants. Biogenic CO_2 emissions do not increase the CO_2 in the atmosphere, contrary to fossil-based CO_2 which stems from carbon that was stored millions of years ago.

[11] Gas for Climate (2020). Market state and trends in renewable and low-carbon gases in Europe. Guidehouse. http//gasforclimate2050.eu/wp-content/uploads/2020/12/Gas-for-Climate-Market-State-and-Trends-report-2020.pdf

[12] Gas for Climate (2021). Market state and trends in renewable and low-carbon gases in Europe. Guidehouse. https://gasforclimate2050.eu/wp-content/uploads/2021/12/Gas-for-Climate-Market-State-and-Trends-report-2021.pdf

1.1.2 Gasification

Two main gasification technologies are available. **Thermal gasification** involves a complete breakdown of dry lignocellulosic biomass (e.g. woody biomass, agricultural residues) and municipal solid waste, at high temperature in a gasifier in the presence of a controlled amount of oxygen and steam. **Hydrothermal (supercritical) gasification** can additionally process wet biomass feedstocks, including organic wastes and residues. Both processes produce syngas, which is a mixture of carbon monoxide (CO), hydrogen (H_2) and CO_2. The syngas is cooled and cleaned of pollutants like sulphur and chlorides. Methanation of the syngas is then performed in a catalytic reactor. With methanation, the clean syngas is converted into biomethane. Residual (biogenic) CO_2 and water are then removed in a gas upgrading unit. Like with anaerobic digestion, the CO_2 could be captured and used in other industries to achieve additional climate benefits.

Biomass gasification with biomethane synthesis is not yet commercially available and only exists at demonstration scale, for example, the Gaya[13] project in France. However, the potential to scale up is large in the mid-term (2030 and beyond). Costs today are estimated to average around 85 EUR/MWh, based on a plant size of 20 to 40 MW, which compares to an estimated cost of 100 to 200 EUR/MWh for green hydrogen.[14] Future biomethane costs are projected to be around 60 EUR/MWh.[15,16]

1.2 European biomethane potential

Many studies have assessed the biomethane potential in Europe, all with their own set of assumptions. The biomethane potential estimated in these studies is driven by the availability of feedstocks and the technologies able to process these feedstocks into biomethane. Assumptions on feedstock availability include considerations such as whether, or not, energy crops or roundwood are included, removal rates for the extraction of agricultural, forestry residues or forestry industry residues and the potential to collect waste streams such as manure or wastes from food and beverage industry. Linked to this, are considerations such as land area (including area of agricultural land and forest cover), climate suitability, population and livestock number and projections trends on how these may develop over time. Ultimately, biomass feedstocks are not inherently 'good' or 'bad', yet efforts are needed to ensure they are produced or collected and valorised in a sustainable manner.

In 2018 the European Commission published the 'A Clean Planet for all' Communication, which sets out the Commission's vision to become climate neutral by 2050.[17] Biogas (including biomethane) is seen to play an important role. Biomethane demand in 2030 is estimated at **349 TWh[18] (30 Mtoe) in 2030**. The 2050 demand estimate depends on the scenario, and ranges from **523 TWh (45 Mtoe) - Energy Efficiency scenario up to 919 TWh (79 Mtoe) - P2X scenario**.[19] All scenarios see greatest demand in the power and heat sectors, followed by industry. The **P2X scenario** estimates an additional demand for renewable methane of **1,058 TWh (91 Mtoe) in 2050** and **1,675 TWh (130 Mtoe) in 2070**. Demand is greatest in buildings, followed by industry and transport (particularly in heavy goods).

A breakdown of the biomethane potential per feedstock or technology is not provided by the European Commission. However, the Communication indicates that there is a large potential from agricultural waste, residues, by-products (e.g. manure), sewage sludge, separated household waste, as well as industrial waste. The Communication also views fast growing grasses (e.g. switchgrass,

[13] https://www.projetgaya.com/en/biomethane-a-green-energy/

[14] Agora Energiewende and Guidehouse (2021). Making renewable hydrogen cost-competitive: Policy instruments for supporting green H_2. https://static.agora-energiewende.de/fileadmin/Projekte/2020/2020_11_EU_H2-Instruments/A-EW_223_H2-Instruments_WEB.pdf

[15] European Biogas Association (2021). Gasification: A sustainable technology for circular economies. Scaling up to reach Net Zero by 2050. https://www.europeanbiogas.eu/gasification-a-sustainable-technology-for-circular-economies/

[16] The cost estimates are based on available literature and range from 48 EUR/MWh to 112 EUR/MWh today, and 37 EUR/MWh to 90 EUR/MWh in 2030-2050.

[17] European Commission (2020). In-depth analysis in support of the Commission Communication COM(2018) 773. A Clean Planet for all, A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy. https://ec.europa.eu/clima/system/files/2018-11/com_2018_733_analysis_in_support_en.pdf

[18] Note that the potential has been 'rounded-up' to 350 TWh in some parts of the report.

[19] Energy Efficiency-scenario: Electrification in all sectors. P2X-scenario: E-fuels in industry, transport and buildings.

miscanthus) and short rotation coppices (e.g. poplar, willow) as the main inputs to gasification, if not hampered by upfront investment costs or land availability and when cultivated in a sustainable manner.

To provide further insights in the potential of biomethane in Europe, we compare the European Commission's own view with several studies. In the remainder of this chapter, we first provide an overview of various potential studies and their main results and assumptions, followed by a discussion on how these studies compare, including with the European Commission's estimate.

CE Delft (2016) – Optimal use of biogas from waste streams[20]

This study provides a review of biogas and biomethane application in the EU (and UK), including key drivers and policies, and develops potential scenarios for 2020 and 2030. Six categories of biomass are included in calculating the potential: energy crops[21], liquid and solid manure, agricultural residue streams, organic waste (e.g. food waste, municipal solid waste) and sewage sludge. Gasification is excluded from the calculations. Two main scenarios are explored, a "Growth" scenario and an "Accelerated growth" scenario. These differ in how fast growth can be realised and the learning effects, for instance through faster cost reductions and higher conversion efficiencies. For 2030, the estimated potential for anaerobic digestion biogas (including biomethane) ranges from 335 to 467 TWh (28.8 to 40.2 Mtoe) for the Growth and Accelerated growth scenarios respectively.

Gas for Climate (2019-2020) – The role for gas in a net-zero emissions energy system[22,23]

The total production potential in the EU (and UK) as estimated by Gas for Climate is 370 TWh per year by 2030 and 1,070 TWh per year by 2050. The latter number consists of 660 TWh produced through anaerobic digestion, 350 TWh produced through gasification and 60 TWh of renewable methane. Sequential crops make up the largest share amongst all feedstocks with 431 TWh (equivalent to 65% of the biomethane potential from anaerobic digestion, or 43% of the total biomethane potential), followed by manure with 157 TWh and landscape care wood and roadside verge grass and post-consumer waste wood both with 94 TWh. The total amount of 1,010 TWh of biomethane could cover about 25% of current levels of natural gas consumption.

In the 2019 study by Gas for Climate, the total potential per Member State was calculated, considering an assessment of the availability of the feedstocks and their conversion yield to biomethane (see Figure 1 below). The potentials differ widely between Member States, with the greatest potentials estimated in France, Spain, Italy and Germany respectively (which are also the largest countries in Europe by land area). These countries collectively represent around 60% of the total potential in 2050. The greatest potential for biomethane via gasification is in France, Germany, Sweden and Finland reflecting the greater availability of woody biomass in these countries.

The potential assumes a significant scale-up of sequential cropping in Europe, with additional maize, triticale, wheat or ryegrass silage to be cultivated as a second crop on 10% of the current total Utilised Agricultural Area[24] in the EU (and UK), equivalent to around 18 million hectares. Furthermore, no additional land is assumed to be used for silage monocropping for biomethane production. This means that no existing food and feed production is displaced towards biomethane production.

[20] CE Delft (2016). Optimal use of biogas from waste streams. An assessment of the potential of biogas from digestion in the EU beyond 2020. https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf

[21] It was assumed that maize is only used in co-digestion with manure in at least a mass ratio of 80% manure and 20% maize. The level of energy crops was fixed at 2014 levels.

[22] Gas for Climate (2019). The optimal role for gas in a net-zero emissions energy system. Navigant. https://gasforclimate2050.eu/sdm_downloads/2019-gas-for-climate-study/

[23] Gas for Climate (2020). Gas Decarbonisation Pathways study. Guidehouse. https://gasforclimate2050.eu/wp-content/uploads/2020/04/Gas-for-Climate-Gas-Decarbonisation-Pathways-2020-2050.pdf

[24] Including: arable land, permanent grassland, permanent crops and other agricultural land such as kitchen gardens.

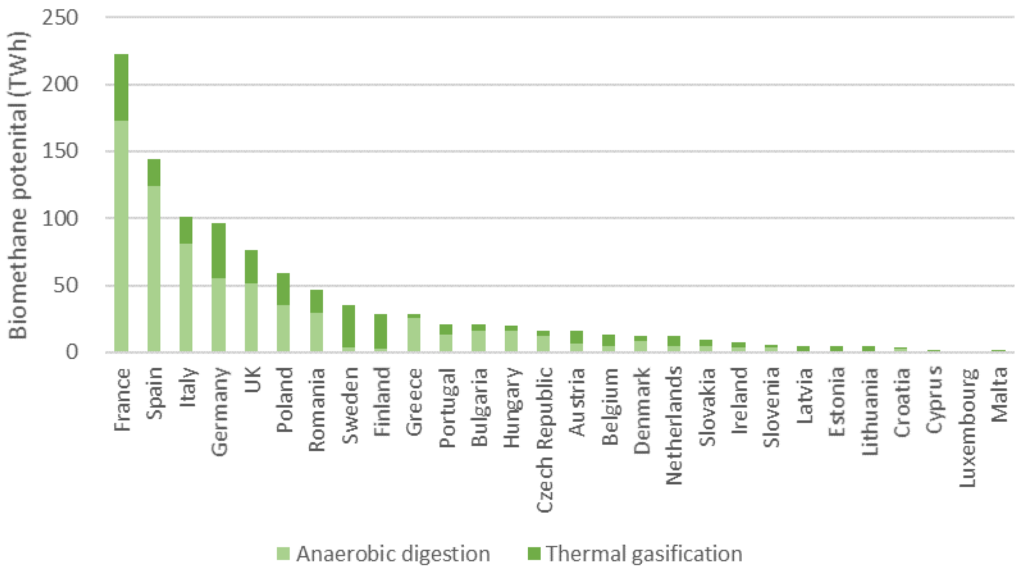

Figure 1: Total biomethane potentials per country in 2050 as estimated by Gas for Climate.

For the purpose of this study, Europe was split into 3 regions: Northern (including Baltics, Scandinavia and Ireland), Central (including Germany, Poland, Romania and UK) and Southern (including France, Italy, Spain and Greece). For this second crop, it was assumed that in the Southern region, 60% additional biomass can be achieved compared to the main crop. In the Central region, 30% additional biomass was assumed. Sequential cropping was not assumed in the Northern region. The extensive and promising experience of implementing sequential cropping in Italy (the so-called 'Biogasdoneright' concept – see Section 4.2 for further details), complemented with recent pilot tests undertaken in France funded by ADEME[25], forms a basis to assume that 60% additional biomass for the second crop could be a realistic assumption in these countries. However, the deployment of sequential cropping in the rest of Europe remains largely untested, which comprises around 50% of the total EU (and UK) land area of 16 million hectares where sequential cropping is assumed (higher if France is split into a southern and central zone).

For manure, only the manure that is produced in stables is considered since this is the manure fraction that can be collected out of the total manure that is produced on a farm. The manure availability is estimated for farms with a size threshold above 100 livestock units and assumes a 50% collection rate for solid manure and a 100% collection rate for liquid manure (underlying data is based on Elbersen et al., 2016).[26]

The gasification potential of 350 TWh is primarily based on woody biomass (forestry residues and waste wood). The potential assumes that over 200 large 200 MW gasification plants are built by 2050. This will require a concerted effort by energy companies and policy makers to realise (see Section 4.1).

ICCT (2018) – What is the role of renewable methane in European decarbonization?[27]
This study looks at the potential of biomethane (and renewable methane) for 2050 in the EU (and UK). In scope are manure and sewage sludge for anaerobic digestion, and agricultural residues, forestry residues and municipal solid waste for gasification. Silage maize and gasified roundwood are excluded. The total potential is estimated to be 382 TWh (36 bcm), of which 211 TWh (20 bcm) corresponds to anaerobic digestion, 120 TWh (11 bcm) to gasification and 51 TWh (5 bcm) to

[25] https://www.arvalis-infos.fr/file/galleryelement/pj/c2/0b/46/c8/plaquette_recitalweb6691942158883491221.pdf
[26] Elberson et al. (2016). Outlook of spatial biomass value chains in EU28. Deliverable 2.3 of the Biomass Policies project. http://iinas.org/tl_files/iinas/downloads/bio/biomasspolicies/Elbersen_et_al_2016_Outlook_of_spatial_biomass_value_chains_in_EU28_(D2.3_Biomass_Policies).pdf
[27] ICCT (2018). What is the role for renewable methane in European decarbonization? https://theicct.org/sites/default/files/publications/Role_Renewable_Methane_EU_20181016.pdf

renewable methane. The potential estimate is significantly lower than the Gas for Climate study. The study authors cite several reasons for the difference.

The first is that sequential cropping is not modelled. ICCT considers it is unlikely that this would deliver the large volumes of biomethane estimated under Gas for Climate and estimate that only 15 TWh (1.4 bcm) could be produced based on current trends. Also, ICCT assume a limited role for gasification in the 2050 timeframe, based on an assessment that feedstock availability, as well as gasification facility deployment, is expected to limit production. In addition, lower gasification yields due to lower efficiency compared to Gas for Climate are assumed. A further difference is that ICCT accounts for reduced biomethane production via anaerobic digestion because of losses in gas conditioning and compression.

IEA (2020) – Outlook for biogas and biomethane[28]
The IEA outlook for biogas and biomethane focuses on the potential for these energy carriers in 2040 globally. The total potential in Europe is estimated to be 1,700 TWh, of which the potential in the EU (and UK) is 1,248 TWh. Both anaerobic digestion and gasification conversion routes are considered, with around 70% of the potential based on anaerobic digestion. Seventeen individual feedstocks were considered for anaerobic digestion, grouped into several feedstock categories, including agricultural residues, manure, the organic fraction of municipal solid waste (food waste, paper and cardboard that is not otherwise utilised and waste wood), industrial waste (specifically distiller dried grains) and municipal wastewater. For gasification, woody biomass (residues from forest management and wood processing) was the only feedstock considered. It was acknowledged that municipal solid waste and agricultural residues could otherwise be used for gasification instead of anaerobic digestion.

Potential estimates for agricultural residues, forestry residues and manure were based on country level FAO datasets and extrapolated to 2040. The residue potentials consider sustainable removal rates to protect soil and competing uses (e.g. livestock, pulp and paper). A sustainable removal rate of 50% was applied for agricultural residues to protect soil quality, whereas a 70% fellings-to-annual-increment ratio was applied to ensure sustainable management of forests. Manure production was estimated by multiplying the manure production per livestock head by the number of heads for each livestock type (cattle, pig, poultry and sheep). Utilisation rates of between 35% and 80% were assumed, depending on the livestock type.

Finally, biomass supply needs for the energy system (electricity and heat generation, transportation, buildings and industry) are subtracted from the total sustainable biomass potential for biogas and biomethane.

DNV-GL (2020) – European Carbon Neutrality: The Importance of Gas[29]
In this study for Eurogas, two different scenarios for 2050 are described for 100% decarbonisation, called the "Eurogas-scenario" and the "1.5TECH-scenario". The study is focused globally, taking the EU, UK, Norway, Switzerland and the Balkans as one region. In the scenarios, the biomethane demand for decarbonisation ranges from 1,008 TWh/yr (Eurogas-scenario) to 928 TWh/yr (1.5TECH-tech). Both scenarios have biomethane from gasification (with CCS) as their core pillar for decarbonisation. The current (2019) contribution of biomethane from anaerobic digestion was assumed to remain relatively stable to 2050.

The study authors assume a 70% conversion efficiency, which implies 1,430 TWh/year and 1,325 TWh/year of biomass feedstock respectively in the two scenarios. Only non-food biomass types are considered. These are agricultural feedstocks (agricultural and crop residues and manure), forestry feedstocks (forestry residues, logging and wood cutting residues and industry residues) and wastes (municipal or industrial). A literature review was undertaken to identify feedstock potentials for each of these three feedstock categories and the average of the potential reported in 12 of the most representative studies was taken. These were 995 TWh/yr for agricultural feedstocks, 1,180 TWh/yr for forestry feedstocks and 758 TWh/yr for wastes, totalling 2,934 TWh/year in 2050 over all three categories, although the feedstock potential was found to range from 1,000 TWh/year to almost 6,000 TWh/year. The total biomass demand required for all end-uses in the Eurogas scenario was

[28] IEA (2020). Outlook for biogas and biomethane. Prospects for organic growth. https://iea.blob.core.windows.net/assets/03aeb10c-c38c-4d10-bcec-de92e9ab815f/Outlook_for_biogas_and_biomethane.pdf

[29] DNV-GL (2020). European Carbon Neutrality: The Importance of Gas. A study for Eurogas. https://eurogas.org/website/wp-content/uploads/2020/06/DNV-GL-Eurogas-Report-Reaching-European-Carbon-Neutrality-Full-Report.pdf

estimated as 3,400 TWh/year in 2050, which is about 15% higher than the average of the studies (the 1.5TECH scenario requires 2,100 TWh by 2050). The modelling considered this to be plausible, with respect to current solid biomass levels and overall global resource availability.

ENGIE (2021) – Geographical analysis of biomethane potential and costs in Europe in 2050[30]
This recent analysis by ENGIE for 2050 covers the EU-27 and 10 neighbouring counties, such as Turkey and the UK. The total estimated biomethane potential in these countries is 1,767 TWh. To make a fair comparison with the other studies, countries outside the EU-27 are excluded except for the UK, making the total estimated potential for biomethane 1,495 TWh. The potentials are calculated using a two-step modelling approach. Firstly, the theoretical potentials (at a spatial distribution of 1x1 km) are derived for each country using geographical databases and statistics. Next, the technical potential as well as cost curve is calculated by simulating development of producing units and applying assumptions on global mobilisation, competitive uses and soil protection.

The potential for anaerobic digestion is 967 TWh and based on agricultural residues, sequential crops, biowaste residues (organic fraction of waste), industrial waste (from agroindustry and milk and meat industries), livestock manure and green waste (grasses or leaves left after roadside management). Energy crops are excluded. Sequential crops contribute the largest share of the anaerobic digestion potential with 388 TWh (equivalent to 40% of the biomethane potential from anaerobic digestion, or 26% of the total potential), which is 43 TWh lower than in the Gas for Climate study. Sequential crops are assumed to occupy 100% of the arable land covered by the main crops (wheat, barley, maize, sunflower, sugarbeet, rapeseed), and yield on average around 5 tonnes of dry matter per hectare. All the sequential crops are used for biomethane production. Agricultural residues (200 TWh), manure (183 TWh) also represent a significant share of the total.

Woody biomass feedstocks (forest residues, stemwood and prunings) are the only feedstock assumed for gasification and contribute 528 TWh biomethane (equivalent to 35% of the total potential), which is higher than in all other studies. The estimates for stemwood and forestry residues are based on EFISCEN[31] model outputs for 2030 and extrapolated to 2050. It is assumed that 100% of the additional woody biomass availability from forest growth is utilised for biomethane production (thus not impacting existing uses of this feedstock).

University of Ghent, European Biogas Association, CIB (2021) – The Role of Sequential Cropping and Biogasdoneright™ in Enhancing the Sustainability of Agricultural Systems in Europe[32]
As discussed above, the potential of sequential cropping deployment for biomethane outside of Italy and France is currently not well understood. This paper estimates the biomethane potential of anaerobic digestion using sequential crops in Europe (EU-27 and UK) under both “Conservative” and “Maximum” scenarios. The scenarios assume different percentages of primary crop land dedicated to sequential cropping and biogas yield.

Sequential crop calendars were developed for each climate region in Europe. The Conservative scenario estimates the potential assuming practically feasible conditions under which sequential cropping could be applied, for example taking into account water limitation in the Mediterranean region. In this scenario, the land considered suitable for sequential cropping was estimated for each European climate region as the percentage of specific summer crops (maize, sorghum, soybean, sunflower and green maize) over the total primary crop land in each region. An average of 20% was applied across Europe. The Maximum Scenario estimates a theoretical maximum potential that would derive from the application of sequential cropping in Europe. It considers 80% of the primary crop land as dedicated to sequential cropping, excluding marginal and small fields.

The estimated biomethane potential ranges from 488 TWh/yr (46 bcm/yr) and 1,963 TWh (185 bcm/yr) in the Conservative and Maximum scenarios respectively.[33] This Conservative estimate is comparable to the Gas for Climate potential of 431 TWh, but the study indicates that the potential could be extended further. The Continental region (covering western France across to Poland and

[30] ENGIE (2021). Geographical analysis of biomethane potential and costs in Europe in 2050. https://www.engie.com/sites/default/files/assets/documents/2021-07/ENGIE_20210618_Biogas_potential_and_costs_in_2050_report_1.pdf

[31] European Forest Information SCENnario Model (EFISCEN). See: https://efi.int/knowledge/models/efiscen.

[32] Magnolo et al. (2021). The Role of Sequential Cropping and Biogasdoneright™ in Enhancing the Sustainability of Agricultural Systems in Europe. Agronomy 2021, 11(11), 2102. https://www.mdpi.com/2073-4395/11/11/2102

[33] No specific time horizon was considered for the analysis.

the Balkans) registered the highest potential compared to other regions, mainly due to the higher number of hectares of suitable land for sequential cropping compared to the other two regions.

Summary of studies and comparison with the European Commission biomethane estimate
All of the studies described above see a potential to scale up biomethane significantly beyond current production levels of 191 TWh. Most studies conclude that towards 2030 a scale up to 335 to 467 TWh is feasible, which corresponds well with the European Commission estimate of 349 TWh.

Towards 2050 a much more diversified picture emerges. ICCT (331 TWh) estimates the lowest potential, which is even lower than the European Commission estimate for 2030. The ENGIE (1,495 TWh) and IEA (1,248 TWh) studies are most optimistic. The Gas for Climate and DNV-GL estimates for 2050 are both around 1,000 TWh, which is slightly higher than the upper range of the European Commission estimate of 919 TWh. These large differences follow from uncertainties and varying perspectives in estimating technological advancements in gasification technology and the uptake of sequential cropping and anaerobic digestion feedstock mix so far ahead in the future.

Figure 2 (overleaf) provides an overview of the potentials for the studies in the timeframe 2030 to 2050 (including the potential ranges for those studies which include multiple scenarios), while Table 1 below provides a detailed summary of the biomethane potentials for those studies that cover the 2040/2050 timeframe, split by technology and feedstock type (where available).

Table 1: Summary of the 2040/2050 biomethane[1] potentials per technology and feedstock. Units: TWh. (Note that numbers are rounded so they do not necessarily add up to the total.)

Technology/ Feedstock categories	ICCT (2018)	EC (2018)	DNV-GL (2020)	Gas for Climate (2019-2020)	IEA (2020)	ENGIE (2021)
Total biomethane potential in 2050 (TWh)	331	523-919	928-1,008	1,010	1,248 (value for 2040)	1,495
Potential per technology (TWh)						
Anaerobic digestion	211	Not reported	Not reported	660	858	967
Gasification	120	Not reported	Not reported[2]	350	390	528
Potential per feedstock category (TWh)						
Energy crops	Not in scope	Not reported	Not in scope	Not in scope	Not in scope	Not in scope
Sequential crops	Not in scope	Not reported		431	N/A	388
Manure	205	Not reported	314-342[3]	157	381	183
Agricultural residues	87	Not reported		52	208	200
Sewage sludge and wastewater	6	Not reported	Not in scope	2	51	Not in scope
Biowaste (food waste/ green waste)	Not in scope	Not reported		21	218	163
Municipal solid waste (MSW) - including RDF/SRF	27	Not reported	240-261	56	Not in scope	Not in scope
Industrial solid waste and wastewater	Not in scope	Not reported		Not in scope	1	34
Roundwood	Not in scope	Not reported	Not in scope	Not in scope	Not in scope	Not in scope
Woody biomass (forestry residues, thinnings, prunings)	6	Not reported	373-406	199	390	528
Waste wood	Not in scope	Not reported	Reported under MSW	94	Not in scope	Not in scope

Notes:
1. Renewable methane potentials are not included in this table. (Relevant for the European Commission Communication, and the ICCT and Gas for Climate studies.)
2. The DNV-GL study authors indicated that gasification is the dominant technology type in 2050.
3. The feedstock potentials for the DNV-GL study included in this table were estimated by Guidehouse based on the share of each feedstock category relative to the overall feedstock potential.

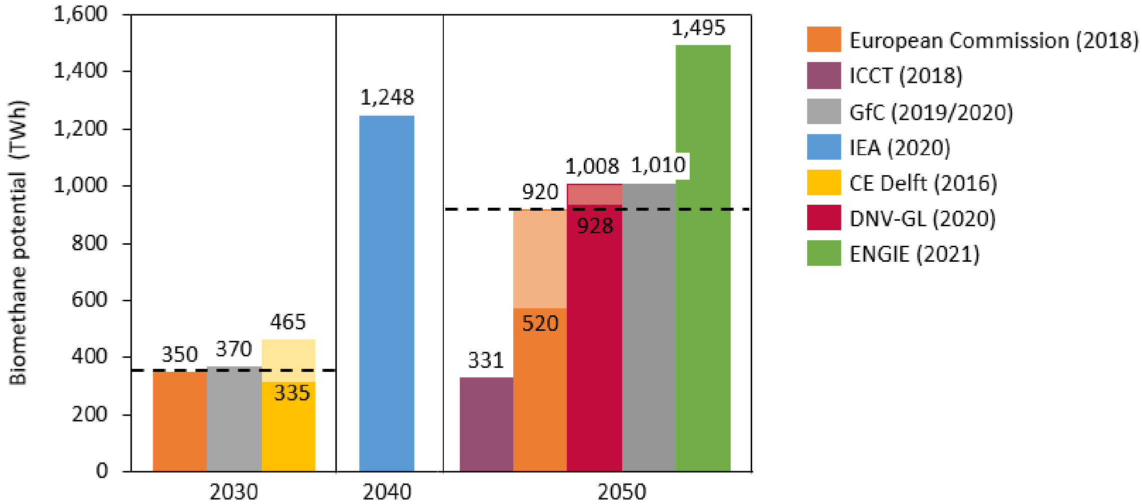

Figure 2: Biomethane potential reported in the studies assessed.[34]

For **anaerobic digestion**, a key difference in the potential estimates stems from the assumptions around the deployment of sequential cropping in the period to 2050. ICCT sees a very limited opportunity to scale up sequential cropping in Europe to 2050. This contrasts to several other studies (in particular ENGIE and Gas for Climate) which see a sizable contribution of sequential cropping in the 2050 potential for biomethane (ranging from 388 to 431 TWh where available). The potential for sequential cropping is furthermore highlighted in the University of Ghent (2021) study, which estimates between 488 and 1,963 TWh. Additional pilot testing will be needed to test this promising concept, complemented by extensive outreach among farmers across Europe to generate awareness and provide training. Finally, the biomethane potential from industrial waste waters (e.g. from the food and drinks sector) is only taken into account in the ENGIE study, with a contribution of 31 TWh. Analysis undertaken by the EBA suggests that this waste stream could in fact contribute a significantly higher biomethane potential of 142 TWh in Europe by 2050.[35] Dedicated energy crops were excluded from all of the studies with the exception of the CE Delft study, although this is restricted to co-digestion with manure in a mass ratio of at least 80% manure and 20% maize.

CE Delft exclude **gasification** entirely from their analysis, which may be explained by the 2030-time horizon of this study. ICCT include a limited potential of biomethane from gasification in their study. In contrast, the recent studies by DNV-GL, IEA and ENGIE both see a more prominent role for gasification based biomethane to 2050. Gas for Climate also sees an important role for gasification. All studies assume that gasification is based entirely on wastes and residues. Woody biomass (forestry residues, thinnings and prunings) is the principal feedstock type assumed for gasification in the majority of the studies (in the case of ENGIE and IEA woody biomass is the only feedstock type assumed). Roundwood is excluded from all studies.

In summary, the potential for biomethane production in Europe is significant. A rapid scale-up will be necessary to ensure that this renewable energy source can fully contribute towards Europe's long-term decarbonisation goals. This is further discussed in Chapter 4.

[34] In some reports, several scenarios are mentioned. In this case both potential estimates are indicated.

[35] European Biogas Association (2021). The role of biogas production from industrial wastewaters in reaching climate neutrality by 2050. https://www.europeanbiogas.eu/the-role-of-biogas-production-from-industrial-wastewaters-in-reaching-climate-neutrality-by-2050/

2. Energy system value of using biomethane

There is significant energy system value in using biomethane to satisfy a portion of the energy demand. Biomethane is an energy dense, storable and flexible energy source with a high greenhouse gas saving potential and even has the ability to generate negative emissions. Biomethane can be transported through existing gas infrastructure and can be used with existing end-use technologies. All of this makes it an appealing energy source in a climate neutral energy system.

Renewable and low carbon gas should be allocated across end-use sectors, by prioritising it first to sectors where it adds the most value. The Gas for Climate 2019 study[36] determined the cost optimal energy system and identified the 'sweet spots' for the use of biomethane in the 2050 net zero emissions energy system. This study estimates a demand for renewable methane of 1,170 TWh in 2050, of which biomethane contributes 1,110 TWh, with the balance being renewable and low carbon hydrogen.[37] Biomethane was found to have a particularly high energy system value in the heating of older buildings with existing gas grid connections through hybrid heat pumps. The study found that across the EU (and UK) this would require 185 TWh of biomethane. Furthermore, biomethane was found to be valuable for the production of dispatchable electricity in an overall electricity mix dominated by some 85% variable renewable power. This would require 320 TWh of biomethane. Chemical industrial feedstocks requiring carbon were also found a valuable source of biomethane demand, requiring some 70 TWh. Any remaining biomethane would be valuable as a fuel for heavy, long-haul transport. Based on the biomethane potential found in the Gas for Climate study, 595 TWh of biomethane would be used in heavy transport.

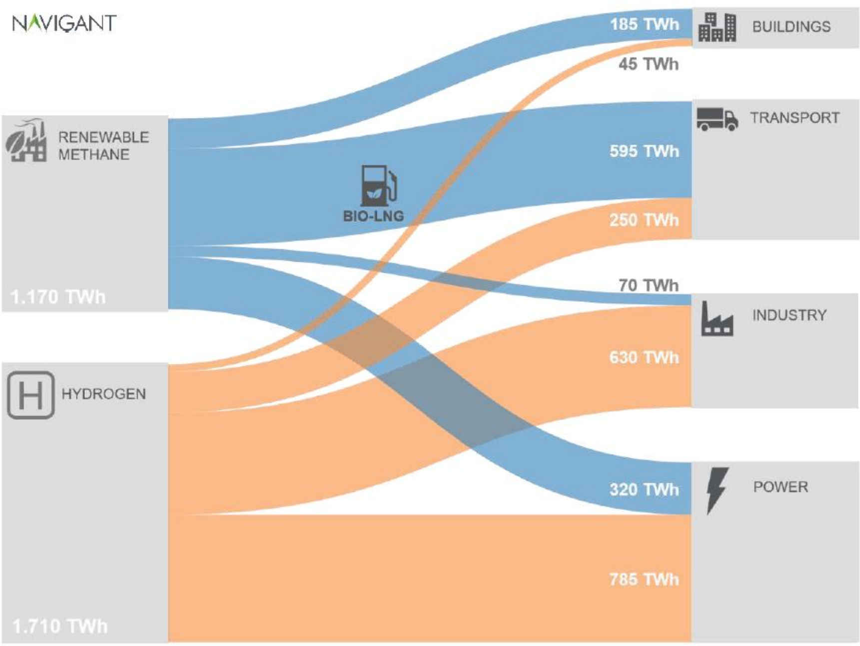

Figure 3: Renewable and low-carbon gas supply and demand in the Gas for Climate 2019 "optimised gas" scenario.

[36] Gas for Climate (2019). The optimal role for gas in a net-zero emissions energy system. Navigant. https://gasforclimate2050.eu/sdm_downloads/2019-gas-for-climate-study/

[37] Renewable methane (including biomethane and renewable methane) contributed to around 40% of the total projected gas consumption in 2050.

Buildings
Renewable gases can help buildings heating systems decarbonise in the most cost-efficient manner. The use of biomethane in hybrid heat pumps, combining electricity and gas, can efficiently utilise existing infrastructure and technology while achieving emission reduction goals. Hybrid heat pumps are cost effective as they can make use of the existing gas infrastructure and therefore reduce the needed expansion of the electricity grid, deliver peak demand efficiently, require less extreme insulation of older buildings and use existing energy infrastructure. Therefore, making hybrid heat pumps a promising option for buildings with a gas connection. Biomethane can be the gas supply to the hybrid heat pumps.

Hybrid heat pumps, supplied with biomethane and renewable electricity are particularly useful to provide a stable, reliable building heating during cold spells in winter, when gas massively reduces peak electricity demand compared to all-electric heat pumps.

Industry
Decarbonisation of the industry sector is a challenging sector to decarbonise, particularly for high temperature processes and feedstock. While low to medium temperature heat processes can be decarbonised through electrification, there are not many options to decarbonise high temperature industrial heat. The options include carbon capture and storage (CCS) or low-carbon, renewable gas. Using low-carbon or renewable gas for high temperature heat processes and for feedstocks can help to reduce industry emissions. Biomethane can be used primarily to decarbonise the production of methanol and in primary steelmaking to reduce iron ore.[38] By 2050, heavy industry is expected to use mostly hydrogen for high temperature heat and feedstock, yet about 70 TWh of biomethane will still be needed to replace the remaining fossil feedstock.

Transport
In heavy-duty road transport, international shipping and aviation, the density of the fuel is more important than in other transport sectors. In these sectors, electrification is more difficult. Transport sectors that require high density fuels can be a particular sweet spot for low-carbon, renewable gas to help achieve emission reduction targets. Biomethane, either in liquid or compressed form, is well suited for long-distance heavy-duty road transport and international shipping.

As the societal costs for various fuel options in vehicles are comparable, non-cost factors are most likely to determine the optimal road transport technology mix, as is the availability of biomethane. Gas for Climate allocated 134 TWh of available biomethane to heavy-duty road transport as bio-LNG plus 461 TWh in long-distance shipping by 2050.

Power
Flexible, dispatchable power sources, such as hydro, biomass, and renewable or low-carbon gas, will be increasingly needed as the power sector decarbonises. These flexible power sources will be required to balance out the intermittency of other renewable energy sources, in particular during extended periods in winter when the power demand is at its highest, but power generation from wind and solar may be very limited. Power production using biomethane in centralised 'peaking' plants can play a very valuable role in a future energy system. In this respect, a future biomethane gas grid serves as a strategic storage infrastructure.

The use of gas in the buildings, transport, and industry sectors helps reduce the peak electricity demand, reducing needed electricity generation capacity. This leads to a much lower societal cost. The power sector needs approximately 15% of the energy sources to be flexible, dispatchable sources. Biomethane can cost effectively help supply the flexible electricity by utilising existing gas turbines to generate electricity. The Gas for Climate study concluded that by 2050, 320 TWh of biomethane can cost efficiently help provide the flexible, dispatchable needed energy sources.

[38] For example, see: https://www.ssab.com/news/2021/07/ssab-has-launched-an-extensive-research-project-in-finland-to-replace-fossil-fuels-with-renewable-en

3. Benefits of biomethane

The production and deployment of biomethane offers significant greenhouse gas savings with furthermore positive impacts on rural employment.

3.1 Greenhouse gas emissions reduction

The greenhouse gas emission reduction potential of biomethane is large. Biomethane typically achieves over 80% emission reduction when it replaces fossil fuels and some pathways even achieve up to 200% emission reduction. This is because, in addition to the emissions avoided from replacing a fossil fuel, a similar amount of greenhouse gases either is effectively removed from the atmosphere (and stored in the land) or is avoided in adjacent systems. In the anticipated large-scale deployment of biomethane to 350 TWh by 2030, the average lifecycle emissions are expected to be slightly below zero, due to a combination of avoiding emissions from alternative waste treatment, soil carbon accumulation, using digestate to replace fossil fertiliser, applying carbon capture and storage or replacement. Compared to a fossil fuel comparator of between 75 and 95 g CO_2eq/MJ,[39] the total savings will be about 100 g CO_2eq/MJ. This means that about 110 Mtonne CO_2eq of emissions could be avoided by sustainable production and use of biomethane.[40]

Sequential cropping combined with the deployment of sustainable agricultural practices, such as the implementation of no tillage or returning digestate to the land can increase the soil carbon over time: the system effectively absorbs CO_2 from the atmosphere. In addition, co-produced biogenic CO_2 could be captured and used in other industries, for example in greenhouses to promote plant growth, thereby avoiding the unnecessary creation of fossil CO_2. It could equally be captured and stored permanently. Alternatively, CO_2 can be reacted with renewable hydrogen to produce renewable methane, or chemicals such as methanol.

If manure is used as a feedstock, rather than left untreated, then methane and nitrous oxide emissions, as well as greenhouse gas precursors such as ammonia, are largely avoided. Methane emissions arising from manure are significant in Europe and represented almost 10% of the total methane emissions in 2017 (or 17% of the methane emissions in agriculture which is the largest contributing sector).[41] Use of manure in biogas can therefore play an important role in helping to reduce fugitive emissions from the agricultural sector, while also producing valuable renewable energy. Importantly, biogas is the only manure treatment method that can do so. Similar greenhouse gas benefits will be realised when organic waste streams in other sectors are treated via anaerobic digestion. This has relevance considering the recently launched Global Methane Pledge which aims to reduce global methane emissions by at least 30% from 2020 levels by 2030.[42]

The greenhouse gas performance of biomethane may be impacted by leakage of methane across the production process. In Denmark, the average leak rate in 2018 for 50% of the biogas production was 1.1%.[43] Leaks may arise from open storage or composting of the digestate, from the digester or upgrader and pressure release valves, the level of which will vary between plants. Importantly, practical measures can be taken to minimise these emissions through the implementation of regular monitoring systems, including daily checks of safety values and use of technology to detect and quantify leaks (e.g. infrared sensors, downwind measurement). The EvEmBi[44] project, supported by the European Biogas Association, aims to develop a European voluntary system for monitoring the greenhouse gas emission performance across the sector. Voluntary systems are already in place

[39] Biomethane replaces mainly natural gas, with a lifecycle emission of about 75 g CO_2eq/MJ, and partially diesel (and other fuels) with a lifecycle emission of 95 g CO_2eq/MJ or above.

[40] 350 TWh on basis of gross calorific value equals 315 TWh on basis of net calorific value, or 1,134 PJ. The 100 g CO_2eq/MJ emission reduction is expressed on basis of Lower Heating Value (=net calorific value). 1,134 PJ * 97 g/MJ = 113 Mtonne CO_2eq emissions avoided.

[41] EEB (2020). EEB input to DG AGRI on the urgency to establish binding measures to reduce methane emissions from agriculture. https://mk0eeborgicuypctuf7e.kinstacdn.com/wp-content/uploads/2020/07/EEB-input_EU-methane-strategy-to-reduce-emissions-from-agriculture.pdf

[42] https://ec.europa.eu/commission/presscorner/detail/en/statement_21_5766

[43] Biogas Denmark (2019). Frivilligt måleprogram for metantab (Voluntary measurement program for methane). GASenergi. Nr. 3. 2019. https://www.danskgasforening.dk/sites/default/files/inline-files/4_%20Frivilligt%20m%C3%A5leprogram.pdf

[44] EvEmBi. Voluntary action for GHG emissions control in the biogas sector. https://www.europeanbiogas.eu/project/evembi/

in Denmark, France, Germany and Sweden and have been found to be an effective way of reducing emissions.[45] Through such initiatives the sustainability of biogas production can further strengthened, thereby making an even more meaningful contribution towards helping Europe achieve its climate goals.

Analysis by the European Biogas Association, indicates that the overall impact of fugitive methane emissions of the European biogas sector is relatively modest and would represent between 0.75% and 3.7% of the total methane emissions, assuming a value of 1% to 5% methane loss respectively.[46] If the avoided emissions from using manure in anaerobic digestion are also considered, then overall the greenhouse gas savings of anaerobic digestion deployment in Europe are significant.

3.2 Rural employment

Rural development is best served by creating jobs. The production of 350 TWh of biomethane through anaerobic digestion could create 105,000–145,000 local and high skilled direct jobs and another 160,000–210,000 indirect jobs. Around a third of the jobs result from the development of anaerobic digestion plants, and the remainder relate to the facility's ongoing operations, including running the plant and the sourcing of the required biomass in the agriculture sector. Since biomethane production through anaerobic digestion is often located on-farm using agricultural biomass, its deployment is expected to bring new local employment benefits to rural regions across the whole of the EU.[47]

Depending on the feedstock and the location of the biogas production facility, the biomass needs to be collected, stored, pre-processed and transported. Biogas production supports the creation of stable jobs in the rural economy, for example in the development of sequential cropping schemes or establishing supply chains for the collection of agricultural residues and wastes. Such job creation can help foster societal support for deep decarbonisation. Furthermore, the development of renewable gas production technologies in Europe enables the export of knowledge and technologies, boosting employment opportunities even further.

A further benefit of biogas production based on locally sourced agricultural residues and wastes is that there is greater control over feedstock supply and costs, which may result in greater price stability.

[45] Technical University of Denmark (2020). The Danish voluntary measuring programme. Workshop on Quantification of GHG emissions from biogas plants. European Biogas Association, Brussels, Belgium. https://www.europeanbiogas.eu/wp-content/uploads/2020/02/The-Danish-voluntary-program-Scheutz.pdf

[46] EBA (2021). Fugitive Methane Emissions from the Biogas sector. Impact scenarios for the EU biogas sector. Unpublished.

[47] Guidehouse (2019). Gas for Climate. Job creation by scaling up renewable gas in Europe. (Note that the jobs creation estimates in this study were based on 660 TWh and have therefore been pro-rated to reflect 350 TWh and rounded.)

4. Strategies to scale-up biomethane

Biomethane is not available in large quantities today and needs to be rapidly scaled up to realise its full potential. Besides technical innovations, this requires a more liquid European biomethane market and ensuring that stakeholders along the value chain are incentivised to produce, trade and deploy biomethane in the most optimal way.

4.1 Actions to scale up biomethane

The European Commission's 'A Clean Planet for all' Communication forecasts around 350 TWh per year of biomethane by 2030, which implies that biomethane production would need to increase almost twofold based on current production. Scale-up of biomethane to meet this quantity will only be possible if companies ramp-up investments, governments provide support, producers work to reduce costs, climate benefits are maximised and a sustainable feedstock supply is ensured. Actions to scale-up supply of biomethane, as presented in the Gas for Climate 2020 study, are presented below. Collectively these actions could provide a meaningful contribution to realising the 350 TWh biomethane supply per year by 2030.[48,49]

Increasing anaerobic digester and biomethane plant size
Today, the average digester in Europe has a raw biogas production capacity of 290 Nm^3/hr, although large variations exist between countries. It would be feasible and cost-efficient to increase the capacity of new digesters to at least 500 Nm^3/hr, preferably even larger. This can be achieved by farmers working together to pool feedstock and help to unlock additional sustainable feedstock supply at lower cost. National support schemes can also encourage economies of scale if set up accordingly, for example by not providing support premiums for small scale biogas plants.

Coupled with this, efforts should be made to increase the average size of biogas to biomethane upgrading plants to at least 1,000 Nm^3/hr by 2050, therefore leading to technology cost reductions as well as lower overall grid connection costs. In fact, research undertaken by the Danish Gas Technology Centre concluded that in the Danish context the cost optimum is at a size of around 1,500 Nm^3/hr of biomethane production.[50] This can be either through developing large integrated biogas and biomethane facilities, or plants that pool biogas supply from multiple neighbouring digesters via small pipes under low pressure to into larger centralised upgrading plants. The 2020 Gas for Climate Market State and Trends report shows promising developments in these areas. For example, the 'biogaspartner' project where 48 biogas plants in the Bitburg region in Germany are pooling 10,000 Nm^3/hr of biogas and transporting it to a central upgrading plant. National policy incentives can play a key role in further stimulating developments.[51]

Constructing 6,000 new digesters, each with an average production of 500 Nm^3/hr and 3,000 new centralised biogas upgrading units that will each convert biogas from two digesters to biomethane would collectively produce 159 TWh of biomethane. A further 53 TWh of biomethane could be produced by constructing 500 new integrated biogas-biomethane plants that each produce 2,000 m^3/hr biogas into biomethane. Such industry growth is entirely possible if we look at past developments in Germany, which saw over 6,500 anaerobic digestion plants being built between 2003 and 2012.[52]

[48] Gas for Climate (2020). Gas Decarbonisation Pathways 2020-2050 study. Guidehouse. https://gasforclimate2050.eu/wp-content/uploads/2020/04/Gas-for-Climate-Gas-Decarbonisation-Pathways-2020-2050.pdf

[49] These actions and associated biomethane volumes correspond to the 'Accelerated Decarbonisation Pathway'.

[50] Danish Gas Technology Centre (2020). Production of upgraded biogas – optimization of costs and climate impact. EUDP-j.nr. 64018-0512. Summary of main report. https://www.dgc.dk/sites/default/files/2021-06/Prod_upgraded_biogas_optimization_uk_summary.pdf

[51] Gas for Climate (2020). Market state and trends in renewable and low-carbon gases in Europe. Guidehouse. https://gasforclimate2050.eu/wp-content/uploads/2020/12/Gas-for-Climate-Market-State-and-Trends-report-2020.pdf

[52] Personal communication with Frank Hofmann (International Affairs). Fachverband Biogas. (Note that this relates specifically to anaerobic digestion plants producing electricity. Additional plants producing heat, or biomethane for transport, were built over this period.)

Upgrading biogas production to biomethane
Over 80% of the 191 TWh biogas produced today is used for local electricity and heat, rather than upgraded to biomethane and injected into the gas grid. Efforts are needed to transition this supply to grid biomethane where it can release greater societal benefit. In addition, all newly commissioned digestion-based biomethane plants should be connected to gas grids. As was discussed in Chapter 2, future use of biomethane for electricity production should be reserved for centralised peaking plants where it can add greatest energy system value.

Implementing grid capacity solutions, such as in-grid compression of gas, can facilitate this by providing more flexibility for the gas system. One such example is allowing bidirectional gas flow from the distribution to the transmission grid and vice versa, which increases the possibility for decentralised biomethane injection. Currently, 11 so-called 'reverse flow' facilities are in operation across the EU, and another 23 are under construction. Gas infrastructure companies can play an important facilitating role in developing such projects.[53]

Investing in commercial scale gasification plants
Currently, around 50 to 100 biomass or waste gasifiers are in operation globally, but very few are targeting biomethane production and these are all in demonstration phase (see Section 1.1.2).

Investment in commercial scale biomass gasification plants needs to start now. This is hampered by the very large investment per individual installation and the high perceived project risk of this technology. The EU ETS Innovation Fund offers a potential source of co-funding for initial first-of-a-kind (FOAK) projects in the period 2020 to 2025. Beyond this, energy companies will need to play a more active role and develop next-of-a-kind (NOAK) commercial scale projects. This will only be feasible under a long-term policy framework that offers the right incentive for biomethane gasification while simultaneously pushing for continuous cost reductions to minimise societal costs.

Continued technology innovation
Further efforts by technology providers and research institutes need to be targeted to maximise digester and gasifier efficiencies through technological improvements and through improved bacterial processes. Developing novel pre-treatment technologies is also important to enable lignocellulose substrates, straw and woody materials, to be more easily biodegraded in an anaerobic digester.

4.2 Implementing Biogasdoneright

Today, the concept of Biogasdoneright is successfully applied by hundreds of farmers in Italy and a growing number in France. Biogasdoneright focuses on producing biogas from a mix of agricultural wastes, residues and sequential crops (see Figure 4 overleaf). The implementation of sequential cropping in conjunction with the Biogadoneright concept has been demonstrated to have multiple environmental benefits relating to soil quality, soil carbon and biodiversity. The concept furthermore does not impact existing food or feed markets as no additional land is used for biogas production. A wider application of Biogasdoneright would therefore be an effective way of increasing sustainable biomethane production across Europe and coupled with this make a positive contribution towards promoting sustainable agriculture in Europe.[54]

In Biogasdoneright, tillage of cropland is kept to a minimum (strip or no tillage) to increase soil carbon and keep more nutrients and moisture locked in the soil. The wet fraction of biogas digestate is brought back to the cropland using drip-feeding systems (fertigation), which allows all nutrients from biogas crops to be recycled back to agricultural soils, thereby minimising the need to use synthetic fertilisers that are likely to have negative impacts on soil quality. The drip-feeding systems are also used for water efficient irrigation during summertime, limiting overall water use. The solid fraction of the digestate can be further developed into biochar, a stable form of carbon in the form of charcoal that can be used as fertiliser as well and adds value to soils suffering from erosion and low fertility.

[53] Gas for Climate (2021). Market state and trends in renewable and low-carbon gases in Europe. Guidehouse. https://gasforclimate2050.eu/wp-content/uploads/2021/12/Gas-for-Climate-Market-State-and-Trends-report-2021.pdf
[54] For example, on carbon farming. See: https://ec.europa.eu/clima/eu-action/forests-and-agriculture/carbon-farming_en

The increased coverage of the agricultural land with cover crops also decreases soil erosion covering the usually bare land with vegetation. This works as an effective instrument against desertification and soil erosion, particularly in southern Europe.[55,56,57] The coverage of land that would otherwise remain fallow can also create positive effects for biodiversity as animals are more able to take refuge on covered land compared to fallow land.[58] Moreover, as fallow land is used for bioenergy cropping, no additional land is needed for bioenergy purposes, thereby preventing pressure on the agricultural system for land conversion which can cause biodiversity (or carbon stock) losses. Finally, the Biogasdoneright concept has found that the prolonged land cover leads to improved health of the soil, reduces the overall use of pesticides per hectare.[59]

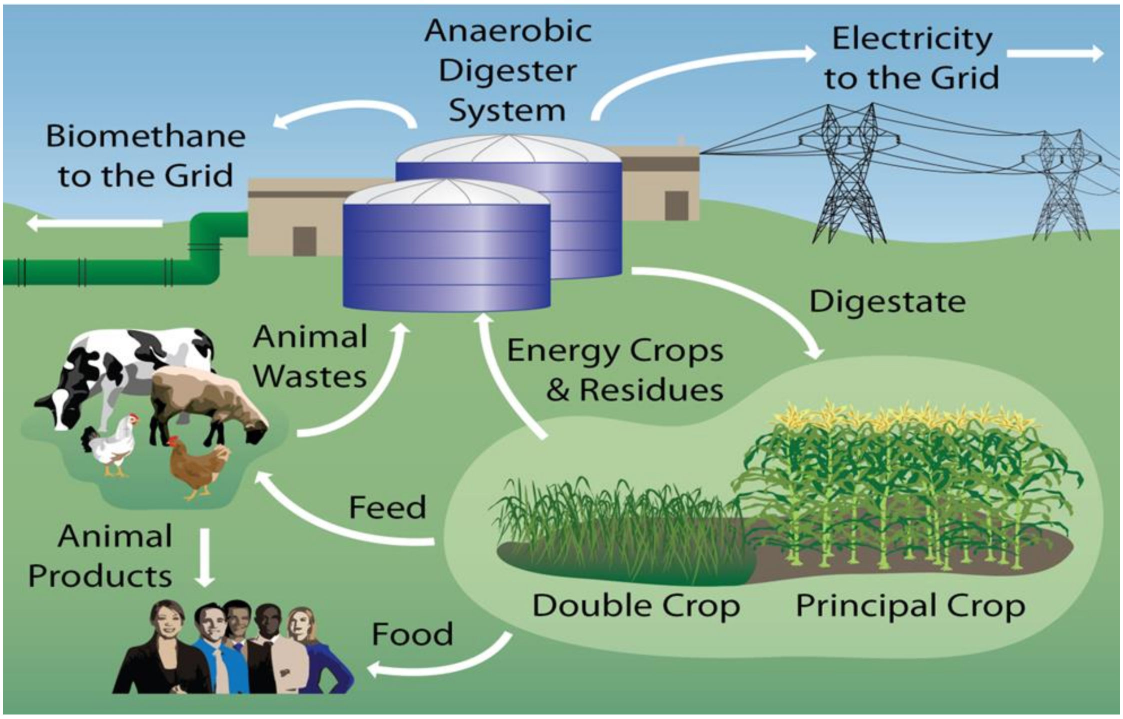

Figure 4: Biogasdoneright concept of sustainable biogas production.

A scale-up of Biogasdoneright requires research to test to what extent it can be implemented in more temperate parts of Europe as well, and in particular in key European agricultural regions such as Germany, Romania and Poland. Large-scale training and awareness-raising programmes would need to be implemented among farmers in all countries in which sequential cropping, organic fertilisation, precision, and conservation farming is demonstrated to be a promising concept.

[55] Sainju UM (2016). Can Novel Management Practice Improve Soil and Environmental Quality and Sustain Crop Yield Simultaneously? PLoS ONE 11(2): e0149005. doi:10.1371/journal.pone.0149005

[56] Pastorelli, R.; Valboa, G.; Lagomarsino, A.; Fabiani, A.; Simoncini, S.; Zaghi, M.; Vignozzi, N. Recycling Biogas Digestate from Energy Crops: Effects on Soil Properties and Crop Productivity. Appl. Sci. 2021, 11, 750. https://doi.org/10.3390/app11020750

[57] CIB (2020). Biogasdoneright: Anaerobic digestion and soil carbon sequestration. A sustainable, low cost, reliable and win win BECCS solution, p21.

[58] de Pedro et al. (2020). The Effect of Cover Crops on the Biodiversity and Abundance of Ground-Dwelling Arthropods in a Mediterranean Pear Orchard. Agronomy (10): 580.

[59] ART Fuels (2018). Position Paper: Biogas Done Right in transport: Sequential cropping to produce food, feed and biomethane. https://artfuelsforum.eu/wp-content/uploads/2018/05/ART-Fuels-Forum_BiogasDoneRight_Position-Paper_May_2018-1.pdf

4.3 How policy can help to remove barriers?

The rapid scale-up of biomethane is being hampered by several barriers, a selection of which are summarised below. It is critical that solutions are proposed to address these barriers to maximise the potential of biomethane to contribute towards EU decarbonisation goals to 2030 under Fit for 55.

Ambition level of policies supporting gas decarbonisation should be raised
Several Member States, such as France, have introduced national targets and objectives for production and consumption of renewable gas by 2030. However, many Member States are not yet fully realising the potential to recycle their wastes and residues for sustainable gas and biofertilizer production.

More recognition and support for biomethane helps to achieve a climate-neutral EU energy system at the lowest societal costs. As this paper describes, biomethane has its specific demand sectors where it adds particularly high energy system value, alongside large and increasing quantities of renewable electricity and hydrogen. While the European Commission has proposed specific targets and incentives for renewable electricity and hydrogen, such EU-level support is lacking for biomethane.

Improve market liquidity and cross-border trading
The European tracking of biomethane through the grid is based on mass-balancing and physical tracking without the possibility to book volumes and claim them in sectors where they are most needed or in regions where there is less production capacity. To make the system more practical, mass-balancing should be followed only until production but once the renewable gas is produced and injected in the grid or transported by other means, guarantees of origin (GOs) should become the main instrument to carry information, including sustainability characteristics. The EU has already created well-functional trading conditions for renewable electricity. The gas sector needs similar mechanisms to trade volumes and GOs of renewable gas across borders.

The forthcoming Union database for liquids and gaseous fuels provides an opportunity to take on board these concerns, particularly if the scope of the database covers all end-use sectors.

Create better understanding of the role of biomethane in climate action across the economy
To reach the 40% renewable energy target for 2030 set out under the Fit for 55 package and greenhouse gas emissions reduction across all sectors, the EU should prioritise sustainable energy sources that are available today and are therefore able to make a meaningful contribution to these targets. Biomethane is needed to complement renewable electricity (as discussed in Chapter 2), and green hydrogen is currently not widely available and at least until 2030 the costs will be high.

Additionally, several studies see a significant biomethane potential from sustainable sequential cropping in combination with carbon farming that also brings multiple other environmental and economic benefits (as described in Chapter 3). The use of manure for biomethane production can also play an important role in reducing fugitive methane emissions in the agricultural sector. These benefits need to be recognised by policy makers.