# The role of biogas and biomethane in pathway to net zero

## Position paper

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## The role of biogas and biomethane in pathway to net zero

Biogas is produced as the main product of anaerobic digestion (AD) of wet biomass. Biogas can be used locally for heat purposes or for power and heat production (CHP); as an alternative, biogas can be upgraded to bio-methane to replace natural gas. As such, it is one of the means to reduce the consumption of fossil fuels and contribute to the transition towards a net zero energy system.

This position paper – developed by members of IEA Bioenergy Task 37 ("Energy from Biogas") – provides a holistic perspective on the roles of biogas and biomethane. The main conclusion is that biogas and biomethane have a range of options which can be employed in pathways to net zero. They provide sustainable flexible systems that play essential roles in circular economy, energy, and environmental systems.

### PERSPECTIVES OF BIOGAS AND BIOMETHANE

#### Pathway to Net Zero

**The pathway to net zero requires far more than provision of renewable electricity**. We must employ renewable hydrocarbons in the form of liquid and gaseous fuels with minimum carbon intensity. Indeed, we must go beyond energy and employ renewable green hydrogen in the production of chemicals such as ammonia ($NH_3$) and methanol ($CH_3OH$), and for steel. When we produce biomethane ($CH_4$) or green hydrogen ($H_2$), we are in both cases producing renewable hydrogen molecules within a renewable gas. We need these renewable gases and renewable hydrocarbons for dispatchable electricity, for long term energy storage and for sectors where electricity has limited applications. These applications (termed the hard to abate sectors) include: heavy-duty, long-distance transport (trucks, ships and planes); high temperature industrial heat (food and beverage sector, steel production, glass production); agriculture (renewable fertiliser such as green ammonia and biofertiliser); and chemical production (such as methanol).

## Biomethane as a replacement for natural gas

Biogas is typically comprised of 60% methane and 40% carbon dioxide ($CO_2$). Biogas when upgraded to greater than 97% methane is termed biomethane.  Biomethane is a renewable gas with almost identical characteristics to natural gas; it can be fed into the existing gas infrastructure and can rely on proven technologies for its transportation and utilization. Within specific industries as well as municipalities, gas boilers, combined heat and power (CHP) generator sets, compressed natural gas (CNG) fuelled vehicles and associated conversion systems are in place to provide the path of least resistance to decarbonise natural gas applications through substitution with biomethane; exemplars of this are industries with end products that range from ammonia to whiskey. **With biomethane the total cost of ownership of the energy system is minimised as the infrastructure for distribution and use is in place** in many parts of the world.

## Biogas and biomethane systems are mature and multi-functional

Biogas and biomethane systems based on anaerobic digestion have been successfully applied in connection with power, heating and/or gas grids, and as standalone solutions in numerous applications worldwide; biogas and biomethane applications are a mature technology. **Biogas systems contribute to energy security since the whole production chain can be set up and operated decentrally and locally.** Moreover, biogas is not the only product of anaerobic digestion; digestate, which is an important co-product in the digestion process, can be used locally as a renewable biofertiliser (directly, or after upgrading), so substituting for the use of energy-intensive fossil chemical fertilisers. In biomethane applications $CO_2$, which needs to be separated from biogas to obtain biomethane, may also be valorised as a co-product.

# POTENTIAL OF BIOGAS RESOURCE

**Biogas production based on anaerobic digestion can utilize a wide variety of organic feedstocks** such as: municipal or industrial organic waste and wastewater; industry residues (such as stillage); agricultural residues (such as manures and straw); or plant materials. When we talk about the resource of biomethane we need to consider what system or process we can improve in terms of environment or climatic impact. As such the resource of biogas depends primarily on the systems we wish to decarbonise or reduce the environmental impact of.

## Biogas systemes are a means of reducing fugitive emissions from wet organic wastes

For many organic wastes and residues, anaerobic digestion is the most competitive utilization pathway. For example, for wet manure or the organic fraction of municipal solid waste, anaerobic digestion reduces fugitive greenhouse gas emissions (such as from open slurry tanks) as compared to the do-nothing scenario; there is also the benefit that if biomethane is used in a hard to abate sector (to fuel a truck for example) then there are additional savings from displaced diesel. This is especially important as fugitive emissions from municipal waste and slurry are largely in the form of methane with a much higher global warming potential (GWP over a 100 year time frame of methane is 28 times that of $CO_2$). **Often the driver for a biogas solution is reduction in fugitive emissions from wastes** and as such the utilization of such substrates should be prioritised.

## Biogas systems as a strategic component of a biorefinery

Industry (such as those within the food and beverage sectors and the paper and pulp industry) is a major source of organic material, much of which is not well valorised as of yet. These industries will need to reduce carbon footprint and improve environmental impact; the use of anaerobic digestion technologies on wet organic by-products could be a major source of biogas. However there may be other utilization pathways for organic residues; in a future decarbonised world these residues may be used in bioeconomy applications depending on economics and on opportunity costs. New applications include the production of volatile fatty acids (VFAs) in an anaerobic fermentation process coupled with inhibition of methanogenic archaea. One major advantage of the anaerobic digestion process is its flexibility and applicability to almost all organic materials and across a range of applications. Anaerobic digestion can be an essential element of any cascaded utilization of organic material and as such **biogas solutions are strategic components in biorefinerie**s.

## Biogas systems as part of circular economy in agriculture

Provision of energy through use of agricultural land that may compete with food production has been debated extensively and is considered controversial if this involves dedication of large swathes of agricultural land to mono-cultures of energy crops. However, cover crops or catch crops (grown in between the primary food or feed crops) can provide important quantities of feedstock for biogas production. Cover crops (or catch crops) have been shown to be of benefit for agriculture soil quality through: reduction of nutrient leaching; avoidance of wind and water erosion; and improving organic matter in soils. Biogas production from cover crops does not reduce volumes or quality of the main food or feed crop. Moreover cover crops can improve the economics of biogas plants. Plant material from such crops can be stored as silage which usually have a relatively high biogas potential. Cover crops can therefore be used as co-substrate in an anaerobic digester to increase biogas yields and may be a primary element in increasing biogas production of manure based biogas plants to a level which is economically viable. The digestate from such biogas systems may be applied back to the land where the crops were grown and crops produced can provide feed to animals whose slurry is digested in a circular economy agriculture system, reducing fugitive emissions, reducing use of fossil fertiliser and improving soil organic content. Still, the availability of feedstocks has its limits and the potential of biogas systems cannot substitute for all energy applications.

## Establishing the resource of biogas systems

**All biogas solutions are technically, geographically and politically bespoke**; the best solution in one region is not always optimal in another region depending on climate and policy of the particular region. Feedstock potentials and characteristics need to be analysed on a regional level (a bottom up approach including for industrial ecosystems) and be merged to a strategy on a higher level (a top down approach such as the recent EU Repower plan targeting a doubling of biomethane production). It is highly recommended to pay attention to specific circumstances impacting the availability and costs of feedstock. In assessing previous resource studies there is a tendancy for significant differences in outcomes. This is impacted by differing: methodologies (with diverging theoretical, technical, economic and ecological restrictions); feedstocks considered; climatic conditions and growth rates; databases; and differing assumptions made regarding the feedstock. It is highly recommended to delve deeper then generic data from previous literature.

## Strategies for regional specific biogas systems

Based on the decision on which feedstocks are included and the available resource of these feedstocks, a specific strategy for a regional biogas system needs to be developed; this applies to both national and local level. When incentivizing the utilization of specific feedstocks for biogas production, consideration must be given to the impact of conditions of incentivisation and the costs of incentivisation on other sectors which may use these particular feedstocks. **A detailed, region-specific analysis of availability, costs and impact of specific feedstock utilization is recommended in order to ensure an effective and sustainable biogas sector**.

## Biogas systems are one of a range of solutions in a net zero future

For clarity it must be stated that the biogas industry of itself, on its own, cannot substitute for present levels of natural gas in future energy scenarios. This is too much of an ask; in the EU and the USA up to twice as much energy is taken from the gas grid as the electricity grid. However, to effect a net zero future there is a demand for a diversity of solutions; **biogas and biomethane can contribute significantly with bespoke sustainable and technically highly customizable solutions**. For example **biogas systems can provide dispatchable electricity and even better, production of biogas may be ramped up to provide increased volumes of electricity when demand on the electricity grid is high.** Given the urgency to act and the availability of technology and infrastructure, it is crucial to explore and deploy existing potential for biogas systems within circular ecomomy, energy, and environmental systems.

## BENEFITS BEYOND ENERGY

## Biogas systems are primarily focused on environmental protection

Anaerobic digestion provides solutions beyond just energy. Biogas is not the only product. Anaerobic digestion technologies are not developed in isolation to produce energy as for example a wind turbine or a PV array. Anaerobic digestion fits into an existing system and typically has a role in environmental protection, such as **reduction in fugitive methane emissions** and protection of water quality. Anaerobic digestion **reduces the pathogen content of slurries** and wastewater; anaerobic digestion **mineralises the nutrients** in slurries and makes them available to plants for growth; anaerobic digestion **removes smells from slurries** and improves air quality; anaerobic digestion can convert stillage or food waste into a biogas that reduces scope 1 emissions in the food and beverage industry (replace natural gas in evaporation process) and a biofertilizer that reduces scope 3 emissions (for example digestate can replace fertiliser in wheat cultivation for whiskey production). Smart agriculture including for anaerobic digestion and biofertilizer production will lessen the requirement for fossil fertiliser, reduce contamination of water courses with pathogens, and minimise eutrophication of waterways.

### Use of $CO_2$ from biomethane systems

Modern facilities that produce biomethane include for carbon capture and reuse. The market for food grade $CO_2$ in Denmark is 65,000 t/a which could be met by scrubbing the $CO_2$ from biogas when generating biomethane. **$CO_2$ in biogas is one of the cheapest sources of $CO_2$ for further utilization**; an example is biomethanation whereby hydrogen is reacted with $CO_2$ to produce synthetic methane ($4H_2 + CO_2 = CH_4 + 2H_2O$). Indeed, in the route from electricity to hydrogen and onto electro-fuels $CO_2$ in biogas may be the cheapest and one of the most sustainable sources of biogenic $CO_2$. **Power to methane applications wherby hydrogen is used to react with $CO_2$ in biogas to upgrade to biomethane (and synthetic methane) results in typically, a 60% increase in energy ouput in the form of renewable methane.** Finally, there is potential for $CO_2$ sequestration as part of a negative emission technology better known as bioenergy with carbon capture and storage (BECCS).

## ECONOMICS OF BIOGAS SYSTEMS

### Compare like with like

The economics and cost competitiveness of biogas systems is an ongoing debate. When discussing economics, it is important to define what biogas systems are compared to and where are the boundaries of the system. Firstly, it is not sufficient to compare costs for fossil fuels with renewable energy carriers. Secondly, low-carbon renewable technologies should be compared with other low-carbon renewable technologies which provide similar services; a renewable source of electricity does not always compare readily with a renewable liquid fuel for heavy duty transport. A methodology for comparison of renewable technologies is the marginal abatement cost, which assesses the cost of the technology per tonne $CO_2$ avoided through use of the technology. It is not always instructive to compare the marginal abatement cost of biomethane for transport with for example that of PV for electricity. Electricity may not fuel heavy duty long distance transport while biomethane will. **Biogas systems and in particular biomethane should be compared with other renewable gases, such as hydrogen or synthetic methane.**

### Comparing economics of biomethane with hydrogen

It is remarkable to see the positivity associated with hydrogen in current (political) discussions; this is not the case for biomethane. Current production costs for biomethane are suggested to vary from a low of 25 €/MWh to a high of 100 €/MWh. As of November 2022,with the war in Ukraine on-going, these prices are below current fossil gas prices in Europe. On an energy basis, this is equivalent to a hydrogen production cost between 0.83 to 3.33 € per kg of hydrogen. At this moment in time it is thought that green hydrogen production through electrolysis would be about €4/kg if it were a commercial industry (which it is not the case yet) and optimistic future scenarios may see costs going down to €1 - 2/kg. It must be stated that cheap hydrogen requires very cheap electricity. Scenarios which suggest cheap hydrogen need to assess the economic viability of the renewable electricity producer. We may say that at the moment **biomethane is cheaper than green hydrogen and is expected to remain so for some time in the future.**

### Hydrogen (and biomethane) are part of larger systems

Of issue with hydrogen at the moment is the infrastructure and the precise end use. Unlike the case for biomethane, the infrastructure for wide distribution and use of hydrogen is not in place. In terms of uses of hydrogen, optimal pathways may be for storage of electricity, for transport fuel, for production of steel, ammonia, or methanol. It may be said the hydrogen economy is not as yet well-defined but there is a belief that hydrogen will be driven by the variability of wind and solar power and future designed overproduction of renewable electricity to satisfy electricity demands and as such overcome variability; this oversupply will allow a source of electricity for hydrogen production. We may say that **both hydrogen and biomethane are part of larger markets and externalities may decide their optimum use and value to society**.

## Putting a value on externalities of biogas systems

Other than replacing fossil fuels and in so doing, reducing GHG emissions, it has to be considered that biogas systems are multi-functional and integrated in larger systems. Therefore biogas and biomethane cannot be directly compared to a wind turbine with an electrolyser next to it for the production of green hydrogen. The biogas system also produces biofertiliser; it can also produce food grade $CO_2$; it can be integrated in food production chains as a waste treatment system; it can sanitize waste materials and slurries. Biogas systems reduce fugitive methane emissions from open slurry tanks; treat wastes that otherwise would cause emissions that impact on air and water quality. **Such externalities are not assigned an economic value, but should be considered in multi critera assessment of decarbonisation pathways**.


# HOW TO INCENTIVISE DEPLOYMENT OF BIOGAS SYSTEMS

## Bankability for developer and long term financial sustainability

**Any incentive should reflect the actual costs of investment and long-term operation of the renewable gas industry to ensure bankability for the developer and to ensure a price effective market environment for the user of renewable gas**. Introduction of quotas or mandates of minimum percentages of renewables in the market is a very effective tool to support sector development. Whilst incentives are currently required to compete with fossil fuels and develop a certain technology maturity, a strategy to transition away from fossil gases towards renewable gases using effective carbon prices/taxes or limiting the market for fossil fuels is needed to end financial incentives. As with fossil gases, trading mechanisms between producers and users of renewable gas are needed to allow sector development and connect areas with higher feedstock potential with areas with higher demand, sometimes in different countries.

## Minimisation of bureaucratic barriers to trade

Future trade schemes need to be able to convey sustainability characteristics (different sources of biogas and biomethane have different carbon intensities) and potential support schemes need to be aligned to avoid market distortion. Unnecessary barriers and inhibitory regulations on both technical and regulatory level should be removed. Grid access for renewable gas should be granted. Administrative barriers such as complicated and extensive permitting processes should be minimized to facilitate development of innovative sustainable biogas systems. Moreover, **a stable and predictable framework is recommended to provide favourable conditions for the sector to grow**.

### Assigning a sufficient carbon tax to allow development of low carbon fuels

Incentive systems need to transition towards an overall system where a tax of sufficient scale and granularity is applied to all $CO_2$ emissions to remove any perceived economic advantage to fossil fuels and to award economic advantage to the fuels of lowest carbon intensity. Such a carbon tax should stimulate development and drive the transformation towards renewables whilst simultaneously providing a common base for competition between renewable technologies. Granularity of such a system should allow renewable technologies in the same sector (electricity or heavy duty transport fuel) compete with each other.

## THE ROLE OF BIOGAS AND BIOMETHANE IN PATHWAY TO NET ZERO

Renewable hydrocarbons such as biogas and biomethane are required in our future net zero world. Without hydrocarbons we will not be able to fuel long distance heavy transport; hydrocarbons are ingredients for chemical such as methanol. Sustainable steel production will require renewable hydrogen molecules. Many industries including the food and beverage industry and the glass industry are optimised for burning a gaseous fuel. Biogas systems provide a solution for these industries; these systems are at a high technology readiness level and have a viable readily available infrastructure. Methane has a higher volumetric energy density as compared to hydrogen. We can not predict the future nor future policy. If methane were not to be envisaged as a future energy source then biomethane may be converted to hydrogen ($H_2$) and $CO_2$ and if this biogenic $CO_2$ were stored underground (carbon, capture and storage) this would be a 'negative emission pathway'. The $CO_2$ could be used (carbon capture and use) to produce carbon-based chemicals. Alternatively biomethane ($CH_4$) can readily be converted to methanol ($CH_3OH$), which is a renewable liquid hydrocarbon which is seen as the future low carbon fuel for shipping. In conclusion, biogas and biomethane have plenty of options to be used in a pathway to net zero. In order to enhance further development, the compatibility with other technologies (both existing and proposed) through a cascading approach should be enabled. **Biogas and biomethane are sustainable flexible systems that play essential roles in circular economy, energy and environmental systems.**

**Highlights:**

**Energy transition**

- The pathway to net zero requires far more than provision of renewable electricity; renewable gases and liquids are as important.
- Biomethane can be fed into the existing gas infrastructure and provides the path of least resistance to decarbonise natural gas applications. With biomethane the total cost of ownership of the energy system is minimised as the infrastructure for distribution and use is in place.
- Biogas systems are one of a range of solutions in a net zero future. To achieve a net zero future there is a demand for a diversity of solutions. Biogas and biomethane can contribute significantly with bespoke sustainable and technically highly customizable solutions. For example, biogas systems can provide dispatchable electricity and even better, production of biogas may be ramped up to provide increased volumes of electricity when demand on the electricity grid is high.

**Multifunctionality**

- Biogas production based on anaerobic digestion can utilize a wide variety of organic feedstocks such as: municipal or industrial organic waste and wastewater; industry residues (such as stillage); agricultural residues (such as manures and straw); or plant materials.
- Biogas systems contribute to energy security since the whole production chain can be set up and operated decentrally and locally. Moreover, biogas is not the only product of anaerobic digestion; digestate, can be used locally as a renewable biofertiliser (directly, or after upgrading). $CO_2$, which needs to be separated from biogas to obtain biomethane, may also be valorised as a co-product.
- Biogas solutions reduce fugitive methane emissions, protect water quality, reduce pathogen content of slurries, produce biofertilisers, reduce smells, and improve air quality. Often the driver for a biogas solution is the reduction in fugitive emissions from wet organic wastes.

**Circular economy**

- Anaerobic digestion can be an essential element of any cascaded utilization of organic material and as such biogas solutions are strategic components in biorefineries.
- Biogas systems can create circular economy systems within agriculture. For example, digestate from biogas systems may be applied back to the land where the crops were grown and crops produced can provide feed to animals whose slurry is digested in a circular economy agriculture system, reducing fugitive emissions, reducing use of fossil fertiliser and improving soil organic content.

**Region-specific solutions**

- All biogas solutions are geographically and politically bespoke. The best solution in one region is not always optimal in another region depending on climate and policy of the particular region.
- A detailed, region-specific analysis of availability, costs and impact of specific feedstock utilization is recommended in order to ensure an effective and sustainable biogas sector.

**Highlights (continued):**

**Use of $CO_2$**

- Modern facilities that produce biomethane include for carbon capture and reuse. $CO_2$ in biogas is one of the cheapest sources of biogenic $CO_2$ for further utilization.
- Power to methane applications whereby hydrogen is used to react with $CO_2$ in biogas to upgrade to biomethane (and synthetic methane) results in typically, a 60% increase in energy output in the form of renewable methane.

**Economics**

- Compare like with like: biomethane should be compared with other renewable gases, such as hydrogen or synthetic methane.
- Biomethane is cheaper than green hydrogen and is expected to remain so for some time in the future. In addition, unlike the case for biomethane, the infrastructure for wide distribution and use of hydrogen is not yet in place.
- Both hydrogen and biomethane are part of larger markets and externalities may decide their optimum use and value to society.
- Other than replacing fossil fuels and in so doing, reducing GHG emissions, it has to be considered that biogas systems are multi-functional and integrated in larger systems. Externalities could be assigned an economic value or should anyway be considered in multi criteria assessment of decarbonisation pathways.

**How to incentivise deployment of biogas systems**

- Incentives should reflect the actual costs of investment and long-term operation of the renewable gas industry to ensure bankability for the developer and to ensure a price effective market environment for the user of renewable gas.
- Unnecessary barriers and inhibitory regulations on both technical and regulatory level should be removed.
- A stable and predictable framework is recommended to provide favourable conditions for the renewable gas sector to grow.
- A carbon tax on fossil fuels should stimulate development and drive the transformation towards renewables whilst simultaneously providing a common base for competition between renewable technologies.

**Role in the pathway to net zero**

- Renewable hydrocarbons such as biogas and biomethane are required in our future net zero world and they have plenty of options to be used.
- Biogas and biomethane are sustainable flexible systems that play essential roles in circular economy, energy, and environmental systems.

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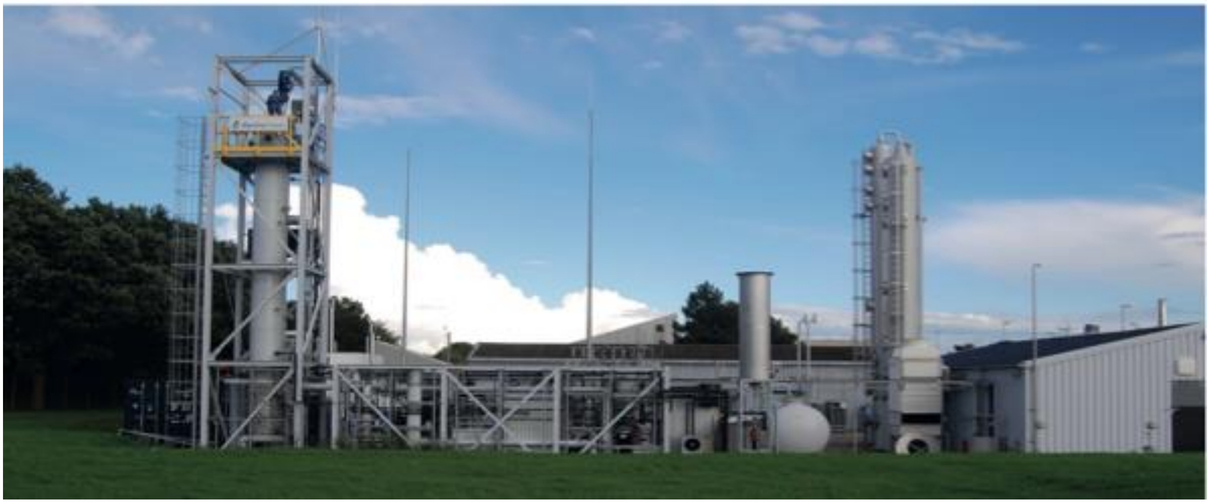

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