Biomethane

Insights on a rapidly changing market

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Introduction

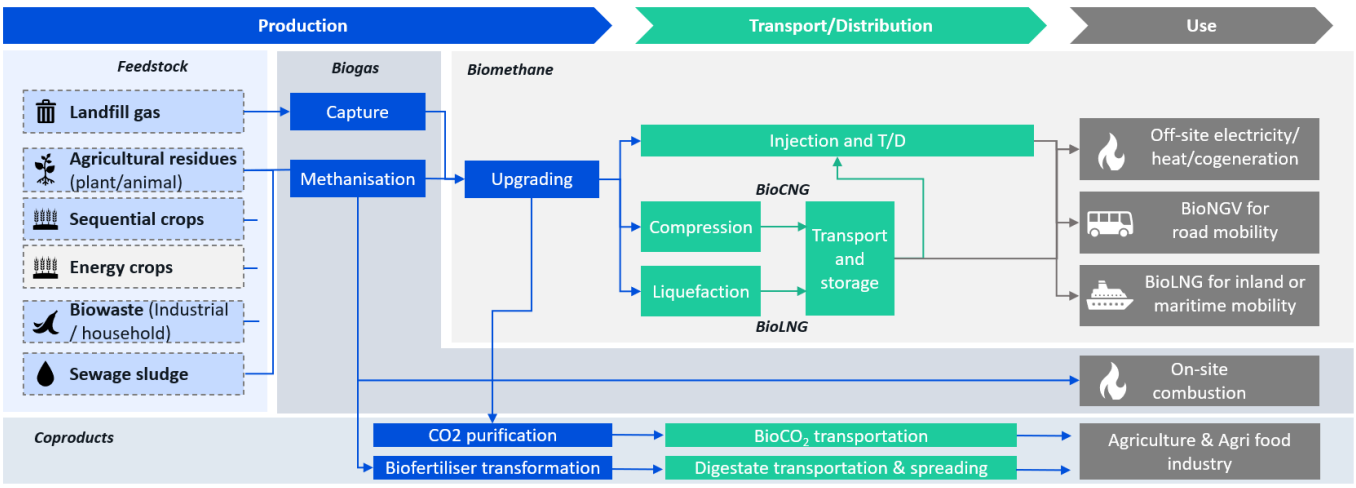
What is biomethane and why is it such a hot topic now?

What is biomethane?

Biomethane, also called Renewable Natural Gas in the US, is almost purely composed of methane, and is very close to natural gas in quality. **The major differences between biomethane and natural gas lie in their origin and impact.**

Biogas is mostly produced from the decomposition of biomass in a digester in the absence of oxygen and with the help of bacteria. The biomass used could be agriculture residues (plant or animal by-products, sequential crops, ...) or organic waste from households. **When derived from sustainable biomass (defined in Europe by RED[1] legislation), biogas and biomethane are considered renewable gases,** while traditional natural gas is a fossil gas.

Biomethane is the "upgraded" form of biogas, after carbon dioxide and trace gas removal. While the biogas and biomethane industry historically developed with Combined Heat and Power (CHP[2]) as the main demand channel for biogas, since 2018 its growth has largely been driven by the uptake of the biomethane pathway. Biomethane can be injected in the existing natural gas pipelines or supplied by truck as a gas (CNG[3]) or a liquid (LNG[4]).



[1] RED: **Renewable Energy Directive (RED)** is the legal framework for the development of clean energy across all sectors of the EU economy, supporting cooperation between EU countries towards this goal. RED II, currently enforced, is a recast of the Directive 2009/28/EC (RED I). RED II sets a binding target of 32 % for the overall share of energy from renewable sources in the EU's gross final consumption of energy in 2030. It also established sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels. A revision of RED II, adopted in October 2023 and expected to be enforced in July 2024, updates some targets to align with increased Green Deal ambition (particularly in the transport and industry sectors) and aims at supporting Europe competitiveness on the global energy market. (Source: European Parliament (europa.eu))

[2] Combined Heat and Power (CHP) is a technology that produces electricity and thermal energy at high efficiencies using a range of technologies and fuels (including biogas). It is often (but not only) used for on-site energy production, which minimises loss.

[4]CNG: Compressed Natural Gas

[3]LNG: Liquefied Natural Gas

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Why is biomethane such a hot topic?

Renewable gases are expected to contribute strongly to carbon-neutrality targets by 2050 whilst reinforcing energy independence:

- Biogas and biomethane production is usually based on local feedstock and processing: they thus **contribute to strengthening energy supply security**, which became a burning issue after the outbreak of the Ukraine / Russia crisis.
- Biogas and biomethane also **support GHG emission reductions across their whole value chain**. They contribute to residue treatment and to the decarbonisation of end use sectors like buildings, industry, transport (with bio-LNG[3], bio-CNG[4]), or agriculture (digestate replacing chemical fertilisers). Biomethane in particular has an important decarbonisation potential as a direct alternative to natural gas that can leverage existing infrastructure to be transported, distributed and consumed.

The European biomethane market, the biggest market in the world, has seen significant growth in recent years, with **production doubling from 2018 to 2022**, **reaching 44 TWh or 4.2 bcm (European Biogas Association)**.

This growth has led to **ambitious targets at the European level: EU 27 targets 35 bcm** (approx. 370 TWh) **of biomethane production by 2030**, which means **multiplying 2022 production by more than 8x in 8 years**. This target also represents roughly **10% of 2022 EU consumption of natural gas (IEA 2023)**.

Key underlying trends are informing the ongoing structuring of the EU biomethane market.

The ongoing structuring of the European biomethane market, developing in parallel to this rapid growth, follows strong underlying trends that cover a range of key topics for biomethane project developers and investors:

- Market entry and organic growth can be challenging due to value chain complexity, but a range of strategies are available for players willing to pursue new strategies.
- Market designs are switching away from “production-side” support toward “demand-driven” market mechanisms, which impact project financing, price setting and trade flows.
- Feedstock competition with alternative biofuel uses is increasing and feedstock exposure to climate change-related risks is still overlooked, but increasingly real, raising the urgency to secure “future-proof” sources of supply.
- Emerging alternative processes could significantly boost green gas production to help meet demand in the future.
- Use of by-products CO2 and biofertilisers have yet to become as mainstream as biomethane and should be encouraged because of their value in monetising positive externalities.
- The impact of climate change on agricultural activities, both livestock and cropping, is starting to take shape and will only accelerate in the coming years – this should be integrated in all biomethane development strategies.

In a fast-moving environment, a strong competitive advantage for market players lies in the capacity to anticipate these trends and position intelligently to maximise captured value from their impact.

[3] LNG: Liquefied Natural Gas
[4] CNG: Compressed Natural Gas

Blunomy is sharing insights through a series of 6 biomethane briefs addressing key industry topics.

Blunomy has been active in the biogas and biomethane sector for the last 15 years, supporting project developers, industrials, large energy players, public associations, and financial investors in understanding this market and capturing its opportunities. Blunomy provides advisory services and develops bespoke tools for actors across the value chain. Blunomy is now publishing regular 'Biomethane Briefs' to share its vision on the biogas and biomethane ecosystems. These biomethane briefs unpack the current trends and changes that drive the development of the sector.

Brief 1

Market entry can be challenging due to value chain complexity, but some new strategies are available.

This article is part of a series of biomethane briefs published by Blunomy on the biomethane market.

Biomethane is increasingly attracting renowned investors and large energy players.

Large energy players and infrastructure funds have recently rushed into the biomethane market globally. Recent large investments include:

- $2bn by Shell to acquire Nature Energy in Nov. 2022
- $4.1bn by bp to acquire Archaea Energy in Oct. 2022
- Macquarie Asset Management's acquisition of Germany's BayWa r.e. Bioenergy in Oct. 2022
- The launch of $1bn platform Verdalia by Goldman Sachs AM
- TotalEnergies' acquisition of Polska Grupa Biogazowa in Mar. 2023
- $0.8bn by Engie to acquire Ixora Energy Ltd in Sep. 2023
- Repsol's deal to acquire 40% stake in Spanish Genia Bioenergy in Apr. 2024.

With a **favourable regulatory outlook in Europe**, biomethane is becoming an attractive solution both for decarbonisation and energy security. Players across the value chain are now looking to capitalise on the industry's long track record in Europe, which has resulted in the emergence of **several mature and well-established project developers across the continent.** Other developers, which until now have remained mostly small, decentralised and local, may now have the opportunity to build on their knowledge and grow their footprint, **leveraging access to new private money and blended finance to scale up their activities.**

Energy players secure strategic green supply, while investors foresee impactful financial returns from biomethane investments.

Two trends have emerged from a financing perspective:

- **The sector attracts large corporate energy players that have a natural strategic fit with biomethane producers** (O&G majors such as Shell, bp, TotalEnergies, or Varo, or large energy companies with gas assets such as Engie), bringing high competition on landmark deals and leaving a reduced pool of opportunities. **Large energy players have embraced the strategic importance of diversifying and decarbonising their energy offering, securing a source of green molecules for the future.**
- Financial investors are focused on **management and team capabilities**, **industrial scale-up potential and commercial / revenue strategy.** Yet the unclear value of carbon, biogenic CO2 and biofertiliser continue to challenge future cash flow projections.

A first way to enter the market is to invest on a long-term basis and capture value from organic growth.

Organic growth is intrinsically a long process due to the naturally distributed nature of the biomethane industry; entering this market is more complex when compared to other renewable energies like wind

or solar energy, where there is a clear "giga-scale" angle. This complexity to scale up is due to the fact that every project brings its own local specificities, including long-term feedstock supply, co-product management and sales. Furthermore, plant operations require skilled & trained workforce, proximity with organic sources and is exposed to evolution over time. **There is a need for in-depth knowledge on both the economics and operational issues of biomethane projects**.

A second approach is to acquire existing active companies or project portfolios on the market.

There are a **limited number of large-scale M&A opportunities remaining** in the market. Competition on well-established biomethane producers is strong, as illustrated by market valuations observed across key recent transactions. There are **some smaller or more exotic deals available, but these can face difficulties to meet buyers' criteria**, especially infrastructure investor requirements for long-term cash-flow predictability.

Many transactions have happened since the beginning of the Ukraine / Russia crisis, highlighting the **sustained appetite of financial investors** driven by the **fundamental infrastructure nature of the sector** and the **amounts of capital required.** According to the European Biogas Association, €18 billion has already been set aside for investment in biomethane production by 2030 in Europe.

Investors investigate multiple options to enter the sector.

In response to this situation, investors keen to enter the sector investigate multiple market entry angles**,** combining **sophisticated industrial approaches** and **re-assessment of risk vs reward profiles**:

- **New frontiers of investment**: acquiring EPC / Engineering companies to launch a biomethane production activity (e.g., launch of CycleØ by Ara Partners)
- **Building platforms incorporating a mix of new project development and brownfield opportunities, with a robust industrial management team** (e.g., Goldman Sachs Verdalia platform)
- **Putting together teams and assets** (e.g., launch of BioTic NRG funded by Palisade Real Assets and managed by its investee Eco2 Management Services)
- **Partnering with off-takers** (utilities or traders) **to mitigate future revenue risk profiles** (e.g., STX Group financing with Biovalue in the Netherlands)

Entering this market remains challenging for new players, but a deep knowledge in the industry can help building a wise strategy.

The biomethane market in Europe represents a complex value chain for usually small units that need to be aggregated**. Defining a comprehensive entry strategy aligned with investor risk appetite and motivations is key.** This needs to be **coupled with robust commercial and technical due diligence** to assess both the existing asset base (sustained revenues, feedstock availability, process optimisation strategies, …) and the ability of the management team to scale up the business in new territories (process industrialisation, feedstock strategy, offtake agreements, diversification of revenues with by-products, …). **The establishment of a pan-European regulatory framework will also help investors to get more comfortable with revenues streams and assess more confidently the sustainability of the business model.**

Brief 2

Market designs are switching away from "production-side" support toward "demand-driven" market mechanisms, which impact project financing, price setting, and trade flows.

This article is part of a series of biomethane briefs published by Blunomy on the biomethane market.

Biomethane markets are switching away from "production-side" support...

The European biogas and biomethane sectors have for a long time **been the sum of extremely diverse national situations with different regulations, practices, and dynamics**. Many national markets were largely (and sometimes still are) supported with **Feed-In Tariffs or Feed-In Premium schemes**. Providing long-term visibility on revenues and sometimes with partial indexation to key OPEX items, these mechanisms played a key role in **kickstarting many markets**.

...toward "demand-driven" market mechanisms.

As the industry matures and pressure on government budgets increases, more and more countries are **introducing market rules that look to directly drive consumer demand for biomethane**. This is performed by:

- **internalising the price of carbon**, increasing biomethane competitiveness vs. fossil fuels (e.g. carbon tax exemption, biomethane EU-ETS[5] eligibility)
- **introducing blending or emission reduction targets for energy consumers or retailers**.

Examples of such models include:

- the Biomethane Production Certificate or TIRUERT[6] schemes in France
- the THG[7] quota market in Germany
- the HBE[8] and the blending obligation for energy suppliers in the Netherlands.

In such 'unsubsidised' systems, the **green characteristics of the gas carries a premium,** while the molecule itself is valued at the natural gas price.

In parallel, these markets tend to be increasingly connected, as there is a growing possibility to perform cross-border exchanges of biomethane. Countries like Germany or Switzerland already exchange significant volumes through bilateral agreements or hubs like The European Renewable Gas Registry (ERGaR). This trend is expected to accelerate and spread across Europe as RED guidelines (promoting exchanges) are being transposed in national market designs. **Exchanges are being facilitated by the availability of EU-wide**

[5] The EU Emissions Trading System
[6] French incentive tax on the use of renewable energy in transport ('taxe incitative relative à l'utilisation d'énergie renouvelable dans le transport').
[7] THG ('Treibhausgasquote') is a legal climate protection instrument that has been used in Germany since 2015 to increase the share of renewable energies in the transport sector.
[8] HBE (Hernieuwbare Brandstof Eenheden), a Renewable Fuel Unit, is a certificate representing 1 GJ of clean energy supplied to transport.

certification schemes that allow the recognition of sustainably-produced biomethane as an advanced biofuel. The integration of biomethane in the Union Database[9] by the end of 2024 will also ease biomethane trading through enhanced traceability and greater standardisation.

Biomethane pricing is exposed to greater volatility and stronger competition with other renewable alternatives.

These systems represent a significant shift for biomethane producers. **Prices can be subject to strong volatility and are driven by complex factors such as competition with other fuels, a fuel's carbon intensity, or parameters linked to specific mechanisms** (blending obligation levels, penalty level, etc.). The value of biomethane can vary across different markets, driven by local market logic.

Switching from a "supply-based" to a "demand-based" support mechanism causes biomethane to **enter into competition with the established biofuel industry, and other alternatives such as hydrogen or electricity**. For instance, Hydrotreated Vegetable Oil **and bioLNG[10]** compete head-to-head as a fuel choice for new trucks that road transportation companies plan to purchase. This dynamic can also drive strategic choices for actors across different markets – one example is VERBIO in Germany, a traditional biofuel producer now becoming a leading biomethane producer.

A good illustration of increased price volatility is the extreme fluctuation observed in the German THG market since 2022. Considered as the European "*El Dorado*" for sustainably produced biomethane with prices peaking above 350€/MWh, values have since dropped significantly as a result of many exogeneous factors (strong foreign biomethane imports, massive imports of low-price biofuels) resulting in a negative impact on the local biogas industry.

This evolving situation brings both risks and opportunities for players.

The nature of biomethane production, coupled with the profound transformations currently shaping the industry, has led to increased complexity for players to navigate. The coexistence of several end markets that value biomethane differently pushes players to sharpen their monetisation strategy by targeting the most attractive segments and optimising their approach (e.g. contract duration, indexation).

The increased possibility to export biomethane allows players to produce biomethane in regions with lower competition on feedstock and land, as well as lower production costs, and ultimately export the production to more attractive demand markets (e.g. recent uptake of the Spanish and Polish markets). Exporting biomethane, however, requires specific skills (e.g. gas shipping) and precise market knowledge to optimise the offtake strategy. The interconnection of heterogeneous national markets and the lack of clarity around future developments lead to opacity and complexity in the short term. Moreover, whilst biomethane exchanges between EU member states are likely to increase, major uncertainty remains around the possibility to trade volumes with external countries, creating challenges for markets like the UK or Ukraine.

Looking to capitalise on this market complexity, many **trading companies have positioned themselves as intermediaries** across the European biomethane market, offering biomethane offtake and sourcing options at both ends of the value chain. Some of these trading companies, sometimes coming from the fossil commodity trading space, are investing directly in production assets to secure access to the molecules in a market where demand is expected to exceed supply.

[9] Union Database for Biofuels (UDB) is based on Clean energy for all Europeans package & Article 28 (2) and (4) of the Renewable Energy Directive (RED II) to Improve the traceability of gaseous and liquid fuels in Transport Sector with the objective to avoid double counting and mitigating the risks for irregularities/ fraud.

[10] Bio Liquefied Natural Gas

Biomethane price projections are a missing yet critical tool to support the industry in reaching its objectives.

In this rapidly-evolving market, players across the value chain need to decrypt future biomethane market conditions and understand the evolution of prices and volumes to strengthen investment decisions and business strategies.

- **Market projections are a standard product on other commoditised energy markets** (fossil fuels, electricity, CO_2, etc.). For biomethane, players now have a clear need to understand how the situation will evolve across different end markets, types of biomethane, etc.
- **In a complex energy transition landscape, it is critical that investors, regulators, producers, and consumers build confidence in the long-term value of biomethane**, in order to engage in ambitious long-term development plans.
- In parallel, **players require detailed projections for a wide range of use cases**:
    1. Support for **transactions, financial modelling, and company valuation**.
    2. Optimisation of **offtake and supply strategies (contract length, pricing, etc.)**
    3. Understanding **how supply and demand sectors compare and where stronger volumes and willingness-to-pay might lie**.

Blunomy is working globally with actors across the value chain to decrypt the risks and opportunities arising from the transformation of local and international market practices. In particular, Blunomy is developing a quantitative market model deriving granular insights on prices and flows, in partnership with Compass Lexecon.

- For **investment funds and banks** to support investment decisions and asset management for biogas assets
- For **energy companies and project developers** to develop their biogas offtake and marketing strategies across countries
- For **T&DSOs and regulators**, to support their long-term biogas planning (infrastructure, legislation…)
- For **large industrial players** to define their biogas feedstock sourcing strategy and assess the potential for biogas value chain integration.

Compass Lexecon & Blunomy are developing a quantitative model that:

- Provides cutting-edge understanding of the various drivers of the biomethane market and their expected evolution.
- Provides and analyses scenarios for biomethane prices and flows across related markets.
- Is based on biomethane offer-demand optimisation across European countries.

Brief 3

Competition on "sustainable" feedstock increases the urgency to secure supply

This article is part of a series of biomethane briefs published by Blunomy on the biomethane market.

The growing interest in bioresources has highlighted the importance of ensuring their availability and sustainability for the future.

The global acceleration of the energy and environmental transitions has triggered significant interest in sourcing bioresources, which are inherently limited, but are now targeted by various industries (agrifood, biofuels, biomethane, composting, animal feed, materials, etc.). Bio-based feedstocks include an extremely wide range of products with specific characteristics and market conditions, for which different monetisation pathways can be contemplated. In response to this transformation, governing bodies across the world are introducing rules aimed at ensuring the mobilisation of bioresources remains virtuous.

These regulations aim to ensure that a proper hierarchy of uses is respected for different types of resources. It is crucial to prioritise food and feed uses over other pathways, such as biosourced materials or bioenergy production, while still supporting the rapid growth of these industries.

RED is shaping feedstock eligibility and sustainability in the EU.

Biomethane production must rely on sustainable feedstock sources to be considered as an actual 'renewable gas'. As an example, the European Union has clarified in the Renewable Energy Directive (RED) the status of bioenergy feedstock and defines the products that are eligible for both conventional[11] and advanced biofuel production.

Indeed, RED II and RED III set mandatory sustainability criteria for biofuel (including biomethane) production to be considered sustainable, allowing it to be counted toward EU targets and to benefit from public support and subsidies. Not only should biofuels demonstrate specific GHG savings, but specific sourcing criteria discard some feedstock options. As an example, food and feed crops are non-RED eligible if considered as responsible for high Indirect Land Use Change (at this stage this mostly concerns palm oil); agricultural feedstock cannot come from land with high biodiversity value or with high carbon stocks, forest biomass must come from an area that ensures legality of harvesting operations & forest regeneration, etc. These constraints are absolutely necessary to ensure a balanced development of bioenergy industries. They do, however, contribute to reducing the available amount of feedstock, thereby increasing competition among players to access what is left.

Biomethane producers need to adapt to market pressures by developing strategic partnerships and in-house sourcing capabilities amid rising feedstock prices and demand.

[11] Conventional - also called 1st generation - biofuels are derived from crops that can also be used for food & feed like sugar, starch or vegetable oil, while advanced - also called 2nd & 3rd generation - biofuels do not compete directly with food & feed and are derived from agricultural waste & residues as well as non-food crops or are produced via less mature production pathways like algae) (source: EU parliament).

Feedstock markets are complex and most of the time very local. Some resources are purchased while others are subject to gate fees (usually waste-based feedstock). Related values can vary significantly from one region to another, depending on local market conditions, and particularly the supply/demand balance.

Historically, the interest of a specific feedstock source for a biomethane producer was based on its economic value (level of cost or gate fee), the distance and volume (and thus logistic costs), the methanogenic potential and its core characteristics (hence the possibility to use it efficiently in the plant). Another key factor for producers to consider is the transposition of RED rules into biofuel market regulations. This can indeed result in differentiated values for fuels based on their status (conventional or advanced biofuels) and their carbon intensity, which is largely determined by the feedstock mix used. Already in place in several markets such as the THG in Germany or HBE in the Netherlands, this differentiation has led to large price spreads and sometimes very high prices for unsubsidised biomethane produced with the best-performing feedstocks.

As a result of these evolutions and the growing competition, some regions have seen an increase in the price of feedstock, and even a correlation between biomethane and feedstock prices in markets relying largely on spot feedstock purchases (where waste traders are active). As setting long-term supply contracts is rarely possible for biomethane producers, it is important for players to identify ways to reduce their risk and adapt to changing conditions. Possibilities include:

- Establishing strategic partnerships with feedstock producers by finding win-win agreements that do not only rely on feedstock purchase and sale.
- Considering vertical integration of the value chain (upstream).
- Developing in-house sourcing capabilities to optimise feedstock mix across a portfolio of plants.
- Entering new markets with untapped potential and opportunity to exploit stronger negotiating leverage with feedstock providers.
- Identifying technological solutions allowing the use of new, complex feedstocks.

Concrete examples include:

- CVE acquiring Ecovalim (specialist in biowaste and used cooking oil collection) in March 2022 and Restovalor (food waste collector) in May 2023, making it the first biomethane producer fully integrated across the biomethane value chain in France.
- TotalEnergies acquiring a 20% stake in Ductor in May 2024. The startup has developed an innovative technology to process high-nitrogen organic waste, such as poultry manure, which is typically challenging to use for biomethane production.
- Major industry players entering new geographies such as the Spanish and Polish markets. The recent boom of the biomethane industry in these countries is largely driven by the interest of established biomethane players from more competitive regions seeking to tap into their vast, underutilised potential.

In such highly competitive markets, granular feedstock mapping can help to prioritise and optimise development strategies.

To prove successful, it is essential for biomethane producers entering a new geography to validate the opportunity of producing local biomethane and optimise their mix by:

- Understanding current and future feedstock market conditions (**volumes**, **prices**, **competition**, …) to prioritise geographical areas as well as the right partners to engage and anticipate risks.
- Decrypting local project development specificities and hurdles to quickly launch first projects.

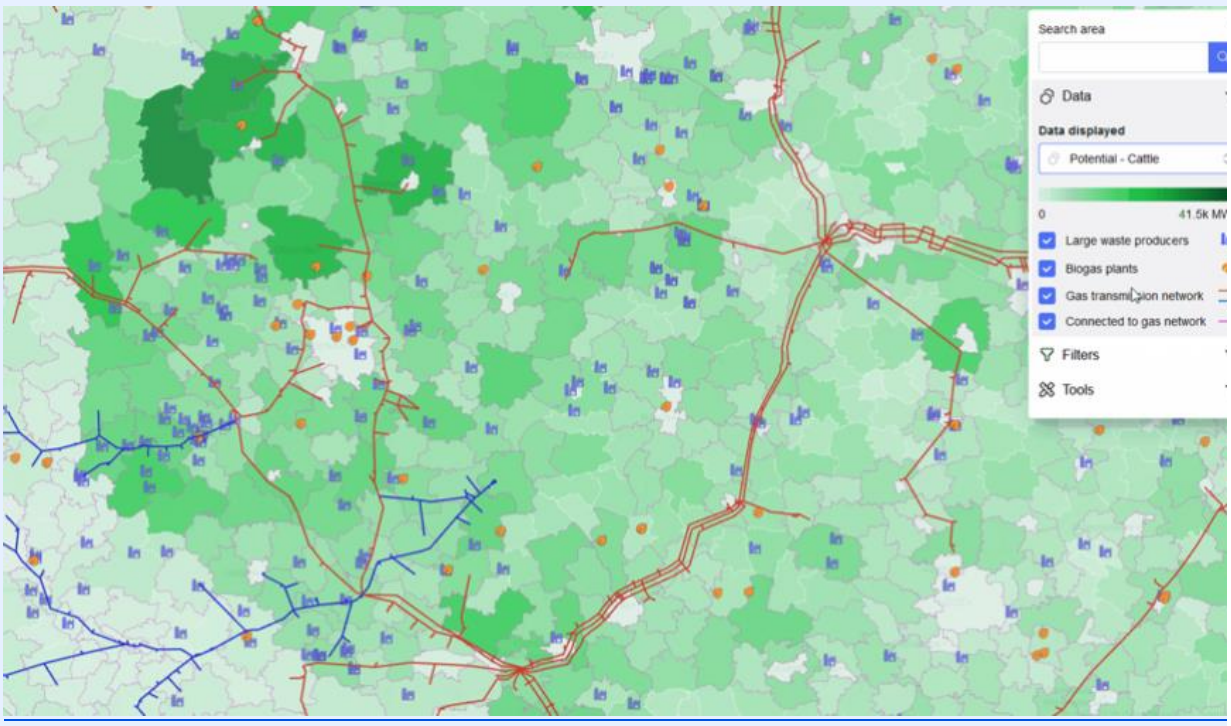
Blunomy couples strong biomethane market knowledge with data analytics & digital tool development capabilities to provide tailored solutions to industry players.

Blunomy has developed a feedstock mapping tool that was successfully rolled out in several geographies to support the market expansion of biomethane producers.

- For **energy players and biogas project developers** to:
  - Build their biogas growth strategy (market entry, infrastructure development) and drive their business development effort.
  - Assess biogas feedstock potential and construct their sourcing strategy (identify partnerships or M&A targets).
- For **C&I players including food and beverage**:
  - Assess local interest for developing circular models around the valorisation of their by-product / waste or those of their partners (i.e. farms).
- For **T&DSOs** to support infrastructure development strategy.

- Gathers data to visualise critical components of the biogas value chain (feedstock, existing plants, producers, potential offtakers, grid…), driving market intelligence.
- Displays strategic results in an operational way for business developers, enabling different layers of analysis to drive strategic decision-making (proximity to gas network, distance from competitors, etc.).

Snapshot of the feedstock mapping tool developed by Blunomy:



Brief 4

An improved valorisation of by-products and 'positive externalities' of biomethane will generate extra-benefits for the whole value chain.

This article is part of a series of biomethane briefs published by Blunomy on the biomethane market.

Despite being at the crossroads of multiple sectors, anaerobic digestion was for too long seen solely through the prism of energy production.

The production of renewable and low-carbon CH_4 molecules, which can be stored and directly substituted for natural gas, has primarily been the key motivation for governments and stakeholders to develop biomethane. The decarbonisation potential of this energy source is widely acknowledged and now fully recognised in regulations and market designs. In some specific cases, national contexts have driven governments to support the development of biogas solutions for other purposes, but such examples remain limited. For instance, India promotes biogas solutions (including at the domestic scale) to offer waste management solutions and produce organic fertiliser, in addition to producing energy.

Anaerobic digestion inherently lies at the intersection of multiple sectors—agriculture, waste management, and energy—thus encompassing various transitions: environmental, social, and energy. It provides a diverse array of critical services that have frequently been overlooked. The growing urgency to accelerate the global transition has, however, recently highlighted the crucial role biomethane can play, extending beyond energy production.

Biomethane by-products will be increasingly valorised as a significant market for bioCO_2 emerges and the competitiveness and standardisation of biofertilisers strengthen.

The agronomic value of digestate and the quality of the biogenic CO_2 obtained from biogas purification have been acknowledged for a very long time and demonstrated by both scientific studies and concrete experiences. However, for many reasons and despite some success stories and specific counterexamples, the full value of these by-products has never been realised until now. Evolving market conditions and practices are progressively paving the way for better valuation of these by-products.

Biogenic CO_2 (bioCO_2) can be easily recovered from the off gas released during the purification of biogas to biomethane. This biogenic CO_2 (mostly vented today) can be captured at a relatively low cost and is of good quality. This CO_2 can then be used or commercialised as an alternative to CO_2 provided by industrial gas suppliers such as Air Liquide, Linde, or Air Products[12]. A key complexity of the CO_2 market is its local nature, with the production of "traditional" CO_2 being centralised and demand scattered across countries, resulting in strong price variations depending on logistic costs. Current CO_2 demand is relatively limited and relies on greenhouses, agrifood industries (beverage carbonation), and specific industrial or chemical processes. The

[12] Industrial gas companies do provide both biogenic (by product of bioethanol production, biomethane off gas) and fossil-based CO_2 (by product of ammonia production, hydrogen production).

emergence of distributed bioCO_2 sources represents a new variable in this market, and some viable local business cases have already been deployed.

In the future, both the supply and demand for CO_2 will change drastically with the rollout of carbon capture solutions on both fossil and bio-sources of CO_2, and the emergence of new demand. In the medium-to-long term, most demand may come from the production of synthetic fuels. Indeed, the production of so-called "e-fuels" requires significant amounts of electricity and CO_2, which will need to be of biogenic origin starting from 2041 according to the EU mandate. Biogenic sources of CO_2 are limited in volume, and potential demand could be very high, making it a critical resource to control. As a good illustration, environmental commodity trader STX has concluded an innovative partnership with biomethane producer Perpetual Next to support the commercialisation of the carbon dioxide across relevant markets.

In parallel, other factors might reinforce the competitiveness of bioCO_2 derived from biomethane production. The recent energy crisis has led to local shortages of "traditional" CO_2, which is a by-product of ammonia and H2 production when these industries were affected by booming natural gas prices. Additionally, the biomethane sector has the unique opportunity to act as a carbon sink while producing energy. Indeed, storing or using biogenic CO_2 derived from methanisation for long-term uses enables the system to be emission-negative (e.g., the mineralisation of concrete aggregates destined for new concrete), opening the door to new business models via the voluntary carbon market.

Digestate is the residue of anaerobic digestion, after labile organic matter is transformed into biogas. Studies and practical experience have demonstrated that digestate has valuable fertilising and soil amending properties. Anaerobic digestion conserves the nutrients contained in the feedstock but favours the transformation of organic nitrogen into mineral nitrogen, a form that is more easily assimilated by plants and closer to industrial fertilisers.

Until now, the commercialisation of digestate has been rather limited due to a combination of several factors. Adoption of digestate by farmers implies significant changes in practices, which are always complex to implement. In addition, the great variety of digestate compositions and the lack of standards defining quality and content do not favour its recognition as a genuine fertilising product. Finally, digestate spreading is often subject to tacit agreements between biomethane producers and farmers providing feedstock, as securing outlets for digestate can in some cases be a key challenge in biogas project development.

However, the demand for bio-based fertilisers is expected to grow in response to the increasing demand for low carbon and organic products. In parallel, the competitiveness of digestate-based fertilisers is likely to increase as the costs of fossil-based fertilisers are affected by natural gas prices and potential CO_2 taxes. The introduction of certification schemes allowing a better and more transparent view of biofertilisers' quality will facilitate their commercialisation. Additionally, several technologies are already being used to turn raw digestate into more valuable products (phase separation, ammonia stripping, etc.) and other innovations are currently being investigated to produce high-quality fertilisers or facilitate digestate management.

Biomethane production provides numerous social and environmental benefits that are increasingly being acknowledged.

At the intersection of multiple sectors, anaerobic digestion generates numerous impacts, which are largely positive provided that good operational quality is ensured. The diagram at the end of the brief presents a panorama of these services. The value of these services has been investigated and demonstrated by Blunomy in 2018 and by the European Biogas Association in 2023.

Key impacts include the resilience brought to agricultural systems and stakeholders, the creation of local and non-relocatable jobs, the development of intermediary cropping systems (which provide agronomic and environmental benefits), the provision of waste management services, and the potential to address water quality issues.

Scientific studies[13] have confirmed the tangible nature of these impacts but have also highlighted that their magnitude highly depends on the context of each project and on operating practices. Just like any other industrial sector, anaerobic digestion can be the source of negative impacts if certain safeguards are not met.

Stakeholders throughout the value chain are trying to harness the full potential of biomethane externalities.

With the exception of waste management services, which already translate into economic compensations (through gate fees), other externalities are complex to monetise. The numerous beneficiaries and the need to quantify impact precisely are the first limitations to turning these impacts into economic benefits. However, more and more stakeholders are understanding that both financial and extra-financial value can be generated by adopting a more tailored approach towards externalities valorisation. Several investment funds, agrifood players, biomethane producers, and governments have rolled out ambitious strategies in this perspective.

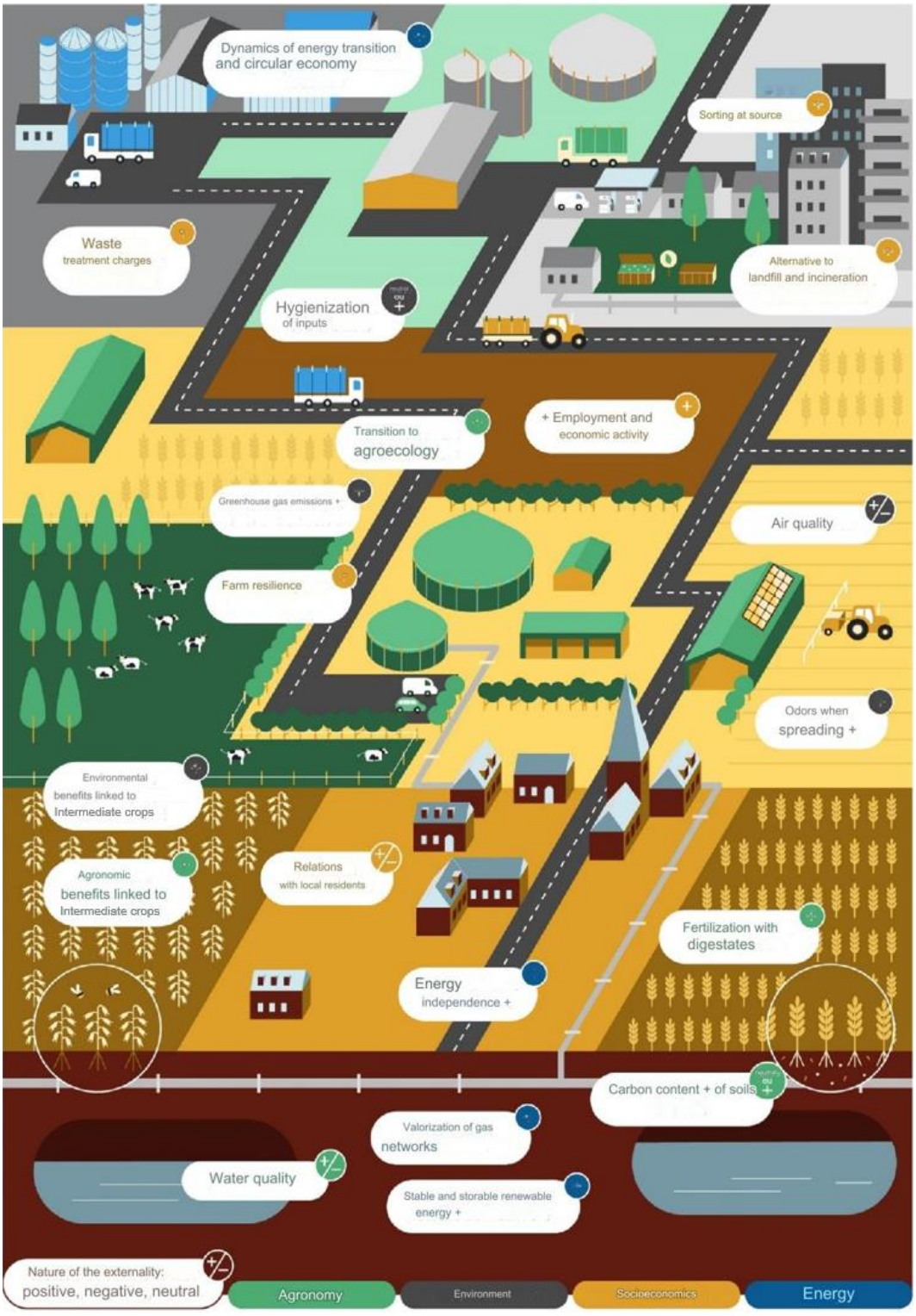
Blunomy has been a pioneer in decrypting, quantifying, and valorising the externalities of biomethane production. It has supported public bodies (e.g., publication for OFEN in Switzerland) and associations (e.g., publication for France Gaz Renouvelables) in advocating for better recognition of externalities by governments, and now supports all types of stakeholders in seizing the opportunities linked to these externalities.

Blunomy, as a strategic advisor and operating partner, is at the forefront and biomethane positive externalities' assessment and valorisation. We support all players in identifying and seizing most relevant opportunities for their business.

- For **investment funds & banks:**
  - To assess & monetise biogas & biomethane assets externalities
  - To link externalities and investment thesis objectives
- For **energy companies & project developers**:
  - To identify sales channels for biomethane by-products
  - To design business models generating value for all stakeholders
  - To monitor and communicate around positive impacts
- For **agrifood players:**
  - To design biomethane roadmaps maximising benefits for their business and stakeholders (e.g.: create value for suppliers, decarbonise scope 3)

- Mapping & characterisation of externalities
- Quantification of externalities
- Definition of impact monitoring schemes and impact valorisation strategies
- Go-to-market strategies for biomethane by-products

[13] Example : MethaLAE programm



Mapping of externalities linked to biomethane production

Source: [France Gaz Renouvelables]

Brief 5

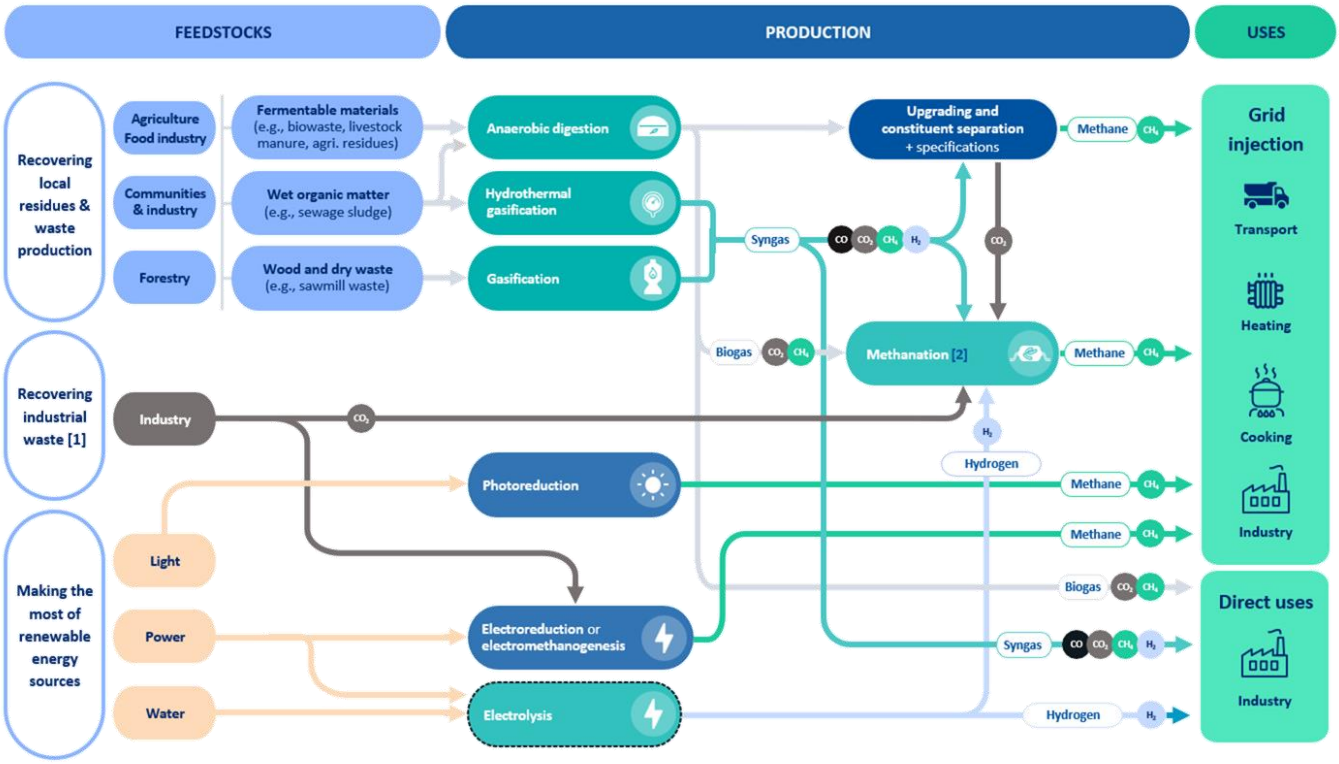
Emerging alternative processes could significantly boost green gas production to meet a significant part of our gas demand

This article is part of a series of biomethane briefs published by Blunomy on the biomethane market.

Renewable methane has surged thanks to anaerobic digestion, but other pathways will contribute boosting green gas production.

Over the past decade, the rapid growth in renewable methane production has primarily been driven by the deployment of thousands of anaerobic digesters around the world. However, current biomethane production is just the tip of the green gas production iceberg. There is still significant potential to increase biomethane production and the development of alternative processes, at the heart of current technological innovation in the sector, could give a further boost to green gas production over the coming years. Relying on a wide range of feedstock types, these production pathways have the potential to meet a significant part of future gas demand. Despite this potential, it is crucial that the rapid development of green gas production technologies does not act as a buffer to slow down the phase-out of fossil fuels, but is rolled out in parallel with sobriety and energy efficiency measures.

Renewable methane production pathways represent a complex ecosystem where some feedstocks can be used in different pathways, many co-products are produced and can be the subject of synergies between technologies, and outputs can be leveraged to decarbonise a wide array of uses:



Source: GRDF and Blunomy – Technology report on green gas production pathways

blunomy

Anaerobic digestion is mature and is the focus of continuous improvement efforts to increase global efficiency and the ability to use even more types of feedstock.

Already a mature technology, anaerobic digestion is subject to continuous R&D efforts which aim to increase performance: increase process yields, optimise energy consumption, improve recovery of co-products, etc. The key challenge is to efficiently capture more market potential, which implies reducing costs for small units and allowing the use of a broader range of feedstocks.

Exploiting the full potential of biomethane will require the cost-efficient deployment of smaller units in areas where feedstock is limited, and that are sometimes located far from the gas grid. Biogas upgrading technologies (required to eliminate CO_2 and obtain biomethane that complies with grid standards) and technologies for injecting biomethane into the grid can represent a hurdle in establishing small-scale plants due to high CAPEX. Solutions could lie in the development of less CAPEX-intensive technologies (e.g., low-cost micro-scrubbers), as well as business model innovations that allow injection costs ("carried biomethane") or even both upgrading and injection costs to be shared ("carried biogas") between several plants. Examples include French company Sublime Energy, which offers centralised purification services, and Ireland, which has developed a central injection facility with a capacity of 700 GWh.

Another challenge consists in identifying ways to allow the efficient anaerobic digestion of new feedstock. Strong R&D efforts are for example being deployed to better monetise dry or fibrous matter (like straw or crop residues). Potential solutions include the development of specific digestion processes (dry route), or rolling out different pre-treatment systems (physical, thermochemical, biological, etc.).

Promising alternative production pathways are seeing an acceleration in their scale-up and R&D efforts.

The main technological challenge over the next few years is not only to improve anaerobic digestion but to scale up the production of renewable methane by developing alternative and complementary pathways. These technologies will contribute unlocking the full energy potential of feedstocks that are currently not recovered or are not suitable/optimal for digestion – such as woody biomass, non-renewable waste, and sludge. Several technologies are being developed, currently at different stages of maturity. Three of them have already reached the industrial or demonstration stage:

Gasification, now in the process of industrialisation, primarily aims to mobilise dry and woody organic materials. The industry can rely on mature technologies that have been tested for several decades, historically oriented towards cogeneration applications but now adapted to the production of synthetic methane from more complex waste feedstocks. With a handful of demonstrators and some reference projects already operational in Europe, the industrialisation of gasification is gathering pace.

Hydrothermal gasification is a promising thermochemical technology, with noteworthy R&D momentum in recent years given its ability to address wet and polluted waste that is difficult to recycle (e.g.: sewage sludge, industrial residues, dredging sludge, digestate which cannot be spread). Several pilots and demonstrators are being set up in Europe, mainly in the Netherlands and Switzerland, to address the main technical challenges necessary for wider industrial deployment.

Power-to-methane produces synthetic methane from green hydrogen and CO_2, enabling the coupling of power and gas systems for higher flexibility. R&D efforts are focused on scaling up (already a handful of commercial projects) and optimising innovative methanation processes to adapt to intermittent renewable electricity sources.

Alongside these technologies, other emerging processes are being developed. Still at an earlier level of maturity, these processes enable the production of synthetic methane by recovering CO_2 and leveraging either electricity (electromethanogenesis, CO_2 electroreduction) or the sun (CO_2 photoreduction, photobioreaction).

Understanding the transformations underway is crucial in order for players to deploy the right strategic responses.

Most of the aforementioned processes are expected to reach industrial maturity in the next decade. Currently, they are primarily developed by laboratories, R&D centres, a few specialised companies, and some large energy companies that align strategically with renewable methane production. The biomethane sector, which has seen the entry of numerous players over the last years, will also have access to opportunities in these technologies as they mature. Understanding the evolving technological landscape is essential for stakeholders to seize the right opportunities and determine the right timing to position. As these technologies develop, they will offer synergies for actors across the value chain: investors, industries, equipment suppliers, engineering companies, gas system operators and renewable energy project developers. Examples of players having made first moves on new green gas pathways include:

- Sugar and ethanol producer Cristal Union investing in Gazotech (2024), a gasification specialist, in order to decarbonise the activity of its agricultural partners
- Biogas pure player Nature Energy (Denmark) diversifying into power-to-methane, with a first project in operation since late 2023
- Engie (energy player), CMA CGM (shipping), Holdigaz (gas utility), Sipchem (chemical industry) participating in the 9M€ funding round of hydrothermal gasification company TreaTech.

Blunomy has 15+ years of experience in supporting players in the renewable gas space, designing innovation and R&D roadmaps, road-to-market strategies for new technologies, or conducting scouting exercises for investment opportunities. Blunomy recently supported French gas DSO GRDF in producing a state of the art study on green gas technologies, published in early 2024. The report examines eight renewable gas production technologies, providing a technical analysis of their current maturity, key projects and players, and identifying opportunities and barriers for future development.

Combining a blend of technical and strategic expertise, Blunomy supports players across the biomethane value chain in identifying and unlocking new opportunities.

- For **investment funds & banks:** identify and qualify new investment opportunities, and support transaction processes
- **For energy companies, project developers, equipment manufacturers, T&DSOs:** understand the green gas landscape, develop and deploy new strategies to access market opportunities

- Conducting technical, regulatory and market analysis
- Structuring R&D and innovation roadmaps
- Supporting go-to-market of new technologies
- Identifying and leveraging synergies with core business
- Supporting fundraising process or assessing acquisition opportunities

Brief 6

Climate change will affect the future quantity and regional distribution of biomethane feedstock.

This article is part of a series of biomethane briefs published by Blunomy on the biomethane market.

Understanding climate change impacts on feedstock sourcing is key for sustainable biomethane production.

The impact of climate change on agricultural activities, including both livestock and cropping, is evident and will only accelerate in the coming years. Both acute and chronic climate risks will directly affect our agricultural systems, and consequently, the biomethane industry. According to the FAO, over the last 30 years, an estimated USD 3.8 trillion worth of crops and livestock production has been lost due to extreme events, corresponding to an average of USD 123 billion per year.

While players typically develop projects for at least 15-20 years, it is critical for biomethane producers to understand the future impact of climate change on their activities. Rarely evoked today, this question however appears as extremely important. Tackling it requires:

1. Identifying the impact of climate risks on production assets and on feedstocks
2. Understanding how these climate consequences ultimately translate on biomethane plants' operations and business plan
3. Developing adequate adaptation measures, considering local context

As climate change impacts are different depending on location, this analysis should ideally be rolled-out at the regional or plant level.

Ensuring climate risk analysis for biomethane plants and long-term feedstock availability is crucial given the challenges posed by climate change.

Biomethane plants face various types of climate risks associated with extreme weather events that can impact their operation. Like other industrial sites, biomethane plants can be directly affected by **frost, heatwaves, floods, forest fires, and storms**. The consequences of such events could be significant, requiring the adoption of appropriate adaptation measures.

However, what sets biomethane production apart is its intrinsic dependence on feedstock, which generally represents a substantial portion of production costs. Climate change can profoundly impact the long-term availability of feedstock, necessitating a deeper understanding of future developments and appropriate strategic planning.

Manure and slurry, for example, are dependent on the condition of livestock, which is influenced by climate change in two main ways. Firstly, the welfare of animals can be directly affected by changing climate conditions, such as extreme heat. According to the IPCC's sixth Assessment Report, at just 2°C of warming, livestock numbers will decrease by 7% to 10% by 2050, resulting in USD 10 to 13 billion in economic losses. Secondly, the availability of sufficient feed for livestock is crucial. Climate change can alter agricultural conditions to the extent that some regions may no longer be able to produce enough feed, potentially ceasing to be viable

agricultural zones. Droughts and other severe climate events may force farmers to abandon these areas, thereby reducing the availability of livestock and, consequently, manure and slurry.

Intermediate crops, another source of feedstock, are also subject to the influences of climate change. It is essential to conduct comprehensive analyses of climate and water risks to determine which regions are best suited for intermediate cropping. This includes assessing how changing climate patterns might affect water availability and crop yields. By understanding these dynamics, it becomes possible to adapt cropping strategies to maintain and potentially enhance feedstock yields in the face of climate change.

The climate risks associated with these crops could also lead to localised tensions with other uses, particularly forage crops. A **report** by **France Gaz Renouvelables** examines this issue and offers several recommendations to anticipate and mitigate potential conflicts. These include properly sizing installations based on available biomass, securing long-term supply, and implementing good agricultural and water consumption practices for intermediate cropping.

The consequences of both acute and chronic climate risks can lead to intermittent supply disruptions and increasing long-term tensions and competition. Ultimately, these situations can directly impact the operation of biomethane plants by driving up prices (due to higher competition), forcing players to source resources from further away (resulting in higher transportation costs), or even causing a temporary decrease in production if alternative sources cannot be efficiently identified.

To ensure the long-term viability of biomethane production, adaptation measures must address climate risks and supply stability.

To address climate risks for biogas units effectively, several adaptation levers can be considered depending on expected impacts:

- Diversifying the feedstock mix and incorporating a variety of inputs that can mitigate the impact of any single resource being affected by climate events, and potentially divert from most exposed resources.
- Working with partners to shift to more resilient or drought-resistant crops, which can reduce dependency on vulnerable feedstock sources (species to be identified based on local context).
- Identifying contractual levers aimed at mitigating price and volume risks.
- Collaborating with local partners and stakeholders to anticipate potential tensions and align on resource management strategies.
- Optimising logistics and storage solutions to minimise the impact of transportation costs and availability issues.

These measures collectively enhance the resilience of biogas production systems, ensuring they can better withstand and adapt to the challenges posed by changing climate conditions, but should be designed on a case-by-case basis.

This issue directly affects stakeholders with long-term investments in the sector, including producers, investors, governments, and feedstock providers. All these parties should work on securing a stable supply of feedstock, safeguarding the long-term viability of biomethane production.

Blunomy develops climate risks assessment and adaptation strategies on biomass activities and has supported many players from the agricultural and industrial sectors.

- For **investment funds & banks**:
  - to assess climate-risk exposure
  - to support investment decisions or asset management strategies
- For **energy companies & project developers**:
  - to characterise risks on feedstock supply and costs
  - to deploy appropriate adaptation measures to face climate risks based on local context
- For **governments and industry associations:**
  - to anticipate global risks and promote appropriate regulation and practices

Blunomy developed a methodology to anticipate feedstock exposure to climate related risks:

- Climate change & water scarcity risks modelling for various type of feedstock (manure, intermediate crops, …) using agronomic data and climate models (e.g., IPCC science-based climate scenarios).
- Exposure quantification & evaluation including impact on the facilities using this feedstock, often combined with local trends analysis (regulatory, socioeconomics, sustainable agriculture principles…).
- Adaptation levers assessment and prioritisation leading to an adaptation roadmap.
- Roadmap design and implementation to mitigate the impacts from climate change on key players' activities.

Conclusion

What are the priorities for key stakeholders?

The renewable gas market is undergoing profound transformations, suggesting an optimistic outlook, despite increased short-term complexity for stakeholders.

The energy, geopolitical, and climate crises that shook Europe in the early 2020s have cemented the pivotal role of biomethane in contributing to global energy and environmental transitions. This heightened recognition has translated into ambitious production targets and significant market dynamism across many regions, which are now driving a strong increase in installed capacities.

This acceleration comes with fundamental transformations, many of which are paving the way for a biomethane market that generates more value and impact:

- Market designs are becoming more homogenous, now primarily relying on concrete demand, supported by carbon-pricing and blending obligations.
- Strong decarbonisation targets are being introduced across various end-use segments (road and marine transportation, industry, gas supply, etc.), likely leading to a sustained supply/demand balance favourable to producers.
- The externalities of biomethane are increasingly recognised, prompting many players to adjust their business models to maximise impact and economic benefit.
- The value of by-products is expected to continue rising, reinforcing the economics of biomethane production and generating more impact.
- New renewable gas production pathways are being developed, contributing to the accelerated decarbonisation of gas systems.

One key challenge lies in feedstock sourcing. While there remains significant untapped potential, competition for certain feedstock categories is expected to increase. This competition can arise between biomethane plants and other uses (e.g., bioenergy, bio-based products) and will be structurally influenced by the growing effects of climate change.

All these trends manifest differently and at varying times depending on the location, making it complex for stakeholders to fully understand and navigate.

These structural trends are generating both risks and opportunities throughout value chain segments.

These structural trends generate both risks and opportunities across value chain segments. This situation presents numerous questions, risks, and opportunities for all stakeholders. In a dynamic and rapidly evolving environment, a significant competitive advantage for market players lies in their ability to decipher ongoing changes and their implications.

Building on the briefs' analysis, here are some key priorities players should consider:

Biomethane producers	• Engage in strategic geographical expansion to target new promising markets with lower competition. • Diversify and sustain activities by exploring alternative renewable gas production pathways, creating value from new co-product opportunities, and seeking value chain integration possibilities. • Anticipate market design changes to develop a robust energy commercialisation strategy. • Identify and form relevant partnerships (e.g., with agrifood companies and other developers) to support development ambitions. • Manage uncertainty over feedstock supply in the short to long term by adopting appropriate measures (partnerships, value chain integration, mix design, climate risk analysis, adaptation measures). • Assess the impact of climate change on the value chain to implement suitable mitigation measures.
Investors	• Investigate alternative market entry and growth strategies to establish or consolidate positions in this competitive sector. • Monitor developments in new renewable gas technologies to time investments appropriately.
Agrifood players	• Define a renewable gas positioning that enables the development of business models and leverages access to feedstock for biomethane production. • Identify and form relevant partnerships and collaborations, leveraging bargaining power associated with feedstock access.
Large gas consumers	• Evaluate the long-term role of biomethane as a decarbonisation tool. • Develop an appropriate sourcing strategy based on local options. • Understand short- to long-term volume and price risks to enter into suitable contractual agreements (volumes, indexation, duration).
Waste and water players	• Maximise value creation from existing biomethane production or captive potential (e.g., sewage, landfills). • Leverage synergies with core business activities to position in competition-exposed biomethane sectors (e.g., municipal or industrial biowaste, agricultural feedstock). • Monitor developments in new renewable gas production pathways that align closely with the waste and water sectors.
Equipment suppliers and O&M companies	• Identify and prioritise new growth drivers (new geographies, developing technologies) and adapt service offering accordingly.

The multifaceted nature of renewable gas invites players to identify the most relevant synergies at their own level to craft an optimised positioning strategy.

Renewable gas production can take many forms and address a wide range of challenges. To maximise value creation and develop differentiated positions, market participants should analyse how their activities intersect with renewable gas production and identify opportunities to leverage. Key considerations include:

- What are the organisation's objectives, and how do they rank in terms of priority?
- Does the organisation have direct (waste generated within its operations) or indirect (network of partners or suppliers) access to feedstock resources or gas consumers?
- What are the organisation's decarbonisation challenges, and is biomethane relevant for addressing scope 1, 2, and 3 emissions?
- Are there skills, geographical footprints, or privileged access to land that could be leveraged?
- Could biogenic CO_2 or biofertilisers be valorised within the organisation's value chain?

Such an analysis will help determine the role renewable gas can play for a given organisation and the appropriate positioning strategy. Ultimately, detailing the preferred model to achieve this positioning is crucial. Based on the intrinsic characteristics of a given organisation, as well as its objectives and risk/benefit appetite, different options can be considered: level of value chain integration, co-development models, third-party financing, etc.