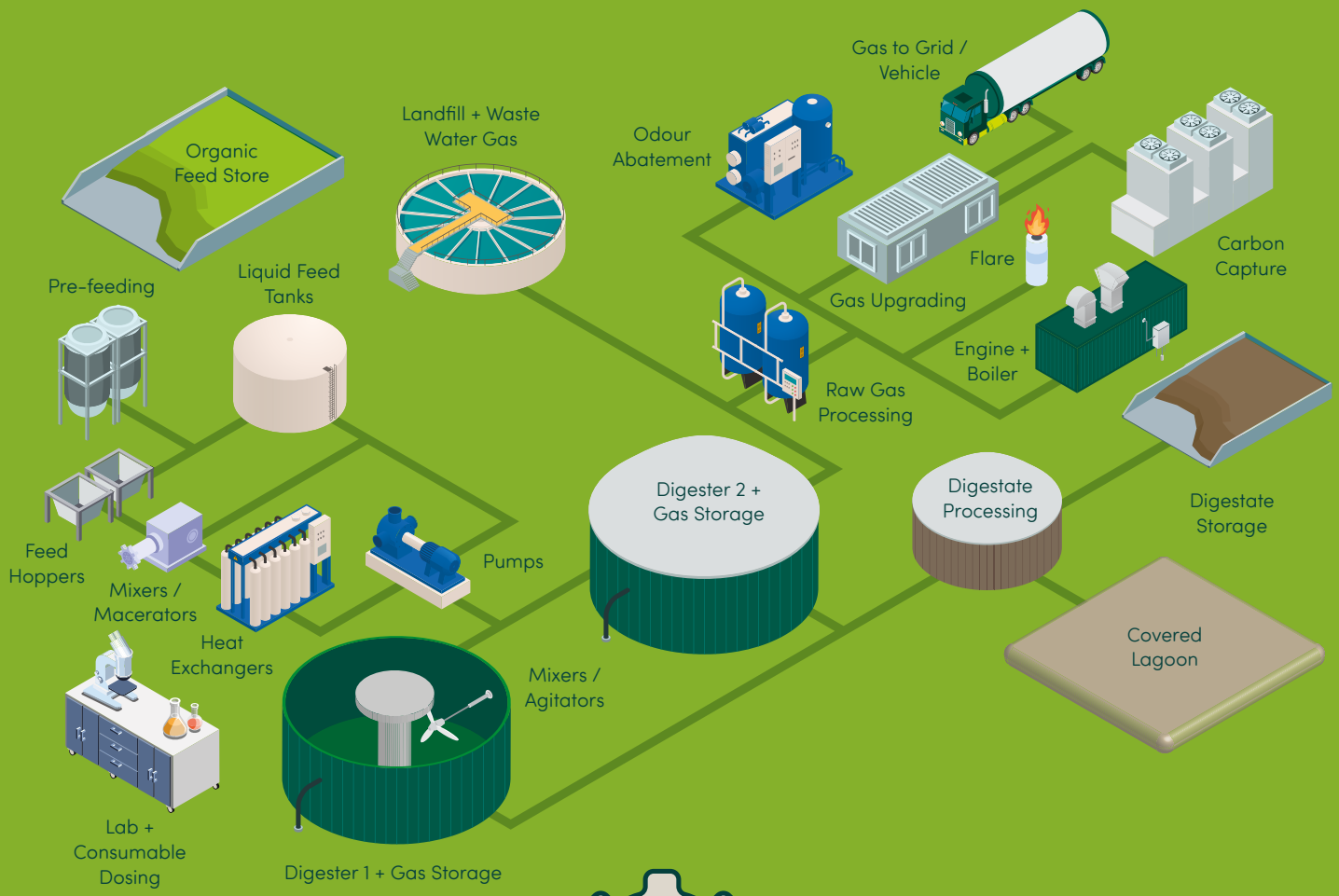
WORLD BIOGAS ASSOCIATION




# World Biogas Technology

# 2026

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12. Revoke site access upon completion.
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# Welcome from WBA Chief Executive Charlotte Morton OBE

Welcome to the World Biogas Association's (WBA) **World Biogas Technology 2026**, conceived and developed to be a definitive reference point for developers, investors, operators and stakeholders seeking high-performance solutions that deliver operational efficiency, environmental compliance and long-term reliability. By providing clear visibility of the processes, technologies and turnkey solutions available across the full biogas value chain, it seeks to enable decision-makers to de-risk projects, optimise investment and accelerate delivery.

As an integral part of the WBA's global **#MakingBiogasHappen** initiative, the World Biogas Technology 2026 publication is a strategic tool that complements the **Global Biogas Regulatory Framework (GBRF)** and **ADCS International**, WBA's best practice certification scheme. Together, these initiatives form a powerful package:

- **GBRF** establishes the enabling policy and regulatory environment for growth.
- **ADCS International** sets performance benchmarks and assures quality and sustainability in plant operations.
- **World Biogas Technology 2026** connects these frameworks to real-world solutions by showcasing the technologies and providers that can deliver on these standards.

In this way, World Biogas Technology 2026 plays an integral role in scaling up the industry worldwide. It not only promotes innovation and the adoption of best practice, but also underpins the creation of a trusted, standards-based global biogas market. By bridging regulation, certification and technology, it helps ensure that biogas realises its full potential as a mainstream pathway for decarbonisation, resource recovery and circular economy growth.

On behalf of WBA, I would like to extend my sincere gratitude to all the technology providers, practitioners and partners who have contributed to this publication. Your expertise, insight, and support have made World Biogas Technology 2026 possible, ensuring it is a comprehensive and authoritative resource for the sector.

It reflects the collective commitment of industry leaders to advancing anaerobic digestion, biogas and biomethane globally. By sharing your knowledge, innovations and experiences, you are helping to strengthen the sector, foster collaboration and accelerate the adoption of sustainable solutions that tackle energy, waste and climate challenges.

I am proud that WBA can provide this platform to showcase your technologies and highlight the critical role they play in shaping a resilient and circular energy future. Your continued engagement and leadership are vital as we work together to drive the biogas and AD sector forward.



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# AD - Far More Than the Sum of its Parts



**Andrew Brown,**
Technical Support Manager,
World Biogas Association

Welcome to World Biogas Technology 2026, your guide to understanding the anatomy of anaerobic digestion (AD), biogas and biomethane processes.

Over the years, as a chemical process engineer specialising in biogas technologies, I have met people from every corner of the sector - investors, developers, operators, policymakers, technology providers and students - all driven by a shared curiosity to understand how AD plants work and why they matter.

This guide to world biogas technology is designed to meet that need. It offers a clear, accessible overview of how these plants work - step by step - demystifying complex processes in straightforward terms. It serves as both a practical reference to current practitioners and a learning tool for anyone seeking to deepen their understanding of this essential technology.

## Biogas in the World

At its simplest, biogas is a renewable gas made by nature itself. Whenever organic matter breaks down in the absence of oxygen - in wetlands, in a cow's stomach or at the bottom of a compost heap - microbes produce a mixture of gases, mainly methane and carbon dioxide. AD plants capture and manage that process, allowing us to turn organic materials and "wastes" into something far more valuable: clean, renewable energy, nutrient-rich biofertilisers and increasingly other bioresources.

This makes biogas unique among renewable technologies. A wind turbine, solar panel or hydro dam produces electricity. But an AD plant does several things at once:

- It produces renewable gas that can be used directly for heat and power or upgraded to biomethane for injection into the gas grid, use as a vehicle fuel or platform for further chemical processing.
- It captures and stabilises organic wastes, preventing uncontrolled emissions.
- It mitigates climate change, not just by displacing fossil fuels but by avoiding methane that would otherwise leak from landfills, manure stores or rotting waste in landfills.
- It recycles nutrients back to land in the form of digestate, supporting agriculture and soil health.
- It supports local and rural economies by creating jobs, providing farmers with an income stream and improving energy security.

Few other technologies can tick so many boxes at once. That is why WBA champions anaerobic digestion and biogas as essential pillars of the global circular economy and net-zero transition.

It is important to stress that biogas is neither new nor particularly complex. The processes involved are well understood and well established. What is evolving is the scale, sophistication and recognition of their importance within the energy and waste landscape. Across the world, tens of thousands of industrial-scale plants already operate - and millions of small-scale plants, particularly in rural regions, provide households and communities with renewable energy every day.

For all this variety, though, the underlying principle is the same: we are working with biology, with microbes that have been here for billions of years, and pairing them with modern engineering to deliver reliable, measurable outputs.

## Anatomy of a Biogas Plant

To understand this better, let us walk through a typical plant, following the same process flow you will see illustrated in this guide. Think of it as walking through the site gates and tracing the path that organic material takes as it becomes renewable gas and bio-fertiliser.

### Feedstock Reception and Preparation

The journey begins with feedstocks - the organic materials that will be digested. These might be food waste from households or supermarkets, manure and slurries from farms, crop residues, energy crops, industrial by-products or wastewater sludges. Each has its own characteristics, and a modern plant is usually designed with flexibility in mind.

On site, solid feedstocks are received and stored, while liquid feedstocks are held in tanks. From there, materials pass through pre-treatment and mass-handling steps: hoppers, macerators, mixers and pumps that ensure a consistent, pumpable feed is delivered into the digesters as part of a very strict routine. An analogy I often use is that this stage is like preparing ingredients in a kitchen - chopping, mixing, measuring - so that the "recipe" can be cooked properly.

*continued>*

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### The Digester and its Biology

The heart of the plant is the digester itself: a sealed, oxygen-free tank where microbes break down the organic material. The process of digesting fresh organic materials typically lasts several weeks for most AD plants. However, plants are designed to process an amount of fresh feedstock at least twice a day to keep the digester and its biology operating well – much like we humans eat meals every few hours whilst our body digests for many days.

Inside the digester, mixers and agitators keep the contents uniform, while heat exchangers maintain the right temperature for productive microbial activity.

As the digester mechanisms sustain a good environment, the biology is solely responsible for the gas production process and is alive every second. Complex organic matter is converted in a multitude of steps into simpler molecules until methane and carbon dioxide are released. The result is biogas: a raw gas mixture usually around 55-65% methane, with the balance mostly carbon dioxide and trace gases.

If the digester is the heart (or stomach) of the plant, then the microbes are its workforce - invisible but powerful, tirelessly converting waste into energy. The digester's conditions and microbial biology must be carefully maintained and monitored, and may be open to optimisation with novel methods as the industry continues to evolve and expand.

### Gas Handling and Utilisation

The raw gas collected from the digester is stored either in the headspace above the active liquid level inside the tanks, and/or in a flexible dome or gas holder, before being processed. Depending on the plant's design and location, the gas can take several routes:

- **Cleaning** via condensate removal and filtering, to remove water and hazardous or corrosive gases that can damage downstream equipment.
- **Direct use** in a combined heat and power (CHP) engine, generating renewable electricity and useful heat.
- **Upgrading** into biomethane by removing carbon dioxide and trace components, producing a high-quality gas equivalent to natural gas. This biomethane can be injected into the gas grid, uniquely utilising existing infrastructure, or it can be compressed or liquefied for use as vehicle fuel.
- ***Additional options***, such as carbon capture systems, can further enhance the climate benefits by capturing $CO_2$ for use or storage.

Alongside these, odour control, flares and safety systems ensure environmental compliance and operational reliability.

### Digestate Utilisation

What remains after digestion is digestate - a nutrient-rich material that contains most of the nitrogen, phosphorus and potassium from the original feedstocks. Crucially, this digestate may be considered stabilised: the methane has already been captured within the controlled plant, meaning far less potential for emissions once the digestate is spread to land, compared with spreading raw manure and slurry or sending food waste to landfill.

Digestate may be separated into liquid and fibre fractions, processed further into concentrated high-value fertiliser pellets or solutions, or stored in covered lagoons or tanks until required. In this way, every part of the input organic material finds a useful output: energy from the gas, nutrients from the digestate.

## Bringing it together

When you look at the whole system, an AD plant is more than the sum of its parts. It is a carefully balanced ecosystem of biology and engineering – the biogas is burned for heat and power, that heat is used to sustain temperatures for the biology, and some of the power is used to run the mechanisms all over the process, in what is often termed "parasitic load". Essentially, an AD plant transforms everyday challenges - waste, emissions, dependence on fossil fuels - into opportunities for clean energy, climate action and circular resource management.

In the pages that follow, World Biogas Technology 2026 will take you through each stage of the anaerobic digestion process in detail, supported by insights from leading technology providers and industry practitioners. The goal is that, by the end of this guide, readers will have a clear and comprehensive understanding of how biogas plants operate and why they matter - whether their interest lies in investment, development, design, operation or policy development.

The mission of WBA is to disseminate knowledge and support the sustainable development of the Anaerobic digestion and biogas sector globally. AD and biogas are proven, scalable technologies that are available today, and their importance will continue to grow as the world seeks sustainable solutions to the energy, waste and climate challenges.

We invite you to engage with this exploration of a biogas plant's anatomy. In doing so, you will gain not only a clear understanding of the technology's operation but also an appreciation of its potential to transform energy and resource systems in a sustainable and impactful manner.

Join WBA in **#MakingBiogasHappen**.

BROWN&CO

The Brown&Co Energy Department have more than a decade of experience in the Anaerobic Digestion (AD) industry providing bespoke consultancy services across our UK, Poland and Caribbean offices.

### Access to grant funding and subsidies

Brown&Co have been successful in achieving grant funding and subsidy applications across a range of sites and technologies. The applications we have worked on amount to approximately £1.5 billion in accessed funding to renewables. We continue to provide ongoing compliance and audit support to over 55 of these applications to ensure sites retain eligible and consistent payments.

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For more information please contact:

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# Pre-Feeding

Biogas plants take organic matter, such as household food waste, farm manure, sewage sludge, crop residues and industrial by-products from food and drink industries and convert it into renewable gas and "digestate", a biofertiliser by-product.

However, these materials do not always arrive in a form that is ready for smooth conversion. For example, organic feedstocks can arrive with unwanted contaminants that can disrupt digestion and damage equipment.

Many substrates, such as food waste, farmyard manure, crop residues, wastewater sludges or industrial by-products contain materials or characteristics that can impair pumps, digesters and downstream equipment if not addressed.

**Mechanical separation and screening** are among the first steps. Coarse and fine screens, vibrating or rotary devices and grit or magnetic separators remove plastics, stones, bones, shells and metal fragments. This protects pumps, pipes and mixing equipment from blockages and abrasion, reducing maintenance and operational downtime. It is also best to capture these contaminants upstream in the process, to prevent contaminant buildup inside the tanks, as this can lead to reduced capacity and performance over time.

For tougher, fibrous materials like straw, maize stalks or long manure fibres, **size reduction through shredding or chopping** may be necessary. Shredders, hammer mills or knife mills reduce particle size, increasing the surface area available to microbes, improving digestibility, accelerating biogas production and preventing clogging of digesters.

Dilute substrates, such as some wastewater sludges, may require **thickening or dewatering** using centrifuges, screw presses, belt presses or gravity thickening tanks. This increases solids content, improving hydraulic handling, reducing separation in tanks and creating a more consistent feed for digestion.

**Homogenisation and blending** address variability in composition, particularly for oily, greasy or highly heterogeneous wastes. Mixing tanks or recirculation loops create a uniform feedstock, preventing separation of liquids and solids, ensuring even microbial contact and enhancing overall biogas yield and process stability.

In some cases, chemical adjustments are necessary. **pH correction or buffering** using lime, acids or other additives stabilises highly acidic or saline industrial by-products, protecting methanogenic bacteria from inhibition and avoiding process upset.

Finally, **pre-heating or thermal treatments** may be applied to soften fibrous materials, reduce viscosity or partially hydrolyse complex organics. Various methods can be used to improve microbial accessibility and increase methane yield.

By combining these mechanical, chemical and thermal pre-treatment strategies, biogas plants can manage diverse and variable substrates, protect equipment, stabilise digestion and maximise biogas production, even when feedstocks contain challenging solids, fibres or chemical characteristics.

Without proper preparation, feedstocks can block pumps, damage equipment or reduce the efficiency of digestion. Pre-feeding technology supports a steady, contaminant-free and digestible input, leading to more reliable gas yields and smoother plant operation.

For these reasons, we often need pre-feeding technology – equipment and processes that can sort, shred, mix, clean or condition the incoming feedstocks. This step alters the physical structure of the material, removes contaminants and ensures a steady, pumpable feed into the digester, giving the bacteria the best chance to do their work efficiently.

## Pre-Feeding Technologies for Biogas Feedstocks

| Feedstock Challenge | Technology / Equipment | Key Benefits |
|---|---|---|
| **Plastics, packaging, bones, shells in food waste** | Depackagers, separators, trommel screens. | Removes non-organic contaminants, recovers clean organic fraction. |
| **Large or variable particle size** | Shredders, grinders, hammer mills. | Reduces material to uniform size, improves pumpability and digestion. |
| **Stones, sand, soil in manure or slurries** | Grit removal systems, hydrocyclones, stone traps. | Protects pumps and tanks from abrasion or blockages. |
| **Woody or fibrous crop residues (straw)** | Grinders, thermal/chemical conditioning, extruders. | Breaks down tough lignin-rich material, increases digestibility. |
| **Dilute sewage sludge** | Thickening units; belt presses, centrifuges. | Raises solids content, reduces overall water volume. |
| **Rags, debris in sewage sludge** | Screening equipment: coarse/rake screens, grinders. | Eliminates large inorganics that can foul equipment. |
| **High oil/fat content in food/ industrial waste** | Fat separators, controlled dosing, mixing tanks. | Prevents floating grease layers, balances feed blend. |
| **Acidic or salty industrial by-products** | Buffer tanks, pH adjustment systems, blending setups. | Neutralises extreme chemistry, protects digestion microbes. |
| **Soil and stones in green or market waste** | Screening, density separation. | Removes heavy inorganic material before digestion. |
| **Seasonal or inconsistent feedstock quality** | Mixing tanks, homogenisers, blending systems. | Delivers a consistent feed for stable biogas production. |

# Cut Your AD Plant Packaging Waste Disposal Costs

## The Langage AD Story

At Langage Farm in Devon, England, their AD plant is central to turning food waste into renewable energy. But like every AD operator, they faced a common challenge: how to manage plastic rejects and other non-organic material. Almost all incoming food waste contains plastics, cardboard and other contaminants. Disposing of this packaging is a major expense, particularly when it carries liquids and organic residues that increase weight, and with it, disposal costs.

## The Challenge

Every tonne of contaminated packaging sent for disposal carries a heavy cost. The plastics and card themselves are unavoidable, but the real problem is the trapped moisture and food residues that add unnecessary weight. For AD plants handling large volumes of waste, this quickly adds up to significant expense.

## The RUNI Solution

To address this, Langage AD invested in the RUNI SK370 compactor. This isn't just a machine that makes plastics smaller for transport. The RUNI compresses the material, squeezing out liquids and loose organics, reducing the overall weight of contaminated plastics by 54%. That means the plant pays less to dispose of packaging, while recovering valuable liquid and organic material that would otherwise have been lost.

**Gary Jones, Managing Director at Langage AD explains:**
*"The RUNI provides a big cost saving in compressing these plastics. It doesn't just make them smaller, it squeezes out the liquids and organics that would cost us a fortune to throw away.* ***The machine pays for itself in disposal savings alone****. I've recommended it to every AD plant I know."*



*RUNI SK370 Output.*




*RUNI SK370 at Langage AD.*

## The Results

- **54% weight reduction** of contaminated packaging
- **Major disposal cost savings**, the RUNI quickly paid for itself
- **Increased recovery** of liquids and organics for digestion
- **Proven reliability**, Langage AD's SK370 has run for six years so far with no downtime

The machine is in near-continuous operation, typically 12 hours a day, five days a week, plus several hours at weekends, and has proved robust, efficient and low-maintenance.

## Why It Matters for AD Plants

Packaging waste is a universal issue in food waste digestion. By tackling this problem with a RUNI SK370, Langage AD has transformed a cost burden into a controllable, predictable process. Instead of paying to haul excess water and organics away, they capture the value on site and send out only compacted, lightweight packaging for disposal.

## Your Opportunity

**If packaging disposal is eating into your plant's margins, RUNI offers a reliable, cost-saving solution. Contact us to arrange a no obligation site assessment and chat to our friendly team about the potential gains for your operation.**

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# Unlock Higher Biogas Yields with Proven Pre-treatments

## Organics recovery technology

Anaerobic digestion (AD) is a proven pathway to turn organic waste into renewable energy, but contamination has always been a persistent challenge. Plastics, grit, glass and other inorganics reduce gas yields, clog equipment and compromise digestate quality. Effective pre-processing is therefore essential for reliable, efficient operations.

For more than two decades, Anaergia has led the field in organics recovery technology. The OREX™ system has become one of the most trusted solutions worldwide for extracting clean organics from mixed municipal and commercial waste. Its proven performance has helped facilities unlock the full energy potential of streams that would otherwise be landfilled or incinerated.




***Proven performance:*** *With over 20 years of operational success, OREX™ continues to set the standard for extracting clean organics from municipal solid waste.*

## Packaged food handling

Building on that foundation, the CleanREX™ 3000H represents the next generation of pre-processing technology. Purpose-built to handle today's most challenging packaged food and industrial waste streams, CleanREX™ efficiently separates organics from contaminants, delivering a slurry that maximises methane potential while minimising operator effort.

**Anaergia** is a global leader in renewable natural gas solutions, with more than 300 patents and a track record of over 1,700 installations globally.




***Next-generation separation:*** *With over 10 years of deployment, the CleanREX™ 2500 removes plastics and contaminants from food waste and OREX™-recovered fractions, ensuring a cleaner feedstock for digestion.*

## Complementary Technologies

Together, OREX™ and CleanREX™ ensure that anaerobic digesters receive a clean, pumpable feedstock that drives smoother, more predictable digestion. The benefits for operators are clear: fewer interventions, reduced maintenance, higher renewable gas yields and digestate that can be applied to land with confidence.

With more than 20 years of proven performance and a new generation of solutions now in operation, Anaergia's pre-processing technologies remain central to the renewable natural gas sector. Crucially, they are not standalone tools but part of Anaergia's integrated AD platform – seamlessly linked with mixing, digestion, upgrading and resource recovery systems. ***See also, Mixing and Turnkey Solutions.***

Get in touch to explore how OREX™ and CleanREX™ can optimise your facility's feedstock and unlock higher biogas yields.

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# Feeding

Once feedstocks have been suitably prepared, they must be reliably introduced into the digestion process. Feeding systems ensure that organic material is delivered at a consistent rate, in the right condition and in a controlled manner. This stage is critical because uneven or inconsistent feeding can lead to process instability and reduced gas production.

**Feedstock storage** provides an intermediate buffer between reception and digestion, giving operators flexibility to manage different Feedstock types, seasonality and logistics. Feed can be stored either in open concrete bays known as "clamps" or in tanks for liquid storage. Some feeding tanks may be heated internally, to prevent certain liquids from solidifying when cooled (for example, food and drink by-products like pot ale syrup).

**Feed hoppers** allow for gradual feeding over hours, by storing a small amount - i.e. 50 tonnes - in a large box container, with a mechanism that pushes a few tonnes at a time into the mechanical feeding system.

Alternatively, some mass-handling operations will feed directly from the storage clamps. This is useful when large quantities of mass need to be moved frequently. In these instances, either **cranes or scrapers** are common. In some systems, **bunker hoppers** are used - large storage bins where bulk material is deposited in significant quantities. These hoppers are equipped with a walking floor feeder at the base, which steadily pushes the material into the downstream process.

Following feed hoppers, there are often **mixer-macerators** to shred and homogenise the substrate, reducing particle size and preventing the formation of blockages. This preparation allows smooth pumping and ensures that a consistent mix of organic material reaches the digester. These mixer-macerators will often introduce liquids recirculated from the main process, to create a pumpable feed mix ready for digestion.

Feeding systems are highly varied and must be matched carefully to the type of substrate being handled. Solid-rich streams, slurries and liquid feeds each demand different technologies, from conveyors and augers to mixers and pumping systems.

Effective feeding is not just about moving material - it is about protecting the digester biology. By supplying substrates in a consistent, well-prepared state, operators help the microbial community inside the digester to remain balanced and productive, directly influencing plant efficiency.

## Feeding Technologies for Biogas Plants

| Equipment / System | Principal Feedstock Application | Key Benefits |
|---|---|---|
| **Conveyor Belts / Screw Conveyors** | Moving shredded biomass, silage. | Controlled transfer; enclosed; low spillage. |
| **Walking Floor Bunker / Hopper Feeder** | Moving and briefly storing bulk silage, coarse solids. | Large volume handling; steady automated dosing. |
| **Hydraulic Piston-Ram Feeder** | Fibrous, bulky solids. | Robust push feed; handles long-fibre material. |
| **Crane Feed (Grab Bucket)** | Bulky/mixed wastes, packaged waste. | Flexible handling; reduced manual labour. |
| **Shredder with Liquid Addition & Recirculation** | Silage, food waste and liquids. | Mixes & shreds to pumpable slurry; uniform particle size. |
| **Pre-treatment & Mixing Tanks with Pumps** | Mixed substrates. | Homogenises, adjusts solids; stable digestion. |
| **Progressive Cavity / Centrifugal Pump** | Slurries, liquid food waste. | Reliable dosing; handles viscous feed. |
| **Auger / Tube Feeders** | Shredded solids, small particles. | Continuous solids dosing; adaptable layouts. |

# Next-Level Feed Systems: Bacteria-Friendly Digester Feeding

## Design and Function

After decades of biogas industry experience, Vogelsang has come to understand that anaerobic digestion performance depends heavily on feed system reliability; robust, well-engineered machinery simplifies plant operation and maximises gas output.

With a dedicated biogas engineering team in Essen, Germany, Vogelsang has produced what it believes is the gold standard in feed systems. The PreMix 4-in-1 feeder is purpose-built to deliver solid feedstock into digesters for maximum gas yield. It macerates and blends the material into a uniform slurry, ensuring optimal conditions for bacteria digestion and efficient biogas production.

Introduced onto the biogas market in 2015, the PreMix feed system has become a preferred choice for AD plant builders and operators worldwide, thanks to its innovative design and durable components. This 4-in-1 system separates, macerates, mixes and pumps using Vogelsang's proven technology, delivering reliable performance with both wet and dry feedstocks.



*On-site solid matter feeder system.*



*PreMix with CC Pump.*



## Versatile Application

A leading UK AD facility processes over 140,000 tonnes of diverse feedstock annually using three Vogelsang PreMix systems. The plant operates three 'clean' and three 'dirty' lines. The 'clean' lines handle maize, chicken litter and energy crops, and the 'dirty' lines take all the commercial food waste (that is de-packaged on site).

'Crops and similar materials form a porridge-like mix in the digesters,' the site manager explains. 'We also wanted to include drier materials, like coffee grounds, which are prone to causing blockages and stoppages. That meant we needed a feed system capable of handling both high-viscosity inputs and large volumes reliably.'

The site turned to Vogelsang for its feed system equipment, installing three PreMix units to handle both waste streams. The PreMix integrates a progressive cavity pump (from Vogelsang's CC or HiCone series) with a RotaCut macerator.

Feedstock enters the system via a screw auger, where it is combined with recirculated liquid. In one continuous process, the material is macerated, blended into a uniform organic suspension and pumped directly into the digester. Each unit supplies multiple digesters through a connected pipe network.

## Operational Impact

The AD plant also wanted to minimise excessive downtime caused by feed blockages at the heat exchanger inlet. Heterogeneous food waste streams - containing tough materials such as leathery avocado skins and wooden kebab skewers - frequently obstructed the entry point, leading to mechanical jamming.



*Increased gas yield.*



*RotaCut cutting screen.*

These blockages, occurring several times per day, resulted in significant operational interruptions and increased maintenance requirements.

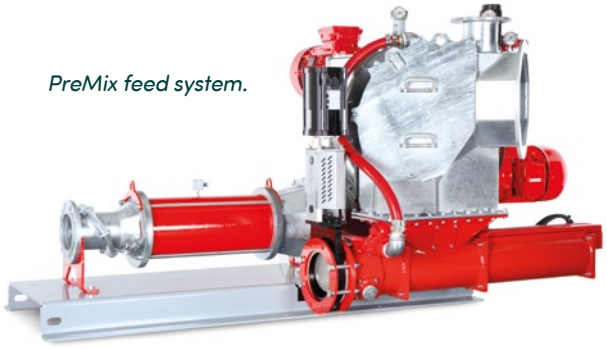
A Vogelsang XRipper macerator was installed to chop and reduce the waste particle size (which subsequently reduces the pressure on the heat exchanger). The plant started with a 12mm blade in the macerator but quickly switched to a 9mm for finer waste feed.

The integration of the PreMix feed system and XRipper has reduced unplanned downtime by up to 90%, by significantly decreasing mechanical blockages and improving overall process reliability. The site manager says: "Before, it was hours of work to clear the blockages. But now we almost never have any problems with the equipment. It's reduced our downtime massively. Vogelsang's equipment has been working faultlessly and is straightforward enough that we can do the maintenance for ourselves."

## Simple and Successful

At another UK site, the PreMix feed system proved so effective with its annual feedstock of about 3,000 tonnes of chicken litter and 6,500 tonnes of maize, silage and farmyard manure that the operators installed a second line with an additional PreMix.

The operations director says: "The PreMix is one of the best elements of our plant and



*PreMix feed system.*



*RotaCut macerator.*

provides an effective and reliable system in one complete unit. It does everything we need to our feedstock to best prepare it for digestion, it's simple to maintain and parts are delivered quickly when we need them."

Satisfied with the feed lines, the plant team worked with Vogelsang to further increase gas production using additional machinery. To get an even finer cut on the feedstock before it went into the digester, a RotaCut macerator was added on the line after the PreMix.

"Our team is very open to trying new ways of working and approach the job with Vogelsang in a collaborative manner. I'd say we've seen an increase of 20% output from the installation of the new equipment, largely down to increased efficiency of feeding, less downtime and increased maceration, and the additional RotaCut has made the feed line a huge success," he added.

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The smart 4-in-1 solid matter feeder separates out heavy material while the solids are mixed with liquid. Coarse particles are crushed and fibrous matter is macerated before the integrated pump. Right from the start, this avoids damage from foreign matter and ensures that the biomass is properly prepared for the bacteria. Its compact design makes it easy to integrate into new systems or retrofit in existing plants.

For more information:
**vogelsang.info/uk/premix**

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# Substrate Pumping

Substrate pumping is the vital link that transfers organic material between different stages of the biogas plant - from feeding, through heating and mixing systems, and both into and out of the digesters and storage tanks.

Efficient substrate pumping in a biogas system depends on matching pump technology to substrate properties, protecting equipment from wear or clogging, optimising energy use and designing for reliable, maintainable operation. A well-designed pumping system stabilises feed rates, maintains high biogas yield and reduces operational costs.

The pumps used in biogas applications must handle challenging fluids: high-viscosity slurries, fibrous matter and materials containing grit or contaminants. For this reason, specific pump technologies are typically employed, including lobe pumps, progressive cavity pumps and other positive displacement systems. Each has unique advantages depending on the solids content, abrasiveness and flow rates required.

In some plants, pumping also plays a role in recirculating heated substrate or transferring substrates through heat exchangers before reintroduction to the process, and so pumps can be found in all areas of a biogas plant (*see Heat Exchangers*).

Poorly matched or undersized pumps are a common cause of operational problems, from clogging and excessive wear to energy inefficiency. By contrast, robust pumping solutions contribute to plant stability, energy savings and reduced downtime. In essence, pumping is the "circulatory system" of the biogas plant, keeping materials flowing smoothly through every stage of conversion.

It must be noted that the piping network plays a central role in ensuring reliable transport of feedstock from storage or pre-treatment units into the digester. The diameter, material and layout of pipes must be carefully matched to the physical properties of the substrate being treated.

For example, substrates such as manure, thick slurry or fibrous agricultural residues are highly viscous and may contain coarse particles or fibres. Transporting these materials requires larger-diameter pipes and smooth, low-friction internal surfaces to reduce the risk of clogging, sedimentation or excessive pumping pressure. In contrast, thin liquid substrates, like food-processing wastewater or diluted sludge, can be conveyed through smaller pipes without compromising flow rates.

## Feedstock Characteristics

| Factor | Why It Matters | Tips for Efficiency |
|---|---|---|
| **Dry Matter Content & Viscosity** | High solids content or thick slurries increase friction losses and risk of clogging. | Use progressive cavity or rotary lobe pumps for viscous substrates; dilute or pre-mix to manageable consistency. |
| **Particle Size & Fibrous Material** | Large particles or long fibres can wrap around impellers or block passages. | Install macerators or shredders upstream; select pumps with large free passages or cutters. |
| **Abrasiveness** | Sand, grit, or bone fragments can erode impellers and housings. | Use wear-resistant materials (e.g., hardened steel); include grit removal before pumping. |
| **Chemical Composition** | Corrosive components (e.g., ammonia, acids) can damage pumps. | Choose chemically compatible seals, elastomers, and coatings. |

## Common Pump Types for Substrate Feeding

| Pump Type | Suitable Applications | Key Benefits |
|---|---|---|
| **Progressive Cavity Pumps** | Thick slurries, fibrous material. | Good for viscous feed, gentle on substrates, accurate dosing. |
| **Rotary Lobe Pumps** | Medium-viscosity slurries, digested sludge. | Compact, reversible, handles solids well. |
| **Centrifugal Pumps** | Dilute slurries, low-viscosity liquids. | High flow rates, simple design. |
| **Submersible Pumps** | Direct use in pits or tanks. | Space-saving, easy retrofit. |
| **Peristaltic Pumps** | Usually found in labs or dosing applications. | For precise dosing of small liquid quantities. |

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- Used for mixing dry bio solids with digestate liquid and pumping into the fermentation tank.
- Customised hoppers available in both round and rectangular designs, with lengths of up to 3 metres.



## Biomass Pump

Capacity - Up to 210 m3/hr (925 GPM) I Pressure - Up to 12 bar (175 PSI)

- Developed on 'Maintenance in Place' platform.
- Used for recirculation of fermentation tank slurry and feeding to digestate storage tanks.
- Vertical configurations, available in various lengths of up to 10 meters, are used in open lagoons for the transfer of organic manure.


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# Heat Exchangers

Anaerobic digestion is a temperature-sensitive process, with a microbial community that is very much "alive" and must be well maintained to ensure plant efficiency. The microbial communities responsible for breaking down organic matter operate within defined ranges - typically mesophilic (around 35–45°C) or thermophilic (around 45–50°C+). Heat exchangers are essential for maintaining these conditions, ensuring stable process temperatures and preventing thermal shock that could destabilise the biology.

In biogas plants, heat exchangers serve several purposes. They recover heat from digestate streams and pre-heat incoming substrates using the site's hot water circuit.

In many biogas plants, particularly those treating food waste or hazardous animal by-products, pasteurisation is an additional temperature-critical step. By heating the substrate (commonly to 70 °C for at least 60 minutes), pasteurisation destroys pathogens and weed seeds, also ensuring the digestate meets regulatory hygiene standards for safe agricultural use (*See Digestate Management*).

Common designs include shell-and-tube, pipe-in-pipe or coaxial systems, plate exchangers, spiral configurations and coils within tanks. The choice of design depends on substrate viscosity, solids content, fouling potential and energy efficiency requirements.

Effective heat exchange significantly increases the plant's efficiency and reduces reliance on external heating sources, improving energy balance and lowering operational costs. Robust exchanger design also minimises maintenance, as fouling and blockages can be significant challenges when handling organic slurries.

Heat exchangers protect the microbial process while improving the overall energy efficiency of the facility. They act as a critical link between mechanical systems and biological processes, ensuring each cubic metre of feedstock enters the digester in the best condition for efficient gas production.

## Common Heat Exchanger Types used in Biogas Plants

| Heat Exchanger Type | Typical Application | Key Benefits |
|---|---|---|
| **Shell-and-Tube** | Pre-heating liquid substrate with hot water or warm digestate, sludge-to-sludge heat recovery. | Robust and proven design; handles high pressures and temperatures. |
| **Plate Heat Exchanger (PHE)** | Transfer heat between two thin, low viscosity liquid streams, usually for smaller applications. | Compact footprint; high heat transfer efficiency; easy capacity adjustment by adding plates. |
| **Tube-in-Tube / Annular Double Pipe** | Pre-heating liquid substrate with hot water or warm digestate, sludge-to-sludge heat recovery. | Simple construction; low maintenance; suitable for viscous or particle-laden fluids. |
| **Spiral Heat Exchanger** | Transfer heat between two liquid streams. | Compact design, may have self-cleaning flow paths but turbulent flow. |
| **Gas-to-Liquid (Condensing) Heat Exchanger** | Cooling and dehumidifying raw biogas before upgrading or CHP use. | Removes water vapour to protect downstream equipment; recovers latent heat. |
| **Immersion / Pipe Coil Heaters** | Directly inside digesters for slurry heating. | Simple retrofit; avoids external piping; cost-effective for small capacities. |
| **Gas-to-Liquid** | Recovering engine exhaust heat to warm process water. | Utilises waste heat efficiently; improves overall plant energy balance. |




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# Pasteurisation Plays a Crucial Role in Award-Winning New Zealand AD Plant

**An award-winning biogas plant** which pioneered food waste collection and treatment in New Zealand has benefitted from using a dedicated pasteurisation system supplied by HRS Heat Exchangers. In July, Ecogas, which operates New Zealand's first and only commercial-scale anaerobic digestion (AD) facility won the *AD Hero of the Year* award at the prestigious 2025 AD and Biogas Industry Awards in Birmingham.

The plant, which was officially opened in October 2022, produces biogas and digestate biofertiliser, with the biogas upgraded into biomethane for injection into New Zealand's gas grid, and the carbon dioxide is supplied to a nearby tomato greenhouse where it helps crop growth.

The co-mingled food waste used as feedstock at the Reporoa plant has the potential to contain organisms which have the potential to impact human, animal or plant health. The HRS Digestate Pasteurisation System (DPS) pasteurises the digestate produced at the plant prior to use to render such pathogens inert, along with other undesirable elements such as weed seeds.

**The HRS DPS** utilises 'waste heat' from the site-based combined heat and power plants (CHP) to heat digestate to >70 °C and holds it for one hour at this temperature, before cooling. This is done with the HRS DTI Series heat exchangers, which are designed in such a way to recover up to 70% of the heat energy required for the process. The tube which carries the digestate through the system's heat exchanger features a unique corrugated design; unlike the smooth or dimpled tubes used in alternative exchangers. This boosts heat transfer by creating extra turbulence and helps reduce fouling, resulting in less downtime and maintenance, increasing the system's lifespan.

The fully automated system provides an auditable kill-step for efficient and effective reduction of pathogens such as Salmonella, Staphylococcus and *E. coli etc.* The DPS was delivered to site and installed in February 2022. The heat exchanger section of the HRS DPS is split into two frame modules, which are stacked and inter-connected for reduced footprint on site.



*The Ecogas AD plant at Reporoa processes c. 75,000 tonnes of organic waste each year and supplies $CO_2$ to a to a nearby tomato greenhouse.*

**Alzbeta Bouskova, General Manager at Ecogas** explained why the company chose to use the HRS DPS system. "Ecogas adopted UK-based PAS110 digestate standards as our primary design and operation principle to ensure that the biofertiliser produced from the Reporoa facility is of the highest quality, safety and value for the potential users. We chose HRS based on their reputation and strong track record in digestate pasteurisation. This was further supported by the highly engaged local HRS team, who worked hard to meet their timelines and quality of the equipment and installation."

For more information on HRS's range of heat exchangers and systems for AD, please contact your local representative or our biogas specialists today.




*The HRS Digestate Pasteurisation System (DPS) installed at Ecogas Reporoa in New Zealand.*

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# Tanks

Tanks (digesters) are the heart of any anaerobic digestion facility, providing a controlled environment where microorganisms convert organic matter into biogas and nutrient-rich digestate. Far from simple storage vessels, digesters function as bioreactors, precisely engineered to maintain the biological, thermal and hydraulic conditions needed for efficient gas generation and process stability.

Several digester designs are used in practice, each tailored to specific feedstocks, operating scales and performance requirements.

**Continuous Stirred-Tank Reactors (CSTRs)** are cylindrical-shaped digesters that are continuously or semi-continuously fed, with mechanical or gas-driven mixing to ensure uniform microbial activity. They are commonly constructed from concrete or steel. CSTRs are particularly suited to wet, homogeneous substrates such as slurry, wastewater sludge or food waste, offering reliable mixing and scalability for municipal or industrial plants. For sites with variations in feedstock (i.e. seasonal food waste), CSTRs offer a large buffer capacity, allowing the biology to adjust to new feed. Dry matter content for CSTRs usually range from 6% to 12% (any higher may be challenging to mix fully), and the tank diameter can range from small, 5 meters, to large, 40 meters or more.

**Plug-flow digesters** consist of long, narrow tanks where the substrate moves gradually from the inlet to the outlet, with minimal back-mixing. These systems, often made of concrete, steel or fiberglass-lined tanks, are ideal for consistent monthly and yearly feedstocks, such as large cattle farms. This is because the plug flow does not have a large buffer volume to mix new feedstocks into a stable volume – all new feed stays separate from the rest of the tank. Hence there is a risk of process upset or fast biological changes in the event of rapid changes to feeding or process instability, i.e. accidental feeding of contaminants. However, with a plug flow there is potential to optimise the biological reactions if managed well. Their design allows them to handle viscous, fibrous materials while requiring relatively low energy for mixing.

**Upflow Anaerobic Sludge Blanket (UASB) digesters** are commonly used for more dilute wastewater streams. Liquid flows upward through a dense microbial sludge blanket, which retains biomass while allowing treated effluent to exit. UASB digesters are usually built from concrete or stainless steel in larger installations and are especially common in wastewater treatment facilities due to their compact size, high treatment efficiency and low energy requirements.

**Covered lagoon digester**s provide a simple, low-cost solution in agricultural and rural contexts. These consist of large, shallow lagoons, often earthen - that is constructed as a large basin or pit dug into the ground with earthen embankments - with HDPE or PVC lining and covers to capture biogas. They are well-suited to warm climates and large volumes of dilute slurry, offering simplicity and low capital cost, albeit with lower gas yields per unit volume.

**Balloon or flexible bag digesters** are similar to covered lagoon digesters, using polymer membranes to contain and digest slurry or manure. These systems are modular, easy to install and particularly appropriate for small-scale farms or remote communities, offering portability and minimal upfront investment.

Additional tanks, such as **liquor buffers**, help regulate flows and balance the process. In multi-stage digestion systems, liquor buffers offer operational flexibility, allowing controlled feeding year-round, adjustment of hydraulic retention times and optimisation of solids loading.

Tanks in biogas systems are exposed to aggressive chemical and thermal conditions throughout their service life. Internally, the slurry and biogas contain corrosive compounds such as hydrogen sulphide, ammonia and organic acids, which can degrade unprotected surfaces. Externally, tanks experience thermal cycling and wind loads due to ambient weather and process heating systems.

Because feedstock composition can vary - ranging from thin slurries to high-solids and fibrous mixes - tanks must be designed to accommodate diverse viscosities and densities without deformation, bridging or excessive wear on internal components like mixers and heating coils.

Tanks must withstand internal pressures, buoyancy forces (for partially buried tanks), wind and snow loads and potential seismic events. Compliance with relevant engineering codes is mandatory. Their design, materials and construction are therefore critical capital decisions in any project. Lining, insulation, gas-tight roofs and corrosion resistance all form part of the specification. The performance of the entire biogas plant is tied to the condition and functionality of its tanks. Well-designed tanks enable efficient digestion, protect microbial health and ensure safe and reliable long-term operation.

## Common Biogas Digester Types

| Digester Type | Typical Application | Key Benefits |
|---|---|---|
| **Continuous Stirred-Tank Reactor (CSTR)** | Agricultural residues, manure, energy crops, food waste; medium-to-large plants. | Uniform mixing prevents stratification; stable process control; widely proven technology. |
| **Plug-Flow Digester** | Same as above, particularly sites with consistent feedstock flow. | Good for fibrous materials; lower maintenance. |
| **Upflow Anaerobic Sludge Blanket (UASB)** | Industrial wastewater with high soluble organic load (e.g., food & beverage effluent). | High treatment efficiency; small footprint; rapid start-up once granules established. |
| **Fixed-Dome Digester** | Small-scale or rural settings (e.g., household or community manure/ food waste systems). | Low-cost, durable design; no moving parts; suitable for off-grid areas. |
| **Floating-Drum Digester** | Household or small farm manure digestion in developing regions. | Easy to construct and operate; gas storage integrated in floating drum. |
| **Two-Stage CSTR Digester System** | Mixed or variable feedstocks requiring separate hydrolysis/acidogenesis and methanogenesis. | Improved stability with difficult feedstocks; higher biogas yield; better process control. |
| **Covered Lagoon Digester** | Liquid manure or agricultural wastewater in warm climates. | Very low cost; simple construction; suitable for large volumes in warm regions. |

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# Tank Mixing

Mixing is a fundamental aspect of digester performance, performing multiple functions essential for efficient anaerobic digestion. Within the tank, substrates must be kept in motion to ensure homogeneity, prevent sedimentation and avoid the formation of floating layers or scum. Proper mixing also distributes heat evenly and maintains intimate contact between microbes and organic material, both of which are essential for stable gas production.

Within the tank, mixing systems:

**Distribute Feedstock Evenly** Ensures new material is quickly incorporated into the digester contents, preventing "dead zones" (areas of no movement) or layering.

**Homogenise the Slurry** Keeps solids, liquids and microbes uniformly mixed for consistent biological activity.

**Suspend Settling Particles** Prevents heavier solids from settling at the bottom, which could reduce tank volume or damage equipment.

**Break Up Floating Layers or Scum** Stops crust formation that can insulate the surface, trap gas or block mixing and become hazardous.

**Equalise Temperature** Distributes heat evenly, maintaining stable conditions for microbial activity.

**Enhance Gas Release** Helps biogas bubbles rise and escape, avoiding gas pockets that reduce mixing efficiency.

**Improve Process Stability and Yield** By preventing stratification and maintaining optimal conditions, mixers support higher and more reliable biogas production.

Technologies for mixing are diverse. Submersible mixers are common for their flexibility, while horizontal paddle or angled mixers can provide targeted agitation for larger scales. Gas mixing and venturi systems offer alternatives that rely on biogas circulation rather than mechanical blades. Each method has advantages and challenges, and often plants use a combination of techniques to balance energy consumption with process effectiveness.

**Unconfined gas mixing (simultaneous)** Biogas is drawn from the headspace of the digester, compressed by an external gas compressor and reintroduced into the base of the digester through several mixing points simultaneously. Mixing takes place within the digester as the gas introduces a recirculating current from top to bottom within the digester. This type of mixing is common in the UK, particularly in the digestion of sewage sludge, and has the advantage that there are no moving parts requiring maintenance within the digester. Simultaneous (sometimes referred to as continuous) gas mixing is particularly effective in digesters with a high aspect ratio (almost as tall as they are wide).

**Unconfined gas mixing (sequential)** Biogas is drawn from the headspace of the digester, compressed by an external gas compressor and reintroduced into the base of the digester through a number of mixing points sequentially i.e. clockwise in one segment at a time. Mixing takes place within the digester as the gas introduces a recirculating current from top to bottom. Again, this system is common in the UK within both sewage sludge and food waste digestion. The main advantage of sequential gas mixing systems is that they can effectively mix high dry matter digesters, where the fluid is very viscous, using relatively low energy. By moving the substrate around the digester, the whole volume of the digester is mixed at relatively low mixing energies.

**Confined gas mixing** Less common in new digesters, confined gas mixing systems introduce compressed gas into the base of the digester through some form of mixing tube. Such systems are designed to produce a large recirculating flow via a 'gas lift' effect, whereby the lower density gas/slurry mixture within the draft tube is pushed upwards by the higher density surrounding slurry to create a recirculating flow (much like heat convection). This process is sometimes called 'blurping' and may be incorporated with heat exchangers (double wall rising tubes that heat as well as conduct fluid from the base to the liquid surface).

**Gas injection (venturi)** Venturi gas mixing systems are a hybrid of pump and gas mixing systems. A pump draws digested slurry from the tank and then passes it through a venturi device. A venturi works by creating a negative pressure within the device, which in turn draws biogas from the headspace of the digester and mixes it with the slurry. The resultant effect is a liquid jet mixed with gas bubbles which then rise within the digester causing the gas mixing recirculation current.

**Pump mixing** Pump mixing is a generic term for any form of mixing which involves a hydraulic pump circulating digested slurry from one part of a digester to another, creating a mixing flow. Pump mixing can either be based on the principle of high flow rates, recycling the entire contents of the digester over a period of several hours, or a smaller flow, passed through small nozzles to create a high velocity jet. All pump mixing systems have the advantage of simplicity and externally mounted mechanical equipment.

**Pump recirculation** These systems rely on pumping the whole digester contents from (typically) the bottom to the top over a period of 2 to 10 hours on the basis that one complete turnover of the digester will fully mix the tank. Generally, these systems are simple, low energy and, whilst requiring large flow rates, do not need large pumping heads as they do not use jet nozzles.

**Jet mixing systems for wet AD** These systems rely on pumping digested slurry through a series of smaller (50 mm to 100 mm) nozzles, creating high velocity jets. These jets then mix the digester contents both by creating bulk movement and by drawing in surrounding material from the bulk digester volume into the jet stream (known as entraining). Jet mixing systems tend to require higher input power to mix a given digester volume and this energy input should be increased with higher dry solids slurries. Jet mixers are sometimes paired with chopper pumps to ensure the jets do not block. Jets can be positioned to scour the base of digesters and entrain floating crust material.

**Impeller mixing for wet AD** Impeller mixing systems work in a similar fashion to pump mixing systems. An internal impeller creates thrust within the digester bulk from rotating blades, which in turn creates a flow. Impeller mixing tends to be either a large top-mounted impeller designed to pump downwards, or a side-mounted impeller designed to create horizontal movement. Impeller mixing systems are simple but commonly require access inside the digester or a method of removing from the digester to maintain. Impellers with a horizontal shaft work typically must be covered by at least half a metre of liquid.

**Top-mounted (large blade) impellers** This is usually a single large impeller with a roof-mounted motor and gearbox with a suspended shaft. The blade will be mounted near the base of the digester and rotate at low revolutions per minute (RPM), creating a large downwards flow that will produce a recirculation within the digester. A second smaller impeller will often be installed just below the top of the water level to ensure an even top-to-bottom flow pattern. When considering roof-mounted impellers it is important to assess additional costs for the digester roof support and access to the motor, shaft and gearbox.

**Side-mounted impellers** Very common in energy crop digesters, these mixing systems come in a number of shapes and sizes but usually incorporate an external motor and gearbox mounted on the digester wall, with a long-angled shaft and impeller. Due to the smaller impeller diameter, these systems tend to run at a higher RPM than large-blade impellers. A vigorous mix can be obtained but success is usually achieved if the mixed fluid does not have much long fibre that could catch on the blades. A mechanism for maintaining the stirring system without the need to drain down the digester is very important for safety and low maintenance costs.

Mixing systems therefore represent both an engineering and a biological challenge. The right approach depends on feedstock characteristics, digestion tank type and energy optimisation strategies, but all serve the same purpose: creating a stable and efficient environment for microbial activity.

## Common Mixer Types used in Biogas Plants

| Mixer Type | Typical Application | Key Benefits |
|---|---|---|
| **Submersible Mixers** | Installed inside digesters or storage tanks; suitable for liquid slurries and mixed feedstocks. | Cost-effective; adjustable positioning; good for homogenisation and preventing sedimentation. |
| **Slow-Speed Propeller Mixers** | Large digesters with medium-to-high viscosity feedstock. | High thrust at low power consumption; gentle mixing protects microbes; reduces energy use. |
| **Biogas-Driven Mixers (Gas Lift)** | Uses recirculated biogas to mix contents without mechanical parts inside the tank. | Low maintenance (no moving parts in slurry); reduced mechanical wear; energy-efficient if surplus gas is available. |
| **Paddle or Arm Mixers** | High-solids or fibrous materials (e.g., plug-flow or dry batch digesters). | Effective for thick substrates; can handle fibrous feedstock without clogging. |
| **Vertical Shaft Mixers** | Smaller or deeper tanks where vertical mixing is advantageous. | Good vertical flow generation; suitable for retrofits where submersible mixers are impractical. |
| **Top-Entry Agitators** | Tanks with external access or where submersible installation is difficult. | Easy maintenance (motor outside tank); avoids tank draining for servicing. |
| **External Loop / Hydraulic Mixing** | Digestate is pumped externally and reintroduced into the digester. | Allows precise mixing control; can integrate with heating loops; reduces in-tank mechanical components. |
| **Gas Recirculation with Ejectors** | Utilised in covered lagoon systems or simple digesters. | Minimal mechanical complexity; effective for low-cost, low-maintenance mixing. |

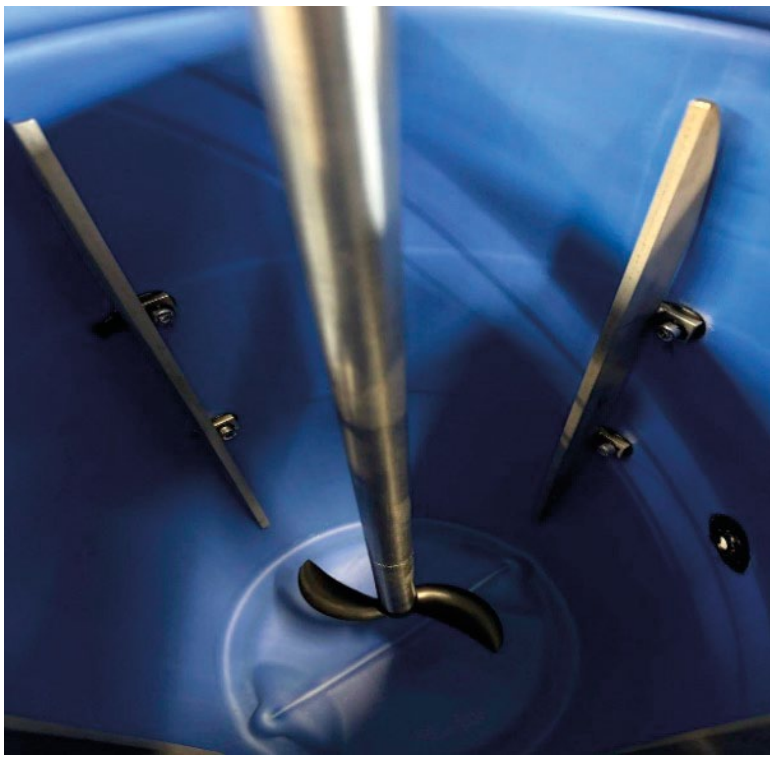
# Investigating the Lifespan Potential of Composite Propeller Material

## Introduction

In biogas plants, mixing systems are exposed to extreme conditions. In addition to high temperatures and chemically aggressive media, abrasive solids act on system components - especially the propellers. This continuous load often leads to significant wear, which not only shortens the service life of components but also impairs mixing efficiency. For plant operators, this means unplanned downtimes, high maintenance costs, and potential performance losses in gas production. To address this problem, PTM GmbH conducted a comprehensive wear test. The goal was to evaluate how different materials and propeller geometries perform in terms of wear resistance under realistic conditions. At the centre of the study was a composite material called Physinit®, which was tested against the established standard material stainless steel.

## Methodology

The test series were oriented on a half-factorial design of experiments. A total of four model propellers were tested: two made of stainless steel (one three-blade standard design and one two-blade Phantom design), and two Phantom propellers made of Physinit®. All propellers had a diameter of 150 mm and were operated at a constant speed of 1493 rpm. This rotation rate resulted in a similar tip speed in comparison to the real scale propellers. The tests were carried out in a test stand with four baffles filled with water and silicon carbide particles: a hard, abrasive material commonly used in industrial wear tests. Two different particle concentrations were used to simulate various load scenarios: 80 g/l and 200 g/l. The experimental setup was designed to allow for reproducibility. The propellers were periodically removed, weighed, and measured to determine mass loss and diameter changes as direct indicators of wear. These quantitative data were supplemented with visual inspections of blade geometry.

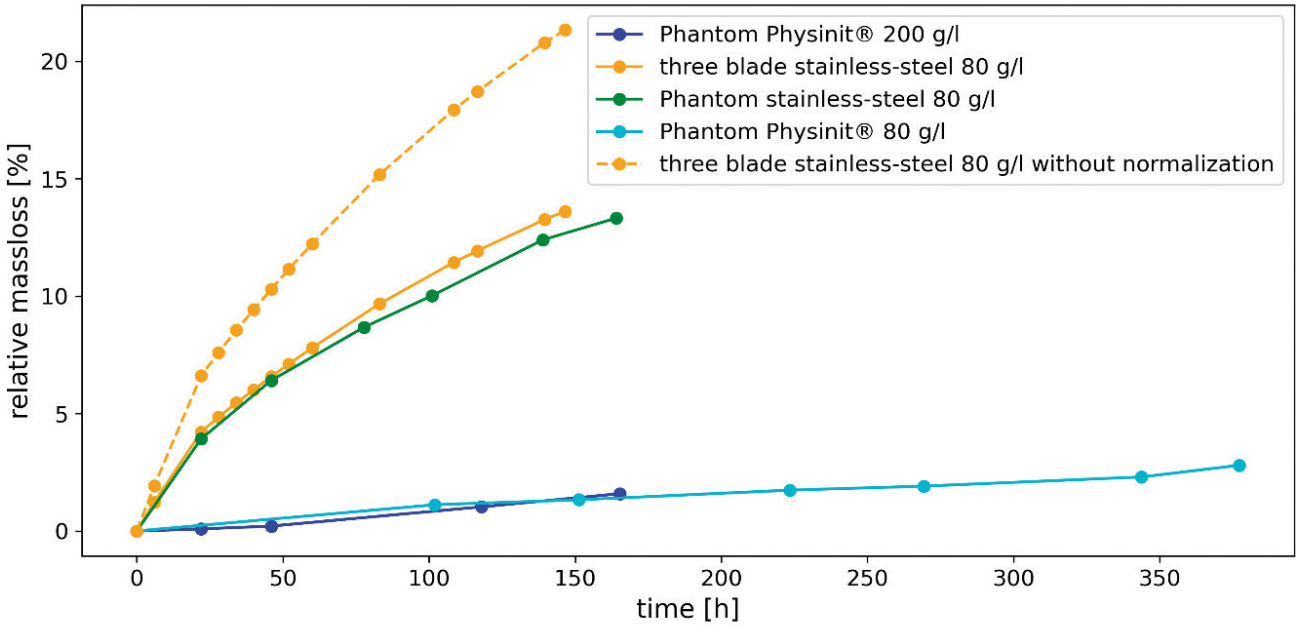


## Results

The graph illustrates the progression of relative mass loss over time for four propeller configurations tested under abrasive slurry conditions, with one configuration shown both with and without surface area normalisation. The three-blade stainless steel propeller at 80 g/l exhibits the highest mass loss, reaching approximately 13% after 146 hours when normalised, and over 21% without normalisation. The Phantom stainless-steel propeller at the same concentration shows a lower final mass loss of about 13% after 164 hours. Both Physinit® propellers display markedly lower values: the Phantom Physinit® at 200 g/l reaches about 1.6% after 165 hours, while at 80 g/l it accumulates around 2.8% after 377 hours. All curves indicate a steady increase in mass loss over time, with stainless steel configurations showing higher initial rates and more rapid accumulation compared to Physinit®. The normalisation of the three-blade stainless steel data reduces its relative mass loss values, enabling a more direct comparison with the Phantom geometry.

## Analysis

The measured data were also normalised based on the surface area of each propeller to accurately assess the influence of geometry. This showed that the wear rates between the stainless-steel propellers were somewhat identical. Therefore, the material behaviour remained the most critical factor. When normalised, Physinit® demonstrated up to 20 times greater resistance compared to stainless steel. The Phantom design also proved advantageous, as wear was evenly distributed across the blade. This shape stability supports longer, safer operation and reduces the likelihood of mechanical failures.




## Conclusion

The PTM GmbH test series demonstrates that Physinit® clearly outperforms stainless steel in abrasive mixing environments. Its 20-fold greater wear resistance, uniform degradation, and geometrical stability make Physinit® a suitable alternative for biogas mixing technology. For operators, this translates into longer maintenance intervals, improved process reliability, and lower operational costs.

These experiments were also covered in more detail in the peer reviewed paper *Comparison of Erosive Wear on Composite and Metallic Propellers in Slurry*, which was published in the MCM2025 conference proceedings and is free to access. If you want to learn more about the products that use the Physinit® propellers contact us or visit our website below.



*Pictures of propellers before (grey) and after wear tests. From left to right: Phantom Physinit® 200 g/l; three-blade stainless-steel 80 g/l; Phantom stainless-steel 80 g/l; Phantom Physinit 80 g/l.*

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# Efficient agitation technology

## Innovative technology and many years of experience

streisal GmbH was founded in 1988 as a manufacturer of submersible motors. Over the course of the years, we have developed into an internationally active, medium-sized full-range provider of agitators and mixing systems for all kinds of applications, thanks to a large number of technical innovations:

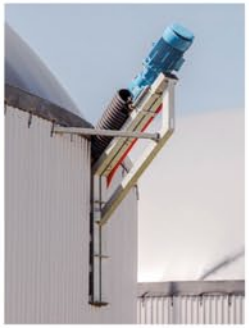
- Biogas plants
- Waste water treatment
- Industrial process technology

streisal's extensive delivery range extends from submersible motors, a modular system of horizontal submersible agitators in a very wide range of versions to vertical agitators and special designs that provide the features required to solve your individual problems.

With our many years of experience and insights gained from innumerable mixing tests, we are capable of selecting the right product for the particular individual case from this wide variety of options every time.

Active support and expert project handling, professional installations and startups, proficient repairs as well as simple and economical maintenance of our products are further reasons why many operating companies have chosen to work together with streisal. Use our expertise in optimising your system. Our employees will be happy to work out individual concepts for you.





## International explosion protection approvals



streisal GmbH has been a certified manufacturer of explosion-proof agitators and agitator drives for more than 30 years. Most of our agitator types can be produced and supplied for operation in potentially explosive atmospheres of zones 1 and 2 according to ATEX Directive 2014/34/EU (formerly Directive 94/9/EC), IECEx and CSA/UL.





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# Modern Mixing Technology Meets Sustainable Agriculture

## Background

Located in Picauville, this state-of-the-art biogas plant was designed, engineered and commissioned by WELTEC BIOPOWER in 2022. It is tailored for the use of agricultural residues and processes approximately 25,000 tonnes per year of various organic substrates, including cattle slurry and manure, horse manure, poultry manure and energy crops.

The facility is equipped with two digesters, each with a diameter of 25.34m and a height of 6.30m, resulting in a gross volume of 2 x 3,176m$^3$.

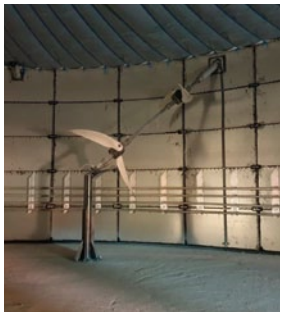


To ensure complete homogenisation of substrates with varying characteristics and to keep sediment-prone particles in suspension, STREISAL designed, manufactured, and supplied two Biobull® agitators and one TSR submersible agitator for each digester.

The complementary mixer types deliver excellent performance and energy efficiency, supporting the operational goals of renewable energy production facilities.

## Configuration

With the agitator shaft installed at an inclined angle and two propellers positioned at different heights, the Biobull® agitators deliver strong hydraulic performance, generating both horizontal and vertical flow components.



Substrate flows freely as the agitating elements are free of obstructive built-in components. The three-dimensional propeller geometry, optimised in the fluid mechanics laboratory, along with large diameters and low rotational speeds, maximises thrust while minimising power consumption.

Important wearing parts are mounted externally and are therefore easy to access for maintenance and servicing. The agitator shaft is sealed by a gas-tight siphon seal with contactless operation.

## Durability



For submersible mixers, practical experience shows that the reliability and durability of shaft seals are critical for trouble-free operation, especially in media containing coarse, abrasive solids or long-fibre materials. STREISAL's patented seal system offers several key advantages: a highly wear-resistant silicon carbide mechanical seal; an upstream labyrinth seal to block contaminants; and a submersible agitator housing with an easily replaceable wearing ring. The mechanical seals are mounted in a stainless-steel holder with internal spring elements, ensuring no contact with the medium and eliminating clogging.

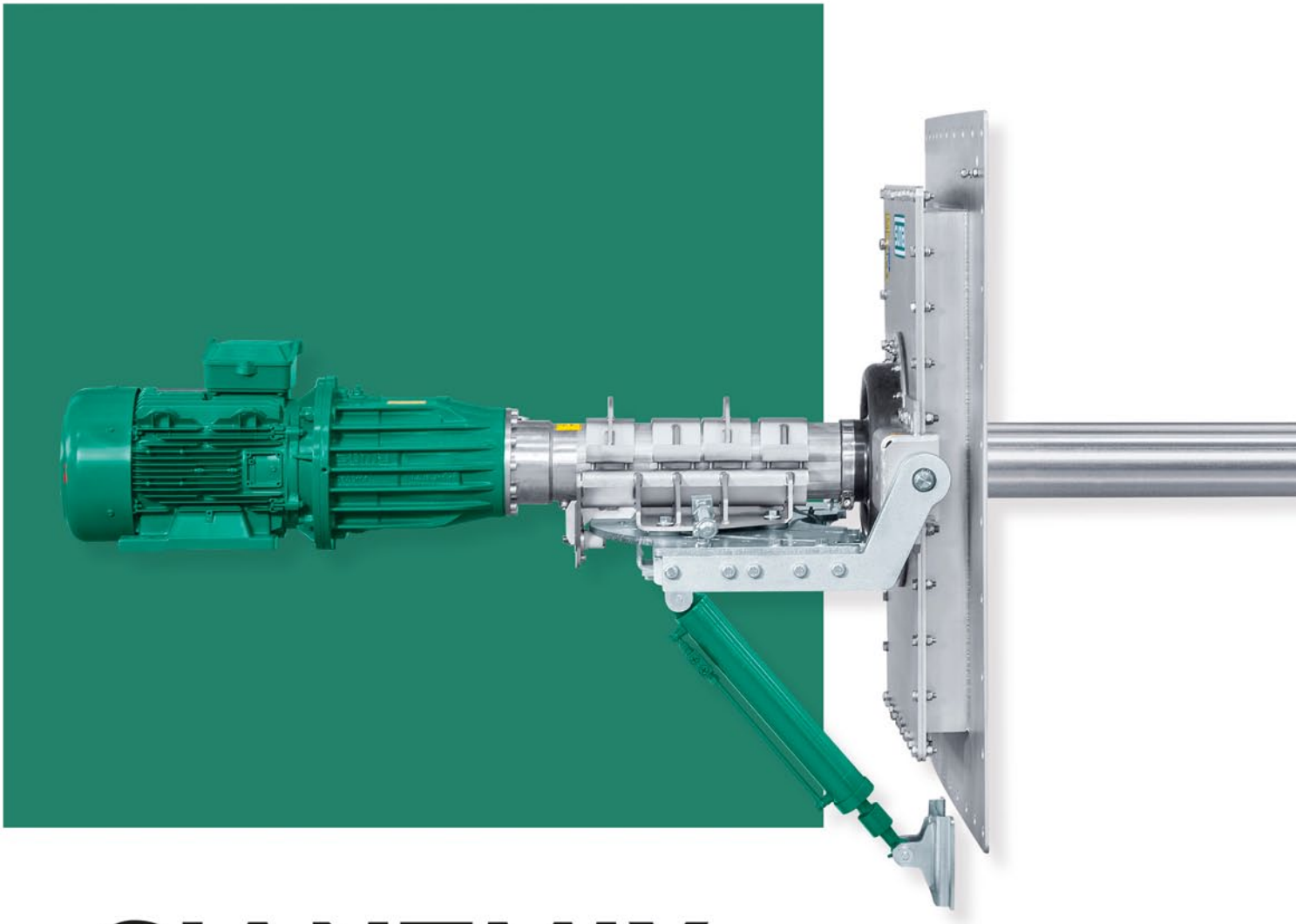
Another key feature of the plant is its integrated biogas upgrading system, which enables the injection of approximately 100 Nm$^3$/h of biomethane into the local natural gas grid - a significant contribution to sustainable regional energy supply.

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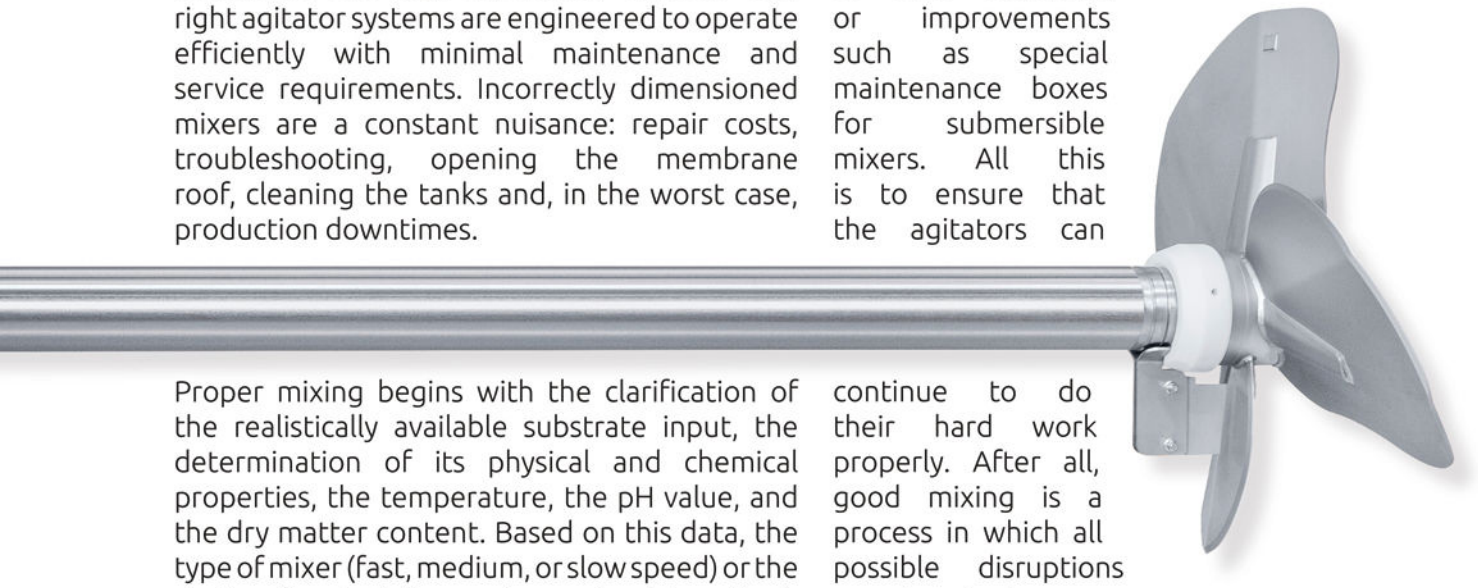
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## Proper mixing is a challenge

Agitators are not a substantial cost factor in the overall budget of a biogas investment. Perhaps for this reason, investors often assign them a less important role in the process and do not participate directly in selecting the right agitator technology. This is a misconception, as agitators play a crucial role in the profitability of a biogas plant.

Agitators ensure that the substrate is properly homogenized and that heat and nutrients are distributed correctly in the tank, which has a direct impact on the well-being of the fermentation bacteria and biogas production. The stirring time and thus the biogas plant's own power requirement depend largely on the efficiency of the agitators. The lifespan of the agitators also depends on the operating time. Even under demanding conditions—such as substrates with high dry matter content—the right agitator systems are engineered to operate efficiently with minimal maintenance and service requirements. Incorrectly dimensioned mixers are a constant nuisance: repair costs, troubleshooting, opening the membrane roof, cleaning the tanks and, in the worst case, production downtimes.



Proper mixing begins with the clarification of the realistically available substrate input, the determination of its physical and chemical properties, the temperature, the pH value, and the dry matter content. Based on this data, the type of mixer (fast, medium, or slow speed) or the choice of material type, etc., can be determined. The second important point is planning the preparation of the substrate before it enters the digester. The tank dimensions can then be used to determine the required W/m3 quantity – a value that is essential for selecting the right number of agitators with the appropriate power and thrust. If the type of substrate and its tendency to form scum or sludge are known, the appropriate positioning of the agitators can be planned. It is worth checking the assumptions made using computational fluid dynamics (CFD), as this is the only way to verify the behavior of the substrate in the tank during the design phase. CFD analysis shows whether the substrate achieves an adequate average velocity across the entire tank volume with the assumed number of agitators, illustrates its behavior at individual liquid levels, and identifies possible dead zones that lead to a reduction in the active tank volume. The simulation will also make it possible to evaluate the quality of mixing in a fixed setting or the advantages of adjusting the position of the agitators in the vertical and horizontal directions during operation.

When selecting mixing technology, consideration should also be given to how the equipment is to be installed, serviced, and maintained, especially in closed tanks used in biogas production. At this point, it is worth taking a look at the operating instructions to determine what maintenance work is required at what intervals to keep the system in operation. Once you are aware of this issue, you can consider agitators that are easier to access for maintenance, such as central or side agitators, or improvements such as special maintenance boxes for submersible mixers. All this is to ensure that the agitators can continue to do their hard work properly. After all, good mixing is a process in which all possible disruptions are minimized.

A well-chosen agitator system is the key to success for an efficient biogas plant. However, to make this possible, you first have to "learn" what agitation is all about. After all, biogas is good business, but only for those who are informed.



# Unlock Process Stability and Higher Yields with Smart Mixing

## EV Technology for Smart Mixing

Proper mixing is one of the most critical - and often overlooked - aspects of successful anaerobic digestion. Without it, tanks can quickly experience floating crusts, grit accumulation, uneven digestion and odour issues. Left unresolved, these problems reduce biogas production and can lead to costly downtime, dredging or even equipment failure.

Anaergia developed the OmniMix™ submersible mixer to address the unique challenges of high-solids digestion. Engineered with the same high-efficiency motor technology found in electric vehicles, OmniMix™ uses a permanent synchronous magnet drive with smart controls to dynamically adjust torque and rotational speed. This ensures efficient mixing of even viscous, high-solids substrates while consuming significantly less energy than conventional mixers.

## Operational efficiencies

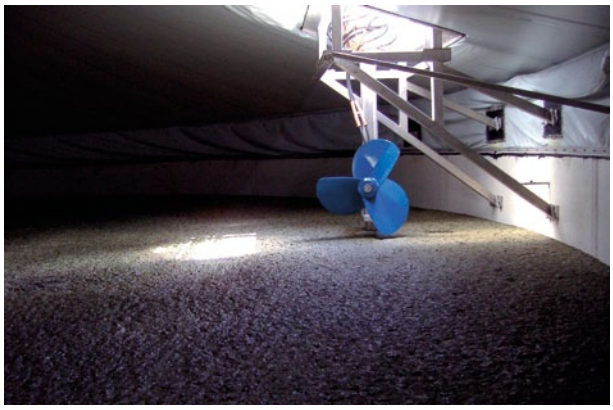
The system features a sickle-shaped, anti-ragging propeller that resists wrapping from fibrous materials. A built-in feedback loop continuously monitors torque and mixer speed, allowing real-time adjustments for optimum performance. Operators can also set mixers to run intermittently, cycling on and off to achieve energy savings without compromising process stability.



***Reliable mixing from the ground up:*** *The OmniMix™ submersible mixer being installed to ensure predictable digester stability and higher biogas yields.*

Beyond energy efficiency, OmniMix™ is designed for operational practicality. Each unit is mounted on a stainless-steel support column with Anaergia's patented Service Box Pro. This enclosure allows maintenance and inspection without taking the digester offline - a major advantage that avoids costly process interruptions. The system also enables height and swivel adjustments for optimal mixing coverage, simplifying installation and operation.

**Anaergia** is a global leader in renewable natural gas solutions, with more than 300 patents and a track record of over 1,700 installations globally.



***From installation to operation:*** *The OmniMix™ submersible mixer at work, delivering the consistent mixing needed for higher yields and reduced downtime.*

By keeping solids in suspension, OmniMix™ maximises volatile solids reduction and prevents sedimentation and crust formation. These improvements translate directly into smooth, predictable operation - the kind operators rely on to avoid costly interruptions. The result is higher methane yields, lower operating and maintenance costs and greater long-term stability of the digestion process.

## Complementary Technologies

At Anaergia, equipment is engineered to address the practical realities operators face on the ground. OmniMix™ is not a standalone mixer, but part of Anaergia's complete anaerobic digestion solution - designed to work seamlessly alongside pre-feeding, digestion and upgrading technologies. By integrating mixing into the broader package, Anaergia ensures higher gas yields, more stable operations and lower lifecycle costs for customers worldwide. ***See also, Pre-feeding and Turnkey Solutions.***

Get in touch to explore how OmniMix™ can reduce energy costs and improve stability in your operations.

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# Digestate Management

Anaerobic digestion produces not only biogas but also digestate - a nutrient-rich by-product with significant potential as a bio-fertiliser or soil improver. Managing this digestate is a key component of plant operation, as it represents both a valuable resource and revenue stream, and a logistical challenge.

Digestate management technologies are designed to stabilise the active substrate leaving the AD tanks, separate the water or liquid fraction, improve handling and enhance market value. **Pasteurisation (hygienisation)** ensures that the material meets sanitary standards, especially when applied to land. **Liquid-solid separation** reduces transport costs and allows the liquid fraction to be spread more easily. **Drying and pelletisation** further concentrate nutrients, creating products that can be stored, transported and sold into broader markets such as horticulture.

The choice of management strategy depends on regulatory requirements, nutrient balance and economic considerations. In some regions, digestate is returned to farmland directly after the anaerobic digestion process; in others, further treatment and processing post-digestion is essential to meet environmental or commercial demands, most commonly pasteurisation.

Pasteurisation may be required in cases where the digestate is being spread to multiple farms or locations - this is to prevent something colloquially known as "digestate tourism", whereby if a pathogen were to enter the AD facility in the feedstock from one location and then mixed in the AD process, it may then be spread to multiple receptors as contaminated digestate.

In many regions, the decision on whether pasteurisation is required will depend on local veterinary offices or regulations. The pasteurisation process will likely involve some form of moderate-high heating for a prolonged period (i.e. 70°C for one hour batch to reach PAS110 in UK, or similar, i.e. 24 hrs at 60°C  in other regions).

By turning digestate from a disposal issue into a valuable output stream, biogas plants can enhance their overall sustainability and revenue potential. Proper digestate management closes the nutrient cycle, reducing the need for carbon-intensive artificial fertilisers, making anaerobic digestion a cornerstone of the circular economy.

After processing, digestate often requires storage before it can be transported, applied to land or further utilised. Digestate storage systems are designed to safely contain large volumes of liquid or semi-liquid material while preventing environmental contamination and maintaining operational flexibility.

Common storage approaches include flexible **membrane bags** and open or covered lagoons. Bags provide contained, sealed environments that minimise odour and emissions, whereas lagoons offer large-scale, lower-cost solutions suitable for rural contexts. The choice depends on land availability, regulatory requirements and economic constraints.

It must be noted that in many countries there is a requirement to cover lagoons, to prevent odour emissions, nutrient leaching and greenhouse gas release. These impacts can be mitigated by covering the lagoon with **floating covers** or implementing **aeration systems**.

Effective storage allows biogas plants to align digestate output with agricultural demand, ensuring nutrients are applied at the right time of year rather than immediately after production. Storage systems must also account for rainfall, runoff and potential leakage, making lining and covers important considerations for compliance and sustainability.

Digestate storage is not just about holding material; it is about safeguarding the nutrient value of the by-product, protecting the environment and giving operators flexibility in how and when digestate is returned to the soil.

## Technology Options for Managing Digestate

| Technology Option | Application | Key Benefits |
|---|---|---|
| **Aerobic Composting** | Composting solid fraction of digestate. | Produces stable, nutrient-rich compost; reduces pathogens and odour. |
| **Mechanical Separation (Screw Press, Centrifuge, Decanter)** | Separates raw digestate into solid and liquid fractions. | Facilitates easier handling, reduces storage space, allows targeted use (solid for soil, liquid for fertigation). |
| **Nutrient Recovery (Struvite Precipitation, Ammonia Stripping)** | Extracts nutrients like N, P, K from liquid fraction. | Produces concentrated fertilisers, reduces nutrient load in effluent. |
| **Drying / Pelletisation** | Converts solid digestate into dry pellets. | Easier transport and storage, longer shelf life, usable as fertiliser or soil amendment. |
| **Thermal Treatment (Pasteurisation, Hygienisation)** | Sanitises and stabilises digestate. | Kills pathogens, reduces odour, produces biochar-like material for soil amendment. |
| **Lagoon / Storage Tanks** | Temporary storage of liquid fraction. | Allows sedimentation, reduces immediate environmental impact, can be used for irrigation. |
| **Land Application (Direct or After Treatment)** | Using digestate as organic fertiliser on crops. | Recycles nutrients, improves soil structure, cost-effective nutrient source, replaces carbon-intensive artificial fertilisers. |

# Why Dewatering Matters and How Flocculants Help

Digestate is an unavoidable by-product of every anaerobic digestion process. While rich in nutrients, it also represents one of the biggest cost and compliance challenges for operators. Transport, storage, and land application are all driven by the water content of digestate, the more water removed, the lower the handling cost and the higher the nutrient value per ton. EU regulations and national directives are tightening requirements, pushing biogas plants to find more efficient and sustainable digestate management solutions.

However, dewatering digestate is often more complex than dewatering conventional municipal sludge. Digestates from mixed or industrial substrates typically have a high anionic charge and contain large dissolved organic substances such as biopolymers and humic materials. These characteristics make flocculation more difficult and increase the demand for tailored treatment chemistry.

**Flocculants play a central role in overcoming** these challenges. By neutralizing charge and creating robust flocs, they improve centrifuge and screw press performance, leading to higher dry matter content and cleaner reject water. The choice of flocculant and its dosage is critical: overdosing can reduce efficiency, while optimized combinations ensure both cost savings and compliance.



Kemira provides a broad portfolio for digestate dewatering:

- Superfloc® C-400 series: high molecular weight flocculants for centrifuge applications.
- Superfloc® C-500 series: for charge neutralization, often used in combination with C-400 or A-100 series.
- PIX® iron coagulants: effective for binding phosphorus and further improve the dewatering performance.

Together with our predictive dewatering tools and laboratory services, these solutions enable operators to reduce digestate handling costs, improve nutrient recycling, and make digestate management a value driver instead of a bottleneck.

## Case Study: Biogas Plant in Finland

A Finnish biogas plant treating 60,000 tons of organic waste annually, primarily sewage sludge and food industry side streams, faced challenges in meeting fertilizer specifications and recycling water back into the process. The target was clear: improve dewaterability to achieve >30% dry matter content in the digestate, while producing reject water with low turbidity suitable for reuse.

Kemira worked with the plant to optimise flocculant selection and dosage. By implementing Superfloc® XD-5300, the customer achieved:

- **33% higher dry matter content:** meeting fertiliser requirements.
- **30% lower turbidity in the reject water**, improving reuse potential.
- **25% lower polymer dosage** compared to previous treatment.
- **Improved centrifuge performance**, enabling stable and predictable operation.
- **Significant cost savings** through reduced treatment costs and more efficient nutrient recycling.

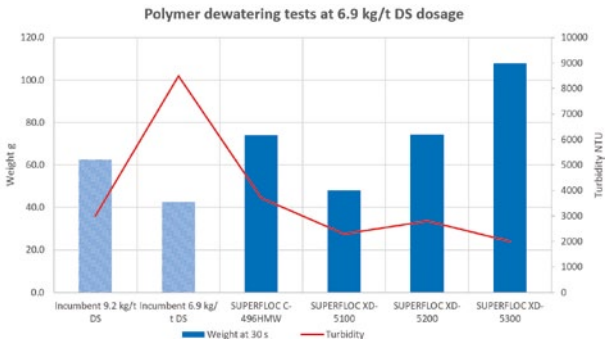



*Figure: Polymer dewatering performance comparison. Superfloc® XD- 5300 achieved higher reject water release and lower turbidity at a 25% lower dosage than the incumbent product.*

This case demonstrates the direct value of optimized flocculant chemistry in digestate dewatering. With the right solution, plants can move beyond compliance to achieve both environmental and economic benefits.

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# Biogas Processing

In a biogas system, gas cleaning and conditioning processes are essential to ensure that the biogas can be safely used for energy generation, upgrading to biomethane or other applications. These processes target moisture, trace contaminants and harmful gases such as hydrogen sulphide ($H_2S$), each of which can impair equipment performance, reduce efficiency or pose safety risks.

**Gas-liquid scrubbing and chilling systems** are used primarily to remove moisture from the biogas. Raw biogas may leave the AD tanks at 100% relative humidity (at 40°C+) and so may precipitate large volumes of water once the gas is cooled. Moisture in the gas can condense in pipelines, engines or upgrading units, causing corrosion, scaling or operational disruptions. In gas-liquid scrubbing, biogas is brought into contact with a liquid - often water or a chemical solution – that cools that gas and absorbs water vapour/liquid and certain soluble contaminants. Chilling systems further reduce gas temperature to condense residual moisture, allowing it to be drained from the system. This combination ensures a dry, stable gas stream suitable for downstream equipment. Many gas grid injection points require the gas to be dried to a very low temperature, to ensure no condensation will occur in the gas lines.

**Gas-solid scrubbing and activated carbon systems** are deployed to remove trace contaminants such as siloxanes, halogenated compounds or volatile organic compounds that are present in small quantities in biogas. These compounds can form abrasive or corrosive deposits when the biogas is transported or combusted, damaging engines, turbines or biogas upgraders. Activated carbon beds are typically used to adsorb these trace chemicals, effectively cleaning the biogas and extending the lifespan of critical equipment.

**Dedicated hydrogen sulphide mitigation systems** address one of the most critical contaminants in biogas: $H_2S$. Hydrogen sulphide is highly corrosive, toxic and can damage metals and catalysts in both energy generation and upgrading equipment. $H_2S$ removal can be achieved through chemical scrubbing, iron-based filtration media or biofiltration systems. Mitigating $H_2S$ protects gas engines, upgrading membranes and other processing equipment, and ensures that the gas meets safety standards for combustion or pipeline injection.

Collectively, these processes ensure that biogas is clean, stable and safe, maximising energy yield, protecting sensitive equipment and reducing health and environmental risks. By carefully integrating these systems, biogas plants can maintain consistent operational performance, whether the gas is used directly for heat and power or upgraded to biomethane for grid injection or vehicle fuel.

## Common Biogas Cleaning Approaches

| Biogas Processing Approach | Type of Technology | Target Contaminants | Key Benefits |
|---|---|---|---|
| **Moisture Removal / Dehumidification** | Condensation, refrigeration, silica gel dryers, desiccant beds. | Water vapour. | Prevents condensation in pipelines, reduces corrosion, avoids microbial growth. |
| **$H_2S$ Removal** | Iron-based media, activated carbon filters, biological scrubbers. | Hydrogen sulphide ($H_2S$). | Protects engines and equipment, reduces corrosion, improves gas quality. |
| **Ammonia Scrubbing** | Water or acidic scrubbers. | Ammonia ($NH_3$). | Improves gas quality, reduces air pollution when combusted. |
| **Biogas Chilling** | Refrigeration-based chillers, heat exchangers. | Water vapour, condensable organics. | Lowers gas temperature to condense moisture and trace organics, protects downstream equipment, reduces corrosion. |
| **Siloxane and VOC Removal** | Activated carbon filters, iron oxide, silica gel adsorption media. | Siloxanes and VOCs (common in landfill and sludge biogas). | Prevents silica deposits in engines and turbines, prolongs equipment life. |
| **Biogas Combustion** | Boilers, Combined Heat and Power (CHP) unit. | - | Produce electricity and hot water from combustion of biogas. |

# Safer and More Efficient Biogas with In-digester Chemistry

Hydrogen sulfide ($H_2S$) is one of the most critical challenges in anaerobic digestion. It is naturally formed when sulfur-containing compounds are degraded in an anaerobic environment, and even at relatively low concentrations it can have severe negative impacts on plant performance. High $H_2S$ levels are toxic to methanogenic microorganisms, suppressing gas yield. For operators, $H_2S$ represents a serious health and safety risk due to its toxicity and odour at leakage, while also causing rapid corrosion of engines, compressors, gas storage tanks and pipelines.

Many plants manage $H_2S$ downstream in the raw gas using biofilters, activated carbon, scrubbers or other technologies. While this can protect engines and gas quality, it does not prevent the negative impacts that elevated $H_2S$ levels cause earlier in the process.

Until gas treatment is applied, microbes are inhibited, and operating costs increase. Removing $H_2S$ only after digestion therefore means ***"treating the symptoms, not the cause."***

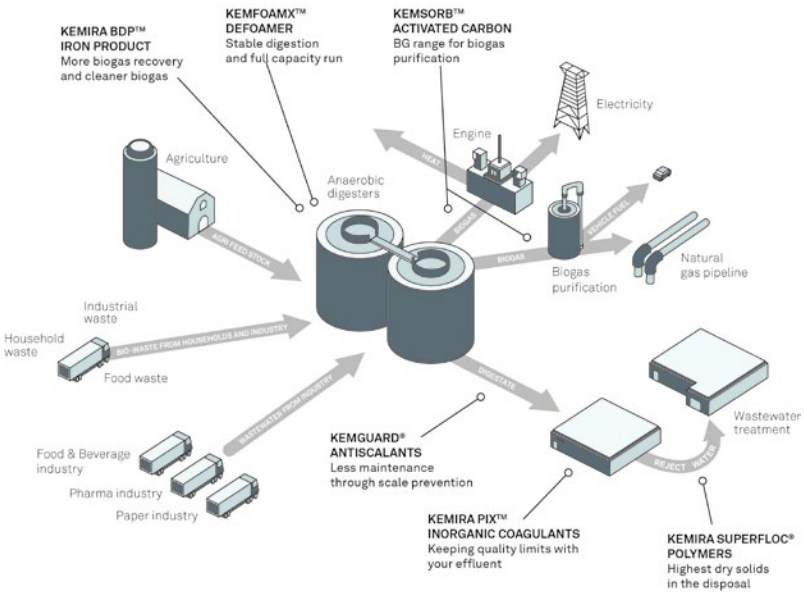
A more effective strategy is to control $H_2S$ directly in the digester. By dosing iron-based additives into the fermentation process, $H_2S$ is precipitated as stable iron sulfide before it enters the gas phase. This in-digester control delivers several benefits:

- **Safer operations:** eliminating high $H_2S$ peaks.
- **Better biology:** methanogens thrive in a more stable, less toxic environment, supporting higher loading rates and gas yields.
- **Lower costs:** chemical dosing in the digester is significantly more cost-efficient than downstream polishing methods.



- **Plant protection:** preventing corrosion at its source extends equipment lifetime.
- **More available micronutrients**.

In addition to $H_2S$, many plants also struggle with a lack of essential trace elements. Micronutrients such as nickel, cobalt and selenium are crucial building blocks in enzymes that drive the methanogenic pathway. When these trace elements are missing, as is often the case in substrates like household food waste or some food industry residues, the microbial community becomes stressed: volatile fatty acids accumulate, pH drops and methane yields decline. Supplementing the digester with the right balance of trace elements restores microbial performance, enhances stability and enables operators to safely increase organic loading rates.




**Kemira offers a broad portfolio of solutions to support in-digester stability:**

- **Iron chloride:** fast-acting, easy to dose, highly effective across substrates.
- **Solid iron hydroxide:** a stable, solid alternative with slower dissolution, suited to operational simplicity.
- **Iron chloride with trace elements:** tailored combinations that both remove $H_2S$ and provide the micronutrients needed for stable, high-yield digestion

Together, these solutions safeguard microbial health, secure $H_2S$ control, and unlock higher gas yields, making plants safer, more efficient and more profitable.

## Case Study: Restoring Stability and Capacity at Tekniska verken, Sweden

The Tekniska verken biogas plant in Linköping, Sweden, has been in operation since 1997. At one point the plant faced persistent operational challenges that limited performance and profitability. Despite access to a steady substrate mix, the digester struggled with poor process stability, foaming and high levels of volatile fatty acids (VFA). Attempts to increase the organic loading rate (OLR) failed, leaving the plant underperforming compared to its potential.

**A closer investigation revealed three critical underlying issues:**

- High hydrogen sulfide ($H_2S$) levels inhibited methanogens and created safety and corrosion risks.
- Ammonia inhibition negatively affected microbial activity and stability.
- Lack of trace elements limited enzyme function, leading to poor methane yields and VFA accumulation.

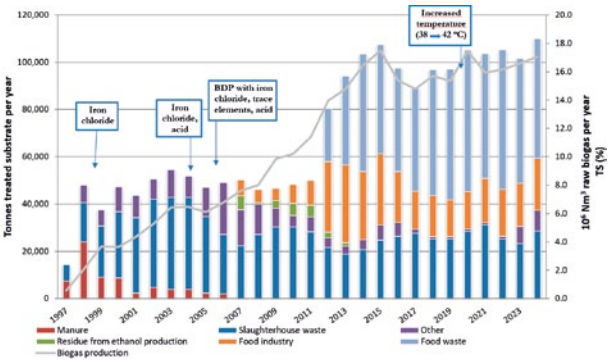
To address these challenges, Tekniska verken partnered with Kemira to co-develop a tailored Biogas Digestion Product (BDP). The solution combined iron for $H_2S$ precipitation, carefully selected trace elements to stimulate microbial metabolism and a low-pH formulation that reduced ammonia inhibition.

This holistic approach targeted the root causes of instability rather than relying on downstream treatment alone.



**The results were transformative:**

- **The plant was able to increase its OLR by 30%**, significantly boosting capacity.
- **VFA concentrations dropped and stabilised** at low levels compared to frequent peaks at destabilizing levels earlier.
- **Methane yield reached 65%**, reflecting more efficient microbial conversion.
- **Methane slip was reduced**, contributing both to better environmental performance and higher energy efficiency.
- **Overall, the economic outcome was greatly improved** thanks to higher throughput and more consistent operation.




*The evolution of biogas production, substrate intake and usage of iron based products at Tekniska verken biogas plant.*

This case demonstrates the importance of addressing both $H_2S$ and trace element deficiencies inside the digester. Iron dosing removed the immediate toxicity of $H_2S$, while tailored trace element supplementation restored the methanogenic microorganisms to full function. Together, this created the conditions for a robust and productive digestion process.

For other biogas plants facing similar challenges, whether linked to food residues, or ammonia-rich and many other substrates, the Tekniska verken experience highlights the value of combining iron-based chemistry with trace element support. By stabilising the microbial environment and preventing harmful compounds from accumulating, operators can unlock higher capacity, better yields and safer, more reliable operations.

Learn more about how Kemira can support your plant performance: **www.kemira.com/biogas**

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# Making Biogas Production Cleaner, Safer and More Reliable

Producing grid-quality biogas consistently is one of the greatest challenges facing plant operators. Managing biological processes, controlling harmful by-products and ensuring equipment reliability all have a direct impact on efficiency and profitability. For many sites, success depends on technology partners that can deliver dependable performance and low lifecycle costs. Atlas Copco provides compressed air, gas and oxygen generation solutions designed specifically to meet those needs, helping operators achieve cleaner, safer and more reliable biogas production.

## Oxygen's Essential Role in Biogas

Although anaerobic digestion is defined by the absence of oxygen, controlled oxygen dosing is crucial for stabilising the process. Introducing pure oxygen into the digesters helps regulate microbial activity and reduces harmful by-products such as hydrogen sulphide. This compound is corrosive, flammable and harmful to both operators and equipment.

Chemical dosing is one method of control, but it is expensive, requires careful handling and adds complexity. On-site oxygen generation offers a sustainable alternative. Atlas Copco's OGP and OGP+ ranges supply oxygen on demand with a purity between 90 and 95 per cent, with operators able to select the concentration that meets their process requirements.

## Leeming Biogas: Technology in Action

The benefits of this approach are demonstrated at Leeming Biogas in North Yorkshire. Operated by Iona Management Services, the facility produces more than five million cubic metres of biomethane annually, which is injected directly into the local grid. Food waste provides the feedstock, and the site's high sulphur content makes hydrogen sulphide control a priority.



*Gas blowers.*



*On-site oxygen generation assists in $H_2S$ removal.*




*Compressed air for $O_2$ generation and instrument air.*

The plant relies on an Atlas Copco OGP10 oxygen generator, supported by GA15FF rotary screw compressors, filtration and oil-water separation systems, and a piston compressor for plant duties. This integrated installation ensures a constant supply of oxygen at the correct purity, with low operating costs and minimal maintenance.

James Smith, General Manager at Leeming Biogas, explains: "Oxygen is fundamental to the generation of grid-quality biogas. It stabilises the biological activity inside the digesters, which promotes efficient gas generation and helps to reduce hydrogen sulphide. The Atlas Copco oxygen generator enables us to regulate and control that activity, which reduces the need for chemicals, improves safety and lowers costs."

With over 62,000 operating hours recorded, the system has proved to be robust and economical. On- site generation has also removed the need for bottled or liquid oxygen deliveries, cutting associated transport emissions while improving operational resilience. Atlas Copco solutions are supporting similar facilities globally, providing the proven reliability and performance that underpin successful renewable energy projects.

*$CO_2$ compressor.*



# Biogas: Say the word and we'll be there

Atlas Copco equipment supports all stages of the biogas production process, ensuring a reliable supply of high-quality biogas with low lifecycle costs.

- **B** **Blowers** - for the transportation of raw biogas for compression, purification and separation
- **I** **International support** - service & sales presence all over the world to support any biogas operation
- **O** **Oxygen generation systems** - for sustainable and cost-effective hydrogen sulphide removal
- **G** **Gas compressors** - to assist in various processes for upgrading biogas into biomethane
- **A** **Air & CO2 compressors** - for instrument air & to bring captured $CO_2$ to the desired pressure and quality for re-use
- **S** **Services & spare parts** - to optimise performance and cost efficiency of biogas plants





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## Supporting the Full Biogas Value Chain

Atlas Copco's involvement in biogas extends far beyond oxygen generation. The company's product portfolio covers the entire process, providing equipment for raw gas handling, upgrading, carbon dioxide recovery and biomethane distribution.

Biogas must be transported from its source for compression, purification and separation. Atlas Copco's powerful ZM blowers are designed for this role, transporting raw, unprocessed biogas to purification systems while ensuring a steady flow for methane and carbon dioxide production.

Once the hydrogen sulphide has been removed the biogas is ready for upgrading. Carbon dioxide is separated through processes such as membrane separation, Pressure Swing Adsorption or chemical scrubbing, leaving high-purity biomethane. Atlas Copco's GG-Series gas screw compressors, developed specifically for biogas upgrading, deliver the reliability required to keep these processes running smoothly.

The resulting biomethane can then be compressed further for final use. At pressures of 200 to 250 bar, it can be used as a clean alternative fuel to diesel and petrol. For grid injection, it is typically compressed to up to 100 bar. Atlas Copco's BBR and CU compressor ranges are engineered for these tasks, featuring pressurised crankcases that eliminate noise and gas losses, air-cooling systems to maximise efficiency, reduce maintenance needs and maintain control over the refuelling process.

## Technology for Resilient, Low-carbon Energy

As more operators upgrade biogas into biomethane and explore options for carbon dioxide recovery, equipment performance and cost efficiency become increasingly important. Compressors, blowers and oxygen generators must be capable of operating continuously with minimal intervention while maintaining the highest standards of safety and efficiency. Atlas Copco designs its systems with these requirements in mind, combining proven reliability with low lifecycle costs, allowing biogas operators to turn waste into energy and contribute to a resilient, low carbon future.

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# Biogas Upgrading

While clean, processed biogas can be used directly for heat and power, many operators choose to upgrade it to biomethane, a purified gas with a very high or pure methane concentration comparable to natural gas. Biogas upgrading technologies separate methane from carbon dioxide and other components, producing a versatile, valuable fuel.

Several technology routes are available for upgrading biogas to biomethane, each with distinct operational principles, advantages and suitability, depending on the feed gas composition, plant scale, site-specific and economic considerations.

The composition of biogas feed gas is influenced by several factors related to the feed substrate characteristics, digestion process and operational conditions of the anaerobic digestion system. These factors determine the relative proportions of methane ($CH_4$), carbon dioxide ($CO_2$) and trace contaminants such as hydrogen sulphide ($H_2S$), ammonia ($NH_3$), siloxanes and volatile organic compounds.

Separation technology includes:

**Membrane separation systems**, which operate on the principle of selective molecule permeability. Semi-permeable membranes allow $CO_2$, water vapour and other impurities to pass through (called "permeate") while retaining and effectively concentrating the methane fraction. Membrane systems are typically compact and modular, making them well-suited to applications where footprint and flexibility are important.

**Chemical absorption systems**, which rely on the selective solubility of gases in a chemical solvent, often amine based. In these systems, $CO_2$ and other unwanted gases dissolve in the solvent, separating them from methane. The loaded solvent is then "regenerated" in a separate area, releasing a concentrated $CO_2$ stream for potential capture or utilisation.

**Water scrubbing**, which similarly uses the solubility of $CO_2$ and $H_2S$ in water to separate these contaminants from methane.

Both chemical absorption and water scrubbing are well-established, reliable technologies that can handle variable feed gas compositions and are effective for larger plants with higher gas volumes.

**Pressure Swing Adsorption (PSA)**, which provides another established pathway for biogas upgrading. PSA systems utilise adsorbent materials that selectively bind $CO_2$ and other impurities under high pressure. By cycling through adsorption and depressurisation phases, PSA produces high-purity methane while generating a concentrated $CO_2$ stream. PSA is highly effective at producing pipeline-quality biomethane and can be integrated with $CO_2$ capture strategies.

Each of these upgrading technologies offers specific advantages depending on the characteristics of the feed gas, such as methane concentration, $CO_2$ and $H_2S$ content, and moisture levels, as well as plant scale, operational goals and economic drivers. Selecting the appropriate technology requires careful consideration of these factors to optimise performance, cost and product quality.

Biogas upgrading is the gateway to grid injection, vehicle fuel markets and advanced chemical applications. Biomethane can displace fossil gas in pipelines or be compressed and liquefied for transport.

By upgrading biogas, operators move from localised energy generation to full integration with energy markets. This step unlocks new revenue streams, reduces greenhouse gas emissions and positions biomethane as a cornerstone of the energy transition.

## Biogas Upgrading Technologies

| Upgrading Technology | Application / Target |
|---|---|
| **Water Scrubbing** | $CO_2$ and contaminant removal from biogas using pressurised gas in contact with water. |
| **Pressure Swing Adsorption (PSA)** | Separates $CO_2$, and contaminant gas from methane using adsorbent media with high surface area under varying pressure. |
| **Chemical Absorption (i.e. Amine Scrubbing)** | Chemically absorbs $CO_2$ and $H_2S$. |
| **Membrane Separation** | Selective membranes separate $CO_2$ and contaminants, leaving behind a purified CH4 stream. |
| **Cryogenic Separation** | Low-temperature liquefaction separates $CO_2$ and $CH_4$. |
| **Biological Methanation** | Converts $CO_2$ to $CH_4$ using hydrogen and methanogenic microbes. Not typically used for upgrading but may be used to generate from $CH_4$ from $CO_2$ by-product stream. |

# Turnkey Solutions

## Optimising Carbon Utilisation at a Food and Agricultural Waste Biomethane Facility

A food and agricultural waste biomethane plant was struggling to maintain gas quality compliance due to the limitations of its fixed activated carbon system, which caused frequent flow restrictions and downtime. The installation of a single VOCSorber® 30 mobile improved productivity, however due to the demands of the site, frequent carbon replacement caused challenges during peak demand periods and breakthrough events. Puragen engineered and installed a dual VOCSorber® 30 in a custom lead/lag configuration within the site's restricted footprint, completing the design, manufacture, and installation within two weeks and aligned to the site's planned shutdown. This agile solution improved treatment capacity, reduced carbon changeout frequency, and eliminated the risk of unplanned interruptions, enabling the plant to operate at full load with enhanced reliability, output, and compliance.




## Installation in just two weeks!

- Design
- Manufacturing
- Pipework Installation

## Key factors for success

### Engineering Agility

Rapid response and on-site customisation made implementation possible in a tight timeframe.

### Lead/Lag Configuration:

Provided increased treatment resilience and reduced the risk of breakthrough.

### Footprint Optimisation:

Careful design allowed installation despite initial concerns around space.

### Downtime Avoidance:

Completion during scheduled shutdown avoided production interruptions.

## The Result

The site is now running at **full load**, with improved biomethane output and plant uptime. The dual-filter setup provides enhanced purification performance and greater operational flexibility, reducing the frequency of changeouts and ensuring reliable grid compliance.

**Scan to read more**

Puragen




## Biogas Engineering Solution

### Quick turnaround on a fully engineered biogas filtration solution.

Puragen delivered a rapid biogas filtration solution for a major packaging manufacturer, restoring renewable power generation after a biofilter failure forced biogas flaring. The project involved extensive pipework and the installation of two VOCSorber® 30 mobile carbon filters—the site's first use of activated carbon. Puragen's in-house engineering team completed the full design, manufacture, and installation within just three weeks.
The customer has a long-established biogas plant on site making renewable energy from the wastewater produced in their paper and board recycling process.

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## WWTP Biogas Case Study

### Using activated carbon to protect CHP engines.

An interesting project at a biogas facility, linked to a major wastewater treatment plant. The site had not previously used activated carbon filtration, but the CHP engine had recently undergone a major overhaul and the client was keen to protect the unit from further damage caused by siloxanes and other VOCs in the biogas stream.

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# Bio-LNG Made Simple with PRISM® GreenSep LNG Membrane Technology

## Background

In the production of (bio-)LNG, a market standard at the inlet of a liquefaction process is <50 ppm $CO_2$. This limit is set due to the risk of freeze-out/crystallisation of $CO_2$ in the LNG liquefaction process. Common methods to reduce the $CO_2$ concentration at the inlet of the liquefaction process typically include amine scrubbing or thermal swing adsorption (TSA).

Generally, the biomethane at the outlet of a membrane unit contains ≤3 mol% $CO_2$. The $CO_2$ concentration needs to be further reduced to <50 ppm $CO_2$ before entering the liquefaction process. Therefore, biogas plants will typically utilise a TSA to meet the inlet specification of <50 ppm $CO_2$.

Air Products Membrane Solutions has successfully developed a specialised membrane called GreenSep LNG and an associated, proprietary membrane cycle that meets <50 ppm $CO_2$ at the outlet of the membrane unit, thus eliminating the requirement for an intermediate method to reduce the $CO_2$ concentration. This leads to reduced CAPEX, a decrease in OPEX and increased LNG production. The membrane and the associated cycle can be used for new installations or retrofit to existing biogas upgrading plants that are converting to bio-LNG production.

## Solution

Air Products Membrane Solutions' direct biomethane to bio-LNG solution consists of two innovative ideas that, combined, make GreenSep LNG possible. This solution allows for simple and direct biomethane to bio-LNG production with a normal power consumption in combination with an increased bio-LNG recovery.

The innovation is put to work in the second stage of the cycle, where cascaded membrane series utilise a concept called "sweep." The permeate of the downstream membranes sweeps the upstream membrane in the cascading stage, improving the $CH_4/CO_2$ separation significantly.

## Annual Savings

### Energy

**Energy reduction due to no heat demand for TSA/amine scrubber regeneration**

### Simplicity

**Straight forward system design with proven static "plug-and-play" membrane technology**

### Production increase

**100% of upgraded biomethane flow directly fed into the liquefication process**

### Maintenance

**Decreased maintenance costs and use of chemicals due to innovative design**

GreenSep LNG
AIR PRODUCTS
Simplified bio-LNG production



| | Current market setup | GreenSep LNG cycle |
|---|---|---|
| $CO_2$ concentration at membrane outlet | 1-3% | < 50 ppm |
| Thermal swing adsorber | ± 5 kWh | ✘ |
| Power consumption heater TSA | ✔ | ✘ |
| % regeneration of pure bio-$CH_4$ to TSA | 5-20% | ✘ |
| % Final bio-LNG production increase | ✘ | 5-20% |
| Cost of TSA | $160-220K | ✘ |
| Membrane count | 1x | 1.5-2x |
| Power consumption | 0.2 0.3 kWh/$Nm^3$ raw | 0.2-0.3 kWh/$Nm^3$ raw |
| Consumables (adsorbent) | ✔ | ✘ |

*Data above is based on estimates, project specific data will vary and impact performance.*

## Comparison

A high-level performance comparison has been made with the GreenSep LNG cycle and a common market setup: a three-stage membrane system producing biomethane at >97 mol% purity, and downstream, a thermal swing adsorption (TSA) unit to meet the <50 ppm $CO_2$ concentration requirement in the biomethane stream.

The reference case uses a standard biogas stream of 55% $CH_4$ and 45% $CO_2$. The flow used is 500 $Nm^3$/hr raw biogas. Operating pressures and temperatures were kept at the same levels. Effects of other components ($N_2$, $O_2$ and $H_2O$) were excluded from the comparison.

## Conclusion

The GreenSep LNG membrane product line and proprietary cycle improve the competitiveness of producing bio-LNG significantly by giving increased conversion from biomethane to bio-LNG. There are many more advantages to utilising Air Products' PRISM® GreenSep technology, contact us to find out more!





*Air Products PRISM® membranes applied in Nordsol's proprietary 'flash-to-sweep' bio-LNG process.*

AIR PRODUCTS Membrane Solutions

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# Integrated Resource Recovery: Boosting Profitability and Environmental Performance

Anaerobic digestion (AD) of biomass spans diverse applications, but all aim to optimise resource use, maximise long-term plant efficiency and reduce their carbon footprint. Examples of turnkey technical solutions for specific needs include:

Integrated resource recovery is growing globally. The US beverage sector is a case in point, with millions of tons of organic waste from wine, beer, and spirits production available to be converted into renewable energy via wet anaerobic digestion.

**A good example is in Kentucky**, where a plant with eight 9,000 $m^3$ digesters processes up to 1 million short tons of distillery stillage annually to produce biogas. Upgraded via an amine scrubber, it delivers 6,900 $Nm^3/h$ (4,300 SCFM) of high purity biomethane/RNG for grid injection. This integrated system maximises renewable energy and fertiliser output while cutting the distillery's GHG emissions by up to 50%.



*Kentucky, distillery with a wet AD plant for $CO_2$ and LNG production and grid injection.*

**In Germany**, the current priority is for solutions to keeping existing AD plants profitable. One example is a wet AD facility, with amine scrubbing gas upgrading, that has been in operation for many years running on substrates such as corn silage.

To meet current regulations, a second fermentation line to process manure and slurry was added. To increase the value, the plant now also features $CO_2$ liquefaction unit, producing food-grade $CO_2$, and a biomethane liquefaction unit, generating bio-LNG as a climate-neutral alternative to fossil fuels - particularly for decarbonising heavy transport.



*Germany, wet AD profit-driven retro-fit through $CO_2$ and LNG production.*

**At a site in Sweden**, by contrast, high throughput volume and varying substrate composition meant that the most suitable process for the recycling of municipal food and green waste was Kompogas™ dry AD technology with plug flow fermenters. Biogas is upgraded via membrane technology and supplied as biomethane to regional CNG stations for buses, garbage trucks and cars.

In view of the challenging raw gas composition, the advanced contaminant removal module, specially developed for waste-based biogas plants, is used in the pre-treatment stage to protect the membranes as effectively as possible.



*Sweden, dry AD and CNG production.*

**In addition to a comprehensive one-stop technology portfolio**, a key factor enabling the use of specific combinations of solutions in the various AD processes is expertise in coordinating the different technologies involved. Finding the best possible solutions for our clients, again and again, is what drives us.

Kanadevia INOVA

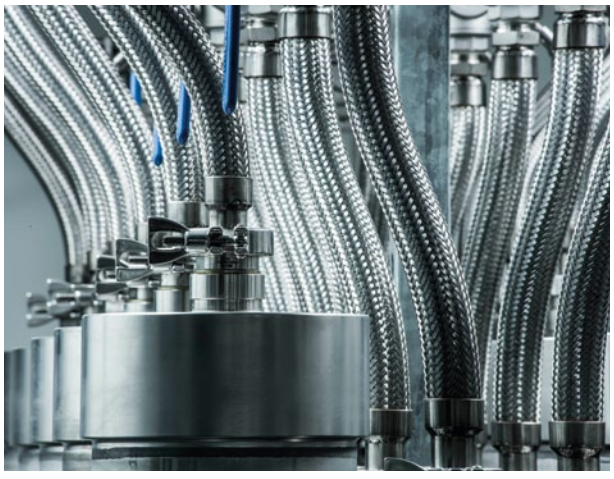
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# PRODEVAL's VALOPUR® Membrane Technology Powers Biomethane Expansion in Brazil

**Brazil's biogas potential is among the world's largest**, estimated at 85 billion $Nm^3$ per year, yet only a fraction - around 3 million $Nm^3$ - is currently upgraded to biomethane. To unlock this opportunity and meet rising renewable energy demand, PRODEVAL established its Brazilian subsidiary, PRODEVAL LTDA, in 2024. The company's first project in the country demonstrates how advanced upgrading technology can transform agro-industrial waste into high-quality, grid-compliant biomethane.

At the H2A Campos Novos site in Santa Catarina State, developed for H2A Soluções Ambientais, PRODEVAL deployed its second-generation VALOPUR® 05 membrane unit. The facility processes livestock by-products to produce raw biogas, which is upgraded using VALOPUR's three-stage membrane separation system. The compact, containerised unit separates $CO_2$ from $CH_4$ with an upgrading efficiency higher than 99.5%, consistently delivering biomethane that meets national (ANP) gas-quality standards.

**The VALOPUR system's pre-equipped container design** simplifies installation and operation, while its three-stage configuration provides operational flexibility, ensuring efficiency across varying feed gas conditions. PRODEVAL selects the most suitable membranes for each project, tailoring performance to customer requirements. Once





purified, the biomethane is compressed to 250 barg for safe transport and direct delivery to an industrial end-user.

Commissioning of the Campos Novos plant was completed in September 2025, officially marking the start of biomethane production. The facility processes 330 $Nm^3/h$ of raw biogas, producing 184 $Nm^3/h$ of biomethane - enough to power 64 urban buses for a year or supply the annual energy needs of 1,303 households. These figures highlight the tangible environmental and economic benefits of converting waste into renewable gas.

**The strategic impact extends beyond local energy supply**. By transforming agricultural residues into compressed biomethane, the project supports Brazil's energy transition and reduces reliance on fossil fuels. It also demonstrates how proven, modular solutions like VALOPUR can accelerate the adoption of renewable gas in markets with untapped biogas potential.

**PRODEVAL, a global leader in biogas treatment and upgrading**, has over three decades of experience and more than 580 installations worldwide. Headquartered in France and operating in about ten countries through seven subsidiaries, the company reported a turnover of €122 million in 2024. Its portfolio includes solutions for biomethane distribution as BioCNG and BioLNG, as well as $BioCO_2$ recovery, reflecting a commitment to sustainable energy and climate action.

PRODEVAL

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# Biomethane Utilisation

Once upgraded, biomethane can be used in a variety of applications. Its versatility as a renewable substitute for natural gas makes it one of the most valuable products of the anaerobic digestion process. After biogas is upgraded to biomethane, it can be utilised in several pathways depending on the end-use required, as will have been defined in the business case for the AD and biogas project.

Most commonly, the biomethane produced from the upgrading stage will be immediately compressed and "injected" into the local gas grid, with little or no buffer storage. This is likely to save costs and reduce on-site hazards, as buffer storage of compressed gas fuel can be expensive and unnecessary if a suitable grid injection point is available and prepared.

**Biomethane grid injection** requires the gas to meet strict quality specifications, including methane content, moisture level and contaminant thresholds. In some cases, a small amount of another gas (typically propane) must be mixed into the biomethane prior to grid entry to increase the energy density (also known as calorific value (CV)) of the injected gas mix, to better match the CV of the overall grid. Operators must manage compression, metering and odorisation if required, and continuously monitor gas composition and pressure to ensure safe and reliable grid injection. Coordination with grid operators and adherence to regulatory standards are essential for compliance and operational efficiency.

Another common approach is methane **compression and storage**. In this process, biomethane is compressed to high pressures, typically around 200–250 bar and stored in secure tanks or cylinders. This enables flexible supply, allowing the gas to be used when needed for vehicles, pipeline injection or as a buffer during periods of high demand. For operators, achieving this requires reliable compressors, pressure monitoring systems and adherence to safety protocols to handle high-pressure gas safely.

Another pathway is **Compressed Natural Gas (bio-CNG) or Liquefied Natural Gas (bio-LNG)** terminals. Here, compressed biomethane is stored for a short time in cylinders before being used as a vehicle fuel, such as for buses, trucks or fleet vehicles. Operators must ensure proper compression, cylinder filling procedures, leak detection and regulatory compliance for vehicle fuel quality, to maintain safety and performance standards.

In the bio-LNG process, biomethane is cooled to approximately –162°C, reducing its volume by roughly 600 times, and stored in cryogenic tanks. LNG allows long-distance transport or use in heavy-duty and marine transport where high energy density is required.

Each utilisation pathway has its own technical and economic requirements, but together they demonstrate the flexibility of biomethane as a renewable energy carrier. From heavy transport to domestic heating, biomethane provides a sustainable alternative to fossil gas, expanding the impact of biogas plants far beyond their site boundaries.

## Technologies Required to Prepare Biomethane for Different Utilisation Pathways

| Technology | Application | Description / Operation | Key Benefits |
|---|---|---|---|
| **Gas Compression Units** | High-pressure storage, CNG terminals, grid injection. | Compresses biomethane to 200–250 bar (or grid pressure) using mechanical compressors. | Enables storage and transport; ensures consistent supply; facilitates grid injection or vehicle fuelling. |
| **High-Pressure Storage Tanks** | Buffer storage, vehicle fuel, seasonal supply. | Stores compressed biomethane safely in pressure-rated vessels. | Provides flexibility in gas delivery; reduces supply interruptions. |
| **CNG Filling Stations / Terminals** | Transport fuel for vehicles. | Transfers compressed biomethane into cylinders or vehicle tanks. | Supports renewable transport fuels; allows fleet refuelling. |
| **LNG Liquefaction Units** | Long-distance transport, heavy-duty or marine fuel. | Cools biomethane to –162°C, converting it into liquid form for storage and transport. | Reduces volume ~600x for easier transport; enables high-energy applications. |
| **Cryogenic Storage Tanks** | LNG storage and distribution. | Stores LNG at extremely low temperatures in insulated tanks. | Maintains liquid state; prevents boil-off; ensures supply for transport or industrial use. |
| **Grid Injection Compressors and Metering** | Injection into natural gas pipelines. | Adjusts pressure and monitors flow and quality to meet grid specifications. | Enables large-scale distribution; allows use in heating, electricity and industry. |
| **Odorisation and Propane Dosing Systems** | Grid injection or safety compliance. | Adds odorant to biomethane for leak detection, and/or propane to increase overall energy density. | Enhances safety by ensuring gas leaks are detectable, meets grid injection requirements. |
| **Monitoring and Control Systems** | All utilisation pathways. | Sensors and automation track pressure, temperature, flow and composition. | Ensures operational safety, efficiency and regulatory compliance. |

# Maximising Biomethane Injection into the Gas Grid with Intelligent Pressure Management

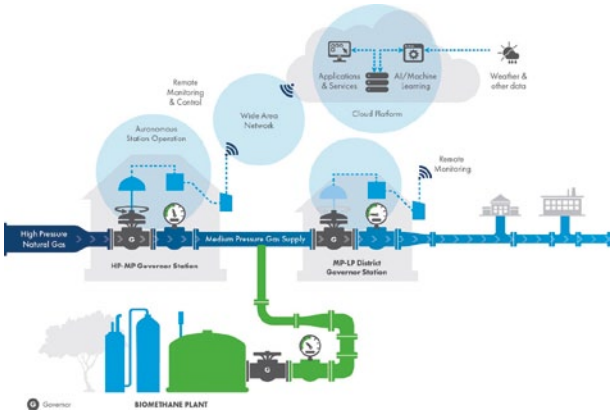
## Background

Biomethane plants are often constrained from injecting into the gas grid during periods of low demand. This challenge is most evident during the 'shoulder months' - spring and autumn - when fluctuating weather and temperatures make domestic heat demand highly variable.

Traditionally, the solution has been for distribution system operators (DSOs) to implement seasonal settings, whereby an engineer visits each regulator station and manually adjusts outlet pressures to suit the season: lower pressures for summer and raised pressures for winter. These seasonal settings are an expensive and time-consuming solution, involving many visits to many stations.

## Why Autonomous Pressure Management is the Solution

Utonomy addresses this challenge through remote control of medium-pressure (MP) gas networks via its autonomous pressure management system UtonomyOne. The company is currently deploying demonstration projects of this technology across gas networks throughout Europe. Implementing UtonomyOne allows gas DSOs to remotely and intelligently control medium pressure regulators to optimise the pressure in the MP network, to prioritise and enable the injection of biomethane - while maintaining and protecting security of supply.




*UtonomyOne combines machine-learning intelligence with innovative control and comms equipment to create smarter networks.*

Utonomy's regulator station hardware equipment communicates securely with remote control and monitoring applications running in Ucloud, the system's cloud platform. By utilising these applications, the DSO can change the timing and pressures of the autonomous set-point schedules remotely, providing greater flexibility and removing the need for costly site visits for manual adjustments.



*Electro-mechanical actuators are retrofitted to existing infrastructure.*

## Benefits of UtonomyOne for Biomethane Injection

- Meeting environmental targets for green gas injection
- Enabling more biomethane plants to be connected
- Avoiding negative publicity from plant operators frustrated at losing revenue
- Reduce travel and site visits for manual adjustment
- Increased network knowledge and control: monitoring and controlling the network enables faults to be diagnosed and rectified quickly.



*UtonomyOne pressure control installation at twin stream medium pressure regulation site.*

**Utonomy** is a leader in intelligent gas grid management, providing unique retrofit-ready hardware and advanced machine-learning-driven software. Our biomethane injection optimisation technology is helping gas networks and nations meet their green gas targets.

utonomy

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# Utilities

Every biogas plant relies on a range of utility systems to provide the energy, heat and power required to sustain operations. Utilities do not directly produce biogas, but they ensure that the process environment is controlled, the equipment functions reliably and the plant maintains stable performance.

A reliable utilities infrastructure is essential to ensure a biogas plant operates continuously and efficiently. **Combined heat and power (CHP) engines** are a cornerstone of this system, converting biogas into usable energy in the form of electricity and heat. CHP units allow the plant to meet its internal energy needs while exporting surplus electricity to the grid, enhancing overall efficiency. Operators must monitor engine performance, maintain fuel quality and ensure regular servicing to achieve consistent operation.

**Heating systems**, such as **biogas-fired boilers, backup fossil gas boilers or CHPs**, maintain the digesters at optimal temperatures for mesophilic or thermophilic digestion. Biogas boilers utilise on-site biogas directly, while fossil gas boilers provide redundancy during low gas production or maintenance periods. Effective temperature control maximises microbial activity and biogas yield, making heating infrastructure critical for process stability.

On the power side, the plant must manage both **electricity import and export**. Power import and export connections link the facility to the wider grid, enabling plants to purchase electricity when required and sell surplus production. Electricity may be imported during startup or maintenance of CHP units, while exported power provides additional revenue streams. Proper metering, synchronisation with the grid and protection systems are required to safely balance generation and consumption.

For additional efficiency, some plants incorporate an **Organic Rankine Cycle (ORC)** system. ORC units recover low-grade waste heat from engines, boilers or other sources and convert it into additional electricity. This process enhances overall energy recovery and reduces reliance on external power, improving the sustainability and economics of plant operations. However, this may introduce higher CapEx, OpEx and maintenance requirements.

Together, these utility systems - CHP engines, heating infrastructure, power management and ORC technology - ensure that a biogas plant can operate continuously, maintain optimal digestion conditions and maximize energy recovery, while providing flexibility for grid integration and energy export. Without robust and well-maintained utility systems, the biological process inside the digester cannot be sustained even if feedstocks and gas handling are optimised.

## Key Utility Technologies on a Biogas Plant

| Technology | Application | Benefits / Advantages |
|---|---|---|
| **Heat and Power Engines (CHP)** | Converts biogas into electricity and heat. | Provides on-site power and heat, allows surplus electricity export, improves overall energy efficiency. |
| **Heating – Biogas Boilers** | Maintains hot water circuit for site heating and optimal digester temperature. | Uses on-site biogas, supports stable digestion, maximises biogas yield. |
| **Heating – Fossil Gas Boilers** | Backup heating for digesters. | Ensures continuous operation during low biogas availability or maintenance periods. |
| **Power – Import and Export** | Balances electricity supply and demand. | Provides grid connectivity, enables revenue from surplus power, ensures uninterrupted operation. |
| **Organic Rankine Cycle (ORC)** | Converts low-grade waste heat into electricity. | Enhances energy recovery, improves overall plant efficiency, reduces external power reliance. |

# Lab, Instrumentation & Control

Biogas plants are complex systems, and their safe and efficient operation depends on accurate monitoring and control. Instrumentation and control systems provide the data and automation required to run the plant reliably, protect equipment and optimise performance.

**Supervisory Control and Data Acquisition (SCADA)** systems act as the central nervous system and brain of the facility, integrating signals from sensors and equipment across the site.

SCADA systems in biogas plants generally control and monitor 80–90% of the continuous operational parameters for all over the whole biogas process - temperature, pressure, flow, gas composition, moisture, and safety systems - allowing real-time adjustments, alarms and automated responses.

Sensors and monitoring devices track parameters such as flow rates, temperature, pressure and gas composition. Gas analysis systems measure methane, carbon dioxide, ammonia and hydrogen sulphide, providing critical information for both safety and efficiency. Flow meters, weight-scales and amperage meters ensure that feedstocks and biogas are moving through the system at the correct rates.

These systems provide operators with real-time data on critical parameters, enabling proactive management, optimisation of gas yield and prevention of process upsets.

**Temperature and Heating Control** Maintaining optimal digester temperature is essential for microbial activity, whether operating under mesophilic or thermophilic conditions (around 35–45°C and 45–50°C+ respectively). Temperature sensors integrated with heating systems, such as biogas boilers or heat exchangers, provide continuous feedback, allowing automated adjustments to maintain setpoints. This ensures stable digestion and maximises methane production.

**pH and Alkalinity Monitoring** pH sensors and online alkalinity probes track the chemical environment within the digester. This may be done in a lab manually rather than automatically, depending on the site. By providing continuous measurement of pH levels and total alkalinity, these instruments help operators detect acidification trends early, supporting timely interventions such as buffer addition or feedstock adjustment.

**Gas Flow and Composition Measurement** Flow meters and gas analysers measure the volume and composition of biogas, including methane, carbon dioxide, hydrogen sulphide and other trace gases. This information is crucial for optimising biogas utilisation, managing upgrading systems and ensuring the quality of gas for CHP units, grid injection or vehicle fuel.

**Level and Pressure Sensors** Level sensors monitor feedstock, digestate and storage tank volumes, while pressure sensors track conditions in digesters, pipelines and storage vessels. These measurements ensure safe operation, prevent overfilling or gas leaks and maintain stable hydraulic and gas flow throughout the plant.

**Moisture and Condensate Monitoring** Moisture sensors detect water vapour and condensate in gas lines, preventing corrosion and blockages in downstream equipment. Proper monitoring protects compressors, valves and upgrading systems, enhancing reliability and longevity.

**Control and Automation Systems** Centralised Supervisory Control and Data Acquisition (SCADA) and/or Programmable Logic Controller (PLC) systems integrate data from all instrumentation, enabling automated control of feedstock dosing, mixing, heating, gas flow and safety systems. Advanced alarm functions alert operators to deviations, allowing rapid corrective actions.

**Safety Instrumentation** Additional sensors, including flame detectors, gas leak detectors, and emergency shut-off systems, protect personnel and equipment. These systems ensure compliance with safety regulations and prevent hazardous incidents.

These systems provide a comprehensive operational picture, enabling continuous monitoring, rapid response to process deviations, optimisation of methane yield and safe, reliable biogas plant operation. By integrating real-time data with automated control, operators can maintain a stable digestion environment, maximise energy production and reduce the risk of downtime or environmental non-compliance.

**Laboratory services also form part of the control function**. Routine tests, such as Dry Matter (DM), "FOS/TAC" or "VFA/Alkalinity" ratios, and Biomethane Potential (BMP), provide insight into feedstock quality and process stability. These tests inform operational decisions and help predict potential upsets before they occur.

**Dry Matter (DM) content** measures the proportion of solids in feedstock or digestate after water removal. Maintaining optimal DM is critical for digester performance, as it influences viscosity, mixing efficiency and microbial activity. Monitoring DM enables operators to adjust feedstock composition, water addition or pumping regimes, ensuring consistent loading and preventing operational issues such as scum formation or localised overloading.

**The FOS/TAC ratio** – the ratio of volatile fatty acids (VFAs) to total alkalinity – provides a direct indicator of process stability. VFAs are intermediates in anaerobic digestion, and their accumulation can lower pH and inhibit methanogenic activity. By tracking FOS/TAC ratios, operators can detect early signs of acidification and take corrective actions, such as adjusting feedstock rates, adding buffering agents or modifying retention times, before biogas production is adversely affected. Stable operation is generally indicated by FOS/TAC ratios below 0.3–0.4.

**Biomethane Potential (BMP) testing** estimates the maximum methane yield achievable from a specific feedstock under controlled conditions. BMP results are invaluable for feedstock planning and co-digestion strategies, as they allow operators to predict biogas output, determine appropriate loading rates and avoid overloading the digester. This is particularly important when introducing new feedstocks, ensuring that operational targets are met while minimising the risk of process upset.

**Together, DM, FOS/TAC, and BMP testing** (among others) form an integrated monitoring strategy. DM addresses the physical characteristics of the substrate, FOS/TAC reflects chemical stability within the digester, and BMP provides foresight into potential biogas yield. By leveraging these routine tests, operators can optimise energy production, maintain stable digestion and proactively mitigate risks, ensuring reliable, efficient and safe biogas plant operation.

In combination, instrumentation and control safeguard both biology and equipment. They allow operators to transition from reactive management to proactive optimisation, supporting higher gas yields, lower maintenance and safer operations.

## Key Routine Tests and their Operational Relevance

| Test / Parameter | What It Measures | Operational Threshold / Indicator | Operational Use / Recommended Actions |
|---|---|---|---|
| **Dry Matter (DM) Content** | Proportion of solids in feedstock or digestate. | Dependent on digester design; typically 6–12% for wet digestion, 20–40% for dry digestion. | Adjust feedstock ratios, water addition or mixing to maintain optimal consistency; prevent scum formation or overloading. |
| **FOS/TAC Ratio** | Ratio of volatile fatty acids to total alkalinity. | Stable operation: 0.3–0.4. | Detect early acidification; reduce loading, add buffering agents or adjust retention times to maintain pH and microbial activity. |
| **Biomethane Potential (BMP)** | Maximum methane yield from a given feedstock. | Feedstock-specific; informs expected $CH_4$ output. | Plan feedstock loading and co-digestion strategies; prevent overloading; optimise biogas production and energy recovery. |

## Key Instrumentation Systems Deployed On A Biogas Plant

| Instrumentation | What It Measures | Purpose / Application | Key Benefits |
|---|---|---|---|
| **Temperature Sensors** | Digester and heating system temperatures. | Maintain optimal microbial conditions. | Ensures stable digestion, maximises methane production. |
| **pH and Alkalinity Probes** | pH levels, total alkalinity. | Monitor chemical stability and detect acidification trends. | Allows early intervention to prevent process upset. |
| **Gas Flow Meters** | Biogas volume and flow rate. | Track gas production, feed upgrading or CHP systems. | Optimizes energy utilization and plant performance. |
| **Gas Analysers** | $CH_4$, $CO_2$, $H_2S$, and trace gases. | Monitor gas quality for utilisation. | Ensures safe and efficient use of biogas in engines, upgrading or grid injection. |
| **Level Sensors** | Feedstock, digestate and storage tank levels. | Prevent overfilling and maintain hydraulic balance. | Enhances operational safety and process stability. |
| **Pressure Sensors** | Digester, pipelines and storage vessels. | Monitor system pressure and detect blockages or leaks. | Prevents equipment damage and ensures safe operation. |
| **Moisture / Condensate Sensors** | Water vapour and condensate in gas lines. | Protect compressors, valves and upgrading equipment. | Reduces corrosion risk and improves equipment longevity. |
| **SCADA / PLC Systems** | Integrated process data (temperature, flow, pressure, gas composition). | Automated control, monitoring and alarms. | Enables real-time control, rapid response to deviations, optimised production. |
| **Safety Sensors** | Gas leaks, flame detection, emergency shut-offs. | Ensure plant and personnel safety. | Prevents accidents, ensures regulatory compliance. |

# ActiSense Live Dashboard

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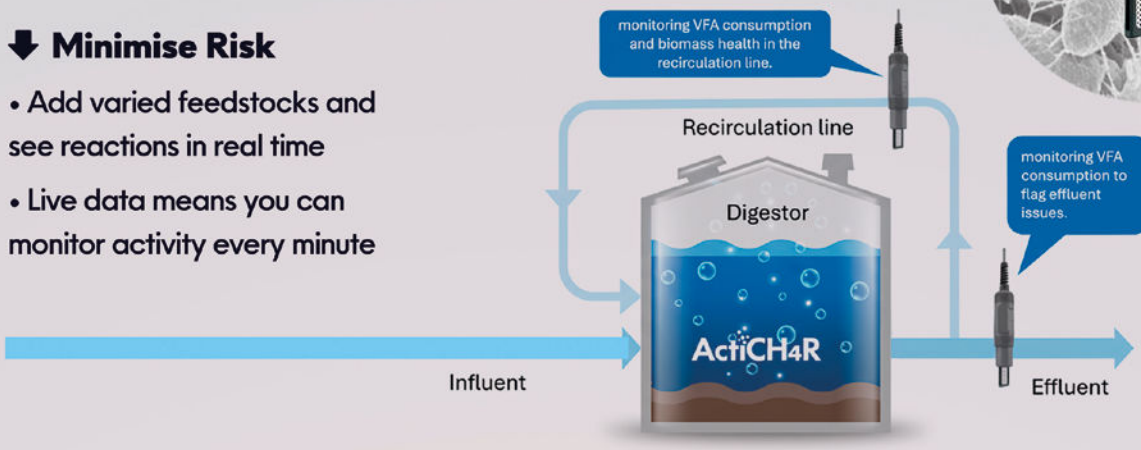


### ⬆ Maximise Loading

- Define the VFA threshold you are comfortable with for your digester
- Source additional feedstocks
- Increase loading while maintaining VFA below defined thresholds

### ⬇ Minimise Risk

- Add varied feedstocks and see reactions in real time
- Live data means you can monitor activity every minute




## How Does ActiSense Work

Unlike traditional monitoring equipment, the sensor does not use light or membranes to provide data but instead relies on the metabolism of microbes present in the system. **An early warning system that can help avoid system shock.**




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# How Cutting-Edge Gas Monitoring Protects People, Plants and Performance

## What is Gas Analysis and Why is it Important in the Production of Biogas?

Gas analysis in biogas production refers to the process of measuring and monitoring the composition of gases generated during the anaerobic digestion process. There are several reasons why it is important to analyse the gas composition:

- **Energy Quality Control**
- **Safety**
- **Process Monitoring & Stability**
- **Regulatory Compliance**
- **Optimisation of Plant Operation**

## What are the Options for Gas Analysis in the Production of Biogas?

Gas Data designs and manufactures a wide range of handheld and fixed location gas analysers, giving users the flexibility to choose from either a portable, handheld gas analyser that gives the freedom to quickly take samples from any location, or a fixed analyser that is installed at a single location, taking samples from fixed points to provide automated sampling at strategic points in a plant.

## GM25 Handheld Gas Analyser

Gas Data offers a wide range of handheld gas analysers for diverse applications. Options include configurable models built to site-specific requirements and fixed configurations for common uses, whether it is for a biogas AD plant, landfill energy generation and more. The GM25 range of gas analysers is highly accurate and reliable while being certified for use in potentially explosive EX Zone 1 atmospheres.



## GM25 Handheld Gas Analyser Benefits

- **Small portable design that's easy to hold in one hand**
- **Robust for site performance**
- **Datalogging via DataField GM25 Connect App**
- **Exhaust connection for easy bag sampling**
- **Servicing only required annually**
- **3 year warranty subject to annual servicing**
- **Fully user configurable**



## Click! Fixed Gas Analysers

Gas Data offers a modular range of fixed gas analysers for biogas and biomethane AD plants, wastewater treatment facilities, and landfill sites. The Click! series can be configured to each site's requirements, with cost-effective servicing, easy upgrades, and modifications to adapt as operations expand or change. The Click! range of gas analysers deliver high accuracy and improved operational efficiency.

## Click! Fixed Gas Analyser Benefits

- **Suitable for biogas, biomethane & landfill**
- **Up to 8 sampling points**
- **Multiple output options (4-20mA, digital)**
- **Modular design for easy servicing and upgrades**
- **Servicing only required annually**
- **Sample & purge sequencing**
- **Fully user configurable**

*Some of our clients*

## What is Methane Leak Detection and Why is it Important?

Methane leak detection is the process of identifying and measuring unintended releases of methane ($CH_4$) from equipment, pipelines, storage tanks, landfills, or natural gas/biogas facilities. Methane is colourless and odourless, so leaks cannot be detected by human senses alone; specialist technology is required to discover methane leaks. Why it is important to detect methane leaks:

- **Environmental Protection**
- **Safety**
- **Economic Value**
- **Regulatory Compliance**
- **Operational Efficiency**

Gas Data supplies a range of portable methane leak detectors for long-range detection up to 100m from the source. All our methane leak detection equipment utilises Tunable Diode Laser (TDLAS) technology for extremely accurate and precise measurements whilst eliminating the need for servicing, thus eliminating any ongoing maintenance costs. The benefits of TDLAS are as follows:

- **Tuned specifically for methane so no cross-gas sensitivity**
- **Near-instant response time (0.1s)**
- **No drift, so no ongoing servicing required, removing ongoing costs and downtime**
- **No specialist training required**
- **More cost-effective than other technologies such as OGI & IR**








## Our Gazoscan Range of Methane Detectors is Built to Suit Your Needs



**The Gazoscan** is an ATEX Zone 1 certified handheld remote methane detector that can detect methane up to and over 100m away. The Gazoscan has integrated Bluetooth, allowing it to be paired with our GAZOSURVEY app. This provides survey reporting options and enables data transmission to a mobile device with GPS for traceability.



**The Gazoscan Mini** is the pocket-sized and lightweight sibling of the Gazoscan, with a 15m range, designed for applications where regular monitoring is required, and you can find and fix a leak in minutes at a more cost-effective price point. The Gazoscan Mini has the same TDLAS technology with all-day battery life.

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# Quick Startup of a Digester using AMPTS Technology



## Introduction

Sustainable Technologies SLR has 15 years of experience in anaerobic digestion (AD) laboratory testing, pioneering a unique method for biological AD process management. To support this work, the company under the leadership of CEO Mario A. Rosato has expanded the application of the AMPTS III (Automatic Methane Potential Test System, 3rd Generation) from BPC Instruments AB - a high-precision respirometric instrument adapted for advanced AD analysis.

Chosen for its accuracy, consistency and ease of use, the AMPTS III enables reliable measurement of metabolic activity in anaerobic digesters. Its remote-access feature allows continuous monitoring without on-site supervision. Originally developed to measure biochemical methane potential (BMP), it now delivers valuable data for optimising anaerobic processes, to improve plant design, operational efficiency and long-term performance in industrial-scale AD facilities.

## The Challenge

After completing the retrofit of an existing anaerobic digester, an Italian wastewater treatment plant needed to accelerate the startup in winter because of budgetary limitations on the purchase of heating oil and commercial 'boosters.' Their operational plan involved processing secondary-stage aerobic sludge, using primary-stage sludge as inoculum, in line with established practices.

## The Solution

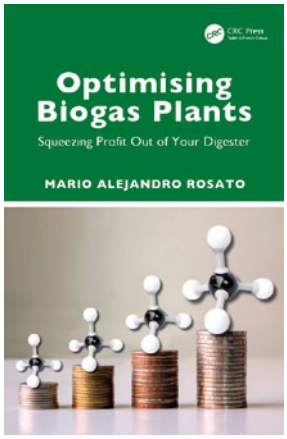
The first step was to check the SMA (specific methanogenic activity) of the primary sludge, which could not reach the minimum acceptable SMA. The second step was to check digestate from three biogas plants within a 50 km radius. The third step was to determine the minimum quantity of inoculum to reach full gas production within a week, the time required to heat the digester with the available thermal power. With 30 reactors at its disposal, Sustainable Technologies conducted duplicate trials of four inocula at three inoculum-to-sludge ratios, enabling the determination of the most effective configuration.

## The Result

The digester was filled with sludge and inoculated with the optimum quantity of digestate calculated from the tests. Four days after starting heating, the digester had not reached the nominal temperature, but the gas production allowed for a steady operation of the CHP. The thermal power was enough to allow turning the auxiliary boiler off, saving 40% of the budgeted heating oil. On reaching the nominal temperature, the CHP was running at full power and excess biogas was having to be flared. The 'unexpected excess' was the consequence of a design flaw: the engineering company calculated the CHP power based on 'the literature' and former operational data. This could have been avoided had they measured the BMP in the lab, using a standard protocol, before designing the system.

## Conclusion

An investment in an AMPTS and supporting equipment represents only a small fraction of a biogas plant's capital expenditure, yet it delivers rapid payback. By providing accurate data from the engineering stage, it enables optimised plant design and long-term performance gains. Sustainable Technologies srl can provide you with a turn-key laboratory, including staff training, consultancy and technical due diligence services.




For a deeper dive into Sustainable Technologies' methodology, see *Managing Biogas Plants – A Practical Guide* and *Optimising Biogas Plants - Squeezing Profit Out of Your Digester*, both written by Mario Alejandro Rosato and published by Routledge. Alternatively, attend one of the training sessions offered in English and Spanish by the World Biogas Association **www.worldbiogasassociation.org/events**.

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*Researching for Mankind and Planet*

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# Safety & Auxiliary Systems

Safety is a fundamental consideration in the design and operation of biogas plants. Biogas plants handle bulk solid and liquid masses, combustible gases, pressurised equipment and biologically active materials that can pose fire, explosion or health and environmental risks if not properly managed. A robust safety framework is essential to protect personnel, equipment and the surrounding environment.

Key systems include flaring units and pressure relief systems, to protect equipment from structural failure, and a large range of operational measures carried out by well-trained operator personnel. These core protections are supported by broader safety considerations such as gas detection, fire suppression and emergency shutdown systems.

The following systems are critical for ensuring safe and reliable operation:

**Flaring Systems** A biogas flare is a fundamental safety device for controlled gas disposal. During maintenance, equipment failure or emergencies where biogas cannot be used or stored, excess gas is directed to a flare stack and combusted safely. High-temperature flares ensure complete oxidation of methane and volatile organic compounds (VOCs), reducing greenhouse gas emissions and preventing uncontrolled releases.

**Pressure Relief Valves and Burst Discs** Digesters, pipelines and gas storage vessels are fitted with pressure relief valves or burst discs to prevent over-pressurisation. These devices automatically release excess pressure, protecting tanks and pipework from rupture. Proper sizing and routine testing of these components are essential to maintain plant integrity. These should only be activated in very rare cases of emergencies, i.e. flare faults, as it can otherwise lead to unmitigated release of greenhouse gases (GHGs) and VOCs to the environment.

**Gas Detection Systems** Fixed gas detectors positioned around digesters, CHP units, upgrading plants and gas storage areas continuously monitor for methane, hydrogen sulphide and carbon dioxide. Portable (handheld) detectors are also used for maintenance activities and for operators or site visitors when walking around the site. These systems provide early warnings of leaks, enabling operators to take corrective action before concentrations reach flammable or toxic levels.

**Fire Suppression Equipment** Fire risk is managed through automatic or manual fire suppression systems, including water sprinklers, foam systems or dry chemical extinguishers. Critical areas such as CHP engine rooms, gas upgrading units and electrical switchgear are typically equipped with targeted fire suppression to minimise damage and downtime in the event of an incident.

**Emergency Shutdown (ESD) Systems** An ESD system integrates valves, pumps and electrical isolation switches to quickly and methodically stop plant operations in response to critical alarms - such as gas leaks, fire or power failures. ESD systems are often connected to SCADA or PLC control, enabling automated responses and minimising human reaction time during emergencies (*See Instrumentation and Control*).

**Ventilation and Explosion Protection** Adequate ventilation in enclosed areas, such as CHP housings or upgrading containers, prevents gas accumulation. Explosion-proof electrical components and intrinsic safety barriers are deployed in hazardous zones to prevent ignition of flammable mixtures.

**Alarm and SCADA Integration** SCADA systems integrate all safety-critical signals - flare status, pressure relief activation, gas leak detection and ESD triggers - into a central interface. This provides operators with a clear overview of plant status and ensures rapid alarm notification and event logging.

**Secondary Containment and Spill Management** Digestate tanks and chemical storage areas may be equipped with secondary containment (bunding) to prevent environmental contamination in the event of leaks or spills. Drainage systems and emergency sumps support containment and cleanup efforts.

**Personnel Safety Measures** Safety showers, eye-wash stations and clearly marked emergency exits support worker protection. Comprehensive training, personal protective equipment (PPE) and lock-out/tag-out (LOTO) procedures are equally important parts of the safety infrastructure, to name a few.

These systems form a layered defence strategy. Together, they prevent hazardous conditions, minimise the impact of failures and ensure compliance with safety and environmental regulations. A well-designed and maintained safety framework not only protects people and equipment but also underpins the reliable and continuous operation of a biogas plant.

Safety systems are not optional extras - they are integral to compliance with regulations, insurance requirements and community trust. They provide redundancy in abnormal situations, ensuring that the plant can respond safely to fluctuations in gas production, equipment malfunction or grid interruptions.

Ultimately, safety systems ensure that the pursuit of renewable energy does not compromise the well-being of workers, local communities or the environment. They are the protective layer that underpins every other element of biogas plant operation.

## Key Safety Systems for a Biogas Plant

| Safety System | Function / Application | Key Benefits |
|---|---|---|
| **Flaring** | Safely combust excess biogas during maintenance or emergencies. | Prevents uncontrolled methane release, reduces greenhouse gas impact. |
| **Pressure Relief Valves / Burst Discs** | Release excess pressure in digesters, pipelines or storage vessels, in emergencies. | Protects equipment from rupture, maintains system integrity. |
| **Gas Detection** | Monitor methane, hydrogen sulfide and $CO_2$ for leaks. | Early leak detection, prevents fire, explosion or toxic exposure. |
| **Fire Suppression Equipment** | Sprinklers, foam systems or extinguishers for critical areas. | Minimises fire damage, ensures personnel and plant safety. |
| **Emergency Shutdown (ESD)** | Automated isolation of valves, pumps and electrical systems. | Rapid response to emergencies, limits escalation of hazardous events. |
| **Ventilation & Explosion Protection** | Prevents gas accumulation and ignition in enclosed spaces. | Reduces explosion risk, protects personnel and infrastructure. |
| **SCADA Alarm Integration** | Centralised monitoring of flares, gas detection, ESD (electrostatic discharge) triggers. | Ensures rapid alerts, coordinated responses and event logging. |
| **Secondary Containment / Spill Management** | Bunds and drainage to contain leaks or spills. | Prevents environmental contamination, aids cleanup efforts. |
| **Personnel Safety Measures** | PPE, safety showers, emergency exits and training programs. | Protects workers, ensures compliance with safety regulations. |

# Additives

In some cases, the natural digestion process benefits from carefully selected additives that improve biological stability and gas yields. By definition, additives are not essential to every plant, but where applied correctly they can support microbial health, mitigate inhibitory compounds and enhance overall process performance.

Nutrients and trace metals are often required to supplement feedstocks that lack the full spectrum of elements needed for microbial growth. Ferric salts are commonly used to reduce hydrogen sulphide ($H_2S$) formation by binding with sulphur compounds, protecting equipment and downstream processes. Bioactive materials, such as enzymes or microbial inoculants, may be introduced to accelerate degradation and increase methane yield or improve resilience against stress conditions. Below we briefly consider the major additive groups.

**Nutrients, Metals, and Ferrics** Anaerobic digestion depends on a balanced microbial community that requires not only organic feedstock but also essential nutrients and trace elements. Macronutrients such as nitrogen, phosphorus and sulfur support microbial growth, while trace metals - including cobalt, nickel, iron and molybdenum - are critical cofactors for key enzymes used by methanogenic archaea (microorganisms). Without sufficient metals, methane-producing microbes can become inhibited, leading to reduced gas yield and process instability.

Ferric compounds (e.g., ferric chloride or ferric hydroxide) serve multiple purposes: they supply iron to the microbial community while also binding hydrogen sulphide ($H_2S$) formed during digestion. This dual role helps reduce corrosion of downstream equipment, improves biogas quality and maintains stable microbial activity. Proper dosing and monitoring are essential, as excessive metal concentrations can become toxic to sensitive microorganisms.

**Catalysts** Catalytic additives are introduced to accelerate or enhance specific stages of anaerobic digestion. These may include enzyme preparations or mineral-based catalysts that promote the breakdown of complex organic molecules - such as lignocellulose, fats or proteins - into simpler compounds that microbes can digest more readily. By improving the hydrolysis and acidogenesis steps, catalysts can increase the rate of biogas formation and improve overall conversion efficiency.

Some advanced catalysts also aid in reducing refractory compounds (e.g., long-chain fatty acids) that can otherwise inhibit microbial activity. Their use can shorten hydraulic retention times, increase throughput and stabilise performance, particularly when dealing with variable or difficult feedstocks such as agricultural residues or food processing waste.

**Bioactive Materials** Bioactive additives include microbial inoculants, biochar and other biologically active agents that support or enhance the microbial ecosystem within the digester. Microbial inoculants introduce robust or specialised strains to outcompete inhibitors or accelerate digestion start-up. Biochar and similar porous materials provide physical surfaces for microbial colonisation, improving biomass retention and creating micro-environments that protect microbes from toxic shocks.

These materials can buffer pH fluctuations, reduce ammonia inhibition and improve gas yields by stabilising the microbial consortia. In some cases, bioactive materials also adsorb inhibitory compounds such as heavy metals or excess volatile fatty acids (VFAs), indirectly maintaining a healthy microbial balance.

The use of additives must be carefully managed, as over-application can lead to unintended effects or unnecessary costs. Their selection should be based on laboratory analysis, demonstrable success and followed with thorough process monitoring, ensuring that interventions are targeted and effective.

When applied strategically, additives are a fine-tuning tool. They allow operators to maintain stable digestion, maximise gas yields and safeguard long-term plant performance.

## Common Additive Groups Utilised in the Biodigestion Process

| Additive Group | Function / Application | Key Benefits |
|---|---|---|
| **Nutrients, Metals & Ferrics** | Supply essential macronutrients (N, P, S) and trace metals (Co, Ni, Fe, Mo) for microbial enzymes; ferric compounds bind hydrogen sulfide ($H_2S$). | Prevents nutrient deficiencies, supports methanogenic activity, reduces $H_2S$ corrosion, stabilises biogas quality. |
| **Catalysts** | Enzyme preparations or mineral catalysts enhance hydrolysis and acidogenesis, improving breakdown of complex organics (e.g., lignocellulose, fats). | Increases digestion rate, improves methane yield, shortens hydraulic retention times, stabilises performance on variable feedstocks. |
| **Bioactive Materials** | Microbial inoculants, biochar or other carriers strengthen microbial consortia, provide colonisation surfaces, buffer pH and adsorb inhibitors. | Stabilises microbial populations, mitigates ammonia or VFA inhibition, increases gas yield and improves process resilience. |

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# LEADING THE NEW GENERATION OF BIOGAS

Liquid nanotechnology for a more circular economy

**Discover our innovative additive!**

## Advantages of Ce-in Biogas

- Increases production by up to 40%
- Efficiently removes $H_2S$
- Provides nutrients for optimal performance
- Improves digestate for use as fertiliser
- Protects the digester
- Reduces operating costs



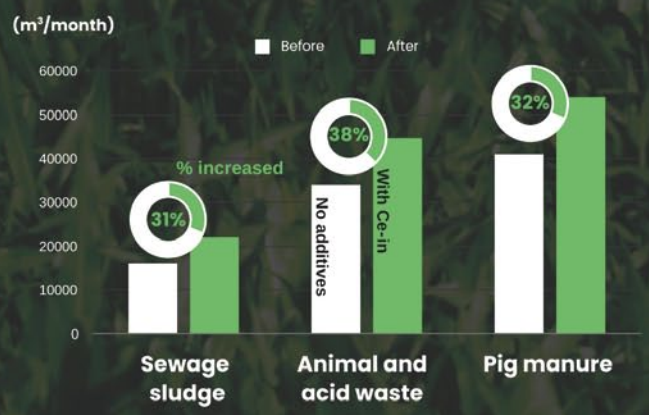

**Neutral pH**

**Chlorine-free**

**Non-corrosive**

**Easy to handle**

### Biogas upgrade




### Removal of $H_2S$




## Why choose us?

- 27 years of research.
- Patented technology.
- Competent staff and specialized laboratories.
- Personalised technical support.

At Calpech, we optimise processes and help you maximise the efficiency and profitability of your biogas plant.

**Innovation with purpose, growth with commitment.**

# From Scientific Breakthrough to Market-Ready Innovation in Biogas

## Boosting Biogas

Calpech, a spin-off from the University of Alicante, specialises in advanced waste treatment and valorisation technologies. Its founding research team has developed a pioneering technology that converts low-value agricultural residues into carbon-encapsulated iron nanoparticles - high-performance materials with significant environmental and industrial applications.

This circular-economy innovation slashes the production cost of iron nanoparticle, removing market barriers and enabling their use in environmental remediation, sustainable fertilisers and - most notably - biogas production optimisation.

## Award Winning

In 2023, Calpech won the Best Young Inventor Patent award from the Spanish Patent and Trademark Office (OEPM), with protection also secured at the European level. The company has since built its first industrial plant to produce nanoparticles from agricultural waste. Calpech also created Ce-in Biogas, an additive for biogas plants that boosts methane production and removes $H_2S$ in anaerobic digesters.

The industry quickly took notice. In 2024, Calpech won the Naturgy – Connecting Energy Award for innovative energy solutions. In 2025, it received the Avelino Corma Award for Innovative Chemical Companies and the Silver Prize in the Biogas category at the Bio360 Innovation Competition in Nantes, France.



**Plant 1 (Catalonia)**
Biomethane upgrade 18%
$H_2S$ level stabilization 37ppm.

**Plant 2 (A Coruña)**
Biomethane upgrade 12%
$H_2S$ level stabilization 150ppm.

**Plant 3 (Toledo)**
Biomethane upgrade 26%
Removal of $H_2S$ 700ppm.

**Plant 4 (Alicante)**
Biomethane upgrade 27%
Removal of $H_2S$ 5000ppm.

**Plant 5 (Catalonia)**
Biomethane upgrade 34%
$H_2S$ level stabilization 150ppm.

**Other plants***



## Industry Impact

Its impact is already tangible. By 2025, Ce-in Biogas had been successfully implemented in more than ten industrial plants across Spain, delivering measurable improvements, including:

- **Alicante** – 7,000 $m^3$ sludge digester: +27% energy efficiency, removal of 5,000 ppm $H_2S$.
- **Catalonia** – Three 1,500 $m^3$ agri-food waste digesters: +34% efficiency, cost reduction, $H_2S$ stabilised at 150 ppm.
- **Catalonia** – 3,000 $m^3$ sludge digester: +18% efficiency, $H_2S$ stabilised at 37 ppm.
- **Toledo** – 6,000 $m^3$ pig slurry digester: +26% efficiency, removal of 700 ppm $H_2S$.
- **A Coruña** – Two 11,000 $m^3$ sludge digesters: +12% efficiency, $H_2S$ stabilised at 150 ppm.

## 'Next Gen' Additives

Ce-in Biogas signals a new generation of sustainable additives - multifunctional solutions that have demonstrated their efficiency across diverse plant types and waste streams. More than just solving the persistent challenge of $H_2S$, Ce-in Biogas boosts energy efficiency to the point of covering its own cost, enabling biogas plants to operate with higher performance, lower environmental impact and greater economic returns.

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OMEX ENVIRONMENTAL

# Biogas & Nutrient Additives

For the Energy, Water & Transport Sectors

A range of non-hazardous iron solutions, enzymes and biogas additives to improve biological health, optimise biogas yields and enhance performance in anaerobic digesters, wastewater & biogas plants.

- **Improve overall plant performance**
- **Maximise Methane production**
- **Reduce H2S levels**



**www.omexenvironmental.com**

Email: environmental@omex.com Tel: +44(0)1553 770092

# Reduce Hydrogen Sulphide with the Active Fe Range from OMEX

OMEX Environmental provides safe, cost-effective products designed to deliver maximum results with minimal risk to operators and sites.

In response to strong demand for a better alternative to traditional hydrogen sulphide treatments, OMEX developed the Active Fe range. After extensive laboratory and field testing, the company created a series of non-hazardous, reactive iron-based blends that directly tackle hydrogen sulphide issues in anaerobic digestion. At the time, this was a first-of-its-kind solution and has since changed the way the industry approaches hydrogen sulphide management.

## The Field Trial Results

Before launching the products, OMEX carried out monitored trials at several anaerobic digestion sites. These trials showed that the Active Fe range effectively reduced hydrogen sulphide levels in digesters, supported methane production and reduced the need for air injection to control hydrogen sulphide in biogas plants.

One trial took place at a small on-farm plant operating under mesophilic conditions. The plant had two primary digesters running in parallel, a gas-mixing system for agitation, and a CHP engine to convert biogas into electricity for export. The feedstock included grass silage, wholecrop wheat silage and wholecrop maize silage.

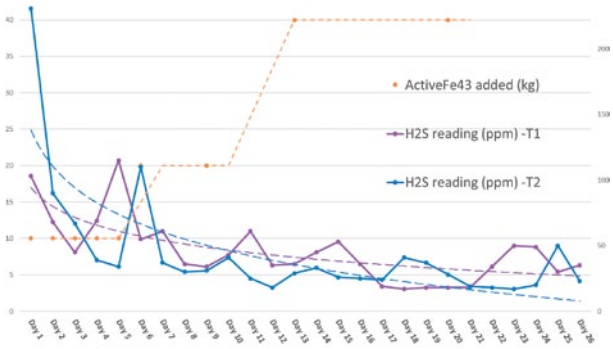
The plant was monitored for several weeks before Active Fe was added, and then tracked daily using online site monitoring and digestate analysis provided by OMEX's technical team.

## Aim 1: Reducing $H_2S$ Content

Before adding Active Fe, the digesters typically ran at hydrogen sulphide levels of 200-400ppm, which was close to the CHP engine's upper limit. The goal of the trial was to reduce these levels to 100ppm or lower and assess how the plant performed. Over four weeks, Active Fe was added in three different stages at varying doses, while all other operating conditions remained stable. The results showed that with an average of 5.5kg of Active Fe added per day, hydrogen sulphide levels could be consistently reduced to around 50ppm - well below the target.

**Active Fe43 addition rates**

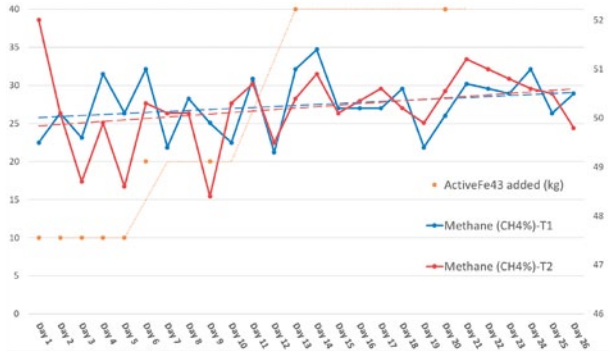
| Day Number | Active Fe43 addition |
|---|---|
| Days 1 – 5 | 10 kg per day |
| Days 6 & 9 | 20 kg per day |
| Days 12 & 21 | 40 kg per day |




*$H_2S$ with Active Fe43 addition.*

## Aim 2: Methane Generation

Before Active Fe was added, the digesters produced biogas with a methane content of around 49-50%, but with frequent, inconsistent spikes. During the trial, the first application of Active Fe led to an average methane content increase of about 1%, with levels continuing to rise as the monitoring period came to an end.




*Methane behaviour with Active Fe43 addition.*

## Conclusions

Adding **Active Fe** to the anaerobic digestion plant proved highly effective. Hydrogen sulphide levels were reduced with minimal iron use, methane content in the biogas increased, and the plant was able to operate with less injected air. For more information on our solutions, contact the OMEX team.

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Nutrient Profiling | Sample Analysis | R+D Facilties

OMEX ENVIRONMENTAL

# Technical Support

Technical expertise and trusted solutions to empower customers to operate more sustainably and efficiently. We have a highly skilled team with extensive experience in the wastewater and anaerobic digestion industry.

We receive and analyse wastewater and biogas samples, reporting results to our sales team who then provide their customers with tailored recommendations.

Equipped with advanced technology, we are constantly innovating to meet our customers' needs.



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RAFT ENERGY

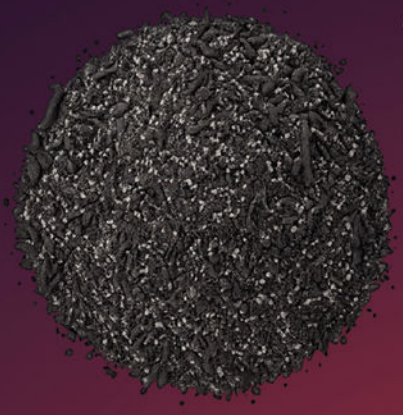
# ActiCH4R™

## Organic Catalyst

ActiCH4R™ is an engineered Activated Biochar, which significantly enhances anaerobic digestion by improving microbial activity, process stability, and biogas yield. **Upgrade your output - without upgrading your plant.**

# Boost Biogas Yield by 25–40%

## Enhance Stability. Backed by Science.



## Waste Loves ActiCH4R™

- Increases $CH_4$, decreases $H_2S$
- Increases microbial population
- Reduces ammonia gas (reduces foaming)
- Improves plant stability (pH, FOS/TAC, VFA & VOC breakdown)

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# Carbon Capture

Beyond biogas upgrading, many plants are exploring carbon capture to further enhance their environmental and economic performance. During upgrading, carbon dioxide ($CO_2$) is separated from methane in a relatively pure form (95%+). This by-product stream was traditionally vented to atmosphere. However, with carbon capture technologies, this $CO_2$ is increasingly being purified and put to beneficial use, particularly as it is so readily available and the capture of this near-pure stream is far more efficient than some other forms of carbon capture (such as direct air carbon capture).

Direct carbon capture during biomethane upgrading (PSA, membranes, water scrubbing – *see Biomethane Upgrading*) is particularly advantageous for biomethane plants because it yields high-purity, low-contaminant $CO_2$ that can be compressed and transported for permanent geological storage or chemical utilisation, making biomethane production a mature and practical platform for carbon capture.

Captured $CO_2$ can be sold into industries such as food and beverage, greenhouses (as a growing agent) and industrial applications, or it can be sequestered for long-term storage as part of carbon removal strategies. Emerging technologies also link captured $CO_2$ with hydrogen to create synthetic fuels and chemicals, expanding the role of biogas plants in the wider energy transition (*see Advanced Biogas Processing*).

While $CO_2$ processing largely leverages the same technologies used for biomethane upgrading, extra drying, purification and compression steps are applied as needed to meet the specifications for transportable or storable $CO_2$.

Initially, the $CO_2$-rich stream contains moisture and trace impurities, such as hydrogen sulfide, siloxanes or volatile organic compounds. To prevent corrosion in pipelines and storage vessels, **condensate removal systems, desiccant dryers or refrigeration units** are used to reduce water content. Any residual contaminants may be removed via activated carbon beds or chemical scrubbing to meet purity specifications.

**Chemical scrubbing** may be added if extremely high purity is required, for example, for food-grade $CO_2$, industrial feedstock or geological injection.

Once cleaned and dried, the $CO_2$ is compressed using **multi-stage compressors** to pressures suitable for pipeline transport, liquefaction or injection into geological formations. Compression is often staged with **inter-cooling** to minimise energy requirements and avoid overheating. For long-distance transport, the $CO_2$ can be liquefied, producing a dense fluid that can be moved via tanker or injected into storage sites such as deep saline aquifers, depleted oil and gas reservoirs or enhanced oil recovery (EOR) operations.

Biomethane production provides a proven, scalable and operationally mature pathway for carbon capture, linking renewable energy generation with permanent carbon sequestration. This combination not only supports decarbonisation of energy systems but also offers a practical route toward negative-emission solutions that can complement other climate mitigation strategies.

Carbon capture not only reduces greenhouse gas emissions but also diversifies revenue streams, positioning biogas plants as integrated hubs for renewable gas and carbon management. As markets and regulations evolve, this area is likely to become an increasingly important part of the industry.

## Technologies Used in Carbon Capture, Utilisation and Storage (CCUS)

| Process / Technology | Application | Key Benefits |
|---|---|---|
| **Thermal/UV oxidation** | Initial purification of the $CO_2$ exhaust stream on site by fully oxidising all VOCs or contaminant gases. | Reduces environmental impacts of $CO_2$ exhaust, improve stability of further processing. |
| **Condensate Removal / Knockout Pots** | Removes water and condensate from the $CO_2$ stream. | Prevents corrosion and blockages in pipelines and compressors. |
| **Desiccant Dryers / Refrigeration Units / Cryogenics** | Reduces moisture content to meet $CO_2$ transport or storage specifications. | Ensures very dry $CO_2$ suitable for compression and long-term storage. |
| **Activated Carbon Beds / Adsorbents** | Removes siloxanes, volatile organic compounds and trace impurities. | Protects pipelines, storage tanks and downstream equipment; improves purity. |
| **Chemical Scrubbing** | Removes residual $H_2S$ or other acid gases not fully captured during upgrading. | Achieves high-purity $CO_2$ suitable for industrial or food-grade applications. |
| **Compression (Multi-Stage Compressors)** | Raises $CO_2$ pressure for pipeline transport, liquefaction or storage. | Produces transportable $CO_2$, reduces volume and facilitates long-distance delivery. |
| **Liquefaction Units / Cryogenic Cooling** | Converts $CO_2$ to liquid form for transport by tanker or injection into storage. | Enables high-density transport, efficient storage and geological injection. |

# Unlocking More Efficient Biogas Upgrading with MOFs

**The ability of metal-organic frameworks** (MOFs) to selectively capture carbon dioxide $CO_2$ from biogas makes them an efficient, low-energy alternative to traditional separation technologies.

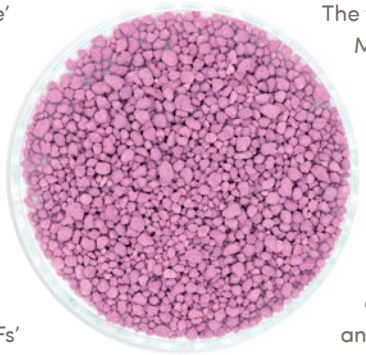
MOFs are highly porous crystalline structures comprised of metal ions joined together by organic linkers (bridging molecules) to create a 3D lattice. These 'cage' like structures have incredibly high surface areas and act as 'sieves' to selectively trap (adsorption) specific gases. The trapped gas can then be released (desorption) by a pressure swing process, and the cycle repeated many times.

The choice of metal ion and organic linker that can be used to form a MOF is almost limitless and allows for the tuning of the MOFs' pore size and functionality to make each MOF highly selective for specific gases.

MOFs are available that can selectively capture $CO_2$ from mixed gas streams, making them an ideal technology for biogas upgrading and separation.

## Did You Know?

**The highest recorded surface area for a MOF was over 7,800 m²/g, that's equal the average size of a football pitch per gram of MOF.**



*MOFs are highly porous crystalline structures.*

The fast adsorption and desorption rates of MOFs make them extremely energy-efficient, reducing the operating cost of a MOF based system compared to other technologies. Coupled with a lower capital cost this makes MOFs a viable alternative to existing gas separation technologies.

**MOFs provide multiple benefits as advanced materials** for biogas upgrading and pressure swing gas separation systems. They can be designed to be highly selective for capturing $CO_2$, delivering high purity biomethane with very low methane loss during purification. MOFs also have the flexibility to work with the varying levels of $CO_2$ and methane which arise from the different feedstocks used in anaerobic digestion.

MOF-based gas separation systems can be modular and scalable. They are well suited for use in remote areas, areas with limited space and/or sites with limited access to utilities. They require no compression and use less regeneration energy than other biogas upgrading technologies, reducing both capital and operating costs.



*Hydrus Renewables biogas upgrading pilot using MOFs from Promethean Particles.*

## Advancing industrial efficiency

**Promethean Particles is a world leading specialist in the synthesis and production of metal-organic frameworks (MOFs). Our proprietary and patented continuous-flow manufacturing process enables the industrial-scale production of high-quality and cost-effective MOFs.**

**Over the past decade we have evolved into a global leader, delivering advanced MOF solutions for a diverse range of industrial applications. Our team of research chemists and process engineers bring deep expertise in the application of MOFs in biogas upgrading systems.**

**Contact us to discuss how you can take advantage of the remarkable properties of MOFs to enable more energy efficient biogas upgrading.**

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# Advanced Biogas Processing

The scope of biogas utilisation is expanding rapidly, moving beyond electricity, heat and grid injection into advanced processing pathways that create new renewable fuels and chemicals. These technologies demonstrate the versatility of biomethane as a feedstock for the wider decarbonised economy.

Both biomethane and carbon dioxide ($CO_2$) are increasingly being recognised as platform molecules to produce chemicals, opening new pathways in sustainable industrial chemistry.

**Biomethane**, a high-purity methane derived from anaerobic digestion (or other biogas upgrading processes), can serve as a renewable feedstock for a wide range of chemical syntheses. Advances in catalysis and process engineering now allow its conversion into hydrogen, methanol, syngas, formaldehyde and other bulk chemicals. By replacing fossil-derived methane with biomethane, industries can reduce their carbon footprint while maintaining existing chemical production routes. Biomethane's compatibility with existing infrastructure, such as pipelines and reformers, further facilitates its adoption as a renewable feedstock.

**Carbon dioxide**, long considered a greenhouse gas to be mitigated, is now being valorised as a raw material for chemical manufacturing. Captured $CO_2$ from biogas upgrading can be converted into urea, polycarbonates, formic acid, methanol and other value-added chemicals through catalytic, electrochemical or biological processes. These approaches not only provide a use for $CO_2$ that would otherwise be vented from biogas sites, but also creates renewable and circular carbon pathways, effectively closing the loop between vented carbon and new chemical products.

Together, the use of biomethane and $CO_2$ as chemical feedstocks represents a paradigm shift: renewable, low-carbon molecules are no longer just energy carriers but also building blocks for sustainable chemical production. This trend supports decarbonisation of both the energy and chemical sectors while promoting circular economy principles, turning gases that were once treated as waste into valuable resources.

**Sustainable Aviation Fuel (SAF)** production is emerging as a major market, with biomethane-derived intermediates offering pathways to lower-carbon aviation. **Renewable Dimethyl Ether (rDME)** can be synthesised as a clean-burning fuel for transport or as a blending agent with LPG. **Power-to-X (P2X)** systems combine biomethane or captured $CO_2$ with renewable hydrogen to produce synthetic methane, methanol or other energy carriers. **Methanisation** processes further expand these options, creating high-purity renewable gas streams.

While these technologies are still developing commercially, they represent the frontier of biogas innovation. Advanced processing allows biogas plants to go beyond waste treatment and energy generation, becoming integrated bio-refineries contributing to multiple sectors of the global energy transition.

## Advanced Processes for AD Outputs

| Feedstock | Pathway / Technology | Products / Outputs | Key Benefits |
|---|---|---|---|
| **Biomethane** | Steam Methane Reforming (SMR) / Syngas Production. | Hydrogen, carbon monoxide, methanol, ammonia, Fischer–Tropsch fuels. | Enables renewable hydrogen and chemical synthesis, reduces carbon intensity of products. |
| **Biomethane** | Direct Methane Conversion (catalytic). | Methanol, formaldehyde, higher hydrocarbons. | Produces valuable chemicals directly from methane, supports renewable chemical production. |
| **Biomethane** | Biomethane-to-Hydrogen (BTH). | Hydrogen for fuel cells or industrial use. | Provides low-carbon hydrogen, supports decarbonisation of hydrogen-intensive industries. |
| **$CO_2$** | Catalytic Conversion (with $H_2$). | Methanol, formic acid, urea. | Converts captured $CO_2$ into renewable chemicals, integrates with hydrogen and energy systems. |
| **$CO_2$** | Electrochemical / Photochemical Reduction. | Carbon monoxide, methane, multicarbon compounds. | Uses renewable electricity or sunlight to generate fuels and chemicals from $CO_2$. |
| **$CO_2$** | Biological Utilisation (microbes, algae). | Bioplastics, organic acids, biofuels. | Converts $CO_2$ into high-value bioproducts, supports circular carbon economy. |

# Turnkey Solution Providers

Building and operating a biogas plant involves integrating dozens of complex systems: feedstock handling, digestion, gas processing, energy generation and digestate management. For many project developers, engaging with turnkey solution providers offers a practical route to delivering projects on time and within contracted budget.

Turnkey providers bring together management, engineering, procurement, construction and commissioning under a single contract or a few contracts. They draw on established technology portfolios and experience to design plants that are cohesive, reliable and tailored to specific feedstocks and markets. This reduces interface risks between multiple suppliers and can provide developers and investors with a single point of accountability.

Turnkey solutions can accelerate project timelines and reduce risk, particularly for first-time developers or investors seeking proven outcomes. Global markets for biogas and biomethane have seen the rise of specialist turnkey companies that deliver standardised designs as well as bespoke facilities.

Turnkey providers are central to the continued global expansion of anaerobic digestion and biomethane production. Their integrated approach - combining feedstock assessment, permitting expertise, technology selection and financial modelling - lowers barriers for new market entrants. By offering training, after-sales service and performance monitoring, they can also help operators sustain plant performance over the long term. This comprehensive support fosters investor confidence and encourages more widespread adoption of anaerobic digestion and biomethane technologies worldwide.

## The Role Of Turnkey Providers In The Biogas Industry

| Benefit / Feature | Description / Value |
|---|---|
| **Project Scaling** | • Enables rapid deployment of multiple projects using standardised designs.<br>• Reduces development time and capital risk. |
| **Standardisation of Best Practice** | • Ensures consistent application of proven technologies, safety systems and compliance measures.<br>• Improves operational efficiency and methane yields. |
| **Technical Expertise** | • Provides access to specialised engineering, permitting and commissioning expertise.<br>• Minimises errors and operational risks. |
| **Financial Confidence** | • Offers predictable costs and performance guarantees that attract investors. |
| **Long-Term Support** | • Offers training, monitoring, and after-sales service to ensure stable plant performance. |
| **Global Expansion** | • Facilitates entry into new markets by handling regulatory, technical and logistical complexities. |

# From Buffalo to Biogas: Closing Italy's Circular Economy Loop

## The Challenge: Valorising Agricultural By-Products

In southern Italy, buffalo farming is central to the tradition of Mozzarella di Bufala, a Protected Designation of Origin cheese renowned for its creamy texture and delicate flavour. Buffalo thrive in fertile lowlands, where farmers prioritise welfare, breeding and natural grazing to produce milk rich in fat and protein. This practice sustains rural economies and preserves centuries-old artisanal heritage.

However, concerns over nitrogen contamination have led to stricter slurry regulations, directly impacting herd sizes and milk supply. Producers now fear reduced mozzarella production, threatening both the local economy and the survival of this iconic cultural and gastronomic product.

Anaerobic digestion offers a sustainable solution by transforming waste into renewable energy and high-quality organic fertiliser. This process not only reduces nitrogen emissions and environmental impact but also provides clean energy. The digestate, rich in nutrients, can replace chemical fertilisers, helping to close the circular economy loop. By integrating this approach, farmers can comply with environmental regulations while safeguarding milk production, thus ensuring the long-term future of the Mozzarella di Bufala industry.

Bioenergy Serre is an industrial initiative developed to support local farming activities while enhancing energy transition. The plant built in Serre wants to be the first of a series of plants designed to promote a sustainable and circular economy in the diary sector.

To succeed, Bioenergy Serre needed a proven partner with the technology and expertise to handle large quantities of agricultural feedstocks, while ensuring reliable biogas production and compliance with international sustainability standards.



***Circular economy:*** *Facility transforms residues into renewable gas and fertiliser.*

**Anaergia** is a global leader in renewable natural gas solutions, with more than 300 patents and a track record of over 1,700 installations globally.

## Solution: Anaergia's Anaerobic Digestion Package

Bioenergy Serre selected Anaergia as technology provider for the project's anaerobic digestion (AD) section. Delivered under an Engineering, Procurement and Construction (EPC) model, the project demonstrates how Anaergia's integrated technology can be deployed flexibly - from custom EP packages to full turnkey EPC delivery.

### Anaergia's scope included:

- **Solid Feeding & Mixing** designed and selected for effective handling of high-solids agricultural residues (*See Pre-feeding and Tank Mixing*).
- **Central Pumping System** designed to ensure consistent slurry movement and stable operation.
- **Gas Handling & Storage** robust gasometers for safe, flexible storage of biogas before utilisation.
- **Biomethane Production** by upgrading biogas into renewable methane used for vehicle fuel.

Together, these technologies form the backbone of a facility that transforms local agricultural by-products into renewable energy while aligning with Bioenergy Serre's sustainability strategy.

### Performance and Environmental Benefits

The Bioenergy Serre plant has positioned itself as a flagship for Italy's renewable energy ambitions.

- **Feedstock Capacity** 480 tonnes/day
- **Biogas Production**
  Wet biogas, ~1,400 $Nm^3/h$ at 51% $CH_4$
  Dry biogas, ~1,300 $Nm^3/h$ at 55% $CH_4$
- **Carbon Reduction** Equivalent of 10,000 tonnes of $CO_2$ avoided annually
- **Resource Recovery** Slurry, cattle manure, dairy and bakery waste are diverted from waste streams and repurposed as feedstock for renewable energy.

By valorising agro-industrial residues, the facility diverts waste from traditional disposal pathways and converts it into high-quality biomethane and organic fertiliser - directly supporting local farming sectors to be sustainable economically and environmentally.

## Voices from the Project

*"At the Bioenergy Serre facility, Anaergia supplied the anaerobic digestion systems that turn different types of agricultural residues into renewable methane and organic fertilizer. Our focus was on delivering robust, proven technology ensuring the plant can operate smoothly and efficiently."*
**Simone Bonizzardi, Vice President, Sales, Anaergia Inc**

*"By transforming local farming by-products into renewable energy and organic fertilizer, we are not only reducing emissions but also creating local value from agricultural resources. Partnering with Anaergia allowed us to integrate a reliable technology platform into our energy portfolio."*
**Renato De Santis, Chairman, Bioenergy Serre**



***Secure storage:*** *Enclosed systems safeguard feedstocks and ensure reliability.*

## Innovation and Integration

Anaergia's technology makes it possible to incorporate different types of feedstocks into a stable AD process. By combining solid feeding, efficient mixing, and high-capacity gas handling and valorisation, the Bioenergy Serre facility ensures smooth and predictable operations.

## A Showcase for Anaergia's Services

**End-to-End Reliability** Proven systems from feed handling to gas valorisation deliver consistent performance.

- **Flexibility** Modular design allows supplier systems to be tailored to different feedstocks.
- **Scalability** Equipment is designed for expansion, ensuring future capacity growth.
- **Circular Economy Leadership** A replicable model for agricultural regions worldwide, demonstrating how waste can be transformed into renewable energy and local value.



***Optimised flow:*** *Separation ensures stability and consistent biogas yields.*

## Conclusion

The Bioenergy Serre facility is more than just a renewable energy project - it is a model for how tradition and innovation can work hand in hand. By transforming buffalo slurry, dairy residues and bakery by-products into renewable gas and organic fertiliser, the plant demonstrates that compliance with stricter regulations can also preserve livelihoods and cultural heritage.

For the producers of Mozzarella di Bufala, this means safeguarding an iconic product while meeting environmental standards. For Italy, it represents progress toward a cleaner energy mix and a more resilient agricultural sector. And for the global market, Bioenergy Serre offers a replicable blueprint: a proven way to turn agricultural residues into energy, value and long-term sustainability.

Anaergia's integrated portfolio covers every stage of anaerobic digestion – from pre-processing and mixing to digestion, upgrading and resource recovery. With flexible delivery models, from turnkey EPC solutions to custom EP and O&M services, Anaergia enables companies like Bioenergy Serre to accelerate the world's clean energy transition. ***See also Pre-feeding and Tank Mixing.***



***Closing the loop:*** *Digestate refined into organic fertiliser.*

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# Turnkey Bioenergy Technology



*Inhouse biogas plant technology by HoSt.*

Utilising efficient and clean energy technology, HoSt's high-tech systems are enhanced with innovative technologies, allowing them to excel in converting biomass and waste to energy. With a complete suite of proprietary technologies under one roof, HoSt delivers fully integrated, turnkey solutions that maximise efficiency, sustainability and value from every residual stream.

By transforming methane-emitting waste into renewable biofuels and renewable gases and leveraging cutting-edge technology we drive the transition towards cleaner energy solutions. With an innovative spirit and a commitment to global deployment, we aim to decarbonise the hard to abate industries while offering economically viable and environmentally impactful technologies and services.



*Biogas plant in Czech Republic.*

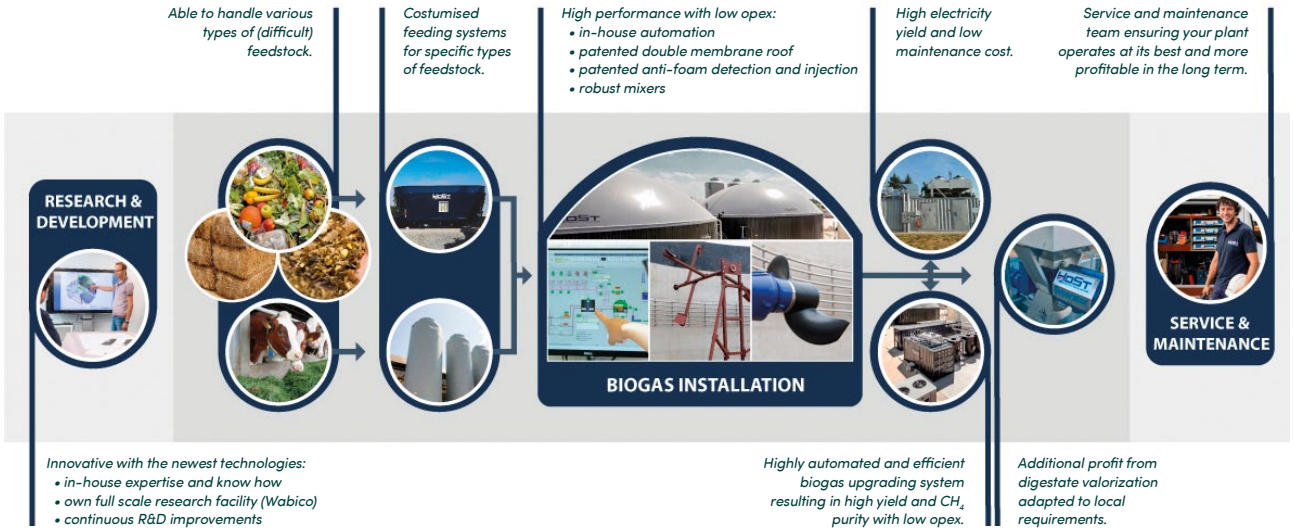
## Maximising Profitability and Efficiency

HoSt offers a comprehensive range of in-house technologies, and each successful biogas project begins with our Biogas Plant Configurator. This digital tool creates detailed models of mass and energy balance tailored to each project, taking the Carbon Intensity (CI) score into account. It helps identify the best mix of feedstocks and offtake options to improve project profitability. The result is a biogas plant designed for maximum efficiency, with the best Total Cost of Ownership (TCO), minimal $CO_2$ emissions and the best possible return on investment.

Partnering with a single supplier for both anaerobic digestion (AD) and biogas utilisation technologies offers clear advantages - lower risk, reduced costs and improved project execution efficiency. HoSt provides full vertical integration, with in-house design, manufacturing and software. To further streamline integration, HoSt employs a prefabricated, containerised design for its biogas upgrading systems. This modular approach enables seamless integration with AD plants, improving CI scores and overall project efficiency. All installations are remotely monitored from HoSt's control centre, enabling us to provide 24/7 service and maintenance.

## Research and Innovation

Rooted in a culture of innovation and entrepreneurship, HoSt has achieved leadership in the field of renewable energy solutions through a focus on in-house technology development. This includes several patented technologies




*The complete chain.*



*Biogas plant in Villemereuil, France.*

and a robust R&D pipeline. Our streamlined product lines stand out for their efficiency, ROI and commitment to sustainability, featuring low emissions and continuous innovation.

At our full-scale research facility and laboratory in the Netherlands, we test and refine renewable gas technologies before launch, while continuously optimising existing systems. Our head-office laboratory supports this work with detailed analyses and small-scale studies. Operating our own biogas plants allows us to validate and fine-tune technologies under real-world conditions - ensuring proven performance before they reach the global market.

## Turnkey Biogas Facility in France

In Villemereuil, France, HoSt Group successfully delivered a turnkey biogas plant in just 12 months. This project shows that HoSt can design, engineer and deliver full biogas facilities that meet local needs. The plant primarily processes organic waste and manure, converting these feedstocks into biomethane, which is directly injected into the French gas network.

The main objective of the project was to provide a sustainable way to manage local agricultural waste while contributing to France's renewable energy targets. By integrating advanced digestate treatment technology and efficient biogas upgrading, the plant maximises energy recovery and ensures compliance with strict environmental standards.

The facility is equipped with two digesters, one after-digester, two solid feeders, a liquid storage tank, a heat recovery system and biogas upgrading technology. With this configuration, the plant combines operational reliability with high efficiency.

## Results & KPIs

**Location:** Villemereuil, France

**Start of operation:** 2023

**Annual biomethane production:** >3,000,000 $Nm^3$/year

**Feedstock utilisation:** 30,000 tons/year of manure and organic residues

**Energy efficiency:** High uptime secured through integrated heat recovery and advanced upgrading technology

## Empowering sustainability ambitions

Building on the success of projects like Villemereuil, HoSt is currently realising new biogas facilities across the United States and Europe, including three landmark projects in Spain that will set a new benchmark for large-scale biomethane production. With additional projects under development in amongst others the Baltics, United Kingdom, Germany, Poland, Ireland and Italy, HoSt continues to expand its international footprint and strengthen its role in decarbonising the hard to abate industries.
By combining proven in-house technology with local execution, we enable industries and communities to unlock value from organic residues while reducing carbon emissions. Our global portfolio of over 450 projects in more than 35 countries underlines one clear ambition: empowering sustainability ambition.



*Construction of a biogas plant in Spain.*

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Its interdisciplinary team combines innovation with proven industry know-how to deliver tailor-made solutions.

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Our gas treatment and production technologies:

- Wet and dry anaerobic digestion to produce biogas
- Biogas upgrading to biomethane for grid injection or use as liquified or compressed biofuels
- Liquefaction of $CO_2$ and $CH_4$
- Recovery and capture of carbon dioxide

**Discover more**

# Operational Optimisation at Afan Wastewater Treatment Works



*Tank cleaning at DCWW.*

In 2022, Dŵr Cymru Welsh Water (DCWW) faced a challenge at its Afan Wastewater Treatment Works (WWTW) in Port Talbot. Two digesters on site had built up significant levels of grit, which were disrupting the mixing system, destabilising the biology and reducing their operational capacity.

The project required taking the digesters offline one at a time as maintaining sludge processing capacity was critical, each tank was decommissioned, inspected, cleaned and recommissioned in sequence.

As Principal Contractor, Marches Biogas coordinated all aspects of the work. Specialist partners were engaged to support dewatering, pumping down liquors and removing grit and heavier residues. A dedicated Marches Biogas Site Manager oversaw operations from start to finish, working closely with DCWW operators.

Safety was a paramount consideration. Before desludging, each digester was purged with nitrogen and forced-air ventilation fans were used to continuously manage the headspace gases. This strict approach to controlling gas mixtures in the digester provided assurance to both the client and the workforce.

## Innovative Inspection and Operational Optimisation

Once emptied and cleaned - including mixer lances and recirculation pipework - Marches Biogas carried out full conditional surveys of the digesters. Rather than erecting extensive internal scaffolding, which is costly and time-consuming, the team used a drone-mounted camera system. This innovative approach provided accurate visual assessments while saving both time and money.

To protect the digesters from Rapid Volume Expansion (RVE) events, foam relief systems were installed. This step provides additional resilience against foam-related process upsets, reducing future risks and downtime.

After the inspections and any needed repairs, the first digester was reseeded using discharge from the operating digester. Once its headspace was purged with nitrogen, it was put back into service and the feed gradually increased. The same process was then repeated for the second digester. The result was two fully cleaned, inspected and optimised digesters returned to service without causing major disruptions to the site's operations.

## More Than Just a 'Project'

This case study stands out for both the project and the collaboration it represents, following Glanua's acquisition of Marches Biogas in 2025. With teams across the UK and Ireland, Glanua leads in water, wastewater and energy infrastructure - expertise that complements Marches Biogas's strong track record in the biogas sector. Since 2009, Marches Biogas has delivered more than 30 AD plants across the UK, from small 50 kWe farm systems to large industrial facilities.

The team's offering goes now well beyond degritting or inspections. It covers every stage of the plant lifecycle:




- **Design and Build**, with in-house process, mechanical and electrical expertise and full principal contractor capability.
- **Commissioning and Decommissioning**, from safe startup to controlled process shut down.
- **Operational Support**, including biological monitoring, performance optimisation, feedstock management and regulatory compliance.
- **Training and E-Learning**, equipping operators with the skills and confidence to run facilities effectively.

This synergy offers clients something rare in the market: the technical depth of a specialist AD contractor combined with the scale and capability of a multi-disciplinary engineering group. Whether delivering new-build plants, optimising existing assets or supporting long-term operations, the partnership ensures reliable, efficient and future-ready solutions.

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# Landfill Biogas

Landfill gas (LFG) capture is a critical strategy for reducing greenhouse gas emissions and recovering renewable energy from decomposing waste. When organic material is buried and compacted in landfills, oxygen is rapidly depleted, creating anaerobic (oxygen-free) conditions, which lead to the production of methane ($CH_4$) and carbon dioxide ($CO_2$), with small amounts of trace gases. Methane, a potent greenhouse gas, with 86 times more warming power than $CO_2$ over the first 20 years in the atmosphere, can escape to the atmosphere if unmanaged - contributing significantly to climate change.

To control these emissions, landfill operators install **gas collection systems** consisting of vertical wells or horizontal trenches connected by a network of pipes. Unlike fixed pipelines in stable environments, landfill gas piping systems must be flexible, modular and easy to relocate. Operators regularly adjust pipe layouts, extend collection systems to new cells and manage condensate to maintain efficient methane capture. This adaptability is critical for maximising gas recovery, preventing emissions and ensuring safe, reliable operation throughout the landfill's active and post-closure phases.

**A vacuum or blower system** is essential for efficiently extracting landfill gas (LFG) and delivering it to treatment or utilisation equipment. By generating slight negative pressure across the network of gas wells and collection pipes, the system actively draws gas out of the landfill, preventing fugitive emissions and odours. Operators adjust suction carefully: if pressure is too low, methane may escape through the landfill cover, but if it is too high, air can be pulled into the waste mass, disrupting anaerobic conditions or creating fire risks.

Once extracted, the blower maintains a steady gas flow through the collection network, moving it through **condensate traps** and **pretreatment units** to remove moisture, particulates and corrosive compounds. The pressurised gas is then directed to its end-use - such as flares for safe combustion, combined heat and power (CHP) engines or turbines for electricity generation, or technologies that upgrade the LFG into biomethane. In some cases, additional **booster compressors** raise the pressure further for pipeline injection or storage of biomethane.

In essence, the vacuum or blower system provides the controlled suction and transport needed to turn a landfill's natural methane production into a safe, reliable and productive energy resource.

Modern landfill gas management also includes many of the technologies found on standard anaerobic digestate plants, such as condensate removal, gas compression and monitoring instrumentation, to maintain efficient capture rates and ensure environmental compliance. In addition to climate benefits and air quality improvements, LFG utilisation supports local energy supply, offsets fossil fuel use and can provide revenue streams for landfill operators.

## Main Technologies Used to Capture And Utilise Landfill Gas (LFG) as Biomethane

| Technology | Application in LFG-to-RNG Process | Key Benefits |
|---|---|---|
| **Gas Collection Wells & Piping** | Vertical wells and horizontal trenches extract landfill gas under vacuum and transport it via pipe networks. | Efficient methane capture, reduces greenhouse gas emissions, prevents uncontrolled migration. |
| **Blowers / Vacuum Systems** | Apply negative pressure to maintain consistent gas flow from wells to processing units. | Ensures stable gas recovery rates and prevents fugitive emissions. |
| **Moisture & Condensate Removal** | Knockout pots, condensate traps, and moisture separators remove water vapour and liquids from raw gas. | Protects downstream equipment, improves gas quality and process efficiency. |
| **Gas Compression Units** | Compress low-pressure LFG for transport to upgrading or pipeline injection systems. | Facilitates further treatment and meets pipeline pressure specifications. |
| **Gas Cleaning Systems** | Filters, activated carbon, or iron sponge units remove particulates, siloxanes, and $H_2S$. | Protects upgrading equipment and ensures high-quality biomethane. |
| **Biogas Upgrading Technologies** | Membrane separation, pressure swing adsorption (PSA), water scrubbing, or chemical scrubbing to remove $CO_2$ and trace gases. | Produces high-purity biomethane (RNG) suitable for grid injection or CNG/LNG production. |
| **Monitoring & Control Systems (SCADA/PLC)** | Real-time monitoring of gas flow, pressure, and composition; automated control of equipment. | Ensures process stability, maximises methane recovery, and supports regulatory compliance. |
| **Pipeline Injection or CNG/LNG Terminals** | Conditioned RNG is injected into the natural gas grid or liquefied/ compressed for transport as vehicle fuel. | Expands renewable fuel supply, offsets fossil natural gas use, and supports decarbonisation. |

# Waste Water Treatment

Anaerobic digestion plays a central role in wastewater treatment (WWT), turning sewage sludge from a disposal challenge into a source of renewable energy and valuable by-products. As wastewater is processed, primary and secondary sludge rich in organic matter is generated. Through AD, this sludge is broken down by microorganisms in oxygen-free conditions, stabilising it, reducing odours and pathogens and cutting sludge volume by up to half. This not only lowers handling and disposal costs but also improves the overall environmental performance of the treatment plant.

A key advantage of AD in wastewater treatment is biogas production. The anaerobic digestion process releases a methane-rich gas, which can be used in combined heat and power (CHP) units to generate electricity and heat for the facility, reducing operating costs. In advanced operations, surplus biogas may be upgraded to biomethane for injection into the gas grid or as a transport fuel, further displacing fossil fuels and reducing greenhouse gas emissions.

While a WWT anaerobic digester shares much of its core equipment with a standard biogas plant, it usually requires specialised sludge feeding, odour and pathogen control, advanced dewatering, nutrient management systems and enhanced corrosion protection to accommodate the characteristics of sewage sludge and meet regulatory standards.

**Feeding systems** in WWT digesters must handle highly viscous, fibrous and variable-consistency sludge, which often necessitates robust pumps, transfer lines and sometimes screening or maceration equipment to remove grit, plastics or other debris not typically found in agricultural or food-waste feedstocks. **To control odours and reduce pathogen risk**, digesters are generally sealed and post-digestion storage or pasteurisation tanks are employed to ensure biosolids meet safety standards for reuse.

**Dewatering and solids** handling require advanced equipment such as centrifuges, belt presses or screw presses, often combined with polymer dosing or conditioning systems to improve dewatering efficiency due to the high moisture content of digested sludge. Some WWT plants also integrate **nutrient recovery systems**, including struvite crystallisers or ammonia stripping units, to reclaim nitrogen and phosphorus for use as fertilisers.

Beyond energy recovery, anaerobic digestion enables nutrient recovery. Digested sludge can be processed to reclaim nitrogen and phosphorus, which are valuable as agricultural fertilisers or soil amendments. **Struvite crystallisers and ammonia stripping** units play an important role in transforming digested sludge from wastewater treatment plants into this resource-rich, environmentally manageable product.

During anaerobic digestion, organic nitrogen and phosphorus in the sludge are mineralised, resulting in ammonium and phosphate compounds in the liquid fraction. If left unmanaged, these nutrients can cause scaling in pipes and equipment or contribute to eutrophication if the liquid is discharged to waterways. Struvite crystallisers address this by inducing the formation of magnesium ammonium phosphate (struvite) crystals, which can be harvested as a solid fertiliser. This not only prevents scaling in tanks and pipes but also recovers phosphorus and ammonium in a form that is safe and valuable for agricultural use.

Ammonia stripping units complement this process by removing excess ammonium from the liquid fraction of digested sludge. Through controlled pH and temperature adjustments, ammonia gas is liberated and can be captured, concentrated and converted into ammonium salts or other nitrogen fertilisers. This reduces the nitrogen load in the treated effluent, mitigates odour issues and generates a recoverable nutrient product.

Finally, because sewage sludge biogas often contains elevated levels of hydrogen sulfide, ammonia and trace metals, pipelines, digesters and gas handling components frequently require enhanced corrosion protection, such as stainless-steel construction or specialised coatings, which may exceed the requirements of typical agricultural biogas plants.

Together, these systems enable wastewater treatment plants to produce digestate that is safer, more stable, and enriched with recoverable nutrients.

## Specialist Equipment Typically Required for Wastewater Treatment

| System | Application | Key Benefits |
|---|---|---|
| **Sludge Handling** | Pumps, conveyors, and feed systems to transfer viscous sludge. | Ensures reliable feeding, prevents blockages, accommodates difficult sludge. |
| **Pathogen and Odour Control** | Sealed digesters, post-digestion storage, pasteurisation tanks. | Minimises odours, reduces pathogen levels, ensures regulatory compliance. |
| **Dewatering** | Centrifuges, belt presses, screw presses, polymer dosing. | Produces manageable solids, reduces disposal volume, improves handling. |
| **Nutrient Recovery** | Struvite crystallisers, ammonia stripping units. | Recovers nitrogen and phosphorus, generates fertiliser, supports circular economy. |
| **Corrosion Protection** | Stainless steel or coated pipelines, valves and digesters. | Protects equipment from $H_2S$, ammonia and trace metals, extends lifespan. |

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The scheme features detailed modules, covering the entire lifecycle of an AD project. A key innovation of ADCS International is its **integration of lifecycle assessment (LCA) methodology guidance**, supporting operators to conduct LCAs in line with global practices. This creates a clear incentive for operators to comply with regulations and lead in **decarbonisation and circular resource use**.

Developed by the World Biogas Association, this global best practice framework supports consistent, confident, and coordinated investment in biogas while remaining adaptable to local contexts. It can also streamline permitting, potentially cutting approval times from years to weeks.

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