CONGRESO INTERNACIONAL BIOENERGÍA
VALLADOLID 1-2.OCT.2025

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Closing the Loop: Transforming Digestate from Biogas Byproduct to Agricultural Resource

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Biometano y otros gases renovables:
El camino hacia una economía sostenible y competitiva.

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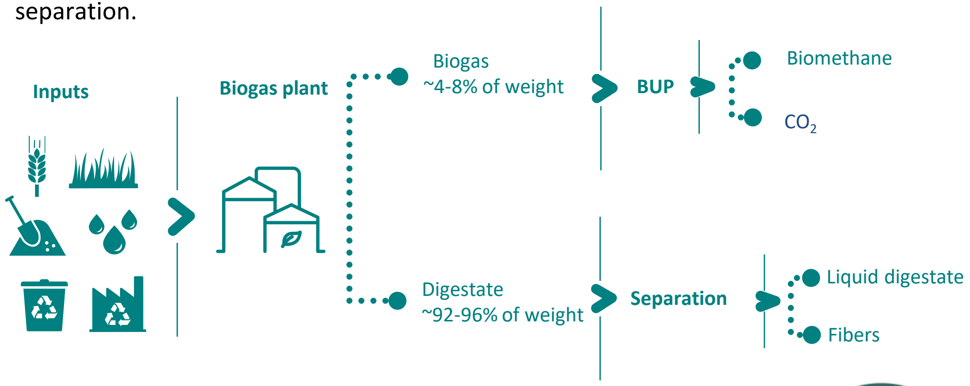
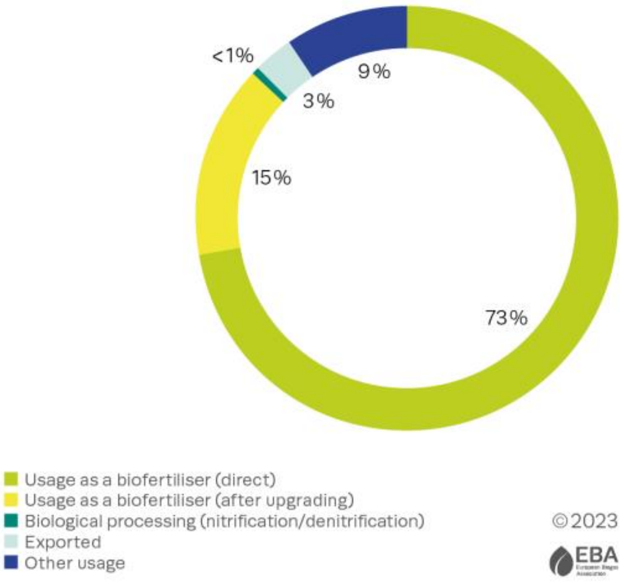
What is digestate and what are its current uses?

Digestate is the **main by-product of anaerobic digestion** and represents a nutrient-rich material resulting from the decomposition of organic matter. It is composed primarily of residual organic matter that is not fully degraded during the process, together with minerals, water, and micro-organisms. Its exact composition and properties vary depending on the input feedstock, the biogas plant configuration, and any subsequent treatment steps. In practice, digestate is typically available in the following forms:

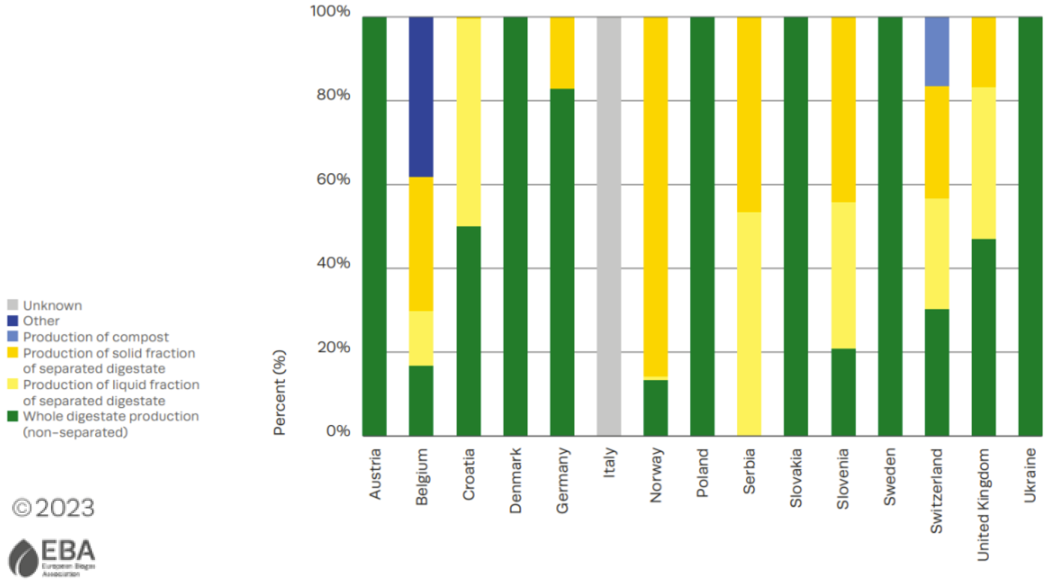
- **Raw digestate** (untreated, directly from the digester)
- **Separated fractions**: liquid digestate and solid digestate obtained after solid–liquid separation.

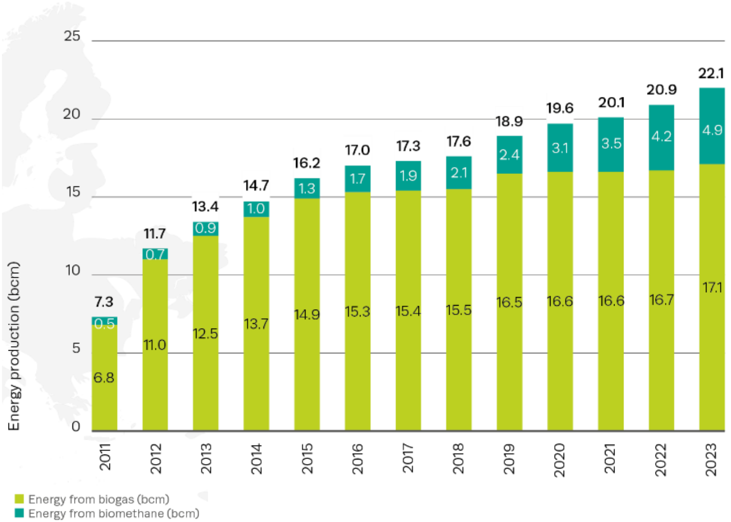


Digestate end-uses in Europe



Digestate uses vary from country to country





EU Regulatory framework

Several pieces of legislation govern the production, application and marketing of digestate in the European Union. These policies cover various aspects of digestate management, including production processes, quality standards, application rates and environmental considerations. They often depend on the inputs used in the anaerobic digestion process.

Waste Framework Directive - 2008/98/EC	Animal By-Products Regulation	Fertiliser Products Regulation 2019/2009	Nitrates Directive	Sewage Sludge Directive
Waste Framework Directive - 2008/98/EC	Animal by-products regulation - European regulation (EC) n°1069/2009	Regulation (EU) 2019/1009 laying down rules for making fertilizers available on the market EU	Nitrates Directive - European Directive 91/676/EEC	Sludge Directive 86/278/EEC purification

These regulations have been modified by subsequent amendments and recent consolidated versions are available

There are others for soil protection and specific inputs.

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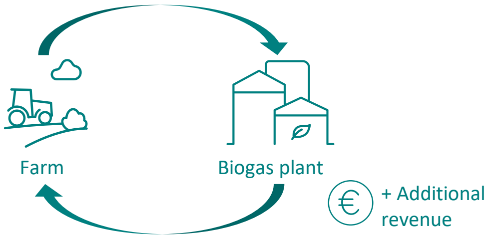
Why is digestate managment important in biogas business model?

There is no one business model, however we have simplified the cases to 3 typical scenarios that Ramboll has come across in projects with mainly agricultural feedstocks in various geographies in recent years. Other feedstocks come with other cases.

Case 1

Mature market with advanced system in place

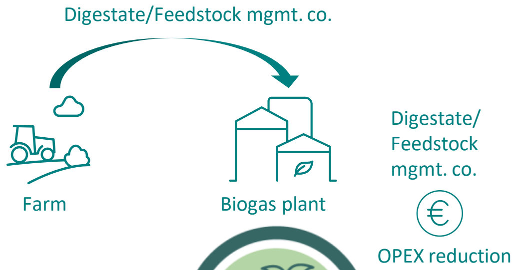
Up-sale or additional revenue stream for added value product.
Price tag of some higher value fertilisers derived from AD plants can be 100-300 EUR/t
CO2 tax for agriculture under way in DK– which will have an impact on the market.



Case 2

Mature market with specific market conditions and regulations that result in high digestate handling cost

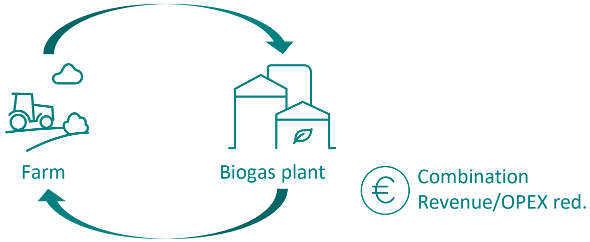
e.g. Plant X – Capacity 300,000 tpy; and digestate handling cost of ~20 EUR/t.
→ 5-6mEUR of digestate handling costs per year, >20% of OPEX. Main driver is OPEX reduction.



Case 3

Country or region with low penetration of AD and lack/limited experience. Farmers unfamiliar with digestate and its benefits.

Combination - Reduce project development risk, facilitate permitting (digestate storage requirements), reduce moderately CAPEX/OPEX, additional revenue stream.



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Five models to handle digestate and distribution emerged, and depend on the country

Five digestate simplified distribution models based on Ramboll's experience through different projects

Model 1 AD Company responsible for digestate management	Model 2 AD Company responsible for digestate management	Model 3 AD Company responsible for digestate management	Model 4	Model 5
Storage of whole digestate	Storage of whole digestate	Solid-liquid separation of digestate	AD Company treats manure and produces digestate	AD company treats manure from different farms and produces digestate
Transportation of whole digestate to farms	Pumping and transfer of whole digestate through buried pipelines to land fields	Solid fraction applied directly to land, dried, pelletized, composted or further processed	Other company (sometimes in charge of feedstock supply) responsible for digestate transport and its application	Owners of the farms are in charge of the supply of the feedstock and the return of the digestate to the lands
Spreading of whole digestate to land by conventional methods for spreading liquid manure [1]	Spreading of whole digestate to land by conventional methods for spreading liquid manure	Liquid fraction recirculated to AD, transported to farmland and spread of further processed		

EU and country-based regulations

- While the EU Fertilizing Products Regulation (Regulation (EU) 2019/1009) provides a harmonized framework, individual member states may have their own national regulations that further specify requirements for the use of digestate as fertilizer.
- Some countries have manure and digestate traders (e.g. Netherlands) while others do not (e.g. Denmark).
- Storage of digestate takes place at the biogas plant (e.g. Germany) or at the farmers site (e.g. DK) depending on local regulation and distribution model.

Country regulations

- Some less mature markets are more reluctant to directly accept digestate as a fertilizer. Thus, further processing of digestate into compost or pellets can be considered for better acceptance.
- National regulations might exist on fertilizer products.

Digestate management and treatment options

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Digestate

Solid/liquid Separation

Solid fraction (20-30% TS)

- Direct Reuse
- Composting → Compost
- Thermal drying → Dry digestate
- Pelletizing → Dry digestate pellets

Pre-drying

- Gasification
- Hydrothermal liquefaction/ carbonization
- Pyrolysis

→ Biochar, Bio-oil, Syngas

Liquid fraction (2-3% TS)

- Bio Fertiliser
- Water Recovery
- Nutrient Recovery

There is increased interest on **digestate treatment** to:

- **Reduce volume**, improve the manageability and reduce transportation/handling costs
- **Recovery of nutrients** in concentrated form

Since digestate treatment has only recently (about the last 10 to 15 years), become a focus of interest, there is no standard procedure and rather a **wide variety of treatment schemes** exist.

Some of the technologies are in early stages and can be **expensive** due to high capital and operation costs. Thus, it is not common to have such technologies in the biogas plants and should only be used in large scale plants after a proper evaluation of the market interest and price of the output products.

Among the newest technologies for digestate solid fraction treatment, **pyrolysis** is often considered to produce **biochar**. **Hydrothermal liquefaction** (HTL) is also receiving a lot of attention however it is less developed than pyrolysis.

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Opportunities and challenges

Opportunities

Energy policy

The increased prioritization and financial support for biogas plants is expected to lead to a greater availability of digestate on the market. As the supply of raw digestate grows, producers will face increased competition to reach consumers. This trend also contributes to reducing European dependence on imported fertilizers.

Waste regulations

Changes in the way digestate is handled, and the way manure is spread. Both are positive driving forces, opening up new consumer markets for producers.

European emissions

The substitution of synthetic fertilizers with digestate offers significant environmental benefits. By replacing mineral fertilizers, digestate reduces the demand for natural gas used in conventional fertilizer production. By 2050, this substitution could potentially avoid the consumption of up to 10 billion cubic meters of natural gas across Europe.

Challenges

Immature markets

Difficulty in changing practices and customs in the agricultural sector.

High investment requirements and development risks

This uncertainty and high investment requirements limit the development of new solutions.

Fertilizer regulation at different speeds

European and national regulations do not go hand in hand; nor do they move at the same speed as the industry.

Local restrictions

Surplus nitrogen applied to farmland is a major concern, and local solutions are needed. Crops and soils have different requirements in different countries and regions. There are also limitations due to raw materials and sanitization requirements, [...].

Potential contamination / Risk

Risk of substances depending on the raw material, which may include microplastics, heavy metals, PFAS or others. This requires further research and evaluation.

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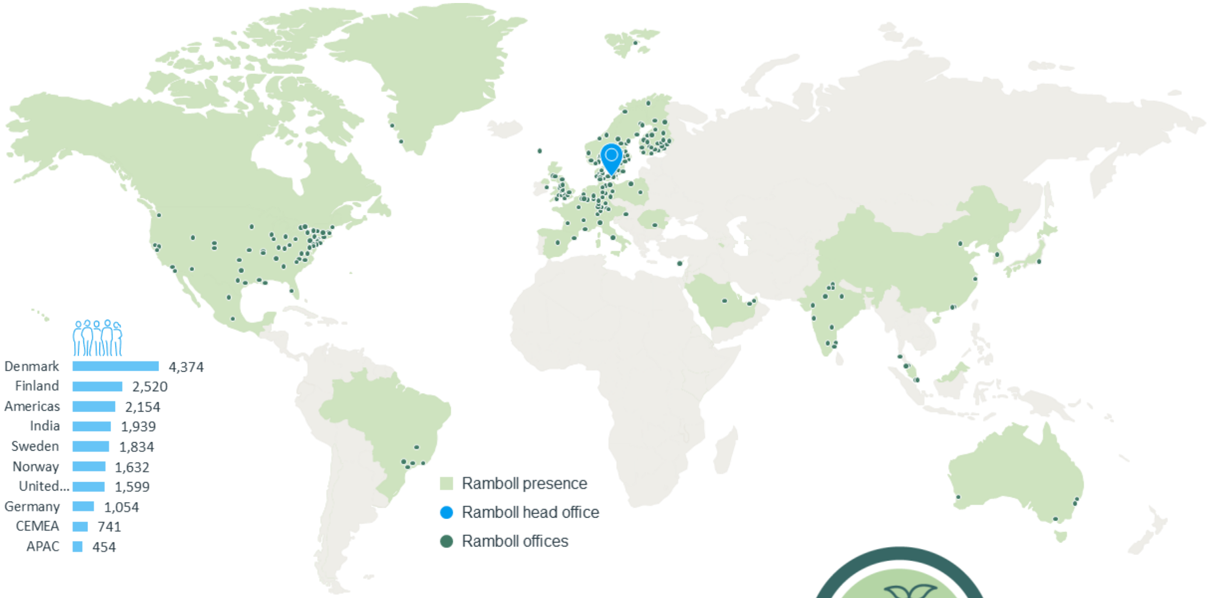
Independent architecture, engineering, and consultancy company founded in 1945 in Denmark

Creating sustainable solutions across energy, real estate, transport, water, waste, industry, finance, technology, healthcare and public sectors.

Owned by Rambøll Fonden – The Ramboll Foundation providing long term stability



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Countries covered by global office network

>18,000

Experts

We work on multidisciplinary projects across our seven markets:

- Buildings
- Transport
- Energy
- Environment & Health
- Water
- Architecture & Landscape
- Management Consulting

Services provided for AD throughout all phases of the project

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PROJECT LIFECYCLE / TECHNICAL AND COMMERCIAL SERVICES / GOAL

Feasibility

- Technical and economic feasibility
- Technology assessment
- Site selection
- Market assessment
- Review of legislative frameworks
- Stakeholder assessment
- R&D Contribution
- Establish high-level scope
- Feasibility studies
- Due diligence (combined Technical, Environmental and Commercial)
- Risk assessment
- Indicative budgeting and time scheduling

Goal: Establish an understanding of viability of the project

Concept design

- Tech. assessments
- Conceptual design
- Process description
- Mass and energy balances
- Layout
- Overall programme
- Environmental Impact Assessment (EIA)
- Permitting
- Time scheduling
- CAPEX/OPEX
- Technical inputs to financial model
- Procurement strategy
- Project setup
- Input for permitting

Goal: Establish the basics of the project

Basic design

- Tech. assessments
- Basic design
- Detailed process description
- Mass and energy balances
- Civil and structural designs for tanks, access, buildings…
- Layout
- Overall programme
- Tender design for AD process and gas utilisation including CHP and BUP
- Prequalification of contractors
- Tender process
- Contract negotiations
- Investment budget

Goal: Establish sound basis for launching the project and ensure contractor signing

Detailed design

- Process engineering and P&ID development
- Mechanical, electrical, CSA, automation and controls
- Civil and structural design
- Project certification and authority approval
- Environmental permitting and licensing
- Procurement strategy
- Project Execution Plan
- Review of design data
- CAPEX/OPEX budget
- Business Model
- Organisational design
- Interface/utility companies
- Progress reports

Goal: Refined design and creation of plans, specifications and estimates

Manufacturing and construction

- Design review
- Construction management and supervision
- Installation supervision
- HSE monitoring
- Inspections: workshops, site, QC-documentation
- Review of programme
- Mechanical completion
- Contract mgmt. / Budget monitoring / Payment assessments
- Progress reports

Goal: Ensure that facility is ready for commission and built in accordance with contract

Test and commissioning

- Inspections of cold/ hot commissioning, performance tests, safety procedure, trial operation period
- Review of CE/ATEX documentation, snagging lists, O&M doc., training programme, commissioning doc.
- Contract Mgmt.
- Budget monitoring
- Payment assessments
- Progress reports

Goal: Ensure that facility is in stable operation in accordance with contract

Operation

- Closing snagging lists
- O&M planning and follow-up
- Day-to-day technical assistance
- Support for complex trouble-shooting
- Asset management
- Asset portfolio and strategy
- Definition and implementation of KPI systems to monitor performance and OPEX of assets
- Pollution control
- Optimization
- Operations Training
- Enhanced Operations Support after Commissioning

Goal: Ensure that facility has high availability and strong performance

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