RE-CORD

Renewable Energy COnsortium for Research & Demonstration

On the synergies and opportunities from integration of AD and pyrolysis, with reference to two case studies on Organic Fraction of Municipal Solid Waste

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Agenda

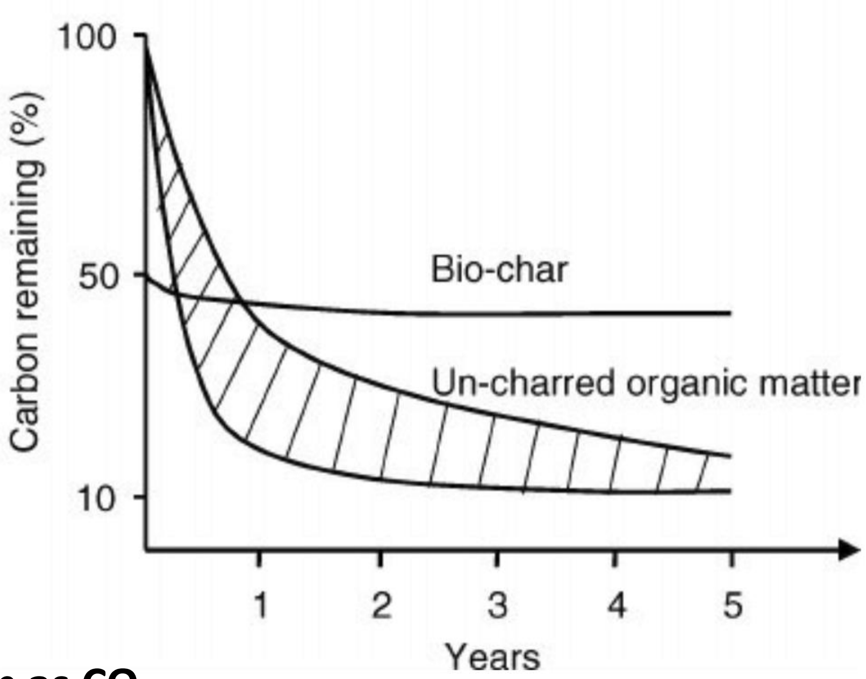
1. Generalities on AD-PYRO integration & products' classification
2. Back-end vs. front-end integration
3. Case study 1: 40 kt/y OFMSW plant (I Cipressi, Tuscany)
4. Case study 2: 1 kt/y OFMSW plant (Pantelleria, Sicily)
5. Opportunities for BECCS & grid balancing services

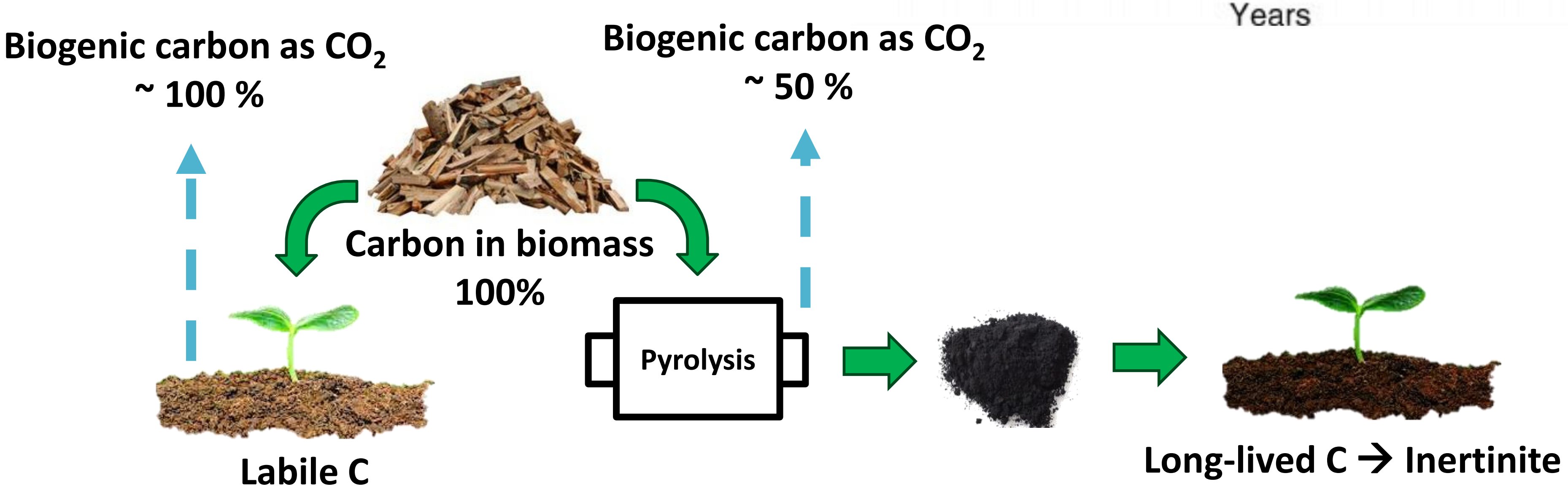
Why biochar?

1 ton of biochar

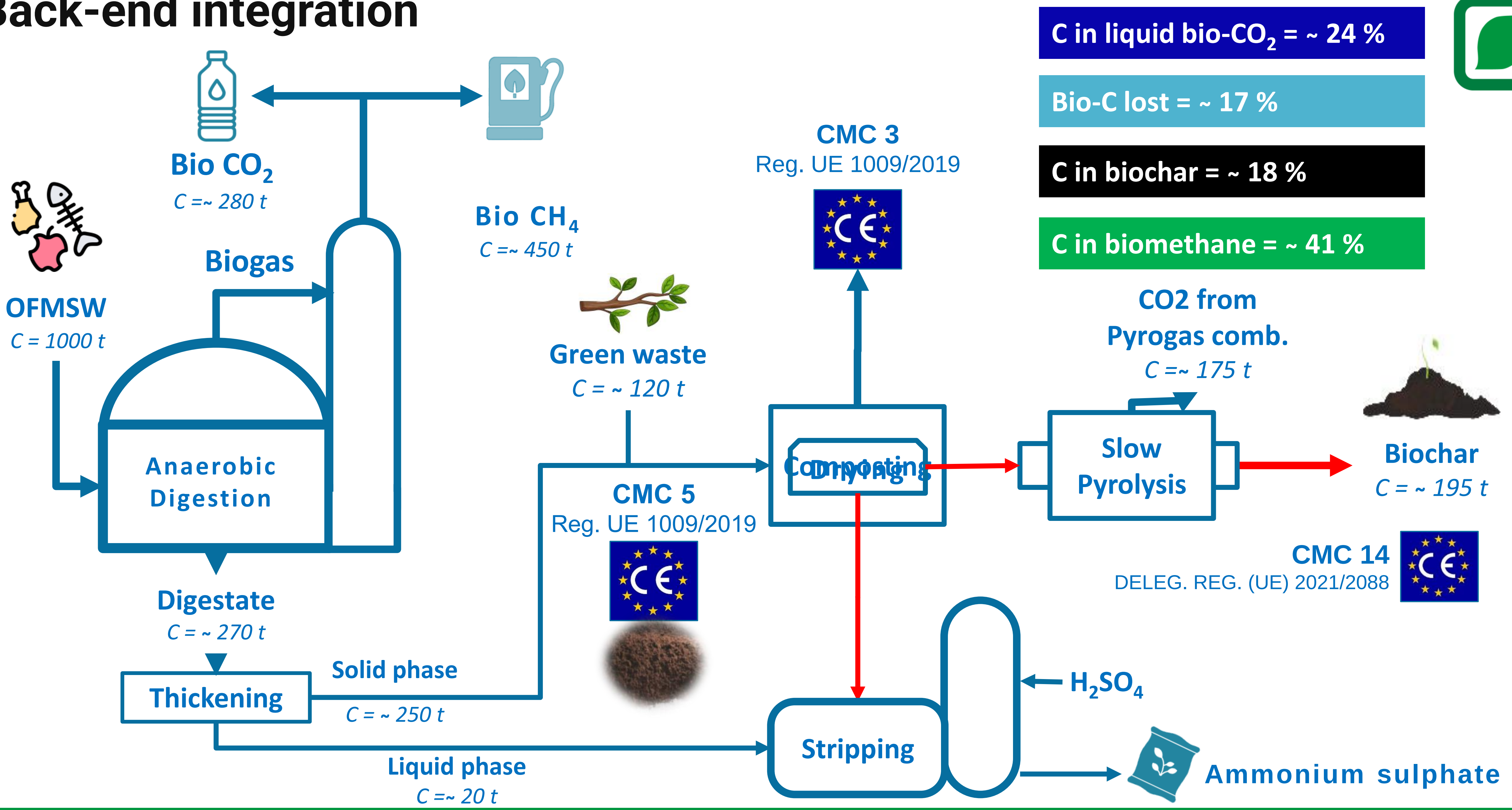
⬇

1.5 – 2.5 ton Bio-CO_2 removed from atmosphere

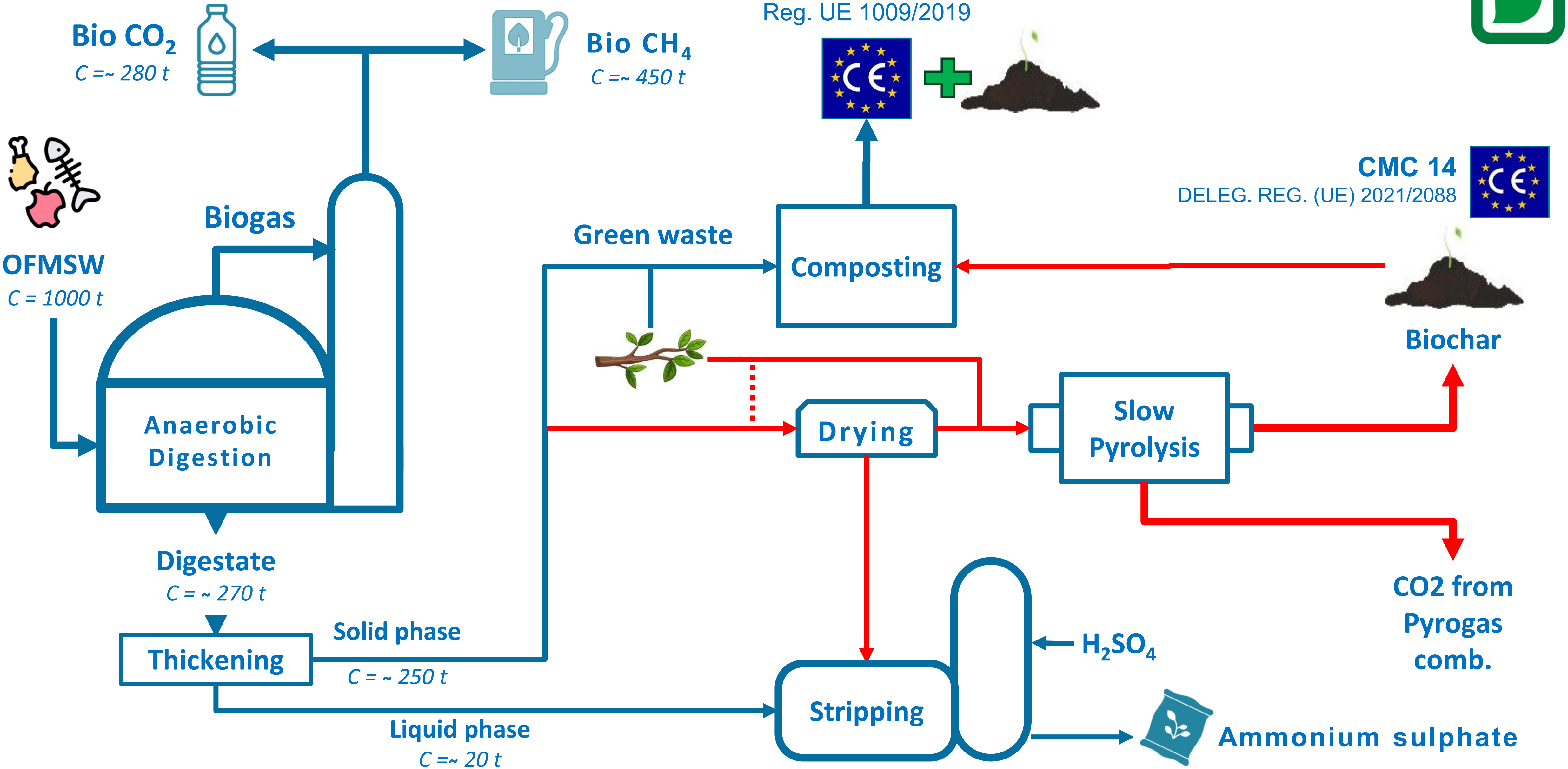




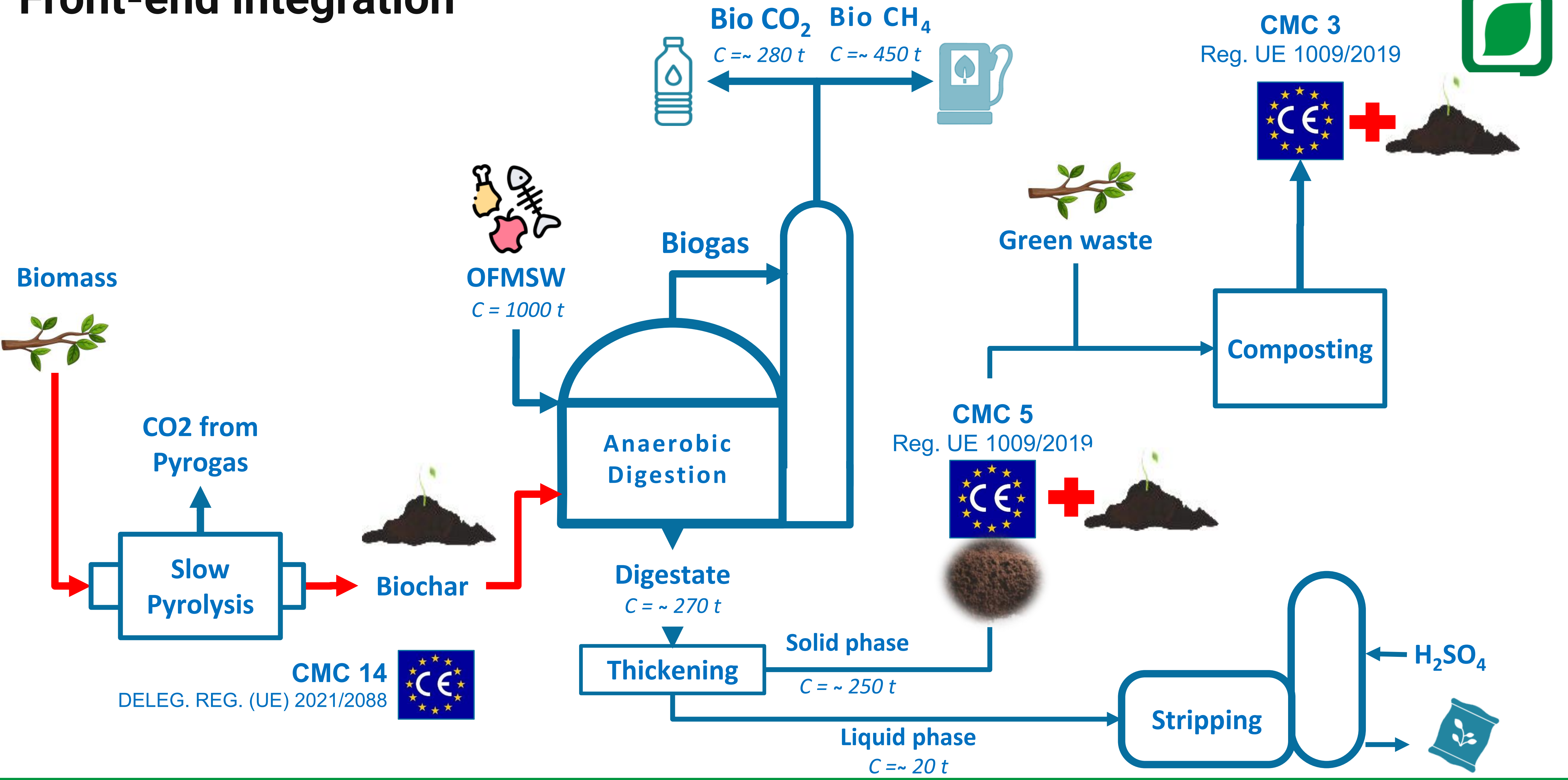
Back-end integration



Back-end integration (2)



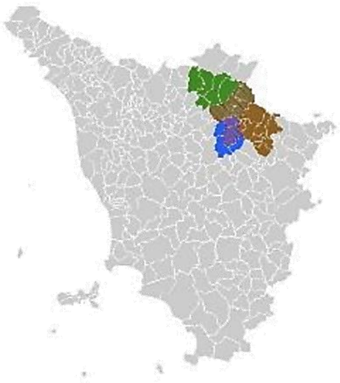
Front-end integration



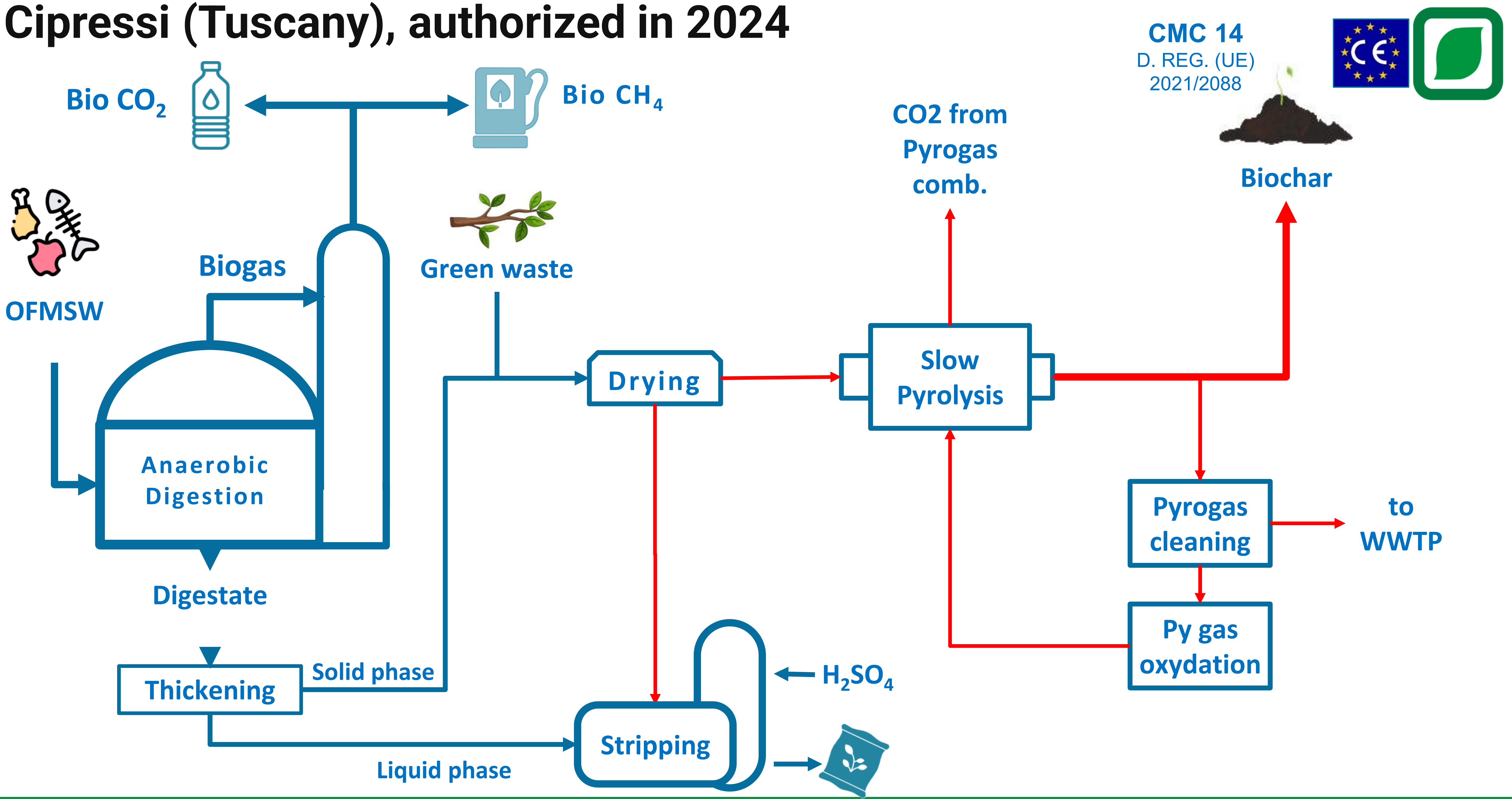
CASE STUDY 1: Tuscany “I Cipressi” – Authorized in 2024

OFMSW 40 000 t/y	Green waste 2 000 t/y

- 2 250 t/y Biomethane
- 3 690 t/y CO_2
- 1 680 t/y Biochar
- 2 420 t/y Ammonium Sulphate

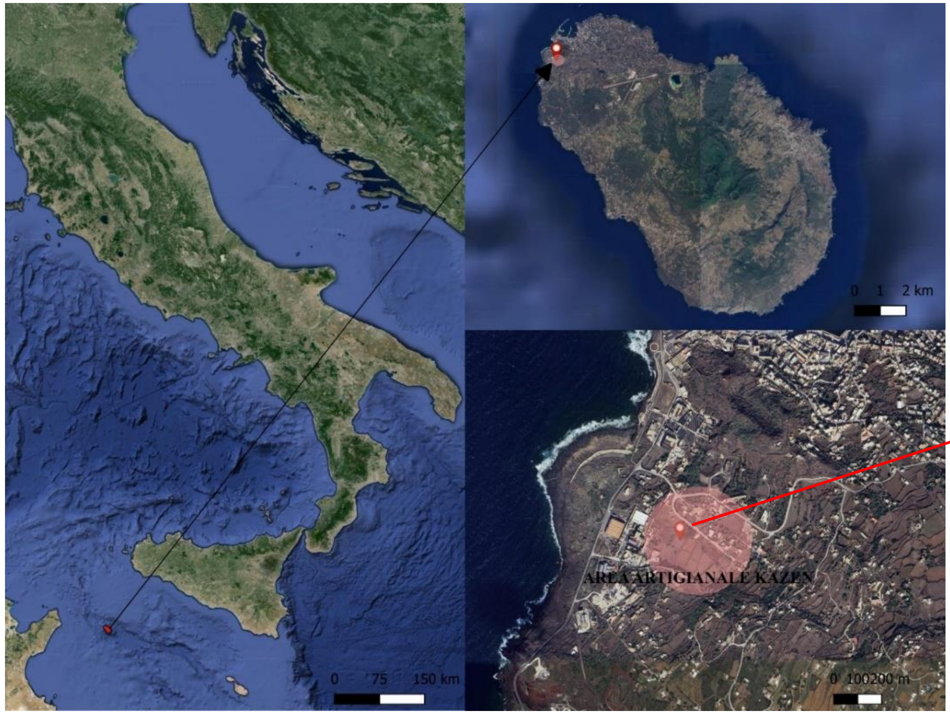


I Cipressi (Tuscany), authorized in 2024



Description of the plant site in Khazen, Pantelleria

The plant for valorisation of **OFSMW** (Organic Fraction of Municipal Solid Waste) will be located on the Sicilian island of Pantelleria, in the industrial area of Khazen, situated in the northern part of the island.

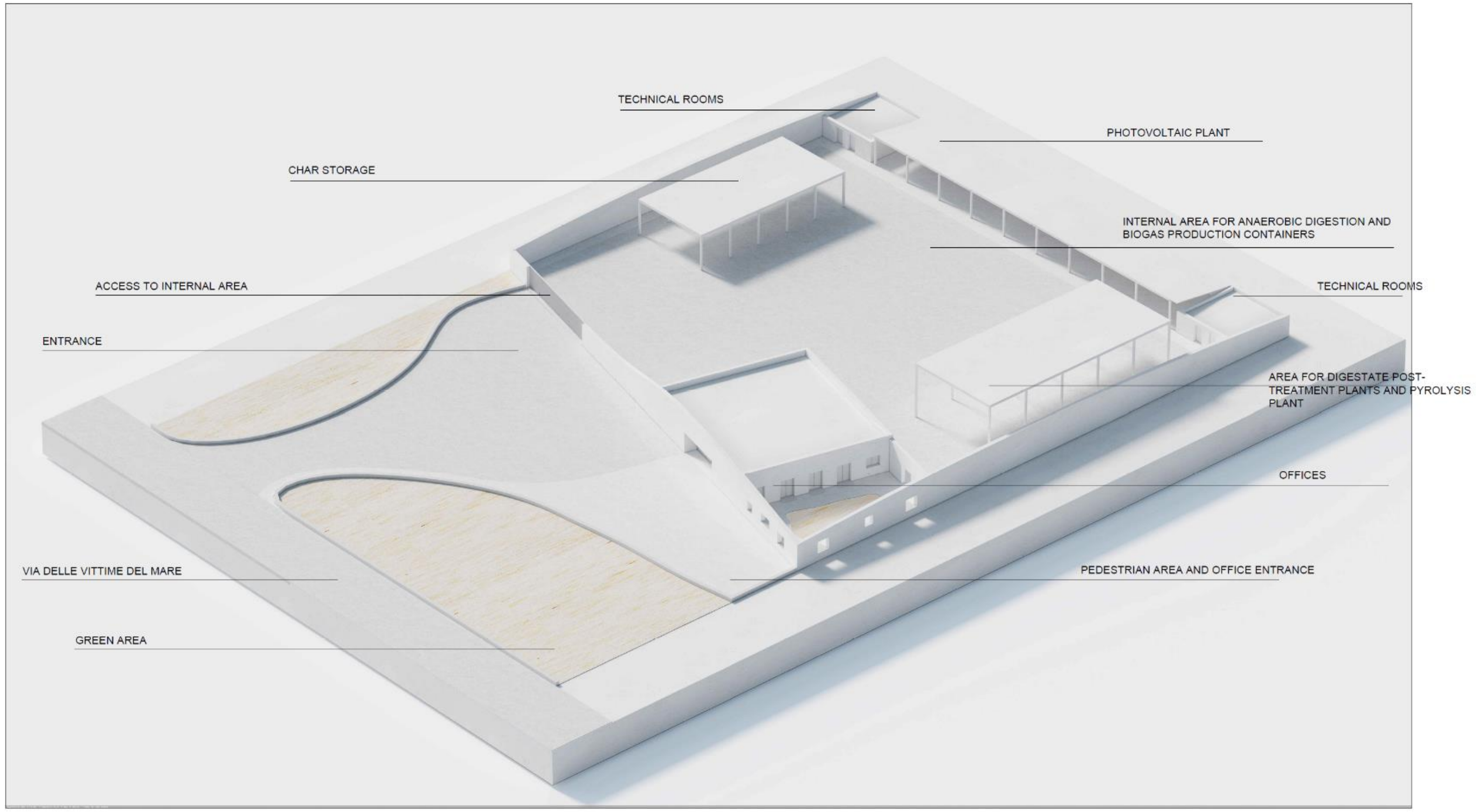


The project was realized in the context of the programme “**Isole Verdi**” [1], for the energy transition of the minor islands of Italy.

The proposed plant aims to **convert all the biowaste** produced in the island, currently representing a considerable environmental and economic cost for the community, into **valuable resources**.

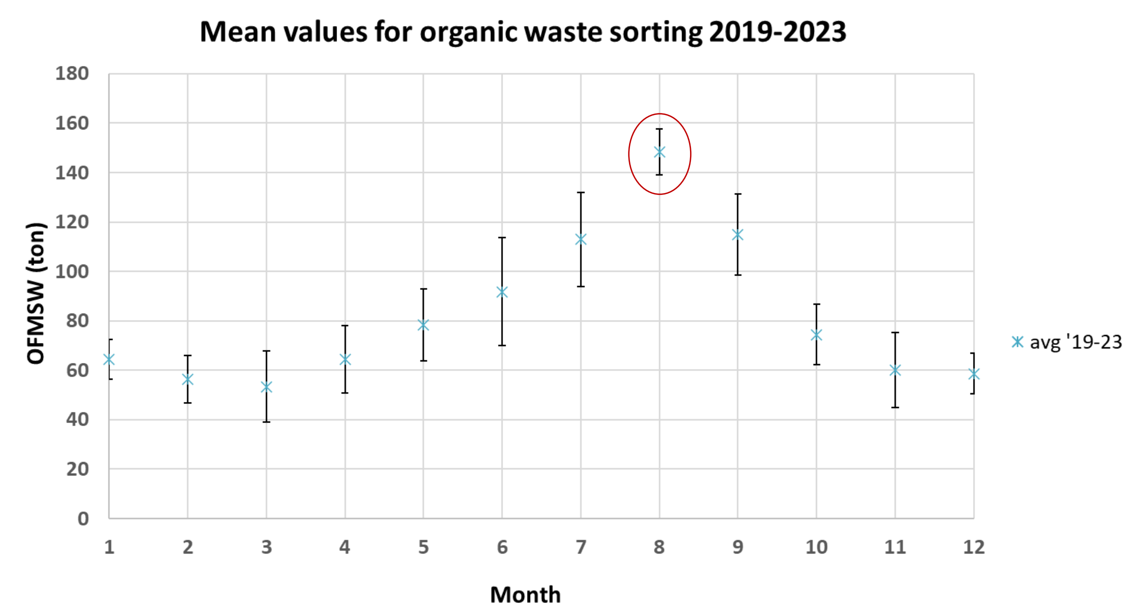
[1] PNRR Isole Verdi - Ministero dell'Ambiente e della Sicurezza Energetica

Architectural project



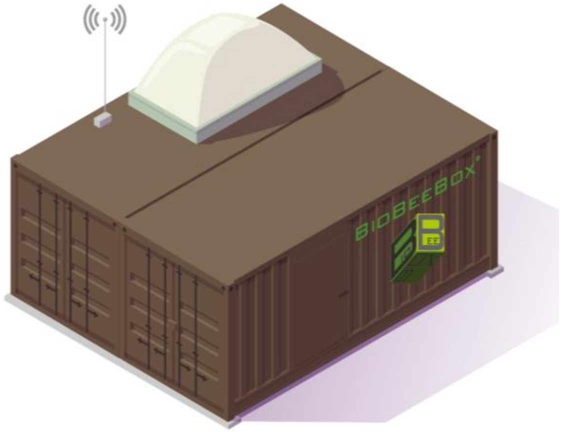
Description of treated waste and applied modular solution

The island is subjected to **significant variations in waste production** due to the seasonality of activities, particularly the influx of tourists during the summer months



The average amount of OFMSW collected in **August** is **148 tons**, more than double the average amounts collected during the winter and autumn months.

To size the AD plant and handle the **high load variability**, a **modular solution** has been designed, with units capable of operating in series or in parallel.



A containerized solution[3], consisting of **7 modular containers** for the OFMSW pre-treatment and AD was designed.

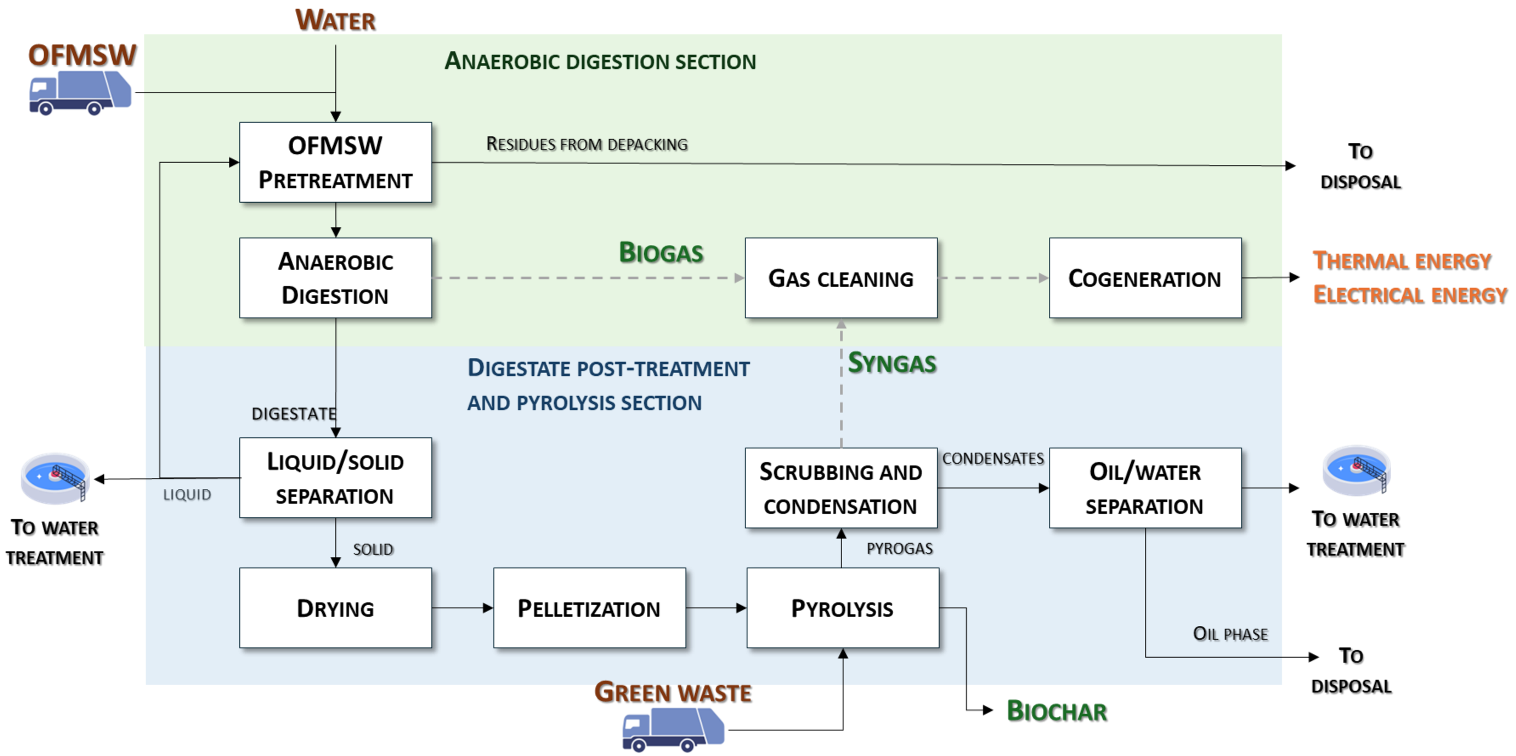
To manage the load fluctuations in the pyrolysis section, green waste is added to the digestate pellets with the aim of maintaining a **constant capacity of material entering the reactor** throughout the year.

[3] Bee&Co

Description and mass balance of the integrated process

The plant is designed as a system comprising two integrated sections:

1. **Anaerobic Digestion and Cogeneration Section**
2. **Digestate Post-Treatment and Pyrolysis Section**



Input mass flows

The plant will have the capacity to process:
- **1337 tons/year** of OFMWS;
- **94 tons/year** of green waste.

The plant will consume:
- **400 tons/year** of water for OFMWS dilution.

Output mass flows

The plant will convert waste in:
- **298 tons/year** of biogas and syngas;
- **88 tons/year** of biochar, to be used as soil amendment[2].

The plant will also produce:
- **161 tons/year** of residues for disposal;
- **1284 tons/year** of a nutrient-rich liquid to treat or, in alternative, to use as fertilizer[2] with the addition of an ultrafiltration step.

Energy production

The **CHP unit** and a **photovoltaic system** installed on the roof will generate electrical and thermal energy for the self-consumption of the plant. A net amount of **108 MWh/year** of electrical energy will be fed into the grid.

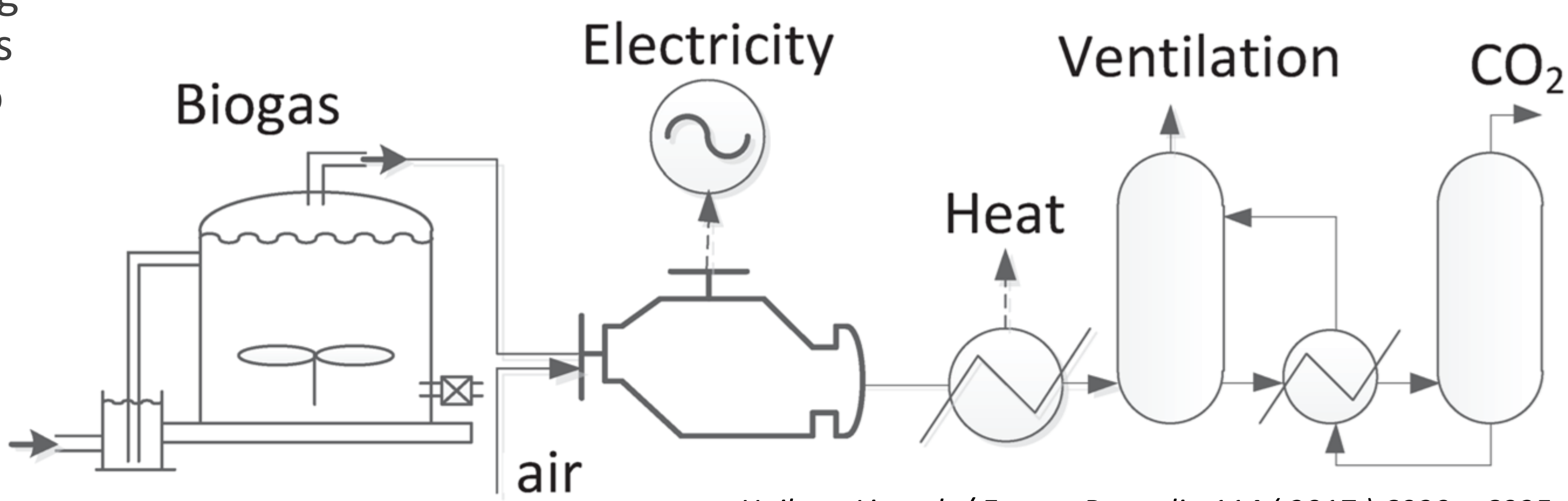
[2] EU Regulation 2019/1009 on fertilizing products

Post Biogas Combustion BECCS

BECCS: the process of capturing and storing CO_2 from processes that use biomass feedstocks to produce heat, electricity, or biofuels (IEA BE23)

Biomass absorbs CO_2 as it grows, releasing it during processing or burning. The released CO_2 is captured and injected into storage such as deep geological formations, thus removing it from the natural carbon cycle.

CO_2 can be captured also from the flue gases post combustion of any carbon-based fuel, from coal to biomass.



Hailong Li et al. / Energy Procedia 114 (2017) 6030 – 6035

In biogas plants, after raw biogas is combusted in the engine, the exhaust gas passes through a chemical absorption process and CO_2 is captured. The heat demand required by the solvent regeneration comes from exhaust gas: the heat production is reduced.

Economics strongly depends on Carbon Credit price. Presently no commercial plant applies this solution.

Flexible power from biogas

Provision / shift	Marketing	Additional technical demands
Up to 5 min	Secondary control reserve (to balance the net frequency)	Control gateway, CHP adjusted to start stop operation
5 – 15 min	Minute reserve (to balance the net frequency)	Control gateway, CHP adjusted to start stop operation
15 min – 6 h	Spot market — intraday (balance forecast errors, larger plant malfunctions, etc.)	Gas storage capacity, additional CHP capacity
6 – 24 h	Spot market — day-ahead (balance residual loads)	Additional CHP capacity, heat storage, additional gas storage capacity Potentially: process control, feeding management, adjustment of substrate and gas management systems
1 – 7 d	Spot market—day-ahead (balance residual loads, in particular macro weather situation)	Additional CHP capacity, heat storage, additional gas storage capacity, process control, feeding management, adjustment of substrate and gas management systems, long-term substrate storage
7 – 90 d	Spot-and derivative markets (balancing residual load, seasonal demand)	Additional CHP capacity, additional gas storage capacity, heat storage, process control, feeding management, adjustment of substrate and gas management systems, long-term substrate storage

Daniela Thrän (2015) Smart Bioenergy;
Chiaramonti et al. (2017). Bioenergy: Role in Balancing the Electricity Grid and as Energy Storage DOI: 10.1007/978-1-4939-2493-6_1045-1

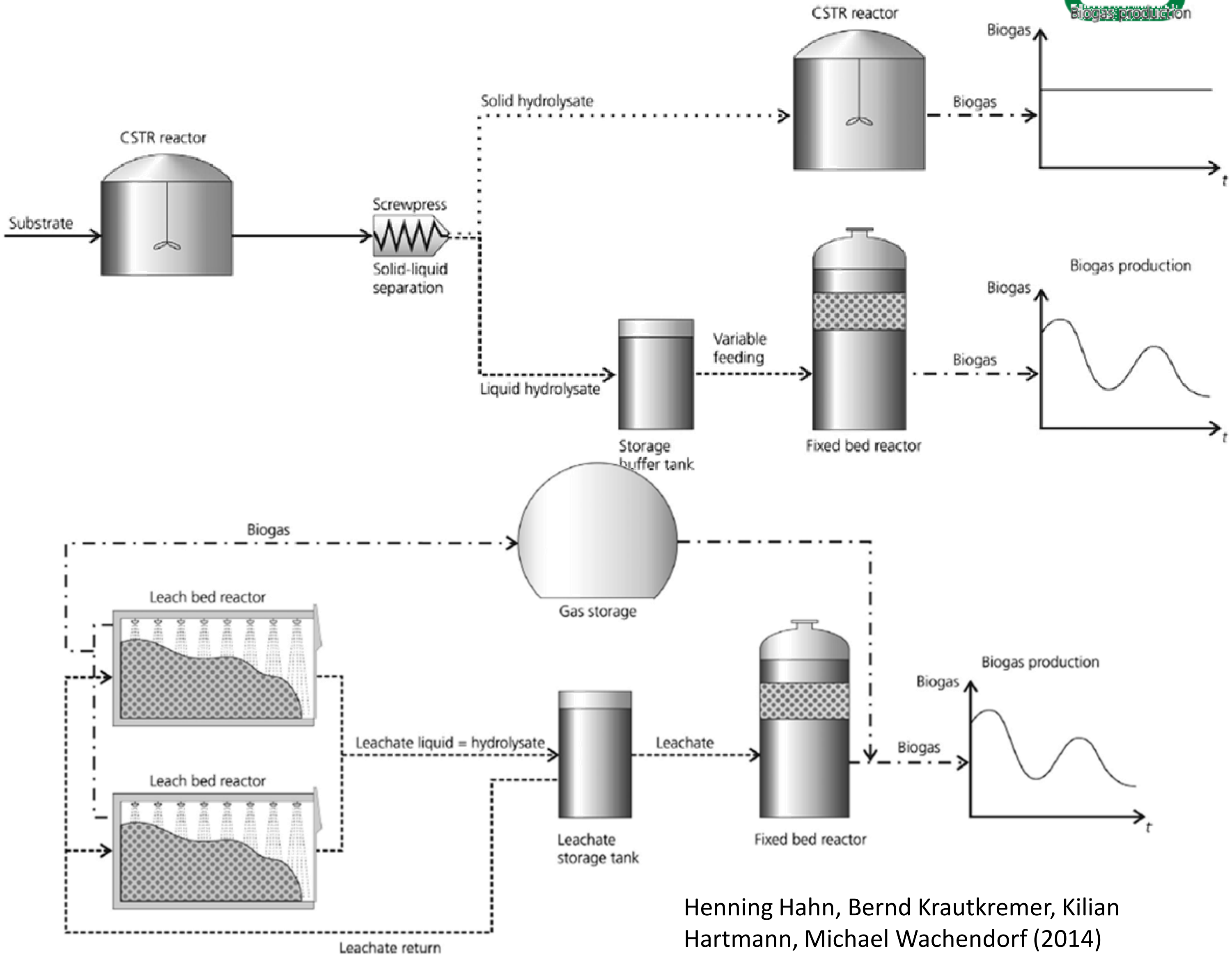
Biogas and Biomethane

Biogas, and in particular biomethane, is of interest for grid balancing as it is burned in gas engines and gas turbines that have a quick response time, even from a cold start, as well as high ramping capabilities.

Biogas is produced in a relatively slow process and consumed as it is generated, with a minimum of storage in low pressure gas holders. This limits the opportunities for balancing services.

Options for grid balancing

- Upgrading to bio-methane: distributed and stored in the gas grid and retrieved for balancing.
- Make the process more flexible with some minor design changes:
  - implement control systems for gas utilization
  - gas storage capacity
  - process control system for the biological process



Henning Hahn, Bernd Krautkremer, Kilian Hartmann, Michael Wachendorf (2014)

Conclusions (1)

The **integrated AD-pyrolysis** plant is a **biofertilizers production facility,** capable of manufacturing **carbon negative, CE Marked, (bio)Fertilizing Products**

- Biochar enables to turn the biowaste digestate into a stable and durable **carbon negative soil conditioner**
- About 50 % of the **biogenic carbon** contained in the processed biomass is sequestered as Biochar
- Multiple options for pyro plant layout (condensation & CHP, full oxidation of pyrogas) depending on fedestock and regulatory constraints
- Local regulations might require to **compromise on plant configuration**

Conclusions (2)

The **integrated AD-pyrolysis** plant is a **biofertilizers production facility,** capable of manufacturing **carbon negative, CE Marked, (bio)Fertilizing Products**

- When added to the back end *along with* composting, biochar can ↓ N emission in composting, ↑ composting speed & product's quality (↑value and ↓cost)
- When added to the back end *instead* of composting, ↓civil work, ↑ ↑ value of product, opens up to C sequestration
- When added to the front end, can improve CH4 yield (↑ revenue) and produce a biochar-enhanced digestate/compost
- The integarted AD plant offers opportunities for BECCS
- Grid balancing services could play a role in additional revenue generation

Thank you for your attention!

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