



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



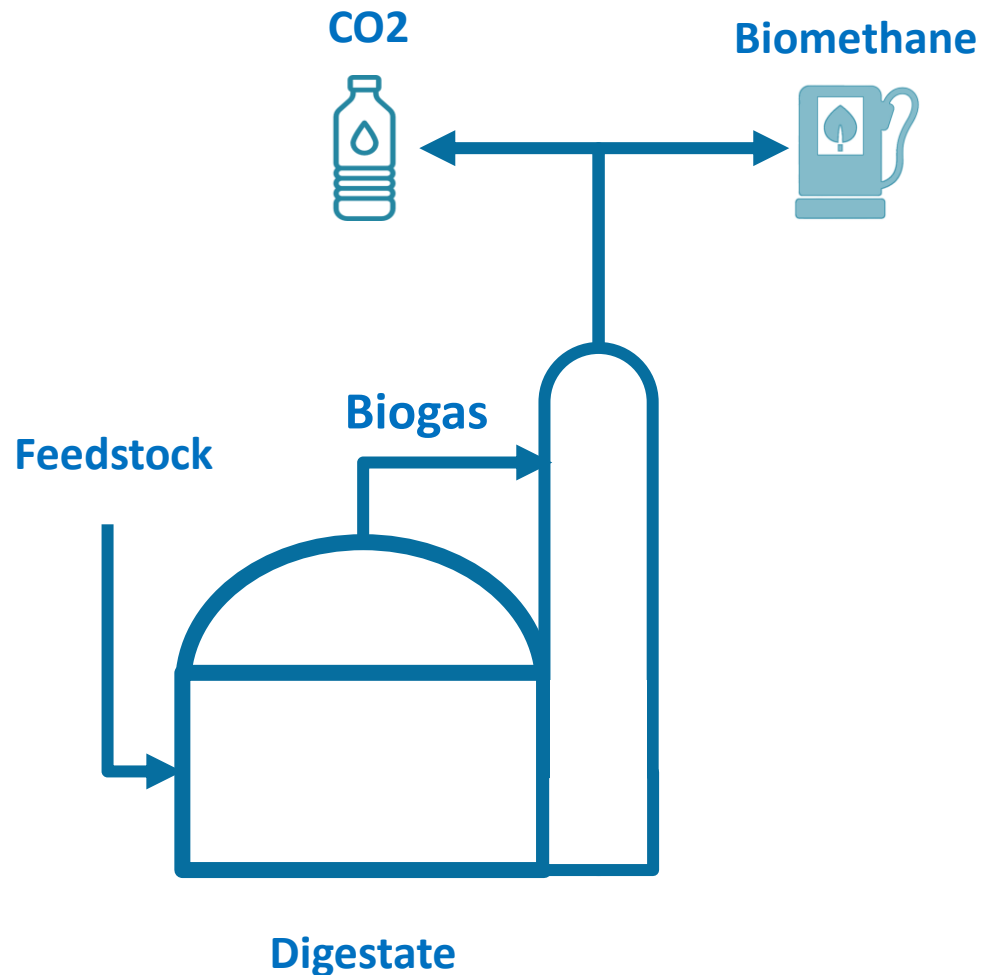
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- 1. Generalities on AD-PYRO integration & products' classification**
- 2. Back-end vs. front-end integration**
- 3. Case study 1: 40 kt/y OFMSW plant (I Cipressi, Tuscany)**
- 4. Case study 2: 1 kt/y OFMSW plant (Pantelleria, Sicily)**



Anaerobic digestion



A great technology...

- ❖ Robust, scalable, reliable, proven
- ❖ Fit easily into NG gas grid
- ❖ GoO extends the geographical reach
- ❖ Feedstock-flexible

...with an Achilles' heel

- ❖ Digestate management
 - Space occupation – civil works
 - Operational cost
 - Poor value

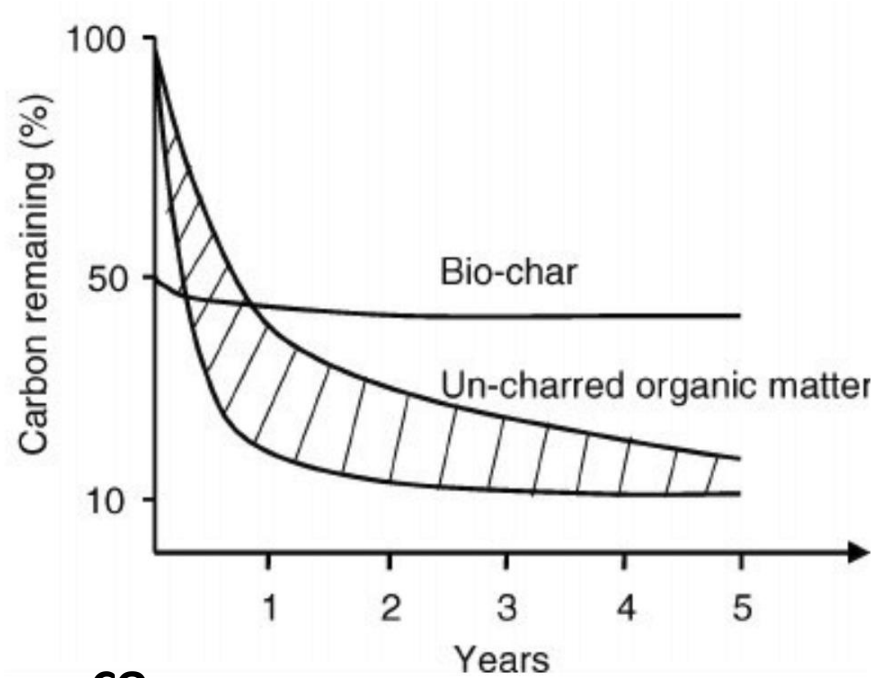
Biochar



1 ton of biochar

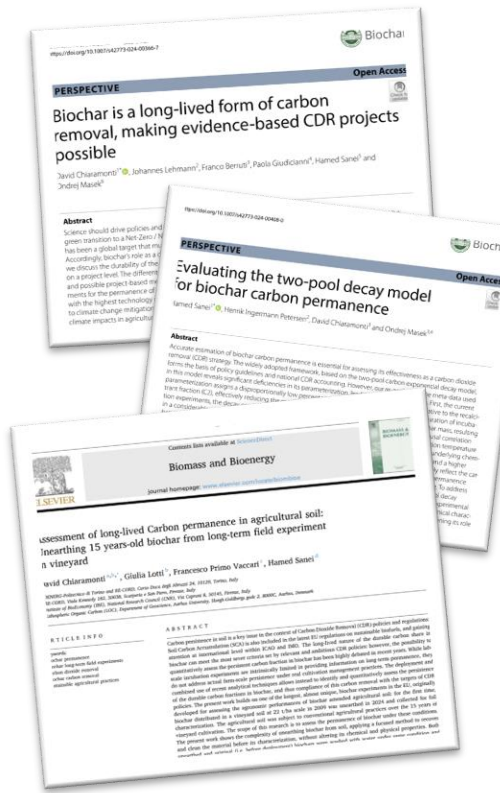
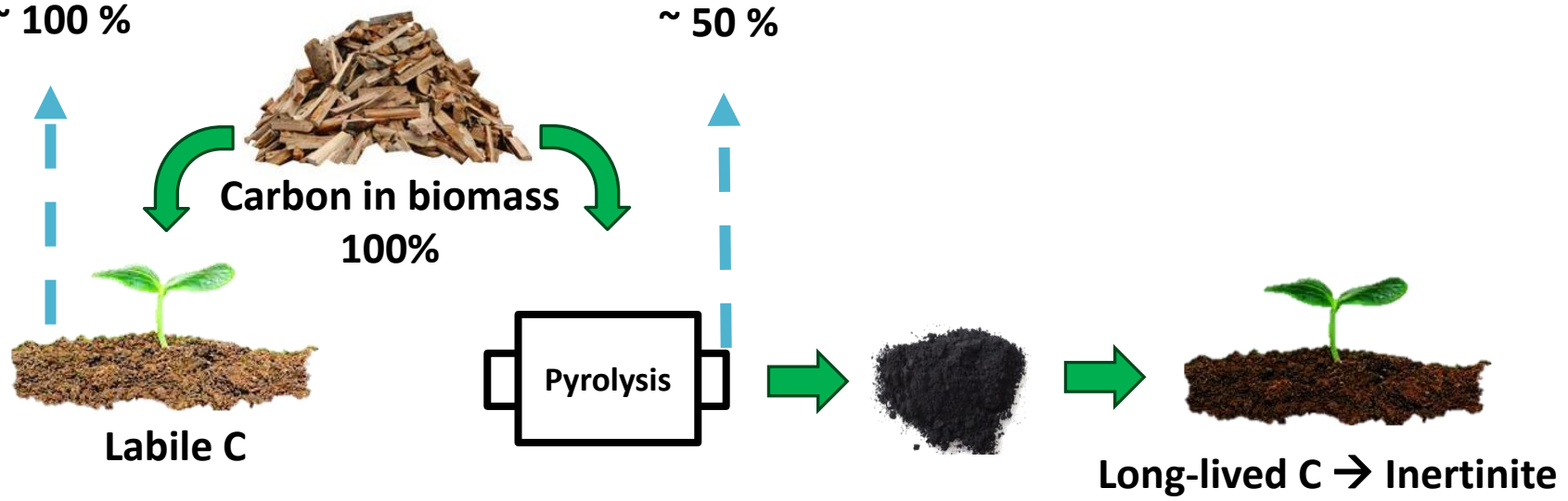


1.5 – 2.5 ton CO₂ removed from atmosphere



Biogenic carbon as CO₂
~ 100 %

Biogenic carbon as CO₂
~ 50 %



Why integrating? A compilation of side benefits



Stability of C in end product

- ❖ C permanence in soil increased by several orders of magnitude, from few years (digestate) to '000s (biochar)

Expanded range of products

- ❖ Biochar is a fully-fledged component material category (n. 14) as per EU FPR Reg. UE 1009/2019 and DELEG. REG. (UE) 2021/2088
- ❖ High-value uses outside agriculture are possible (e.g. construction products, adsorbents, fillers, coal-substitute)

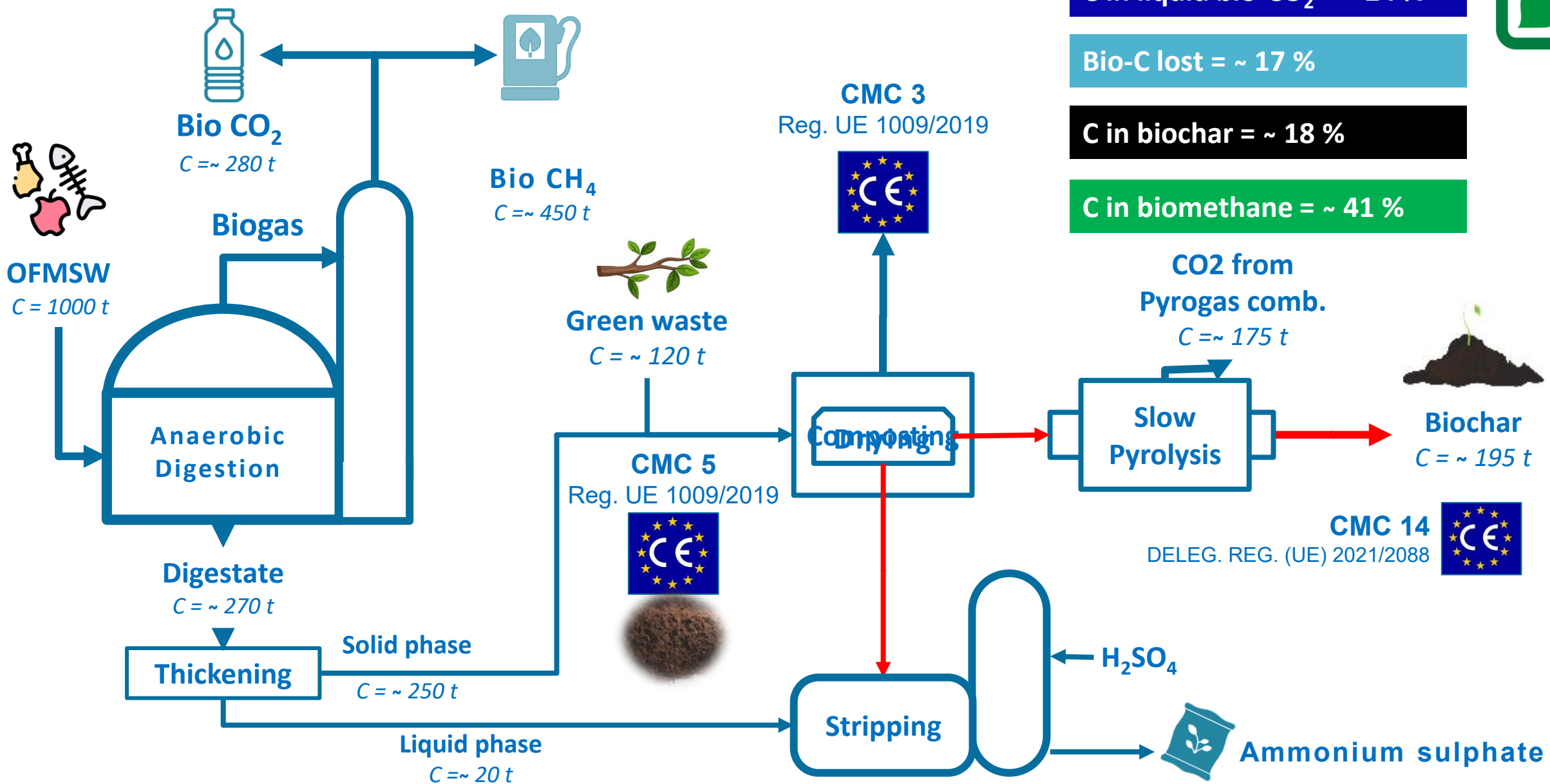
Increased value of product

- ❖ Biochar → >>200 €/ton vs. digestate <10 €/ton, suitability for carbon credit

Contaminants

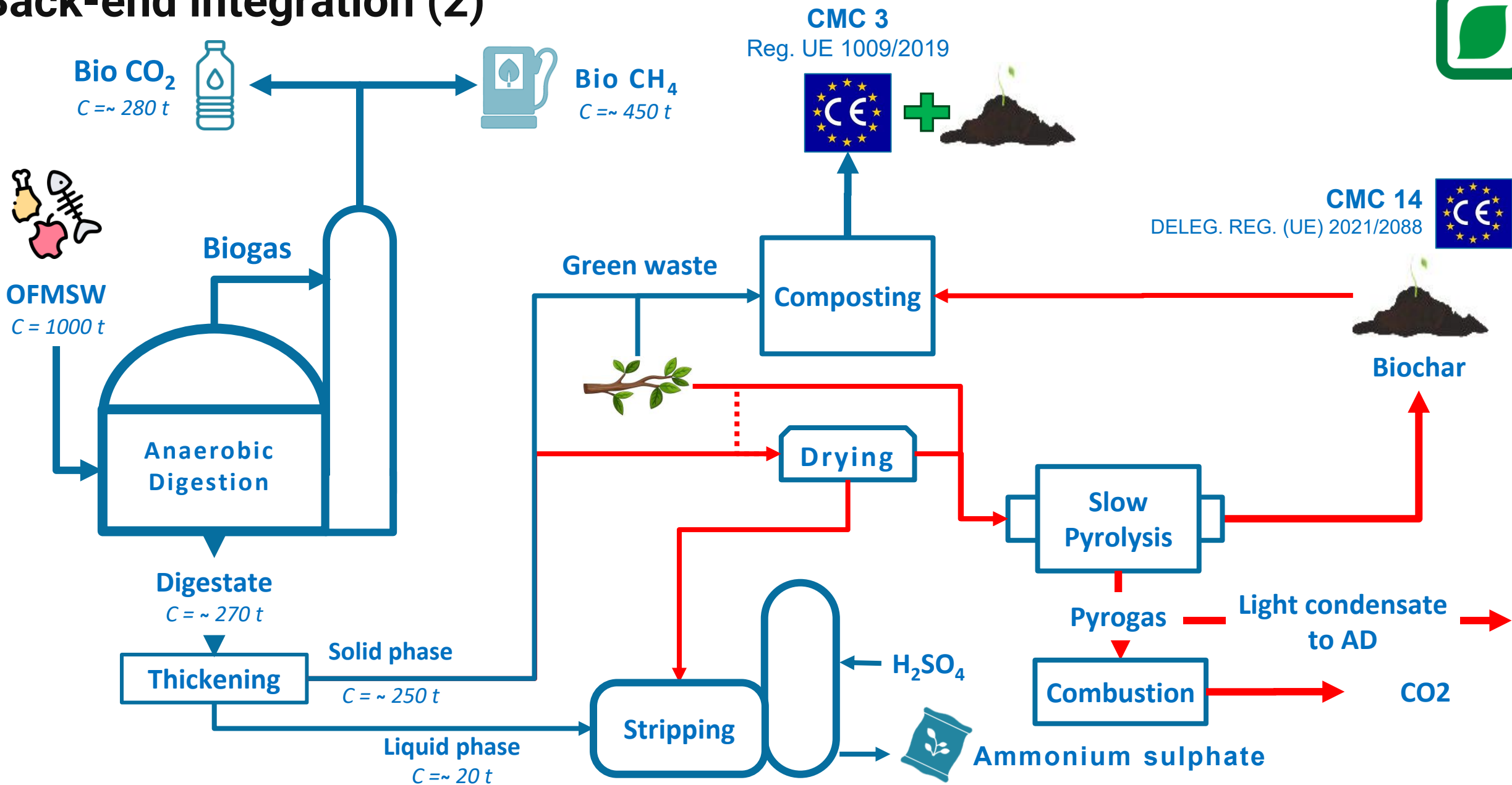
- ❖ Experimental evidences suggest that under appropriate conditions (e.g. temperature, additives) PFAS in feedstock can be effectively abated → reduction/complete conversion

Back-end integration

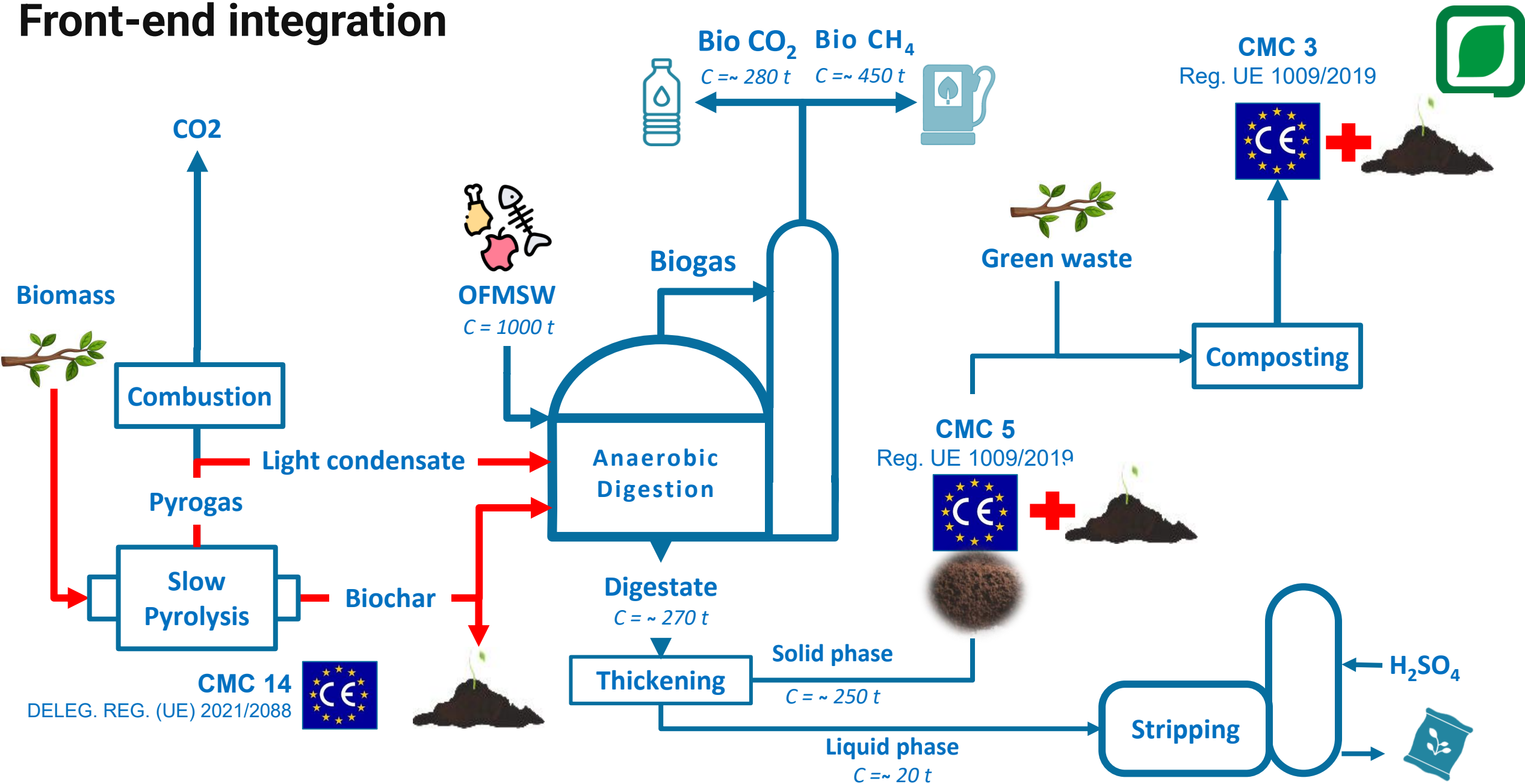


- C in liquid bio- $\text{CO}_2 = \sim 24\%$
- Bio-C lost = $\sim 17\%$
- C in biochar = $\sim 18\%$
- C in biomethane = $\sim 41\%$

Back-end integration (2)



Front-end integration





Electricity

- ❖ Electrical demand for the integrated AD-pyro plant increases wrt baseline
Pyro plant w/dryer net EE consumer, unless ORC configurations are being considered
- ❖ The extent of feedstock pretreatment and solid/liquid separations can impact heavily on EE demand

Heat

- ❖ Heat balance of the pyro plant w/dryer strongly dependent on 1) feed moisture content, 2) effectiveness of dryer, 4) pyrolysis temperature, 4) system losses.
→ *highly-integrated solutions exists for digestates/sludges*  
- ❖ Biomethane plant would benefit of any available heat stream from pyro plant, e.g. to **reduce self-consumption** (*already in mild climates*)

Emissions

- ❖ **1 Additional chimney** (pyrogas/dry pyrogas combustion) + 1 flare

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



OFMSW
40 000 t/y

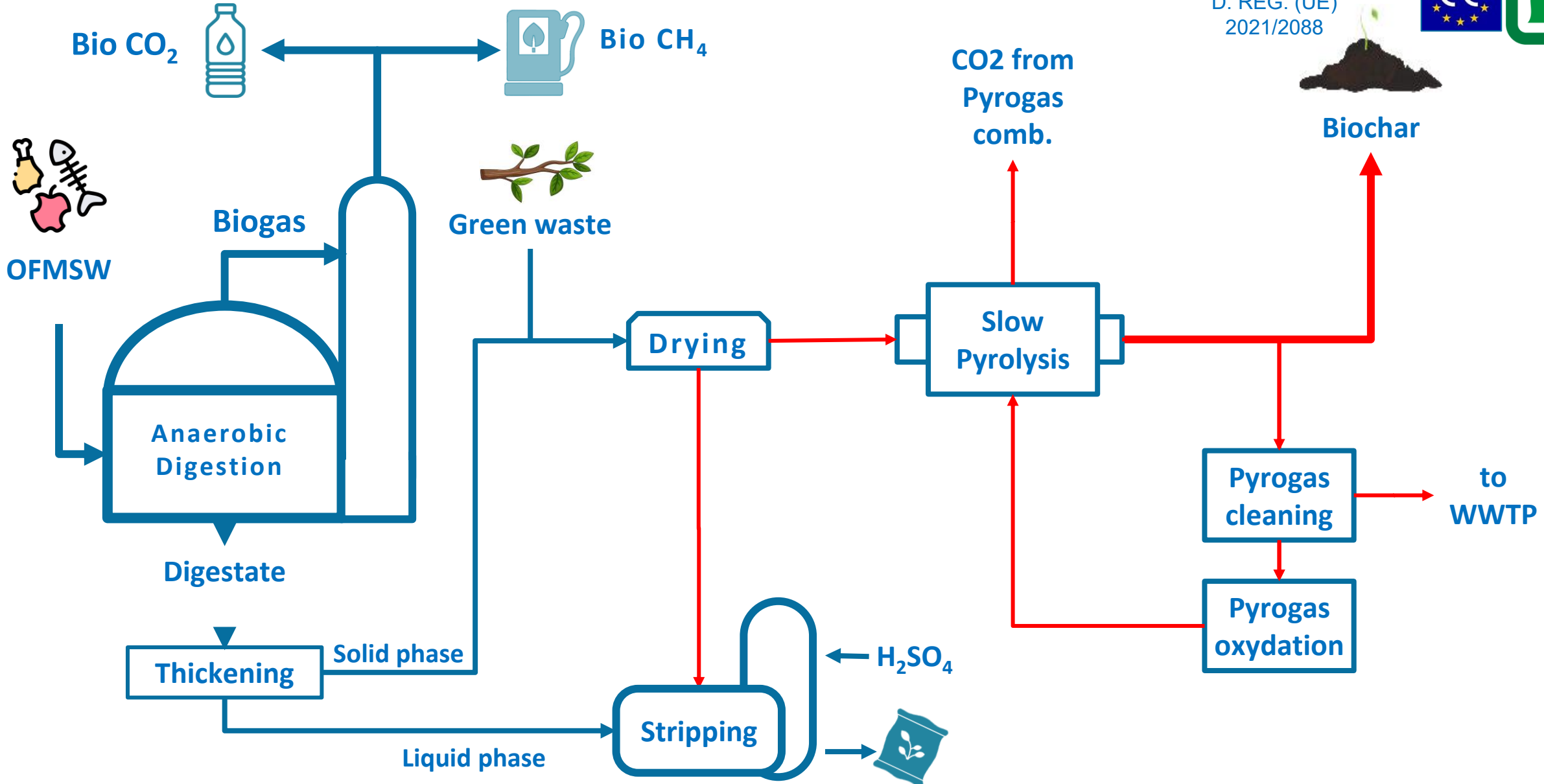
Green waste
2 000 t/y

- 2 250 t/y Biomethane
- 3 690 t/y CO₂
- 1 680 t/y Biochar
- 2 420 t/y Ammonium Sulphate



I Cipressi (Tuscany), authorized in 2024

CMC 14
D. REG. (UE)
2021/2088



CASE STUDY 2: Khazen, Pantelleria (ITALY), authorization pending

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**.

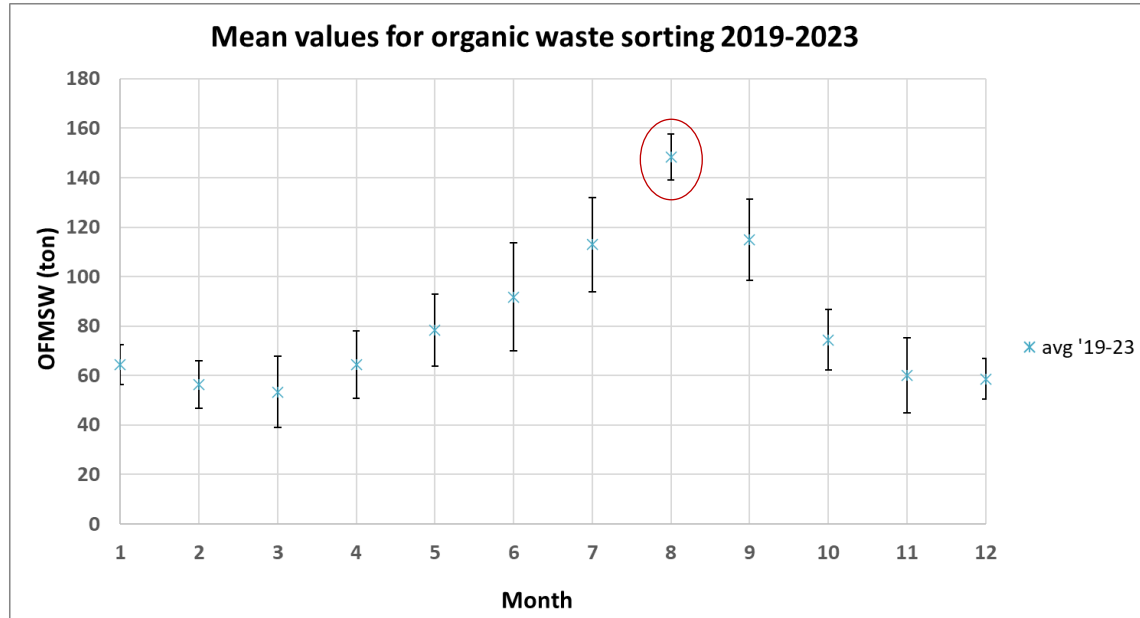
¹ [PNRR Isole Verdi - Ministero dell'Ambiente e della Sicurezza Energetica](#)

Description of treated waste and applied modular solution

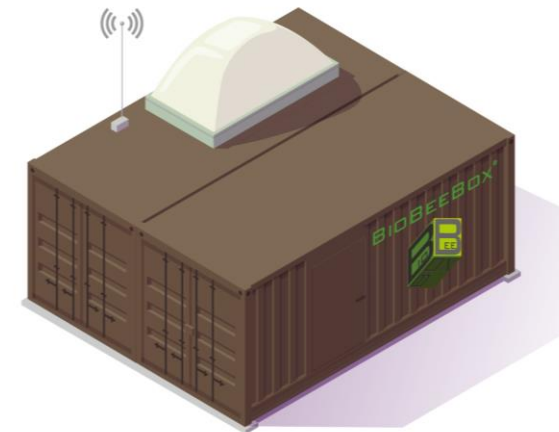
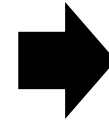


The island is subjected to **significant variations in waste production** due to the seasonality of activities, particularly the influx of tourists during the summer months

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.



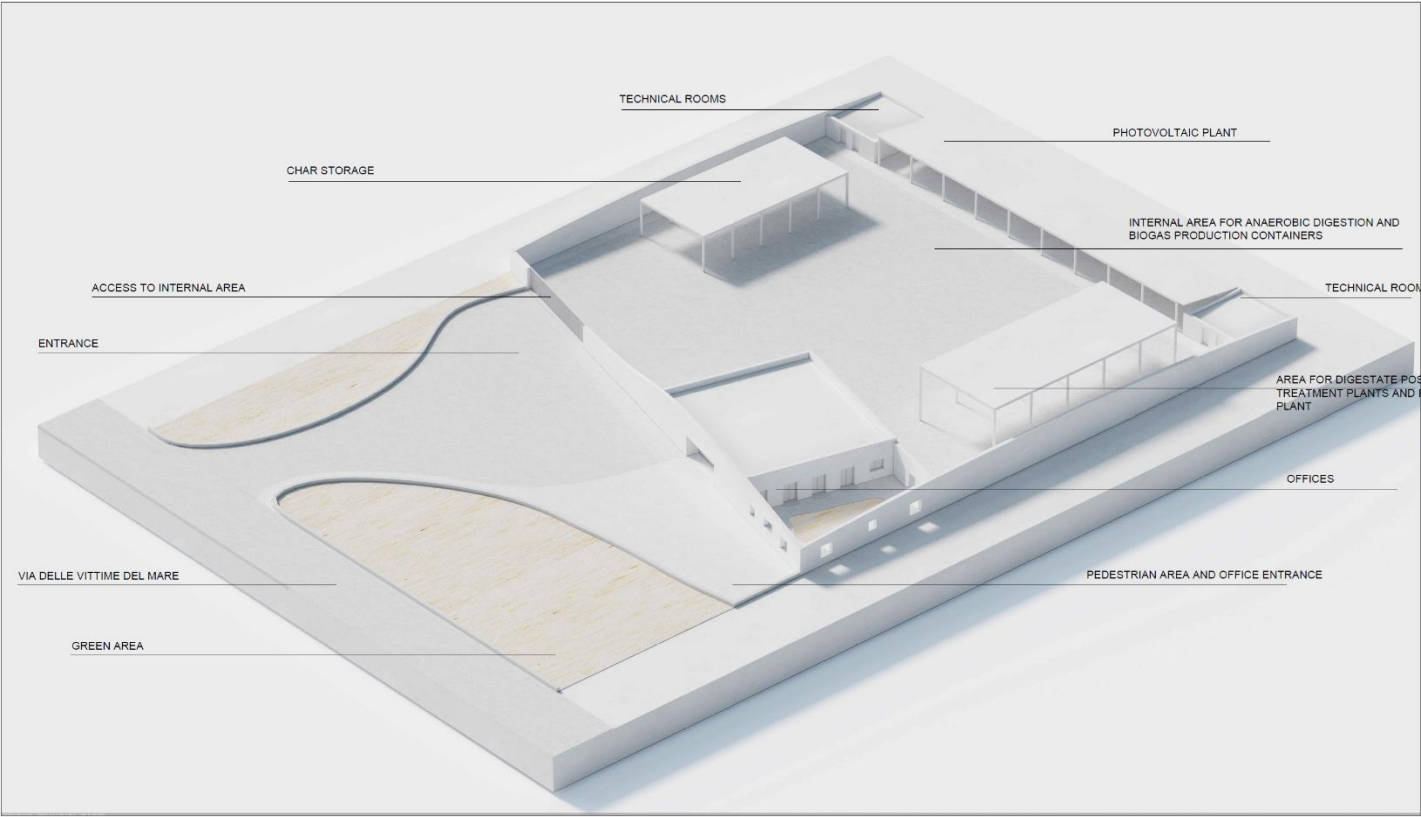
The average amount of OFMSW collected in **August** is **148 tons**, more than double the average amounts collected during the winter and autumn months.



A containerized solution³, 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.

Architectural project

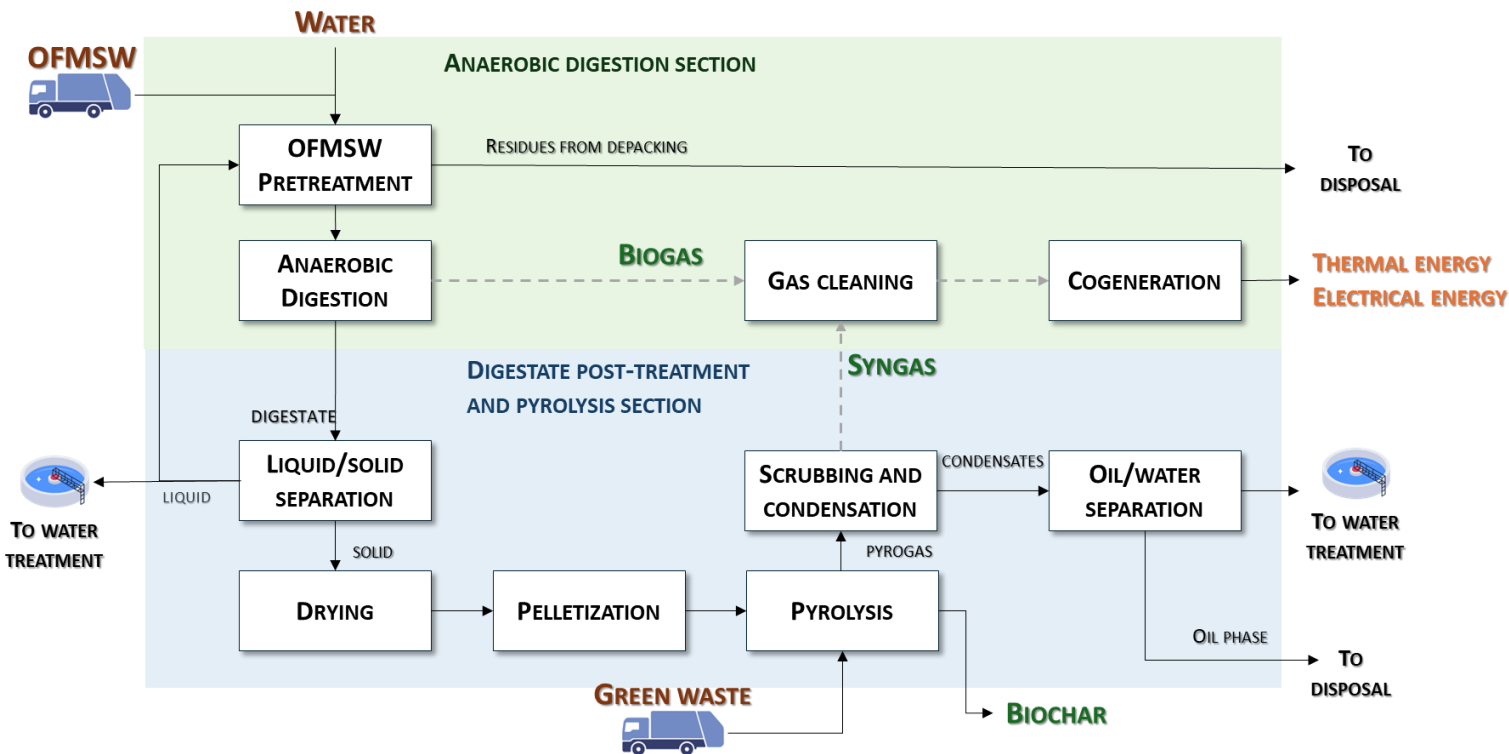


Description and mass balance of the integrated process



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 amendment².

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 fertilizer² 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](#)



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
- ❖ Technical option to **reduce the contamination from PFAS** (*very relevant for specific substrates*)
- ❖ Multiple options for pyro plant layout (condensation & CHP, full oxidation of pyrogas, ...) depending on feedstock 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
- ❖ When pyrogas condensation is needed, valorization of light condensates within AD is possible (↑ CH₄ output)
- ❖ The integrated AD plant offers opportunities for BECCS



Thank you for your attention!

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