Integration of Anaerobic Digestion and Pyrolysis (AD-Py) for Biomethane Production in a Circular Bioenergy System

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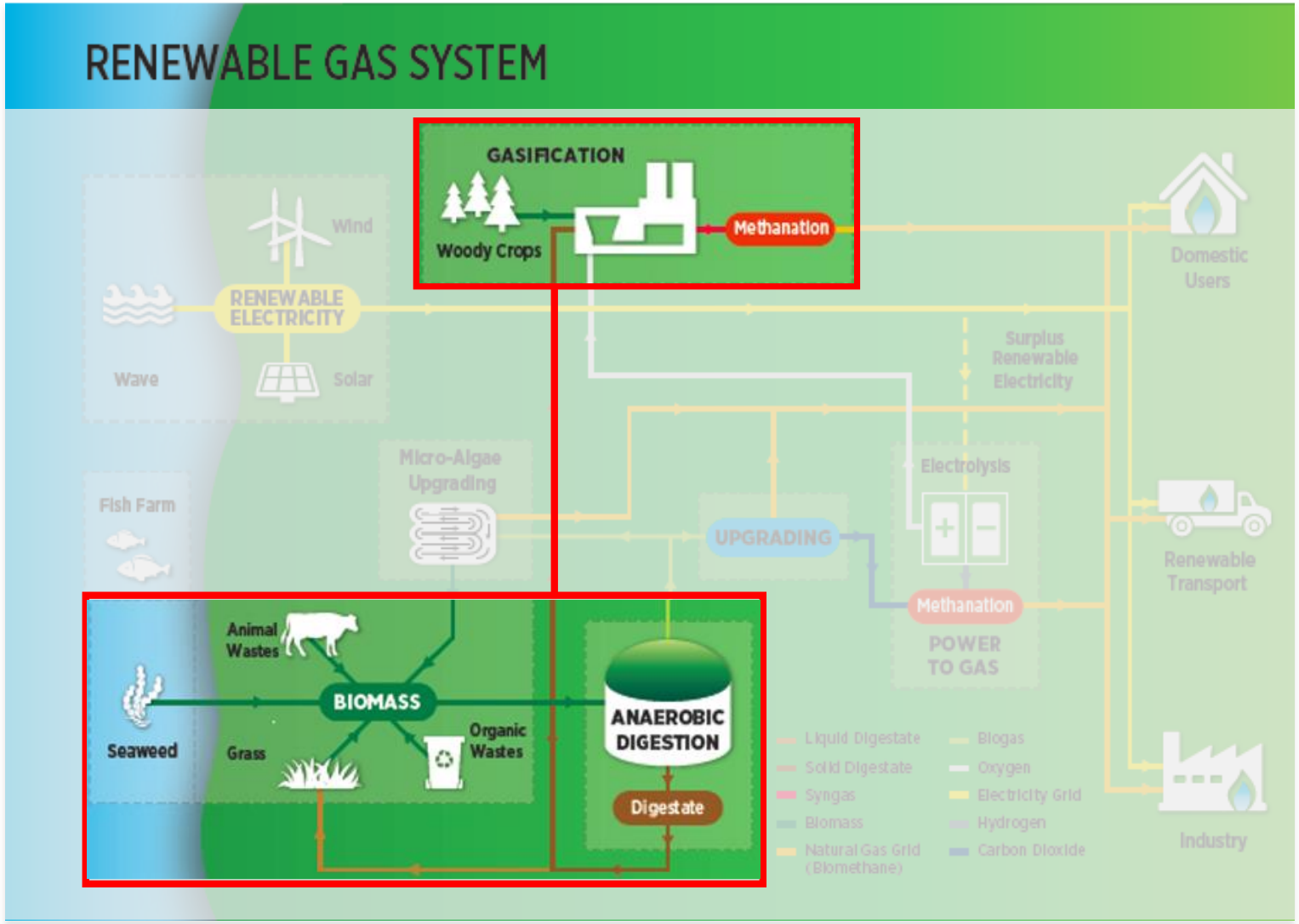
Role of integrated AD-Py in the circular biogas system



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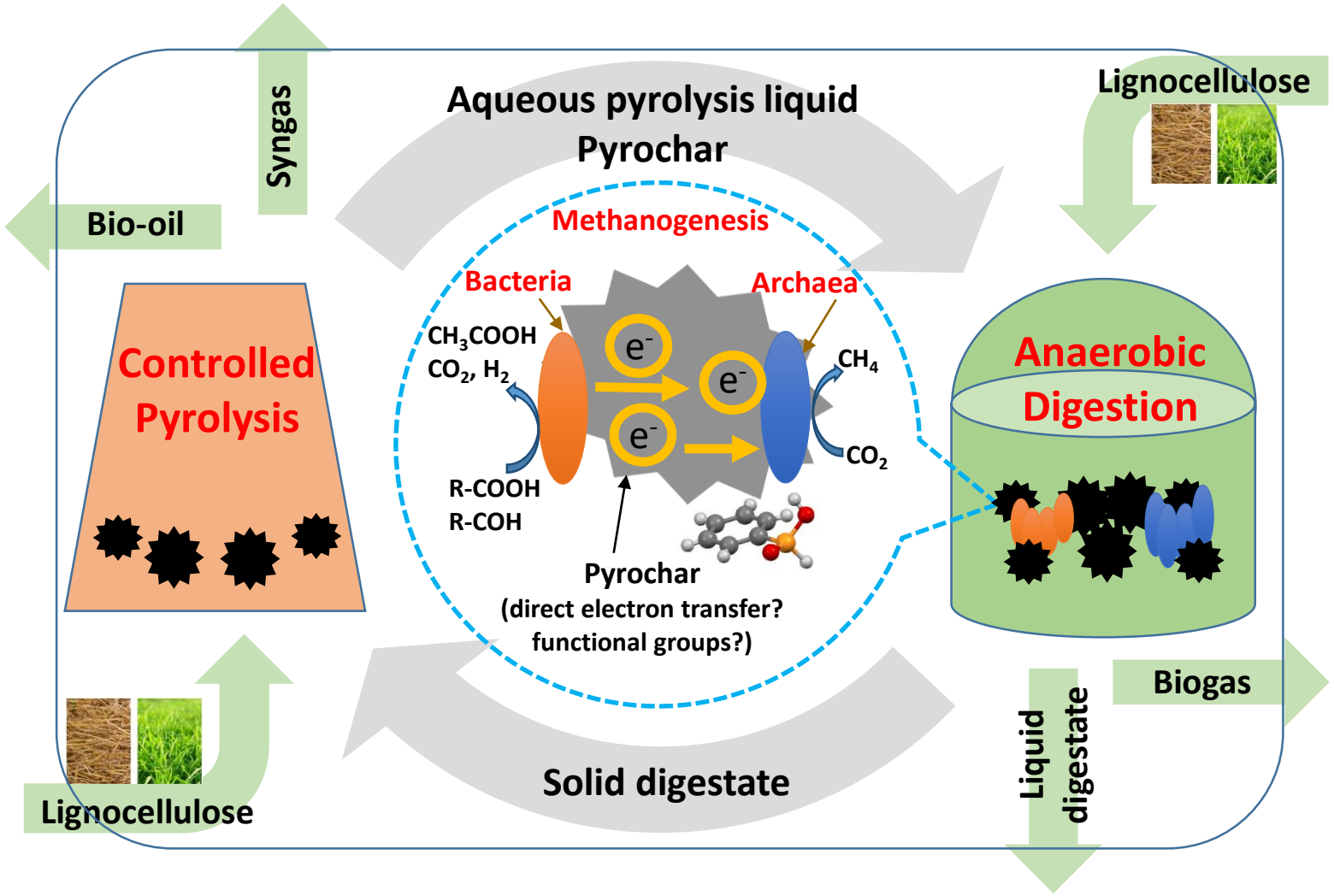
AD-Py: How?



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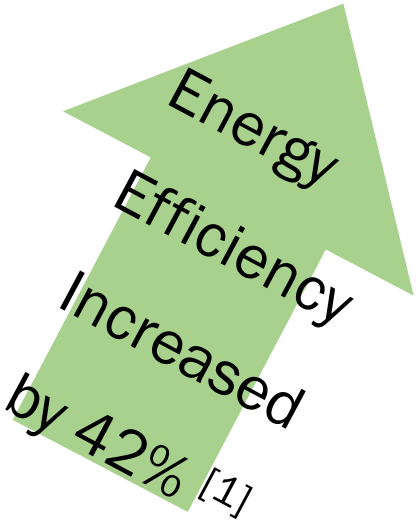
AD-Py: What's the advantages?

- overcome the recalcitrant feature of lignocellulose feedstock
- avoid problematic land application for digestate management
- reduce groundwater contaminant
- Improve energy recovery in a circular bio-economy



[1] Feng, Q., & Lin, Y. 2017. Integrated processes of anaerobic digestion and pyrolysis for higher bioenergy recovery from lignocellulosic biomass: A brief review. Renewable and Sustainable Energy Reviews, 77, 1272-1287

AD-Py: What's the problem?

Challenges

- Unsatisfactory selectivity for targeted pyrolysis products
- Low biodegradability of aqueous pyrolysis liquid
- Unclear energy recovery and environmental benefits of the integrated system

Strategies

- Optimizing the pyrolysis conditions for desired pyrochar
- Using pyrochar as an additive to enhance biomethane production
- Assessing the techno-economic and environmental benefits of the optimized system

My Research

Objective 1: Evaluate the **dominant factors** determining the pyrolysis reaction network and **the derived pyrochar properties**.

Raw & digested biomass （grass/seaweed）

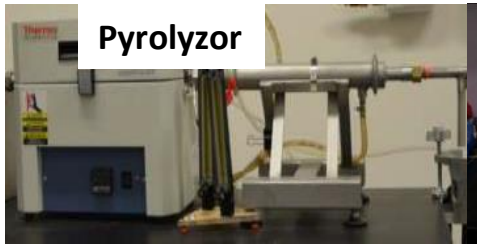
T1.1 Pyrolysis under different conditions

Syngas | Liquid products | Pyrochar

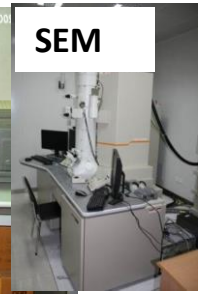
T1.2 Characterization

- Syngas: Gas Chromatograph (GC)
- Liquid products: GC
- Pyrochar: Scanning Electron Microscope (SEM), N^2 adsorption, X-ray Photoelectron Spectroscopy (XPS), Fourier Transform Infrared Spectroscopy (FTIR)

Expected results: dominant factors and the properties of pyrochar



Surface area and porosity analyzer



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My Research

Objective 2: Identify **the role of pyrochar in AD** and correlate the effects of pyrochar with its **specific physicochemical properties** (especially the surface area, functional group, and electrical conductivity).

Aqueous pyrolysis liquid

T2.1 Anaerobic digestion with & without pyrochar

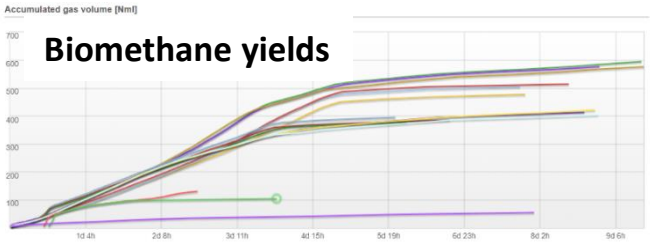
T2.2 Characterization

Biogas

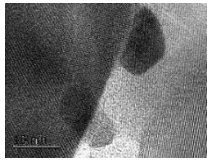
Liquid digestate

Solid digestate

Expected results: role of pyrochar in AD and the related properties



Pyrochar enhanced digestion model



$CH_3CH_2OH+H_2O=CH_3COOH+4H^++4e^-$

$4H^++4e^-+1/2CO_2=1/2CH_4+H_2O$

$$i = k \cdot \frac{S_{conduit}}{d} \cdot (E_{met}-E_{syn})$$

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My Research

Objective 3: Demonstrate the **technical and environmental benefits** of the optimized AD-Py system and identify the **bottlenecks** in this system from a techno-economic perspective.

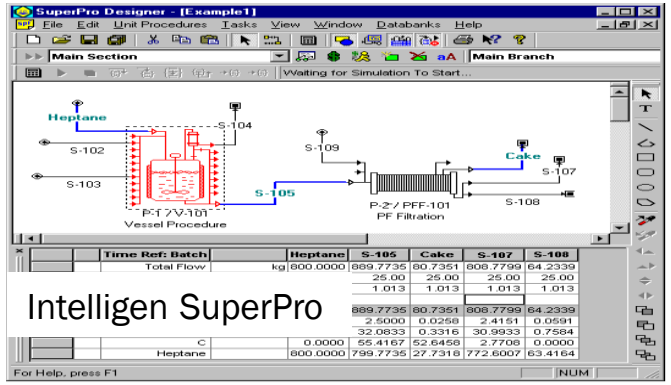
T3.1 Optimizing the integrated AD-PY system

- Pyrochar design
- Fermentation optimization
- Microbe acclimatization

Continuously stirred tank reactors

T3.2 Techno-economic assessment

- Resource & inventories
- Costs & profits
- Environmental impacts



Intelligen SuperPro

Expected results: biomethanation increased by 20-40%

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Expected Output of My Research

- To **identify the interactions between AD and Py processes** in terms of the role of pyrochar in AD and the impacts of specific properties of pyrochar.

- To **increase the biomethane production by 20%-40%** in an optimized AD-Py system through optimization of fermentation conditions and directional design of pyrochar.

Thank you for your attention!

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