Lodz University of Technology (TUL)
Faculty of Proces & Environmental Engineering

Visegrad Fund

INVESTIGATIONS OF HYDROTHERMAL PRETREATMENT OF WET BIOMASS INTEGRATED WITH DARK FERMENTATION TO OBTAIN THE MAXIMUM YIELD OF BIOHYDROGEN.

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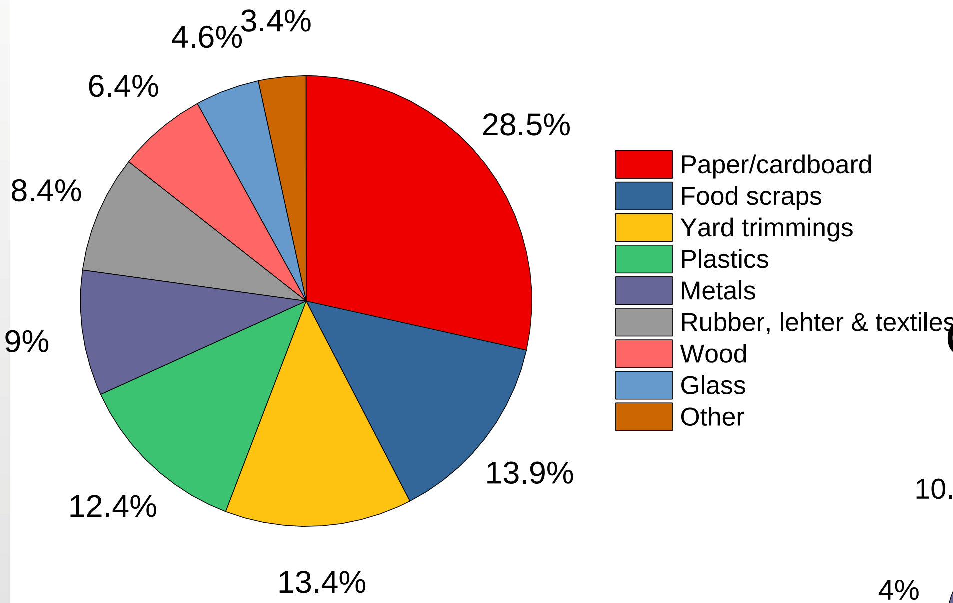
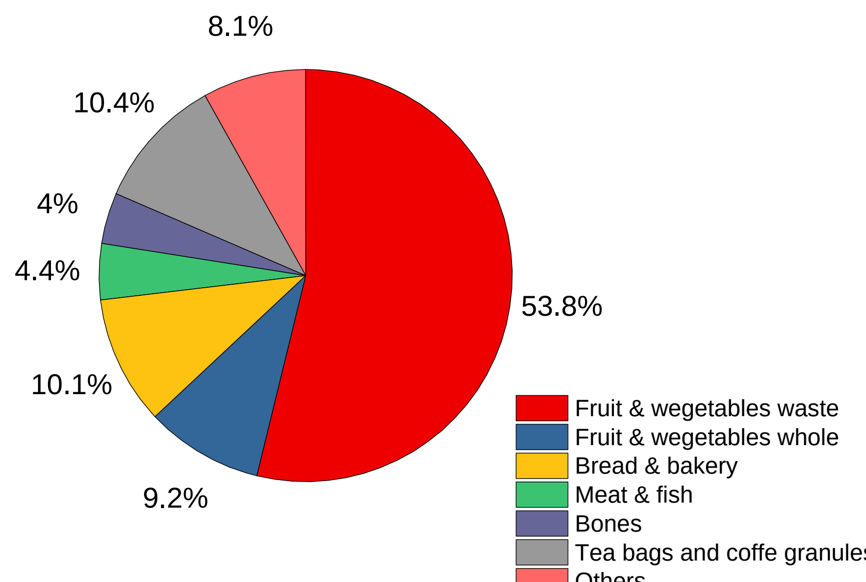
Food wastes

Composition of municipal solid wastes



http://www.epa.gov/epawaste/nonhaz/municipal/images/index_pie_chrt_900px.jpg.

Composition of food wastes



http://www.valorgas.soton.ac.uk/Deliverables/VALORGAS_241334_D2-1_rev[1]_130106.pdf

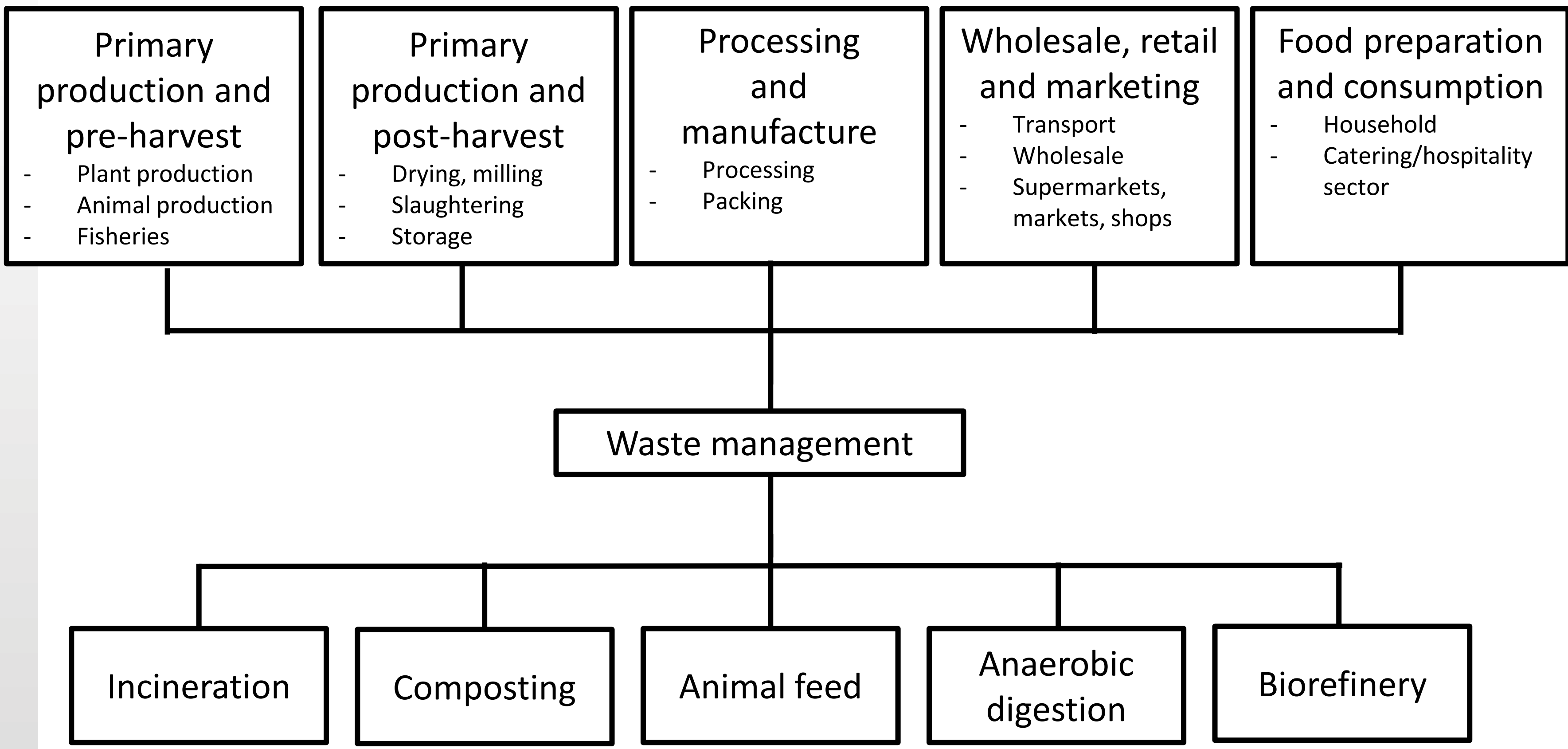
Food wastes

Paramter	Unit	Typical value
TS	% fresh matter	20
VS	% fresh matter	18
TKN	$g \cdot kg^{-1}$ fresh matter	7.4
HHV	$MJ \cdot kg^{-1} TS$	22
Carbohydrates (starch and sugar)	$g \cdot kg^{-1}$ VS	480
Lipids	$g \cdot kg^{-1}$ VS	150
Crude proteins	$g \cdot kg^{-1}$ VS	210
Hemicelluose	$g \cdot kg^{-1}$ VS	70
Lignin	$g \cdot kg^{-1}$ VS	30
Biochemical methane potencial (BMP)	$m^3 \cdot CH^4 \cdot kg^{-1}$ VS	450

TS – total solid
VS – volatile solid
TKN – total Kjeldahl nitrogen
HHV – higher heating value

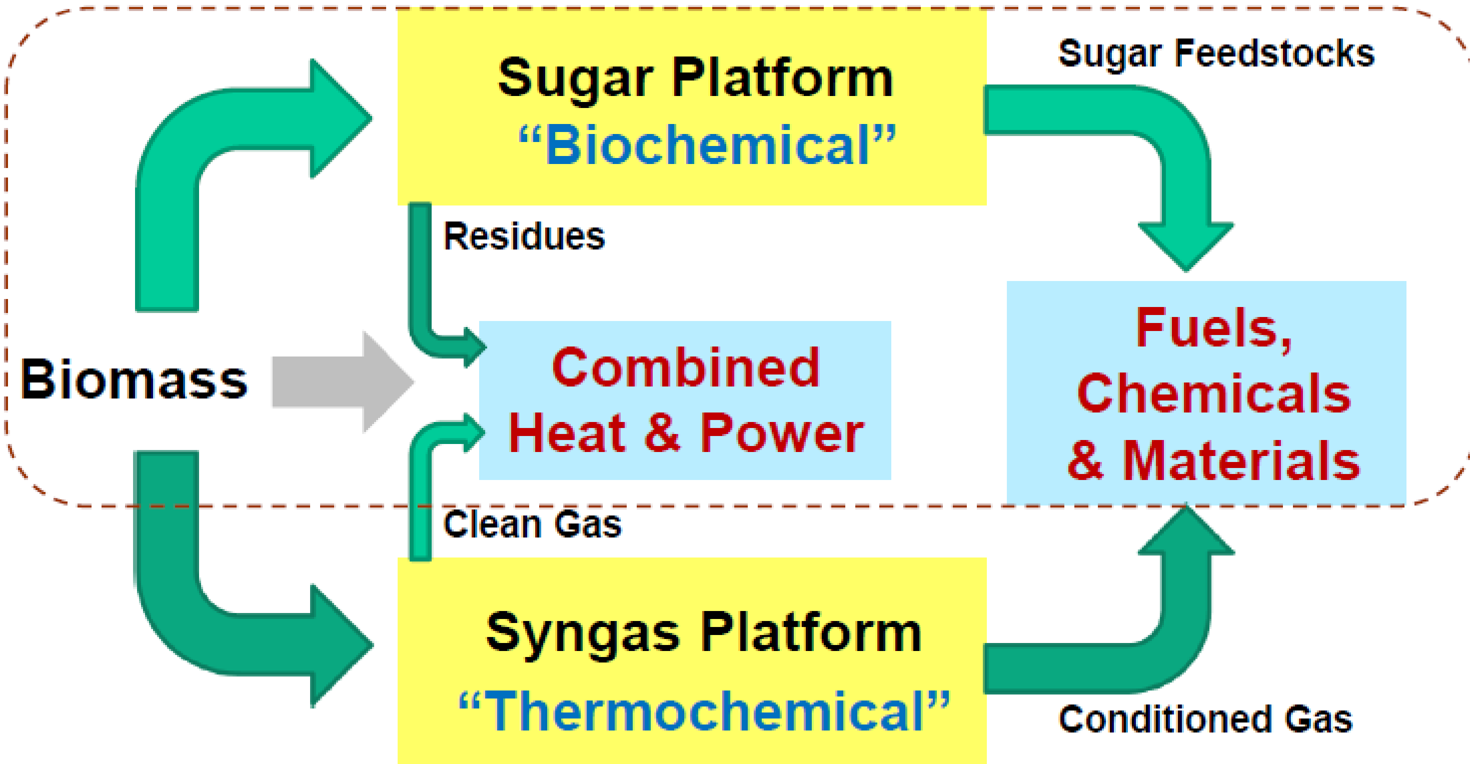
http://www.valorgas.soton.ac.uk/deliverables.htm,

Food supply chain

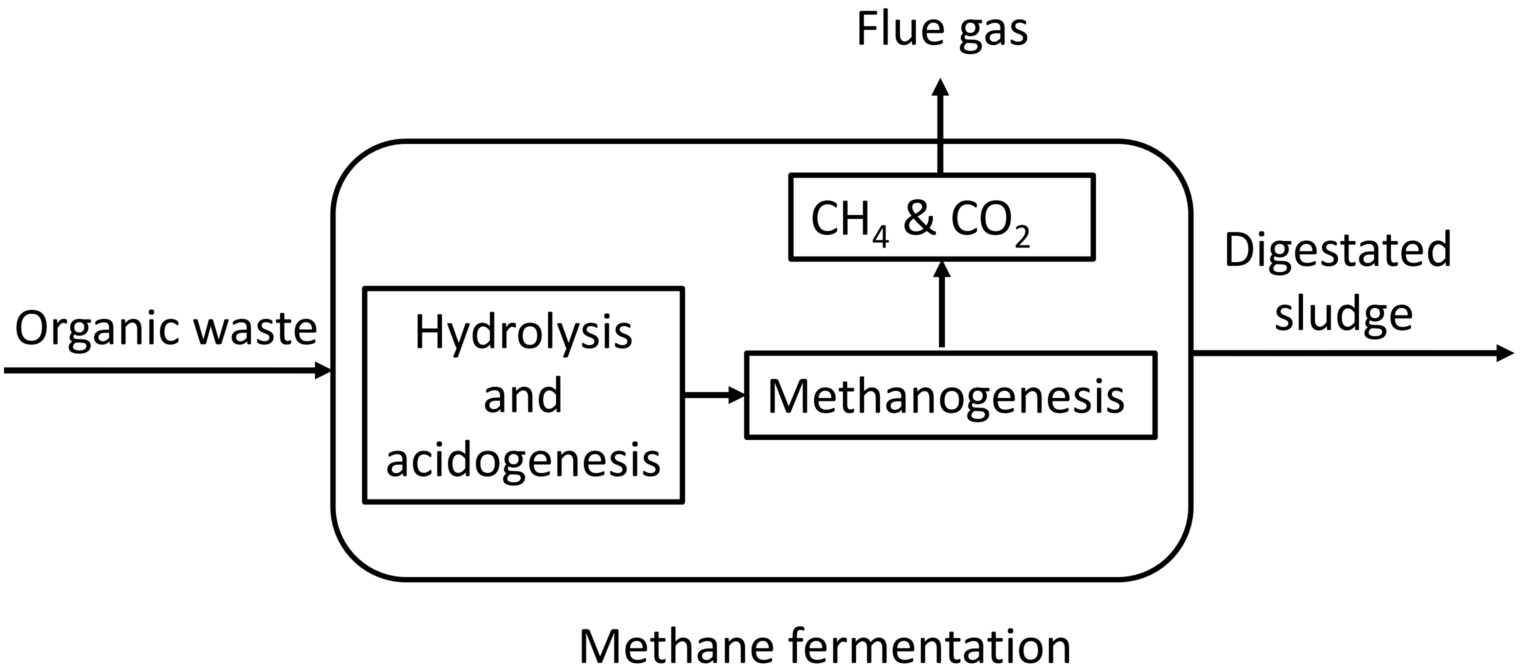


http://publications.jrc.ec.europa.eu/repository/bitstream/JRC109202/jrc_technical_report__food_waste_rev_2_online_final.pdf,

Biorefinery concept

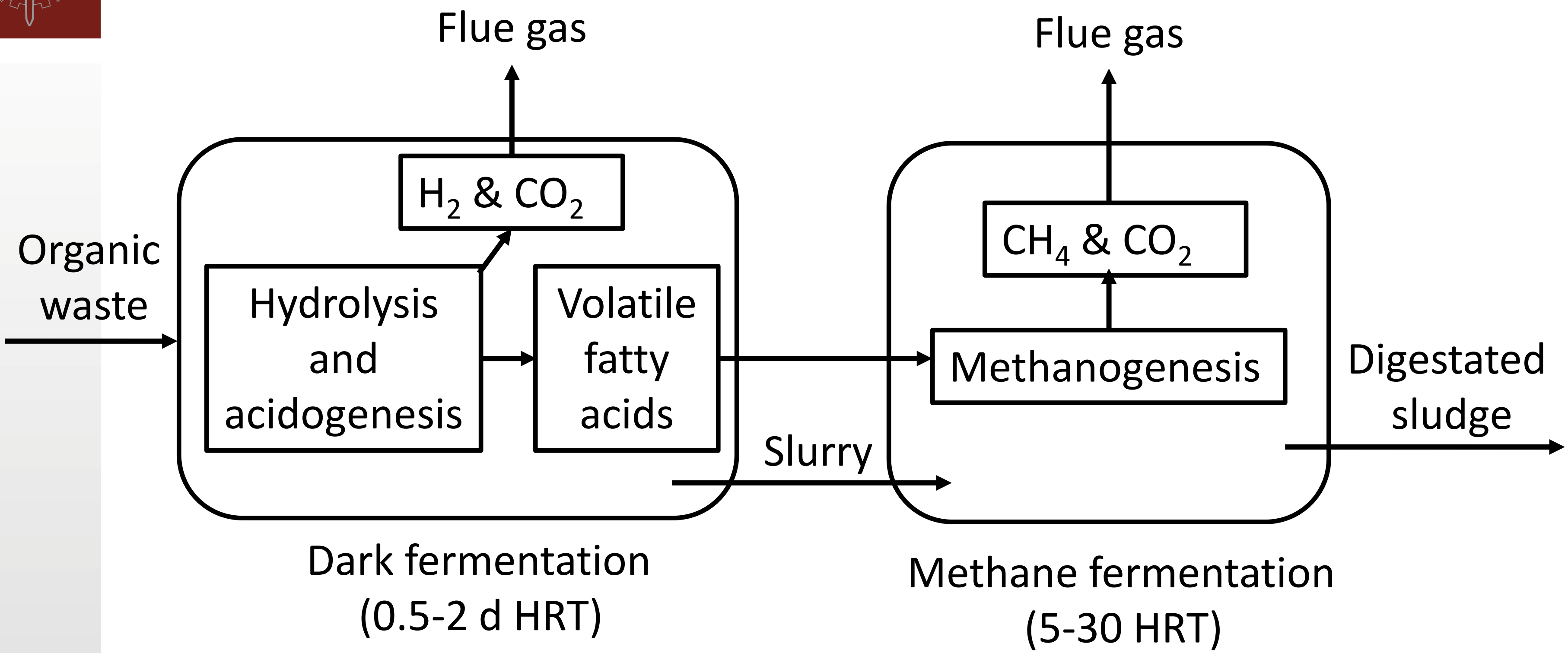


Anaerobic digestion



Digestated sludge:
- TS < 4%
- conversion of carbon c.a. 50%

Dark fermentation

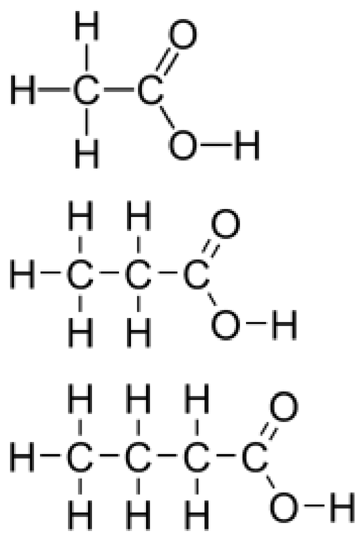


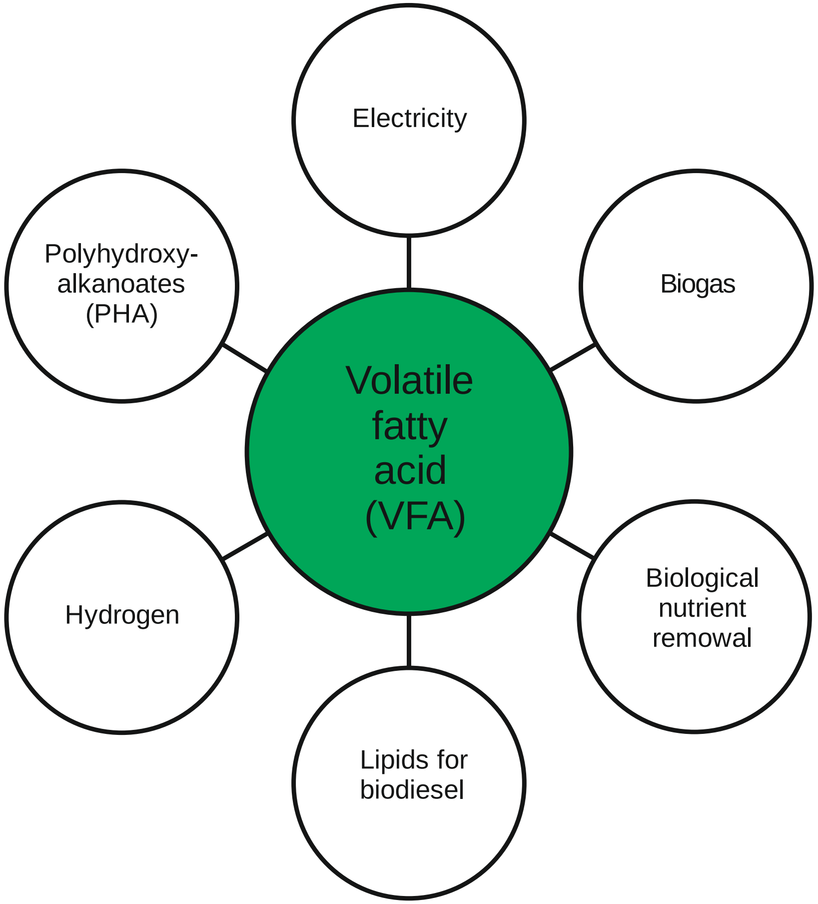
Inoculum: mixed-culture

HRT – hydraulic retention time

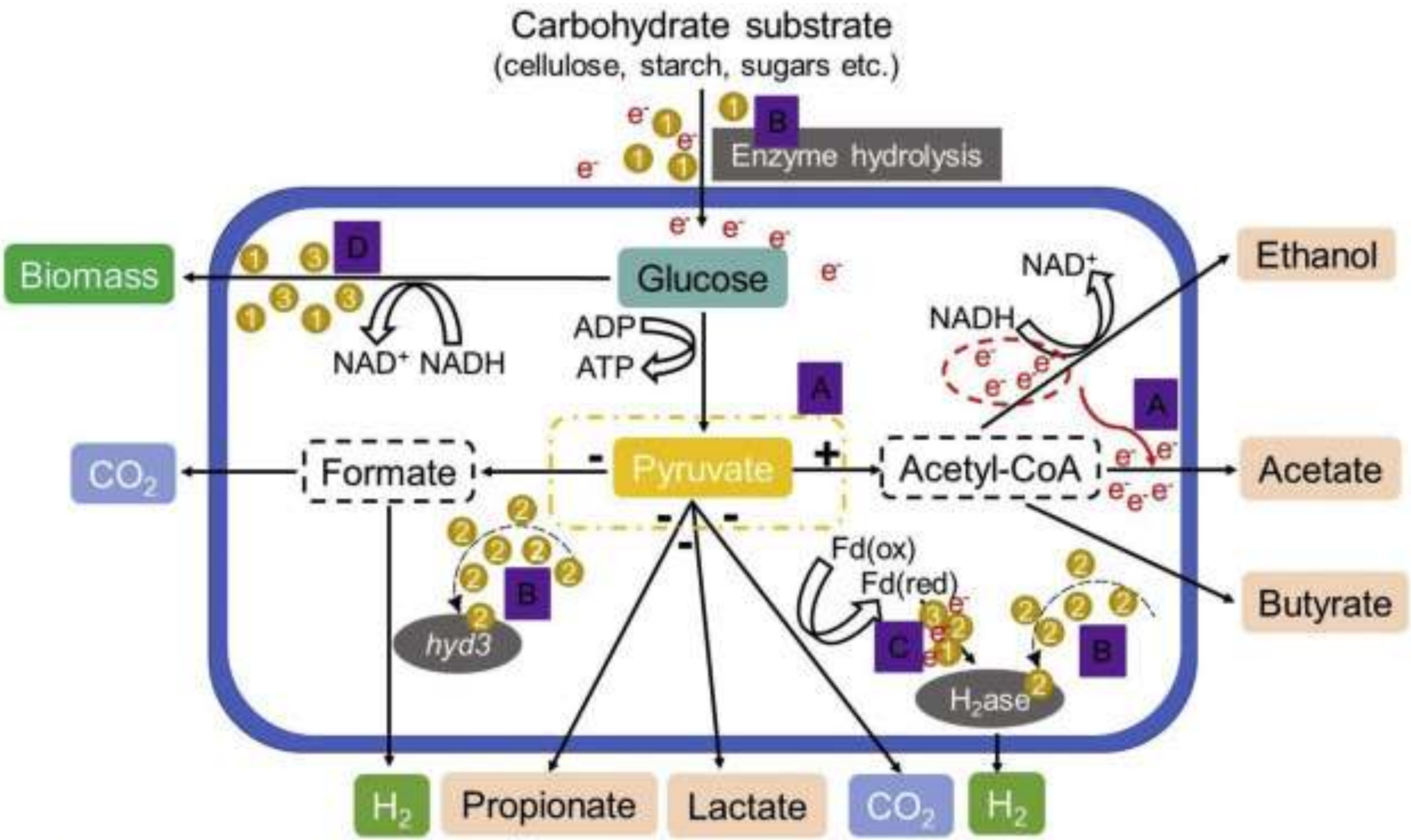
Dark fermentation

Volatile fatty acids (VFA):
- acetic acid,
- propionic acid,
- n-butyric acid,
- iso-butyric acid
- n-valeric acid,
- iso-valeric acid,
- n-caproic acid.





Dark fermentation – metabolic pathways



Ren, Yi, et al. "Promoting dark fermentation for biohydrogen production: potential roles of iron-based additives." International Journal of Hydrogen Energy 47.3 (2022): 1499-1515.

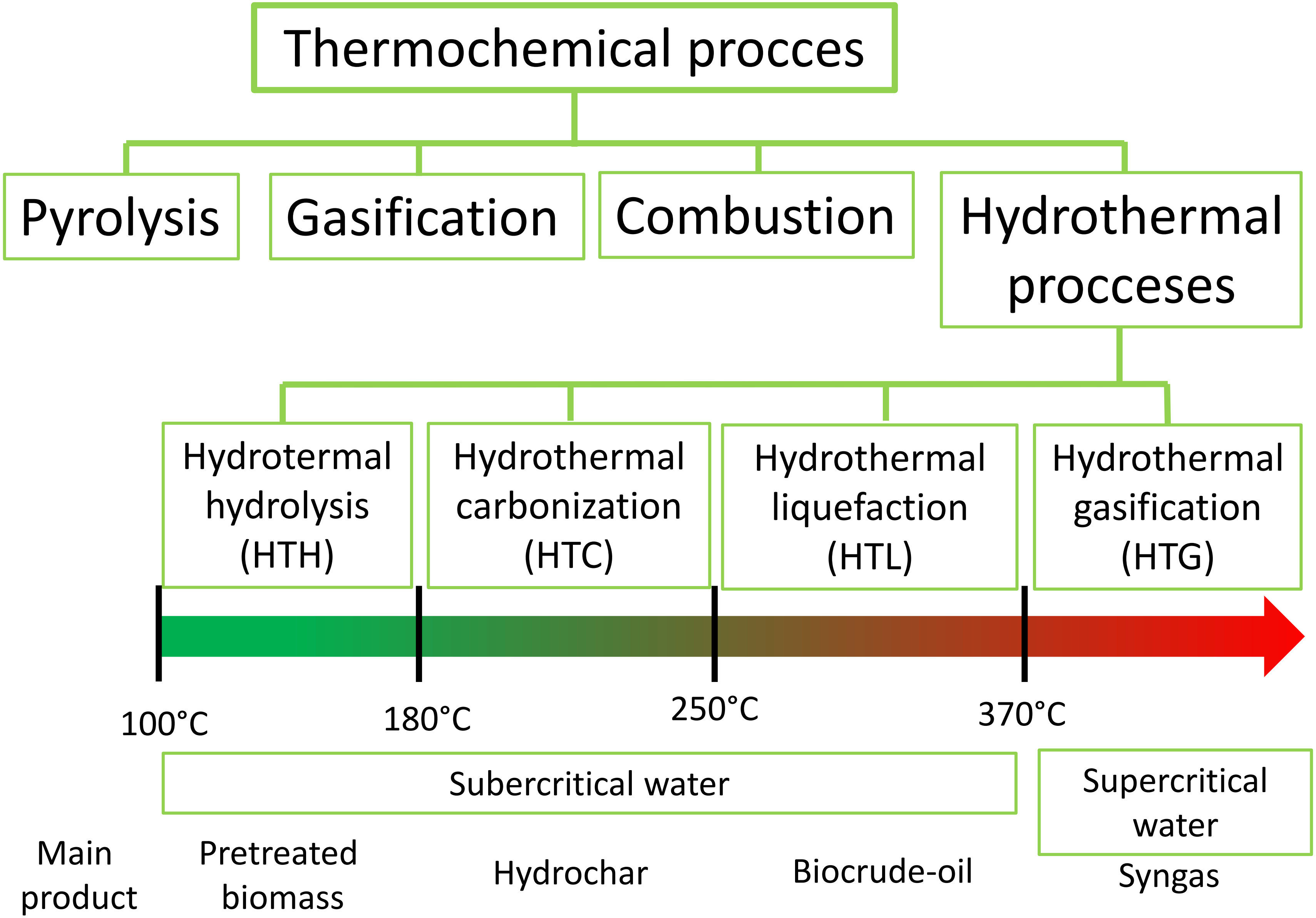
Experimental set-up for dark fermentation investigation

Batch reactor.
Volume: 1 L

Semi continuous reactor.
Volume: 10 L

Parameters of the process:
- pH
- HRT (hydraulic retention time)
- OLR (organic loading rate)

Hydrothermal carbonization (HTC)



Hydrothermal carbonization (HTC)

Biomass

Dry carbonization
(Pyrolysis)

250°C, 1 h

Wet carbonization
(Hydrothermal
carbonization)

Char yield = 55%,
ED = 1.25

Char yield = 55%,
ED = 1.4

In HTC process feedstock doesn't need to be dried.

E.D. - Energy densification

Hydrothermal carbonization (HTC)

Biomass

Hydrothermal carbonization (HTC)

	Char	Liquid fraction	Gas
			CO_2
Yield	50-80%	5-30%	2-5%

The char from HTC process is easily dewatered.

Libra, Judy A, et al. 2011. *Hydrothermal carbonization of biomass residuals: a comparative review of the chemistry, processes and applications of wet and dry pyrolysis.* s.l. : Biofuels 2(1), 89-124, 2011. %

Hydrothermal carbonization (HTC)

Use of char:
- Renewable energy carrier
- Soil amendment
- Carbon sequestration
- Activated carbon adsorbents

Char properties:
- carbon: 75-85%
- H/C: 1.0-1.2
- O/C: 0.2-0.3
- surface area: 1-40 m^2/g

Activated carbon: 3000 m^2/g

Hydrothermal carbonization (HTC)

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Use of liquid phase:

- Substrate for anaerobic process

Liquid phase properties:

pH	3.7-7.2
TOC (g/L)	9.0-27.8
BOD (g/L)	10.0-42.0
COD (g/L)	14.4-69.7

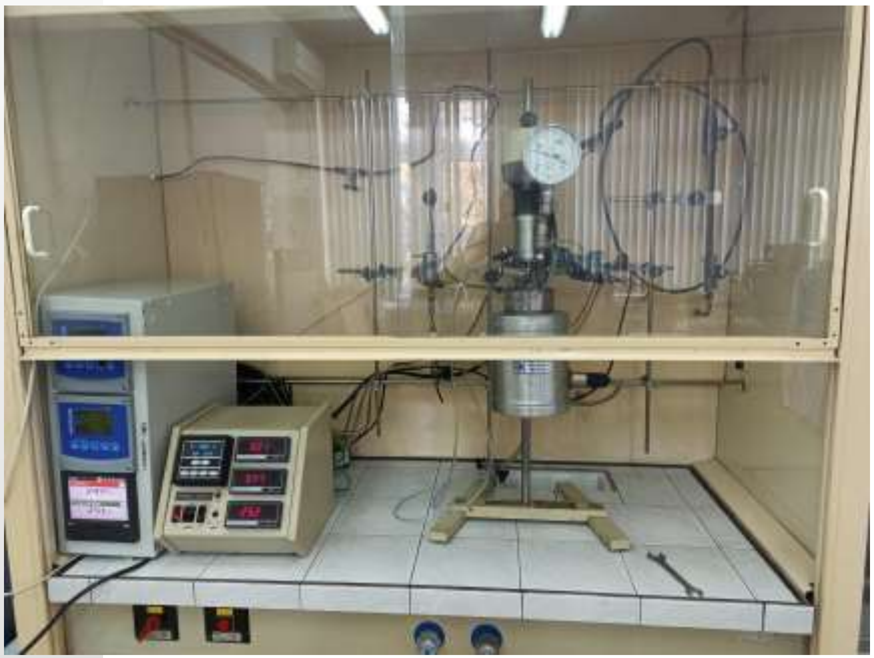
TOC – total organic carbon
BOD – biochemical oxygen demand
COD – chemical oxygen demand

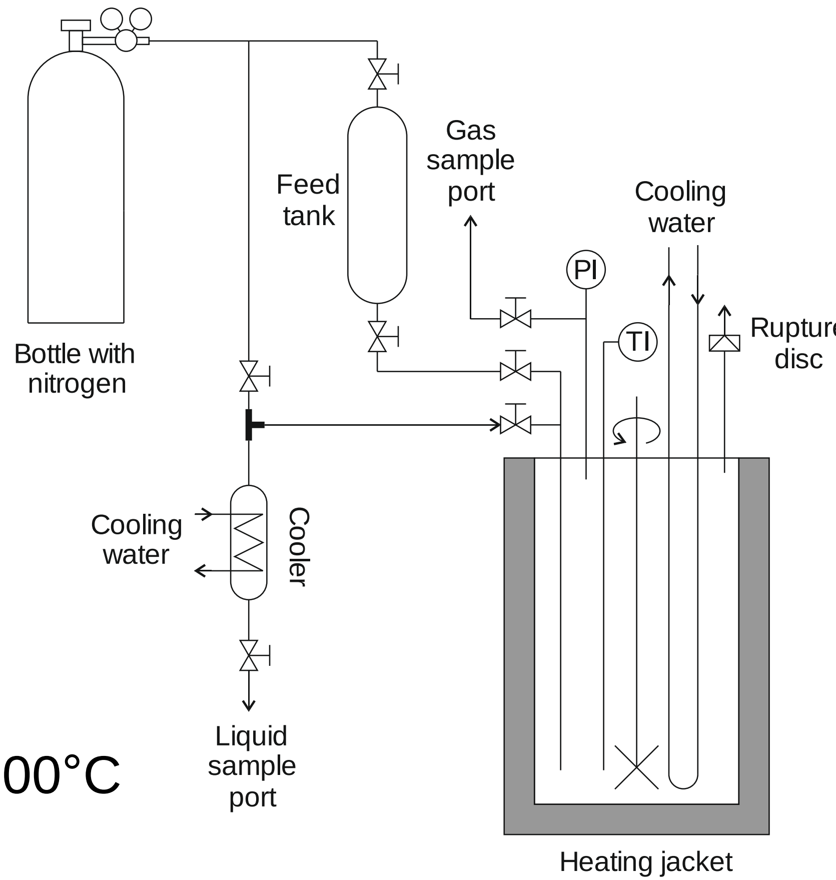
Others compouds:

Phenole, acids,…

Ramke, Hans-Günter, et al. 2009. Hydrothermal Carbonization of Organic Waste. Sardinia : Twelfth Interntional Waste Management and Landfill Symposium, 2009.

Experimental set-up for HTC kinetic investigation



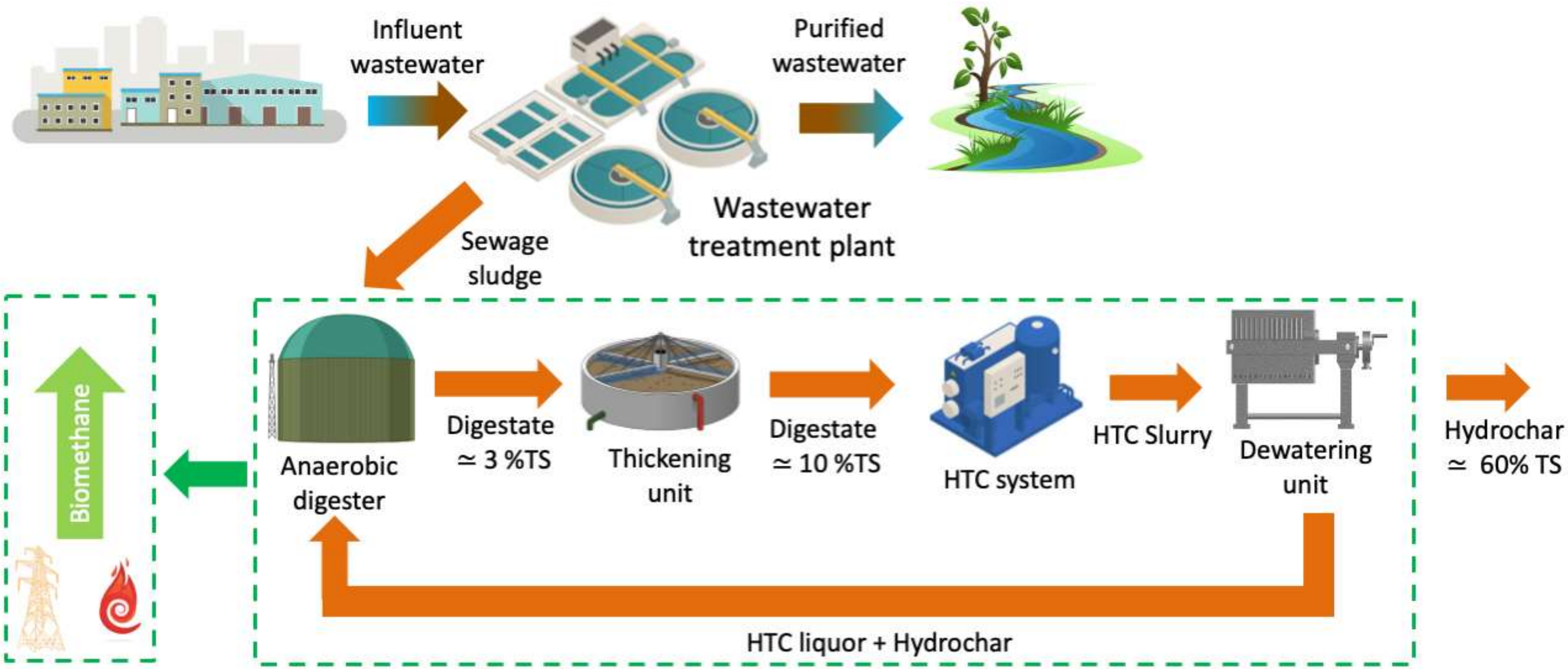


Volume: 0.6 L; P_{max} = 90 bar at 300°C

Parameters of the process:

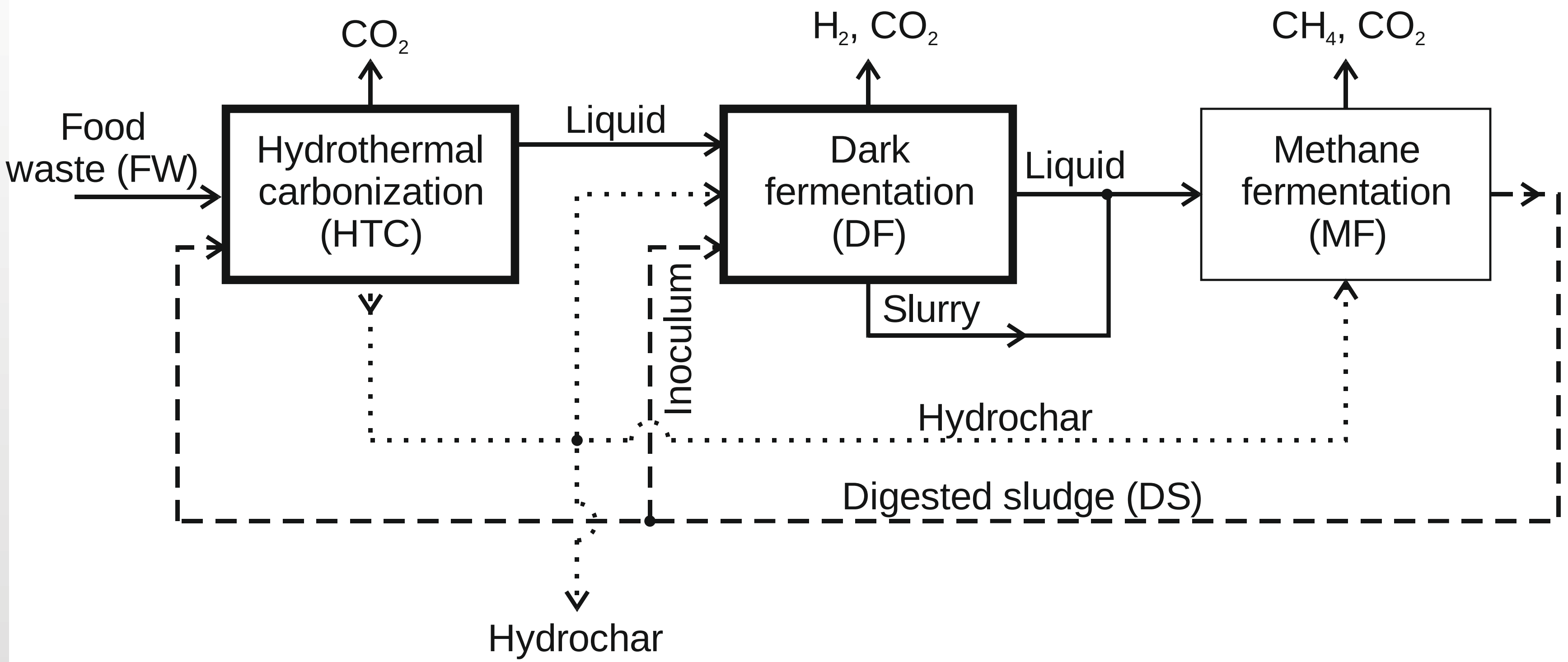
- temperature,
- residence time.

Coupling Hydrothermal Carbonization with Anaerobic Digestion for Sewage Sludge Treatment



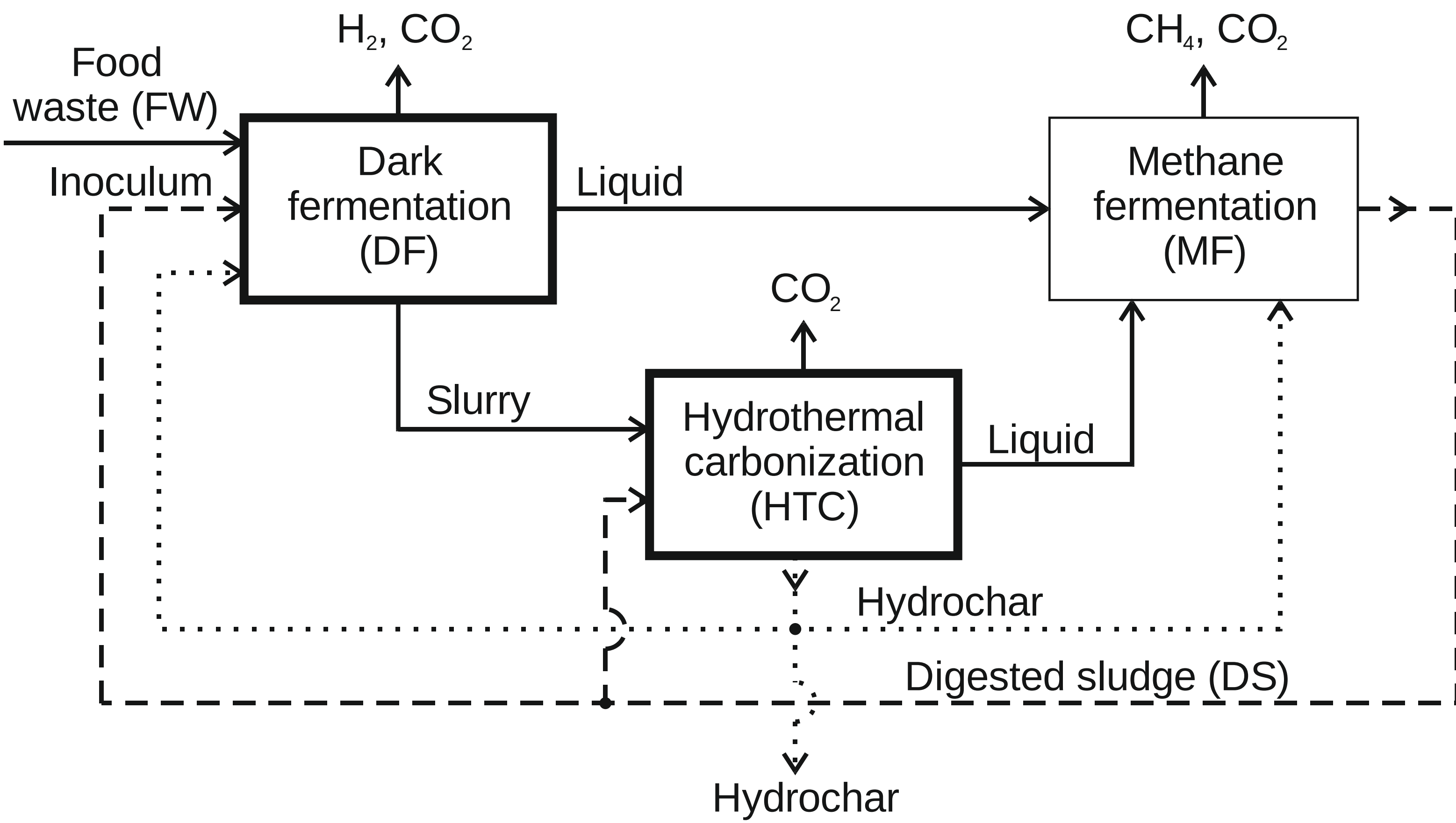
Ferrentino, Roberta, et al. "Coupling hydrothermal carbonization with anaerobic digestion for sewage sludge treatment: Influence of HTC liquor and hydrochar on biomethane production." Energies 13.23 (2020): 6262.

Biorefinery - Concept 1



Closed–loop system for substrate pretreatment

Biorefinery - Concept 2



Closed–loop system for substrate post-treatment

Expected results of the research

- Proper sequence of the process steps,
- Knowledge of the kinetics of HTC integrated with DF,
- Proper selection of raw material composition
- Optimum residence time in the HTC reactor
- Optimal process temperature will optimize **energy recovery from wet biomass waste and maximize bioH_2 production.**

The results obtained will contribute to the basic knowledge of the HTC and DF processes, which will enable **scaling-up of these biorefinery processes** using wet food waste.

It is important to be actively engaged in the **green hydrogen** ecosystem – one of the pathways to **decarbonisation**.

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Thanks for your kind attention ☺

Acknowledgement

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