Anaerobic Digestion:
Research area in Borås

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Swedish Centre for Resource Recovery
School of Engineering
University of Borås
Sweden

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SCIENCE FOR THE PROFESSIONS

- Advanced area of research:
  - Textile
  - Library
  - Resource Recovery

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Swedish Centre for Resource Recovery (SCRR)

Wastes and by-products
(Municipal, agricultural, forest, industries)

Social aspects

Thermal processes

Chemical processes

Biological processes

Material Recycling

Logistic optimization

Heat
Chill
Electricity

Chemicals
Diesel Gasoline

Biopolymers
Biogas Ethanol

Metals
Plastics
Papers
Glass

Sustainable Society

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Biotechnology group (Aug. 2019)

- Seniors:
  - Mohammad Taherzadeh
  - Ilona Sarvari Horvath
  - Patrik Lennartsson
  - Akram Zamani
  - Päivi Ylitervo
  - Jorge Ferreira
- Postdocs/Researchers:
  - Mukesh Kumar
  - Swarnima Agnihotri Kumar
- + Visiting PhD students
  - Normally 4-5 persons in Borås
  - (from Indonesia, Poland, Algeria, Iran, Malaysia, Germany Turkey, Nigeria, China…)

- Current PhD students:
  - Mostafa Jabbari
  - Konstantinos Chandolias
  - Amir Mahboobi
  - Lukitawesa
  - Rebecca Gmoser
  - Steven Wainaina
  - Anette Jansson
  - Gülru Bulkan
  - Amir Badiei
  - Mohsen Parchami
  - Sofie Svensson
  - Hanie Moshtaghian
  - Neda Rousta

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Biotechnology graduated PhDs since 2010

1. Mohammad Pourbafrani, 2010
2. Akram Zamani, 2010
3. Azam Jeihanipour, 2011
4. Patrik Lennartsson, 2012
5. Gergely Forgacs, 2012
6. Supansa Youngsukkasem, 2012
7. Anna Teghammar, 2013
8. Isroi, 2013
9. Johan Westman, 2014
10. Solmaz Aslanzadeh, 2014
11. Hamidreza Barghi, 2014
12. Päivi Ylitervo, 2014
13. Mofoluwake Ishola, 2014
14. Rachma Wikandari, 2014
15. Maryam Mohseni Kabir, 2015
16. Julius Akinbomi, 2015
17. Karthik Rajendran, 2015
18. Jorge Ferreira, 2015
19. Jhosane Pagés Díaz, 2015
20. Ramkumar B. Nair (2017)
21. Regina J. Patinvoh (2017)
22. Osagie Alex Osadolor (2018)
23. Pedro Ferreira (2018)
24. Veronika Bátori (2019)

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Our vision:

Waste is a ”Resource”

but our knowledge is not enough to utilize it!

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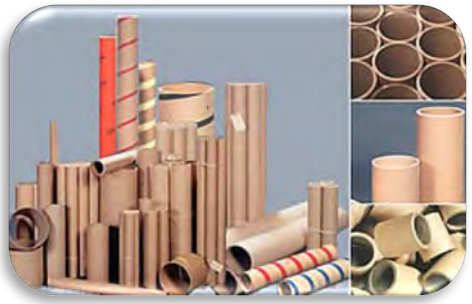
Challenging wastes = Research subjects













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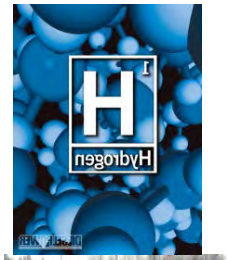
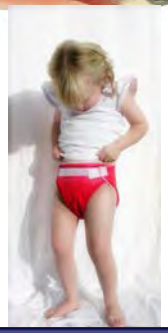
Our products!





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What we do:

Developing
pretreatment and **fermentation**

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Research platforms

- VFA
- H2
- MBR
- Syngas ferment.
- Rapid fermentation
- Dry digestion
- Textile reactors
- Pretreatment
- Process simulation

- 2nd generation ethanol
- Ethanol from wastes
- Process development
  - Pretreatment
  - Fermentation
  - MBR
- Integration 1 & 2nd generations ethanol
- BioPolyethylene

- Waste as raw materials
- Ethanol & Feed/Food
- Biopolymers
- Process development
- Pellet formation
- Pigment

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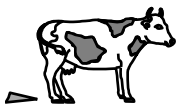
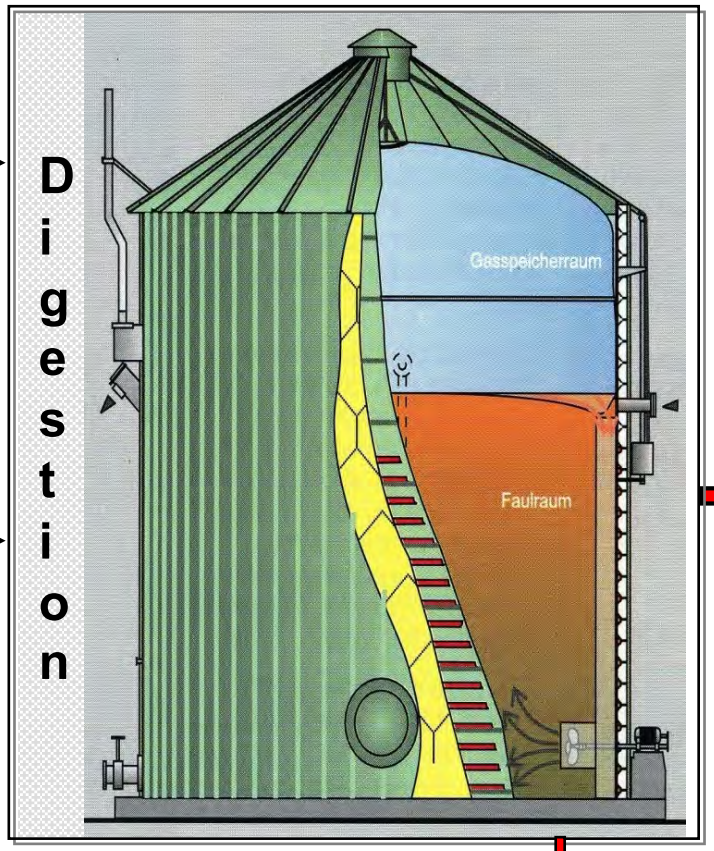
Overview of biogas industry (biochemical processes)



Agricultural residues (manure, slurry, etc.) & biowastes

Energy crops, grass from Landscape maintenance (grass, maize, beets)



Feeding in gas grid

Vehicle fuel

Biogas upgrading

Biogas cleaning

Biogas utilisation

Direct burning

Cooking
Lighting
Cooling
Heating

Cogeneration

Electrical energy

Thermal energy

Storage

Transport

Spreading

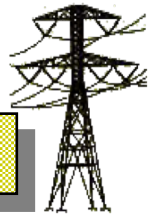
Separation

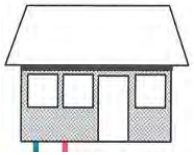
Agriculture

Gardening

solid components become compost

liquid components back to the fermentation or spreading





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Material of construction for biogas reactors?

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Textile reactors for biogas

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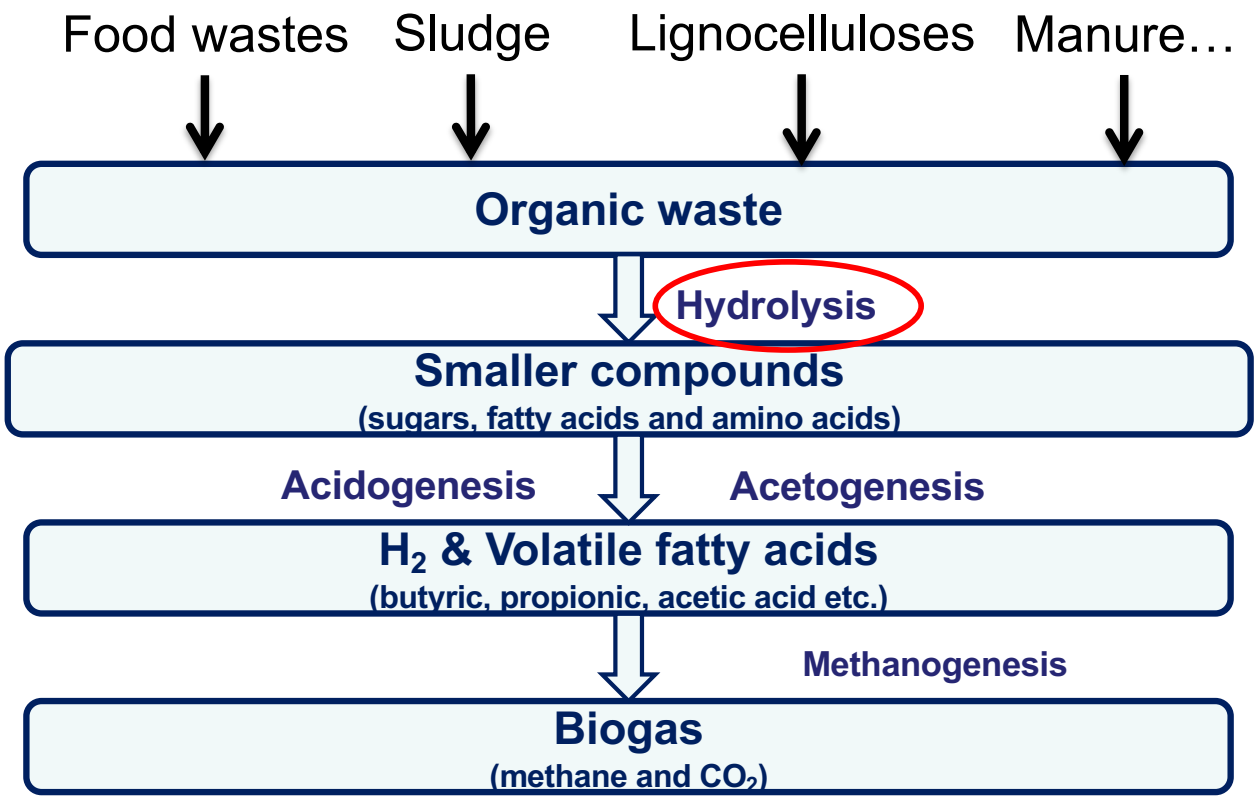
Anaerobic digestion (AD) for methane production



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Do we need a pretreatment?

- Biomass recalcitrance
- Indigestible materials
- Inhibitors







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Pretreatment methods?

- Physical/thermal
- Chemical
- Biological







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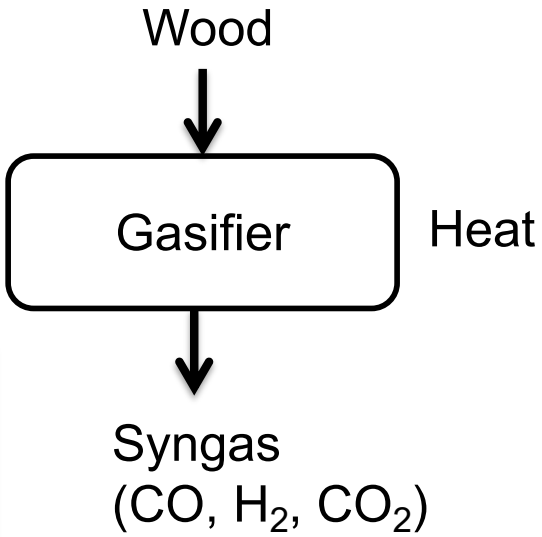
Gasification as one pretreatment

- Biomass recalcitrance
- Indigestible materials



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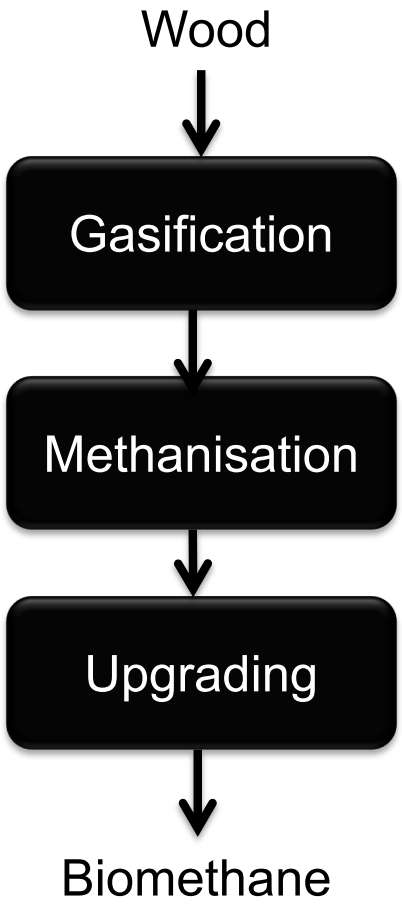
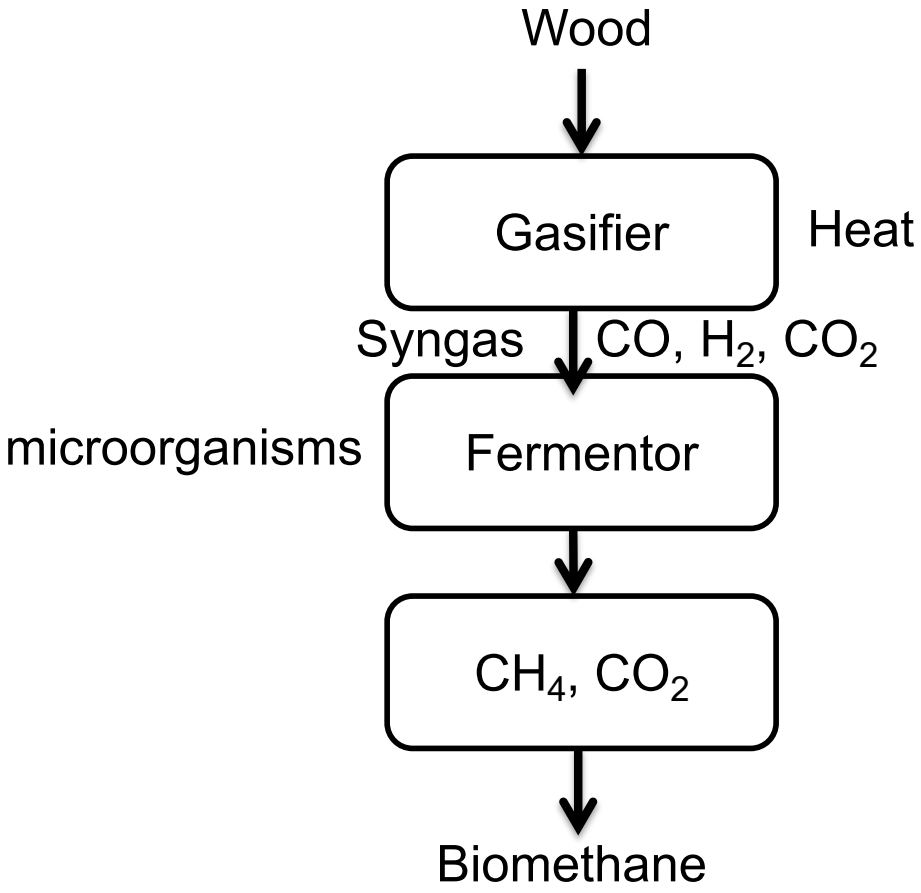
Biomethane via Thermochemical processes + biochemical process





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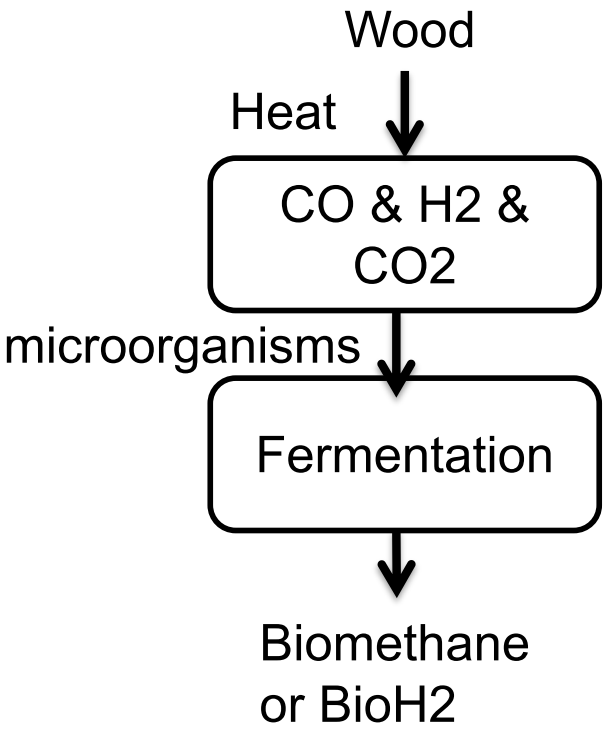
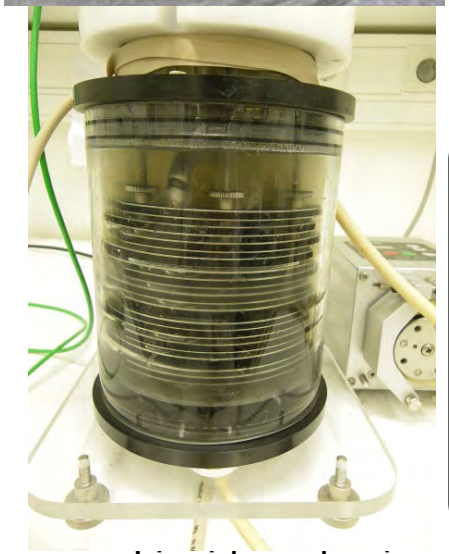
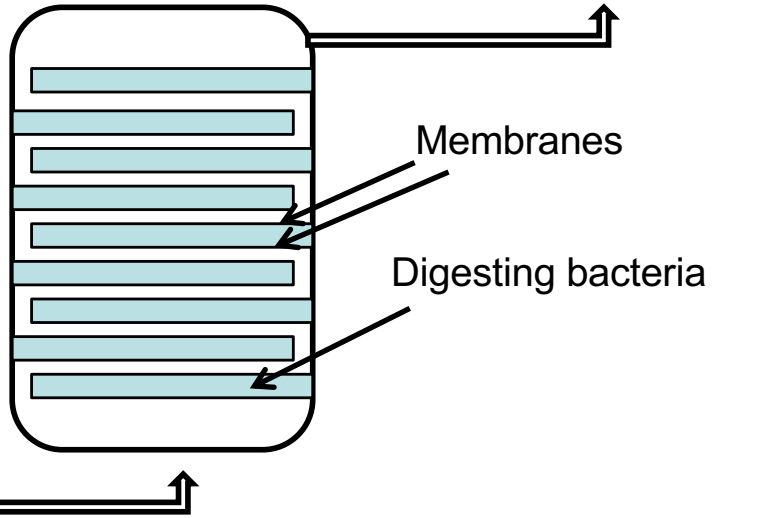
Biogas & H2 from syngas using membrane reactors







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Dry or wet digestion?

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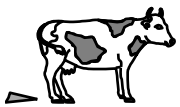

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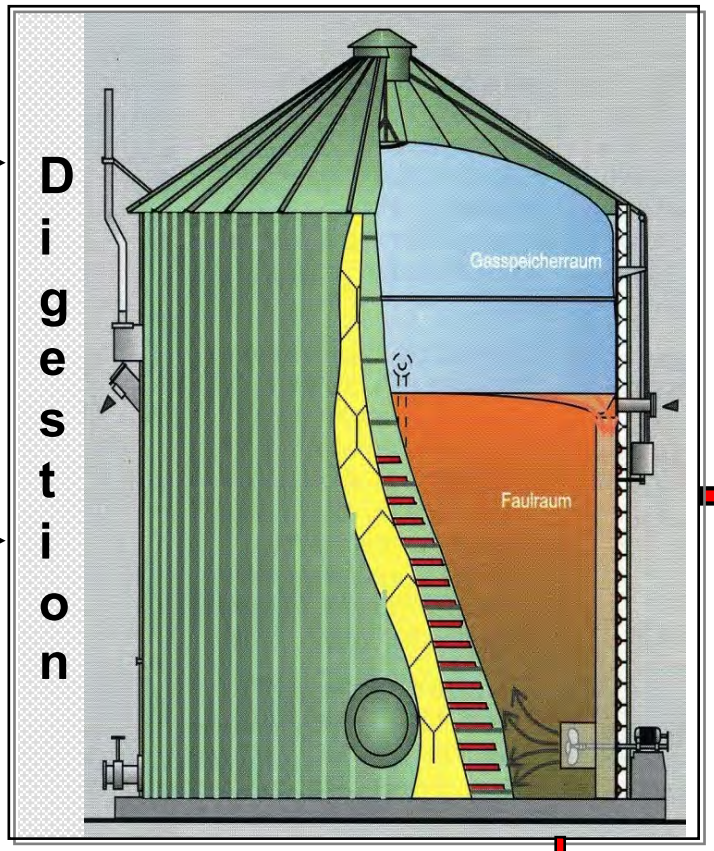

Feeding in gas grid

Vehicle fuel

Biogas upgrading

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Biogas utilisation

Direct burning

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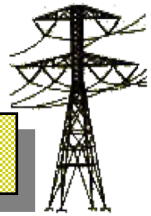
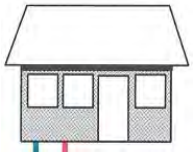
solid components become compost

liquid components back to the fermentation or spreading





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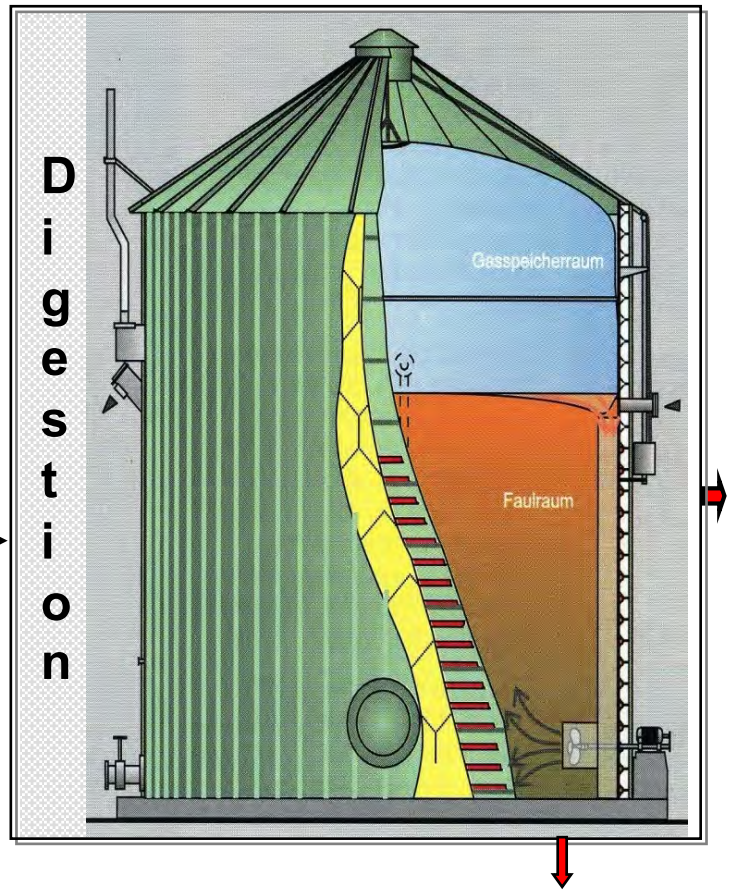
Water content? Total solid (TS)?



TS=10-12%

Addition of water?

TS=3-4%

What to do with wastewater?

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Dry digestion:
Go up with TS!

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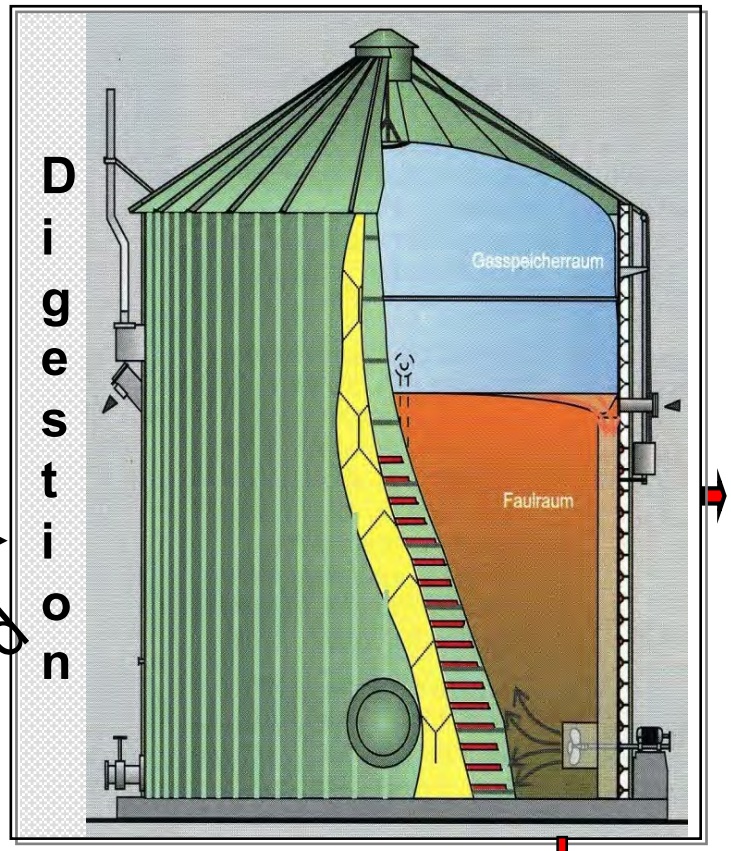
Water content? Total solid (TS) in dry digestion?



TS=30-50%

Less or no water added

TS=5-17%

Much less or no slurry

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Dry digestion: Batch process

http://www.bioferm-energy.com/

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Dry digestion: Batch process

- A sealed room:
  - Just outlet for biogas
- Control temperature and humidity:
  - Add little air in the beginning
  - Add water to compensate evaporation
- Leave some digestate as inoculum
- Retention time: 1-4 months

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Dry digestion: Batch process

A textile bioreactor
For dry digestion

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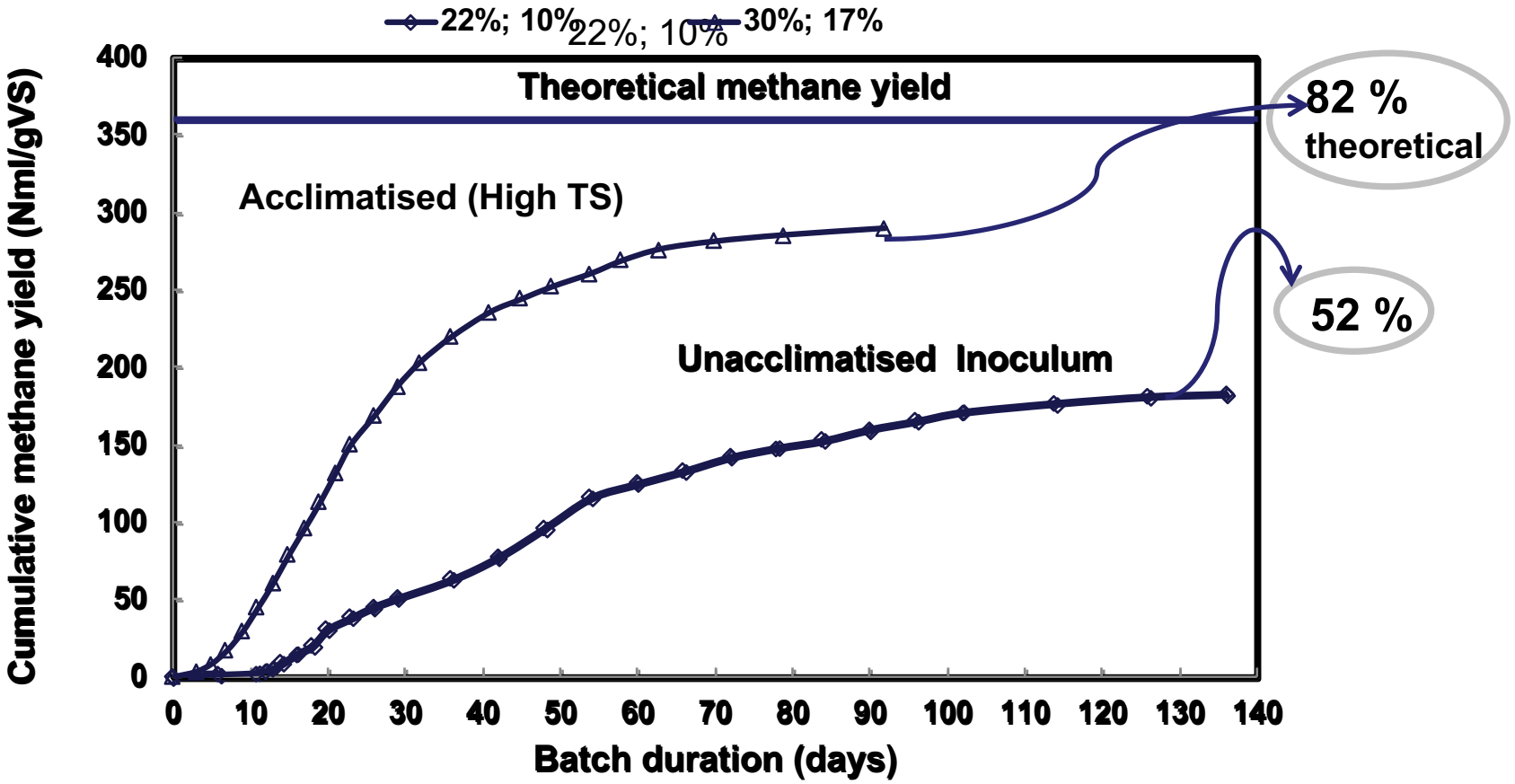
Effect of acclimatisation in dry digestion



(Paper IV and V)
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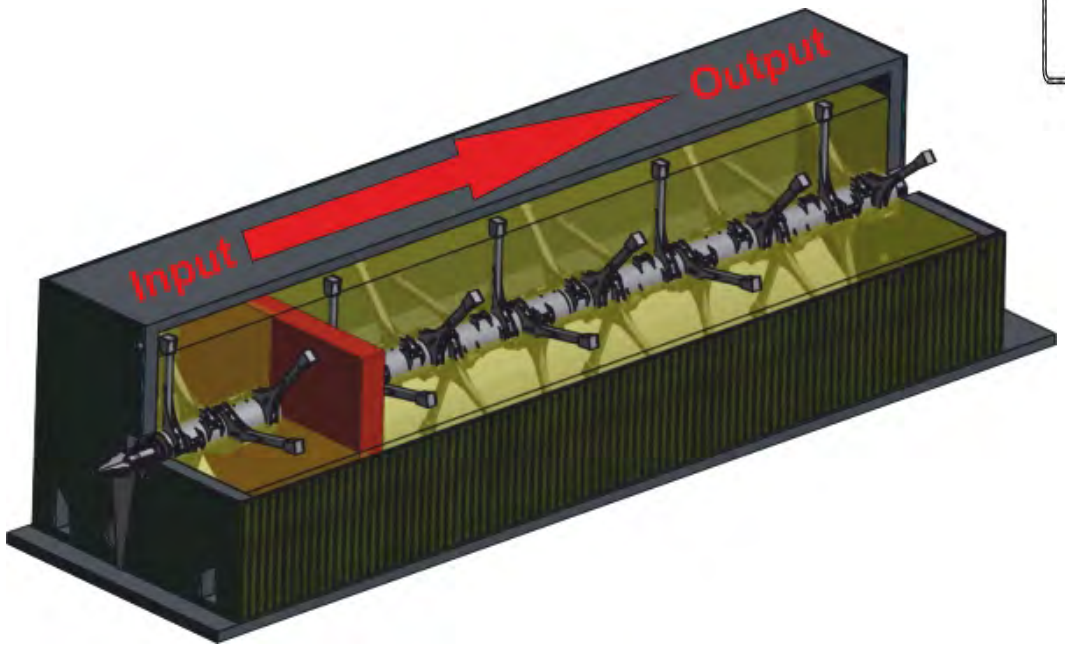
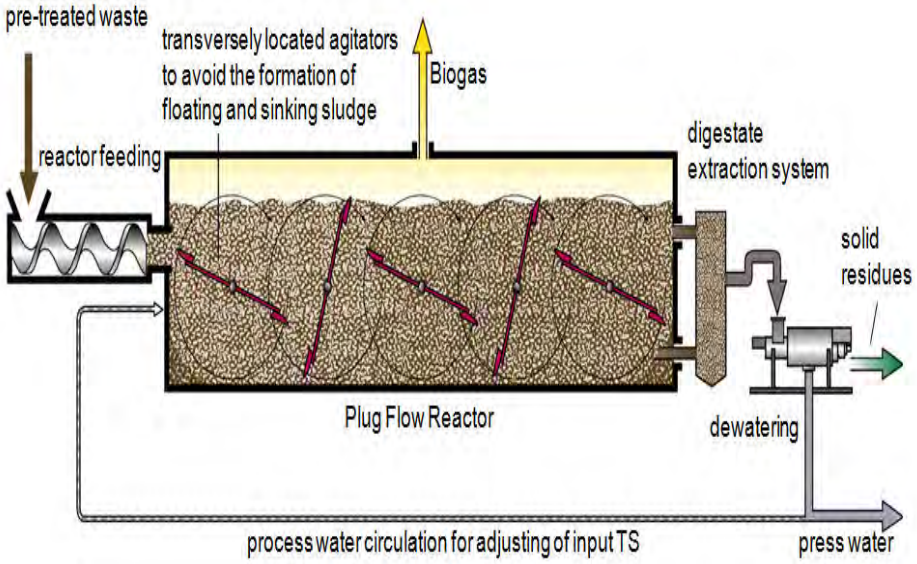
Continuous dry digestion (horizontal)





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Continuous dry digestion (horizontal)

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Continous reactors in lab

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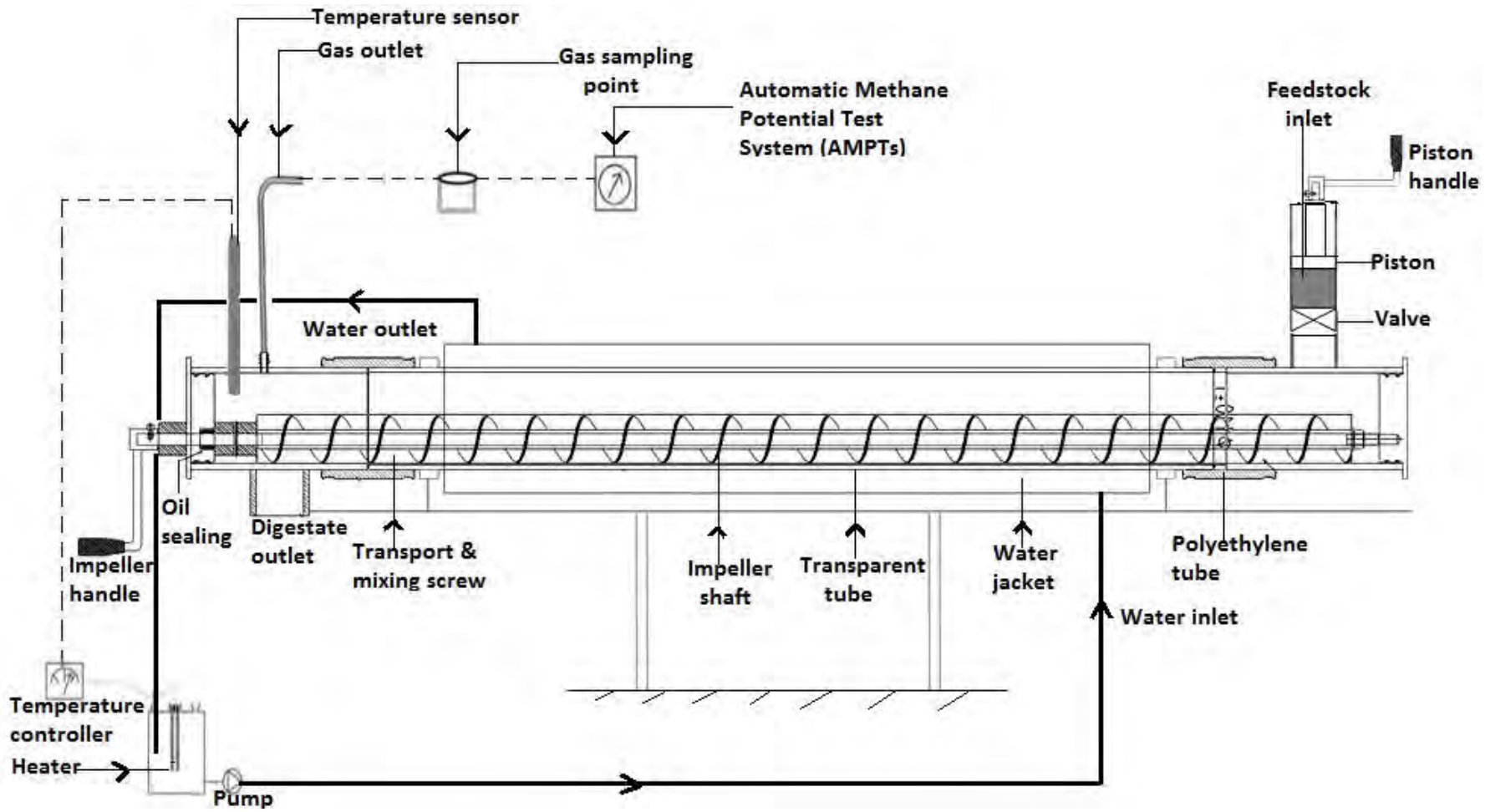
Continous reactors in lab



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Other products than methane from ADs?

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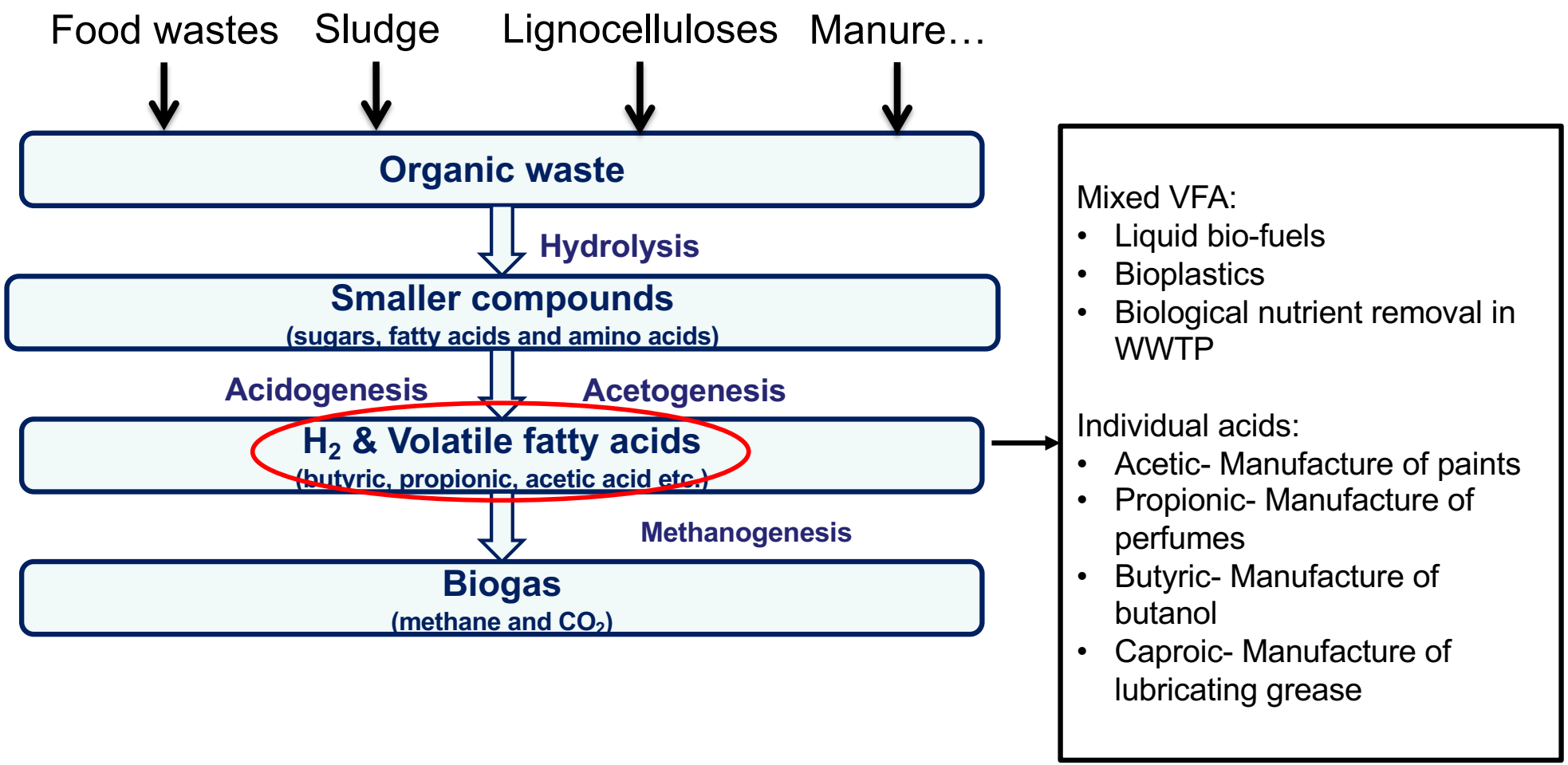
Anaerobic digestion (AD) for methane or VFAs?



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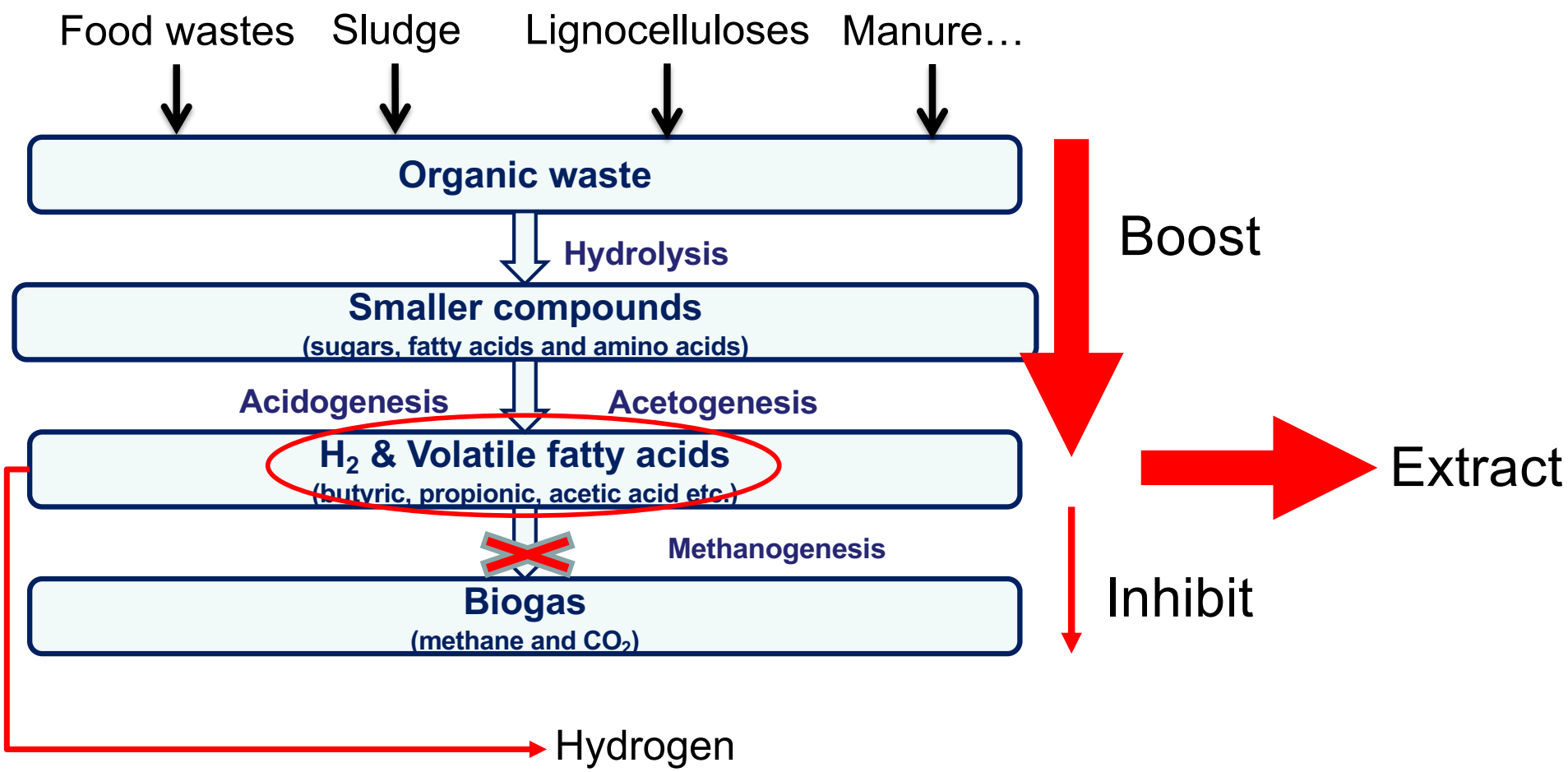

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VFA recovery

- Centrifugation
- Adsorption e.g. On:
  - Activated carbon, polystyrene-divinylbenzene, Amberlite resins
- Chemical extraction
- Membrane processes

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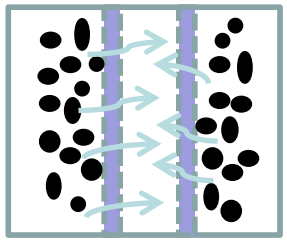
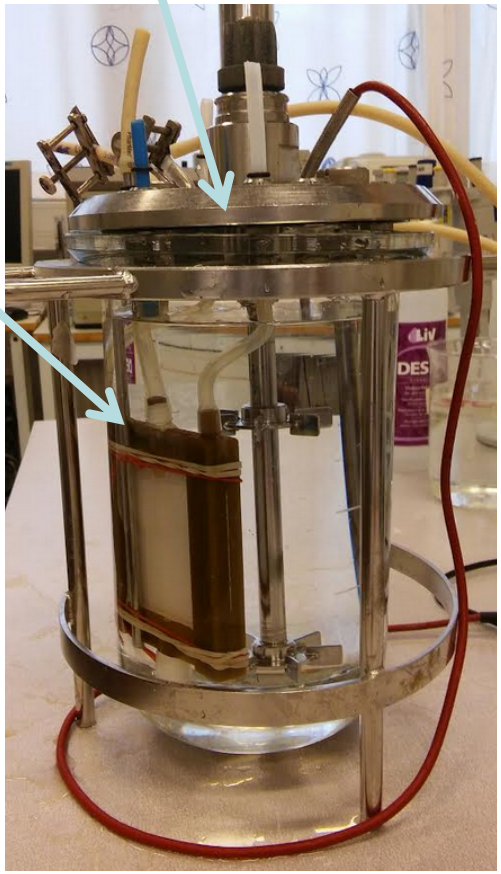
Submerged membrane bioreactor (sMBR)



Flat sheet membrane

CSTR



Empty sMBR

Bacteria and substrate (food waste)

Permeate

sMBR in operation

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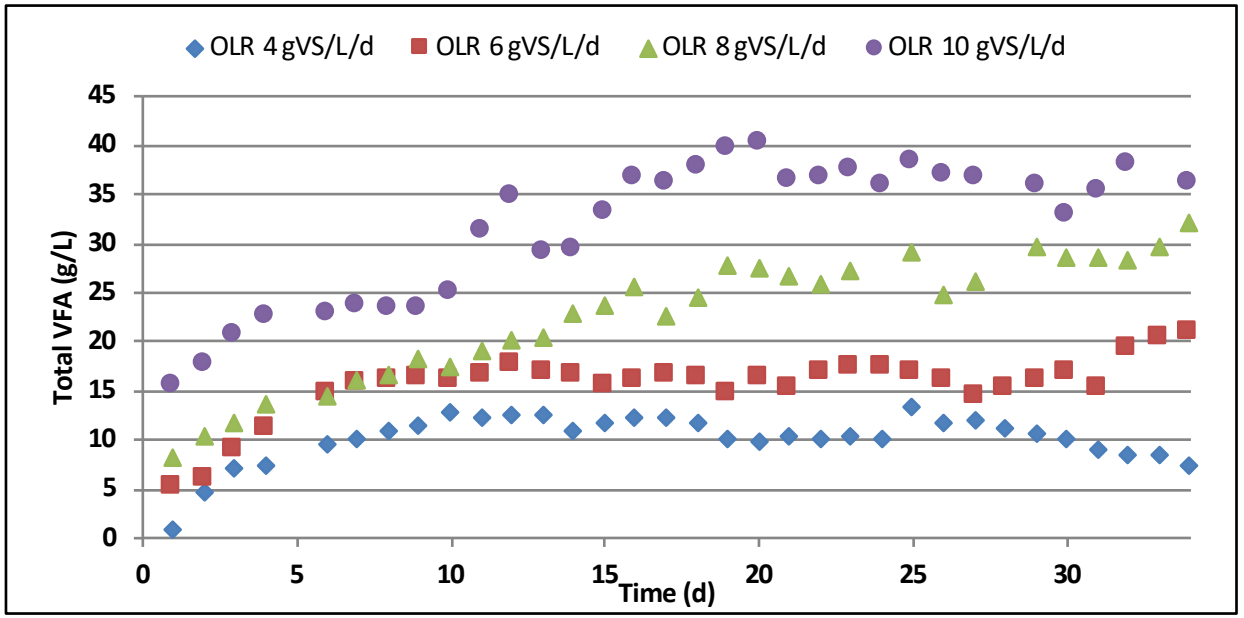
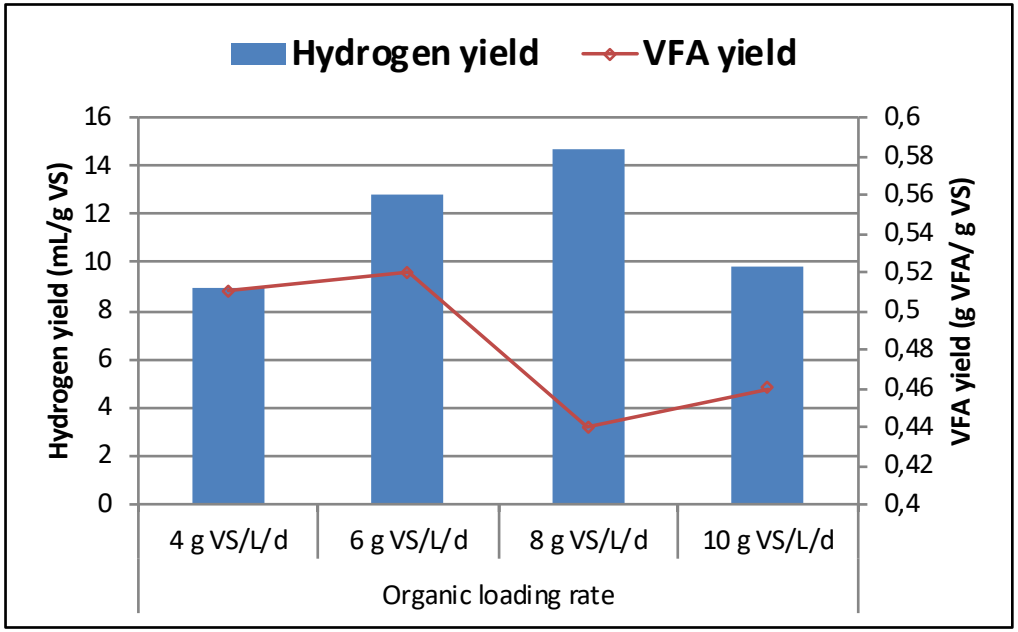
Continuous extraction at high organic loading rate

- ✓Food waste as substrate
- ✓pH controlled at 5.5
- ✓Optimum **organic loading rate** (OLR) in biogas systems = 2.5 g VS/L/d





Immersed

Membrane bioreactor

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Thank you!

Questions?

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