

### Research in organic waste as resources: How to implement circular bio-economy in the urban context?

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## Research in organic waste as resources: How to implement circular bio-economy in the urban context?

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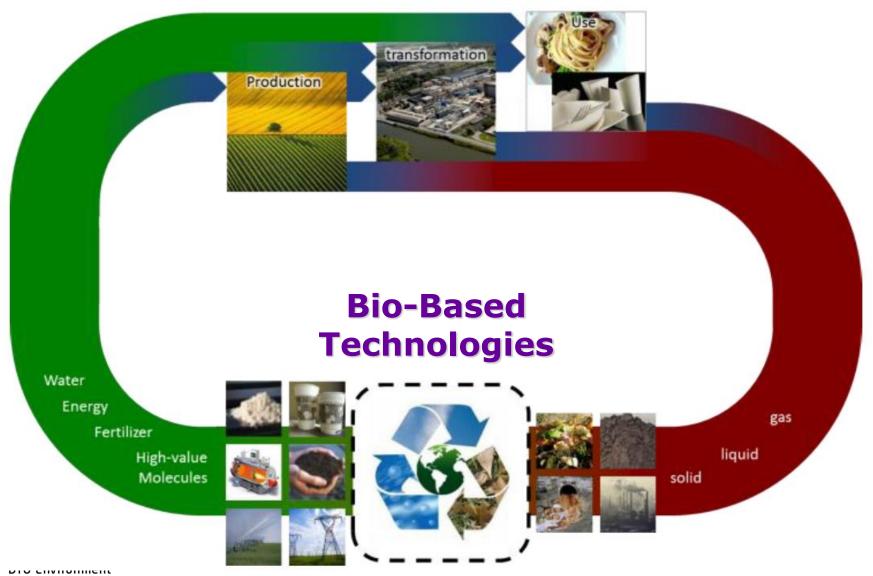
### Agenda



- Introduction to Circular Bio-Economy
- Overview of emerging approaches to recover resources
- Technology selection

### What is circular Bio-economy?





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### **Motivation?**



### Sustainability goals for 2030





### Why do we need to recover resources?



- Present and future regulations on GHG footprint from waste treatment facilities
  - Nutrient recovery as a mean to reduce carbon footprint

### Old infrastructure

Opportunity to include resource recovery in the retrofitting





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# **Overview of waste production and recycling in Europe**

# Municipal solid waste in 2020 → <u>271 M-t</u> Urban biowaste → <u>96 M-t</u>

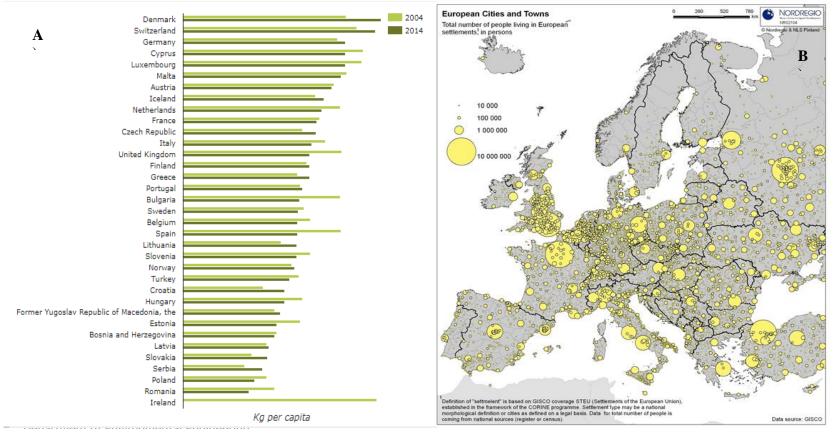
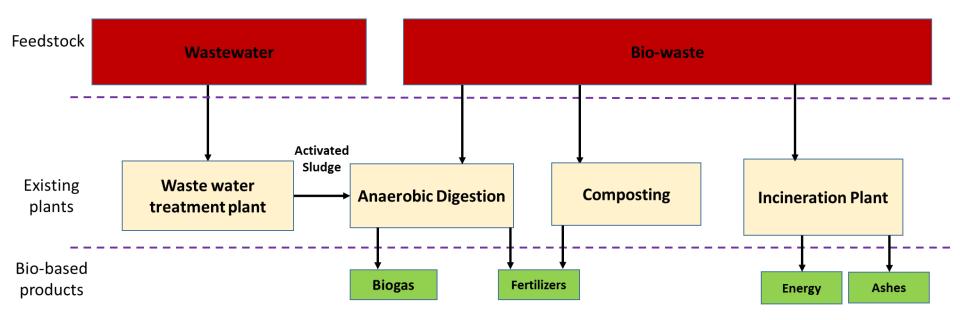


Fig 11. A) Bio-waste recycled per capita; B) population in European municipalities.

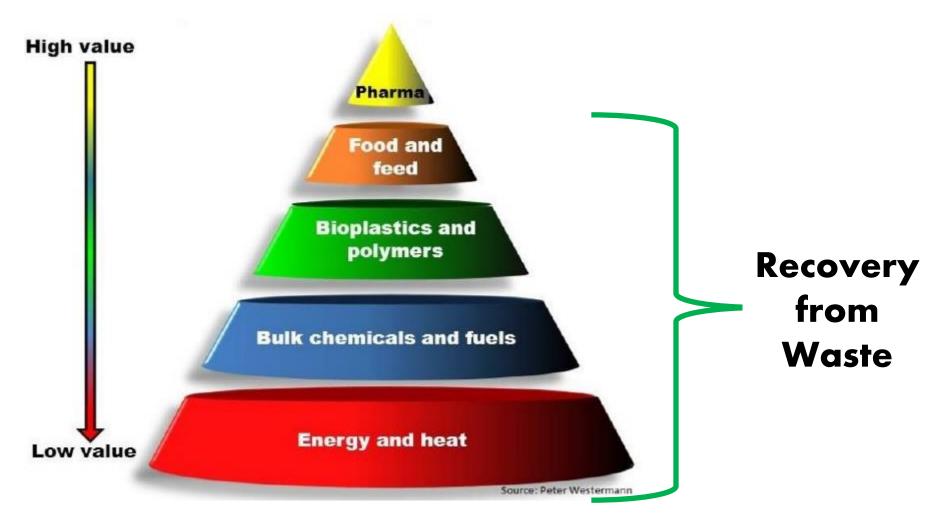
### **Traditional Organic Waste Managment**



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### **Classification of Bio-products**





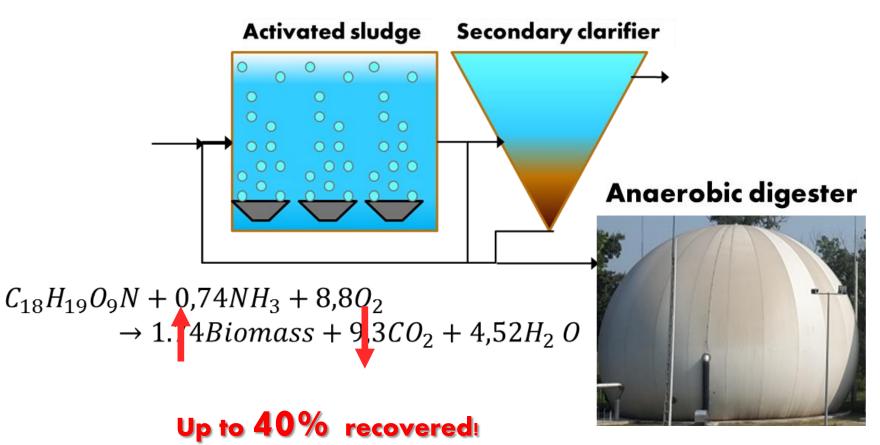


## Improving conventional approaches – biogas and fertilizers

### Wastewater treatment– what's new? Carbon recovery from sewage



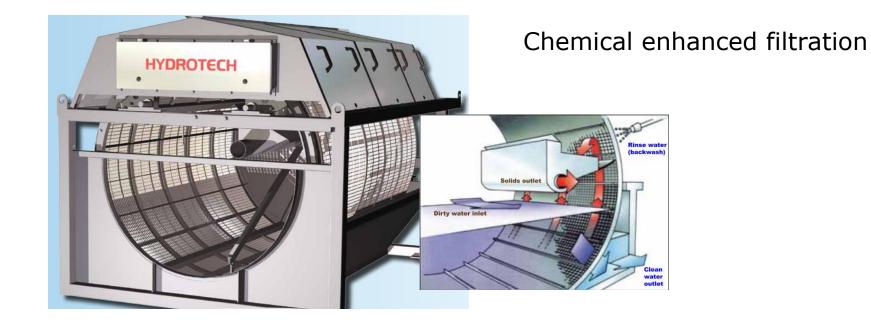
- Traditional water treatment plant
- Less than 10% organic carbon recovery!!



### Wastewater treatment– what's new? Carbon recovery from sewage



Direct water filtration



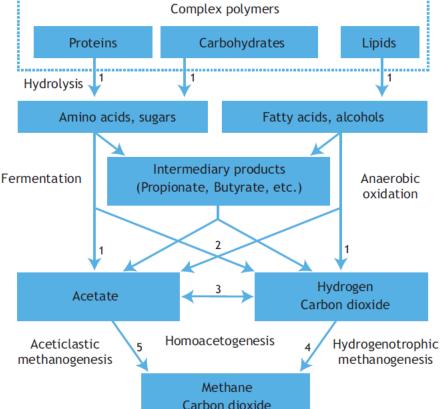
### **Biogas production – what's new?** Biogas Upgrading

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### **Biogas composition and valorization:**

- 60% of CH<sub>4</sub> and 40% CO<sub>2</sub>
- Co-generation plants to produce heat and electricity
- Biogas upgrading  $\rightarrow$  CO<sub>2</sub> removal to achieve >95% CH<sub>4</sub> concentration
  - Natural gas grit
  - Vehicle fuel





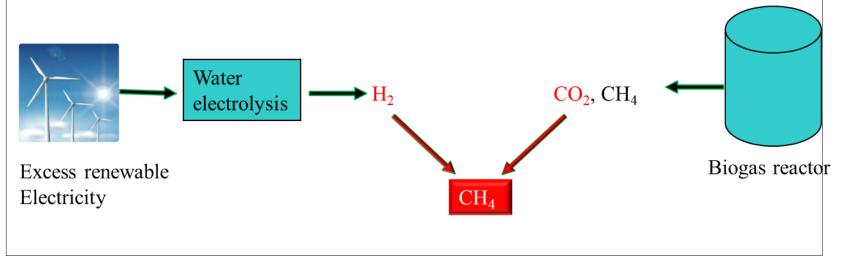
### Biogas production – what's new? Biogas Upgrading



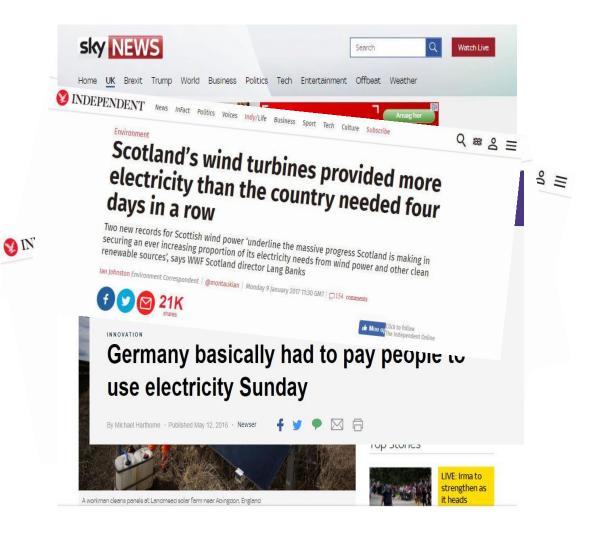
 CO<sub>2</sub> together with H<sub>2</sub> could be used by hydrogenotrophic methanogens for methane production.

 $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$ 

 H<sub>2</sub> could be obtained by electrolysis of water using the surplus electricity from eg. wind mills, or photovoltaics.

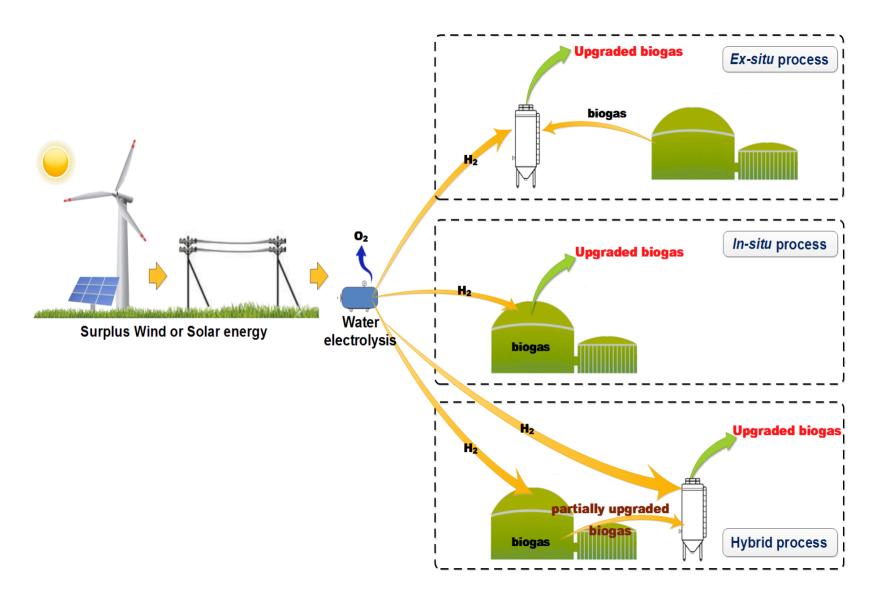


### Surplus Energy/Energy Storage?



### **Biogas production – what's new?** Biological biogas Upgrading

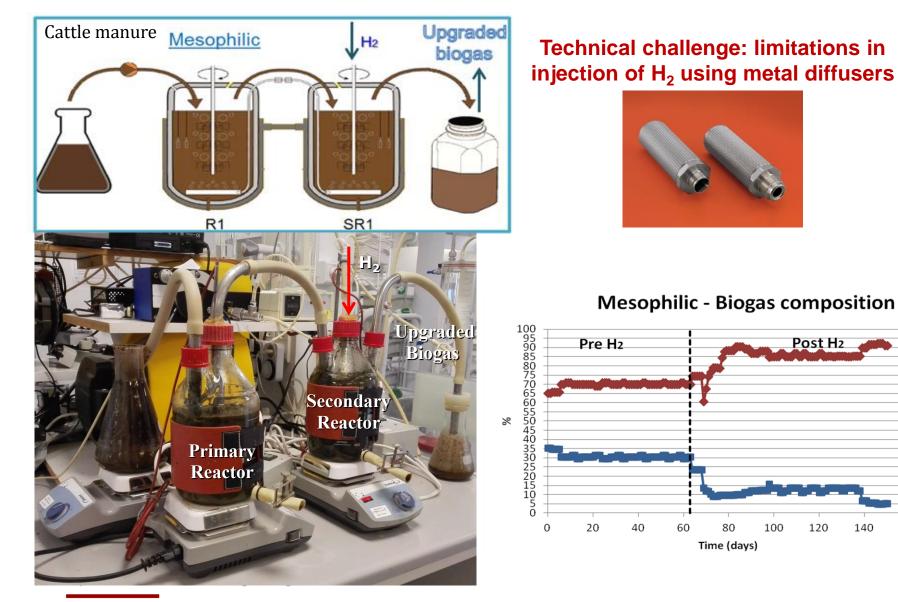




### **Biogas production – what's new?** Biological biogas Upgrading



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### **Biogas production – what's new?** Biological biogas Upgrading

### **Pilot Scale-VARGA Project**

### Full Scale: in 2 to 3 years

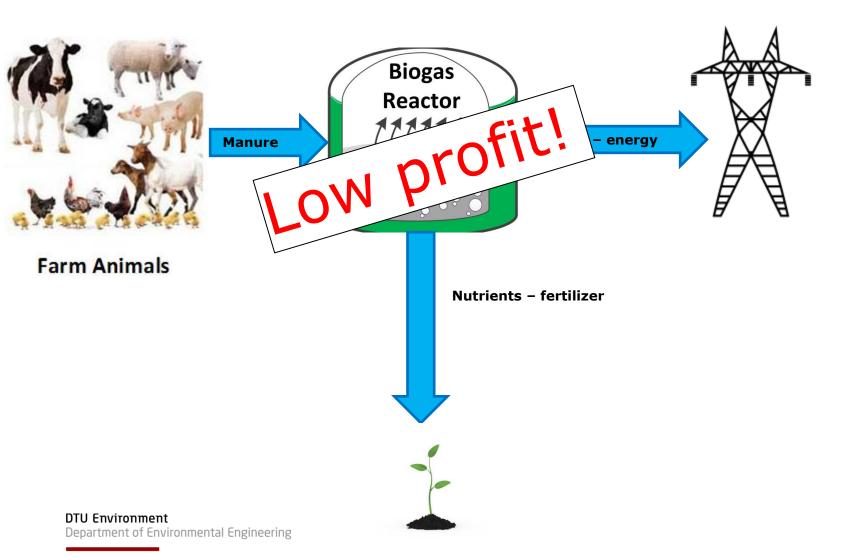


### At Avedøre Rensningsanlæg we demonstrate both the bioaumentation and the upgrading technology

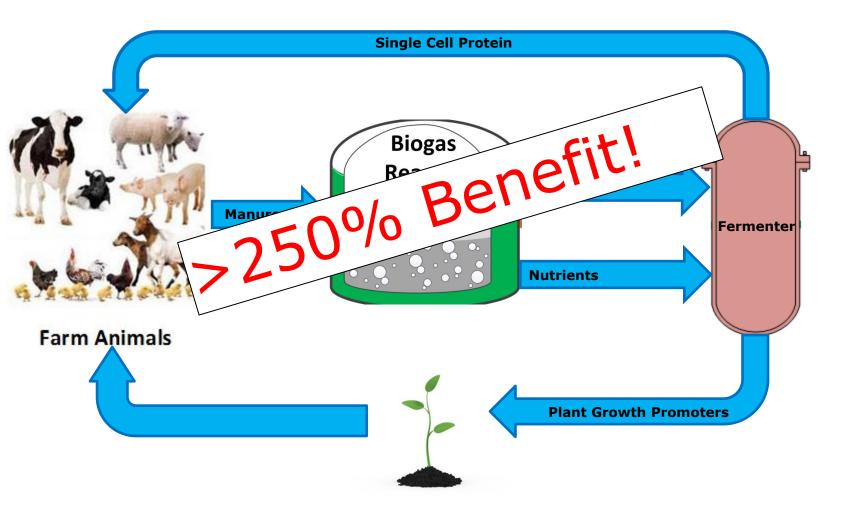


## Beyond biogas and fertilizers – novel resource recovery strategies

# Nutrient Management – Traditional approach

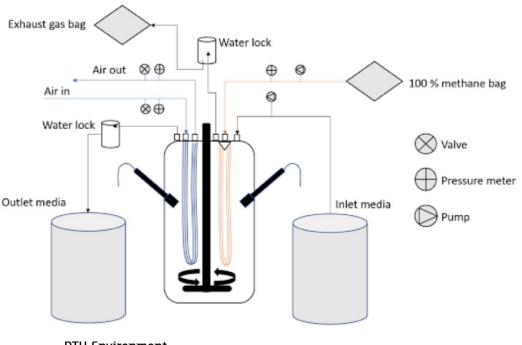


### Nutrient Management – Nutrient Upcycling and Reuse in Agriculture



### Examples of nutrient valorisation as Single Cell Protein – Gas supply through membranes

<u>Methane</u> <u>Oxidizing</u> <u>Bacteria</u> store proteins (EU approved as feed ingredient!) <u>Technical challenge:</u> gas bubbling produces explosive atmospheres!

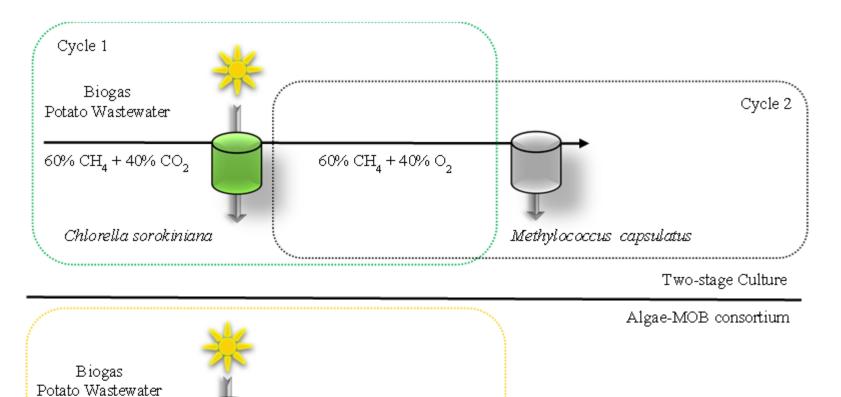




### **Examples of nutrient valorisation as Single Cell Protein**



#### **Co-cultivation of algae and methanotrophs**

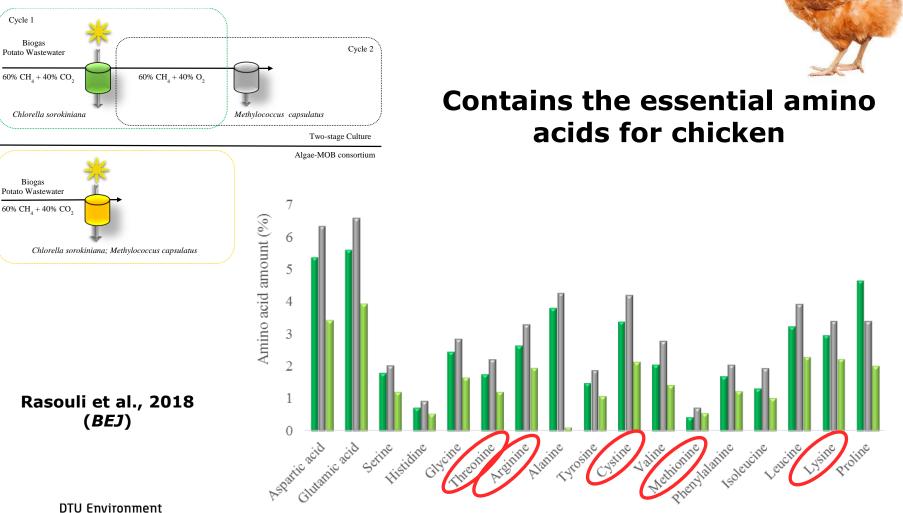


Chlorella sorokiniana; Methylococcus capsulatus

60% CH<sub>4</sub> + 40% CO<sub>2</sub>

### Examples of nutrient valorisation as Single Cell Protein

**Co-cultivation of algae and methanotrophs** 



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### What happens with the real pollutants?

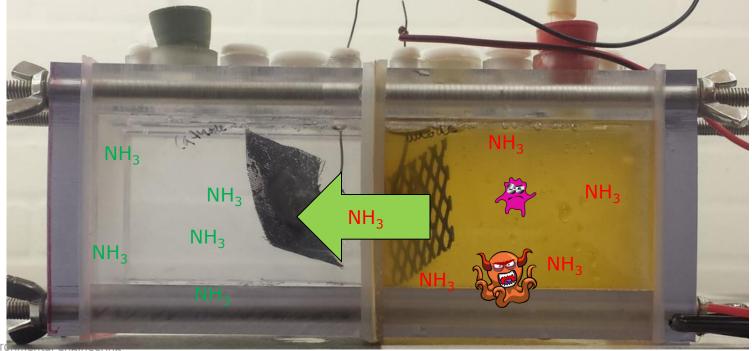


Who are the bad guys?

- Heavy metals
- Impurities
- Pathogens
- Pharmaceuticals
- Antibiotic resistance genes

How do we get read of them?

- Membrane filtration
- Bio-electrochemical systems



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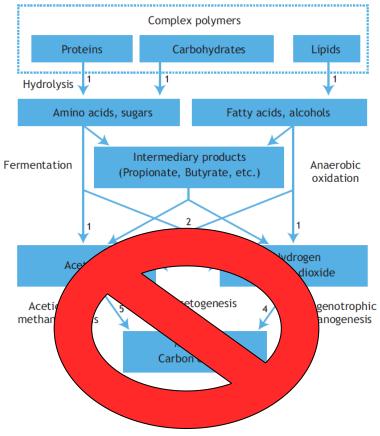
### **Carbon valorization – Platform chemicals**



<u>What is a platform chemical</u>:small molecules derived from biomass that could be utilized as building blocks for higher-value chemicals (e.g., solvents) and materials (e.g., polymers)

### Volatile fatty acids

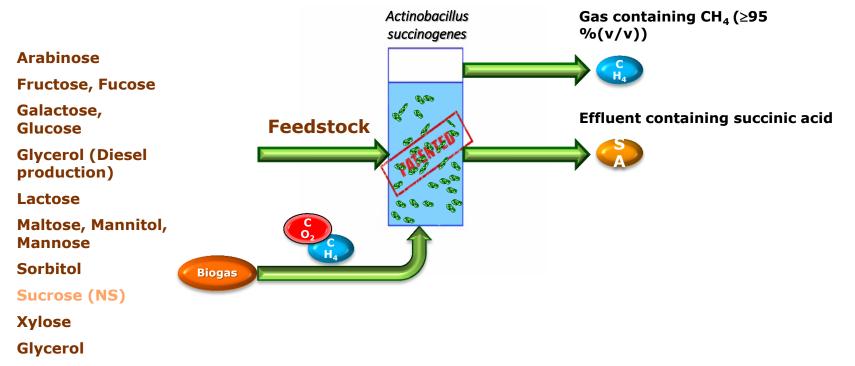
- Fermentation of bio-waste
- Main challenge: purity of the VFA
- Example of propionate
  - additive or flavoring agent
  - mold and bacteria inhibitors in food products
  - building block for herbicides, vitamin pharmaceuticals, dyes, plastics, cosmetics...
  - de-icing salts



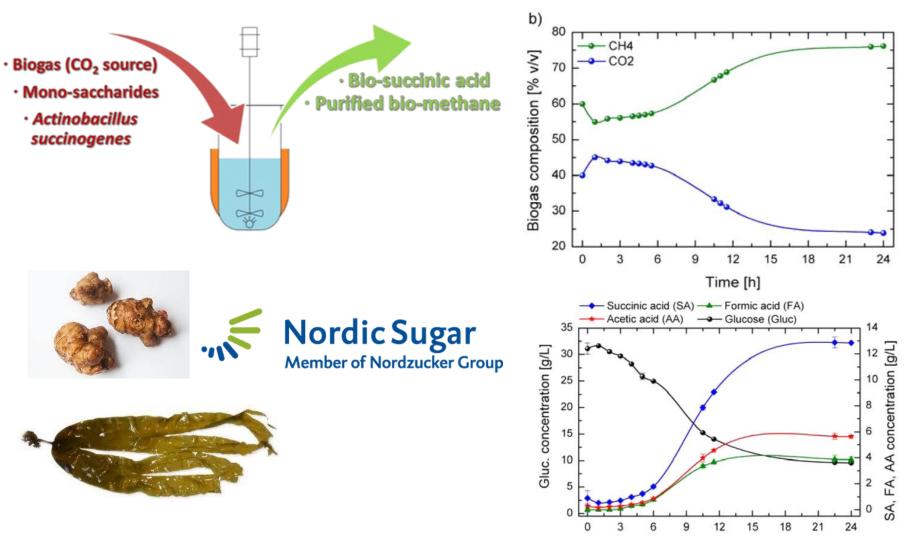
### **BIOSUCCESS – A Unique Technology**

Simultaneous biomethane and biosuccinic acid production

### $7C_6H_{12}O_6 + 6CO_2 \rightarrow 12C_4H_6O_4 + 6H_2O_2$



## Biogas Upgrading and Bio-Succinic Acid $\Xi$

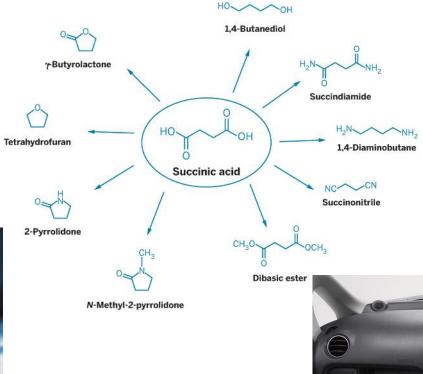


### **Succinic Acid**

### > Succinic acid applications include:

### > Pharmaceuticals, coatings, biopolymers, green solvents



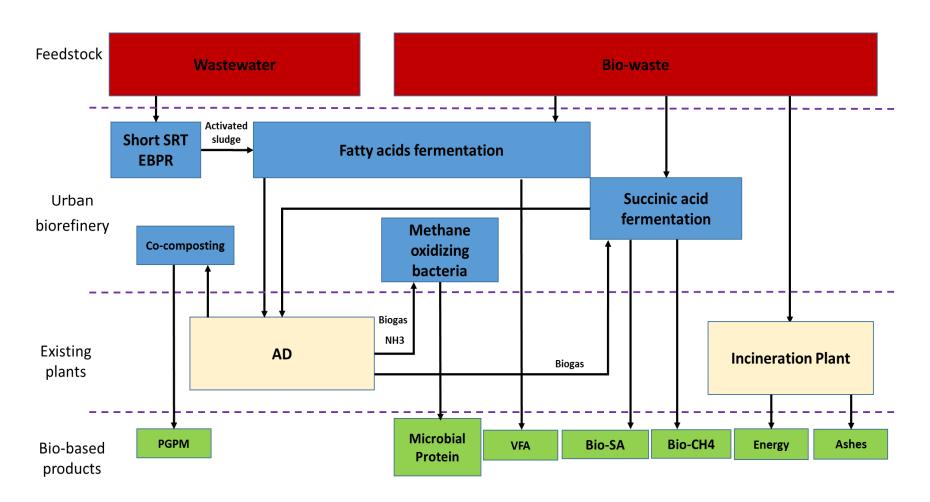


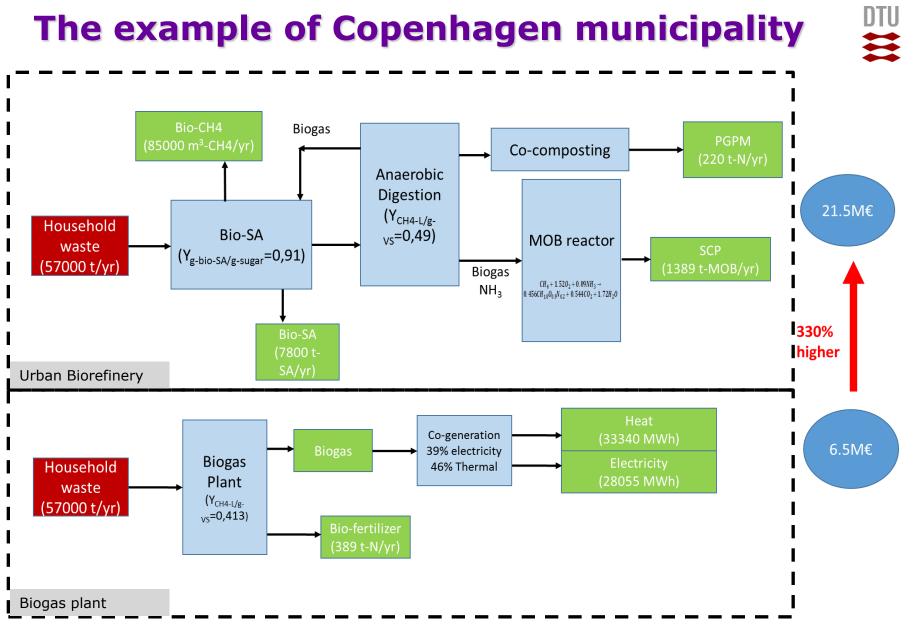






### **Urban biorefineries**





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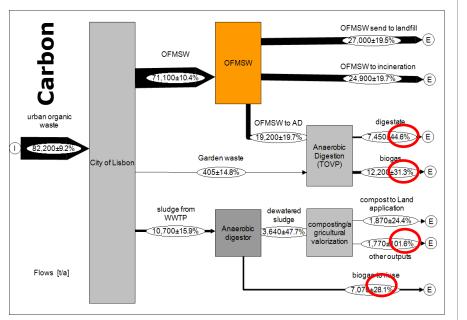
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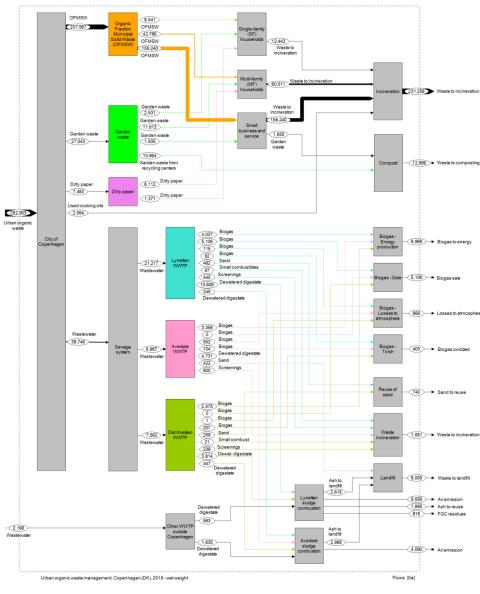
## How to select best resource recovery strategy?

### **Resource mapping**



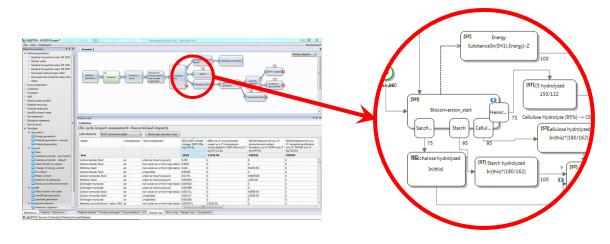


- Full system:
  - Materials
  - Energy
  - Substances
- Uncertainty characterization



### Sustainability Assessment of Residual Bioresource Engineering



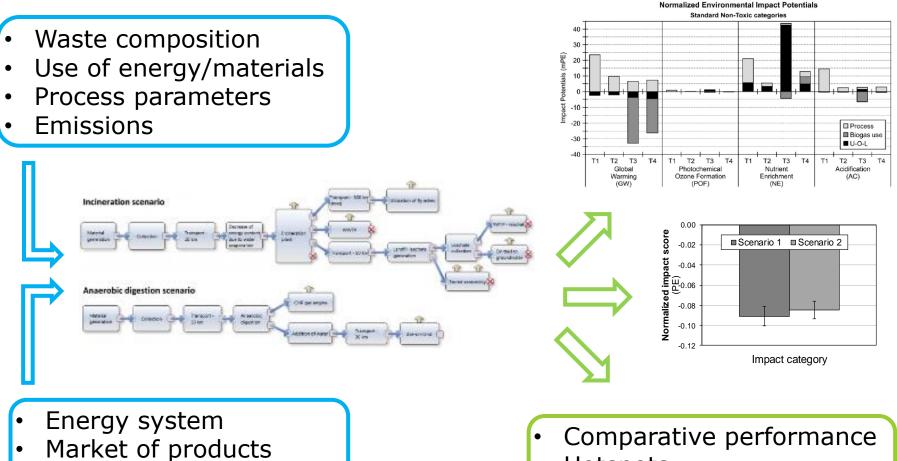




- LCA and LCC: EASETECH, a DTU developed model
- Assessment of full value-chain with focus on residual resources
- Process-oriented modelling of technologies reflecting actual conversion pathways
- Integrated conversion and recovery of multiple outputs based on properties of substrates
- Optimal system integration and process configuration
- Identification of critical process parameters

# Life Cycle Assessment (LCA) and Costing (LCC)





Hotspots

**Uncertainties** 

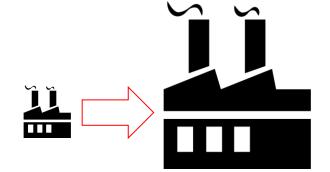
Background conditions

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### Challenges

- Upscaling of technology
- Local conditions
- Scope:
  - Technology data
  - Substitutions
  - Framework conditions:
    - Energy mix
    - Fossil vs biomass-based plastic
  - Production of mineral fertilizers
  - Capital costs















### Acknowledgement





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