



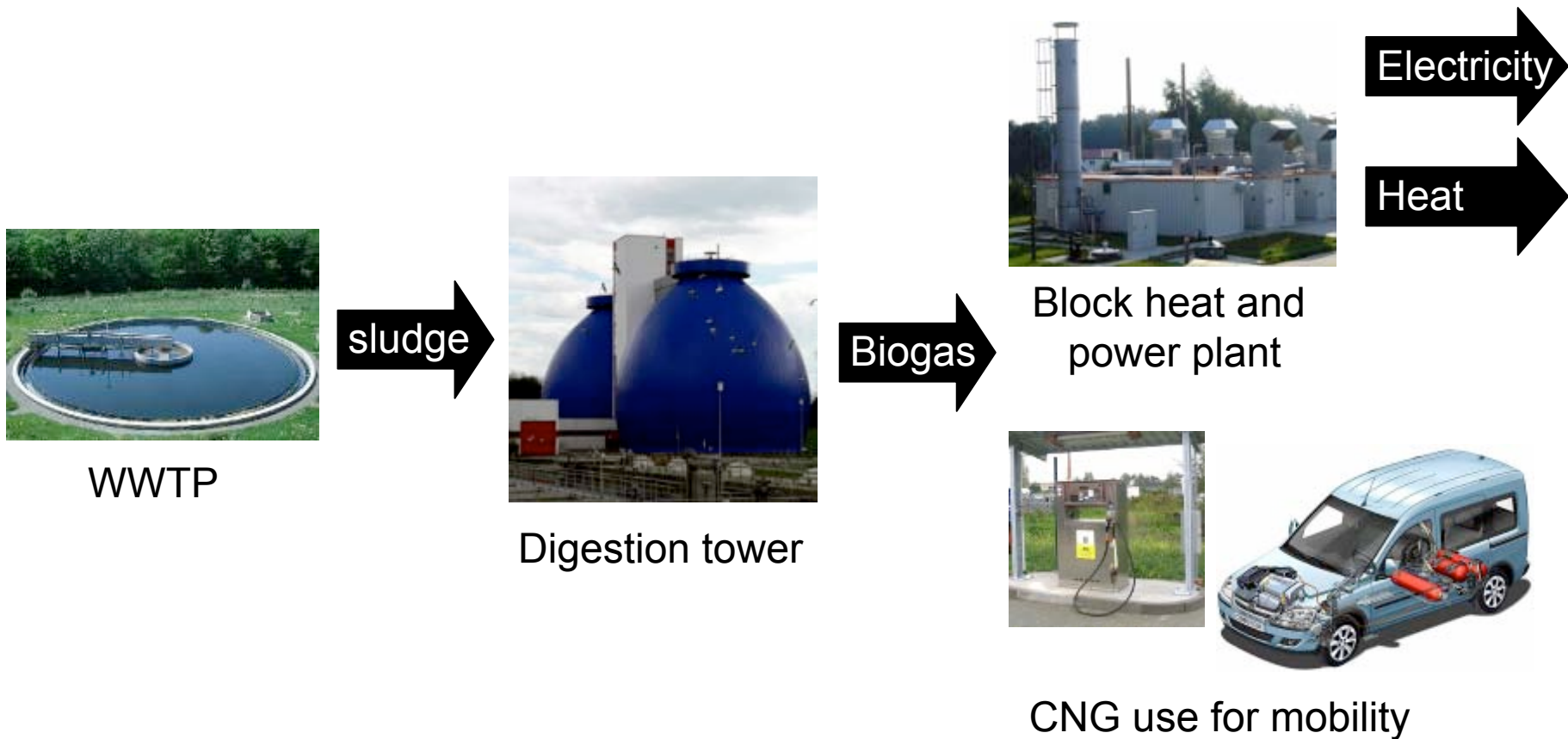
**Biological hydrogen production as a new  
source of energy for waste water treatment  
plants**

**Thorsten Mietzel  
Ruth Brunstermann  
Renatus Widmann**

# Content

- History and use of biogas
- Biological hydrogen production
- Determining suitable substrate using batch tests
- Determining suitable inoculums using batch tests
- Lab scale continuous hydrogen production
- Combining hydrogen and methane reactors
- Future prospects

# Common Practice for Energy Production on Sewage Treatment Plants Today



# History of Use of Biogas

**1948 to 1956: The Emschergenossenschaft sells Biogas at the waste water treatment plant in Essen-Frohnhausen**



# History of Use of Biogas

**Today: The Emschergenossenschaft operates a biogas station for the company cars**



## Advantages of Hydrogen over Methane

- Hydrogen can be produced from electricity (solar panels, wind power plant, hydropower plant)
- When used in fuel cells, no emitting of pollutants
- More energy efficient regarding electricity
- No green house effect when emitted through leakage

# Areas of Application for Hydrogen

Energy production



Mobility

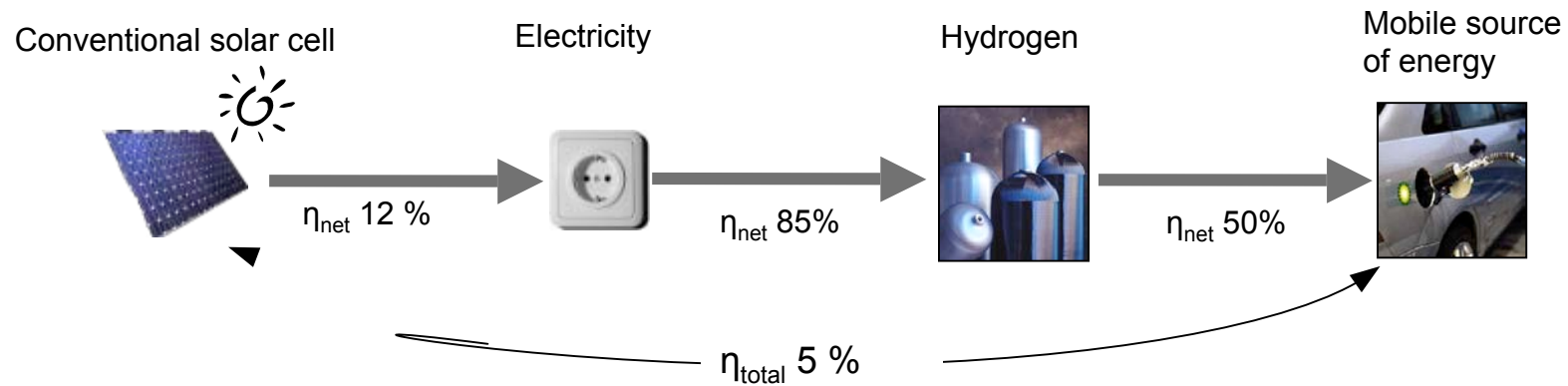


Portable appliances

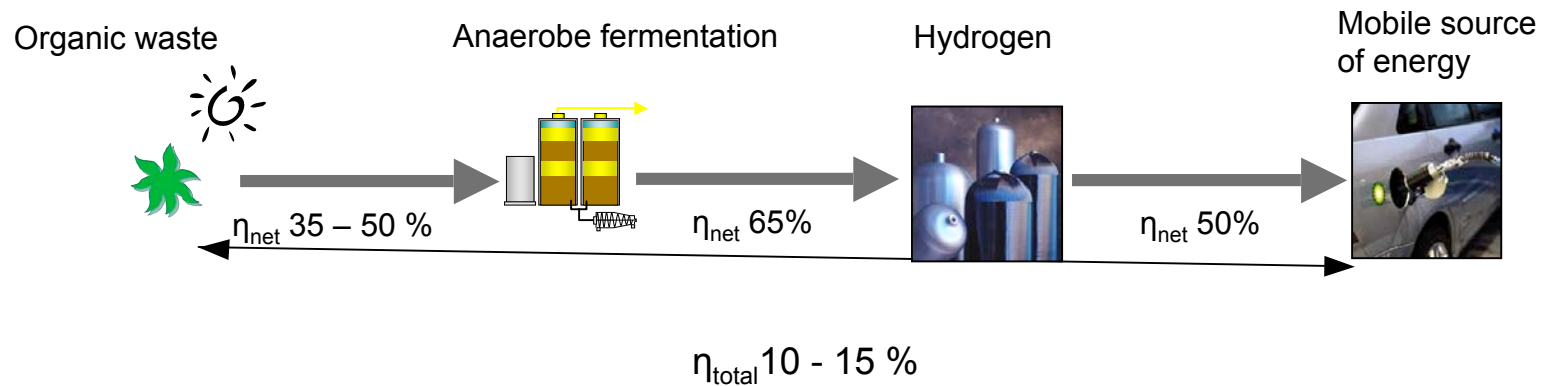


# Solar vs. Biological Hydrogen Production

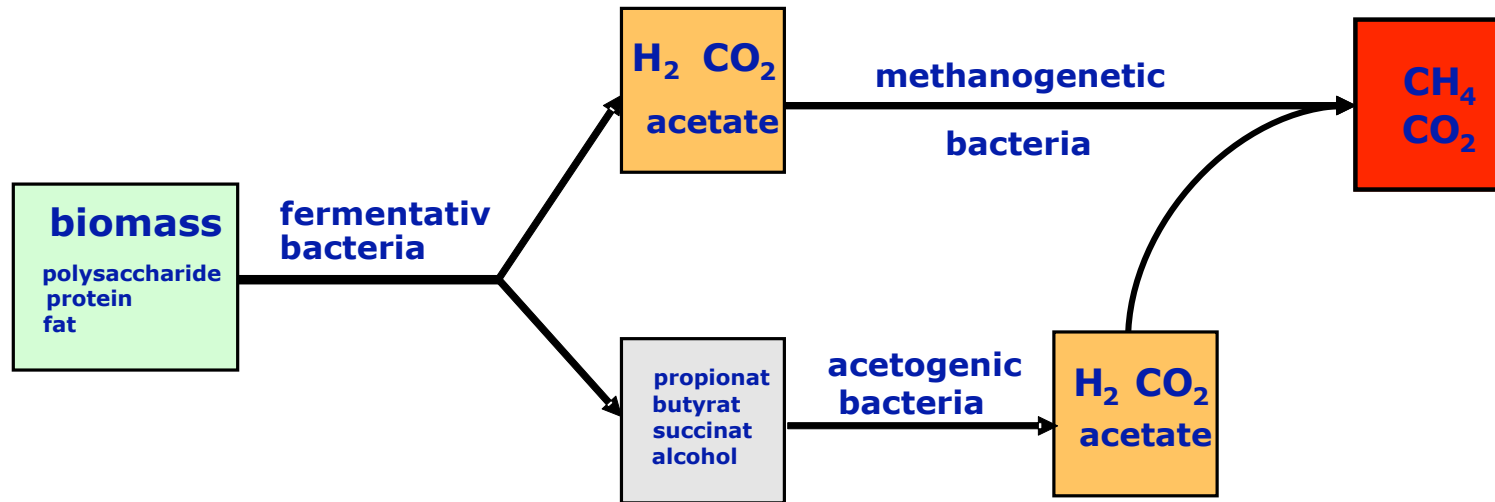
## Photovoltaic



## Bio-solar cell



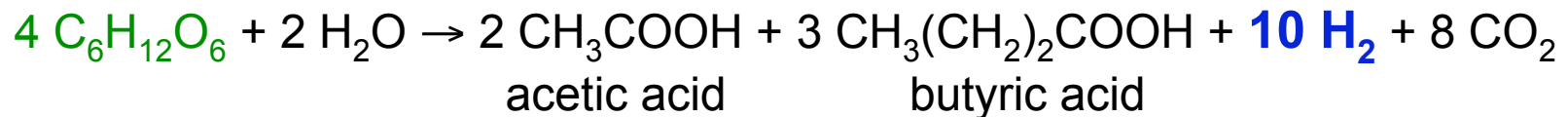
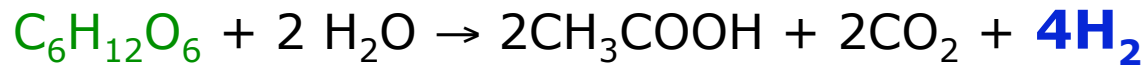
# The Four Steps of Anaerobic Digestion



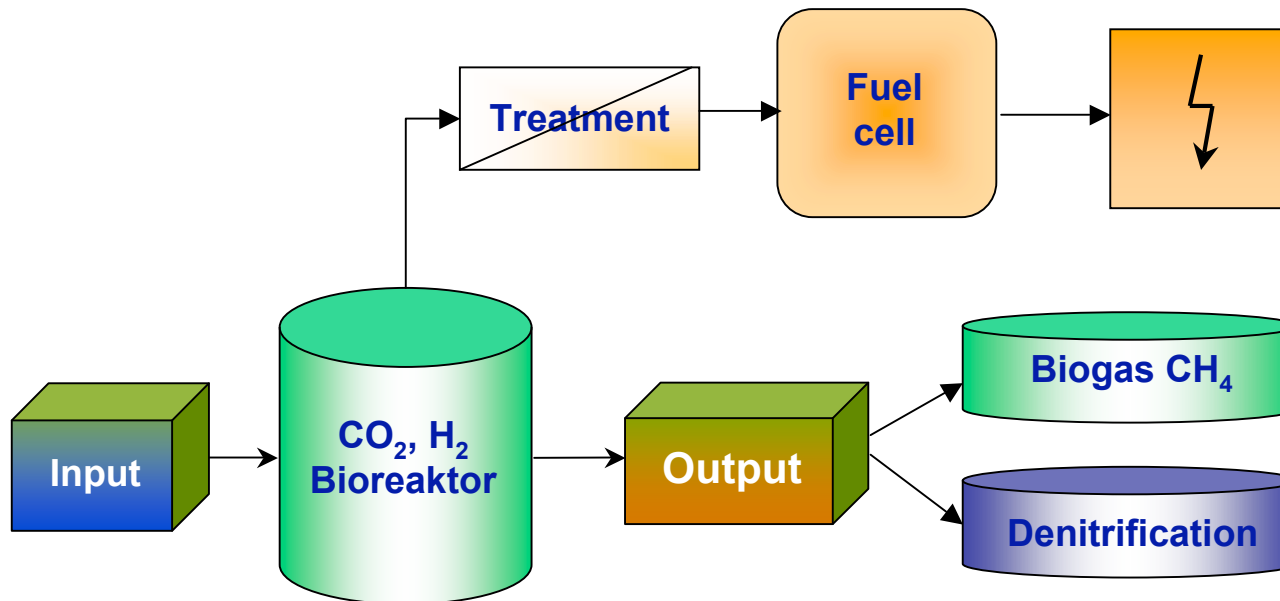
**1. and 2. step:**  
hydrolysis and fermentation  
T<sub>opt.</sub> about 30°C  
pH<sub>opt.</sub> about 6

**3. step**  
Acetic acid formation  
 $C_6H_{12}O_6 \rightarrow 3CO_2 \uparrow + 3CH_4 \uparrow$

**4. step**  
methanogenesis  
T<sub>opt.</sub> about 35-45 °C  
pH<sub>opt.</sub> about 7



# Goal: Development of a Full Size Plant for Biological Hydrogen Production



# Potenital Organic Matter for Hydrogen Production

Defined carbohydrates



Fruit and vegetables



Dairy products



Biogenic waste



Waste/waste water from sugar manufacturing

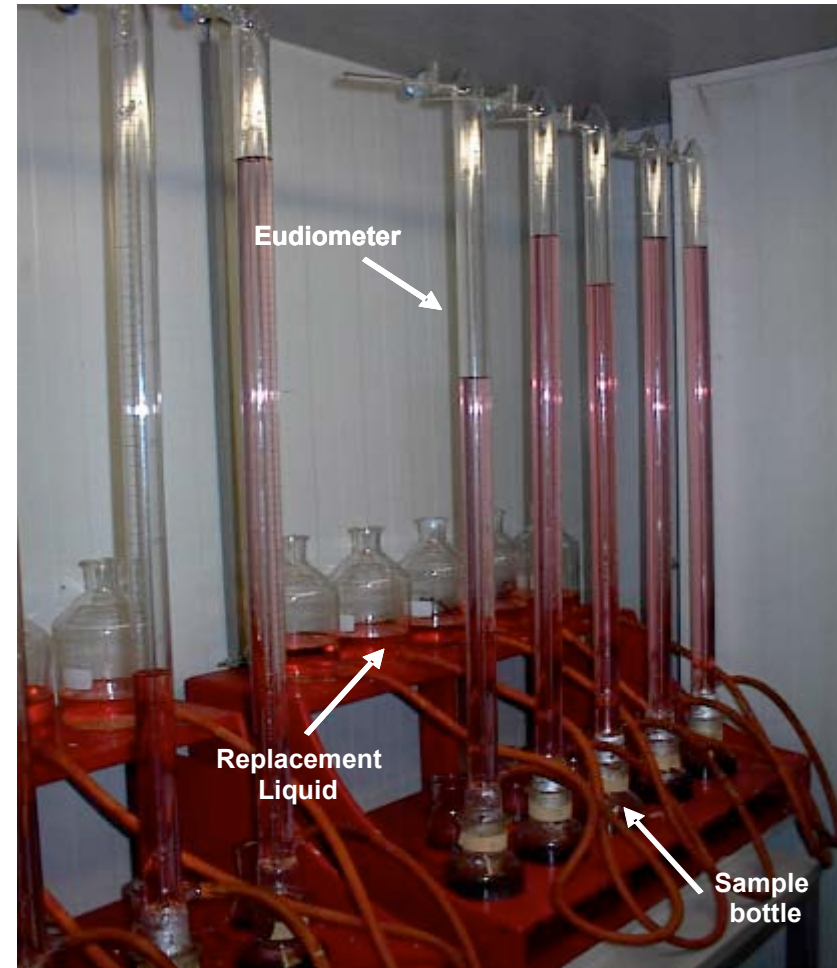


# Batch Test to Estimate the Hydrogen Potential of Different Organic Matter

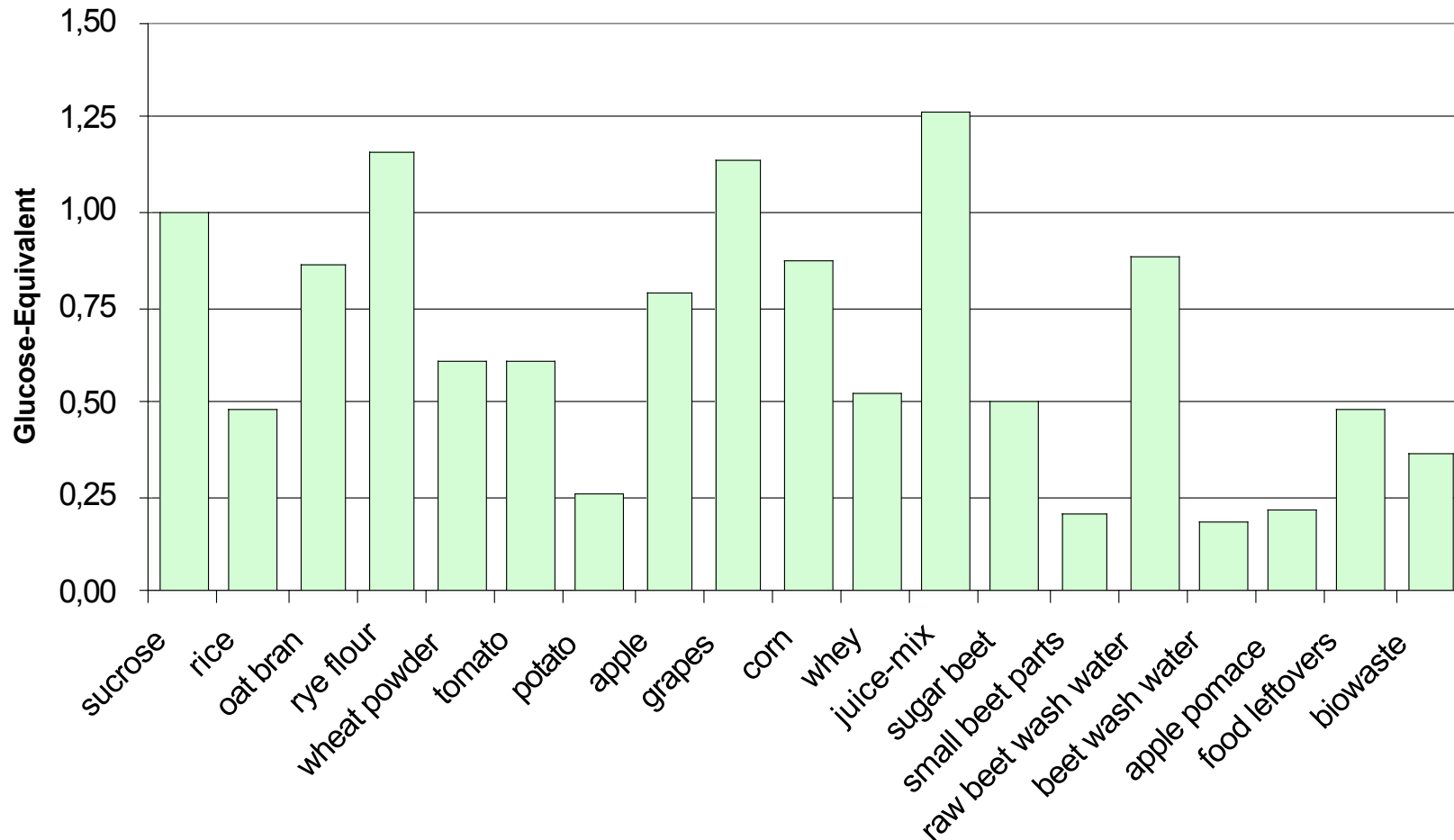
- Volume of reactor: 500 ml
- Volume Eudiometer: 400 ml filled with sealing liquid
- Pressure equalization

## Sample

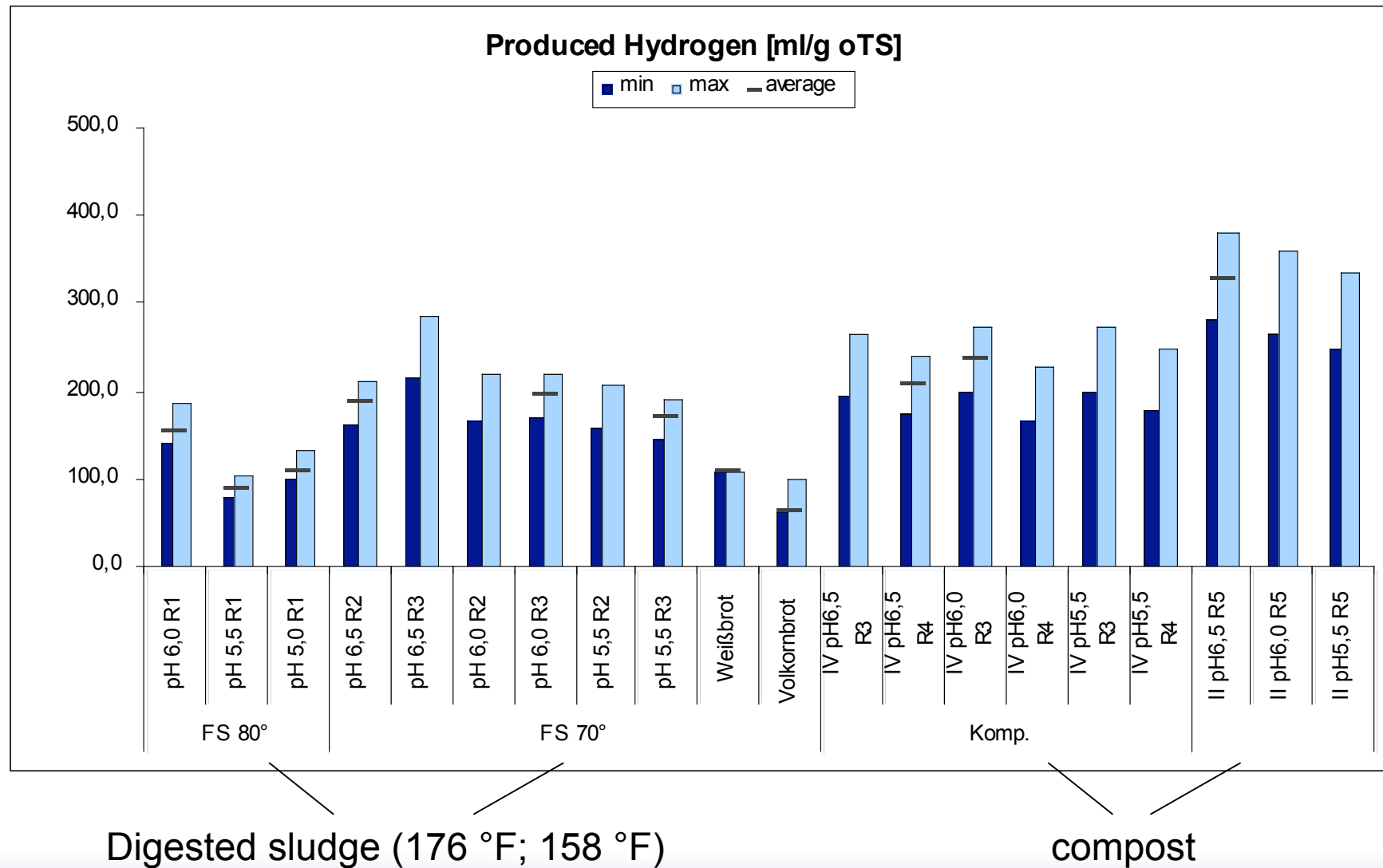
- 1g organic solid of inoculum
- 1g organic solid of glucose
- Filled up to 300ml with tap water
- References only 1g organic solid of inoculum
- pH- adjusted to 5.0, 5.5, 6.0, and 6.5



# Substrates Suitable for Hydrogen Production



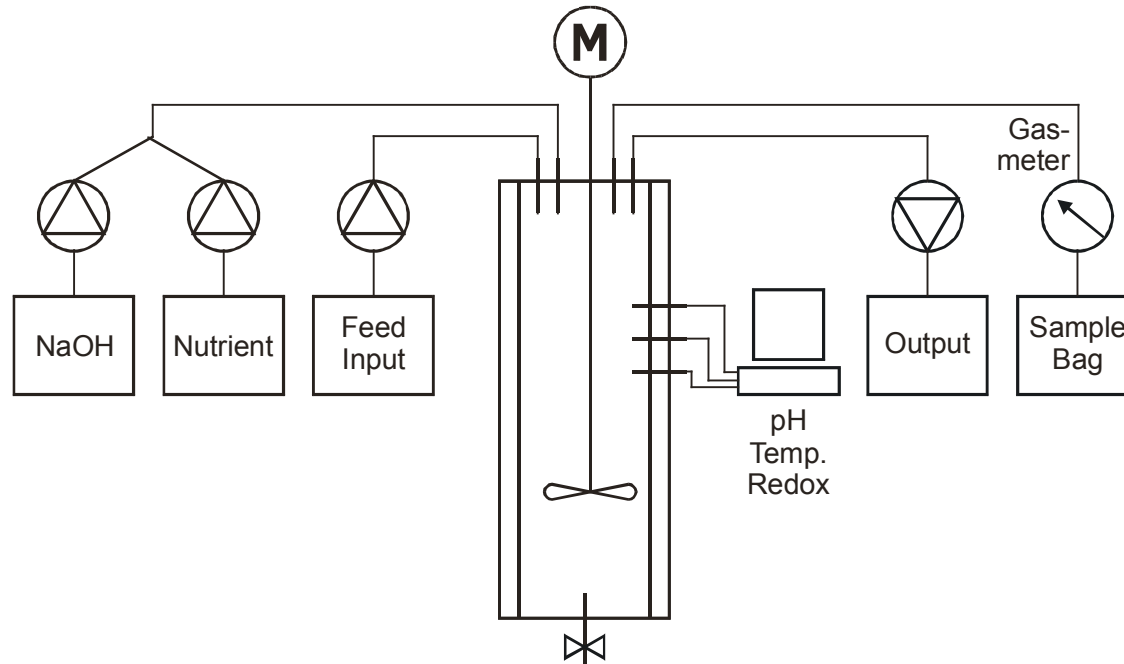
# Batch Tests for Determining the Best Inoculum



# Batch Tests for Determining the Best Inoculum

- All tested materials are suitable inoculums
- Fresh compost (degree of rotting II)
  - Best results with no pretreatment => 2,5 to 3,0 molH<sub>2</sub>/mol glucose
  - Longer starting period
- Digested sludge
  - Gas production starts earlier
  - Lower hydrogen production
  - Different pretreatments are relevant
  - Best results with pretreatment at 70°C for 60 Minutes => 1,5 molH<sub>2</sub>/mol glucose
- Bread with pretreated digested sludge
  - Approx. 50% less hydrogen production

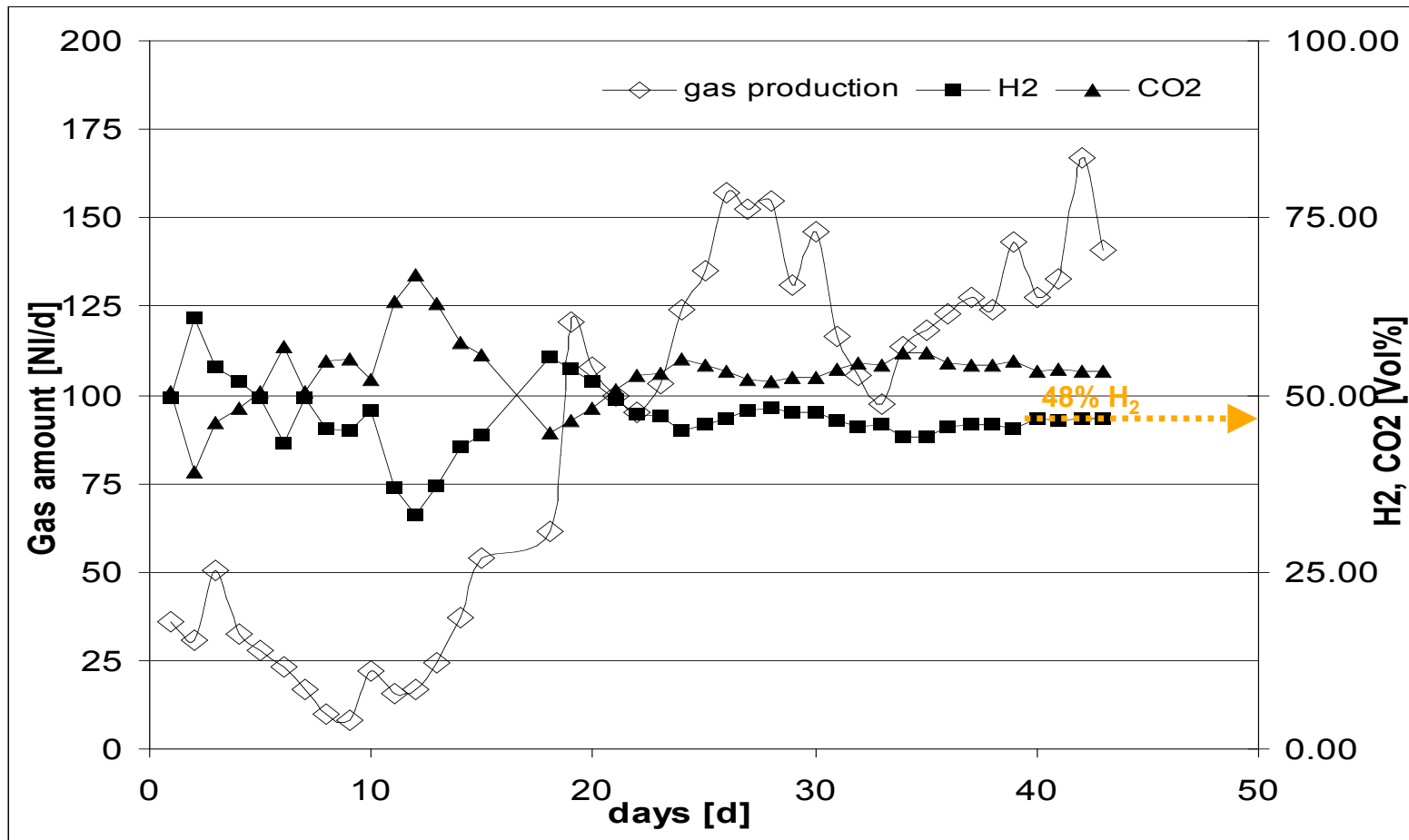
# Lab Scale Continuous Hydrogen Production



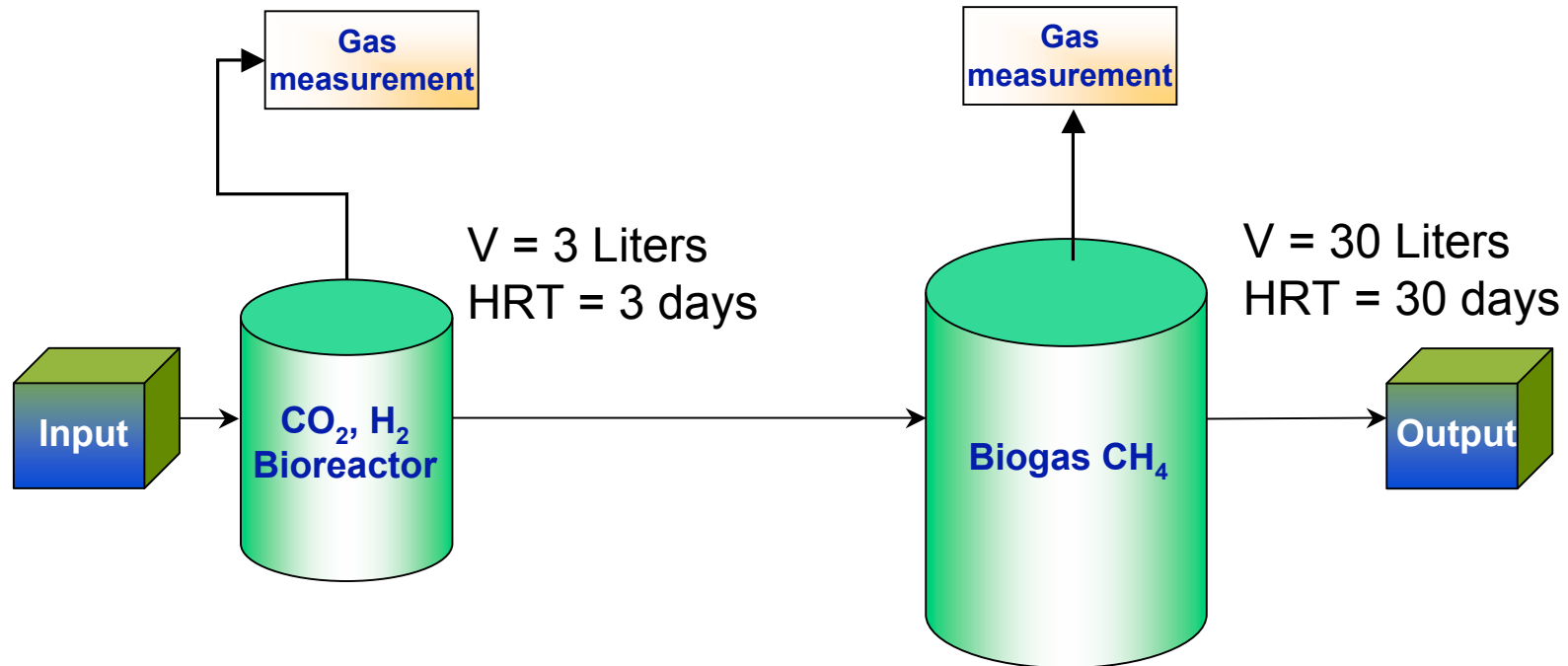
- Total of 9 test series
- HRT: 120, 40, 20, 15, 12.5 hours
- Temp.: 30-35 °C, 55-60 °C, 25-30 °C
- Online pH-Adjustment to 6,5

# Continuous Hydrogen Production

HRT 15 h



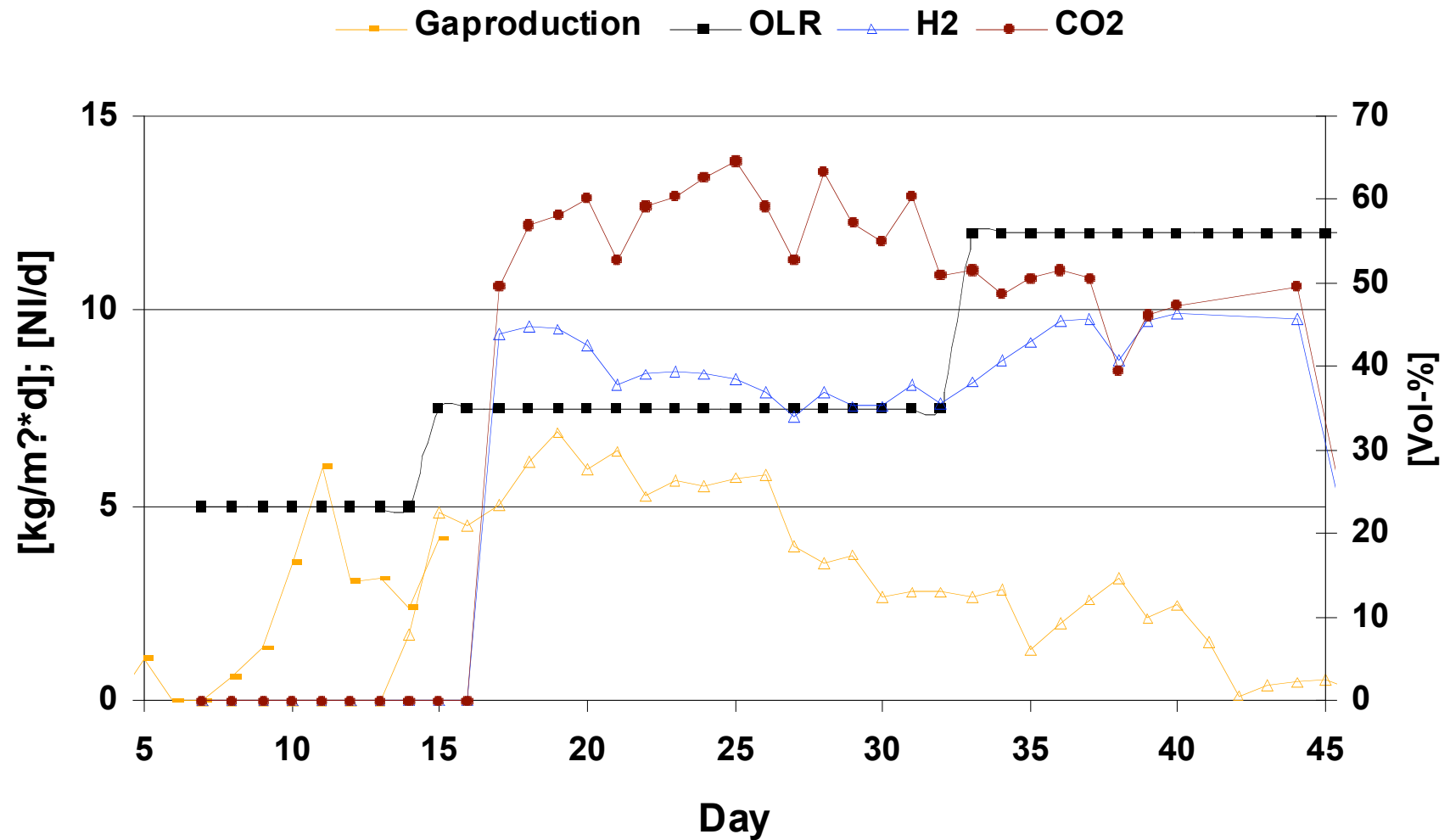
# Combination of Hydrogen and Methane Reactors



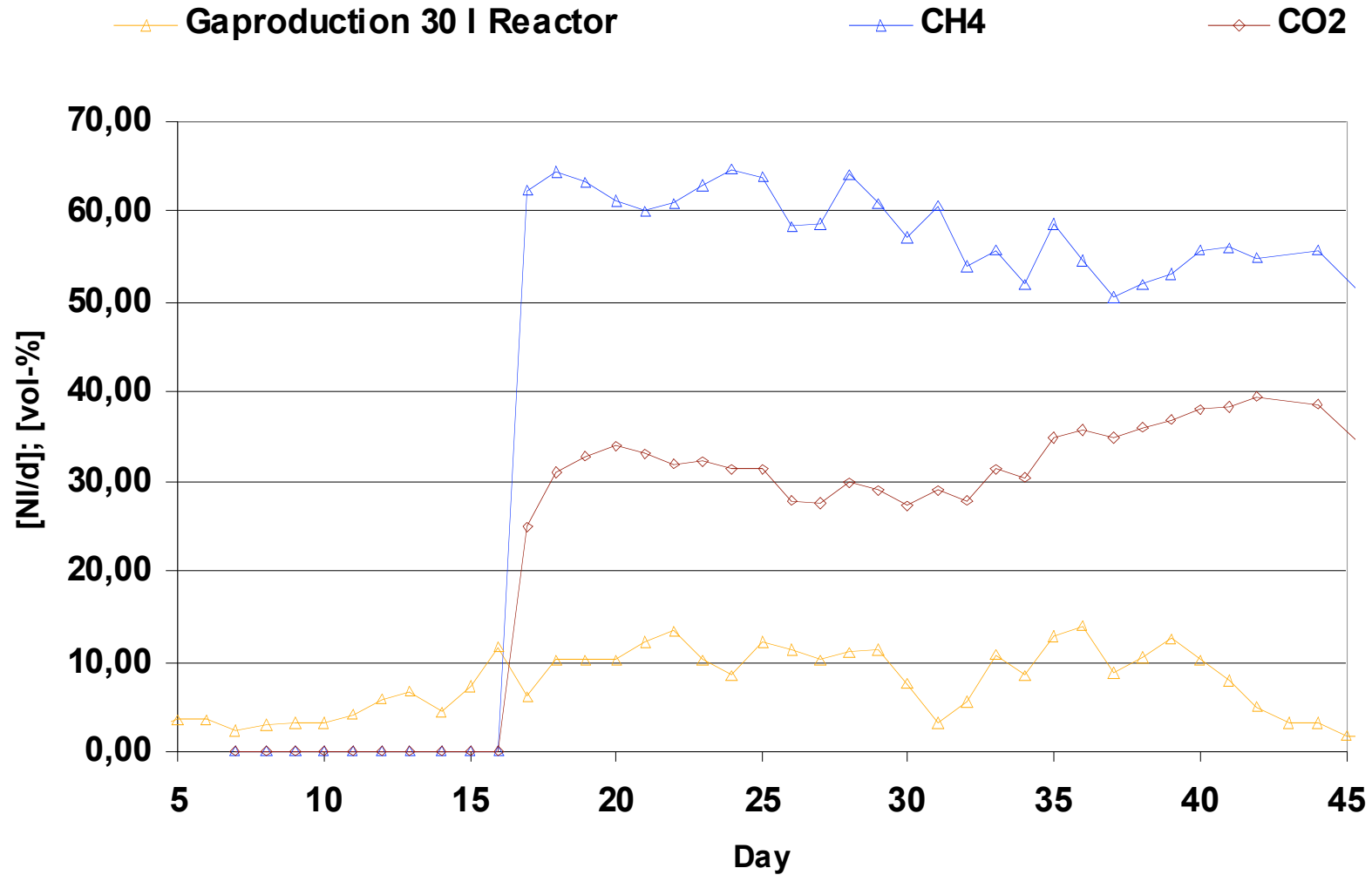
**nutrient solution**  
**pH-Adjustment**  
**PC-driven In-/Output control (PC)**

**pH-Adjustment**  
**PC-driven In-/Output control (PC)**

# Gas Production and Quality of the Hydrogen Reactor



# Gas Production and Quality of the Methane Reactor



## Future Prospects

- Continued operation of the hydrogen and methane reactor
- Use of different substrates (waste and waste waters from food and sugar manufacturing)
- Energy recovery using a fuel cell
- Operation of a large scale reactor at a waste water treatment plant
- Gas processing (e.g. CO<sub>2</sub> separation using membranes)

Thanks for your interest

