MoDe ProBio

HOCHSCHULE FURTWANGEN UNIVERSITY HFU

Development of a modular eight-chamber Multifunctional Anaerobic Baffled Reactor

6th Biorefinery Day: Key technologies for bio-based products and fuels

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Why Anaerobic Baffled Reactor?

- **Resilient and stable:**
  Compartmentalised design tolerates shocks and feed variability better than conventional ADs.

- **Efficient design:**
  Simple, low-maintenance, cost-effective setup that improves methane quality and recovery.

- **Biomass retention:**
  Staged chambers specialise microbes, reduce sludge, and boost robustness.

- **Beyond biogas:**
  Enables high-value products and chemicals, supporting circular bio-economies.

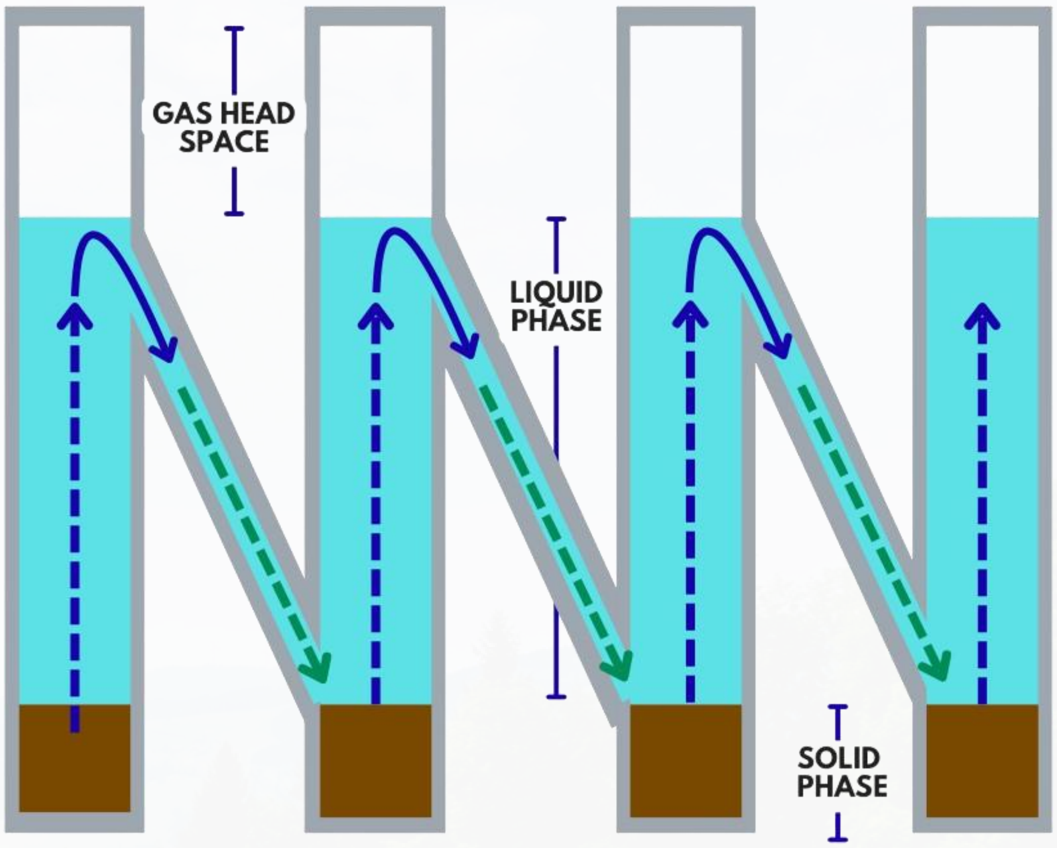

Fig 1 : Modular Anaerobic Baffled Reactor with separated chambers

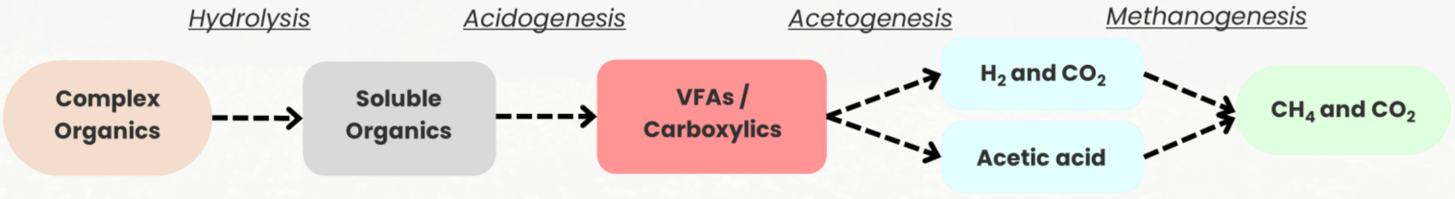

Fig 2: Anaerobic Digestion Stages

mABR: The Engine of a Circular Biorefinery

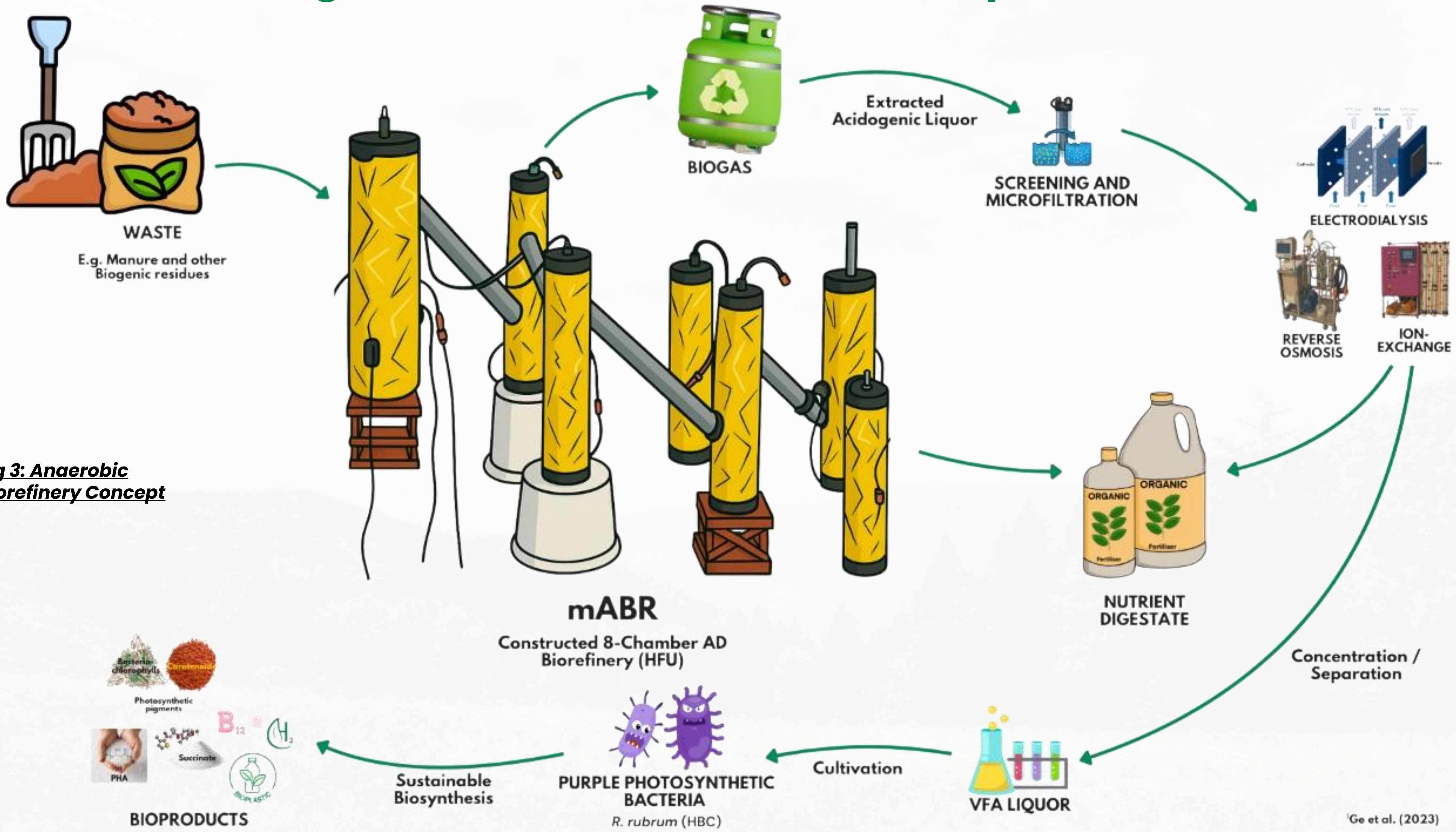

Fig 3: Anaerobic Biorefinery Concept

Our Design: 8-Chamber ABR ≈ *17 L*

- **PVC/PP Tube Frame**
  Chamber No. 1, 7, 8: Ø 110 mm, H 420 mm ***≈ 3.25 L***
  Chamber No. 2-6: Ø 75 mm, H 440 mm ***≈ 1.4 L***

- **Heating**
  Electric 14 W and 20 W heating pads (each chamber)

- **Sensing:**
  DS18B20 temperature sensors and Webcam connected to Raspberry Pi microcontroller

- **Sampling:**
  Liquid/Solids: Metal Valves and internal tubes.
  Gas: Biogas collection bags.

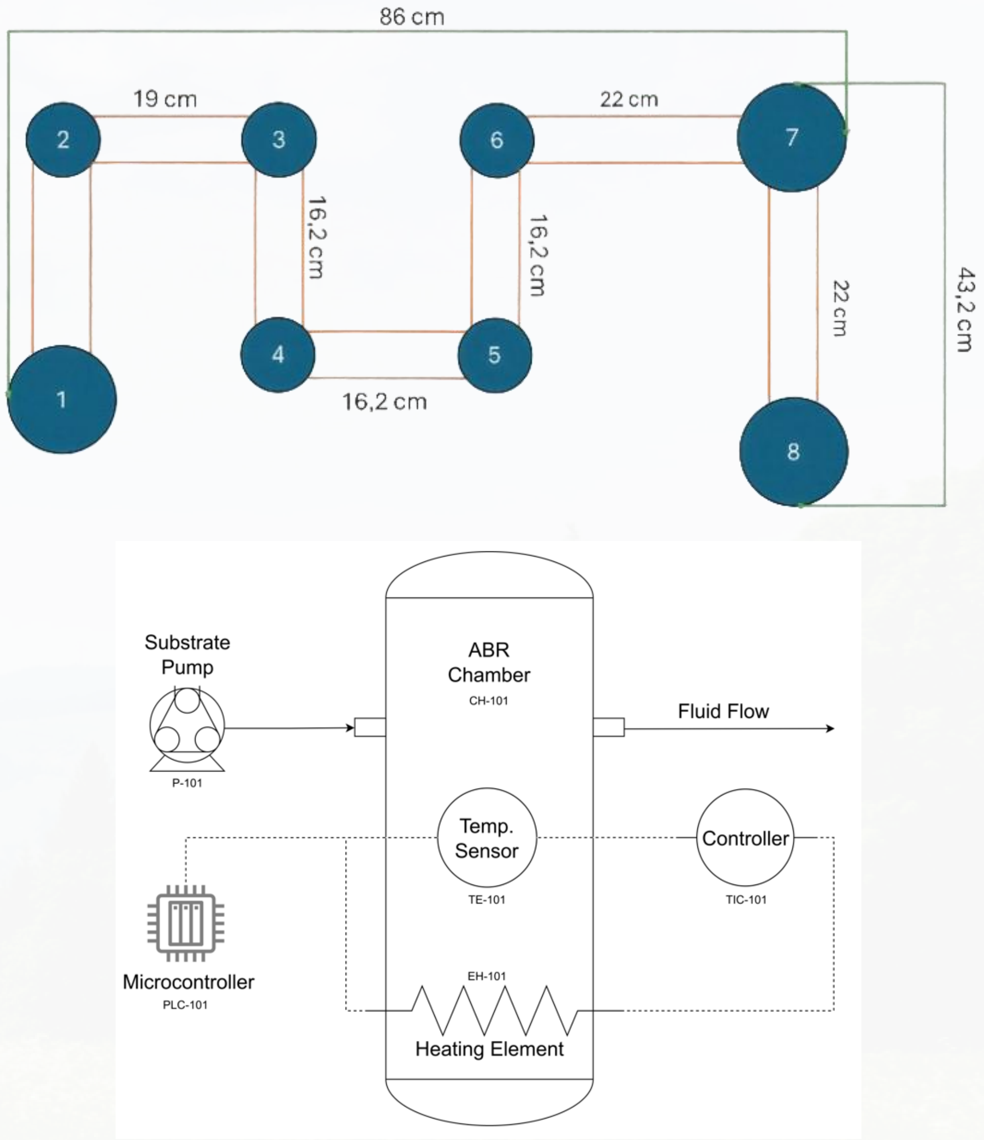

Fig 4: (a) Plan view of ABR layout, (b) Simplified P&ID Diagram

Unique Features of our ABR

- **Low-cost Construction (PVC/PP):**
  Standard fittings, durable; markedly lower capex (≈ *800€*) than glass/steel.

- **Modular 8-chamber series (17 L):**
  Isolated stages for sampling/control; less short-circuiting.

- **Zoned thermal control:**
  Per-chamber heating pads enable setpoint gradients and energy efficiency (~0.4 kWh/L/day)

- **Online temperature:**
  DS18B20 sensors for continuous profiles and tighter process control.

- **Intermediate scale:**
  17 L bridges bench- to pilot-scale, improving hydrodynamics, sampling and data relevance.

Fig 5: Assembled 17 L 8-Chamber ABR

Mesophilic–thermophilic phase anaerobic co-digestion Trial

- Stable, VFA-rich intermediates, while elevating methanogenesis (≈ 45.0 °C) accelerates kinetics without instability of full thermophilic digestion
- 46 °C → 44 °C: Lower free NH_3 toxicity; methanogen niches; residual VFA polishing

Set points:

- Flow: 6.94 mL/ min ≈ HRT 1.7 days
- Temperature:
  - Chamber 1 (preheat 42 °C)
  - Chamber 2-6: 37.0 °C
  - Chamber 7: 46.0 °C
  - Chamber 8: 44.0 °C

Initial Findings:

- Settles around targets; but, additional heating pads caused fluctuations in later Chambers

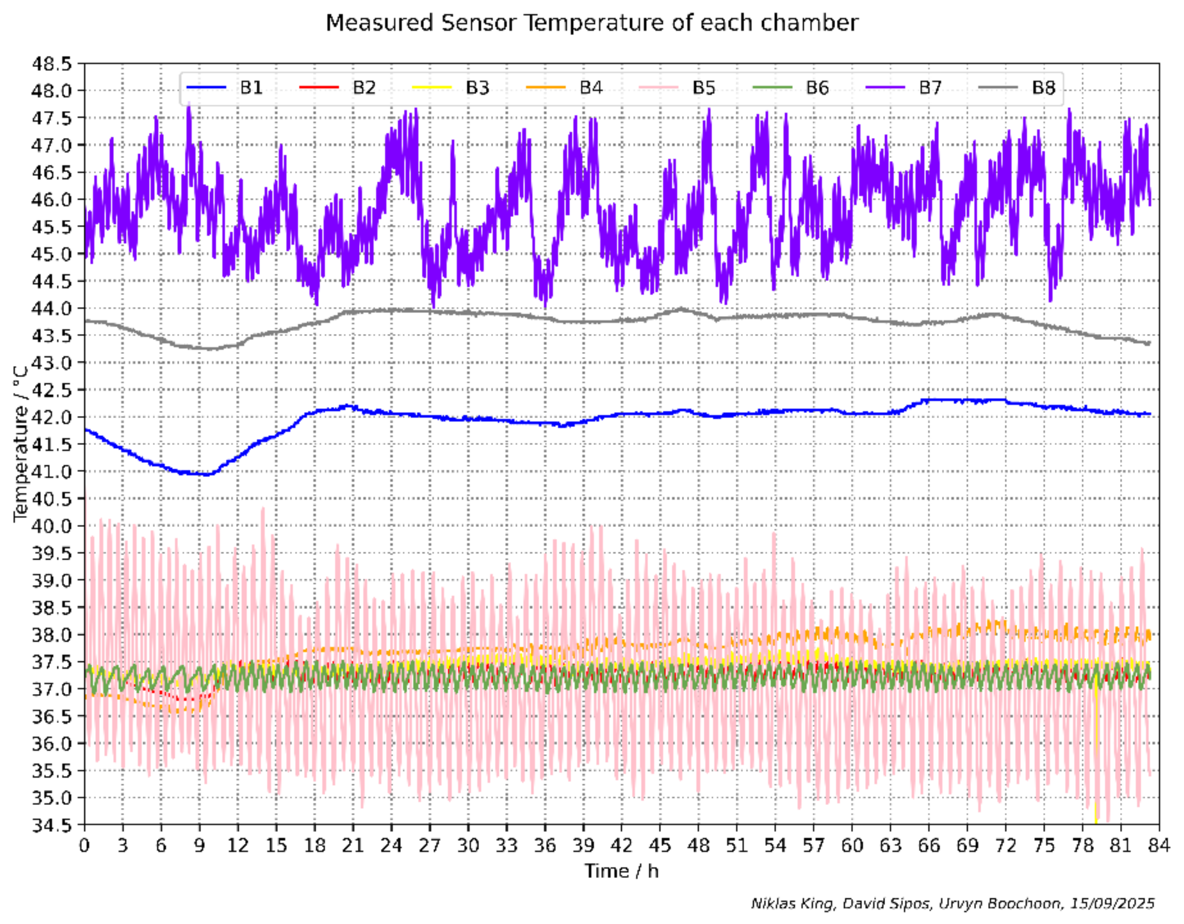

Fig 6: Results of preheated operation using water as substrate; B1 - B8 (Chamber 1 – 8)

Temperature results

- **Attained Temperature averages**
  Chamber 1 (preheat)
  Chamber 2-6 ≈ 37.35 °C
  Chamber 7 ≈ 45.77 °C
  Chamber 8 ≈ 43.73 °C

- **Temperature zones**
  Mean confirms temperature gradient between the mesophilic (Chamber 2-6) and (low) thermophilic chambers (Chamber 7-8)

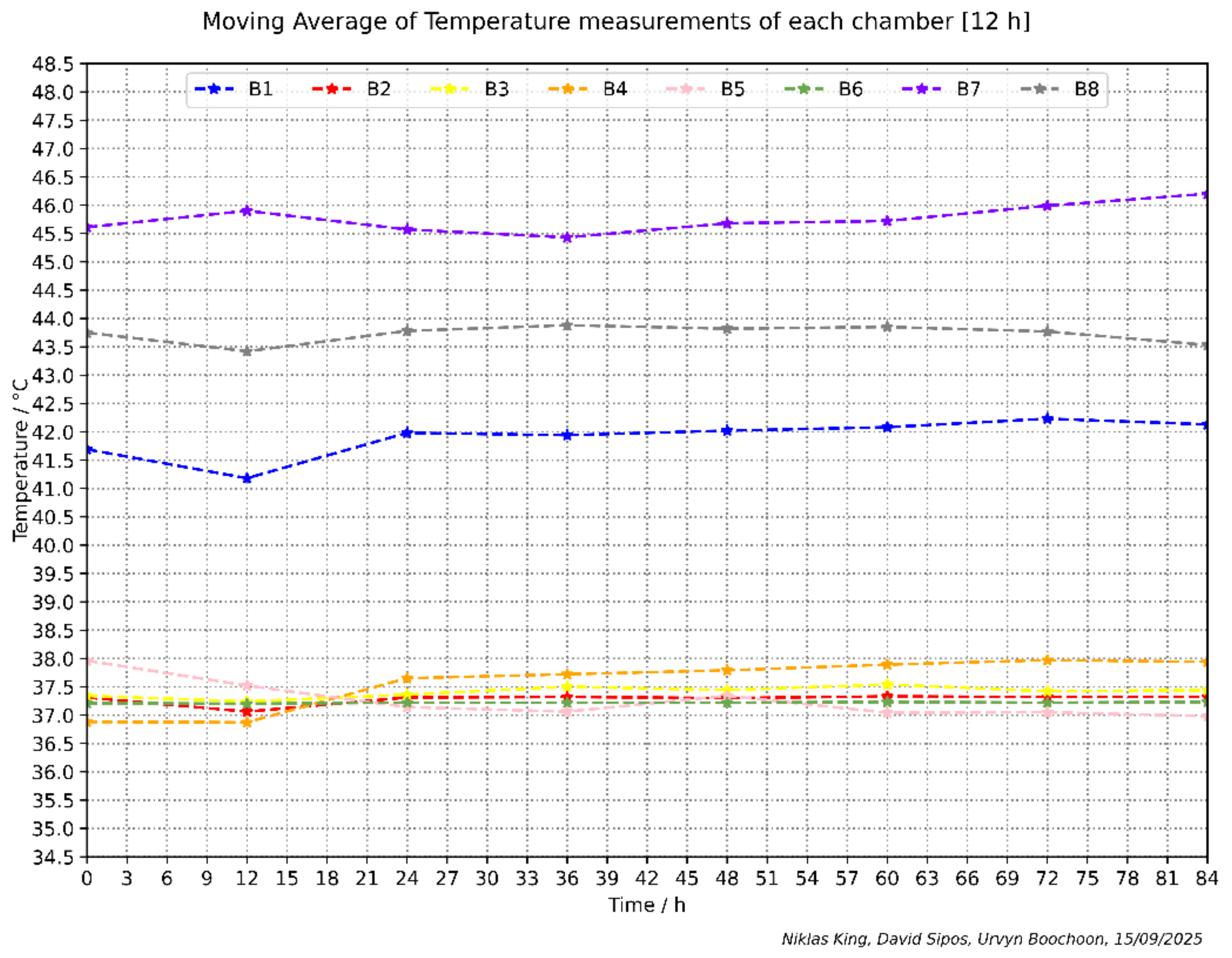

Fig 7: Moving average results every 12 hours of preheated operation using water as substrate; B1 - B8 (Chamber 1 – 8)

Temperature Control – Problems & Solutions

⚠️ Problems

- Large fluctuations (±1–2 °C)
- Uneven heating from concentrated pads
- Insufficient heat (preheating)
- Ambient losses due to insulation

✅ Solutions

- Add more, lower-power pads for smoother heating
- Improve insulation (bubble foil / wrap)
- Optimise pad placement for even coverage
- Use Pi-relay control with tighter switching thresholds
- Position sensors away from direct pad contact

Fig 8: Heating pad, insulation, sample points and sensors

Next Stage – Anaerobic Digestion Experiments

- **Baseline:**
  Starch/manure feed, 37 °C all chambers
- **Zoning trials:**
  Heat zones (44-46 °C in Ch. 7–8, later 1–2 & 7–8)
- **Monitoring:**
  COD/VFAs, CH_4 yield, 16S microbiology, energy balance
- **Outcomes:**
  Rate effect of warm zones, energy trade-off, operating rules

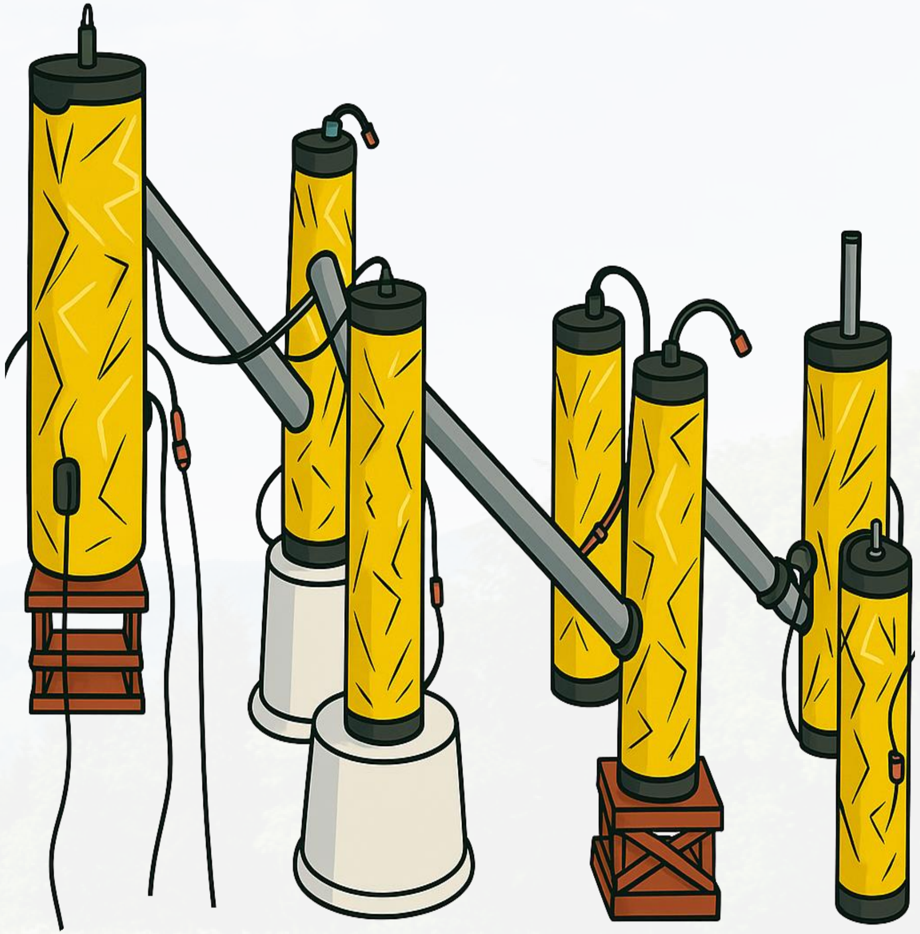

Fig 9: mABR concept

ACKNOWLEDGEMENTS

PROJECT

MoDe ProBio

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