Anaerobic Digestion Twinning Workshop

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Centre for Renewable Energy Systems Technology

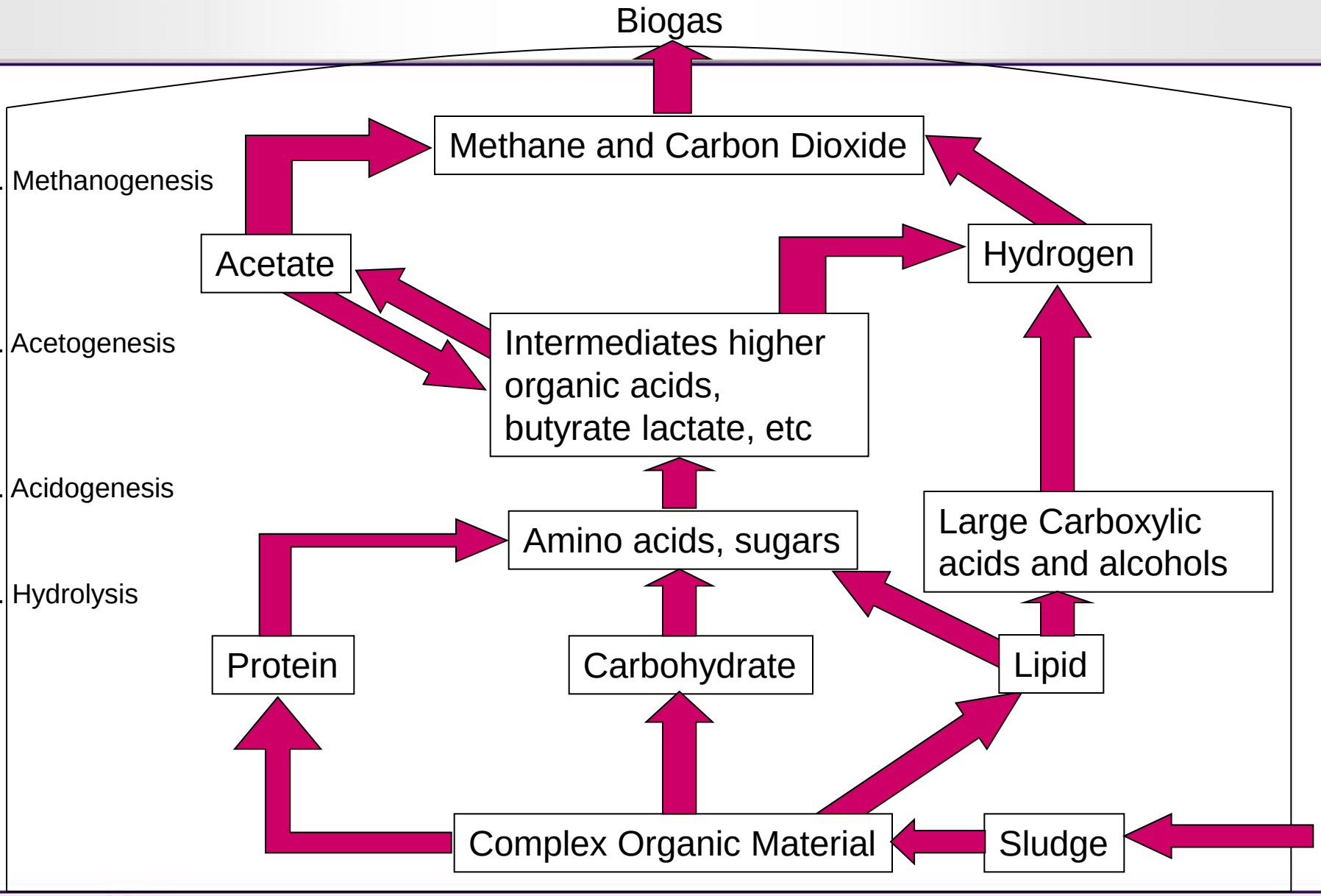
Introduction

- Anaerobic Digestion
- AD Applications
- Hybrid Systems RHESS
- Network and twinning

Anaerobic Digestion

- Anaerobic breakdown of organic matter from complex to simple molecules.
- 4 Stage process with a Symbiotic association between organisms in colonies.
- Requirements
  - Anaerobic reactor vessel
  - Regular organic loading
  - Mesophilic or Thermophilic conditions
    - Mesophilic 37^{o}C, longer HRT, tolerant of temperature variation
    - Thermophilic 55^{o}C, shorter HRT, narrow temperature range, better conversion of solids

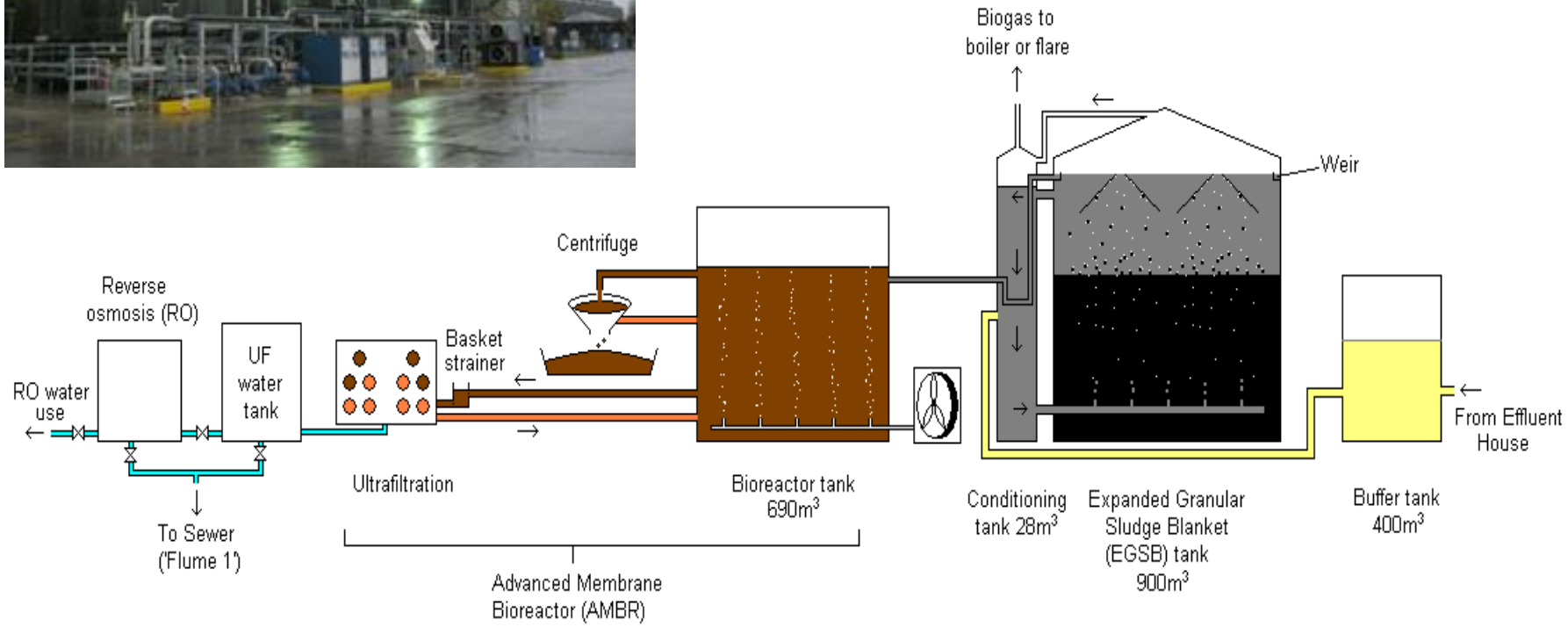
Biochemical steps in Anaerobic Digestion



AD Applications

- Sewage treatment
- Food and drink
- Organic chemicals
- Organic fraction of municipal solid waste
- Kitchen and garden waste

Food processing waste



EU Biogas Projects

- www.urbanbiogas.eu
  - Developing waste-to-biogas in 5 EU cities
  - Zagreb, Abrantes, Graz, Rzeszow, Valmiera
- www.energy4farms.eu
  - Work with pig and dairy farmers to determine feasibility of biogas and providing a network of support
- www.all-gas.eu
  - Use algae residues to produce biogas after oil for biofuels extraction
- www.biomax.eu
  - FP6. To create a network of biogas demonstrations for urban transportations
- www.sebe2013.eu
  - Sustainable and Innovative European Biogas Environment
  - Developing biogas utilization, policies and knowledge management in central Europe

Supported by INTELLIGENT ENERGY EUROPE

All-gas

CO-FINANCED BY THE EUROPEAN COMMISSION

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Rural Hybrid Energy Enterprise Systems 2012-1014

- Focus on UK and India
- Technological innovations in small-medium scale energy generation
  - Biomass gasification , anaerobic digestion, storage
- Appropriately tailored rural enterprise/ business models
- Systems adapted for local need
- Enabling communities:
  - Tackle energy poverty
  - Increase revenue generation
  - New opportunities for rural industries & generate employment
  - Improve socioeconomic status
  - Reduce environmental / health impact
  - promote efficient resource use
- Goal = Sustainable Livelihoods

Work programme (Scientists, engineers, economists, geographers in UK/India)

- Resource and Demand Mapping
- Community Engagement
- Enterprise and Business Models
- Developments in Anaerobic Digestion
- Advances in Biomass Gasification
- Wastes and Residues
- Storage
- Demonstration
- Whole System Analysis

Rural Hybrid Energy Enterprise Systems (RHEES) Project
WP4: Small scale anaerobic digestion

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Dr Richard Blanchard (R.E.Blanchard@lboro.ac.uk)
Dr Tanja Radu (T. Radu@lboro.ac.uk),

Loughborough University

Anaerobic Digestion at Loughborough University

- Develop small-medium scale systems.
- Combine solar thermal heat integration for pre-treatment of feedstock and pasteurisation of digestate.
- Design prefabricated systems.
- Develop remote monitoring of digesters.
- Working with partners and stakeholders throughout.

Results of our research on feedstock availability

- Waste for AD:

- Municipal solid waste
- Energy crops
-Animal slurry
- Food waste
- Biodiesel
- Sewage sludge

- UK: the main crops are wheat, barley, maize, oats
- India: the main crops include: rice, cotton, wheat and maize
- 141 MT surplus of crop residues available for AD
- 869 MT dung recoverable- potential to produce ~36 billion m^3 biogas

- Maize is the most commonly grown crop in the world

Severn Trent AD plant in Nottingham

- Using 37000 t of feedstock (34500 t maize and 2500 t wheat)
- Maize grown purposely for AD plant on 2200 acres of sacrifical polluted land
- 6-9 mm particle size (the whole plant is chopped)
- Ensilaged for 12 months
- 3-stage reactor- retention time of 90 days (40-40-10)
- The primary digester is fed 40 tonnes a day in half hour batches
- 42^0C

- Great real-life example of AD- to be used for initial comparison with the lab-scale digesters

- Severn Trent kindly donated their maize for our research

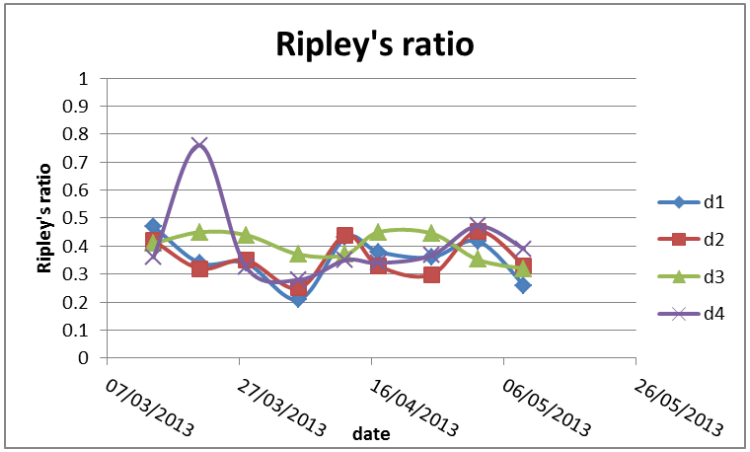
Experimental work

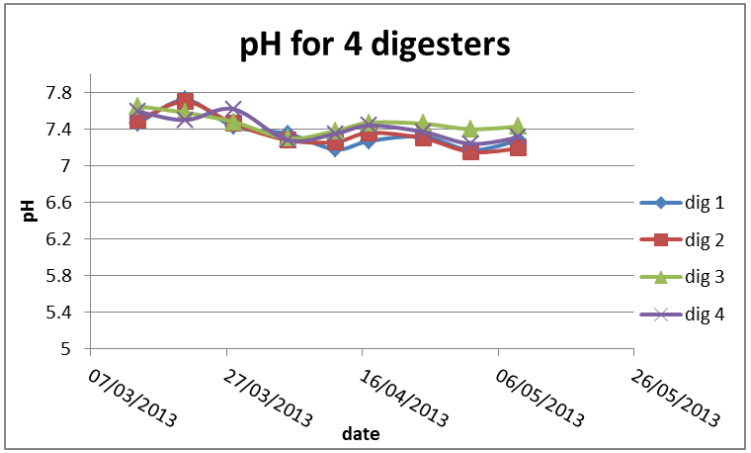
- **Chosen feedstock:**
  - Maize (availability)/food waste
  - Sewage sludge (more homogeneous than animal waste)

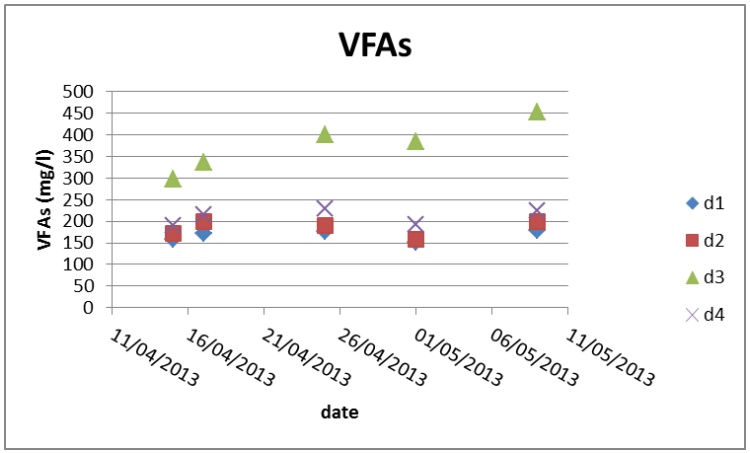
- **Experiments completed:**
  - May-September 2012 (test run, many issues with the equipment, leaks)
  - October 2012-February 2013 maize
  - February 2013-present food waste

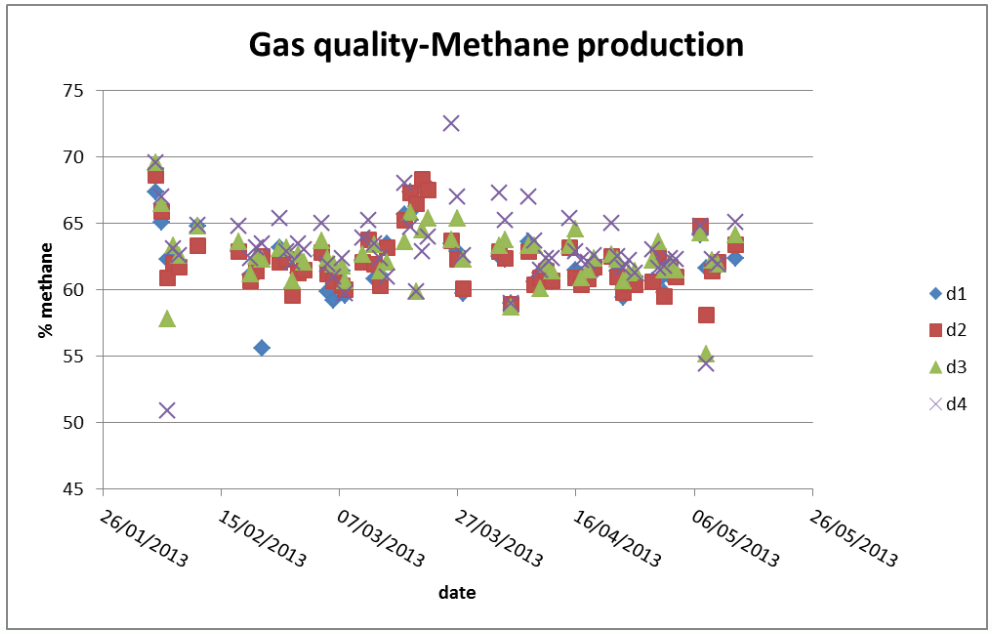
- **4 digesters running for each exp.**
  - Control (sewage sludge)
  - 3 test digesters

Experimental results-monitoring stability and gas quality



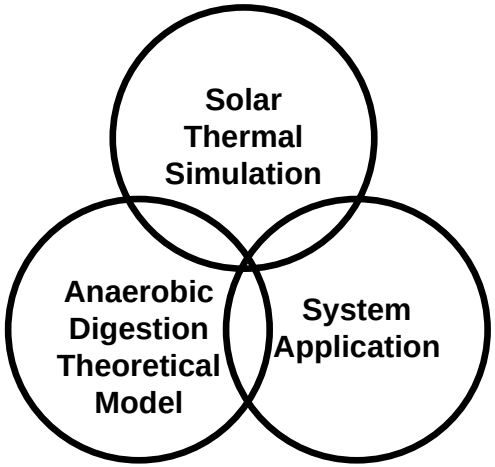


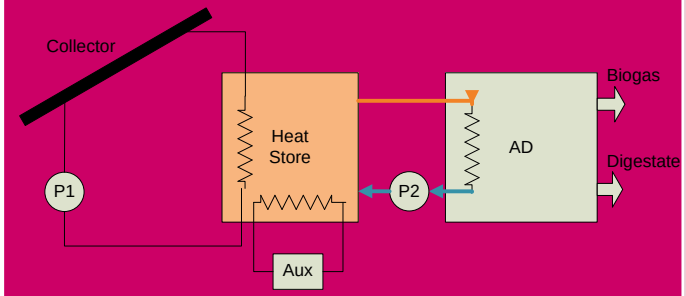




Hybrid Solar-Thermal Biogas Model

- Aim to model a solar-thermal-AD system based in India (Kolkata) operating under thermophilic conditions using OFMSW from hotels.



System Configuration	Technical Considerations
	Pumped solar collector with heat store supported by auxiliary heater connected to AD. Considerations: - Heat storage facility providing stored solar thermal energy; - Heat store manages temperature fluctuations; - Minimal AD temperature management complexity due to single heat source at AD; - Reduced demand on auxiliary heater response; - Additional heat transfer stages with corresponding hardware, losses and physical interfaces; - Additional hardware and physical interfaces; - Secondary heating control circuit;

Key: Collector = Solar Thermal collector; P1 = Solar thermal system pump; Aux = Auxiliary heater; AD = Anaerobic Digester; P2 = secondary system thermal pump

Theoretical Modelling

- Anaerobic Digestion

Reference	Per capita	Downing 1999	Byer (2006)	Matsui	Sridang	Average
kg MSW/guest/day	0.59	3.00	0.49	1.94	0.81	**1.56**
Notes		Higher level of waste per person assumed to be due to all inclusive properties retaining persons and therefore all waste generation localised and b) High proportion of restaurant usage (guest consume all meals onsite)		7 day average. Estimation of waste generation rate through sample measurement and subsequent scaling by buisness scale indicaors such as number of beds for hotels. Scaling by star rating data correspond to research [illegible] 2007.	Done per hotel room NOT per guest = 1.62 Assuming average of 2 persons per room = 0.81kg/guest/day	

Degradability	Waste Category	Waste	Kerr et al (2008)	Alexander et al (2002, pg6)	P Byer (2006, pg469)	Heeb (2009, pg9)	Average
			%	%	%	%	%
Biodegradable	Organic & Compostibles	Food waste	47.4	46.0	64.3	66.9	29.5
		Garden					29.5
	Compostible / Recyclable	Cardboard		11	0.0	0.0	3.9
		Paper					
Non-biodegradable	Recyclables	plastics					
		glass					
		metals					
	Miscellaneaous	Other					
		Inert					

MSW	OFMSW	Ratio	Qty (kg/c/	Ratio of OFMSW	C:N (a) Ratio	pH (a) pH	Dry Matter (b) (%)	DM (c) (kg/g /d)	VS (% of DM)	VS (kg/g /d)	Biogas Potential (d) (m3*kg-1 VS)	Biogas (e) (m3/g/d)	CH4 content (f) (%)	CH4 (m3/g/d)
		(%)												
Organic & Compostibles	Food	29.5%	0.46	39.8	10.6:1	4.99	10%	0.05	80%	0.04	0.55	0.020	62%	0.01
	Garden	29.5%	0.46	39.8	31.7:1	6.52	60%	0.28	90%	0.25	0.35	0.087	62%	0.05
Compostible / Recyclable	Cardboard	3.9%	0.06	5.3	65.8:1	7.61	93%	0.06	95.2%	0.05	0.52	0.028	63%	0.02
	Paper	11.3%	0.18	15.2	101:1	7.97	91%	0.16	95%	0.15	0.52	0.079	63%	0.05

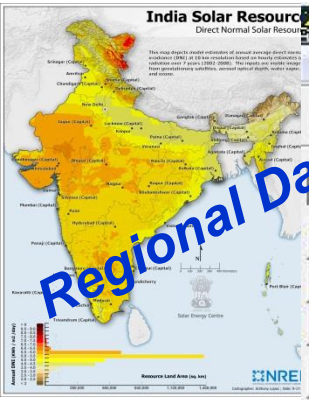
Hotel Waste Quantities

Waste Characteristics

Methane Yield

Theoretical Modelling

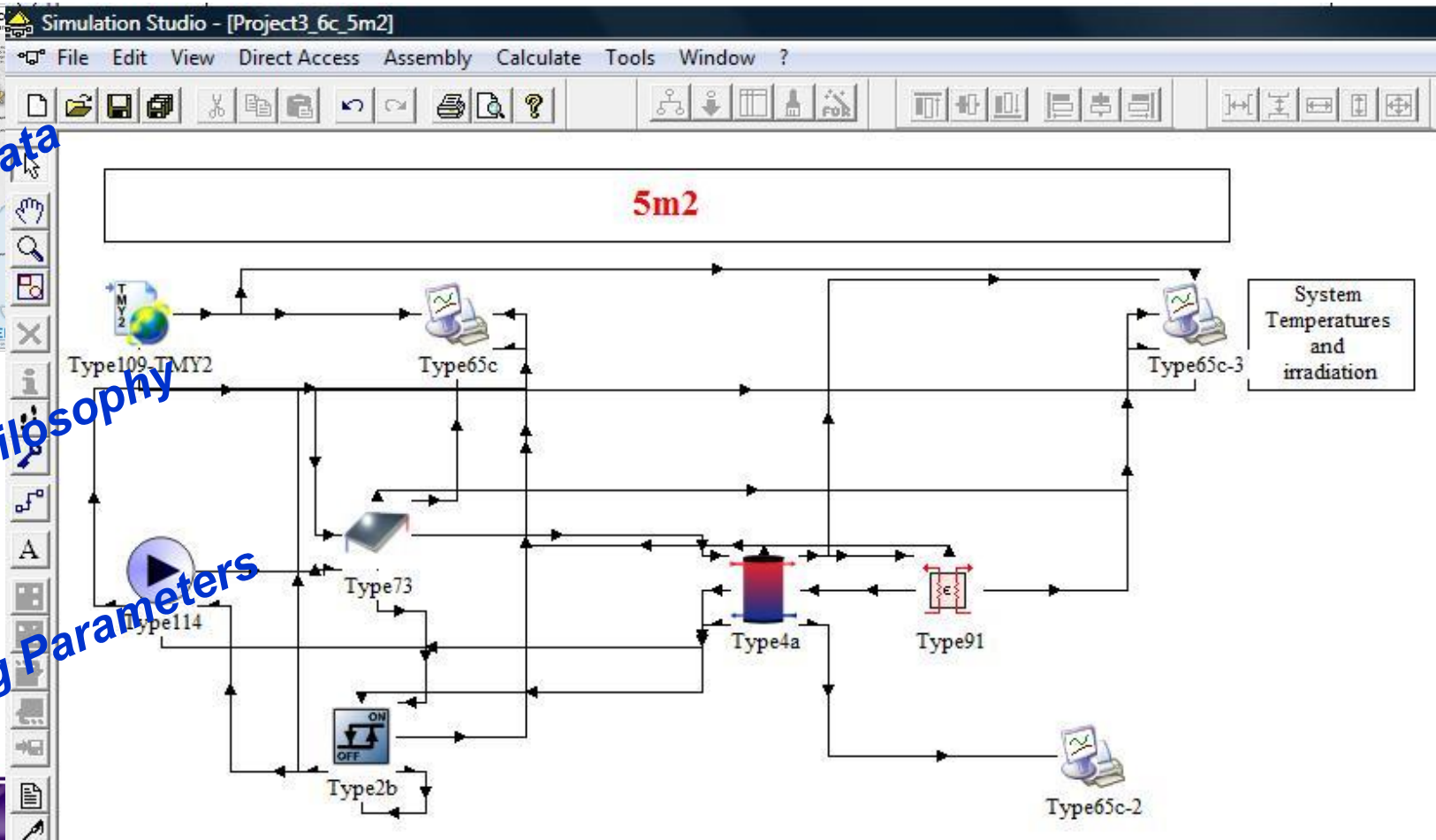
- Solar Thermal



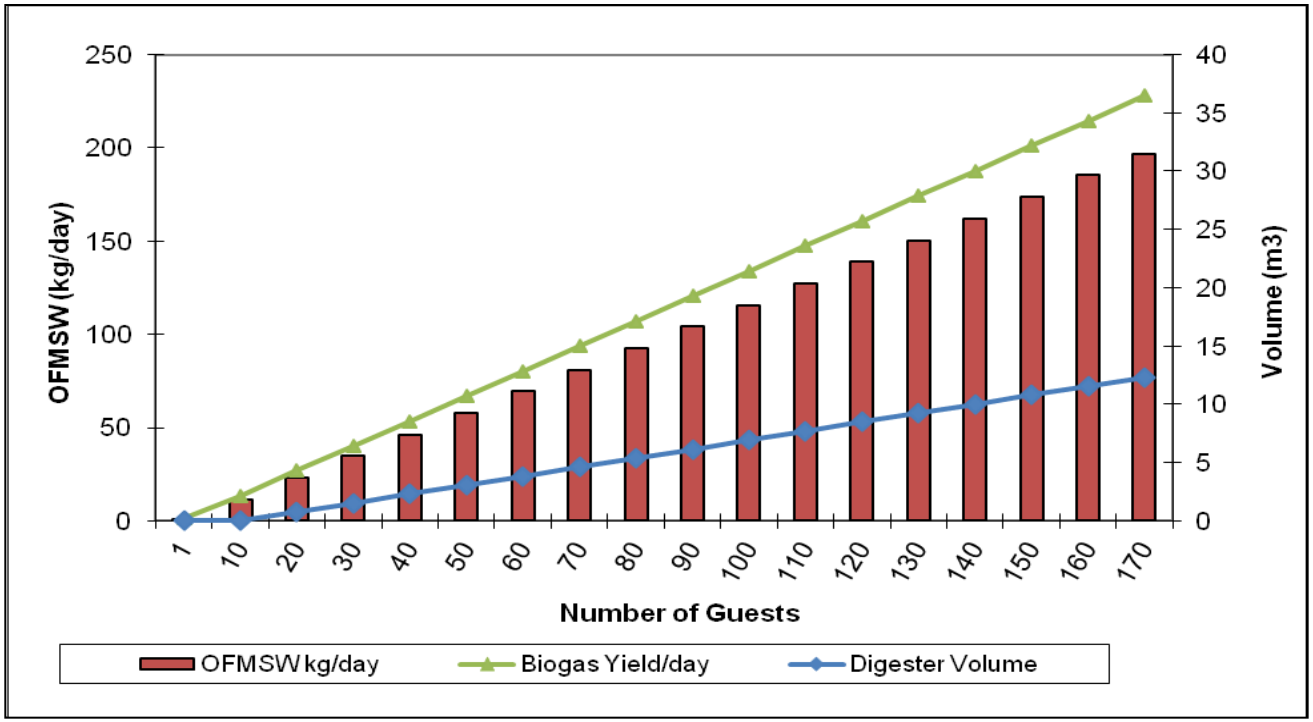
Regional Data

Control Philosophy

Operating Parameters



Results

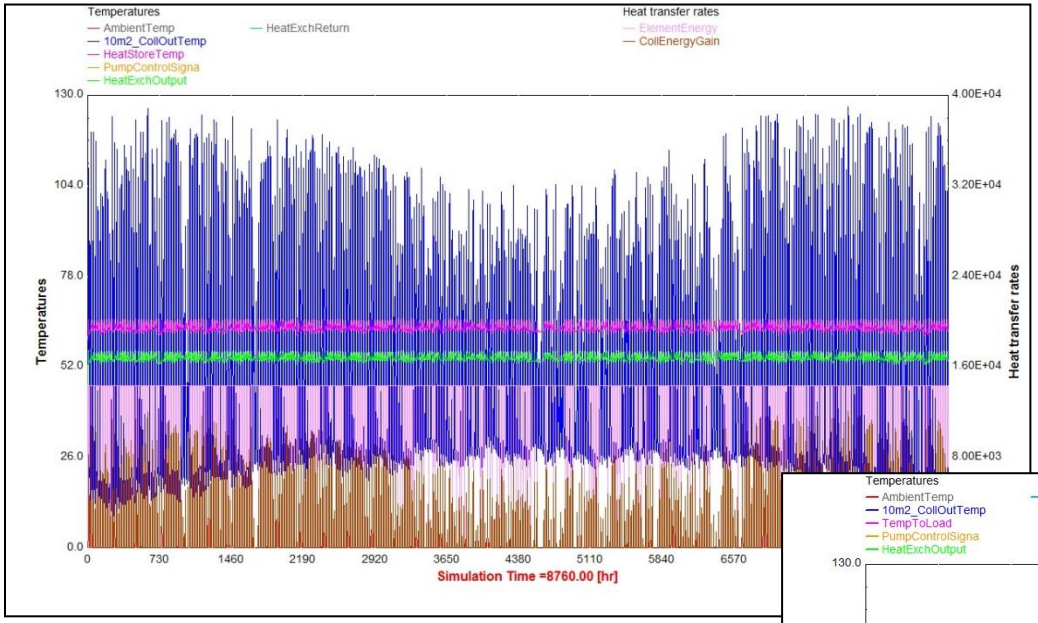


Biogas Yield
0.21m3/g/d
0.44m3/kgVS

C/N Ratio
35:1

$$BY_F = ((OFMSW_F * DM_F) * VS_F) * B_{PF}$$

Results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HeatStoreTemp
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HeatExchOutput
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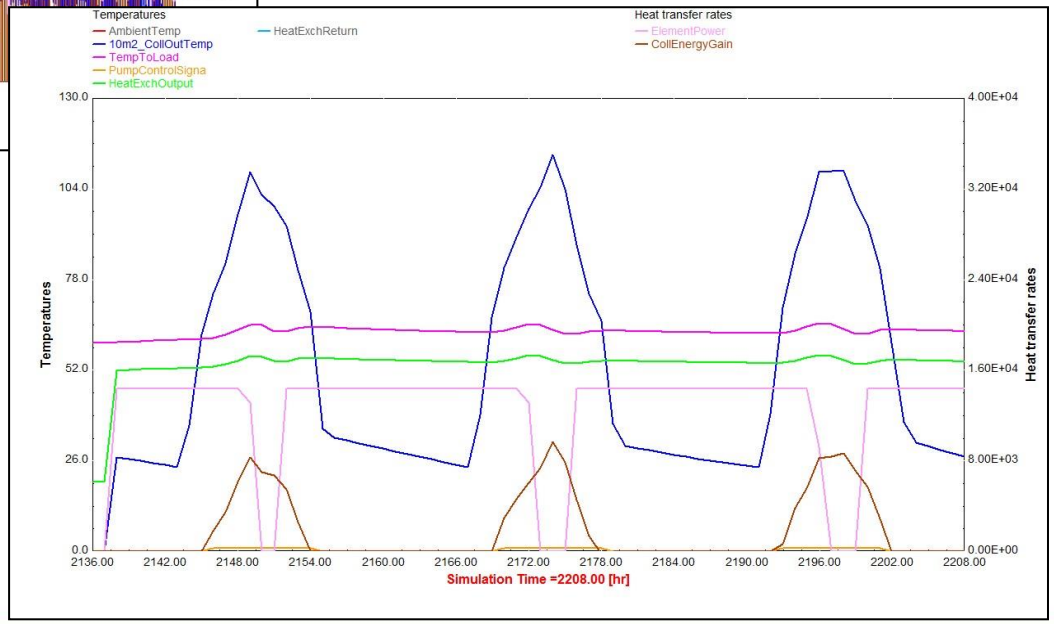
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Simulation Time =2208.00 [hr]

Autonomous Biogas Monitor for Developing Countries Concept

Concept for Design of box

PV panel

GSM MODEM (SIM 300)

Communications and tracking

Rechargeable Battery

Control board and Data storage

Sensors

Research Dissemination

Conferences:

- Tanja Radu, Andrew Wheatley and Richard Blanchard, “Anaerobic digestion at Loughborough University”, at **The Anaerobic Digestion and Biogas Association's (ADBA) third annual trade show and conference**, UK AD & Biogas 2012 held on 3-4 July 2012 in Birmingham, poster presentation
- Tanja Radu, Andrew Wheatley, and Richard Blanchard, “Providing energy for rural Indian communities- Anaerobic Digestion at Loughborough University”, **Loughborough University Research Conference- Research That Matters** on 7th March 2013. poster presentation
- Tanja Radu, Richard Blanchard, Vincent Smedley, Helen Theaker, and Andrew Wheatley, “Anaerobic Digestion of Brewery Effluent- 3 Year Operating Experiences and Key Effects on Performance” **BIT’s 3rd World Congress of Bioenergy (WCBE-2013)** in Nanjing, China 24-27th April 2013, poster presentation
- Tanja Radu, Andrew Wheatley and Richard Blanchard, “Anaerobic co-digestion of maize and sewage sludge: providing energy for rural communities in India” accepted for the **Anaerobic Digestion 2013 Conference** (Santiago de Compostela, Spain, 25-28 June 2013)

Loughborough University

TIDE

Bridging the Urban and Rural Divide

UNIVERSITY OF BIRMINGHAM

Loughborough University

The University of Nottingham

JNU

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
Indian Institute of Technology Guwahati

teri

University of Leicester

IISc

TEZPUR UNIVERSITY

NEERI

Liverpool Hope University EST. 1844

Manchester Metropolitan University

MSE
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MADRAS SCHOOL OF ECONOMICS
post-graduate teaching and research in economics

Network and Twinning

- All aspects of biogas production:
  - Feedstock mapping
  - Feedstock characterization
  - Pilot plants
  - Solar-biogas hybrid
  - Digester optimisation
  - Biogas quality
  - Remote monitoring

- Also interested in thermal bioenergy, energy-water-food nexus, value chains, EIA, LCA and sustainable livelihoods.

Thank you. Any questions?

- Email: r.e.blanchard@lboro.ac.uk
- CREST
  - http://www.lboro.ac.uk/departments/el/research/centres/crest/index.html