VALORGAS

Valorisation of food waste to biogas

Rationale

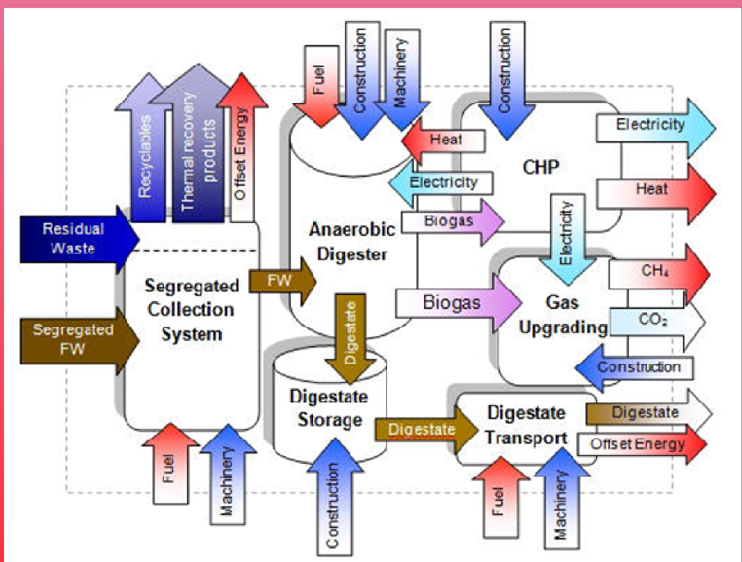
Food waste arising from homes, restaurants and catering facilities, food markets and food processing activities represents a large fraction of the municipal waste stream. Actual proportions vary across the EU, but as an example in the UK food wastes that can be segregated account for around 24% of the total weight of household waste, with an approximately equal tonnage arising from industry and commercial sources.

This material has a very high energy potential but is unsuited to energy generation through conventional combustion processes, as its high moisture content gives it an unfavourable lower heat value. The energy can, however, be efficiently recovered through biologically-mediated routes, provided that the process can be stabilised to deal with the high nitrogen content of these wastes. In terms of overall energy balance and carbon footprint the anaerobic digestion of food waste makes a very positive contribution to energy generation both directly, and indirectly through energy savings.

Benefits and likely impacts of the research

Recovery of food waste through anaerobic digestion

- provides the opportunity for highly efficient recovery of a second-generation gaseous fuel product with multiple applications for the end user.
- captures nutrients present in the waste and allows these to be returned to agricultural use, with associated economic, energy and carbon gains from offsetting requirements for artificial fertiliser.
- reduces moisture content in the residual waste stream, thus improving the calorific value and the efficiency of thermal energy recovery in Energy-from-Waste (EfW) facilities, creating new opportunities for refused-derived fuel (RDF) production and increasing the range of thermal technologies that can be applied.
- enhances opportunities for recovery of commodity grade recyclable materials and of the embodied energy in them by reducing the moisture and contamination levels of the remaining waste and allowing the use of advanced automated sorting technologies in materials reclamation facilities.



Energy inputs and outputs in the anaerobic digestion of source segregated food waste

Key concepts

To valorise the energy from food waste by anaerobic digestion (AD), with full evaluation of the overall life cycle energy balances associated with this process. AD is not a new technology, but its application for energy recovery in the field of municipal waste treatment is only just becoming established in Europe, and only for mixed wastes. The use of source segregated food wastes as substrate is not yet widespread, possibly because of technical challenges linked with collection, handling, pretreatment and digestion of this material. The research includes a number of closely related components with a common underlying goal: to evaluate and where possible improve the energy production process from the perspective of the overall net energy gain achieved within defined system boundaries that include collection, sorting, processing, and beneficial use of recovered material.

Scientific and technical objectives

- To evaluate the efficiency and yield of source segregated food waste collection schemes from domestic properties, restaurant and catering facilities, food markets and food manufacture.
- To determine the energy and carbon footprint of the biowaste-to-energy process including collection, transport, treatment and final product use, considering both direct and indirect inputs. This provides the basis for full life cycle assessment of the environmental impacts and benefits of this technology.
- To optimise pre-treatment of the source segregated waste stream for biogas production and biosecurity of the residual product by development and trialling of novel cell disruption and autoclaving techniques.
- To balance the digestion process using interventions to improve the carbon to nitrogen ratio for optimal volumetric biogas productivity and added value of the digestate product.
- To gain a deeper understanding of the interaction of fundamental chemical and microbiological factors affecting the potential for energy gain from the substrate, and to convert this into practical operational protocols for stable and effective digestion of high-nitrogen wastes at loading rates that allow maximum volumetric biogas production.
- To achieve a mass and energy balance around two full-scale digesters treating food waste, one at mesophilic and one at thermophilic temperature, which will act as a benchmark for industry in the drive for widespread implementation of the process at commercial scale.
- To further develop low-cost small-scale biogas upgrading technologies and storage systems for application in transportation and local low-pressure distribution systems.
- To estimate the potential for small-scale biogas upgrading in local transportation in the EU and India.
- To evaluate the appropriateness of scale of digestion and end-use energy conversion technologies, with particular reference to matching public and private community needs.
- To evaluate the potential for food waste digestion as a second generation biofuel source across the EU in terms of energy yield, environmental benefit and end user requirements.

Work carried out to date

The Ludlow food waste collection scheme

WP2. Collection and sorting/ segregation systems

- Work done on determining food waste yields in different types of collection system
- Data collected for developing energy footprints models food waste collection and transport
- A methodology developed and trialled to allow comparative assessment of food waste recovery and processing schemes

WP3. **Pre-treatment and technical scale trials**

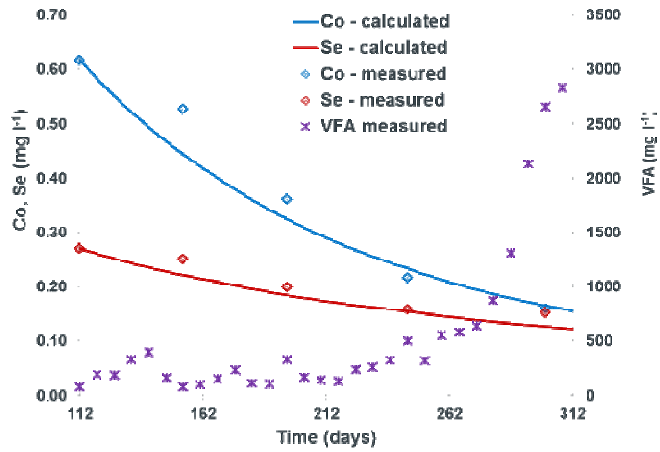
- Initial laboratory-scale work has been carried out investigating the effect of novel cell disruption and autoclaving pre-treatments to improve biosecurity and biogas production
- Significant progress has been made in understanding key factors affecting gas stripping of ammonia in mesophilic systems, and nutrient removal by chemical precipitation in thermophilic systems

Andigestion pilot-scale AD facility

Work carried out to date

WP4. **Fuel conversion technology optimisation**

- Laboratory digestion studies designed to understand the interactions that take place in mesophilic digestion where ammonia has a detrimental effect on process performance have been carried out.
- Preliminary mass and energy balances have been successfully completed for the two full-scale digesters and plant operators have compiled detailed operational and performance records over the reporting period



Optimising trace element additions to digesters

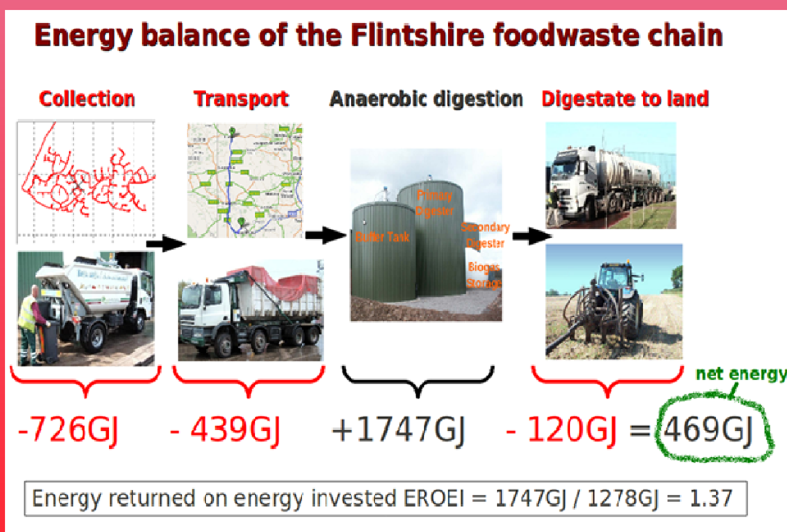

Construction of Metener's gas upgrading equipment

WP5. **Energy utilisation and end user requirements**

- Next generation small scale biogas upgrading units have been fabricated and tested by Metener. IIT have established baseline data on low cost upgrading and bottling systems used in India.
- Case studies on small-scale biogas utilisation for transport have been completed for 5 European sites and one site in India
- A draft report on 'Evaluation of potential technologies and operational scales reflecting market needs for low-cost gas upgrading systems' has been prepared

WP6. **Energy, environmental and life cycle evaluation**

- Data have been gathered to allow preliminary assessment of the appropriateness of scale of digestion and biomethane conversion technologies
- Development and application of in-house models and external assessment tools, including the UK Environmental Agency's WRATE software, have been used for energy and carbon footprinting



Major achievements at the end of the first reporting period

- Production of hythane, a mixture of methane and hydrogen with excellent combustion characteristics, has shown promising results at pilot scale. Hydrogen is produced in the first stage of digestion, and then mixed with methane produced in the second stage. Initial test runs gave high yields of 74 litres of H_2 per kilogram dry weight of organic material added.
- Adding essential trace elements to the digester has solved the problem of unstable operation and allowed the amount of food waste added each day to be increased by 2.5 times, with a corresponding increase in methane production.
- Methods have been developed to extract and concentrate the methane-producing microorganisms in the digester so that they can be identified and changes in the population can be analysed using advanced gene probe methods.
- Recovery of ammonia and phosphate, which are valuable plant nutrients, has been achieved by precipitating them as struvite from food waste digesters operating at thermophilic temperatures.
- Initial trials with pilot-scale equipment designed to operate at low pressures have succeeded in upgrading the biogas to meet one of the key European standards for natural gas quality

Partners on a site visit to the Valorsul anaerobic digestion plant in Lisbon

Expected results and impacts

- The current research will contribute to meeting EU targets for both second generation biofuel and renewable heat and power
- It is expected to confirm that food waste digestion in Europe could replace 12.86 Mtoe of vehicle fuel
- Digestate recycling will help to close the loop between urban and agricultural nutrient cycles
- Separation of food waste will help to reclaim other commodity-grade recyclables from waste
- Recycling of food waste will reduce greenhouse gas emissions through fossil fuel substitution, fertiliser replacement and landfill diversion

Project partners

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Aerothermal Group Ltd, UK

Eco-Solids International Limited, UK

Greenfinch Ltd, UK

Metener Oy, Finland

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Project website: **www.valorgas.soton.ac.uk**