Programme Area: Bioenergy

Project: Energy From Waste

Title: Executive Summary

Abstract:

The objective of the Distributed Energy (DE) Programme is to increase the up-take of DE through the development of integrated systems in order to reduce through-life costs, improve ease of installation and increase efficiency in the combined generation of heat and electricity. Within this programme framework the Energy from Waste project seeks to quantify the opportunity for the use of UK Waste arisings as a fuel to be used in the combined generation of heat and electricity.

The UK generates around 330 million tonnes of waste per annum, of which around 90 million tonnes is energy bearing. Government legislation seeks to incentivise the diversion of waste from landfill through the existing landfill tax and landfill diversion targets. In parallel the UK is committed to reducing its GHG emissions by 80% by 2050 and supplying 15% of its energy demands from renewable sources by 2020. These drivers lead to a requirement for technology solutions which enable wastes to be used as a cost effective, low carbon and indigenous energy resource for the UK. The Energy from Waste FRP was commissioned to address these requirements and identify potential opportunities for a large scale demonstration project in this area.

Context:

The Energy from Waste project was instrumental in identifying the potential near-term value of demonstrating integrated advanced thermal (gasification) systems for energy from waste at the community scale. Coupled with our analysis of the wider energy system, which identified gasification of wastes and biomass as a scenario-resilient technology, the ETI decided to commission the Waste Gasification Demonstration project. Phase 1 of the Waste Gasification project commissioned three companies to produce FEED Studies and business plans for a waste gasification with gas clean up to power plant. The ETI is taking forward one of these designs to the demonstration stage - investing in a 1.5MWe plant near Wednesbury. More information on the project is available on the ETI website. The ETI is publishing the outputs from the Energy from Waste projects as background to the Waste Gasification project. However, these reports were written in 2011 and shouldn't be interpreted as the latest view of the energy from waste sector. Readers are encouraged to review the more recent insight papers published by the ETI, available here: http://www.eti.co.uk/insights

ETI Executive Summary

Programme: Distributed Energy

Project Name: Energy from Waste

Deliverable: DE2001

Introduction

The objective of the Distributed Energy (DE) Programme is to increase the up-take of DE through the development of integrated systems in order to reduce through-life costs, improve ease of installation and increase efficiency in the combined generation of heat and electricity.

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The objective of the project is to provide the following outputs:

- Detailed analysis, characterisation and mapping of UK waste arisings to be used as the basis for the subsequent technology assessment and economic analysis within this Project.
- Assessment of the available Energy from Waste technologies for the whole energy value chain from waste input to power and/or heat output and identification of gaps / opportunities in this value chain.
- Identification of combinations of technologies for development and related technology improvement opportunities to fill gaps in the value chain.
- Clear UK benefits case for development and deployment of the identified technologies. The benefits will be judged against criteria agreed with the consortium at the beginning of the project under the headings of Affordability / GHG Reduction / Energy Security / Robustness

The project is split into 4 work packages, represented schematically below.

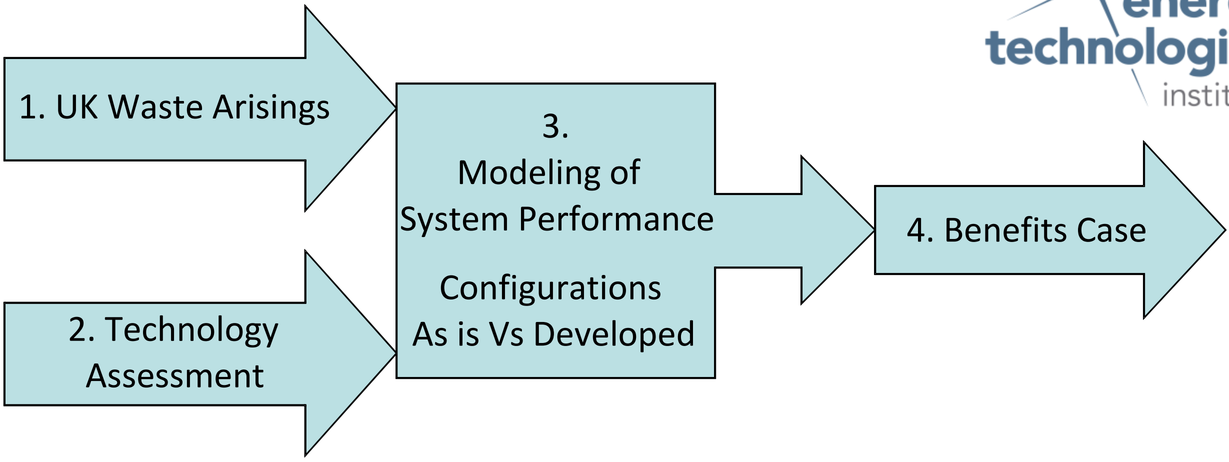

Figure 1: Energy from Waste Project Structure

The UK government's approach to waste management is driven by the adoption of the waste hierarchy in the EC Waste Framework Directive:

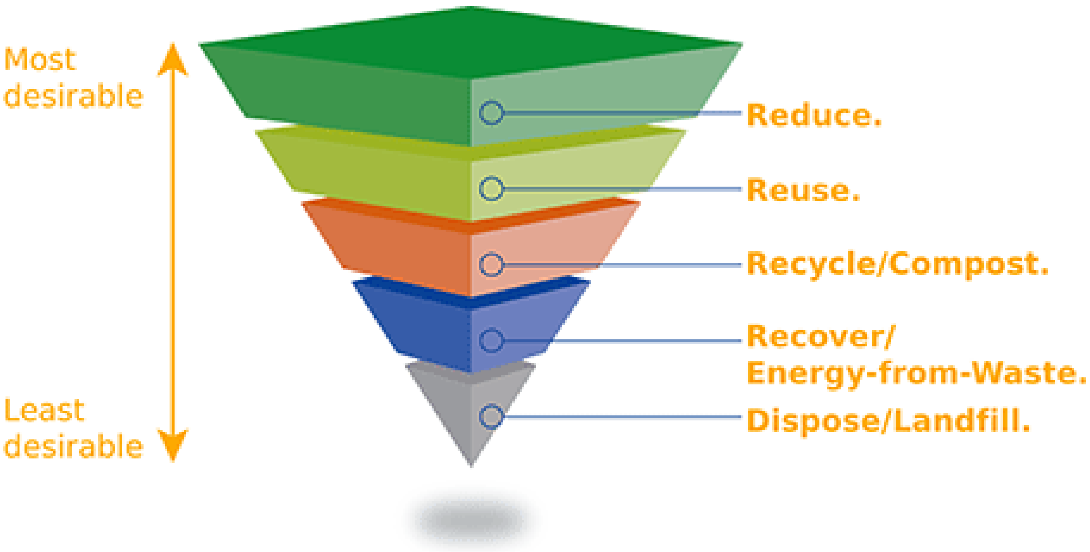

Figure 2: The Waste Hierarchy

Adoption of the waste hierarchy approach is leading to a reduction in the generation of wastes and an increase in the extraction of materials with an alternative commercial value. This means that the amount and nature of waste generated over time is changing, consequently any generic energy from waste conversion system much has the ability to cope with the future changes.

Of the energy remaining in the waste stream, the proportion of this that can be converted to energy is dependent on a number of factors including the amount of residual waste available for energy conversion and the efficiency which the embodied energy is converted to useful heat, electricity and other energy vectors.

Understanding the potential benefits of converting the available waste produced in the UK into energy is needed to guide future investment in technology development in this area. This report is the final report for the ETI Energy from Waste FRP and as such it seeks to quantify the benefits to the UK energy system associated with Energy from Waste.

Basis of Designs

As highlighted in figure 1 the project was split into 4 work packages, the objectives of each work package were as follows:

WP1 – Waste Assessment

The objective of WP1 is to collate all relevant waste arisings data for the UK required to enable an economic assessment of the potential for exploitation of these wastes to be made.

WP2 – Technology Assessment

This Work Package will consider the broad range of technologies suitable for processing, conversion and power generation from waste. Experimentally derived data from testing at Cranfield (Thermal processes) and EDF (Anaerobic Digestion) is used to supplement already published data.

WP3 – Technology Performance Monitoring and Assessment

This Work Package asses the identified technology improvement opportunities for Energy from Waste technologies through a systematic approach of empirical modelling of the waste and technology data collected from Work Packages 1 and 2 This is achieved by using modelling systems that have been identified through a staged approach of component then system optimisation.

WP4 – UK Benefits Case

This Work Package will integrate the findings of Work Packages 1, 2 and 3 in order to assess the benefits and costs associated with the individual development of the identified technology improvement opportunities. It will also determine the benefits to the UK with the commercial deployment of the identified technology improvement opportunities and compare these against technological, environmental and economic factors of the current energy from waste opportunity.

Results and Key findings

The key findings for each work package can be summarised as follows

Work Package 1: Waste Assessment

- The calculated energy potential from C&I, MSW and C&D wastes could contribute 1 to 5% of UK energy overall
- Whilst there is significant variation in wastes, the main variable that determines energy content consistency is moisture content [which is also seasonal]
- Plastic and textiles contribute significantly to the material CV – driven by policy & economics
- Future recycling trends are important
- Wet waste volumes can deliver small amounts of energy, whilst dry has higher volumes

Work Package 2: Technology Assessment

- Wastes that can be sorted should be sorted, where economic.
- Segregated wastes should go to recycling in closed loops.
    - There are a very wide range of established processes.
- Wet (> 80% water) organic wastes should ideally go to anaerobic digestion.
    - The technology can be developed to improve yields and costs.
- Incineration is used at large scale where there is electricity and heat demand and no demand for fuels.
- Advanced Thermal Conversion (e.g. gasification or Pyrolysis) could be used on at small/medium scale (or where there is a demand for chemicals and fuels).

Work Package 3: Technology Performance Monitoring and Assessment

A system level model of a fully integrated EfW plant was created to support the analysis of the opportunities available to the UK from energy from waste. This is represented schematically below:

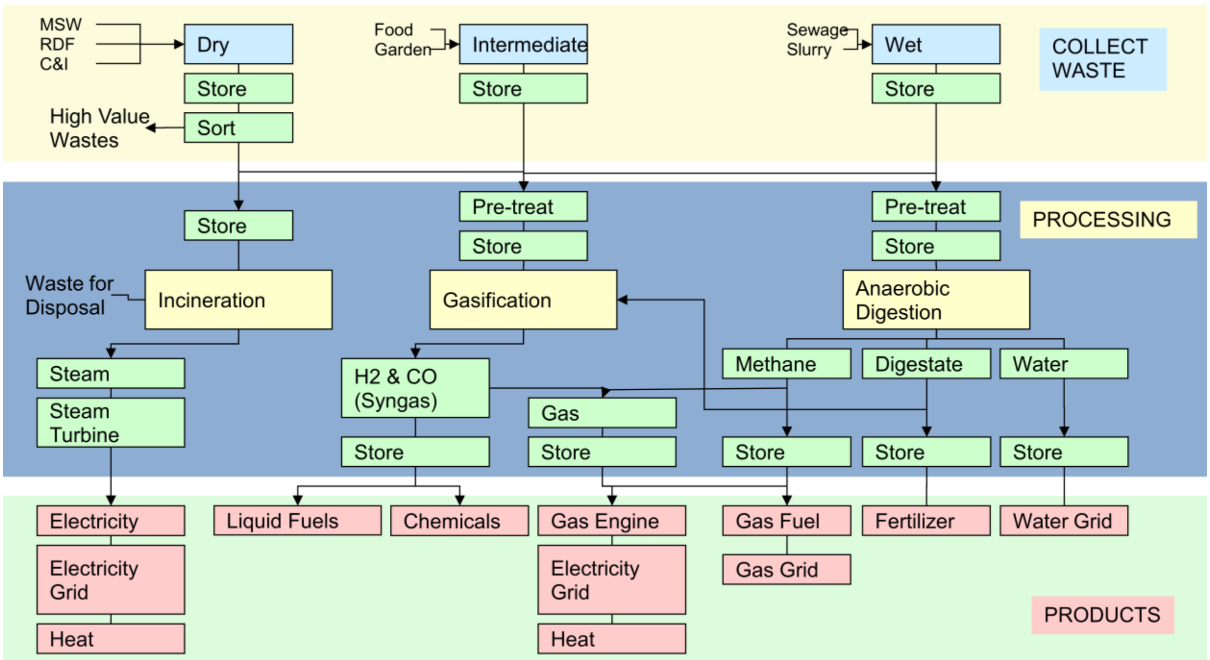

Figure 3: Energy from Waste System Level Model

For the purposes of modelling the UK was broken down by community scales as follows:

- City
  - 34% 0f UK population live in cities
  - 500k people taken as scenario scale
    - UK has 5 cities over 500k people and 26 between 200k and 500k
  - Mixed economy of residential, industrial and service
  - No agricultural
- Town
  - 43% of UK population live in towns
  - 50k people taken as scenario scale
  - Residential and commercial (with surrounding agricultural).
- Village
  - 21% of UK population live in villages
  - 5k people taken as scenario scale
  - Residential, little commercial
- Rural Agricultural
  - 2% of UK population live in a rural setting
  - 500 people taken as scenario scale
  - Mainly farming and light industrial (arable or livestock)

The waste availability within each community scale was then analysed and the potential energy available calculated.

Scenario	Population	Dry Waste (kt/yr)	Dry Waste Energy Content (MJ/yr)	Wet Waste (kt/yr)	Wet Waste Energy Content (MJ/yr)	Comment
City	500k	490 (306-673)	$4.8x10^9$ ($4x10^8$-$5.6x10^9$)	408 (255-560)	$9.2x10^8$ ($7.7x10^8$-$1.1x10^9$)	Urban with little agriculture
Town	50k	49 (31-67)	$4.8x10^8$ ($4x10^8$-$5.6x10^8$)	41 (25-56)	$1.0x10^8$ ($8.7x10^7$-$1.2x10^8$)	Residential and commercial
Village	5k	4.9 (3.1-6.7)	$4.8x10^7$ ($4x10^7$-$5.6x10^7$)	4.1 (2.5-5.6)	$1.1x10^7$ ($9.7x10^6$-$1.3x10^7$)	Residential with little commercial
Rural Community	500	0.49 (0.31-0.67)	$5.1x10^6$ ($4.3x10^6$-$5.6x10^6$)	20	$6x10^7$	Mainly farming with residential

Table 1: Energy from Waste Available by UK Community

As part of the analysis a number of key technology drivers were identified which would add value to any future energy from waste technology development:

- Turn-up and Turn-down without damage
- Turned-on and off without damage
- Reduce the capital per unit
- Increase the yield of high value products
- Handle variable feedstocks (moisture content and material form in particular)
- Pyrolysis is only a real option for well segregated streams
- Use specialist facilities for segregated wastes E.g.:
    - PVC Window recycling
    - Car batteries: Pb, polypropylene, nitric acid
    - Fridges: polystyrene, CFCs
    - Tyre pyrolysis

Work Package 4: UK Benefits Case

As a result of the scenario analysis and modelling work carried out by the consortium the following key points can be made:

1) Applying forecast values for low to high waste availability and conversion efficiencies, the amount of useful energy from waste (both heat and power) which may be generated ranges from **5 to 230TWhrs**.
2) Projected achievable electrical generation is approximately **25TWhrs** per year
3) This equates to between **5% and 8% of the UK's electricity demand**
4) For each of the technology and waste arisings scenarios, the deployment of advanced energy from waste technologies is projected to contribute to a net decrease in UK CO_2e emissions of between **5 and 10 MTCO_2e/year** at midpoint technology conversion and waste arisings scenarios
5) Greater emissions reductions are associated with high total conversion efficiency technologies, both to electricity and from utilising heat.

The consortium have forecast that if the total wastes arising in the UK (both wet and dry waste) are divided by the number of communities at each scenario scale, the number of possible energy from waste plant opportunities would be up to the number identified in table 1 below.

City	Town	Village	Rural
500kt/yr	50kt/yr	5kt/yr	500t/yr
76	946	4,544	4,544

Table 2: Maximum Number of UK EfW Plants at Each Community Scale

Further details are available in the reports produced and the executive summaries prepared by the ETI, these are available via the ETI member portal

Further work

A key step to fulfilling the opportunities described above is technology development in a number of key areas. Based on the testing, modelling, technology assessment and integration work carried out by the project consortium, the following Technology Development Opportunities (TDOs) have been identified:

1) The development of integrated advanced thermal (gasification and/or pyrolysis) systems for energy from waste at the community scale. City scale technology is well served by incineration and the focus on the development work should be on town and village scale technologies.
2) Cost effective gas clean-up is essential to the development of community scale advanced thermal systems.
3) Low cost, high efficiency distributed scale anaerobic digestion (AD) plants that can be integrated with advanced thermal technologies.
4) The development of community scale integrated distributed energy from waste facilities link thermal and AD technologies into highly efficient systems that can maximise resource efficiency.

The consortium has identified four project stages to address the above TDOs, which are identified below in table 6. The costs at this stage are rough order of magnitude and would be refined during the definition phase of any follow on project:

Project	Capital	Project Costs	Timescale	Priority
Advanced Thermal Processes	£10m - £15m	£10m	3-5 years	1
Gasification Gas Cleaning	£5m	£3m	2-3 years	2
Anaerobic Digestion	£3m	£2m	3-5 years	3
Integrated Facility	£15m - £20m	£5m - £10m	3-6 years	4
Total	£33m - £43m	£20m - £25m		

Table 3: Elements of Energy from Waste Development Programme

Figure 5 below shows how the four projects integrate into a development programme for the demonstration of an integrated system approach to energy from waste.

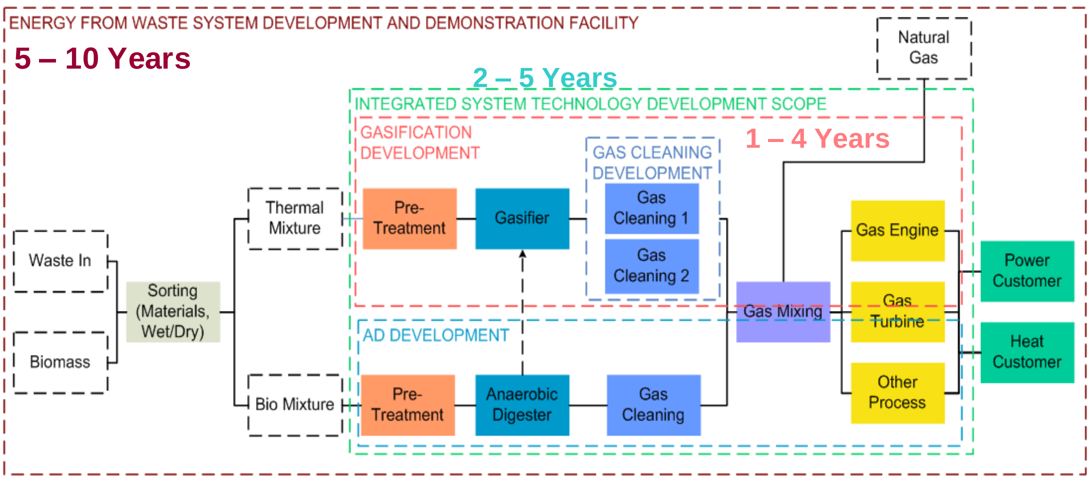

Figure 4: Structure for Integrated Energy from Waste Programme

The preferred approach advocated by the ETI's DE SAG and by the external reviewers consulted is for a demonstration project to focus on projects 1 and 2 highlighted above, namely **an advanced thermal conversion process with integrated gas clean up**.

To achieve the benefits described above, considerable technical development and demonstration is required, particularly around the end-to-end waste to power generation system integration of advanced thermal conversion technologies. The collaborative structure and ability to bring together a range of cross disciplinary skills would uniquely position the ETI to enable the successful development and demonstration of an advanced thermal conversion process with integrated gas clean up.

It should be noted that the scope of the Energy from Waste FRP is focused on the generation of heat and power from waste, looking outside this scope the consortium identified a number of additional areas that could add value in the future. These are:

1) Low cost heat networks
2) The use of syn-gas generated from EfW technologies to create fuels / chemicals
3) The use of pyrolysis to create transport fuels
4) The injection of bio-gas and syn-gas from EfW technologies into the gas grid
5) The injection of bio-gas and syn-gas from EfW technologies into the gas grid with CCS

The issue of heat networks is being addressed in the ETI Macro DE project. Additional work was commissioned to explore opportunities 2 to 5 as counterfactual and / or complementary to the technology development approach advocated. It is critical that these areas be evaluated prior to the definition of a follow-on project.

References

1. D1.3 Final Waste Assessment Report

   Dr Stuart T Wagland, Dr Phil J Longhurst

2. D2.2 Technology Assessment Report

   Contributing authors

   Mathieu Brulé – EIFER Institute

   David Eyler – EIFER Institute

   John Oakey – Cranfield University

   Kumar Patchigolla – Cranfield University

Giacomo Pellegrini-Susini – Cranfield University

Zane van Romunde - Caterpillar

3. D3.3 Technology System Improvement Opportunity Report

   Graham Hillier and Steve Donegan

4. D4.2 UK Benefits Case for Energy from Waste