Programme Area: Bioenergy

Project: Energy From Waste

Title: Deliverable 3.3 Technology System Improvement Opportunity Report - Executive Summary

Abstract:

This is the executive summary of the Work Package 3.3 Report which describes the findings and outputs from the technology system modelling work carried out by the consortium.

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

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ETI Energy from Waste Programme

Deliverable 3.3 Technology System Improvement Opportunity Report

Executive Summary

Final

23rd May 2011

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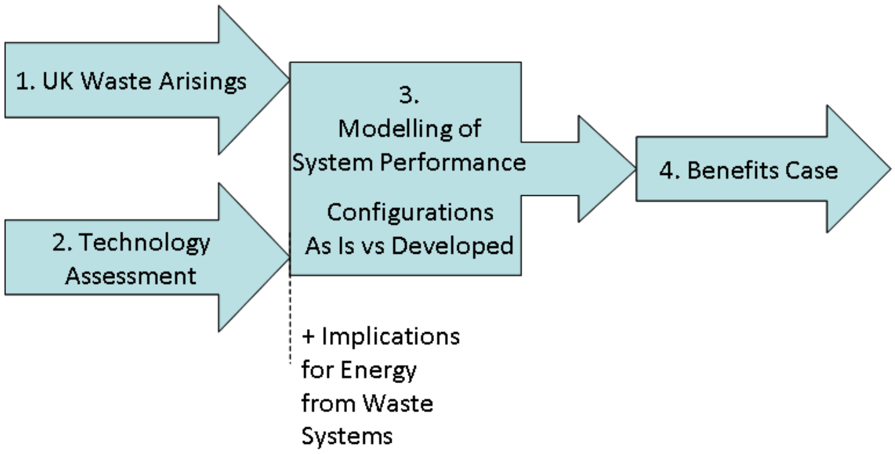
1. INTRODUCTION

This is the executive summary of the Work Package (WP) 3.3 Report that has been produced by the Centre for Process Innovation (CPI) for the Energy Technologies Institute's (ETI) Energy From Waste (EFW) Project Consortium that forms part of the ETI Distributed Energy Programme. The project structure is shown below in Figure 1. This report is the deliverable from WP 3.3 of the EfW project.

Figure 1. Outline of the Project Structure



Increasing population is creating increasing amounts of waste that have to be stored for a long period of time. In many cases the wastes have a calorific value and could be used as energy feedstocks. There are significant opportunities to reduce emissions and fossil fuel use by developing effective strategies to generate energy from waste. This has the multiple benefits of:

- Decreasing the need for landfill,
- Reducing the consumption of fossil fuels,
- Reducing emissions of greenhouse gases,
- Improving energy security,
- Creating more localised distributed energy systems.

A significant part of the energy from waste (EFW) approach involves closing loops between waste production and the demand for power and heat.

This report draws on the waste analysis and technology work in WP 1 and 2. It combines these data in an economic, mass and energy model that takes into account the changing availability of wastes in the UK and aligns technology choices with the likely waste arisings.

The data are combined to create models for each of four community scenarios to identify the most appropriate feedstock and technology options for EfW systems at each scale. The scenarios analyse potential throughputs, product yields, profitability and emissions to describe potential operating regimes for the communities. The model outputs have been used to identify technology development opportunities for each scenario.

The report concludes by combining the technology opportunities to identify technology development opportunities that could form the basis of practical development and demonstration work that the ETI could pursue in the next stages of its Distributed Energy Programme.

In addition to the work carried out by the project consortium this report also incorporates the output of a workshop organised by the ETI for interested project stakeholders from academia, the public and the private sector members of the ETI[1].

The output from this report forms a core part of the modelling and UK benefits work reported in the WP 4 benefits case reports.

2. DRIVERS FOR TECHNOLOGY DEVELOPMENT OPPORTUNITIES

- **Reduce the capital cost per unit of investment.** This could be through the economies that come from large-scale plants or through long production runs of similar units leading to economies from repetition. All current plants require some support mechanism through either the landfill tax at the supply end or the feed in tariff (FIT) or renewable obligations certificate (ROC) system to be economically viable. A capital cost reduction of over 30%/tonne of feed would be required to remove the need for public sector support mechanisms;
- **Improve the yield of higher value products and make by-product streams with value**. The technology study and experimental work indicates that all technologies studied have low conversion efficiencies for the transformation of feedstock into energy. In many cases the electricity yield can be half that of the conventional fossil fuel alternatives;
- **Increase the efficiency of energy conversion both electrically and thermally.** Pure thermal systems that convert gas into heat for local use can reach conversion efficiencies as high as 85%. This requires a different approach to gas use either in grid or in local heat networks;
- **Handle variable feedstock form and moisture content**. The evidence from the work to date indicates that mixed wastes have similar elemental composition to biomass, but differ widely in form, moisture content and trace contaminants. Feedstock pre-treatment through processes such as Including the production of homogenised feedstocks through mechanical, biological or thermal pre-treatment can help to produce more homogenized feedstocks for all technology option;

The technologies identified for development for MSW and C&I waste streams are advanced thermal processes (such as gasification) and incineration for dry wastes and anaerobic digestion for wet wastes. Gasification and pyrolysis processes that primarily produce syngas are treated as advanced thermal processes in this study.

There is a need to investigate innovative investment models**.** Current models are tied to large plants that can prove they have secure low cost feedstock supply for enough years to ensure that the investment in the facility pays back with little or no risk to the investor. This approach is unlikely to work with smaller scale distributed technologies and it is suggested that investment options are studied to assess options such as leasing, third party investment based on off-take or supply agreements and outright purchase by individuals or communities.

[1] Notes from ETI Energy from waste Project Stakeholder Workshop, November 2010

3. POTENTIAL DEVELOPMENT RISKS

3.1. Physical Form, Moisture Content and Impurities

Although waste is chemically similar to biomass materials and the modelling project has assumed that it performs the same thermodynamically, the physical form of the materials may have impacts that cannot be predicted. The biggest risk to the technologies is how this physical form will affect operations and stability in any process. Whether these difficulties are in the reactor itself or associated feed system or gas treatment. As discussed in the WP 2.2 report Cranfield University had difficulty with certain materials in feeding the pilot gasifier. More confidence needs to be developed in the non-incineration processing of these materials.

3.2. Feedstock Prediction

The ability to assess feedstocks that can be used in a project would be critical for the success of future EFW programmes. The development of criteria or nomographs for different materials based on their chemical and physical properties could be of value in the assessment and optimisation of feedstock mixes or blends.

3.3. Technologies

The technologies that seem most ripe for further development for use with mixed MSW and C&I wastes are the advanced thermal processes and AD processes. The construction and utilisation of a facility that can test and develop technology is recommended. The facility must be at a scale that can evaluate solutions that address processing difficulties. The project should not limit itself to just the processing but have the ability to create the added value products such as methanol or fuel oil.

3.4. Next Phase Modelling

The modelling done in WP3 is at a necessarily high level, but as the distributed energy programme develops and options are narrowed down there will be a need to develop more detailed models that will show how materials will behave in the processes but also develop enough knowledge to be predictive in what the outputs will be. It will give an assessment of what the best product is for the waste that is to be handled.

3.5. Controllable and Uncontrollable Variables

The project has feedstock cost, feedstock quality, product value, capital investment and process efficiency as the major variables driving business profitability and emissions production. These variables split into to two groups: Controllable and uncontrollable variables. These are summarised in the table below.

Variable	Controllable/ Uncontrollable	Effect on Profitability	Effect on Emissions	Comments
Feedstock cost	Uncontrollable	Higher price lowers profitability	None	Set by a combination of legislation and market conditions
Product value	Uncontrollable	Higher price increase profitability	None	Set by regulation and market conditions
Feedstock quality	Controllable	Balance quality and price to manage returns	Higher yields of products lowers emissions	Blending of feedstocks and feedstock flexibility allows this to be

				managed both to reduce cost and improve process yield
Capital investment	Controllable	Lower capital increases profitability	None	Need to guard against loss of function as capital reduced
Process efficiency	Controllable	High conversion to high value products increases profitability	High conversion to high value products reduces emissions	

Controllable variables offer the best opportunities for successful technology development.

4. CONCLUSIONS

- Each person in the UK produces about 1 tonne of MSW per year and about 0.8 tonnes of Commercial and Industrial (C&I) wastes. These figures include wet wastes such as slurries and sewage. These sources of waste amounted to around 90 million tonnes in 2009 and could be used to generate up to 3% of the UK's heat and power need each year.
- If wet wastes, garden wastes and food wastes are to be used to produce energy there are a limited number of options with the most attractive being anaerobic digestion. Although in certain circumstances garden and food wastes can be included in the MSW stream and would be treated as described below.
- The evidence is that the amount of residual MSW and C&I waste produced each year is reducing as recycling rates increase and the mix of materials within the MSW is changing. This reduction is linked to a combination of: the commodity value of recyclable materials and increased efficiency in material use.
- Elemental analysis of MSW and C&I waste indicates that, although it contains different mixtures of materials, the elemental composition of the dry waste is consistent. However, it is noted that it changes in its form (shape) and its moisture content.
- It is concluded that MSW composition will continue to change in both volume and mix over time, but that the elemental composition is likely to remain the same.
- Any energy from waste technologies must therefore be able to cope with wastes in various forms and with a moisture content of up to 40%. The number of technology options is reduced based on this requirement for flexibility of the range of feedstock materials and the production of readily useable products that can be consistently produced. These are most likely to be medium to high temperature thermal processes.
- The project has focused on two main thermal technologies that theoretically have the capability to handle mixed wastes and have the capacity to deal with changing form and moisture content. The technologies are:
    - Incineration at temperatures up to 1200°C.
    - Advanced Thermal Processes (such as gasification and high gas yield pyrolysis) between 650°C and 1200°C – with a particular emphasis on fluidised bed and downdraft gasifiers for general use.
- Gasification is the preferred technology as pyrolysis is a complex process in the treatment of highly variable MSW and C&I waste. It is more appropriate for use with consistent feedstock streams. However, pyrolysis routes that produce gas or are combined with gasification steps are appropriate technologies.
- The project modelling, using a number of community scenarios to define waste arisings, shows that most UK communities produce tonnages of MSW that are less than the current economic scale for incineration and gasification plants. EfW – including CHP - technologies that work economically on the scale of a town or village are a major development opportunity.
- The modelling work undertaken in WP 3.3 is based on the current available waste data. Additional work could be undertaken to create further data sets that assess the effect of changing composition and changing recycling levels on energy from waste generation. This work could be undertaken in follow-on projects and draw on the outputs of WP 3.2. However, this additional modelling will not affect the technology development ideas generated from this work package.
- As the electricity production from current thermal technologies is of the order of 20% to 25%, a significant amount of the energy content of the waste is lost.
- It is concluded that distributed energy from waste plants of an appropriate size to local communities could bring significant benefits in efficiency and reductions in transport costs.

- The modelling also shows that the economics of waste to energy plants are very highly geared to the cost of the feedstock, the capital cost of the plants, the efficiency of conversion of the waste to useful energy, the product value and the local use of waste heat. It is concluded that any future energy from waste development project must address the operational efficiency of the process plants with a major focus on the conversion efficiency of the processes to electricity or fuels and the local use of heat produced by the plant.
- The emissions of energy from waste plants are driven by the transport costs of bringing wastes to the plant, distribution loses once energy is produced, the efficiency of heat use and the conversion efficiency of the plants themselves. It is concluded that the best way to reduce emissions from energy from waste is to have local plants that are of an appropriate size and scale to the local community with high conversion efficiencies and local use of heat.
- It is concluded that there is a need to develop gasification and incineration plants of an appropriate size and scale for local communities with high energy from waste conversion efficiencies.
- Anaerobic digestion plants have been identified as the best route to process wet bio wastes. Although AD technology is well established it has low efficiency for the size of plant. It is concluded that AD for energy production should be targeted with a view to increasing the yield of gas per unit of feedstock and increasing process intensity to reduce plant size.
- AD plants produce methane rich gas that is akin to natural gas and in the UK this is typically burnt to produce electricity. It is concluded that lower emissions will result if AD plant conversion efficiency is increased and if the biogas produced is injected into the UK national gas grid or used locally for high efficiency CHP systems.
- It is concluded that although SRF plants and autoclaves are becoming increasingly common there is a continuing need for all technologies identified to improve technologies that prepare feedstock to a consistent shape and moisture content.
- The gas produced by gasification and AD contains contaminants and it is concluded that there is a need to clean-up technologies before these gases can be used effectively. In the case for gasification, there has been little evidence that indicates the industry has resolved the issue of gas cleaning for use in downstream processes beyond boilers.

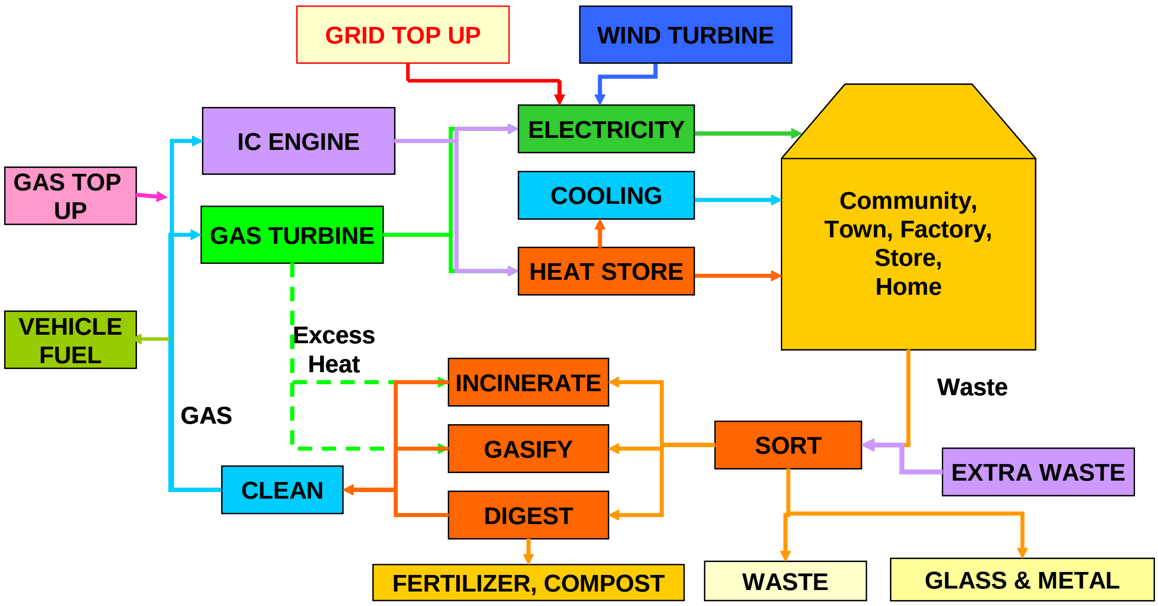
5. RECOMMENDATIONS

It is recommended that the ETI develop programmes in the following areas.

5.1. Within the Next Phase of the Energy from waste Project

5.1.1. Integrated Gasification/Advanced Thermal, Incineration and AD Technology Systems

This project indicates that there is an opportunity to develop integrated distributed energy systems of technology that can service smaller communities with a particular emphasis on town and village scale systems. Combinations of technology are likely to be AD, gasification/advanced thermal processes, incineration with upstream and downstream processing. This approach could reduce emissions for both electricity production and in CHP systems. There is a need for the ETI to sponsor work to develop and demonstrate the combinations of technology that meet appropriate local needs. It is believed that this brings a significant commercial opportunity.



5.1.2. Medium, Small and Micro Scale Advanced Thermal Processes for Wastes

The advanced thermal processing of waste materials in fluidized bed and downdraft gasifiers has been identified as a technology development opportunity. There are few if any processes that work using mixed feedstocks at feed rates of 50kt/yr or less. Units down to domestic scale are likely to have value. It is proposed that the ETI creates a technology programme to develop innovative gasification solutions that reduce capital cost and increase operability of small-scale units. These units could be significant in the development of community and domestic energy from waste technologies and are aligned to the localism agenda in the UK.

5.1.3. Small and Micro Scale Anaerobic Digestion Plants

Anaerobic digestion is a well-established technology that has been deployed around the world for many years. However this study indicates that there is an opportunity to develop an economic small and micro AD technology for volumes of waste below 5kt/yr. It is proposed the ETI supports work to develop small AD plants for the community and domestic scale, which is also consistent with the UK localism agenda. The replacement of septic tanks with micro units may add value to the disposal of waste material.

5.1.4. Low Cost Gas Clean-up

Both gasification and AD produce gas that requires at least some cleaning up before it can be effectively used. This also applies to gas produced from pyrolysis processes. Technology exists to do this, but it is prohibitively expensive for widespread adoption. It is proposed that the ETI supports work to develop lower cost and smaller scale clean-up technology for all types of gas produced from energy from waste processes.

5.2. Opportunities For Exploitation in Other Projects

5.2.1. Biogas for use in Vehicles and in the Natural Gas Grid

Biogas from AD processes has been proven in vehicle and grid use across Europe and trials are being run in the UK. Technology exists to implement both options for gas use but costs appear prohibitively high to convert biogas to meet the UK gas specification. In addition, slight changes in specification that lower cost gas clean-up technologies would be beneficial. An example is the permitted oxygen content in pipeline gas. A number of European countries have a different specification to the UK, which makes the injection of biogas more attractive. Others use non-sulphur gas stenchants that reduce the need for sulphur cleaning technologies. There is a need for legislation to allow injection of appropriately formulated biogas or product gas into the grid.

5.2.2. Low Cost Heat Networks

There are very large amounts of low-grade waste heat produced in UK energy systems of all types, particularly from waste incinerators and from the gas engines of AD plants. The technology for heat distribution exists but it is costly to fit into new build facilities and expensive when retrofitted to existing communities. However, if the heat is used in CHP installations on the scale of a city it will save over 120kt/yr of carbon dioxide. It is proposed that the ETI Macro Distributed Energy programme is used to develop lower cost heat distribution systems that are easy to install and are combined with control systems that demonstrate that home owners and industrial users have as much control over their heat supply as with an independent gas boiler. Social adoption of heat networks in the UK is low – although this is not true in Europe. There is a need for a regulatory and legislative environment that makes it attractive to join and use a community heat network.

5.2.3. Low Cost Processes to Convert Syngas into Chemicals or Fuels

The modelling shows that there are potentially good margins to be had from taking syngas and producing methane, chemicals or liquid fuels such as methanol, ammonia or through Fischer Tropsch reactions. There has been much work over the years to develop lower cost conversion technologies for syngas, but despite this the technology is under-developed. A number of companies are developing a range of solutions, but a more systematic public-private partnership to drive value creation may be of value to developing this market further.

5.3. Overarching Industry Development Opportunities

All the previous technology development ideas will require parallel work to support the development of a supply chain that can create value for the UK. Activities could include:

- Focused research programmes
- Technology development facilities
- Development and proving sites
- Assistance to help organisations meet new market demands
- Assistance to create new companies in the market
- Favourable legislative and regulatory environment

It is proposed that the ETI runs a supply chain development programme in parallel to any technology development programmes that are created as a result of this project.

6. POTENTIAL FOLLOW-ON PROJECTS

6.1. Integrated advanced thermal processes and AD programme

- Create a reconfigurable test and development site for the proving of energy from waste technologies;
- This should be at a scale of at least 10kt/yr of throughput for the development and demonstration of technology systems and should have a dedicated infrastructure and operations team;
- This demonstration facility could be followed-up with a full scale resource efficiency demonstration at a town or village scale – Up to 75kt/yr throughput;
- The aim of this work would be to develop appropriate scale mixed feed plants and systems for advanced thermal processing (e.g. gasification and high gas yield pyrolysis), incineration and combined systems with appropriate upstream and downstream technologies to improve capital efficiency and productivity.
- This will include network management to link into the electricity grid.

14.2 Small Scale Plant Development

- This project indicates that there is a technology and market opportunity to develop gasification and AD at domestic or very small community scale.
- The replacement of septic tanks with micro AD units may add value to the disposal of wastes.
- The development and application of small-scale gasifiers based on existing trials and ideas are an additional opportunity.
- There are also opportunities to create development links with producers of small-scale plants in other countries.