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Advanced Thermal Treatment; Technology Challenges

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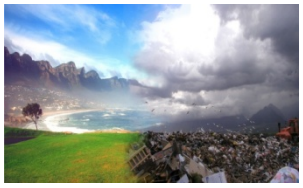
Presentation Overview

- Waste to Energy – Legislative Drivers
- Advanced Thermal Treatment Technologies
- Technology Challenges
  - Feedstock
  - Energy Generation
  - Syngas Uses
- Regulatory and Socio-Economic Challenges
  - Economics
  - WID
  - Environment
- Advantages and Limitations
- Opportunities

Current Energy and Waste Climate

- Increasing energy prices
- High demand for renewable and clean electricity
- Increasing waste disposal and landfill costs
- Lack of efficient & safe waste disposal systems
- Increasingly stringent environmental regulations
- Increasing interest in novel energy generation technologies e.g. Fuel Cells and Hydrogen Gas



Waste to Energy

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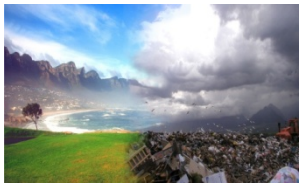
At present 62% of all MSW generated in England is disposed of in landfills.

The EU's landfill directive has set the target of reducing the amount of biodegradable municipal waste landfilled to 75% of that produced in 1995 by 2010.

The EU has a target that by 2010, 20% of all energy generated is from renewable sources.

Waste to Energy schemes therefore have a vital role to play in helping the UK meet such targets.




Advanced Thermal Treatment

Advanced Thermal Treatment technologies are those which employ pyrolysis or gasification to process Municipal Solid Waste (MSW).

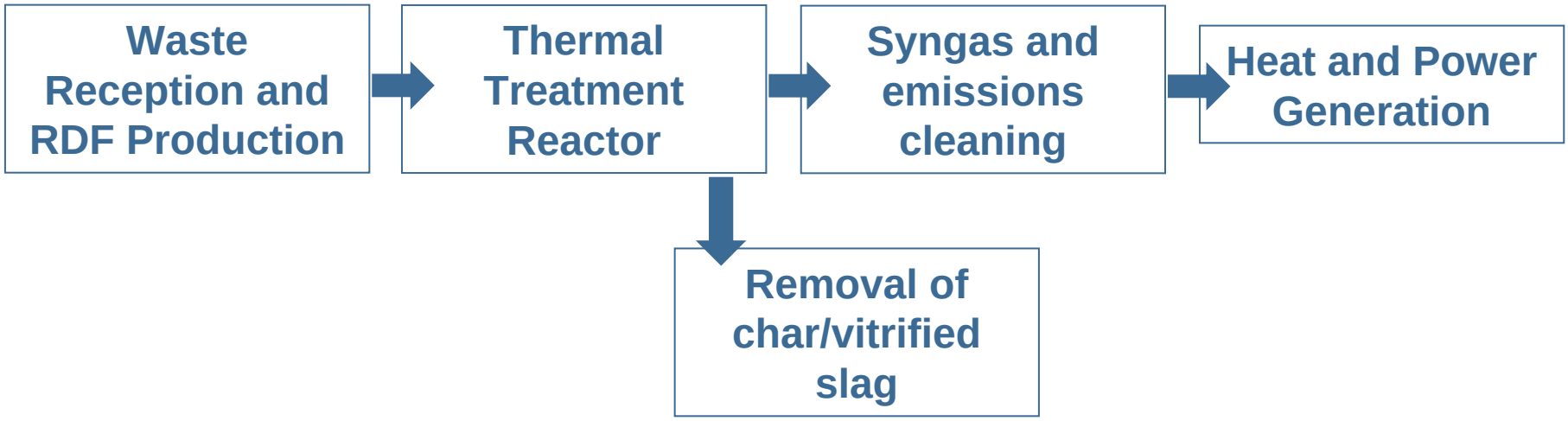
Gasification and pyrolysis are both established processes:

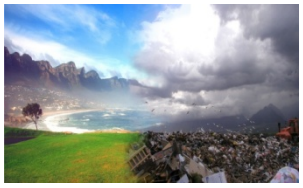
- **Charcoal via pyrolysis of wood**
- **Coke via pyrolysis of coal**
- **Produce gas via gasification of coke**

- **However the application of these technologies is yet to be widely deployed for the treatment of MSW in the UK.**




Schematic of a typical ATT Plant:





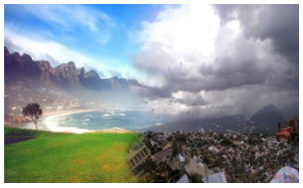
Technology Challenges

Technological

- Feedstocks
- Energy Production
- Alternative uses of syngas
- Operational Data

Regulatory & Socio-Economic

- Economics
- Regulations
- Environmental
- Social Perception



Waste Reception, Handling and Pretreatment

Municipal Solid Waste (MSW) typically undergoes a processing step prior to thermal treatment. Non-combustables and recyclables are removed before the stream is dried and shredded to produce a Refuse Derived Fuel (RDF).

The pre-treatment process results in a high net calorific (NCV) RDF that is:

- **Dry**
- **Relatively free of pathogens**
- **Relatively free of odours**
- **Easy to transport**
- **Easy to store and handle**

Quality & Security of Feedstock

The NCV of RDF is typically between 11-15 MJ/kg, with the RDF containing between 35-50% of the original mass of waste.

The composition of the waste stream has a significant effect on the quality of products from advanced thermal treatment technologies. Therefore a continuous supply of a homogenous RDF is essential.

A CEN Committee is currently working on standards for fuels prepared from waste to ensure quality standards for:

- **Thermal value MJ/kg**
- **Moisture Content**
- **Elemental Composition**

Long term waste contracts – Local Authority/Waste Management Companies

Synthesis Gas

Syngas is produced in both pyrolysis and gasification processes.

The advantage of these processes is that the production of energy from syngas is potentially more efficient than direct combustion of the original fuel.

Pyrolysis syngas is comprised of carbon monoxide, hydrogen, methane and some longer chain hydrocarbons

Gasification syngas is comprised of carbon monoxide and hydrogen

Gas Type	Typical NCV (MJ/Nm3)
Pyrolysis Gas	10-20
Gasification Gas	10-15
Natural Gas	~38

Energy Generation

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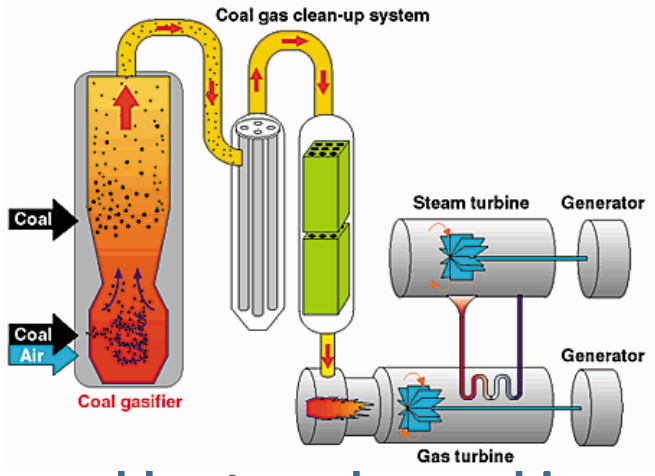
The quality of the syngas is dependent on the composition of the waste stream and the operating conditions of the reactor (e.g. temperature profile, oxygen content and residence time).

Typically the syngas is used for energy production via:

- Steam Boiler & Turbine
- Gas Engine
- Combined Cycle Energy Generation



Increased efficiencies of can be achieved if recovered heat can be used in other parts of the waste to energy plant, for instance in RDF production.

Steam Turbine

Almost all currently available gasification and pyrolysis waste to energy plants use steam turbines as part of the power generation process.

The combustion of the syngas is used to generate steam in a boiler, which is subsequently used to drive a steam turbine for electricity production.

Modern steam turbines can typically achieve electrical generation efficiencies of ~31%.

$$\text{Electrical Generation Efficiency} = \frac{\text{Power Output}}{\text{Power Input}}$$

Gas Engines

Gas engines operate similarly to petrol/diesel engines

Gas engines running on natural gas are typically between 35-44% efficient.

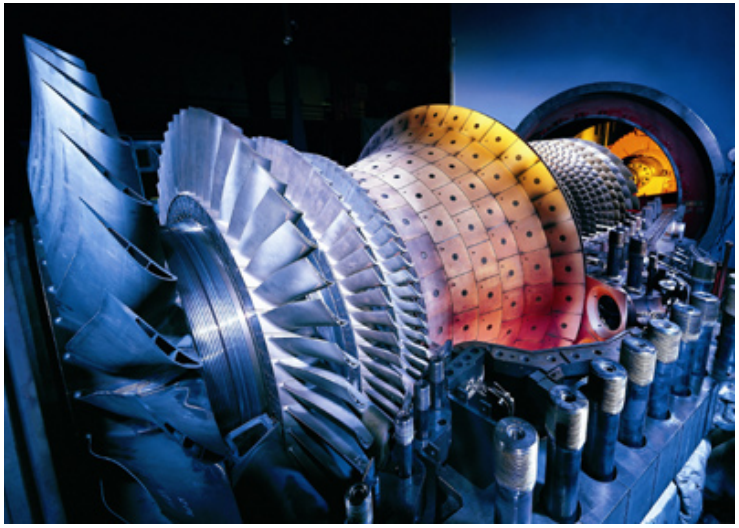
However electrical generation efficiencies are reduced when using low calorific value syngas (13-24%).

Fuel energy arises at the output shaft, the remainder appears as waste heat.

Combined Cycle Energy Generation

Combined cycle gas turbines operate by combusting syngas in gas engines or turbines to generate electricity. The waste heat is then used to make steam to generate additional electricity via a steam turbine.

The electrical generation efficiencies of CCGT systems using natural gas are high ranging from 26% – 41% for small and large scale plants respectively.



Electrical Generation Efficiencies

Overall Net Electrical Efficiencies Claimed by Technology Providers

Thermal Treatment	Combustion	Gasification and Pyrolysis			
Power Generation	Steam Cycle	Steam Cycle	Gas Engine	Combined Cycle	Co-fired with fossil fuel
Overall Net Electricity Efficiency – Claimed		14-20%	13-24%	34%	33-35%
Realistic	19-27%	9-20%	13-24%	23-26%	27-35%

Fichtner Consulting 2004

Electrical Generation Efficiencies

Perceived benefits of gasification and pyrolysis is that the use of gas engines or gas turbines will lead to higher electrical efficiencies

However currently available data shows that gas turbines are not enough to increase the net electrical efficiency above that currently achievable by modern combustion technology coupled to a steam cycle.

Electrical Generation Efficiences

Combined cycle systems may increase the net electrical efficiency above that currently achievable by currently available combustion technologies coupled to a steam turbine.

However for the use of gas turbines the synthesis gas from the ATT process must be cleaned to remove tars, sour gasses, contaminants and cooled to reduce temperature.

Whilst syngas cleaning plant is available, the additional processing stages result in greater operational inefficiencies and plant capital costs.

The use of combined cycle systems for electricity generation, using MSW as a feedstock , are currently in their infancy.

Electrical Generation Efficiences

One of the main reasons for the low electrical conversion efficiencies of standalone waste to energy plants is their relatively small size.

The electrical output of conventional power plants can be over 30 times higher than standalone energy from waste plants.

To capitalise on the greater conversion efficiencies of larger power stations, is to co-fire the syngas produced from pyrolysis and gasification plants.

- **Higher efficiencies of large boiler and power island**
- **Syngas does not require to be cleaned**
- **Energy in pyrolysis char can be recovered by firing in a conventional boiler**
- **Capex savings on waste to energy plant**
- **Replacement of fossil fuel with waste fuel**

Production of Synfuel

The Fischer-Tropsch synthesis (FTS) is the process which is used to convert syngas into liquid hydrocarbons (chemicals composed of hydrogen and carbon) over a transition metal catalyst.

The FTS process can be used to produce synfuels (gasoline and diesel) and other chemicals (e.g. waxes, lubricants, phenol and cresol, kerosene, alcohols, ammonia, etc).

Production of synfuel via the FTS process is an established technology, with the fuel being used to power cars, trucks and planes.

Methanol Production

Used as a chemical intermediate for the production of methanol.

$CO + 2H_2 \rightarrow CH_3OH$

(mixed catalyst comprising copper, zinc oxide, and alumina)

Second Generation Biofuels

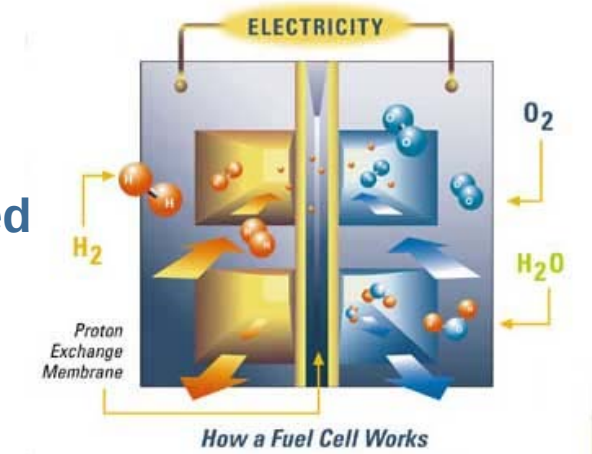
Production of second generation biofuels using biomass consisting of the residual non-food parts of current crops, such as stems, leaves and husks, as well as other non-food crops such as switch grass, jatropha and cereals that bear little grain, and also industry waste such as wood chips, skins and pulp from fruit pressing.

Hydrogen Production

Hydrogen can be readily separated from syngas using membrane filtration.

Hydrogen is used extensively in the manufacture of ammonia, methanol, gasoline, heating oil and rocket fuel.

Hydrogen is also a fuel in Hydrogen Fuel Cells. The application of syngas derived hydrogen in fuel cells may offer a greater conversion efficiences for energy production when compared alternative technologies.



Operational Data

There are more than 150 companies globally that are marketing ATT technologies for the processing of MSW.

There are more than 100 plants operating globally, however there are only a small number of plants that have been in operation for greater than 5 years.

There are are an additional number of small scale proprietary systems being promoted however many have only operated on a pilot scale.

Uncertainty over CAPEX and OPEX for waste to energy plant

Energos – Case Study

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The first full-scale UK gasification plant was comissioned on the Isle of Wight in late 2008 and was constructed by Energos (part of UK-based Ener-g).

The plant cost £10 million to build and was part of Defra's New Technology Demonstrator Programme which provided £2.7 million in funding support.

The plant will generate 2.3 MW of electricity and will power more than 3000 local homes.

Potential Revenue Streams

- Tipping Fee on Feed Stock
- Electricity Sales
- Sale of Synthesis Products:
  - Pyrolysis: Coke, Biofuels & Biochar etc
  - Plasma gasification: Vitrified slag, chemical intermediates & biofuels

- Alternative Revenue Streams
  - Government and EU Incentives
  - Subsidised Electric Purchase for Renewable Energy
  - Environmental Remediation Subsidies

Potential Revenue Streams

Capital Cost
A typical 100,000 t/y WtoE plant cost app. £50-60 million (may vary by 2-5% depending on the location, ground conditions the size of the plant (economic scale) etc.

Gasification WtoE Plant (based on a typical 100,000 t/y waste processing capacity with an output of 40 MW)

Return of investment

Landfill Gate Fee
Currently £35 to £55 p / t potentially rise to
£65 or more
(the Landfill Directive)

Return of investment

Under the UK Energy Review Gasplasma qualifies for double ROCs.

Operating Cost App.£0.07/kW

Depending on
the disposal routes from landfills
the level of engineering
the equipment & machinery
the distribution network

Return of investment

Sale of Electricity
App.450 kWh of electricity produced from per tonne of waste which has a value of £11.25 at £25/MWh.

Return of investment

Sale of recovered metal
App. 5,000 t/ y of ferrous metal can be recovered for recycling

Return of investment

Sale of Vitrified Slag
Can be used in construction of road, building foundation or tiles

Planning Application

All waste development projects are now classed as a "Major Development" under changes in the planning system in 2006.

Waste Incineration Directive

The WID imposes requirements on the types of waste permitted at a given plant, delivery and reception of the waste, the thermal conversion equipment used and the operating conditions required, abatement plant, emissions monitoring requirements and emission limits values to air and water.

Landfill Directive

Disposal of ash is not specifically covered by the WID, thus the EU Landfill Directive is more relevant.

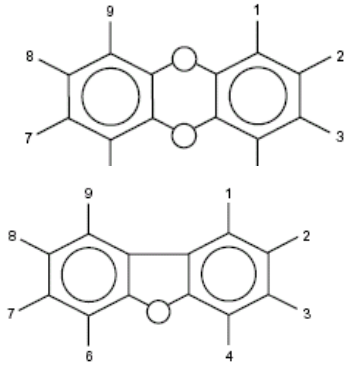
Environmental Performance

Pyrolysis and Gasification:

- Enables the production of Renewable 'green' energy
- Displaces the use of fossil fuels
- Provides a sustainable waste disposal solution - an alternative to landfill
- Reduced Green House Gas and CO_2 emissions
- Contributes to achieving Kyoto protocol commitments

Plasma Gasification:

The high operational temperatures destroy any hazardous organics within the waste stream (>99% for persistent organic pollutants e.g dioxins/furans).
All toxic components are immobilised in the inert slag.



Limitations of Advanced Thermal Treatment Technologies

- Viewed as a novel technology
- High initial capital costs
- Lack of operational data
- Lack of strict environmental legislative framework
- Planning regulations
- Landfill cheaper in short term
- Public perception

Advantages of Advanced Thermal Treatment Technologies

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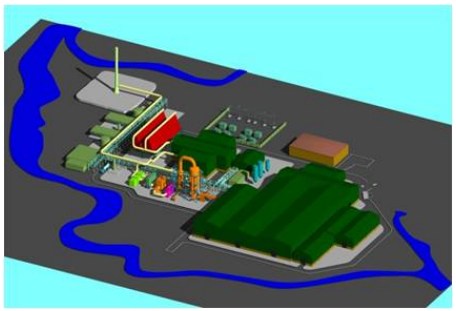

- Technology is available
- Proven technology
- Suitable for multiple waste streams
- Enables the local handling of waste
- Emissions are easier to control because they are scrubbed to remove contaminants;
- The plants are modular, therefore they can be readily modified to encompass changes to the constituents and volume of the waste stream.
- The gasification and pyrolysis processes produce more useful products than standard incineration e.g. syn-gas

Energy From Waste – The Future

There will be substantial growth in the number of waste to energy plants over the next 10 years as 35 plants currently planned come on stream.

Funding will remain challenging for the rest of 2009, especially on long-term PFI projects. It is expected that this will become easier from early 2010 onwards.

Merger and aquisition activity to will increase due to consolidation and the desire of new investors entering the sector.

There will be a significant increase in gasification and pyrolysis units in the UK over the next five years.

Catalyst Corporate Finance "Clean Technology" 2009

Any Questions?

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