RECYCLING FACILITIES

Basic facilities exist for plastics, glass and metals recycling so there is scope for segregation of general solid waste at source for introduction into the local recycling markets.

There are small collectors of waste oils. These oils are however not re-refined and are generally utilised as supplementary fuels in heating applications. Some of these uses are considered acceptable by EPA but many of the other common uses, such as the practice of using oily sludges as wood preservatives, are unacceptable to the EPA and cannot be regarded as being appropriate from a health and safety perspective.

There are no facilities in country for recycling of dry cell batteries or fluorescent lamps. There is ad hoc recycling of lead-acid batteries however the method of recycling and the treatment/final disposal method and destination of the acids is unclear.

WASTE TREATMENT AND PROCESSING

There are no known facilities in Ghana for physical/chemical treatment of industrial wastes and no known facilities for thermal treatment of hazardous wastes.

With regard to healthcare wastes, it is understood that some hospitals have basic combustors for healthcare wastes but that none of these currently meet European Union Waste Incineration Directive standards.

The Takoradi Power Station has a small liquid/sludge incinerator for residues from its oil/water separation system and on-site tank cleaning operations. It is understood however that this incinerator was never fully commissioned and has remained unused. The arrangement between Zeal Environmental and the Takoradi Power Station does not include use of this facility.

Cement kilns are now commonly used to dispose of certain hazardous wastes in many countries with higher energy content wastes being used as supplementary fuels in the kilns. Although there is cement production in Ghana (Ghacem and Diamond Cement), the cement is produced from imported clinker and there are no cement kilns in Ghana. Thus, this potential waste management route is not available.

EXPERIENCE AND CAPABILITIES OF WASTE MANAGEMENT CONTRACTORS

Waste management contractors are emerging in Ghana with improving experience. These are largely limited to collection and transportation companies serving Metropolitan areas. At stated above the largest and best equipped appears to be ZoomLion. There are also a number of MARPOL waste collection contractors, all of whom are relatively small, relatively recently established organisations with limited capabilities. From discussions with the companies evaluated for the purposes of this assessment, these facilities typically have just gravity separation in storage tanks and no wastewater treatment capabilities to process separated water.

Zeal Environmental Technologies has acquired a 6.5 acre site zoned for industrial use well away from residential areas and plans to develop Ghana's first integrated industrial waste management facility. There are significant challenges in developing an environmentally sound, commercially viable, facilities.

This historic concept was for phased development of a facility which will ultimately include the following.

(i) A MARPOL Annex 1 oily waste reception and treatment facility (first phase element replacing the facility they currently use within the Takoradi Power Station).

(ii) A further tank cleaning waste reception facility for other, principally inorganic waste, transportation tanks (waste would come from Zeal's own mobile tank cleaning operations) is planned but has yet to be constructed.

(iii) Chemical treatment system (details not finalised but probably incorporating acid/alkali neutralisation and metal hydroxide precipitation).

(iv) Hazardous waste incineration system (details yet to be finalised). Other physical treatment systems including washing, shredding and container crushing.

Associated waste reception and storage systems.

The management of Zeal Environmental Technologies has expressed its keen interest in developing the proposed waste management facilities but, like many such small enterprising companies, it lacks the practical experience of the required technologies. This may result in a protracted timescale for development of the above facilities. Partnering and international experienced support could be appropriate to bring forward this project and similar ones.

INTERNATIONAL SUPPORT INITIATIVES

In terms of waste management, international support initiatives have resulted in the funding of two strategic sanitary landfills for domestic-type solid wastes. This has clearly been valuable although both the sites have had operational issues related to plant. ERM is not aware of any current international initiatives supporting industrial and hazardous waste management in Ghana.

WASTE MANAGEMENT PRINCIPLES

There are a number of key principles which should be considered when determining waste management requirements and these are developed in the following sections.

The Waste Management Hierarchy

The waste management hierarchy is summarised below. The hierarchy ranks the different generic methods of waste management in order of general preference from an environmental perspective and shows that priority should be given to avoidance and minimisation of waste generation followed by recovery, reuse and recycling. The least preferred option being disposal (e.g. landfill or injection).

Fig 37. Waste Management Hierarchy

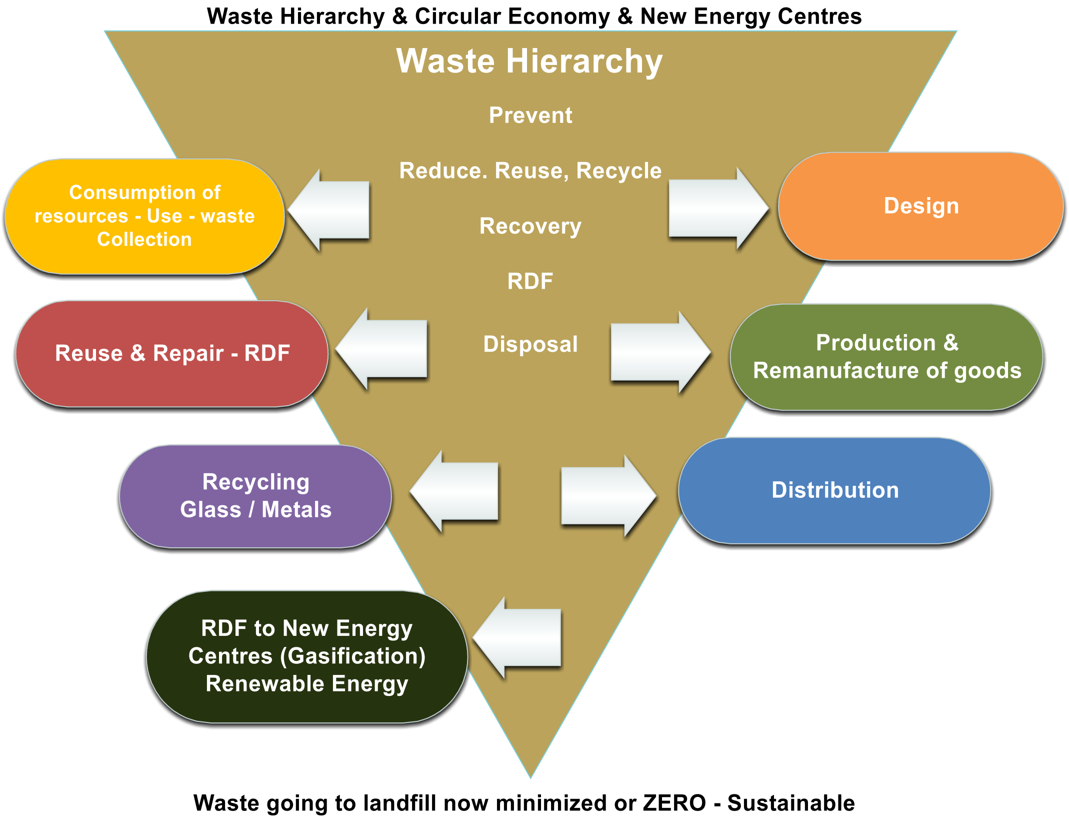
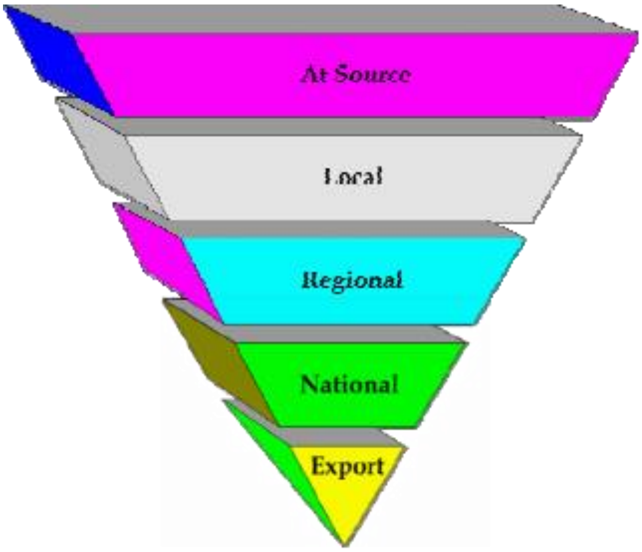


Fig 38. The Proximity Principle

A second internationally accepted principle of waste management is the 'Proximity Principle' which states that waste should be managed as close to the point of generation as is practicable. This can be illustrated in the form of a hierarchy with treatment/disposal at source being the most preferred option and export being the least preferred option.



The Use of Best Practicable Environmental Option – our New Energy Centres

This is the principle that waste should be managed by the 'best' means choosing an option which minimises the impact upon the environment taking into account issues of availability and affordability.

In choosing the best environmental practicable option, a balance often has to be struck in that strict application of one principle may result in being unable to comply with another principle. For example, currently in Ghana there is no high temperature incineration facility available, and while this may be deemed to be the best technology option it currently necessitates export which is the least desirable option under the proximity principle.

10. INTRODUCTION TO WASTE MANAGEMENT NEEDS in Ghana

A preliminary waste generation inventory for Tullow is being developed to inform the development of a project Waste Management Plan. Tullow, in common with other companies undertaking oil and gas exploration, development and production need to have access to environmentally acceptable facilities for the management of:

- (i) general solid wastes, including recyclables (domestic-type, bio-degradable non-hazardous wastes);
- (ii) oily liquids/sludges and oil/water mixtures (hazardous wastes);
- (iii) oil contaminated solid wastes (hazardous wastes);
- (iv) organic chemical wastes (hazardous wastes);
- (v) inorganic chemical wastes (hazardous wastes);
- (vi) end of life electronic equipment; and
- (vii) small quantities of healthcare wastes.

FACILITIES REQUIRED TO MEET WASTE MANAGEMENT NEEDS

Summary of Needs

Wastes require the following waste management options: recovery, recycling and reuse; general solid waste landfill; hazardous waste landfill; high temperature thermal treatment; and physical/chemical treatment.

The waste management options required for the most common waste streams are outlined below.

Recovery, Recycling and Reuse

In accordance with the waste management hierarchy, environmentally sound reuse, waste recovery and recycling should take precedence over waste treatment and disposal.

There may be opportunities to return unused materials, which are surplus to requirements, to the original suppliers thereby enabling their reuse. This is very likely to be the most environmentally sound option if available.

There are likely to be local markets for prime recyclables such as metals, cardboard and plastics. There are no suitable facilities for more sophisticated recovery/recycling such as would be required for dry cell batteries, lead-acid batteries, fluorescent light tubes etc.

Tullow plans to implement segregated collection of prime recyclables as far as practicable for handling by local recycling contractors.

General Solid Wastes

BPEO for disposal of general solid wastes (i.e. municipal type wastes) would be sanitary landfill or incineration. High density aerobic (HDA) landfill as defined in Ghana's Landfill Guidelines would be an acceptable second best to sanitary landfills.

Currently, disposal of general solid wastes in the Sekondi-Takoradi region is not being undertaken to the defined standards of HDA landfilling and is more akin to uncontrolled dumping. As a result there are associated environmental, health and safety (EHS) risks. However, if the World Bank funded Takoradi landfill project is reactivated a sanitary landfill could be available for these wastes eighteen months to two years from now. Residual concerns over the standard of operation would still exist (there are currently two World Bank funded sanitary landfills operating in other Regions of Ghana, Ashanti and Northern Region, both of which have run into operational difficulties). Apart from the potential Takoradi landfill (if it is developed), there is no BPEO option in the Western Region.

Waste Oils and Oil/Water Wastes

BPEO for management of waste oil s and oil/water wastes (including MARPOL Annex I Wastes) would be recovery/recycling via purpose built oil water separation systems or re-refining in the case of oils.

The Zeal Environmental Technologies arrangement with Takoradi Power Station means that a BPEO solution for oily waste separation is currently available in Ghana.

The only residual EHS concerns in relation to this are the pathways for use/disposal of the recovered materials (oil and water) and residual wastes (oily solids). As part of their duty of care, oil companies should aim to ensure, by periodic facility auditing, that:

(i) recovered oils are utilised in environmentally acceptable processes;
(ii) any water that is discharged is compliant with the facility discharge consents;
(iii) oily sludges are disposed of by environmentally acceptable means (see
(iv) previous discussion about use as fuel for heating or as wood preservative and discussion in the next sub-section).

Solid Wastes Contaminated with Oil or Other Organic Compounds

BPEO for such wastes would be high temperature incineration for heavily contaminated combustible materials. For inert solid wastes contaminated with oils (drill cuttings for example), low temperature thermal desorption would generally be the BPEO. Neither of these options exists in Ghana at the moment although Zeal Environmental Technologies is considering incorporating high temperature incineration at its newly acquired site. Whether or not such a facility is developed, and the timescale for it to become operational, will depend on several factors such as Zeal's confidence that there is sufficient market interest in such a service and its technical and financial capabilities.

Some wastes with low organic content, such as some drill cuttings, may be suitable for treatment by biological means (e.g. on land). Other wastes with levels of contamination may be suitable for hazardous waste landfill, however, this currently does not exist in Ghana.

Organic Chemical Wastes (Solid and Liquid)

BPEO for such wastes is high temperature incineration and the same comments as above apply. These wastes will need to be stored pending export for high temperature incineration.

Inorganic Chemical Wastes (Solid and Liquid)

Low toxicity non-hazardous solid inorganic wastes may potentially be disposed of to controlled landfill and in the absence of a reuse or recycling option this may be considered to be BPEO. Otherwise BPEO for liquid inorganic chemical wastes would be chemical treatment (not currently available in Ghana) or, in the case of some low concentration, low hazard, inorganic chemical wastes, treatment in wastewater treatment plants.

Whilst these options are not currently available in Ghana, Zeal Environmental Technologies has indicated that it is contemplating inclusion of physical/chemical treatment facilities at its newly acquired site. Given that the capital cost for this would be relatively low, there is a reasonable chance that Zeal will be able to develop such a treatment facility and so this option may possibly become available in the medium term (one or two years).

Solid and sludge products of chemical treatment would require disposal to sanitary landfill or hazardous waste landfill.

Healthcare Wastes

Small quantities of healthcare wastes are generated by oil and gas companies. These require incineration (preferred) or autoclaving and controlled landfill. A common solution employed is to have these wastes disposed of by a hospital locally. From discussions with the EPA, however, it is understood that none of the local hospitals have modern incinerators but instead use very basic combustors. This is therefore not an ideal route for the disposal of medical wastes although it may be the best practical solution at the moment

WASTE MANAGEMENT OPTIONS AND STRATEGY

SHORT TERM – four temporary Landfill sites

Ghana currently has a BPEO solution for MARPOL in Takoradi however there are few options for the management of most other types of wastes.

There are two sanitary landfills operating in Ghana, in Tamale and Kumasi, although these have operational issues, such as plant breakdown. In Takoradi, general solid waste management is still at the stage of uncontrolled dumping although there may be sanitary waste capacity in eighteen months to two years time.

There are no hazardous waste landfill facilities, no chemical waste treatment facilities and no thermal treatment facilities other than basic combustors for medical waste at some hospitals. This situation dictates that, in the short term, Tullow will undertake the

following.

1. Segregate those prime recyclable wastes for which there are recovery and
2. recycling markets in Ghana, periodically auditing the activities of the
3. recovery and recycling contractors to ensure that these wastes are managed in an environmentally sound manner.

Use the current STMA service for disposal of general solid domestic-type wastes ensuring that, as far as practicable, hazardous wastes and other wastes unsuitable for landfill are segregated from this waste stream.

Investigate the use of the oily waste processing facility at the Takoradi Power Station, and if used then implement a periodic audit to ensure that residual materials are managed in an acceptable manner.

Segregate and store industrial and hazardous waste that are unsuitable for landfill in a safe and environmentally sound manner pending export for environmentally sound treatment and disposal. Establish and implement procedures and plans for export of wastes from Ghana. The reliance on export, at least in the short term, will necessitate robust and effective documentation systems and procedures.

MEDIUM AND LONG TERM – Energy Plants and MRF's

As the situation in Ghana stands, Tullow have the following four choices in the medium and long term.

1. Continue to export wastes from Ghana for management in a country with suitable technology options for treatment and/or disposal.
2. Develop additional facilities for their own use.
3. Co-operate with municipalities and/or local companies to develop facilities for shared use.

While it is possible to continue the export of wastes for the foreseeable future, Tullow is currently considering options for encouraging the development of improved waste management facilities in Ghana. Other international oil companies operating in Ghana are in the same situation and therefore these companies may wish to cooperate with each other in promoting in some way the development of additional facilities.

Such support will focus on the development of new treatment and disposal options including some or all of the following.

1. Development of a hazardous waste landfill (potential for inclusion of a
2. hazardous waste cell in the design of the Takoradi Sanitary Landfill
3. project, the design of which is currently being reviewed by a local company on behalf of STMA for application for World Bank funding).
4. Development of a small-scale high temperature incineration facility.
5. Development of a physical/chemical treatment facility for predominantly inorganic wastes.

11. *Finance Energy Plant BOOT Model*

For these calculations we assume that a plant takes in 620 MT/day of MSW to produce the required 500 MT/day of RDF we remove the Metal, Glass, Stone and excess moisture if any from the incoming waste to produce the required 500 MT/day of RDF. This 500 MT/day with an average calorific value of 4,000 Kcal/kg will produce circa 32 Mwh per hour or 768 Mwh per day, also the average value for the metal, glass and stone will be after processing and commission paying in the region of US$ 20/- per ton sold at the gate. The 25 MT of Basalt type sand or gravel has no specific value so is set at US$ 5/- per ton at the gate. Carbon credits and methane credits have not been considered in this matrix.

Whilst we require a rate of US$ 185/- per plant for single or double plants, we require a slightly lower figure for multiple plants,

No.	Element and weight	Calculations	Contribution to PPA in US$
1	Metal, Stone and Glass	Here we assume that in any 620 MT/per day of MSW we get approximately 100 MT per day of Metal Glass and Stone 100 x 20 / 768 =	2.60
2	RDF	500 MT per day, 95% Organic, produced 32 Mwh per hour or 768 Mwh per day	85.36
3	Basalt type sand or Gravel	Production of average 25 MT/day at US$ 5/- = US$ 125/- per day	0.17
4	MSW not going to Landfill	620 MT/day of MSW not going to landfill at US$ 120/Mt US$ 74,400/- per day, this is an average world figure calculated for the proper construction of sanitized landfills to the accepted international standards with operation and monitoring costs of the landfill for its 30 year life. But is does not include End Of Life disposal Costs, because as of not this has not been considered but it will be high.	96.87
		Combined total cost of PPA including Zero Landfill and Electric Cost	**185.00**

NOTE :- Even if Ghana could manage to construct proper Sanitized Landfills at three quarters of the cost that it costs the rest of the world it would increase the Electric cost from US$ 85.36 per Mwh to US$ 109.58.10 per Mwh which lower than the Government is paying now for electricity, the only difference being is that our electricity is Green, Clean fully sustainable does not pollute the atmosphere and gains both Methane credits and Carbon Credits.

David J, Burton 29th November 2017

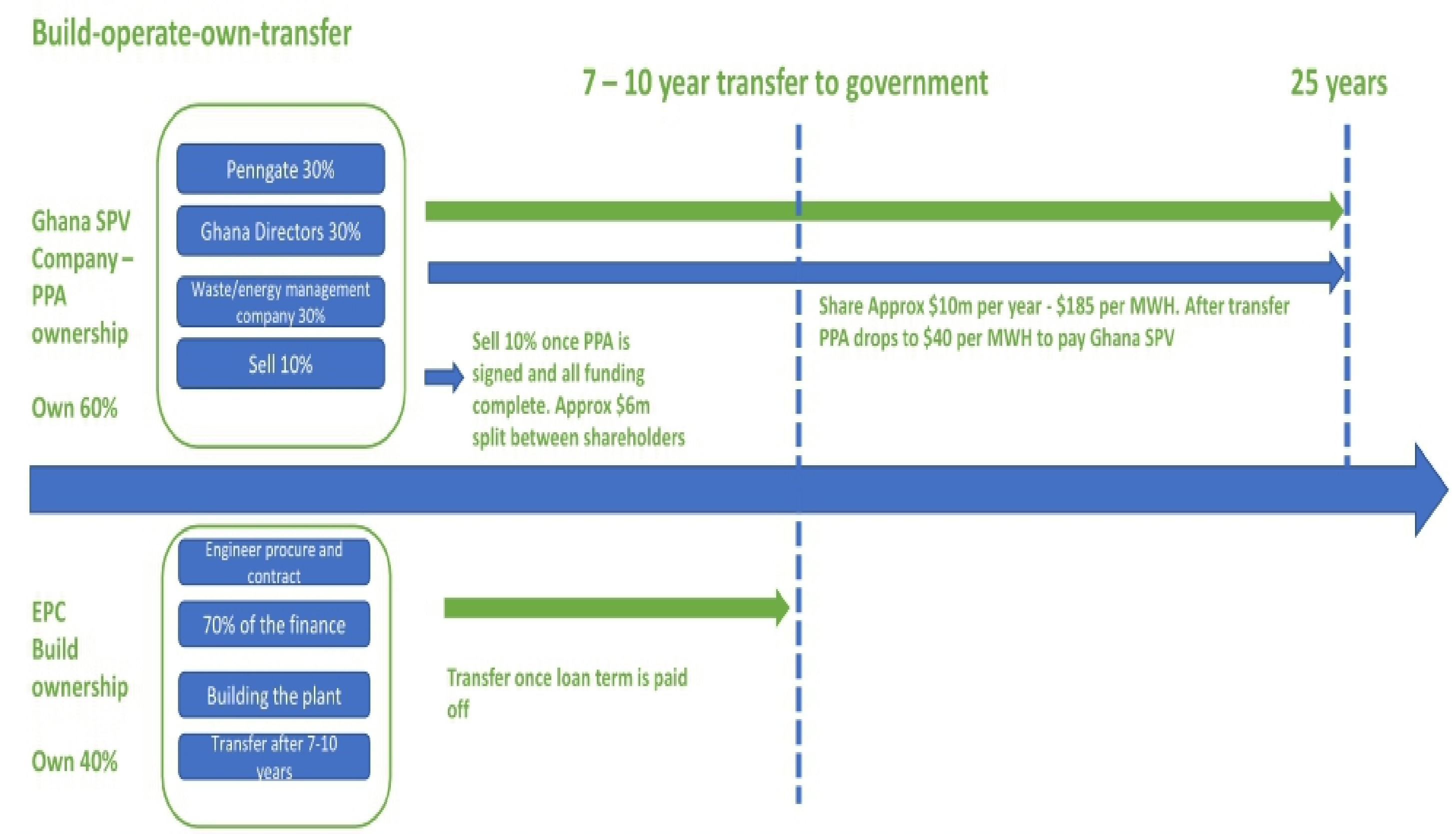

Build-operate-own-transfer
7 – 10 year transfer to government
25 years
Ghana SPV Company – PPA ownership
Own 60%
Penngate 30%
Ghana Directors 30%
Waste/energy management company 30%
Sell 10%
Sell 10% once PPA is signed and all funding complete. Approx $6m split between shareholders
Share Approx $10m per year - $185 per MWH. After transfer PPA drops to $40 per MWH to pay Ghana SPV
EPC Build ownership
Own 40%
Engineer procure and contract
70% of the finance
Building the plant
Transfer after 7-10 years
Transfer once loan term is paid off

Table 12 Energy Plant Revenue per annum

Assumptions - Based on Syngas Volume

SYNGAS

OP Assumptions	Value	Unit	Quantity
Operating Days per year		Day	365
MSW Consumption/Day		MT	630
RDF Consumption/day		MT	504.00
RDF Shred Size mm	8		
Number of 25MT UHTH Units	25		20
Calorific Value of RDF			4,200
Syngas Output/MT	31.25%	M3/MT	1,313
Syngas Produced /Day		M3/Day	661,500
TM Units per day @ Syngas M3/H	1140	No.Units	24.18
Electricity Output KW	1970	KW/Hr	47,630
Electricity Output MW		MW/Hr	47.63
Total MW Electricity Output/Day		MW/Day	1,143.12
Total Electricity Usage		MW/Day	215.81
Solar Roof Contribution		MW/Day	0.00
Wind Power Contribution		MW/Day	0
ORC - Heat Recovery 7%		Mw/day	114.31
Total Available Electricity For Sale		MW/Hr	43.40
Total Available Electricity For Sale		MW/Day	1,041.62
Total Available Electricity For Sale		MW/Year	380,190.72
Plant electrical usage as % of total UHTH supply			17.16%

FIXING CALCULATION			
Conversion of Calorific Value to Syngas	3200	Kcal = M3	1,000
Ratio of M3 Syngas from Kcal		MT to M3 %	31.25%

Price Setting Assumptions		
$ Per MW	(550) $ Per MT	$/MW
Energy PPA fee	Waste Rec. Fee	Total
185.00	0.00	

OMR to $ Rate	2.6
OMR to €	2.37
$ to €	0.91
Equity %	0%
Finance %	100%
Finance Term	10
Finance Rate %	3%
Dpcn Dclng Bal.%	10%
Corpt Tax Rate %	0%

Escalation Per Anum	
Sales Rev.	4%
Labour Cost	3%
Others	2%

Investment arranged by Penngate	
Cash raised	$10,000,000

Revenue Assumptions	Unit		Quantity
ENERGY REVENUES			
Primary Revenues			
PPA Contract Fee	US $/MWh	$	185.00
Days of Operation			365
Saleable Energy/ day	MWh		1,041.62
Yearly Energy Revenues		$	70,335,284
MSW Tipping Fee in US $ per ton/day	630	$	-
Annual	365	$	-
OTHER REVENUES			
Basalt Sand/Gravel (MT/day)	25.2	$	0.35
Annual	365	$	3,219
Aluminum Recovery /ton	22.05	$	65.00
Aluminum Revenues (yearly)		$	523,136
Other elements /ton	40.95	$	35.00
Other Elements Revenue (yearly)		$	523,136
Carbon Revenues			
Crediting Period (Years)			10
Net Carbon Credits for sale			135,000
Carbon Credit Value / ton		$	0.50
Yearly Carbon Credit Revenues		$	67,500
Total Annual Other Revenue		$	1,116,992
Total Revenue per Year $		$	71,452,276

Appendices

Appendix 1	**Municipal Solid Waste Management in Developing Countries (Separate document)**
Appendix 2	**Energy Plant**
Appendix 3	**Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana (Separate document)**
Appendix 4	**Financial Investment Package**
Appendix 5	**Making-waste-Work-Toolkit_Vol - 2-How-to-guides-1.pd (Separate Document)**
Appendix 6	**Energy Plant Financial Spreadsheets**

Appendix 2 Energy Plants & Financial Capex

Technical Introduction

of the

Ultra High Temperature Hydrolysis (UHTH)
Waste to Energy Technology

1

Energy Plant CAPEX assumptions

Assumptions - Based on Syngas Volume

SYNGAS

OP Assumptions	Value	Unit	Quantity
Operating Days per year		Day	365
MSW Consumption/Day		MT	630
RDF Consumption/day		MT	504.00
RDF Shred Size mm	8		
Number of 25MT UHTH Units	25		20
Calorific Value of RDF			4,200
Syngas Output/MT	31.25%	M3/MT	1,313
Syngas Produced /Day		M3/Day	661,500
TM Units per day @ Syngas M3/H	1140	No.Units	24.18
Electricity Output KW	1970	KW/Hr	47,630
Electricity Output MW		MW/Hr	47.63
Total MW Electricity Output/Day		MW/Day	1,143.12
Total Electricity Usage		MW/Day	215.81
Solar Roof Contribution		MW/Day	0.00
Wind Power Contribution		MW/Day	0
ORC - Heat Recovery 7%		Mw/day	114.31
Total Available Electricity For Sale		MW/Hr	43.40
Total Available Electricity For Sale		MW/Day	1,041.62
Total Available Electricity For Sale		MW/Year	380,190.72
Plant electrical usage as % of total UHTH supply			17.16%

FIXING CALCULATION			
Conversion of Calorific Value to Syngas	3200	Kcal = M3	1,000
Ratio of M3 Syngas from Kcal		MT to M3 %	31.25%

Price Setting Assumptions		
$ Per MW	(550) $ Per MT	$/MW
Energy PPA fee	Waste Rec. Fee	Total
185.00	0.00	

OMR to $ Rate	2.6
OMR to €	2.37
$ to €	0.91
Equity %	0%
Finance %	100%
Finance Term	10
Finance Rate %	3%
Dpcn Dclng Bal.%	10%
Corpt Tax Rate %	0%

Escalation Per Anum	
Sales Rev.	4%
Labour Cost	3%
Others	2%

Investment arranged by Penngate	
Cash raised	$10,000,000

Revenue Assumptions	Unit		Quantity
ENERGY REVENUES			
Primary Revenues			
PPA Contract Fee	US $/MWh	$	185.00
Days of Operation			365
Saleable Energy/ day	MWh		1,041.62
Yearly Energy Revenues		$	70,335,284
MSW Tipping Fee in US $ per ton/day	630	$	-
Annual	365	$	-
OTHER REVENUES			
Basalt Sand/Gravel (MT/day)	25.2	$	0.35
Annual	365	$	3,219
Aluminum Recovery /ton	22.05	$	65.00
Aluminum Revenues (yearly)		$	523,136
Other elements /ton	40.95	$	35.00
Other Elements Revenue (yearly)		$	523,136
Carbon Revenues			
Crediting Period (Years)			10
Net Carbon Credits for sale			135,000
Carbon Credit Value / ton		$	0.50
Yearly Carbon Credit Revenues		$	67,500
Total Annual Other Revenue		$	1,116,992
Total Revenue per Year $		$	71,452,276

Total Revenue Per Year €	€	65,021,571

INDEX

Page Number

1 Executive Summary

1.1 Ultra High Temperature Hydrolysis (UHTH) technology is a patented highly efficient proven technology, which offers a Waste to Energy (WTE) solution; where by the Municipal Solid Waste (MSW) is converted to initially a Syngas and then immediately to Electricity.

This technology employs the application of:

Intense induction heating system and specially developed materials which withstand high temperatures above well above the normal operating temperatures, of between 1150 - 1300°C, without corrosion or oxidation.

The UHTH technology is the most efficient convertor of Waste to Power currently on the market, in terms of MSW received and processed to Kw/hr produced and supplied.

It is also one of the only process's that can convert all MSW (that has a carbonaceous and organic content) to a usable clean electrical energy.

1.2 The Ultra High Temperature Hydrolysis reaction used to produce Syngas is "the destructive distillation of an organic or carbonaceous material". This distillation process involves the application of intense, indirect, thermal energy in the absence of oxygen, which reduces the organic/carbonaceous material 100% to a combustible gas, and the inorganic content to a non-hazardous, non-toxic, non-leachable, basalt-like residue.

1.3 The WTE Plant will receive ALL fresh, unsegregated and un-recycled MSW material in sufficient daily volumes, which are processed to produce a segregated and shredded Refuse Derived Fuel (RDF) that is then converted by the UHTH reactors to a clean Syngas. The Syngas is then used to power specially developed efficient gas engine generators, which together with an Organic Rankin Cycle (ORC) to recover waste heat, will produce power for the local MV/HV Electrical Grid system.

1.4 All MSW and industrial waste materials, including toxic waste can be handled, and there are no emissions from the reaction process, and no waste materials are sent to landfill.

The UHTH technology process eradicates existing toxic substances within the MSW, and it prevents formation (or reformation) of these toxic substances.

The only MSW items not processed into RDF are items such as glass, ceramics, metals and stone/rocks. These are removed during the process of MSW to RDF production, and are sent for normal recycling.

No Segregation of MSW is needed, and all types of MSW, including clothing, paper, rubber, vinyl, chlorinated plastics etc are converted into Syngas.

1.5 Highly efficient Waste to Energy conversion. 1 Metric Tonne (MT) of RDF (at 3,700 Kcal/kg) = ~1,924 Kwh of electrical power.

The WTE Plant is a fully scalable size: Capable of receiving from 650 MT to 2,000 MT of MSW per day which converts to ~500 – 1500 MT of Refuse Derived Fuel (RDF) per day.

500 MT of RDF Plant = ~42.5Mw/hr = 1,020 Mwh/day

1,000 MT of RDF Plant	**=**	**~85 Mw/hr**	**=**	**2,040 Mwh/day**
1,500 MT of RDF Plant	**=**	**~ 127.5Mw/hr**	**=**	**3,060 Mwh/day**

1.6 Short construction and commissioning periods 18-22 months (for a typical WTE Plant).

1.7 A UHTH WTE Plant operates 365 days per year, in a 3-shift system, and will employ approximately 150 - 200 staff (for a standard 500 MT of RDF per day WTE Plant).

1.8 There are no planned total plant shutdown requirements, as all plant maintenance is scheduled using the parallel and in-built redundancy of the plant's system/units.

1.9 The UHTH Plant saves the municipality the Landfill costs and management of approximately $120/MT. Therefore the UHTH based WTE Plant will save the Municipality:

650 MT/day of MSW Plant saves $28.4M/yr

1500 MT/day of MSW Plant saves $65.7M/yr

2250 MT/day of MSW Plant saves $98.5M/yr

2 Introduction & What is UHTH Technology?

2.1 New Centre Energy's 'Ultra High Temperature Hydrolysis' (UHTH) technology is a patented and highly efficient proven waste to energy technology, owned and developed by New Centre Energy's major shareholder, Peter Jeney, Switzerland.

The UHTH Technology offers a green and completely emission free Waste to Energy (WTE) solution, where by all Municipal Solid Waste (MSW) is converted to a Syngas with no toxic emissions, and then into 'clean' Electricity.

The process works by taking **ALL** MSW material destined for landfill waste dump sites, and removing the inert type materials for normal local recycling, such as metal, glass, stones, ceramics etc. All other items can remain within the MSW to be produced into a usable RDF for the UHTH reaction process. This way there are no residue items to be taken for landfill.

Unlike traditional Incinerators and other Waste to Energy technology, the UHTH reaction process does not require organics or the highly toxic plastics to be removed from the RDF produced. In effect, and for the first time, the UHTH technology can process all organic and carbonaceous waste materials cleanly and efficiently by eradicating existing toxic substances within the MSW, and it preventing formation (or reformation) of these toxic substances.

The UHTH Reactor converts organic and carbonaceous waste materials in an oxygen free environment at very high temperatures to form a syngas for power generation.

The syngas undergoes a cooling and scrubbing treatment process that removes unwanted particulates prior to the gas being sent the gas engine generators for power production.

The UHTH Reaction process is highly efficient and produces high amounts of power. Typically, and depending on the kcal/kg values of the MSW, one ton of MSW/RDF can produce between 1500kWhr to 2000kWh of power. This power can then be stepped up to 132kV for connection on to a local HV grid.

2.2 UHTH technology uses the application of **intense, indirect thermal energy in the absence of oxygen in a controlled environment;** so that there is a chemical distillation of the organic material, which reduces that material to a combustible gas (Syngas) and a hazard free, non-leachable inorganic basalt type sand/gravel.

The absence of oxygen means that the process is not a burning or incineration process. It is a controlled chemical reaction resulting from the application of very high temperature.

The use of steam shift technology (introduces $H^2 0$ molecules at over 200°C into the reactor when moisture is lacking or there are particularly high CO levels) to improve the overall conversion process and the quality of clean Syngas produced.

In order to smooth the reaction times and make the whole process more predictable, the MSW material is processed into a consistent Refuse Derived Fuel (hereinafter called 'RDF') with a nominal shred size of < 10mm, which is control fed to the UHTH units.

The resultant Syngas is converted to electricity using gas engines generators plus the application of a waste heat recovery system. The non-leachable, inert basalt sand/gravel can be used for construction.

No Landfill – No Harmful Emissions

2.3 A Plant's effective performance is therefore the combination of 3 key main processes; MSW Treatment to an RDF material, the UHTH RDF conversion process to a Syngas, and the Power Generation process to produce Electricity for sale to the Grid.

3 Environmental and Emissions Statements (The Toxic Issue)

3.1 The UHTH technology is able to process **treat and eradicate** the most harmful toxic and problem waste streams. This is because it operates at temperatures in excess of 1100°C and it will therefore destroy the toxicity of the input feed material.

Existing Dioxins are destroyed in the UHTH process and none are created. The UHTH completely eradicates those previously locked-in problems emanating from Chlorinated Plastics, other Plastics, Rubbers and Vinyl's of all types.

The Syngas directly from the UHTH rectors is quenched in an oxygen free environment at high speed from 1300°C to 50°C, and therefore there is insufficient time for Dioxins and Furans to form or reform.

An additional benefit of the UHTH process over the older incinerator and pyrolysis technologies is that tar formation is avoided thus improving operational output levels and reducing the maintenance costs.

There are no harmful or toxic emissions or residual toxic substances from the UHTH process. Therefore this UHTH technology is able to handle a wide variety of waste types and especially those problem types that are toxic and contain Environmentally Persistent Organic Pollutants (POPs) also known as PBTs (Persistent, Bio-accumulative and Toxic) or TOMPs (Toxic Organic Micro Pollutants), particularly from Chloride based plastics and synthetic materials, which our UHTH can process and eradicate effectively.

This means that ALL MSW material from the Municipal waste streams can be processed through the UHTH WTE Plant thus avoiding the need for segregation.

NO REMOVAL OF CHLORINATED PLASTICS/VINYL'S/RUBBERS.

3.2 The UHTH technology meets the "BImschV" certificate, one of the top Environmental Certificates, earned during a 3-5 year period whilst operating industrial plant under the scrutiny of the German Environmental Ministry monitoring under German rules, which is one of the most stringent in the world. The Plant will meet and exceed the Government of India regulations on emissions and will comply with world health legislation.

An Environmental Company, will conduct an in-depth Environmental Impact Assessment (EIA) and to ensure that the project and the technology is fully registered and approved by the appropriate authorities.

Plans are in hand to collect and process any water emanating from the plant area and this includes the sewage.

The UHTH Plant saves the municipality the Landfill costs and management by converting MSW to either recyclables or electrical energy. As each MT of landfill has a "lifetime cost" of around $120/MT , (2015 UAE Waste Disposal Cost Report). The UHTH Plant will save the Municipality

650 MT/day of MSW Plant saves $28.4M/yr

1500 MT/day of MSW Plant saves $65.7M/yr

2250 MT/day of MSW Plant saves $98.6M/yr

4 The Energy To Power Calculation

4.1 Locked-In Calorific Values

The following chart gives the average calorific values of various waste streams

ENERGY MATERIAL	APPROXIMATE Kcal / kg	ENERGY MATERIAL	APPROXIMATE Kcal / kg
Bamboo	3'800	Paper sludge	3'910
Braun coal	4'500	Paper coated	6'390
Cacao shrub	3'300	Paper adhesive coated	4'200
Cardboard	3'800	Newspaper	3'910
Cardboard corrugated	3'910	Tar paper	6'390
Citrus peels	4'500	Paraffin	10'340
China grass	4'030	Polyethan foam	9'770
Car Tyres	8'300	Polyethylene	10'990
Coconut shell	3'800	Polypropylene	11'030
Coffee bean shells	6'000	Polystyrol EPS	9'800
Compost	4'200	Polystyrol carbon reinforced	10'840
Cork	6'300	Rice pods	2'900
Corn	4'400	Rubber	5'600
Cotton seeds	3'300	Sewage sludge (dried)	3'300
Hay	3'200	Sunflower residue	4'200
Household Waste (pulverized)	3'500 – 4'500	Straw	4'000
Hospital waste	6'780	Tobacco powder	3'000
Leather	4'020	Tar & Refinery residues	9'200
Manure (dried)	3'760	Tar acid	5'600
Neoprene	7'100	Textiles	4'000
Nylon	7'570	Treated wood	4'500
Oil sludge	8'800	Untreated wood	4'200
Paper	4'400	Plywood	4'500

4.2 UHTH Test Results/Analysis

The following chart provides the detailed results from various RDF UHTH process runs

Pos.	Waste Type	Abfalltyp	Calorific Va / Kalorienwert / kcal	Humid / Feuchtgkeit / in %	Theoreti Gas Volu / Theoretsiches Gasvolumen / m3	Gas Composition in Vol % / Gaszusammensetzung: CO	CO2	CH4	H2	Tota / Summe / Vol. %	Other Gases / Andere Gase / Traces / Spuren
1	Tobacco Husks	Tabackpflanzen		32		30.43	14.87	2.42	26.99	74.71	NH3, H2SO3
2	Coal Fines	Kohlestaub	3600	9	1080	45.51	20.02	1.72	28.12	95.37	
3	Coal Fines	Kohlestaub		16		22.78	19.80	2.82	30.44	75.84	
4	Chicken Droppings	Hühnermist	3300	20	990	30.34	14.31	15.84	30.49	90.98	H2SO3, C2H2
5	ASR	Autoshredderrückstände		37		19.00	9.50	9.80	31.90	70.20	
6	Recycling Residue Pellets	Recyklingabfall pelletiert	7600			24.27	5.83	11.72	35.69	77.51	
7	Platic Wood Mix	Plastik-Holz Mix	3900	23	1170	45.33	8.87	2.50	43.19	99.89	
9	MSW	Haushaltsabfall	4900	18	1470	22.04	4.62	22.11	45.66	94.43	H2SO3, C2H2
10	Animal Farine	Tiermehl	4700	60	1410	41.50	3.75	3.00	46.00	94.25	N2, CH2H2, CH2H4
11	Wood Pellets	Holzpellets		11		40.19	4.85	1.64	48.00	94.68	
12	MSW	Haushaltsabfall	5200	20	1560	23.50	0.95	11.46	48.74	84.65	H2SO3
13	Automobile Waste (ASR)	Autoshredderrückstände	6500	15	1950	26.76	2.21	0.73	49.67	79.37	NH3, H2SO3, NO2, C2H2
14	ASR - Low Grade	Autoshredderrückstände	2900	18	870	28.28	4.91	16.25	49.88	99.32	NH3, H2SO3, C2H2
15	Extruder Waste (PET)	Extrudermaterial (PET)	6000	20	1800	35.05	3.77	5.67	52.54	97.03	H2SO3, C2H2
16	Tires	Altreifen		2		14.11	1.90	2.60	52.71	71.32	NH3, H2SO3, NO2, C2H2
17	Cotton Shrub Pellets	Baumwollstauden pelletiert		16		34.34	6.14	2.48	56.54	99.50	
18	Filter Cake	Filterkuchen		17		29.87	2.63	1.79	62.96	97.25	
19	Tires	Altreifen		2		13.46	1.40	4.46	65.35	84.67	
20	Plastic Granulate	Plastikgranulat	7600	14	2280	10.94	0.74	2.89	66.90	81.47	H2SO3

The Trace Gases are either scrubbed or allowed to flow through to the electrification Gas Engine Generators as part of the input specification of the desired Syngas.

4.3 Example Process Calculation of RDF to Electricity

For a simple base case analysis, using the Syngas volume calculation, run over a 24 hour period the results would be:

- **1 MT of 3700 Kcal/Kg RDF creates ~1104 M^3 of Syngas : 20 off 25MT/day UHTH = 551,989 M^3 /day**
- **Each JMS 620 GEG uses 1,140 M^3/Hr of Syngas = ~20.18 GEGs**
- **Each GEG produces 1,970 Kw/Hr = 37,464Kw/hr = ~37 Mw/Hr**
- **Off-Heat ORC recovery contributes 7% extra power = ~2.6 Mw/Hr**
- **Plant total electrical output = 42.53 Mw/Hr = 1,020 MW/day = 372,536 Mw/Hr/yr**

MSW RECEIVING
MT/DAY
650

RDF BUFFER
MT/DAY
500.00
Kcal VALUE/Kg
3,700

UHTH PROCESSING / DAY		
MT/Unit/Day	% Syn/MT	Vol. Syn M3
25	29.84%	551,989.15
UHTH UNIT QTY		
20.00		

ELECTRIFICATION	
Vol/Unit/Hr	UNIT KW/Hr
1140	1970
UNIT QTY	Off-Heat
20.18	137.9

ELECTRIC REVENUE
Produced MW/Hr
42.53
Produced MW/Day
1,020.65
Produced MW/Yr
372,536.27

RECLAIMED MT/DAY				BASALT SAND/GRAVEL MT/DAY
Glass	Metal	Stone	Moisture	
22.75	23	22.75	182	25
250.25				

5 The Process Overview

Under the principal that energy can neither be created nor destroyed but can be changed, the UHTH technology converts efficiently all the organic and carbonaceous matter in the RDF into a Syngas.

This Syngas is scrubbed and cleaned. The residue from scrubbing is fed back into the system and eventually chemically incorporated into the Syngas or basalt like gravel or sand, which is non-leachable and inert. The cleaned Syngas is then used to feed gas engines generators to produce electricity, whilst the exhaust gas is fed into an ORC Waste Heat Recovery system, which produces additional electricity.

Essentially therefore there are three core processes:

Waste Receiving, Treatment and Processing (MSW processing to an RDF)

Hydrolysis *(Gasification)* *(production of Syngas, scrubbing and buffering)*

Electrification (Syngas conversion to electricity and supply to Grid)

The supporting facilities and systems on the site are:

Plant enclosure buildings, Staff changing/cleaning and small canteen, Other Facilities such as:

Offices and Medical Centre, Observation and Control Centres, Security/gates entry buildings with weigh bridges, Security and staff access control systems, Fire and Safety systems, Maintenance and Spares storage area and buildings

The UHTH waste to energy Plant works 24/7 therefore there is an uninterrupted sustainable power supply to the National Grid based on the constant supply of fresh and decaying Municipal Solid Waste from the Municipality.

6 Plant Input

6.1 Types of waste received

The list of waste that can be received and processed by the UHTH system is very comprehensive. A outline (but not exhaustive) descriptive list is therefore:

General Municipal (including supermarket, hotel, restaurant and shops etc.)

General Industrial

Organic Demolition Waste

Old Municipal Waste (from existing landfill/dumps)

All types of Plastics, Rubber, Vinyl's

Auto Shredder Residue (ASR) and Car Fluff

Vehicle Tires and Inner Tubes

Heavy Oils and Tar sands

Coal Fines

Biomass, Bio Diesel & Black Liquor

Animal Waste/Manure

Animal Rendering (meat and bone)

Agriculture and Forestry Waste

Bark and Woods, Rapeseed Residue

The following waste streams are not currently part of this proposal however if desired NCE are ready to examine the feasibility of their inclusion.

Sewage, Waste Water & Industrial & Oil – Sludge*

These can be handled by the UHTH system, however, the types and volumes will need to be discussed in order that special receiving and processing can be included in the plant design. Special areas can be allocated for later development to accommodate such material.

Hospital/Infectious, Hazardous and Toxic Waste**

This can be treated, however, special handling conditions will need to be discussed. If desired either a special receiving area (with controlled conditions of receipt and staffing) would be planned, or, alternatively, a pre-treatment system could be installed closer to the waste source for immediate treatment so that safe transport of the residue can be made to the Waste to Energy plant. Local Authority requirements will need to be considered.

Of Special Note: *The only waste that cannot be feasibly processed by the UHTH system is* ***Radioactive*** *and* ***Nuclear****.*

The Plant as presented in this proposal is primarily designed to receive all types of Municipal Solid Waste (MSW) emanating from private, commercial and light industrial sources.

6.2 Waste Receiving Area

The purpose of the waste receiving area is the safe receipt of MSW material being delivered to the Plant, be it municipal, special delivery oils, liquids/sludge or hazardous/toxic as finally agreed with the authorities.

There are therefore up to five primary receiving areas:

Standard municipal waste

Non-standard municipal waste

Special Tyre and/or a battery area (if required)

Toxic/hazardous (by special arrangement)

Liquid station (oils and fats) as agreed

The primary input will be the daily arrival of predominantly MSW. Each truck entering the site will be recorded, photographed and weighed. It will tip into the receiving bins/areas and exit having been fully recorded and weighed.

All records will be consolidated into daily, weekly, monthly and annual charts, shared with the municipal authorities.

The plant will be designed to safely and consistently receive sufficient MSW so that the waste processing system can convert it to a finely shredded Refuse Derived Fuel (RDF), ready for UHTH processing.

6.3 Waste Processing System

The main purpose of processing MSW prior to UHTH Syngas production is to remove all possible inert/inorganic non-carbonaceous material and to prepare the waste as an RDF for feeding to the UHTH units

The MSW will arrive in truck form and will be tipped into the receiving area, which have the capacity to hold 1-2 days of MSW.

The MSW is then processed through a series of shredders, trommels, magnets, ballistic separators and screens that separate ferrous, non-ferrous, glass, and other inert material. The final material is shredded to a consistent maximum 10mm size and becomes the Refuse Derived Fuel (RDF).

The RDF is buffered at this point ready for feeding to the gasification intake vessels. The RDF buffer volume is equivalent to around 1-2 days UHTH processing capacity.

The ejected inert materials are collected separately in appropriate bins ready for disposal into the recycling market. This is mainly hard-core, glass and metals.

Capacity of Waste Input

The waste to energy Plant will be capable of receiving MSW in sufficient weights of MSW that allows sufficient weights of RDF per day to be produced. This means to create sufficient RDF, depending on typical local conditions and moisture/water content a larger volume/weight of MSW will be received and converted to dry-ish and finely shredded RDF ready for the UHTH process.

6.4 UHTH Syngas Production

The UHTH system is essentially superior to all existing waste disposable technologies. The core of each UHTH Plant is the worldwide, patented ultra-high temperature hydrology reactor.

This technology employs the application of:

Intense induction heating system and specially developed materials which withstand high temperatures above well above the operating temperatures of between 1150 - 1300°C, without corrosion or oxidation.

Ultra High Temperature Hydrolysis reaction to produce Syngas is the destructive distillation of an organic or carbonaceous material. This distillation process involves the application of intense, indirect, thermal energy in the absence of oxygen, which reduces the organic/carbonaceous material 100% to a combustible gas, and the inorganic content to a non-hazardous, non-toxic, non-leachable, basalt-like residue.

Moreover the UHTH process does not have any environmental emissions and therefore it does not have a chimney or flue, meaning there is no toxic ash residue associated with most other incineration type systems.

As temperatures are very high all Toxins and Toxics in the feed material are broken down and eradicated. The formation of the gas and its subsequent quenching eliminate the potential reformation of any Toxins or Furans due to the absence of oxygen and the speed of quenching.

The technical reason for no flue with a UHTH System is that UHTH gasification produces a high calorific syngas in a "closed circuit". This gas can then be used to operate a steam turbine or gas turbine. The NOX and CO2 emissions are extremely low, NOX 2 and CO2 virtually zero, because the CO2 is converted into dirty Methanol, which is again gasified in the UHTH reactor, therefore no emissions and no flue or venting to atmosphere.

Cracking of the organic material into a low molecular combustible gas, using high temperatures in an oxygen-free environment:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

$$C + H_2O \rightarrow CO + H_2$$

$$C_nH_m \rightarrow CH_4 + H_2 + C$$

$$C + CO_2 \rightarrow 2\,CO$$

Cracking of organic material with added Steam Shift technology.

$$C + H_2O \rightarrow CO + H_2$$

$$CH_2 + H_2O \rightarrow CO + 2H_2$$

$$CO + H_2O \rightarrow CO_2 + H_2$$

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

The above formulas are the conversion of non-useable organic energy to a useable energetic Syngas. This transformation only happens above a temperature of 1150°C, the result is an exceptionally clean gas. Only at such elevated temperatures can the tar content be converted to energy, which does not result in contaminating the gas.

"Competitive" systems rarely operate above 900°C and consequently suffer from various well-known disadvantages including the tar contamination of the gas that generally limits the commercial use.

Special care is therefore taken by the UHTH process to ensure that no tar formations are allowed to form. However, if any small particulate trace elements of tar do form, it is only permitted at the quenching stage where it can be easily collected in the water quenching system and these fine particulate trace elements can be easily removed within the water treatment phase of the gas treatment facilities.

The UHTH technology is the most efficient convertor of Waste to Power currently on the market, in terms of MSW received and processed to Kw/hr produced and supplied.

It is also one of the only process's that can convert all MSW (that has a carbonaceous and organic content) to a usable clean electrical energy.

An Example of the typical conversion factors based on a standard size (500 MT RDF) UHTH WTE Plant are shown in the below table; which illustrates the amount of potential Syngas and electricity from various calorific values using the UHTH process and generator package (with heat recovery process):

Average Calorific Value	Average Syngas/Day	Approximate Electrical Output (incl. Off-Heat)	
Kcal/Kg	Cubic Meters	MW/Hr	MWH/Day
3500	522,151	40.23	965.52
4000	596,745	45.98	1103.52
4500	671,338	51.72	1241.28
5000	745,931	57.47	1379.28
5500	820,524	63.22	1517.28

The typical composition of the Syngas produced is

Element			UHTH Syngas
Methane	CH4	Vol. %	~4
Ethan	C2H6	Vol. %	~6
Propane	C3H8	Vol. %	-
Nitrogen	N2	Vol. %	>5
Carbon Monoxide	CO	Vol. %	40 – 60
Carbon Dioxide	CO2	Vol. %	>2
Hydrogen	H2	Vol. %	40 - 60
Low Heating Value	LHV	MJ/NM3 Kcal/NM3	13 3,100

However some variation can be expected depending on the MSW/RDF composition and using Steam shift can be adjusted to meet gas engine feed composition requirements.

The standard size NCE WTE Plant uses twenty individual 25 MT/day reactors, operating in parallel. There are usually one or two extra units installed to provide high levels of availability and maintainability, so that the Plant never shuts down for maintenance. Maintenance is therefore a scheduled cycle through the units and processes.

The Syngas is scrubbed using standard Acid and Caustic Soda scrubbers and the scrubbed elements are either sold if they have intrinsic value, or re-inserted back into the front of the gasification system to be re-treated.

7 Plant Output

7.1 Electrical

The available Syngas (depending on Calorific value of MSW/RDF) is the primary power feed supply to the engines/turbines and may be sufficient to allow production of circa 60,000 KW/hr of electricity per hour or 1,440 MW per day. This will only be known as MSW is received and processed and Plant data is built up based on local MSW conditions and Kcal values of that MSW.

Gas Engine/Turbine Generators

Each gas engine/turbine generator will produce circa 1900 - 2,000 KW per hour and consume approximately 1140 m3/hr of syngas.

The electrical output from the Gas Engine Generation facilities will be consolidated in to a single synchronised feed of 11 Kva.

7.2 Electrical Output Grid Feed & Monitoring Facilities

The Plant will have multiple gas engines/turbine generators, each capable of producing around 1900 - 2,000 KW/hour. A typical configuration of a Standard WTE Plant, will have 24 - 30 off Gas Engine Generators available. This gives the plant both full maintenance cover, as well as flexibility to increase plant output if RDF is of particularly high calorific value.

There will be two grid connection terminals on this switchboard, which will provide 100% redundancy for connection onto the grid.

The Monitoring facilities will be fiscal meters with secondary metering.

7.3 Off-Heat Electricity

A key technology used by the plant is the Waste Heat Recovery System (Organic Rankin Cycle) steam turbine generators. These capture substantial power using standard steam technology.