WASTE TECHNOLOGIES LTD
PLASICS TO DIESEL PROCESS

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FREQUENTLY ASKED QUESTIONS

1. What is the solution to the growing stockpiles of waste plastic destined for landfill?

The production of gasoline, kerosene and diesel from waste plastics is an emerging technological solution to the vast amount of plastics that cannot be economically recovered by conventional mechanical recycling operations. This involves the use of pyrolysis which permits recovery of valuable gasoline and diesel-range hydrocarbons from waste plastics that are otherwise landfilled.

Pyrolysis recycling of mixed waste plastics into generator and transportation fuels is now seen by many as the answer for deriving value from unwashed, commingled plastics as well as managing their desired diversion from landfill.

The viability of pyrolysis is assured by the lack of other recovery options for such waste plastics besides landfilting and incineration. Factors such as the increasing pressure on companies to adopt sustainable outlets for their end-of-life plastics; the introduction of extended producer responsibility and product stewardship directives; together with the implementation of legislative measures to deal with waste plastics, are significant drivers that will further increase the adoption of the pyrolysis route for waste plastics.

2. What is the Waste Technologies Process?

The Waste Technologies Plastic-to-Diesel process reliably produces transportation-grade (road use), low-sulphur diesel from mixed waste plastics. The Waste Technologies process has solved all the traditional problems associated with pyrolysis technology. The process employs patented highly-energetic far infra-red (FIR) heating rods that promote efficient cracking and minimise coking problems. Far infra-red radiation is highly energetic and close to the microwave region of the electromagnetic spectrum.

3. What feed stocks does the Waste Technologies process handle?

The Waste Technologies plant currently handles mixed waste plastics, waste oils and crude oils in any combination. In addition, Waste Technologies engineers are presently developing a plant to process tyre chips but the pre-processing unit and the desulphurization system are different.
4. What is Pyrolysis?

Pyrolysis of plastics thermally degrades the plastic, breaking the bonds of the polymer to produce lower molecular weight oligomers and monomers. The vapours resulting from the process are condensed to produce an oil/wax hydrocarbon product which has a high degree of purity and which are further refined in the process by selective fractionation to give predominantly diesel fuel. Pyrolysis typically takes place at relatively low temperatures in the range 350-450 deg.C. Pyrolysis transforms organic materials into carbonaceous char, oils and gases.

During pyrolysis, the macromolecular structures of polymeric materials are broken down into smaller molecules, resulting in a wide range of hydrocarbons being formed. These pyrolytic products can be divided into a non-condensable gas fraction, a liquid fraction (consisting of paraffin’s, olefins, naphthenes and aromatics), and solid residues (i.e. char).

Pyrolysis of waste plastics appears simple in concept. However, thermal cracking often yields low-value mixtures (cocktails) of hydrocarbons having very broad compositional range, sometimes extending from light alkane gases to coke. It is therefore necessary to find the optimal pyrolysis conditions and upgrading process (e.g. fractionation and desulphurization) to obtain marketable products (e.g. diesel fuel or gasoline) from plastic wastes.

5. How does the Waste Technologies process ensure a high quality diesel output?

Controlled thermal degradation using internal far infra-red heating, as used by Waste Technologies in its plant, yields a much narrower product distribution of carbon atom number and reduces the reaction temperature as compared with other processes.

The temperature and heating rates have considerable influence in the pyrolysis process and can be controlled to produce desired solid, gas and liquid products. Pyrolysis at very slow heating rates coupled with a low final maximum temperature maximizes the yield of solid (char). Waste Technologies plant is capable of faster heating rates than conventional processes (because it utilises internal far infra-red heating) and this reduces the yield of solid (char) resulting in increased efficiency. Far infra-red radiation is highly energetic since it is close to the microwave region of the electromagnetic spectrum (see figure below)
In addition to temperature, the type of pyrolysis reactor is also important in determining product yield. High heating rates with short hot zone residence times and rapid quenching of the products are regarded as favouring the formation of diesel products. The removal of pyrolysis products from the hot zone reduces the extent of secondary reactions which are known to increase the yield of char and gas at the expense of liquid fuel formation.

6. What are the product yields from pyrolysis?

Product yield is related directly to the type of plastic feedstock used, the reactor type and the process conditions, particularly pyrolysis temperature.

Through the use of low-temperature pyrolysis and efficient cracking, liquid fuel yields of up to 80–85% are possible, with the resultant product resembling diesel fuel, kerosene, gasoline or other useful hydrocarbon liquids. An added advantage of pyrolysis is that the light product gases (LPG and gasoline) produced (additionally to diesel) can be used to provide the energy requirements for the process.

The product yield depends on the distinction drawn between Mixed oil (Burnable industry fuel) (also called 'agricultural diesel') and Refined transportation diesel (which meets the EN590 specification). The liquid fuel yield (that consists of both
diesel and petrol) is 80-85% while the yield for the refined transportation diesel (the gasoline fraction has been extracted) is 50-55%.

7. What is the principal advantage of the Waste Technologies process over conventional mechanical recycling of plastics?

Post-consumer plastics are often commingled and contaminated with extraneous materials such as soil, dirt, aluminium foils, paper labels and food remnants. While soil, dirt and glue can be removed from post-consumer plastics by washing, this is a fairly expensive operation and it leads to secondary waste streams such as waste-water.

The major advantage of the Waste Technologies process is its ability to handle unsorted, unwashed used plastic. This means that heavily contaminated plastics such as mulch film (which sometimes contains as much as 20% adherent dirt/soil) can be processed without difficulty.

Significantly, other normally hard to recycle plastics such as laminates of incompatible polymers, multilayer films or polymer mixtures can also be processed with ease, unlike conventional plastic recycling techniques. In fact, most plastics can be processed directly, even if contaminated with dirt, aluminium laminates, printing inks, oil residues, etc.
8. Describe the Waste Technologies Concept?

Using Waste Technologies’ technology, the process takes post-consumer plastics and thermally converts them into gasoline and low-sulphur diesel fuel. This diesel fuel meets or exceeds both European and Federal EPA standards for emissions and is designed specifically for the solid waste disposal industry that has significant investment in diesel-powered equipment. The types of plastic targeted as feedstock for this project have little or no commercial value and would otherwise be landfilled.

9. Which plastics are suitable for the Waste Technologies process?

Most commodity hydrocarbon plastics are suitable for pyrolysis. The Waste Technologies plant can be used to convert all kinds of PP, PE, PS waste plastics into diesel by pyrolysis. It can also process waste plastics containing PVC, but the PVC content must be less than 1-2%.

Plastics suitable for the Waste Technologies Process include:
• Low-density polyethylene (LDPE) used in plastic bags, cling film, flexible containers.
• High-density polyethylene (HDPE) used in piping, shampoo and detergent bottles, oil bottles, milk crates.
• Polypropylene (PP) used in food containers, battery cases, bottle crates, automotive parts and fibres.
• Polystyrene (PS) used in dairy product containers, tape cassettes, cups and plates.
The following waste plastics are all highly preferred:
- Pallet wrapping film (pallet wraps)
- Shrink and stretch film
- Shopping bags
- Silage and mulch films
- Commercial plastic packaging film
- Shredded PP Diaper Scrap
- Plastic packaging scrap
- Oil bottles and plastic oil containers
- Plastic packaging waste from curb side recyclables sorting stations -polystyrene foam

Note: plastic films are generally polyethylene (PE) or polypropylene (PP) and these are the preferred feedstock for the process.
10. Which plastics are not suitable for the Waste Technologies Process?

Pyrolysis recycling of mixed plastics thus has great potential for heterogeneous plastic waste that cannot be economically separated. However not all plastics can be processed by pyrolysis.

Plastics such as PET (also called PETE) and PVC are not suitable for pyrolysis. PET is not recommended as a feedstock for conversion into diesel fuel product because the pyrolysis of polyethylene terephthalate produces large quantities of gas dominated by carbon dioxide and carbon monoxide, in addition to a wax and significant yield of char.

PVC is also not recommended as a suitable plastic feedstock for pyrolysis. Polyvinyl chloride gives hydrogen chloride as by far the main gas. The carbon-chlorine bond in the PVC structure has lower bond energy than other bonds in its structure and upon heating has a tendency to break first. As a consequence, PVC thermal degradation begins around 150°C which is a much lower temperature than the other common plastics but the hydrochloric acid that is evolved can cause fuel quality and corrosion issues and problems.

11. What is the largest capacity Waste Technologies plant?

Our engineers have designed a 25,000 tonnes a year plant comprising of two double reactor systems, each system 12,500T/Y, and each reactor 6,250T/Y.

12. Is the Waste Technologies technology protected by patents?

The technology underlying the PV-Oil Generator™ is supported by a series of patents which are either pending or granted. Those patents include PCT/IB2004/000306 relating to “Enhanced oil recovery from waste plastics reactor” and Japanese Patent pending No. 2002-145569 relating to “Moveable apparatus & method for extracting fuel from waste plastics and waste oil”. Additionally, there are a series of granted patents in China being Patents No. 00 2 365 77.4, 00 2 365 81.2, 00 1 207 28.8 and 01 2756083.
13. How does the Waste Technologies plant differ from other systems?

There are other machines which have been developed to convert plastic and waste oils into diesel and other fuels but many of these use external heating sources for the reactor to melt the plastic to enable pyrolysis to take place. Outer heating is inefficient (due to radiant heat losses and due to the low thermal conductivity of plastics) and not capable of precise and uniform heat temperature control.

The heating system in the Waste Technologies pyrolysis reactor uses multiple far infra-red heating rods to give precise and efficient heating of the mass of molten plastic. Inner heating is the opposite of the more conventional external heating where the pyrolysis chamber is externally heating either directly by gas flame or indirectly by hot air. The novelty of the Waste Technologies design lies in the Far Infra-red internal heating rods which are not prone to 'coking' problems.

"The novelty of the Waste Technologies design lies in the far infra-red internal heating rods which are not prone to 'coking' problems"
Far Infra-red (FIR) is that region of the electromagnetic spectrum lying between the middle infra-red and microwaves. This covers the wavelength range approximately from 15 m to 1 mm and thus is electromagnetic radiation with wave frequencies longer than that of thermal infra-red (between 25 and 1000 micrometres). The Waste Technologies heating rods use ceramic far infra-red heaters, which have a 96% radiant efficiency, built into stainless steel sleeves.

Far Infra-red internal heating rods used in the Waste Technologies plant show no coking after many thousands of hours of operation. Coking is one of the main technical barriers to the pyrolysis of plastic wastes using conventional external heating for the reactor.

14. What technological barriers have been engineered around by Waste Technologies?

The development of commercially viable plastic pyrolysis processes has up to now been hindered by the need to engineer around various process problems such as reactor fouling by carbon deposits, poor heat transfer of molten plastics, the requirement for integrated fractionation of products, separation of water and suspended carbon from the liquid fuels and integrated desulphurization.

Problems with many pre-existing plastic cracking technologies include:
• Non-continuous (batch) processes (not commercially viable);
• Coking and carbon deposits on heat exchanging surfaces;
• Stickiness of sand particles in fluidized-bed processes;
• Unsatisfactory fuel quality;
• Relatively high sulphur levels (100–700 ppm) in end product.

The Waste Technologies plastic-to-diesel process has been specifically engineered to overcome these limitations.

The Waste Technologies has solved all FIVE problems with this technology to date:
• Continuous operation: (both the input and solid residue removal are continuous).
• No coking: (the plant uses a novel heating process to minimize coking).
• Full fractionation and distillation: (diesel meets performance standards).
• Desulphurization: (< 50 ppm residual sulphur).
• Minimised emissions: (joint development with Co-Generation vendor to eliminate problematic emissions).
15. What grade of diesel is produced by the Waste Technologies Process?

The Waste Technologies process can produce either industrial-use diesel oil (also known as 'agricultural diesel') or refined transportation-grade diesel (road use diesel which conforms to the European diesel fuel standard EN590).

<table>
<thead>
<tr>
<th>The Waste Technologies process can produce two main types of fuel:</th>
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<tr>
<td>1. Mixed oil (Burnable industry fuel) (also called 'agricultural diesel')</td>
</tr>
<tr>
<td>2. Refined transportation diesel (which meets the EN590 specification)</td>
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</table>

The Waste Technologies process which produces automotive grade diesel produces diesel that meets the road fuel standards. This is a specific cut of hydrocarbons with a specific property profile. Not all the liquid fuel that is formed from the pyrolysis of plastics is auto diesel. There is also heavy oil, light oil, gasoline (octane) and char (solid carbonaceous residue). Only by distillation and fractionation of the liquid fuel can specification diesel been produced. Extensive development work has found that actual auto diesel yields of 50-60 wt. % are the highest that can be achieved with any technology.

The Waste Technologies process is designed to produce automotive grade diesel or transportation-grade diesel, from a range of feedstock compositions. In addition to boiling point curves, cetane rating, flash point and viscosity there are low temperature properties such as pour point, cloud point, CFPP that must be in specification.

The difference between the plant designs is the cheaper plant which produces mixed diesel oil only, does not include the following:

A. the second fractionation/distillation tower  
B. the desulphurization system  
C. the additive dosing system and additive storage tanks (the additives are cloud point depressants and pour point modifiers)

Hence, the lower capital cost of the mixed oil plant.
16. What are the attributes of the Waste Technologies process compared to competitive processes?

The attributes of the Waste Technologies plant that sets it apart from the competition are:
• Excellent temperature control
• No 'hot spots' (no coking)
• No naked flames such as gas burners or flares (safe)
• Steady-state operation
• Continuous feeding
• Continuous removal of heavies/residues
• High degree of automation
• Reproducible operating conditions
• Energy savings by use of focussed far infra-red heating
• No radiant heat losses
• Accurate and high-efficiency heating system (economical)
• Versatile shredder drum to handle a wide variety of plastics
• Vented extruder with melt filtration to remove contaminants
• No expensive catalysts or consumable reagents
• Integrated distillation, fractionation, refining and stabilization steps
• No hydrocarbon emissions/ no flare
17. What waste oils can the Waste Technologies process handle?

Waste oils can be fed into the Waste Technologies process *via* a liquid injection port. The following are waste oils that can be used for cracking:

- Waste Lubricating Oils
- Engine lubrication oils
- Industrial lubrication oils
- Various mechanical lubrication oils
- General hydraulic liquid oils
- Anti-friction and anti-wearing liquid oils
- Break-in lubrication oils
- Brake oil
- Cutting oils
- Electrical usage oils
- Transformer oil
- Electric insulation oils
- Heat treatment oils
- Quenching oils
- Residue oil from refineries
- Heavy oil from tank bottoms that have been cleaned
- Shipping fuel oil & lubrication oil from ship cleaning
- Waste asphalt and associated oils
- Basically any hydrocarbon-based oils

Due to the high viscosity of plastics materials the continuous feeding to a conventional reactor can be problematic. Waste lubricating oils can be advantageously used as carriers.

18. What are the main features of the Waste Technologies process?

The main features of the PV-Oil Generator™ are:

- Easy Installation: This facility is assembled on several movable base platforms whose size is 6000mm x 2100mm (19.7 feet x 6.9 feet). In most cases no civil engineering is needed for installation.
- Flexible operation: It can be operated continuously or in batch runs. The feeding of plastics and discharging of char (solid residue) can be done while the unit is in operation.
- Stable Operation: There is minimal or no coking in the reactor and it can operate for extended periods.
- No Secondary pollution: In general, there are three by products in the plastic decomposing unit, char and generator flue gasses.
• Economical Operation: Cost of operation is far less than other conventional systems currently available on the market. Utilizing the inner heating system powered by electricity, the average cost per tonne of waste plastic to convert to oil is about $27.00 USD using the average cost of $0.15 per kWh. Since there is <20% loss of heat efficiency, the savings are immediately realized as compared to other fuels or heating systems.

19. Is the Waste Technologies Process Automated?

The Waste Technologies plant is highly automated with Telemecanique Master Automation and an Austrian-built shredder drum/extruder/venting/melt filtration pre-processing unit. The plant can be run on a 7 day per week rotating shift basis.

20. What happens to the petrol produced by the Waste Technologies process?

All the LPG and gasoline produced by the process is fed into a state-of-the-art generator for power generation and hence no hydrocarbon emissions. The entire process is electrical heated (hence no flame heating, gas burners, etc.) and the shredder drum/extruder is a large European extruder with a heavy-duty drive and multiple resistance band heaters.

21. Who are the main competitors to Waste Technologies?

There are only three competitors to Waste Technologies (namely, Ozmotech, Cynair and Clyvia). Also there are only a handful of waste plastic to diesel plants commercially operating around the world and none are yet producing transportation-grade diesel on an efficient continuous commercial basis.
22. What types of pre-processing machinery is used before the pyrolysis reactor:

The pre-processing unit is supplied by Artec Maschinenbau GmbH of Austria
http://www.artec.co.at/seiten/default_engl.htm

(See figures below)

23. If we have pre-granulated scrap plastic can the pre-processing system be omitted?

Despite the feedstock already being size reduced the Artec pre-processing system is still required to homogenize, compact, agglomerate, melt, degas (remove water), filter and meter the waste plastic stream into the reactor. The importance of a reliable and efficient pre-processing system cannot be over emphasized.
24. Who manufactures the novel inner heating rods used in the main cracking reactor?

The proprietary inner heating rods in the reactor are manufactured by Waste Technologies in house engineering team and based on patented far-infra-red (FIR) emittance technology.

25. What is the process flow for the Waste Technologies process?

The flowchart for the plant is also attached.
26. Is the Waste Technologies process catalytic?

The depolymerisation (i.e. cracking) is not catalytic but thermal. The key is the far-infra-red (FIR) heating which enables the best temperature control.

27. What is the cost for a Waste Technologies Plant?

The pricing depends on the capacity of the plant, the type of output product and the number of plants ordered. Three different capacity plants are available and these can produce either Industrial-use diesel oil (also known as 'agricultural diesel') or refined transportation-grade diesel (road use diesel which conforms to the European diesel fuel standard EN590):

The options are summarized in the table below:

<table>
<thead>
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<th>Product</th>
<th>Capacity</th>
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<td>6,000 T/Y</td>
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<tr>
<td>1. Industrial-use diesel oil</td>
<td>A</td>
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<tr>
<td>2. Refined transportation diesel</td>
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</tbody>
</table>

29. What is the annual plant uptime?

The plant uptime is 7000 hr./yr. (minimum) since preventative maintenance and predictive maintenance are factored in.