WRAPAI
Document 5
Concept Exploration Document
(PRELIMINARY VERSION)

“In theory there is no difference between theory and practice. In practice there is.”
~ Yogi Berra

5.00.00 CUSTOMER REQUIREMENTS DOCUMENT

5.00.01 Configuration Management

Version	Date	Name
v1	090529	nwk & ce

5.01.00 SCENARIO OVERVIEW

The scenario is that garbage trucks deliver household waste to the refinery. The refinery then processes the waste. Energy in the form of biogas is extracted from the waste and used to fuel a combined heat and power generator (CHP genset). Some of the energy will be used by the refinery, but surplus electricity or gas will be sold. End products of the refinery are deposited into industry standard containers, and shipped to raw material consumers.

The waste refinery will transform industry by creating a mechanism which will enable products to become part of a cradle-to-cradle cycle. Materials can be perpetually re circulated thru a waste refinery. Maintaining materials in a loop with a waste refinery will maximise material value and minimise damaging effects to the environment. This is unlike the current cradle-to-grave scenario where products after their useful life, are routinely dumped in landfills.

5.02.00 REFINERY DIGESTING COMPONENTS

The refinery will consist of 8 trains which will process the waste. At each stage of the train, waste will be sorted and some of the material passed on to the next stage of adjacent trains. In this way, much like an oil refinery, the waste will be sorted so that light materials will be moved towards one side to the refinery, and heavy materials to the other. The performance of the refinery will depend on how much waste can be accepted, and how fast it can be processed.

Each train of the refinery digestion system consists of five phases. The initial phase is to mechanically break down the waste in to a fine powder, and place it in a solution. Material in a fine powder form can be more easily and more completely digested. Also small particles are more chemically reactive and this will also enhance the break down of complex chemicals.

The next phase is to pass the mixture thru an array of low temperature methane digesters. After that, the mixture is fed into algal digesters which will add biomass for a secondary methane digesting process, this time thru an array of high temperature methane digesters. The biogas given off during digestion is used to generate heat and electricity to power the refinery, and the surplus is sold.

At the same time as digestion takes place the material is sorted by the array of digester tanks, so that all the un-digestible solids are accumulated in discrete groups. At the end of the process the solid material is filtered off and sold, and the water is re-used for the next batch of waste.
SEE DIAGRAM WR-001 showing the overall refinery layout

5.02.01 INPUT LOADING BAY

Industry standard garbage trucks will deliver unsorted household waste to the refinery. The truck on it's arrival is weighed on on a weigh bridge, on departure the truck is weighed again. The difference is the weight of waste delivered. On arrival each truck will be assigned a delivery bay, each delivery bay will have clear identification signage. Each train of the refinery will have 2 delivery bays, the loading bay for each train will be about 440m2, about 3,520m2 for whole refinery.

For a right hand drive scenario, the trucks will enter from the train H side and exit on the train A side. The first truck will deliver in the first bay of train A, and each subsequent truck will use the next bay towards train H. This will mean that each driver makes a safer left turn pulling out, and the truck in the bay to his right should still be busy unloading when he pulls out. The first bay of train A will only be allocated when the loading bay is clear of traffic. Any trains or bays that are not available due to maintenance can be skipped out.

The loading bay area will have a small vehicle which can push any garbage into a pit, that has be mistakenly dumped in the loading bay maneuvering area. It can also move disabled trucks that may block the process. Also it must have a back actor that so that it can manually empty a pit.

5.02.02 LOADING PIT

The waste delivery trucks will deliver waste into a 40m3 pit that can accommodate 2 load 10,000kg truck loads. The pit will be covered on three sides and the roof so that wind does not blow the garbage away. The side walls will be elastic fabric structure so that truck contact will not damage the wall. The roof will be 7m above the truck bay level so that as the trucks tip they will not touch the roof. The bay will be lit for low light operations. The pits will drain into a sump which will be pumped and discharged into the grinding mill. The pits will be concrete, with galv steel wear plates. All fixings counter sunk and flush. The pits should be have an automatic hose down facility so as to maintain them in a clean and odour free condition.
SEE DIAGRAM WR-002 showing the loading pit

5.02.03 LOADING CONVEYOR

Incorporated into the loading pit is a conveyor to transport the waste from the loading pit to the grinding mill. We propose to use a belt conveyor at an angle of about 45 degrees. The bay will be located as high as possible relative to the mill, so as to shorten the conveyer travel. The minimum internal dimension of the path to the mill will be 2000mm. The idea being to accommodate any unusual shaped load from a garbage truck without getting stuck.

The conveyor should be capable of transporting a peak flow of 100,000kg or 200m3 in 8 hours. At the top of the conveyor an air extraction should maintain a nominal negative pressure so that any odours are not detectable from the device. The air should be delivered to a bio filter or for use in biogas combustion. The device should incorporate an automatic wash down to maintain clean operations. The wash down water is to be delivered to the mill via a sump pump with a grinder attachment. Each part of the conveyor should consist of components that can be delivered on a 6m open container bed, and bolted on site. Parts should be designed to be inter changeable, and easy to maintain. The bearings of device should be high pressure water fluid bearings that drain into the mill. The conveyor motor can be hydraulic or electric.

The device should be able to detect when waste has been delivered and turn on and off as required automatically. The device should be able to be manually operated, or remotely via web controls. There should be visual feed to web controls.

A local switch should be able to stop the device, in case of emergency or maintenance.

5.02.04 WASTE MILL

The conveyor delivers the waste to a 2,000mm diameter shaft, 2m above the top to the mill.

The mill will consist of conventional waste shredder mounted below a wet hopper. So that the shredding takes place under water. The first shredder will break the waste down to a particle size of less than 50mm.

After the 50mm shedder, a 7mm spiral lift screen will lift all particles larger than 7mm into a 7mm waste shredder. Again this will take place under water.

After the 7mm shedder, a 1mm spiral lift screen will lift all particles larger than 1mm into a 1mm waste shredder. Again this will take place under water.

To deal will material that may be difficult to shred, a typical waste shredder will reverse itself and take a series of small bites to nibble away at a hard material. Also a series of pneumatic rams could be operated, like a hammer mill or shear, when the shredder detects a hard material. Additionally, some of the water jets will be at very high pressures, so as to cut up difficult flexible material. And a hydraulic claw could be automatically deployed to remove difficult material to a separate bin for disposal by other means.

The temperature of the water added will be 35 deg C, the source of the heat will be from the CHP gensets. Also the shredding will heat up the mixture, but this will not be as significant as a roller mill which generates a great deal of heat. The mill should be able to accept a peak of 100,000kg of waste in 8 hours. The mill should be able to process this waste in 24 hours. Less than 10% of waste consists of metals and other hard material so this should not be a difficult task. The waste should be reduced to particles of less than 1mm3.

The mill should be able to add 400,000kg of water to the waste in 24 hours. The mill should be able to discharge 500,000kg of material in 24 hours. The mill should be able to calculate the amount of water to be added to the mill to achieve a 20% solid ratio.

The device should be able to be manually operated, or remotely via web controls. There should be a visual feed to web controls.

A local switch should be able to stop the device, in case of emergency or maintenance.
SEE DIAGRAM WR-003 showing the waste mill

5.02.05 LOW TEMPERATURE DIGESTERS

This will be a low temperature anaerobic digestion methane producing phase, using mesophilic bacteria at about 35°C. Mesophilic bacteria are able to cope with a wide range of conditions and are well suited to the start of the array where the waste is relatively un-sorted. New bacteria will make their way into the digesters with each batch of waste, and this will constantly upgrade the bacteria in the digesters. These digesters will sort the waste and produce biogas.

The tanks will have an internal diameter of about 8m, and 8m high. Therefore when full the tanks will have a capacity of 400m3, and allowing for about 500mm of ‘free board’ the usual capacity will be about 375m3.

The tanks will be made of concrete. The reinforcing will be galvanised. The wall and floor will contain two independent sets of pex hydronic heating coils. The concrete will contain an additive, such as xyplex, penetron or equal, to close any cracks and so prevent water leaks. The surface of the tank to be smooth as possible to achieve a low friction surface for the liquid. The contents for the tank will be acidic, and products like sealants and tank liners will be used. Companies like Jotun and Parchem (and others) make sealants for concrete sewerage tanks which will be suitable for use in these digesters, the only additional requirement is the higher than normal temperature. An alternative will be to use a polypropylene tank with a steel or concrete support framework. Another alternative will be to use a metal tank with an appropriate corrosion system.

All piping will enter over the lip of the tank and there are no penetrations of the tank. All piping will have high pressure back flow of air and water for cleaning.

Over the tank a fabric dome will collect gas, the fabric must be gas tight, and must prevent light from entering the digester. The fabric must be demountable for maintenance. From the dome structure the spray nozzles will be suspended to prevent the formation of crusts and scum.

The over all dimension of the tank and it’s gas enclosure will be 10m in diameter.

Biogas contains CH_4 and CO_2, CH_4 is lighter and will be more concentrated at the crown of the gas enclosure. Gas at the crown of the roof will rich in CH_4 and be collected for combustion. Gas at the base of the enclosure will be rich in CO_2 and collected to be used for insulation, inducing vertical flow in the digester tanks and in the algal tanks to promote algal growth.

Tanks will contain a number of sensors, including temperature, spin rate, volume, density, light level, camera. The sensors will be mounted in housings so that the will be easy to replace from the outside.
SEE DIAGRAM WR-004 showing the low temperature digester

5.02.06 ALGAL DIGESTERS

Sunlight and CO_2 separated from the biogas are introduced. In these digesters the algae will increase the biomass available for the next phase, at the same time as digesting some of the waste.

The tanks will have an overall diameter of 10m, and an overall height of 7m. Allowing for about 500mm of ‘free board’ the usual capacity will be about 390m3.

The tanks will be made of 1200x1200 glass panels in a hd galv steel frame. The frame of the wall and floor will contain two independent sets of pex hydronic heating/cooling coils to maintain the mixture a just below 20 deg C. The internal surface of the tank to be smooth as possible to achieve a low friction surface for the liquid.

All piping will enter over the lip of the tank and there are no penetrations of the tank. All piping will have high pressure back flow for cleaning.

Over the tank a mesh fabric dome to prevent the ingress of rain and animals, and allow the dispersion of O_2 from the algal digestion to disperse. The mesh will be translucent to allow sunlight to promote algal growth. The fabric must be demountable for maintenance.

From the dome structure the spray nozzles will be suspended to prevent the formation of crusts and scum. Gas will be blown thru the tank to create a vertical flow along the side walls of the tank. As the mass of the algae increases, so the solid ratio of the mixture will increase. Therefore additional water will be added from the sand filter tank, to maintain the solid ratio.

Tanks will contain a number of sensors, including temperature, spin rate, volume, density, light level, camera. The sensors will be mounted in housings so that they will be easy to replace from the outside.
SEE DIAGRAM WR-005 showing the algal digester

5.02.07 HIGH TEMPERATURE DIGESTERS

This will be a high temperature anaerobic digestion biogas producing phase, using thermophilic bacteria at about 50°C. Thermophilic bacteria are not as resilient to changing conditions and are more suited to the end of the array where the waste in each digester is more consistent.

The high temperature digester will be similar to the low temperature digester, the major difference will be that it will be maintained at 50 deg C. The pumps piping and sensors will be upgraded to accommodate the higher temperature.

5.03.00 REFINERY FILTER COMPONENTS

For the refinery as a whole at the end of the digester process, there should be 150,000kg of solids, 1,600,000kg of continuously recycled water and 80,000kg of additional water from the digestion of organic material. This would leave the solid to water ratio at less than 9% unless water was continuously filtered off so as to maintain the 20% ratio. Therefore about 1,080,000kg of water will be filtered off the digesters and pumped into the biomass tanks before the filtering process. This will leave a mixture of about 750,000kg of to be filtered, from which the 150,000kg of solids will be extracted.

The refinery will use cyclone and sand filters to remove solid particles from the refinery. There are many other methods that could be employed, for example to extract materials that are in solution, however it is not envisaged that other types of filter will be required.

The 150,000kg of end products per day, which will be shipped from the refinery in 6m ISO containers which can take a load of 30,000kg each, this will mean that about 5 containers will be shipped out each day. Each train will generate 18,500kg of solid material per day, this will be divided up into 4 different types of end products. Therefore the refinery will produce 24 different types of products.

In addition, the reed beds will generate a smaller about of material, this will be deposited into 1,000kg FBIC bags.

5.03.01 CYCLONE FILTERS

The mixture that is processed thru the cyclone filters is about 95,000kg per day, the solid component of which is 19,000kg.

A series of 3 cyclones will extract the heaviest components, each cyclone will extract 9,000kg per day.

Cyclonic separation is a method of removing particulates from a mixture, without the use of filters, through vortex separation. Rotational effects and gravity are used to separate mixtures of solids and fluids.

A high speed rotating fluid flow is established within a cylindrical or conical container called a cyclone. The mixture flows in a spiral pattern, beginning at the wide top end and ending at the narrow bottom end before exiting the cyclone in a straight stream through the centre of the cyclone and out the top. Larger and dense particles in the rotating stream have too much inertia to follow the tight curve of the stream and strike the outside wall, falling then to the bottom of the cyclone where they can be removed. In a conical system, as the rotating flow moves towards the narrow end of the cyclone the rotational radius of the stream is reduced, separating smaller and smaller particles. The cyclone geometry, together with the flow rate, defines the characteristics of the cyclone performance.

Cyclones are commonly used in industrial applications like refineries, waste water and sewage treatment plants. When used to filter water they are sometimes referred to as hydrocyclones or hydroclones.

From the bottom of the cyclone the particles will be moved by means of a flexible screw conveyor to a hopper.
SEE DIAGRAM WR-007 showing the cyclone filters

5.03.02 SAND FILTER

After the cyclone filter process has removed 9,000kg of solids, the mixture that is processed thru the sand filter process. Each day the mixture would be about 87,000kg, the solid component of this would be about 10,000kg.

The mixture will have a volume of about 87m3 and be fed into a tank with a volume of about 300m3. At the base of the tank a sand will be a 2m thick sand filter. Above the sand filter a shaped slip surface which will concentrate all settled sediments to a screw conveyor. Below the slip surface a layer of fungus will be encouraged so as to clean the sand filter. Also air will be intermittently injected into the sand layer which will stop the sand from becoming blocked by crusting or congealing.

The ‘sand’ of the filter will consist of concrete crusher dust, limestone, charcoal, pumice, and other carefully chosen material that have a physical and chemical characteristics that will interact with the water from the digesters.
SEE DIAGRAM WR-008 showing the sand filter

5.03.03 SCREW CONVEYORS
The use of flexible screw conveyors to fill hoppers is well established in industry. Generally the smallest commercial conveyor would be more than sufficient to cope the the volume of material that needs to be moved. Also the screw conveyors will compress the mixture and remove water in industry standard ways

Also, if a market were established for particular type of product and if the re-cycle plant were located in close proximity the material could be conveyed with a belt conveyor or other appropriate device directly to the plant.

5.03.04 DRYING HOPPERS
From the screw conveyor the filtered material will be fed into a series of hoppers where surplus heat from the CHP gensets will be used to dry the material. The atmospheric pressure of the hopper can be reduced to lower the evaporation temperature to enhance the drying process.

Once the material in a hopper was dry enough the hopper can be emptied into a 6m bulk tank container, or an open top containers with a bag liner. A 6m container can take 30,000kg, and in most cases the container is likely to reach its weight limit before it’s volume limit.

Material from each part of the train’s filtering process will produce a consistent material, and this material can be shipped to appropriate recycling plants.

5.03.05 END PRODUCTS
At the end of the train, 4 different high volume material groups will be filtered off, 3 from the cyclone filters and 1 from the sand filter.

From the filter process, the refinery as a whole will generate 150,000kg of end products per day, this will be an average of 5 full containers per day. And also, 5 replacement containers day. To maximise the available use of space it is envisaged that industry standard side lifting trucks are used to supply and remove containers.

In addition each train will produce some material from the biomass tanks, and reed bed tanks. This material will need to be removed on a periodic basis. The sediment could be used by being incorporated into concrete, or could be used as clean fill. A larger amount of material will be biomass, mostly in the form of reeds and hyacinth. These are commercial products which could be sold, or could be digested by the refinery.

From the bottom of the reed bed tanks excess sediment in the tanks will be removed by a screw conveyor and deposited into a FIBC (Flexible Intermediate Bulk Container) bag.

FBIC bags are an alternative to containers for smaller volumes, they are also known as a big bag, bulk bag, or super sack.

FIBC bags have been used since the 1940s. By the 1960s development of polypropylene, combined with advances in weaving, the bags were adopted to store and transport powdered and granular products. FIBC bags are highly cost effective, easily recyclable and ideal for virtually all granules, powders, pellets or flakes. It is most often made of thick woven polyethylene or polypropylene and normally measures around 1,1m by 1,1m and varies in height from 1m to 2m. The mass is normally around 1,000 kg to 2,000 kg, but can be more. Transporting and loading is done using pallets or by lifting it with loops. Emptying is made easy by a special opening in the bottom or by simply cutting it open.

As an alternative, there are many off the shelf 'integrated pallet containers' that are available and could be used as an alternative to FBIC bags. In Australia the use of a integrated pallet containers, often from a shared pallet pool, is a well established industry practice.

5.03.06 CONTAINER FILLING

To provide flexibility and prevent the occurrence of bottle necks container loading hoppers should be able to reach a truck in the truck lane and discharge material into a waiting container mounted truck. The loading should be fast enough to provide a practical alternative should a container become disabled and cause a blockage.

5.03.07 OUTPUT LOADING BAY

The output loading bay should be able to handle on average the replacement of six 6m iso containers out per day. In addition it should be able to have enough storage space so that FBIC bags can be consolidated so that full iso containers can be shipped. Alternatively material could be shipped to a depot, where space is available for consolidation of loads.

An alternative is to redesign the refinery so that all solid material is deposited into bulk containers only. However for a refinery of this size a combination of containers and a few FBIC bags is considered appropriate.

5.04.00 WATER TREATMENT COMPONENTS

The water which exits the refinery will be about 1,600,000kg to be re-cycled and 80,000kg of surplus water. For each train the amount of water will be 210,000kg, of this 70,000kg will be from the end of the train and 140,000kg which has been filtered off before the end of the digester process.

The 210,000kg of water drawn off earlier in the process will be treated in biomass tanks, which will contain aquatic plants and algae, the principle purpose these tanks will be to make the water less acidic, and a secondary purpose is to generate biomass. The 70,000kg of water form the end of the train will enter a vertical flow reed bed. The water that exits from the reed bed should be clean enough to release into the environment.

5.04.01 BIOMASS TANK

The two biomass tanks will receive the water filtered off thru commercial filters at various stages from the train, the total flow into the tanks will be about 210,000kg per train. The water will be low in O_2, high in CO_2 and have a low PH (acidic) and the solid content will be negligible This is ideal for aquatic plants like water hyacinth, and algae.

The water for each tank will have a volume of about 105m3 each and will be fed into a tank with a volume of about 700m3. This will allow for a retention time of about 6,5 days.

At the top of the biomass tank will be a layer of aquatic plants, principally hyacinth, the side walls of the tank will be glazed from the ground level to 2m below the top of the tank. This will allow for algal growth below the surface level. At the base of the tank a sand will be a 2m thick sand filter. Above the sand filter a shaped slip surface which will concentrate all settled sediments to a macerating submersible pump. Sediments in this case will come from the plants, and algae. Below the slip surface a layer of fungus will be encouraged so as to clean the sand filter. Also air will be intermittently injected into the sand layer which will stop the sand congealing. From the screw conveyor the the material will be

fed into hoppers where surplus heat from the CHP process will be used to dry the material. After this process the water will be ready for re-use in the grinding process.
SEE DIAGRAM WR-009 showing the biomass tank

5.04.02 REED BED TANK

Because the process will produce a surplus of about 80,000kg of water per day, a vertical flow reed bed tank is proposed. The tanks would be 10m by 20m and 6m deep.

The loading would be 50kg of water per m2. Water that exits these tanks should be acceptable for release into the environment. Alternatively, rather than having reed beds, the water could be sold for industrial purposes. If a refinery incorporated a steam generator, or a concrete block plant, large quantities of water could be released as steam, or incorporated into concrete.
SEE DIAGRAM WR-010 showing the reed bed tank

5.04.03 BIOMASS HARVEST

From the biomass tank submersible pumps with a macerator attachment will chop up the biomass and feed it into the mill. From the reed bed tanks biomass material will be harvested by conventional reed harvesting machines. Reeds, algae and water hyacinth can all be sold commercially, however it is most likely the the best use for them will be to be digested to make biogas.

5.04.04 SURPLUS WATER

Surplus water from the refinery could be sold. Depending on it's use, it may need little or no treatment. However if it were to be returned into a river, it would have to be oxygenated and the ph raised to make it less acid.

5.05.00 BIOGAS COMPONENTS

The pressure of the gas enclosures should be slightly above the outside to prevent the ingress of O_2. Biogas is primarily made up of methane (CH_4) and carbon dioxide (CO_2)

5.05.01 BIOGAS CH_4 CONCENTRATION

Methane is much lighter than CO_2 so the gas removed from the dome should be mostly methane, and gas from the base should be mostly CO_2. The digesters from one end of the train to the other will be used to concentrate CH_4 at one end and CO_2 at the other.

5.05.02 BIOGAS CO_2 DISPOSAL

Gas rich in CO_2 which has been separated from the biogas will be bubbled thru the algal digesters and the water treatment tanks. The fabric dome of the digesters will consist of two layers of material to form an insulating air mattress, and the gas in the mattress will be CO_2. In addition CO_2 could be sold for industrial use.

5.05.03 BIOGAS PRE COMBUSTION PREPARATION PROCESS

Biogas rich in CH_4 will be used to generate electricity and heat by CHP gensets. Biogas can contain contaminants like CFC's, siloxanes and H_2S. Biogas from landfills typically contain more contaminants than digester gas. There are a number of off the shelf treatment methods that are available for landfill gas. Except for CFC treatment , the gas from the refinery is unlikely to require treatment. The proposed method of dealing with CFC's is to pass the gas thru a uv light source, which breaks down the chemical into it's component parts. In coming years CFC's are likely to be found less and less in current waste because CFC's are no longer widely manufactured.

The amount of siloxanes and H_2S are expected to be very low and will not adversely affect the type of generators proposed. Therefore it is envisaged that no other treatment of the biogas will be required. However, should the biogas require treatment there are a number of industry standard treatment applications that are available

5.05.04 BIOGAS CHP COMBUSTION

The estimated electrical generation is 4,4MW per hour. This would be a power station consisting of 3 running Cummins (or equal) CHP gas generator sets and 1 spare . The genset price would be about $9 million consisting of the gas generators, complete electrical installation with switchboards, generator mechanical and electrical and installation, cooling systems, and so on. The genset would operate to deliver continuous base load electricity. If the genset were used for peak loads then it would need some gas storage infrastructure, and a larger gas genset.

It is currently estimated that the heat generated by the gensets should be surplus to the refinery's requirements.

5.05.05 BIOGAS EXHAUST

Biogas exhaust contains mainly CO_2 and H_2O. It is not envisaged that the exhaust will require treatment.

5.05.06 SURPLUS ENERGY

The total amount of energy in the form of gas, or heat and electricity that can be generated from a CHP genset, will be much more than the refinery's requirement.

Gas can be distributed via a pipe line directly to industrial customers. If the gas can be easily made to match the specifications of the commercially available consumer grade natural gas, then gas could be sold directly to the natural gas distributor. Electricity will be distributed via a sub-station to the general grid. Heat can be distributed via a hydronic pipe line, however distribution of heat over long distances is not usually a practical option.

5.06.00 REFINERY SYSTEMS AND CYCLES

The refinery has a number of concurrent systems and cycles. The success of the refinery will depend on the ability of these systems to be integrated with each other.

5.06.01 MATERIAL SORTING SYSTEM

The waste, after it has been reduced in particle size to less than 1mm3 is added to water to form a mixture with a consistent solid to water ratio.

Each digester will be a circular tank with an internal dimensions of 8m high and a diameter of 8m. The intention is to rotate the fluid in the tanks by means of pumps located external to the tank. The speed of the rotation should be sufficient to prevent solids settling in the tanks.

The idea is to rotate the fluid without having any mechanical devices that would require maintenance in the tank. The intention is to have the pumps located externally so that they can be maintained without entering the tank.

The pipes into the tank should be over the top of the tank so that there are no penetrations in the tank wall. All pipes should be able to be blown clean with high pressure water or CO_2. The pipes should be arranged so that the rotational motion takes place. Also gas given off from the tank can be pumped into the mixture to induce upward vertical flow along the walls of the tank. An array of jets of water are arranged on the surface of the liquid to prevent the formation of crusts and scum, to clean the rim, and any pipes the break the water surface, and also to provide rotational flow to the surface.

An array of jets are arranged on the base of the tank to prevent settlement of solids. Alternatively to prevent settlement, if needed, filtered water could be introduced to produce a cushion of fluid thru an array of small holes at the base of the tank. This will prevent materials adhering to the base of the tank.
SEE DIAGRAM WR-012 again

5.06.03 SOLID RATIO SYSTEM

Given that the refinery will have a fixed volume, the solid ratio of the mixture in the refinery will be a critical factor in determining how much waste can be accepted. The higher the solid ratio, the more waste that can be accepted. However, the higher the solid ratio, the more difficult it will be to pump and circulate, and so sort the mixture. Also the higher the solid ratio, the longer it will take to digest the waste. It is envisaged that the solid to water ratio will be in the region of 20% for this refinery. The solid ratio for a digester is normally less than 20%, however in this case there will be higher proportion of dense material because of the metal and glass content. The characteristics of the mixture will have to be adjusted so that the mixture is easy to pump and stir, and this will in turn depend on the type of waste that is processed. The mixture will have to be dynamically adjusted to maintain workability.

As solid material is digested, the solid ratio of the mixture will fall. Therefore water will need to be filtered off, to maintain the determined solid ratio.

On average a tank will accept and discharge 200,000kg per day at the start of the process, with a peak capability of 500,000kg per day. However as the solid material is digested this will fall.

Tank	change kg	mixture kg
lt1		2,000,000
lt2	-110,000	1,890,000
lt3	-110,000	1,780,000
lt4	-110,000	1,670,000
lt5	-110,000	1,560,000
lt6	-110,000	1,450,000
a1	+100,000	1,450,100
a2	+110,000	1,450,210
ht1	-110,000	1,340,210
ht2	-110,000	1,230,210
ht3	-110,000	1,120,210
ht4	-110,000	1,010,210
ht5	-110,000	900,210
ht6	-110,000	790,210
	1,080,000 total change	

To vary the performance of the refinery more or less material can be digested, or the retention time could be varied. Other options are to vary the type of waste, or the refinery temperature.
SEE DIAGRAM WR-012 again

5.06.04 INOCULATION SYSTEM

Waste entering the refinery will be constantly introducing new organisms into the digesters, more successful organism types will displace less successful types.

As material flows from the input side towards the output side, this will provide a method for more successful digesting organisms to pass from one side of the digester array to the other.

The inoculation system will provide a method for organisms to propagate themselves in the without regard to the material flow. The inoculation system is a practice where each day one of the digesters in a train will pump a small of amount of it's mixture into each of the other digesters in the train. The amount shared, will be say 500kg, it is envisaged that this would be enough to allow the organism's in each tank to be constantly improved by means of introduced competition.

5.06.05 RETENTION TIME SYSTEM

The proposed retention time is an estimate and can be varied depending on the digestion rate of the mixture

Tank	Mix m3	Tank m3	days retention
lt1	2,000	3,000	1.5
lt2	1,863	3,000	1.6
lt3	1,725	3,000	1.7
lt4	1,588	3,000	1.9
lt5	1,450	3,000	2.1
lt6	1,313	3,000	2.2
a1	1,438	2,000	1.4
a2	1,575	2,000	1.3
ht1	1,438	3,000	2.1
ht2	1,300	3,000	2.3
ht3	1,163	3,000	2.6
ht4	1,025	3,000	2.9
ht5	888	3,000	3.4
ht6	750	3,000	4.0
			31.0 days

The quicker waste can be processed the higher the performance of the refinery will be.

5.06.06 WATER CYCLE

The water which is added to the waste to form a mixture with a 20% solid ratio, will be sourced from recycled water that exits the refinery.

The combination of digester types will manage the temperature, PH and oxygen content of the water. Water should be able to be cycled thru the refinery indefinitely.

If any unforeseen build up or imbalance occurs in the mixture of material as it cycles thru the refinery, it is envisaged that the biological processes will adjust to this situation. In addition various factors can be adjusted in the refinery cycle to change the dynamics. These factors include the waste load, the solid ratio, the retention rate, filtration systems, temperature and type of digester.

5.06.07 TEMPERATURE CYCLE

The waste will arrive at an average temperature of about 10 deg C. The water with which it will be mixed will be at 19 deg C. The mixture will require about 160,000 MJ to heat it up to 35 deg C for the low temperature digesters.

The mixture will remain at 35 deg C in the low temperature digesters until it enters the algal digesters which are at 19 deg C. The temperature drop will release about 135,000 MJ

Before entering the high temperature digesters the mixture will be heated up to 50 deg C, this will require 260,000 MJ. Before entering the water treatment tanks the mixture will be cooled to 19 deg C, this will release about 260,000 MJ.

Assuming that the heat from cooling is lost, the refinery will consume 420,000 MJ each day just to change the temperature of the mixtures. Heat will also be required to maintain the temperature of the digesters, this will be mitigated by good insulation.

Also as the waste material is broken down, by organisms, and chemically, heat should be generated by the process of decomposition. In addition, when the mixture is cooled, a heat exchange system should be able to harvest the heat given up.

All things considered the refinery should still have a surplus heat generation of about 300,000 MJ per day. This heat can be sold, or used in the production of concrete products. It could also be used to vent surplus water as steam.
SEE DIAGRAM WR-012 again

5.06.08 PH CYCLE

The primary phases of anaerobic decomposition generate acids, and the mixture in the low temperature digesters should be acidic. The PH of the mixture should be low (acid) by the time the mixture reaches the algal digesters.

The algal digesters, will raise the PH and by the time the mixture leaves the algal digesters it will be alkali with a high PH. The high temperature digesters will lower the PH again. The water treatment phase will raise the PH again. And when the material is re-cycled the PH cycle will repeat itself again.
SEE DIAGRAM WR-014 showing the PH flow system

5.07.00 OPTIONS

The project presents a few major options that need to be considered. . Overall, the option of whether to proceed with the project or not needs to be reviewed from time to time.

The major operational options will be concerning how to deal with the end products of the refinery. A major issue will be which option to choose to deal with unsold low value combustible products. Another issue will be to choose the option of how to deal with the surplus water the refinery generates.

There are a number of options to consider when a refinery is constructed. Some of these will refer to local issues which will affect the refinery's ability to sell end products. Other issues will be the commodity prices of end products, and of electricity and gas.

5.07.01 METHODS FOR EVALUATING OPTIONS

Generally the criteria for evaluation of options will be financial and environmental.

However local regulations and customs, however irrational, can affect the options taken. For example, some societies will allow the burning of coal, but not allow any combustion of waste, even if this is done in a very clean way. Also, some societies will restrict the type of aquatic plants that can be used. Or they may have industrial regulations that can rule out the proposed industrial process.

5.07.02 DO NOTHING OPTION

There are many waste processing alternatives available, however it is our current view that there is no process which matches the potential benefits of a waste refinery. But it is possible that a better alternative becomes available in the future, in which case it would be sensible to abandon the project.

5.07.03 END PRODUCT COMBUSTION OPTION

The principle products from the refinery that are combustible are digestate and plastics. In the event that these products can not be sold, then it may be best to combust them. The 60,000kg of digestate would be part of the current carbon cycle, but the 40,000kg plastics would usually be made from fossil carbon, and therefore a less desirable combustion candidate.

The major advantage of combustion is the reduction in size of the material, or ash left over, which would be about 10% of the original material. So the 100,000kg of combustible material would be reduced to 10,000kg of ash. This would reduce the amount of material that would be needed for incorporation in concrete.

It is possible that only the digestate is combusted, and in this case then only 6,000kg of ash would be produced. Another disadvantage of combustion would be the production of aerosol particulates, however this would be mitigated by the fact that the material to be combusted would be sorted and consistent and easy to combust in a very clean way.

When coal is combusted only a portion of the ash is suitable for incorporation into concrete, and the bulk of the ash, because of contaminants, has no known industrial use. However, in this case because the material will be free of contaminants, all the ash will be incorporated into concrete.

5.07.04 CONCRETE PRODUCTS FROM UNSOLD END PRODUCTS OPTION

The principle concrete product envisaged is side walk paving. Pavers do not require the high strength and exacting standards of commercial concrete. There are a number of other products that can be produced, such as road base, water features, rip-rap, ornaments or kerbing and so on. Because of the consistency of the end products from the refinery, it should be possible to produce concrete of a consistent strength, even if it is not as strong as commercial general purpose concrete.

5.07.05 SURPLUS WATER OPTION

A potential advantage of the combustion of combustible products, is the use of a steam turbine to generate more electricity. In addition, the surplus heat from the CHP gensets could also be used to help drive a steam turbine. One advantage of a steam turbine would be the opportunity to vent surplus water generated by the digesters as water vapour, this would be a good way to return water to the environment.

5.07.06 USE OF SEWERAGE OPTION

Instead of using re-cycled water the refinery could use sewerage. This would digest sewerage in a more complete and useful way compared to most conventional sewerage plants.

However this would result in a large amount of surplus water at the end of the process. If there was a market for this water then this could be a viable scenario. Water exiting the refinery would have a very low O_2 content and a very high CO_2 content. For release into the environment, this would require an additional process, and therefore additional cost.

However the water would be suitable for many industrial uses, and also it would be very good for use on certain agricultural products. The energy content of the human or animal sewerage would have to be assessed to determine if the viability (or not) of using sewerage water. Certainly the if the cost of a sewerage plant were factored in, then the incorporation of sewerage could be viable.

5.07.07 BIOGAS EXHAUST OPTION

If a market were established for surplus water, then the gas could be bubbled thru the algal digesters, the CO_2 would enhance biomass growth, and the water vapour in the exhaust would condense. The particulate matter in biogas exhaust is low and will have a negligible environmental impact.

5.07.08 ENERGY SALES OPTION

The heat requirement of the refinery would be approximately half the amount that could be produced by a CHP genset. Therefore it may be an option to have a smaller CHP genset, and sell the surplus gas, as this would reduce the capital cost of the CHP genset. The viability of this option can be calculated once the cost of CHP gensets, the electrical and gas revenues, and the cost of capital have been determined.

5.08.00 REFINERY CONTROL SYSTEM

Each digester or device of the refinery array will be an independent software entity, in practice each device will act as an cellular automaton. Therefore every device will be aware of it's own status, and the status of devices around them which it will interact with.

Using information form each device around them, every device is able to cope with a neighbouring device being out of commission, or not working a full capacity. Devices are able to communicate with each other and to the web via wireless and a hardwired communications network.

Devices to report their status to the web, and this is to be constantly updated. Also devices are to have direct communication with each other, so that they can transport discrete amounts of the mixture between them in a verifiable manner.

5.09.00 SAFETY

Because the refinery project will be subject to large cost and benefit risks, a proper risk assessment, and safety management program for the refinery is fundamental to a successful outcome.

The waste refinery will comply with normative safety, in that all situations will meet applicable design and safety standards. In addition the waste refinery will meet substantive safety concerns which means that the real-world safety is important, whether or not standards are met. Also the perceived safety and comfort of all stake holders must be addressed, so that people feel safe in regard to the refinery.

The waste refinery will amongst other things contain mechanical, water, gas, explosive, heat, electrical, disease, financial and environmental risks. Eliminating all risk is not practicable, a safe situation is one where the likelihood of negative events is low and manageable. Continuous changes in technology, environmental regulation and public safety concerns make the analysis of complex safety-critical systems demanding and an ongoing concern.

Safety issues can not be readily deduced, so safety issues have to be discovered in a continuous process. A knowledge of the literature, the standards and customs is a critical part of safety engineering. A safe refinery is one of the performance requirements of this project.

5.10.00 FINANCE

To be a viable project, a waste refinery will have to have an acceptable level of financial performance. The expectation is that a waste refinery will be a profitable enterprise, however this may turn out not to be the case.

5.10.01 SOURCES OF CAPITAL FUNDING

The sources of funding for the research for the refinery are expected to be from grants from government, scientific and philanthropic organisations.

The same sources of funds will be used to finance the refinery. However once research suggests that the project could be viable, then it is possible that the project could find funding from commercial sources.

5.10.02 ESTIMATED CAPITAL COST

The cost of constructing a refinery will include the following items -

Item	Description (Number)
1	Land, the refinery will need about 57,000m2
2	Administration offices
3	Workshops
4	Consultant fees
5	Software control system
6	Weigh bridges at entrance and exit to refinery
7	input loading bay of approx 4,750m2
8	loading pit (8)
9	conveyors (8)
10	mills (8)
11	low temp digester (56)
12	algal digester (16)
13	high temp digester (56)
14	cyclone filter (24)
15	sand filter (8)
16	output loading bay 2,250m2
17	electrical CHP genset (1) 4,4MW CHP genset
18	heat distribution system
20	biomass tanks (16)
21	reed bed tanks (8)
22	concrete product plant

5.10.03 ESTIMATED INCOME

The refinery income will be sourced from a combination of the following items -

Item	Description
1	Dump fees
2	Electricity sales
3	Heat sales
4	Gas sales
5	Water sales
6	Metal sales
7	Plastic sales
8	Glass sales
9	Sand sales
10	Digestate sales
11	CO_2 sales
12	Concrete product sales
13	Biomass sales
14	Refinery tours

5.10.04 PROJECTED RUNNING COSTS

The refinery running costs will include -

Item	Description
1	staff costs and administration
2	programmed maintenance
3	energy costs
4	refinery efficiency upgrades
5	concrete product manufacture

5.10.05 PROJECT VIABILITY

The project viability will be determined when the following items are quantified -

Item	Description
1	Income
2	Running costs
3	Cost of capital

-end.