GREATER LONDON AUTORITY

SCENARIO SOLUTIONS for the City Solutions Stakeholder Day

13 March 2003

THERMOSELECT - An Advanced Field Proven High Temperature Recycling Process

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1 Introduction

Over the past decade, an innovative waste recycling technology – the THERMOSELECT process – has been developed, proven in a large scale demonstration facility and commercialized by the THERMOSELECT S.A. company. Solid wastes, including MSW, are continuously processed in a fixed bed oxygen blown gasification and residue melting reactor to achieve a maximum recovery of recyclable raw materials, with simultaneous utilization of the chemical energy contained within the waste material and minimum impact to the environment. Commercial plants have been recently erected in Karlsruhe, Germany, and in Tokyo-Chiba, Japan. The Karlsruhe plant has a waste treatment capacity of 720 Mg/d and the Chiba plant of 300 Mg/d.

2 Process Description

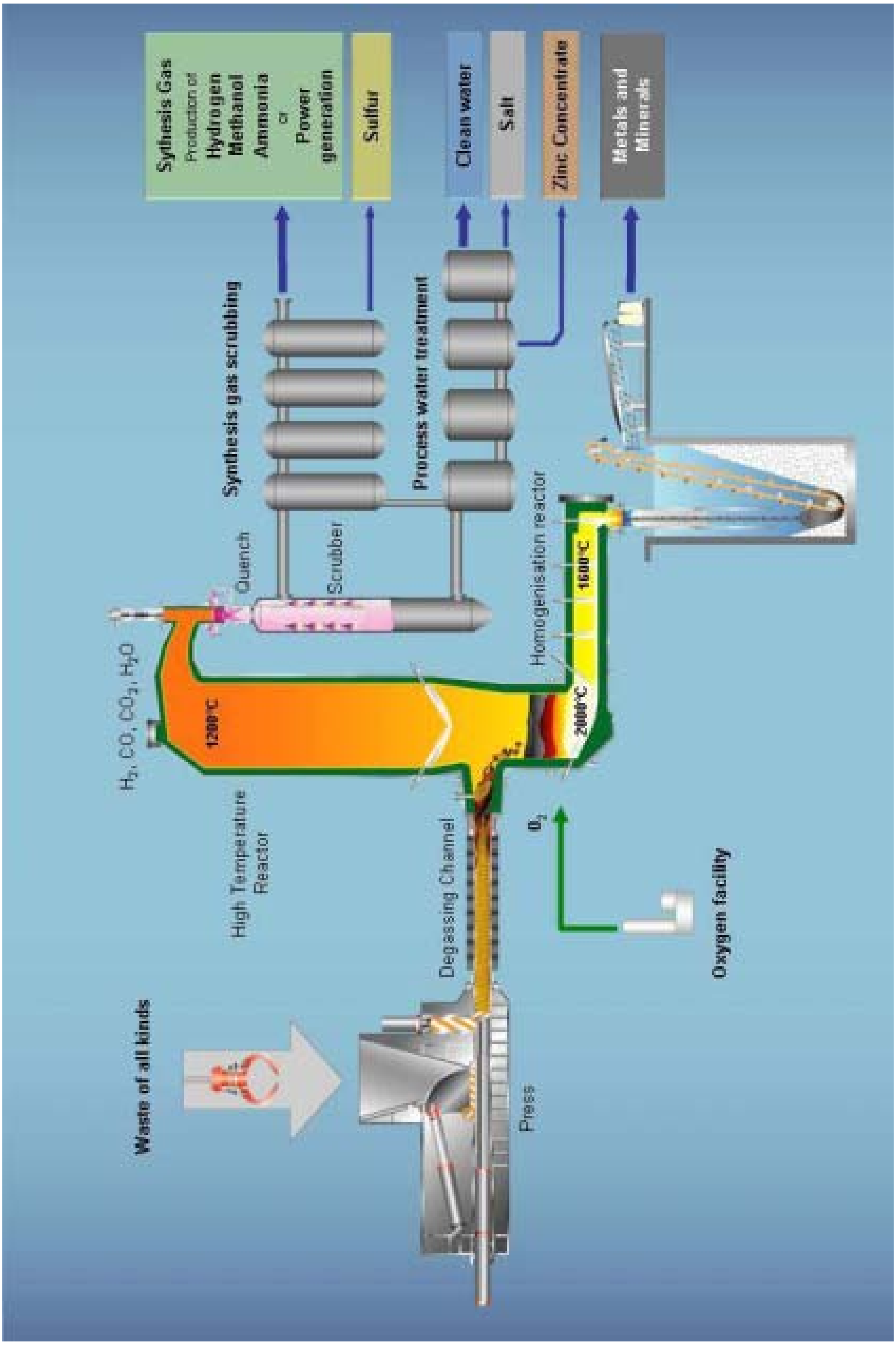
The THERMOSELECT Resource Recovery Facility recovers pure synthesis gas, useable vitreous mineral substances and iron rich materials from mixed wastes such as Municipal Solid Waste (MSW) and Commercial and Industrial Wastes. In an uninterrupted recycling process the organic waste fractions are gasified and the inert materials are simultaneously molted down. The subsequent purification of the synthesis gas and process water yields clean water, salt, zinc concentrate and sulfur as products. In contrast to other processes, no ashes, slag, inerts, chars or filter dusts have to be deposited in a costly manner or subjected to secondary treatment.

2.1 Waste Feed System

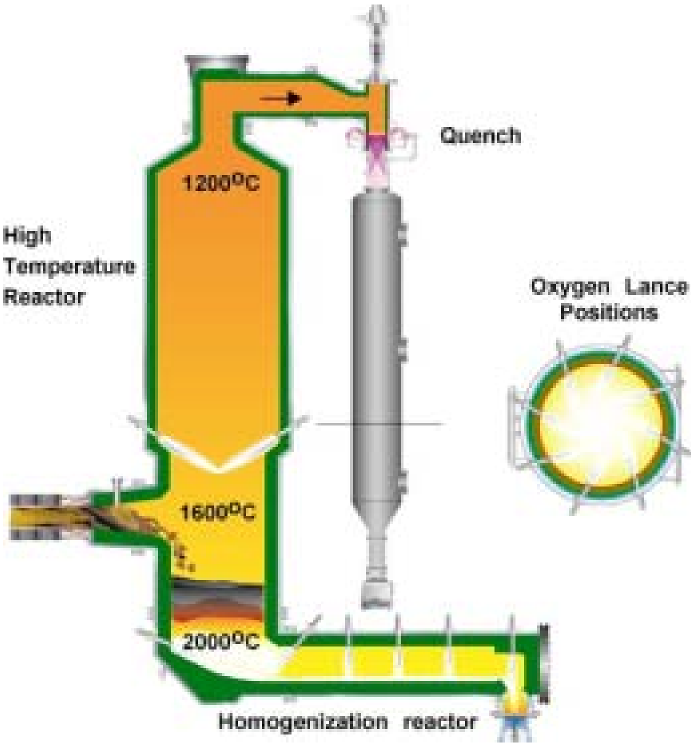
In the first process step the untreated as received municipal solid waste is discharged directly into a storage bunker. The bunker has about 5 days storage capacity and is used to dampen out fluctuations in waste receival cycles. A grapple crane is used to transfer the waste to the feed chute of the bailing press. The press in turn compacts the waste, distributes liquid within the bail and forces out the residual air (nitrogen ballast). Dense waste plugs are thus formed which are fed one after the other into the degassing channel of the reactor. These waste briquettes also form the seal of the reactor at the inlet.

2.2 Gasification of waste

The press is directly connected to the degassing channel. The channels cross sectional area increases slightly as the gasification reactor is approached, which eases the movement of the waste plugs and the transportation of the gases (evaporation of water, pyrolysis and synthesis gases) from the waste into the reactor.
Radiated heat from the gasification reactor initiates the waste drying and decomposition processes in the degassing channel and are brought to completion within the reactor itself. The dried and charred briquettes emerge from the degassing channel and are exposed to steam (from water in the waste) and controlled injection of pure oxygen as the gasification medium.



THERMOSELECT Resource Recovery Process



All organic materials in the waste are transformed into a synthesis gas with a composition that reflects the thermodynamic equilibrium of the temperature at the top of the reactor (approximately 1200°C).

The high temperature, oxygen free environment and long residence time of 2 seconds in the upper part of the reactor ensures that only small molecular species such as H_2, CO, CO_2 and H_2O leave the reactor as prime constituents of the synthesis gas. The main prevailing exothermic reactions occurring in the upper part of the reactor are:

$$C + ½O_2 \rightarrow CO$$

$$C + O_2 \rightarrow CO_2$$

$$2C_xH_y + (2X+Y/2)O_2 \rightarrow 2x\ CO_2 + yH_2O$$

with a simultaneous endothermic Boudouard reaction, e.g.

$$C + CO_2 \rightarrow 2CO$$

and the endothermic water shift reaction

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

$$C_xH_y + X\ H_2O \rightarrow (x+Y/2)H_2 + XCO$$

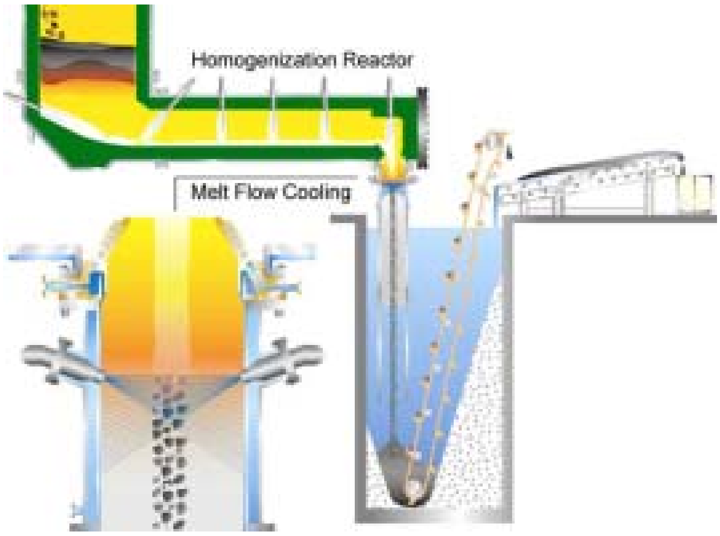
After gasification at a gas exit temperature of 1150-1200°C, a synthesis gas is obtained being typically composed of 25-42 Vol.-% H_2, 25-42 Vol-% CO, 10-25 Vol.-% CO_2 and nitrogen.

2.3 Melting of inorganic materials

In the lower part of the reactor all metals and mineral components are molten. Metals such as mercury, zinc etc are volatilized at the high temperatures in the lower part of the reactor (locally up to 2000°C) and are extracted with the synthesis gas. The oxides of the base metals form a mineral melt in the lower part of the reactor. Simultaneously other metals are also molten down. A typical iron alloy is formed containing nickel, copper and traces of other heavy metals. The typical iron content is more than 80%.

The mineral and metal melts collect in the lower homogenization reactor, which is heated with natural gas and oxygen. A two phase flow occurs in the melt with the minerals and metals separating automatically as a result of the differences in relative density (RD 3 and 7 respectively). Any residual carbon in the melt is synthesized to further syngas.

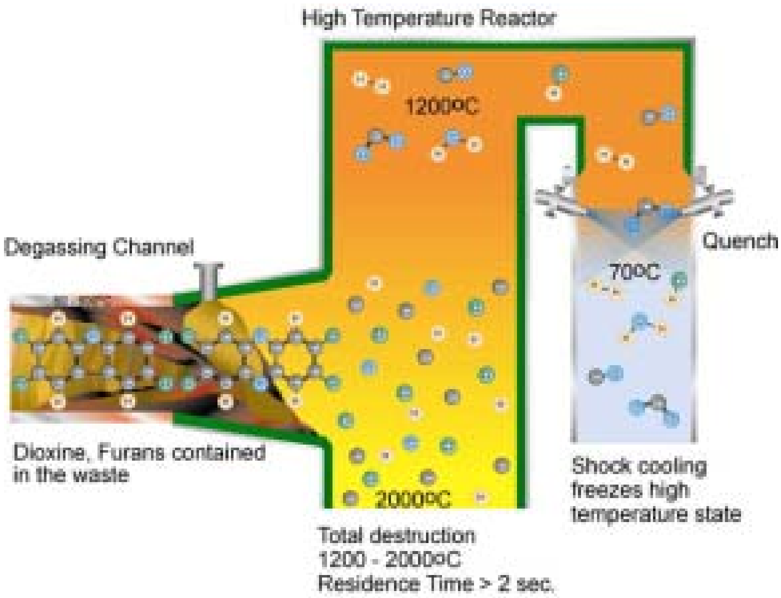
The molten substances are then granulated by water quenching and extracted from the quench basin using a bucket elevator. The difference in thermal conductivity between mineral and metal melt results in the two products automatically granulating separately within the same quench basin. The metal granules are then separated from the mineral granules by magnetic separators.



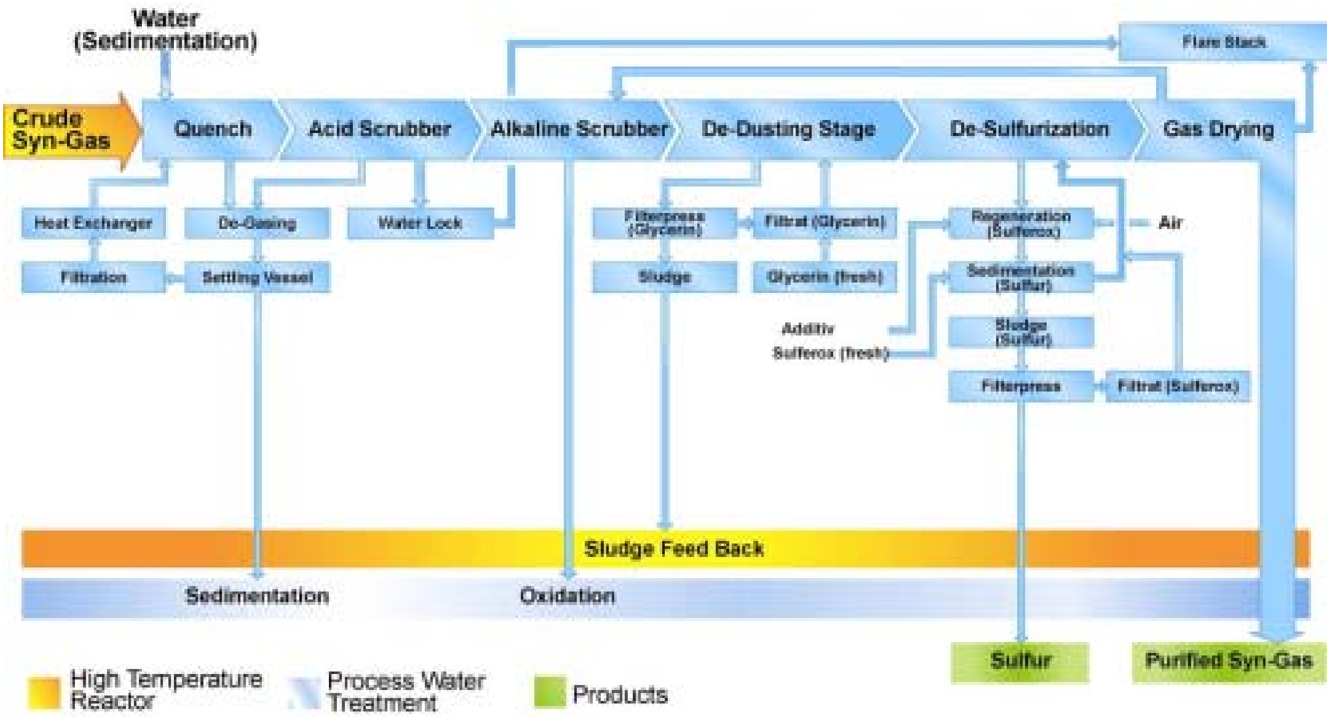
2.4 Synthesis gas cleaning

The synthesis gas passes through a water quench, acidic scrubber, alkaline scrubber, a scrubber for fine dust removal, desulphurization and gas drying stages.

Firstly the crude synthesis gas exits the reactor at approximately 1200°C and flows into a water jet quench where it is cooled almost instantaneously to about 70°C. The shock-like cooling avoids the formation of dioxins, furans and other organic compounds from elementary molecules in the syngas due to the "De Novo Synthesis" back reactions. "De Novo Synthesis" reactions are known to occur in waste heat boilers where a slow cooling in the range from 400°C to 250°C of flue gases with chlorine compounds, uncombusted organic molecules and catalysts such as dust will result in dioxin formation.



Measurements have proven that this is avoided in the THERMOSELECT process. Entrained particles such as graphite and mineral dusts are also separated out in the quench.
The gas path is connected to a water lock tank serving as a safety pressure relief device. In case of a sudden pressure rise above 500 mbar in the gasifier, for example due to a propane bottle burst, the synthesis gas is relieved to the safety flare where it is combusted.
Following the quench the synthesis gas flows through an acidic scrubber where further HCl and HF acids are removed. The acid content of the gas depresses the flushing liquid of these scrubbers to pH~3 which results in the volatilized heavy metals and their compounds dissolving as metal ions. Weaker acid formers such as H_2S, SO_2, and CO_2 do not dissolve at this pH value.

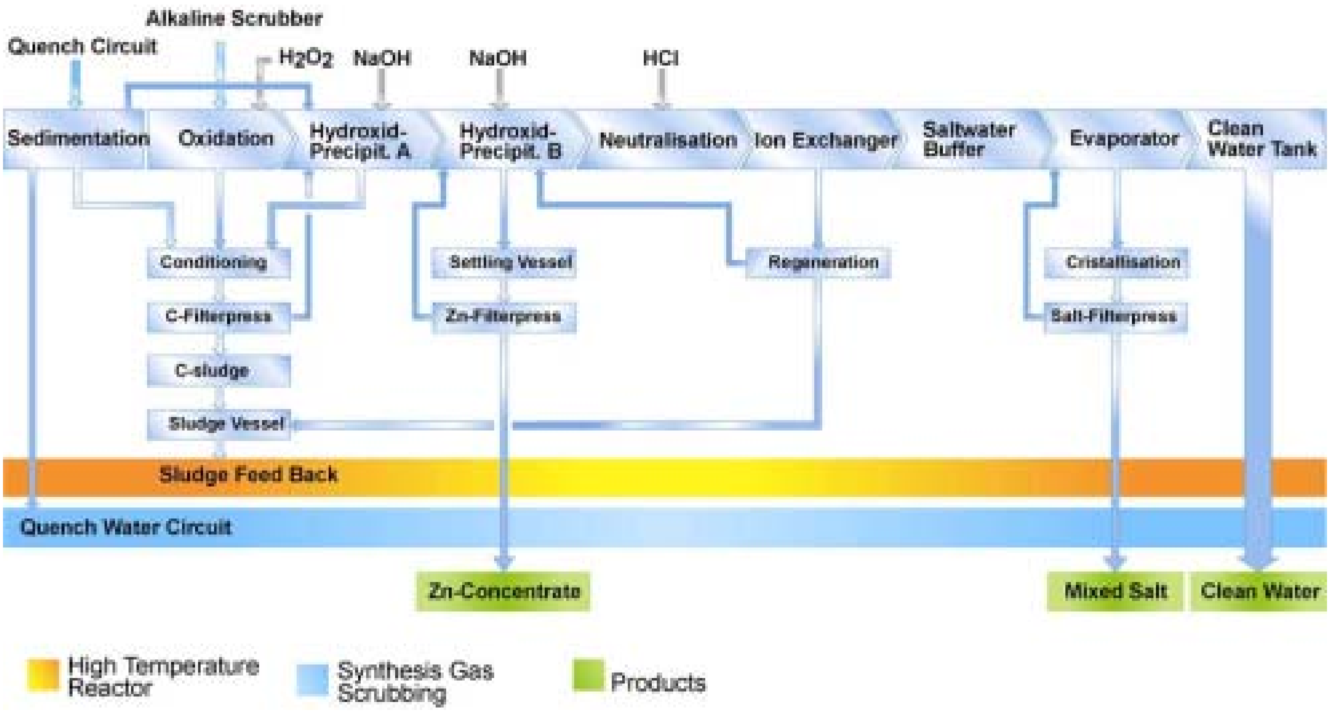


The acid scrubber is followed by an alkaline scrubber which uses NaOH in solution to knock out any residual acid liquid droplets.
The alkaline scrubber is followed by a water scrubber for fine dust removal. The water/solids solution is transferred to a filtration system where the solids are separated out. The solids are transferred back into the high temperature reactor.
The synthesis gas is then passed through a desulphurization process. The scrubbing liquid contains an Fe-III complex which is used to remove the H_2S from the gas. The process allows the conversion of the H_2S into elemental sulfur. The process is a redox-process in which the H_2S is oxidized to elemental sulfur and water by the conversion of the Fe-III into a sulfur Fe-II complex. This conversion process takes place within the scrubber. In a regeneration unit, the scrubbing liquid is then oxidized by blowing air through it which converts the Fe-II back into the Fe-III complex. Elemental sulfur precipitates during this stage which is removed from the liquid by means of a filtration system.
Following desulphurization, the dew point of the gas is lowered by direct contact with triethylene glycol (TEG) in a gas drying scrubber. The lowering of the gas dew point prevents

condensation in downstream equipment such as the power generation infrastructure and also removes residual traces of vaporized heavy metals.

2.5 Process water treatment

The process water originates from the condensed water vapour inherent in the processed waste and from the reaction products of the gasification process. Other small process water streams are generated from the gas scrubbing processes.
The water from the quench circuit is settled, solids are removed and returned back into the high temperature reactor.



The water from the alkaline scrubber, with traces of hydrogen sulfide dissolved in it, is fed into vessels and oxidized using hydrogen peroxide. Soluble sulfate is formed and prevents the evolution of H_2S gas in later processing stages. Also Fe-II is converted to Fe-III which assists in subsequent precipitation steps.
A two stage precipitation then takes place. In the first stage NaOH is added to raise the pH to about 5.5. At this point aluminum and iron hydroxides precipitate which are settled out. The sludge is captured and dewatered in a filtration operation. The solids are returned to the high temperature reactor.
In the second precipitation stage the pH is raised to about 9 through the addition of NaOH. This causes heavy metals such as zinc to precipitate as a hydroxide, which is settled out. The resultant sludge is dewatered by a separate filtration system. The resultant cake is a product of the process.
The next process is a neutralization step in which the pH of the water is reduced to 7 with the addition of HCl acid.
Thereafter the water is passed through an ion exchange unit. The ion exchanger reduces any residual concentrations of multi-valent ions such as zinc and traces of other heavy metals.

The metal ions are exchanged for sodium ions. The regenerate from the ion exchanger is returned to the first precipitation step. The increased concentration of ions in the regenerate will allow capture of these residual ions in the subsequent precipitation processes.
In the final step the process water is passed through a two stage evaporation unit. Condensing clean water is reused in the plant. The remaining salt is extracted by a filtration system and is a product of the process.

3 Synthesis gas utilization

3.1 Energetic use

Synthesis gas can be used as a replacement for fossil fuels in existing power stations, and so substitutes valuable resources. The THERMOSELECT process then works without direct emissions.

If the local circumstances do not permit use in an existing power station, a THERMOSELECT facility can be equipped with its own power production. The following variants are possible:

- High efficiency gas engines (η = 36 – 41 %)
- Single (η = 30 – 36 %) or combined cycle (η = 38 – 50 %) gas turbine processes
- Steam turbine process (η = 20 – 35 %)
- Fuel cells (η = 40 – 65 %)

The choice of power generating equipment is dependent on the price of power. Higher power generating efficiency processes would need to be supported by higher electricity prices.

3.2 Material usage

If the synthesis gas is used to produce chemical products, the THERMOSELECT process operates without direct emissions.

Hydrogen production H_2

The simplest and most widespread element in the universe. Approx. 600 m3 hydrogen can be produced from one ton of waste. See chapter 6.4 for more information.

Methanol production (CH_3OH)

The production of methanol from synthesis gas is state of the art:

$$CO + 2\,H_2 \Rightarrow CH_3OH$$

Approx. 300 kg methanol can be produced from each ton of waste. Methanol is used e.g. as a fuel and petrol substitute, in fuel cells and as chemical feedstock for various other chemical products.

Ammonia (NH_3)

Modern synthesis techniques produce ammonia from hydrogen and nitrogen. Both basic elements are provided during the THERMOSELECT process. Pure hydrogen can be produced from the synthesis gas; nitrogen is available as a side product of the air separation plant integrated in a THERMOSELECT facility.

Ammonia is a starting material in the fertiliser industry and as chemical feedstock in the chemical industry.

4 Technology Maturity

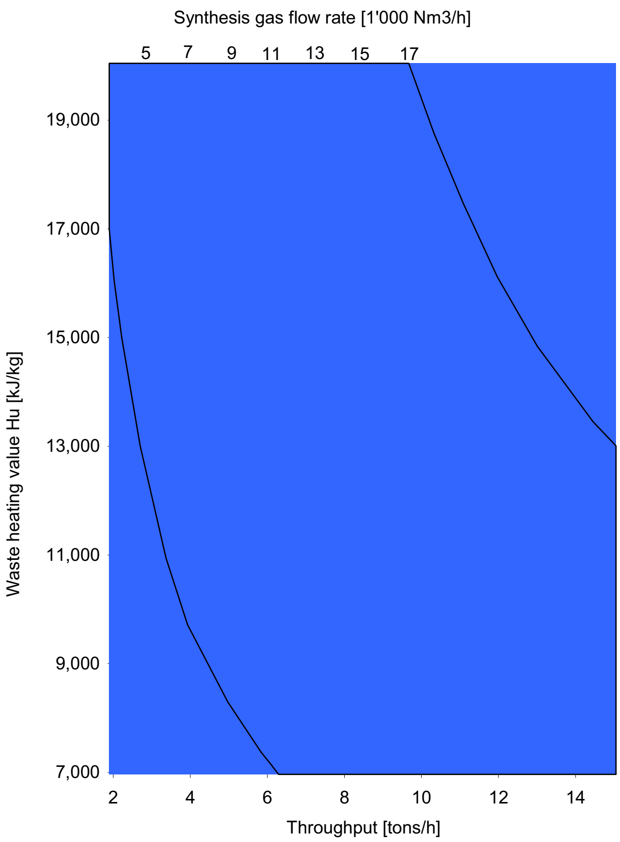
The THERMOSELECT Resources Recovery Facility process has been one of the most exhaustively assessed processes in the world. All assessments have been carried out by 10 independent Government audit authorities from Germany, Switzerland and Italy including the German TÜV (Technischer Überwachungs-Verein) and several Universities. A wealth of information exists on the process, documented in books and International Journal papers. This extensive independent evaluation process has been undertaken primarily to satisfy community and government perceptions on emerging technologies. THERMOSELECT has shown that combined gasification and smelting of the inorganic fractions of waste is a desirable alternative to incineration since it does not create dioxin contaminated dusts, ash, slag and flue gases.

5 Input Quality & Quantity Flexibility

The chemical composition of the waste will determine the quality and amount of raw synthesis gas. This in turn will determine the extent of gas refining required. It has been shown that the automated nature of the THERMOSELECT process adjusts itself to any deviations in waste quality (for example water content). Also, within reason, the quality of the products produced has been shown to vary very little as the waste source is changed from one to another.

One significant advantage of the THERMOSELECT process is its flexibility to handle untreated waste of various kinds. Large bulky items (e.g. furniture) may be shredded and tipped into the bunker.
Liquid wastes such as sewage sludge etc. can also be processed. They are metered into the high temperature reactor together with the recycle streams into the transition section between the degassing channel and the reactor.
The process can also treat industrial wastes. The Chiba plant in Japan has been specially configured for this.

The capacity range of a standard thermal train is depicted right-hand as function of waste heating value. The upper bound of the process is the capacity of the gas scrubbing and process water treatment equipment, whereas below the lower bound the consumption of secondary fuel becomes excessive.

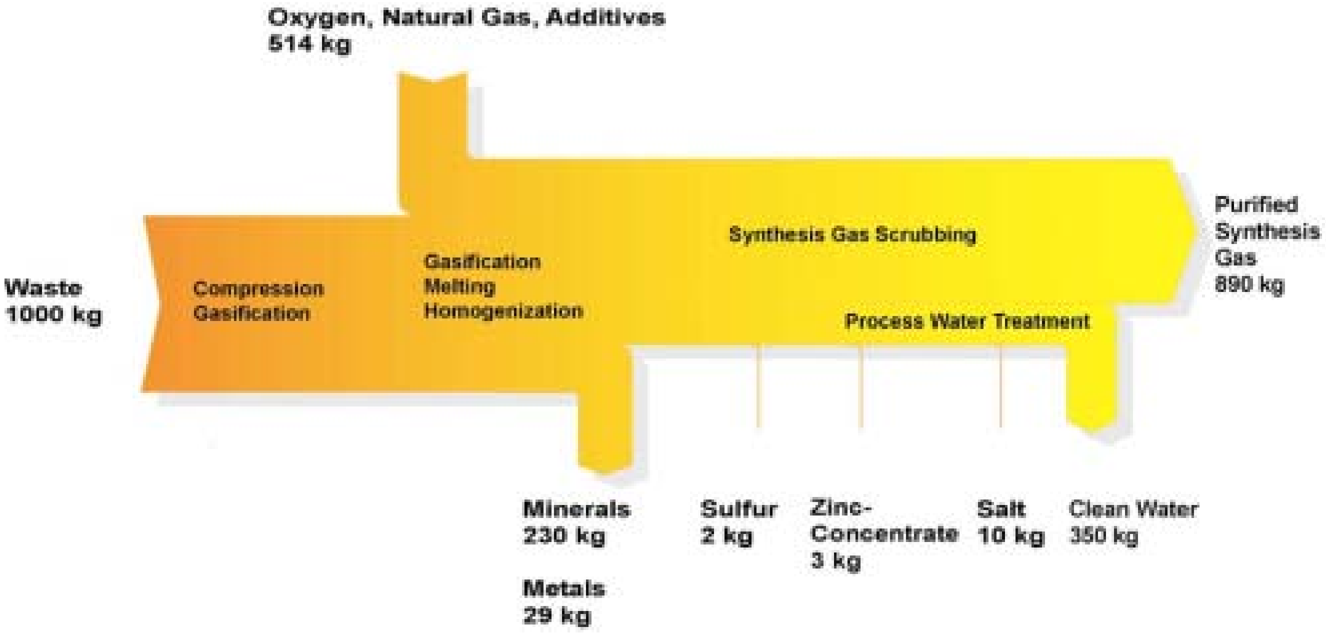


6 Environmental Issues

6.1 Resource Conservation

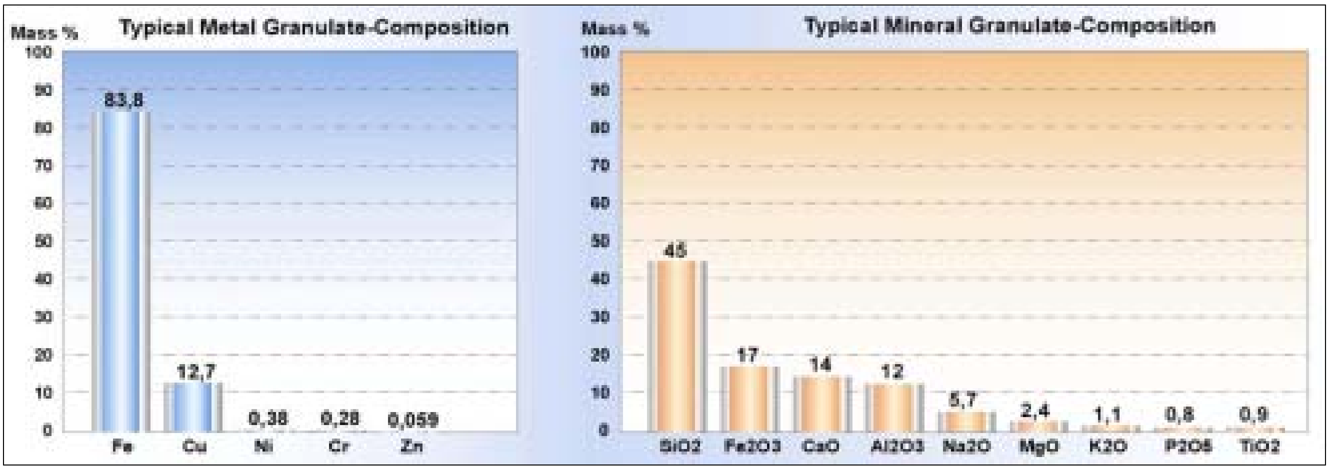
The THERMOSELECT Resource Recovery Facility was conceived as a means to recover the maximum possible benefit out of mixed wastes that cannot be economically recycled. The process is for the continuous processing of mixed wastes with the primary goal of achieving the highest possible yield of high quality recyclable products at the lowest possible ecological pollution level, with simultaneous utilisation of the chemical energy contained in the waste.
The products that are manufactured together with their reuse potential are:

- Mineral granulate reused as gravel substitute in concrete, as shot blast or as road base
- Metal granulate recycled into the metal industry
- Sulfur reused in the sulfuric acid and fertilizer industry
- Zinc concentrate reused in the zinc smelting industry
- Salt reused in the chlorine manufacturing industry
- Water reused in the process
- Synthesis gas either converted to further chemicals or power



6.2 Solid Residues

Unlike other pyrolysis/gasification processes THERMOSELECT does not produce any chars or oils or ashes which need subsequent disposal.
The mineral granulate is a completely inert glassy granulate that has been molten down at high temperature (>1600°C). The leachability of the mineral granulate is negligible and a typical composition is shown below.



The metal granulate is a iron – copper alloy which is reusable in the metals industry.
The Karlsruhe experience has shown that it is possible to reuse the entire above product range within a relevant industry.

6.3 Air and Water Emissions

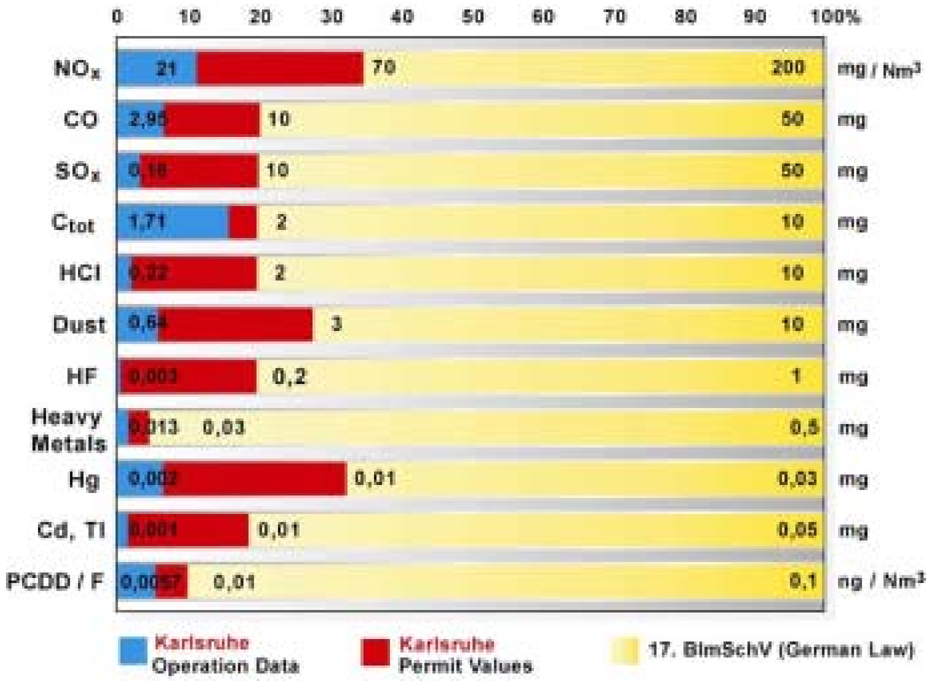
There are no water emissions from the process. The water in the waste is purified and is reused in the process as cooling tower make up.

Air is extracted from the waste receival and bunker areas and routed through a small bag filter. It is then used as combustion air in the power generation facility.

Other emissions to air are the exhaust gases from the unit that converts the synthesis gas into power. These emissions have been extensively tested in Karlsruhe and are monitored continuously (CEM) for compliance. The following figure indicates emission levels obtained in the Karlsruhe plant.

The diagram shows the most stringent emission limits in the world are the German Law (17. BImSchV- yellow bars).

THERMOSELECT have under-taken to achieve at least 70% lower emission values than the current law (permit values as red bars). The actual measured emission values achieved are lower than the permitted values (blue bars). No other thermal technology treating waste in the world today can achieve such low gas emission levels at competitive conditions.



6.4 Hydrogen – energy carrier of the future

Hydrogen is the energy carrier of the 21st century: During combustion it leaves no residues apart from water, especially no carbon dioxide, and therefore relieves the problems of the greenhouse effect. Together with regenerative primary energies it provides a basis for the energy and transportation industry of the future.

The trendsetting fuel cell technology for producing electrical energy with the highest possible efficiencies requires hydrogen or fuels containing hydrogen. Fuel cells for stationary energy production are operated commercially worldwide.

Leading companies in the vehicle and transport branch are backing hydrogen as the fuel of the near future. Technology carriers gone over with a fine toothcomb have proven the feasibility and fitness for everyday use. Motor vehicles run on hydrogen will soon be launched on the market. Aircraft propulsions run on hydrogen are currently being developed.

Fuel cell driven car

Fuel cell bus

Over 30% of the synthesis gas produced during the THERMOSELECT process consists of hydrogen and over 30% is carbon monoxide. By using a conventional reformer – which converts the carbon monoxide fraction into pure hydrogen when water vapour is added – approx. 600 m³ hydrogen can be produced from 1000 m^3 synthesis gas or one ton of waste.
This is equivalent to approx. 100 liters of liquid hydrogen having the energy content of about 30 liters of gasoline.
One garbage truckload of 20 tons of waste yields hence the equivalent of 600 liters of gasoline, an amount sufficient to drive a garbage truck over a distance of about 1’500 km.

7 Scenario Solutions

The THERMOSELECT high temperature recycling process can treat waste of various kinds in a lower calorific value range of approx. 7 – 14 MJ/kg and having a moisture content of up to about 50%.

It is also capable to treat waste streams considered as hazardous, as the inherent process operation conditions fully comply with the European Community Directive 2000/76/EC on the Incineration of Waste, which states

"If hazardous wastes with a content of more than 1% of halogenated organic substances, expressed as chlorine, are incinerated, the temperature has to be raised to 1'100 °C for at least two seconds".

In fact, the THERMOSELECT process guarantees gas residence times of at least 2 seconds at temperatures exceeding 1'200°C. It is therefore perfectly suited to treat MSW as well as commercial and industrial waste streams as defined in the scenarios.

THERMOSELECT has optimized its gasification and direct melting reactors for a capacity of up to 15 tons/h. The plant concept is highly flexible and modular, depending on the project specific capacity requirements an appropriate number of thermal treatment lines may be installed in a plant.

The following assumptions have been adopted for both scenarios:

- THERMOSELECT plants treat MSW as well as commercial and industrial waste
- Commercial and industrial waste recycling rates increase from today 33% to 35.5% in 2020
- Commercial and industrial waste landfill rates decrease at the same pace as MSW landfill rates
- Household waste recycling rates of 25% are achieved in 2006 and of 30.5% in 2020.
- The overall waste amounts are considered invariant in the future.
- The incinerated amount of waste remains unchanged until 2020.
- MSW has a lower calorific value of 10 MJ/kg.
- Commercial and industrial waste has a lower calorific value of 12 MJ/kg.

as well as the boundary conditions:

- THERMOSELECT plants are 100% financed at 5% interest rate and a pay-back period of 25 years.
- Electricity revenues amount to 0.033 GBP/kWh

- Electricity is produced in high efficiency gas engines
- Site costs are difficult to establish and have therefore not been considered in the capital costs and the gate fee.
- Profit is not included in the gate fee
- The exchange rate €/GPB is 0.6539

In the following gate fee calculations, the following break down is presented:

- Revenues generated by sold electricity
- Capital costs
- Operational Costs
- Other Expenditures

The calculations are based on the assumption that cost increases can be compensated by an increase of the gate fee.

7.1 The London Borough of Livingstone

For the London Borough of Livingstone THERMOSELECT's proposal is based on the following assumptions:

- The quantity of generated MSW as well as commercial and industrial waste does not change, but the quantity of waste which will be landfilled, will drop. Thus the total quantity of waste which will be treated in a two line THERMOSELECT plant will increase from 150'093 tons in 2010 to 198'636 tons in 2020 per annum.
- The designed THERMOSELECT plant with two thermal treatment lines will have a throughput of up to 12.5 tons/h per line and an availability of up to 8'000 hours per annum.
- The THERMOSELECT plant operation company receives an operation permit to treat MSW as well as commercial and industrial waste jointly in the plant.
- After the permission is granted and the site is available, approx. 2 years are required to realize the project.

The capital costs are based on a total investment of 69.3 Mio GBP including investment, interim financing, fees, training of the staff, spare parts and working capital. The annual capital costs are the sum of interest and paying back for these investment costs.

The gate fees per ton of waste are in the range of 49.7 to 65.5 GBP, depending on the plant load. The scenario and financial details are spread out in Table 7.1.

Obviously, a large cost fraction is independent of the actual plant throughput. Therefore, at increasing throughput, the gate fee per ton decreases considerably.

Based on these figures, it is therefore in general questionable, if waste should be further landfilled when a THERMOSELECT plant is in operation.

The London Borough of Livingstone					
	2003	**2006**	**2010**	**2013**	**2020**
Household waste, total	150,000	150,000	150,000	150,000	150,000
Recycling rate	8%	25.0%	29.0%	30.0%	30.5%
Household waste, recycled	12,000	37,500	43,500	45,000	45,750
Household waste, incinerated	0	0	0	0	0
Household waste, residual	138,000	112,500	106,500	105,000	104,250
Municipal commerical waste, total	40,000	40,000	40,000	40,000	40,000
Municipal commerical waste, incinerated	0	0	0	0	0
Municipal commerical waste, residual	40,000	40,000	40,000	40,000	40,000
TOTAL MSW, residual	**178,000**	**152,500**	**146,500**	**145,000**	**144,250**
Landfilled	178,000	152,500	61,141	40,761	28,533
MSW, THERMOSELECT	**0**	**0**	**85,359**	**104,239**	**115,717**
Commerical and Industrial, total	**210,000**	**210,000**	**210,000**	**210,000**	**210,000**
Recycling Rate	33.0%	34.0%	35.0%	35.3%	35.5%
Commerical and Industrial, recycled	69,300	71,400	73,500	74,130	74,550
Commerical and Industrial, re-used	31,500	31,500	31,500	31,500	31,500
Commerical and Industrial, landfilled	105,000	102,900	36,066	24,044	16,831
Commerical and Industrial, incinerated	4,200	4,200	4,200	4,200	4,200
Commerical and Industrial, THERMOSELECT	**0**	**0**	**64,734**	**76,126**	**82,919**
No. of thermal treatment lines			2	2	2
Throughput per line [tons/h]			9.4	11.3	12.4
Waste heating value [MJ/kg]			10.9	10.8	10.8
Investment, total [Mio GBP]			69.3	69.3	69.3
Capital costs [Mio GBP/annum]			4.920	4.920	4.920
Operational costs [Mio GBP/annum]			5.987	6.686	7.087
Other Expenditures [Mio GBP/annum]			0.998	1.028	1.045
Total Costs [Mio GBP/annum]			11.905	12.634	13.052
- sold electricity [Mio GBP/annum]			2.081	2.736	3.176
Gate fee (excl. site, excl. profit) [GBP/annum]			9.824	9.898	9.877
Gate fee (excl. site, excl. profit) [GBP/ton]			**65.5**	**54.9**	**49.7**
Electricity surplus [kWh/ton]			424	464	489
No. of employees			40	40	40

Table 7.1

7.2 Capital Waste Authority

For the Capital Waste Authority scenario, we recommend to decentralize the waste treatment. Thus, three THERMOSELECT plants equipped with two thermal lines (nominal capacity 240’000 tons/annum), respectively, are required to achieve the diversion from landfill targets. As compared to one or two plants with higher capacity, the advantage of three medium sized plants is the ability to spread them out in a manner that waste delivery trajectories do not become excessively long and that the local traffic does not increase too sharply because of the garbage trucks.

As in the London Borough of Livingstone scenario, MSW as well as commercial and industrial waste are treated jointly in the plants also in this scenario.

In a first step, two plants are erected and put into operation to deal with 478’129 tons of waste in 2010. A third plant needs to be operational by 2013, when the total waste amount reaches 621’742 tons/annum. The total capacity installed at this point of time will suffice until 2020, when the waste stream reaches 708’221 tons per annum.

The disposal costs per ton of waste are in the range of 42.4 to 49 GBP, depending on the load of the plants. For details on the scenario and the financial aspects, see Table 7.2.

The Capital Waste Authority					
	2003	**2006**	**2010**	**2013**	**2020**
Household waste, total	535,000	535,000	535,000	535,000	535,000
Recycling rate	8.6%	25.0%	29.0%	30.0%	30.5%
Household waste, recycled	46,000	133,750	155,150	160,500	163,175
Household waste, incinerated	80,000	80,000	80,000	80,000	80,000
Household waste, residual	409,000	321,250	299,850	294,500	291,825
Municipal commerical waste, total	140,000	140,000	140,000	140,000	140,000
Municipal commerical waste, incinerated	40,000	40,000	40,000	40,000	40,000
Municipal commerical waste, residual	100,000	100,000	100,000	100,000	100,000
TOTAL MSW, residual	**509,000**	**421,250**	**399,850**	**394,500**	**391,825**
Landfilled	509,000	421,250	218,071	145,380	101,766
MSW, THERMOSELECT	**0**	**0**	**181,779**	**249,120**	**290,059**
Commerical and Industrial, total	**1,115,000**	**1,115,000**	**1,115,000**	**1,115,000**	**1,115,000**
Recycling Rate	33.0%	34.0%	35.0%	35.3%	35.5%
Commerical and Industrial, recycled	367,950	379,100	390,250	393,595	395,825
Commerical and Industrial, re-used	167,250	167,250	167,250	167,250	167,250
Commerical and Industrial, landfilled	557,500	546,350	238,850	159,233	111,463
Commerical and Industrial, incinerated	22,300	22,300	22,300	22,300	22,300
Commerical and Industrial, THERMOSELECT	**0**	**0**	**296,350**	**372,622**	**418,162**
No. of plants			2	3	3
No. of thermal treatment lines per plant			2	2	2
Annual throughput [tons/annum] per plant			239,065	207,247	236,074
Throughput per line [tons/h]			14.9	13.0	14.8
Waste heating value [MJ/kg]			11.2	11.2	11.2
Investment, total [Mio GBP]			76.8	76.8	76.8
Capital costs [Mio GBP/annum]			5.452	5.452	5.452
Operational costs [Mio GBP/annum]			8.117	7.450	8.152
Other Expenditures [Mio GBP/annum]			1.172	1.145	1.174
Total Costs [Mio GBP/annum]			14.741	14.047	14.778
- sold electricity [Mio GBP/annum]			4.612	3.889	4.538
Gate fee (excl. site, excl. profit) [GBP/annum]			10.129	10.158	10.240
Gate fee (excl. site, excl. profit) [GBP/ton]			**42.4**	**49.0**	**43.4**
Electricity surplus [kWh/ton]			590	574	588
No. of employees per plant			40	40	40
No. of employees, total			80	120	120

Table 7.2

8 Previous Experience and Operational Plants

8.1 Fondotoce, Italy.

Plant Capacity: Single line, 30’000 t/a
Operation: Demonstration plant in operation from 1992 to 1998
Synthesis gas utilisation: Gas motor power generation

Reference: Mr Gustavo Ruga
Thermoselect Engineering S.r.l.
Via Dell’Industria, 2 – Loc. Piano Grande
28924 Verbania-Fondotoce / Italy
Tel: +41 – 91 – 756 25 25


Fondotoce / Italy


Process hall / Fondotoce

The Thermoselect process concept was developed at the end of the nineteen eighties. Following detailed preliminary trials, the design of a large scale pilot facility was carried out in 1991.
In 1991/1992 the facility in Fondotoce was constructed on the banks of the Lago Maggiore with a waste treatment capacity of 30’000 tons per year and commenced operations in March 1992. The equipment was tested in practical operation for several years and was continuously optimized. Leading international testing institutes such as the German TÜV attested excellent results.
This plant has been operated by THERMOSELECT.

8.2 Karlsruhe, Germany.

Plant Capacity: 3 lines, 225’000 t/a
Operation start: 1999
Synthesis gas utilisation: Steam turbine power and district heating

Reference: Dr Bernd Hüvel
Thermoselect Südwest GmbH
Hansastr. 50
76189 Karlsruhe / Germany
Tel: +49 - 721 - 9 50 99-10
e-mail: n.gagliano@enbw.com

Karlsruhe / Germany

Control room / Karlsruhe

The THERMOSELECT facility in Karlsruhe (www.thermoselect-karlsruhe.de) has 3 thermal lines for treating waste and has an annual throughput capacity of 225'000 tons p.a., with a calorific design value of 12 GJ/ton. The residual waste of the City of Karlsruhe, Karlsruhe Rural District, the City of Baden-Baden and Rastatt Rural District are disposed of in the facility. It is operated by Thermoselect Südwest GmbH, a wholly-owned subsidiary of Energie Baden-Württemberg AG (EnBW).

Waste delivery by truck

Waste delivery by train

At the start of the nineteen nineties a conventional waste incinerator plant was planned for the City of Karlsruhe at the location in the Rhine harbor area. Due to the outstanding ecological and economic benefits of the THERMOSELECT technology this project was given up in favor of the THERMOSELECT process – despite the costs already incurred for the preliminary design of 10 million Euros.

The THERMOSELECT facility was started up in January 1999 after a twenty month construction period and is today in unlimited continuous operation.

The synthesis gas is used in a steam turbine power station for electricity and district heating generation.

8.3 Chiba, Japan, Kawasaki Steel licensee.

Plant Capacity: Two lines, 100’000 t/a (MSW and industrial wastes)
Operation start: September 1999
Synthesis gas utilisation: Gas engine, fuel cell, and as fuel in Chiba Steel Works

Reference: Mr Masuto Shimizu
Kawasaki Steel Corporation
Chiba 260-0835 / Japan
Tel: +81 - 43 - 262 - 45 08
e-mail: m-shimizu@kawasaki-steel.co.jp

Chiba / Japan

Control room / Chiba

The first THERMOSELECT facility in Japan has been in operation in Chiba in Greater Tokyo since autumn 1999. It is a 2-line facility with a capacity of 100’000 tonnes per annum.

On 13th April 2000, the THERMOSELECT licensee in Japan, Kawasaki Steel Corporation (KSC), received a permit from the Japan Waste Management Association for the general use of the THERMOSELECT technology in Japan. The facility is used for waste disposal of domestic, commercial and industrial waste.

Fuel cell / Chiba

Gas engine 1.5 MW / Chiba

Approx. 80% of the synthesis gas is passed on to a neighboring steelworks in Chiba. A 1.5 MW gas motor module is used to generate electricity in the THERMOSELECT facility. Working in collaboration with Toshiba, a 200 kW fuel cell is currently undergoing trials for synthesis gas utilisation in order to achieve highest possible efficiencies for the conversion into electric energy in future.

8.4 Ansbach, Germany.

Plant Capacity: One line, 75000 t/a
Operation: Under construction, Startup in 2003
Synthesis gas utilisation: Gas motor power generation

Ansbach / Germany

9 THERMOSELECT Company Information

9.1 Name

THERMOSELECT S.A.

The Company is the main engineering resource of the THERMOSELECT Group of companies, responsible for development, engineering, design, construction and sales of Turn Key THERMOSELECT Plants worldwide.

9.2 Address

Via Naviglio Vecchio 4
CH – 6600 Locarno

Tel.: +41 – 91 – 756 25 55
Fax.: +41 – 91 - 756 25 26
E-mail: gl@thermoselect.ch

9.3 Ownership Details

The THERMOSELECT S.A. is a non public joint-stock company, located and registered in Locarno / Switzerland, Register No. CH-509.3.001.101-7.

The THERMOSELECT S.A. is held 100% by the Holding Company THERMOSELECT AG, Vaduz / Fürstentum Liechtenstein

The shareholders of the Holding THERMOSELECT AG are:

7.0 %	EnBW, Energie Baden – Württemberg AG, Karlsruhe, Germany
43.1 %	Mr. Günter Kiss, (Inventor of the Technology)
49.9 %	several private shareholders

9.4 Company Profile

The THERMOSELECT Company is the developer and sole supplier of the THERMOSELECT®-Process, which is a high temperature recycling process of all kinds of waste, based on high temperature gasification technology.

THERMOSELECT S.A.

Operative Headquarter of the THERMOSELECT group of Companies, located in Locarno / Switzerland, containing 60 employees and is responsible for:

- Management
- Administration
- Buyers
- Marketing
- Sales
- BOO / BOT
- Development
- Engineering / approval-stage planning & design
- Project management
- Training

THERMOSELECT Heavy Machinery AG

Production and assembly company, located in Dottikon / Switzerland, specialized for heavy machinery equipment made of steel as well of high quality stainless steel, also for third parties. The company is equipped with newest machining facilities, among others one of the largest CNC-tooling centers within Switzerland. This company employs 85 employees and is responsible for:

- Mechanical engineering & plant construction
- Planning, design & engineering
- System solutions for apparatus construction
- Production
- Processing high-alloy materials
- Assembly & testing
- Customer service
- Spare parts management
- THERMOSELECT plant maintenance

THERMOSELECT Engineering S.r.l.

Engineering company, located in Fondotoce / Italy

- Components development
- Engineering
- Construction site supervision
- Commissioning/Start-up

9.5 Licensees

THERMOSELECT has sold exclusive regional licenses to:

- THERMOSELECT SÜDWEST GmbH, Karlsruhe / Germany
- AGR - Abfallentsorgungsgesellschaft Ruhrgebiet, Essen / Germany
- KAWASAKI STEEL CORPORATION, Tokyo /Japan
- DAEWOO Corporation, Seoul / Korea

10 Thermoselect's staff involved in presenting the solution

Curriculum Vitae - Dr. Jürgen Riegel, President

Personal Details

date of birth:	15th of June, 1946
place of birth:	Königstein / Germany
nationality:	German

Professional Experience:

Since 1991	President of Thermoselect S.A., Locarno, Switzerland
1986 - 1990	Lignotock GmbH, Sontra
	1986 - 1990 Managing Director
	1989 - 1990 Chief Executive Officer
1973 - 1985	Rütgerswerke AG, Frankfurt
	1973 - 1974 Cooperate Controlling
	1975 - 1976 Deputy Head of Cooperate Controlling
	1976 - 1979 Head of Controlling of the Vedag (Subsidiary Company)
	1979 - 1981 Head of Branch Controlling
	1982 - 1985 Managing Director of Lignotock fiber technology, Scheuerfeld (Associated Company)

Education:

1970 - 1972	Academic tutor for statistics at the Johann-Wolfgang von Goethe University of Frankfurt and doctoral degree, research subject "Possibilities for the Elimination of Quality Change Impacts on Cost Statistics"
1966 - 1970	Study of business management at the Johann-Wolfgang von Goethe University, Frankfurt

Curriculum Vitae - Dr. Uwe Drost, Project Manager

Personal Details

date of birth:	6th of March, 1969
place of birth:	Frankfurt on the Main / Germany
nationality:	German

Professional Experience:

Since June 2000	Thermoselect S.A., Locarno, Switzerland
Aug. 1998 - May 2000	Development Engineer, gas turbine cooling and heat transfer at ABB Alstom Power, Baden, Switzerland
May 1994 – July 1998	Doctoral assistant at the Laboratoire de Thermique Appliquée et de Turbomachines, EPFL. Research project: "An Experimental Investigation of Gas Turbine Airfoil Aero-Thermal Film Cooling Performance", subsidized by ABB, Switzerland and grantee of the scholarship "E+RB Doctorants"
Feb. 1990 - April 1990	Mech. Eng. internship at Porsche A.G., Stuttgart
Oct. 1988 – Sept. 1989	Compulsory military service

Education:

July 1998	Doctoral degree from the Swiss Federal Institute of Technology - Lausanne (EPFL)
March 1994	Graduation as Dipl. Ing. EPFL, grantee of the Vevey-Technologies price for the best years diploma in ME
Oct. 1993 – Feb. 1994	Diploma work entitled "An Experimental Investigation of the Corner Stall Behavior of a Linear Compressor Cascade at High Angles of Attack" carried out at the Virginia Polytechnic Institute and State University, USA
Oct. 1991 – Sept. 1993	Study of mechanical engineering at the Swiss Federal Institute of Technology - Lausanne (EPFL)
Oct. 1989 – Sept. 1991	Study of mechanical engineering at the University of Stuttgart / Germany