THERMAL MUNICIPAL SOLID WASTE GASIFICATION

STATUS REPORT

by
Erwin Altmann
Paul Kellett

JULY 1999

IRISH ENERGY CENTRE
RENEWABLE ENERGY INFORMATION OFFICE
SHINAGH HOUSE, BANDON, CO. CORK, IRELAND. TEL: (023) 42193 FAX: (023) 41304

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Waste gasification is on the way to full commercialisation, and full competition with commercial waste incinerators. The key players are Thermoselect, TPS and Lurgi. Thermoselect has built a plant (industrial scale) in Italy, which has been in operation since 1992. According to Thermoselect, this process is the only closed loop process with energy and raw materials as products.

Lurgi's CBF gasification technologies are at present applied in two industrial plants. It is the key process for advanced biomass or waste treatment plants and integrated gasification combined cycle.
The Lurgi CBF gasifier operates at near atmospheric pressure and is therefore well suited for smaller capacities.

TPS (Sweden) technology is already proven at commercial scale in two RDF- fuelled gasifiers in Greve-in-Cianti in Italy, which have been in operation since 1993.

A TPS study for a 90 MWth waste-fuelled co-generation plant in Sweden has shown that, already today, gasification of solid waste can compete economically with conventional incineration technologies. Compared with modern waste to energy (WtE) plants, the gasification process will permit an increase in electricity output of more than 50 %.

A techno-economic feasibility study for a waste fuelled gasification plant in the Netherlands showed, that the economics were favourable and the technical risk low, but the project has been delayed as the alternative costs of landfilling the waste remains competitive at present.

Plans for closure of the landfill site in Athens are underway, and as a result, TPS is working with an engineering company in Greece to promote the use of gasification technology to handle a part of the waste stream.

The overall strategy proposed in Athens is an integrated waste handling system that will include waste separation, recycling, aerobic composting, anaerobic digestion and gasification. The gasification plant alone is expected to reduce the amount of waste to be landfilled by 170 000 tonnes per annum. If the project receives the go-ahead the gasification plant is expected to be in operation by the year 2002.

I. PREFACE

The Renewable Energy Information Office is a part of the Irish Energy Centre. The aim is to promote renewables by making people aware of the possibilities and the positive effects of using renewable energy sources. Our main renewable energy sources in Ireland are wind energy, biomass (especially wood), hydropower and solar energy as well as geothermal energy.

The aim of the following report was to get an overview of the current situation in Gasification Technology, especially for municipal solid waste (MSW). The information presented in this report was gathered from existing international reports dealing with these areas and through contact with companies who are working in the area.

The aim was to compile current information by directly contacting the people and companies and by using reports not more than 3 years old. We also tried to get the most recent information available on the Internet, so that this report mainly represents the situation of the year 1998 and early 1999.

II. INTRODUCTION

Waste gasification has been proposed as an alternative solution for waste destruction with energy recovery. It is claimed that waste gasification is as environmentally clean as a state-of-art waste incinerator, that the capital cost of systems based on gasification is comparable with (or even cheaper than) that of conventional waste to energy (WtE) plants. The electric efficiencies of such systems can be up to 50% higher than conventional WtE plants, the overall cost of treating waste can be significantly reduced.

[1]Advanced thermal conversion technologies for wastes are currently in transition between research and demonstration phases, although a few technology developers claim that they can offer plant on a fully commercial basis. Most companies developing equipment have pilot scale plant with a few operating full scale demonstrations.

[1] Advanced Thermal Conversion technologies fir Energy from Solid Waste, IEA Bioenergy, Aug. 1998

1.0. WASTE GASIFICATION PROCESSES

1.1. THE THERMOSELECT PROCESS

Thermoselect is a process that provides a wide-ranging solution to the problem of refuse. Continuous high temperature recycling ensures that all types of waste - household and industrial refuse, chemical residues and sewage sludges are completely converted in an environmentally sound manner into products which can replace natural raw materials and are suitable for re-use in industrial operations.

There is no need for a residual waste dump of the kind required by other processes. In the Thermoselect process municipal solid waste (MSW) is gasified and melted in two steps: firstly indirect drying/pyrolisis and secondly a high temperature gasification with of oxygen.
The high temperature treatment produces a molten slag and enables the process to handle a large range of solid wastes.

The product gas is treated in a rather complex gas cleaning system. This gas may be used in power production, through a conventional steam cycle or a combined cycle.

STATUS

The Thermoselect Process is established in a 32, 000 tonnes per year of MSW pilot demonstration plant in Fondotoce in Italy (2.5 t/h).
Thermoselect is the world's first closed loop process - realised in an industrial scale plant - integrating a direct melting system for the inorganic components of waste.

1.2. THE TPS GASIFICATION AND HOT GAS CLEANING PROCESS[2]

The TPS gasification process is based on atmospheric pressure circulated fluidised bed (CFB) gasifier coupled directly to a tar-cracking vessel. The gas product is cooled and cleaned in conventional equipment and then fired in either a gas boiler, engine or gas turbine without requiring extensive flue gas cleaning, as is normally required in conventional waste incineration plants. Producing clean fuel gas in this manner facilitates the use of efficient gas fired boilers which means that net electrical efficiencies of close to 30% can be obtained.

TPS has performed a considerable amount of pilot plant testing on waste fuel in their gasification/gas cleaning pilot plant in Sweden. Two gasifiers of TPS design have been in operation in Greve in Chianti in Italy since 1992.

A study for a 90 MWth waste-fuelled co-generation plant in Sweden has shown that, already today, gasification of solid waste can compete economically with conventional incineration technologies. Compared with modern waste to energy

[2] TPS Termiska Processer AB, Nykoping, Sweden

(WtE) plants, the gasification process will permit an increase in electricity output of more than 50 %.

Table1. Data for 87 MW RDF-fuelled Cogeneration plant (1993)

	Electrical efficiency (%)	**Investment (ECU/kW)**	**Investment (ECU/kW)**
		El + heat	El
Gasifier – gas furnace[1]	27.8	1483	4551
Gasifier – gas turbine[2]	35.5	1585	3784
Mass burning[3]	22.5	1738	7006
Mass burning – 50 MW (Germany)		3068	

[1]Gasification, gas cleaning and steam boiler cycle
[2]Gasification, gas cleaning and combined cycle utilising a gas turbine
[3]Conventional grate fired boiler

TPS are involved in two on-going projects to demonstrate the CFB tar cracking technology developed by TPS. These projects aim to demonstrate the operation of a biomass-fuelled combined cycle plant. Each plant will employ a CBF gasifier, a CBF tar cracker, fuel gas cooling equipment, filter and wet scrubber to produce a clean gas for firing in a gas turbine. Both of these plants are sheduled for start up in 2000. Although these plants will use biomass as feedstock, the gasification/gas cleaning technology is equally suited to waste fuels.

TPS believes that in the long term the use of waste as a feedstock to combined cycle systems is feasible. Firing the clean process gas from waste gasification in a gas turbine/combined cycle system will allow electrical efficiencies of >40% to be achieved.

STATUS[3]

The TPS gasification/hot gas cleaning has been extensively tested in pilot plant scale (2 MW fuel), and is to be demonstrated in IGCC plants. The plants are due for start-up in 1999. The fuel is woody biomass. For RDF pellets and to some extend fluff, initial pilot testing took place 1990-91, and further pilot tests in 1996.

1.3. LURGI UMWELT GmbH

CFB units are state of the art and have proven their capability of converting biomass, waste or coal into power and/or steam.

Lurgi's CBF gasification technologies are at present applied in two industrial plants. It is the key process for advanced biomass or waste treatment plants and integrated gasification combined cycle.

[3] TPS, IEA Biomass Agreement, Task 10, 1996

The Lurgi CBF gasifier operates at near atmospheric pressure and is therefore well suited for smaller capacities.

Tested feedstock, such as wood, miscanthus, tree bark, sorghum, RDF (refuse derived fuel), contaminated wood and rubber waste, are suitable for the atmospheric CFB gasification process. Therefore CFB gasification can be effectively used as a front-end process in the following applications:

Biomass to electric power:

- CFB gasification attached to Power Plant Boiler
  Gas from biomass is used as a substitute in existing coal or heavy oil fired power plants.

CFB gas for combined power cycle

- CFB gas from biomass is cleaned and conditioned for combined cycle power generation or utilisation in a gas motor.

Table 2. CBF Gasification Plants from Lurgi[4]

Location	**Capacity**	**Product**	**Operation since**	**Fuel**
Ruedersdorf, Germany	100 MWth	fuel gas	1996	Wood,waste wood, **RDF**, Lignite waste
Thermie Project, Flensburg, G	20 MWth	Fuel gas	-	**Municipal waste**
Noord Holland Project	30 MWe	El. Power	Test runs performed	Wood, **waste**

1.4. DANECO[5]

The Italian waste treatment company is now actively marketing an RDF gasifier in addition to RDF plants. The 10 MW air blown updraft gasifier is coupled to a gas cleaning system with a novel tar cracking unit and fuel gas cooling and cleaning.

[4] Fax from Lurgi, June 1999
[5] IEA Biomass Agreement, Task 10, 1996

1.5. VTT ENERGY – WASTE CONVERSION REASEARCH PROGRAMME[6]

In most western countries 30 - 80% of combustible wastes are incinerated in mixed waste incinerators. The principle of this process is that unsorted waste is combusted in grate boilers with efficiency of 0 - 20% (normally only electricity is produced). The cleaning of flue gases is extremely expensive and a typical incinerator costs about 500 million USDollars. This kind of incinerator can handle about 500 000 tons of waste and produce about 40 MW of electricity.

In Finland there were several technical and economical reasons why a new way was needed in thermal waste recovery:

- The quantity of wastes is too small for traditional waste incineration.
- The investment costs of incinerators are too high.
- The image of mixed waste incineration is poor.
- There are about 60 fluidised bed boilers in Finland designed for solid high moisture containing fuels. Also small grate boilers are used for district heating in small towns. High number of boilers save transportation needed.
- The use of chlorine containing PVC is very low with almost none in packaging materials. Also the attitude of common people is very positive to waste source separation.

For those reasons source separated waste is used to produce high quality recovered fuel, RDF, which is then used as secondary fuel in existing boilers.

VTT Energy has worked with this process for over 5 years and was involved in about 25 full scale trials, which showed that this is a way to solve the thermal waste recovery problem, but many new items must be studied to maximise the economy and to minimise the environmental influence.

To help different waste management companies, energy producers, companies manufacturing equipment and boilers and other parties, VTT Energy started a waste conversion programme. All the activities of VTT Energy in the waste handling and conversion area are collected to get the best available knowledge for their customers and to start research projects to create new information and know how for VTT and the companies involved.

Subjects to be studied in Waste Conversion in VTT are:
- Waste sources, sorted waste types suitable for fuel production.
- Handling and fuel processing.
- Feeding of recovered fuel (REF).
- Converting technology.
- Fouling and high temperature corrosion.
- Emissions and ash properties.

[6] http://www.vtt.fi/ene/program/WASTE.htm

In most projects VTT Energy utilises its advantage of wide expertise. Other project partners are typically experts only on one or two subjects.
Most of the projects are company projects, this means that there is an emphasis in solving existing problems in today's processes or in future processes to be invested in.

2.0. ECONOMICS[7]

It is difficult to compare the costs of advanced thermal conversion processes with conventional combustion on a direct basis. This is due to the fact that the costs available are for different specifications of plant, for example meeting different emissions standards, having varying ash content and water treatment requirements.

Another factor that complicates cost comparison is the multitude of countries from which the published data originates. Labour, raw material financing and other costs will vary between countries. Therefore probably the most reliable comparison of cost does not result from actual plant data but from theoretical studies carried out by individual organisations, such as those undertaken by Novem and NREL (USA), where they normalise the data and adopt standard plant specifications.

CAPITAL COSTS

Capital costs of mass burn combustion (MBC) plants are typically 240-280 ECU per tonne per year of MSW capacity for plant of 400 - 100kt/y designed to meet the current EU standards (this typically means semi-dry scrubber, fabric filter and active carbon injection).

The cost for advanced conversation technologies, 210-340 ECU per tonne per year clearly overlap the range for MBC and should therefore be able to compete, especially for smaller-scale-plants. The more expensive advanced conversion plants are generally likely to have better environmental performance than MBC plants, particularly with respect to ash and waste water.

OPERATING COSTS

Operating costs for advanced thermal conversion plants range from 30-70 ECU per tonne according to the literature. Typical operating costs for MBC plant in the UK, which are designed to meet EU standards, are 21-29 ECU per tonne of MSW.

[7] IEA Advanced Thermal Conversion Technologies for Energy from Solid Waste, August 1998

3.0. PROJECTS

3.1. Grève-in-Chianti WASTE GASIFICATION PLANT

In 1989, TPS sold a license for its CFB gasification technology to Ansaldo Aerimpianti SpA for the construction of a waste-fuelled gasification plant in Grève-in-Chianti, Italy. As part of this project, TPS conducted test work in its pilot plant using refuse-derived fuel (RDF) pellets as feedstock.

The gasification plant has a total capacity of 200 tonnes of RDF per day. The RDF is delivered to the plant in pellet form, which is fed into the lower sections of two CFB gasifiers, each of 15 MWth fuel capacity. The TPS-designed gasifiers operate at close to atmospheric pressure at approximately 850°C, employing air as the gasification/fluidising agent.

The raw gas from each gasifier passes through two stages of solids separation before being fed to a furnace/boiler. Alternatively, part of this raw gas stream can be led to a nearby cement factory to be used as fuel in the cement kilns. Ash and lime are fed to the cement factory as ballast material. The flue gas exiting the boiler is cleaned in a three-stage dry scrubber system before being exhausted through the stack. Steam produced in the boiler drives a 6.7 MWe steam turbine.

3.2. BERRENRATH PROJECT, GERMANY[8]

The objective of this project is to demonstrate the suitability of the High-Temperature-Winkler gasification process (HTW) for efficient use of brown coal and municipal solid waste by co-gasification in a fluidisised bed system at commercial scale.

STATUS

The co-gasification of brown coal and MSW has been successfully demonstrated. At present it is unclear whether Berrenrath consortium will continue the operation of the plant on the co-gasification mode. One of the problems faced is the continous quality of the pre-treated waste, which is supplied by more than one producer.

3.3. PLANNED PROJECTS[9]

Over the last 3 years, TPS has worked with Shelde Engineers and Contractors, in the Netherlands, on a techno-economic feasibility study for a waste fuelled gasification plant in the province of Zealand, the Netherlands. As part of this study, the possibility of firing the product gas either in a boiler, gas engine or gas turbine was investigated. It was concluded that the option of building a 50 000 tonnes per annum waste

[8] Power Production Biomass III, VTT-Seminar, September 1998
[9] Waste Gasification, IMECHE HQ, London, Nov. 1998

(=25,000 tonnes per annum RDF) gasification plant to produce a fuel gas that would be co-fired in an adjacent coal-fired boiler was the preferred option.

Although the economics were considered favourable and the technical risk limited, the project has been delayed as the alternative costs of landfilling the waste remains competitive. This situation is likely to change in the near future as landfilling will soon be stopped completely in accordance with government policy of banning the disposal of organic material and thus, alternative solutions for treating waste will have to be found.

The largest operational landfill site in the European Union is at Ano Liosia, Athens, Greece. This site, which serves the population of greater Attica (about five million people) processes about 3 600 tonnes of waste per day. Plans for closure of this site are underway, and as a result, TPS is working with an engineering company in Greece to promote the use of gasification technology to handle a part of the waste stream.

The overall strategy proposed is an integrated waste handling system that will include waste separation, recycling, aerobic composting, anaerobic digestion and gasification. The product gas from the gasification/gas cleaning plant will be fired in a dedicated boiler. The gasification plant alone is expected to reduce the amount of waste to be landfilled by 170 000 tonnes per annum. If the project receives the go-ahead the gasification plant is expected to be in operation by the year 2002. The project is supported by the EU THERMIE-programme.

3.4. STATUS OF TECHNOLOGY FOR MSW[10]

Technology	Status
Siemens TWR (Pyrolysis)	• 150 kt/a plant in hot commissioning at Fuerth in Germany • Experiencing commissioning problems • 7 other orders announced but currently on hold pending outcome of Fuerth
Thermoselect	• Edmo plant 2.5t/hr in Fondotoce, Italy, commissioned in 1992 • 225kt/a plant in commissioning at Karlsruhe in Germany • 9 other orders announced
Von Roll (Pyrolysis)	• 50 kt/a demo plant operating at Bremerhaven, Germany
Nippon Steel	• 4 plants operating 120-450t/d • 1 plant under construction 180t/d
TPS	• plant (2x15 MW) has been gasifying RDF at Greve in Italy since 1992 with syngas used in an adjacent cement kiln.
PKA	• plant constructed at Aalen in Germany (20 kt/a) currently in commissioning
Mannesmann (Pyrolysis)	• plant (32 kt/a) operating on unsorted MSW at Burgau, Germany since 1987 • contract awarded for a 100kt/a plant for Dortmund, Germany

[10] Waste Gasification, November 1998, Seminar in London

Table 4. Developing Technologies for MSW Processing[11]

Large Scale (>100kt/a)	**Small Scale (<100 kt/a)**
Thermoselect, Switzerland	PKA, Germany (pyrolysis+gasification)
Nippon Steel, Japan	
Krupp Uhde, Germany	
TPS, Sweden	
EPI, USA	
Battelle, USA	
MTCI, USA	
NKK, Japan	
Ebara, Japan	

[11] Waste Gasification, November 1998, Seminar in London

4.0. WASTE GASIFICATION PLANTS FOR THE PROVISION OF ELECTRICITY

LOCATION/OWNER	TYPE	STAGE	FUEL	GAS USE	PLANT SIZE
Greve in Chianti Project, TPS, Ansaldo	Atm. pressure CFB	Demo, 1993	RDF, biomass	CHP, The demoplant (200t/d) is close to the point of commercial availability.	6.7 MWe
Berrenrath Project, Rheinbraun, Germany	HTW	Demo	RDF	Co-gasification with coal	22 MWe
Shegers Engineering N.V., Belgium	FBG	Pilot	RDF, plastics, rubber, hospital waste	0.5 t/h	
Ecomake Ltd., Finland	Gasifi.	Demo	Tyres	500 t/y	
ANDCO-TORRAX/KVAERNER, France	Fixed bed slagging updraft	Comm	Hosp. Waste, MSW tested	1.6 MWe 10.5 MWth	
Thermoselect S.A.	Gasifi	Demo/comm	Co-mingled MSW, and selected ind. Wastes	The 2.5 t/h pilot plant at Fondodoce, Italy is practically at the commercialisation stage. Demonstration plant of 100 kt/y is under construction in Karlsruhe.	
Lurgi, Ruedersdorf Germany	Atm. FBG	Demo/comm	RDF tested, wood, ..		100 MWth
Thermie project, Germany, Lurgii			Municipal waste	Fuel gas	20 MWth
TPS, Sweden	FBG	Demo, 1996	RDF, biomass		
BPI Projects, UK	Gasifi.	Pilot	Tyres	The pilot plant is no longer operational. The commercial plant is expected to be 45 kt/y	
Noord Holland Project		Test runs performed	Wood, waste		30 MWel
Wellman Process Engineering Ltd, UK	Gasifi	Demo.for heat, pilot for electr.			

FBG…fluidised bed gasification
Gasifi…gasification
Demo…demonstration
Comm…commercial
Atm…atmospheric pressure
HTW…high temperature Winkler process
CHP…combined heat and power

5.0. COMPANIES AND ORGANISATIONS INVOLVED IN WASTE GASIFICATION

DENMARK

Ansaldo Vølund, Denmark
Ansaldo Vølund have in the course of the recent years developed a back-current gasifier. A 4 MW gasification plant for wood chips has already been in commercial operation for more than 3 years and will now be extended to include 2 motors and generators.
Also working on medium scale power plant based on fixed bed, updraft gasifiers.

FINLAND

VTT EnergyNew Energy Technologies
Gasification research
VTT Energy is one of the nine research institutes of VTT, the Technical Research Centre of Finland. VTT Energy carries out high level and impartial R&D work on the areas of energy production, energy transfer, and energy use and process industry. With a staff of 300 the turnover in 1998 was FIM 158 million.
Contact:
P.O.Box 1601, FIN-02044 VTT, Finland
Tel. +358-9-4561 Fax +358-9-460493
Gasification technology: Esa Kurkela, M.Sc. BIK +358 9 456 5596
Or Kai Sipila (kai.sipila@vtt.fi)

ECOMAKE FINLAND OY LTD
TASAVALLANKATU 22
70620 KUOPIO
Tel +358-(0)17-2652100 Fax +358-(0)17-2652155

Kvaerner Pulping Oy
Boiler plant manufacturer
P.O. Box 109, FIN-33101 Tampere
Tel. +358 3 241 31111 Fax. +358 3 241 3275

GERMANY

Lurgi Environment GmbH, Germany
Gasification Technology for the utilisation of biomass and waste.
Contact: Mr. Claus Greil
Frankfurt am Main
Tel. +49 69 58 08 30 59 Fax. +49 69 58 08 2757
http://wwwlurgi.com

ITALY

ABB Daneco Unit
An EPC company world leader in Power plants
Via Linussio, 52 - Z.I.U.
I-33100 Udine
Tel. 0432 / 605 1 Fax. 0432 / 600 863

SWEDEN

TPS Termiska Processer AB
TPS is a privately owned research and development company with commercial interests in the exploitation of its in-house developed gasification system.
The TPS (Sweden) technology is already proven at commercial scale in two RDF-fuelled gasifiers in Greve-in-Cianti in Italy
Contact:
Erik Rensfelt
Studsvik, 611 82 Nyköping
Phone: +46 155 221300. Fax: +46 155 263052. E-mail: tps@tps.se

SWITZERLAND

Thermoselect S.A.
Gasification plants for MSW
Contact:
Mr. Roland Schubert
CH-6600 Locarno
Tel. +41 91 7516792 Fax. +41 91 7522370

THE NETHERLANDS

Shelde Engineers
Planned MSW gasification plant in the Netherlands together with TPS
Contact:
P.O.Box 3571
4800 DN-Breda

UNITED KINGDOM

Wellman
Wellman Robey is a major supplier of CHP schemes to a wide range of users in the power, food, paper, oil and gas related industries. It has considerable expertise and is able to take the customer's conceptual ideas and provide a complete turnkey installation.
Developing biomass gasification technologies (medium scale power plant based on fixed bed, updraft gasifiers).

Contact:
Newfield Road, Oldbury
West Midlands, B69 3ET
Tel. +44 121 552 3311 Fax. +44 121 552 4571
e-mail: sales@wellmanrobey.com

6.0. SOURCES OF INFORMATION

Waste Gasification, IMECHE HQ, Seminar in London, Nov. 1998

Power Production Biomass III, VTT-Seminar, September 1998

Advanced Thermal Conversion Technologies for Energy from Solid Waste, IEA Bioenergy, Aug. 1998

TPS, IEA Biomass Agreement, Task 10, 1996

http://www.vtt.fi/ene/program/WASTE.htm