The incineration of waste, and the harvesting of energy from that process, has been in common use globally for many years. As its incomes and consumption rise, Asia too is turning to Waste to Energy as a win-win solution. Hiroshi Ikeda, Minoru Mizuno and Dr. Son Le Mong discuss key drivers and look at one of China's largest thermal waste treatment facilities scheduled to go online in 2013.

The Far East Embraces Waste to Energy

Shanghai Laogang Municipal Solid Waste Project

Thermal waste treatment has long been the norm in most industrialised nations. But now it is also emerging in Asia as the region's environmental burdens escalate. Landfills often fail to comply with mature waste management concepts, resulting in seriously polluted drinking water in almost all Asian countries, and can take up real estate that could be put to better use.

While waste treatment plants are not cure-alls, they do significantly mitigate such problems. They can massively reduce pollutant volumes and end-of-process residues can be so concentrated that systematically landfilling them has no negative consequences.

Demand for waste treatment plants is now considerable not only in Japan, Korea, Taiwan and Singapore, where incineration is the accepted standard, but increasingly also in China and emerging economies such as Thailand, Vietnam, Malaysia, Indonesia and India. Studies reveal a critical threshold: once average annual income exceeds about $3000 per capita, a country's economy develops the typical characteristics of a consumer society. It is at this point that waste becomes a serious problem for potable water as well as air and soil quality – especially near landfills, of course.

Megacities such as Bangkok, Ho Chi Minh City, Mumbai and Manila are especially under threat. Their factories and explosive population growth are responsible for ever-greater volumes of waste, sometimes discarded at illegal landfills or fly-tipping sites.

While fully aware of these problems, authorities often lack the resources to address them. Unquestionably, the top priority is to improve existing landfills, especially with the installation of impermeable liners that prevent leachates from eventually migrating into the underlying geological formations, where they can contaminate the groundwater of an entire region.

As a next step, it is advisable to systematically separate reusable substances from the waste with adequate recycling concepts. Only then, as a third measure, will it be appropriate to leverage thermal waste treatment with energy recovery as an


Creating
New Sources
of Energy

extra incentive. About 1300 plants of this kind have already been built in Japan but 300 of them are more than 25 years old and about 100 will have to be replaced in the coming years. This will create an interesting market for substitution and modernisation projects.

China has also emerged as a growth engine for WtE plants. Currently, about 80 facilities (grate type and fluidized bed) are operating and a further 10 to 15 are under construction, among them one of the world's largest in Shanghai (see box). In the next five years, some 300 new plants are likely to be built in China. Conversely, the markets in countries such as Korea or Taiwan are deemed saturated, even though they have fewer than 50 facilities.

Insufficient awareness of benefits

It is a fact that many decision-makers in these markets have not yet fully recognised the clear benefits of WtE technologies in reducing pollution, helping preserve liveable environments, easing the consumption of precious resources, and cutting greenhouse gas emissions.

While it is known that WtE plants deliver free energy, so to speak, rumours abound that they will eventually pay for themselves with energy revenues. In Asia, where utilities receive only very paltry incomes for the electricity they feed into the grid, this is an unrealistic scenario. Thus, the operators of waste treatment plants, like their counterparts in landfills, have no option but to charge disposal fees for their services.

Unlike Europe, Asia has neither landfill bans nor mandatory incineration. Furthermore, emission limits could prompt communal authorities to impose restrictions vary greatly from region to region.

Some progressive countries like Singapore, Korea, and Taiwan have adopted European limits because they recognise that Europe is several years ahead in waste management. Many communes in China have adopted EU-2000 regulations, but India has defined thresholds only for dust. Some other countries impose no limits whatsoever, because they are still unaware of the consequences.

Asian authorities place exacting demands on suppliers when planning the construction of new waste treatment plants. On the one hand, the principals demand plants be built to the latest state-of-the-art standards (which must be corroborated by references). On the other hand, they want very low prices.

To be specific: a waste treatment plant that finds a buyer in Europe for $100 million will not sell in Asia if it costs more than $20 to $50 million. This enormous pressure on prices means that the technology leaders among European manufacturers are only called upon to supply core components such as combustion chambers. Everything else comes from local companies.

> **Asian authorities place exacting demands on suppliers when planning the construction of new waste plants**

A market for established providers

In Asia, waste management is not a get-rich-quick scheme. The markets are largely dominated by big international waste management companies. Only they have realistic chances of winning tenders and, ultimately, they are the ones that select the suppliers.

The Maishima facility in Osaka, Japan. In the Far East waste treatment projects are now frequently finalised under BOT instead of DBO contracts

The implementation of such projects generally follows an established pattern. The engineering phase begins after the RFQ and the selection of the contractor. Half a year later, construction begins and engineering continues. China already has enough specialists for the engineering tasks but elsewhere the principals must often rely on the contractor's experienced personnel.

In Asia, boilers tend to be manufactured locally for cost reasons. But the associated engineering services as well as the combustion system at the heart of the plant come from foreign suppliers. Apart from the price, the supplier's experience in completing such projects is the second most important criterion.

The often-distressed financial situation of Far Eastern governments in past years has influenced the form of contracts. Instead of design-build-operate (DBO) contracts, waste treatment plant projects are now frequently finalised under build-operate-transfer (BOT) contracts.

An example of the latest form of contracts can be seen in a Shanghai plant currently under construction, one that will rank among China's largest thermal waste treatment facilities and scheduled to go online in 2013..

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A Waste to Energy facility in Incheon, South Korea - a country which has progressively adopted forward-thinking European limits

Shanghai Laogang Municipal Solid Waste Project

Client: Shanghai Laogang Solid Waste Utilization Co Ltd
Location: Laogang Nanhui, Pudong District
Type of Contract: DBO
Expected start-up: June 2013
Combustion unit: DeRoll (AE&E Inova) Hitachi Zosen Corporation (Hitz) type grate, of four lines with 750 t/d each
Energy Production: 60 MW of Electricity

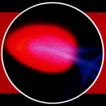
Construction work on the Shanghai Laogang Phase 1 Project, among mainland China's largest municipal solid waste plants, was started by the special purpose company (SPC), Shanghai Laogang Solid Waste Utilization Co Ltd, in August 2010 on the reclaimed land site of Laogang Nanhui, in Pudong New Area.

The plant features a DeRoll (AE&E Inova) Hitz Grates combustion unit and a Dry + Wet FGC flue gas cleaning system to meet EU 2000/76 emission criteria. The plant capacity is 3000 t/d, 750 t/d each, with a production of 60 MW electricity by the waste heat boiler and the turbine generator (BTG).

The contract for the waste incineration line design, supply of equipment, and technical services was awarded to Hitachi Zosen Corporation, the sole licensee of AE&E Inova in East Asia. The company will supply the design, key components and technical services.

The plant is expected to be a model plant in China for large scale waste treatment plant to ensure efficient mass treatment and the maximum output of electricity.

Various thermal processes are now available for managing solid waste but which one comes out top when it comes to both environmental and economic grounds? Dr Gary Young discusses a comparative study of the five forms of thermal pyrolysis/gasification technology - including plasma arc.



Plasma Arc
The Leading Light?

Pyrolysis/gasification technology is emerging as one of the most attractive and economically viable ways to manage and treat waste. This includes municipal solid waste (MSW), solid wastes (SW) and/or semi-solid waste (SSW). With these five thermal processes and syngas options for managing waste solids, what thermal process should be considered for converting waste solids to syngas energy? To answer this question, the thermal efficiency and economics of the five technologies were determined and compared.

The typical choice of thermal process technologies is pyrolysis, pyrolysis/gasification, conventional gasification and plasma arc gasification. Mass burn (incineration) is another alternative thermal process technology.

A key product from these thermal gasification technologies is the conversion of solid waste into syngas, which is predominantly carbon monoxide (CO) and hydrogen (H_2). This syngas can be converted to energy (steam and/or electricity), other gases, fuels and/or chemicals.

The five competing technologies have differing features and applications:

Pyrolysis: the thermal decomposition of carbon-based materials in an oxygen deficient atmosphere using heat to produce a synthetic gas (syngas). No air or oxygen is present and no direct burning takes place. The process is endothermic.

Pyrolysis/gasification: a variation of the pyrolysis process in which a close-coupled reactor is added to further gasify any carbon char or pyrolysis liquids from the initial pyrolysis step using air, oxygen and/or steam for the gasification reactions.

Conventional gasification: a thermal process that converts carbonaceous materials, such as solid wastes, into a syngas using a limited quantity of air or oxygen. Conventional gasification conditions are sometimes stated as 790°C - 1650°C (1450°F - 3000°F).

Turning waste into energy. Who manages the risks?

Modern communication media and unprecedented opportunities to travel are making the world smaller and smaller. Borders are blurring and economic markets are becoming more and more international. This also counts for the liberalized energy and waste sector. Partnerships and take-overs result in larger market players with the corresponding responsibility for energy provision and waste management. In our present-day society that runs on energy, financial consequences related to failures can quickly lead to losing the overall view. Risk management is, therefore, essential.

Waste is being processed more and more often by applying environmentally friendly and economically responsible methods. Energy, power and heat are produced from waste while valuable base materials are produced from waste products. Market developments and legislation demand innovative solutions. KEMA is your partner when it comes to business improvements, optimizing your strategy and operational efficiency, both from a technical, environmental and economical perspective.

Since 1927 KEMA has been active as a testing and certification organisation for the Dutch energy sector and it has developed to become a market-focused company with a global scope. KEMA ensures you can control risks with its high-quality consultancy services provided on a business strategic, technical and process-focused level and its inspection, testing and certification services.

The correct operation of the free international energy and waste market demands an intensive exchange of information. Consultants translate the extensive experience that KEMA has in this field to produce fully-fledged solutions for complex issues. KEMA's solutions are, moreover, cost-efficient due to the combination of specialist technical and operational knowledge and business economics insight. KEMA's work constitutes all types of challenges that our customers supply. These customers can fully trust the experience and effort of our experts regardless of where they may be based in the world. **www.kema.com**

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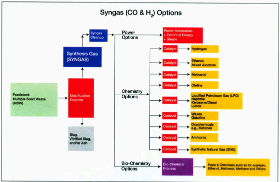

Figure 1. Converting MSW, solid waste or semi-solid waste into energy, gases, fuels and Chemicals

Type of Thermal Process Technology	Net Energy Production to Grid
Mass Burn (Incineration)	493 kWh/tonne MSW (544 kWh/ton MSW)
Pyrolysis	518 kWh/tonne MSW (571 kWh/ton MSW)
Pyrolysis/Gasification	621 kWh/tonne MSW (685 kWh/ton MSW)
Conventional Gasification	621 kWh/tonne MSW (685 kWh/ton MSW)
Plasma Arc Gasification	740 kWh/tonne MSW (816 kWh/ton MSW)
Note: Except for plasma arc gasification, these processes present environmental issues in the disposing of ash and slag.	

Table 1. Thermal Process Technology(s)

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Table 2. Thermal Process Technology and Net Energy to Grid

Plasma arc gasification: a high-temperature pyrolysis process whereby the organics of waste solids (carbon-based materials) are converted to a synthesis gas while inorganic materials and minerals produce a rock-like glassy by-product, called vitrified slag. The synthesis gas (syngas) is created in an oxygen-deficient atmosphere and is predominantly carbon monoxide (CO) and hydrogen (H_2). The high temperature of this process is created by an electric arc in a torch whereby a gas is converted into plasma. The process containing a reactor with a plasma torch processing organics of waste solids (carbon-based materials) is called plasma arc gasification. The reactor for such a process typically operates at 4000°C - 7000°C (7200°F - 12,600°F).

Finally, mass burn (incineration) can be defined as a combustion process which uses an excess of oxygen and/or air to burn the solid wastes. The mass burn process operates with an excess of oxygen present and is therefore a combustion process. Mass burn is not a pyrolysis process.

The management of MSW, solid waste or semi-solid waste by gasification to syngas can be accomplished in various ways. Figure 1 shows a typical configuration for gasifying MSW or other solid or semi-solid waste into syngas. The syngas can be converted to energy via several methods:

- A power option to produce steam and/or electricity
- A chemistry option using catalysts such as Fisher-Tropsch catalysts to produce a wide variety of gases or chemicals such as hydrogen, ethanol, methanol, mixed alcohols, olefins, liquid petroleum gas, kerosene, waxes, ammonia and synthetic natural gas
- The bio-chemistry approach using specific microbes for the conversion of the syngas into natural gas or fuels such as ethanol, methanol and methane.

With these five thermal processes and syngas options for managing waste solids, what thermal process should be considered for converting waste solids to syngas energy? To answer this question, the thermal efficiency and economics of the five technologies were determined and compared.

For the comparison, a 454 tonne/day (500 ton/day) MSW facility using each of the five thermal processes was considered with power option to produce electricity from the syngas. The five thermal processes included: plasma arc gasification, conventional gasification, pyrolysis gasification, pyrolysis, and mass burn (incineration).

Performance/thermal efficiency of technologies:

For the Thermal Process Technologies discussed, the typical range of process operation is presented in Table 1.

Computations on each thermal process technology were done to determine the net energy production of electricity to the grid per ton of municipal solid waste (MSW) processed as shown in Table 2.

Economic parameters for the five thermal technologies were determined such as capital investment, operation and maintenance, by-product production and sales, and residue produced and costs. Using the parameters of capital investment, plant capacity, energy production, operation and maintenance

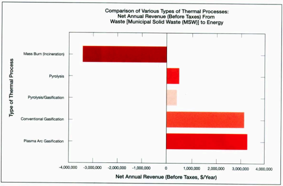

Figure 2. Comparison of Various Types of Thermal Processes

> Plasma arc can minimise if not eliminate the need for landfills... old waste can be mined and used to feed a plasma arc gasification facility

costs, tipping fee, green tags, energy sales, and by-product residues - an economic analysis was performed to determine the net revenue (before taxes) of each thermal process as shown in Figure 2.

From reviewing the Net Energy Production to Grid of the various types of thermal process technologies in Table 2, plasma arc gasification produces about 740 kWh/tonne (816 kWh/ton) of MSW compared to only about 621 kWh/tonne (685 kWh/ton) of MSW for a conventional gasification technology. Plasma arc gasification can therefore be considered the most efficient thermal gasification process.

Figure 2 suggests plasma arc gasification is the most attractive process for handling solid wastes such as MSW, both in terms of thermal efficiency and economics, although conventional gasification and plasma arc gasification yielded similar results.

Plasma Arc Gasification also combined these attributes:

- Thermal efficiency
- Process variety of different solid wastes
- Minimal pretreatment/presorting of solid wastes
- Production of syngas for conversion into energy sources such as steam, electricity and/or liquid fuels
- Environmental appeal as the solid by-product, vitrified slag, can be used as a construction material
- Environmental appeal from the use of syngas to produce various energy products, while any discharged gaseous effluents can be treated by currently acceptable environmental processes
- Minimised if not eliminated need for landfill
- Ability to process and eliminate wastes from existing landfills.

Next, the plasma arc gasification process was studied regarding economy of scale to determine what capacity of facility is commercially feasible. For economy of scale analysis, MSW was gasified to syngas and vitrified slag. The syngas was used to generate electricity and the slag used as a road material. The basic plasma arc gasification process being evaluated is represented in Figure 3. Pre-processing is considered minimal for a well-designed plasma arc gasification facility.

Several economic analyses for the various plant capacities (MSW tons/day) and various revenues (net annual revenue) at various selling prices of electricity (cents/kWh) were collected to analyse economy of scale.

The analyses suggest that a plasma arc gasification facility is near break-even at a capacity of about 180–270 tonnes waste/day (200–300 tons waste/day). The net annual revenue before taxes and the influence of plant capacity as mentioned is known as economy of scale.

With a feed rate of about 656 tonnes/day of waste (724 tons/day), the plasma arc gasification facility generates about $10 million annually in terms of net annual revenue before taxes (total annual revenues minus total annual expenditures), if electricity is sold at 4.50¢/kWh.

At a selling price to the grid of 5.50¢/kWh, net annual revenue before taxes is about $13 million per year. Electricity sold at 6.50 ¢/kWh generates net annual revenue before taxes of about $16 million per year. Capital investment would be about $130 million.

At a feed rate of 454 tonnes/day of waste (500 tons/day), net annual revenue before taxes is about $5 million/year at 4.5 ¢/kWh, $7 million/year at 5.5 ¢/kWh, and $9 million/year at 6.5 ¢/kWh. Capital investment would be about $102 million.

A plasma arc gasification facility at a capacity of 907 tonnes/day of waste (1000 tons/day) generates a net annual revenue before taxes of between $15 million and $23 million per year, depending upon the selling price of electricity. Capital cost is about $154 million.

Thus, the logical approach is a co-operative effort between one or more governmental bodies and industrial entities, so that the economy of scale is fully realised.

As a final note, the net energy production from a plasma arc gasification facility power plant is estimated at about 21 MW, 30 MW and 43 MW for a capacity of 454 tonnes/day (500 tons/day), 636 tonnes/day (700 tons/day) and 907 tonnes/day (1000 tons/day) of waste, respectively. A review of both the net energy