Energy from Waste
Turbines for Waste-to-Energy Plants

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Energy from Waste

Not only in times of increasing urbanization and population or of the growing industrialization of countries becomes waste treatment more and more demanding. Each year thousands of acres of land are lost to landfills. The methane produced from decomposing waste is a potent greenhouse gas. And the costs associated with using a landfill are rising as cities and counties truck their waste ever farther away.

Reasons like these, and others, are causing municipalities to re-evaluate the benefits of energy-from-waste facilities. Some municipalities are considering new facilities and others are looking at expanding the ones they have.

Additionally, more and more governments establish subsidies for an ecological friendly waste treatment.

Energy from Waste (EfW) is often viewed as primarily a waste management solution rather than a valuable energy resource. Consequently, its full potential has not always been realized. Still, worldwide more than 2,200 EfW plants with an overall capacity of about 255 million tons per year are installed.

The heart of virtually every EfW plant is a steam turbine generating electrical power out of the heat from the combustion of waste. An efficient and customized steam turbine is the key to harnessing energy from waste and provides many benefits.

Waste-to-Energy in Europe

Waste-to-Energy Plants operating in Europe (not including hazardous waste incineration plants)
Environmental Benefits
EfW plants are part of the environmental portfolio and contribute significantly towards reducing carbon emissions and meeting renewable energy targets. They have a very good sustainability and greenhouse gas saving characteristics, as they make further use of materials that have already been discarded. Waste seen as source for energy saves the limited fossil fuel resources for the production of sustainable energy.

Sustainability
Waste is produced by mankind. Re-cycling and waste avoidance are still the major ways of waste reduction. The beyond that existing community refuse can be a valuable energy source. One kilogram of waste has a calorific value of around 10,000 kJ and can ideally replace about 0.25 liters of high-grade fuel oil.

Efficiency
The plant makes use of up to 75% of the calorific value of the fuel, since all of the steam produced during incineration is utilized. The high usage factor is also a result of the most advanced techniques in thermal waste disposal. An even higher investment in the power generating technology employing the latest design of steam turbines (see Enhanced Platform design, p. 10) can result in up to 4% more output compared to the well-proven standard design.

Reliability
EfW plants use waste incineration as a valuable source of fuel. Thus, they help to reduce the dependency on energy imports. When used for electricity generation, these technologies have a steady and controllable output, sometimes referred to as providing “base load” power.
Energy can be recovered from waste by different technologies. It is important that recyclable material is removed first, and that energy is recovered from what remains, i.e. from the residual waste.

- Combustion, in which the residual waste is burned at >850°C and the energy recovered as electricity or heat
- Pyrolysis and gasification, where the fuel is heated with little or no oxygen to produce “syngas” (CO+H₂) which can be used directly to generate energy or as a feedstock for producing hydrocarbons such as methane, chemicals, advanced biofuels, or hydrogen
- Anaerobic digestion, which uses microorganisms to convert organic waste into a methane-rich biogas that can be combusted to generate electricity and heat or converted to biomethane. This technology is most suitable for wet organic waste or food waste. The other output is a biofertiliser

**Combustion**
EFW plants typically use a boiler to capture and convert the released heat into electricity and steam. Extensive air pollution control systems are installed to clean the combustion gases and to comply with regulatory emission limits before they are released to atmosphere through a chimney. These plants typically take between 50 – 500 thousand tonnes per year of waste-derived fuel.

**Typical fuels are**
- Municipal Solid Waste
- Commercial & Industrial Waste
- Processed Waste to Refuse derived fuel (RDF) or Solid Recovered Fuel (SRF)

**Outputs**
- Electricity or Heat – or both together if a Combined Heat and Power Plant (CHP)
- Bottom ash, which is typically landfilled or processed further to building aggregate
- Fly ash, generally collected by the pollution control equipment.

**GÄRSTAD PLANT, Linköping, Schweden**
At the Gärstad waste incineration plant, operated by Tekniska Verken, a total of 420,000 tons of sorted waste per year is incinerated for energy recovery. The heat of the waste incineration is used for district heating in Linköping and other local communities. Since 2011, two SST-110 steam turbines are used to produce electricity in addition. Both, electricity and district heat are sold via the energy exchange market, and power and heat loads can be balanced to run the plant always with maximum profitability.

**Steam turbine:** 2x SST-110  
**El. power output:** up to 11.5 MWe  
**Heat capacity:** 65 – 83 MWth
Gasification & Pyrolysis
Gasification and pyrolysis plants thermally treat fuels without allowing enough oxygen for complete combustion. They are typically smaller and more flexible than combustion plants and consume between 25 and 150 thousand tonnes of waste per year, although some variations can consume up to 350 thousand tonnes per year.

Typical fuels
- Refuse derived fuel or Solid Recovered Fuel
- Non-waste fuels, e.g. wood / other forms of biomass

Outputs
- Electricity or Heat – or both together if a Combined Heat and Power Plant (CHP)
- Syngas, which can be processed to produce “biomethane”, biofuels, chemicals, or hydrogen
- Pyrolysis oils – these can be used to fuel combustion engines, or turned into diesel substitute
- Feedstocks for the chemical industry – allowing biomass to substitute for oil in the production of plastics for example
- Bottom ash, char, or slag – by-products which can be used for beneficial purposes such as aggregates or road bed material
- Fly ash produced by some but not all plants

Anaerobic Digestion & Biogas
Biogas & AD plants operate at low temperature, allowing microorganisms to work on the feedstock, turning it into biogas, which is a mixture of carbon dioxide and methane. They are typically much smaller than the combustion or gasification plants. A biogas plant is most appropriate for wet organic wastes, such as food waste, sewage sludge, agricultural residues or energy crops.

Typical fuels
- Food waste
- Some forms of industrial and commercial waste, e.g. abattoir waste
- Agricultural materials and sewage sludge.

Outputs
- Biogas, which can be used to generate electricity and heat – CHP is the norm for such plants
- Biomethane for the gas grid, with the appropriate gas scrubbing and injection Technologies
- Digestate – a material which can be used as a useful fertiliser / soil conditioner on agricultural land in lieu of chemical fertilisers
Solutions: High Efficient Steam Turbines

Whichever turbine is used in your EfW plant, a Siemens steam turbine will ensure high plant performance. These flexible machines can even optimize electric output in plants which have steam parameters affected by inconsistent feedstock moisture content. This is possible by integrating industry-leading steam cycle technology.

Energy from Waste with Steam Turbines
The Siemens industrial steam turbine portfolio can be used with any waste-fired steam boiler to generate power from 75 kWe up to any size. Due to subsidiary and municipal regulations in many countries typically steam turbines up to 100 MWe are used in EfW plants. The Siemens experts will assist in selecting the optimum turbine that meets all application requirements while at the same time it minimizes the investment costs.

The Siemens steam turbine portfolio is characterized by efficiency and durability. Turbine generator sets have been deployed in EfW plants in the past decade with an outstanding record of applicability and reliability. Siemens can also supply your steam turbine with auxiliary equipment such as generator, a condenser system, monitoring and control systems and power transmission and distribution equipment.

Tailored Turbines & Leading Technology
Siemens turbines are available for back-pressure or condensing operation in a single or multi-stage design. They can also be equipped with single or multiple controlled (pass-out) and uncontrolled extractions (bleeds) to satisfy particular process or district heating as well as cooling requirements. Additionally, Siemens offers turbine-generator packages with a reheat feature, further optimizing plant performance and efficiency.

Turbines with reheat can improve overall plant efficiency by up to 3%, further mitigating the release of harmful emissions by burning less fuel. Each turbine, along with its customized features, is built to meet specific demands.

Afval Energie Bedrijf
Amsterdam, Netherlands

Afval Energie Bedrijf (AEB; Waste and Energy Company Amsterdam) burns 1.7 million tonnes of waste per year and has recently increased its energy generation efficiency from 22% to 31%. This 8% increase resulted from installing a new SST-700 with a steam reheat system. AEB not only generates power from Amsterdam’s municipal waste, but also recovers and sells materials from the waste stream such as metals and gypsum.

Steam turbine: SST-700, Reheat
Power output: 74 MW
Inlet pressure: 125 bar / 1,813 psi
Inlet temperature: 440 °C / 824 °F
Fuel: Municipal solid waste
Capacity: 1.5 Mio + 850,000 t, each line with 93.6 MWth
Steam Turbines with Enhanced Platform Design

The Enhanced Platform Design is marked by an enhanced blading design and an optimized steam path. The design has been tested and approved in extensive tests with a fully assembled turbine. The symmetrical casing design and the special valve-chest concept combined with the unique Siemens know-how for steam path and blading result in shorter start-up times, faster load changes and an increased availability. The new design allows for simplified installation and extended maintenance intervals.

Benefits

- High Reliability
- Reduced start-up time
- Faster load changes
- Reduced CO₂ footprint because of improved efficiency
- Long life cycle – increased life time

Reheat Improves Efficiency

Integrating a steam reheat system into a biomass plant is one of the best ways to increase overall plant performance. With the Siemens reheat turbine package, live steam is run through a high pressure (HP) turbine, sent back to the steam generator to increase steam temperature, then run through a low pressure (LP) turbine. Raising the temperature of steam that is going from a high to a low pressure turbine allows for greater output using the same amount of fuel. Geared single-casing reheat solutions up to 60 MW are also available in the Siemens portfolio.
Benefits of the SST-600 Enhanced Platform

- New steam inlets allow for higher steam parameter
- Improved CO₂ footprint (15% reduction of CO₂ emissions)
- Faster load changes
- Long life cycle – increased life time
- Optimized casing design for reduced start-up times of up to 50%.
- Extensive tested and verified first turbine
- Well proven blading and root-clamping design for high reliability and availability
District Heating and Cooling

District heating and cooling using a cogeneration system is one of the most efficient applications of a power plant. Usually a plant generates thermal energy at a centralized location and distributes steam to a larger number of buildings for space and water heating. District heating plants can provide higher efficiencies and better pollution control than stand-alone solutions. The process is normally governed by the total heat load and electrical energy is supplied as an additional benefit.

Whether a cogeneration application is for a district energy system, a heating or cooling system, or any other application, Siemens expertise ensures that your project will maintain optimal performance in markets with demand fluctuation. Any Siemens steam turbine can also feature extraction customization as required. The Siemens engineering staff is expert at designing turbines which can maximize output and plant value for seasonal load and demand variations.
Energy from Waste with Gas Turbines

Gas derived from waste, such as biomass or sewage, is used as fuel for gas turbines where the fuel constituents satisfy certain constraints. Knowing these constraints prior to designing the gasification plant is important. Plant sizes using these gases tend be a maximum of 5 to 8MW due to the amount of waste product required, however, there is no physical reason why bigger plants cannot be designed. Siemens gas turbines have been used for power generation out of biogas, sewage and landfill gas.

Digester Gas
Digester systems are used mostly at facilities which have access to large amounts of feedstock that emits methane as part of its decomposition. One unique feature of this type of gaseous biomass is that it can be used both for steam-generation and as a fuel for gas turbines. This flexibility makes building digester systems very attractive for many food and beverage, agricultural, and municipal solid waste process facilities.

Sewage Gas
The global shortage of freshwater will drive the growth in the global water treatment market. Only 47% of wastewater produced in Asia is treated. Treatment of sewage water, using anaerobic digestion, produces a gas consisting of methane and carbon dioxide. This mixture is ideal for use in a gas turbine. The anaerobic process is accelerated by heating the water, and this heat can be obtained from the gas turbine exhaust gas making the process more efficient.

In addition to the heat supplied to the digester further heat can be extracted from the gas turbine exhaust, this can be used from process requirements, steam raising or even district heating. Using the exhaust heat wisely can raise the overall plant efficiency above 80%.

UNH Cogeneration Plant
Durham, New Hampshire, USA

The University of Hampshire (UNH) cogeneration plant, fired on landfill gas, supplies 85% of the heat and 75% of the power demand of UNH Durham. By utilizing a Siemens gas turbine with a Heat Recovery Steam Generator (HRSG), UNH Durham was able to cut their greenhouse gas emissions by 40%. UNH Cogen was recognized by the US Environmental Protection Agency (EPA) as a “Project of the Year 2010” at their Landfill Methane Outreach Program annual conference.

Gas turbine: SGT-300
Power output: 7.9 MW
Combustion system: Dual-fuel
Dry-Low Emissions (DLE)
Fuel: Landfill gas, natural gas, distillate fuel
Siemens industrial steam turbines
The complete product portfolio

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Siemens industrial gas turbines
Gas turbines suitable for EfW plants

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Frequency: 50 Hz or 60 Hz