A Zero-Waste and Energetically Optimized Waste-to-Energy Concept
– The Santo Domingo Este Waste Treatment Plant –

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In many poor and developing countries the situation of waste management as well as energy supply is dominated by uncontrolled waste dumping and shortage of affordable energy, especially electrical power.

In the Dominican Republic, in particular the densely populated capital Santo Domingo and adjacent Santo Domingo Este (SDE) are affected by such problems. Waste is collected and transported to transfer stations, from which the waste is routed to a large open landfill. This landfill is illegal according to Dominican legislation and the capacity is limited. Figure 1 shows one of the transfer stations near the site of the planned SDE Waste Treatment Plant to be described below.

![Image of waste management in Santo Domingo](image-url)

**Figure 1:** Current situation of waste handling in Santo Domingo, a so-called transfer station

Source: Heiner Zwahr

On the other hand, the energy demand of the country exceeds the available production capacity and is expected to rise in the future.

As a solution to resolve the waste problem as well as to reduce power shortages, Green Conversion Systems, LLC of Rye, New York, USA developed under consideration of the described local conditions, the SDE Waste Treatment Project: A Waste-to-Energy (WtE) plant combined with a Combustion Turbine Generator (CTG) and Heat Recovery Steam Generator (HRSG) to form a combined cycle WtE/CTG process. As indicated above there are no legally operated landfills available. Accordingly the facility had to be designed as a zero waste facility producing practically zero residues that would have to be disposed.
1. Boundary conditions of the project

1.1. Local and site conditions

The economic situation in the Dominican Republic is still weak, although there has been considerable economic growth in recent years. The low living standard of the majority of inhabitants with a gross domestic production (GDP) per capita in 2012 of approx. 5,800 USD per year [5] affects the composition of the waste delivered to the plant (ref. Section 2.3 below). Currently, the country’s economy relies mainly on agriculture and tourism as well as on transfer from emigrants, whereas the productive industry is scarce and only slowly developing. Nevertheless, there is a constant increase in the demand of energy.

The energy situation in the Dominican Republic is dominated by a high demand exceeding the available capacity. In addition, the country highly depends on imported fossil fuels. 86 percent of the installed capacity are fossil, only 14 percent are hydropower and thus independent of the international fuel market and its ever increasing prices [9]. Owing to the island situation, neither the direct import of electricity from neighboring countries is feasible, nor can fuel be imported by land transport. Renewable energy sources such as wind and solar are developing slowly, even though there is a lot of wind available (trade winds). As a result the price of electricity is significantly higher than in Europe or the United States.

A site has been dedicated to the project, land that was expropriated by a governmental decree. The plant will be located in the outskirts of Santo Domingo Este, adjacent to the transfer station shown in Figure 1. The site is currently unused and located on elevated ground in the direct vicinity of the Ozama River (Figure 2).

Figure 2: Overview of project location of SDE Waste Treatment Plant
The site borders directly to the Humedades del Ozama National Park, which leads to a number of consequences:

- It is forbidden to construct anything within the geographical limits of any superficial water bodies, consequently no water intake structure can be built at the river;
- Effluents may not be discharged into the river, even after treatment and purification;
- The entire water demand of the plant should be covered by other sources such as wells and precipitation.

The site is a genuine green field covered with trees and shrubbery, where all infrastructure, services and utilities still need to be established.

The plant can be accommodated on the determined site (Figure 3).

![Site layout of SDE Waste Treatment Plant](image)

Figure 3: Site layout of SDE Waste Treatment Plant

The traffic generated by the delivery of the waste to the site will be heavier than in comparable European plants as many small vehicles are used for waste collection.

Another very important condition of this project is the absence of a developed waste disposal sector, not only for municipal solid waste (MSW) but also for any other waste.

Hence, the plant design must consider that all by-products from the WtE process need to be recyclable, re-usable or completely harmless. The usual sink for heavy metals or organic pollutants bound to fly ash and activated carbon – a controlled, safe landfill – doesn’t exist and probably cannot be built in time either.
1.2. Legal framework

The legal framework for this project is defined by both the environmental and the energy legislation. Environmental legislation indeed exists, but – as typical for many similar countries – there apparently is a lack of implementation, supervision and enforcement.

The respective laws and standards prohibit disposing of waste in other places than controlled, dedicated and approved landfills or incineration installations. The latter must be subject to an environmental impact assessment. The emission control standard is less stringent than the current European Directives. Regardless of the local legislation the plant will be designed with a flue gas treatment system, which allows meeting the emission limit values as defined in the European Industrial Emission Directive.

Important conditions are set by the legal framework regarding the energy side of this project with regard to renewable energy:

- energy from waste is classified as renewable energy;
- the maximum power output is limited to 160 MW;
- the plant shall be entitled to a guaranteed power price for renewable energy, if at least fifty percent of the produced power are coming from renewable energy sources;
- the limit of capacity for this guaranteed price is set to eighty MW electrical power;
- if a plant or project is implemented in phases, the eighty MW limit applies separately for each of the phases.

1.3. Waste quantities and quality

According to the local authorities, more than 4,000 tons of municipal solid waste are collected every day in the Santo Domingo metropolitan area [10]. At the moment, this amount is completely landfilled.

![Composition of Santo Domingo waste](image-url)
When the project was started about four years ago Santo Domingo Este had already big problems with the disposal of their waste and hence a sincere interest in finding a solution for this problem. Accordingly the Mayor of SDE visited MVR in Hamburg to get an impression of modern WtE technology. At first the capacity of the SDE WtE facility was defined at 1,000 tons per day, which later had to be raised to 1,250 tons per day to meet the requirements of the above mentioned legal framework with regard to renewable energy.

The design of the WtE facility is based on the waste composition shown in Figure 4. The waste composition renders an LCV of approx. 7,850 kJ/kg, which is the basis for the design of the WtE units of the SDE Waste Treatment Plant.

2. Overall concept of the SDE waste treatment plant

The SDE Waste Treatment Plant is designed as a WtE facility for municipal solid waste coupled with a Combustion Turbine Generator (CTG) unit. The energy recovery from the WtE facility will be enhanced by the operation of the gas turbine, fueled by the combustion of liquefied natural gas (LNG) or liquefied pressurized gas (LPG). The overall process is described by the following block diagram in Figure 5.

---

Figure 5: Block diagram of the Waste-to Energy Plant Santo Domingo
The plant as a whole will consist of

- a 1,250 tons per day (410,000 tons per year at ninety percent availability) solid waste incineration facility consisting of two lines, generating only slightly superheated steam at about 375 °C and about one hundred bar,
- a Combustion Turbine Generator (CTG) that produces about 71.5 MW of electric power at ambient temperature,
- a Heat Recovery Steam Generator (HRSG) for utilizing the CTG waste heat to superheat and re-heat the steam produced by the WtE boilers and the HRSG,
- a steam turbine capable of generating approximately 75.2 MW of electric power,
- air pollution control equipment to achieve stringent emission limits from the solid waste combustion unit, and
- several systems for handling process residues of the combustion and the air pollution control equipment to produce recyclable or re-usable by-products and thereby reduce the amount of materials that would have to be landfilled.

The fundamental design concept of the SDE Waste Treatment Plant is to increase the temperature of the standard solid waste combustion-based steam cycle, thereby increasing thermal efficiency and generating significantly more power from the steam cycle. This efficiency increase is achieved by superheating the steam, after it is produced in the WtE boiler, to 540 °C by using residual energy of the exhaust gases of the CTG. The energy input to the plant is provided by (i) the solid waste supplied from Santo Domingo Este and (ii) natural gas to fire the gas turbine.

3. Zero-waste WtE process

3.1. Solid waste combustion process

Waste enters the facility in collection vehicles or in transfer trailers. Each truck is weighed and directed into the tipping building. The tipping building is maintained at a slight negative air pressure to keep odors within the building. The waste is discharged from the collection or transfer vehicles into a large refuse storage pit. Some of the waste deliveries will be inspected on the tipping floor prior to tipping the waste into the pit to remove any waste inappropriate for incineration. Two overhead travelling bridge cranes equipped with grabs mix and stockpile the waste within the storage compartments of the pit to ensure that a homogeneous mixture of appropriate waste is fed into the process lines, in general after a few days of intermediate storage. Any waste unsuitable for incineration detected by the crane operators will be removed from the pit and directed back onto the tipping floor.

The acceptable waste is fed into the feed hoppers of each combustion unit, which direct the waste down a chute into a continuous thermal waste incineration process. The waste enters the furnace and is first dried by the flow of under grate air. It is then exposed to the extreme heat of the furnace where it is combusted and reduced by the thermal process.
An air-cooled, forward moving grate with two steps is used, specially adapted to the relatively wet feed material. Modern combustion controls ensure smooth, efficient, automatic and low emission operation.

The residue of the combustion process is cooled by the under grate air and then discharged into a bottom ash quench extractor, where it is further cooled by water. The bottom ash extractor periodically extends to push this residue out and de-water it at the same time. This bottom ash residue contains a very low percentage of unburned carbon due to the intensity of the combustion process.

3.2. Flue gas treatment system

In parallel with the waste incineration and recovery of energy, flue gas cleaning begins in the boiler by ensuring an optimum incineration process for the destruction of dioxins and furans and to minimize de novo synthesis of dioxins and furans, which occurs in the 200 to 300 °C (400 to 575° F) temperature range.

The WtE flue gas treatment process will consist of a Selective Non Catalytic System (SNCR) NOx control system, carbon injection upstream of a bag house filter for particulate control and for control of organic as well as mercury and heavy metal emissions, and two wet scrubbers for acid gas (hydrochloric acid HCl, sulfur dioxide SO2) control.

The WtE facility will be designed to fulfill the emission limits required by the applicable legislation of the Dominican Republic and relevant European air pollution control regulations as well.

3.3. Integrated recovery of by-products

There are four process-residues produced in the process of waste incineration and flue gas treatment that require further processing to be converted into by-products that can be returned to the material cycle for recycling or re-use, namely

- bottom ash,
- filter fly ash,
- crude hydrochloric acid, and
- gypsum-slurry.

3.3.1. Bottom ash treatment

The de-watered bottom ash from the bottom ash extractor will be treated in an extensive process consisting of the following main steps:

- sizing with screens of different mesh sizes,
- washing to remove small particles (< 0.1 mm) and soluble salts,
- recovery of metals by means of magnetic respectively eddy current separators,
- recovery of glass for fraction size ≥ 4 mm with optical separators, and
- cleaning of separated glass to improve quality.

The relevant steps of bottom ash processing and material recovery are shown in Figure 6.
The treatment process results in differently sized fractions of bottom ash aggregate, which can be used either separately or mixed according to the requirements of the customers. The quality is adequate to substitute natural aggregates in road construction, asphalt production, or in the cement industry. There are a lot of gravel roads in the Dominican Republic, and natural aggregate for construction or maintenance of these roads is scarce.

Furthermore, metals – ferrous and non-ferrous – are recovered at an extremely high rate and with excellent quality because of the integrated washing process for the reduction of fine particles. The glass can be recycled together with other collected waste glass. The recovery rate of ferrous metals will exceed ninety percent and eighty percent for non-ferrous metals. The metal content in the recovered bottom ash aggregate is less than one percent.

**3.3.2. Filter fly ash treatment**

Filter fly ash treatment consists of three main steps:

- leaching in two steps to dissolve the metals in the filter fly ash, followed by the separation and washing of the remaining residue,
- separation of the dissolved metals from the leach solution by precipitation of carbonates,
- production of pellets out of the mineral fraction (leach-end residue) to be returned to the incineration process for incorporation in newly formed bottom ash.
The process concept as shown in Figure 7 includes basically amoniacal and hydrochloric acid leaching, followed by solid-liquid separation. Resulting liquids are further treated to recover ammonia and carbon dioxide from the leach solution and precipitate mainly zinc and lead as carbonates. The liquid filtrate, containing calcium, potassium and sodium chlorides, is a solution of different salts similar to sea water, which after precipitation of mercury by TMT 15 is intended to be disposed in the ocean.

![Block flow diagram of filter fly ash treatment](image)

**Figure 7:** Block flow diagram of filter fly ash treatment

### 3.3.3. Hydrochloric acid rectification

The acid scrubbing process in the initial HCl scrubber of the flue gas treatment system produces raw hydrochloric acid with a concentration of about ten percent to twelve percent. The crude acid is purified and concentrated in an HCl rectification unit to produce a technical grade twenty percent strength hydrochloric acid.

The HCl rectification unit consists of the following components:

- stripping of bromine and iodine with the addition of sodium hyper-chlorite and absorption of these halogens with the addition of soda lye and sodium thiosulfate,
- evaporation of crude acid and separation of hydrogen fluoride (HF) by the addition of aluminum chloride,
- HCl distillation and concentration to twenty-percent-strength hydrochloric acid,
- activated carbon filter to retain any remaining impurities.
In most applications of hydrochloric acid, the acid is diluted with water to create a desired lower concentration necessary for each particular industrial use. Therefore at this stage the production of twenty percent acid is foreseen.

The residues produced in the hydrochloric acid rectification process are mainly salts of the halogens Br, I, F that are neutralized and recovered as brine (solution of salts for disposal in the sea).

Figure 8: Scheme of HCl rectification unit (exemplary, SDE Waste Treatment Plant without CaCl stage)

3.3.4. Gypsum processing

The removal of sulfur oxides in the neutral scrubber of the flue gas treatment system results in the formation of gypsum suspension, which will be further processed to reach market quality.

In gypsum centrifuges the gypsum suspension is washed with fresh water and desiccated to a moisture content of less than ten percent. Because of the low chloride content of the scrubbing fluid in the SO₂ scrubber, the chloride content of the gypsum is reduced to a very low residual concentration of less than one hundred mg/kg of dry substance by washing. Both filtrate and washing water are returned from the centrifuge to the flushing water tank and from there back to the SO₂ scrubber.

The cleaned and dried gypsum drops down from the gypsum centrifuges by the force of gravity onto a conveyor belt and is consequently delivered to the gypsum silo, where it will be stored until loading onto a transfer vehicle for sale to commercial customers.
3.4. Water management

The water management system of the SDE Waste Treatment Plant is designed to minimize both consumption and discharges according to the zero-waste philosophy of the project. Therefore, water use is governed by the cascade principle. Discharges of low salt content are used in processes with higher salt content, for example the concentrate from the demineralized water plant is routed to the wet cooling tower and the cooling tower blow-down is discharged to the flue gas treatment system.

Most of the water used will be derived from wells on the site, about 2.5 percent of the total water consumption will be gained by the collection of precipitation of rain on roofs, roads and paved surfaces.

Sanitary waste water will be disposed at public water pollution control facilities.

Most of the water used will be evaporated in the cooling towers and in the flue gas treatment system, primarily in the hydrochloric acid scrubbers, and consequently will be emitted into the atmosphere in the form of water vapor.

The only waste water produced in the process will be a solution of different salts (brine) with a concentration of salt of about four percent, which is comparable to sea water. As there are no toxic contaminants contained in the brine the intention is to dispose the brine in the ocean.

A very small amount of water will be exported by means of the by-products such as hydrochloric acid, bottom ash, and gypsum.

Figure 9 shows the simplified water balance of the SDE Waste Treatment Plant.
3.5. Mass balance

Figure 10 in combination with Table 1, Table 2, and Table 3 indicate the material flows in the WtE facility of the SDE Waste Treatment Plant.

**Figure 10:** Mass balance of the WtE unit of the SDE Waste Treatment Plant

**Table 1:** Annual input materials utilized for the operation of the WtE unit of the SDE Waste Treatment Plant

<table>
<thead>
<tr>
<th>Item</th>
<th>Input Material</th>
<th>Unit</th>
<th>Annual Input/Consumption</th>
<th>Waste input %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Municipal Solid Waste</td>
<td>ton</td>
<td>410.000 1(^{(*)})</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>Process Water</td>
<td>m(^3)</td>
<td>Incl. in Water Balance</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>Air (dry)</td>
<td>m(^3) STP</td>
<td>1.250 E+9</td>
<td>-</td>
</tr>
<tr>
<td>D</td>
<td>Urea (wet)</td>
<td>ton</td>
<td>1,000</td>
<td>0.25</td>
</tr>
<tr>
<td>E</td>
<td>Activated Carbon</td>
<td>ton</td>
<td>400</td>
<td>0.1</td>
</tr>
<tr>
<td>F</td>
<td>Hydrous Ammonia</td>
<td>ton</td>
<td>4 2(^{(*)})</td>
<td>0.001</td>
</tr>
<tr>
<td>G</td>
<td>Lime</td>
<td>ton</td>
<td>750</td>
<td>0.2</td>
</tr>
<tr>
<td>H</td>
<td>Soda Lye (NaOH)</td>
<td>ton</td>
<td>4</td>
<td>0.001</td>
</tr>
<tr>
<td>I</td>
<td>Sodiumthiosulfate (Na(_2)(_2)O(_3))</td>
<td>ton</td>
<td>25</td>
<td>0.006</td>
</tr>
<tr>
<td>J</td>
<td>Sodium-Hyperchloride (NaOCl)</td>
<td>ton</td>
<td>20</td>
<td>0.005</td>
</tr>
<tr>
<td>K</td>
<td>Aluminium-Chloride (AlCl(_3))</td>
<td>ton</td>
<td>250</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Table 2: Annual output of by-products of the WtE unit of the SDE Waste Treatment Plant

<table>
<thead>
<tr>
<th>Item</th>
<th>By-Product</th>
<th>Unit</th>
<th>Annual Production</th>
<th>Waste Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bottom Ash Aggregate</td>
<td>ton</td>
<td>82,000</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Glass</td>
<td>ton</td>
<td>16,500 (1)</td>
<td>4.0</td>
</tr>
<tr>
<td>3</td>
<td>Ferrous Metal (Scrap)</td>
<td>ton</td>
<td>6,000 (2)</td>
<td>1.46</td>
</tr>
<tr>
<td>4</td>
<td>Non-Ferrous Metal</td>
<td>ton</td>
<td>550 (3)</td>
<td>0.13</td>
</tr>
<tr>
<td>5</td>
<td>Metal Carbonates</td>
<td>ton</td>
<td>430</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Hydrochloric Acid (20%)</td>
<td>ton</td>
<td>4,200</td>
<td>1.0</td>
</tr>
<tr>
<td>7</td>
<td>Gypsum</td>
<td>ton</td>
<td>1,350</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Table 3: Flue gas and waste for disposal of the WtE unit of the SDE Waste Treatment Plant

<table>
<thead>
<tr>
<th>Item</th>
<th>Waste</th>
<th>Unit</th>
<th>Annual Production</th>
<th>Waste Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Flue gas (wet)</td>
<td>m³ STP</td>
<td>1,911 E+9</td>
<td>-</td>
</tr>
<tr>
<td>Z</td>
<td>Salt Content of Brine (DS)</td>
<td>ton</td>
<td>1,500</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>4 % Solution</td>
<td>m³</td>
<td>37,500</td>
<td>-</td>
</tr>
</tbody>
</table>

1*) 1,250 tons per day, 90% availability
2*) 1% only of annual consumption, because 99% will be recycled internally in the filter fly ash treatment unit
3*) 50% recovery rate assumed, because only glass particles > 4 mm can be detected and recovered
4*) Ferrous metals 90% assumed of total metal content according to waste composition, thereof assumed 95% recovered
5*) Non-ferrous metal content usually is about 10% of total metal content. Thereof about 20% are lost due to oxidation during combustion. Assumed 90% recovered from the remaining non-ferrous metal contained in bottom ash.

4. Optimised energy utilisation

The optimized energy utilization concept of the SDE waste treatment plant is shown in Figure 11.
4.1. Waste-to-energy boiler

The heat released in the combustion process is used in the WtE boiler to convert the feed water into high pressure steam.

Usually, in a WTE boiler the steam parameters are limited due to the corrosiveness of the flue gas if reasonable service intervals want to be achieved. Despite all efforts undertaken in recent decades, it is widely accepted that 40 bar and 400 °C are a limit, which should not be exceeded without risking extensive corrosion. This limit is determined mainly by the steam temperature, or correctly speaking by the resulting tube temperatures. The pressure then is a function of the expansion diagram of the typical industrial-type steam turbine and the acceptable steam wetness at the outlet of such a turbine.

One possible option to increase the thermal cycle efficiency is to increase steam temperature and pressure. As this cannot take place in the WtE boiler itself, the superheating is transferred to an external superheater fired with gas or a heat recovery steam generator (HRSG) of a combustion turbine. Higher steam temperatures can be achieved there due to the non-corrosive nature of the combustion turbine exhaust gas [4].

In case of the Santo Domingo project, the steam parameters have been selected as follows in cooperation with the suppliers of the WtE boilers and the gas turbine:

- WtE steam pressure about 100 bar
- WtE steam temperature about 375 °C

Experience from WtE plants operating at similar conditions show that the increased steam pressure and temperature may result in an increased corrosion risk which needs to be taken into consideration in the boiler design. Additional corrosion protection increases the boiler cost but pays back in the long run by providing additional profit through safe and reliable operation [3].

The steam leaving the WtE boiler is then routed towards the HRSG. After being combined with the high pressure (HP) steam generated there, both steam flows are fed to the HP superheater of the HRSG. Finally, steam with the following parameters is routed to the steam turbine:

- live steam pressure about 95 bar
- live steam temperature about 540 °C

4.2. Combustion turbine generator and heat recovery steam generator

The combustion turbine generator (CTG) is fed with liquefied natural gas (LNG) or liquefied pressurized gas (LPG) and will have an exhaust gas temperature of approximately 600 °C, which will be exhausted to a heat recovery steam generator (HRSG).

The steam generated by the combustion of the solid waste in the WtE boilers is directed to the HRSG. In this unit, the steam is superheated up to 540 °C using the
waste heat of the exhaust gas from the CTG. This superheated steam is used to drive the steam-turbine coupled to an electric generator. The superheated steam, after being cooled by the conversion of thermal energy into electricity in passing through the high pressure section of the steam turbine generator, will be cycled back into the HRSG and re-heated to approximately 540 °C and returned to the medium pressure part of the steam turbine to generate additional electric power.

4.3. Concept of combined cycle steam process

The main objective when setting up the steam process of a combined cycle plant must be to exploit the heat flow coming from the combustion turbine with the lowest possible losses. Therefore, not only one steam pressure is applied but two pressure or even three pressure processes are realized, combined with intermediate reheating. Finally a condensate reheating loop is installed as well to further reduce the temperature of the gases leaving the HRSG. In case of the SDE project, a balance had to be found between optimum efficiency and operability under the conditions of a developing country. Therefore the two pressure process was selected.

Table 4: Thermal calculation results for dual and single pressure process

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Dual-pressure process</th>
<th>Single-pressure process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas turbine electric power</td>
<td>MW</td>
<td>71.5</td>
<td>71.5</td>
</tr>
<tr>
<td>HP steam flow to turbine</td>
<td>t/h</td>
<td>177</td>
<td>190</td>
</tr>
<tr>
<td>HP steam pressure/temperature</td>
<td>bar/°C</td>
<td>95 / 540</td>
<td>95 / 540</td>
</tr>
<tr>
<td>MP steam flow to turbine</td>
<td>t/h</td>
<td>208</td>
<td>190</td>
</tr>
<tr>
<td>MP steam pressure/temperature</td>
<td>bar/°C</td>
<td>25 / 540</td>
<td>25 / 540</td>
</tr>
<tr>
<td>WtE steam flow</td>
<td>t/h</td>
<td>141</td>
<td>141</td>
</tr>
<tr>
<td>WtE steam pressure/temperature</td>
<td>bar/°C</td>
<td>100 / 375</td>
<td>100 / 375</td>
</tr>
<tr>
<td>Steam turbine electric power</td>
<td>MW</td>
<td>75.2</td>
<td>67.8</td>
</tr>
</tbody>
</table>

As the primary purpose of the SDE Waste Treatment Plant will be disposal of waste the WtE plant will also have to be operable when the combustion turbine is not running. A bypass is used in this case to route the steam coming from the WtE plant directly to the medium pressure part of the steam turbine. Thus, waste treatment is not jeopardised by possible interruptions of the combustion turbine operation.

Following the medium pressure section of the steam turbine-generator, the steam will pass into a condenser. During final design will be determined whether water can be obtained in sufficient quantity and quality for using a water-cooled condenser in combination with wet cooling towers. If this is not the case, an air cooled condenser will be applied. The following energy balance is based on a concept with wet cooling towers and a water-cooled condenser.
4.4. Energy balance

The overall energy balance of the SDE Waste Treatment Plant is characterized by the energy input of natural gas (LNG or LPG) and waste and the output of usable power (electricity) and losses caused by unavoidable thermal losses and parasitic consumption of electrical power. The solid waste energy input provides approximately 35 percent whereas the combustion turbine energy input provides approximately 65 percent of the total energy to the facility. The fuel efficiency of the enhanced process is about 42 percent, much higher than the efficiency of stand-alone WtE facilities, which is only about 25 percent, or the efficiency of the combustion turbine, which is about 33 percent at the ambient temperature of about 25 °C.

Regarding the input energy, the usable chemical energy of waste and natural gas (in this example LNG) based on their LCV is considered only. Sensible heat does not make a significant contribution to the overall balance.

The input can be specified as follows:

- waste: 26.7 t/h * 7.85 MJ/kg * 2 lines equal 116.4 MW<sub>th</sub>
- LNG: 15.6 t/h * 50.6 MJ/kg equal 219.4 MW<sub>th</sub>

These values are based on the average LCV of the SDE waste and LNG and will be subject to variation during operation, especially as far as waste is concerned.

The power output of the turbines has been calculated as follows based on the supplier data (gas turbine) and thermodynamic calculations of the combined WtE/CTG process:

- steam turbine 75.2 MW<sub>el</sub>
- combustion turbine 71.5 MW<sub>el</sub>

The parasitic consumption of the plant has been conservatively estimated at 6.7 MWel. Losses are mainly caused by:

- flue gas losses of the WtE boiler,
- flue gas losses of the HRSG,
- condensation of steam of the steam/water cycle,
- radiation and blowdown.

Figure 12 below gives an overview of the major energy flows of the SDE Waste Treatment Plant.

The majority of the power generated – about 95 percent of total gross generation – is fed into the utility grid for sale, after in-plant electric consumption is satisfied. The facility will generate about 146 MW (gross) and 140 MW (net) for export and sale, more than fifty percent of this energy produced by the steam turbine derived from waste (solid waste and residual heat from the gas turbine).
5. Summary and outlook

The boundary conditions in the Dominican Republic, particularly the zero-waste requirements and the high energy demand, require a complex and especially elaborated concept for the implementation of a Waste-to-Energy project. The design of the SDE Waste Treatment Plant combines resource and energy efficiency in one. The extensive treatment of residues such as bottom and filter fly ash as well as washing water of wet scrubbers lead to a zero-waste process as the recovered by-products reach the necessary quality to be returned to the material cycle.

Besides, energetic optimization of the plant is achieved by a combined WtE / CGT cycle process, where the steam generated in the boiler of the waste incineration process is superheated and re-heated in a heat recovery steam generator by using the waste heat of the exhaust gas from a combustion turbine.

An Environmental Impact Study has been submitted in April 2013. The environmental permit was granted at the end of June 2013. The EPC contractor was selected January 2014. The power purchase agreement and the final concession are expected to be awarded in June 2014. Financial closing is expected in the middle of 2014, and ground breaking for the start of construction of the facility will occur immediately afterwards. Commercial operation is planned to start at the beginning of 2017.
6. References


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