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(54) Title: SOLID WASTE GASIFICATION

(57) Abstract: The present invention relates to a process for producing, heat, power and combustible gases from the solid wastes, such as sorted / unsorted municipal solid wastes, industrial wastes including waste water treatment plant sludge, leather industry residues, agricultural wastes etc., comprising the steps of feedstock preparation (4, 5, 7, 10, 11), gasification (12), syngas (known as leangas) cleaning up (17, 19, 21, 22), heat and power generation (28) and optionally valuable chemicals production.
TECHNICAL FIELD

The present invention relates to a process for producing, heat, power and combustible gases from the solid wastes such as sorted / unsorted municipal solid wastes, industrial wastes including waste water treatment plant sludge, leather industry residues, agricultural wastes etc.

More particularly, the present invention relates to a process for producing, heat, power and combustible gases from the solid wastes comprising the steps of feedstock preparation, gasification, syngas (known as leangas) cleaning up, heat and power generation and optionally valuable chemicals production.

BACKGROUND OF THE INVENTION

The year 1970's brought a renewed interest in the technology for power generation at small scale. Since then work is also concentrated to use fuels other than wood and charcoal. Several countries and organizations have developed policies to support the market for energy from renewables, including biomass.

The technology developed under thermal processes umbrella is widely known in worldwide arena and applicable in various scales to different materials with the exception of municipal solid wastes (MSW). The latter, being a heterogeneous feedstock is difficult to process and requires an extra effort for the output gas cleaning which will than can be utilized for several productions.

New environmental laws and regulations for the re-use of materials are having a major impact on the entire Earth waste scenario. Residual wastes, i.e. material not suitable for material re-utilization, has to be disposed of in a disposal area - if permitted - or by thermal treatment. The latter may be via conventional combustion on a grate, pyrolysis or by gasification.

Compared to the former two methods; gasification offers the following advantages. These are production of synthesis - or fuel gas under atmospheric or elevated pressure, recovery of mineral matter in the waste as slag, environmentally friendly, high thermal efficiency, feedstock flexibility (solid and liquid wastes) and favorable economics.

Among the above; gasification process is used to make synthetic fuels and chemicals such as methanol, ammonia, diesel fuel and even (with more difficulty) gasoline. Parallel to the needs
for alternative transportation fuels, this one of the system's outputs can be considered as a green fuel.

Syngas production can be broadly defined as the thermochemical conversion of a solid or liquid carbon-based material (feedstock) into a combustible gaseous product (combustible gas) by the supply of a gas production agent (partial oxidation) under the application heat. Oxidation can be done either by using air or oxygen. If only oxygen is used, the resulting gas (synthesis gas) will have a higher calorific value.

The thermochemical conversion changes the chemical structure of the feedstock by means of high temperature. The agent introduced allows the feedstock to be quickly converted into gas by means of different heterogeneous reaction. At operating conditions, synthesis gas or "syngas," is produced. The combustible gas contains CO₂, CO, H₂, CH₄, H₂O, N₂, and trace amounts of higher hydrocarbons, (like ethylen and propylene etc.) inert gases present in the gas production agent, various contaminants such as small char particles, ash and tars.

A key factor of the gasifier is the capacity to produce a gas with low tar content (condensable bituminous compounds). A high tar concentration causes a lot of problems to energy recovery systems because of its corrosive characteristics. There are hundreds of gasifiers in the patent literature, however that is divided into four principle types.

In updraft (counterflow) gasification the air/oxygen/steam contacts charcoal on a grate, generating gas temperatures of 1000-1400°C. This hot gas rises through the down coming biomass, pyrolyzing it at successively lower temperatures and eventually drying it. All of the types of tar occur in the final gas, with primary tars dominating, typically at a level of 10-20%.

Updraft gasifiers are useful for producing gases to be burned at temperature 1000°C, but the high tar level up to 10-20% makes them difficult to clean for other purposes. The pyrolysis happen much faster and rapid pyrolysis produce more tar in raw gas. Updraft gasifiers have poor loading capability and they are not suitable for running engine to produce electrical energy.

In downdraft (coflow) gasification air/oxygen/ and fuel enter the reaction zone from above and burn most of the tars to pyrolyze the fuel, in a process called "flaming pyrolysis". The flame temperatures are 1000-1400°C, but the flame occurs in the interstices of the pyrolyzing particles whose temperatures are 500-700°C, so that about 0.1 % of the primary tars are converted to secondary tars and the rest are burned to supply the energy for pyrolysis and char gasification.
Very few of the compounds found in downdraft gasification are found in updraft reactors and vice-versa. The tar level is intermediate between updraft and downdraft, typically 1-5% in fluidized bed reactors. The low tar levels of downdraft reactors make them more suitable for uses requiring clean gas, which contain 0.1% tar. Unit capacity restriction, a lower overall efficiency and difficulties in handling higher moisture and ash content are disadvantages of this type of gasifiers and also multiple units operating in parallel when higher capacity is desired.

Crossdraft gasifiers, although they have certain advantages over updraft and downdraft gasifiers, they are not of ideal type. Crossdraft gasifier operates well on dry air blast and dry fuel. The several disadvantages of this type of gasifier are high exit gas temperature, poor CO2 reduction and high gas velocity. Unlike downdraft and updraft gasifiers, the ash bin, fire and reduction zone in crossdraft gasifiers are separated. These design characteristics limit the type of fuel for operation to low ash fuels such as wood, charcoal and coke. The relatively higher temperature in cross draft gasifier has an obvious effect on gas composition such as high carbon monoxide, and low hydrogen and methane content when dry fuel such as charcoal is used.

In fluidized bed gasifiers air/oxygen/steam levitate the incoming particles which recirculate through the bed. Some of the oxidation contacts biomass and burns the tars as they are produced as in a downdraft gasifier; some of the oxidant contacts charcoal as in an updraft gasifier. The biomass preparation and feeding systems are more complicated and can be sources of outages. Transportation of fuel to the plant increases the operational costs. Due to high pressure operation, such systems are less safe and require higher capital investment.

In order to prevent above mentioned disadvantages, the gasifier is needed which has unique and optimum design, produces less tar and heavy metals, prevents explosion risk and uncontrolled air leakage. Also it must be harmless to the environment and economically viable.

During the literature survey completed and as a result of many investigations realized at similar plants it is well understood that gas production plants do not deal with fuel preparation stages of the system. They do prefer to buy the material (already prepared feedstock) from suppliers such as agricultural farms, waste minimizing companies, municipalities, etc.

Thus, a complete system handling different types of waste for their conversion into economically feasible outputs is required. The complete system which can run either downdraft or down/updraft; according to the request made by the users enables the system to offer multiple outputs as a result of its innovation and integration flexible structure.
BRIEF DESCRIPTION OF THE INVENTION

The main scope of the present invention is to develop a complete system handling different types of waste for their conversion into economically feasible outputs.

A different objective of the present invention is to densify and downsize the wastes for obtaining a homogenous material.

A further objective of the present invention is to enable the system to offer multiple outputs which are sorted municipal solid wastes, economically valuable materials including recyclables (glasses, metals, etc.), refuse derived fuel (RDF), ash, tar, heat energy, electricity energy, steam and valuable chemical raw materials, such as CO, CH₄, H₂.

Another objective of the present invention is to develop a complex process comprising the step of feedstock preparation, syngas (known as leangas) production, leangas purification and the heat and power generation for the minimization of municipal solid wastes in an environmentally sound manner.

The aim is to clean the leangas to a level acceptable thus it can be used for direct firing of steam turbines (31) and/or internal combustion engines (26).

Other objective of the present invention is to develop a complete system which produces low tar and low dust content.

In order to achieve the scope, a developed process comprises the steps of waste reception and truck weighting, source separation, primary shredding, sieving, drying, secondary shredding, briquetting and/or pelletingizing, feeding weighting, fuel feeding, solid waste gasification, ash/dust discharging, gas cleaning up, gas cooling and drying, heat and power generation, grid connection and energy distribution, gas chemicals production.

BRIEF DESCRIPTION OF THE FIGURES

The embodiment and advantages of the present invention shall be made clear with the figure described as following and the present invention is to be evaluated by taking into account such descriptions.

Figure illustrates one example of the process of the present invention.
REFERENCE NUMBERS

1. Solid Waste Gasification Plant
2. Waste Receptor
3. Bunker
4. Magnetic Separator
4.1. Recyclable Materials
5. Primary Shredder
6. Trommel
6.1. Conveyor Belt
7. Dryer
7.1. Dust / Odor Control System
8. Leangas Burner
9. Secondary Shredder
10. Briquetter
11. Pelletizer
12. Solid Waste Gasifier
13. Air Preheater
14. Steam Generator
15. Oxygen Supplier
16. Ash / dust collector
17. Cyclone collector
18. Plasma Catalytic Reactor
19. Scrubber
19.1. Scrubber Water Tank
20. Tar Collector
21. Wet Electro Static Precipitator (WESP)
22. Filter
23. Cooled Gas Vacuum Fan
24. Water Chiller
25. Heat Exchanger
26. Internal Combustion Engine (ICE)
27. Hot Gas Vacuum Fan
28. Heat / Power Generation Unit
29. Burner
30. Steam Boiler
31. Steam Turbine
32. Energy Distributor

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates the solid waste gasification plant (1) comprising the stages of feedstock preparation, gasification, gas cleaning up, heat and power generation and gas chemicals production including necessary equipments.

Solid waste minimization and energy production via gasification process which is the subject to the present invention comprises the following steps.

Solid Waste Preparation

Waste Reception and Weighting

As requiring limited land, the power plant can be constructed at a central location not so far from the suppliers which can bring ease to continuous municipal solid waste supply decrease the
costs, emissions and resource requirements associated with the transportation and diminishing cabling costs for energy distribution via grid connection.

For efficient process control it is necessary to know the incoming material to the plant and weigh it before the manual and magnetic separation. Sometimes polluters themselves bring the feedstock material to be disposed. But generally, municipal solid waste (MSW) is transported by waste receptors (2) to the plant and kept in a well isolated bunker (3). Leachate is prevented by using impermeable basement such as geomembrane, geotextile and concrete. In order to prevent odor thus insects and flies attraction problem the bunker (3) is covered.

Source Separation

Front end separation for municipal solid wastes (MSW) allowing recovery of recyclable materials (4.1) and non-combustible components is a priority to minimize toxic releases. Both magnetic and manual separation methods are applied in order to separate and recycle the non combustible and commercially precious recyclable (glasses and metals) materials (4.1) from the mixed solid waste. Apart from the technicians' interventions a magnetic separator (4) is integrated to the system.

Primary Shredding

The first equipment located right after the source separation is the primary shredder (5) which reduces the material size down to 5-10 cm, 15 ton/h capacity Hammel 450D model. The output material is then brought to trommel (6) via conveyor belt (6.1). If there are materials not proper to downsize such as textiles and plastic bags then the primary shredder (5) automatically stops and pushes out the material.

Sieving

After primary shredding, materials are sieved by means of a trommel (6). A trommel (6) is a revolving cylindrical sieve used for screening or sizing rock and ore. Screen hole size ranges between 5-25mm. Materials other than stones and glasses with the particle size of less than 25 mm are separated items (stone, sand and glasses) and directly landfilled or recycled. Materials with the particle size of more than 25 mm are sent to the remaining stages of the normal process.
Drying

In order to ensure reliable, consistent feeding and optimize final products, the feedstock must be properly dried and sized. Most gasification systems prefer moisture in the range of 8-15%. Moist fuel is likely to clog the feeding system and can lower the heating value of the gas, while improperly sized fuel will also result in poor feeding and inhibit gasification process.

According to the present invention, shredded municipal solid wastes with moisture content around %40-%50 are dried until the moisture content decreases down to approximately %10 by the rotary drum dryer (7). Rotary drum dryer (7) boast from 500-2000 kg water evaporation per hour.

Rotary drum dryer (7) which consists of two cylinders in one line with different rotating speed, rotated upon suitable bearings and usually slightly inclined down from feed to discharge at an angle of 2 degree. The initial section of the rotary drum dryer (7) has spiral flights to rapidly move the material out of the feed section.

Material moves from one end of the rotary drum dryer (7) to the other by the motion of the material falling "forward" or rolling "downhill" due to the angle of inclination of the drum. Frequently, there also is a discharge spiral section to prevent blocking of the rotary drum dryer (7) discharge. Both ends of the drum are enclosed by suitable seals between the hood and the rotary drum dryer (7).

The hot gases are fed in the opposite direction to the wet material (counter-current operation) which is fed into rotary drum dryer (7) through which hot exhaust gases are taken suction fan via cyclone. There is a dust / odor control system (7.1) which has a suction fan with coupled by cyclone to separate of dust and to remove the odor from hot exhaust gases taken from rotary drum dryer (7). Solid wastes are dried by hot gases, lpg or leangas which is produced in the gasification process heated by leangas burner (8). But there is a remarkable advantage in using leangas firing for the system economy.

Secondary Shredding

In order to produce appropriate size materials for pelletizing / briquetting, the output material from the primary shredder (5) should even be smaller, therefore the secondary shredder (9) is integrated in the solid waste gasification plant (1). Material output size from the secondary shredder (9) is maximum 25 mm.
Briquetting and / or Pelletizing

Briquetting or pelletizing processes are important techniques to densify biomass materials to increase the particle size and bulk density. The reasons for densification are reducing transportation costs, easy storage and handling and process efficiency.

Shredded and dried solid wastes are transformed into small and high density refuse derived fuel (RDF) pellets via briquetter (10) and pelletizer (11). The refuse derived fuel (RDF) pellets have diameter of 20 - 100 mm order to be properly gasified in the gasification process. Feedstock input (RDF pellets) before gasification is assumed to be the best with the below characterization.

Table 1. Ultimate analysis of refuse derived fuel (RDF) pellets and briquettes (%w).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Humidity</th>
<th>Volatile Matter</th>
<th>Fixed Carbon</th>
<th>Ash</th>
<th>Gross Calorific Value (kcal / kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pellet (MSW)</td>
<td>8.10</td>
<td>33.90</td>
<td>24.50</td>
<td>33.50</td>
<td>3.300</td>
</tr>
<tr>
<td>Briquette (MSW)</td>
<td>9.15</td>
<td>30.50</td>
<td>30.55</td>
<td>29.80</td>
<td>3.520</td>
</tr>
</tbody>
</table>

Table 2. Proximate analysis of refuse derived fuel (RDF) pellets and briquettes (%w, daf)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Carbon</th>
<th>Hydrogen</th>
<th>Nitrogen</th>
<th>Sulphur</th>
<th>Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pellet (MSW)</td>
<td>48.80</td>
<td>8.45</td>
<td>6.50</td>
<td>1.85</td>
<td>34.40</td>
</tr>
<tr>
<td>Briquette (MSW)</td>
<td>53.5</td>
<td>7.90</td>
<td>6.15</td>
<td>1.75</td>
<td>30.70</td>
</tr>
</tbody>
</table>

Feeding Hopper Weighting

The system is made of two hoppers. Upper one to receive refuse derived fuel (RDF) and the bottom one is to weigh. It is equipped with 4 load cells and continuously weighs and the capacity is 30 - 40 kg weight per time.

Fuel Feeding

The fuel-feeding systems convey the fuel from storage bins and hoppers to the reactor. An ideal feeding system provides smooth and continuous feeding and allows for accurate control of the feed rate by hopper weighing and rotary valve. The system should be relatively insensitive to variations of fuel size and must maintain sufficient pressurization to prevent the backflow of gases from the gasifier to the feeding system. Typically, the fuel-feeding system consists of two parts: fuel transport from storage to the solid waste gasifier (12) and injection into the solid.
waste gasifier (12). Feedstock flow to the waste gasifier (12) is controlled over the rotary valve.

**Solid Waste Gasification**

Solid waste gasification process can be broadly defined as the thermochemical conversion of a solid or liquid carbon-based material (feedstock) into a combustible gaseous product (combustible gas) by the supply of a process agent (partial oxidation) under the application of heat.

According to the present invention after the step of drying, particles of fuel 20 to 100 mm in diameter are introduced into the solid waste gasifier (12) from the top, while the oxidant agent (preheated air or O₂) enters from the top oxidation zone and throat zone. In the first zone, drying, the solid waste is heated and dried while cooling the product gas that is about to leave the solid waste gasifier (12). This zone ranges from 250 - 400°C. Briquetted waste is broken down to coke, tar, CH₄, H₂, in the pyrolysis zone which is between 400 - 600°C. In the throat zone the solid waste gas is between 1000 - 1200°C, the H₂O and O₂ in the introduced air or O₂ reacts with coke and output gas is called solid waste gas which mainly consists of CO, H₂, CO₂, CH₄ at temperature between 1000 - 1200°C.

Steam feeding to the reaction zone is optional. As the solid waste runs through the descendent zone the solid waste gas cools down to 600 - 800°C. Solid waste gas is sucked to the cleaning stage after it reaches 400 - 600°C in the solid waste gasifier (12). The solid waste gasifier (12) operates at close to atmospheric pressure at approximately 600°C, employing air or O₂ as the process oxidiser.

The rotary valve integrated to the system prevents uncontrolled air leakage for security purposes and controls fuel feed rate. Air inlet from the top of the solid waste gasifier (12) from the throat zone is the difference from the other type of gas producers. Safety valve and weighting level indicator for the feedstock are mounted in the solid waste gasifier (12). Vibrator is mantled to the solid waste gasifier (12) since the feedstock material in the solid waste gasifier (12) is not at the same level all the time, but there may become small peaks inside. In order to evenly distribute the feedstock vibrations are applied at certain periods. No slurried form feedstock is fed to the reactor; only briquetted solid waste is accepted.

Solid waste gas is produced which mainly consists of CO, H₂, CO₂, CH₄. Reactant agent for the process to occur is only the air at environmental conditions. Air preheater (13) steam generator (14), oxygen supplier (15) are used to provide necessary air, O₂ and steam for the solid waste
gasification reactions. The amount of produced tar at the end of the reactions is low. Solid waste gasifier (12) can be operated under the vacuum conditions.

**Ash Discharging**

There is an ash / dust collector (16) that accumulates the ash residues extracted from the solid waste gasifier (12). Solid waste gasifier (12) ash residues could be used to fertilize the ground (rarely if the feedstock is not agricultural waste), as the concrete material or disposed in a sanitary landfill. Instead, solid residues of gas pre-treatment and air pollution control systems are typically disposed in landfills, because of their high heavy metal concentration level. Sometimes, solid residues can be used in industrial processes, such as cement mills, for a complete integration between gasification and industrial processes. Table 3 indicates ash components from solid waste gasification process.

<table>
<thead>
<tr>
<th>Components (%) Weight</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>Fe₂O₃</th>
<th>Na₂O</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>51.68</td>
<td>10.08</td>
<td>15.77</td>
<td>1.57</td>
<td>9.40</td>
<td>2.19</td>
<td>2.35</td>
</tr>
</tbody>
</table>

**Gas Cleaning Up**

Raw synthesis gas from the solid waste gasifier (12) contains tar, char, mineral matter, and other impurities. These contaminants must be removed before the synthesis gas can be used in heat / power generation unit (28).

Tars can foul heat exchange surfaces and engine valves or they may not burn adequately in combustion chambers of engines. Alkali forms deposits on cold heat exchange surfaces and engine blades where it promotes corrosion. Removal of tar and alkali is essential to the long-term success of gasification processes.

Particles bigger than 1 µm may need to be removed from synthesis gas taken from the solid waste gasifier (12) and thus, cyclone collectors (17), scrubbers (19) filters (22), wet electrostatic precipitators (21) and air cooling / drying units have all been employed for particulate removal with varying degrees of success.

Cyclone collectors (17) are very effective for removing all but the finest particles. The gas stream exits through the top of the cyclone collectors (17), while particles settle at the bottom of the cyclone collector (17). But, particles smaller than 10 µm which can degrade performance of
many kinds of power systems are captured in cyclone collectors (17).

While the dust particles over 10µm in size are mostly collected in the first cyclone collector (17). The fine dust in the gas is agglomerated and deposited as it flows through the subsequent filtration processes. Collection efficiencies of up to 99.9% are achieved.

**Scrubbing**

After the plasma catalytic reactor (18) which is optionally used, scrubbers (19) are chiefly used for cooling, saturating and pre-cleaning of gases for subsequent cleaning in wet electro static precipitators (21). The scrubbing liquid is injected through a central nozzle or several nozzles in the inlet cone preceding the throat where the high velocity gas atomizes the liquid droplets which trap the solid particles. The scrubbed gas and liquid droplets leaving the throat pass through the diverging section where further agglomeration takes place producing larger droplets.

Downstream of the syngas coming from the cyclone collectors (17) any unconverted carbon fines (char) and light ash material are scrubbed from the syngas with water in the scrubber (19) and removed. The solids are recovered from the water in the scrubber water tank (19.1) by a technique including filtration through a filter (22) which is optionally made of re-generable microporous polymer. The tar is collected in the tar collectors (20) below the scrubber water tank (19.1).

**Precipitation**

After the step of scrubbing, wet electro static precipitator (21) is used to provide the efficient emission control for submicron particles, heavy metals, acid mists, fumes, dioxins and furans. It collects fine particles, humidity and saturated water in the gas flow, thanks to its cooled water walls.

It is self cleaning due to gravity, water drops condensed at the water walls and panels goes downwards by gravity and carry down the particles collected at the surfaces. The gas enters the wet electro static precipitator (21) from the bottom gas inlet and is evenly distributed across the panels upward. In the collecting area, incoming particles are given a strong negative charge by high intensity ionizing corona produced by high voltage wires evenly distributed in all passages.

As the gas flows through the areas between collecting panels, the action the electric field on the
charged particles causes them to migrate to the grounded panel walls where they are attracted. The self washing action of the water film condensed on the water cooled walls, that falls down, removes the attracted-collected particles to discharge. The self forming water film reduces clean water usage due to less flushing requirements. In addition to normal systems, the wet electro static precipitator (21) used in the present invention offers better tar precipitation via water cooled precipitation plates.

**Filtration**

After the step of precipitation, various materials for water capturing are used as gas filters (22) such as polymer, active carbon and silica gel.

**Producing Flame Of Methane (optional step)**

Plasma technology is a new approach for hydrogen rich gas or synthesis gas production from hydrocarbon fuels. Plasma catalytic reactor (18) can sustain an ultra rich flame of methane at desired power level and very effective in achieving the conversion. Dust and ash disposal are collected in the ash / dust colector (16) after this step.

**Gas Cooling and Drying**

After the step of filtration, the product gas transfer is handled by the help of the centrifugal type cooled gas vacuum fan (23). The cooled gas vacuum fan (23) keeps the process under vacuumed control, therefore minimizes explosion risks. The capacity 3000m$^3$/h and the pressure is 320 mbar.

Whilst there are significant grounds for optimism, there remain a number of areas requiring additional development to make the technology of solid waste gas generation both technically and commercially viable. These include pre-sorting of waste streams, the clean up of the product gas to remove potentially corrosive gases and the development of the systems required to maintain product-gas consistency in terms of gas composition and calorific value.

In the present invention, air cooled water chiller (24), gas cooling heat exchanger (25) high performance shell and tube recuperator are the main items of the system. Syngas is cooled, dehumidified and reheated up to 40°C and relative humidity is less than 60% through the system.
The air cooled water chiller (24) is the most versatile, dependable, effective and environmentally friendly air conditioning and process cooling technology available today. This because absorption chillers use natural refrigerants and are fuel flexible thermally activated systems utilizing clean fossil fuels, biofuel, steam, hot water, solar energy or exhaust gas to power the absorption cycle.

In the context of the present invention, absorption chiller provides the following advantages; efficient cooling and heating, zero breakdown during the life-span and operator-free all the year round.

**Heat and Power Generation**

The major gaseous stream produced in the gasification process is cleaned by means of gas cleaning processes. After gas cleanup processes, the clean gas goes to an internal combustion engine (26) and are converted to electrical and thermal energy. For 1000 kgs of incoming dried and briquetted municipal solid waste (which is actually equivalent to 2000-3000 kgs in non source separated form), 1 MW electrical energy and 2 MW thermal energy output are obtained through the internal combustion engine (26) used in the present invention.

Upstream of the syngas coming from the cyclone collectors (17) goes to hot gas vacuum fan (27) to keep the process under vacuumed control, therefore minimizes explosion risks, and then the syngas alternatively can be burned via burner (29) to produce steam and the produced steam goes to steam boiler (30).

Excess steam energy can be taken and used and the steam energy converted easily to electrical power by steam turbine (31). Burner (29), steam boiler (30) and steam turbine (31) are the main components of the heat / power generation unit (28).

**Grid Connection and Energy Distribution**

Above mentioned energy output can be backwarded and sold to the selected region. In case there is excess energy than profit can be made over by selling the excess energy to other industries or to dwelling areas by using an energy distributor (32).

**Chemicals Production from Syngas (optional step)**

After gas cleaning up processes, optionally product syngas can be used in the chemicals production processes vary depending on the process and products produced. The following
reactions take place for the chemicals production and the following chemicals are produced by these reactions.

**Manufacture of Synthesis Gas**

Biomass (or coal + O₂ → CO + H₂ (carbon monoxide and hydrogen)

**Water gas shift adjusts CO/H² ratio**

CO+H₂O ←→ CO₂ + H₂

**Synthesis with catalyst**

CO+2H₂ → CH₃OH (methanol)

CO+H₂ → "(CH₂)n" (diesel or gasoline, the Fischer Tropsch reaction)

3H₂ + N₂ → 2NH₃ (ammonia)

**User Friendly Process Control**

The process control in order to maximize the plant efficiency should be integrated which collects data on the flow, temperature, pressure measurement and control along with the gas analysis and the feedstock tracking both for the moisture and ash content.

**Tar Production and control**

Tar; which actually is formed during the process and carried via the syngas can be classified into four categories: primary products, secondary products, alkyl tertiary products, and condensed tertiary products.

The types of tars produced are functions of both the time and temperature over which reaction occurs. As temperatures and residence time increases, the tars produced are more likely to be secondary and tertiary products. Methods to remove tars from producer gases fall into one of the three categories: physical removal, thermal conversion of tars, and catalytic destruction of tars.

Physical processes for tar removal include wet scrubbers (19), demisters, wet granular bed filters (22) and wet electrostatic precipitators (21) and the composed tar is collected in the tar collectors (20).

These processes are only effective for tar removal when the producer gas has been cooled to less than 100°C, which is thermodynamically inefficient for power systems. A second problem
with these methods of tar removal is that the water used in the applications must be treated to remove the tars before it can be disposed. The costs of water treatment may prohibit the use of these methods. Dry applications such as fabric and ceramic filters (22) may be used if the producer gas temperature can be reduced to less than 150 °C.

Generally tar control process consists of the following steps mentioned below. First of all, engine exhaust heat is transferred to the evaporator using a hot water loop, the tar-water is evaporated partly and separated into a combustible liquid - highly contaminated phase - and a (more or less) clean steam phase.

The tar remaining in the steam phase is thermally cracked in the reactor at a high temperature using heat derived from the combustible fraction, the reactor may be operated in oxidation mode (resulting in flue gases) or in reduction mode (combustible gases). The oxidation mode is preferred solution.

A mixture of clean steam and gasses - combustible or inert depending on the operational mode-leaves the reactor. A part of the hot exit gases are used as the process agent. However, the major part of the hot exit gases can be used for district heating (by means of a steam condenser) or vented through a flue stack.

The gas conditioning system used for the present invention involves the following step. The product gas is cooled - using direct heating grid- to about 45 °C, during which a considerable amount of water/tar condensate and also aerosols (microscopic water/tar droplets) is released. The aerosols are subsequently removed from the gas stream by means of a wet electrostatic precipitator (21). After this treatment the gas is clean and applicable for the gas engines (both tar and dust contents are below 25mg/Nm³.

The gas is boosted to a slightly higher pressure to accomplish engine inlet pressure regulation - by means of a traditional "gas train" - to slightly below atmospheric pressure. At full engine output, the amount of tar contaminated waste scrubbing and cooling water from the present solid waste gasification plant (1) amounts to about 1200 litres/hour containing about 18% of various organic acids and tars.

During the waste water treatment process about 100 litres/h of light (low molecular) tars are separated, which has a gross calorific value of 13-15 MJ/kg and is used for re-injection in to the solid waste gasifier (12) gasification agent preparation system or mixing with the feedstock material or selling it as the by-product or gasification in a small entrained flow solid waste
The re-introduction of tar is important for the overall plant energetic economy and by re-introducing the tar into the plant and joining this additional gas production with the leangas stream before the main gas coolers.

Whilst the protection scope of this application is determined in the annexed claims, it is not to be restricted with the foregoing disclosure given only for exemplifying purposes. It is obvious that a person skilled in the art can produce the novelty under the present invention with similar embodiments and/or can apply the present embodiment to other fields with similar technical purposes. In brief, it is clear that such embodiments shall lack the criteria of novelty and particularly of surpassing the known status of the relevant art.
CLAIMS

1. A process for producing combustible gases and their conversion into heat and electricity energy from a wide range of solid waste types, like sorted / unsorted municipal solid wastes, industrial wastes including waste water treatment plant sludge, leather industry residues, agricultural wastes etc., comprising the following steps of,
   - Solid waste minimization,
   - Solid waste reception and weighting,
   - Separation of solid wastes by manual and magnetic separation methods recovery of recyclable materials (4.1) and non-combustible components,
   - Primary shredding to reduce the material size down to 5-10 cm and separation of the particles which are not proper to downsize,
   - Sieving the recyclable materials (4.1) with the particle size of less than 25 mm and to recycling and with the particle size of more than 25 mm to the remaining stages of the normal process,
   - Drying the solid wastes by hot gas which is fed into the rotary drum dryer (7),
   - Separation of dust and removing the odor from hot exhaust gases taken from rotary drum dryer (7) by the dust / odor control system (7.1),
   - Secondary shredding in order to reduce material size less than 25 mm,
   - Briquetting and / or pelletizing dried solid wastes into pellets which have diameter of 20- 100 mm via briquetter (10) and pelletizer (11),
   - Fuel feeding to the solid waste gasifier (12),
   - Gasification of solid wastes into a combustible gases in the solid waste gasifier (12) by the supply of preheated air, O₂ and steam,
   - Accumulating ash residues extracted from the solid waste gasifier (12) into the ash / dust collector (16),
   - Cleaning up the upstream of the synthesis gas from the cyclone collectors (17) by removing dust particles over 10µm in size, scrubbing light ash material from the syngas with water in the scrubber (19), precipitation to provide the efficient emission control for submicron particles, heavy metals, acid mists, fumes, dioxins and furans by wet electrostatic precipitator (WESP) (21) and filtration,
   - transferring the gas by the help of the cooled gas vacuum fan (23),
   - gas cooling and drying by the water chiller (24) and heat exchanger (25),
   - heat and power generation of another upstream of the syngas from the cyclone collectors (17) by the heat / power generation unit (28) comprising at least a burner (29), a steam boiler (30), a steam turbine (31),
   - grid connection and energy distribution by energy distributor (32).
2. A process according to claim 1, comprising the step of producing an ultra rich flame of leangas at desired power level by plasma catalytic reactor (18) before the step of gas cooling and drying.
INTERNATIONAL SEARCH REPORT

International application No
PCT/TR2005/000053

A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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* Special categories of cited documents

*A* document defining the general state of the art which is not considered to be of particular relevance

*E* earlier document but published on or after the international filing date

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Date of the actual completion of the international search 15 May 2006

Date of mailing of the international search report 23/05/2006

Name and mailing address of the ISA

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Authorized officer van der Zee, W
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