



# Means for Increasing the Specific Capacity of WTE Combustion Units

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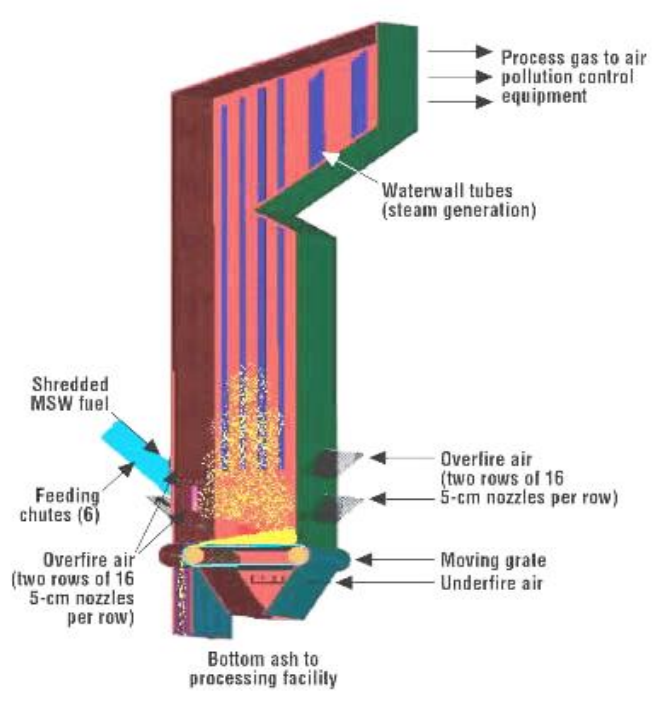
## Introduction:

The global generation of post-recycling municipal solid wastes (MSW):

- ❑ Nearly one billion tons
- ❑ 80% landfilled without CH<sub>4</sub> recovery
- ❑ So, contributing 3 - 4% of CO<sub>2</sub> emissions.

The environmental benefits of using WTE instead of landfilling?

- ❑ WTE plants conserve fossil fuels by generating electricity
  - ✓ 1.0 ton of MSW combusted reduces oil use by 1.0 barrel or 0.25 tons of coal.
- ❑ WTE plants reduce greenhouse gases
  - ✓ 1.0 ton of MSW combusted rather than landfilled reduces greenhouse gas emissions by about 1 ton of carbon dioxide.
- ❑ WTE plants do not have aqueous emissions that might be experienced in landfills.
- ❑ WTE plants reduce the space required for landfilling by about 90%.



❖ Novel WTE Technologies  
- Combustion Chamber in a RDF system  
Ref: N. J. Themelis 2003

## Problem Discussion:

The most efficient waste-to-energy (WTE) facilities co-generate:

- ❑ Electricity
  - ✓ About 500 kWh; and
- ❑ District Heating
  - ✓ About 500 kWh; per ton of MSW processed.

There is potential for thermally treating another 800 million tons of MSW that are globally landfilled

✓ **Therefore, it is necessary to increase the world's thermal treating capacity.**

This may be done by using:

- ❑ The dominant technology of mass burning with energy recovery
- ❑ By means of a number of novel thermal treatment technologies
  - ✓ Refuse Derived Fuel (RDF),
  - ✓ Direct Smelting,
  - ✓ Fluidized Bed Reactors,
  - ✓ Thermoselect Gasification Process (commercial)
  - ✓ Thermal Plasma processes in small scale as now are being proposed for large urban WTEs.

The dominant existing WTE technology:

- ❑ Combusts MSW as received
  - No shredding or other preparation of the wastes delivered by trucks, except pulling out very large objects.
- ❑ This technology is also referred to as “stoker” or “mass burn”
  - By now has reached a high state of development
  - In particular with respect to the capture and sequestration of undesirable emissions such as chlorine, sulfur, carbon monoxide, particular matter, volatile metals and dioxins/furans.

Engineering Design of WTE Combustion Units:

- ❑ Thermal Design
  - **Heat Release Rate per unit surface area of grate (flux) in MWh/m<sup>2</sup> which determines the dimensions of the combustion chamber (L, W, H)**
- ❑ Hydraulic Design
  - Tube Bundles Sizing, Pressure Drop Calc., Mass Balance, Steam Generation Rate., etc.
- ❑ Mechanical Design
  - Material Selection, Strengths, Corrosion Allowances, Operation and Maintenance, etc.

The Capital Cost of the facility depends on the above factors. Presently the capital costs range from \$150,000 to \$200,000 per daily ton of capacity.

The question is: Can the capital cost be decreased by reducing the size of the WTE combustion chamber?

## Experimental Data:

Comparison of geometry and operating parameters of some WTE and Biomass to Energy operations (MSW):

- ❑ Compared physical dimensions, rates of MSW feed, and combustion air throughputs for:
  - SEMASS RDF semi-suspension combustion chamber (1988)
  - Combusting pre-shredded MSW and the stoker WTE of ASM Brescia (1998)
  - Mass burn WTE of Union County (1994)
  - Mass burn WTE of Essex (1990).
- ❑ The residence time of MSW on the grate:
  - About 1 hour
- ❑ Heat Transfer in the first three meters of the grate:
  - Principally by radiation from the surrounding walls and the combustion flames above the bed to surface. In this region, heat is conducted through the bed and serves to heat, dry, and volatilize the solid wastes; these processes are assisted by the upward flow of air, usually preheated to 150°C.

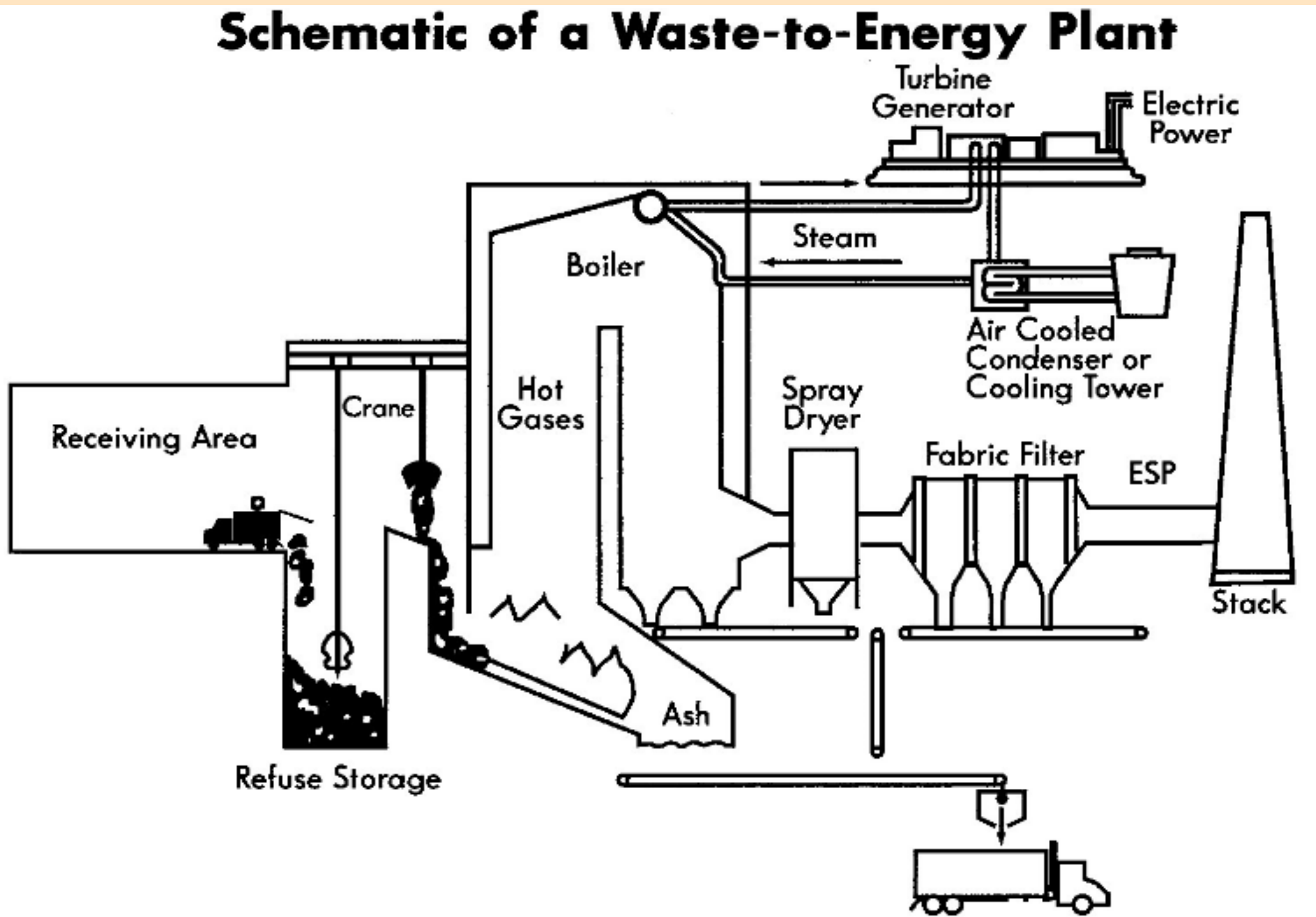
| Comparison of geometry and operating parameters of several WTE and Biomass to Energy operations (MSW) | SEMASS MA, USA RDF | Brescia ITALY Mass burn | Union Cty. NJ, USA Mass burn | Essex County Mass burn |
|-------------------------------------------------------------------------------------------------------|--------------------|-------------------------|------------------------------|------------------------|
| Starting year                                                                                         | 1988               | 1998                    | 1994                         | 1990                   |
| Capacity, Tons/day (per unit)                                                                         | 910                | 792                     | 480                          | 845                    |
| Combustion gas volume/ton, Nm3                                                                        | 5000               | 4100                    | 5000                         | 5000                   |
| Height, m (H)                                                                                         | 30                 | 22                      | 19                           | 20.42                  |
| Length of grate, m (L)                                                                                | 6                  | 8                       | 7.48                         | 10.7                   |
| Width of grate, m (W)                                                                                 | 11                 | 12.8                    | 7.8                          | 6.14                   |
| Grate area, m <sup>2</sup> (L x W)                                                                    | 66                 | 102.4                   | 58.344                       | 65.698                 |
| Grate area, ft <sup>2</sup>                                                                           | 710                | 1102                    | 628                          | 707                    |
| Grate productivity, tons/day/m <sup>2</sup>                                                           | 13.79              | 7.73                    | 8.22                         | 12.86                  |
| Combustion chamber cross sect. area, m <sup>2</sup>                                                   | 66                 | 62                      | 38                           | 32                     |
| Volume of combustion chamber, m <sup>3</sup> (LxWxH)                                                  | 1980               | 1210                    | 663                          | 1205                   |
| Process gas volume, Nm3/hour                                                                          | 189583             | 135300                  | 100000                       | 205532                 |
| Flue gas flow, Nm3/ton                                                                                | 5000               | 4100                    | 5000                         | 5000                   |
| Velocity of gas in main section of chamber, m/s                                                       | 3.41               | 2.61                    | 3.12                         | 7.62                   |
| Average minimum residence time, s                                                                     | 8.80               | 8.43                    | 6.08                         | 2.68                   |
| Grate combustion intensity, tons/day/m <sup>2</sup>                                                   | 13.79              | 7.73                    | 8.23                         | 12.87                  |
| Net electricity (kwh/ton)                                                                             | 680                | 682                     | 550                          | 513                    |
| Net electricity generation, MW                                                                        | 26                 | 23                      | 11                           | 18                     |
| Heat value of fuel, kJ/kg                                                                             | 11000              | 11300                   | 11000                        | 11000                  |
| Heat release rate, MJ/(h.m <sup>2</sup> )                                                             | 6319               | 3642                    | 3771                         | 5898                   |
| Heat release rate, kBtu/(h.ft <sup>2</sup> )                                                          | 556                | 321                     | 332                          | 519                    |
| Heat release, MW/m <sup>2</sup>                                                                       | 1.76               | 1.01                    | 1.05                         | 1.64                   |
| Net electricity generation, MW/m <sup>2</sup>                                                         | 0.39               | 0.22                    | 0.19                         | 0.27                   |
| Thermal efficiency (conversion to electricity)                                                        | 22.3%              | 21.7%                   | 18.0%                        | 16.8%                  |
| Comparative Indices                                                                                   |                    |                         |                              |                        |
| Net power generation, kwh/ton fuel                                                                    | 682                | 682                     | 550                          | 513                    |
| Ave heat flux on grate (completed combustion), MW/m <sup>2</sup>                                      | 1.76               | 1.01                    | 1.05                         | 1.64                   |
| Thermal efficiency, MWe/MWt                                                                           | 22.3%              | 21.7%                   | 18.0%                        | 16.8%                  |
| Comparison with coal-fired stoker:                                                                    |                    | Refuse                  | Wood                         | RDF                    |
| Stoker/grate typical release rate, Btu.h ft <sup>2</sup>                                              |                    | 300,000                 | 1,100,000                    | 750,000                |
| Compare with SEMASS etc. (1 Mj = 947.817 Btu)                                                         |                    | 68,000-179,000          | 68,000-179,000               | 68,000-179,000         |

Excess Air:

- ❑ An obvious advantage of the Brescia WTE is that the % excess air used is lower than others, resulting in a substantially lower volume of combustion gas per ton of MSW;
  - ✓ One reason for this is that Brescia recalculates part of the process gas to the combustion chamber, thus achieving higher utilization of oxygen.

The grate productivity:

- ❑ SEMASS has 78% higher grate productivity than Brescia,
  - ✓ An obvious advantage of pre-shredding and homogenizing the feed.
- ❑ Gasification:
  - ❑ WTE is combusted or gasified and the resulting residue is vitrified in the same furnace.
- ❑ Thermo-chemistry:
$$\text{C}_6\text{H}_{10}\text{O}_4 + 6.5\text{O}_2 \Rightarrow 6\text{CO}_2 + 5\text{H}_2\text{O} + 23.5 \text{ MJ/kg} \quad (1)$$
  - ✓ On the average, U.S. MSW contains about 25% moisture and an equal amount of metals and other inorganic materials, as indicated by the fact that the ash generated in U.S. WTEs amounts to an average of 25% of the MSW processed.
  - ✓ Therefore, the chemical heat contained in MSW is one half of the heat of the chemical reaction (1), that is about 11.75 MJ/kg.
  - ✓ The average E.U. MSW, presumably because of better sorting and recycling, contains 10.1 MJ/kg, equivalent to 2800 kWh.



## Discussion and suggestions:

Following parameters/features may increase the specific capacity of WTE combustion units:

- ❖ Removing large metallic and inorganic objects from MSW, pre-shredding and partial drying of MSW.
- ❖ Feeding the combustion chamber in way that part of the combustion takes place in suspension and part on the moving grate (as SEMASS)
- ❖ Possibly using partial oxygen enrichment
- ❖ Using Ca(OH)<sub>2</sub> injection in combustion chamber to sequester some of the HCl and thus allow higher steam temperature
- ❖ Using recirculation of the heavier particles in the gas flow out of the combustion chamber back into the combustion chamber (as is done in CFB combustion of MSW and wood chips), or using a cyclone separator ahead of the APC system and thus minimize the amount of fly ash collected in the bag filters after the APC system.

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