



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

INCINERATION 1

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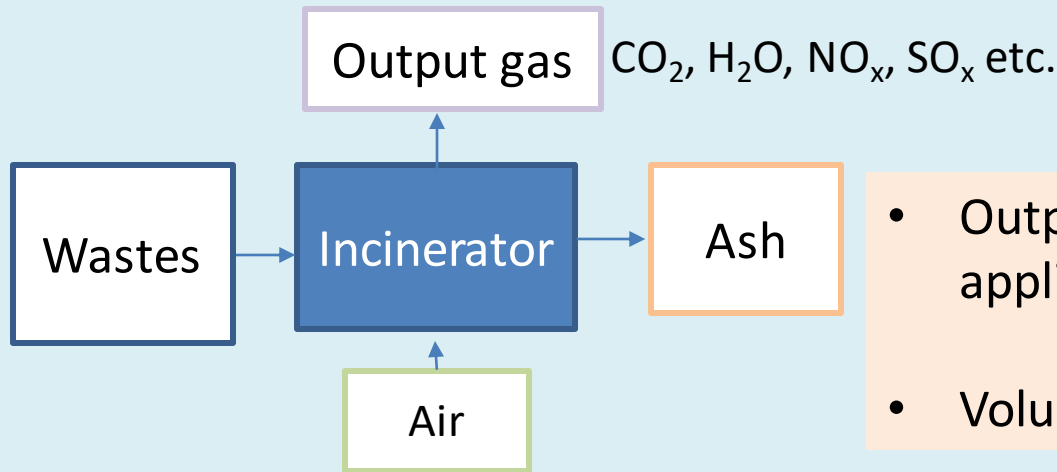
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Incineration and its scope of application

- **Incineration** is a waste treatment process that involves the combustion of organic substances contained in waste materials.
- Combustion is the sequence of exothermic chemical reactions between substrates and oxidant accompanied by the production of heat and conversion of chemical species.



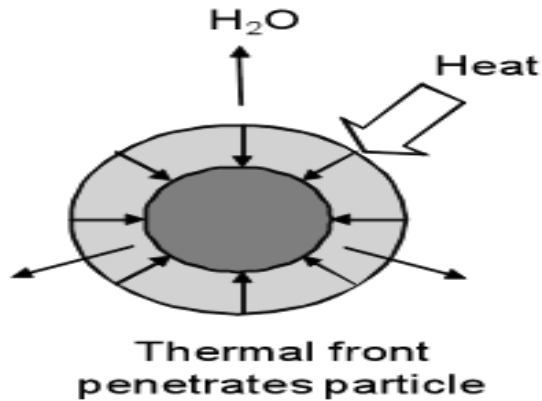
- Output gas can be used for heat application/electricity production
- Volume of wastes reduces

Mechanism of combustion

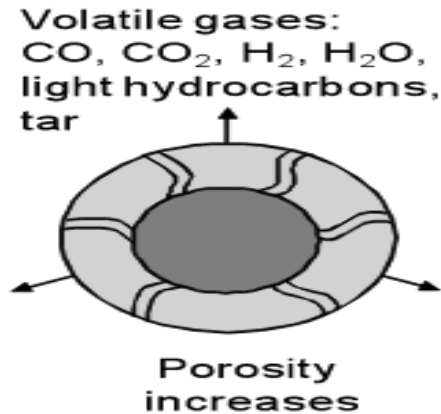
Combustion takes place through three major steps as stated below:

- Drying
- Pyrolysis and reduction
- Combustion of volatile gases and solid char

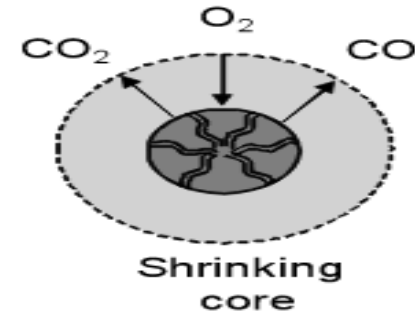
Heating and Drying



Pyrolysis



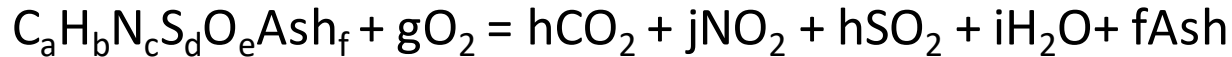
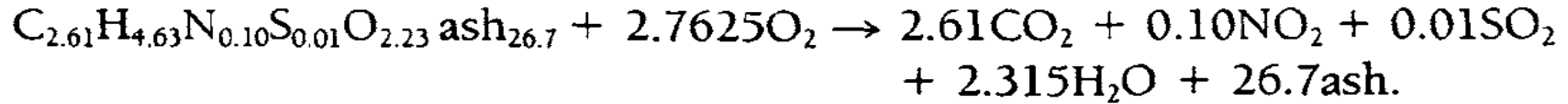
Char Combustion



Source: <http://www.uaex.edu/publications/pdf/FSA-1056.pdf>

Air requirement for incineration

- Complete combustion will occur when the proper amounts of fuel/substrate and air (fuel-to-air ratio) are mixed for the correct amount of time under appropriate conditions of turbulence and temperature.
- Knowing the typical composition of the wastes stoichiometric air requirement can be computed as described through Equation*.



- In practice, in order to achieve complete combustion (mass burn/ incineration), it is necessary to increase the amount of air to the combustion process to ensure the burning of all of the fuel



- The percentage of **excess air** is the amount of **air** above the stoichiometric requirement for complete **burning**.
- The excess oxygen is the amount of oxygen in the incoming air not used during combustion and is related to percentage excess air.
- Typical excess air required for various combustion systems is in the range of 5 to 50 percent, depending on the fuel characteristics and the system configuration.

Performance factors

- Successful combustion of solid waste is accomplished by controlling the '3 Ts of Combustion' – Time, Temperature and Turbulence.

Time – The period taken for solid waste to pass from the charging hopper until the bottom ash is discharged at the end of the grate subsystem (usually 45–60 minutes);

Temperature – Usually exceeds 1,800F (982 °C) within the furnace and is directly proportional to the residence time. If there is insufficient time in the furnace, the combustion reaction cannot proceed to completion and temperature declines; and

Turbulence – Provided by the grate subsystem moving the solid waste downward through the furnace to expose it to and mix it with air.



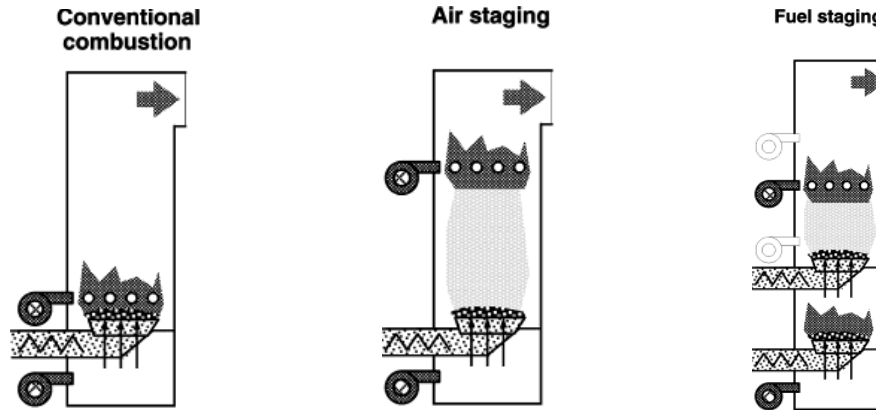
Staged combustion to achieve enhanced combustion

- The primary air injection is made in the fuel bed and secondary air injection is made in the combustion chamber.
- This enables good mixing of combustion air with the combustible gases formed by de-volatilization in the fuel bed.
- Good mixing supports an operation at low excess air (i.e., excess air $\lambda < 1.5$), which gives high efficiency as well as complete burnout and high temperature
- Concentrations of unburnt pollutants become close to zero (e.g., $\text{CO} < 50 \text{ mg/m}^3$ and $\text{C}_x\text{H}_y < 5 \text{ mg/m}^3$ at 11 vol % O_2). It also reduces NO_x formation.
- Air staging applies air injection at two levels as well whereas in fuel staging, fuel is fed into the furnace at two different levels.



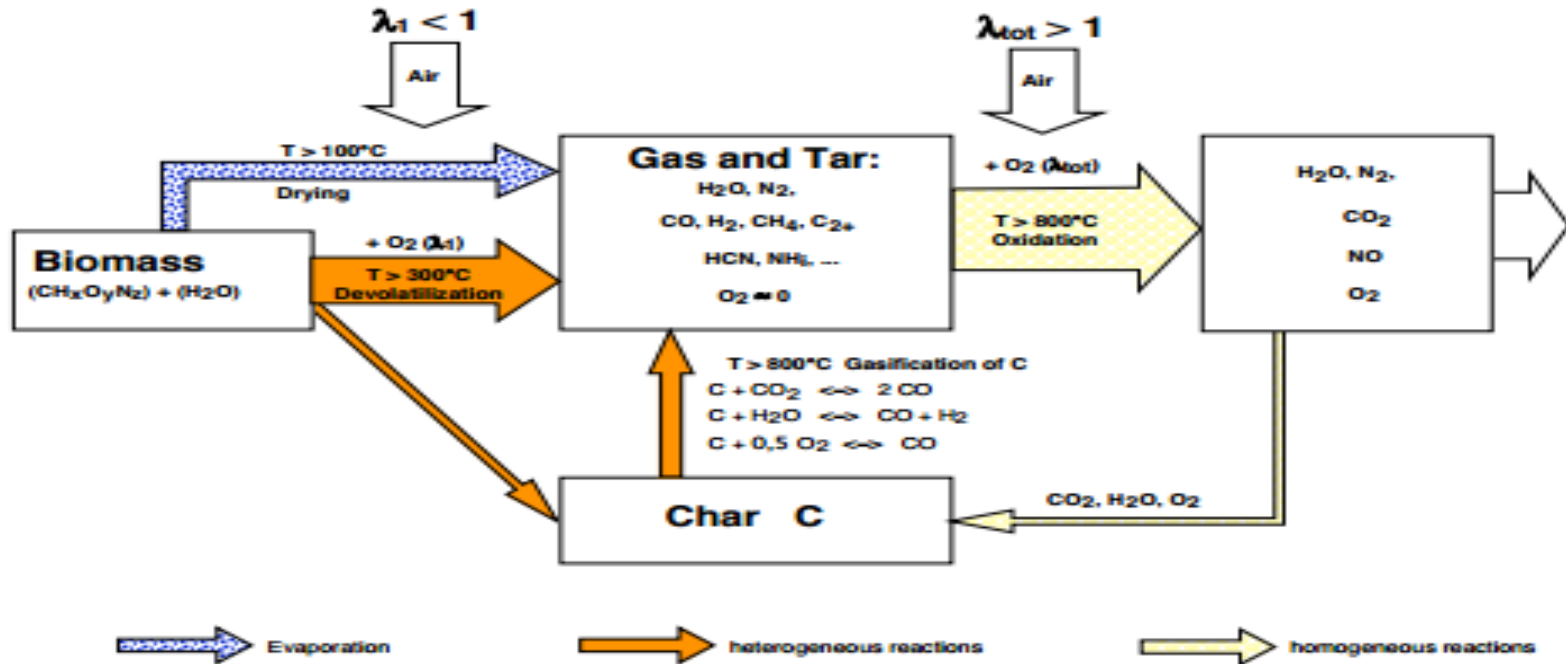
Staged combustion to achieve enhanced combustion

- In air staging primary air is injected under stoichiometric (λ primary < 1). Secondary air inlet is in the reduction zone of the furnace.
- In fuel staging, the primary fuel is combusted with excess air > 1 . A consecutive reduction zone is achieved by feeding secondary fuel and late inlet of final combustion air for the secondary fuel.



Principle of two stage combustion

Reactions during two stage biomass combustion



Injection of primary air for gasification and secondary air for gas-phase burnout.

Ref: Nussbaumer, T. In Energie aus Biomasse; Springer: Berlin 2001

Factors affecting combustion

- Particle size and specific gravity
- Ash content
- Moisture content
- Extractive content
- Element (C, H, O, and N) content
- Structural constituent (cellulose, hemicelluloses, and lignin) content



Advantages

- Combustion is a proven low-cost process
- Highly reliable technology
- Relatively well understood
- Commercially available
- It is the most common means of converting biomass to usable heat energy
- It account for around 90% of all energy attained from biomass
- It contributes over 97% of bio energy production in the world



Disadvantages of combustion

- Fuel quality and consistency can vary significantly
- Produces more indoor and outdoor air pollution than conventional heating fuels, even with the use of advanced combustion technology
- Creates the risk of fire and carbon monoxide poisoning
- Requires regular monitoring and maintenance
- Fuel storage requires a lot of space



Preferable waste compositions for incineration

Source

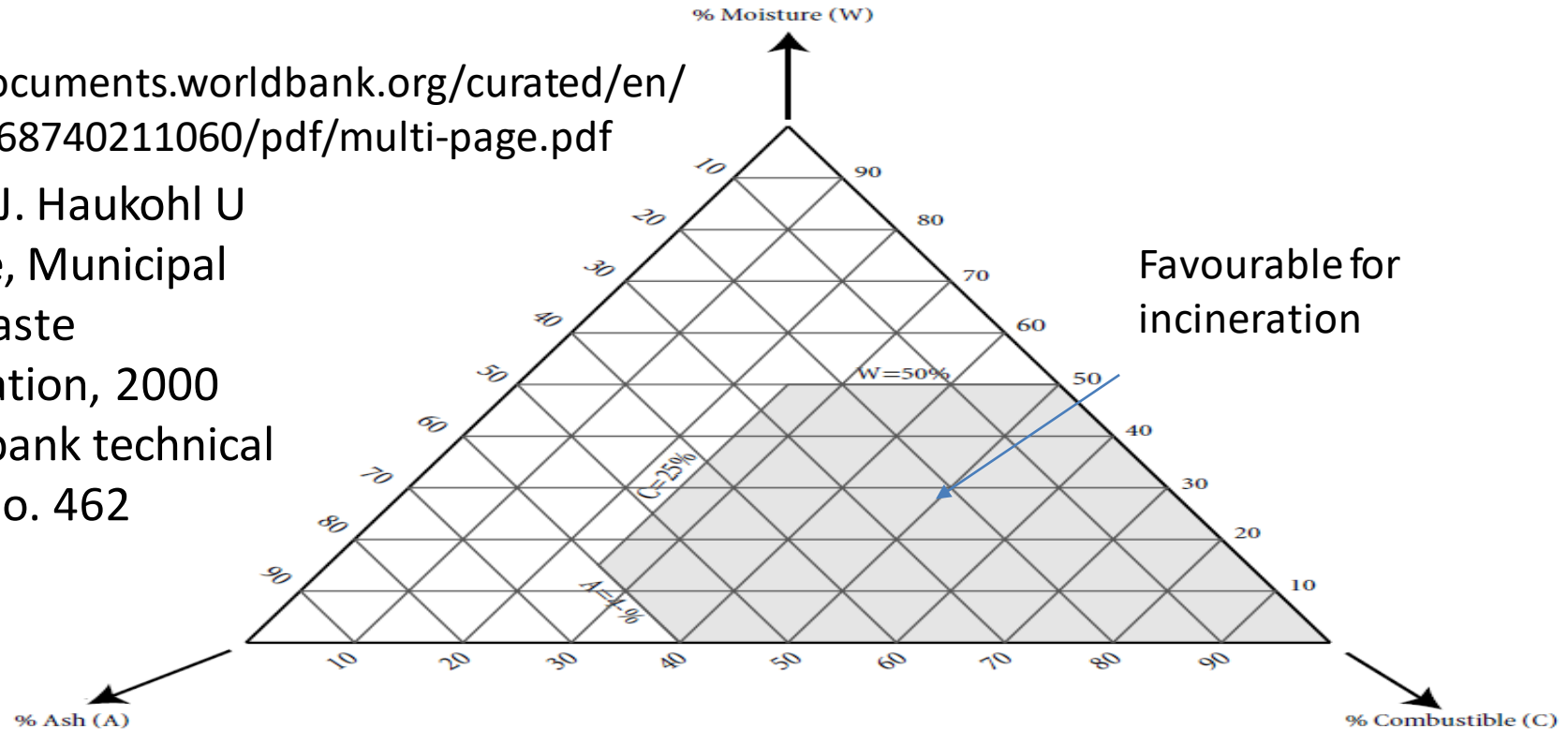
<http://documents.worldbank.org/curated/en/886281468740211060/pdf/multi-page.pdf>

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Amarxe, Municipal
solid waste

Incineration, 2000

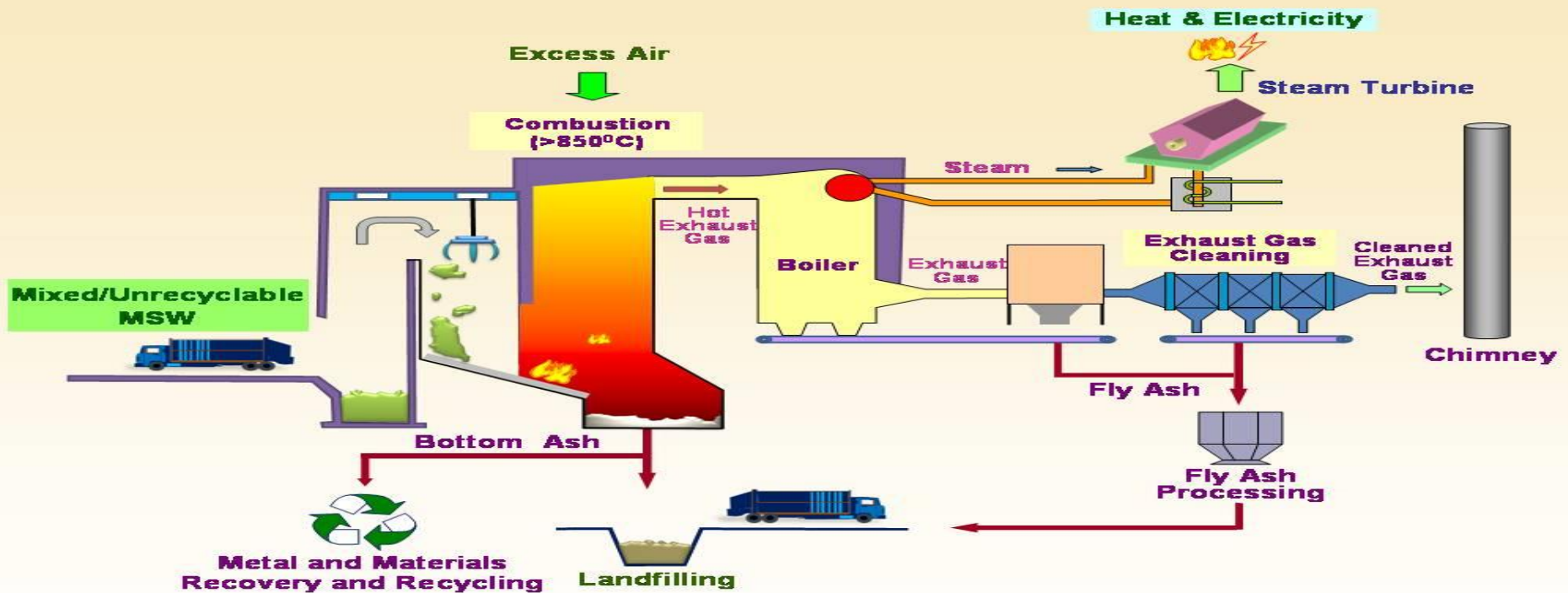
World bank technical
paper no. 462



Tanner triangle for assessment of combustibility of MSW

Flowsheet

Pre treatment, incineration, energy recovery, ash management, gas treatment



<http://erean.eu/wordpress/municipal-solid-waste-a-potential-source-of-rare-earth-elements/>



Sorting

- May be sorted manually, automatically, or mechanically or as a combination thereof
 - Coarse mechanical sorting may not be sufficient for fluidized bed incineration
 - Advanced sorting processes, however, are time consuming and costly, take up a lot of space, and require special precautions.
-
- ☐ With a movable grate, the waste may be burnt without sorting, shredding, or drying.
 - ☐ An overhead crane typically removes in appropriate bulky waste from the pit through a coarse and simple sorting.

Homogenization

- Required for efficient combustion
- For mass burn incineration, the mixing is typically done by the overhead crane in the pit.

Shredding

A shredder may be used when there are large quantities of bulky waste. For fluidized bed incineration, shredding is a minimum requirement and further pre treatment is necessary



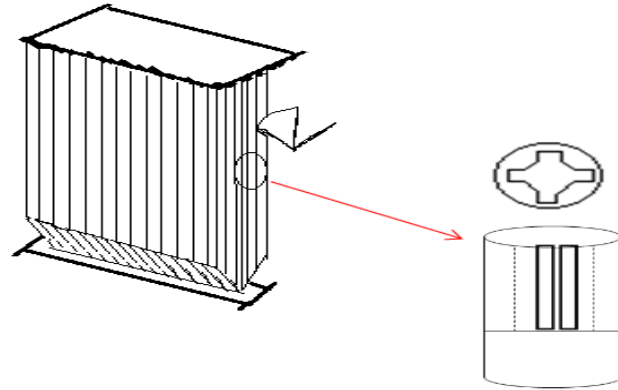
WTE solid waste combustors

- In incinerator, the heat released from combustion is used to generate steam in a boiler. Refractory or water wall furnace systems are used for this purpose. The major difference between these two designs is the location of the boiler.
- Refractory units – This design consists of boilers located downstream of the combustion (furnace) chamber. The hot combustion gases pass through the boiler tubes to create steam;
- Boilers convert the heat of the hot gases to steam, which can be used either to generate electricity or for industrial steam



WTE solid waste combustors

- Waterwall units – In this design furnace is constructed with water tube membrane walls to recover the heat energy directly from the furnace unit. Waterwall designs have higher thermal efficiency than that with refractory units.



Vertical tube wall
with rifled tube

Thanks...

