# Fluidized Bed Combustion of MSW

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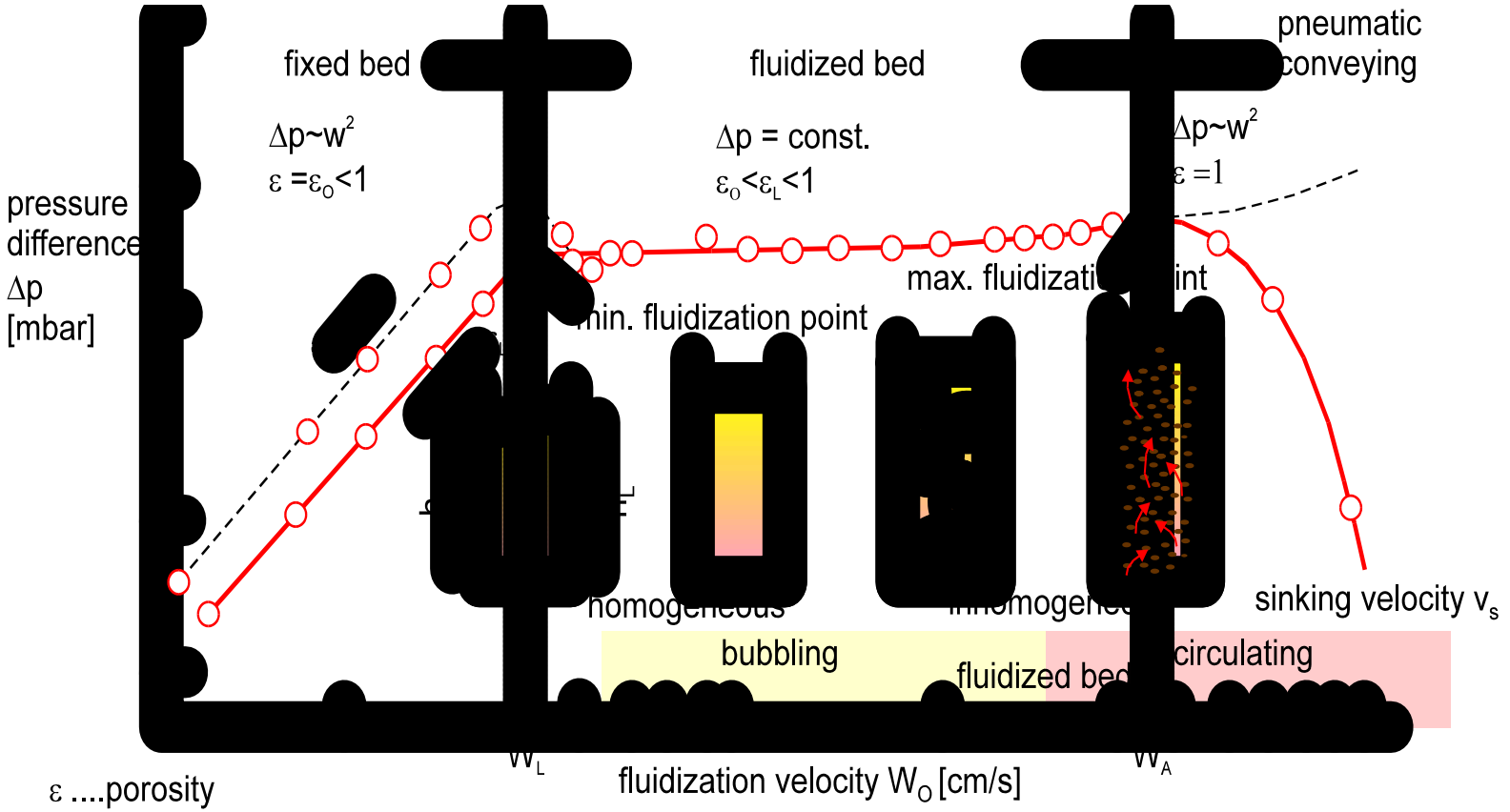
# Outline

1. Combustion reactors & fluidized bed combustion
2. Design of CFB combustion system for wastes
3. Introduction of commercial fluidized bed waste to energy plants

# 1. Combustion reactors & fluidized bed combustion

- Fixed bed
- Fluidized bed
- Features of fluidized bed combustor

# Parameter Determination



# Basic differences of mass fired incineration and SRF fluidized bed combustion (FBC)

**Mass fired incineration on grate**

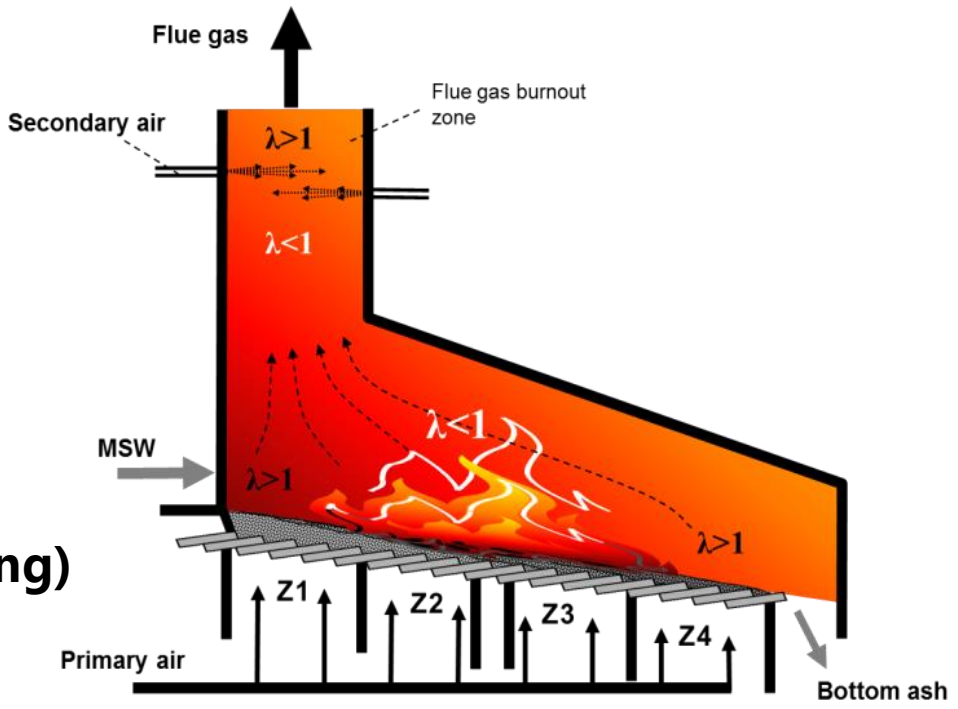
- Combustion in a moving bed (layer)
- Bed on the grate
- Supply easy also for large particles
- Mechanical transport of the waste during combustion
- Large pieces of waste allowed

**Fluidized bed combustion(FBC)**

- Combustion in a fluidized sand bed
- Particles burn ”separately”
- Particles have to float in the air flow
- Effective mixing of particles with sand and air
- Particle size has to be reduced (max. appr.50-100 mm)
- Effective heat transfer between fuel particles, bed particles and gas

# Grate furnace

**Grate combustors** place the fuel on a grate (often sloped), with combustion air provided both below and above the grate.



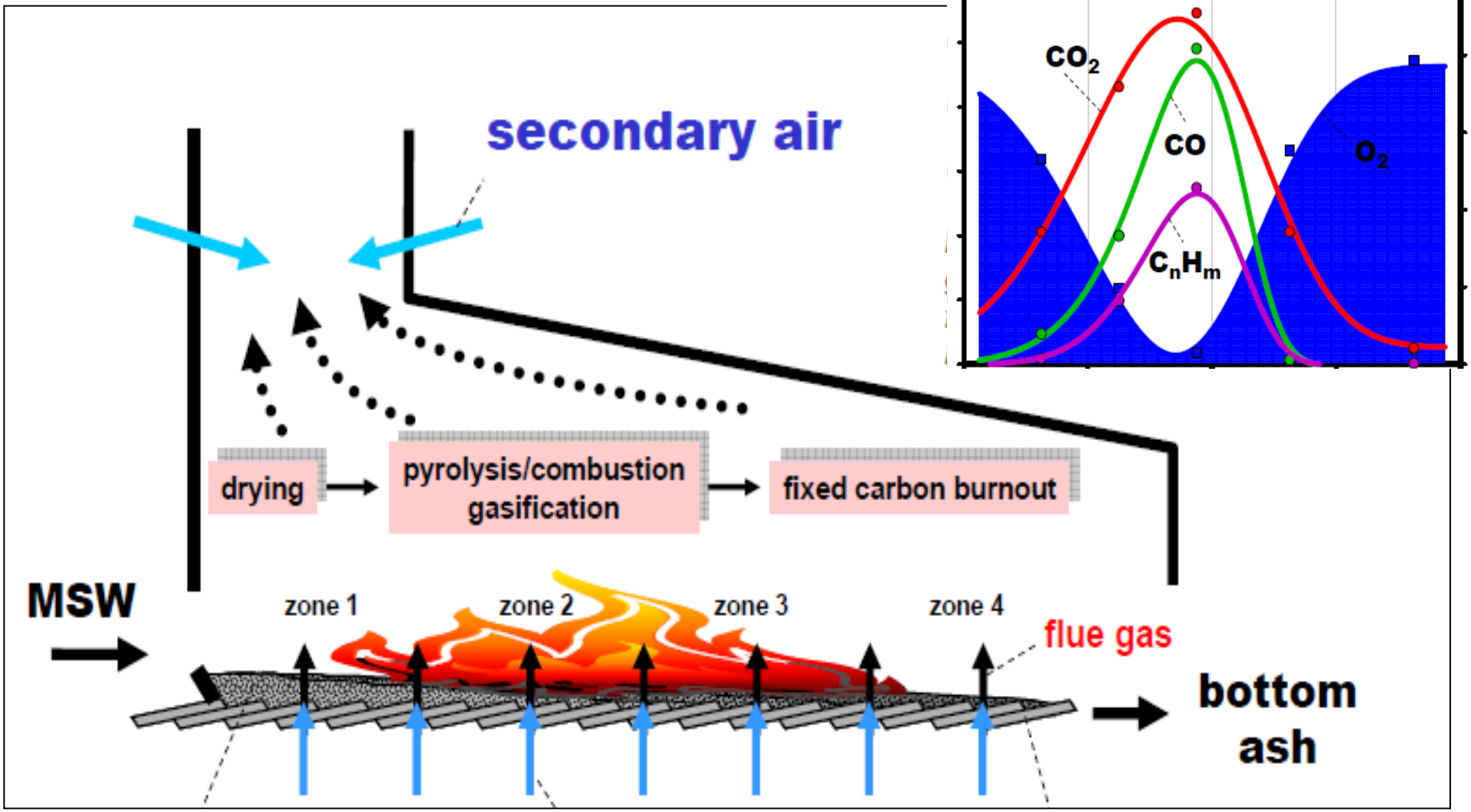

## Advantages

- □ Simple and reliable structure
- □ Easy to operate
- □ Low cost (investment & operating)

## Disadvantages

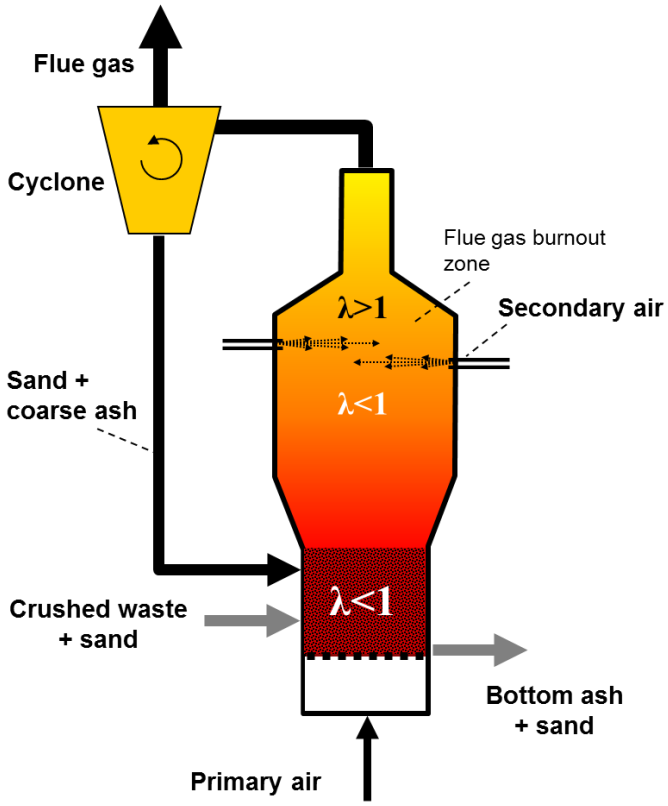
- □ Grate firing
- □ Burning out time
- □ Low energy efficiency

# Combustion on moving grate



# Fluidized bed reactor

**Fluidized bed combustor** burns fuel by adding it to a continually stirred bin of heated sand-like material. This arrangement allows for extremely even heating of the fuel and high efficiency of combustion.




## Advantages

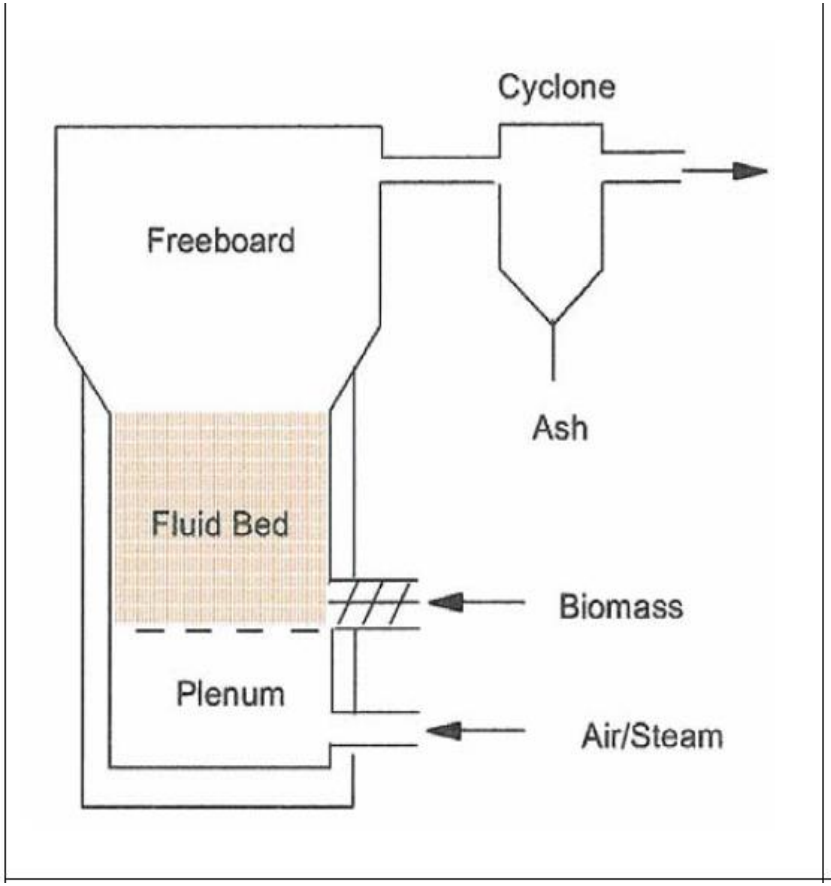
- □ Good gas-solid contact & mixing
- □ High specific heat capacity
- □ Can accommodate variations in fuel quality

## Disadvantages

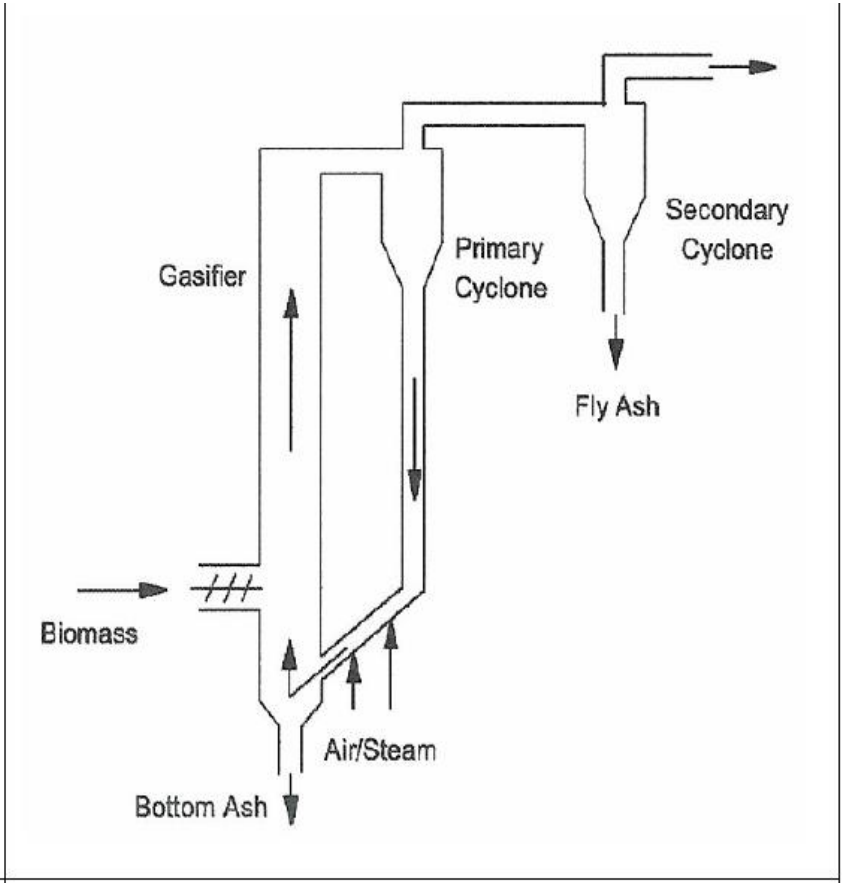
- □ Carbon loss with ash
- □ Feed pre-processing required

# Fluidized bed reactor

## Fluidized bed combustor




Bubbling fluidized bed

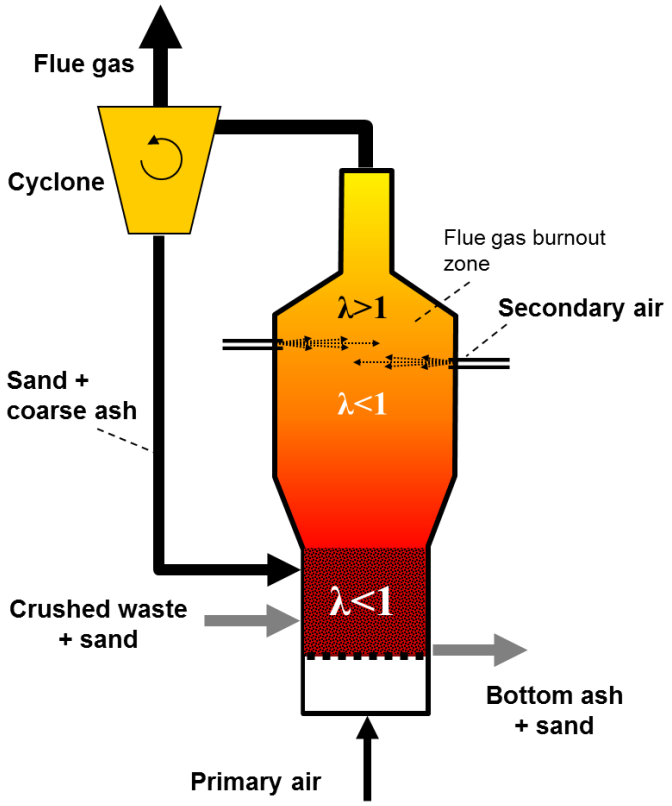



Circulating fluidized bed

# Fluidized bed reactor

## Why Fluidized Bed

- Capable burning different kinds of waste
  - low heating value high moisture waste
- Incineration residue can be easily treated
  - very low combustible content in residue ash
  - dry ash
- Low pollutants emission
- Coal can be used as assistant fuel
- Effective energy recovery
- Good operation performance
- Low operation cost

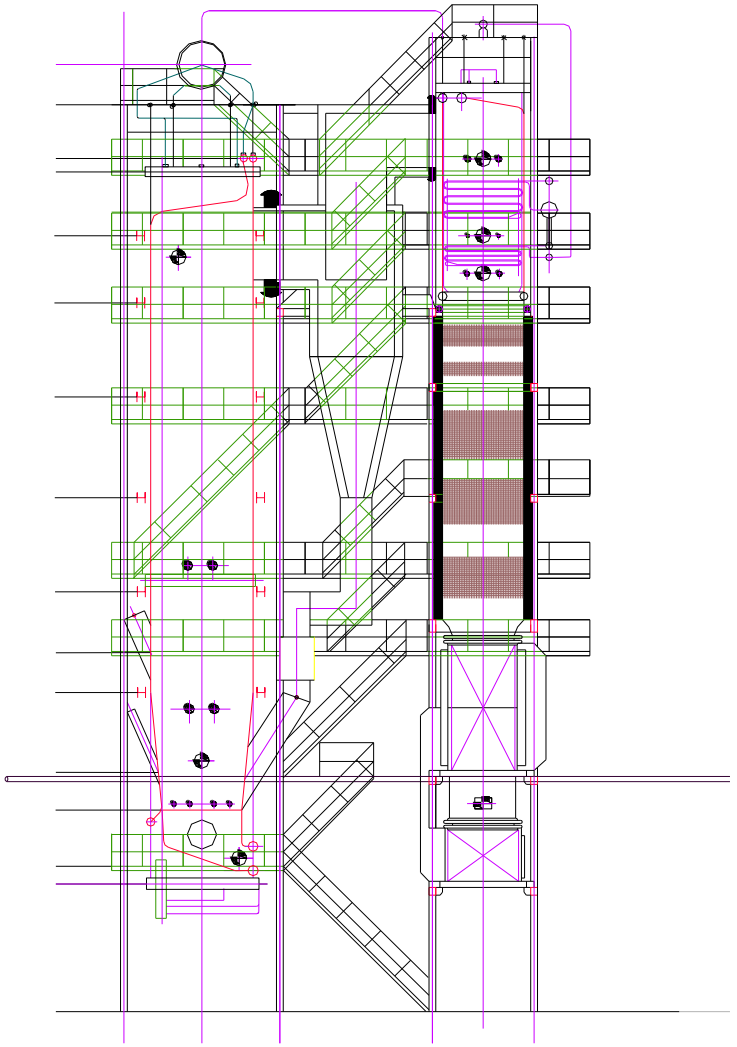


# Comprison between Grate furnace and CFB

| Comparison items | | Grate Furnace | CFB |
|---|---|---|---|
| Life Cycle Cost | CAPEX(Capital expenditures) | Relatively higher | Low |
| | OPEX | Similar | Similar |
| Feedstock Composition | Quality requirements on feedstock for furnace | Relatively low | Relatively high and pretreatment is needed |
| | Adaptability to feedstock heat value | Average | High |
| Operating Efficiency | MSW burn-off rate | Hard to control | High |
| | Feedstock reduction | Relatively low | High |
| | Utilization ratio of thermal energy | Low | High |
| Pollution Control | Atmospheric pollutant | Higher content of dioxin and NOx | Lower content of dioxin and NOx |
| | Leachate treatment | Hard | Complete incineration can be reali |

# Features of fluidized bed combustion

- ***Suitable for low heating value fuel***
- ***Stable operation at 850 - 900℃***
- ***High combustion efficiency and intensive heat transfer***



# 2. Design of CFB combustion system for wastes

- Waste pre-treatment and feeding
- Furnace and waste heat boiler

# Waste feeding - Pretreatment

## Waste pretreatment (mechanical treatment) processes

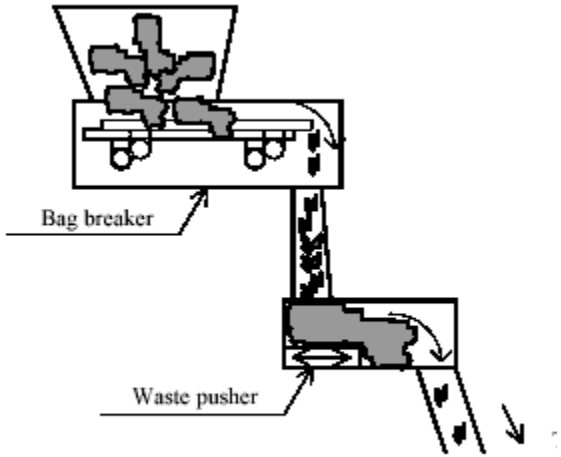
- Particle **size reduction** – Crushing

- Separation based on particle size – Screening
- Separation based on **density** differences – Air separation, floating/sinking
- **Magnetic separation** – Ferrous metals
- Separation based on **electric field** – Eddy current - Aluminum
- Optic separation – Near Infrared (NIR), colour – identifying separable materials
- Separation based on X-ray absorption

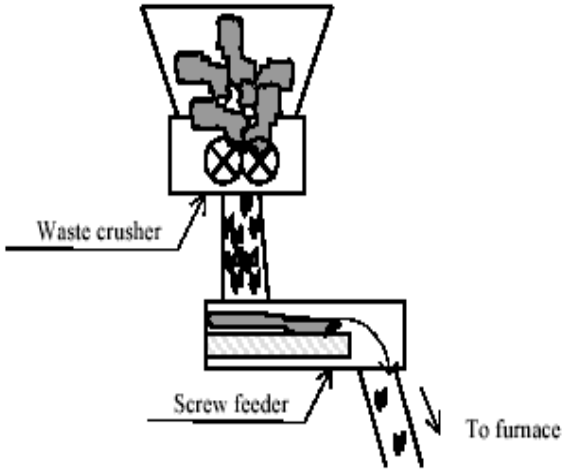
- **Conveying** between unit processes – belt conveyors, screw conveyors, scraper conveyors
- **Packing** – bales, briquettes, pellets
- **Storing**

# Waste feeding

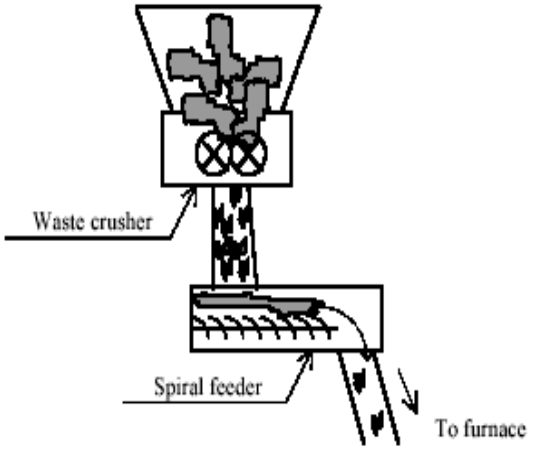
## Crush and feed




(1) Bag breaker + Waste pusher




(2) Waste crusher + Screw feeder




(3) Waste crusher + Spiral feeder

- **In a fluidized bed incinerator, stable and uniform feeding is of great importance.**

# Waste feeding - Pretreatment

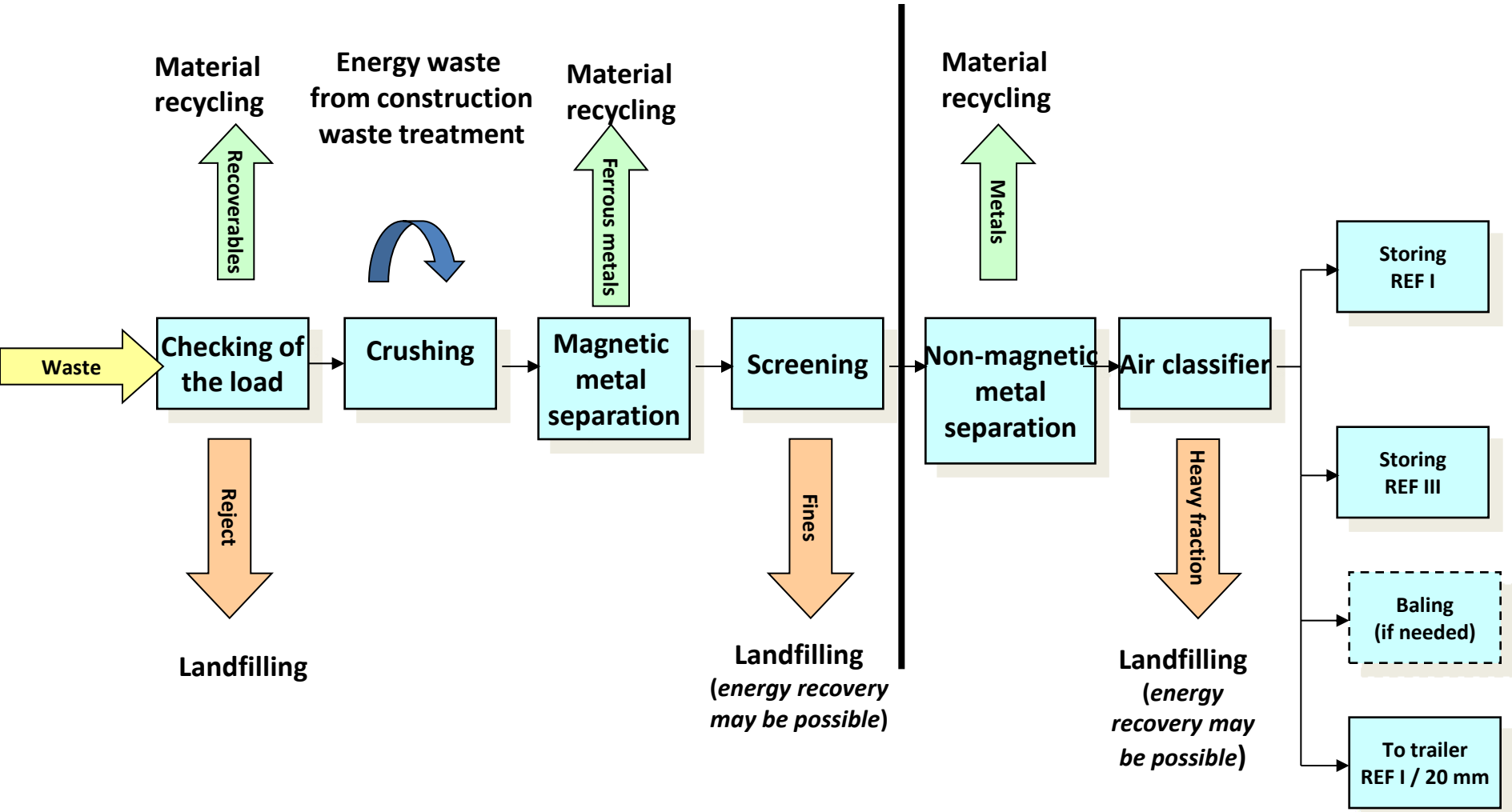
## SRF production

Objectives

- More uniform quality of the fuel
  - Better known heating value
  - More equal particle size => better operation and less maintenance of conveying and supply equipment
  - Reduction of harmful material
  - Reduction of corrosion and fouling of the boiler
  - Lower emissions, not so expensive fuel gas treatment
- Increase of material recovery

# Waste feeding - Pretreatment

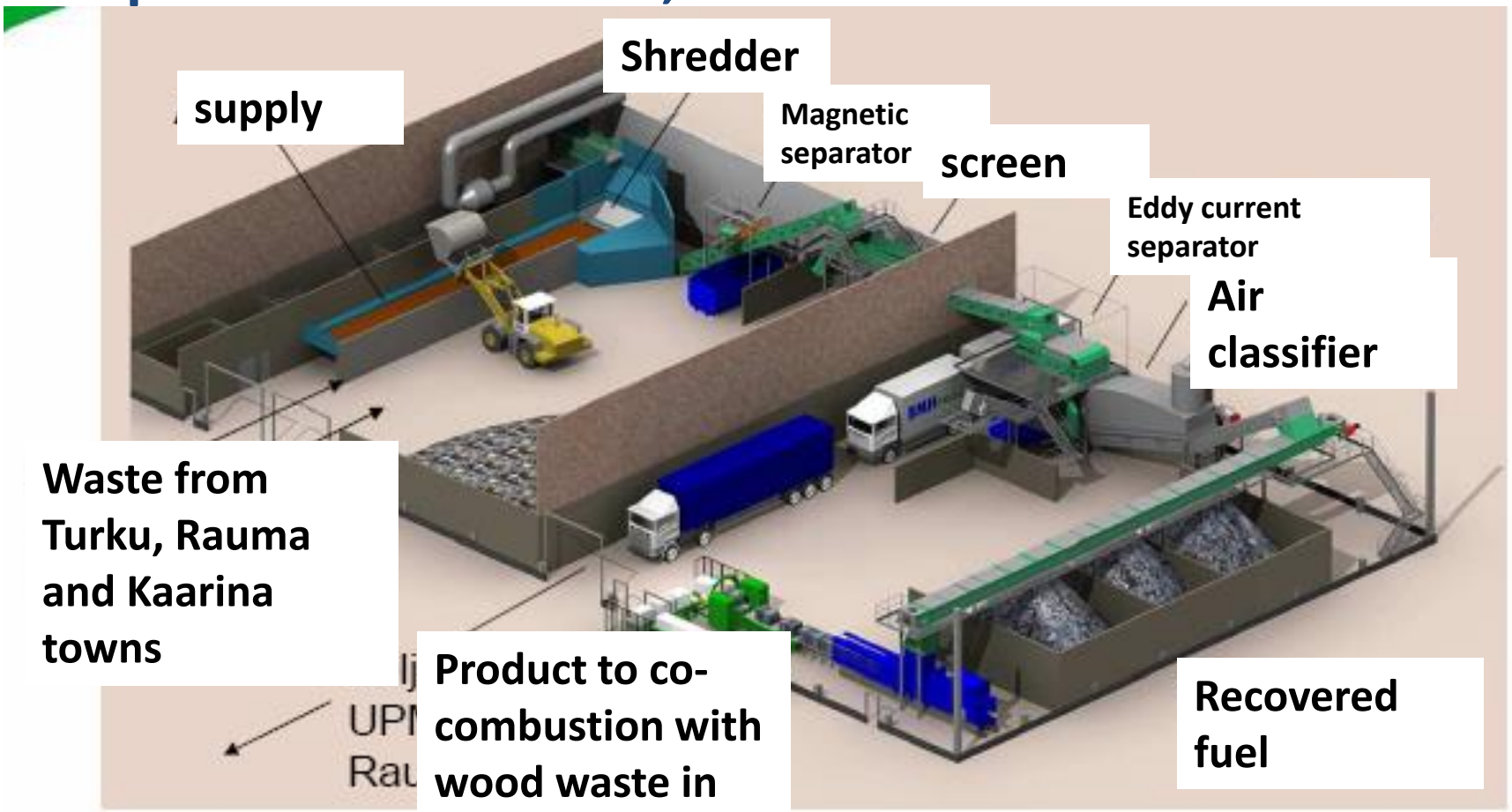
## Turku Pretreatment of wood, energy and landfill waste




Source: Lassila & Tikanoja

# Waste feeding - Pretreatment

## SRF production in Turku, Finland




Source: Lassila & Tikanoja

# Furnace - air distributor

## Tube air distributor

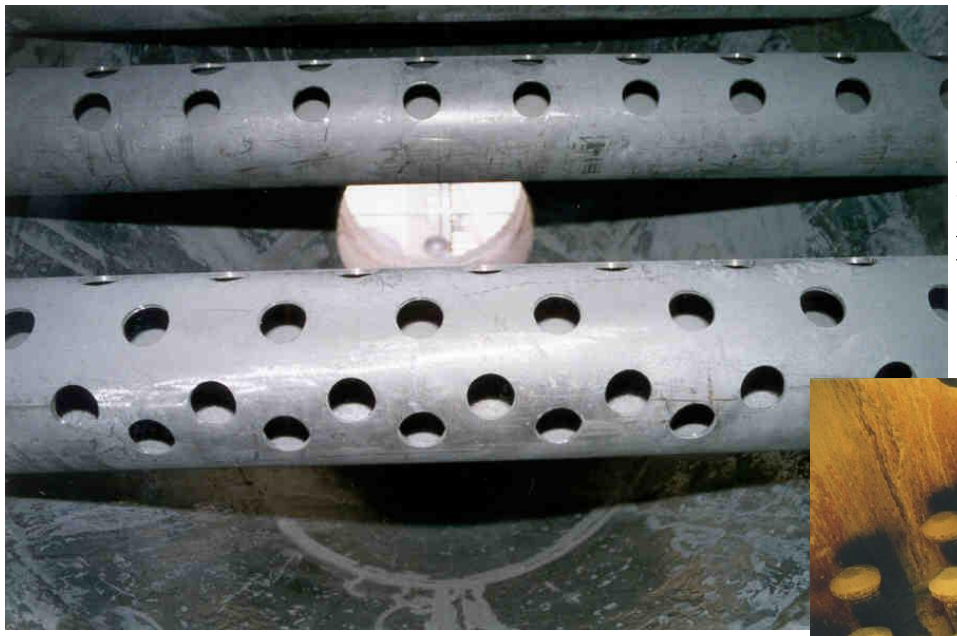

Standard solution for non-problematic fuels ash drain via center tube (low bedash forming fuels) or ash cooler (high bedash forming fuels)


Solution for multi-fuel fired applications with high plugging tendency (wires, stones)

ash drain over complete furnace section and bed material recirculation

# Furnace - air distributor

## Tube air distributor

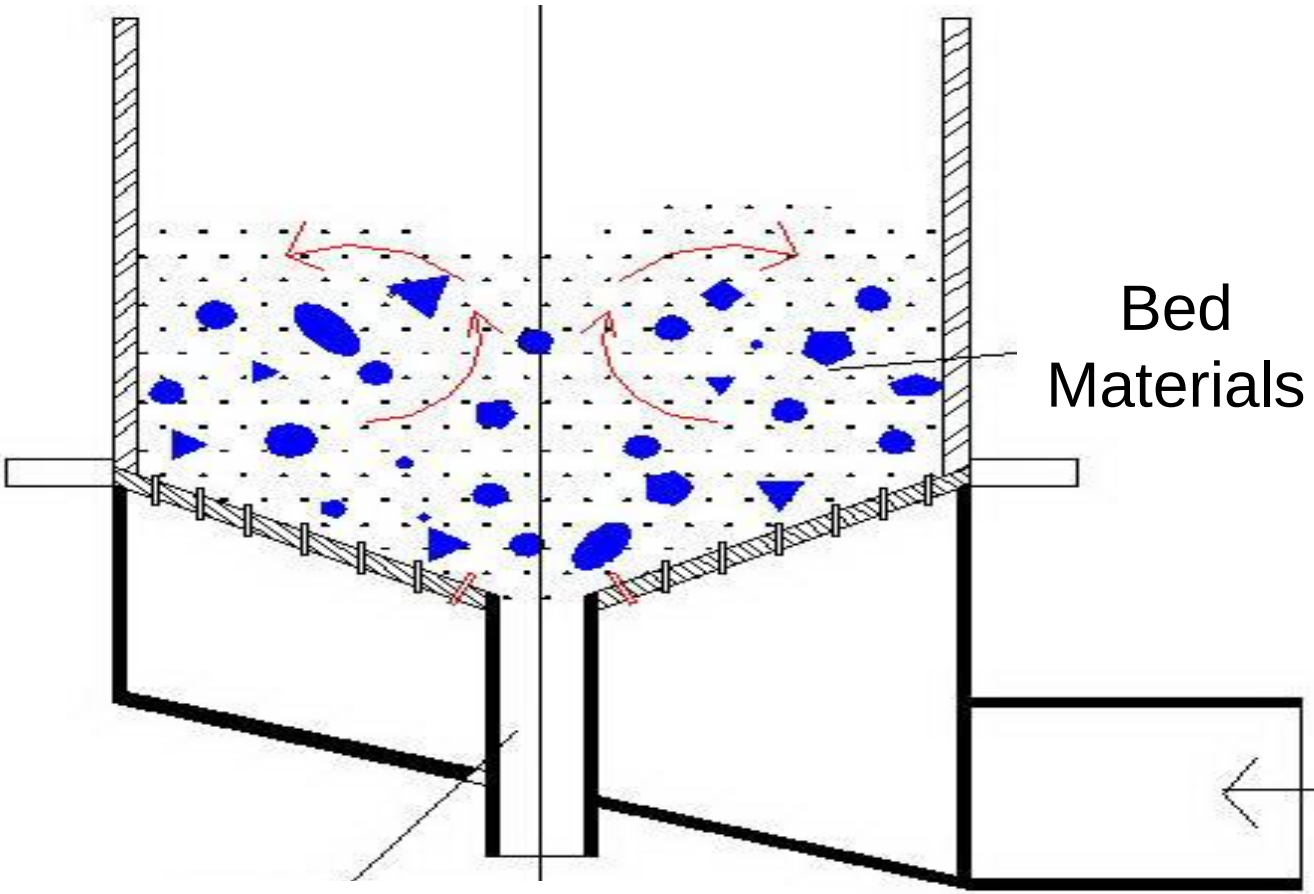


Primary air pipes before installing the nozzles of the nozzle grid

The nozzle grid

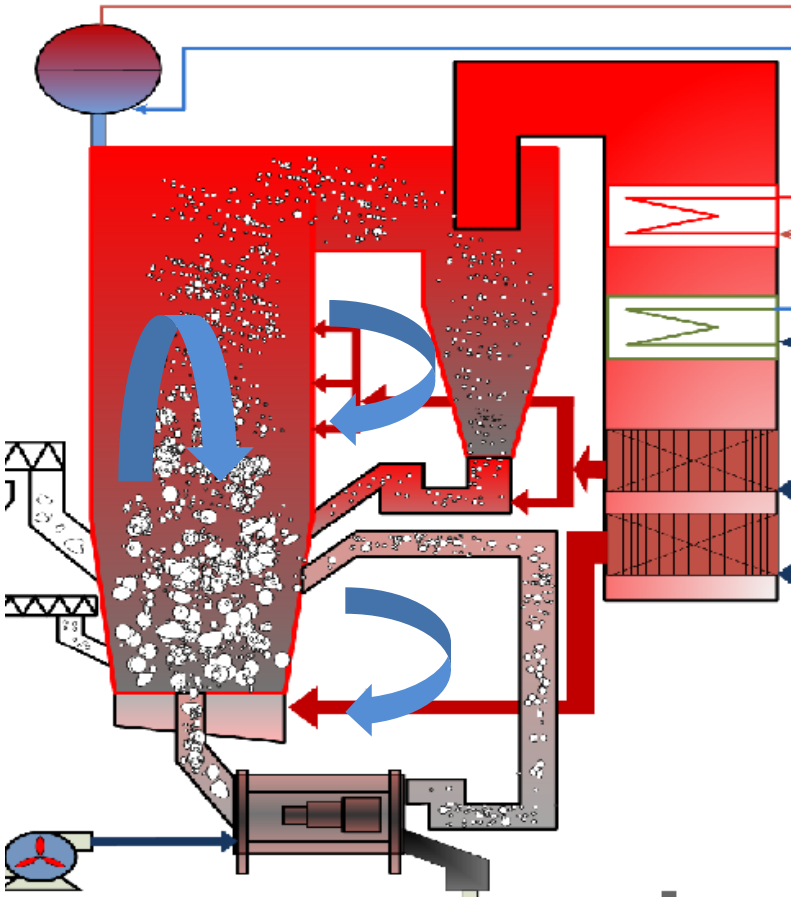
# Furnace

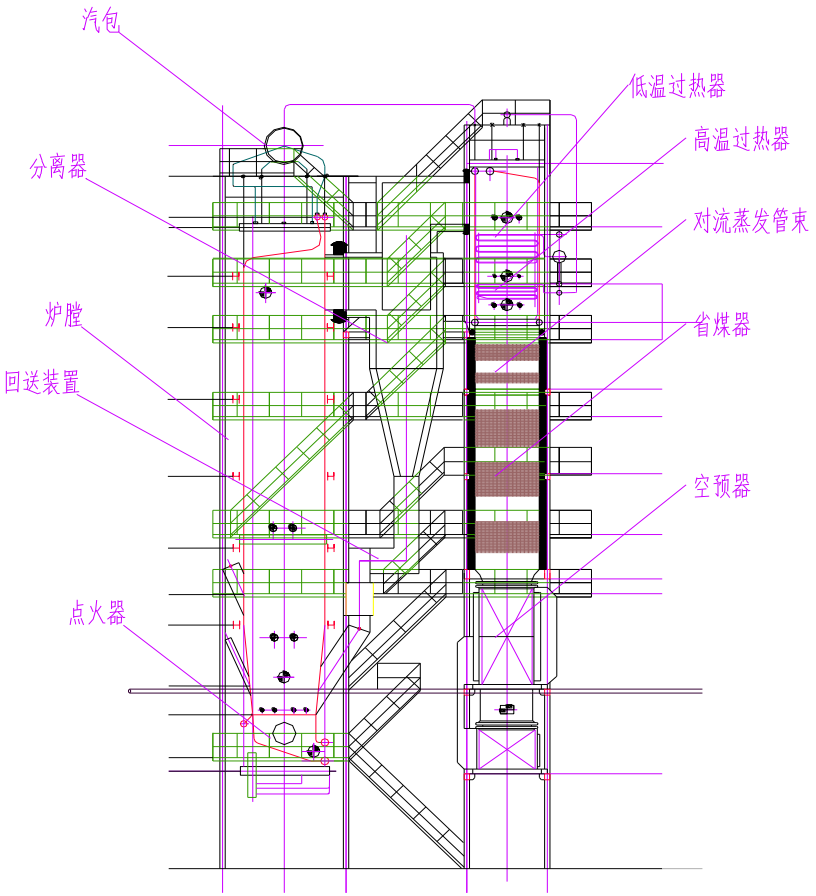
## Inner-circulated fluidized bed




# Furnace

## Combined-circulated fluidized bed





# Furnace

- **High density inert bed material**

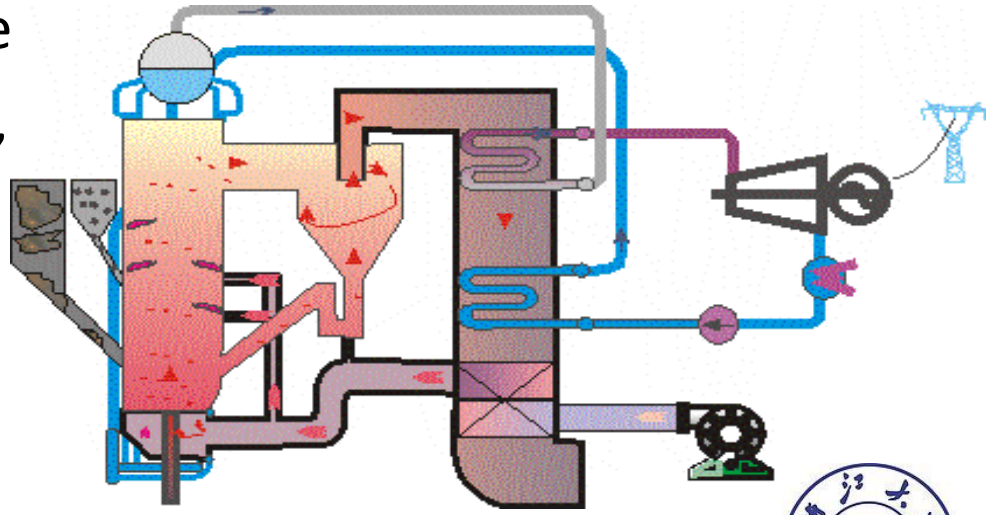
  ⇨ Prevent large waste from depositing and light waste from floating

- **Special distributor with directional wind caps**

  ⇨ Uniform incineration and unhindered slagging

- **Secondary air swirl**

  ⇨ Homogeneous temperature at high temperature region, strong flue gas mixing, enough residence time, and emission control.



# 3. Introduction of commercial fluidized bed waste to energy plants

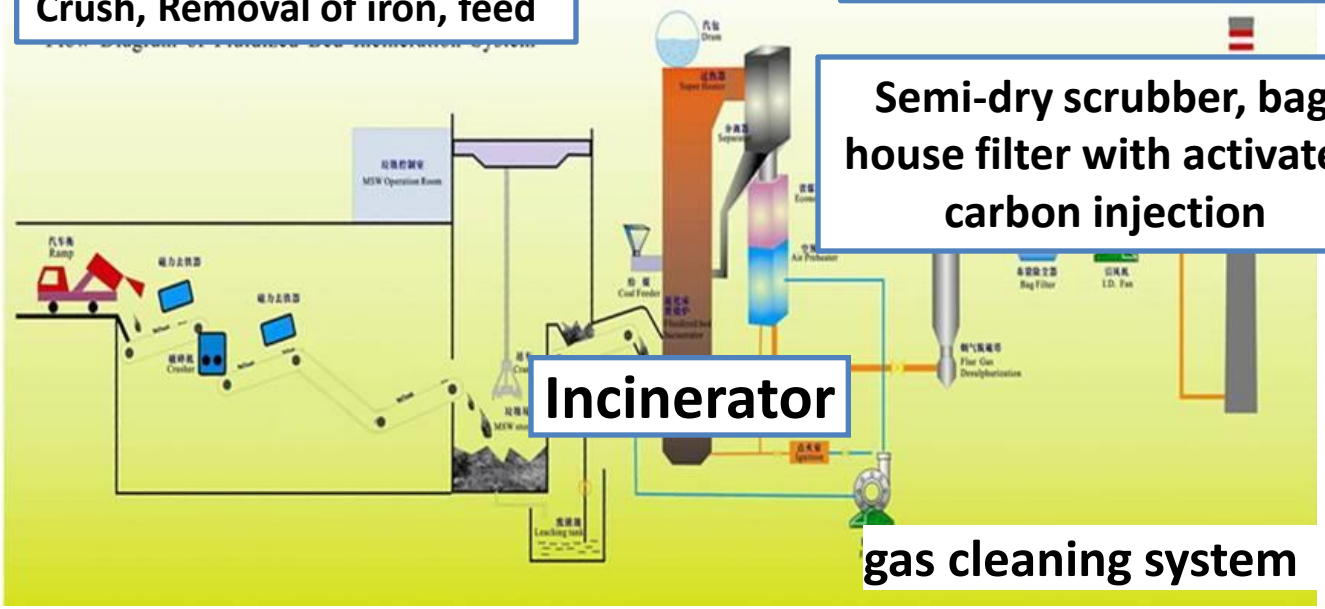
# Large scale CFBI integration technology for MSW

➢ *Key incineration technology and systems dispersed different levels*
➢ *Lack of targeted technology*

- ✓ **Development of circulating fluidized bed technology integration systems and equipment to adapt to a variety of different capacity**
- ✓ **Co-development of waste disposal capacity of various incineration unit with 150, 200, 250, 300, 350, 400, 600, 800 tons / day with Nantong Wanda Boiler Corp.**

**Waste pretreatment and feed**

Crush, Removal of iron, feed

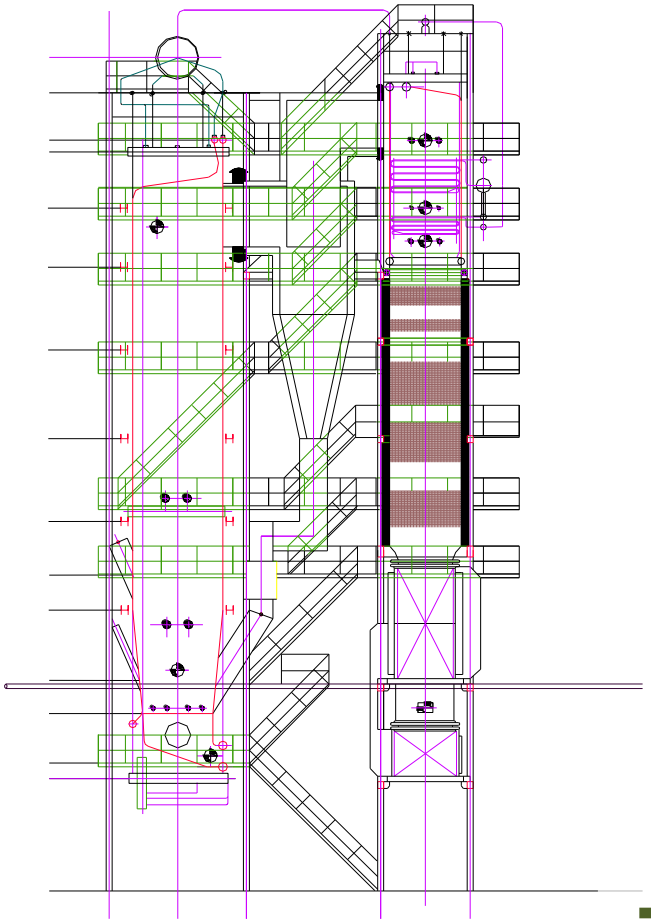



**High level integration system**

ZHEJIANG UNIVERSITY 1897

# Features of fluidized bed combustor

## Fluidized Bed Incineration Technologies in China

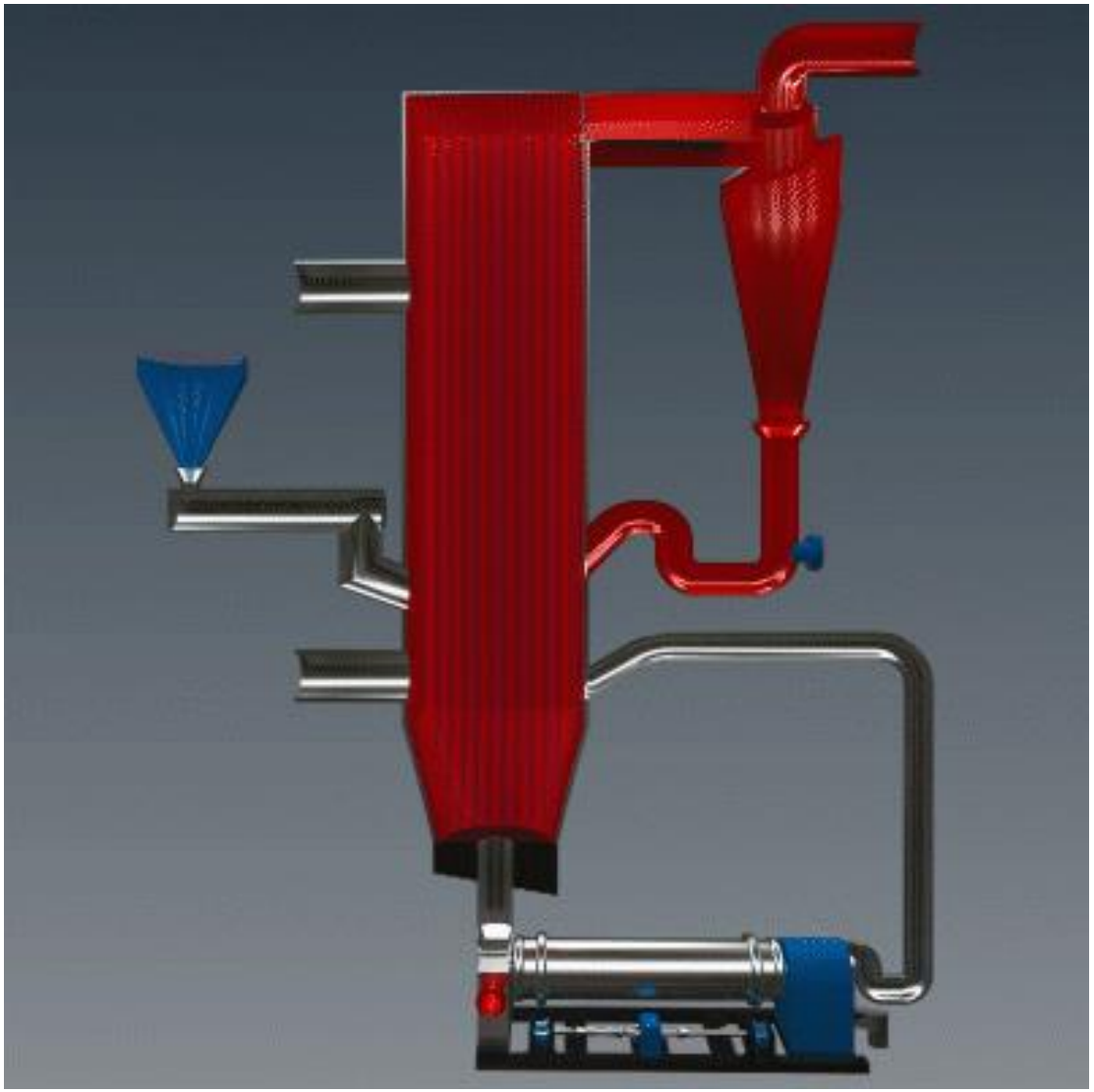


### CFB technology from ZJU

- Muiti solid circulation
- Moderate circulating rate
- Special air distribution
- Special heat transfer surface design

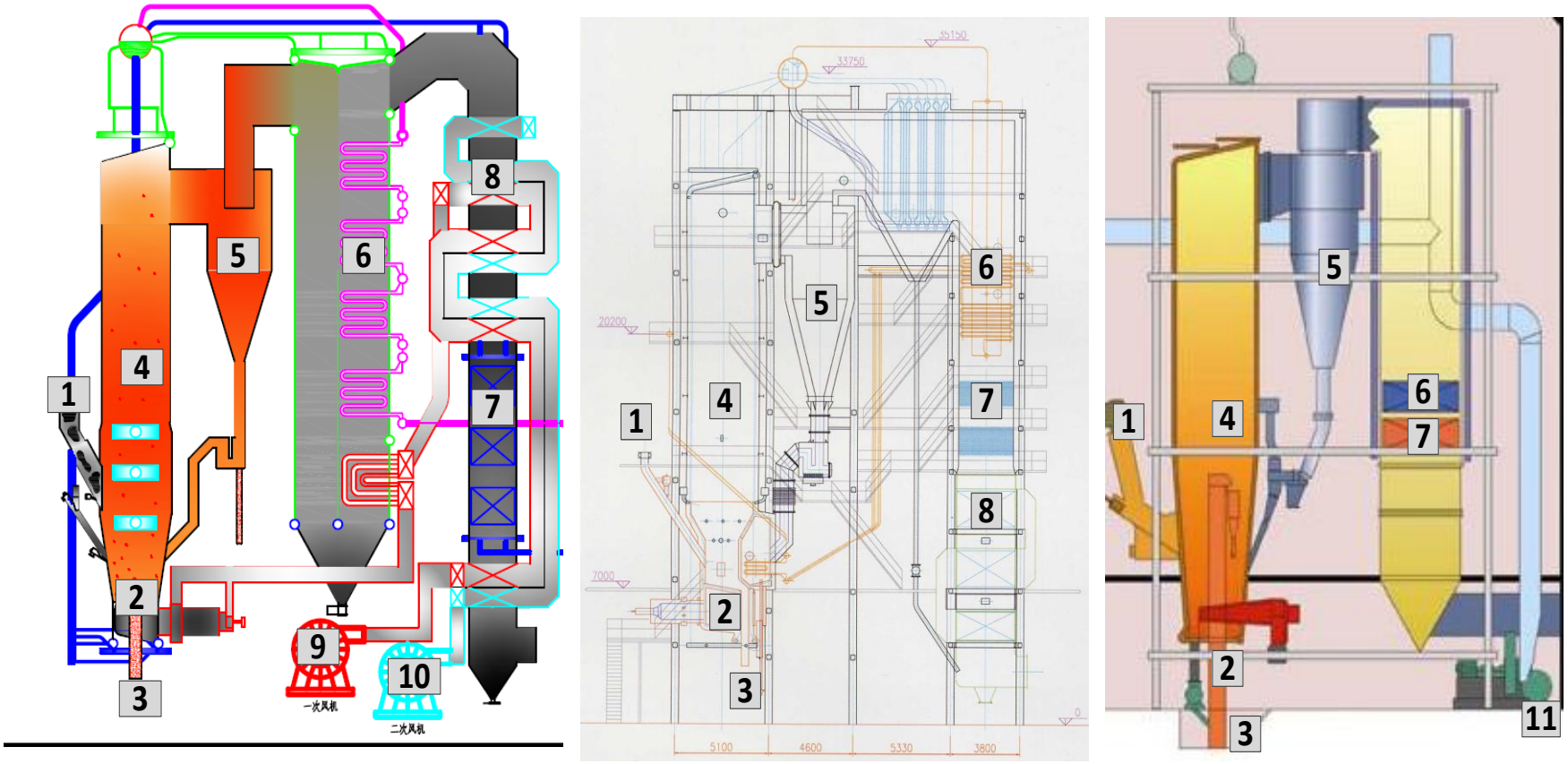
- **44** waste incineration plants

# Combined-CFB incinerator of ZJU



- Combined circulation inside and outside the furnace
- Semi-adiabatic membrane wall
- Hot-cold grading air supply

# WTE Technology



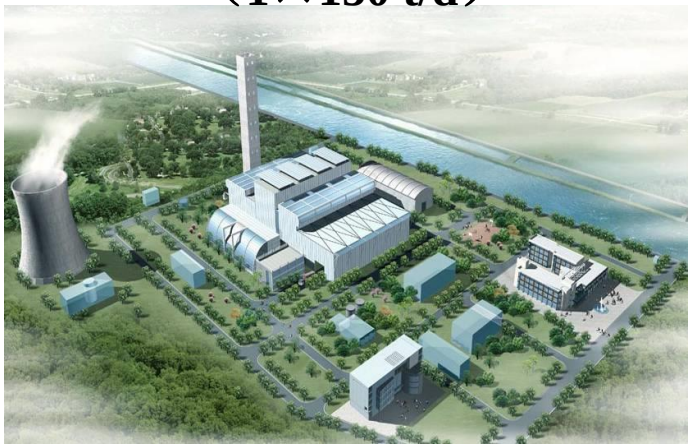

(a) Zhejiang Univ. (b) Chinese Academy of Sciences, (c) Tsinghua Univ.

1) msw feeder; 2) air distributor; 3) bottom ash discharger; 4) CFB combustion chamber;5) cyclone seperator;6) super heater 7) economizer;8) air preheater; 9) primary fan 10) secondary fan 11) induce fan

# CFB WTE Plants

1998, Hangzhou
（1×150 t/d）

2002, Hangzhou
（2×300 t/d + 1×200 t/d）



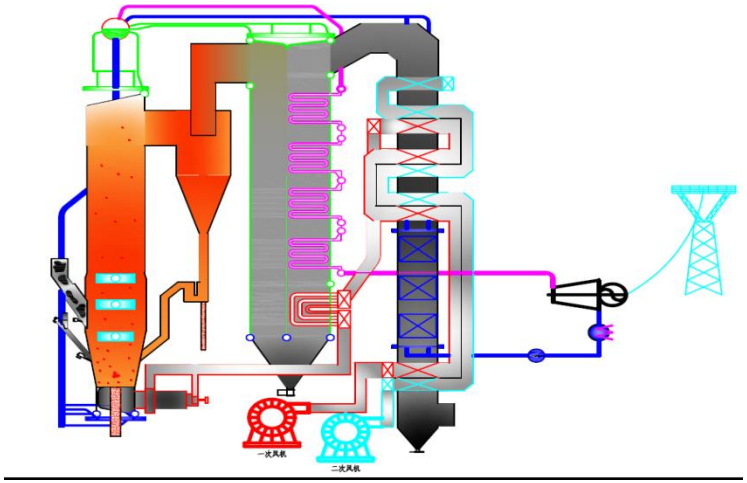
2007, Zibo
（3×400 t/d）


2012, Zhengzhou
（4×800 t/d）

# Wuchang Plant, Hubei Province

**650 t/d×3=1,950 t/d**

# Cixi Plant, Zhejiang Province (800 t/d)



# Combined Drying-Incineration system for sludge

## Shaoxing – co-fired in MSW incinerator

- **Location**

  Shaoxing, Zhejiang Province

- **Year**

  2008

- **Fuel**

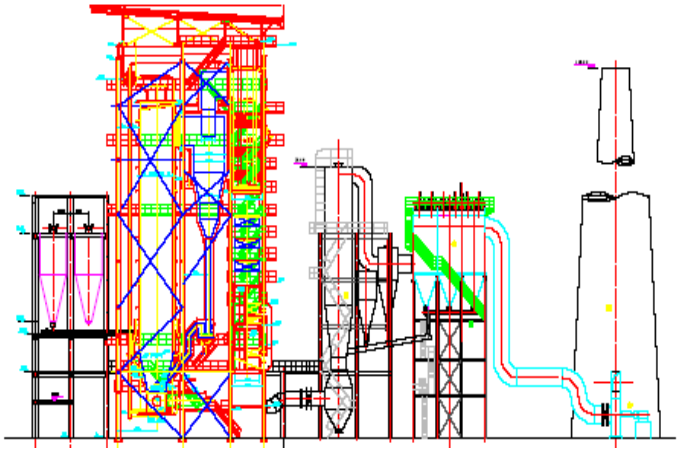
  Sludge and MSW

- **Capacity**

  Sludge 1000t/d, MSW 1200t/d

- **Routine**

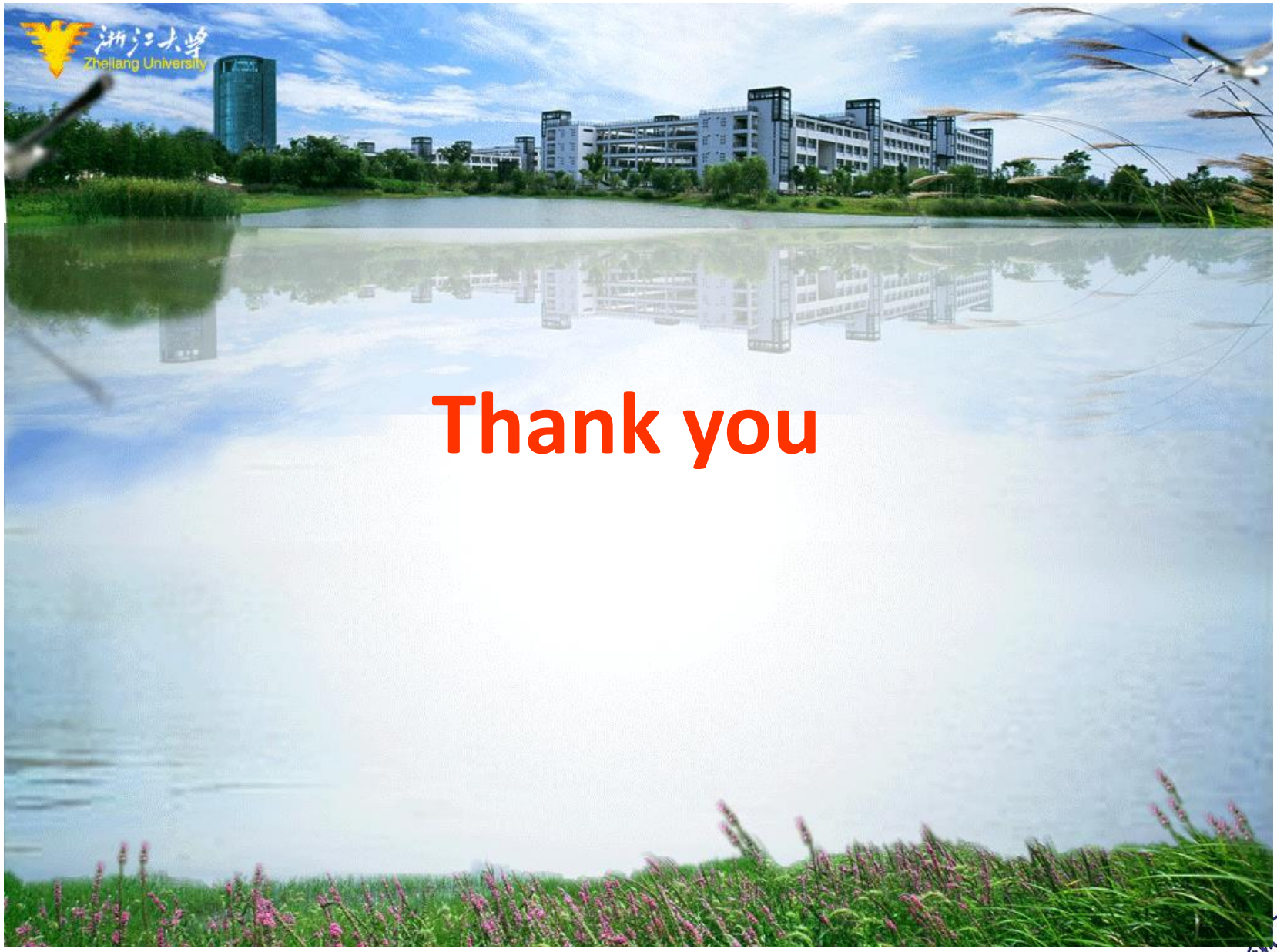
  Dried sludge with moisture content 40%, as the assistant fuel of MSW



# Combined Drying-Incineration system for sludge

## Fuyang – co-fired in FBC boiler

- **Location**
  Fuyang ba-yi sewage treatment plant
- **Year**
  2010
- **Sludge**
  The papermaking sludge
- **Capacity**
  1500t/d
- **Routine**
  Sludge is dewatered to 45-50% with sludge deep dewatering technique

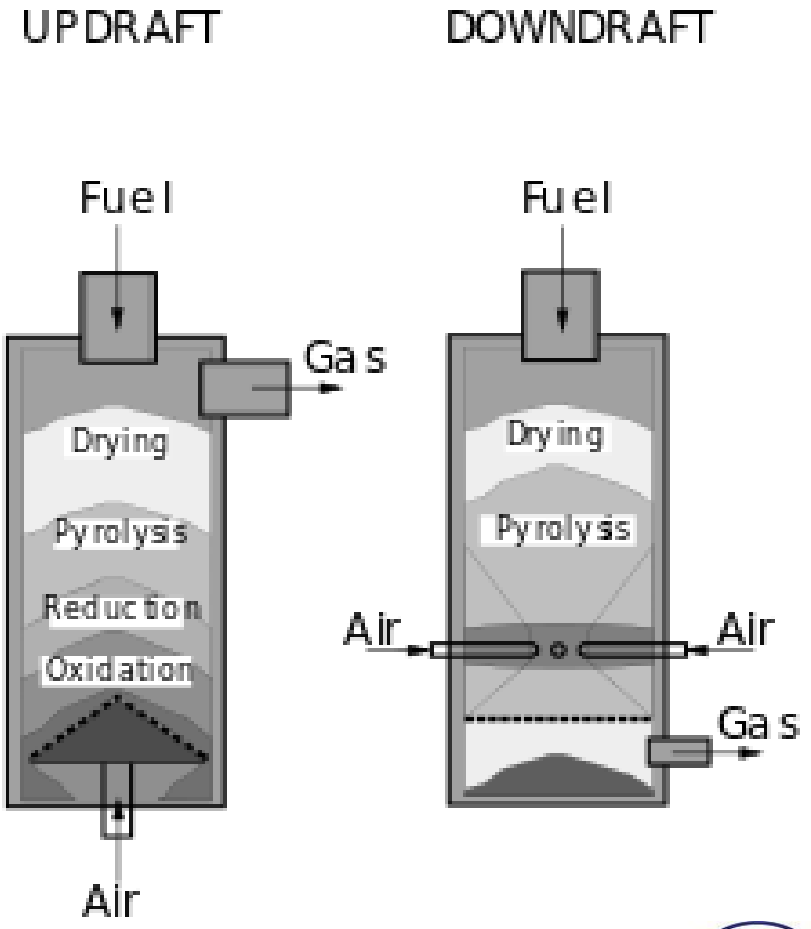

浙江大学
Zhejiang University
Thank you

# Fixed bed reactor

## Fixed bed combustors

- **Counter-current fixed bed ("up draft")**
  A fixed bed of fuel through which air flows in counter-current configuration

- **Co-current fixed bed ("down draft")**
  Similar to the counter-current type, but air flows in co-current configuration with the fuel

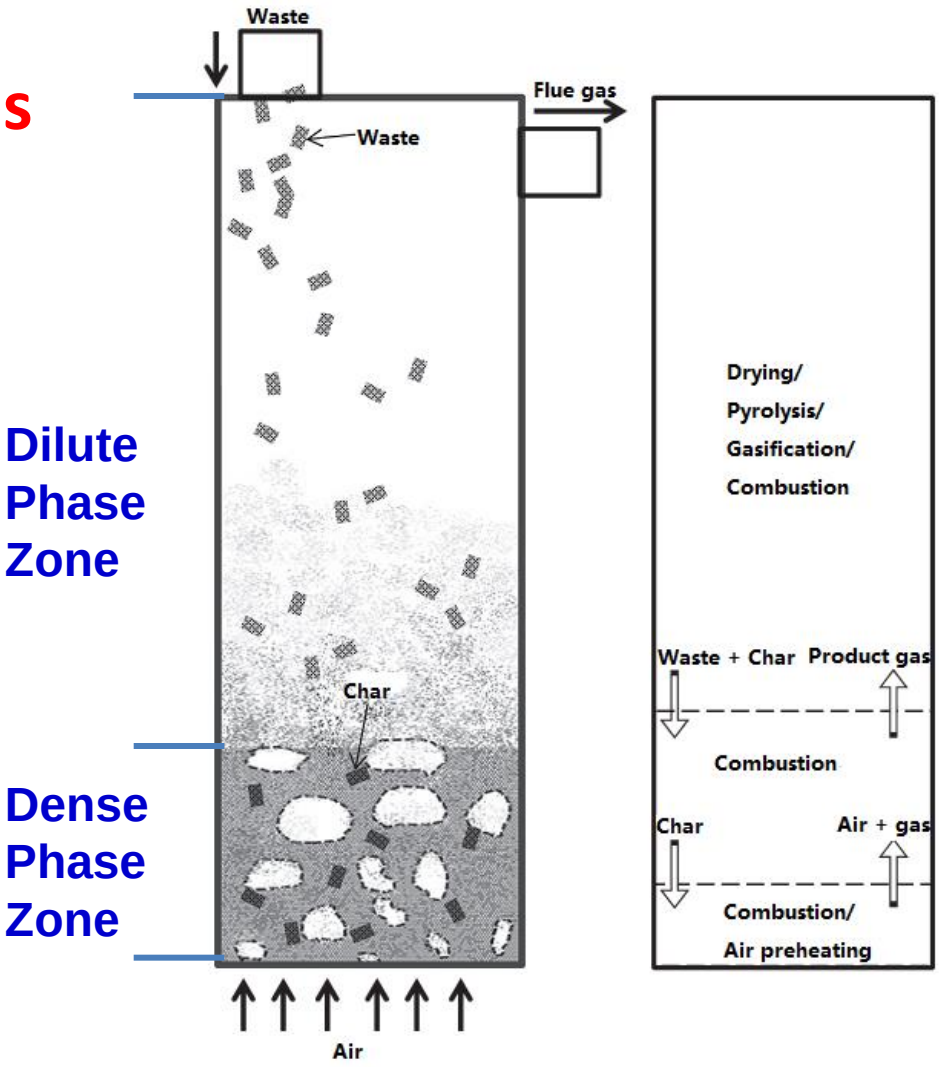


# Comprison between Grate furnace and CFB

| Operation Parameters | Grate Furnace | CFB |
|---|---|---|
| **Steam pressure** | medium pressure 4.0Mpa | medium pressure 3.82Mpa |
| **Steam temperature** | 400℃ | 450℃ |
| **Exhaust gas temperature** | around 190℃ | around 150℃ |
| **Primary air pressure** | low within 8Kpa | high, 15Kpa is needed in general |
| **Primary air temperature** | Low, 220℃ in general, primary and secondary air are equipped with steam heater. | high, the primary air temperature of latest type furnace can reach above 350℃ and 250℃ generally. It makes use of the waste heat of tail flue gas to heat the air. |

# Features of fluidized bed combustion

## Reaction zones of BFB



# Features of fluidized bed combustion

- *different density*
- *different sizes*
- *high moisture*

✓Circulating Fluidized Bed with different density can prevent deposit of waste in bed.

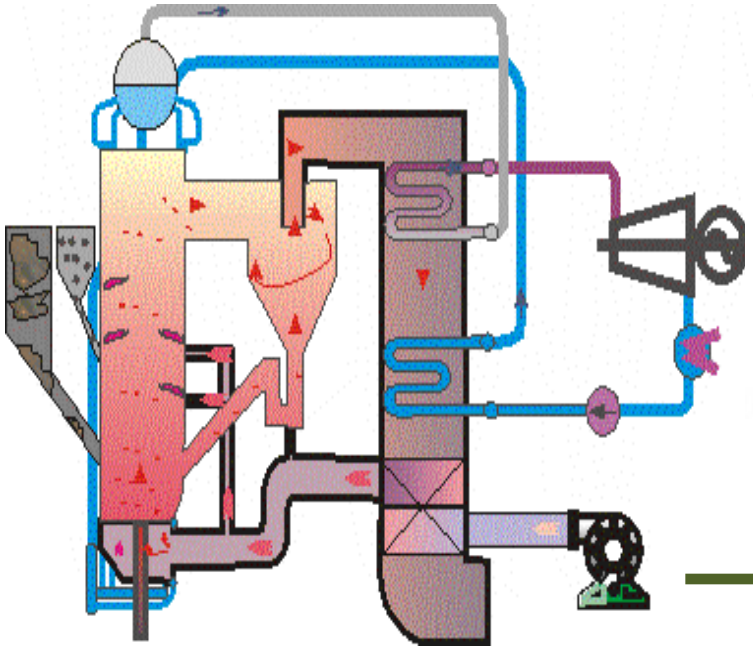
✓New CFBI technology, combined fuel inner and outer cycle, ensures combust stably.

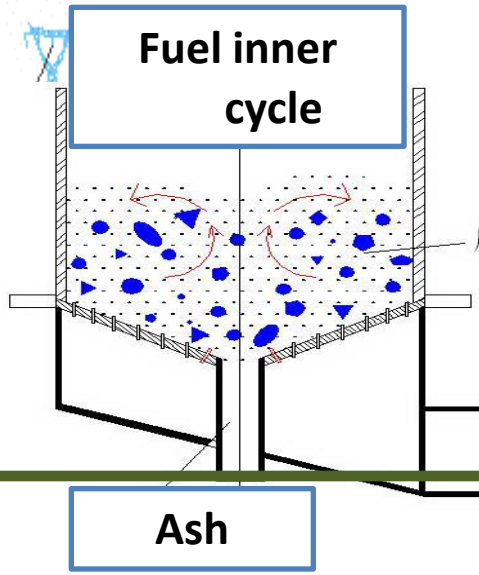
- *low heat value*
- *difficulty to burned out*
- *low combustion efficiency*

✓Circulating ratio is 10-20;

✓ loss rate of slag is <2%;

(GB is 5%), loss rate of Stoke Grate Incinerator slag is ~ 5%.



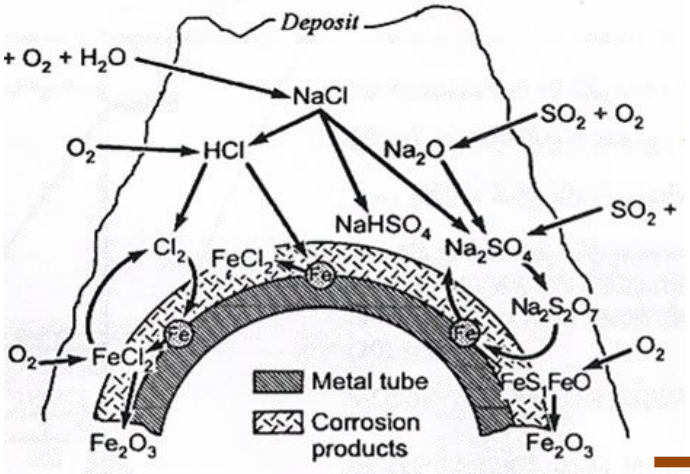



Bottom residue

# Features of fluidized bed combustion

- ***low steam parameters***
- ***high temperature corrosion***

- ✓**Steam parameters 485℃, 5.3MP, 2~5% higher than the stoke grate incinerator (*400℃, 4.0MP*)**
- ✓**Unconventional layout for super-heater**
- ✓**High fly ash purge, overcome high temperature corrosion**




Higher parameters make High Energy Utilization Efficiency

## Characteristics of MSW

- **Mixed collection - complex source and composition**

  ⇨ Size, chemical and physical characteristics differ a lot

- **High moisture content & low LHV**

  ⇨ Higher requirement of incineration technology

- **Properties vary a lot**

  ⇨ adverse effects on combustion process & stable operation