



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

GASIFICATION 2

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Contents

- Definition and Basic chemistry of gasification
- Gasification reaction schemes and steps
- Syngas production and efficiency and Factors influencing gasification
- Advantages of gasification
- Typical process flowsheet and Utilization schemes for gasification products
- Syngas conditioning and clean up
- Gasifier types
- Gasifiers for biomass and wastes
- Advanced gasification (Plasma gasification) process
- Comparison between incineration and gasification



Major Types of Gasifiers for coal and petcoke

Gasifier	Typical Process conditions
Fixed bed	Combustion Temp. : 1300 °C (slurry feed) and 1500-1800 °C (dry feed) Gas out let Temp. : 400-500 °C; Pressure: 0.15 - 2.45 MPa R.T. : 15-30 min ; Feed particle size : 2-50 mm $O_2/\text{Feed} : 0.64 \text{ Nm}^3/\text{kg}$
Fluidized bed	Combustion Temp. : 900-1200 °C ; Gas outlet Temp. : 700-900 °C; Pressure : 0.1 -2.94 Mpa; R.T : 10-100 s ; Particle size : 0.5-5.0 mm; $O_2/\text{Feed} : 0.37 \text{ Nm}^3/\text{kg}$
Entrained bed	Combustion Temp. : 1500 °C; Gas out let Temp.: 900-1400 °C; Pressure : 2.94-3.43 Mpa; R.T : 1 -10 s; Particle size : < 200 mesh (90%); $O_2/\text{Feed} : 1.17 \text{ Nm}^3/\text{kg}$



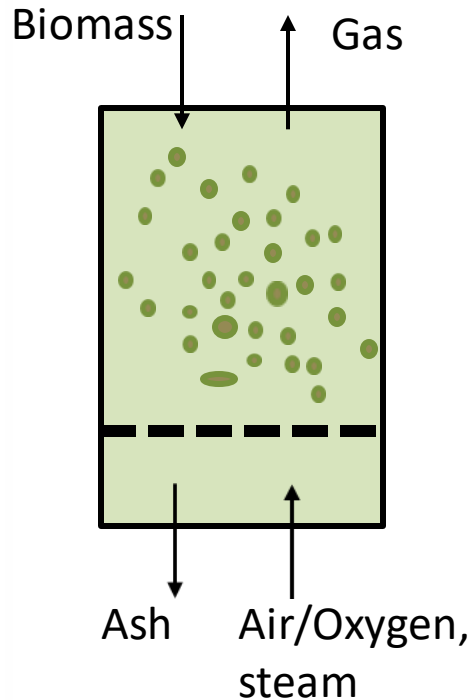
Gasifiers for biomass and wastes

Source : Review of technology for the gasification of biomass and wastes E4tech, June 2009

- Fixed bed
 - Updraft
 - Down draft
- Fluidized bed
 - Bubbling fluidized bed
 - Circulating fluidized bed
 - Double fluidized bed
- Entrained bed
- Plasma gasifier



Fixed bed gasifier



Up draft

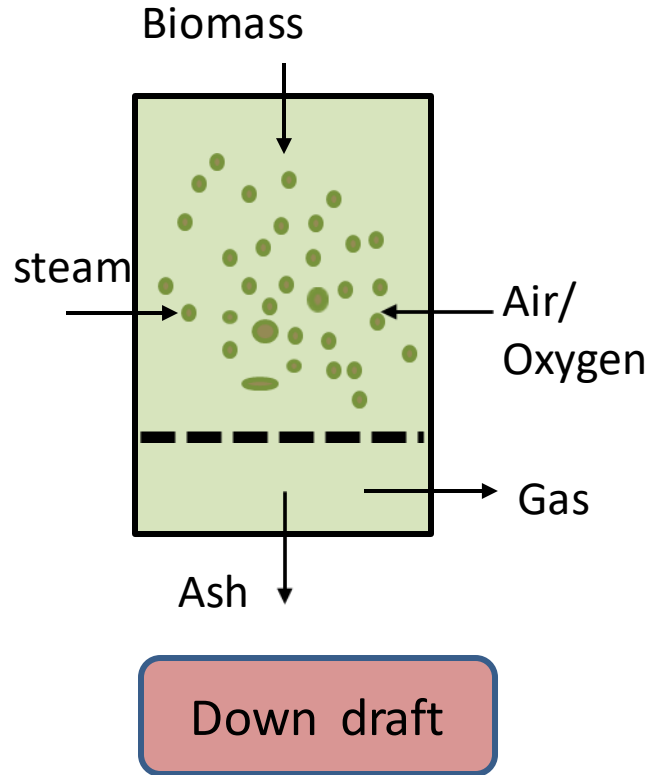
Fresh feed is added to the top of the bed while air enters through the bottom. Countercurrent flow.

- This approach was developed at Georgia Institute of Technology (Tatom et al., 1976).
- Syngas contains about 25% water insoluble tars.
- Simple & inexpensive process
- Exit gas temperature about 250 °C , combustion zone 1000°C
- Operates satisfactorily under pressure
- High carbon conversion and thermal efficiency
- Low dust levels in gas;
- Potential for channeling, bridging and clinkering

Source:

<http://www.e4tech.com/wpcontent/uploads/2016/01/gasification2009.pdf>

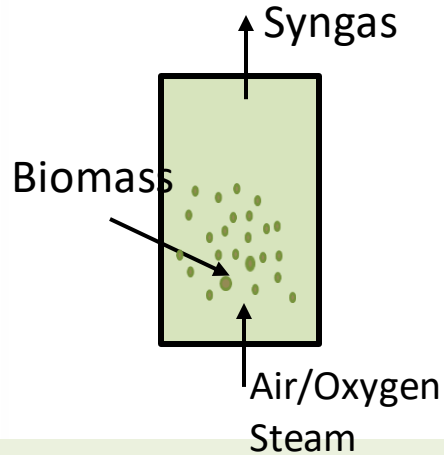
Fixed bed gasifier



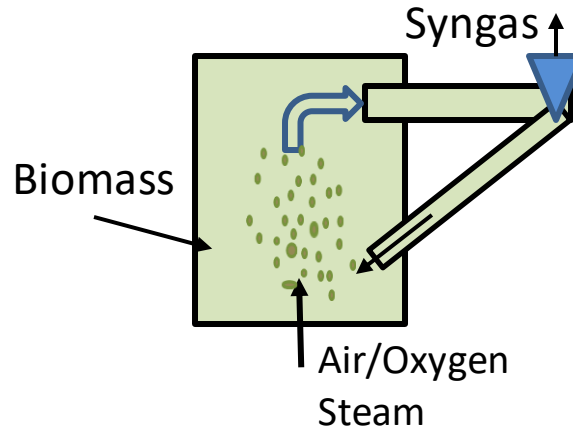
- Feed enters at top and air from sides.
- Concurrent flow fixed-bed gasifier .
- Suitable for dense high quality feedstock such as briquettes, hog fuel, or high quality wood chips.
- Suitable for small scale engine applications.
- Both pyrolysis products and oxygen are free to react with the charcoal.
- Tar content in syngas is lesser than updraft
- The feedstock for these gasifiers should have:
 - low moisture and ash contents or high ash sintering temperatures
 - very low fines contents,
- Limits to scale up capacity
- Potential for bridging and clinkering

Fluid bed gasifier

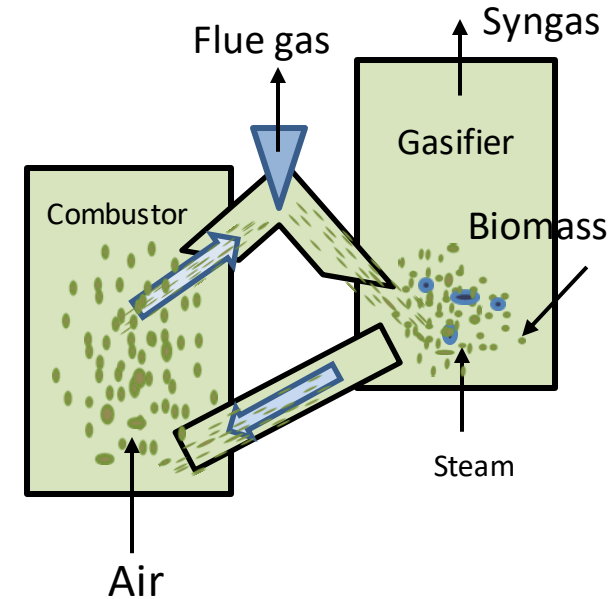
Bubbling Fluidized bed



Circulating fluidised bed (CFB)



Dual fluidised bed (Dual FB)

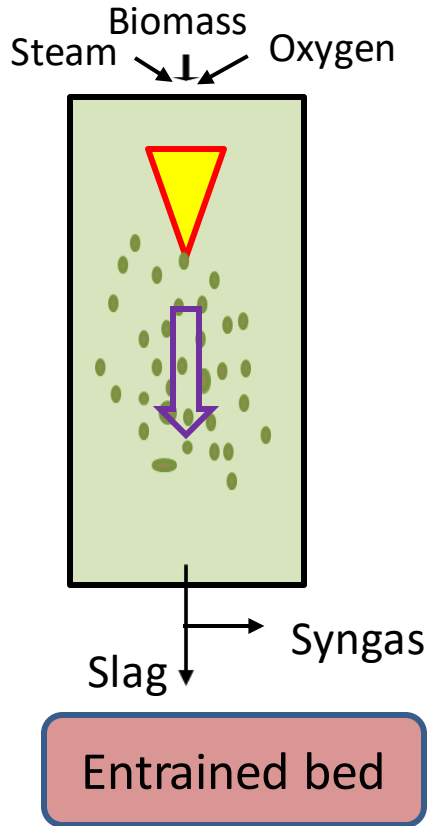


- The feed fluidized in the gasifier.
- Heat transfer media is required.
- Syngas quality vary widely , high volumetric capacity
- Flexibility in feed properties
- Gasifier temperature may be $> 500^{\circ}\text{C}$ and $< 900^{\circ}\text{C}$.

- High CH_4 , tar and fines in gas
- High C in fly ash

Gasifiers for biomass and wastes

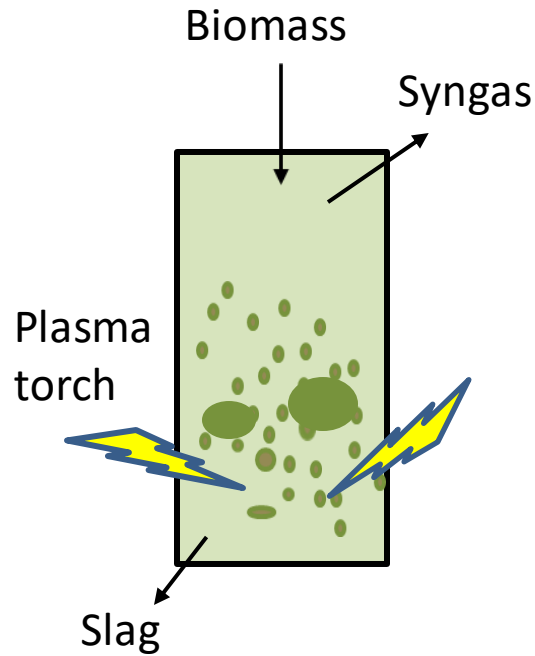
Entrained Gasifier



- Feed, air/ oxygen and steam are entered from the top and syngas exits at bottom
- Can be used for large scale plants
- Requires fine and dry feeds
- Handling of low density feed in pressurized reactor is difficult
- gasification temperatures in the order of 1100-1400 °C
- No tar and less CH_4 and CO_2 in syngas
- Slugging potential, pretreatment of feed is required

Gasifiers for biomass and wastes

Plasma Gasifier



Plasma gasifier

- High temperature 4000- 7000 °C through plasma torch
- High quality syngas ; suitable for all types of wastes
- Hazardous compounds broken down to elemental constituents; acid gases readily neutralized
- Salable residues (e.g., metals and aggregates)
- No direct gaseous emissions to the atmosphere
- Recover fuel value of wastes
- Heating value of output gas/ Electricity input = 21.4
- Residual vitrified mass include inorganics, heavy metals, etc. and highly resistant to leaching
- No landfill requirements

- High voltage applied across the electrodes accelerates (energize) free electrons. The energized electrons ultimately collide with and ionize, dissociate or excite the ambient molecules thus producing more free electrons and finally an electron avalanche called a streamer, which further propagates and form spark or arc [7,8].

Plasma arc



- Torch power levels from 100kW to 200 MW produce energy densities (up to 100 MW/m³)

- The high energy electrons can work on all types of molecules and create radicals such as O, OH, N₂ (A) and indirectly H₂O₂, O₃ and others[9-10].
- All these radicals start chemical reactions to form final products.
- For carbonaceous materials CO and H₂ becomes major share in the produced gas.

http://www.plastep.eu/fileadmin/dateien/Events/2011/110725_Summer_School/Plasma_water_treatment.pdf

Gasifiers for biomass and wastes

Feedstock properties

Gasifier type	Suitable feedstock	Other
Fixed bed Updraft and down draft	Typical Particle size 50-150 mm; Moisture 10-60 %	
Fluidized bed (BFB)	Particle size <50-150 mm , Moisture 10-55 %	
Fluidized bed (CFD)	Particle size <20 mm; Moisture 5-60 %	
Entrained bed	Particle size <1 mm; Moisture 15 %	Pre-treatment steps being used
Plasma	Not important	Used for a variety of wastes

Source: Review of technology for the gasification of biomass and wastes E4tech, June 2009



Gasifiers for biomass and wastes

Technology licensors for some important biomass and wastes gasifiers

Type of gasifier	Some important Technology licensors
Entrained bed	Mitsubishi Heavy Industries ; Pearson Technology Range fuels; Karlsruhe Institute of Technology (KIT); CHOREN
Bubbling fluidised bed	Carbona ; FosterWheeler Energy BFB ; TRI, ENERKEM ; Iowa State University ; EPI
Circulating fluidized bed	FosterWheeler Energy CFB ; VIT; Fraunhofer ; Uhde HTW , CUTEC
Plasma	Westinghouse Plasma ; Plasco ; Startech; Solena; InENTec

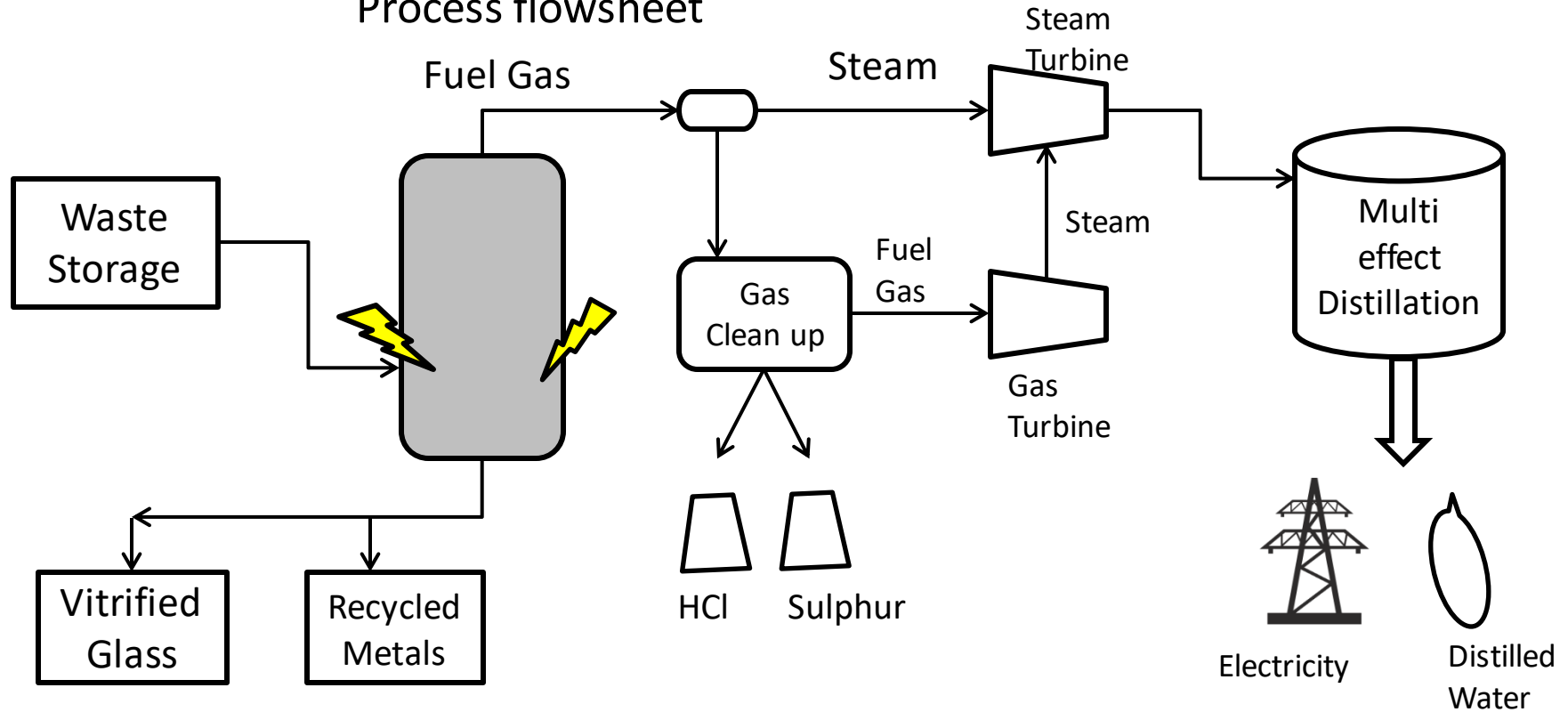
Most of the above Biomass gasifier development started after 1980.
Upto 2010 maximum capacity of a plant was below 500 TPD(Oven dry basis)
Plant capacity increases upto 3000 TPD after 2010

Source: Review of technology for the gasification of biomass and wastes E4tech, June 2009



Advanced gasification (Plasma gasification)

Process flowsheet



Source: <http://gasificationsolutions.com/waste-gasification-process/>

Some biomass and waste gasification plants

Country	Plant Name	Feedstock	Products	Syngas cleaning option	Year
Australia	Whytessgully waste to energy plant	Biomass	Electricity	-	1999
Brazil	Brazilian BIGCC plant	Biomass	Electricity		2003
Canada	MSW plant	Biomass	Electricity		2000
Canada	Toronto MSW plant	Municipal waste	Electricity		2000
Germany	Schwarze pump gasification plant	Municipal waste	Electricity and methanol	Rectisol	1992
Germany	Fendoteoc gasification plant	MSW	Electricity		1999
Sweden	CHRISGAS project	Biomass	H ₂ , automotive fuels		2008/09

Comparison of gasification and combustion

Features	Gasification	Combustion
Purpose	Generation of valuable gaseous products	Generation of heat or destruction of waste
Process Type	Thermal and chemical conversion using limited oxygen	Complete combustion using excess oxygen (air)
Raw Gas & utilization	H ₂ , CO, H ₂ S, NH ₃ , PM Heat, electricity, chemicals	CO ₂ , H ₂ O, SO ₂ , NO _x , PM Heat, electricity
Solid Products & handling	Char or slag Char: fuel Slag: Construction materials	Bottom and fly ashes Land filling Or sold as a material for making concrete
Pressure	Atmospheric to high	Atmospheric



Thanks...

