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Renewable Energy generation
Gasification

Renewable energy generation Gasification

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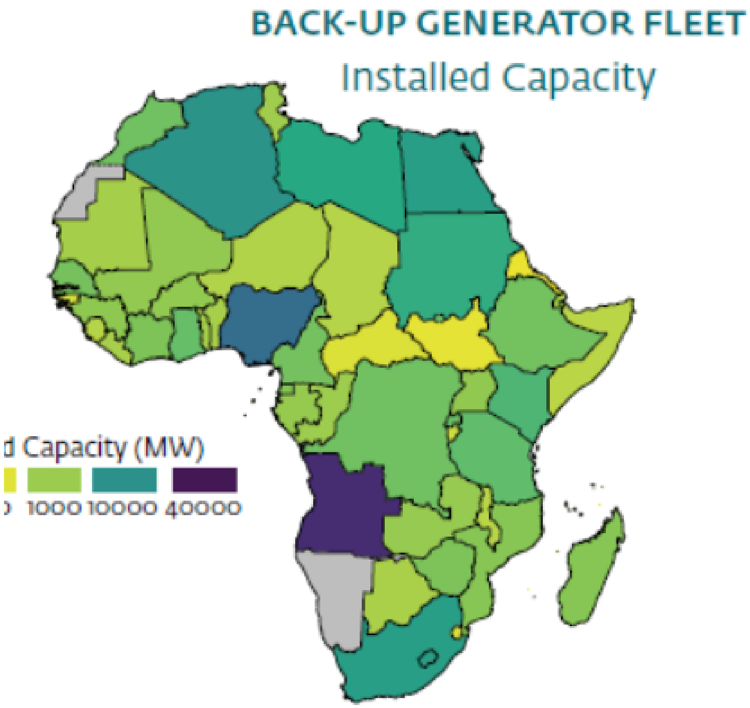
- Where anaerobic digestion fails e.g. lignocellulosic bio-wastes
- When solar (PV/thermal), hydro or wind power can't be used or stored
- Sheer volume of bio-waste, need fast conversion to avoid worse HS & Env impacts



- Makes use of the current technology on the ground,
- Ready for the population boom and the bio-wastes surge that comes with it

Renewable energy generation
Gasification

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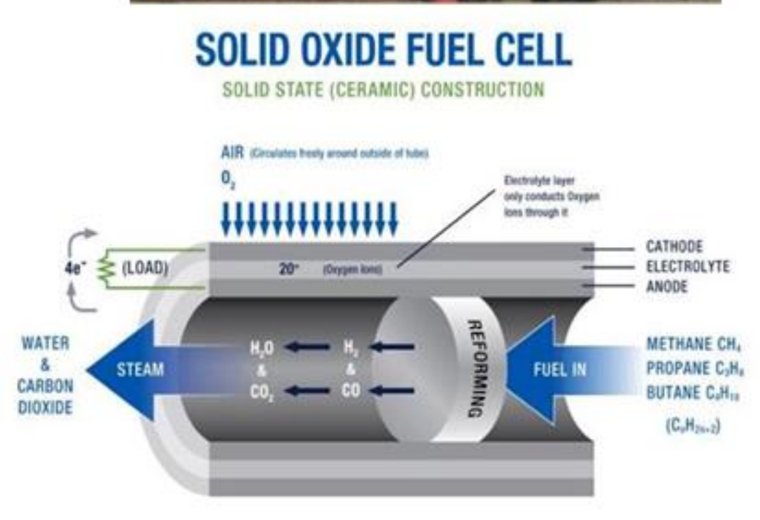

- Gas suitable as diesel generator fuel but also SOFC and MCFC fuel.
- 1st step to synthetic liquid fuels
- H_2 feedstock for pet- and bio-refinery
- CO feedstock for chemical industry
- CH_4 for cooking, transport fuel, gas turbine fuel - electricity
- Reduced PM, NOx, SOx, VOC & CO_2 emissions compared to diesel

Renewable energy generation Gasification

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- Use of dry agricultural wastes or wood from the local area
- Produces a low calorific value gas ($CO + H_2 + N_2 + CO_2$)
- Must avoid tars and slagging
- Can run an engine on the gas or with conventional fuels
- Requires someone to operate
- Typically operated solely for the peak evening load
- Relatively simple technology
- Low responsiveness

Renewable energy generation
Gasification

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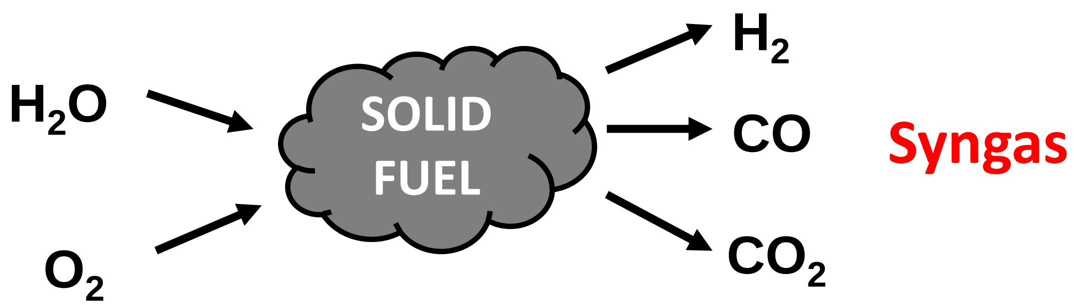
- **Gasification** is a process that converts carbonaceous materials, such as coal, petroleum coke or biomass, into carbon monoxide and hydrogen.

- In a gasifier, the carbonaceous material undergoes three processes: pyrolysis (devolatilization), combustion, and gasification



Gasification (and combustion forming CO_2)

- Coal gasification occurs when coal is heated together with steam and sub stoichiometric amounts of oxygen in a gasification chamber.

Renewable energy generation

Gasification

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The important reactions involve the reaction of coal and steam, and coal and carbon dioxide. These two reactions are endothermic i.e. require heat in order to proceed.

$C + H_2O \leftrightarrow CO + H_2$ $\Delta H_{298} =$ +131 MJ/kmol

$CO_2 + C \leftrightarrow 2CO$ $\Delta H_{298} =$ +172 MJ/kmol

Gasification reactions

Therefore, the heat required for these desired reactions is supplied by combustion of a small proportion of the coal in oxygen or air (exothermic reactions).

$C + ½O_2 \rightarrow CO$ $\Delta H_{298} =$ -111 MJ/kmol

$CO + ½O_2 \rightarrow CO_2$ $\Delta H_{298} =$ -283 MJ/kmol

Combustion reactions

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Gasification

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- Gasification is a **partial oxidation process**. In comparison with conventional combustion which uses a stoichiometric excess of oxidant, gasification typically uses only 25 to 40 percent of the theoretical oxidant (either pure oxygen or air)

- As a "partial oxidation" process, the major combustible products of gasification are carbon monoxide (CO) and hydrogen, with only a minor portion of the carbon completely oxidized to carbon dioxide (CO_2).

- The heat produced by the partial oxidation provides most of the energy required to drive the endothermic gasification reactions.

- The synthesis gas can be used as a fuel to generate electricity(IGCC) or used as a feedstock for synthetic fuel or chemicals (GTL Process)

Renewable energy generation
Gasification

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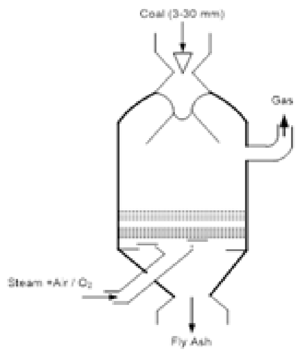
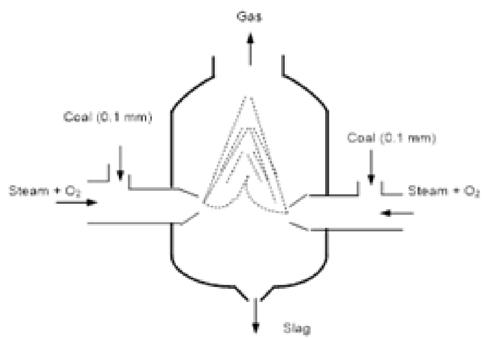
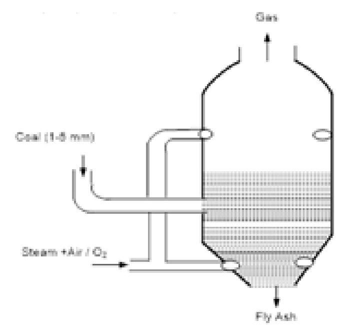


Fixed bed-

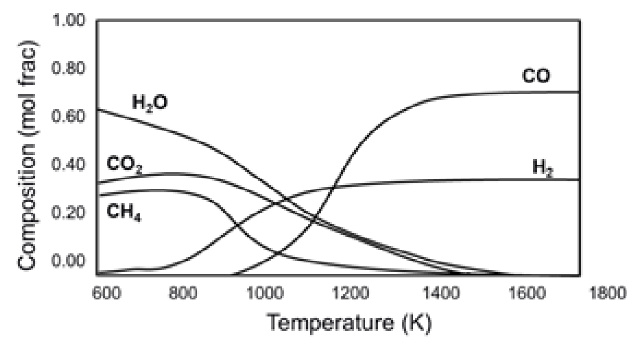


Entrained-flow gasifier



Fluidized-bed gasifier

	Entrained Flow	Fluidised Bed	Moving Bed
Fuel Types	Solid – Liquid	Solid	Solid
Fuel Size	<500µm	0.5-5mm	5-50mm
Fuel Residence time	1-10s	5-50s	15-30min
Gas outlet temperature	900-1400°C	700-900°C	400-500°C



Ability to describe differences and characteristics of reactor configurations

How composition of syngas varies with different gasification reactor designs?

Renewable energy generation
Gasification (large scale)

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- Cleanest, most efficient designs
- Require significant pre-treatment of the biomass source to avoid post gasification clean up, high separation costs.
- Multiple units process (costly), each unit optimised for highest efficiency
- E.g.: feed= forestry waste, final product = syngas ($CO/H_2/CH_4$ mix), high purity hydrogen, high purity methane.
- techno-economic-sustainability modelling is a first stage to demonstrate feasibility at N^{th} plant
- https://www.energy.gov/eere/fuelcells/hydrogen-production-biomass-gasification

Renewable energy generation
Gasification (small scale)

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- Small scale: least efficient designs
- Require some pre-treatment of the biomass and post gasification clean up, but no separation costs (syngas product =‘producer gas’)
- Single unit, multi stages (not optimised).
- Drying / vapourisation / air preheat
  can be assisted by solar thermal
- Best adapted to decentralised production
- Suitable for domestic or communal gensets
- Use of local sustainable forestry and agri-wastes
- Supplements electricity by intermittent Solar PV/wind
- Bio-Waste used as (Chemical) Energy Storage medium

Renewable energy generation
Gasification stages

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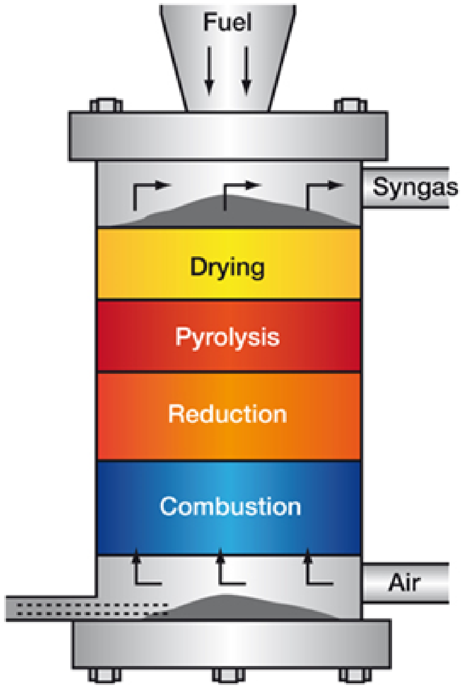
There are 4 main gasification stages



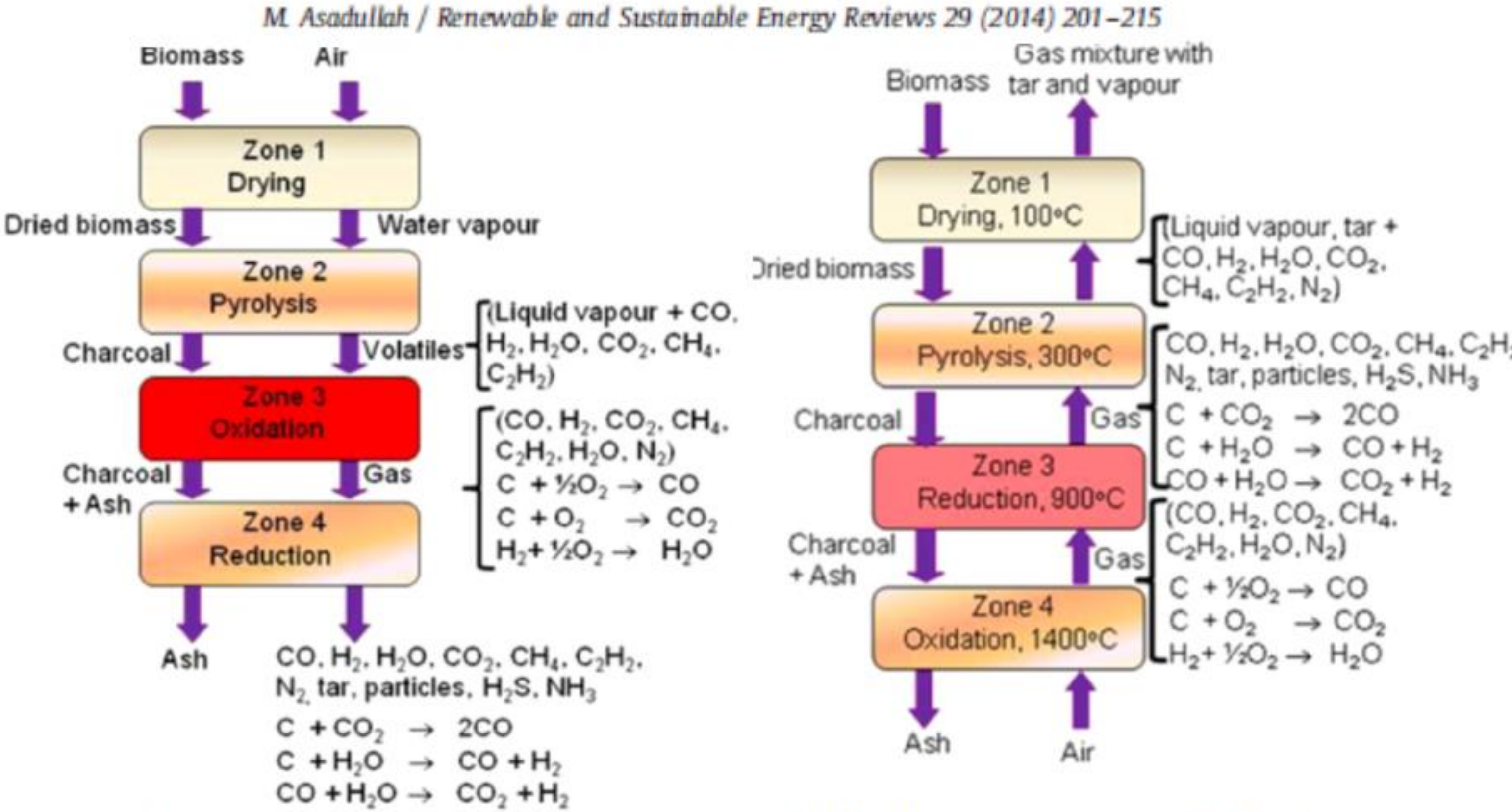
Drying – Any water evaporates evolving vapor which may enter into later chemical reactions.

Pyrolysis –Devolatization and breaking of the weaker chemical bonds as the temperature increases releasing volatile gases and tars and a char which will undergo gasification reactions.

Reduction – This is where the gasification reactions occur and remaining char reacts with CO_2 and steam to produce CO and H_2.

Combustion – The volatile products and some of the char react with limited oxygen to form CO_2, CO, providing heat.

Renewable energy generation
Gasification stages



Downdraft Gasifier: Gas at higher T, needs cooling, lower tar, lower clean up requirement, suitable for SI engine

Updraft : Gas more calorific but higher tars content, potentially higher clean up requirement

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Gasification

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There are a number of Gen Set configurations available for use with syngas including gas engine and duel fuel engines.

Dual fuel SI (Spark Ignition) engine.
Modification of the basic SI engine in which a gas carburetor is attached to the inlet valve of the SI engine.

Dual fuel CI (Compression Ignition) engine.
Modified CI engine, in which a gas carburetor is installed at the inlet valve of the engine.

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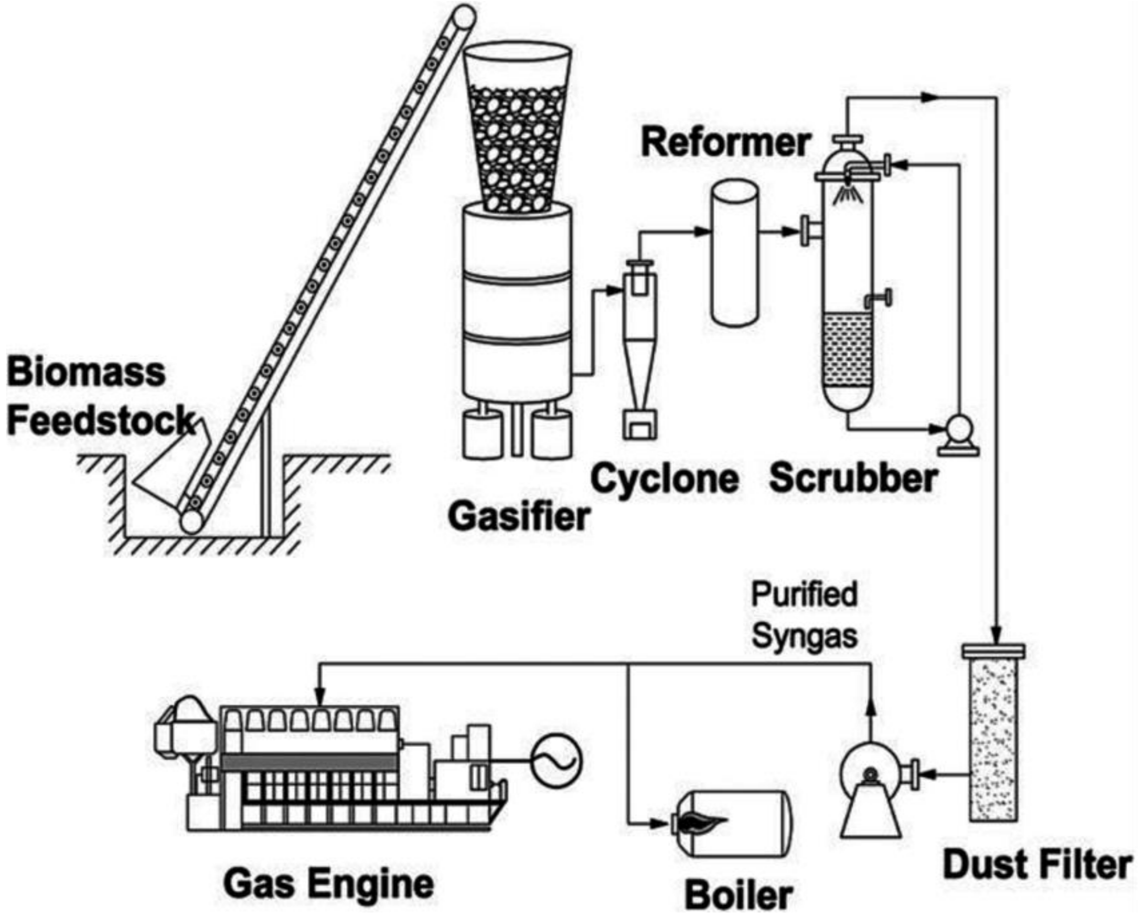

Yoon SJ, Son Y Il, Kim YK, Lee JG. Gasification and power generation characteristics of rice husk and rice husk pellet using a downdraft fixed-bed gasifier. Renewable Energy 2012;42:163–7.

Renewable energy generation
Challenges with Gasification

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- Challenges with gasification include tar build up, fouling and corrosion
- Certain fuel types result in large amounts of fouling in pipework and can result in corrosion and failure
- Tar can build up in fuel lines resulting in blockages
- CO content in the syngas- can’t have leakages
- Controlled cooling of syngas before engine
- Gas clean-up maybe needed before injection into engine
- Calorific value of syngas is lower than diesel




Case studies - Gasification

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Pamoja gasifier – Mpigi district, Uganda

- Locals bring their waste corn cobs and get electricity
- 32 kW capacity
- Run in the evenings
- Watch the news report on Minerva

Case studies - Gasification

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Pamoja gasifier – Mpigi district, Uganda

- Project ran into problems
- Energy demand less than expected
  - Connected industrial centre did not happen
- Demand so small it was uneconomical to run the system
- Many people could not afford the connection cost
- Wet scrubber created toxic waste
- Only 170 connections