Biomass gasification – Status

Indian Institute of Science
Bangalore

The presentation

- Introduction to Biomass energy
- Status of the technology
  - International
  - India
- R and D at IISc
- Some field experiences
- Conclusions

Biomass conversion routes

- Thermo chemical conversion
  - Direct combustion of the fuel for heat or power
  - Converting to gaseous fuel
- Biological conversion
  - Through bacterial route – convert to gas and the gas for end use application
- Bioliquid route
  - Using edible/non-edible oils
  - Ethanol

Introduction biomass energy

- Biomass energy utilisation
  - Basically for heat
    - Domestic stoves, industrial process heat, steam generation, district heating, etc
  - Power generation using conventional approach
    - Steam route

In India about 30 % of energy comes from biomass

Power generation at small scale capacity – The thermo chemical route

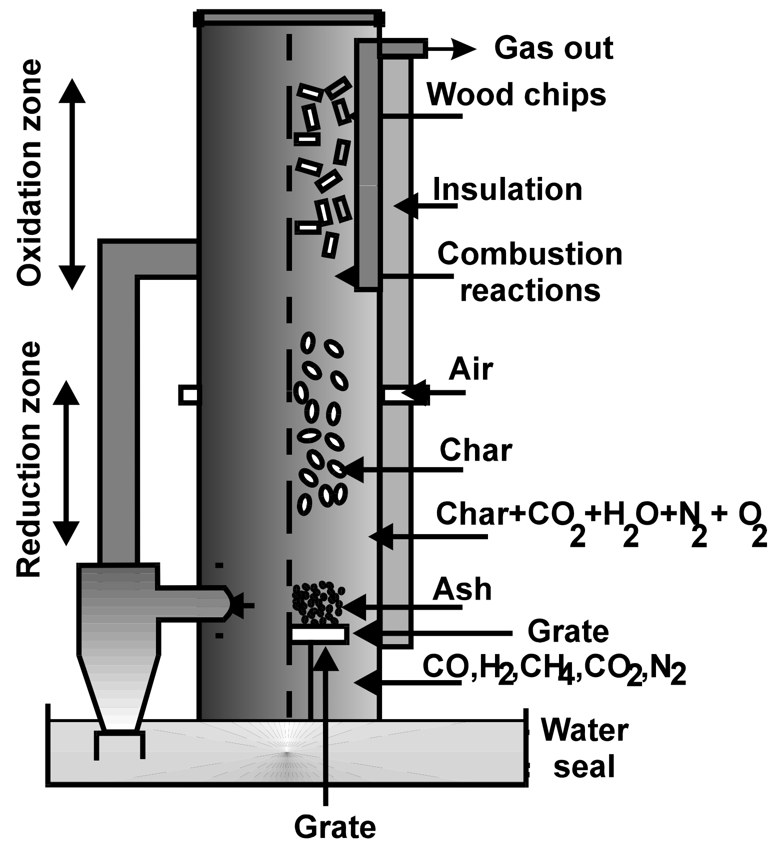
- Power generation – gasification route to fuel the internal combustion engines
  - Technology has been in existence since World War II.
  - Had limitation with quality of gas for power generation
  - Fuel was confined to charcoal in most cases, otherwise wood

The challenge was to

- adopt gasification technology for high grade heat and power level
- Use of biomass as a fuel

Typical process in a gasifier

- Drying
- Pyrolysis – gives volatiles and char
- Volatile burns with air to for CO_2 and H_2
- Char combines with CO_2 and H_2O to form combustible gas



What is tar and how it could be eliminated?

- Tar is a product of pyrolysis and is a CHO complex
- Made up of large number of organic compounds
- This has to be eliminated in the reactor by providing enough residence time and reactive surface at high temperature
- Thus the char reaction with the products of pyrolysis combustion is very important

Early developmental days

- Technology was acceptable even though the systems had
  - Low efficiency
  - Not user friendly
  - High emissions

  When there was no access to other technologies

The ease of fossil fuel availability has resulted in

- Use of fossil fuel technology for major applications
- Use of fossil fuel technology continued until recently when
  - Environmental conditions driving for CO_2 neutral technologies
  - the cost of fossil fuel energy was found high
  - Motivation to improve the efficiency of current biomass utilization pattern

Energy needs

- Rural
  - To provide a source for improving or meeting new energy needs
- Industrial
  - To provide solutions for substituting fossil fuel based energy

Biomass gasification, the thermochemical process

Process that converts solid fuel to gaseous fuel

- Used in an internal combustion engine for power generation to substitute fossil fuel
  - Diesel engine – for dual fuel application
  - Gas engine – for single fuel
- Used in heat application
  - Low temperature – drying, etc
  - High temperature – furnaces, kilns, etc
- Combination of the above - heat and power

International status - 1

- Large capacity system - use of biomass in CHP

- Space heating is a large consumer of energy, large plants using biomass are existing (a MW to ten's of MW)
- In the large power range steam route for power generation and heat for space heating have been reasonably well established
- Standard combustion technology options are chosen for power generation
- Recently a few IGCC concepts being addressed
  - Technical feasibility of IGCC have been established, while commercial operations need to be established
- A few to mention at large capacity system using the above technology packages
  - Varnamo, Sweden, Ahlstrom Pyroflow, Pietarsaari, Finland, SEI fluidized bed in Florida, USA, Carbona at Tampere, Finland, Burlington, Vermont, USA, Corenso United Oy ltd, Varkaus, plant, Bioneer,

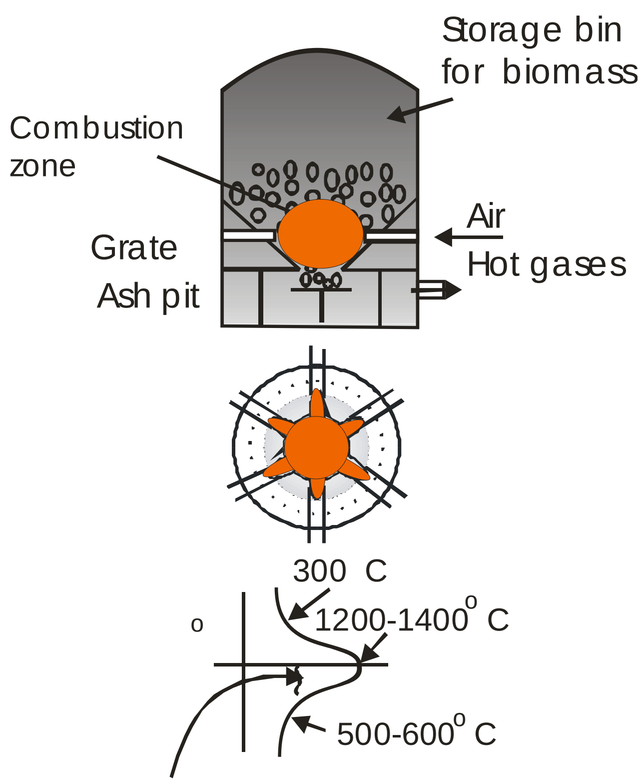
International status - 2

- Small capacity requirements
  - In the recent times, to compete with the fossil fuel or biomass combustion technologies significant efforts are directed towards developing combustion and gasification systems with the aim to generate heat and power
  - Gasification plays an important role in power generation

Reactor design

- II WW design - Closed top

Most of the technologies are focused around this design



Results

- Can handle only woody biomass
- Turn down ratio limited
- Problem of consistent gas quality

Experience in using World War II design -1

- The limitations found the downdraft closed top WW II design
  - Even with the use of good quality fuel
    - Consistent gas quality to meet the turbocharged application
  - Not much experience in large capacity with limitations from
    - fuel flow due to gravity and channeling
    - Residence time being larger could result in ash sintering
  - No fuel flexibility; only wood or woody like fuels

Requirements of gas quality for reciprocating engines

- Quality of gas in the reciprocating engines depends on the mode of operation
  - Naturally aspirated can tolerate higher contamination (~ 50 ppm)
  - Turbo charged engine very critical (< 5 ppm)
- Achieving this depends on the reactor and the gas conditioning designs
  - Poorer the raw gas quality greater is the complexity in the gas conditioning and the effluent treatment

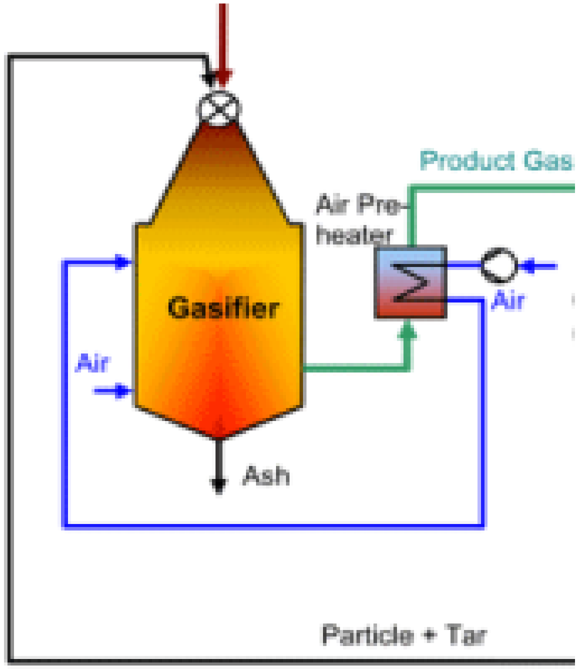
Approaches by various groups

- Develop reactor configuration to generate good quality raw gas
  - twin fire configuration – Austrian design
  - staged gasification – DTU, Denmark
  - dual air entry configuration - IISc

- The consideration for the designs has been to reduce the tar level in the raw gas, improve the carbon conversion in the reactor and eliminate any channeling
- The central part of the argument, tar cracking is promoted by two means – uniform distribution of high temperature across the char bed and presence of reactive char.
    - Intention to reduce the complexity in the gas conditioning system
- Existing CHP plants using updraft and CFB
  - Incorporate far more extensive gas conditioning system to meet engine quality gas

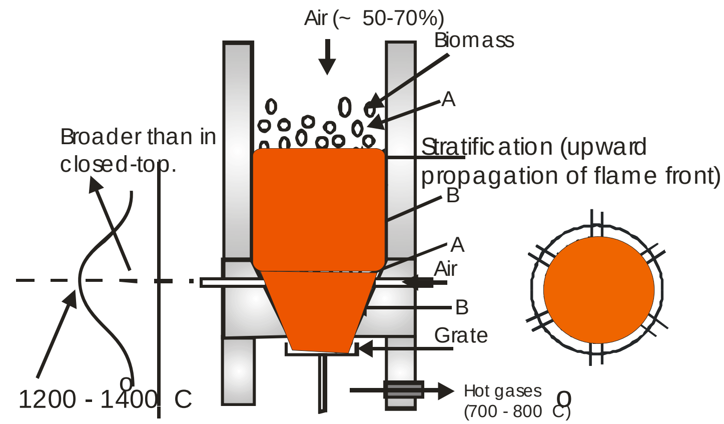
CIVITAS NOVA (Wiener Neustadt)

- Under the ReNET program
- The gasifier has two reaction zones and tries to combine the benefit of up and down draft gasification systems. The use of bottom air helps in consuming char, while the air through the nozzle serves the purpose of downdraft gasification.
- The raw gas has about 400 – 450 mg/Nm^3 of tar
- The gas is taken to a 500 kW gas engine from Jenbacher and about 700 kW of thermal load for district heating.
- The plant has a well designed wood chip drying system to dry the wood chips to about 15 % moisture.



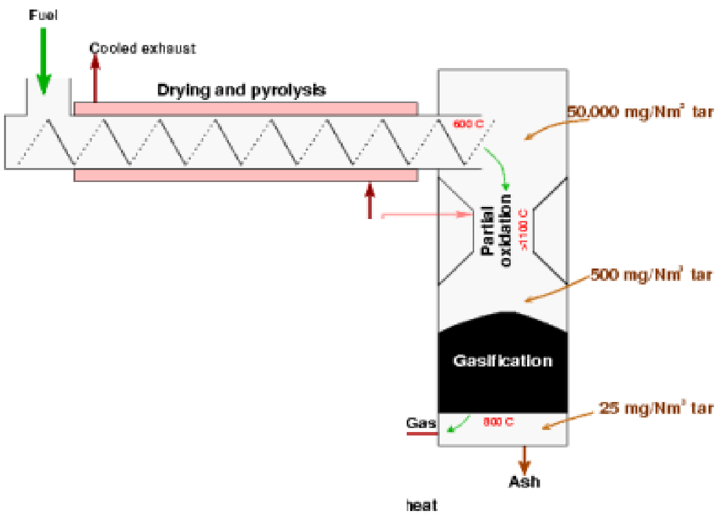
Dual air open top down draft - IISc

- Air is drawn from the top and from the air nozzles –
  - Uniform distribution
- Broader high temperature zone and enough residence time
- 100 – 250 mg/Nm^3 of tar and about 1000 mg/Nm^3 of particulates has been found the raw gas
- 50 kW gas engine and heat to preheat boiler feed water
- Similar design tested at 1 MWe capacity



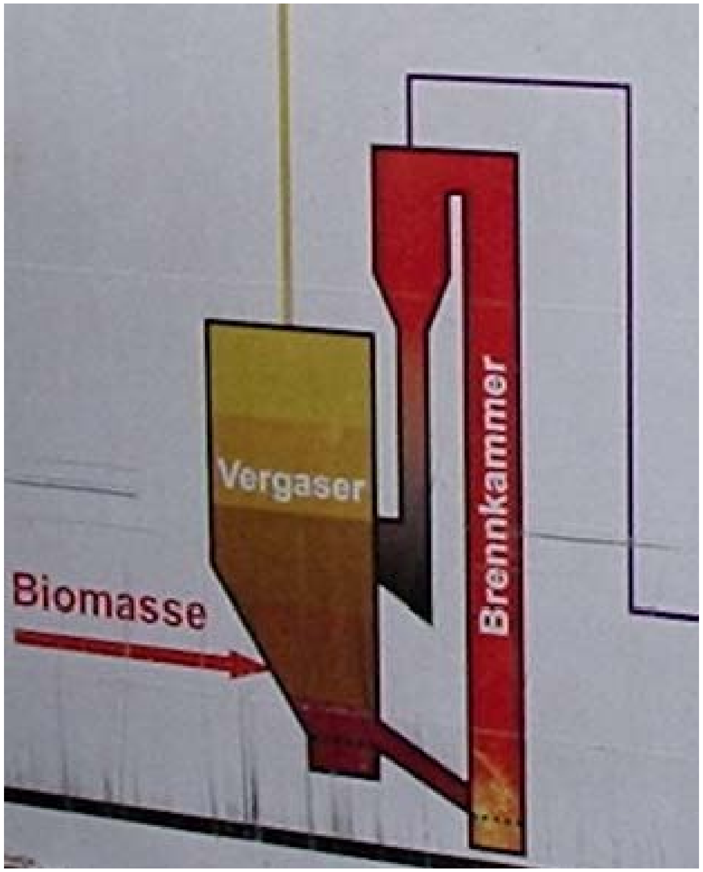
Technical University of Denmark

- Two stage gasification
- The basic concept in this design is to split the reactions to two reactors, namely, pyrolysis process in one reactor, and the gasification reactions in the separate char reactor
- Between the two stages there is a combustion chamber, where the gases produced in stage one are partially oxidized: temperature is thereby increased to about 1100 C. In this design the tar is intended to be reduced by during the oxidation and reduction process in the second reactor.
- The raw gas tar content is less than 20 mg/Nm^3 and particulate less than 5 mg/Nm^3.
- It is claimed that the scaling up of the system is better than the fixed bed design.



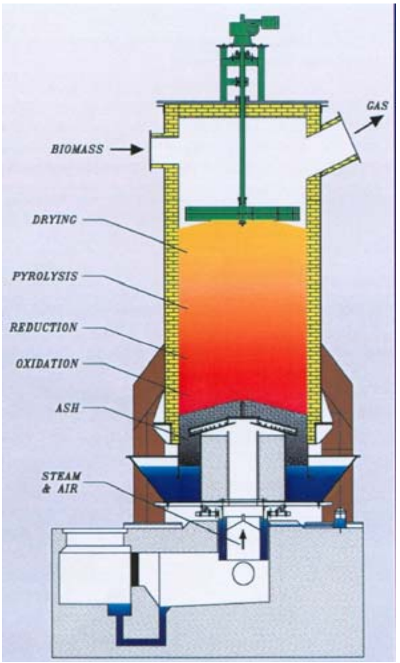
Fluidised bed gasifier Guessing

- Under ReNET program
- The gasification zone is fluidized with steam which is generated by waste heat of the process
- The combustion zone is fluidized with air and delivers the heat for the gasification process via the circulating bed material.
- The plant produces about 4.5 MWth and 2 MWe output with a gas engine.
- Part of the gas generated is taken to a backup boiler to produce heat for district heating



Updraft reactor Harboore

- The updraft gasification system at Harboore is rated for 4.0 MWth to provide heat for district heating using wood chips installed during 1993.
- The Harboore gasifier has a proven long-term capacity of 3.7 MWTH
- The rated capacity is about 1900 kg/h wood-chips (35 – 55% moisture)
- The ash from the gasifier has a (dry) heavy metal content etc. below 100 mg/kg and organic carbon content below 1%
- The raw product gas has a temperature of 72OC – 75OC and a tar content of 80 – 100 g/Nm3
- The system has operated over 70,000 hours of operation.
- In 2000, two Jenbacher engines rated at 650 – 750 kW capacity were installed



Summarising the performance of various reactor for meeting engine quality gas

- The dual air entry open top down draft design has been in the field at 1 MWe capacity
- The updraft and the circulating fluid bed have been tested at much larger capacities
  - Adopted from the biomass based heating systems
  - Requires elaborate gas conditioning technologies
- The staged gasifier system has been tested at low power and the scaling has to be examined.

Gas conditioning systems

- With an attempt to reduce complexity of the gas conditioning equipment to meet the end use device, in particular a reciprocating engine.
- Various gas conditioning systems used are related to the inlet concentration of the contaminants and the gasifier capacity.
- Further, attempts has been made by several groups to eliminate water and gas contact; thus eliminating the effluent treatment plant.

Summarizing the performance of the gas conditioning system

- It is clear that higher the tar level generated greater is the effort in eliminating.
- One important feature that becomes evident is the handling of effluent liquids.
- Most of the plants have large scale heat component; where the condensable or the scrubbing liquid is being burnt or evaporated.

Global Overview

- Various groups in Europe are actively involved in the area of gasification
- Basic fuel is wood chips – clean fuel
- Advantage – use the plant as CHP
  - Can also burn some wastes generated in the boiler
  - Overall economics better
- Total package
  - Gas and water treatment still remain as challenge
- Commercial operation on power generation still awaited

Status on gasification technology in India

- **Only country to have a separate division in the ministry**
  - Work initiated in this country during early 80’s
  - Many institutions and commercial agencies involved over a long period of time
  - Technology for various power levels up to 1.0 MWe is available
  - About 3 different technologies
    - Over 15 manufacturers in the field
- Programs
  - Remote village electrification
  - Village Energy security program
    - Biogas for cooking
    - Gasifiers for electricity
  - Industrial requirements
    - Captive heat and power generation
    - Grid based systems

Biomass gasification at IISc

- Major initiative on Energy technologies
  - Early 1980's - accepted a challenge to look into the energy needs of agricultural sector through the route of gasification [as a part of activity of ASTRA (CST)]
  - Both basic research and developmental activity

Brief history at IISc

- Gasification research commenced in 1980’s
  - Emphasis was on 5 hp diesel pump sets
- Over 350 Man-Years of R&D effort
- Evolved State-of-the art technology
- Undergone critical third party evaluation – by various groups
- Commercial applications ~ four years

Technology package - IISc

At IISc (Open top down draft technology)

- Technology package for agro residue as the fuel
- Power range 5 – 1000 kWe
- Both power and high quality thermal applications
- Over 150,000 hours of operational experience
- Gas cleaning system for turbo-charged engines
- High pressure gasification for micro-turbine

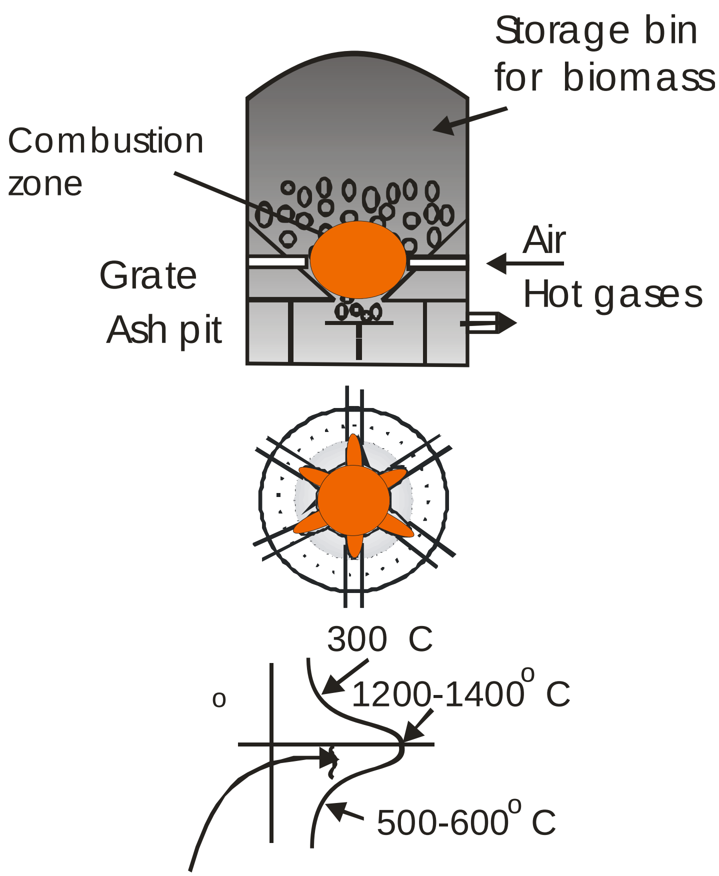
Specification drawn for the package

- Use of locally available material
  - Ability of the system to use agro-residues or forest residues – a reality
- Reliable supply
  - Designed as a power plant
    - Ability to provide quality power as required
    - Meet the local standards for environment and safety standards
    - Act as role model for replication

Reactor design

- II WW design - Closed top

Initial development activity began using a closed top design



Findings

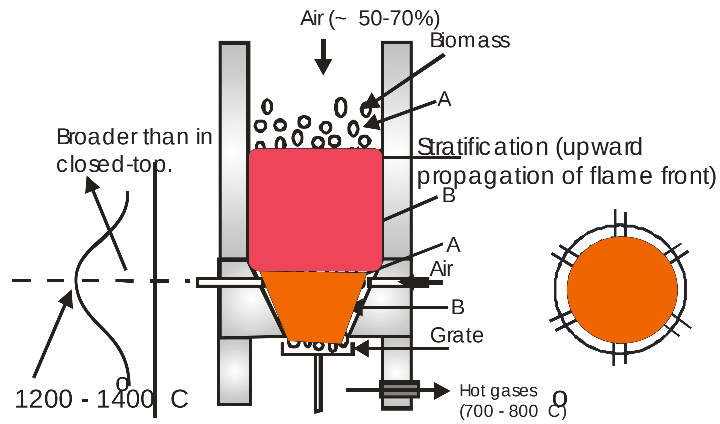
- Combustion zone confined to a small region
- Regions of low temperature
- Can handle only woody biomass
- Turn down ratio limited
- Problem of consistent gas quality

Reactor design

- IISc design – open top

Novel reactor design

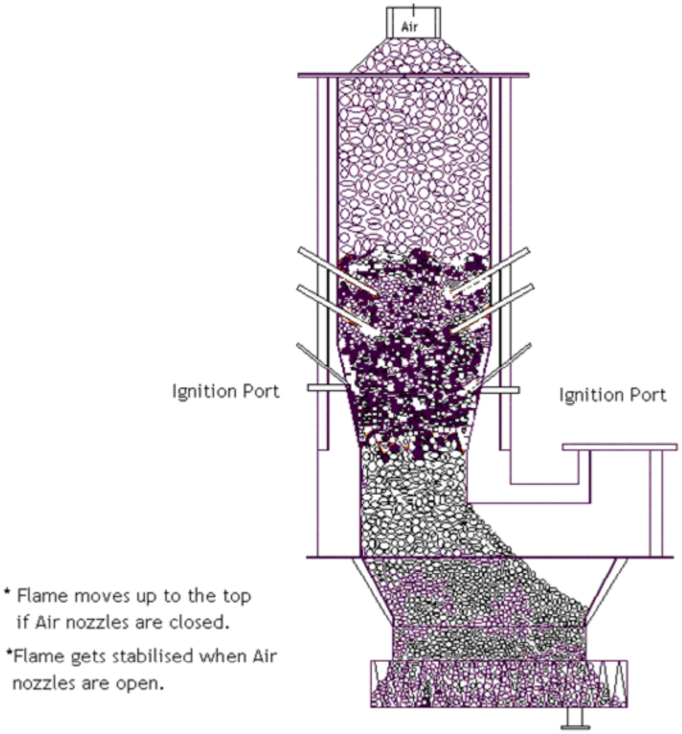
- Air is drawn from the top and from the air nozzles –
  - Uniform distribution
- Broader high temperature zone
- Enough residence time



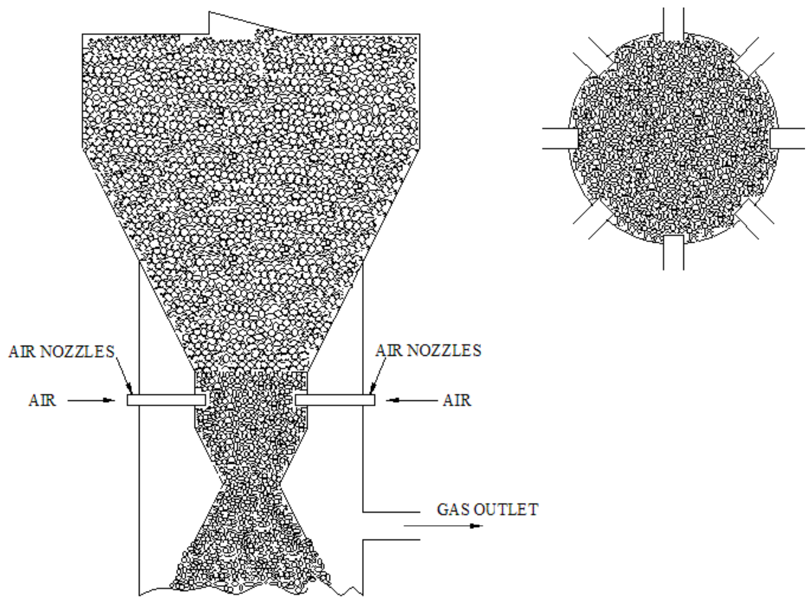
- Consistent high quality gas over the turn down ratio
- Varying biomass quality – can accept all agro residues

The ratio of air flow rate from the nozzle to the top depends on the fuel properties – size, density; the char consumption rate, etc

Open top gasifier

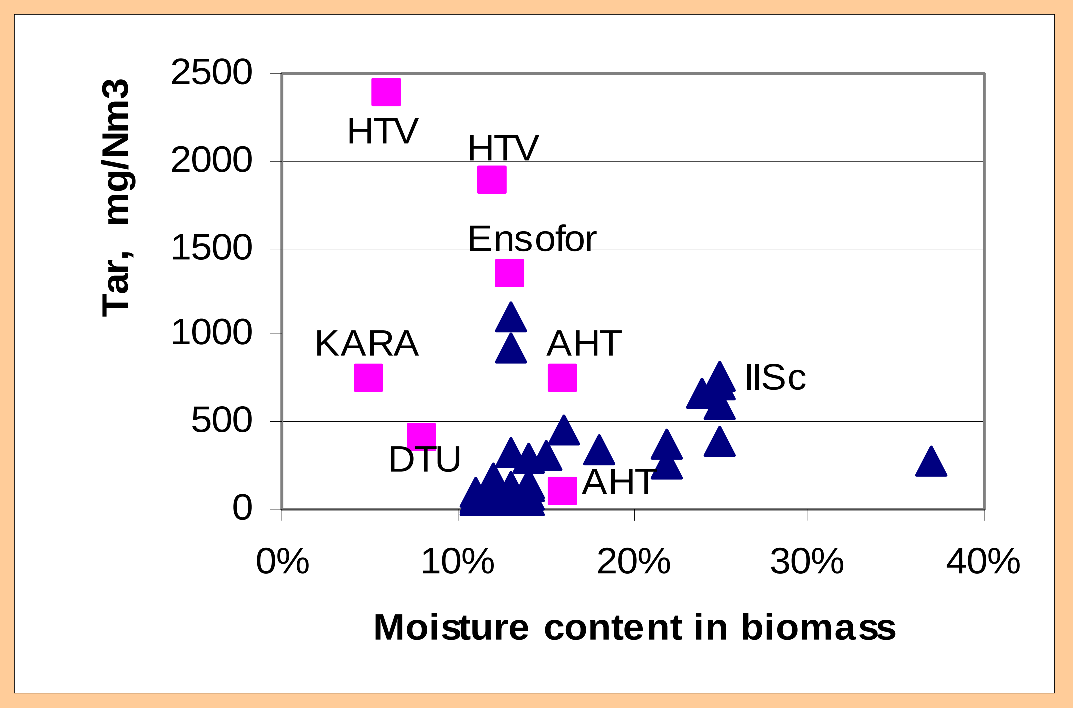


Closed top gasifier



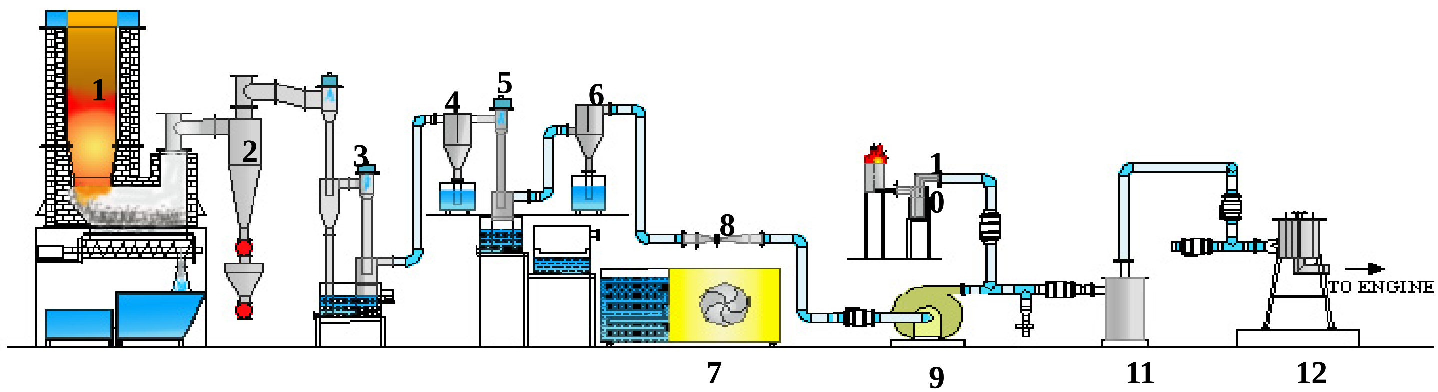
CLOSED TOP DOWN DRAFT GASIFIER

Hot gas contamination



Source :Hasler P (1997)

Technology elements



Salient features

- Well insulated reactor
  - Ceramics – to stand high temperature and meet industrial standards
  - No metal would stand the oxidizing and reducing environment
- Necessary cooling and cleaning system
  - to meet the end use requirements

Gas cleaning process

- Gas has to be cooled and cleaned for end use application

  T and P levels of 100 ppm and 1000 ppm respectively in the raw gas at 350 – 650 C
- After cooling
  - Gas is saturated with moisture
  - Contains fine dust and condensable (~ 25 ppm) even after filtering – not acceptable to turbo charged engines
- Use the principle of condensation nuclei
  - Scrub the gas using cold water (< 10 C)
    - Dries the gas by condensing the water vapor
    - This happens using the particles (Cloud Condensation Nuclei) – thus removing the particulate < 10^{-3} microns
    - The gas is dry and clean to ppb level

With this gas cleaning process it is possible to restrict the contaminants to ppb levels

Typical applications serviced

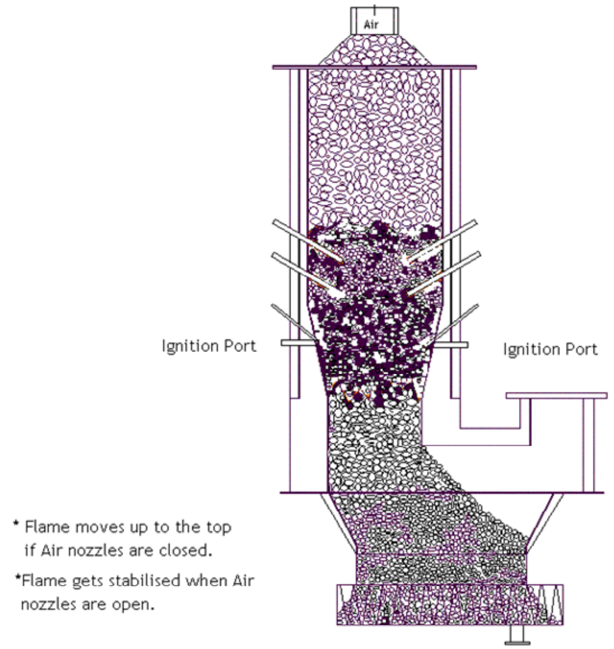
- Electricity generation
  - Village electrification
  - Captive power generation
  - Grid linked power generation
  - Energy Service Company - ESCO
- Thermal application
  - Low temperature (drying, etc.,)
  - High temperature (furnaces, kilns, etc.,)

Biomass








Air
Ignition Port
Ignition Port
* Flame moves up to the top
if Air nozzles are closed.
*Flame gets stabilised when Air
nozzles are open.

Field Installations

- Total installed capacity
  Thermal : 22 MWth
  Power : 2.5 MWe

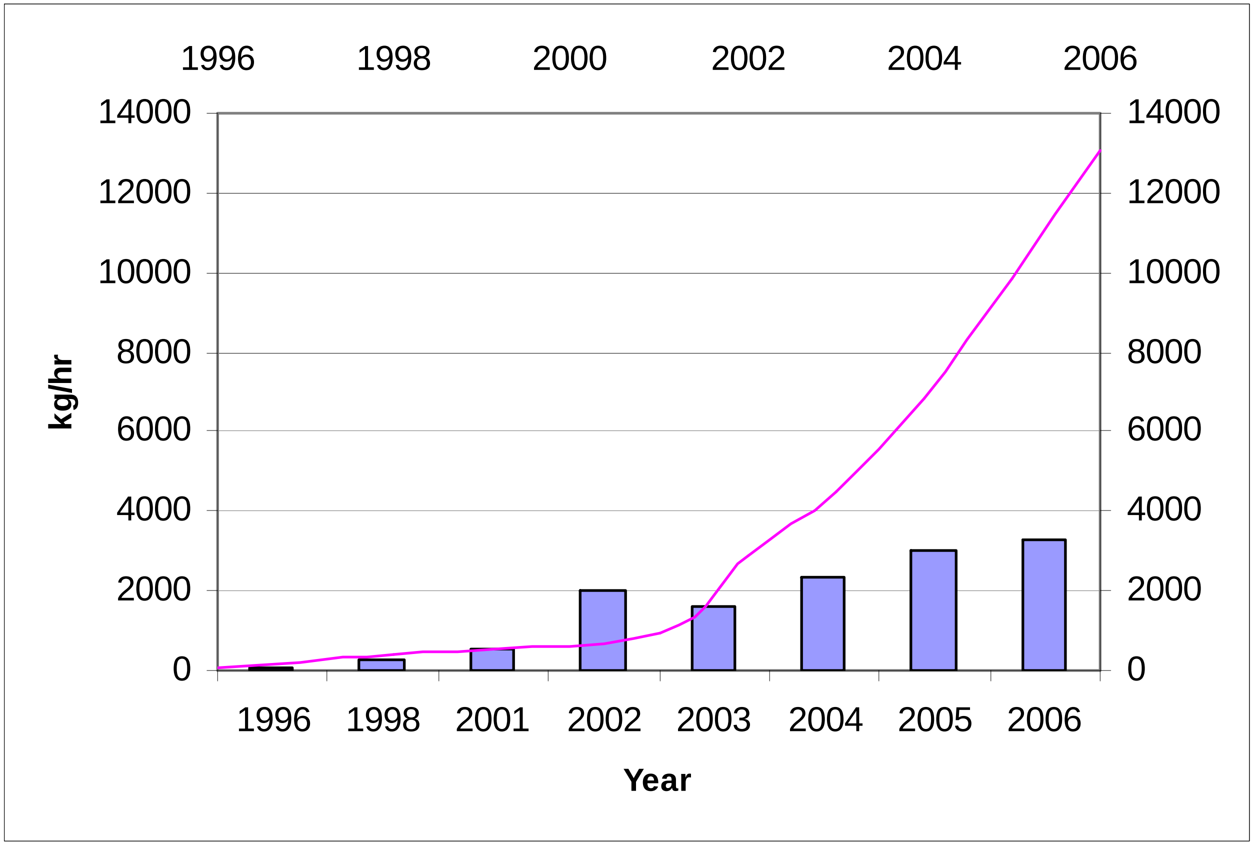
By June 2006 additional

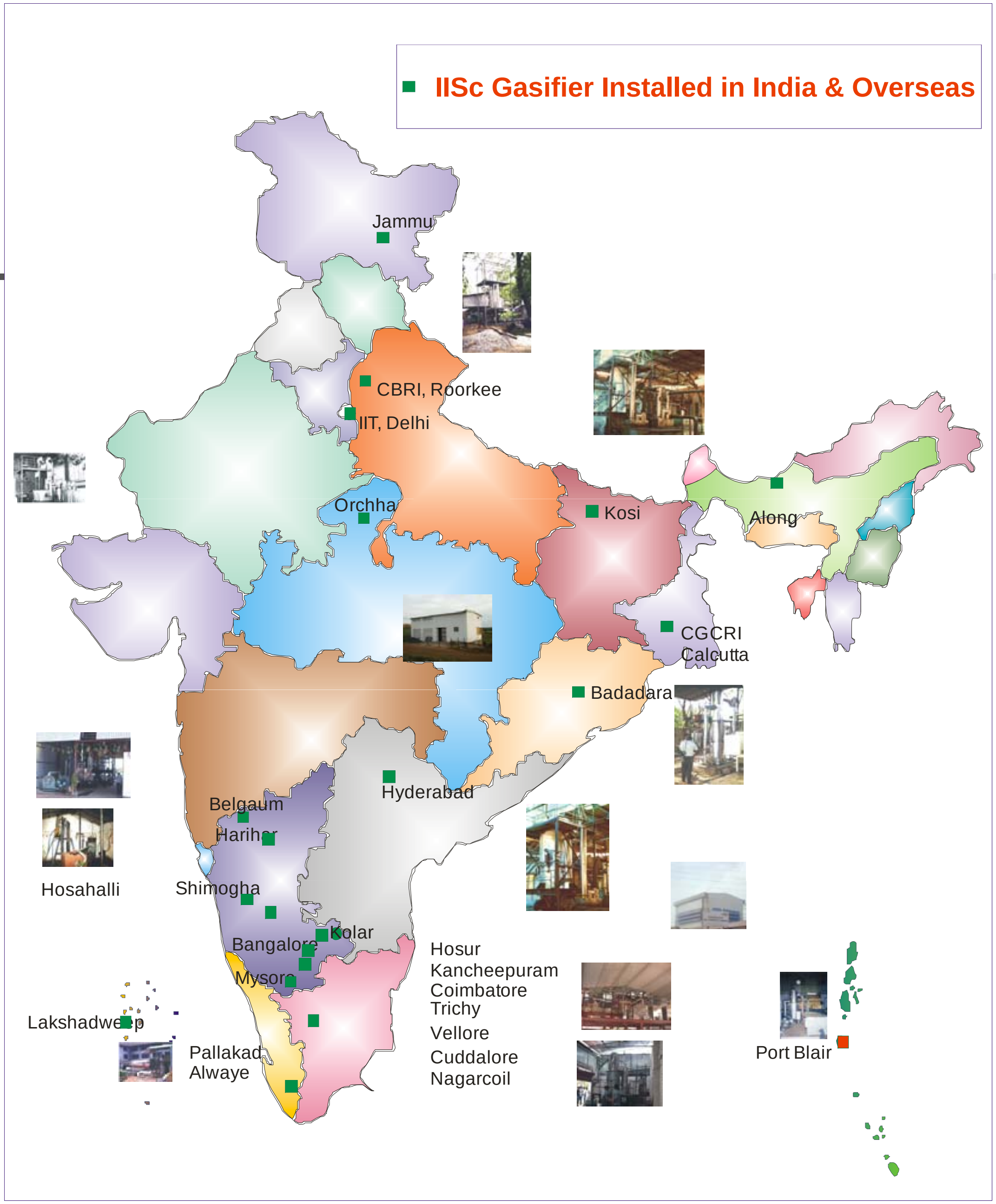
Thermal : 12 MWth
Power : 2.3 MWe

- Over 150,000 hours of operation
- Saving 18 -20 Tons of fossil fuel/day
- 6 Licensees in India and 3 in overseas

Approximately Rs. 300 Million of private investment

Growth of IISc systems




IISc Gasifier Installed in India & Overseas
Jammu
CBRI, Roorkee
IIT, Delhi
Orchha
Kosi
Along
CGCRI Calcutta
Badadara
Hyderabad
Belgaum
Harihar
Hosahalli
Shimogha
Kolar
Bangalore
Mysore
Lakshadweep
Pallakad
Alwaye
Hosur
Kancheepuram
Coimbatore
Trichy
Vellore
Cuddalore
Nagarcoil
Port Blair

Some economics

- Capital cost:
  - Up to 100 kW capacity - 1500 USD/kW
  - Beyond 100 kW - 1200 USD/kW
- Thermal
  - 1 kg of fossil fuel replaced by 3.5 kg of biomass
- Power
  - Biomass consumption, 1.0 – 1.4 kg/kWh

- **Operating cost**
  - Fuel cost - 2.5 – 3 US c/kWh
  - Maintenance cost
    - Upto 100 kW capacity – 2.5 US c/kWh
    - Beyond 100 kW - 1.0 US c /kWh
- Grid cost in India – 6 – 10 c
- Fossil fuel based captive generation
  - 12 – 20 US c/kWh

Overall Performance

- Technology transferred to 6 manufacturers in India
- Total number of systems installed : 34
- Total thermal : 9 System
- Total electrical : 25 System
- Over 150,000 hours of operation
- Type of biomass used: wood coconut shells, cotton stalks, mulberry stalks, saw dust briquettes, etc.
- Biomass to diesel in thermal mode – 3.0 to 3.5 kg/liter
- Biomass to diesel in dual fuel engine mode – 3.8 to 4.0 kg/liter

Fossil fuel saved per day ~ 20000 lts

IISc's experience

- System reliability at industrial mode
- System packaging as IPP
- Increasing demand for gasification systems to meet various energy demands

Major feature in the program at IISc

It is important to note that the group involved in R & D has also been involved in the projects. This has resulted in actions to meet the users demand

Acknowledgements

The work carried out on the biomass gasification technology has received significant funding from the MNES.

...Thank you

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