Biomass based power generation – an overview

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Contents

- Brief about IISc
- Historical trends in biomass energy
- Technological options
- Revenue streams

Conceived in 1896 by the inspired vision of the pioneering industrialist Jamsetji Tata

- Established in1909 as a Trust (Charitable Endowments Act 1890)
- Deemed University from 1957
- Funded by MHRD since 1993

Vision

Founder’s mandate: Institute designed to promote original investigations in all branches of learning and to utilise them for the benefit of India.

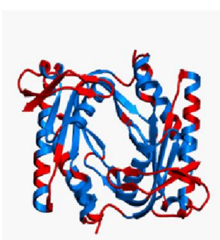
21st century: to be among the world’s foremost academic institutions through the pursuit of excellence and the promotion of innovation.

Student and Faculty Profile

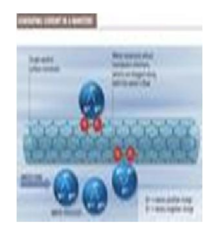
- **Deans**
- **Faculties: Science and Engineering**
- **Students: ~2050 (Men ~ 1650 ; Women ~ 400)**
- **Research: (PhD, Int. PhD) ~ 1250**
- **Course: [ME, MTech, MDes, MBA, MSc (Engg.)] ~ 800**
- **Faculty: 321 (Academic) 114 (Scientific)**

Divisions

- **Biological Sciences**
- **Electrical Sciences**
- **Mechanical Sciences**
- **Chemical Sciences**
- **Information Sciences**
- **Physical and Mathematical Sciences**





Broad area of research activities at CGPL

- The broad areas include laminar premixed and diffusion flames, heterogeneous combustion, nozzle flows and combustion flow interaction in practical systems.
  Lifted diffusion flames, sandwich composite propellant burning,
- Modeling of combustion in hybrid rocket engines and solid propellants and ingredients; combustion of liquid droplets and instability in liquid rocket engines; propagation of premixed flames with complex chemistry and diffusion; reacting flows in nozzles and air inlets in aircraft and missiles;
- Experiments and modeling of wood combustion in gasifiers and in stoves
- Hydrogen and liquid fuel from biomass
- Modeling of in-cylinder processes in internal combustion engines
- Heat transfer in large pressure vessels of petrochemical

Biomass as a source of energy

- Biomass has been used by mankind for meeting various energy needs
  - Both tree cover as well as agro residues have been used to meet the energy needs
  - In the developing countries basic objective has been to meet the end use with little or no concern on efficiency and emissions

Biomass usage

- Pre oil crisis (before 1980's)
  - Biomass used to meet the needs
  - Heat
    - Domestic : Cooking stoves, agro processing, etc
    - Industrial : Kilns, furnaces, boilers, driers, space heating, in various sectors – small, medium and large scale
  - Power
    - Steam route using direct combustion technology

- Post oil crisis (After 1980's)
  - With the ease of oil availability and energy cost being smaller fraction in the product, facilitated fossil fuel technology deployment
  - Significant R and D on fossil fuel technology coupled with automobile research, penetrated fossil fuel technology to meet a large number of domestic as well as industrial requirement

Reduced use of biomass

Revisiting Bioenergy - Post 1990

- Various scenarios
  - In developing nations
    - with increase in fossil fuel cost, and to meet the ever growing energy demand, bioenergy utilization being considered as a key contributor to the energy mix
  - In developed nations
    - With the changes in environmental conditions, global requirements has brought in key changes in addressing bioenergy solutions through efficient utilisation

- Biomass Technology was acceptable even though
  - Low efficiency
  - Not user friendly
  - High emissions

When there was less competition from other technologies

- Use of fossil fuel technology continued till the component of energy cost was small fraction of the overall product cost.
- Recently alternates are being looked both for heat and power

Modern Biomass technological utilization routes

- Thermo chemical conversion
  - Direct combustion of the fuel for heat or power
    - For large scale capacities and co-generation mode with industries
  - Gasification for heat and power
    - For medium (few kW to 2 MWe for distributed, grid linked and captive)
- Biological conversion
  - Through bacterial route – convert to gas and the gas for end use application
- Bio-diesel route
  - Using edible/non-edible oils

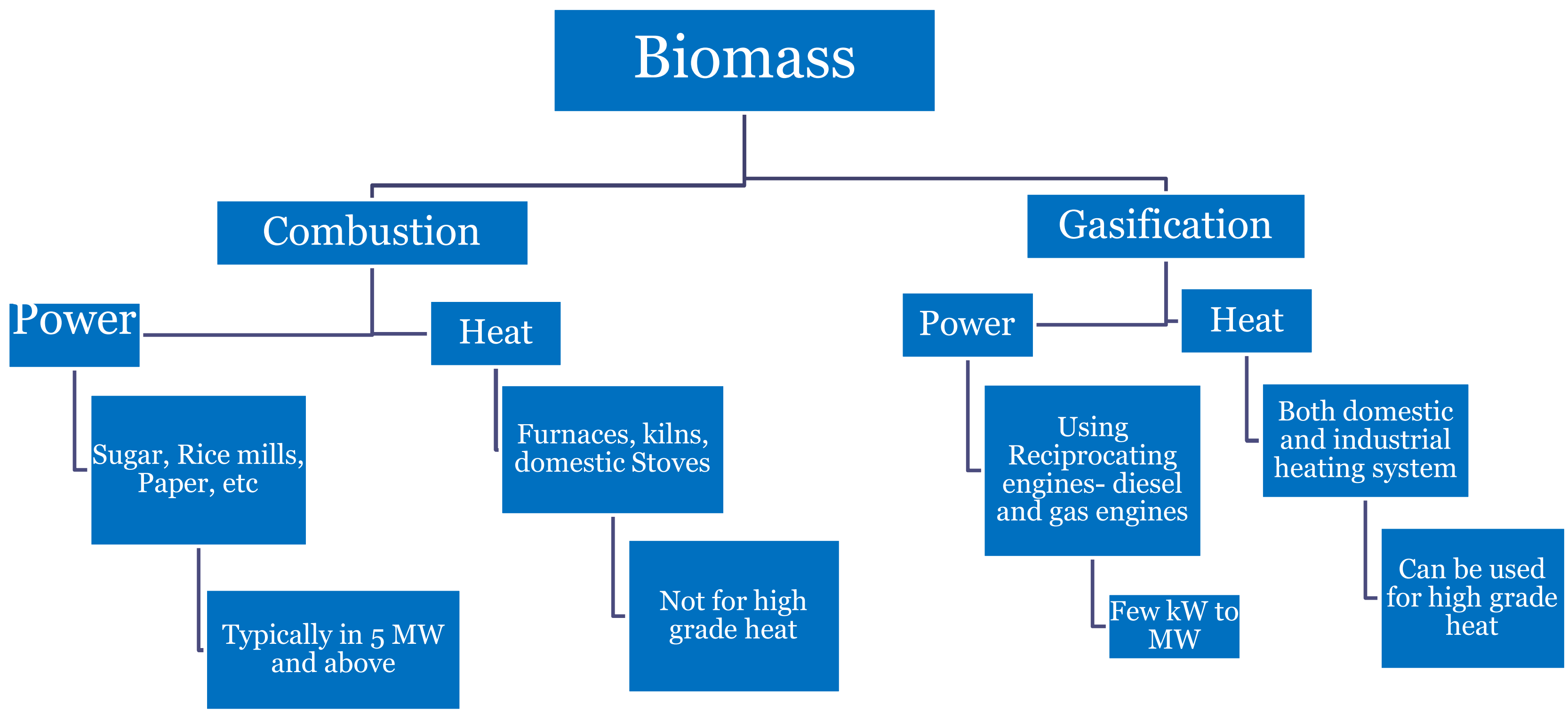
SWOT analysis – fossil power

Strengths Decentralised; Established technology, Significant research input to meet various end use, Centrally processed fuel available; Sales, service and other support network well established; Energy cost **(was)** a small fraction of the product cost - Not anymore, Ideal fuel for transport	**Weakness** Fuel price linked to international market **(now);** Driven by governmental subsidy pattern; Global warning **(now)** ; Competition in product line – establish to reduce the fuel cost **(now)**
Opportunities Small scale industries growing rapidly; Gestation period nearly zero; Energy costs **(was)** lower than grid cost	**Threats** Environmental; Climate change requirements, Governmental dependence on the pricing

SWOT analysis – biomass gasification power

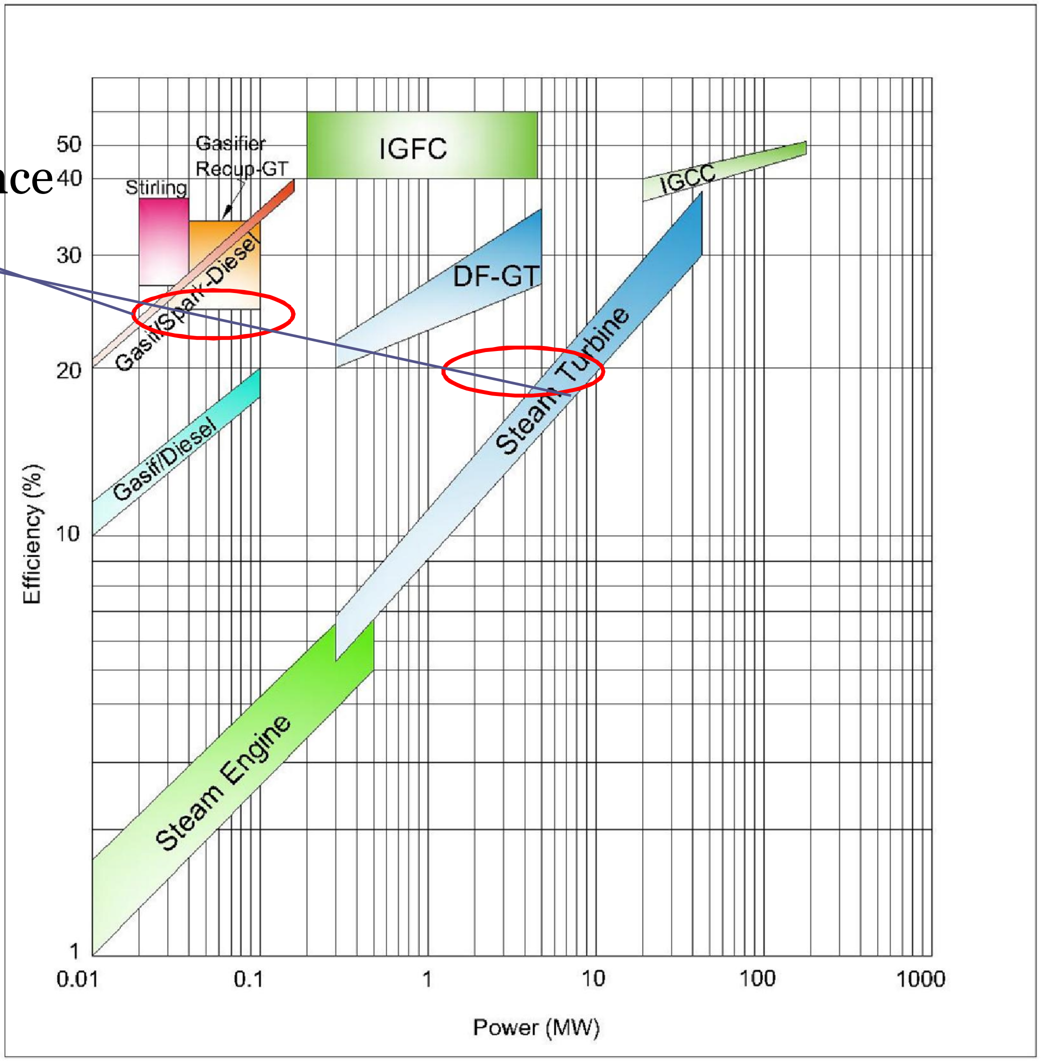
Strengths	**Weakness**
Decentralised; Strengthens self-reliance , Environmentally sound; Locally available fuel	Replicability not yet proven at distributed power generation scale; Present costs may **(claimed)** be too high; Potential not adequate to replace fossil fuelled energy conversion; Fuel dispersed; Standardization of technology package with services, etc; Low visibility
Opportunities	**Threats**
Costs are declining; Gestation period nearly zero; Power generation costs lower than fossil fuel system; Fossil fuel substitution very high; Potential very high	Power sector reforms may under emphasize biomass based systems; Inefficient and environmentally hazardous technology implementation, Overemphasis on solar and wind

Possible thermo-chemical routes for using biomass as an energy source



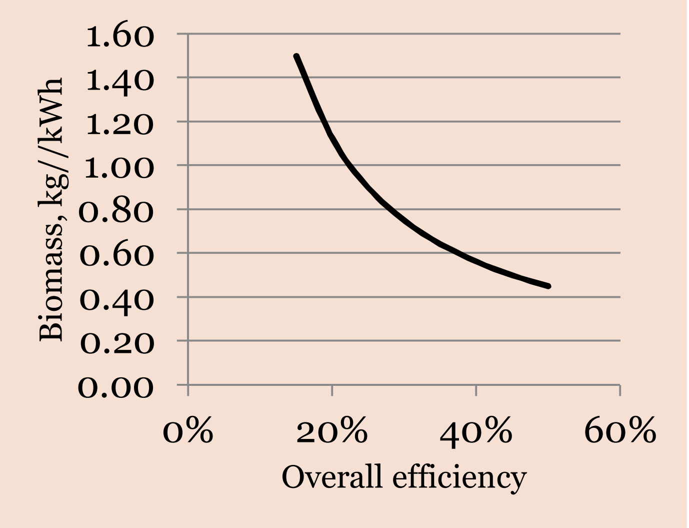
Performance of various power generation systems

Achieved performance



What does the performance chart indicate?

Technology	Fuel/ capacity	SFC kg/kWh
Steam	Biomass, fossil fuel • < 100 kW • 100 - 500 kW • 500 - 2000 kW • ~ 4000 kW	~ 6 -8 kg/kWh ~ 4 - 6 kg/kWh ~ 2 - 3 kg/kWh ~1.5 – 2 kg/kWh
Gasification •Dual fuel and gas alone operation •Gas turbine with recuperator	Agro residues • < 100 kW • < 100 - 500 kW • ~ 1000 kW	~ 1.2 – 1.5 kg/kWh ~ 1.0 – 1.3 kg/kWh ~ 0.8 - 1.0 kg/kWh
Stirling engines	Can be agro residues • < 100 kW	< 1.5 kg/kWh
IGCC	Agro residues > 2000 KW	~ 0.7 – 0.8 kg/kWh



Power from biomass

- Combustion route
  - Ideal for heat and power application and at capacities > 5 MW (~ 6 – 7.5 tons per hours)
    - Where steam and electricity is needed

  - Fuel is used in the boiler integrated with various designs of combustion systems depending upon the feed stock
    - Grate bases, FBC, bubbling bed, entrained, etc

Boiler

- Most of the design are for wood or fuel specific
- Higher pressure – better efficiency
  - Issues related to higher skill requirement for operation and maintenance, etc
- With agro residues challenges are related to
  - Super heater deposition and erosion
  - Ash fusion
  - Carbon conversion

Challenges and mitigation

- Challenges
  - Meeting emission standards (Particulates, NOx, etc)
  - High water consumption
  - Multi-fuel capability
- Mitigation
  - Closed loop control system with flue gas treatment
  - Co-firing in large capacity to reduce the complexity
  - Gasification of fuel before use in the boiler
  - Working fluids other than water

Research trends

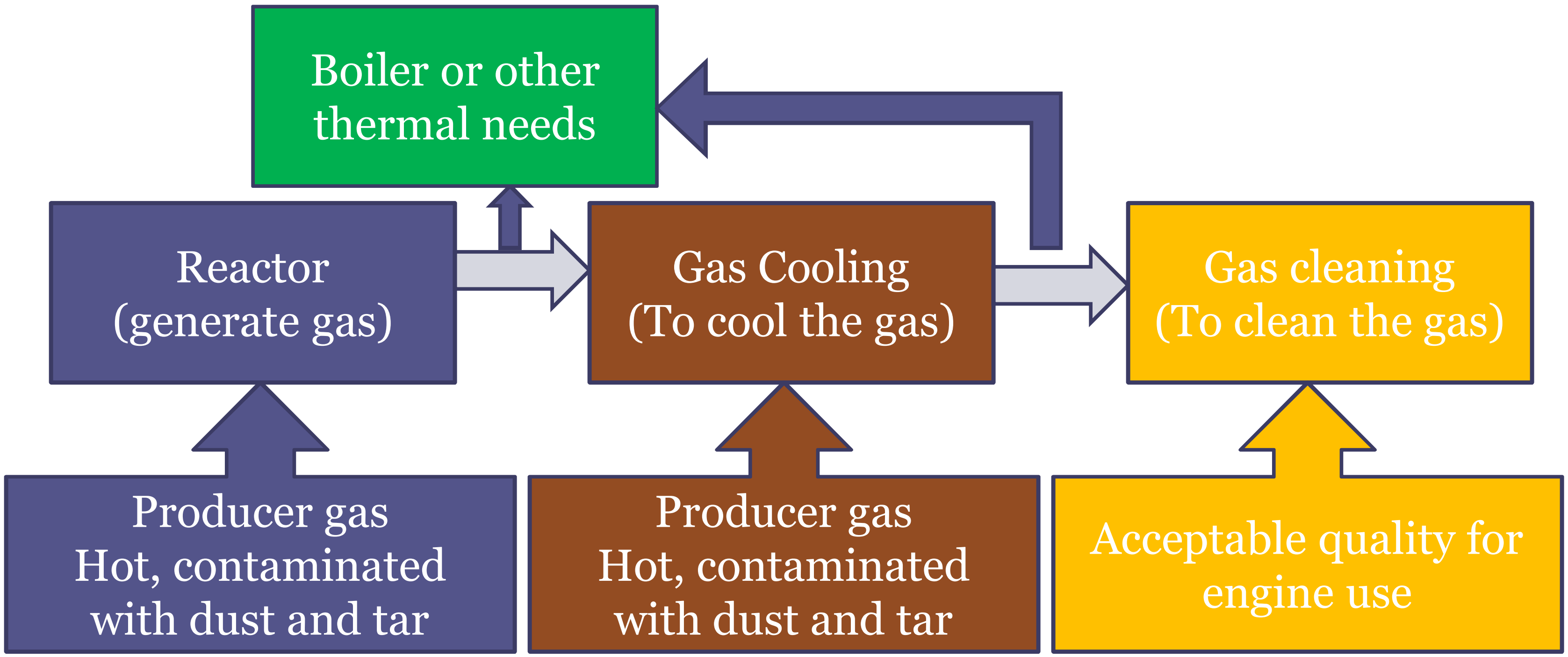
- Multi-fuel capability
- Issues related to super heater tube
- Co-firing
- Emission control techniques
- Hybridization

Biomass gasification

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

Gasification process



Experience in using World War II design

- The limitations found the down draft 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

System designs adaptation

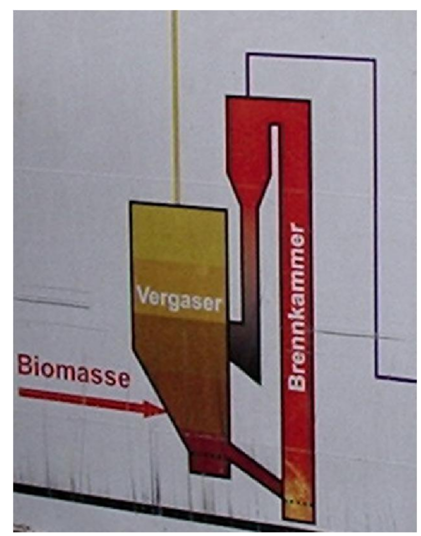
- Even with these limitations, the reactor design is accepted by some of the groups (may be with small modifications) as a possible technology option at small capacities (< 1000 kWe).
  - Limited commercial operations are existing (Europe).
- Several other groups are looking into variations to the downdraft designs, updraft design and CFB designs as possible alternates for the reactor
  - Updraft and CFB designs have been used for heat application and adaptation of gas conditioning systems to meet the requirements of a reciprocating engine

Approaches by various groups

- Develop reactor configuration to generate good quality raw gas (low tar and particulate and high gas conversion efficiency)
  - Reduces the complexity in the gas conditioning system
- Existing CHP plants using updraft and CFB
  - Even though the raw gas quality is poor, incorporate gas conditioning system to meet engine quality gas

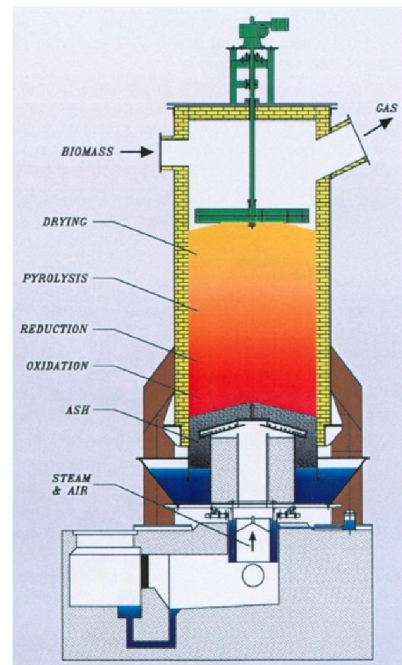
Fluidised bed gasifier, Guessing

- 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.
- The gas conditioning system consists of indirect cooler, bag filter and an oil scrubber
- Water cooled heat exchanger reduces the temperature from about 900 C to about 180 C.
- The first stage of the cleaning system is a fabric filter to separate the particles and some of the tar from the producer gas.
- In the second stage oil is sprayed in a scrubber to remove the tar. The spent scrubber liquid saturated with tar and condensate is vaporised and fed for thermal disposal into the combustion zone of the gasifier. The scrubber is used to reduce the temperature of the clean producer gas to about 40 C.
- Cold gas efficiency of about 64 % has been achieved and an electric efficiency of 21 %.



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 – 75O °C and a tar content of 80 – 100 g/Nm^3
- The system has operated over 70,000 hours of operation.
- In 2000, two Jenbacher engines rated at 650 – 750 kW capacity were installed



Thermo-chemical conversion

- Combustion route
  - Well established process
    - Extensively used in industries as captive CHP unit
    - Used for space heating and power generation

- Co-generation
  - Additional energy utilization
    - Heat or Cool
    - Power
    - or combination
  - Tri-generation
    - Along with the above by products

Typical examples

- Sugar, paper and many process industries
  - Power and steam
- Boiler – for steam generation
  - Used for power generation in a steam turbine
  - Steam used for process heat

Wish list as perceived by a user

- To be able to use all types of fuel; nearly as is where is condition implying multi-fuel option
  - More particular in the developing countries context – use of agro residue important
  - Developed countries generally centralized wood processing and hence woody biomass is available
- To be able to operate like a liquid fuel system; simplicity in design technology to be simple, automation
- Lower down time - reliability of the system; service support
- Economic viability; return on investment- guaranteed performance
- Environmentally benign - low on pollutants and emissions
- Should see a system of comparable application/capacity of what is being intended to be bought; not a guinea pig - no risk option
- Fuel source to be identified - a necessity for substituting large scale fossil fuel technology package

Success story definition for gasifier based power generation

This is a difficult question because the answer is normally very subjective. In this report a gasification plant is considered as successful if the process is demonstrated successfully at full scale. This criterion can be further split in two parts: the degree of commercialization and the hours of operation.

Degree of Commercialization

It is evident that biomass gasification is still under development and fully mature systems are the exception (e.g. co-firing). Nevertheless, a lot of demonstration plants have been built in the past and operated with different success. From some of these good results could be obtained and further development is going on, from others the results were not encouraging and therefore the development was stopped. One criterion for a success story can therefore be formulated in that way, that the degree of commercialization must be such as that a full scale demonstration plant already exists and this demonstration plant is operated under commercial conditions.

Hours of Operation

The second criterion is related to the hours of operation. Of course the numbers of hours of operation of a demonstration plant is not as high as for a fully mature commercial system. In case of gasification more than 2000 hours per year seems to be a good value. In some cases this number may not be reached due to different reasons but the operation is continued. Such demonstration plants can also be considered as success story if the total number of hours of operation is more than 6000 hours.

Source: Hand book on biomass gasification 2012

Gasification - Challenges

- Challenges
  - Small capacity systems for distributed power generation
  - Meeting emission standards (solid, liquid and gaseous)
  - Safety standards
  - Limited designs for Multi-fuel capability
  - Limited availability Engines for producer gas operation

Brief history on the gasification technology at IISc

- Gasification research commenced in 1980's
  - Emphasis was on 5 hp diesel pump sets
- Over 450 Man-Years of R&D effort
- Evolved **State-of-the art** technology
- Undergone critical third party evaluation – by various groups
- Commercial applications ~ five years
- Licensed the technology in India and abroad

- **At IISc (Open top down draft technology - distinctly different from other designs)**
  - Multi-fuel capability
  - Power range 5 – 2000 kWe
  - Both power and high quality thermal applications
  - Over **450,000** hours of operational experience
  - Annual operational hours ~ 7000 hours
  - Gas cleaning system for **turbo-charged engines**

Financial aspects -1

- Capital cost
  - Depends strongly on the hours of operation
    - A less serious concern in the case of grid connected system
    - Technology should be able to provide long term operation capabiliyt

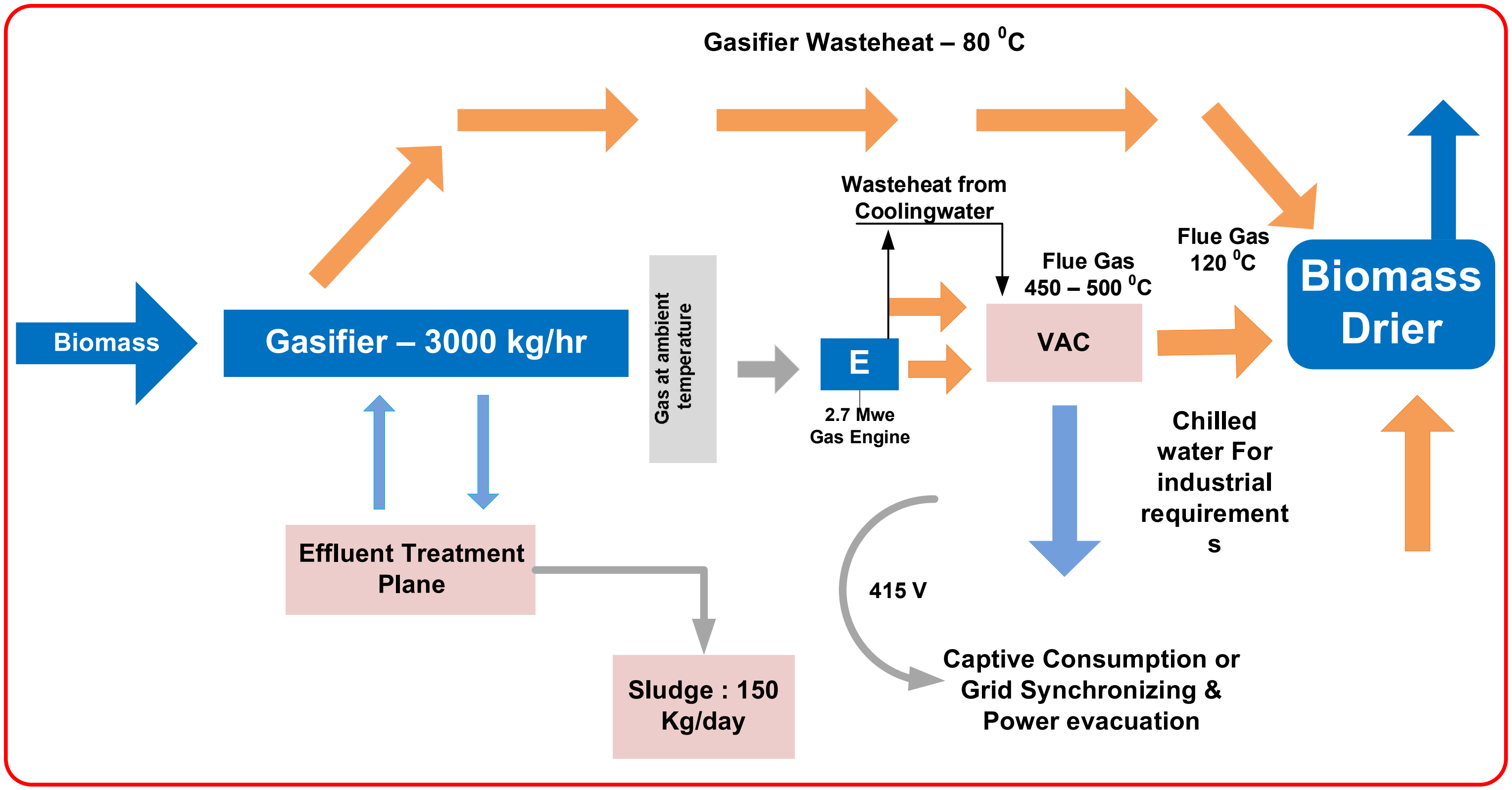
Financial aspects -2

- Operation and maintenance cost
  - Fuel
    - The component is a function of
      - Efficiency – higher , lower the cost per /kW
      - Multi-fuel capability – possibility of using various fuel depending upon the availability and seasonal variations
  - Gasifier O and M
  - Engine O and M
    - These depend on the technology packages – primarily the gasification system

Revenues

- Technology independent
  - Tariff structure
    - State grid - Depends on SERC's
    - Third party sales
- Technology dependent
  - Improves with multiple output towards
  - Reliability improves output kWh
    - Lowers O and M

Co-generation



Points that need attention

- Level playing field for biomass as an energy resource
- Possible solutions
  - Generation based incentive
  - Time bound support programs
  - A mission mode of operation
  - Promote integration approach
    - From fuel to energy (Well to Wheel)

……………….Thank you

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