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Integration of MGT with Biomass Based Technologies: Technology Challenges

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MGT Group Leaders Meeting

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Outline

- **MGT Key Opportunities**
- **Main Competing Technologies**
- **MGT Current Challenges**
- **MGT Combustion Requirements**
- **Fuel Flexibility in MGT systems**
- **Renewable MGTs**
- **Biomass MGT - SWOT Analysis**
- **Biomass MGT Combustion Strategies:**
  1- Pyrolysis/Gasification/Anaerobic digesters
  2- Indirect Firing
  3- Direct Firing
- **Renewable CHP – Government Incentives**
- **Concluding Remarks**

MGT Key opportunities

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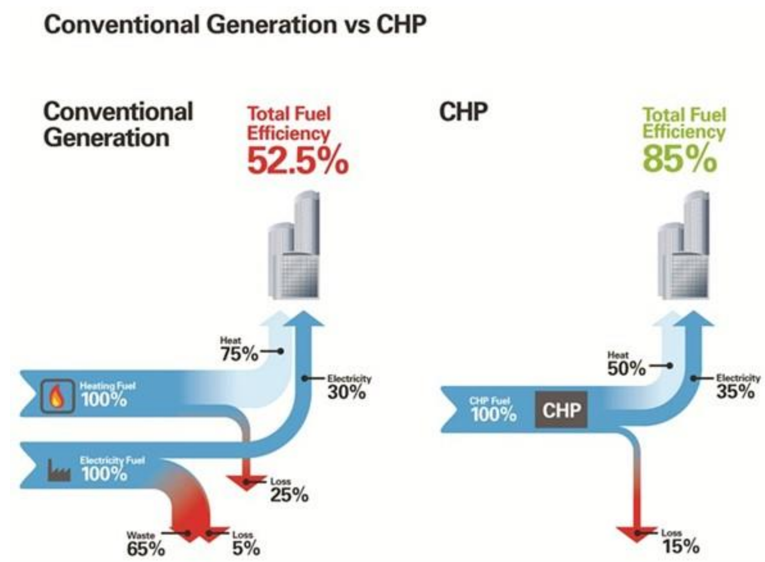
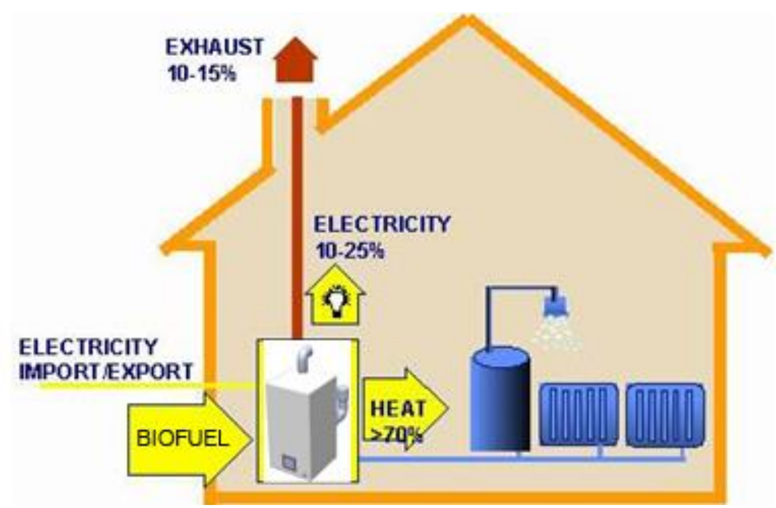
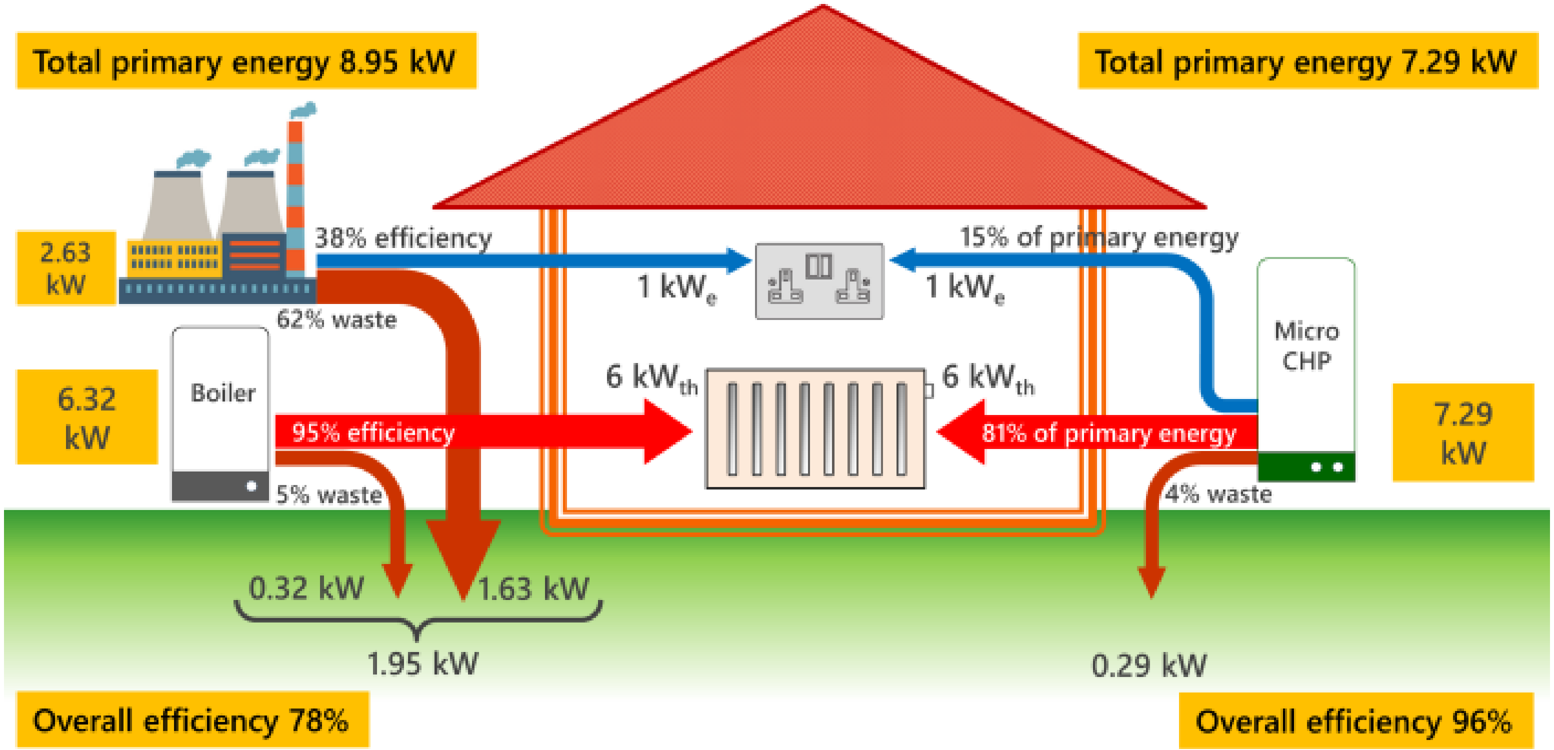
- Change of energy industry in global level
- Constant rise of energy price
- Concern of global warming and emissions
- The Electricity Market Reform
- Heat Strategy
- Smart grid and distributed power generation (higher efficiencies)
- Government supports including, Renewable Heat Incentive (RHI) and Feed-in Tariffs (FIT)
- Wide rang of applications including:
  - Distributed production of heat and electricity (CHP)
  - Transportation (e.g. as range extender)
  - Auxiliary power unit
  - Aviation (auxiliary power unit)





Traditional Power Plants vs. CHP

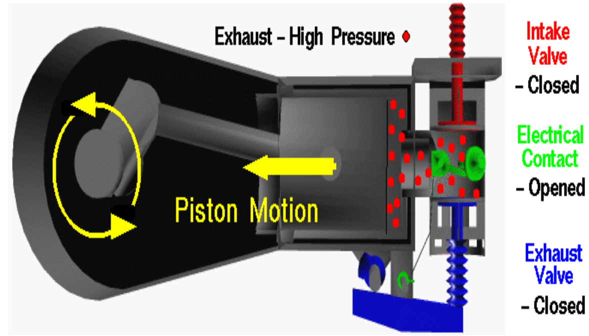


Ref: http://www.energysavingadvisor.co.uk/micro-combined-heat-and-power

Main Competing Technologies

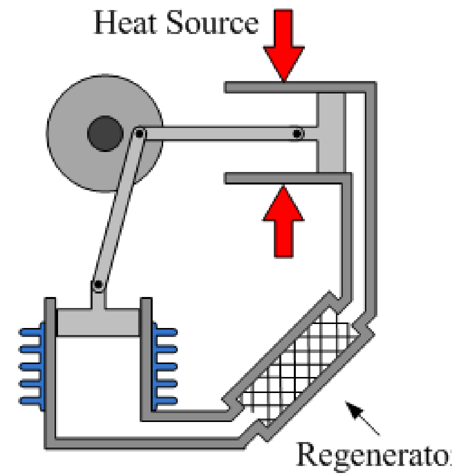
1. Gas Engines

Initial price: £ 5600/kWe
Fast start up time
High vibrations and noise

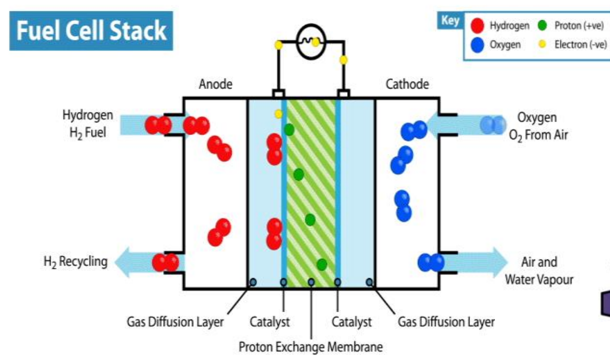


2. Sterling Engines

Initial price: £ 3000/kWe
External combustion
Long life span



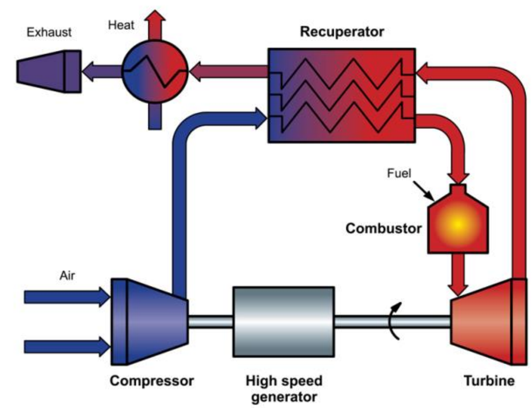
3. Fuel Cells



Initial price: £ 20,000/kWe
Environmentally friendly
Long start up time

4. Micro Gas Turbines

Initial price: £ 2700/kWe
Fuel flexibility
Relatively fast start up



MGT Schematic (in CHP form)

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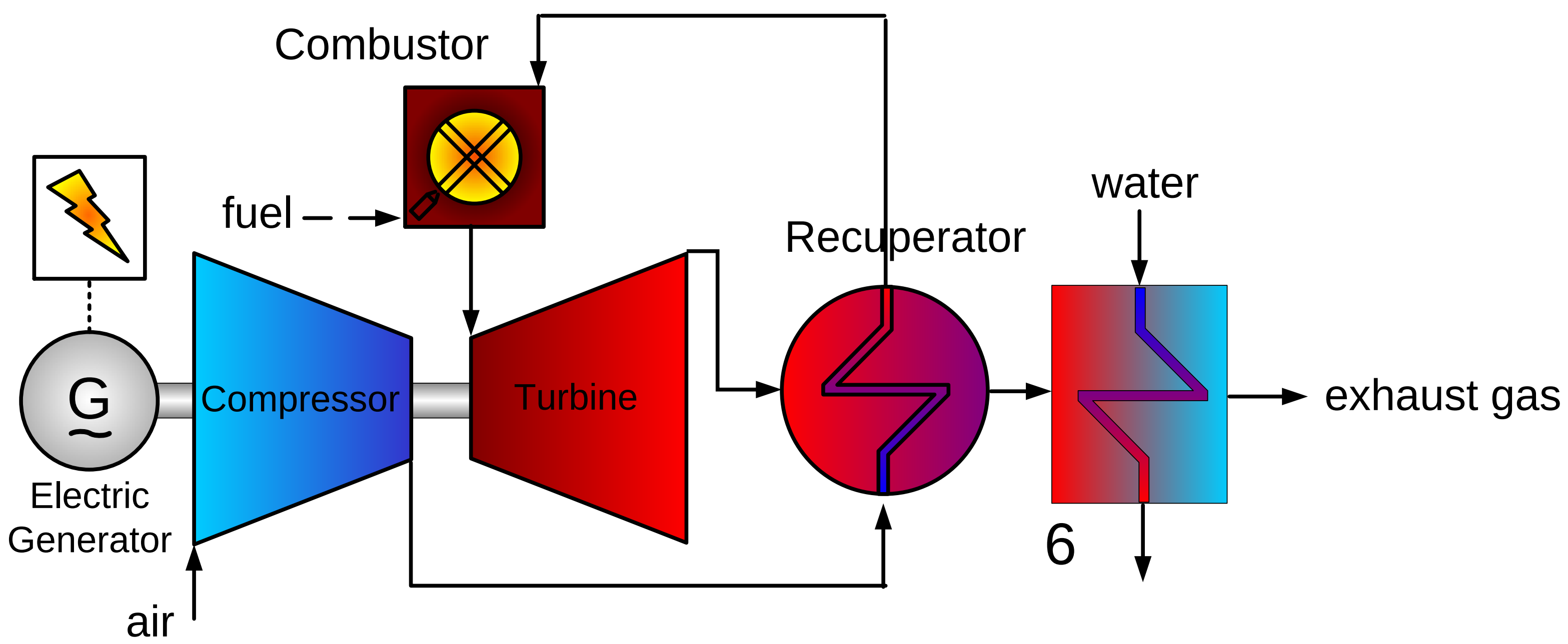
Typical operating conditions are:

- **Combustion chamber pressure = ambient -4.5 bar**
- **Turbine Inlet Temperature = 800-1000°C**
- **Turbine exit gas temperature = 620-800°C**
- **Combustor inlet temperatures = ambient – 730°C**
- **Exhaust gas temperature (downstream recuperator) = 230-300°C**
- **Rotation speed = 70000 – 240000 rpm**



MGT Current Challenges

The current challenging performance targets for micro-turbines include:

- ❑ Fuel-to-electricity efficiencies of 40% or higher,
- ❑ Capital costs less than $500/kW (depending on engine size),
- ❑ NOx and CO emissions reduced to single parts per million or rather below 25 ppm (@ 15 Vol. % O_2) even at low part load conditions,
- ❑ Several years of operation between overhauls, operating live of 40,000 hours and fuel flexibility.
- ❑ Addressing the renewable MGT systems challenges

What are the common myths surrounding renewable CHP

- CHP systems are not renewable as they emit CO_2
- CHP systems are too complex for a users to manage
- CHP systems are too big for a single community building

MGT Combustion Requirements

- Wide, stable operating range
  - ✓ stable combustion without flameout
  - ✓ severe thermo-acoustic pulsations/combustion induced instabilities
  - ✓ wide range of air fuel ratio, power pressure and combustor inlet temperatures
- Reliable and smooth ignition
- Low pressure loss
- Low exhaust gas emission
- High combustion efficiency
- Low combustion noise emissions
- Low production costs and maintenance effort
- High durability / lifetime (e.g. 30 000 h)
- Uniform temperature distribution at combustor outlet to maximize efficiency and lifetime of turbine
- Fuel flexibility

Fuel Flexibility in MGT systems

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- **Gaseous Fuels: Natural gas, Biogas, Landfill gas, Manufactured gases, City gas, Wood gas, Hydrogen, Industrial waste gas, Blast-furnace gas**
- **Liquid Fuels: Heating oil, LPG / NGL , Diesel , Kerosene , Liquid hydrocarbons , Alcohols , VOCs** (Volatile Organic Compounds) , **Pyrolysis oil , Glycerin**
- **Solid Fuels: Wood, Agricultural waste, Municipal and industrial waste**

Calorific values of various biofuels

Fuel	GCV (MJ/kg)
Biodiesel(from oilseed rape or recycled vegetable oil)	37.27
Veg. oil	39
Processed biogas	22
Agricultural waste (straw)	15.8
Animal waste	18
Waste food/fruits	15
Wood pellet/chips	17.6
Gas/diesel oil	48
Landfill gas	$22/m^3$
Natural gas	$39/m^3$

Renewable MGTs

Community benefits

- Protection against rising fuel prices
- Make money for your community
- More local jobs
- Very efficient technology
- Reduce your carbon emissions
- Improve community well-being

Different types of renewable fuel

Biomass

Biogas

Bio-oil / Bio-diesel

Biomass MGT-From SWOT Analysis

Strengths
Enabling diversification in agriculture and forestry
Create rural revenue streams and local jobs
Help to improve land management practices such as forestry thinning and clearing
Biomass and waste fuels can be stored, meaning that biomass driven plants are dispatchable (compared to other RES that are stochastic)
Parts of the fuel to energy chain are well proven, like solid biomass combustion, production of landfill or sewage gas
Less combustion design complications with external firing for biomass fuels at atmospheric pressures

Weaknesses
External costs of fossil fuelled power plants are not cared for in today's energy system
Biomass energy wrongly perceived by policy makers as old and unattractive
The establishment of biomass fuel supplies is novel and risky in some countries
Chicken and egg problem to invest in biomass cogeneration until fuel supply chains are in place and vice versa
Biomass has relatively low calorific value to make transport viable
Parts of the fuel to energy chain are still unproven, especially at the scale of a micro-turbine, including biomass gasification and pyrolysis
Many biomass applications have a low heat demand or operate seasonally (agro-industries)
Occasional mismatch between biomass cogeneration site and site of heat demand
Only larger biomass handling and supply chains are potentially commercially viable
Low gas to gas recuperator systems' efficiency when external firing

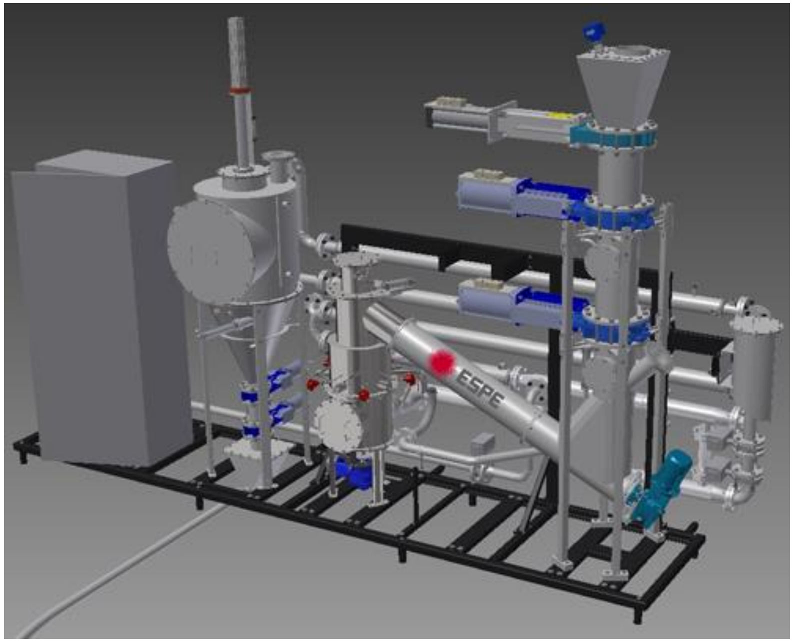
Ref: MICROTURBINES AND THEIR APPLICATION IN BIO-ENERGY -2004- **EESD Contract No: NNE5-PTA-2002-003 / 1**

Biomass MGT Combustion Strategies:
1- Through Pyrolysis/Gasification/Anaerobic digesters

Electricity output	49 kW
Thermal output	110 kW
Fuel input	woodchip EN/TS 14961:2005 @ 10% moisture content
Fuel type	G50 virgin wood chips
Flow temp	Up to 85 Deg C
Return temp	Up to 75 Deg C

CHiP50 Biomass CHP system (ESPE and Helec)

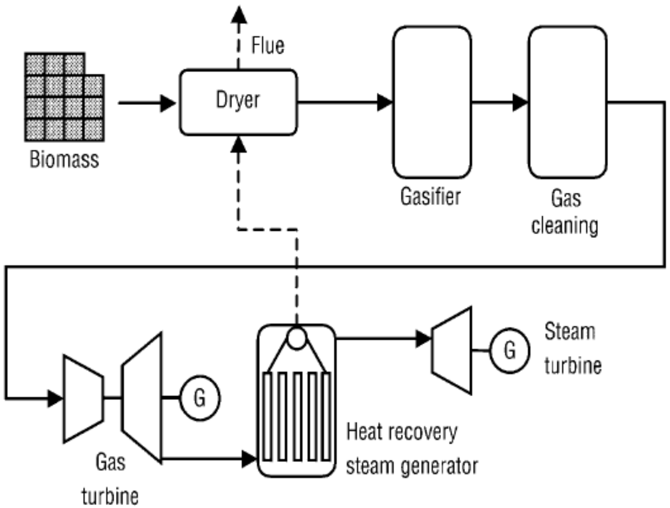
Gasification derived MGT



http://helec.co.uk/biomass-chp-system/

Advantage/Disadvantage of using Gasification Technologies in GT systems

- Achieving stable combustion without flashback while premixing hydrogen and air to maintain low nitrogen oxide (NOx) emissions
- Obtaining consistent fuel composition from a gasifier working with variable biomass feedstock



Relative advantages and disadvantages of GTCC systems based on three different gasifier designs

Gasifier design	Advantages	Disadvantages
Low-pressure, air blown (Variant 1)	- Easier fuel feed to gasifier than Variant 3 - Conventional gas cleaning equipment - Economically suited for modest size	- Waste water produced from gas cleaning system - Fuel gas compressor adds cost, reduces efficiency - Limited economically to modest size
Low-pressure, indirectly-heated (Variant 2)	- Easier fuel feed to gasifier than Variant 3 - Conventional gas cleaning equipment - Economically suited for modest size - Higher energy content fuel gas	- Waste water produced from gas cleaning system - Need fuel-gas compressor, but smaller than Variant 1 - Limited economically to modest size - Gasifier operation more challenging than Variant 1
High-pressure, air blown (Variant 3)	- Higher efficiency due to lack of gas compressor - Dry hot-gas cleanup system - Economically suited to larger scale than others	- More difficult fuel feed to gasifier than others - More challenging gas cleaning than others - Higher NO_x emissions than others - Limited economically to larger scale

Ref: Eric D. Larson et al. 2001

Real Application Case with Biogas- AE-T100B

Area: Europe , Country: Sweden,
Installation context: Waste Water Treatment Plant (WWTP),
Micro Turbine model: AE-T100B
Fuel: **biogas by anaerobic digestion** of the sewage sludge
Electrical Power: 100 kW – used by WWTP facilities
Thermal Power (hot water): 165 kW – used by anaerobic digesters of the sewage sludge

Investment Pay Back Period< 2 year

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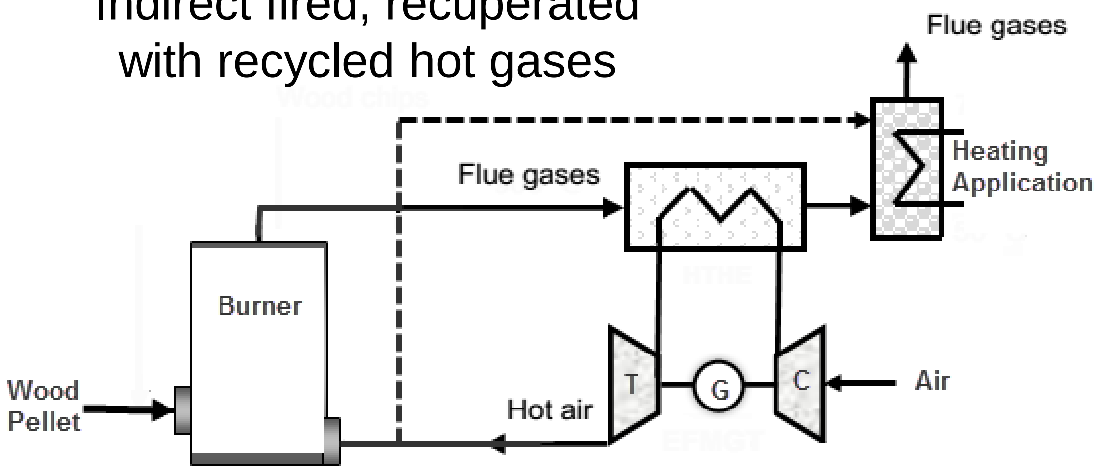
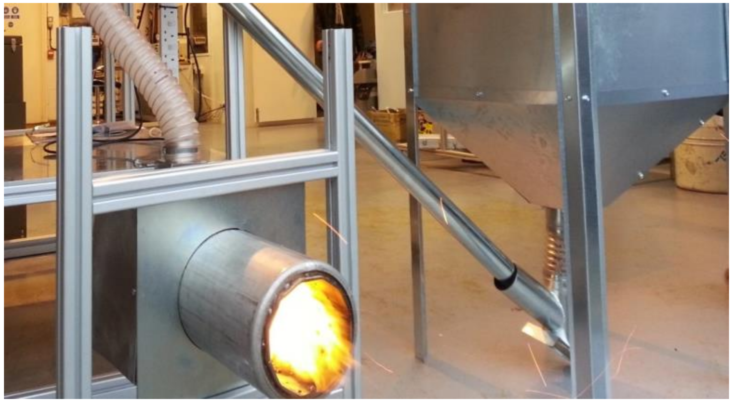
Biomass MGT Combustion Strategies:
2- Indirect Firing

Indirect fired, recuperated with recycled hot gases



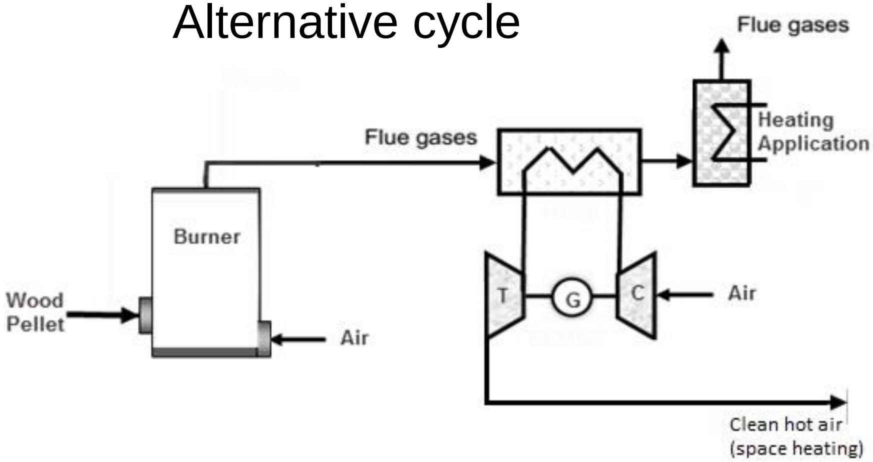
Project funded by Low Carbon KEEP (Cranfield University + Samad Power ltd.) - £83.5k

- Aspen plus process simulation completed
- Combustion system is designed
- Burner is commissioned
- Recuperator system tested
- Awaiting further funding for technology development



PellasX 70kW wood pellet burner

Alternative cycle



Biomass Fuelled Indirect Fired Micro Turbine

Main Challenges include:

- Commercially available high temperature heat exchanger materials and to determine their suitability for indirect firing.
- Addressing corrosion and deposition issues while burring biomass fuels
- Availability of economical small scale biomass feeding/gasification systems

Talbott's Heating Ltd Project funded by UKERC

Measured performance:

Combustion temperature testing range 900-1150 C
Turbine entry temperature testing range 700-850 C
Net electrical output testing range 18-35 kW
Heat exchanger efficiency 71%
Exhaust gas temperature 300-330 C (for CHP)
Compressor isentropic efficiency 62%
Turbine isentropic efficiency 80%
Overall efficiency 15%

Measured emissions:

CO 0.001 to 0.01 vol %
CO_2 7.4 to 7.5 vol %
NOx 2-10 ppm
Particulate emission 50 mg/m^3

Talbott's biomass boilers

Ref: http://ukerc.rl.ac.uk/pdf/DTI_BT1008090000_file14923.pdf

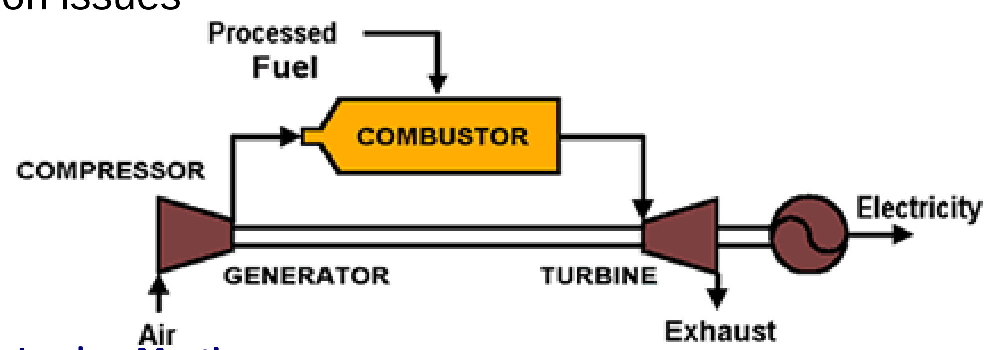
Biomass MGT Combustion Strategies:
3- Direct Firing

- High pressure solid fuel combustion
- Direct-fired in which the combustor exhaust gases form a pulverised fuel combustor can be fed in to a gas turbine.
- The wood fuel is fed through an air lock valve arrangement and transported with the primary air at a pressure of about 5 bar from the gas turbine compressor.
- Bioturbines Ltd, in the UK worked to exploit the technology, which the company claims, requires significantly lower capital cost and yields higher cycle efficiency, than competing technologies that involve gasification or steam-raising plant.
- Solid particulates erosion/deposition/corrosion issues over the turbine blades
- Commercially availability!

http://bioturbines.co.uk/linked/refocus.htm

ARITERM-Hakejet 60-300 kW

- designed primarily for burning wood chips.
- Its open, half-circle burning head
- makes the fire grate very durable and long-lasting
- Due to the ceramic burning chamber, the temperature of the flame can be raised sufficiently high and **the burning will be clean**



Renewable CHP – Government Incentives

Generating a source of income for your community from renewable CHP

Which Government incentives support renewable CHP

- Feed In Tariff: for the electricity generated by micro CHP
- Renewable Heat Incentive: for the heat generated by CHP using biomass, geothermal or biogas
- Renewables Obligation: for heat and electricity instead of the above. More complex, for large projects.

Visit the UK Government website for further information and updates
http://www.decc.gov.uk/

Concluding Remarks

- ✓ MGT systems can positively change the energy industry in the global level
- ✓ Biofuel MGT a viable and attactive technology
- ✓ The technology addresses the concern of global warming and emissions
- ✓ Smart grid and distributed power generation (higher efficiencies)
- ✓ Government supports including, Renewable Heat Incentive (RHI) and Feed-in Tariffs (FIT)
- ✓ Wide rang of applications
- ✓ Public need to be informed about the benefits of this technology
- ✓ Research funding required to accelerate the technology development/deployment

THANK YOU FOR YOUR ATTENTION