Forestry Commission

BIOMASS Energy Centre

Information Sheet No. 4
Combined heat and power (CHP)

Combined heat and power (CHP), or co-generation, is the simultaneous generation of usable heat and electricity. Conventional power generation plants usually dissipate the heat generated using cooling towers, wasting a considerable amount of energy. With CHP, this heat is used for domestic or industrial space heating or for process heat. Tri-generation also provides cooling using an absorption chiller.

Large scale (>2 MWe) biomass CHP usually uses conventional, steam turbine generating technology, but below this more exotic technology is required to achieve good efficiency. Many of these technologies are under active development and they cannot yet be expected to perform as commodity items.

A biomass CHP installation should always be considered and specified in terms of the thermal output, not electrical. It is considerably easier to import or export an imbalance in electricity via the National Grid than to dissipate excess heat. Heat generation will always accompany electricity generation and a suitable load will be required during all operation, including in summer. For this reason, an industrial application requiring process heat, or hotel or hospital is likely to be much more suitable than a purely domestic development. Small scale biomass electricity generation is a relatively low efficiency use for biomass, if the heat is not used profitably. Tri-generation may allow summer use for excess heat but is not currently well established.

Current small scale biomass CHP technologies

Above about 1-2 MW_e conventional superheated steam turbine technology can be used with reasonable efficiency. Alternatively, biomass gasification used with a gas turbine in a number of configurations may also be appropriate at high output levels. However, at lower output requirements neither of these options is suitable. Many of these technologies are under active development and cannot be viewed as mature, especially those at the smaller scale. This should always be remembered when considering such a system.

Organic Rankine Cycle (ORC)

Both reciprocating steam engines and steam turbine use the thermodynamic Rankine Cycle. At small scales this becomes very inefficient and expensive owing to the high temperatures and pressures required. It is possible to replace water as the working medium with an organic compound with a lower boiling point, such as a silicone oil, freon or organic solvent. This allows the system to work more efficiently at much lower temperatures, pressures and at smaller scale. As the working medium may be less corrosive to components such as turbine blades, superheating is no longer necessary and also the turbine can operate at a lower speed, potentially improving reliability.

Biomass CHP systems based on ORC technology are now commercially available from a number of manufacturers. Electrical outputs are typically in the range 300 kW_e–1.5 MW_e with thermal to electrical output typically around 5:1.

Internal combustion engine

Small scale biomass gasifiers exist that can convert biomass into a flammable product gas. Following suitable clean up and cooling, this can be used to run an internal combustion engine such as a gas or modified diesel or petrol engine.

Many commercial biomass CHP systems are available based on this technology, at scales from around 10 kW_e to 1 MW_e, and typically give heat to electrical output ratio of 2:1, even down to 1:1. Gasifiers are however inherently more complex than a simple combustion based system and there are a number of areas that can potentially give difficulties.

There are a number of different designs of gasifier, however the majority of systems for use with an internal combustion engine are of down-draft (fixed bed) design. These tend to produce low levels of tars, but they also tend to require a high degree of consistency in the fuel supply, and cannot readily be scaled up above about 1 MW_{th}. A fuel pre-processing unit of some kind can help ensure consistency, and can allow the use of a wide range of feedstock, including dried sewage sludge. Good gas clean up is critical to reliable operation of the engine, and this may include a particle filter and/or a cyclone as well as tar removal.

This tends to be the most widely available technology to meet biomass electricity generation needs at around 100 kW_e output levels.

Stirling engine

The Stirling engine is an external combustion engine, using differential expansion of the working gas (such as air, helium or hydrogen) in different regions of the engine drive the piston(s). As combustion is external and the system is sealed, contamination can be less of a problem than with an internal combustion engine, and maintenance accordingly eased.

Heat can be provided by direct combustion of biomass, or by combustion of product gas from a gasifier. Owing to the lower purity requirements for the gas in the latter option, an up-draft gasifier can be utilised, potentially easing the fuel supply constraints.

Stirling engines are available commercially with electrical output from 1 kW_e to about 75 kW_e. This is less well proven, more experimental technology than a conventional internal combustion engine, and they tend to be less efficient, giving a higher heat to electricity output ratio of 4:1 or greater.

Steam engine (reciprocating)

Although possibly viewed as rather old fashioned technology, a conventional reciprocating steam engine can be used for electricity generation at a range of scales. It offers robust, well proven technology, and commercial systems designed for woodfuel CHP applications are available.

Efficiencies tend to be low, however, with a thermal to electrical output ratio of perhaps 15:1, depending on the system and scale.

Gas micro-turbine

A gas micro-turbine can be driven either directly by flue gas, or by air indirectly heated via a heat exchanger. A compressor is required to raise the gas pressure to a suitable value, which requires significant power input.

There is a growing number of micro-turbine based biomass CHP systems in operation at present, however again this should be regarded as technology still under development. A relatively low heat to electrical output ratio of around 2:1 has been quoted by a manufacturer, suggesting good efficiency.

Some small scale (≤2 MW_e) biomass CHP systems

Adoratec GmbH, Germany
ORC systems 315–1,600 kW_e No current UK agent
www.adoratec.com

Alternative Energy Solutions (AES Energy), USA
Steam boilers plus steam turbines 400 kW_e – 8 MW_e+
www.aesenergy.net

Bioenergy Technology Ltd.
Steam boiler plus Spilling steam engine 50 kW_e
www.bioenergy.org

Bioflame Ltd.
Steam boiler plus steam turbine 1 MW_e+
www.bioflame.co.uk

Biomass CHP Ltd.
Downdraft gasifier plus IC engine 120 kW_e – 5 MW_e
www.biomasschp.co.uk

Biomass Engineering Ltd.
Downdraft gasifier coupled with gas engine 250 kW_e
www.biomass-uk.com

Entimos Oy, Finland
Gasifier plus gas or diesel engine, from 400 kW_eupwards
www.entimos.fi

Innovation Technologies (Ireland) Ltd.
Fluidyne downdraft gasifier plus gas/IC engine, 35 kWe+
www.innovation-tech.co.uk

KARA Energy Systems B.V., Netherlands
Gasifier plus gas engine 4 – 500 kW_e or steam turbine above
www.kara.nl

Kohlbach, Austria
ORC based systems 200 – 1,600 kW_e
or steam turbine
www.kohlbach.at

Puhdas Energia Oy, Finland
Retrofit wood gasifier for oil boilers, available in units of 1MW_{th}

Mawera UK Ltd.
Biomass boilers plus Stirling (35 or 70 kW_e), ORC (300–1,500 kW_e), or steam turbine (100–2,500 kW_e) www.mawera.co.uk

Sunmachine GmbH, Germany

1.5-3 kWe Stirling engine running on wood pellets; 4.5-10.5 kW_{th}
www.sunmachine.com

Stirling Denmark ApS, Denmark
Updraft gasifier plus Stirling engine 35 & 75 kW_e
www.stirling.dk

Talbott's
Stepped grate combustion plus indirect micro-turbine 100 kW_e
www.talbotts.co.uk

TK Energi AS Denmark
Gasifier plus IC engine
www.tke.dk

Turboden, Italy
(ORC) turbines 200 – 2,000 kW_e
www.turboden.it

Wartsila Biopower Oy Finland
Rotating grate boiler plus steam turbine 1.1 MW_e+
www.wartsila.com

Waste to Energy Ltd.
Gasifier technology 10 kW_e -1 MW_e or multiple units
www.wastetoenergy.co.uk

Information Sheet 4
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General information

(Some web sites contain details of case studies)

Combined Heat and Power Association
Promotes use of CHP and community heating
www.chpa.co.uk

European Bio-CHP
Examples of CHP plants in Europe
www.dk-teknik.dk/cms/site.asp?p=1042

Irish CHP Association
Representative body for CHP in Ireland, North and Republic
www.ichpa.com/index.php

DECC
Department for Energy and Climate Change
www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/emerging_tech/chp/chp.aspx

Cogen Europe
The European Association for the Promotion of CHP
www.cogeneurope.eu/

Renewable Energy Association
General information on renewable energy
www.r-e-a.net/