Department for
Business, Energy
& Industrial Strategy

CHP
FOCUS

COMBINED HEAT AND POWER – ADDITIONAL GUIDANCE FOR RENEWABLE CHP

A detailed guide for CHP developers – Part 6

April 2020

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1. Introduction

Implementing Combined Heat & Power (CHP) greatly increases the overall efficiency of power generation processes by recovering and using heat that would otherwise be wasted. These efficiency gains can result in fossil-fuel fired CHP saving significant carbon emissions over standalone fossil-fuel power generation and fossil-fuel heat generation. Renewable CHP has even greater potential for carbon savings, by using a low or zero-carbon fuel. As such, government policies that support renewable CHP have been put in place to stimulate its uptake.

Government support for renewable CHP has increased the number of such schemes and has diversified the range of CHP prime movers in use. Notably, in recent years and largely due the Renewable Heat Incentive (RHI), there has been an increase in CHP schemes using Organic Rankine Cycle (ORC) systems and steam screw expanders as the prime mover. These technologies are typically coupled with solid biomass boilers that generate heat (in the form of hot water or steam) which is used to induce mechanical motion in the prime mover.

The existing developer guides provide guidance on a range of renewable CHP considerations. The content covers all renewable fuel types and a range of renewable technologies such as Anaerobic Digestion (AD), gasification, biomass combustion, gas engines, gas turbines and steam turbines. This guide has been developed to complement the existing guidance and provide additional information to suit the recent developments in renewable CHP. The content in this guide focusses on CHP schemes that use ORC and steam screw expander technologies.

2. Technologies

Organic Rankine Cycle (ORC) systems and steam screw expanders were first developed as power-only generation technologies. They were designed to make use of low to medium-grade waste heat, which would otherwise be wasted, to generate useful electricity. The extension of the Renewable Heat Incentive (RHI) in 2016[1], to provide an enhanced tariff for renewable CHP, has encouraged the use of these technologies in a CHP operational mode, such that the low-grade heat from the output side is recovered and utilised.

The electrical efficiencies achieved by ORC systems and steam screw expanders are significantly lower than that of other prime movers, however, they can make use of heat streams that may otherwise be wasted.

2.1. Fuels

Bioenergy has the potential to be carbon-neutral, as the carbon released from combustion of the fuel was absorbed via photosynthesis during the growth of the plant. However, there are net carbon emissions associated with the use of bioenergy that arise from its cultivation, processing and transport. The net carbon emissions are highly dependent on the type of fuel used; however, they are likely to be significantly lower than any fossil-fuel alternative. The fuels must be obtained from sustainable biomass sources or recovered from waste material arising from business operations to be considered renewable.

There are three core categories of renewable fuel:

- **Solid biomass** – including sustainably sourced wood fuels, energy crops and organic material processing waste and residues.
- **Liquid biofuel** – including bioethanol and biodiesel.
- **Gaseous biofuel** – including biogas and synthesis gas.

See Section 4 of the accompanying CHP Technology guide for further guidance on renewable fuel types.

[1] The RHI will close to new entrants from 31 March 2021.

2.2. Fuel conversion

Liquid and gaseous biofuels may be combusted directly in prime movers such as gas turbines and reciprocating engines. Solid biomass however, with its inherently bulky nature, must first be converted into a secondary fuel before direct combustion in a prime mover. Two well established conversion processes include:

- Anaerobic digestion to produce biogas.
- Gasification/pyrolysis to produce syngas.

Solid biomass materials can also be combusted to generate heat in the form of steam, hot water or thermal oil, which can then supply energy to a prime mover – such as steam to a steam turbine. ORC systems and steam screw expanders similarly use such heat energy to produce mechanical power to drive an electrical generator. In a CHP system, they are therefore coupled with a boiler that combusts a fuel for conversion to heat. Such systems can utilise any fuel type, as long as it is compatible with the boiler, though using solid biomass is common.

Section 4 of the CHP Technology guide provides further guidance on biomass fuel conversion technologies.

2.3. Prime movers

The prime mover of a CHP plant is the main component that generates mechanical power from the input energy, which in turn usually drives an electrical generator. The most commonly thought of example is a reciprocating engine, that uses the pressure build ups from a series of combustion reactions to force the movement of pistons.

ORC systems and steam screw expanders involve no direct combustion and instead utilise heat (typically generated from combustion) to produce mechanical power to drive an electrical generator. There are a wide range of possible applications for these systems, including:

- Industrial waste heat recovery
- Industrial drying applications
- Agricultural drying applications

More detail on other prime movers such as reciprocating engines, gas turbines and steam turbines can be found in Section 2 and 3 of the accompanying CHP Technology guide.

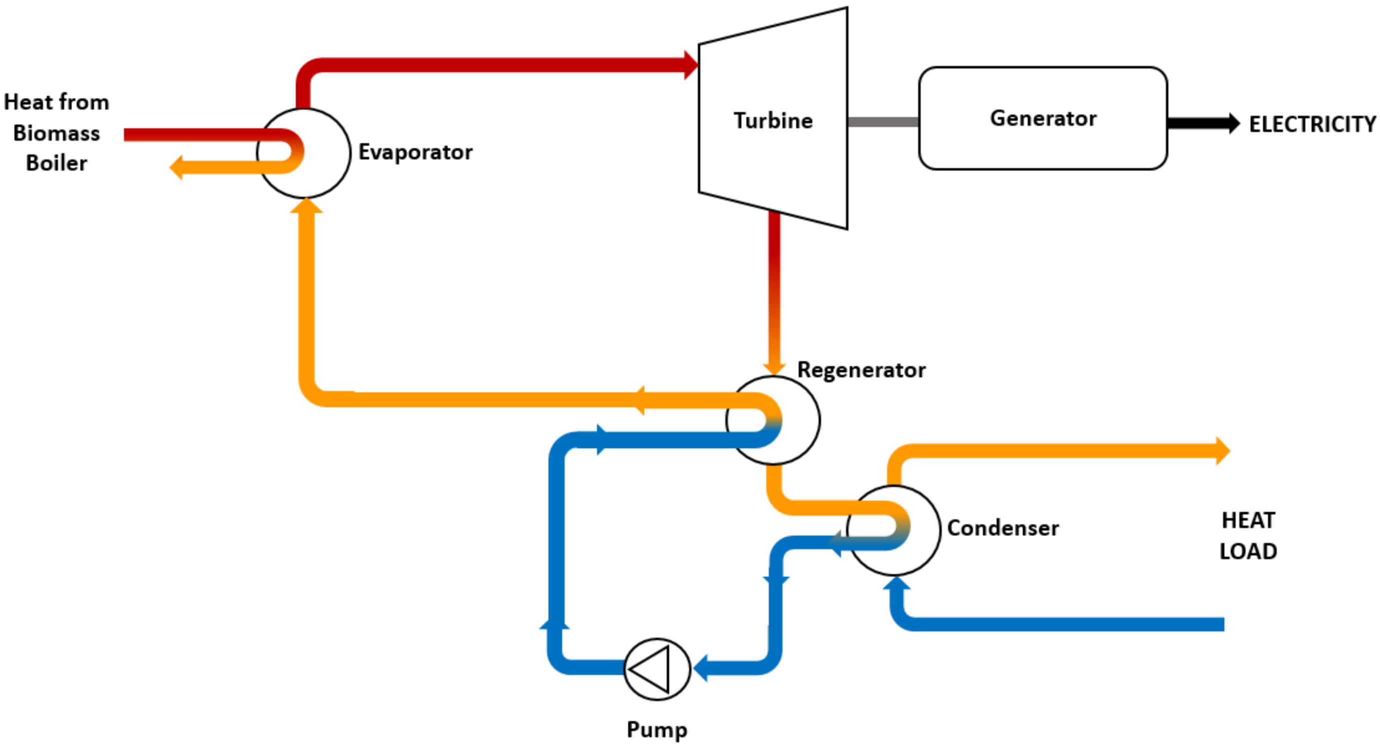
2.3.1. Organic Rankine Cycle (ORC) systems

The ORC uses the same working principle (the Rankine cycle) as the steam cycle in conventional power generating stations. In such power stations, the working fluid is water, which is evaporated to steam (using heat from combustion); the steam is then allowed to expand through a turbine, inducing rotation in the turbine and the electrical generator to which it is connected. An ORC operates similarly but uses an "organic" working fluid that has a lower boiling point and a higher vapour pressure than water. This allows the ORC plant to operate on lower temperature heat sources. Organic fluids are chosen that best fit the temperature provided by the heat source to maximise system efficiency.

ORCs are well suited to biomass heated applications and systems are typically available in electrical capacities from 50kWe to 2MWe. Electrical efficiencies are low in comparison to other prime movers, typically between 5%-20%, and heat-to-power ratios are high, typically 5:1 and above.

Heat from a biomass boiler is transferred to the ORC working fluid via a heat exchanger, often referred to as the evaporator. The evaporating working fluid expands and builds pressure that drives the turbine coupled to the generator. The fluid is then channelled to a condenser where heat can be recovered for other processes and returned to a liquid state. The liquid passes through a pump where it is pressurised ready for the evaporator to complete the cycle once again. A diagram of this process is shown in Figure 1.

Figure 1: Organic Rankine Cycle (ORC) working principle



ORCs are designed to operate at lower temperatures than conventional steam cycles. Feed fluids vary between 80°C and 120°C and return temperatures are within 50°C and 100°C. Temperature differentials can vary between 15°C and 50°C dependant on the design. The higher the temperature differential, the higher the system efficiency.

For ORC systems using certain working fluids, a regenerator may be included between the turbine and condenser and between the pump and evaporator (see Figure 1). Gas to fluid heat exchangers lower the heat of the gas prior to condensation and increase the heat of the liquid before evaporation, thereby increasing system efficiency.

Advantages	**Disadvantages**
Ability to utilise low-grade heat between 80-120^{o}C.	Low electrical efficiency (5-20%).
Available in small electrical capacities down to 50kWe.	Some working fluids are combustible or environmentally hazardous.
Ability to working with a variety of feed fluids (hot water, steam or oil).	Working fluids are more expensive than water.

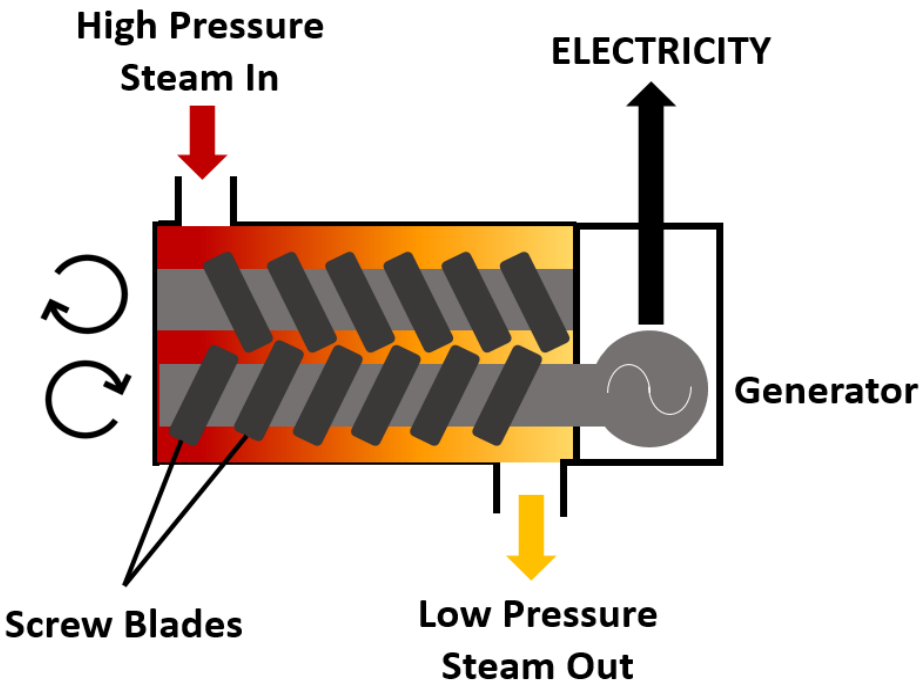
2.3.2. Steam screw expanders

Steam screw expanders are generators that convert heat to electricity using the expansion of steam to rotate a mechanism that is similar to a screw compressor but operating in reverse. They are typically sized between 70kWe and 700kWe and have electrical efficiencies of less than 10%, which is comparably lower than other CHP prime movers. Subsequently, the heat-to-power ratios are high, typically 10:1 and above.

The key difference in the technology from traditional steam turbines is that they are designed to operate on medium-grade energy in the form of saturated steam. Saturated steam contains water droplets which cause detrimental erosion to steam turbine blades.

Steam with a gauge pressure of up to 25MPa (25 bar) is fed from a boiler to provide a force to turn twin-rotor screws within the unit that drive a generator to produce electricity (see Figure 2). The saturated steam creates a seal between the two rotor screws to block fugitive steam from escaping through gaps between the screws. The low-pressure exhaust steam can be used to supply useful heat where there is a demand.

Figure 2: Steam screw expander working principle



Advantages	Disadvantages
Ability to utilise medium-grade waste heat and saturated steam.	Low electrical efficiency (<10%).
Working fluid is water/steam.	Limited number of technology suppliers.
Available in small electrical capacities down to 70kWe.	
Lower mechanical complexity compared to steam turbines (fewer parts).	
Accepts fluctuating steam mass flow rates.	

3. Project development considerations

There are many project development considerations specific to renewable CHP which are not required for conventional fossil-fuel schemes. In the accompanying Project Development guide, many of these additional considerations have been detailed including: fuel supply security, conversion of fuel and delivery of fuels. The points discussed below focus on considerations specific to CHP schemes utilising ORCs and steam screw expanders.

3.1. Technical characteristics

The technical characteristics of ORC systems and steam screw expanders differ greatly from other conventional prime movers. As discussed in the technology section above, the renewable fuel must be first be converted into useful heat to drive the prime mover.

The key benefit of ORC systems and steam screw expanders is that they can utilise low to medium-grade heat to generate useful electrical power. Whereas steam turbines for instance, do not operate as well with low-grade heat and instead require steam at comparatively higher temperatures and pressures in order to generate electricity. ORC systems and steam expanders therefore present the opportunity to exploit industrial process waste heat sources which are typically low to medium-grade.

There are, however, thermodynamic limitations in utilising low-grade heat, which results in comparatively lower power efficiencies being achieved. Subsequently, ORC systems and steam expanders have high heat-to-power ratios compared to other prime mover technologies and thus better suited to sites with higher demands for heat than for power. The lower power efficiencies and higher heat-to-power ratios of ORCs and steam screw expanders need to be factored in the feasibility stage to ensure that the selected technology suits the site's requirements.

3.2. Procurement

The market for ORC and steam screw expanders is relatively small compared to fossil-fuel CHP technologies; there are a limited number of technology providers, but this has been increasing in recent years. The supply chain is still developing and there are a limited number of suppliers. Consequently, the procurement risks of such technologies need to be carefully considered, including:

- How well established are the potential suppliers?
- Will the plant be available in the expected timeframe of the project?
- How effectively can suppliers provide after-sales support?

3.3. Environmental permissions

CHP schemes that use a waste[2] feedstock may benefit financially from low fuel costs and the avoidance of waste disposal costs such as landfill gate fees. However, it must be determined whether there are any environmental regulations in place that either restrict, or place rules on the use of the waste feedstock. Where necessary, any environmental permissions will need to be obtained. Normally, the combustion of waste will require an environmental permit or an exemption from holding such a permit.

Irrespective of fuel, the Medium Combustion Plant Directive (MCDP) places requirements on installations with a capacity more than or equal to 1MW and less then 50MW rated thermal input.

3.4. Government incentives

The market for renewable CHP is still developing, therefore the cost of the technologies has not yet benefitted from the economies of scale that conventional CHP technologies have experienced. Some renewable CHP schemes are therefore dependent on government support to remain economically viable. It should be considered at feasibility stage whether any financial support can be gained and any developments in government policies should be monitored.

The incentive scheme may stipulate metering requirements (for fuel, heat or power) such as the accuracy, or class type of the meters used. The meters must be positioned to measure the relevant energy flows as required by the incentive scheme.

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2 Article 3(1) of the European Commission Waste Framework Directive (2008/98/EC) defines waste as: ‘waste’ means any substance or object which the holder discards or intends or is required to discard. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

4. Financial Incentives

There are three key UK Government financial incentives which are specific to renewable CHP:

- Renewable Heat Incentive (RHI)
- Renewables Obligations (RO/ROCs)
- Contracts for Difference (CfD)

The sections below provide detail on the above measures including their background, how the financial mechanisms work and how to claim. Details of the full set of incentives available to CHP (including those that are fossil-fuelled) are available on the combined heat and power incentives webpage.

4.1 Renewable Heat Incentive (RHI)

The Renewable Heat Incentive (RHI) was launched in November 2011, with the aim of stimulating the renewable heating market and increase deployment of such technologies in the UK. The RHI is split into two schemes: Domestic and Non-domestic. Support for renewable CHP is only available under the Non-domestic RHI. The Non-domestic RHI is due to close 31 March 2021, however, those already accredited will continue to receive the tariff payments for the full lifetime of support (20 years).

Renewable CHP can gain a fixed tariff for 20 years (on a pence per kWh basis) for heat that is recovered from the prime mover. The heat must be used for what is deemed as an ‘eligible’ purpose, which can be either: space heating, domestic hot water or heat used for a process. Heat that is used for wood fuel drying, digestate drying, waste drying or processing, and for domestic swimming pools on non-domestic premises were removed as eligible uses from 22 May 2018 onwards. The eligible heat recovered from the prime mover must be measured by compliant metering equipment in order to make a claim for RHI.

Solid biomass CHP installations with a date of accreditation on or after 1 August 2016 will have their CHP tariff scaled back if their CHPQA power efficiency does not meet a threshold of 20%. See Chapter 14 in the Non-domestic RHI Guidance vol. 2 for more information on this scale back mechanism.

Further details on the requirements for renewable CHP eligibility in order to claim for RHI and its interaction with the CHPQA programme can be found on the Ofgem website.

How to claim

The Non-domestic RHI scheme is due to close on 31 March 2021. Applicants should first determine whether they believe their plant and use of heat will be eligible. Following this, an account must be created with the Non-Domestic Renewable Heat Incentive (RHI) Register. Solid biomass CHP schemes must first gain certification under CHPQA to be eligible for accreditation under the RHI. For such schemes, the CHPQA certificate will require annual renewal via ongoing submission to CHPQA.

Support for those who need help or can't apply online can be gained via:

Email: rhi.enquiry@ofgem.gov.uk

Phone: 0300 003 2289

Monday to Thursday, 9am to 5pm, Friday, 9am to 4:30pm

4.2. Renewables Obligations (RO/ROCs)

The Renewables Obligation (RO) was launched in 2002 to provide an incentive for the deployment of large-scale renewable electricity in the UK. The RO closed to new generators on 31 March 2017, however, electricity generation that was accredited before this date will continue to receive support for its full lifetime (20 years) until the scheme closes in 2037.

The RO enforces licensed UK electricity suppliers to source a specified proportion of the electricity they provide to customers from eligible renewable sources. The required proportion is known as the supplier's 'obligation', which is set each year and increases annually. Suppliers are required to provide evidence of their compliance with the obligation with Renewable Obligation Certificates (ROCs). A single ROC represents 1MWhe of electricity generated from eligible renewable sources.

Eligible renewable generators multiply the amount of electricity they generate by a multiplier known as the RO band. The RO banding varies for different renewable technologies and an enhanced banding (known as the CHP uplift) is given to generators that are CHP (as opposed to the power only alternatives). See the RO banding list for all technologies.

How to claim

The RO closed to new generators from 31 March 2017. For biomass CHP schemes commissioned before this date receiving the CHP uplift via the CHPQA GN44 certificate, they are required to be certified by CHPQA for the duration of the incentive (up to 2037).

The CHPQA Guidance Note 44 provides details on how to use CHPQA to obtain RO incentive for renewable CHP electrical output.

Where a CHPQA GN44 'ROC eligible' certificate has been issued (thus able to claim the CHP 'ROC Uplift'), participants are ineligible to claim support on the heat output under the RHI.

For questions relating to the administration of the RO, you may contact Ofgem's renewables team:

Email: renewable@ofgem.gov.uk

Phone: 020 7901 7310

4.3. Contracts for Difference (CfD)

The Contracts for Difference (CfD) scheme is a mechanism that supports low carbon electricity generation. It came into effect in August 2014 and was introduced as the replacement for the Renewables Obligation (RO), which is now closed to new capacity. The scheme protects generators from volatile wholesale electricity prices by guaranteeing a 'strike price' of electricity over a 15-year period.

CHP schemes that successfully acquire a CfD will enter into a private law contract with the Low Carbon Contracts (LCCC), a government owned company. The generator will have an agreed electricity 'strike price' across the duration of the contract and this strike price reflects for the cost of investing in that low carbon technology. Then there is the 'reference price', which reflects the average market price of electricity. The LCCC pays the generator the difference between the strike price and the reference price. This difference will fluctuate due to the volatile nature of the electricity market. Should the reference price exceed the strike price, the generator must pay the difference to the LCCC.

How to claim

CfDs are awarded competitively to the best value projects via an allocation round process. Three rounds of CfD allocations have taken place from 2014 to 2020, the next is due in 2021.

Support under the CfD will be paid only on the proportion of metered electrical output assessed by CHPQA scheme to be "Good Quality". The generator must be certified with CHPQA to obtain a Guidance Note 44 (GN44) certificate which will detail the proportion of electrical output deemed to be Good Quality. The certificate will require renewal via annual submission to CHPQA.

Energy from waste CHP (EfW CHP) schemes are ineligible to apply for CfDs if they have also applied for support under the RHI, as the CFD strike prices for EfW CHP are based on both the power and heat component supplied (unlike those for biomass CHP schemes that are based on ‘power only’). For each Allocation Round, an Allocation Framework document is published by BEIS, which specifies, inter alia, any supplemental requirements on particular generation types and any generation types excluded from that round.

For questions relating you CfDs, you may contact the LCCC:

Email: info@lowcarboncontracts.uk

Phone: 0207 211 8881

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www.gov.uk/beis