Biomass CHP

Implementation Guide

Biomass CHP

Implementation Guide

September 2020

Sustainable Energy Authority of Ireland
SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with Government, homeowners, businesses and communities to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

SEAI is funded by the Government of Ireland through the Department of Communications, Climate Action and Environment.

Report prepared for SEAI by:
Ricardo Energy & Environment

Table of Contents

1. Introduction

Ireland has a long-term vision for a low-carbon energy system. It aims at reducing greenhouse gas emissions from the energy sector by between 80% and 90% (compared with 1990 levels) before 2050. Achieving this target will require a radical transformation of Ireland's energy system, a reduction in energy demand, and a move away from fossil fuels to zero- or low-carbon fuels and energy sources.

Biomass combined heat and power (CHP), as a renewable energy source, is counted towards Ireland's renewable energy targets.[1] In 2018, the operational biomass CHP capacity in Ireland was 5.4MWe (1.7% of the total 348MWe total CHP capacity) with support provided through the Government's Renewable Energy Feed-in Tariff (REFIT) schemes.[2]

In conventional electricity generation, a large proportion of the primary (input) energy is lost to the atmosphere. CHP systems channel this lost heat to useful purposes so that usable heat and power are generated in a single process. The efficiency of a CHP system can typically be 20% to 25% higher than the combined efficiency of heat-only boilers and conventional power stations. A CHP system can achieve overall (electrical and heat) efficiencies of 80%. A biomass-fuelled CHP system where the biofuel has been sourced sustainably can offer the additional benefit of reducing carbon emissions by almost 100% when compared to a traditional fossil-fuel-fired CHP system (provided the biofuel has been sourced sustainably). As an example, a biomass CHP installation with an electrical efficiency of 25% and a heat efficiency (based on useful heat demand) of 50% can provide primary energy savings (PES) – as defined in the Energy Efficiency Directive (EED) (Directive 2012/27/EU on energy efficiency)[3] – of 20.5% (in comparison to a heat-only biomass boiler and a biomass power station).[4]

Therefore, biomass CHP systems offer a great opportunity for helping Ireland achieve primary energy savings. These systems differ significantly from CHP systems fired on natural gas. To ensure a well-functioning, safe and efficient biomass CHP system, these differences need to be properly addressed in planning, design and operation.

The guidance presented in this Implementation Guide and the accompanying Technology, and Operation & Maintenance Guides is intended as a comprehensive starting point for readers wishing to gain a better understanding of the biomass CHP technology, its implementation and ongoing management. The guidance presented here focuses on biomass conversion and biomass CHP technologies. Details on biomass feedstocks can be found in the accompanying set of biomass boiler guides available on the SEAI website.

1.1 The Support Scheme for Renewable Heat

The Support Scheme for Renewable Heat is a Government-funded scheme, to encourage the installation of renewable sources of heat in non-domestic applications in the Republic of Ireland. These guidelines will help applicants identify the appropriate standards and best practice required for the Support Scheme for Renewable Heat and other relevant schemes. These guidelines provide applicants with guidance on good practice only. The Terms & Conditions, the Grant Scheme Operating Rules, Guidelines and the Tariff Scheme Operating Rules, where relevant, set out the basis on which the Support Scheme for Renewable Heat will operate.

1 https://www.seai.ie/resources/publications/CHP-Update-2018.pdf

2 The Renewable Energy Feed-in Tariff closed for new applications in December 2015.

3 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN

4 See the Commission Delegated Regulation EU 2015/2402 on harmonised efficiency reference values for separate production of electricity and heat for further details.

1.2 Purpose of this guide

This Implementation Guide is principally intended for site or facility owners who are considering installing a biomass CHP system. It has two principal aims:

- **To provide the reader with a sound appreciation of good practice in implementing biomass CHP systems.** It is assumed that the reader has already considered different options appraisal for heat and power provision, and has decided to investigate biomass further (see Section 3.9 for details of such an initial financial assessment).
- **To direct the reader to sources of more detailed information on specific aspects of the technology**. This guide and its two companion guides do not seek to duplicate existing publications on biomass CHP systems; rather, they are intended as a comprehensive starting point for those wishing to better understand the technology, and its implementation and management.

1.3 Scope

The biomass CHP guides concentrate on solid biomass CHP systems for non-domestic premises in the installed power capacity range of 20kWe to 2MWe. However, much of this guidance will also apply to smaller and larger scale systems. The guides cover combustion-based and gasification-based solid biomass CHP technologies that are available on the market.

The distribution of heat from a CHP system focuses on hot water systems for non-domestic space heating, water heating and process heating. Steam and thermal oil systems can be used where higher temperatures are required. Direct-air heating systems are not covered in this set of biomass CHP guides. Certain systems are designed to provide cooling as well as heat and power. These are known as combined cooling, heat and power (CCHP) systems – sometimes referred to as trigeneration systems. However, they are more common for larger scale biomass CHP systems. While trigeneration is mentioned in these guides, it is not discussed in detail.

Regarding fuels used in biomass CHP systems, the guides focus on wood (virgin and waste), mainly in the form of pellets and chips as these are the most commonly used. Other less common fuels include straw, chicken litter (agricultural residues), and energy crops such as short rotation coppiced (SRC) willow and miscanthus (elephant grass).There is also an accompanying set of guides available on the production and use of biogas from an anaerobic digestion plant.

2. Overview

This section provides an overview of biomass CHP technologies (further details in the accompanying Technology Guide). The first steps and considerations needed prior to implementing and developing a biomass CHP system are also discussed.

2.1 Commercial biomass CHP technologies

Biomass CHP systems consist mainly of a biomass conversion technology and a prime mover. The discussion in this Guide and the accompanying Technology, and Operation & Maintenance Guides centres on **solid** biomass conversion technologies rather than liquid and gaseous biomass.

Biomass conversion technologies involve converting biomass into energy that will be used in a prime mover to generate heat and power. The three main categories of biomass conversion technologies are combustion, gasification and anaerobic digestion. This guide and the accompanying Technology, and Operation & Maintenance Guides on biomass CHP focus on solid biomass combustion and gasification systems. Anaerobic digestion systems are covered in detail in an accompanying set of guides available on the SEAI website.

Prime mover technologies convert the energy from the biomass conversion technologies into mechanical motion to drive a generator, which produces electrical power.

In biomass combustion systems, heat energy (in the form of steam or organic working fluid) is used to drive a steam turbine, a screw-type steam expander or an Organic Rankine Cycle (ORC) type system.

Biomass gasification systems produce a gaseous fuel (syngas, consisting mainly of hydrogen and carbon monoxide) that is then combusted in a reciprocating engine. Combustion and gasification biomass CHP systems are available as packaged and custom-made systems.

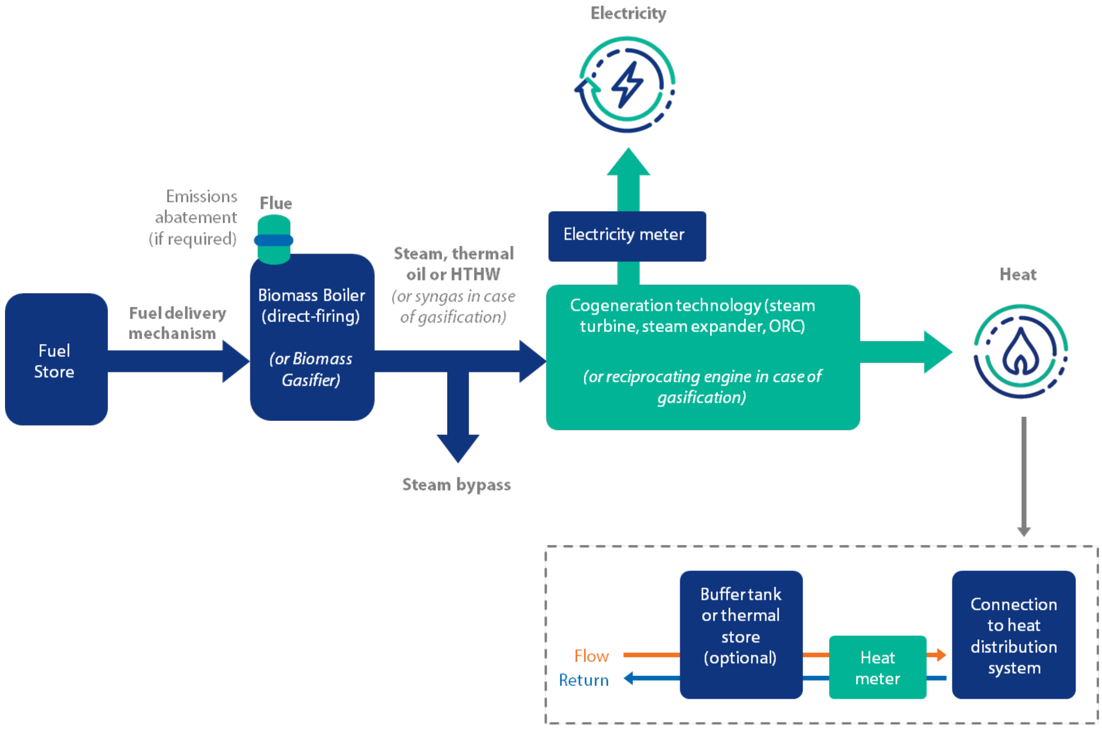
Combustion-based biomass CHP systems with a steam turbine as the prime mover are the most established. These typically have generation capacities greater than 0.5MWe. In recent years, Organic Rankine Cycles and screw-type expanders have also become very common on a smaller scale. Organic Rankine Cycle systems, which typically have sizes in the range 0.05kWe-2MWe, can use high temperature hot water (HTHW), hot clean exhaust gas or thermal oil for power generation. Screw-type expanders can be up to 0.75MWe and can use steam or low temperature hot water (LTHW) in the prime mover for power generation. See *Table 1* for further details.

Table 1: Commercially available biomass CHP technologies

Biomass conversion technology	Combustion (direct-firing)			Gasification
Typical range of capacity	Over 0.5MWe	0.05MWe-2MWe	0.05MWe-0.75MWe	0.02MWe-0.15MWe
Input to prime mover for power and heat generation	Steam	Steam, HTHW and thermal oil	Steam and LTHW	Syngas
Prime mover for power generation technology	Steam turbine	Organic Rankine Cycle	Screw-type steam expander	Reciprocating syngas engines

Figure 2.1 shows a simplified biomass CHP system. Biomass fuel is delivered from the fuel store to the boiler (or gasifier) where it is converted to steam or high temperature hot water (in the case of combustion boilers) or to syngas at very high temperatures (in the case of gasification). In the case of Organic Rankine Cycle systems, heat from the biomass boiler is passed via steam, thermal oil or high temperature hot water through a heat exchanger to another working fluid for use in an Organic Rankine Cycle unit to generate heat and power. In the case of steam turbines and steam expanders, steam can be used directly in the prime mover. For gasification systems, the resulting gas is first treated and conditioned before it is admitted to a gas engine for power and heat generation.

Figure 2.1: Typical biomass CHP system components



Details on prime movers for power and heat generation and energy conversion technologies (combustion versus gasification) is provided in the accompanying biomass CHP Technology Guide.

A biomass CHP system is more complex than an equivalent fossil fuel-based CHP system. In a gas-fired CHP system, the natural gas can be combusted directly in a reciprocating engine or a gas turbine. No boilers or gasifiers are required, which simplifies the design and operation of such systems significantly and reduces costs. In a gasification biomass CHP system, the syngas needs to be treated before it is combusted in a syngas engine.

Biomass CHP systems require a large physical space for the fuel delivery, storage supply area; the boiler or gasifier; and the buffer tank (if applicable). Biomass systems also have greater maintenance requirements in comparison to those for gas systems and they need an ash disposal system. In comparison to traditional fossil-fuel-based boilers (e.g. gas, oil or coal), a biomass boiler system needs to be designed differently. The design has to take into account the particular characteristics of the boiler itself, including a slower response time than oil or gas boilers and a smaller turndown ratio.[5] These issues, and ways of addressing them, are described in the accompanying Technology Guide.

5 The turndown ratio of a boiler is a measure of its ability to operate at heat outputs less than the full rated output. It is the ratio of the maximum heat output to the minimum level of heat output at which the boiler will operate efficiently or controllably. For example, a boiler with 2:1 turndown ratio will be able to operate down to 50% of its full rated output.

2.1.1 Biomass CHP prime movers

Biomass CHP prime movers can be steam turbines, steam screw expanders and Organic Rankine Cycles for combustion-based systems or reciprocating engines for a gasification-based system. The typical characteristics of these technologies is shown in *Table 2* below.

The heat-to-power ratio is one of the key parameters for selecting the type of CHP prime mover and is defined as the ratio of the maximum heat that can be generated by the prime mover to the electrical energy generated. Different types of cogeneration systems will have different designs and abilities to simultaneously recover waste heat while generating power. Steam turbine-based systems offer a wide range of heat-to-power ratios. While a gas engine has a fixed heat-to-power ratio, steam turbine systems can have a variable heat-to-power ratio (i.e. the maximum heat which can be recovered increases as power output increase) as detailed in Table 2.

As the heat-to-power ratio needed varies by site, the prime mover should be carefully selected to match demand on site. A plant may be set up to provide part or all of a site's heat and electricity demand or an excess of either may be exported to suitable customers.

Table 2: Typical characteristics of CHP prime movers

Prime mover	Electrical output range	Biomass fuels	Heat-to-power ratio	Grade of heat output	Electrical efficiencies
Steam turbine (back pressure)	Over 0.5MWe	Any, used to produce steam	3-10	Medium	10%-20%
Steam turbine (pass out/condensing)	Over 2MWe		3-10	Low	10%-20%
Steam screw expanders	0.05MWe-0.75MWe		10	Low	Low efficiencies (less than 12%)
Organic Rankine Cycle	0.05MWe-2MWe	Any, used to heat working fluid	5	Low	5%-20%
Gas engine	0.02MWe-0.15MWe	Biogas (from gasification)	1-1.7	Low to high	25%-40%

2.2 Implementation of a biomass CHP system

The key steps needed to successfully evaluate and develop a biomass CHP system are described in this guide. Further information on how to operate the system efficiently and safely is given in the accompanying Operation & Maintenance Guide.

Two important considerations to be taken into account prior to undertaking a project feasibility study are engaging with stakeholders and ensuring that energy efficiency measures have been explored and implemented.

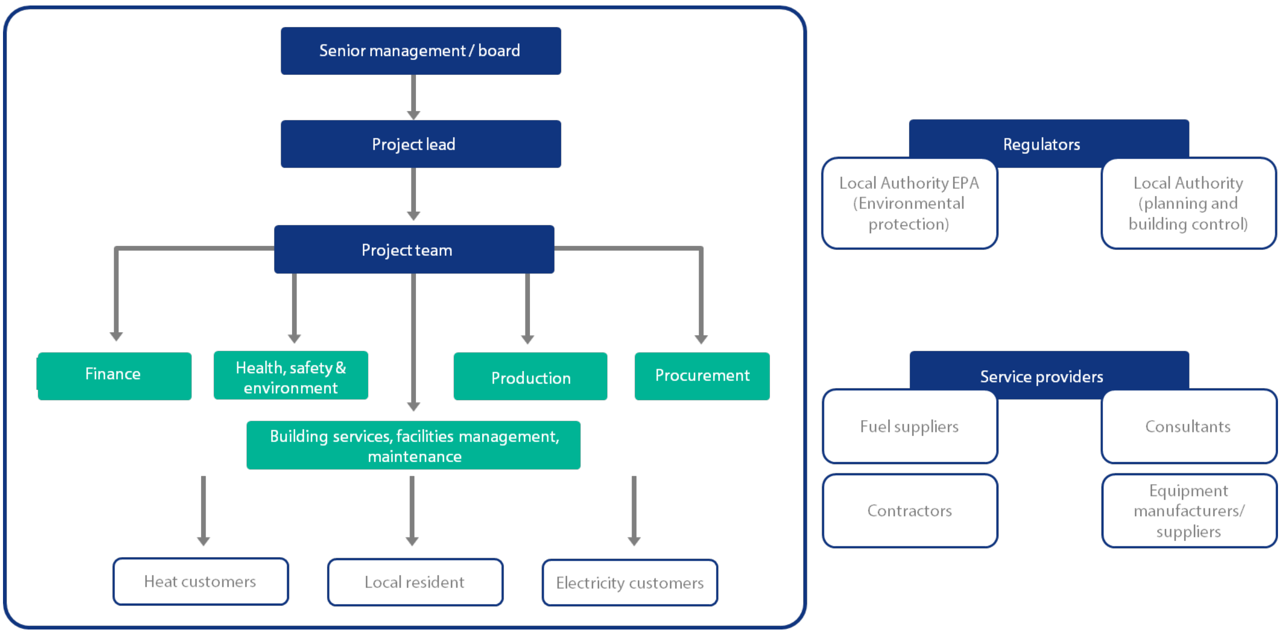
2.2.1 Communications plan

It is crucial to identify key stakeholders and liaise with the key parties involved at an early stage. *Figure 2.2* provides a summary of the stakeholders that developers need to work with as part of the process.

The first step in developing a CHP project is to produce a stakeholder communications plan, the following areas should be considered:

- Identify all the internal parties who will need to be involved and/or informed about the prospective project (for example the local fire services), enabling them to understand the implications for their areas of responsibility and opportunities to raise ideas or concerns.
- Contact relevant regulatory and planning authorities should be made at an early stage. This will help provide clarity to the project team on what requirements will need to be met and whether there is any current or future legislation that may affect the project.
- Involve prospective customers in discussions from the initial stages if supplying heat to external customers is likely to be a key aspect of the project. Electricity connection should also be discussed with the relevant stakeholders at an early stage.
- Early engagement with biomass suppliers and CHP service industries will also be valuable in providing the project team with information and in exploring the options for the feasibility, detailed design, construction, operation and maintenance stages of the project. Depending on the scale and location of the project, consult nearby residents and other businesses.
- As well as identifying the various parties, the communication plan should identify the nature and timing of communications, and who in the project team is responsible for each.

Figure 2.2: Internal and external stakeholders involved in the development of a biomass CHP system



2.2.2 Energy efficiency first

Another early step when designing a biomass CHP system is to qualify and quantify on-site electricity and heat demands. It is strongly recommended that all viable actions to minimise heat and power demand are undertaken before installing a biomass CHP or other low carbon system (see Section 2.2.2.1). Assistance in improving energy efficiency may be available through certain SEAI programmes. One such programme is SEAI EXEED (Excellence in Energy Efficiency Design.

SEAI EXEED

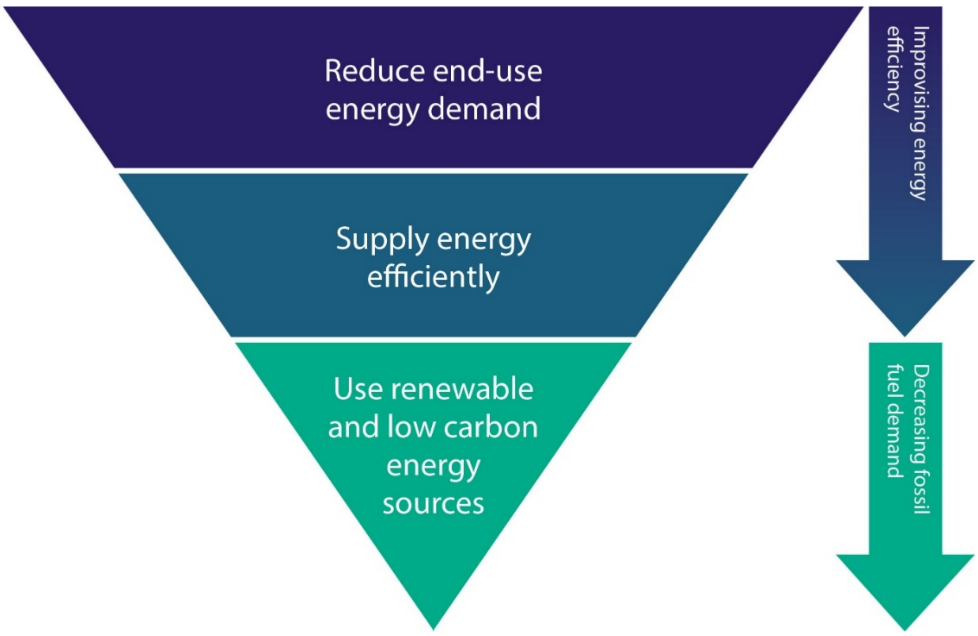
Excellence in Energy Efficiency Design (EXEED) enables organisations to establish a systematic approach to design, construction and commissioning processes for new investments and upgrades to existing assets. The EXEED Certified programme aims to influence and deliver new best practices in energy efficient design management. EXEED designs, verifies and manages optimum energy performance and management at the earliest stages of a project's lifecycle. There is also an EXEED grant scheme worth up to €500,000 per year per project. For further information, please visit www.seai.ie.

Of course, the biomass CHP system itself should be designed to be energy efficient, and include measures such as effective system controls and good-practice levels of insulation for building fabric, heat pipework, heat storage vessels, etc.

When developing any low-carbon energy system, it is good practice to follow the energy hierarchy (see *Figure 2.3*). This identifies which measures to undertake first to minimise the total energy demand of a project in a cost- and resource-efficient manner.

Firstly, end-use demand is limited to what is necessary. Secondly, measures that increase the efficiency of supplying the total demand are installed (these are usually of moderate cost). Finally, renewable and low-carbon technologies are sized and installed correctly.

Figure 2.3: Energy hierarchy



2.2.2.1 Reduce end-use energy demand

Reduce end-use energy demand encompasses reducing demand through end-use energy efficiency technologies and measures, including eliminating wastage, such as:

- Insulating and draught-proofing of buildings;
- Reducing the heat loss through external doors by replacement or addition of door closers and/or draught-proofing;
- Optimising time and temperature settings to eliminate heat energy being used unnecessarily;
- Switching to more efficient appliances and lighting such as light emitting diodes (LEDs);
- Introducing zoning or local controls to allow heating and lighting to be adjusted so that it is used only where and when required; and
- Improving the energy efficiency of heat-using processes (e.g. better control systems, heat recovery and plant insulation).

In addition to the above, introducing low-cost measures to increase awareness and develop practices to improve how staff interact with energy services can result in significant energy and cost savings.

2.2.2.2 Supply energy efficiently

This includes measures such as improving heat distribution system insulation, the efficiency of circulating pumps and control strategies.

2.2.2.3 Use renewable and low-carbon energy

This involves installing renewable and low-carbon technologies to satisfy the reduced demand. As well as biomass CHP systems, this could include heat pumps, and solar thermal and solar photovoltaic (PV) technologies.

3. Biomass CHP system feasibility study

3.1 Introduction

The main purpose of a system feasibility study is to identify if the project is suitable for development. It is vital to establish the technical and financial viability at the earliest possible. It may be appropriate at this stage, depending on site characteristics and requirements, to evaluate the biomass CHP system against a wider set of technology options (e.g. heat pumps, biomass boilers and gas CHP).

A key step in developing a CHP system is to define and quantify the on-site heat and power demand profiles. Selecting the most suitable biomass fuel, including its source, type, quality and quantity is also crucial. It is important that the relevant energy efficiency measures have already been implemented (see Section 2.2.2).

It should be noted that the approach to a biomass CHP system sizing and design is different from that of gas-fired CHP systems. As part of the feasibility of a biomass CHP system, the following aspects should be considered carefully:

- Availability of space for fuel delivery, handling and feeding;
- The type of CHP prime mover;
- The type of biomass conversion system (boiler or gasifier) and the number of biomass boilers or gasifiers;
- Cleaning of ash bins and additional maintenance requirements;
- The need for buffers/thermal stores;
- Provision of top-up and standby capacity; and
- Integration with existing heating and electrical distribution systems and connection to the electricity distribution network.

Assuming biomass fuel is available and can be sustainably sourced, the basic steps for assessing the feasibility of a biomass CHP system are:

- Determining site heating (cooling if required) and power demands based on records – accounting for any planned energy efficiency measures and operational changes that will affect demand.
- Assessing space requirements. Biomass systems require more space than traditional fossil-fuel-fired CHP systems and may necessitate a plant room extension or new plant room. Access for fuel deliveries and space for fuel storage should also be investigated.
- Selecting a CHP system of an appropriate rating and type.
- Assessing operating costs/savings when using the CHP system.
- Determining where/how the CHP system will be installed and connected to fuel, heat and power systems.
- Assessing the capital costs of the installation or the energy supply costs if an energy supply contract is being considered.
- Assessing the economic, energy and environmental benefits of the installation.
- Assessing the nature of other relevant issues (e.g. permits and consents).

A feasibility study can be undertaken by suitability qualified engineering consultants or technology suppliers, or it can be conducted by in-house staff. In practice, the assessment will require some in-house effort even if most of the work is undertaken by consultants or suppliers. In-house staff will still need to evaluate proposals and assumptions on which the study was based to see if they match expected business needs.

3.2 Preliminary considerations in undertaking a feasibility study

The feasibility study of a biomass CHP systems can take a considerable amount of time, typically between 2 and 3 months. As discussed above, an early step is to evaluate the site heat and electricity demand, the biomass resource and space availability to install the technology. As well as establishing the technical and financial viability of the CHP system, the aim of the feasibility study is to outline provisional high-level system design and system criteria that can lead to the detailed design stage. It should cover, as a minimum, the areas discussed in this section. The depth of the feasibility study will be dictated by the size and complexity of the project; more complicated projects will require a more detailed assessment and an appropriate level of experience.

It is important that a suitably qualified person/s undertake a CHP feasibility study as this will ensure key issues are captured in the assessment. One of the key risks includes missing necessary details regarding the performance of the systems. This could lead to drawing the wrong conclusions regarding the optimal solution. Also, if an inexperienced team is assigned to the feasibility study, key system costs may be overlooked or miscalculated.

The range of skills needed include:

- Experience with the different types and characteristics of prime movers and CHP systems;
- Knowledge of the required tasks and risks associated with developing CHP systems; and
- Good understanding of biomass combustion and gasification technologies (including technology providers on the market) to enable the optimum solution for the specific site to be identified.

When selecting a team to conduct a feasibility study, it is important to include people who have:

- Techno-economic, financial and environmental analysis skills;
- Knowledge of relevant EU Directives (e.g. Directive 2012/27/EU on energy efficiency (the Energy Efficiency Directive (EED)) and how high efficiency (HE) CHP and primary energy savings (PES) are assessed;
- Knowledge of incentivisation schemes available for CHP systems in general and for biomass CHP specifically; and
- Understanding of different feedstock characteristics, their availability, suppliers on the market and supply projections.

The feasibility study can be undertaken in-house or contracted to a consultant, installer or supplier who are suitably qualified. Undertaking an in-house study provides a low-cost solution and ensures that the feasibility study is closely monitored. However, in this case, individuals may not have the complete set of skills needed to ensure all relevant options are compared adequately, and they could overlook. The risk is that key cost considerations may be overlooked leading to sub-optimal systems being recommended or put forward. Consequently, an in-house team undertaking a feasibility study will need to work closely with industry and other consultants as part of the wider communication plan (see Section 2.2.1).

Alternatively, a developer may choose to contract the study to a consultant or an installer. Selecting an experienced consultant to undertake the study helps the developer get access to a wider set of skills that may not be available internally. However, this is likely to be a more expensive option than an in-house study. A key risk in this case is that the consultant may not be fully engaged and may deviate from the objectives set for the study. An installer will have a high level of knowledge of the relevant systems, but this knowledge is likely to be limited to the systems most familiar to the installer. Another risk is that installers may not be independent and may recommend or lead the study in a certain direction.

3.3 Initial site assessment

At the start of the feasibility study, a physical inspection of the site and discussions with site staff should be conducted to establish relevant key features and aspects relevant to the prospective project. The site visit should review:

- Overall site layout, calculating the availability of space for fuel storage and for the installation of a new CHP system (packaged versus custom-built CHP) or the conversion of existing plant;
- Access conditions for delivery of biomass fuel (including the width and condition of local roads and byways);
- Possible planning restrictions for the flue stack (height), fuel storage facilities (e.g. tall silos) and any new buildings or extensions for the plant room;
- Location and nature of heat and power loads to be served;
- Existing electrical distribution system, availability and suitability of connections to the electricity distribution network to export power, and any relevant planning requirements and potential issues;
- Type, configuration and condition of the existing heating plant and distribution systems, and possible modifications required for the extension of the heating network if applicable;
- Proximity of neighbouring properties – potential for noise or emissions nuisance;
- Local air quality restrictions;
- Removal of ash bins;
- Availability of an internet connection (some biomass boilers systems allow for remote monitoring); and
- Level of ongoing operational input that site staff can provide and any training needs.

3.4 Fuel selection

A key step in conducting a feasibility study for a biomass CHP project is to investigate the source of the biomass fuel needed, whether sufficient quantity is available, how sustainable the sourced biomass is, and the availability of storage for the fuel.

The most common choices for fuel are wood pellets, wood chip or logs. Other biomass fuels used in CHP systems include poultry litter, straw and waste wood. There may also be sites where owners have their own forestry fuel resource or are interested in using energy crops – crops grown specifically for use as a biomass fuel. Such energy crops could include willow, which is grown using a short rotation coppice (SRC) technique and is harvested every three to four years or miscanthus (a woody rhizomatous grass), which is harvested every year.

Details on selecting fuel for biomass boilers can be found in the accompanying set of biomass boiler guides available on the SEAI website.[6]

3.5 Assessing heating and cooling demand

3.5.1 Estimating on-site heating and cooling demand

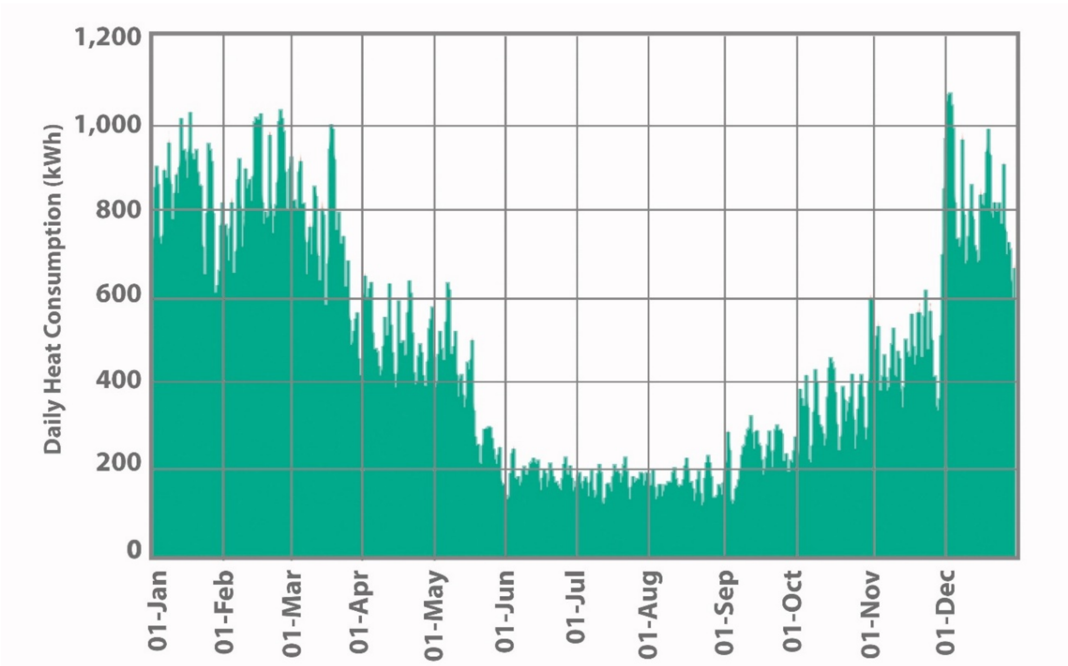
Assessing the patterns of heat and power demands (and cooling for trigeneration systems) is the most important step in a CHP feasibility study, as this is required for later stages of the study for initial sizing. When estimating the on-site heat demands, the assessor needs to consider the definition of 'useful heat' and whether the installation will meet high efficiency CHP (HE CHP) criteria (see Section 3.5.3 for further details).

Heat from a biomass CHP system may be used to heat premises (space heating), produce hot water, provide process heating (e.g. for drying or manufacturing process) or provide cooling (using heat to drive absorption chillers).

The variability in heat demand will depend on the nature of the heating requirements. Heating for industrial processes tend to be the least variable. Hospitals, care homes and leisure centres (particularly those with swimming pools) tend to exhibit medium variability. Where heat is used primarily for space heating, there will be significant variability of demand between day and night, and seasonally. Therefore, heat-demand profiles need to be produced for at least winter and summer days. It can also be helpful in the sizing process for annual heat-load duration curves to be produced.

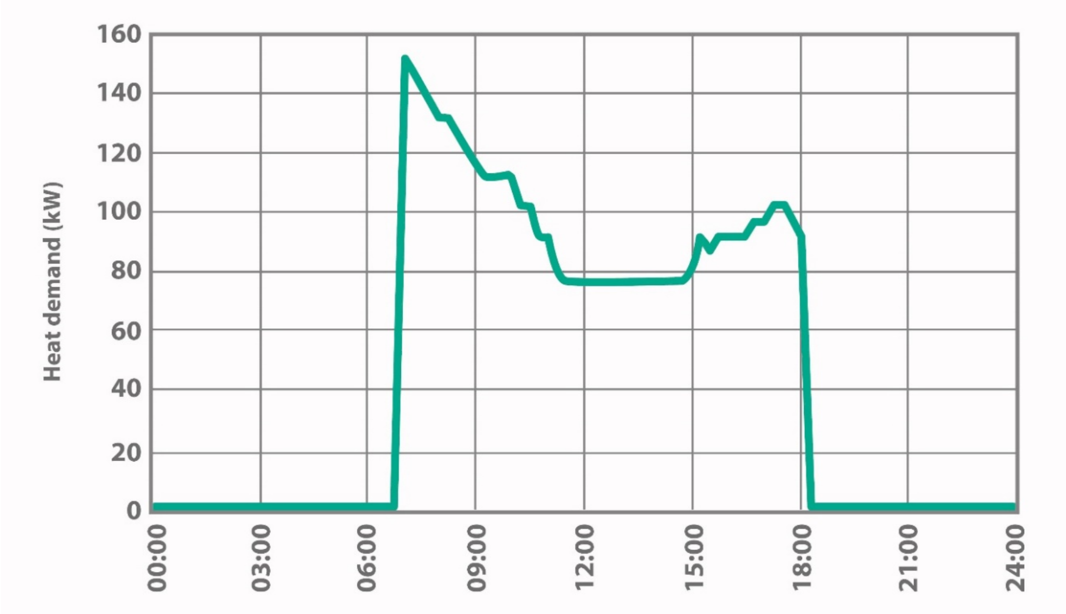
Looking at a typical demand profile for space heating and hot water services (see *Figure 3.1*), the demand will be mainly during the winter months. For commercial buildings, the demand for space heating and hot water might only be during office hours. In summer, the heat load will mainly, if not exclusively, be to provide hot water. For a typical winter's day, demand is mainly during the day time, with high demand during periods of high occupancy, i.e. in the morning before working hours and in the evening after working hours (see *Figure 3.2*).

Figure 3.1: Illustrative daily heat consumption (annual profile)



6 https://www.seai.ie/resources/publications/index.xml

Figure 3.2: Illustrative heat load profile for a winter's day



It is important to obtain the clearest picture of demand as possible. In undertaking the steps below, care must be taken to ensure alignment with best practice and where applicable from the Excellence in Energy Efficiency Design (EXEED) programme. The site heat demand can be established as follows:

- Examine **existing fuel or meter records** covering at least one full year of consumption but, ideally, two or three years to observe any normal variations.
- Weather (via degree days[7]) and operational variations during this time and their impact on the heat demand should be noted.
- Check delivery notes for oil and liquefied petroleum gas (LPG) as these will state the volume delivered. The volumes will need to be converted into energy units (for conversion details, please visit https://www.seai.ie).
- Examine the rating plates on existing boilers or CHP systems, if fitted, will state the maximum rate at which they can supply heat. However, do not assume that heat demand will match the capacities quoted on the rating plates.
- Take account of the efficiency of the existing boilers or CHP systems (i.e. the difference between input [fuel entering the boiler/CHP] and output [heat output of the boiler/CHP]). Efficiencies stated on a rating plate represent efficiency under particular test conditions and as such are likely to be optimistic. Efficiency degrades over time.
- Take on-site spot measurements, which can be used if no metering data is directly available. This can be done manually (e.g. manually logging the main meter at the site) or by hiring temporary 'strap-on' heat metering with data logging capability. Care should be taken when taking spot measurements as heat demands can vary considerably by time of day and time of year. Therefore, a range of readings should be taken.
- Estimate heat-demand profiles if it is a new building or a new heat load. Estimates may be based on a combination of dynamic simulation modelling, benchmark data of similar buildings and consumption codes of the building type.
- Use the services of a chartered engineer at this or at the full design stage if the heat load assessment is not straightforward. Check the lists of qualified consultants published by The Chartered Institution of Building Services Engineers (CIBSE) and other professional bodies.

7 Degree days is used to determine the heating requirements of buildings, representing a fall of one degree below a specified average outdoor temperature (usually 18°C) for one day.

Consider how site demands may change in the future (e.g. as a result of implementing energy efficiency measures, expanding the site, or changing operation or occupancy). Make an assessment of how the change would affect the CHP system's viability and whether the system can be future-proofed.

Ideally, obtain half-hourly or hourly data of heat demand throughout the year. Using averaged data for a whole day or week identifies how seasonal variations of consumption, but may hide too many variations in demand level, particularly between the day and night. An accurate demand profile makes it relatively easy to optimise the size of the CHP system based on a simulation over a full year.

3.5.2 Exploring potential for heat export

The heat efficiency of a CHP system is based on the amount of useful heat used and not on the heat generated by the system. An important early consideration is how the heat recovered from the CHP system can be used to maximise overall efficiency and achieve high efficiency performance (see Section 3.5.3). It is important to explore the potential for connecting nearby heat customers adjacent to the biomass CHP generation site, where possible. It may be possible to generate revenue via a heat sales agreement to a neighbouring site. Examples could include a local district heating network or a neighbouring industrial plant.

As with assessing the on-site heat demand, it is necessary to understand the nature of the neighbouring heat load in terms of its peaks and variability. Take the same steps as above to establish the nature of the heat export demand. The extra heat capacity required to counter distribution losses associated with the transportation of heat must also be calculated.

Extra care must be taken to consider the future changes to the neighbouring heat load. It must be considered if the CHP system will still be viable if the revenue from the heat export was to stop. There must also be contingency in place to supply heat to the customer if the biomass CHP system malfunctions or is undergoing maintenance.

3.5.3 Meeting the requirements for high efficiency CHP

High efficiency CHP (HE CHP) heating systems that use biomass may receive operational support for the eligible heat output. Some support schemes in Ireland (e.g. the Support Scheme for Renewable Heat) require that a CHP system must be certified as high efficiency CHP by the Commission for Regulation of Utilities (CRU) to be eligible for support. In addition, the CHP system must maintain this certification to continue to receive ongoing support.

The definition of (HE CHP) originates from Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market (repealed in 2014) and later in Directive 2012/27/EU on energy efficiency (the Energy Efficiency Directive (EED[8])).

When evaluating the feasibility of a CHP system, a developer should consider whether it qualifies as HE CHP, which will mean it is eligible for support under certain support schemes. This will influence the economic and financial assessment of the system being developed. For a biomass CHP system to gain HE CHP status, it needs to use a certain level of heat for 'useful' purposes. As part of the feasibility study, a site needs to consider what existing fossil-fuel-based heat demands can be replaced with heat from the biomass CHP system and what additional potential 'useful' heat loads can be connected for the system to achieve HE CHP status.

8 Available at: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive

The objective of the Energy Efficiency Directive defined criteria is to maximise the energy efficiency of CHP systems and to encourage the recovery and use of heat. Many operational CHP systems tend to maximise their electrical output while dumping large amounts of heat and so do not operate as HE CHP system. The spirit of the Energy Efficiency Directive is to encourage heat utilisation from CHP which will in turn improve HE CHP performance.

3.5.3.1 High efficiency CHP certification in Ireland

The Commission for Regulation of Utilities (CRU) is the authority responsible for high efficiency CHP certification in Ireland (appointed under S.I. No. 299/2009 – Electricity Regulation Act 1999 (Appointment of Person to Calculate Power To Heat Ratios of Combined Heat and Power Units). A decision paper (Commission for Energy Regulation (CER) Certification Process for High Efficiency CHP Decision Paper (CER/12/125))[9] on the certification process was published in March 2012. This decision paper put in place a process to assess and certify HE CHP as set out in the Energy Efficiency Directive. Several clarification notes have since been published by CRU on matters relating to HE CHP assessment and certifications, on which heat loads qualify as 'useful heat' by default and which need to be shown to be economically justifiable.[10]

The HE CHP certification process by CRU is based on operational data for schemes in operation or on design data for new schemes. Requirements for certification include demonstration that the heat load is useful heat and submission of the HE CHP calculation spreadsheet. The calculation methodology is based on that laid out in the EED and requires assessment of:

- The power-to-heat ratio of the CHP system based on maximum heat conditions. For reciprocating engines, this is a fixed value and is typically the value reported by the manufacturer in the data sheet. However, for steam turbines, this needs to be determined at non-condensing mode using the Z-ratio[11] at the relevant steam conditions of pressure and temperature.
- Determination of electrical, heat and overall efficiencies (based on a net calorific value of the fuel).
- If the overall efficiency is larger than or equal to 75%, then all the electricity generated by CHP can be used in the calculation of primary energy savings (as described below). However, if the overall efficiency is less than 75% (on net calorific value basis), then the proportion which should be used in calculating primary energy savings is estimated based on the multiplication of the calculated power-to-heat ratio (see above) by the actual 'useful' heat demand on site.
- Primary energy savings, which is calculated according to Paragraphs 3 and 4 of Schedule 3 of the Electricity Regulation Act 1999 Revised (Updated to December 2018).[12] The PES calculation is dependent on the installation's operational electrical and heat efficiencies in comparison to reference electrical and heat efficiencies for separate production of heat (from a boiler) and power (from a power station) using the same fuel. For biomass fuels, the current applicable reference electrical and heat efficiencies are 37% and 86% respectively.[13]

9 https://www.cru.ie/wp-content/uploads/2012/07/cer12125.pdf

10 According to Article 2 of the Energy Efficiency Directive, economically justifiable heat demand is heat demand which does not exceed the needs for heating or cooling and which would otherwise be met at market conditions by energy generation processes other than cogeneration. This is the definition which is also adopted by CRU in the certification of high efficiency CHP.

11 **Z ratio** is the ratio of 'heat extracted from a pass-out condensing steam turbine' to the 'resulting reduction in power output'. It provides a means of accounting for the interdependency between heat and power outputs. At maximum heat conditions, a steam turbine operates in a non-condensing mode (maximum heat mode) and so the power-to-heat ratio will be at a minimum.

12 http://revisedacts.lawreform.ie/eli/1999/act/23/revised/en/pdf?annotations=true

13 See The Commission Delegated Regulation (EU) 2015/2402: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2402&from=DE

It is the calculation of the primary energy savings, rather than the overall energy efficiency, that ultimately determines whether a CHP system qualifies as high efficiency. The specific requirements with respect to primary energy savings for high efficiency CHP certification are:

- Primary energy savings greater than or equal to 10% for plants with capacity greater than or equal to 1MWe.
- Positive primary energy savings (i.e. greater than zero) for plants below this capacity threshold (i.e. plants less than 1MWe).

All certified high efficiency CHP systems are required to report annually to the CRU detailing whether the standards have been met and including key defined parameters that are based on 12 months' operational data. Audits must be carried out and certification may be revoked at any time.

Example of primary energy savings calculation and high efficiency CHP determination

The CRU certification process for high efficiency CHP is based on actual operational data of power output, heat output and fuel input. Applicants are required to demonstrate that the heat load is **useful heat,** maintain operational records, and install metering and measurement systems where necessary. Worked examples are shown in Annex D of the CRU Decision Paper. The high efficiency CHP determination process involves the following steps:

- Determining useful heat output (based on whether the heat delivered is economically justifiable). Assuming an engine with total power capacity of 500kWe, electrical efficiency of 33.3% (net calorific value (NCV)) and power-to-heat ratio of 0.67, the total maximum heat output is 750kWth and total fuel input is 1500kW.
- If a site has heat demand of only 600kWth for space heating (considered as useful heat by default), then if the engine is operating at full load, a 150kWth will be dumped and the useful heat should be calculated based on a total heat demand of 600kWth (i.e. useful heat demand).
- If the heat demand is 600kWth for drying woodchip (rather than space heating), then the project needs to provide a business case to show that the heat demand is economically justifiable and would have existed in the absence of the CHP system. This will require a cost-benefit analysis showing sales of dried woodchip as a revenue stream that justifies investment in a heat source other than CHP (i.e. in the absence of fiscal benefits).
- For the calculation above, for space heating application (considered useful heat by default), the overall efficiency is 33.3% + 40% = 73.3% (NCV).
- As the overall efficiency is less than 75%, only a proportion of the total power output is used in the calculation of primary energy savings. This is estimated based on the power-to-heat ratio. This called the total electrical output qualifying as HE CHP and for the calculation above is estimated as 0.67 ×600 = ~400kWe (i.e. only 80% of the total power generated by the CHP qualifies as HE CHP). Based on this the electrical efficiency which should be used in the PES calculation is 400/ 1500 = 26.7% (not the actual 33.3%).
- Determining PES according to Paragraphs 3 and 4 of Schedule 3 of the Electricity Regulation Act. Based on electrical efficiency of 26.7% (NCV) and heat efficiency corresponding to the certified 'useful' heat delivered to site (40% NCV) and assuming wood pellets as the fuel (reference electrical efficiency = 37%, reference heat efficiency = 86%), the PES is calculated as 15.7%. As the PES is larger than 10%, the installation qualifies as HE CHP.
- If 'useful' heat utilisation over a certain reporting period reduces, then overall efficiency reduces further and so there will be a point where the schemes will not be considered HE CHP. For the calculation above, if the heat demand reduces to 560 kWth in a given year, the PES will be less than 10% and the installation will not be considered HE CHP.

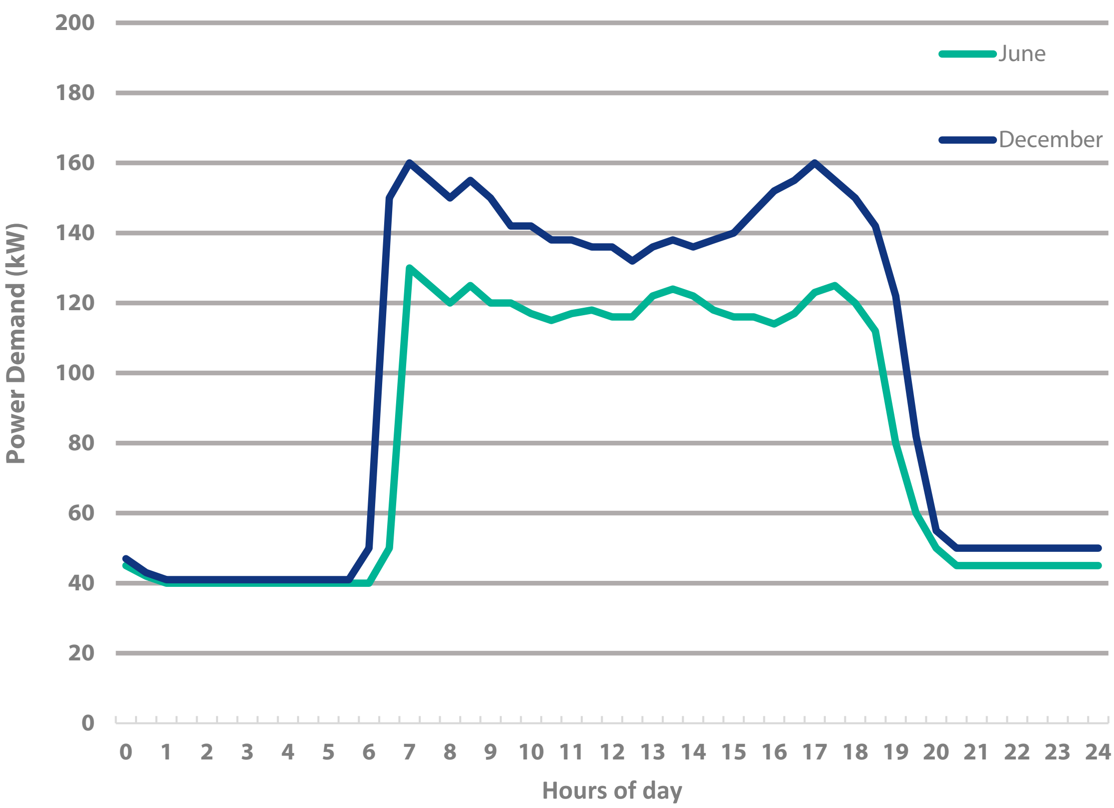
3.6 Assessing electricity demand

3.6.1 On-site electricity use

Electricity generated from a biomass CHP system may be consumed on site via the local distribution system. The purpose of installing a CHP in the first place on some industrial sites is to satisfy their high electricity demand. Where the CHP system power generation exceeds the demands of the site, electricity may be exported to the electricity distribution network and sold to an electricity supplier. It is recommended that biomass CHP plant developers in Ireland contact the CRU early in the project for further details on electricity supplier licensing and additional requirements. Further details are available on the CRU website.

In commercial buildings, there is significant daily variation in electricity demand determined by human activity (see *Figure 3.3*). Demand is usually low during the night, with a surge in the mornings as people arrive at work and begin using lighting and electrical appliances. Demand will then begin to fall in the evenings and eventually drop again to night-time levels. There are seasonal variations in this pattern, which need to be considered, such as a greater surge in evening demand in the winter due to increased lighting use.

Figure 3.3: Typical weekday electrical demand of commercial building



In designing a CHP system, it is important to obtain the clearest possible picture of power demand by:

- Examining existing electricity bills or meter records covering at least one full year of consumption but, ideally, two or three years to observe any normal variations.
- Examining the rating plates on existing CHP systems (if fitted), as these will state their maximum power capacity. However, it must not be assumed that this represents the current peak load as they are likely to have been oversized when installed and loads may also have changed.

- If electricity demand is based on existing CHP systems which are being replaced, then direct measurements of electricity generated (if all utilised on site, with no export) can be used. In the absence of electricity data, fuel input to the CHP unit can be used in combination with the electrical efficiency to estimate electricity demand, bearing in mind that efficiencies stated on a rating plate represent efficiency under particular test conditions and as such are likely to be optimistic, and that efficiency degrades over time.
- Taking on-site spot measurements, which can be used if no metering data is directly available. This can be done manually (for example, logging the main meter at the site) or by hiring temporary 'strap-on' heat metering with data logging capability. Take a range of measurements as heat demands can vary considerably by time of day and time of year.
- If it is a new building or new load, power demand profiles must be estimated. In the case of new buildings, estimates may be based on benchmark data of similar buildings and consumption codes of the building type.
- Using the services of a chartered engineer at this or the full design stage may be advisable if the power load assessment is not straightforward. The Chartered Institution of Building Services Engineers (CIBSE) and other professional bodies keep lists of suitably experienced people.

Just as with heat, care must be taken to consider future changes in power demand that may arise due to implementing energy efficiency measures, site expansion, or changes in operation or occupancy. It must be assessed whether the change would enhance or detract from the CHP system's viability and whether the system to be installed can be future-proofed.

Ideally, half-hourly or hourly data of electricity demand throughout the year should be used. Using averaged data for a whole day or week will identify seasonal variations in consumption, but may hide too many variations in demand level, particularly between the day and night. Using a demand profile with this accuracy will make it relatively easy to optimise the CHP size based on a simulation over a full year.

3.6.2 Exporting electricity

As discussed above, compared to heat, electricity has the additional flexibility that it can be exported to the electricity distribution network if the demands of the site exceed generation from the CHP system. This may provide a revenue stream.

Some CHP developers in Ireland have previously considered the possibility of installing a private wire[14] with a direct electrical connection to potential customers. However, this is currently not possible as private wire connection is still prohibited under Irish legislation.

In designing a biomass CHP system, extra consideration must be given to any future changes to the electricity export potential. This is to determine the future viability of the system if the revenue from the electricity export were to stop. There must also be contingency in place to supply electricity to the customer if the biomass CHP system malfunctions or is undergoing maintenance. However, the customer is most likely to be connected to the electricity distribution network as a back-up source of power in these situations.

3.7 Regulatory review

An early review of regulatory issues is needed to identify possible restrictions on the biomass CHP system project. A useful reference for understanding planning requirements for biomass CHP projects in Ireland is the Planning Guidance Recommendations for Bioenergy Projects in Ireland report by the Irish Bioenergy Association (IrBEA)[15]. The need to obtain planning permission may arise if, for example:

---

14 A private wire is electrical infrastructure that is independent of the electricity distribution network in Ireland (i.e. Electricity Supply Board (ESB)) and whose purpose is to supply electricity directly to another party located on the same site (e.g. an industrial estate) as the generator.
15 https://www.seai.ie/resources/publications/IrBEA-Bioenergy-Planning-Report-RDD-00112-2017.pdf

- New buildings, such as a plant room or fuel store, are required.
- The boiler chimney (stack) is going to be particularly visible (at boiler start-up), especially when the boiler is started and a plume may be visible.
- The CHP installation will require modified or additional vehicle entrances to the site or give rise to increased vehicle movements.
- Planning permission for heat and/or electrical distribution systems if sales to an external customer are to be part of the review.

Restrictions on the proposed project may arise if it is intended to burn contaminated waste wood or agricultural by-products, or if tighter restrictions on air emissions are in place (e.g. in built-up areas). In cases where local emissions levels are already high, there could also be restrictions on further developments that would add to emissions. As air quality legislation is evolving, it is important to confirm regulatory requirements at the time of project development.[16]

Once the nature and scale of the biomass CHP project is understood, approaches should be made to the relevant competent authorities (at least, initially, the relevant departments of the local authority) so that potential restrictions can be identified and assessed before significant development costs are incurred.

There are other regulatory requirements, such as adherence to all sections of the building regulations will need to be met, the department of housing planning and local government website houses all sections of the building regulation https://www.housing.gov.ie/housing/housing

Where the CHP plant is being considered for a site that is regulated under any Licencing or Permitting regulations it is important to confirm that the proposed change is in compliance with all the relevant licences or permits. This would include sites regulated by way of an Industrial Emissions Licence (IED) as issued by the EPA or any other licence or permit that may require a review depending on the terms and conditions of the licence or permit in place

3.8 Initial sizing and design

An initial size and outline design of a biomass CHP system needs to be established to enable the feasibility of the system to be assessed. Further detail on biomass CHP systems is provided in the accompanying Technology Guide. See Section 3.9 for assessment of other low-carbon heat and power technologies. Publicly available CHP tools can be used for quick initial assessment are available on the SEAI website. Sizing of the CHP system should aim to maximise its use across the year to get the best return on investment.

3.8.1 Initial sizing and system design

The sizing of a CHP system must be undertaken on a site-by-site basis to determine the most economically and environmentally advantageous solution. Typically, biomass CHP systems are designed primarily to satisfy a site's base-load heat demand on the grounds that excess heat cannot be stored or exported easily. It is recommended that the developer should contact the CRU if they are considering exporting electricity to the grid. Further details on connecting to the electricity grid are available on the CRU website.[17]

Where the site has a significant heat demand that the CHP system will satisfy and electricity cannot be exported to the grid, then careful attention to the electricity load will be required. In this case, modulation of output should be considered in the design.

---

16 Environmental Protection Agency (EPA) – Air quality legislation: http://www.epa.ie/pubs/legislation/air/quality/
17 https://www.cru.ie/professional/licensing/electricity-supply-license-2/

Best practice for optimum sizing of a CHP system requires a spreadsheet to determine the annual energy flows of the system and evaluate operating costs and savings. It will need to model the variability of the site's energy demands and sensitivity to changing energy costs. For an accurate model, heat and power demand data at half-hourly or hourly granularity over the course of a year should be used.

Before the construction of the model, there are several initial sizing approaches and strategies to consider:

- **Greater consideration must be paid to base demands rather than peak loads**. CHP systems require high plant utilisation to ensure their economic viability, so it is best that they run at full output for long hours to meet base loads. Strategies to help meet peak heat and power loads should also be incorporated. These include installing thermal stores and importing power from the electricity distribution network.
- **Will the sizing of the CHP system be heat-led or power-led?** In other words, will the CHP system be sized to meet the heat demands or will it be sized to meet the power demands of the site? In the case of biomass CHP systems, where electrical efficiencies are low, the system is most likely to be heat-led. However, this should not be considered an absolute rule for all sites and power-led sizing should still be investigated.
- **Will the system consist of a single or multiple CHP systems?** Biomass CHP prime mover efficiencies decrease as they modulate down to supply lower heat and power demands. If there is a large variation in demand, then having multiple prime movers will allow the system to modulate down without the same loss in efficiencies.
- **Will the system dump heat in the event that generation exceeds demand**? Is heat rejection more worthwhile than part-load generation?
- **Will the system be importing or exporting power to the electricity distribution network?** Is exporting power more worthwhile than part-load operation?
- **What prime mover technology will be used?** Is a combustion or gasification system more appropriate? Commercially available gasification biomass CHP systems are very small in scale and are only applicable for small-scale operations. Combustion biomass CHP systems can be applicable on a small scale, but also at a large industrial scale. Initial considerations should also establish whether the demands are most suitable for steam turbines, screw expanders or Organic Rankine Cycle. See the accompanying Technology Guide for more information on biomass CHP prime mover technologies.
- **If there is existing CHP system on site, what is its capacity?** If it is an existing fossil-fuel-fired CHP system, the existing heat and power generating capacities may be used as an indication of size. However, the biomass CHP system should not be a like-for-like replacement in terms of capacities. Also, consider that the demands of the site may well have changed since the existing system was specified.

A useful method in initial sizing of heat demand is to create a heat-load duration curve (HLDC). This plots the heat demand of each operating hour in a year in descending order. From the HLDC, it can be determined how much of the demand over a year can be met with a certain CHP size.

Once consideration has been made to the initial strategies and approaches, the operating model may be constructed for detailed analysis. If detailed data is not available, the model can be simplified using the following approaches:

- 24-hour model of a typical day (or typical weekday and weekend day) in each month. This approach will lose the variation of demand across each month.
- Create a day and night demand for each month. This will not account for the variation over a 24-hour day.

Once the detail of the model has been established, it will be necessary to have the following data for each CHP system considered:

- Heat and power capacities and efficiencies;
- Minimum turndown ratios (to determine what capacities the CHP system can ramp down to);
- The impact of the number of start-ups; and
- Capital and operating costs (maintenance, fuel and electricity costs).

The model should be built to determine and include:

- Whether the CHP system is economically beneficial based on the fuel and electricity costs;
- Whether the output of the CHP system is to follow the heat or power demand;
- The operation of the thermal store;
- The peak heat demand and whether it can be met by the thermal store or if standby boilers are also required;
- The import and electricity costs/revenue; and
- A range of different CHP system sizes (and different CHP prime movers if needed).

The analysis required for the detailed model is complex and is best carried out by an appropriately experienced person such as a chartered building services engineer or the installer. It is strongly recommended that readers refer to the Chartered Institution of Building Services Engineers (CIBSE) publication AM12 Combined Heat and Power for Buildings for a detailed explanation of CHP sizing.[18]

3.8.2 Integrating with the existing distribution system

Depending on the nature of the project, a new biomass CHP system may require a new distribution system, although it can often be integrated into the existing system. The heat transfer medium of the existing system will need to be established:

- Most buildings use a water system that operates at a flow temperature of less than 95°C (typically 80ºC to 85ºC), this is referred to as low temperature hot water.
- Some heating systems (particularly very large installations, older buildings or production facilities) use water at between 95°C and 120°C, this is known as medium temperature hot water (MTHW). Medium temperature hot water systems operate at higher pressures than low temperature hot water systems.
- Other systems use high temperature hot water or steam.

To understand any existing system, the system's schematics and operation and maintenance manuals should be examined and responsible site staff consulted. For a system to be considered a CHP system, heat should be recovered after power generation (e.g. from the economiser or condenser of an Organic Rankine Cycle system rather than from the evaporator). The amount and quality of heat available depends on the type of prime mover used and, in some cases (e.g. in steam turbines), on the location from where heat is extracted. Further information on heat distribution systems can be found in the accompanying Technology Guide.

To distribute power within an on-site electrical distribution system, the CHP's generator must be connected at an appropriate location. It may be connected onto a spare breaker cubicle on an existing busbar or onto a new bus section. The existing power distribution system must be checked to ensure that system fault levels are not exceeded. Additional reinforcement of the distribution system may be required if the fault levels are likely to be exceeded.

The electrical power from a CHP system is most likely to be three-phase alternating current at 50Hz and 415V. Typically, commercial properties operate at this voltage, but where a distribution system operates at 11kV, a step-up transformer will be required. Low voltage generators and transformers (415V) are the most likely option for CHP systems below 2MWe.

18 CIBSE, Combined Heat and Power for Buildings, AM12: 2016' : https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q20000008I7nsAAC

Consideration must be given to whether or not the site is to be connected to the electricity distribution network. Most CHP applications will be connected to the electricity distribution network, this is known as parallel operation. Where a site is not connected to the electricity distribution network, the CHP system is said to be in 'island mode'. It should be noted that even in island mode, when site power demands are met solely by the CHP system, the electricity customer will still incur fixed electricity costs, such as the Public Service Obligation (PSO) levy. When implementing parallel operation, it will be necessary to make an application to the Electricity Supply Board to obtain an electricity distribution network connection.

For operation in island mode, the maximum load of the site must be within the generator's capacity. If the electrical load is critical to the site, provisions for back-up power must be installed (e.g. such as standalone generators) if the biomass CHP system malfunctions or is undergoing maintenance.

3.8.3 Buffer vessels and thermal stores

As biomass boilers can take hours to heat up from cold or to cool down, most systems are used in conjunction with an appropriately sized thermal store or buffer tank. While the terms buffer vessel and thermal store tend to be used interchangeably, refer to vessels with different functions:

- Buffer vessels are used in many biomass systems to receive the residual heat from the biomass boiler and prime mover that must be removed once the heat demand is no longer present. If the downtime is not too long, the heat stored within a buffer vessel is used when the demand for heat returns. This improves efficiency and protects the boiler from excessive heat.
- Thermal stores smooth out (from the perspective of the boiler and prime mover) a variable heat demand, enabling a smaller system to be used and to run for longer at peak efficiency. Thermal stores contain a large volume of water, usually several thousand litres, that is heated up and is then available to meet peaks in heat demand. This is likely to improve the overall efficiency of the system and enable a biomass CHP system to meet a greater proportion of the annual heat energy required than would otherwise be the case. Thermal stores are often configured to also provide the role of a buffer vessel. A thermal store may be used to provide a body of water that other technologies can feed into (e.g. solar thermal).

3.8.4 Plant room options

Biomass CHP systems are significantly larger than their fossil-fuel counterparts. Space is required for the biomass boiler and the prime mover. In addition to this, in comparison to the size of equivalent capacity conventional boilers and CHP systems, the biomass alternatives are much larger. Additional equipment must also be considered, such as the fuel store, thermal store and expansion vessels.

In sizing a plant room, dimensions should be obtained from suppliers together with the recommended minimum access space required for maintenance. Plant room options include the following, for which planning permission may be required:

- In some larger plant rooms, there may be space for a biomass boiler and prime mover or it may be possible to extend the plant room. Areas used previously for fossil fuel storage (oil or liquified petroleum gas (LPG) tanks) can potentially be used for biomass fuel storage. However, it must be considered that the energy density of biomass is lower than that of oil or LPG, so extra space is required to store an equivalent amount of energy.
- If space is not available in the existing plant room, then a new one may need to be built.

3.9 Initial financial assessment

An initial financial assessment, which compares a biomass CHP system with other potentially suitable technologies, should be conducted. The aim of this is to provisionally establish if there is a commercial case for biomass. It is recommended that the financial assessment is carried out over the whole lifetime of the CHP system (e.g. over a 20-year period). Standard techniques such as calculating the internal rate of return that will be achieved from the investment in the system or the simple payback period for the system can be used to assess viability.

Costs that should be included in the calculation are:

- Capital costs – these can often be established from other similar installations, benchmark figures or discussions with suppliers.
- Maintenance costs – comprise regular servicing; allowance for breakdowns and spare parts; and day-to-day tasks carried out by on-site staff such as boiler cleaning, ash removal and attending to fuel blockages.
- Biomass fuel costs – to be established through discussion with fuel suppliers. Quantities required can be estimated from the site's heat and power demands, and the system's heat and power efficiencies.

Savings and income streams include:

- Savings in fuel costs of the existing fuel that will be displaced by the biomass. This can be established from historical fuel invoices.
- Government incentive payments, where applicable.
- The value of any heat sales and electricity exports.
- Avoided waste disposal costs – If the biomass system uses waste, then it may offset the costs of disposing of the waste by another means.
- Avoided costs of standard boiler replacement (if applicable).

A sensitivity analysis to compare the impacts of different parameters on the feasibility of the CHP installation should be undertaken. This should particularly consider future fuel prices (biomass and existing fuels). It is worth noting that biomass prices have not tended to follow oil prices and have shown greater stability. The sensitivity analysis should consider the impact of the difference in fuel price between the biomass and fossil fuel. The stability of biomass prices still needs to be carefully considered, as volatile fluctuations have been seen in the last two years.

Biomass CHP systems have higher initial capital cost than fossil-fuel systems of equivalent rated capacity. However, this difference can be recouped through annual fuel cost savings. Given this, biomass CHP systems tend to be most cost-effective in:

- Situations that are off the national gas network. The capital recovery from the annual fuel cost savings is fastest when biomass heating replaces heating oil, LPG or electricity, sites that are off the national gas network.
- Situations that are off the electricity distribution network. Recovery in the annual fuel cost savings when generation is from a fuel-efficient CHP system, rather than from a standalone electrical generator.
- Situations that have relatively consistent and high heat and power loads. The more the biomass system is used in meeting the heat and power demands, the greater the impact of the fuel cost savings on the payback of the capital expenditure.
- Situations where there is a readily available, low-cost and reliable supply of biomass fuel of sufficient quality.
- Situations requiring limited building/reconfiguration works. Compared with fossil-fuel alternatives, the larger size of biomass plant and the associated fuel storage/handling equipment means that space must be found to house these. If existing buildings can be used or modified slightly for this purpose, capital costs will be kept lower.

3.10 Installer availability

The biomass CHP market is still developing, with the supply chain more mature for some technologies than others. For gasification biomass CHP, Organic Rankine Cycle and screw-type steam expanders, the number of installers and suppliers of equipment is still small, but has increased significantly in recent years. Therefore, the availability of the plant needs to be considered when implementing a biomass CHP system. Also, the geographic location of suppliers needs to be considered; it is likely that they are located abroad. The import costs and any long delivery times need to be factored in as part of the feasibility study.

3.11 Implementation options

Table 3 summarises the options for implementing the design, installation and commissioning phases for a CHP system.

Table 3: Summary of biomass CHP system implementation options

Option	Suitability	Advantages	Disadvantages
In-house design, installation and commissioning.	Suitable for an owner with strong in-house capabilities and knowledge of CHP systems including prime movers and biomass conversion systems.	• Likely to be lower costs. • Gives owner complete control. • Can work within own timeframes.	• Requires a strong knowledge, and preferably prior experience, of biomass CHP systems. • Owner takes on all the project risk. • Risk of voiding warranties on the plant. • Potentially fewer supplier connections.
In-house design with third-party installation and commissioning.	Suitable for an owner with strong design capabilities, but not manufacturer connections. Not a very common situation.	• Requires less knowledge of biomass systems. • Third party potentially has strong contacts and connections with technology suppliers which provides an advantage.	• Still requires a certain knowledge of biomass systems. • Requires close collaboration between in-house design team and third party. • Risk of lack of ownership of errors. Requires clearly defined responsibilities.
Consultancy design with third-party installation and commissioning.	Suitable for most situations. A common solution. Consultant and contractor should be experienced in biomass systems.	• Does not require the owner to have knowledge of biomass systems. • Reduced project risk with owner. • Third party potentially has strong contacts and connections with technology suppliers which provides an advantage. • Consultant can also act as project manager. • Design not influenced by installer bias for particular manufacturers.	• Likely to be higher cost. • Requires definition of the interface between and role of consultant and contractor. • Risk of lack of ownership of errors. Requires clearly defined responsibilities.

Third-party design, installation and commissioning (turnkey model) – standard systems.	Suitable for smaller, less complex installations. A common solution. Requires experienced third-party provider.	• Requires least knowledge on the part of the owner. • Reduced risk for owner. • Third party potentially has strong contacts and connections with technology suppliers which provides an advantage. • Lower cost solution than bespoke as standard system.	• Often the second most expensive option. • Loss of some control. • May not be suitable for a site with unusual requirements.
Third-party design, installation and commissioning (turnkey model) – bespoke systems.	Suitable for larger, complicated installations which are fewer in nature.	• Requires least knowledge on the part of the owner. • Reduced risk for owner. • Supplier connections. • Produces a system specific to the site's requirements.	• Often the most expensive option. • Loss of some control.
Energy service company (ESCO).[19]	Suitable where the client organisation is unable or does not wish to provide the capital investment. Also, where the client wishes to focus on its core business.	• The energy services company provides the capital for the plant • Client avoids the management and technical burden of operating and maintaining the plant • Client avoids most of the technical and operating risk.	• The financial benefits to the client are lower. • Client becomes reliant on the ESCO, but this risk can be mitigated via contractual terms.

19 The energy services company model is a type of energy contracting employing a 'pay for performance' approach to installing energy technologies for client organisations. Usually, the energy company will design, build, own and operate the plant, and sell the client heat (and other forms of energy) at an agreed price. Both organisations will have contractual obligations related to performance. There are many possible variations of this model.

See https://www.seai.ie/energy-in-business/energy-contracting/

4. Project development

This section describes the key stages of developing a combined heat and power (CHP) project (this is not an exhaustive list):

- Procurement – identifying and selecting a suitable installer, including producing a technical specification and reviewing quotations.
- Detailed sizing assessment and system design and detailed financial assessment – this should normally be undertaken by the contractor with oversight by the client or the client's consultant. Detailed financial assessment aims to improve the initial financial assessment with the sizing, system details and prices provided by procurement and detailed design stages.
- Developing a heat and/or power sales system – where heat or power is to be sold by the installation owner to a third party, a heat and/or power supply agreement should be developed.
- Carefully considering and addressing metering and monitoring requirements and arrangements.
- Considering and evaluating operation and maintenance requirements.
- Considering and addressing the requirements of connecting to the electricity distribution network.
- Reviewing regulatory considerations (requirements such as planning permission, environmental permitting, emission standards and building regulations that need to be addressed prior to installation).
- Following mandatory and best practice health and safety practices in the design and during construction.

4.1 Procurement

4.1.1 How to procure a contractor

The process for procuring a contractor is shown in *Figure 4.1*. Depending on the implementation option chosen (see *Table 3.1*), it may be necessary to appoint a competent designer and an installer or a contractor who will cover the whole process. Regardless of the option selected, in general the procurement processes are very similar except for the energy services company (ESCO) option. As part of the process, it is important to ensure that energy efficiency measures are taken into account and that the impacts of these measures on power and heat demand of the sites are also considered when sizing the system.

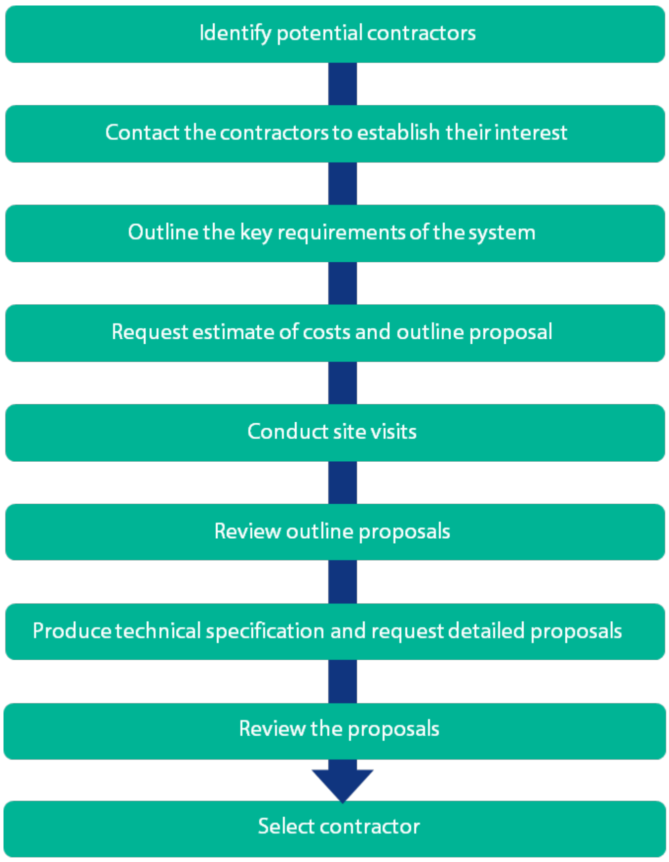


Figure 4.1: Process for procuring contractor

4.1.2 Supplier and installer identification

CHP manufacturers will often have local accredited installers or business partners. As part of their communication plan, developers are advised to plan to visit other sites and to talk to their trade associations and industrial bodies. Contacting organisations with existing installations for information and recommendations is also a valuable method of identifying suitable suppliers. Suppliers and installers should be able to provide potential customers with several reference sites that can be visited. The experience, training and certification of the companies should be reviewed to assess their suitability.

4.1.3 Producing a technical specification

A well-developed technical specification underpins a successful procurement process. It helps contractors to deliver proposals more quickly and accurately, ensures the proposals meet the requirements for the system and allows for easier comparison of the proposals. Potential content includes:

- General description and scope of work.
- Overall biomass system requirements – heat and power requirements, operational requirements (such as level of involvement from site staff), control system, thermal store, integration with existing heat and power distribution systems, connection to the electricity distribution network and additional technologies.
- Boiler requirements – boiler output, tested to applicable standards, grate system, boiler efficiency, turndown capability, ash removal/disposal and boiler emissions.
- Prime mover requirements – heat input, heat and power efficiencies, power requirements (voltage, frequency, single phase/three phase).
- Fuel requirements – fuel type and moisture content, fuel store capacity, fuel store location and fuel-handling mechanism including burn-back[20] protection.
- Building requirements – location of boiler and prime mover, building changes or construction, aesthetics and flue size (dictated by planning and air quality standards/restrictions).
- Additional site details – power supply, power consumption and water supply.
- Access arrangements – for installation and ongoing fuel deliveries, boiler room and fuel store maintenance, and flue cleaning.
- Associated works – who will do them and when (these are discussed further in Section 5.2).
- Ongoing support and maintenance – technical support, warranties, remote monitoring, operator training and service agreements.
- Additional requirements – crucial timings, external activities on which the impact needs to be minimised and site-specific requirements such as site security arrangements.

4.1.4 Tender proposal review

When reviewing installation proposals, the following should be considered:

- Technical specification – check each proposal to ensure suppliers have quoted on what has been asked for. If not, ask why.
- Exclusions – check for exclusions and seek separate quotations for any work that is outside the main contractor's scope.
- Assumptions – check for suitability and accuracy. If a contractor's assumptions are wrong (e.g. regarding annual operating hours), the system proposed may be inappropriate.
- System design – if the contractor is designing the system, check this against the designs from other contractors.
- After-sales support and servicing – many contractors provide extended guarantees or servicing agreements. Compare differences, including proximity of engineers to the site. Review the training that will be offered to on-site staff.

---

20 Burn-back refers to fuel within the delivery system being ignited by the burning fuel in the combustion chamber and burning back towards the fuel store.

- Capital cost of buying the system and installing it – this must include all works to ensure a complete and operational system, including any enabling works within the contractor's scope.
- Operating costs – this should include maintenance, repair, any additional labour to operate the system if the contractor is providing the ongoing servicing and any additional items within scope (e.g. fuel deliveries).
- Time validity of price – it is common practice for tenders to include a time validity on the price quoted. However, the time between the receipt of tenders and finally placing an order may exceed this validity. If so, the ability to extend the validity period should be discussed.
- References – review examples of the contractor's work and speak to people who have used them. It is also worth finding out if anyone is experiencing problems with that contractor. It is not uncommon with any technology to have some teething problems, but it is important to know if the contractor resolves these issues in agreed timeline. The contractor's training and certification should also be reviewed. The developer can also ask to visit some of the sites where the contractor has carried out other installations. As part of the due diligence, the developer should ask to see the contractor's insurance and liability documentation (i.e. if insurance is in place to cover the full period of the project).

4.2 Review of sizing, design and financial assessments

At this point, once more detailed costs and technical specifications have been obtained from the supplier, the initial sizing and design of the system may be reviewed to refine design elements and provide more accurate project costs. The sizing model built in the initial sizing phase may be revisited with the most up-to-date costs and system performance characteristics.

Whatever procurement process is followed, the financial review should provide firmer capital and operating costs. Other operational costs, particularly assumed fuel prices, should be reviewed, as should any projected loan interest payments. With this and any other revisions to assumptions previously made, the project financial assessment should be re-run to determine whether the project cost and economic assessment remain acceptable.

4.3 Developing a heat sales system

It is recommended that CHP system design is based on the heat load only and not the electrical load. For projects where the biomass CHP system will supply heat to a third party, a heat sales process/agreement will be required. In such cases, there will be financial risks associated with the future loss of customers. These need to be assessed against the benefits of heat sales and managed through the contract terms.

Selling heat enables CHP system owners to install systems that are larger than required for their own demand, potentially decreasing costs through economies of scale and generating potential income from what otherwise might have been waste heat. The latter may be particularly pertinent for sites where the primary purpose of the biomass CHP system is disposal of waste biomass products rather than production of heat for an organisation's own heat demand. The heat buyer benefits from potentially cheaper, low-carbon heat with reduced space requirements and reduced responsibility for maintaining a heating system. To sell heat to a customer, a meter is installed and users are billed for each unit (kWh) of heat used.

Considerations for establishing a heat sales system include:

- **Heat sales customers**. These need to be in reasonable proximity to the biomass CHP system to minimise heat losses in distribution. The customers' demand level(s) and profile(s) need to be understood. Customers will need to update the heat supplier with any substantial changes in their demand, and provision for this and the commercial consequences will need to be set out in the heat sales contract.
- **Pipework route**. The route for pipework to transport heat from the biomass system to the buyer will need to be determined and agreement reached with the relevant landowners.

- **Pricing**. The tariff established is likely to be a compromise between a price that is competitive with traditional fossil-fuel heat generation (for the buyer) and one that allows the heat supplier to make a suitable return. It might be indexed by setting an initial price based on the full costs of supplying the biomass heat to the site and an appropriate profit margin. This can then be adjusted in the future according to indices such as fossil-fuel costs, retail price of heat or costs of operating the biomass system including fuel costs. The price can be split into a unit charge for the heat used and a standing charge for administrative costs.
- **Contract**. Readily available templates for heat sales or supply contracts can be used, or these can be tailored as needed. Both parties are advised to seek legal advice before entering into a legally binding contract. An annual review of the contract will be required, including reviewing heat consumption, generation, costs and pricing.
- **Sales system**. Buyers will need to be regularly invoiced for the heat they have consumed. This will require the biomass CHP system owner to produce invoices and process payments.
- **Maintaining the biomass system and its performance**. If the biomass system decreases in efficiency, the profit margins on each unit of heat sale will drop. It is therefore important to maintain the good operation of the system to maximise profits. If the buyer does not have a back-up heat supply, this places additional importance on the reliable operation of the biomass boiler. Compensation for periods without heat provision may be included in the contract.

4.4 Grid connection and electricity export

In many countries, revenue for CHP systems can be realised by selling electricity back into the electricity distribution network and sold on a contract to a licensed electricity supplier. It is recommended that biomass CHP plant developers contact the CRU early in the project if they are considering grid connection and selling excess electricity to the grid. Further details are available on the CRU website for the procedure of certification as high efficiency CHP and licensing as an electricity supplier.[21]

The Irish electricity market is undergoing a period of significant change, with the introduction of a new set of market arrangements in the form of the Integrated Single Electricity Market (I-SEM). Under the single electricity market, generators will need to find a route to market for their power, and will be faced with new risks – notably, balance responsibility and imbalance costs. The Commission for Regulation of Utilities (CRU) is the independent body responsible for overseeing the liberalisation of Ireland's energy sector and is the regulator for the electricity industry in Ireland.

Electricity Supply Board Networks DAC, a ring-fenced subsidiary within ESB Group, carries out the licensed function of the Distribution System Operator (DSO), and is responsible for the operation, maintenance and development of the electricity distribution system in Ireland.

4.5 Metering and monitoring requirements

Several funding schemes, such as the Excellence in Energy Efficiency Design (EXEED) programme, require that the operator provides a heat energy measurement plan that includes metering requirements, and ongoing energy performance measurement and monitoring. Applicants to such schemes are required to provide evidence that demonstrates the effectiveness of the energy management process in place, or proposed in the case of new operations, and the ongoing energy efficiency improvement targets. Therefore, biomass CHP system developers should be familiar with metering requirements, and control and performance monitoring requirements.

21 https://www.cru.ie/professional/licensing/electricity-supply-license-2/

4.5.1 Metering

Metering of fuel inputs, and electricity and heat outputs, is good practice when implementing a CHP system, as it is essential to monitoring the system's performance.

Typically, for conventional gas-fired CHP systems, the metering arrangement of fuel inputs is relatively straightforward with a flow meter on the incoming gas supply. The metering of solid biomass fuel has to be recorded by alternative means, either through using a solid fuel weighing station, logging fuel deliveries or recording opening and closing stocktakes of the fuel store. Then the energy input of the fuel can be calculated by using its calorific value. If such information is not readily available, the fuel can be sampled and tested to determine its energy characteristics. Further information on the monitoring of fuel consumption is available in the accompanying Operation & Maintenance Guide.

It should be noted that the Wood Fuel Quality Assurance (WFQA) scheme and other similar schemes allow for more certainty on the calorific value of fuels. End user should sample fuel from every delivery to be sure that they are getting fuel to the standards they have ordered.

It is essential to measure and log the heat and electricity outputs to ascertain if the installed biomass CHP system is performing correctly. This is also likely to be a requirement for any incentive scheme. Reviewing metering data regularly can also help the early detection of problems (which may not necessarily relate to the biomass plant).

It is easier and cheaper to integrate metering into the original system design rather than retrofitting it. There are several accuracy classes of meters and the standard of meter required for any incentives being applied for should be checked prior to installation. Incentive schemes may stipulate the accuracy class and standard of meter as well as its position.

The heat generation or heat delivered by the biomass boiler should be metered, with additional meters used to measure the output of any other heat generating technology and the consumption of individual or groups of loads.

Support schemes require that heat meters are installed for all installations to measure and validate eligible heat. Such schemes require that meters and metering systems comply with Directive 2014/32/EU on the harmonisation of the laws of the Member States relating to the making available on the market of measuring instruments (MID) and the Measuring Instruments Statutory Instrument (European Conformity Assessment of Measuring Instruments) Regulations 2018 (S.I. No. 2 of 2018) and must be certified to accuracy Class 2.

Meters should be installed, commissioned, calibrated and maintained appropriately. Where a fossil fuel back-up plant is present, it will need to be metered separately and must not contribute towards the heat generation meter readings of the eligible plant.

Participants are likely to be required by support schemes to retain documented evidence demonstrating ongoing compliance (including maintenance and calibration records and meter readings), which will be subject to inspection by the relevant authority.

The electrical energy generated by the CHP system should be metered. There should also be a meter at the connection to the electricity distribution network to measure the energy imported and/or exported. The energy supplier will stipulate guidelines on the installation of any import meters. Where possible, meter displays (integrators) should be clearly labelled and located at eye level. More detailed information on meter types is available in the accompanying Technology Guide.

4.5.2 Control and performance monitoring

Biomass boilers and CHP prime movers usually incorporate controls and performance monitoring equipment that:

- Detect faults and malfunctions, and provide warnings or automatic shutdowns if necessary;
- Monitor operating conditions and facilitate the planning of maintenance activities;
- Monitor energy inputs and outputs to determine system performance; and
- Monitor emission levels such as oxides of nitrogen (NOx) and particulate matter (PM).

CHP systems typically operate for long periods of time with no control or supervision from site staff. Therefore, it is good practice to connect the control and performance monitoring system to some wider network, such as a building management system (BMS) or remote control and monitoring operated by the supplier or operation and maintenance contractor. There are many benefits of using this approach including:

- The CHP system can be controlled and monitored by the same system that controls and monitors site heat and electricity use.
- The system can be stopped and started safely by the wider control system.
- Monitoring of the heat and power outputs can be automated and logged into the site's energy management activities.

4.6 Operation and maintenance

To operate efficiently and reliably, a biomass CHP system needs to be regularly maintained. This includes regular boiler and prime mover checks, cleaning, interim services, annual service and responding to breakdowns. Include the access necessary for maintenance in the system design.

It is often possible to set up an operation and maintenance (O&M) contract with the company that installed the biomass system. Alternatively, O&M responsibilities and duties may be contracted out to a third-party facilities manager or can be allocated to on-site staff. Remote system monitoring may enable the responsible O&M contractor to carry out simple maintenance tasks or performance adjustments before a major intervention is required and without needing to visit the site.

4.7 Connection to the electricity distribution network

As highlighted above, operators and developers of biomass CHP systems who are looking for an electricity connection to the electricity distribution network are recommended to contact CRU in the first instance.

5. Installing and commissioning

Following the evaluation of tenders, a decision will be made and a preferred supplier selected. Contract negotiations will then start for the installation and commissioning of the biomass CHP system. This section provides guidance on what needs to be considered when the biomass system is being installed and commissioned, including:

- **Contracting**: producing a suitable contract between the owner and installer.
- **Installation:** installing the biomass CHP system with all its components and enabling works.
- **Commissioning**: formal acknowledgment from the contractor that all components, including the biomass boiler and cogeneration system, are operational.
- **Warranty**: the written guarantee from the installer declaring responsibility, within a specified time period, for repairing or replacing the system or parts of it when issues arise.

The following sections discuss the areas that should be covered and processes that should be followed, including potential risks. However, it does not provide a definitive solution for every situation and should not be used as a substitute for appropriate professional advice.

5.1 Contracting

Biomass CHP systems have to a large extent been developed outside the mainstream building services sector by specialist biomass installation companies that are often associated with a particular manufacturer. As a result, some projects have used less rigorous contractual approaches than would have been applied in mainstream construction. This may increase the risk to the developer of unnecessary additional costs and of the installer's inability to resolve performance issues. It is therefore crucial to agree a robust contract before installation works commence. This is discussed in further detail below.

5.1.1 Factors to consider

Biomass CHP systems include complex technologies (e.g. Organic Rankine Cycle and screw-type steam expanders) that have only been commercialised in the last decade. There are many recent examples of technologies not operating to the standard claimed by suppliers and so careful consideration is needed in drafting contracts. Factors that should be considered include:

- **Project size**. A larger project will pose a greater commercial risk and will merit additional effort in setting up the contract.
- **Technical complexity**. A more complicated project, such as one integrating into a complex system, will require a more detailed contract.
- **Associated works**. There is likely to be additional construction work and infrastructure associated with installing a biomass CHP system. These may include the installation of a gas back-up boiler or the construction of an access road. Clarity on the parties responsible for this additional work needs to be established before drafting the contract. If it is agreed that this is the responsibility of the contractors, then all additional work should be listed clearly in the contract and details provided.
- **Familiarity with form of contract**. If the contractor or the client have experience working with a particular form of contract, then this may be used. Using a form of contract with which the contractor is unfamiliar may result in an increase in price.
- **Client capability**. A client's capability and risk appetite will determine which roles and risks they will be willing to undertake.

5.1.2 Contract contents

The contract should include the following:

- **Performance measure**. Some form of contracted performance measure is essential to ensure the biomass system meets the site heat and power demands. It should at least include hours of operation, guaranteed performance parameters in terms of the boiler combustion efficiency and electrical efficiency of the CHP system, reliability and guaranteed temperature of the heat delivered. It should also include remedial measures if these criteria are not met and could include damages to cover any costs of underperformance.
- **The full scope of works under the contract**. This should include a full description of the boiler and CHP systems and their intended function (general requirements and restrictions about the design, location and operation of an installation project, but leaving the detailed design choices to the installer) and any interfaces with the existing system. In some circumstances, customers may have the skills to provide aspects of the works like civils and infrastructure construction (with biomass installers offering only aspects of their full service). This is acceptable as long as limits and extents of responsibilities are agreed.
- **The programme of works**. This is needed to ensure that all associated works are completed on schedule. If the programme is time critical, then clauses covering delay costs and measures could be built into the contract. Work plans need to be put in place to, e.g. what if the site is without electricity and heat if the installation and commissioning is not completed according to the schedule.
- **Contract preliminaries**. These include details of items such as site access arrangements; site working hours; setting down areas for equipment; facilities for contractor's staff; site agent provision and any site accommodation; site electrical and water supplies; insurance requirements; quality, safety and environmental requirements; and requirements for approvals, testing and sub-contracting.
- **Dispute resolution**. The procedure for resolving any potential disputes should they arise.
- **Details of guarantees**. Details of the warranty and any other guarantees as discussed in Section 5.4. This should include a detailed explanation of warranted performance and any maintenance requirements that need to be fulfilled for the warranty to be valid. Additional contractual protection may be needed where the project is complex, of significant financial value or where there could be contractual complications. For example, a bond may be put in place to cover the costs of plant replacement or remedial works should the contractor default or where the plant does not meet specified performance standards. A bond may extend through the contract period until the works are taken over and the purchaser becomes the legal owner.
- **Insurance and liability details**. The standard terms and conditions of contract will require the contractor to have in place third-party liability, employer's liability insurance and, very often, to insure the works and materials – usually until handover. For larger or complex projects, the purchaser might also consider an 'all-risks' insurance policy, which will afford additional recourse if the contractor defaults or if the plant underperforms. The value required for these insurances should be set on a case-by-case basis proportionate to the size of the project and the risks involved. Professional advice should be sought to ensure that correct levels and extents of coverage have been requested. Copies of certificates should be available from the contractor as proof of cover.
- **Reference to key documents**. These should include a full set of contract drawings, a full set of specifications, a risk assessment, a health and safety plan, a cost breakdown and a payments schedule.

In addition to agreeing and finalising the contract with the supplier for the biomass CHP installation, the site developer should, at the same time, aim to finalise any other agreements, such as organising the fuel supply and maintenance.

5.1.3 Form of contract

In some circumstances, it will be appropriate to use a standard **design-and-build contract**, using a set of formal contract terms and conditions. There are a number of forms of contract that are commercially published. If a design-and-build contract is to be used, it is recommended that one of these publicly availably forms is adopted. In the event of a dispute, these forms of contract are reasonably well understood by the legal profession and the courts.

While other, bespoke, forms of contract exist, it should be noted that, generally, these have been drafted to favour the party presenting them and they will not have the same degree of established legal precedent. Particular attention should be paid to payment terms, as installers will tend to seek a deposit and off-site payments for ordering the CHP system and other large items of equipment.

There are various Irish standard forms of contract:

- The Royal Institute of Architects of Ireland (RIAI)[22] form of contract, with or without quantities for building works.
- The Engineers Ireland[23] (formerly the Institute of Engineers Ireland) (IEI) 3rd edition form of contract, which is generally used for civil engineering works. There is also a standard form of subcontract for use with the IEI third edition.
- The Government Construction Contracts Committee (GCCC) developed a suite of contracts for use in public sector works.
- Standard forms for construction professionals developed by the key industry bodies (the RIAI, IEI and the Society of Chartered Surveyors (SCS)[24]. The GCCC has also developed standard conditions of engagement for construction professionals in public works.

Using UK and international forms is also common. These include:

- The Institution of Civil Engineers (ICE).
- Joint Contracts Tribunal (JCT)
- New Engineering Contract (NEC).
- International Federation of Consulting Engineers (Fédération Internationale des Ingénieurs-Conseils) (FIDIC) ;
- Institution of Chemical Engineers (IChemE); and
- Institution of Engineering and Technology MF/1 (amended for the Irish market).

Fédération Internationale des Ingénieurs-Conseils is probably the international form most commonly used in Ireland, particularly in the energy sector.

5.1.4 Project risks

Table 5.1 details risks that could arise during the project and how these could be mitigated within the contract. The larger the CHP system, the greater the need to address these kinds of risk in detail in a contract.

22 https://www.riai.ie/
23 http://engineersireland.ie/home.aspx
24 https://www.scsi.ie/

Table 4: Potential project risks and mitigation measures

Risk	Impact	Example mitigation
Commercial construction delay	Installation is completed later than expected, potentially incurring temporary heat and power generation costs.	• Allow reasonable construction window, including time contingencies. • Use the contract terms to manage the timetable and deal with liability for delay.
Capital overspend	Total capital cost of installation exceeds that which was originally budgeted for.	• Maintain contingency budget. • Enter contracts on fixed-price basis, passing risk to contractors.
Commercial risks	Boundaries of responsibility are not defined and an area ends up without ownership.	• Ensure all technical and contractual interfaces are documented (e.g. by defining physical boundaries and termination points) and understood by all parties.
Inappropriate allocation of risk	If a particular risk is not placed on those who understand it and can manage it, the project costs will rise (e.g. where a contractor does not understand the risk fully, the price will be increased to give protection to the contractor).	• Place risks with those who understand them and can manage them.
Limited scope	Higher costs caused by gaps in scope. Any gaps discovered during the works will cost more to rectify at the time of discovery than if they were included in the original scope.	• Examine the completeness of the scope rigorously before any contract is agreed. • Pay particular attention to integrating the biomass system with the existing system.
Technically immature technology	System breaks down due to shortfalls in design, manufacturing or installation. This is an issue for some of the Organic Rankine Cycle and screw-type steam expanders where, although the technology is now mature, some units available on the market are still showing some operational issues.	• Choose well-tested technologies and reputable installers – backed up by customer references. • Include performance and reliability terms in the contract.
Technical risks	Fault in installation.	• Ensure design, installation and operation are in accordance with pre-established quality control standards – perhaps independently verified.
Overly detailed system design (if contractor is designing)	This blurs the lines of responsibilities and creates contractual disputes. May result in less-suitable components/arrangements being used and prohibit contractors from using their supplier relationships to secure installation warranties.	• Do not produce a contract with an overly prescriptive design. • The use of performance standards and output requirements allows the installer to provide technical solutions that do not transfer risk back to the client.

No provision for performance measuring or for addressing under performance	Incorrectly installed and commissioned boilers and CHP systems are unlikely to yield the expected energy performance.	• Performance criteria need to be specified and then monitored after installation. • The performance clauses should lay out the solution.
Incorrect plant operation	System is not operated or maintained as required, causing outages and/or increased operating costs.	• If operated by in-house staff, ensure personnel are properly trained. • Enter into an appropriate call-out support contract.
Unreliable fuel supplies	Supplies insufficient to maintain required operation of the system.	• Choose system amenable to fuels from a range of potential suppliers. • Include fuel quality and timely delivery terms in contract if the contractor is supplying fuel.

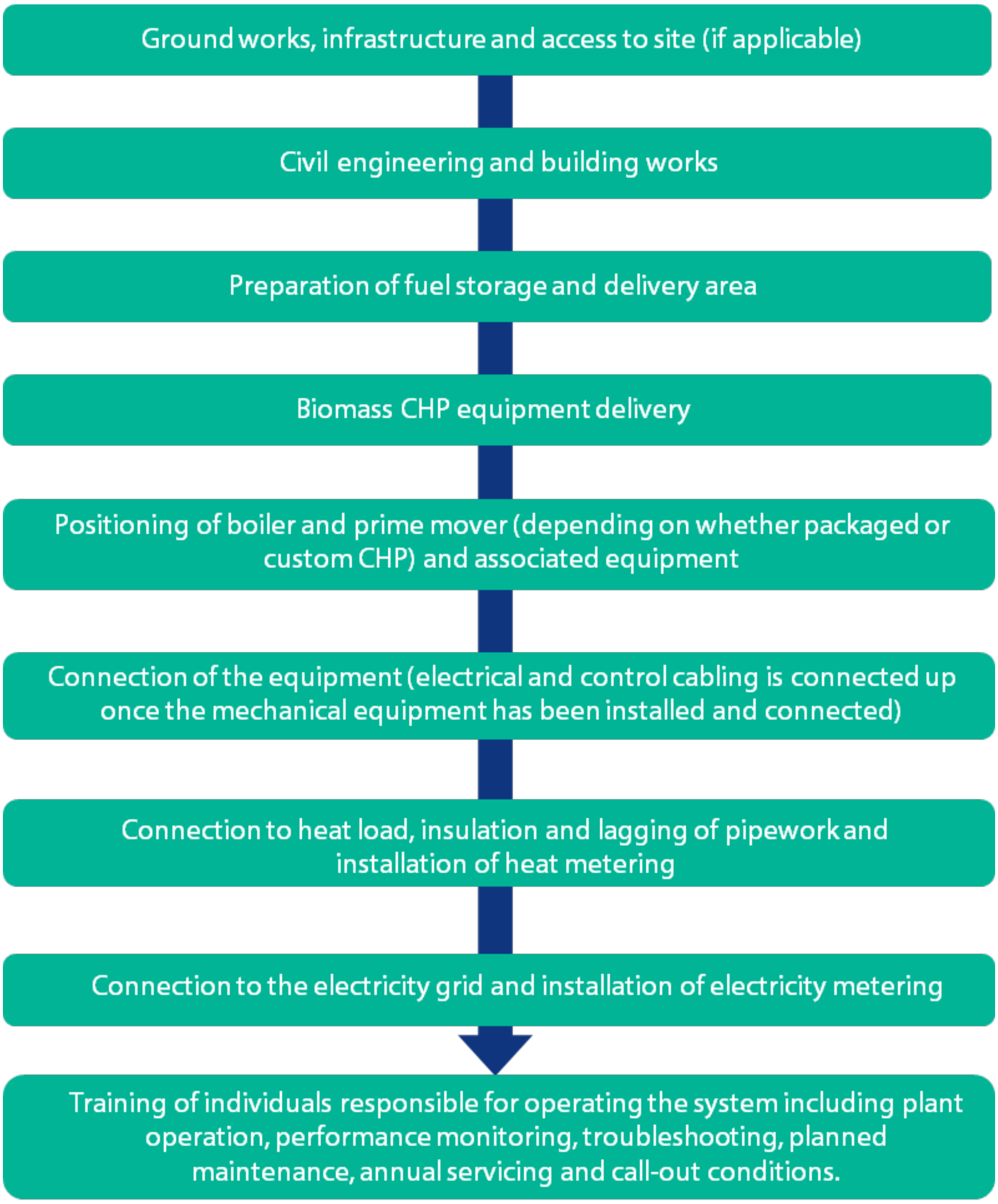
5.2 Installation

As with any project, creating an accurate project plan is key to success. It is recommended that a professional project manager is appointed to ensure the installation stage runs to time, budget and quality. This does not have to be someone with in-depth technical knowledge of biomass CHP systems, as this should be provided by the contractor.

Considerations when developing a project plan for the installation phase include:

- Any potential disruption to the organisation and how this can be mitigated. For example, it may be necessary to identify alternatives sources of fuel, heat and power until work is completed. Precautions will also need to be put in place to address health and safety issues including additional noise and/or dust.
- With large size units, consideration must be given to ensuring that access to the boiler house is sufficient to enable the boiler and prime mover to be installed (e.g. enlarged doorways).
- Specification drift may occur, especially if several contractors are involved. Therefore, all contractors should be aware of the site owner's original specification and all sub-contractors should treat this as the primary technical reference.
- Where projects are awarded on a fixed-price basis, the main contractor and sub-contractors naturally tend to minimise their costs. Performance penalties should be clearly outlined in the specification.
- When placing an order, it is important to note that lead times for delivery of a biomass CHP system are most likely to be longer than those for fossil-fuel-fired CHP systems. This is true for packaged and custom biomass CHP systems as they comprise the boiler and the prime mover, and involve additional components (e.g. generator, evaporator and turbine), which need to be provided according to the specification. This should be taken into consideration in project planning. The lead time will depend on the size of the system (whether it is packaged or custom), the type of technology and time of year.
- Site access arrangements and security arrangements will need to be agreed.

Figure 5.1: Typical key steps during the installation phase



5.2.1 Associated works

There will often be associated works to enable the biomass installation to take place. These may include:

- Removal and safe disposal of existing plant;
- Plinths for new plant;
- Water supply;
- Internal power supply;
- Changes to lighting and emergency lighting;
- New power supply from statutory authority;
- Connection to the electricity distribution network and installation of export and import electricity meters;
- Hard-standings for manoeuvring delivery vehicles;
- Changes to road access;
- Internal building alterations;
- Extensions to buildings;
- Groundworks for pipe runs and in readiness for the construction of building foundations;
- Fuel bunker construction;
- Hydraulics and fuel-handling systems;
- Cleaning/flushing, testing and repairs to the existing heat distribution system pipework; and
- Replacement and/or integration/reconfiguration of existing control systems with the biomass system.

The construction discipline (building, civils and infrastructure, mechanical and electrical) and quantity of associated works will determine the number of internal projects. Each of these interfaces poses a risk to the delivery and the project costs.

5.3 Commissioning

Commissioning of a biomass CHP system involves testing the boiler and prime mover individually and as a single system to confirm that it is operational and meets its design specifications. Cold commissioning takes place gradually following installation and leads to the final commission date to ensure individual items of equipment are operating as required. Hot commission involves testing the whole process and the ability of the biomass CHP system to provide heat and power as specified. The commissioning process will also cover the heat and power loads, connection to the electricity distribution network and all ancillary components. A commissioning certificate is usually issued to confirm that all equipment has been commissioned and is compliant.

Commissioning will require pressure testing of components, electrical testing of equipment, testing controls and meters, ensuring safety devices are correctly installed and working. It will also require operational testing of individual components of the system including the boiler, the fluid transfer pumps, the prime mover individual components (evaporator, turbine, generator, condenser, and collection and pumping systems), the heat and power distribution system, and the biomass feeding systems. Commissioning will also include testing the whole system under the range of normal operating conditions; and conducting extended plant performance and reliability tests.

Commissioning completion should be marked by a commissioning certificate that shows the scope and date of the commissioning, and should be signed by a qualified person. The date is important as it is likely to be required by any incentive scheme and can determine the rate of support that is applicable. Commissioning certificates should be kept on site as part of the installation records.

Completion of the commissioning will result in the handover of the system from the contractors to the operators. The operators should receive an operating, maintenance and safety manual, and should have received training in operation and basic maintenance. Systems should have a regular servicing regime in place based on the manufacturer’s guidance.

5.4 Warranty

Even with well-planned and executed installation and commissioning, faults may still occur. An initial teething period, where the system is modified to ensure optimum performance, should be expected.

It is important to be familiar with the warranties on all equipment, the overall system and workmanship. Any moving parts (such as electric motors and gearboxes, especially those inside the boiler or fuel delivery mechanism) and those subjected to high temperatures (such as refractory linings in the boiler combustion chamber) are particularly important as they are the most likely to fail.

The length of the warranties available is a good indicator of the confidence level manufacturers have in their products. Extended warranties are sometimes available to buy and the cost benefit of this should be assessed.

To ensure the warranty is comprehensive and fully used:

- Ensure it covers the whole system, all the components within it and the workmanship. If several installers were involved, check there are no gaps between the coverage of the warranties.
- Check the terms and conditions, especially any that may void the warranty (e.g. using the incorrect fuel, operating the system outside the manufacturer's specifications) and ensure that the system is maintained as per the manufacturer's requirements.
- Ensure the company providing it has a reasonable likelihood of remaining in business for the duration of the warranty. This can be done by checking company history and financial performance.
- Check if it is for parts, labour or both.
- Keep copies so they can be referred to. Create a schedule of the warranties so it is clear when they expire. Operating hours should be verified and monitored as some warranties are based on whichever occurs first – a given time period or number of operating hours.
- Schedule a service before the end of the warranty period to ensure any repairs and replacements can be identified and rectified under the warranty. Replaced parts are likely to have a warranty and a record of these should be kept in case the part requires a second replacement within that warranty period.

5.5 Record management systems

A structured information system should be set up to contain all records associated with the feasibility, design, procurement and implementation of the project, including full as-built drawings, full system schematics and specifications.

The system should be set up to accommodate all operational records into the future regarding maintenance and repairs and future systems changes. Also, all records on fuel use, electricity and heat generation and sales should be kept as described in the accompanying Operation & Maintenance Guide.

6. References and other sources of information

A substantial amount of guidance on biomass systems has been published over recent years. With the passing of time, not all of this guidance will remain correct or accurate. Factors that are likely to vary and should always be cross referenced against other sources are:

- Technology: develops and improves over time.
- Costs: these may be out of date, or specific to a certain technology or location.
- Fuel availability: this may be specific to a certain location.
- Financial support schemes: these are subject to change over time.
- Legislation: this is subject to change over time.

6.1 General

Sustainable Energy Authority of Ireland (SEAI)
www.seai.ie

SEAI, Combined Heat and Power in Ireland, 2016 Update
https://www.seai.ie/resources/publications/Combined%20Heat%20and%20Power%20in%20Ireland%20Update%202016

Chartered Institution of Building Services Engineers (CIBSE), 2016, AM12 Combined Heat and Power for Buildings (CHP)
https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q20000008I7nsAAC

Carbon Trust, 2012, Biomass heating: A practical guide for potential users
https://www.carbontrust.com/media/31667/ctg012_biomass_heating.pdf
It should be noted that the costs and Renewable Heat Incentive (RHI) are mainly UK specific.

Invest Northern Ireland, 2014, Biomass: A best practice guide for businesses in Northern Ireland
http://www.elementconsultants.co.uk/wp-content/uploads/2018/02/biomass-a-best-practice-guide-for-businesses-in-northern-ireland1.pdf

6.2 Energy efficiency

SEAI Excellence in Energy Efficiency Design (EXEED) Certified Program
https://www.seai.ie/energy-in-business/training-and-standards/exeed-certified-program/

6.3 Fuel

SEAI Conversion Factors
https://www.seai.ie/resources/seai-statistics/conversion-factors/

Wood Fuel Quality Assurance (WFQA) scheme for Ireland
http://wfqa.org/

En*plus*® certification scheme for wood pellet quality
https://enplus-pellets.eu/en-in/

Enterprise Ireland (2015) Animal By-products legislation: an explanatory guide
https://www.leanbusinessireland.ie/wp-content/uploads/2017/05/2015-Animal-By-Products-OCTOBER.pdf

6.4 Sustainability legislation

The proposed revised EU Renewable Energy Directive, which will come into effect in 2021, extending the scope of the existing EU sustainability criteria for bioenergy to cover biomass and biogas used for heating, cooling and electricity generation.
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016PC0767R%2801%29

6.5 High efficiency CHP

European Union, Energy Efficiency Directive, 2012/27/EU
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN

European Union, Commission Delegated Regulation, 2015/2402
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2402&from=EN

Certification Process for High Efficiency CHP Decision Paper, CER/12/125
https://www.cru.ie/wp-content/uploads/2012/07/cer12125.pdf

6.6 Health and safety

Combustion Engineering Association (CEA) website: https://cea.org.uk/

Health and safety authority, 2013, safety, health and welfare at work (construction) regulations 2013
http://www.hsa.ie/eng/Legislation/Regulations_and_Orders/Construction_Regulations_2013/.

Details of the duty holders and responsibilities are included on this website.
http://www.hsa.ie/eng/Your_Industry/Construction/Construction_Duty_Holders/

6.7 Procurement and contracts

Carbon Trust, 2012, Biomass installation contracting guide, practical procurement advice
https://www.carbontrust.com/media/88611/ctg073-biomass-contracting-guide.pdf

Carbon Trust, 2012, Template contracts for supply of biomass fuel, supply of heat energy, operation and maintenance agreement and services agreement
https://www.carbontrust.com/resources/guides/renewable-energy-technologies/biomass-heating-tools-and-guidance/

Energy network (produced by North Karelia University of Applied Sciences), 2003, Heat sales contract
http://elearn.ncp.fi/materiaali/kainulainens/nwh/heat_energy_entrepreneurship/business_models/material/Contract%20for%20supplying%20district%20heat.pdf

SEAI, Energy Contracting
https://www.seai.ie/energy-in-business/energy-contracting/

US Department of Energy, A Guide to Performance Contracting with ESCOs
https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20939.pdf

ESB Network, Connecting a renewable embedded generator
https://www.esbnetworks.ie/new-connections/generator-connections/connect-a-renewable-embedded-generator

ESB Network, Conditions Governing Connection to the Distribution System. Sets out requirements for Customer equipment at the interface between the Distribution System and the Customer's installation.

https://www.esbnetworks.ie/docs/default-source/publications/conditions-governing-connection-to-the-distribution-system

ESB Networks, Standard Connection Agreement for Embedded Generating Plant is available here:
https://rmdsie.files.wordpress.com/2014/03/standard-connection-agreement.pdf

Glossary

Absorption chiller	Refrigeration plant that uses heat instead of electricity as the driving energy source. Heat can be in the form of hot water or steam. Various working fluids are utilised, such as water, ammonia or lithium bromide.
Alternator	A machine whose shaft is driven by an engine or turbine and converts mechanical energy into alternating current (AC) electricity. See also 'Generator'.
Associated works	Works that are not included but instead act in support of the main scope of works, e.g. installation of concrete base for support of biomass boiler.
Base load	The minimum heat demand from a system which is maintained throughout a defined period.
Back-up boiler	An alternative boiler used to provide heat when the primary system is out of service.
Bioenergy	Renewable energy from living (or recently living) plants and animals, e.g. wood chippings, crops and manure.
Biomass	Any organic matter that can be burned for energy. Typically derived from solid wood into wood chips and pellets. Also, from short rotation coppice, miscanthus, sawdust and straw.
Boiler efficiency	The thermal transfer of energy contained in a fuel to the fluid in the boiler.
Buffer vessel	A form of thermal storage used to capture residual heat on boiler shut-down to improve system efficiency and to protect the boiler. Must be sized to have sufficient thermal capacity to absorb residual heat on boiler shut-down. Smaller than a thermal store.
Calorific value (CV) – net	The net calorific value of a fuel is the total energy released during combustion excluding that needed to evaporate any water arising as a combustion product and the moisture content of the fuel. Also known as the Lower Heating Value (LHV) of the fuel.
Calorific value (CV) – gross	The gross calorific value of a fuel is the total energy released during combustion including that needed to evaporate any water arising as a combustion product and the moisture content of the fuel. Also known as the Higher Heating Value (HHV) of the fuel.
Capital costs	Initial setup costs of plant or a project, after which there will only be recurring operational or running costs.
Carbon monoxide (CO)	A toxic product of the incomplete combustion of a fuel. Biomass-fired boilers operating in slumber produce high levels of CO and therefore airtight exhaust flues and proper dispersion are essential.
Carbon dioxide (CO_2)	A normal product of combustion – the result of complete combustion of CO.
Client	The ultimate person or organisation procuring the biomass plant.
Cogeneration	The simultaneous production of heat and electrical power from a single fuel source for useful purposes. See also 'Combined Heat and Power (CHP)'.
Cogeneration scheme	All the equipment and operating systems for the total system defined by a boundary. It will include one or more boilers, prime movers driving electrical generation or mechanical equipment and a means of recovering heat for useful purposes.
Combined Heat and Power (CHP)	The simultaneous production of heat and electrical power from a single fuel source for useful purposes. See also 'Cogeneration'.

Combustion efficiency	The optimum balance of air to fuel in a combustion process.
Commissioning	The process of verifying that a new heating plant meets the performance specifications as per design and the installation contract.
Consultant	Professional person or organisation appointed to provide assistance of an advisory nature under a predetermined contract.
Contractor	Person or organisation appointed for the task of executing the scope of works.
Distribution System Operator (DSO)	The companies that own and operate the public electricity distribution network under licence.
Energy Services Company (ESCo.)	Services company that sells heat (and/or other forms of energy) to the customer instead of a CHP and/or fuel. May install, own and maintain the CHP, or may sub-contract some or all of that.
Energy crops	Crops grown specifically for energy production purposes e.g. miscanthus
Energy density	Measure of the energy contained within a unit of fuel in MJ/m^3.
Expander	A device that transforms pressure in a working fluid (such as steam) into mechanical energy.
Fault level	The maximum current that would flow in case of a short circuit fault at that point on the network. The magnitude of the fault level affects the choice and design of equipment.
Frequency	The number of times per second that alternating current changes direction. Expressed as Hertz (Hz). Public electricity supply in Ireland is 50Hz.
Feedstock	The raw biomass material subsequently used as a fuel.
Flue	The passageway between combustion device and terminal of a chimney which acts as a duct to exhaust combustion gases to a position and height where they will not cause annoyance or health hazard.
Generator	A machine whose shaft is driven by an engine or turbine and converts mechanical energy into electricity. See also 'Alternator'.
Grate	Metal construction that supports a solid fuel during combustion. It allows the ash to pass through or over to collection. Various designs available with moving components to mix and move the fuel.
Header	A pipe connecting two or more boilers in parallel and to other parts of the boiler house. Flow header connects outputs from the boilers, return header connects boiler returns. In a cogeneration system, the headers can also be on the heat demand side of the scheme.
Heat demand	The demand of heat of a site at any one time, typically expressed in kW or MW.
Heat exchanger	A device that transfers heat between two fluid systems e.g. water flows from boiler system and heating pipework. Many different configurations available but plate-heat exchangers most commonly found.
Heat Supply Agreements (HAS)	The contract underpinning the relationship between a supplier and a customer for the sale of heat.
Heat meter	Device that measures the rate of heat transferred by a system by monitoring the flow rate of water and temperature difference between flow and return pipes.
Heat-to-power ratio	The amounts of heat energy and electricity produced by a cogeneration scheme, expressed as a ratio.
High efficiency CHP	High efficiency CHP is combined heat and power production which on annual basis (i) in the case of small scale CHP (total power capacity smaller

	than 1 MWe) and micro-CHP achieves primary savings calculated in accordance of paragraphs 3 and 4 of Schedule 3 and (ii) in the case of larger scheme with total power capacity exceeding or equal to 1 MWe achieves primary energy savings larger than 10% calculated according to paragraphs 3 and 4 of Schedule 3. If the overall efficiency exceeds a defined level of 75%, or 80% (for combined cycle gas turbines with heat recovery and for steam condensing extraction turbine-based plants), then all of the electricity from the plant is taken into account in the primary energy savings calculation. Where this overall efficiency threshold stated above is not met, the share of electricity deemed to be produced by the CHP plant for the purpose of the primary energy savings calculation is calculated on the basis of the power-to-heat ratio at maximum heat conditions.
High temperature hot water (HTHW)	Pressurised hot water at 120°C and above.
In-house	Work or activities conducted by employees within an organisation.
Installer	Organisation or person contracted for the installation of equipment. May also be the supplier.
Liability	A person or organisation's legal responsibility to pay debts or fulfil obligations.
Low temperature hot water (LTHW)	Hot water at up to 95°C.
Medium temperature hot water (MTHW)	Pressurised hot water at 95°C to 120°C.
Moisture content (MC)	Percentage, by weight, of biomass fuel that contains water. For example, wood pellets typically have an MC of less than 10. Wood chips and logs are likely to have a more variable MC of between 20% and 60%.
Network	The distribution system which links energy production to energy usage. Can describe electricity and heat supply.
Operating costs	Costs of maintaining the ongoing operation of a process or facility. Does not include any capital outlays or costs incurred in the design or commissioning phases of a project.
Oxides of nitrogen (NOx)	Produced from the combustion of biomass at high temperatures. Exposure to a significant amount of the gases can be detrimental to human health and the environment.
Oxides of sulphur (SOx)	Produced by the combustion of sulphur in a fuel. Presence in flue gases can cause corrosion on heat exchange surfaces if temperatures are not properly controlled.
Parasitic load	Electricity used within the cogeneration scheme and therefore reducing the amount available for utilisation or export.
Particulate	Particles of solid matter, usually of a very small size, derived from the fuel either directly or as a result of incomplete combustion.
Peak load	The maximum heat demand a site experiences across a year, typically expressed in kW or MW. Used to size heating systems.
Primary Energy Savings (PES)	Primary energy savings is a function of the heat efficiency and the electrical efficiency of the CHP process relative to the reference values (as in the Commission Delegated Regulation (EU/2015/2402)) for separate heat and

	electricity production. Key to this equation is the amount of heat that can be defined as 'useful' heat.
Short rotation coppice	Dense growth of small trees or bushes regularly trimmed back for re-growth. Willow or poplar grown as an agricultural crop on a short (2–5 year) rotation cutting cycle and at a planting density of 10,000 to 20,000 cuttings per hectare.
Solar thermal	Device designed to receive solar radiation and convert it into thermal energy for a useful output, typically to heat water for space heating or domestic hot water.
Steam – superheated	Steam at a temperature that is higher than its vaporisation (boiling) point at the absolute pressure. It is steam which is formed at the temperature which exceeds that of saturated steam at the same pressure.
Steam – saturated	Saturated steam occurs at temperatures and pressures where steam and water can coexist, which is when the rate of water vaporisation is equal to the rate of condensation.
Supplier	Organisation or person contracted for the delivery of a goods or assets.
Technical specification	A document that outlays the design of a system such that a contractor can provide a quotation for its installation.
Thermal store	A reservoir of heat energy provided from the boiler to enable the heating system to meet the majority of energy demands. Allows the boiler to be of a smaller size as well as improving its operating efficiency by allowing running for longer continuous periods. May also perform the role of a buffer vessel.
Transformer	A device with primary and secondary windings to convert the voltage of electricity from one value to another (step-up or step-down).
Trigeneration	Combination of cogeneration with absorption chilling to give the simultaneous production of heat, power and cooling. See also Combined Cooling, Heat and Power (CCHP).
Turndown ratio	The turndown ratio of a boiler is a measure of its ability to operate at heat outputs less than the full rated output. It is the ratio of the maximum heat output to the minimum level of heat output at which the boiler will operate efficiently or controllably. For example, a boiler with 2:1 turndown ratio will be able to operate down to 50% of its full rated output.
Warranty	Agreement provided by an organisation such as a contractor or manufacturer that it will remedy, without additional charge, deficiencies in their service or goods that have arisen within a stated period after their installation.

Appendix 1. Key players in electricity industry

The Irish electricity industry comprises the following key players:

- The Transmission System Operator (TSO) operates the transmission system. The transmission system transports the electricity, generated by generating units, to and from the distribution system, through which most customers will be supplied. Some generating plant is connected directly to the distribution system and is referred to as generation. EirGrid holds the TSO licence.
- The Transmission System Asset Owner (TAO) owns the transmission system. ESB holds the TAO licence.
- The Distribution System Operator (DSO) is responsible for operating and maintaining a secure, reliable and efficient electricity distribution system in accordance with its DSO licence obligations. The distribution system transports electricity to or from the transmission system or from generation units to the final customer. ESB Networks Ltd holds the DSO licence.
- The Distribution System Asset Owner (DAO) owns the distribution system. ESB holds the DAO licence.
- Suppliers supply electricity to customers. For this purpose, suppliers will be entitled to use the Transmission System and the Distribution System for the transport of electricity from generating units to customers.
- Generators generate electricity, which is fed onto the Transmission System or Distribution System. Generating units are classified according to their voltage, output power and whether or not they are subject to central dispatch (i.e. supplying electricity centrally through the TSO).
- Customers purchase electricity from suppliers. Some customers have their own generating plant for supplying all or part of their own needs. These are referred to as 'customers with CHP' or 'customers with auto-production'.
- Dispatchable demand customers are customers who are subject to central dispatch and have a demand reduction capability of 4MW or more.
- The Commission for Energy Regulation was established in 1999 and changed name to the Commission for Regulation of Utilities (CRU) in 2017.

SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Rialtas na hÉireann
Government of Ireland

Sustainable Energy Authority of Ireland
Three Park Place
Hatch Street Upper
Dublin 2
Ireland
D02 FX65

e info@seai.ie
w www.seai.ie
t +353 1 808 2100