Department for
Business, Energy
& Industrial Strategy

GUIDANCE NOTE FOR ADVANCED CONVERSION TECHNOLOGIES

Compliance with the ACT Efficiency Standard criterion in the Contract for Difference scheme

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Contents

Important considerations

This document provides guidance to Generators on how to calculate the ACT Efficiency and what evidence to provide in order to demonstrate compliance with the ACT Efficiency Standard. However, it is not intended to provide a comprehensive list of methods for the determination of the parameters used in the calculation of the ACT Efficiency. The onus is on the Generator to agree these methods with the Low Carbon Contracts Company as part of the Fuel Measurement and Sampling procedures. For the ACT Efficiency Standard this may include:

- A clear and detailed methodology for the determination of each of the parameters required in the detailed ACT Efficiency calculation formula,
- A methodology for the determining the uncertainty associated with the calculation of the ACT Efficiency,
- A definition of boundaries of the ACT Efficiency calculation and detailed mass and energy flow diagrams to help identify internal and external processes,
- A sampling procedure to ensure that the different parameters in the ACT Formula are determined for the same time period and how time lapse issues between the feedstock and Advanced Fuel measurements are minimised,
- A methodology to ensure that all process energy inputs to the Advanced Fuel generation and conditioning processes are used on a primary energy-basis (i.e. methodology to convert electricity inputs to primary energy).

It should be noted that the list above is not intended to be exhaustive. Specific requirements should be agreed with the Low Carbon Contracts Company on a case-by-case basis according to Fuel Measurements and Sampling Guidance.

Should this guidance note conflict with the ‘CfD Standard Terms & Conditions’, the ‘CfD Agreement’, the Allocation Framework or any relevant legislation (together ‘the scheme rules’), such conflict should be resolved in favour of the scheme rules.

Introduction

1. A Contract for Difference (CfD) is a private law contract between a low carbon electricity Generator and the *Low Carbon Contracts Company (LCCC)*, a Government-owned company. The electricity Generator is paid the difference between the 'Strike Price' – a price for electricity reflecting the cost of investing in a specific low carbon technology – and the 'reference price'– a measure of average GB market price for electricity. The CfD scheme provides direct funding support to renewables schemes from a levy imposed on consumer electricity bills.

2. Advanced Conversion Technologies (ACTs) including *Gasification* and *Pyrolysis* participate in the CfD scheme as one of the 'fuelled technologies'. An eligible ACT station is a generating station which generates electricity by the use of *Advanced Fuel* (gas or liquid formed by *Gasification* or *Pyrolysis* of *Biomass* or *Waste*). Most existing ACT plants produce a gaseous product (i.e. a mixture of methane, hydrogen, carbon monoxide, carbon dioxide and other hydrocarbon gases). However, there are some processes in development that either produce combustible liquids or mixtures of combustible liquids and gases.

3. The Government has introduced two new criteria that will apply to ACT Generators applying for CfD support from the third CfD allocation round. These are a minimum efficiency of the conversion process (*ACT Efficiency*) and a requirement for physical separation of the synthesis process from the combustion process. This guidance document focusses on the first criterion which requires that the *ACT Efficiency Standard* be met or exceeded (defined in the *ACT Efficiency Formula* section of this document).

4. Setting this *ACT Efficiency Standard* for *Gasification* and *Pyrolysis* processes ensures that support is directed at the most efficient forms of these technologies. Generators who do not comply with this standard will not receive payments for the period of non-compliance.

5. This document is a technical guidance note produced as part of the third allocation round, intended to provide guidance for CFD applicants on how to apply the *ACT Efficiency Formula*. When proposing the necessary evidence and calculation methodology to the *LCCC*, the Generator should refer to its 'CfD Standard Terms & Conditions', as amended from time to time. It is up to the Generator to decide which method they wish to propose and regardless of the method chosen, the applicant should, as part of the agreement of *Fuel Measurement and Sampling (FMS) Procedures*, provide a clear description of the methodology they intend to use including a determination of uncertainty.

Glossary

This explains the key terms used in this Guidance, please note that some of these terms are the same as in 'CfD Standard Terms & Conditions' or 'CfD Agreement' and in that case this is noted by an asterisk.

ACT Efficiency* means, for each ACT Efficiency Period to which it relates, a whole number integer expressed as a percentage (%) which is calculated using the ACT Efficiency Formula, rounded down to the nearest integer.

ACT Efficiency Formula* means

$$\text{ACT Efficiency} = E_{\text{products bio}} / (E_{\text{bio}} + E_{\text{inputs bio}})$$

ACT Efficiency Period* means

- the seven (7) day period beginning at 00:00 on the first day of an RQM Calculation Month and ending at on 23:59 on the seventh (7th) day of that period, and every subsequent seven (7) day period of that RQM Calculation Month beginning at 00:00 after the end of the previous seven (7) day period (each such seven (7) day period being a **"Long Period"**), and
- any period of days in which the last day of the RQM Calculation Month occurs before the seventh (7th) day of such a period, in which case the last day of that period shall end at 23:59 on the last day of the RQM Calculation Month (each such period being a **"Short Period"**)

ACT Efficiency Standard* means 60%.

Advanced Fuel* means gaseous or liquid fuel which is produced directly or indirectly from the Gasification or the Pyrolysis of: (i) Waste; or (ii) Biomass, provided that, in the case only of a gaseous fuel, such fuel must have a gross calorific value (when measured at 25 degrees Celsius and 0.1 megapascals at the inlet to the Combustion Chamber) which is at least 2 megajoules per cubic metre.

Biomass* means material, other than fossil fuel or peat, which is derived directly or indirectly from plant matter, animal matter, fungi, algae or bacteria (and includes any such material contained in Waste).

Calorific value (CV) **(MJ/kg)** is the amount of energy released (MJ) when a known quantity of a substance is completely combusted under specified conditions.

Carbon dating refers to a method for determining the Biomass content of a substance by determining the relative proportions of carbon-14 (^{14}C) and carbon-12 (^{12}C) in the substance. An example of a standard for the application of the carbon dating method is the ISO 13833:2013 standard.

Combustion Chamber* means that part of a Facility, the Facility Generation Technology of which is Advanced Conversion Technology, in which Advanced Fuel is combusted.

Conditioning Process(es) means the processes of treating and upgrading the Advanced Fuels resulting from gasification or pyrolysis before combustion in a Prime Mover or their utilisation for the production of other products (gas to grid, transportation fuels etc.) with the objective of removing contaminants present in these products. These processes correspond to the processes that will take place in what has been defined as the Purification Unit and Compression Unit in the '*CfD Standard Terms & Conditions*'.

$E_{products\ bio}$* means the energy (MJ) from Biomass in the Advanced Fuel which is produced from the material to which E_{bio} relates.

E_{bio*} means the energy (MJ) from Biomass in the material from which the Advanced Fuel to which $E_{products\ bio}$ relates was produced.

$E_{inputs\ bio}$* means any energy (MJ) used in the production of the Advanced Fuel to which $E_{products\ bio}$ relates.

Electrical Output refers to the electrical output of the prime mover (MWh) measured at the Prime Mover terminals. This can be used in combination with the Prime Mover's design electrical efficiency to determine the Energy Content of Advanced Fuels immediately before entering the Prime Mover.

Energy Content (MJ) means for the purposes of this guidance, in relation to any substance, the energy contained within that substance (whether measured by a calorimeter or determined in some other way), expressed in terms of the substance's "gross calorific value" within the meaning of British Standard BS 7420:1991 (as such standard may be amended, supplemented, restated or replaced from time to time);

FMS is Fuel Measurement and Sampling

FMS Procedures* means the fuel measurement and sampling procedures to be documented and agreed between the CfD Counterparty (LCCC) and the Generator pursuant to paragraph **Error! Reference source not found.** (***Error! Reference source not found.***) of **Error! Reference source not found.**, Annex 7 of the 'CfD Standard Terms & Conditions' (version [3]) to, among other things, fulfil the FMS Purposes, as such procedures and tests may be amended, supplemented, restated or replaced from time to time by agreement between the Generator and the CfD Counterparty,

FMS Purposes* means enabling and assisting the CfD Counterparty (including by way of audit, check, examination, inspection or stocktake):

(A) to calculate the Renewable Qualifying Multiplier in accordance with: (i) Condition 11 (Renewable Qualifying Multiplier); and (ii) Part E;

(B) where the Facility is a Baseload Dual Scheme Facility, to determine the Imported Electricity Allowance in accordance with Condition 13.6;

(C) to verify that all FMS Reports (including all of the FMS Data) used for the purposes of calculating the Renewable Qualifying Multiplier are accurate, complete and not misleading;

(D) to assess compliance or non-compliance:

  (i) by the Generator and the Facility with the FMS Exemption Criteria;

  (ii) of the Facility with the Fuelling Criteria; and

  (iii) by the Generator with Part A (including with respect to the FMS Procedures);

(E) to determine the ACT Efficiency Multiplier in accordance with: (i) Condition 12A (ACT Efficiency Multiplier); and (ii) Part G, provided that this paragraph (E) shall apply only if the Facility Generation Technology is Advanced Conversion Technology;

Gasification* means the substoichiometric oxidation or steam reformation of a substance to produce a gaseous mixture containing two or more of the following: (i) oxides of carbon, (ii) methane and (iii) hydrogen.

LCCC is the Low Carbon Contracts Company.

Long Period* has the meaning given to that term in the definition of ACT Efficiency Period.

Permitted Ancillary Activities* means the cleansing of other fuels from the Facility's combustion system prior to heating the combustion system or Synthesis Chamber to its normal temperature, the heating of the Facility's combustion system to its normal operating temperature or the maintenance of that temperature, the ignition of fuels of low or variable calorific value, emission control, standby generation or the testing of standby generation capacity, corrosion control and fouling reduction.

Primary energy (MJ) is the energy contained in raw fuels, and other forms of energy received as input to a system.

Prime mover is a machine (or component of a machine) that converts energy from a source energy into mechanical energy (shaft power).

Process Energy Inputs (E_{input1} and E_{input2}) is the energy (MJ) consumption required to enable Gasification/Pyrolysis (E_{input1}) and conditioning (E_{input2}) respectively.

Pyrolysis* means the thermal degradation of a substance in the absence of any oxidising agent (other than that which forms part of the substance itself) to produce char; and a gas or a liquid, or both.

RQM Calculation Month* means each calendar month during the Term for which the Renewable Qualifying Multiplier is required to be calculated, provided that: (i) if the Start Date occurs other than on the first (1st) day of a calendar month, the first (1st) RQM Calculation Month shall be deemed to mean the period from and including the Start Date to and including the last day of the calendar month in which the Start Date occurs; and (ii) if the Specified Expiry Date (or the Termination Date) occurs other than on the last day of a calendar month, the last RQM Calculation Month shall be deemed to mean the period from and including the first (1st) day of the calendar month in which the Specified Expiry Date (or Termination Date) occurs to and including the Specified Expiry Date (or Termination Date);

Selective Dissolution Method ('SDM') refers to a method for determining the Energy Content of the Biomass of a substance based on the principle that Biomass fuel components (but not fossil fuel) dissolve in sulfuric acid or hydrogen peroxide. An example of a standard for the application of the SDM method is standard EN 15440 2011.

Short Period* has the meaning given to that term in the definition of ACT Efficiency Period.

Synthesis Chamber* means that part of a Facility, the Facility Generation Technology of which is Advanced Conversion Technology, in which Advanced Fuel is produced

Waste* has the meaning given in Article 3(1) of Directive 2008/98/EC of the European Parliament and of the Council on waste (but does not include landfill gas or sewage gas): any substance or object which the holder discards or intends or is required to discard.

ACT Efficiency Formula

6. The formula used for calculating the *ACT Efficiency* is as defined in Paragraph 1.1 of Part 1 of the 'CfD Standard Terms & Conditions' (version [3]):

$$ACT\ Efficiency = \frac{E_{products\ bio}}{(E_{bio} + E_{inputs\ bio})}$$

Where:

$E_{products\ bio}$ is the energy (MJ) from *Biomass* in the *Advanced Fuel* which is produced from the material to which E_{bio} relates,

E_{bio} is the energy (MJ) from *Biomass* in the material from which the *Advanced Fuel* to which $E_{products\ bio}$ relates was produced;

$E_{inputs\ bio}$ is any energy (MJ) used in the production of the *Advanced Fuel* to which $E_{products\ bio}$ relates;

7. The boundaries for the calculation of the *ACT Efficiency* are defined by the dashed line in the diagram.

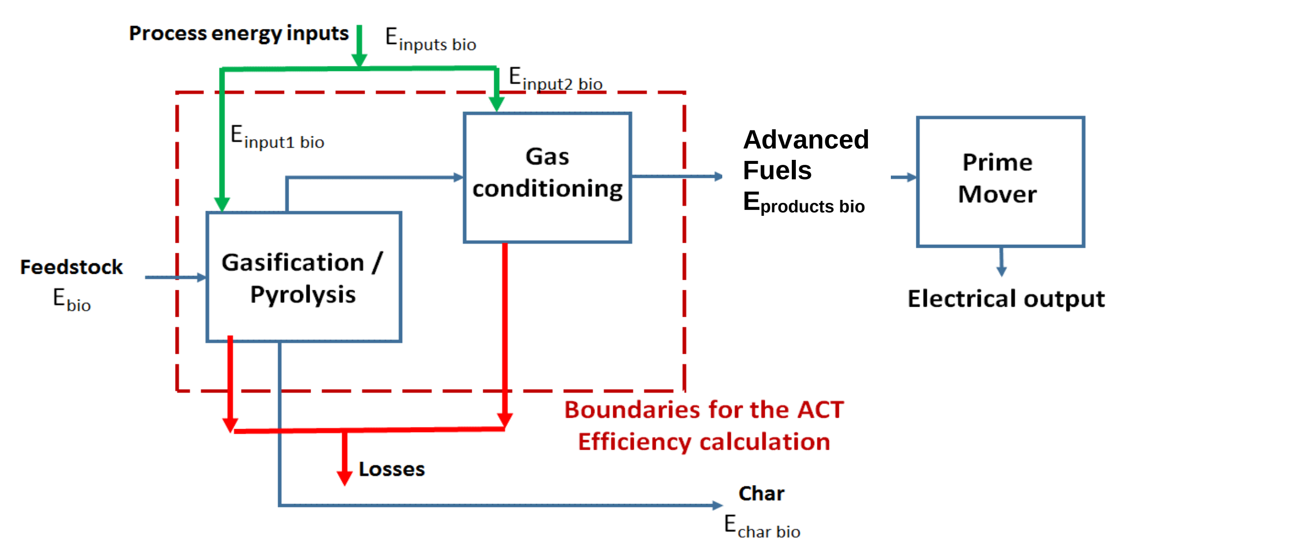

Figure 1: Boundaries for the *ACT Efficiency* calculation (showing energy flow of *Biomass* component)

8. The *gasification* process involves the partial oxidation of *Biomass* or *Waste* at high temperatures (around 600 ^oC) in a limited supply of oxygen, to produce syngas. This can then be used as a fuel to produce electricity or heat or as an intermediate for chemicals or fuels production. In addition to hydrogen, light hydrocarbons, CO, CO_2, H_2O and tar, char and ash are also produced. Char is then gasified with oxygen, air or steam at higher temperatures (from around 800 ^oC to 1000 ^oC or more).

9. *Pyrolysis* is a similar process to *gasification* but occurs in the absence of air or oxygen at lower temperatures (normally around 400-600 ^oC) and may produce, in addition to syngas, liquid bio-oil and char. Both *gasification* and *pyrolysis* are endothermic and require energy to kick-start and maintain the process, which can be

provided with the partial oxidation of the feedstock or externally (E_{input1}). Depending on the feedstock used, the operating conditions and the type of contaminants, the resulting gas or bio-oils may require conditioning and further treatment through a series of processes which also require energy input (E_{input2}).

10. The *ACT Efficiency Formula* outlined under paragraph 6 can be expanded as shown below

$$\text{ACT Efficiency} = \frac{E_{products} \times \%_{products\ bio}}{E_{feed} \times \%_{feed\ bio} + E_{input1} \times \%_{feed\ bio} + E_{input2} \times \%_{products\ bio}}$$

Where

($E_{products}$ x $\%_{products\ bio}$) is equivalent to $E_{products\ bio}$ as defined in the 'CfD Terms and Conditions' and 6 above,

(E_{feed} x $\%_{feed\ bio}$) is equivalent to E_{bio} as defined in the 'CfD Terms and Conditions' and 6 above,

(E_{input1} x $\%_{feed\ bio}$ + E_{input2} x $\%_{products\ bio}$) is equivalent to $E_{inputs\ bio}$ as defined in the CfD Terms and Conditions and 6 above,

$E_{products}$ is the *Energy Content* (MJ) of the *Advanced Fuels*, determined at the entry of the *Combustion Unit* for electricity production (or at the outlet of the boundaries for the *ACT Efficiency* Calculation in the case of other products, e.g. gas-to-grid, or transportation fuels). It should be ensured that the *Energy Content* of the *Advanced Fuels* (whether metered or calculated based on Electrical Output of the prime mover) corresponds to the feedstock used to produce these *Advanced Fuels* in a given *ACT Efficiency Period.*

$\%_{products\ bio}$ is the proportion (expressed as a percentage) of the *Energy Content* of the *Advanced Fuels* ($E_{products}$) which is attributed to *Biomass*, determined at the entry to the *Combustion Unit* for electricity production (or at the outlet of the boundaries for the *ACT Efficiency* Calculation in the case of other products, e.g. gas-to-grid or transportation fuels),

E_{feed} is the *Energy Content* (MJ) of the feedstock, determined at the entry to the *gasification* or *pyrolysis* unit,

$\%_{feed\ bio}$ is the proportion (expressed as percentage) of the *Energy Content* of the feedstock (E_{feed}) which is attributed to *Biomass*, determined at the same point as E_{feed},

E_{input1} is the energy input (MJ) used in the main conversion process (*gasification* or *pyrolysis*). This should be proportioned to the *Biomass* content of the feedstock and this is the reason why it appears multiplied by $\%_{feed\ bio}$ in the formula,

E_{input2} is the energy input (MJ) used in the *Conditioning Process(es)* of the *Advanced Fuels* (either gas or liquid) prior to their utilization in the production of electricity or prior to leaving the boundaries for the *ACT Efficiency* Calculation where they are used in the production of any other energy products (gas-to-grid, transportation fuels, etc.). This should be proportioned to the *Biomass* content of the *Advanced Fuels* which is being treated with this energy (and so the reason why it appears multiplied by $\%_{products\ bio}$ in the formula.) It should be noted that $\%_{products\ bio}$ can vary slightly after each conditioning step and so this needs to be measured at the entry of the *Combustion Unit* (or any other transformation unit or *Conditioning Process* outside the boundaries for the *ACT Efficiency* Calculation in the case of other products, e.g. gas-to-grid or transportation fuels) after *Advanced Fuel* cleaning and conditioning has been implemented.

11. The formula above accounts for the external energy required for the *gasification / pyrolysis* and conditioning processes to take place and so these inputs will be factored into the 60% *ACT Efficiency Standard*. However, energy required in the preparation of the feedstock and transporting it to the gasifier would not normally be accounted for as there is the potential for this to occur off-site, and in some cases even in a different country, making providing evidence of this difficult. Similarly, the energy required to dispose of ash and char after it leaves the gasifier is not included in the equation above. It should also be noted that some by-products from the *gasification / pyrolysis* processes may be used in the process (e.g. reusing some of the char or the syngas to improve process performance.) As these by-products do not leave the boundaries for the *ACT Efficiency* Calculation they are not accounted for in the calculation of the *ACT Efficiency*.

12. As part of the agreement of *FMS Procedures*, the Generator should fully describe the boundaries of the *ACT Efficiency* calculation and provide detailed mass and energy flow diagrams to help identify internal and external processes.

13. Each of the parameters in the expanded formula above can be determined in a number of ways. The determination can be based on direct measurement of the relevant quantity or calculated from measured quantities. The methods referred to in this guidance are not comprehensive and Generators should agree with the *LCCC* as part of the agreement of *FMS Procedures* which method will be used and to demonstrate that it is a reliable method for determining the *ACT Efficiency*.

Uncertainty in the calculation of the ACT Efficiency

14. In calculating the *ACT Efficiency* as described above, the uncertainty associated with the calculated value of the efficiency should also be reported. The uncertainty in the calculated efficiency will depend on the uncertainty in each of the parameters listed above which in turn depend on the measurement.

Energy Content of the Advanced Fuels ($E_{products}$)

15. A sampling procedure for all metered parameters (amount of *Advanced Fuel*, *Energy Content* of the *Advanced Fuel* , or measurement of the *Electrical Output* of the *Prime Mover*) needs to be agreed with *LCCC* in order to form part of the *FMS Procedures*. It should be ensured that the *Energy Content* of the *Advanced Fuel* (whether metered or calculated based on *Electrical Output* of *the Prime Mover*) corresponds to the feedstock used to produce these *Advanced Fuels* in a given *ACT Efficiency Period*.

16. In practice, there is a time lapse between the moment the feedstock is introduced into an ACT system and the moment the *Advanced Fuels* corresponding to that feedstock are generated. The applicant should outline a methodology with their proposed *FMS Procedures* and agree with *LCCC* how the impacts of this time lapse will be minimised. This will be evaluated on a case-by-case basis.

17. The most accurate and preferred method for determining $E_{products}$ is the direct measurement of the amount of energy (MJ) contained in the *Advanced Fuels* generated in a given reporting period. The *Energy Content* (MJ) of the products can be determined from direct measurement of the amount of products generated in a given reporting period (in kg or Nm^3) multiplied by the weighted-average *calorific value* (CV, MJ/kg or MJ/Nm^3) of the products measured over the same reporting period at normal conditions. The best method to obtain an average figure of the syngas *CV* is to use an analyser to measure the *Advanced Fuel* at frequent intervals. An alternative to analysers is to undertake bag sampling of the *Advanced Fuel* and have these samples analysed for *CV* using an appropriate standard. Generators may propose alternative methods and *LCCC* will review each proposal on a case-by-case basis.

18. If utilising the direct measurement approach, the Generator should provide details of gas / liquid flow meters (e.g. type, make and model, inaccuracy, range) and of the methodology as part of the agreement of *FMS Procedures*. This will include:

- *Advanced Fuel* quantity metering and meter calibration strategies and corresponding standards
- *Calorific value* determination, whether determined directly using in-line gas analysers or offline measurements (e.g. mass spectroscopy or gas chromatography techniques) using bag sampling; or indirectly (e.g. based on *Advanced Fuel* composition analysis and using that in combination with thermodynamic data, i.e. gross calorific values of individual gas components). Sampling methods and frequency should be described clearly.

19. An alternative approach for determining $E_{products}$ is based on using the metered *Electrical Output* of the *Prime Mover* (MWh), where the *Advanced Fuels* are combusted, divided by the maximum electrical efficiency of the *Prime Mover*. This is a more conservative method which leads to an underestimate of the *ACT Efficiency*. An alternative approach to direct measurement is acceptable as long as it leads to

more conservative estimate of the *ACT Efficiency* and is presented clearly to the *LCCC*.

20. The maximum electrical efficiency (based on gross calorific value, GCV[1]) as reported by the manufacturer should be used in this case. This method is considered to be inaccurate as small variations in *Prime Mover* electrical efficiency can lead to large inaccuracies in the calculated fuel input. If this approach is used, the *Electrical Output* of the *Prime Mover*.

21. Applicants using this approach should provide as part of the agreement of *FMS Procedures* details of the *Electrical Output* metering approach, the proposed maximum electrical efficiency (supported by manufacturer's data) and, as applicable, methodology for converting from NCV to GCV-based efficiency.

[1] The majority of manufacturer's report efficiencies on a net calorific value (NCV). The factor used to convert NCV to GCV depends on the composition of the Advanced Fuel. Typically for syngas, the efficiency on a GCV basis is obtained by dividing the NCV-based efficiency by 1.077.

Energy Content of the feedstock (E_{feed})

22. The *Energy Content* (MJ) of the feedstock can be determined by direct measurement of the amount of feedstock (kg) used in a given reporting period, multiplied by the weighted-average *Calorific Value* (CV, MJ/kg) of the feedstock over the same reporting period.

23. The Generator should provide to *LCCC*, as part of the agreement of *FMS Procedures*, details of the feedstock metering methodology (e.g. feedstock weighbridge type and model, inaccuracy, calibration schedule, relevant standards[2]).

24. The Generator should describe how fuel will be sampled, including the method and frequency, and to give an accurate measure of Gross Calorific Value (GCV). Sample tests needed to establish the GCV should be outlined. Standards for sampling fuels and determination of the *Calorific Value* of feedstocks should be followed.

25. The 'Fuel Measurement and Sampling Process' guidance should be considered when proposing the *FMS Procedures*. Information on fossil fuel use for the purposes of *Permitted Ancillary Activities* (PAA) should be fully explained.

26. A sampling procedure should also be provided to ensure that the quantity of feedstock used and the quantity of *Advanced Fuels* produced are metered and reported over the same timescale. The *CV* values used in the calculation of the *Energy Content* of the feedstock and the *Advanced Fuels* should also correspond to the same reporting period.

[2] Guidance for calibration requirements for weighbridges are available in the Code of Practice for the Calibration of Industrial Process Weighing Systems issued by the Institute of Measurement and Control

Process Energy Inputs (E_{input1} and E_{input2})

27. The *ACT Efficiency* calculation outlined in paragraph 10 should take into account all energy inputs used in the *Advanced Fuel* generation (E_{Input1}) as well as *Conditioning Processes (E_{Input2})*[3]. This energy input can be in the form of fuel, heat or electricity.

28. For Fossil and renewable fuels the *Primary energy* is treated as being the same as the energy used to site. For electricity imported from the grid or private sources and liquid nitrogen and oxygen the delivered energy must be multiplied by a factor to obtain the primary energy. The General Electricity Imports factor published in Climate Change Agreements Operations Manual will be the reference for this calculation[4]. The method for accounting for the electricity inputs included in E_{Input1} and E_{Input2} should be agreed with *LCCC* as part of the *FMS Procedures*.

29. In cases where a proportion of the *Advanced Fuels* is recycled back into the process as energy input (e.g. thermal cracking), this does not constitute a part of the energy input since this is not an energy input from outside the boundaries of the *ACT Efficiency* calculation.

30. For mixed feedstocks, energy inputs to the process should be proportioned according to the percentage of *Biomass* energy content in the feedstock ($\%_{feed\ bio}$) or the *Advanced Fuel* ($\%_{products\ bio}$), depending on whether these energy inputs are used in the *Gasification* / *Pyrolysis* process or in the *Conditioning Processes* respectively.

Determination of Energy input to ACT processes (E_{input1})

31. *Gasification* and *Pyrolysis* are both endothermic processes which require energy input in order for *Advanced Fuels* to be produced. A wide range of process designs exist where energy can be either directly or indirectly supplied to the feedstock as part of the *Gasification* / *Pyrolysis* process or to other components (e.g. electricity supplied to air compressors). The Generator should agree a methodology for quantifying the different energy inputs with the *LCCC* as part of its proposed *FMS Procedures*.

32. The preferred method for determining main conversion process energy inputs associated with *Advanced Fuel* generation is the direct measurement of the different heat and/or electricity inputs to the process. However, alternative methodologies, supported by detailed evidence can be presented for consideration and agreed with the *LCCC* as part of the *FMS Procedures*.

[3] As shown in Figure 1, ACT processes may require energy input into the process unit where the Synthesis Chamber is placed to enable the effective generation of Advanced Fuels (Einput1).In addition, energy input (Einput2) may also be required by conditioning processes needed to remove undesired contaminants (such H_2S, NH_3, tars or ashes) to produce a high-quality Advanced Fuel before entering the prime mover or before leaving the boundaries for the *ACT Efficiency* calculation where the Advanced Fuel is used in the production of other energy products.

[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/617716/LIT_7911.pdf

33. It should be noted that different operational regimes (such as start-up, maintenance, continuous operation or batch processes) can be used within the same *ACT Efficiency Period* or from one *ACT Efficiency Period* to another. As a result, the methodology for metering the process energy inputs can vary and this will be assessed on a case-by-case basis and agreed as part of the *FMS Procedures*.

Determination of energy input to conditioning processes (E_{input2})

34. The *Advanced Fuel* leaving the *Gasification* / *Pyrolysis* process contains a wide range of contaminants including particulates (unconverted ash and char as well as bed material), ammonia, nitrogen, hydrogen sulphide, sulphur dioxide, tar and alkali compounds. These need to be removed for the *Advanced Fuels* to be used. The cleaning / conditioning processes and the tolerable amounts of contaminants in the *Advanced Fuel* depends on what these *Advanced Fuels* will be utilised for. *Conditioning Processes* need energy inputs.

35. The preferred method for determining process energy inputs associated with *Conditioning Processes* is the direct measurement of the different heat and/or electricity inputs to the process. Detailed metering information and schematics of the *Gasification* and *Pyrolysis* processes indicating flow of heat and electricity in the process should be proposed to *LCCC*.

Biomass Content of the feedstock ($\%_{feed\ bio}$)

This section is only applicable to Generators using mixed feedstocks, and such does not apply to generators with 100% *Biomass* feedstock who will apply the *ACT Efficiency Formula* in Paragraph 10 with $\%_{products\ bio}$ and $\%_{feed\ bio}$ equal to 100%.

36. The *Biomass* content of the feedstock and that of the *Advanced Fuels* are needed to determine the *ACT Efficiency* as outlined in the formula in Paragraph 10. The *Biomass* content of the feedstock is determined using similar methods to those used for the *Advanced Fuels*.

37. Several methods are described in the literature for the determination of the *Biomass* content of feedstocks. Generators need to provide *LCCC*, as part of the *FMS Procedures*, a detailed outline of the methods to be used including description of the methods, sampling methodology, sources of inaccuracy and expected uncertainties.

Selective Dissolution Method

38. *Selective Dissolution Method* (SDM) is a technique for the determination of *Biomass* content of a solid substance. This method is based on the principle that *Biomass* fuel components but not fossil fuels dissolve in sulfuric acid or hydrogen peroxide[5]. The uncertainty of this method increases when the feedstock has biodegradable components that are not *Biomass* or when *Biomass* materials are present that are not fully biodegradable. Appropriate standards (for example, EN 15440 2011 on 'Solid recovered fuels - Method for the determination of *Biomass* content') should be used.

Carbon Dating Method

39. *Carbon Dating* based on carbon-14 (^{14}C) measurement is an alternative approach for the determination of *Biomass* content in feedstocks. This is based on the principle that fossil fuels only contain ^{12}C while *Biomass* contains both ^{12}C and ^{14}C. This approach is more expensive than the *SDM* and requires skilled personnel but can be applied to any type of substance including solid, liquid or gas and in addition usually requires fewer samples.

40. A range of methods are available for determining the carbon isotope ratio using this approach including scintillation and mass spectrometry. By comparing the levels of ^{12}C and ^{14}C, the efficiency of conversion of the energy of the *Biomass* content of the feedstock into *Advanced Fuels* can be determined according to the equation in Paragraph 10.

[5] The SDM method relies on the fact that, under the conditions specified in the standard, *Biomass* materials will dissolve and whatever is left undissolved will therefore be fossil-derived. This method can be used to directly determine the GCV of the *Biomass* in the sample. Annex G of standard EN 15440 2011 states that the method can also be used for wood fuels but that its reliability may be compromised due to the high *Biomass* contents of such feedstocks (>95%). Other methods (e.g. manual sorting) are also described in the EN 15440 2011 standard. *Carbon Dating* (carbon-14) can also be used and is associated with lower uncertainty. Depending on the type of *Biomass* feedstock, specific types of liquid scintillation[5] may be more convenient than others (e.g. CO_2 in LSC or benzene in LSC).

41. Generators willing to use this technique for evidence of the *Biomass* content are requested to provide and agree as part of their *FMS Procedures* a detailed methodology describing sampling procedures (and associated sampling standards), inaccuracy in the measured parameters and any assumptions and calculation methods.

42. Alternative techniques and proposals used by industry can be presented for consideration and agreed with the *LCCC* as part of the agreement of *FMS Procedures*.

Biomass Content of Advanced Fuels ($\%_{products\ bio}$)

43. Appropriate approaches for the determination of the *Biomass* content of the *Advanced Fuels* include *Carbon Dating*. Methods of determining the *Biomass* content need to be presented and agreed with the *LCCC* including a detailed methodology describing sampling procedures (and associated sampling standards), inaccuracy in the measured parameters and any assumptions and calculation methods.

44. Direct measurement of the $^{14}C:^{12}C$ ratio in *Advanced Fuels* is the preferred approach. However, alternative methods, for example, based on a calculation of the *Biomass* content using and energy balance approach (see below) are also acceptable subject to agreement with *LCCC* as part of the *FMS Procedures*.

45. An alternative calculation method is to measure (using *SDM* or *Carbon Dating*) the *Biomass* content of the feedstock and that of char and to undertake an energy balance to determine the *Biomass* content of the *Advanced Fuels*. Evidence, assumptions and calculation methodology should be provided to the *LCCC* as part of the agreement of *FMS Procedures*, to justify any methods alternative to the direct measurement method.

46. The energy balance calculation for the determination of $\%_{products\ bio}$ can be simplified by assuming that the total carbon content of the char is all *Biomass* thus eliminating the need for $^{14}C:^{12}C$ ratio measurement for char. This, however, still requires knowledge of the carbon content of the char (X_{carbon}).

47. Further simplification can be achieved by assuming that the total mass of the char is *Biomass* carbon.

48. The drawback of the two assumptions above is that they lead to conservative estimate of $\%_{products\ bio}$ and consequently a lower *ACT Efficiency*. The applicant may choose to apply either or both of these assumptions in the energy balance as long as they feel comfortable they will meet the *ACT Efficiency Standard* when using them.

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