ECOGI
Pre-treatment of biomass for anaerobic digestion

Mechanical pre-treatment and separation of organic waste from households to obtain pulp for biogasification

Test report

J.no.1005

Version 1: 23 September 2015

Revised version 6: 11 November 2015

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1. Introduction

This test plan is the implementation of a test design developed for verification of the performance of an environmental technology following the ETV method Ref.1.

1.1. Name of technology

The technology name is ECOGI.

1.2. Name and contact of proposer

Proposer
Komtek Miljø af 2012 A/S, Drivervej 8, DK-6670 Holsted
Contact: Jens Peter Jensen, phone: +45 7020 5489, e-mail: jpj@komtek.dk

1.3. Name of test body/test responsible

Danish Technological Institute, Verification Centre, Life Science Division, Kongsvang Allé 29, DK-8000, Aarhus, Denmark
Test responsible: B. Malmgren-Hansen (BMH), phone: +45 7220 1810, e-mail: bmh@teknologisk.dk
Internal reviewer: Nils H. Nilsson (NHN), phone: +45 7220 1825, e-mail: nhn@teknologisk.dk

1.4. Reference to test plan and specific verification protocol

The specific verification protocol is the revised revision 9, from 19th June 2015
The test plan is the revised revision 6, from 19th June 2015

2. Test design

The test design is based on 3 repeated test runs of the ECOGI for the tested waste in order to evaluate the customer claims concerning the following issues:

- Recovery of organic matter[1] in pulp
- Purity of organic matter in pulp
- Energy consumption per ton waste
- Water consumption per ton waste

The test is performed on the following waste:

1. Organic source separated waste from households

[1] Organic matter is defined as material, which can be converted into biogas within a normal period of operation of approx. 25-30 days of mesophilic operation and 18-21 days of thermophilic operation. Wood pieces of size >5*5*5 mm are not included as they are not considered digestible within a normal operation period in a biogas plant.

The waste is collected and delivered to the plant in plastic bags. The waste typically contains some impurities of metal, glass, textiles, plastic objects etc. apart from plastic bags used for transport.

Every test run consists of 3 batch runs. The samples taken under the 3 batches are combined to one test run sample (Figure 1). Approximately 2-3 tons of waste is processed per batch.

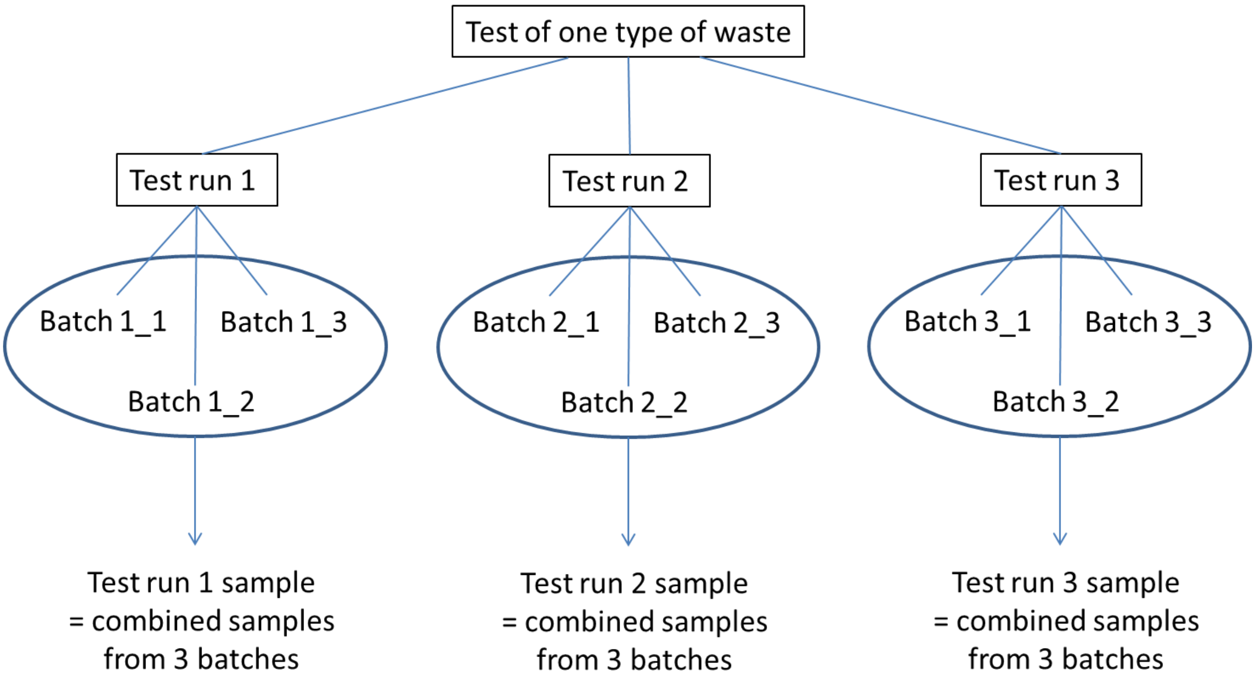

Figure 1: Test runs and sampling for the two waste types.

Calculation of purity:
Purity of biopulp is calculated as given in the test plan appendix 3, in-house test methods part A.

Recovery of biopulp:
Recovery of biopulp is calculated as given in the test plan appendix 3, in-house test methods part B.

2.1. Test site

The test site is Komtek Miljø af 2012 A/S, Drivervej 8, DK-6670 Holsted

2.1.1. Types of test sites

The site is a plant that performs composting operation with a separate treatment of organic waste using the developed ECOGI process.

2.1.2. Addresses

Test site
Komtek Miljø af 2012 A/S, Drivervej 8, DK 6670 Holsted

2.1.3. Descriptions

The ECOGI plant is placed in a separate closed building at Komtek. All equipment in the building including necessary ventilation is run by electrical power which can be logged separately from other facilities at Komtek.

2.1.4. Special needs

The test personnel are instructed in safety at the plant and the test methods used in Figure 2.

2.2. Tests

2.2.1. Test methods

The test is performed by taking samples and measuring flows for the ECOGI plant shown in Figure 2.

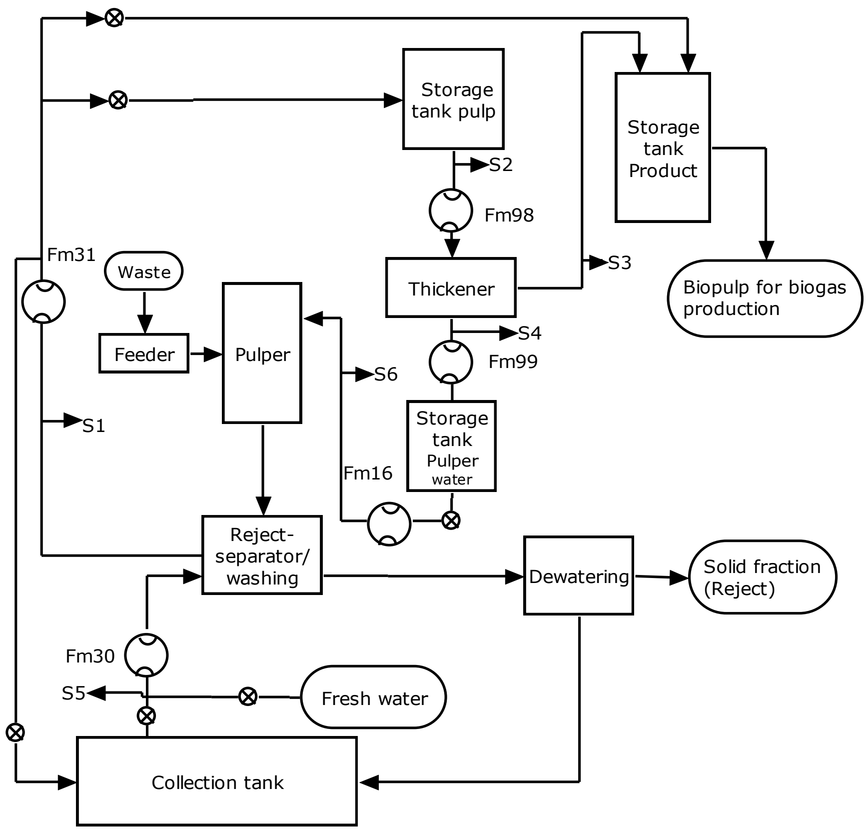

Figure 2: Diagram of ECOGI process elements showing inputs and outputs, flowmeters (Fmx) and sampling points (Sx).

Tests methods include measurement of:

- Purity of biopulp
- Recovery of organic matter
- Electricity consumtion
- Water consumption

Measuring biopulp purity

The test method for measuring biopulp purity is described in the test plan, appendix 3, part A.

In short, the test is based on:

- Sorting impurities like metal, glas and plastic out of a biopulp sample with measured weight by sieving the biopulp, flushing with water and hand-sorting the residues from the sieve.
- Drying and weighing of impurities.
- Analysis of the biopulp for dry matter (TS) and volatile solids (VS).

Measuring recovery of organic matter

The test method for measuring recovery is described in the test plan appendix 3, part B.

In the test an analysis of the loss of organic matter in the ECOGI process is performed. The loss is the organic matter present in the solid fraction (reject) in the ECOGI process.

In short, the test is based on:

- taking representative samples from the reject.
- dividing samples into different particle sizes with the aid of a specially designed washer and screens.
- weighing the sub fractions and hand-sorting the content of organic matter.
- analysing fractions with organic matter for TS (Total solids) and VS (Volatile solids).
- the measured content of TS and VS in the added organic material in the test run, which can be calculated from mass balances - see “mass balances”.

Measuring electricity consumption

The electricity consumption is measured by reading the electricity-meter of the hall the ECOGI is operating in, before and after every test run. The ECOGI is the only operating machine in this hall. The ventilation system is included in the measurement.

Measuring water consumption
Water consumption is measured by using the flow measurement equipment for pure water in the plant. All consumptions are logged for each batch test.

Mass balances
A mass balance is performed for each test run.

The data and samples, which must be collected, are the following:

- Input of waste (waste in ton)
  The amount is weighed for the sum of 3 batch tests (one test run)

- Amount of fresh water used in the process
  The amount of fresh water added in each test is measured by reading the flow from the flow measurement meter (Fm30) while the fresh water valve is open.

- Pulp to storage tank for product
  The amount can be measured in two ways:
  1: From level before test and after test and the inner dimensions of the storage tank.
  2: From flow measurement meter Fm31, Fm 98, Fm16 and the levels in the storage tank for pulper water at the beginning and at the end of each test run.

- Reject
  The amount is weighed for the sum of 3 batch tests (one test run).

- Collection tank
  The amounts transferred from the collection tank to the reject separator/washer is recorded by Fm30 when the valve from the collection tank is open. The level at the beginning and at the end of each test run is recorded to be able to correct for differences in the mass balance.

- Storage tank for pulp
  The amounts transferred from the storage tank for pulp to the thickener are recorded by Fm 98. The level at the beginning and at the end of each test run is recorded to be able to correct for differences in the mass balance.

- Storage tank for pulper water
  The amounts transferred from the storage tank for pulper water to the pulper is recorded by Fm16. The level at the beginning and at the end of each test run is recorded be able to correct for differences in the mass balance.

The mass balance can be expressed as :

Waste in+fresh water in = biopulp product out + Reject out + difference in collection tank level+ difference in storage tank pulp level + difference in storage tank pulper water level

If one parameter is difficult to measure, then the parameter can be calculated from the mass balance.

Regarding organic content (VS) in the added waste which is used in the calculation of recovery it can be calculated from the organic content in all the outputs when the TS, VS are known for all outputs. This method will be used for calculating the total amount of VS added in the test run as it is nearly impossible to measure the VS amount in the inhomogeneous input.

Calibration procedures

Weights
All weights must have a calibration procedure.
Lab-scale and small-scale weights for hand-sorting should be tested at least with one known mass in the weighing range used in the test period.
A proper calibration requires 2-3 calibration points within the measurement range.

Flow measurement equipment
The function of flow and level measurement equipment must be controlled before the test, and the calibration of the equipment has to be performed regularly (e.g. once a year) shown in internal calibration reports from Komtek.

A calibration of a flow meter can be performed either by:

- pumping the liquid used through the flow measurement equipment and filling a container at a given interval and weighing the content of the container on a calibrated weight for comparison with the amount calculated from the flow and the time for filling the container. Correction for density may be necessary, but the density can typically be assumed to be close to 1 g/cm^3 for liquids with low dry matter.
- pumping the liquid used through the flow measurement equipment and filling a container with known dimensions where the level is measured at the beginning and at the end of the filling process. Based on geometry, level before and after filling the amount added to the container can be calculated and compared with the amount calculated from flow and time of the flow.
- pumping the liquid used through the flow measurement equipment and through another flow measurement equipment which has been calibrated.

Proper calibration requires several calibration points within the measurement range depending on the linearity of the equipment.

Level measurement
Level measurement equipment can be calibrated by adding liquid and using calibrated flow meters or by measuring the exact level before and after adding an amount of liquid.

A proper calibration requires several calibration points within the measurement range depending on the linearity of the equipment.

2.2.2. Test staff

The test staff comprises:

Bjørn Malmgren-Hansen (BMH)	Responsible for sampling, data analysis and reporting (DTI)
Christian Holst Fischer (CHFI)	Sampling, analyses, data analysis, reporting (DTI)

2.2.3. Test schedule

Task	Timing
Contracts	April 2015
Verification protocol and test plan	June 2015
Test	August 2015
Analysis phase	August-September 2015
Test reporting	September-October 2015
Verification report	November 2015

2.2.4. Test equipment

Besides the ECOGI sampling containers, the test equipment includes buckets, sieves with different mesh sizes, small wheel loader, pitchfork, sorting table with drain for water collection, small shovels, drying ovens, concrete mixer with attached 10 mm sieve, weights, flow meters. For further details, please see the test plan, Appendix 3, part A, part B.

2.2.5. Type and number of samples

The type and number of samples per type of waste is summarized in the following.

Sample	Sampling position	Number of test samples	Test
Biopulp	S1	3 (average of test run)	TS, VS, purity
Solid fraction		3 (average of test run)	Organic degradable content as VS
Collection tank 1)	(S5)	4	TS,VS
Storage tank pulp 1)	(S2)	4	TS,VS
Storage tank pulper water 1)	(S4)	4	TS,VS
Output thickener	S3	3 (average of test run)	TS,VS

1) Sample at beginning and end of each test run where end = beginning of next run.

In general, the following practise for sampling, subsampling and sample handling of suspensions will be used.

Sampling of main sample from inlet and outlet
The main samples are taken from valves with sufficient dimension (1”) to ensure that no material is stuck in the valve. Before obtaining the sample at least 2 litres are discarded. A 10-20 litre bucket is used for sampling the main samples. For details see Appendix 3.

Preparation of subsamples
In all subdividing of samples, care must be taken to produce representative subsamples as some fibre material may float or sink.

Depending on type of the homogeneity of the biomass pulp, the subsamples will be obtained in the following way:

1) ***Homogenous pulps:*** a subsample is made by stirring the main sample well during transfer to subsample
2) ***Inhomogenous pulps with floating layers or fast sinking layers***: Sieving of fibres is performed followed by proportional weight of solid and liquid fractions into subsamples.

The most appropriate subsampling method will be decided when inspecting the main samples

Handling of samples
All fibre material is refrigerated if tests are performed within 2-3 days or frozen down for later analysis.

2.2.6. Operational conditions

Before each test of waste, the system has been operated with the same waste for at least 3 batches to be in operational equilibrium. Each batch test uses a defined period for pulping and a given rotational speed in the pulper. The actual operation condition is listed in the test report. When a new reject portion is ready for transport out of the reject/separator/washer a bale of straw is added to the transport system. In that way, the output stream of reject is marked with the position where the batch material starts.

2.2.7. Operational measurements

- Total power consumption during treatment will be recorded
- Water consumption during treatment will be recorded

2.2.8. Technology maintenance

The test is a short-term performance test that takes one day for each type of tested waste. Maintenance requirements are not covered in the test.

2.2.9. Health, safety and wastes

While testing, the staff wears protective suits and gloves, safety glasses in case there is risk of splashes and if necessary breathing protection. The waste can be deposited in a general waste container for treatment of household waste.

3. Test results

3.1. Test data summary

In the tests, a large number of dry matter and volatile solid analyses were performed. All analysis values are given in appendix 2.

3.1.1. Purity of biopulp

The purity of the pulp was measured by analysing the biopulp pumped into the process tank as well as the fibre fraction from the thickener. From these data and the produced volumes of biopulp and fibre fraction, the purity of the final product was calculated for each test run as described in appendix 2.

The results shown below are calculated for 100% dry matter as well as for the products that have a typical dry matter content of 17%.

Table 1 Analysed purity of products (100% dry matter)

	Test run 1%	Test run 2%	Test run 3%	Average %	Standard deviation %
Purity product all impurities (100% dry matter)	99.691	99.808	99.766	99.76	0.06
Purity mix plastics (100% dry matter)	99.954	99.972	99.975	99.97	0.01

Table 2 Analysed purity of products (17% dry matter)

	Test run 1%	Test run 2%	Test run 3%	Average %	Standard deviation %
Purity product all impurities (17% dry matter)	99.948	99.967	99.960	99.96	0.01
Purity mix plastics (17% dry matter)	99.992	99.995	99.996	99.996	0.002

As seen in the tables, the purity of the biopulp is very high.

3.1.2. Recovery of organic matter

The recovery of biopulp has been calculated from the analysis of content of organic waste as VS in the reject, in the produced biopulp and fibre fractions added to the product tank and in the accumulation tanks in the plant as described in appendix 2.

The organic waste is defined as organic material which does not include wood and bones >5*5 mm. Nuts, straw and fibres have been included as organic waste.

The results are shown below.

Table 3 Recovery of organic waste in plant

Test run	1	2	3
% recovery	92.75	93.81	92.33

The average recovery of organic waste is calculated to 92.96 % with a standard deviation of 0.77.

Most of the organic fraction of the reject consisted of material which is not easily degradable in a biogas plant e.g. straw, shells from nuts and wall nuts etc.

3.1.3. Electricity and water consumption

The electricity and water consumption per ton waste added are shown in the table below:

Table 4 Electricity and water consumption

Test run	1	2	3	Average	Standard deviation
Electricity consumption kwh /ton waste added	34.97	37.98	34.19	35.71	2.00
Water consumption ton water/ton waste added	0.68	0.69	0.79	0.72	0.06

3.1.4. Operational conditions

The operational conditions (capacity and dry matter of produced pulp) used in the test is listed in the table below:

Table 5 Capacity and Dry matter of produced biopulp

	Test run 1	Test run 2	Test run 3	Average	Standard deviation
Waste added tons/hour (Capacity)	6.87	6.88	5.88	6.54	0.6
Dry matter of produced pulp (%w/w)	16.21	16.32	16.98	16.5	0.4

3.2. Test performance observation

The test was designed to test the ECOGI equipment performance under realistic operating conditions and with a typical type of separately collected organic waste in Denmark. By choosing the amount of replicate operating cycles used in the test, the data observed can be judged as being representative for operation of the equipment on similar waste compositions.

The plant operated well with no accidental operational stops during the test.

3.3. Test quality assurance summary, incl. audit results

3.3.1. Weight calibration

The waste fractions added to the plant and the reject transported out of the plant were weighed using a certified weighing bridge with a resolution of 20 kg. The weighing bridge was verified 17th march 2015 (see Appendix 4).

During the test at the ECOGI plant, lab weights were used for weighing different fractions of reject in connection with analysis of recovery. The accuracy of the weights were verified on sight by using different containers with weights measured using calibrated certified weights in the DTI analysis laboratory, and for small weights the weights were tested with known calibration weights.

At DTI the used weights were tested /calibrated against known weights (1, 50 gram) and some objects in the range 500 gram to 5 kg which were weighed at certified lab weights for internal calibration reference.

Results of calibration are listed in the table below:

Table 6 Calibrations

Instrument	Resolution mg	Ref. weight g	Accuracy %	Calibration factor
Fine weight used for purity measurement	0.1	1	0.01	
	0.1	50	0.0004	
3 kg lab weight	10	50	0.03 *	1.0017
80 kg lab weight		4357	0.85	
Spring based weight at Komtek	(100 grams)	4357	3.3	

* after using 3 point calibration

3.3.2. Calibration of flow and volume measurement equipment at Komtek

Komtek has made a calibration of all flow and level measurement equipment at the plant. The report is in Danish and made in week 23 and 24, 2015.

The major results from the calibration report are listed below.

The following levels are required for calculating recovery of pulp:

Fm 98 Flow from storage tank of pulp to thickener
Fm 99 Flow of pulper water from thickener
Flow of pure water

L1: Level in tank for finished product
L2: Level in tank for pulper water
L3: Level in collection tank
L4: Level in tank for storage of pulp

The accuracy of Fm 98, Fm 99 have been assessed by measuring the level differences in the tank for storage of pulp and the tank for pulper water. The accuracy of Fm98 was within a 13% measurement error based on 12 measurements and the accuracy of Fm 99 was approximately within 10% measurement error where measurement error =(measured value-reference measurement)/reference measurement *100

The flow of pure water has been assessed by filling an exact amount of 2600 litres while measuring the flow. The flow was measured to 2600 litres which gave a measurement error of around 0%.

L1: Finished product tank. The accuracy (two point measurement) was measured to around 3% measurement error (1.2 and 3.4) based on measuring the level manually and calculating the volume.

L2: Level in tank for pulper water. The accuracy (six point measurement) was measured to around 6% measurement error (0 to 10) based on measuring the level manually and calculating the volume.

L3: Collection tank. The accuracy (two point measurement) was measured to around 7% measurement error (6.8 and 7.5%) based on measuring the level manually and calculating the volume.

L4: Tank for pulp. The accuracy (two point measurement) was measured to around 3% measurement error (3.1 and 0%) based on measuring the level manually, calculating the volume and that the level in the tank is at least 13% of maximum.

It has been assumed that the density is close to 1 g/cm3 in all calibration tests.
A measurement of the density of biopulp produced in the test gave a density of 1.04 g/cm^2 which is within the margin of accuracy of the measurement equipment. Therefore, no correction for density was performed.

In total, the calibration report is considered to be of a quality that is acceptable to use in the test. The accuracy of the system was further tested during the 3 separate tests by calculating the individual mass balances.

3.3.3. Mass balances

A mass balance was calculated for each test run. The results are shown below.

Table 7 Mass balances

Mass balance	Test run 1	Test run 2	Test run 3
Input			
Waste	6.64	6.54	5.68
Water	4.5	4.5	4.5
Sum input	11.14	11.04	10.18
Output			
Reject	1.32	1.14	1.12
Pulp accumulated in product tank	10.50	9.70	6.50
Level difference in internal tanks	-0.70	1.30	2.80
Sum output	11.12	12.14	10.42
Difference %	-0.18	9.96	2.36

The table shows that the mass balance for each test run is correct within 10%.

3.3.4. External audit

In connection with the tests, one expert from ETA-Danmark visited the test site and audited the test practices. The audit report is included in Appendix 4.

3.4. Amendments and deviations from test plan

A few adjustments in the procedure for reject sorting were introduced in the analysis phase as described in Appendix 3.

4. References

1. EU general verification protocol version 1.1 July 7th 2014.

2. DTI DANETV Test Centre. Center quality manual. April. 2015.

3. DANETV "ECOGI - Pretreatment of biomass for anaerobic digestion". Journal no. 1004. Verification protocol, Test plan, test report and verification report 2012, 2013.

Appendix 1Terms and definitions

Terms and definitions used in the protocol are explained in **Fejl! Henvisningskilde ikke fundet.**.

Table 8 Terms and definitions used by the EU ETV test centres

Term	Definition	Comments
Accreditation	Meaning as assigned to it by Regulation (EC) No 765/2008	EC No 765/2008 is on setting out the requirements for accreditation and market surveillance relating to the marketing of products
Additional parameter	Other effects that will be described but are considered secondary	None
Amendment	A change to a specific verification protocol or a test plan done before the verification or test step is performed	None
Analytical laboratory	Independent analytical laboratory used to analyse test samples	The test centre may use an analytical laboratory as subcontractor
Application	The use of a technology specified with respect to matrix, purpose (target and effect) and limitations	The application must be defined with a precision that allows the user of a technology verification to judge whether his needs are comparable to the verification conditions
DANETV	Danish centre for verification of environmental technologies	None
Deviation	A change to a specific verification protocol or a test plan done during the verification or test step performance	None
Environmental technologies	Environmental technologies are all technologies whose use is less environmentally harmful than relevant alternatives	The term technology covers a variety of products, processes, systems and services
Evaluation	Evaluation of test data for a technology for performance and data quality	None
General verification protocol (GVP)	Description of the principles and general procedure to be followed by the ETV pilot programme when verifying an individual environmental technology.	None

Term	Definition	Comments
Innovative environmental technologies	Environmental technologies presenting a novelty in terms of design, raw materials involved, production process, use, recyclability or final disposal, when compared with relevant alternatives.	None
Matrix	The type of material that the technology is intended for	Matrices could be soil, drinking water, ground water, degreasing bath, exhaust gas condensate etc.
Method	Action described by e.g. generic document that provides rules, guidelines or characteristics for tests or analysis	An in-house method may be used in the absence of a standard, if prepared in compliance with the format and contents required for standards, see e.g. [4]
Operational parameter	Measurable parameters that define the application and the verification and test conditions.	Operational parameters could be temperature, production capacity, concentrations of non-target compounds in matrix etc.
(Initial) performance claim	Proposer claimed technical specifications of technology. Shall state the conditions of use under which the claim is applicable and mention any relevant assumption made.	The proposer claims shall be included in the ETV proposal. The initial claims can be developed as part of the quick scan.
Performance parameters (revised performance claims)	A set of quantified technical specifications representative of the technical performance and potential environmental impacts of a technology in a specified application and under specified conditions of testing or use (operational parameters).	The performance parameters must be established considering the application(s) of the technology, the requirements of society (legislative regulations), customers (needs) and proposer initial performance claims.
Potential environmental impacts	Estimated environmental effects or pressure on the environment, resulting directly or indirectly from the use of a technology under specified conditions of testing or use.	None
Procedure	Detailed description of the use of a standard or a method within one body	The procedure specifies implementing a standard or a method in terms of e.g.: equipment used.
Product	Ready to market or prototype stage product/technology, process, system or	In the EU ETV GVP [1] the term "technology" is used instead of the term "product".

Term	Definition	Comments
	service based upon an environmental technology.	
Proposer	Any legal entity or natural person, which can be the technology manufacturer or an authorised representative of the technology manufacturer. If the technology manufactures concerned agree, the proposer can be another stakeholder undertaking a specific verification programme involving several technologies.	Can be vendor or producer
Purpose	The measurable property that is affected by the technology and how it is affected.	The purpose could be reduction of nitrate concentration, separation of volatile organic compounds, reduction of energy use (MW/kg) etc.
Ready to market technology	Technology available on the market or at least available at a stage where no substantial change affecting performance will be implemented before introducing the technology on the market (e.g. full-scale or pilot scale with direct and clear scale-up instructions).	None
Specific verification protocol	Protocol describing the specific verification of a technology as developed applying the principles and procedures of the EU GVP and this quality manual.	None
Standard	Generic document established by consensus and approved by a recognised standardization body that provides rules, guidelines or characteristics for tests or analysis	None
Test body	Unit that that plans and performs test	None
Verification body	Unit that plans and performs the verification	None
Test/testing	Determination of the performance of a technology for measurements / parameters defined for the application.	None

Term	Definition	Comments
Test performance audit	Quantitative evaluation of a measurement system as used in a specific test.	E.g. evaluation of laboratory control data for relevant period (precision under repeatability conditions, trueness), evaluation of data from laboratory participation in proficiency test and control of calibration of online measurement devises.
Test system audit	Qualitative on-site evaluation of test, sampling and/or measurement systems associated with a specific test.	E.g. evaluation of the testing done against the requirements of the specific verification protocol, the test plan and the quality manual of the test body.
Test system control	Control of the test system as used in a specific test.	E.g. test of stock solutions, evaluation of stability of operational and/or on-line analytical equipment, test of blanks and reference technology tests.
Vendor	The party delivering the technology to the customer. In the EU ETV GVP and in this quality manual referred to as proposer.	Can be the producer.
Verification	Provision of objective evidence that the technical design of a given environmental technology ensures the fulfilment of a given performance claim in a specified application, taking any measurement uncertainty and relevant assumptions into consideration.	None

Terms and definitions used by the DANETV test centres.

Appendix 2 Test data report

Conditions used for testing

The test was performed on August 6th 2015 using organic waste collected from households in Vejle.

The test included the following steps according to the test plan:

- Recording all input and output weights as well as power consumption for each test run
- Sampling and analysis of TS,VS according to 2.2.5

Documentation photos from selected individual steps in the test are shown below.

Before the test was started, the system was emptied and an initial test run consisting of 3 batch runs with pulping of waste was performed without taking samples. At the end of this test run, all levels in tanks were recorded and the planned 3 test runs were performed. In order to process all waste in the thickener it was necessary to wait approximately one hour after each 3 processed batches (one finished test run) to allow the thickener to be emptied. Each test run lasted 1 hour for the 3 processed batches and one additional hour was used to empty the thickener. In that way, it is possible to obtain a proper mass balance and to separate each test run. The table below presents data for the 3 test runs.

Table 9 Operational data collected during test runs

Test run	Added waste (ton)	Added water (m3)	Average pulping time per batch (min)	Increase in Product tank level (m3)	Produced reject (tons)	Increase in level storage tank for pulp (m3)	Increase in level storage tank for pulper water (m3)	Increase in level collection tank (m3)	kwh used
1	6.64	4.5	19.3	10.50	1.32	-0.8	-0.7	0.8	232.2
2	6.54	4.5	19.0	9.70	1.14	0.1	0.6	0.6	248.4
3	5.68	4.5	19.3	6.50	1.12	2	0	0.8	194.2

Test run	Amount of produced fibres from thickener (m3) 1)	Storage tank pulp start level (m3)	Storage tank pulp end level (m3)	Storage tank pulper water start level (m3)	Storage tank pulper water end level (m3)	Collection tank start level (m3)	Collection tank end level (m3)
1	2.3	3.8	3.0	16.1	15.4	17.7	18.5
2	2.5	3.0	3.1	15.4	16.0	18.5	19.1
3	2.2	3.1	5.1	16.0	16.0	19.1	19.9

1) Measured as difference between Fm 98 and Fm 99.

Sampling of produced pulp, fibre fractions etc.

Subsamples were taken of the biopulp during pumping to storage tank (3 times for each batch). The subsamples from each batch were mixed proportionally to one sample for each test run.

Samples of fibre fraction were taken, by making subsamples directly from the output at regular intervals during a complete test run and mixing them to a representative sample.

Further samples were taken from the collection tank, the storage tank for biopulp and storage tank for pulper water at the beginning of test run 1 and at the end of each test run.

Analysis of purity of pulp

For each test run, 1 litre subsample of the biopulp was washed with hot water in a sieve with holes with a dimension of 1.7 mm as shown below before collection of particles for drying and weighing. The same procedure was performed for the fibre fraction from the thickener, but only 250 g of the product was used due to a higher dry matter.

Figure 3: Washing of pulp to estimate purity.

Sampling of reject

The reject is removed from the reject separator with a screw conveyor, which removes most of the liquid content. At the end of a test run, a bale of hay was added as that makes it possible to identify when all reject material from one test run has passed the conveyor.

The output from each test run was weighed and put in a pile on a clean floor.

Figure 4: Collection of reject from one batch in 60 l container.

From pile of 3 mixed batches, a representative sample was taken by using a grab randomly picking and producing a pile of approximately 200 litres from which a new subsample was prepared with a weight of 10 kg in a 60 litre square bucket.

Sorting of reject

The square bucket was now sorted according to a slight modification of the procedure in appendix 3 of the test plan. It was decided to use only one washing step with hot water. This was decided after an inspection of the surfaces of the green plastic foil from bags of the reject. The surface did not contain many organic particles (parts of fibres, leaves etc). This may be partly caused by the more effective dewatering which is implemented in the tested ECOGI plant compared to the earlier version of the plant which was tested in a DANETV test of the previous version of ECOGI ***DANETV "ECOGI – Pre-treatment of biomass for anaerobic digestion ETV verification statement 6/5-2013".*** ***http://www.etv-danmark.dk/filer/energi/ecogi_Verification%20statement.pdf***

The procedure used was the following;

1: The content of 10 kg was transferred to a cement mixer with a 40 mm screen in front together with washing water. 50 kg of warm water (app. 50 ˚C) was added to the water.

2: The reject was washed for app. 10 minutes, decanting of water by tilting into a collecting bucket with a 3 mm screen.

3: Removal of >40 mm reject for sorting.

3a: The material was dried during regular mixing until it was sufficiently dry for sorting (>5 days at 65 ˚C).

3b: The reject fraction >40 mm was hand sorted in non-degradable material (plastics, metal, glass a separate fraction of bones and sticks with dimensions larger than 5*5*5 mm and the fraction of organic material.

3c: The material was finally dried and weighed (organic material at 105 ˚C for 24 hours).

4: removal of 3 - 40 mm reject for sorting.

4a: The material was dried during regular mixing until it seemed sufficiently dry for sorting (>5 days at 65 ˚C).

4a: The reject fraction 3-40 mm was hand sorted in non-degradable material (plastics, metal, glass a separate fraction of bones and sticks with dimensions larger than 5*5*5 mm and the fraction of organic material.

4b: The material was dried and weighed (organic material at 105 ˚C for 24 hours).

5: From the organic fractions > 40 mm and 3 - 40 mm proportional subsamples were prepared by thorough mixing. The materials were down-sized before taking a sample for analysis of VS.

6: Sampling of washing water.
A representative sample was taken from the washing water for further analysis of TS and VS.

The sorting steps and examples of the sorted fractions are shown below.

Figure 5: Washing process in cement mixer with 40 mm screen. The mixer is emptied by tilting, which transports particles <40 mm to the 3 mm sieve below. The black bucket below collects the washing water.

Figure 6: Sorted fraction of non-organics (mostly plastics) >40 mm.

Figure 7: Sorted fraction of non-organics. The fraction contained a number of plastic textile cleaning cloths.

Figure 8: Example of removed wood and bones >5*5mm.

Figure 9: Example of removed organic content. A large amount of the material are not easily degradable (straw, walnut and nutshell, etc.).

Total Solids and Volatile solids analysis

TS was analysed on organic samples in an amount between 25% and 100% of the sorted out material.

The drying method for the organic fraction used was 65 °C for at least 5 days, and then one day at 105 ˚C where an additional small amount was removed .
Samples of the organic dried material were taken. The samples were down-sized and subsamples were taken for analysis of VS.

Figure 10: Organic sample before and after down-sizing to prepare homogeneous sample for analysis of VS.

All results of analysis of TS and VS are given in the tables below:

Table 10 analysed TS and VS values (all values are weight %)

Biopulp	%TS	Standard dev	%VS	Standard dev
Test run 1	14.93	0.08	86.86	0.08
Test run 2	15.68	0.21	85.23	0.22
Test run 3	15.75	0.32	85.26	0.41

Fibre fraction thickener	%TS	Standard dev	%VS	Standard dev
Test run 1	20.31	0.42	85.07	0.38
Test run 2	18.19	0.63	85.40	0.09
Test run 3	20.52	0.03	85.66	0.78

Storage tank pulp	%TS	Standard dev	%VS	Standard dev
Before Test run 1	10.75	0.07	85.32	0.13
After test run 1	11.52	0.06	86.20	0.12
After test run 2	11.11	0.12	86.24	0.15
After test run 3	11.18	0.07	85.68	0.01

Storage tank pulper water	%TS	Standard dev	%VS	Standard dev
Before Test run 1	8.49	0.13	86.21	0.21
After test run 1	9.65	0.01	86.57	0.10
After test run 2	9.28	0.01	85.83	0.02
After test run 3	9.04	0.00	85.81	0.03

Collection tank	%TS	Standard dev	%VS	Standard dev
Before Test run 1	2.70	0.03	83.79	0.22
After test run 1	3.48	0.05	85.64	0.49
After test run 2	3.47	0.02	84.48	0.30
After test run 3	3.43	0.00	85.33	0.00

Washing water reject	%TS	Standard dev	%VS	Standard dev
Test run 1	0.37	0.00	77.52	0.50
Test run 2	0.50	0.00	80.95	0.02
Test run 3	0.40	0.00	78.76	0.31

Organic fraction >40 mm	%VS	standard dev
Test run 1	92.03	0.66
Test run 2	91.79	0.12
Test run 3	90.06	0.32

Organic fraction 3-40 mm	%VS	standard dev
Test run 1	85.10	0.95
Test run 2	86.02	1.15
Test run 3	87.80	0.25

Calculation of purity of biopulp
The analysis data is shown for pulp and fibres with the given analysed dry matter content of the pulp.

Table 11 Analysed purities of sub fractions

Sample	Impurities (g)	Plastics (g)	Sample amount (g)	TS%	Purity % at measured TS%
Test run 1 biopulp	0.32	0.0354	1000	14.93	99.97
Test run 1 fibre	0.27	0.0505	250	20.31	99.89
Test run 2 biopulp	0.1669	0.0155	1000	15.68	99.98
Test run 2 fibre	0.1854	0.034	250	18.19	99.93
Test run 3 biopulp	0.1372	0.0159	1000	15.75	99.99
Test run 3 fibre	0.28601	0.0301	250	20.52	99.89

The calculation formula used for calculating purity from the test plan appendix 3 is shown below:

$$Purity\% \text{ at } TS_{pref} = 100 \cdot (1 - TS_{pref} \cdot \frac{m_{impurity}}{m_{pulp} \cdot TS\%})$$

The amount (weight) of dry impurities is $\boldsymbol{m_{impurity}}$
The amount (weight) of used pulp for the analysis is $\boldsymbol{m_{pulp}}$ with total solids TS%
TS_{pref} is the preferred total solids % used for calculation of the purity.

In the table above TS_{pref} was set equal to the measured TS%.

In order to calculate the purity of the product the amount of produced biopulp (produced to product tank and to storage tank for biopulp) and the amount of produced fibre fraction from thickener is used to calculate the purity of the final product.

The analysed amounts of impurities in the two sub fractions biopulp and fibre fraction from thickener are shown in the figures below. In each figure organic dry matter is shown in the top container and inorganic impurities (plastic, textile, glass, metal) in the bottom container.

Figure 11: Test run 1, impurities biopulp (left), fibre fraction from thickener (right).

Figure 12: Test run 2, impurities biopulp (left), fibre fraction from thickener (right).

Figure 13: Test run 3, impurities biopulp (left), fibre fraction from thickener (right).

The amount of biopulp produced to the product tank and storage tank for pulp as well as the amounts produced from the thickener and the distribution between produced biopulp and fibre fraction from thickener is shown in the table below.

Table 12: Operational data for calculating purity of product

	Test run 1	Test run 2	Test run 3
Biopulp produced to product tank+storage tank pulp (ton)	7.4	7.3	6.3
Output from thickener (ton)	2.3	2.5	2.2
Wet biomass produced (ton)	9.7	9.8	8.5
% biopulp produced	76.3	74.5	74.1
% output thickener	23.7	25.5	25.9

From the data above, the purity of the products are calculated, see the following.

Table 13 Analysed purity of products (100% dry matter)

	Test run 1 %	Test run 2 %	Test run 3 %	Average %	Standard deviation %
Purity product all impurities (100% dry matter)	99.69	99.81	99.77	99.76	0.06
Purity mix plastics (100% dry matter)	99.95	99.97	99.98	99.97	0.01

Table 14 Analysed purity of products (17% dry matter)

	Test run 1 %	Test run 2 %	Test run 3 %	Average %	Standard deviation %
Purity product all impurities (17% dry matter)	99.948	99.967	99.960	99.96	0.01
Purity mix plastics (17% dry matter)	99.992	99.995	99.996	99.996	0.002

Calculation of operational conditions

Based on the data in Table 9, Table 10 and Table 12 the following operational data has been calculated

Table 15 Capacity and dry matter of produced biopulp

	Test run 1	Test run 2	Test run 3	Average	Standard deviation
Waste added tons/hour (Capacity)	6.87	6.88	5.88	6.54	0.6
Dry matter of produced pulp (%w/w)	16.21	16.32	16.98	16.5	0.4

Calculation of recovery

The analysed dry matter of the 10 kg samples of reject from the 3 test runs is shown in the table below.

Table 16: Analysis results from sorting of the reject

Fraction (g)	Test run 1	Test run 2	Test run 3	Average	Standard deviation
Non organic material>40 mm	3468.18	3231.18	3248.66	3316.01	132.07
Organic waste>40 mm	514.09	390.34	383.67	429.37	73.45
Bone and wood >5*5mm	173.01	179.30	75.97		
Non organic material 3-40 mm	492.04	578.11	704.09	591.41	106.65
Organic waste 3-40 mm	479.29	304.49	436.11	406.63	91.05
Bone ,wood 3-40 mm	34.34	47.76	64.15		
Sum TS	5160.94	4731.19	4912.66	4934.93	215.74
Organic sum	993.38	694.83	819.78	836.00	149.93

In the table below the amount of kg VS/kg reject is calculated:

Table 17: Calculation of kg VS/kg reject

Test run	1	2	3
Washing water kg	38	39.5	38
TS%	0.37	0.50	0.40
VS%	77.52	80.95	78.76
Washing water kgVS/kg reject	0.010837	0.015947	0.012083
Organic waste >40 mm kgVS/kg reject	0.047313	0.035828	0.034552
Organic waste 3-40 mm kgVS/kg reject	0.040788	0.026194	0.03829

Table 18: Recovery of organic waste in biopulp

Test run	1	2	3
Biopulp ton VS	1.06	0.96	0.58
Biopulp from thickener ton VS	0.40	0.39	0.39
Difference VS in intermediate tanks (ton)	0.21	0.00	0.18
Reject tons	1.32	1.14	1.12
Organic waste ton VS/ton wet reject	0.099	0.078	0.085
Organic waste VS ton loss in reject	0.131	0.089	0.095
Organic ton VS in input (added waste)	1.80	1.44	1.24
% recovery	92.75	93.81	92.33

The average recovery of organic waste is calculated to 92.96 % with a standard deviation of 0.77.

Most of the organic fraction of the reject consisted of material which is not easily degradable in a biogas plant, e.g. straw, shells from nuts and walnuts etc.

The calculation method is shown in the example below:

Calculation example for recovery, test run 1:

1: VS of organic waste in reject:
VS of organic waste = VS in organic fraction >40 mm + organic fraction 3-40 mm + VS of washing water.

The organic amount of dry matter was analysed to 514.09 gram TS organic waste in the fraction >40 mm and 479.29 grams organic waste in the fraction 3-40 mm out of an analysed amount of reject in 10 kg (see Table 16). Using the analysed VS values (see Table 10), we calculate 0.51409*92.03/100/10 =0.0473 kg VS/kg reject from the organic fraction >40 mm (see Table 17). The same procedure is used for the organic fraction from 3-40 mm.

The organic waste in ton VS/ton wet reject is calculated to 0.010837+0.047313+0.040788=0.099 ton VS/ton wet reject and therefore the amount of VS in the reject (***mR_{vs}***) from test run 1 is 1.32*0.099=0.131 ton VS (see Table 18).

2: VS of organic waste added to the test run
VS of all organic waste added = VS of Biopulp sent to product tank + VS of fibre fraction sent to product tank + Difference of VS in storage tank pulp, storage tank pulper water and collection tank + VS of Reject.

The amount of produced wet biopulp can be calculated as the difference in level in the product tank (10.5 tons) - the produced amount of fibres (2.3 tons) = 8.2 tons (see **Fejl! Henvisningskilde ikke fundet.**).

The amount of VS in the produced biopulp is therefore 8.2*14.93/100*86.86/100=1.06 ton VS
The produced amount of VS in the fibre fraction from the thickener is 2.3*20.31/100*85.07/100=0.397 ton VS
Apart from this, there is a build-up of VS in the 3 tanks (storage tank pulp, storage tank pulper water and collection tank) of 0.21 ton VS (can be calculated from data in **Fejl! Henvisningskilde ikke fundet.** and Table 10).

In total, the production of VS without reject is 1.06+0.397+0.21=1.67 ton.

The VS in the added waste (***$mtot_{vs}$***) is the VS without reject +VS of reject = 1.67+0.131=1.798 ton VS

3: Recovery
The recovery is calculated from data for the total amount of volatile solids of biodegradable organic matter ***$mtot_{vs}$*** and the amount of volatile solids of biodegradable organic matter in the reject ***mR_{vs}***

$$Recovery\ \% = 100 \cdot \frac{mtot_{VS} - mR_{VS}}{mtot_{VS}}$$

The recovery is calculated to 100* (1.798-0.131)/1.798=92.9% for test run 1.

Calculation of electricity and water consumption

The electricity and water consumption are calculated in the table below based on data from **Fejl! Henvisningskilde ikke fundet.**:

Table 19 Electricity and water consumption

Test run	1	2	3	Average	Standard deviation
Electricity consumption kwh /ton waste added	34.97	37.98	34.19	35.71	2.00
Water consumption kg/ton waste added	0.68	0.69	0.79	0.72	0.06

Appendix 3 Amendment and deviation report for tests

There was a minor difference in the procedure for sorting the reject as it was decided to simplify the sorting procedure by using only one washing step with warm water and avoiding the middle sorting step from 10-40 mm. The reason for the deviation was that the new plant removes much more liquid from the reject by using a screw conveyor and because there was a very low content left of easily degradable organic material. Most of the residual organic material in the reject was straw, nutshell etc. It was judged that it would not be easier to sort by introducing a middle step from 10-40 mm. Regarding washing, one step was considered sufficient and the amount of VS in the washing water accounted for a minor amount of the total VS (10-20%).

Appendix 4 Audit report

ETA Danmark Test System Audit Report

Project no.:011987-14	Date of audit: 27. August 2015
Testing project: ECOGI Pulp for biogas made from domestic waste	Site: Drivervej 8, DK6670 Holsted
Test system audit – Materials and waste	
Present during audit: Jens Peter Jensen Komtec, Bjørn Malmgren DTI Auditor: Peter Fritzel	
Checklist *Conformity with test plan:* **Test method in general.** Section 2.2.1.: The test is performed by taking samples and measuring flows on a running ECOGI-plant. A mass balance is calculated in connection with each test run. **Operation of technology/treatment unit:** Section 2.2.1.: After having loaded domestic waste, it is a fully automatic process, resulting in a pulp which is pumped **Data logging and retrieval.** Section 4.2: Transfer of data from printed media to digital form is checked twice. Spot checks on digital media are made on at least 5 % of the data. The data logging system is a part of the plant – it is not made specially for the testing. **Sampling and sample storage** Section 2.2.5 Samples are taken from valves. Before taking the sample a pre-sample is discarded in order to get a homogenous sample. A 10-20 litre bucket is used for the main samples. All fibre material is refrigerated or frozen for later analysis **Calibration** The calibration certificates of the weights was presented and a sample is shown in appendix A. *Other issues identified by auditor:* Non-conformities noted by auditor: None	
Auditor's conclusions There is consistency with the test plan and the handling of measurements are carried as described. All in a safe manner	
Date: 16. September 2015	Signature: Peter Fritzel

Date: 2015.09.09
Ref. ETA-DK / PF 1