Verification report
New Substrate Technology Concept

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Status:	Final version
Version:	16-03-2015

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1. Introduction

Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and quality assurance. This verification is performed under the EU ETV Pilot Programme. The verified technology is categorised under the EU ETV technology area “Materials, waste and resources”.

1.1. Name of technology

This document is the verification report for the verification of two key components of the New Substrate Technology Concept: 1) The biomass dryer unit and 2) the nitrogen stripper unit.

1.2. Name and contact of proposer

The proposer is the Danish company J.S. Trading, Kelstrupvej 31, DK-6100 Haderslev, Denmark. Website of J.S. Trading: www.golesen.dk. Contact person of the proposer is Mr. Geert Olesen. E-mail: geert@golesen.dk. Telephone: +45 74 58 30 06.

1.3. Name of verification body and responsible of verification

This verification is performed by ETA-Danmark A/S, Göteborg Plads 1, DK-2150 Nordhavn, Denmark. Website: www.etadanmark.dk. Verification responsible is Peter Fritzel, ETA-Danmark. Phone: +45 72 24 59 00. E-mail: pf@etadanmark.dk.

1.4. Organisation of verification including experts and verification process

The verification is conducted by ETA-Danmark in cooperation with Danish Centre for Verification of Climate and Environmental Technologies, DANETV.

An internal and an external technical expert have provided reviews of the planning, conducting and reporting of the verification. The internal verification expert is: Thorkild Qvist Frandsen, DANETV, tqf@agrotech.dk. Phone: +45 21 71 77 61.

The external technical expert assigned to this verification and responsible for review of the specific verification protocol and the verification report is Bjørn Malmgren-Hansen, Danish Technological Institute. E-mail: bmh@teknologisk.dk. Phone: +45 72 20 18 10.

The test and the verification tasks were conducted in two separate steps, as required by the EU ETV pilot programme. Test activities were undertaken by the AgroTech DANETV Test Centre (test body) whereas the verification activities were undertaken by ETA-Danmark (verification body).

The relations between the organisations involved in the present test and verification are shown in Figure 1.

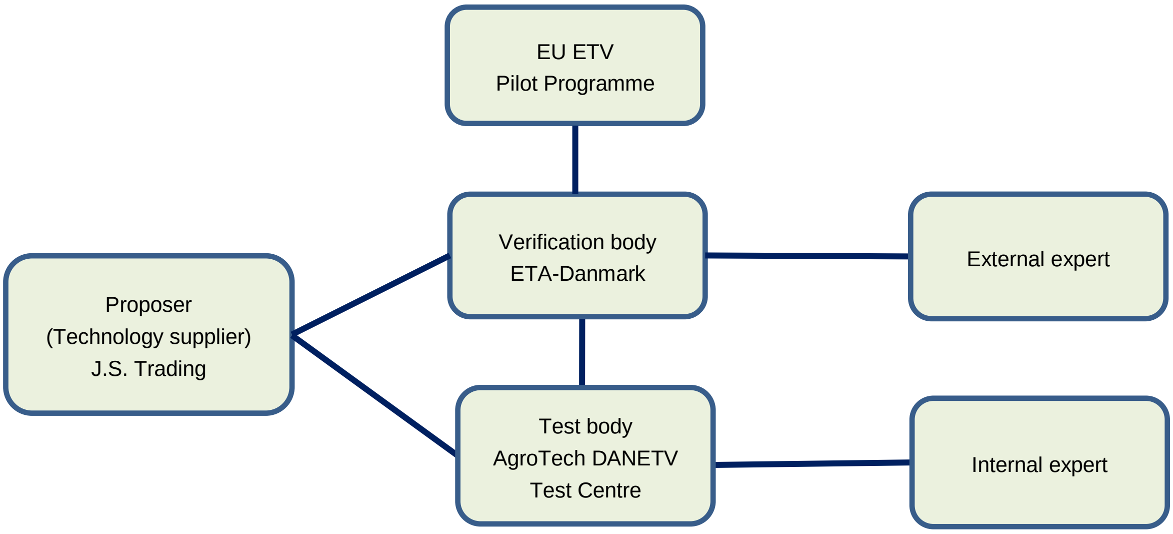

Figure 1. Organisation of the test and verification of the New Substrate Technology Concept.

The verification was planned and conducted to satisfy the requirements of the EU ETV Pilot programme as described in the EU ETV General Verification Protocol (European Commission, 2014) and ETA-Danmark´s internal procedure. An overview of the verification process is given in Table 1.

Table 1. Overview of the three main phases in the verification process and the corresponding documents for each phase.

Phase	Responsible	Document
Preparation phase	Verification body	Quick scan
		Contract with proposer
		Specific verification protocol
Testing phase	Test body	Test plan
		Test report
Verification phase	Verification body	Verification report
		Statement of Verification

Quality assurance was undertaken using both internal and external experts. An overview of the quality assurance of the whole verification process is given in section 5. The Statement of Verification will be issued by the ETA-Danmark Verification body after completion of the verification process.

1.5. Deviations from the specific verification protocol

Four deviations from the specific verification protocol are reported from the implementation of the test activities. The deviations and their impact on the verification process are described in section 4.2.3.

2. Description of the technology and application

2.1. Summary description of the technology

The purpose of the New Substrate Technology Concept is to upgrade a waste product (digested biomass from a biogas plant) to useful products with added value. The main new product is a new substrate suitable for cultivation of edible mushrooms. This new product has given name to the New Substrate Technology Concept.

Today mushroom production in Europe is normally based on substrate made from organic material like deep litter from poultry, horse manure, straw or similar types of organic wastes with high content of cellulose, hemicellulose, and lignin. Such resources can also be used for production of biogas and biofuels.

Problems related to high content of organic nitrogen (N) in the substrate materials are normally solved by composting and mixing with other biomasses. Water is added to reach the desired moisture content for mushroom production and the temperature is controlled by adding air and oxygen. A lot of heat is developed during the composting as a consequence of changes in chemical composition and evaporation of water. Carbon (C) in the basic raw material (especially the easy degradable volatile solids) is degraded and emission of CO_2 and loss of N cannot be avoided during the process.

Basic raw material for mushroom substrate can instead be made from partly digested biomass produced in connection with a biogas plant. By adding water and additional ingredients to the extracted digested biomass a high quality substrate for mushroom production with desired structure, moisture and nutrients content can be composed.

By enzymatic activities the mushrooms contribute in degrading the structures in cellulose, hemicellulose, lignin, and other organic compounds and use part of it as nutrients for their growth and development. When the mushrooms are harvested a spent substrate is left that is a suitable and valuable feed stock for biogas production.

The New Substrate Technology Concept is developed to:

- Separate organic material from a flow of partly digested biomass taken from a biogas reactor tank
- Dry this organic material so that it can be utilized for substrate for mushroom production

At the same time the New Substrate Technology Concept includes units to treat the liquid fraction resulting from extraction of the organic material. These units include:

- 2 sedimentation units
- 2 nitrogen stripper units
- 1 nitrogen absorber unit

The conceptual design and mass flow is illustrated in Figure 2.

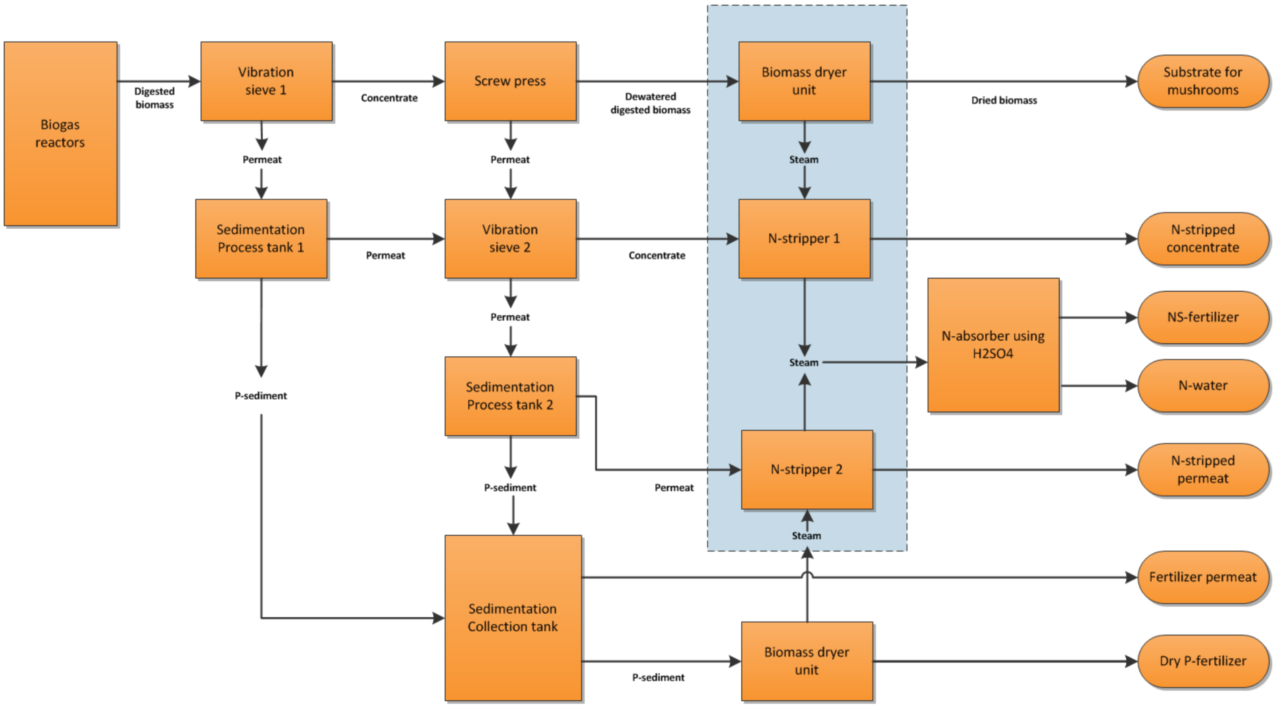

Figure 2. Overview of the different components in the complete New Substrate Technology Concept. Note that in most cases only one biomass dryer unit will be included since one dryer unit normally will have sufficient capacity to treat both the de-watered digested biomass and the P-sediment. The present verification focusses on the key components highlighted in the blue box: 1) The biomass dryer unit (drum dryer) including a biofuel burner unit. 2) The two N-stripper units.

The flow and scope of each of the steps is described and explained in the following.

Extraction of coarse particles in vibration sieve 1 followed by a screw press

The partly digested biomass is taken from the biogas reactor and led to a two-step separation unit. In vibration sieve 1 the larger particles are extracted from the liquid. The solid fraction (concentrate) is led to a screw press for further dewatering. The dewatered digested biomass creates the basic raw material for production of new substrate for mushroom production.

Biomass dryer unit

The New Substrate Technology Concept includes a biomass dryer unit, which is used for drying the dewatered digested biomass. During the drying process the water content of the dewatered biomass can be reduced from approximately 70 % to approximately 10 %. The main scope of drying is to control the ratio between inorganic and organic content in the biomass and to assure that the fiber material is hygienic clean. Inorganic N is stripped of in parallel with evaporation of water. Furthermore, as a result of the drying process the biomass is stabilized so that it can be stored for longer time. The biomass dryer unit is a drum dryer heated by burning biofuel in form of wood pellets.

Sedimentation tanks

The liquid fraction (permeate) from vibration sieve 1 is first led to a sedimentation process tank. The purpose of the sedimentation tank is to eliminate inorganic dry matter (mineralized nutrients, sand, etc.) by sedimentation. The sediment contains part of the phosphorous and after drying the sediment a valuable P-fertilizer is produced.

Extraction of fine particles in vibration sieve 2
After a certain holding time in the sedimentation tank the liquid fraction (permeate) is led to vibration sieve 2 with smaller openings than vibration sieve 1. In vibration sieve 2 the finer particles are extracted from the liquid. The solid fraction from vibration sieve 2 (concentrate) still has some potential for biogas production and therefore it will be recycled to the biogas reactor tank. The recycling leads to a more efficient use of both energy and nutrients potentials in the biomass.

However, the nitrogen content of the concentrate from vibration sieve 2 can be quite high. This is a problem for efficient biogas production since the anaerobic digestion process is inhibited when ammonium-N concentration is high. To reduce the risk of nitrogen inhibition the New Substrate Technology Concept includes two N-stripper units to be used for extraction of ammonium-nitrogen before the concentrate is recycled to the biogas reactor.

N-stripping by heating and control of pH-level
The purpose of the two N-strippers is to reduce ammonium-N content in the concentrate and permeate from the vibration sieve 2. This is done by heating the concentrate/permeate by injecting the warm N-rich exhaust steam from the biomass dryer unit. When the temperature has reached 85°C in one tank the exhaust steam is shifted to the other stripper tank. Holding time in the stripper tanks is around 1 hour. After that the stripper tank is emptied and a new portion of permeate/concentrate is led into the stripper tank.

N-absorption by adding H_2SO_4
The air leaving the N-stripper units is led through a H_2SO_4 absorber, where the ammonium-N is captured. Treatment in the N-absorber results in a liquid NS-fertilizer.

A simplified overview of the biomass dryer unit and the nitrogen stripper unit is given in Figure 3 below.

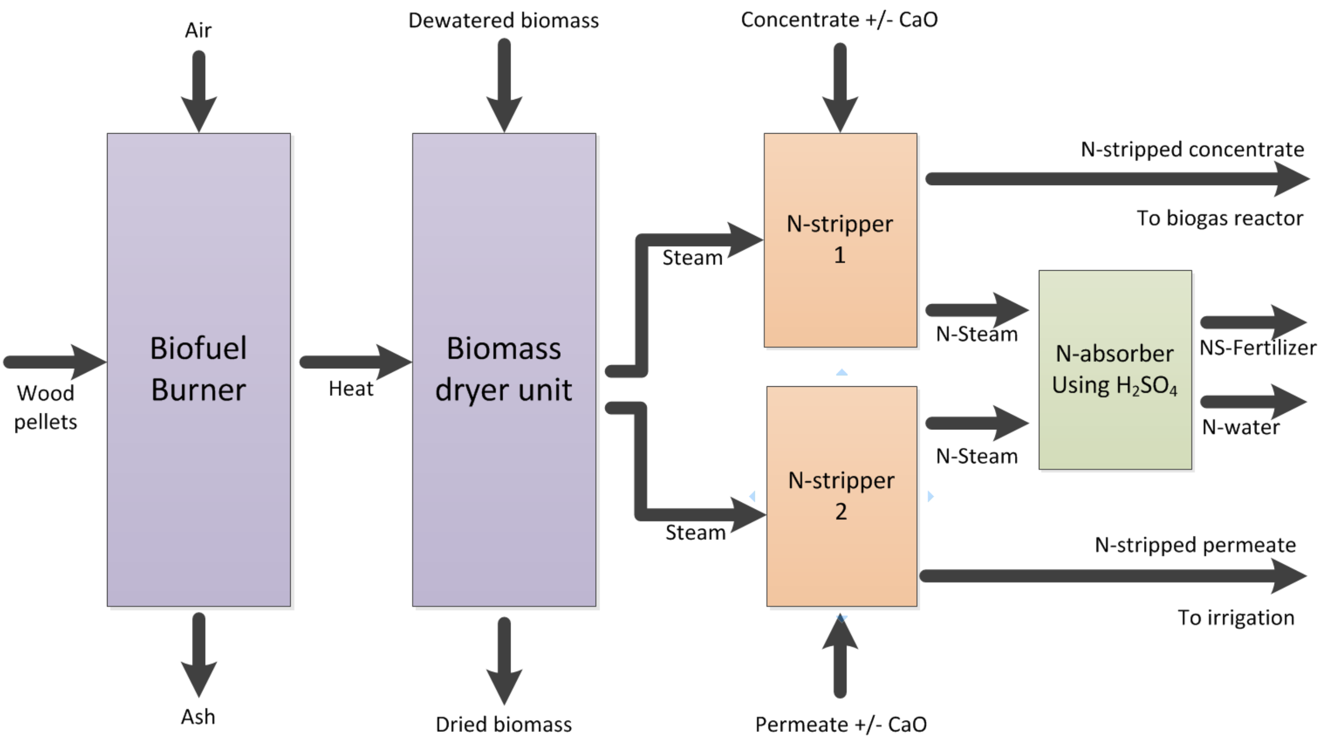

Figure 3. Simplified overview of the biomass dryer unit and the nitrogen stripper units of the New Substrate Concept.

2.2. Intended application including matrix, purpose, and technical conditions

In the following the intended application of the New Substrate Technology Concept is described in terms of the matrix and the purpose. Matrix is the type of material that the technology is intended for. The purposes of the technology concept are the measurable properties that are affected by the technology and how it is affected.

2.2.1. Matrix

The New Substrate Technology Concept is verified for treatment of the waste product from a biogas plant, the digested biomass. More specifically, in the present verification the matrix is the solid output fraction resulting from the separation of the digested biomass. Normally, the dry matter content of the dewatered digested biomass is between 25 % and 33 % in the outlet from the screw press unit (see Figure 2 above).

2.2.2. Purposes

The overall purpose of the complete New Substrate Technology Concept is to upgrade a waste product (digested biomass from a biogas plant) to useful products with added value.

This verification includes a performance test of 1) the biomass dryer unit and 2) the two nitrogen stripping units (N-strippers). The other units in the complete New Substrate Technology Concept are not tested as part of this verification.

The specific purpose of the biomass dryer unit is to dry the dewatered digested biomass (solid output fraction) from the screw press. Drying is needed to make the digested biomass a stable product that can be stored and transported without composting process starting.

The N-strippers are used for reducing the nitrogen content in the concentrate from the second vibrating sieve and in the permeate from the second sedimentation tank (see Figure 2). As a result of the treatment in the N-strippers:

- The concentrate is now warm and low in nitrogen-content making it useful for recirculation to the biogas reactors as substrate more suitable for anaerobic digestion
- The nitrogen stripped from permeate can be utilised for production of a concentrated fertilizer product by leading the N-rich steam to the N-absorber unit. The N-stripped permeate can be used for irrigation purposes.

<u>Exclusions:</u>
The performance of the vibration sieves, the sedimentations process tanks, the screw press and the N-absorber is not evaluated as part of this verification.

2.3. Verification parameters definition

In this section the different parameters examined as part of the verification are described.

Performance parameters are defined taking into account e.g. regulatory requirements, application based needs, and state of the art performance. For the verification of the New Substrate Technology Concept the following 3 performance parameters have been defined:

- Bioenergy consumption of biomass dryer unit per ton of liquid evaporated from the dewatered digested biomass.
- Share of bioenergy input to the biomass dryer unit transferred to the concentrate/permeate in the N-stripper units.
- Reduction in the concentration of ammonium-nitrogen in the output-concentrate compared to the concentration in the input concentrate.

The operational parameters evaluated as part of this verification are:

- The capacity of the biomass dryer measured as amount of liquid evaporated per hour in operation
- The measured consumption of biofuel for heating up the biomass dryer unit.
- The measured time needed for heating up the biomass dryer unit to desired operation temperature..
- The measured power consumption of the biomass dryer unit.
- Consumption of lime per ton of concentrate/permeate treated in the N-strippers.
- pH change of concentrate/permeate as a result of treatment in the N-strippers.

The user manual and implications on occupational health and environment will not be evaluated as part of this verification.

The relevant environmental parameters are included as performance parameters described in section 3.1.

In addition to the performance parameters a number of other parameters are evaluated as part of this verification. In order to characterise the dried biomass and evaluate its quality as substrate for mushroom production the content of selected nutrients have been measured in the dewatered input biomass and dried output biomass from the dryer unit. In Table 2 the nutrients are listed.

Table 2. List of nutrients that were analysed in the input biomass to and output biomass from the dryer unit.

Parameter	Analytical method	Unit
Total nitrogen (total-N)	DIN ISO 13878	Kg/ton
Ammonium nitrogen (NH4-N)	DIN 38406-5-2 (E 5-2)	Kg/ton
Phosphorous (P)	DIN EN ISO 11885 (E 22)	Kg/ton
Phosphate (P2O5)	EN ISO 11885	Kg/ton
Potassium (K)	DIN EN ISO 11885 (E 22)	Kg/ton
Potassium oxide (K2O)	EN ISO 11885	Kg/ton

In Table 3 below the performance parameters for this specific verification are presented. The figures mentioned in the Value-column refer to the performance claims of the proposer.

Table 3. Parameter definition table.

Parameter	Value	Existing legal requirements	Test or measurement methods	Available test data
Bioenergy consumption of biomass dryer unit per ton of liquid evaporated from the dewatered digested biomass.	Maximum 1 MWh	Not applicable	The consumption of wood pellets for drying a specific amount of biomass is measured. The content of dry matter content (TS) and volatile solids (VS) of the biomass is measured in input biomass and output biomass to be able to calculate amount of liquid evaporated. Analytical method for measuring TS is DIN EN 12880. Analytical method for measuring VS is DIN 19684-3.	The technology has not been tested previously.
Share of bioenergy input to the biomass dryer unit transferred to the concentrate/permeate in the N-stripper units.	Minimum 70 %	Not applicable	The amount of energy transferred to the N-stripper unit is calculated from measuring the increase in temperature of the concentrate/permeate.	The technology has not been tested previously.
Reduction in the concentration of ammonium-nitrogen in the output-concentrate compared to the concentration in the input concentrate.	Minimum 75 %	Not applicable	Samples are taken from the inlet to the N-stripper and from the outlet from the N-stripper. Samples are analysed using analytical method DIN 38406-5-2.	The technology has not been tested previously.

3. Existing data

3.1. Accepted existing data

No existing data have been used in the present verification.

4. Evaluation

4.1. Calculation of performance parameters

The performance parameter related to bioenergy consumption is calculated this way:

$$\text{Bioenergy consumption} = \frac{(\text{Lower } heating\ value\ of\ wood\ pellets) * (kg\ of\ pellets\ used\ during\ batch)}{(\text{ton of liquid evaporated during the batch})}$$

Table 4. Results from evaluation of bioenergy consumption for drying dewatered biomass.

Batch no.	Heating value of wood pellets (kWh/kg)	Amount of pellets used during batch (kg)	Amount of liquid evaporated (ton)	Bioenergy consumption (kWh / ton liquid)
1	4.759	75.0	0.234	1,525
2	4.759	70.5	0.196	1,712
3	4.759	68.5	0.209	1,563
4	4.759	91.8	0.246	1,777
Mean	***4.759***	***76.5***	***0.221***	***1,644***
Standard deviation				***0,120***
95 % confidence interval				***1,454 – 1,835***

The performance parameter related to energy transfer is calculated this way:

$$\text{Energy transfer} = 100 * \frac{(\text{Amount of energy recovered in the liquid in the N} - \text{stripper})}{(\text{Lower } heating\ value\ of\ wood\ pellets) * (kg\ of\ pellets\ used\ during\ batch)}$$

Table 5. Results from evaluation of the amount of energy transferred from biomass dryer to liquid in N-strippers.

Batch no.	Energy input to biomass dryer (kWh)	Amount of liquid (litres)	Temperature change (°C)	Energy recovered[1] (kWh)	Energy transferred (%)
1	357	N.a.	+19	N.a.	N.a.
2	336	3,223	+19	71.1	21 %
3	326	2,249	+18	47.0	14 %
4	437	N.a.	+16	N.a.	N.a.

[1] The amount of energy recovered is calculated as amount of liquid in N-stripper * heat capacity * change in temperature. The heat capacity (C_p) is approximately 4.18 J/g/˚C for water and liquids with low dry matter content in the operational range 20-90 ˚C.

Due to lack of data the energy transfer performance parameter could be calculated only for batch 2 and batch 3. In average 18 % of the energy input to the biomass dryer was transferred to the liquid in the N-stripper tank. To verify this performance parameter results from the 3 batches were required.

The performance parameter related to reduction in ammonium-nitrogen concentration is calculated this way:

$$\text{AmmoniumN Reduction} = 100 * \frac{(AmmoniumN\ content\ in\ input) - (AmmoniumN\ content\ in\ output)}{(\text{AmmoniumN content in input})}$$

Results regarding reduction of ammonium-N (NH4-N) from dewatered biomass during the drying process are presented in Table 6. It is seen that the ammonium-N content is reduced by 35 – 51 % as a result of the treatment in the biomass dryer. In average over 4 batch tests the ammonium-N concentration was reduced by 41 %.

Table 6. Reduction in ammonium-N concentration of biomass resulting from treatment in biomass dryer.

Batch no.	NH4-N content in input to biomass dryer (kg/ton)	NH4-N content in output from biomass dryer (kg/ton)	Reduction in NH4-N content (%)
1	1.56	0.91	42 %
2	1.70	0.84	51 %
3	1.42	0.92	35 %
4	0.85[1]	0.55[1]	35 %
Mean	***1.38***	***0.81***	***41 %***
Standard deviation			***7,3 %***
95 % Confidence interval			***29 % – 52 %***

[1] It is seen that the ammonium-N concentration is significant lower in batch 4 than in batch 1-3. The reason is probably that in batch 4 lime (CaO) was added to the digested biomass before it was treated in the screw press.

Based on the figures in Table 6 and the measured weight of the input to and output from the biomass dryer (see Table 11) an ammonium-N mass balance have been calculated for the 3 batches without addition of CaO to the digested biomass. The resulting mass balances are shown in Table 7.

Table 7. Amount of ammonium-N stripped off the dewatered digested biomass in the biomass dryer.

Batch no.	Amount of NH4-N in input to biomass dryer (kg)	Amount of NH4-N in output from biomass dryer (kg)	Amount of NH4-N stripped off in biomass dryer (kg)	Share of NH4-N stripped off in biomass dryer (%)
1	0.59	0.13	0.46	78 %
2	0.52	0.09	0.43	82 %
3	0.47	0.11	0.36	77 %
Mean	***0.52***	***0.11***	***0.41***	***79 %***
Standard deviation				***3 %***
95 % Confidence interval				***72 % – 86 %***

The mass balance shows that the biomass dryer removes 79 % of the ammonium-N present the input biomass as an average over batch 1 - 3.

Results regarding stripping ammonium-N of liquid from screw press are presented in Table 8. It is seen that ammonium-N content in the liquid is reduced by 23 – 34 % as a result of the treatment in the N-stripper unit. In average over 3 batch tests the ammonium-N concentration was reduced by 29 %. It is seen that the uncertainty is relatively large for the reduction in NH4-N content.

Table 8. Reduction in ammonium-N concentration of liquid from screw press after treatment in N-stripper.

Batch no.	NH4-N content in input to N-stripper (kg/ton)	NH4-N content in output from N-stripper (kg/ton)	Reduction in NH4-N content (%)
1	2.41	1.60	34 %
2	1.88	1.29	31 %
3	Data not available	1.22	Data not available
4	1.45	1.12	23 %
Mean	***1.91***	***1.34***	***29 %***
Standard deviation			***6 %***
95 % Confidence interval			***15 % - 44 %***

4.2. Evaluation of test quality

4.2.1. Control data

A test system control was performed by Amparo Cortina Gomez during visits at the test site on the 3rd of September and 17th September. The test system control included an evaluation of the following measuring equipment:

- pH-meter: Measurement results compared with results from parallel measurements using alternative pH-meters.
- Temperature measuring equipment: Measurement results compared with results from parallel measurements using alternative temperature sensors.
- Weighing devices: Calibration of devices checked on test site by weighing units with known weight.

It was concluded, that the equipment was suitable for the test activities.

Spread sheets used for the calculations were subject to control on a sample basis (spot validation of at least 5 % of the data).

4.2.2. Audits

A test system audit on the test site was undertaken by Amparo Cortina Gomez (internal auditor from AgroTech test body) on the 3rd of September 2014 and on the 17th of September 2014. Furthermore, a test system audit with inspection of the test set-up on the test site was done by Peter Fritzel from ETA-Danmark Verification Body on the 15th of December 2014.

As part of the test system audits it was evaluated whether the testing was done according to the requirements specified in the test plan and in the specific verification protocol. It was concluded from the audits, that there was consistency with the test plan and set up and that handling of measurements were carried out as described. It should be mentioned though, that the power consumption of the biomass dryer and the lime consumption were not measured (see section 4.2.3 Deviations). However, these parameters are not key performance parameters.

The test data provided in the test report were evaluated against the requirements set in the specific verification protocol and the objectives set in the test plan.

4.2.3. Deviations

Three deviations from the Specific verification protocol are reported. An overview with a description of the deviation and the impact/consequence is given in Table 9.

Table 9. Summary of deviations from the specific verification protocol.

No.	Description of deviation	Impact / consequence
Dev1	Power consumption of biomass dryer was not measured during any of the four batch tests.	It is not possible to verify the power consumption based on the results from this test. However, the power consumption of the biomass dryer is not one of the key performance parameters.
Dev2	Some components of the complete New Substrate Technology Concept were not installed and in operation during the test.	This deviation has no impact on the test results and the evaluation of the biomass dryer and N-strippers.
Dev3	There was no measurement of the amount of lime consumed to increase pH and thereby accelerate the N-stripping process.	It is not possible to verify the lime consumption based on results from this test. However, lime consumption is not one of the key performance parameters.
Dev4	An additional performance parameter was defined after testing was initiated: Reduction in ammonium-nitrogen concentration of biomass resulting from treatment in biomass dryer.	This deviation has no impact on the way the test should be undertaken since the additional performance parameter could be calculated based on results from the already planned test activities.

4.3. Verification results – verified performance claims

4.3.1. Performance parameters

An overview of the verified performance claims are given in Table 10.

Table 10. Verified performance for the selected performance parameters. 95 % confidence intervals are shown in brackets.

Parameter	Verified performance	Comments
Bioenergy consumption of biomass dryer unit per ton of liquid evaporated from the dewatered digested biomass.	1.64 MWh *[1.45 – 1.83]*	Average of four batch tests.
Share of bioenergy input to the biomass dryer unit transferred to the liquid in the N-stripper units.	Performance could not be verified due to lack of data.	Data available from only two batch tests (three required).
Reduction in ammonium-nitrogen concentration in the output from N-stripper compared to the concentration in the input to the N-stripper.	29 % [15 % - 44 %]	Average of three batch tests.
Reduction in ammonium-nitrogen concentration of biomass resulting from treatment in biomass dryer.	41 % [29 % - 52 %]	Average of four batch tests.

One of the key benefits of the New Substrate Technology Concept is that, part of the energy input to the biomass dryer is transferred to the liquid in the N-stripper units. In other words, the wood pellets are not only used for drying the biomass. The consumption of wood pellets also contributes to the process of stripping ammonia from the liquid in the N-stripper units. Furthermore, when the N-stripped concentrate is recycled to the biogas reactor the energy consumption for heating the reactor is reduced because the concentrate is already warm. Thus, the bioenergy consumption of 1.64 MWh per ton of liquid evaporated should be seen in a broader perspective and related to the New Substrate Technology Concept as a whole.

4.3.2. Operational parameters

The capacity of the biomass dryer is calculated this way:

$$\text{Capacity} = \frac{(Weight\ of\ dewatered\ input\ biomass) - (weight\ of\ dried\ output\ biomass)}{(\text{Duration of batch measured in hours})}$$

Results from the measurement of capacity of the biomass dryer are presented in Table 11.

Table 11. Capacity of the biomass dryer in terms of amount of water evaporated per hour.

Batch no.	Amount of dewatered input biomass (kg)	Amount of dried output biomass (kg)	Duration (hours)	Capacity (kg water/hour)
1	377	143	1.28	182
2	306	110	1.57	125
3	327	118	1.43	145
4	440	194	1.65	150
Mean	***363***	***141***	***1.48***	***151***
Standard deviation				***24***
95 % Confidence interval				***113 - 188***

The consumption of biofuel for heating up the biomass dryer was measured by weighing the amount of bio pellets used from the starting up of the bio fuel burner to the biomass dryer was ready for feeding in dewatered biomass. In addition the time needed for heating up the biomass dryer to the desired operation temperature was measured. The results are presented in Table 12.

Table 12. Time and wood pellets used to heat up the biomass dryer before drying is started. Time and wood pellets used during the process of drying the biomass.

Batch no.	Time used to heat up dryer (minutes)	Wood pellets used to heat up biomass dryer (kg)	Time used to dry biomass (minutes)	Wood pellets used to dry biomass (kg)
1	20	12	77	75.0
2	21	4	94	70.5
3	17	5.5	86	68.5
4	Data not available	Data not available	99	91.8
Mean	*19*	*7.2*	*89*	*76.5*

The pH change of the liquid as a result of treatment in the N-strippers is measured for batch 1, 2 and 4. See results in Table 13.

Table 13. pH change of the liquid resulting from treatment in the N-stripper.

Batch no.	pH before treatment in N-stripper	pH after treatment in N-stripper	pH change
1	7.7	8.7	+ 1.0
2	8.1	8.8	+ 0.7
4	12.0	9.3	- 2.7

Neither the lime consumption of the N-stripper nor the power consumption of the biomass dryer was measured even though it was planned. Deviations from the specific verification protocol are described in section 4.2.3.

4.3.3. Environmental parameters

The relevant environmental parameters are included as performance parameters as described in section 4.3.

4.3.4. Additional parameters with comments or caveats where appropriate

In order to facilitate an evaluation of the dried biomass as substrate for mushroom production some key characteristics have been analysed. The results are presented in Table 14 and Table 15.

Table 14. Nutrient content of biomass before and after treatment in biomass dryer.

Parameter	Batch 1		Batch 2		Batch 3		Batch 4	
	Before	After	Before	After	Before	After	Before	After
Total-Nitrogen (kg/ton)	4.64	8.58	4.08	8.12	3.76	7.76	3.27	5.76
Ammonium Nitrogen (kg/ton)	1.56	0.91	1.70	0.84	1.42	0.92	0.85	0.55
Organic Nitrogen (kg/ton)	3.08	7.67	2.38	7.28	2.33	6.84	2.43	5.21
Phosphorous (kg/ton)	1.17	3.55	1.26	3.61	1.05	3.05	1.26	2.73
Potassium (kg/ton)	2.63	6.51	2.63	7.55	2.49	6.93	2.67	5.96

Table 15. Content of total solids and volatile solids of biomass before and after treatment in biomass dryer.

Parameter	Batch 1		Batch 2		Batch 3		Batch 4	
	Before	After	Before	After	Before	After	Before	After
Total solids, TS (%)	33.9	89.4	33.1	92.1	34.1	94.2	37.1	84.1
Volatile solids, VS (%)	30.9	80.2	31.2	86.0	31.4	85.6	31.7	72.8
VS/TS (%)	91	90	94	93	92	91	85	87

4.4. Recommendations for the Statement of Verification

Based on the verified performance described in section 4.3 above it is recommended to issue a Statement of Verification including results on the following parameters:

Performance parameters:

- Bioenergy consumption of biomass dryer unit per ton of liquid evaporated from the dewatered digested biomass.
- Reduction in ammonium-nitrogen concentration in the output from N-stripper compared to the concentration in the input to the N-stripper.
- Reduction in ammonium-nitrogen concentration of biomass resulting from treatment in biomass dryer.

Operational parameters:

- Capacity of biomass dryer in terms of amount of liquid evaporated per hour in operation
- Biofuel and time used for heating up the biomass dryer

Additional parameters:

- Content of main nutrients in biomass before and after treatment in biomass dryer
- Content of total solids and volatile solids before and after treatment in biomass dryer

Due to lack of data the following parameters could not be verified:

- Share of bioenergy input to the biomass dryer unit transferred to the liquid in the N-stripper units.
- Power consumption of the biomass dryer
- Consumption of lime to promote the N-stripping

5. Quality assurance

The test activities were undertaken by AgroTech Test Centre (test body). AgroTech has a quality management system in place that follows the principles of EN ISO 9001. It is judged that the quality management system fulfils the requirements of the General Verification Protocol (Chapter C.III) and thereby AgroTech Test Centre is qualified for participation in the EU ETV verification process.

A test system audit on the test site was done by Peter Fritzel from ETA-Danmark Verification Body on the 15th of December 2014. As part of the test system audit it was evaluated whether the testing was done according to the requirements specified in the test plan and in the specific verification protocol. Based on the audit it is concluded, that there was consistency with the test plan and set up and that handling of measurements were carried out as described.

Furthermore, a test performance audit was done by Thorkild Frandsen from ETA-Danmark verification body. The performance audit included an evaluation of the external laboratory used for the chemical analyses of the samples taken. The external laboratory used was Agrolab, Institut Koldingen GmbH, Breslauer Strasse 60, 31157 Sarstedt, Germany. To evaluate the external laboratory (Agrolab) extra samples were taken by the test body during the four test batches. Five of these samples were sent to an alternative laboratory (Steins Eurofins) for analysis of total solids, total nitrogen, and total potassium. The results from Eurofins were compared with the results from Agrolab. The differences in analysis results are within acceptable range.

The specific verification protocol and the verification report require external review according to the EU ETV General Verification Protocol (European Commission, 2011). The external review was undertaken by Bjørn Malmgren-Hansen (BMH) from Danish Technological Institute. The verification body will review and approve the test plan and review the test report. The review was done by Thorkild Qvist Frandsen (TQF).

During the verification process the proposer represented by Geert Olesen (GO) had the following tasks:

- Review the specific verification protocol
- Review and approve the test plan
- Review the test report and the verification report
- Accept the Statement of Verification.

6. References

European Commission (2014): EU Environmental Technology Verification pilot programme. General Verification Protocol. Version 1.1 - July 7th, 2014.

International Standardization Organisation (2008): EN ISO 9001. Quality management systems - Requirements. 15.11.2008.

Appendix 1 - Terms and definitions

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
Innovative environmental technologies	Environmental technologies presenting a novelty in terms of design, raw materials	None

Term	Definition	Comments
	involved, production process, use, recyclability or final disposal, when compared with relevant alternatives.	
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 service based upon an environmental technology.	In the EU ETV GVP [1] the term "technology" is used instead of the term "product".
Proposer	Any legal entity or natural person, which can be the technology manufacturer or an	Can be vendor or producer

Term	Definition	Comments
	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.	
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
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.

Term	Definition	Comments
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

Appendix 2 – Quick scan

The report from the quick scan is attached to the verification report as a separate file.

Appendix 3 – Proposal

The verification proposal is attached to the verification report as a separate file.

Appendix 4 – Specific verification protocol

The specific verification protocol is attached to the verification report as a separate file.

Appendix 5 – Amendment and deviation report for verification

No amendment report has been made for the verification of the New Substrate Technology Concept. The deviation report is attached to the verification report as a separate file.

Appendix 6 – Test plan

The test plan is attached to the verification report as a separate file.

Appendix 7 – Test report

The test report is attached to the verification report as a separate file.