# Statement of Verification

EU Environmental Technology
Verification pilot programme

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| **Technology:** | New Substrate Technology Concept |
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This Statement of Verification summarises the main results from the verification of two key components of the New Substrate Technology Concept: 1) The biomass dryer and 2) the nitrogen strippers.

The verification was performed under the EU Environmental Technology Verification (ETV) Pilot Programme. The EU ETV Pilot Programme was established to help innovative environmental technologies reach the market by providing a framework for independent evaluation of the performance of such technologies.

This verification was undertaken by the Danish verification body, ETA-Danmark A/S. ETA-Danmark is accredited by the Danish Accreditation body, DANAK, according to EN 17020 for performing environmental technology verifications. This Statement of Verification is available on the website of the EU ETV Pilot Programme: http://iet.jrc.ec.europa.eu/etv/verified-technologies

## 1. Technology description

New Substrate Technology Concept is intended for installation on biogas plants for treatment of the digested biomass. Today the digested biomass is typically applied to the fields without further treatment. However, by introducing New Substrate Technology Concept the digested biomass is upgraded to new products with added value. Thus, it is a tool to increase the resource efficiency. An overview of how New Substrate Technology Concept fits into a biogas plant is given in figure 1.

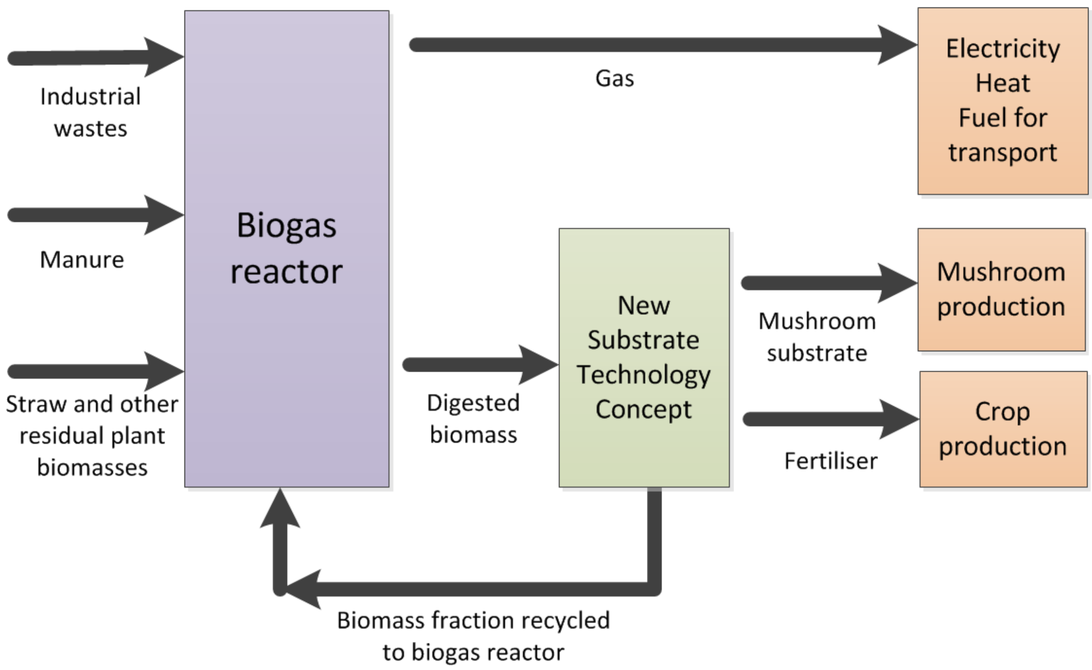


*Figure 1. Schematic overview of biomass input flow to New Substrate Technology Concept and resulting products.*

New Substrate Technology Concept consists of a number of components, which are combined into a treatment plant, which is functioning automatically. In the first step dry matter is separated from the liquid digested biomass from the biogas reactor. A screw press is used for the separation. The water content of the resulting dry matter fraction is now within the range of 64 – 68 %.

The dry matter fraction (wet digested biomass) is now fed into a biomass dryer. It is a rotating drum heated by a biofuel burner fed with wood pellets. During the drying process the water content of the wet biomass from the screw press is reduced to approximately 10 %. Furthermore, ammonium nitrogen is stripped off together with evaporation of water. As a result of the drying process the biomass is stabilised so that it can be stored and transported without changing its properties due to composting processes.

The warm air leaving the biomass dryer is utilised for heating two nitrogen strippers (N-strippers) which are also part of the New Substrate Technology Concept. The N-strippers are used for treatment of a liquid fraction from the separation of digested biomass. This fraction, the concentrate, will be fed back into the biogas reactor after treatment in one of the N-strippers.

The functioning principle of the N-strippers is to inject the warm air from the biomass dryer in the bottom of the N-stripper. When the temperature of the liquid inside the N-stripper increases ammonia evaporates from the liquid and leaves the N-stripper via the outlet air.

The nitrogen rich air leaving the N-stripper is subsequently led through a $H_2SO_4$ absorber, where the ammonia-N is captured. The absorbed nitrogen is used for production of a liquid fertilizer rich in nitrogen and sulphur. Figure 2 shows the key components of the New Substrate Technology.

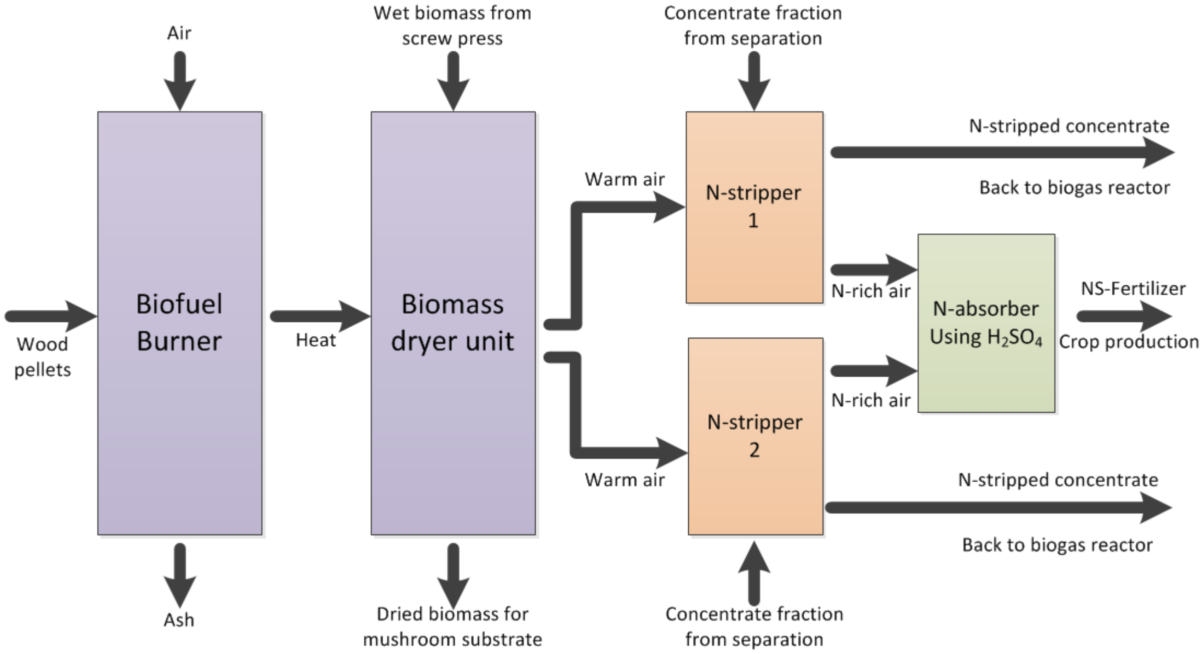


*Figure 2. Simplified illustration of the biomass dryer and the N-strippers of the New Substrate Technology Concept.*

## 2. Application

### 2.1. Matrix

The biomass dryer of the New Substrate Technology Concept was verified for treatment of the dry matter fraction resulting from separation of the digested biomass with a screw press. The N-strippers were verified for treatment of the liquid fraction from the screw press.

## 2.2. Purpose

The New Substrate Technology Concept is developed for production of a new substrate for mushroom growing which is based on digested biomass from a biogas plant. In addition, a fertiliser for crop production and increased biogas yields are also results of the treatment of digested biomass with New Substrate Technology Concept (see figure 1 above).

Specifically for the biomass dryer the purpose is to dry the wet biomass from the screw press to achieve a stabilised product with reduced nitrogen content suitable for mushroom production.

The purpose of the N-strippers is to reduce the content of ammonium-nitrogen of the liquid fraction treated and to increase the temperature of this fraction before it is fed back into the biogas reactor. As a result of these effects a more effective biogas production is achieved and the net energy production is increased.

## 2.3. Conditions of operation and use

Both the biomass dryer and the N-strippers were verified under normal conditions of operation. The test of the biomass dryer was designed so that it was possible to evaluate the performance during the heating up-phase separately from the performance during the operation phase.

## 2.4. Verification parameters definition summary

In table 1 the performance parameters are presented together with a description of the applied test or measurement methods.

*Table 1. Overview of performance parameters evaluated as part of this verification.*

| Parameter | Test or measurement methods |
|---|---|
| Bioenergy consumption of biomass dryer unit per ton of liquid evaporated from the dewatered digested biomass. | 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. |
| Reduction in ammonium-nitrogen concentration of liquid resulting from treatment in N-stripper. | Representative samples are taken from the inlet to the N-stripper before treatment and from the outlet from the N-stripper after treatment. Samples are analysed using analytical method DIN 38406-5-2 at accredited laboratory. |
| Reduction in ammonium-nitrogen concentration of biomass resulting from treatment in biomass dryer. | Representative samples are taken from the wet biomass before drying and from the outlet from the biomass dryer after treatment. Samples are analysed using analytical method DIN 38406-5-2 at accredited laboratory. |

# 3. Test and analysis design

## 3.1. Existing and new data

The New Substrate Technology Concept has not been tested previously. Therefore, this verification is based on new data only since no existing data were available.

## 3.2. Laboratory or field conditions

A full scale version of the New Substrate Technology Concept was used for the test. The test took place at the biogas plant established in connection with Foulum Research Centre at Aarhus University. It is judged that this biogas plant is managed in a way that the digested biomass is representative for commercial biogas plants where the New Substrate Technologies could be installed. The samples taken during the test were analysed in an accredited laboratory.

Figure 3 shows two photos from the test set up at the biogas plant. The left photo shows the biomass dryer and the right photo shows the two N-strippers.

*Figure 3. Left photo: The biomass dryer. The warm outlet air is led to the N-strippers via the bended pipe seen in the left side of the biomass dryer. Right photo: The two N-strippers.*

### 3.3. Matrix compositions

The dry matter fraction from the screw press (matrix of the biomass dryer) was characterised by a total solids content of 33 - 37 %, a total nitrogen content of 3.3 - 4.6 kg/ton, an ammonium nitrogen content of 0.9 - 1.7 kg/ton and a phosphorous content of 1.1 - 1.3 kg/ton. Additional data on matrix compositions are presented in section 4.4 below.

### 3.4. Test and analysis parameters

The analysis parameters and the respective analytical methods are presented in table 2.

*Table 2. Overview of analysis parameters applied for the test of the New Substrate Technology Concept.*

| Parameter | Analytical method | Unit |
|---|---|---|
| Total solids (TS) | DIN EN 12880 | % |
| Volatile solids (VS) | DIN 19684-3 | % |
| 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 |

### 3.5. Tests and analysis methods summary

The test was done as a series of 4 batch tests, which took place on four days in 2014. In each of the 4 batch tests the biomass dryer was tested for drying dewatered digested biomass and at least one of the N-strippers was tested for treatment of liquid fraction from the screw press.

### 3.6. Parameters measured

In addition to the performance parameters listed in section 2.4 above the following parameters were measured and evaluated as part of the verification:

- Capacity of the biomass dryer: kg water evaporated per hour of normal operation
- Time used to heat up the biomass dryer to desired temperature: Minutes
- Wood pellets used to heat up the biomass dryer to desired temperature: kg

## 4. Verification results

### 4.1. Performance parameters

In table 3 the verified performance is presented as a mean value together with the respective 95 % confidence intervals.

*Table 3. Verified performance. 95 % confidence intervals are shown in brackets.*

| Parameter | Verified performance |
|---|---|
| Bioenergy consumption of biomass dryer unit per ton of liquid evaporated from the dewatered digested biomass. | 1.64 MWh<br>[*1.45 – 1.83*] |
| Reduction in ammonium-nitrogen concentration in the output from N-stripper compared to the concentration in the input to the N-stripper. | 29 %<br>[15 % - 44 %] |
| Reduction in ammonium-nitrogen concentration of biomass resulting from treatment in biomass dryer. | 41 %<br>[29 % - 52 %] |

It is seen in table 3 that as a mean value over 4 batches the bioenergy consumption was 1.64 MWh per ton of liquid evaporated from the dewatered digested biomass. This energy consumption is relatively high. However, 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 wood pellets also contribute to the ammonia stripping from the liquid in the N-strippers. 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.

### 4.2. Operational parameters

Results from measurements of the capacity of the biomass dryer are presented in table 4.

*Table 4. 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*** |

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In average it took 19 minutes and 7.2 kg of wood pellets to heat up the biomass dryer to the desired temperature so that drying of biomass could start.

### 4.3. Environmental parameters

The relevant environmental parameters are included as performance parameters described in section 4.1.

### 4.4. Additional parameters (with comments or caveats where appropriate)

In order to facilitate an evaluation of the dried biomass as substrate for mushroom production key parameters have been analysed. The results are presented in table 5 and table 6.

*Table 5. 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 6. 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 |

An ammonium-N mass balance has been calculated to show the share of the ammonium-N which is stripped off in the biomass dryer. The resulting mass balance is presented 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 3 batches.

## 5. Additional information

Additional information can be found in the verification report.

## 6. Quality assurance and deviations

The test and verification activities were planned and undertaken in order to satisfy the requirements on quality assurance described in the General Verification Protocol developed for the EU ETV Pilot Programme.

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 and it is judged that it fulfils the requirements of the EU ETV General Verification Protocol (Chapter C.III). Laboratory analyses were performed by Agrolab, which has an accreditation for the relevant analyses.

An external review was performed for the specific verification protocol and the verification report. The external review was done by Bjørn Malmgren-Hansen from Danish Technological Institute.