



Dall Energy Biomass Furnace

Verification Protocol

Low particle, CO and NO_x emission furnace

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2. 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.

2.1. *Name of product*

The Dall Energy Biomass Furnace is a low emission and high efficiency biomass furnace, without any moving parts. The combustions principle is gasification in the bottom of the furnace and gas combustion in the upper part. This gives a very low emission of particles, CO and NO_x, which stays low during load changes, and even when operated as low as 10 - 20 % load.

2.2. *Name and contact of vendor*

Dall Energy
Venlighedsvej 2
2970 Hørsholm
Denmark
Phone: +45 29 87 22 22
Contact: Jens Dall Bentzen
E-mail: info@dallenergy.com

2.3. *Name of centre/verification responsible*

FORCE Technology, verification body at the Danish Centre for Verification of Climate and Environmental Technologies (DANETV).

FORCE Technology DANETV Air emission and Energy Centre:

Verification Test Centre (DANETV)	Verification responsible
FORCE Technology	Ole Schleicher
Park Allé 345	E-mail osc@force.dk
DK - 2605 Brøndby	Phone +45 4326 7540
Denmark.	Cell phone +45 2269 7540

2.4. *Verification and test organization*

The verification was conducted by the Danish Centre for Verification of Climate and Environmental Technologies, DANETV, which performs independent tests of technologies and products for the reduction of climate changes and pollution.

The verification will be conducted by the Danish Test Centre DANETV. The verification is planned and conducted to satisfy the requirements of the ETV scheme currently being established by the European Union (EU ETV).



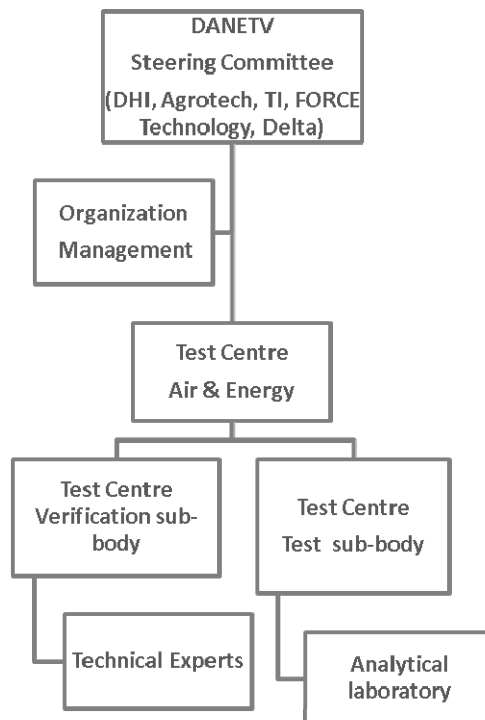
Verification and tests will be performed by FORCE Technology as Verification body at DANETV Test Centre.

The day to day operations of the verification and tests will be coordinated and supervised by FORCE Technology, with participation of the vendor, Dall Energy. The testing will be conducted at the 8 MW Dall Energy Furnace, which is under construction at Andelsselskabet Bogense Fjernvarme, Fynsvej 5, 5400 Bogense, Denmark. The furnace will be operated by the local operators, supervised by Dall Energy, which also will provide the necessary documentation and operation instructions for the tests. Dall Energy will also assist FORCE Technology in the development of the protocol and test plans.

An expert group is established to support FORCE Technology in planning, conducting and reporting the verification and tests, and to review plans and reports.

The organization chart in Figure 1 identifies the relationships of the organization associated with this verification and tests.

Figure 1 Organization of the verification and tests





2.5. *Technical experts*

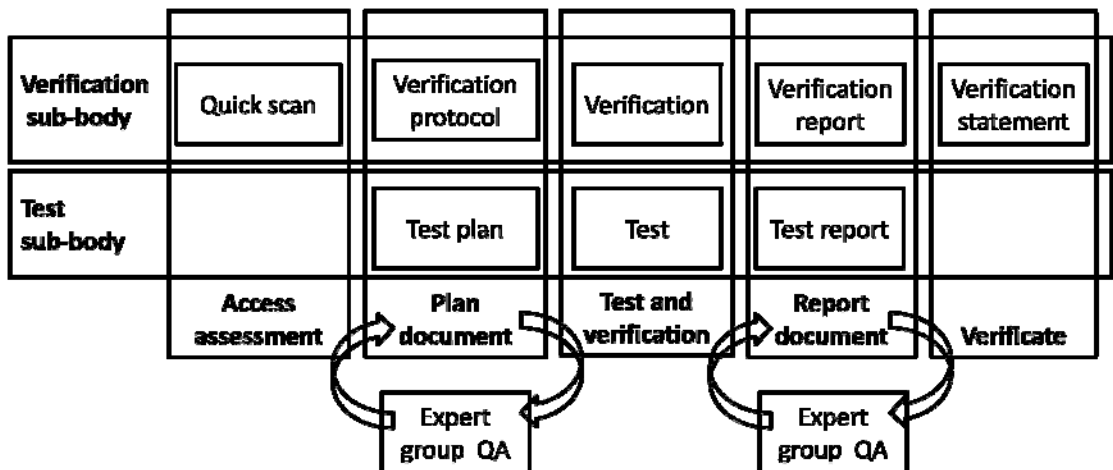
The expert group assigned to this test and responsible for review of test plan and test report includes:

Arne Oxbøl (AOX)
 FORCE Technology
 Phone: +45 4326 7130
 E-mail: aox@force.dk

2.6. *Verification process*

Verification and tests will be conducted in two separate steps, as required by the EU ETV. The steps in the verification are shown in Figure 2.

Figure 2 Verification steps



References for the verification process are the Quality Management Plan for DANETV /1/.

A verification statement will be issued after completion of the verification.

3. DESCRIPTION OF THE TECHNOLOGY

The Dall Energy furnace is a newly invented combustion design, which in one special designed unit combines the well known updraft gasification technology with a gas combustion section above the gasifier. The unit has no hot moving part inside the furnace.

The technology can only work as an integrated part of a biomass combustion plant, consisting of a fuel feeding system, a system to utilize heat and a chimney. To achieve the highest energy efficiency the heat utilizing system includes a wet condensation system. Several other units, e.g. blowers, instrumentation and a



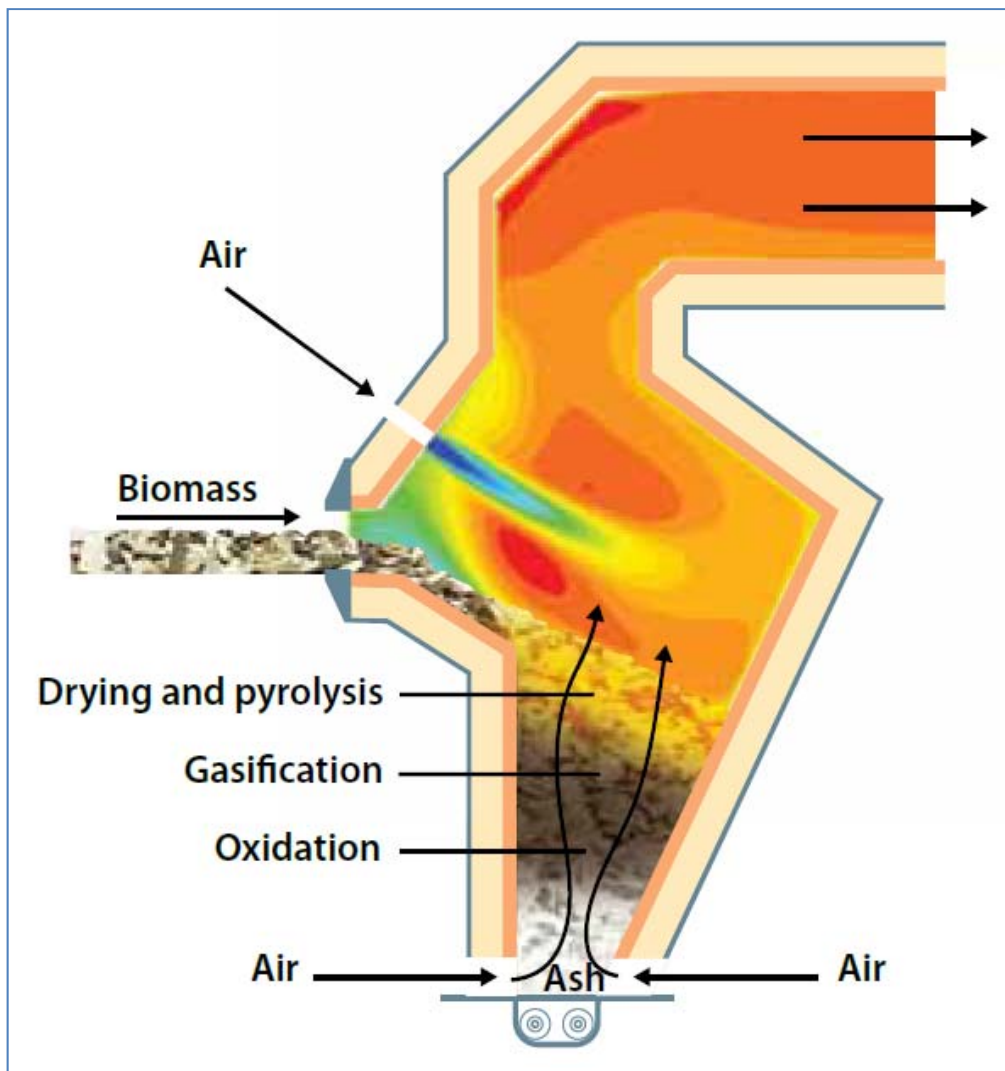
process control system are necessary to operate the plant. Only the furnace is included in the ETV verification test, as all the surrounding equipment can be selected among different technologies and suppliers.

The furnace can be delivered in sizes ranging from 1 MW to 20 MW. The furnace to be verified is 8 MW.

4. DESCRIPTION OF THE PRODUCT

The product is a multipurpose biomass furnace, without any hot moving parts which combines the well known updraft gasification process with a gas combustion section above the gasifier. The following Figure 3 shows the Dall Energy furnace principle diagram.

Figure 3 Dall Energy furnace - Principle diagram





In the bottom part, the solid fuel is converted into a burnable gas and fine ash. In the top layer, the fuel is dried and pyrolysed.

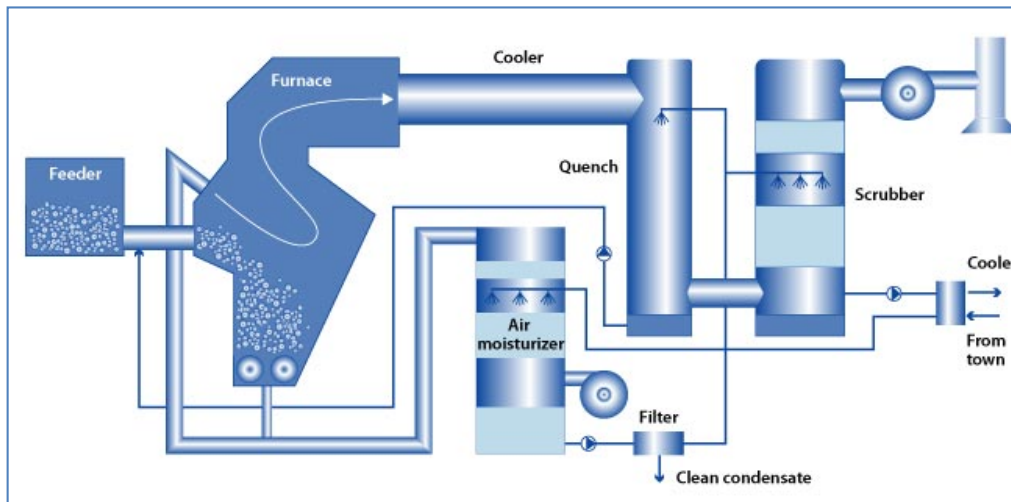
The heat for the drying and pyrolysis process is a combination of convective heat from the gasification gases below and radiation heat from the gas combustion part above.

The gas velocity in the bottom part is very low. Consequently, ash particles remain here and the dust emission of the furnace is very low. Due to the very efficient gas combustion the CO emission is very low. Moreover the emission of the fuel NO_x is relatively low due to the gasification process.

Gas from the bottom part is combusted in the upper section. The gas combustion can operate at low oxygen concentration and maintain very stable flow, temperatures, emissions etc.

In combination with a flue gas condensation system and a fuel or combustion air moisturizing system, a very high thermal efficiency is achieved, and biomasses with up from 0 % to 60 % moisture can be used for fuel. The following Figure 4 gives an overview of the Dall Energy Biomass Combustion Plant.

Figure 4 Dall Energy Biomass Combustion Plant





5. APPLICATION AND PERFORMANCE PARAMETER DEFINITIONS

The intended application of the Dall Energy Biomass Furnace is defined in terms of the matrix, the target and the effect of the biomass furnace.

The application is defined in the application definition appendix, Appendix 3, in terms of matrix for use, targets and effects.

5.1. ***Matrix***

The matrix of the application is combustion of biomass. The biomass type is wood chips.

5.2. ***Target***

The target is the composition of the flue gas where it leaves the furnace.

5.3. ***Effects***

The effect is:

- low concentrations of particles, condensable, CO, NO_x
- stable concentrations by operation in the whole possible operation area from 20% to 100 %
- stable concentrations of particles, condensable, CO, NO_x during load changes

5.4. ***Performance parameters for verification***

The performance parameters for the verification are the concentration of particles, condensable, CO and NO_x, and the stability of the concentrations when changing load, and when operating at the lowest possible load.

5.5. ***Additional parameters***

Several parameters will be measured or values achieved at the plant, to calculate the performance parameters into standard and reference conditions, and to verify and document the operating conditions during the verification:

- flue gas temperature and humidity
- samples of the biomass feed will be collected, and one or two samples will be analysed for: Humidity, ash-content, heat value and nitrogen content.
- biomass feed to calculate the total heat value in the biomass feed.
- produced energy



6. EXISTING DATA

6.1. *Summary of existing data*

Some measurement results from operating a 2 MW test furnace are available in an EUDP report (Appendix 2, Ref. /3/), and the main results are shown in Table 1.

Table 1 Existing data

Parameter	Load	Measured value	Unit
Particles	100 %	20 - 30	mg/Nm ³ and 10% O ₂
NO _x	100 %	175	mg/Nm ³ and 10% O ₂
CO	20-40-100 %	15	mg/Nm ³ and 10% O ₂

The results indicate that the claims of being a low emission furnace, with stable operation in a wide operational range are reliable.

6.2. *Quality of existing data*

The existing data has not been measured accredited according to the requirements of ISO 9001. There is no information on the instruments and methods used for the measurements, and no detailed data is available.

6.3. *Accepted existing data*

The existing data can only be seen as indicative values, which however clearly indicate the good performance of the furnace, and the low emission of CO, NO_x and particles.

7. TEST PLAN REQUIREMENTS

7.1. *Test design*

Emission and operation parameters shall be measured continuously and/or manually during stable operation for the furnace at different loads.

The concentration of particles and condensable shall be measured manually, by isokinetic sampling of flue gas, and subsequent analysis. The flue gas is app. 1000 °C, and special equipment and adjusted sampling procedure must be applied. The sampling will consequently not directly follow any existing standard, and cannot be reported accredited, but all standard procedures for accredited sampling will be followed.

Continuously measurement shall be performed for the parameters CO, O₂, NO_x and flue gas temperature. The measurement point shall be after the boiler, where the flue gas temperature is more suitable for the measurement. The measured



parameters will not be affected by the reduced flue gas temperature from the furnace and to the outlet of the boiler. The flue gas temperature shall also be measured at the outlet of the furnace.

The test shall be carried out during 3 – 4 days, with different loads and while changing the loads, according to this program:

1. stable operation at 100 % load (maybe also at 120 %?)
2. changing load from 100 % to 20 % and if possible further down to 10 %.
3. stable operation 20 % load (or 10 % load if possible)
4. changing load again up to 100 % (maybe also up to 120 %)

Continuously measurement shall be made during the whole test period, while the manual measurements of particles and condensable only shall be made in the two periods with stable operation.

7.2. Reference analysis

The test measurement will be performed according to FORCE Technology's DANAK accreditation no. 51, except for the manual sampling of condensable, which will be performed by a modified method, taken from one or more standards.

7.3. Data management

Data storage, transfer and control will be done in accordance with the requirements described in the DANETV FORCE Technology verification centre quality manual. Similarly, filing and archiving requirements are described in the DANETV FORCE Technology verification centre quality manual (Appendix 2, Ref. /1/).

7.4. Quality assurance

The quality assurance of the tests must include control of the reference system, control of the test system and control of the data quality and integrity.

The test plan and the test report will be subject to review by the expert group as part of the review of this verification protocol and the verification report, see Figure 2.

7.5. Test report

The test report will follow the template of DANETV FORCE Technology verification centre quality manual with data and records from the tests presented (Appendix 2, Ref. /1/).

8. EVALUATION

The evaluation includes calculation of the performance parameters, see Section 5.4 for definition, evaluation of the data quality based upon the test quality assurance,



see Section 7.4 for requirements, and compilation of the additional parameters as specified in Section 5.5.

8.1. Calculation of performance parameters

Calculations are done according to generally accepted mathematical and statistical principles such as those described in the standards behind the DANAK accreditation number 51 (Appendix 2, Ref. /2/) and as described in Section 7.3.

8.2. Evaluation of test data quality

The information of the test plan and the test system together with data quality and integrity control will be evaluated against the requirements set in this protocol and the objectives set in the test plan.

8.3. User manual

The user manual for the furnace to be verified, is an integrated part of the manual covering the whole Biomass Combustion Plant, as all parts are integrated in the same process control and monitoring system. As the boiler is still under construction, the manual is not yet available.

Consequently it is at present not possible to evaluate the user manual in this verification protocol. Instead the manual will be evaluated in the test report.

8.4. Occupational health and environment

The use of the product does not imply special health, safety and waste issues different from the operation of other furnaces.

The work during testing will be done according to the FORCE Safety Rules that are compliant with the extensive Danish rules for safe occupational health and the European regulations of work with chemicals.



9. VERIFICATION SCHEDULE

The verification is planned for mid April 2011. The overall schedule is given in Table 2.

Table 2 Verification schedule

Task	Timing [week]	QA	Expert
Verification protocol	10	10	-
Test plan	11	11	14
Test	15	19	-
Test Report	20	21	22
Verification report	24	25	-
Verification statement	26	27	-

The time schedule is based on an uncomplicated start up of the furnace, which is planned to be in week 11. The schedule will be postponed if the start up is delayed, or stable operation is not achieved in time before the scheduled test.

10. QUALITY ASSURANCE

The quality assurance of the verification is described in Table 3 and Figure 2, and the quality assurance of the tests in the test plan.

Table 3 QA plan for the verification

Task	Initials	Internal audit	Expert Group
		MKO	AOX
Plan document with the application definition, verification protocol and test plan		QS	Review
Report document with the test report and verification report		QS	Review

Appendix 1

Terms and definitions



Word	DANETV
Condensable	Condensable particulate matter (CPM). Condensable PM is organic and inorganic compounds in vapour phase at stack conditions, which forms liquid or solid particles, when cooled down to below 30 °C.
Effect	The way the target is affected
ETV	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 adequate quality assurance.
Evaluation	Evaluation of test data for a technology product for performance and data quality
Matrix	The type of material that the product is intended for
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis
Performance claim	The effects foreseen by the vendor on the target(s) in the matrix of intended use
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance
QA	Quality assurance
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Target	The property that is affected by the product
Test/testing	Determination of the performance of a product for parameters defined for the application
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance

Appendix 2

References



/1/	DANETV Centre Quality Manual, FORCE Technology. February 2009
/2/	DANAK accreditation number 51
/3/	EUDP. Multi brændselsovn, Proces verifikation. Slutrapport. Januar 2010
/4/	ISO 17125.
/5/	ISO 9001. Quality management systems - Requirements

Appendix 3

Application and Performance parameter definitions



This appendix defines the application and the relevant performance parameters application as input for verification and test of Dall Energy Biomass Furnace following the DANETV method.

1. *Application*

The intended application of the Dall Energy Biomass Furnace is defined in terms of the matrix, the target and the effect of the biomass furnace.

1.1. **Matrix**

The matrix is the type of material that the product is intended for.

In the case of Dall Energy Biomass Furnace the matrix of the application is combustion of biomass.

The biomass furnace to be verified is suitable for many types of biomass.

In this verification the biomass type is wood chips.

1.2. **Target**

Targets are the measurable properties that are affected by the product for verification.

In the case of Dall Energy Biomass Furnace the target is the composition of the flue gas where it leaves the furnace.

1.3. **Effects**

The effects describe how the targets are affected by the product.

In the case of Dall Energy Biomass Furnace the effect is:

- low concentrations of particles, condensable, CO, NO_x.
- stable concentrations by operation in the whole possible operation area from 20% to 100 %.
- stable concentrations of particles, condensable, CO, NO_x during load changes