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Verification Report

Reduction of ammonia and odour emission from mink houses using the SmartScrape system from Columbus Aqua

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Prepared for proposer Columbus Aqua
Status Final version

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1. Introduction

The test is designed to test how efficiently a new method of frequent removal of manure using the SmartScrape system can reduce odour and ammonia emissions from mink production. The test was performed based on the test requirement of the VERA test protocol for Livestock Housing and Management systems. The primary purpose of this test was to verify the effect on ammonia and odour reduction using the SmartScrape system from Columbus Aqua designed for frequent removal of manure under cages in mink production. This verification report will deliver the required documentation to apply for a verification statement granted by ETA-Danmark.

1.1 Abstract

The verification has been successfully preformed and has found a significant reduction. The overall efficiency is calculated as the average efficiency between the two locations and is found to be 37.3 %. The mean emission for the reference was found to be 142.9 and 168.3 kg NH_3 year^{-1} LU^{-1} and 100.7 and 94.4 kg NH_3 year^{-1} LU^{-1} using SmartScrape at the farm locations in Barrit and Søndersø, respectively. A non-significant odour reduction of 37.5 % was found. The SmartScrape system have shown stable operation without breakdowns during the test period. Energy consumption was calculated to be 33 % lower than under normal operation.

1.2 Name of technology and unique identifier of the technology

The name of the verified technology is SmartScrape. This verification is designed to test how efficiently a new method of frequent removal of manure using the SmartScrape system which can reduce odour and ammonia emissions from mink production. The test was performed based on the test requirement of the VERA test protocol for Livestock Housing and Management systems. The primary purpose of this test was to verify the effect on ammonia and odour reduction using the SmartScrape system from Columbus Aqua designed for frequent removal of manure under cages in mink production. The final verification report will deliver the required documentation for application for a general admittance of this type of slurry gutters systems to the “Danish Technology List” published by the Danish Ministry of Environment and Food

1.3 Verification protocol reference

The test preformed was based on the requirements defined in the VERA Test Protocol for Livestock Housing and Management Systems, version 3 2018-29-09 (VERA, 2018). The VERA protocol is however not designed to cover mink production and due to the low number of animals housed during the period between December and May the test period was reduced and more samples were allocated to August-October where mink offspring are producing the most manure and the highest emissions are expected.

1.4 Name and contact of proposer
The company producing the technology is:
COLUMBUS AQUA A/S
Tårnvej 73, 7200 Grindsted, Denmark

Contact person:

Lars Fisker Rasmussen

Phone: +45 75310311

Dir.phone: +45 61465375

www.ColumbusAqua.dk

Mail: Lars@columbusaqua.dk

1.5 Name of Verification Body and responsible of verification
This verification is undertaken 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. Email: pf@etadanmark.dk.

The appointed verification expert assisting the verification body (ETA-Danmark) with technical expertise is Arne Grønkjær Hansen, DANETV. Email: arnh@teknologisk.dk. Phone: +45 72 20 33 19.

1.6 Organisation of verification including experts and verification process
In addition to the verification responsible and the verification expert mentioned above an internal and an external technical expert provide independent reviews of the planning, conducting and reporting of the verification. The external technical expert assigned to this verification and responsible for review of the verification protocol and verification report is:

External expert appointed by ETA Danmark: Expert member of "MELT-udvalget".

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

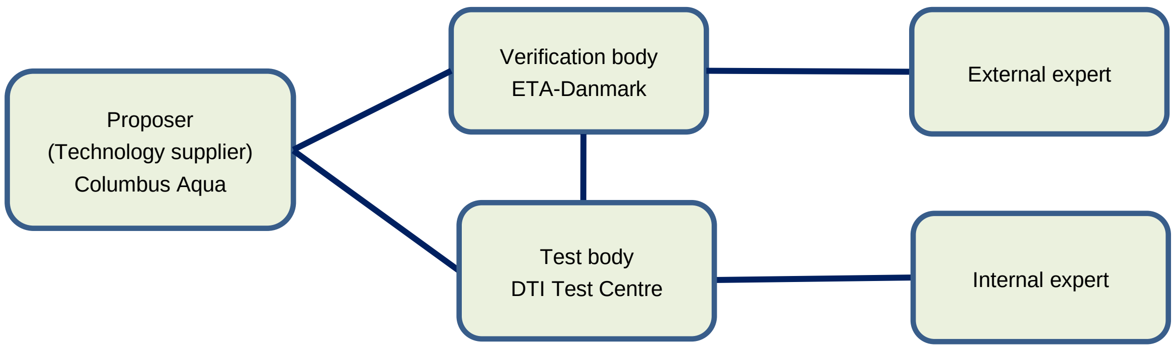

Figure 1. Organisation of the test and verification of SmartScrape from Columbus Aqua.

The test and the verification were conducted in two separate steps, as required by the EU ETV pilot programme (European Commission, 2018). Test activities were undertaken by Danish Technological Institute's Test Centre (test body) whereas the verification activities were undertaken by ETA-Danmark (verification body).

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, 2018) and ETA-Danmark´s internal procedure description. Requirements regarding quality assurance of the test body are described in section 5.4.

The Statement of Verification will be issued by ETA-Danmark (verification body) after completion of the verification process.

1.7 Name and contact address of the test body

The test is performed by Danish Technological Institute, AgroTech, Agro Food Park 15, DK-8200 Aarhus N, Denmark.

1.8 Test responsible

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1.9 Technical experts

The technical experts assigned to this test and responsible for review of test plan and test report includes:
Arne Grønkjær Hansen, Phone: +45 72203319, E-mail: arnh@teknologisk.dk
Agro Food Park 15, Skejby, DK-8200 Aarhus N, Denmark.

1.10 Technician responsible

Sune Petersen, Teknologisk Institut, Agro Food Park 15, Skejby, DK-8200 Aarhus N. Phone: +45 72203315. E-mail: spet@teknologisk.dk

Technician, assistant: Louise Hjorth Nørremark, Teknologisk Institut, Agro Food Park 15, Skejby, DK-8200 Aarhus N, Phone: +4572201280, E-mail: lon@teknologisk.dk

1.11 Deviations from the verification protocol

This section addressing deviations from the test plan. This section will compile all changes of the test plan occurring during testing with justification of deviations and evaluation of any consequences for the test data quality.
There have been 6 incidents where the farmer has manual overridden the system and activated the scraping in a reference period. In the appendix A, Operation log, a full list of all actions is described. Data was removed from 9-11 June due to unauthorized scraping in a reference period. Data was removed from 26-27 June due to unauthorized scraping in a reference period. Data was removed from 7-8 July due to unauthorized scraping in a reference period. Data was removed from 2-4 September due to unauthorized scraping in a reference period. These four incidents were evaluated to have small effect of the final result because we still have at least 4 days with close to reference conditions. It will however have negative effect on the measured effect of the technology because 1/3 of the reference conditions is closer to 2 scrapings per week than 1. In one measuring campaign the data quality was very poor, and we had to remove data from 22-22 June and 29 June to the 2. of July due to system failure. This resulted in a quite short measuring period 2 at Barrit and led to a non-significant effect. Measuring period 6 is generally a bit squeezed because we needed to finish before the mink was taken out of the building. This is evaluated not to have a significant effect on the results. Five odour analyses were removed from the dataset as outliers because the values were > Q3+3*IQR.

2. Background and Aim

Mink production facilities cause odour and ammonia emissions which are mainly deriving from manure handling. Columbus Aqua A/S wanted to test whether a new method of frequent removal of manure can reduce the emissions of ammonia and odour from mink in open housing systems.

Slurry gutters scraping once per week is characterised as normal procedure and has an emission of 1,75 kg NH3-N per mink bitch per year with 28 cm gutters, 31 % protein in feed and 2 % N-loss from storage, (normtal 2018). According to the Danish ministry of environment, 2 times gutters scraping every week can reduce ammonia emission by 27 %. The standard emission factor is according to Danish law/guideline reduced by 1.5% for every cm of gutter width greater than 28 cm (MST 2017). Pre-studies of the SmartScrape technology suggest that we can reduce the emissions even further by enhancing the scraping frequency to several times per day in the peak season.

Principle used: The principle of the technology is to reduce the wet surface area in the slurry gutter which theoretical is directly proportional with the ammonia emission. The amount of slurry in the mink house is also drastically reduced which theoretically will reduce greenhouse gasses and odour.
The aim is to quantify the reduction of both odour and ammonia emission by removing the manure frequently, up to 6 times per day, in the slurry gutters. Prior to the test the expected reduction was more than 50 % for both odour and ammonia emissions. The test was performed as a case/control test on two commercial farms using the on/off approach one each farm.

A large part of the odour is coming from the slurry drains especially when the slurry is backflushed, typically after scraping when the drains are filled. Columbus Aqua have developed a valve for the slurry drain that automatically closes when the drain it is not in use.
The test was performed on housing systems that best possibly represent typical mink management practice. This includes for the reference house:

- Weekly manure removal from slurry gutters
- Monthly straw and manure removal below mink cages (except May and June)
- Feeding of mink according to normal feeding practice
- Management of mink according to normal management practice.

3. Description of the technology and application

3.1 Summary description of the technology

The SmartScrape system is a new scraping system for slurry gutters in mink houses. The system automatically adapts scraping frequency to slurry load. On an average the slurry gutters are emptied every 8th hour to minimize the wet slurry surface which reduces ammonia, odour and greenhouse gas emissions. Fast removal of slurry from the mink house results in greater nutrient value of the slurry and higher biogas potential. The slurry gutters are made from a special plastic where the slurry does not stick. The system has a level meter alarm that efficiently turns off scraping if the slurry drainage tubes are full. The system adapts the scraping frequency to feeding load which is direct correlated to the slurry load. In the summer period where the slurry load and temperature are high the scraping frequency is six times per day, and in the winter season where only the bitches are left in the mink houses scraping is reduced to one scraping per day, se the above graph. Scrapings are evenly distributed over one day.

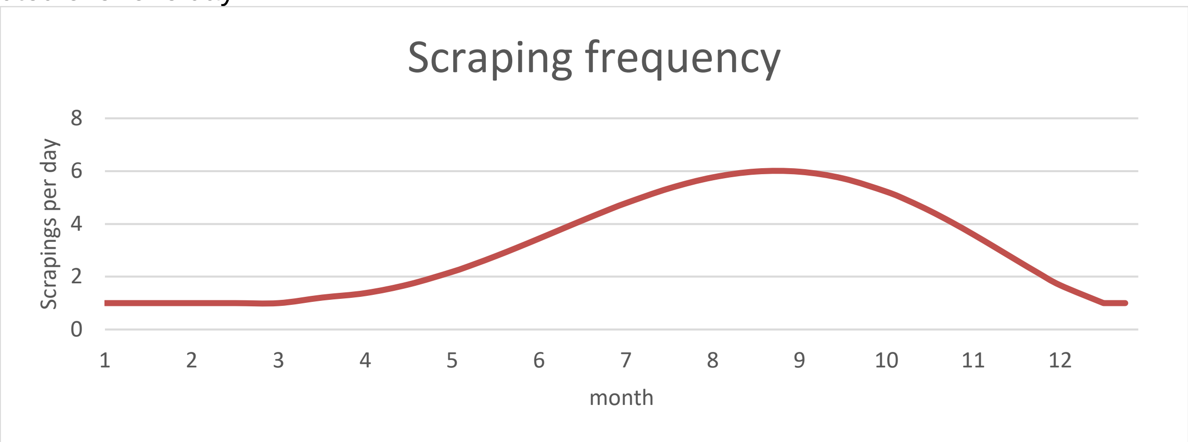


*Figure 2 shows scraping frequency as a function of the time of the year. The algorithm can be explained as: y =if 12<x>3;(0,0143x⁵ - 0,4712x⁴ + 5,2004x³ - 22,138x² + 36,326x)/78*6;1*

*x = month + ((1 / 10) * months)   1 month = approximately 30.42 days   y= Scrapings per day*

The main purpose of the technology is to reduce ammonia, odour and greenhouse gas emissions.

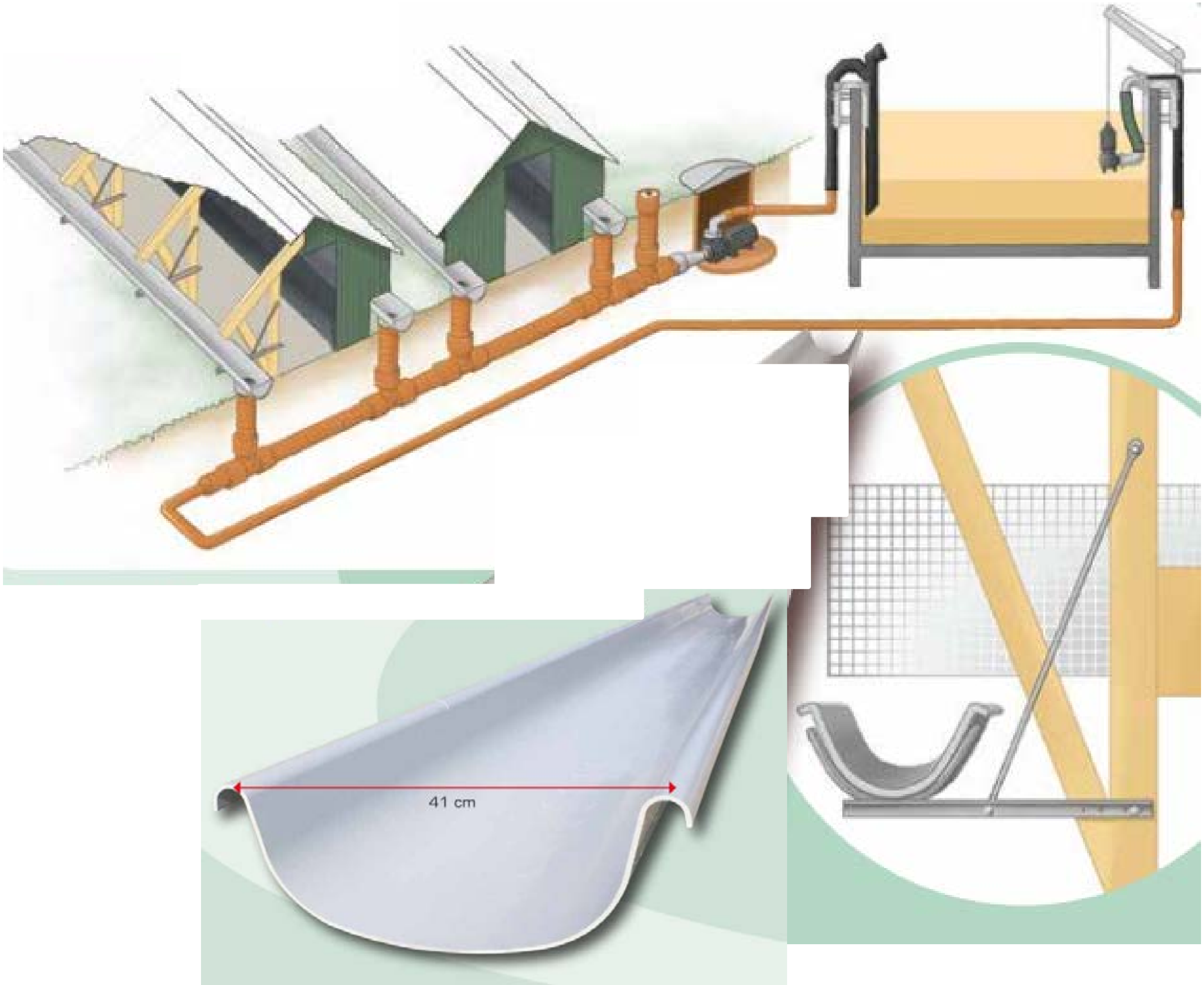


Figure 3 Illustration of slurry gutters from Columbus Aqua and the position under the cages. The gutters are made from PVC with a width of 410 mm.

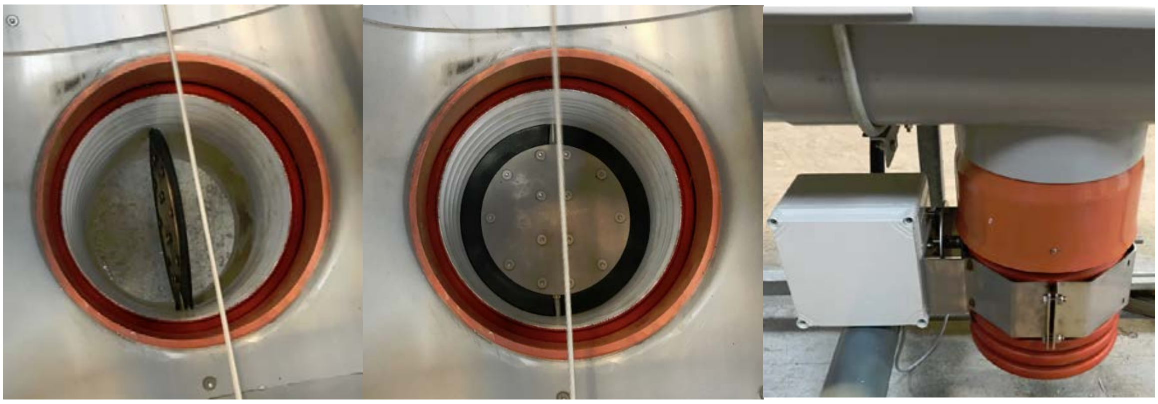


Figure 1 Valve in drain for automatic open and closure of slurry drain. The valve opens automatically 2 meters before the scraper flap meets the slurry drain, and is otherwise closed all the time.

When the technology is off, the slurry drain valves are open all the time.

3.2 Test sites

The test was conducted at two commercial mink farms. Both farms produce standard types of mink in a typical housing system for mink production. On each test site, one house was selected as test unit. The technology was tested after the on/off case control principle, where the technology is tested in the same house while switching on and off periodically. Most of the samplings did take place during summer and early autumn when temperatures were high, and the number and mass of mink were highest.

3.2.1 Characterization of the test sites

The specification of the test units can be seen in Table 1. The actual number and size of mink is reported for each measuring period together with the evaluation of the results.

*Figur 2*a. and 4b. Overview of test site 1 and 2. Test sections for both reference and technology are marked with a blue square.

The mink production can be described as traditional at both test farms. Mink offspring are born in the beginning of May and taken out of production (pelted) in November - December. In the period from December until May only adult females and males are required for mating and production the following year are housed.
The housing systems are naturally ventilated, and no external heating is introduced.
The test unit is marked with a blue square in figure 4a-b. The selection of test unit is done according to specific test requirement regarding identical ventilation and housing system, stocking rate (Approximately same number of housed animals per m^2) etc.

3.2.2 Characteristics of the test units

The characteristics of the test units can be seen in Table 1.

Table 1 Key characteristics of test farms and test units.

	TEST FARM AND TEST SITE CHARACTERISTICS			
Parameter	**Farm 1 On**	**Farm1 1 off**	**Farm 2 On**	**Farm 2 off**
Farm owner	TORBEN JENSEN	TORBEN JENSEN	RASMUS BUE	RASMUS BUE
Address	SKULSBALLEVEJ 6 7150 BARRIT	SKULSBALLEVEJ 6 7150 BARRIT	GULLØKKEN 36 5471 SØNDERSØ	GULLØKKEN 36 5471 SØNDERSØ
Contact Info	TLF: 21467686	TLF: 21467686	TLF: 23425347	TLF: 23425347
CHR No.	20135	20135	114544	114544
Number of adult females per farm	2800	2800	5000	5000
Number of mink per test unit	690	690	445	445
Weight range (g) adult males	3700-4500	3700-4500	3700-4500	3700-4500
Weight range (g) adult females	1250-2000	1250-2000	1250-2000	1250-2000
Weight range (g) male offspring	10-4500	10-4500	10-4500	10-4500
Weight range (g) female offspring	10 – 2000	10 – 2000	10 – 2000	10 – 2000
Bedding material	Straw	Straw	Straw	Straw
Dimensions of test unit, (w, l)	10m x 182m	10mx 182m	14m x 73m	14m x 73m
Dimensions of cages (w, l, h)	0.3 m, 0.9 m, 0.45 m	0.3 m, 0.9 m, 0.45 m	0.3 m, 0.9 m, 0.45 m	0.3 m, 0.9 m, 0.45 m
Dimension slurry gutters, w	41 cm	41 cm	41 cm	41 cm
Floor system	Solid floor	Solid floor	Solid floor	Solid floor
Manure system	SmartScrape	Scrapping 1/week	SmartScrape	Scrapping 1/week
Manure removal system	Aut. Scraping system for-slurry gutters	Mechanical scrapping system	Aut. Scraping system for-slurry gutters	Mechanical scrapping system
Feed composition	Mix of poultry, fish and slaughter residues, balanced with soybean, wheat vitamins and essential amino acids	Mix of poultry, fish and slaughter residues, balanced with soybean, wheat vitamins and essential amino acids	Mix of poultry, fish and slaughter residues, balanced with soybean, wheat vitamins and essential amino acids	Mix of poultry, fish and slaughter residues, balanced with soybean, wheat vitamins and essential amino acids
Feeding system	Daily manual food delivering system	Daily manual food delivering system	Daily manual food delivering system	Daily manual food delivering system
Feed analysis	http://www.danskpelsdyrfoder.dk/Default.aspx?ID=276	http://www.danskpelsdyrfoder.dk/Default.aspx?ID=276	http://www.danskpelsdyrfoder.dk/Default.aspx?ID=276	http://www.danskpelsdyrfoder.dk/Default.aspx?ID=276
Ventilation	Natural ventilation, plates with holes in side of building.	Natural ventilation, plates with holes in side of building.	Natural ventilation, plates with holes in side of building.	Natural ventilation, plates with holes in side of building.
Heating system	No	No	No	No

3.3 Intended application (matrix, purpose, technologies, technical conditions)

The intended application of SmartScrape is described in terms of the matrix and the purpose.

The matrix refers to the type of material the technology is intended for. SmartScrape is developed for treatment of mink slurry. Optimal performance of SmartScrape is achieved when the slurry level in the gutters is less than 1 cm. because this minimizes the area with uncovered liquid manure and thereby the ammonia emission.

The purpose is a measurable property that is affected by the technology. The purpose of the SmartScrape technology is to minimize the emission of ammonia in a cost-efficient way.

3.4 Verification parameters definition

This section describes the parameters that were examined in the verification of SmartScrape.

3.4.1 Performance parameters

Odour and ammonia are the two-primary performance parameters. In addition, operational parameters were measured throughout the test period. A list of the parameters can be seen in Table 2.

Table 2 Performance parameters, analytic methods, detection limits and uncertainty.

Parameter	Analytical method	Limit of detection	Uncertainty
Odour	Olfactometric analyses, EN 13725/AC:2003	11 OUE/m3	+161% -62% Incl. sampling, analysis and delusion
NH3	PICARRO G2508 Gas Analyzer Reference: Impingers	0.14 mg/m3	<1 ppb +0.05% of reading

3.4.2 Operational parameters

The verification involved measurements of the following operational parameters:

Table 3 Operational parameters, analytic methods, detection limits and uncertainty.

Parameter	Analytical method	Limit of detection	Uncertainty
Air Temperature	Testo 174H	0.1 °C	±0.5 °C (-20 to +70 °C)
Relative air humidity	Testo 174H	0.1 %	±3 %RH (2 to 98 %RH)
CO2	PICARRO G2508 Gas Analyzer Reference: GC-TCD	2.5 mg/m3	<200 ppb +0.05% of reading
Electricity consumption of tested technology	Calculated from electrical effect and on-time		
Number and weight of mink	Manually logged every period		

The user manual and implications on occupational health were not evaluated in this verification.

3.4.3 Environmental parameters

Table 4 Environmental parameters, analytic methods, detection limits and uncertainty.

Parameter	Analytical method	Limit of detection	Uncertainty
Wind • direction [°] • speed [m/s]	Davis vangate pro2	0.1 m/s 1°	±5 % ±3 %

3.5 Test design and sampling methods

The overall principle for testing the performance of frequent removal of manure, using a scraping system for slurry gutters, is to quantify the odour and ammonia emission leaving the test-unit (mink housing with scraping system for slurry gutters installed), and compare it with the quantification of odour and ammonia emission from the reference-period (mink housing with weekly manure removal from slurry gutters).
The mink house was operated as a normal mink production, in reference mode (technology off), meaning weekly manure removal from slurry gutters. Ammonia and odour were measured 6 periods during the production circle from May to November. Each period consisted of min. 3 days of measurements in reference mode followed by a cleaning of the gutters, a 2 days' stabilization period using SmartScrape system, where slurry drain valves will be turned one, (technology on). The stabilization period was followed by min 3 days' measurements where the house was operated with the SmartScrape system activated.

3.6 Detection limit and uncertainty

The detection limit for the Picarro G2508 gas concentration analyzer is for ammonia, is very low (<1ppb) + 0.05 % of reading. In reality NH3 are limited by the adsorption of these species to the surfaces of the experimental apparatus. On the countryside in Denmark NH3 concentrations are rarely under 20 ppb. The Picarro's precision for CO2 after 5 min measurements is less than 200 ppb + 0.05 % of reading, (Picarro G2508 2014). Cavity ring-down spectroscopy is generally found to have no interferences of the VOCs and is therefore well suited for measurements of NH3 emissions from livestock productions (Kamp et al. 2019). In this study they have used a Picarro G2103 which have de same absorption band for ammonia as G2508.
One key issue is to estimate the ventilation rate and then to quantify the gaseous emissions. The quantification of ammonia emission from livestock houses with natural naturally ventilated buildings is a big challenge and it is associated with some uncertainties. In naturally ventilated livestock buildings, it is practical impossible to measure the ventilation rate directly. In this test, CO2 balance is used to calculate the ventilation rate, which is the most commonly used method for continuous measurements in naturally ventilated livestock buildings (S. Pedersen & K. Sällvik, 2002).
The CO2-balance has several error sources such as the calculation of metabolic energy(E), the CO2 produced per energy unit (P), the amount of CO2 produced by manure(M), the location of the CO2 sampling points(L) and measurement system uncertainty (S), (Samer et al., 2011). It has been estimated that the method has an uncertainty between 2 and 50 %, (Ngwabie, 2011).

3.7 Determination of flow rate

The air flow rate is a measure of the air volume added to or removed from a farm building in a given time.

Based on the measured difference of in-house and background concentrations of a tracer gas (CO_2) the air exchange was determined for each set of samples.

The emission of odour (E_g) was calculated on basis of the odour concentration (C_g) and the calculated air exchange (Ventilation (V)). As the air exchange cannot be measured directly in naturally ventilated housing systems, the air flow rate must be measured indirectly by a tracer gas method (Demmers et al., 2001). In this test, the air exchange will be measured by the tracer gas CO_2 produced by the mink housed in the test sections. The weight specific emission of CO_2 (E_S) from the housed mink was calculated on basis of CO_2 emission measurements conducted by the University of Copenhagen (Data provided by Elnif J, 2012, pers com) (Hansen MN. 2016, Figure 3 p14). The weight specific CO_2 production was found to be:

$$E_{CO_{2p}} = \sum_{j=1}^{4} N_{jp} * (33.7 \times {W_{jp}}^{0.34})$$

Where

E_{CO_2} = total production in CO_2 in l day^{-1}

W = Average weight of type j mink in kg

N = Number of mink

j = type of mink (adult male, adult female, female offspring, male offspring)

p = measuring period.

An example from a mink production with 14456 mink with an average weight on 1,22 kg. using Elnif's formula:

$E_{CO_2} = \sum_{j=1}^{4} 14456\, Mink * (33.7 \times 1{,}22\, kg^{0.34})$ = 523.1 L/d

E_{sp} = 523.1 L/d /24h = 21.8 m^3/h

The air exchange (qv) of each house can be calculated by this formula:

$$qv = \frac{E_{sp}}{(C_{in} - C_{out})_t}$$

Where qv is the air flow rate in $m^3\ h^{-1}$

E_{sp} is the tracer gas production/emission in l h^{-1} in period p, E_{sp} = E_{CO_2}/24
C_{in} og C_{out} are the measured concentrations of tracer gas in ppm inside the house and outside/background air.
An example from a mink production where the CO_2 concentration outside on average for 24 hours is 505 ppm and the CO_2 concentration inside is 608 ppm:

$$qv = \frac{10^6 \cdot 523.1\ m3/24}{(608-505ppm)} = 211,6\ m^3/h$$

qv applies to the whole 24 h period where, large diurnal variations can occur.
Elnif´s algorithm is based on respiration chamber measurements and does not include a CO_2 contribution from manure. It is assessed that CO_2 production from the manure can be neglected due to relatively small amounts of manure in the building in comparison with other livestock productions.
According to (GIGR, 2002) where Dr. Jan Elnif, The Royal Veterinary and Agricultural University in Copenhagen has contributed, the CO_2-production from mink can be calculated as following:

Φ_{tot} = 8 $m^{0.75}$, W
1 HPU = 1000 W = 185 L CO_2 h^{-1} HPU^{-1}
Example from a mink production with 14456 mink with an average weight on 1,22 kg. using the Elnif´s algorithm:

Φ_{tot} = 8 x $1,22^{0.75}$= 9,286 W
9,286 W x 14456 mink = 134.248 KW
134.248 KW x 0.185 m^3/h CO_2 = 24,8 m^3/h CO_2

Elnif´s newest formula gives a 12 % lower CO2 production per kg mink than the formula from (GIGR, 2002). This is probably due to the animal's average growth in sizes over the years which have led to a more heat efficient body metabolism.

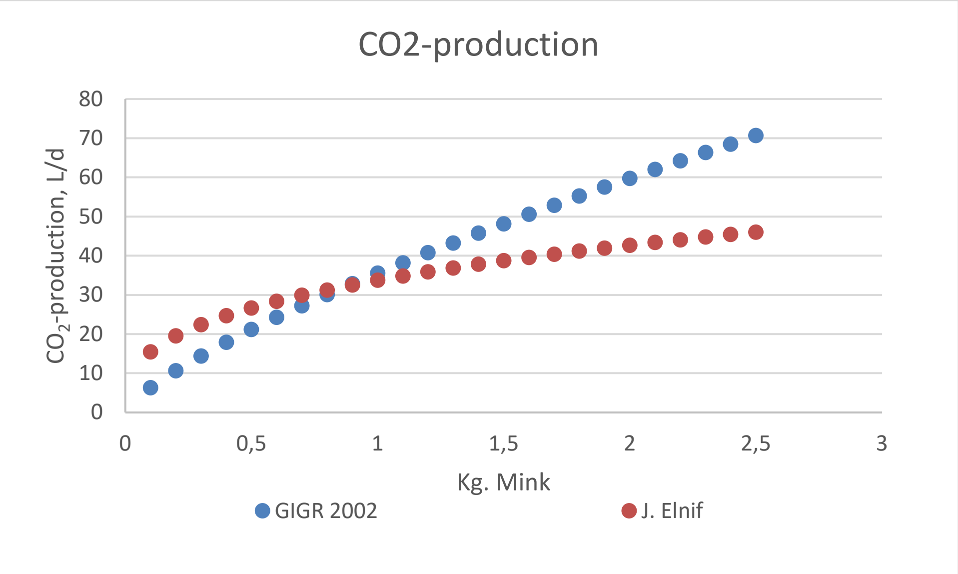


Figure 5 CO2-production per kg. mink per 24 h. calculated from CIGR 2002 formula and J.Elnif's.

3.8 Determination of odour emission

Due the very low number of animals in the production system between November and May and the fact that the animals are relatively small in the first two living months, odour sampling was sampled 6 times in the period from May to November. Odour sampling was therefore sampled when the number of animals, their weight and temperatures were highest.

The principle for determination of odour emission was sampling of air followed by olfactometric analysis according to the CEN standard. The air was sampled in 30 l nalophan bags. The bags were filled using a vacuum container with a pump. Sampling points was at the center of the house using the same sampling system described for the continuous sampling of air for ammonia and CO_2 analysis. The odour concentration of the sampled air was subsequently quantified by dilution and olfactometric analyses within 24 hours after sampling.

Once the odour sampling system was at the site, the vacuum containers were prepared and connected to diaphragm pumps that allow a controlled airflow from the vacuum containers. The vacuum was regulated so that the odour sampling time was 30 minutes per sample. Marked odour bags were inserted into the vacuum containers, and the inlet of the bag were connected to the measuring point by a Teflon tube.

Before test sampling, the odour bags were conditioned by filling the bags with in-house air and afterwards emptying the bags. After test sampling the odour samples must not be exposed to direct sunlight or bright daylight, as light or heating may enhance the chemical changes and diffusion can take place. Filled odor bags were stored and transported in black plastic bags or closed cardboard boxes. Climatic and environmental conditions that may influence the odour emission was recorded during the odour sampling event in prepared logbook.

Odour samples were sampled just before and during scraping in the reference period and similar in the test period in order to sample under worst case situations. 3 samples per sampling day were sampled between 10-12 am. The sampling was timed so that the 2 first samples were sampled with maximum level of manure in the pits and the last sample is sampled when scraping is activated.

The odour emission is calculated by the following:

$$E_{OU_E j} = N_j * \overline{OU_{Ej}} * (V_j)/3600$$

Where

E_{OU_E} = *Odour emission per animal per sec, Odour Units (OU_E) head^{-1} sec^{-1}*
$\overline{OU_E}$ = *Average measured odour concentration, OU_E m^{-3} air*
V_j = Air exchange in test section, *m^3 air h^{-1},* V_j = V(calculated from E_{CO2} /24t)
N = Total number of animals in test section
j = Actual measurement event.

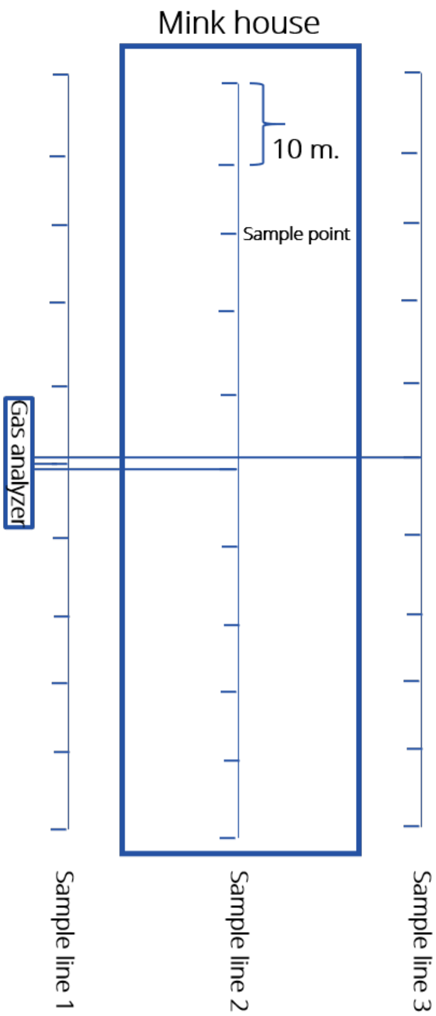
3.9 Determination of ammonia emission

Ammonia measurements were sampled six times distributed over a production cycle when offspring are present. Each time was with a minimum of 4 days of continuous measuring. The test schedule is presented in Table 4.
Sample tubes were placed at both sides of the barn and in the middle of the barn in the entire length of the building approximately 2 meters above the floor. Each line has a sampling point for every 10 meters equipped with critical orifices, and dust filters. Air flows through the critical orifices were tested with a bobble flowmeter to ensure even distribution of air.
The sample air was pumped to the PICARO analyzer via an external membrane pump for each line to ensure high pressure drop trough the critical orifice and rapid stabilization of the concentration. The pump used was a: Capec L2 SE AC 8 with a capacity of 8,0 l/min. Gas concentrations were measured with a special build PICARRO G2508 Gas Concentration Analyzer, with internal coating and higher flow for fast NH3 measurements, using the Cavity Ring-Down Spectroscopy (CRDS) principles, (Picarro G2508 2014).

The sample tubes were between 80-180 meters long, the outside diameter of the tubes are 8 mm and the inside diameter 6 mm.
The sample tubes were insulated and heated from the mink houses to the analyzing station to avoid condensation. In Figure 6 and 7 the location of sampling lines (tubes) on the two test sites, a cross compartment of the barn and the position of the sample lines are shown.
Background concentrations were determined by using the outdoor sampling line closest to the wind direction. The prevailing wind direction was determined by a local weather station. The background concentration is defined as the inlet concentration and is used for the emission calculation.

3.10 Sample location for air

Figure 6 and 7a are diagrams of the sampling position (from above and from the side). Sampling tubes were installed longitudinal in 3 parallel lines through the mink house. Each line had several inlets. The middle line was located at the center of the mink house in a height of approximately 2 meters. The lines outside the barn were located on both sides of the barn approximately 1 meter above the ground. For each 10-meter line a single sampling point was plahced. To allow a constant and homogenous



sampling flow rate, the sampling points were equipped with critical orifices and dust filters. The orifices consist of syringes needles (BD 0.8 mm x 4) in opposite directions, see figure 7b. The flow was tested in each sample point before each measuring campaign. The flow into each sample point was around 0.4 L/min. If the flow in one sample point differed more than -10 % from the mean in the sample line, the filter was changed. The outside sampling points were covered with rain protection. The sampling lines allows to connect the sampling points to a single pump and to be analyzed as a mixed sample, see figure 6 and 7. All the sample tubes were connected to the gas analyzer in the mobile analyze station.
The line that was nearest the luv side was chosen as inlet, while the line in the middle was outlet. I case of no wind or wind parallel to the barn, both lines in the sides was chosen as inlet. Definition of sample points can either be established from the wind direction and from the flux of ammonia.
Before every measuring campaign the flow rate of all sample points was checked.

Fig 6 Position of sampling lines (tubes) at test houses of the two farms.

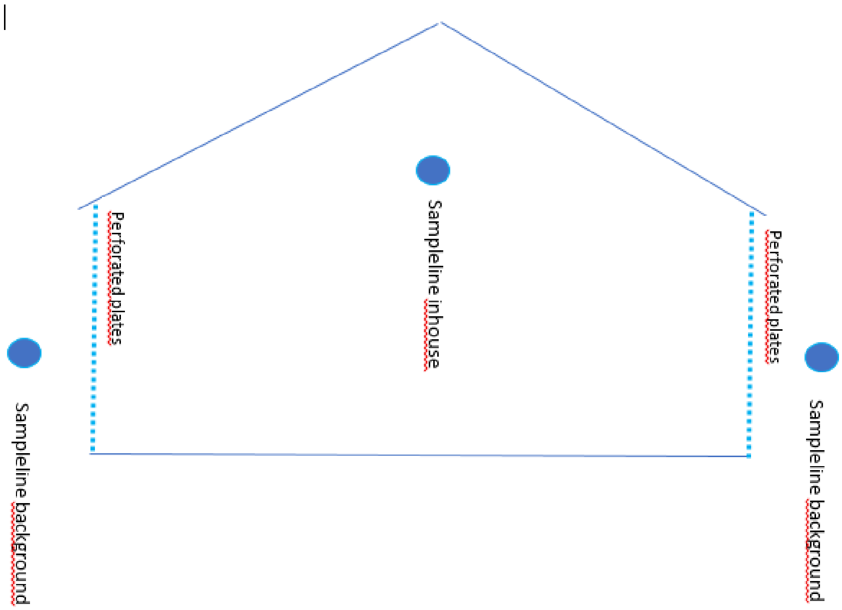


Figure fig 7a location of sampling points

Figure 7b critical orifice and filter

3.11 Energy consumption

The tested technology and the standard technology in the reference house shares the same scraping motor and flush pump, so to measure the energy consumption, the pump's ampere consumption was compared to the time the pump is operating in technology and reference housing, respectively.

3.12 Test periods

Table 5 Test schedule for 2018 and 2019. The specific measuring dates will depend on the start of the test period and practical and management preconditions.

Year	**2018**								**2019**												**2020**
Task/month							11	12	1	2	3	4	5	6	7	8	9	10	11	12	6
Test plan							X	X	X												
Acceptance of test plan										x											
Installation and pre-testing										x	x	x									
Start test period													x								
Odour sampling periods													X	X	X	x	X	X			
Ammonia measurements													X	X	X	x	X	X			
End of test period																		X			
Test report draft																			X		
Test report quality assurance																			X	X	
Test report final version																				X	X

Table 6 Test schedule 2019

Month	April				Mai			June					July				August					September					October				November					
Week	14	15	15	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Pretest																																				
Barrit off																																				
Barrit on																																				
Søndersø off																																				
Søndersø on																																				

The specific measuring days were completed according to the schedule under practical management preconditions like periods of fluctuating number of animals due to mating, birth, relocation and pelting of mink. Specific odour sampling dates were also conducted in accordance with the schedule (Table 7)

Table 7 Sampling dates for odour analyses.

Odour samples technology off						
Barrit	21-05-19	19-06-19	31-07 19	28-08 19	25-09 19	23-10 19
Søndersø	06-06-19	03-07-19	14-08 19	11-09 19	09-10 19	06-11 19

Odour samples technology on						
Barrit	3.6.19	2.7.19	13.8.19	10.9.19	8.10.19	5.11.19
Søndersø	19.6.19	16.7.19	27.8.19	24.9.19	22.10.19	19.11.19

3.13 Product maintenance

The farm owner was responsible for the housing and production system during the test. The farmer was reporting number, sex and age of adult mink and offspring for each test period, and eventual problems regarding the housing and manure management system in a logbook prepared by the test institute. Any technical problems regarding the scraping system for slurry gutters during the test period were reported to the test responsible and the producer of the scraping system for slurry gutters. The exact period for mal function/down-time for repair was reported.
The farmer has not reported any malfunctions regarding the manure management system during the test.

3.14 Health, safety and wastes

Not relevant.

3.15 Analytical laboratory

Odour samples was analysed by dynamic dilution olfactometric analyses by accredited odour analytic institute (Danish Technological Institute -DMRI. Address: Gregersensvej 9, DK-2630 Taastrup, Denmark. Phone: +45 72202000.

3.16 Analytical parameters

The primary analytical parameter is presented in **Error! Reference source not found.**. Odour and ammonia are the primary measurement parameters.

3.16.1 Primary parameters

Table 8 Primary analytical parameters, analytical methods, number of samples and sample time.

Parameter	Analytical method	Number of measuring periods	No. of samples/ measuring period	Sampling time/period
Odour	Olfactometric analyses, EN 13725/AC:2003	6 measuring periods	3	30 minutes
NH_3	PICARRO G2508 Reference: Impingers	6 measuring periods	Continuous measurements in situ.	

3.16.2 Conditional parameters

Table 9 gives the conditional parameters, which may influence the emission level of the primary environmental pollutants. In addition, the table includes electrical consumption.

Table 9 Conditional parameters and corresponding analytical methods.

Parameter	Analytical method	No. of measuring periods	Sampling time/period
CO_2	PICARRO G2508 Gas Concentration Analyzer Reference: GC-TCD sampled in Tedlar bags	6	Continuous measurements in situ.
Temperature	Testo 174H	6	Continuous during sampling
Relative humidity	Testo 174H	6	Continuous during sampling
Electricity consumption of tested technology	Calculated	6	Log book
Wind • direction [°] • speed [m/s]	Davis vangate pro2	6	Avarages during sampling.

3.17 Preservation and storage of odour samples

Odour samples was sampled and stored during transport according to the description given by the Danish EPA, Miljøstyrelsen (2006) regarding sampling and analyses of odour samples from livestock production units. Samples were sampled just before and under scraping for both technology and reference.

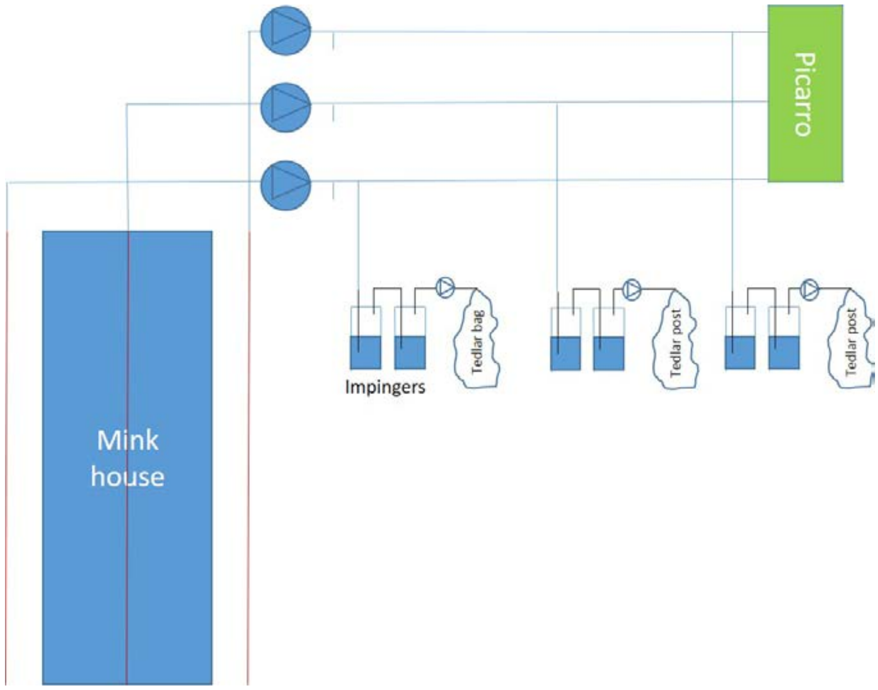
3.18 Analytical methods

The analytical methods of the primary parameter are presented in Table 8 The analytical methods of the operational parameters are presented in Table 9.

3.18.1 Ammonia and CO2

The ammonia and CO2 concentration sampled inside and outside the mink production building was analyzed continuously using Cavity Ring-Down Spectroscopy (CRDS), PICARRO G2508 Analyzer specially optimized for ammonia. The analyzer collects data every second and changes measuring

point every 5 minutes. Because of the response time for ammonia only the last minute for every 5 minutes was used for the emission calculations.
As standard reference method, Impinger system is used for validation of NH3 concentration and parallel gas samples are analyzed by gas chromatography with thermoconductivity detector (GC-TCD) for validation of CO2 concentration.
From each sampling line 0,18 L/min. flow is drawn for a period of one minute, each hour equals to around 30 L every week. The air first passes two 400 ml impingers (12 mM H2SO4) and is then col-



lected in a 30 L Tedlar bag for later analysis og CO2. The flow was measured before and after every measuring period and the flow was checked by the volume of the Tedlar bag. Se measuring setup above. Ammonia sampled by the impingers were later analyzed with photospectroscopy using the indophenol reaction.

Figure 7 Measuring setup at a mink house where Picarro G2508 multigas analyzer is measuring along with parallel sampling for ammonia (impingers) and CO_2 (Tedlar bag).

3.18.2 Odour anlyses

The odour samples from the mink houses were analysed by olfactometric, where odour concentration is determined by dilution and odour panel evaluation by the internal odour analytic institute (DMRI-Taastrup) according to the standard EN 13725/AC:2003.

4. Existing data

4.1 Accepted existing data

No data from previous tests have been used for calculation of the performance parameters. It means that the verification is based solely on measurements done by the test institute in the test period specified.

5. Evaluation

5.1 Calculation of verification parameters

The emission of a specific gas *g* was calculated by following equation:

$$E_g = qv \times \rho_g(t) \times (C_{in} - C_{out})_g$$

Where E_g is the emission of a specific gas *g*, qv is the ventilation in m^3/h, ρ_g (t) is the density of the gas in kg/m^3 at a given temperature t, and $(C_{in} - C_{out})_g$ is the difference in concentrations of the specific gas *g* in ppm (m^3 / m^3), between, inside and outside.

Hereunder is an example of how emission can be calculated. ρ_g (t) is the density of the gas in kg/m^3 and will change with the temperature. The densities used in this example is the densities at 20 ° C, 1 atm.

ρ_{NH3}: 17.037g/mol x 1 atm/ (0.0821 x (273.15 K + 20 ° C)) = 0.708 g/L

Example for average emission at a mink production where

$$E_{NH3} = 211.602\ m3/h \times 0.708_{mg/l} \times (9.5_{ppm} - 6.5_{ppm})_{NH3}$$

E_{NH3}= 449 g NH_3/h corresponding to 10.8 kg NH_3/d

5.2 Evaluation of test quality

5.2.1 Control data

Data transferred from registrations on paper to spread sheets and test report were controlled on a spot check basis during the internal review process.

5.2.2 Audits

A test system audit was undertaken by Peter Fritzel from ETA-Danmark. The audit report is included as Appendix 8 to this verification report.

5.2.3 Deviations

There have been 6 incidents where the farmer has manual overridden the system and activated the scraping in a reference period. In the appendix A, Operation log, a full list of all actions is described.

Data was removed from 9-11 June due to unauthorized scraping in a reference period. Data was removed from 26-27 June due to unauthorized scraping in a reference period. Data was removed from 7-8 July due to unauthorized scraping in a reference period. Data was removed from 2-4 September due to unauthorized scraping in a reference period. These four incidents were evaluated to have small effect of the final result because we still have at least 4 days with close to reference conditions. It will however have negative effect on the measured effect of the technology because 1/3 of the reference conditions is closer to 2 scrapings per week than 1. In one measuring campaign the data quality was very poor, and we had to remove data from 22-22 June and 29 June to the 2. of July due to system failure. This resulted in a quite short measuring period 2 at Barrit and led to a non-significant effect. Measuring period 6 is generally a bit squeezed because we needed to finish before the mink was taken out of the building. This is evaluated not to have a significant effect on the results. Five odour analyses were removed from the dataset as outliers because the values were > Q3+3*IQR.
These deviations are evaluated not to have a significant effect on the results.

5.2.4 Amendments

This section addressing amendments to the test plan. This section will compile all changes of the test plan occurring before testing with justification of deviations and evaluation of any consequences for the test data quality. There have been only 3 changes from the plan. Odour samples which were planned to be sampled the 20-06-2019 was instead sampled the day after 19-06-2019 due to logistical problems. 11-11-2019 we also planned to sample odour but this sample was instead sampled 6-11-2019 because the farmer at Søndersø wants to start emptying the mink house the 19-11-2019 which meant we had to move forward the odour sample and reduce the ammonia sampling period a bit as well. However, the sampling period was still acceptable according to VERA standards.

5.3 Verification results (verified performance claim)

The verification claim was minimum 50% reduction of ammonia emission from the mink housing system with SmartScrape installed compared with a similar mink housing system without SmartScrape installed (reference measurements are undertaken).
The ammonia reduction was in this test found to be 40.7 %.

The verification claim was minimum 50% reduction of odour emission from the mink housing system with SmartScrape installed compared with a similar mink housing system without SmartScrape installed (reference measurements are undertaken).
The odour reduction was verified in this test and found to be 71.5 %.
Odour sampling included periods of scraping in both technique and control houses - The highest odour emissions were found during scraping after a reference period.

5.3.1 Description of statistical methods used

The annual emissions of both the test and reference housing systems were calculated. For each test location the daily emission means were calculated over the whole sampling period, for both the reference and technology applied periods. Daily emission means were calculated as mean of hourly emissions.

A statistically significant reduction at each farm location was obtained and a verified emissions reduction was calculated as the overall proportional effect given by the average of each location mean. For ammonia, the means and standard deviations of the case and control compartment was also reported for each test location. P-values for t-test of the significance of differences between case and control for each pair of units for both odour and ammonia are reported.

5.4 Verification parameters

5.4.1 Ammonia

In the table below the ammonia reduction is reported including date of the measurement, 24 hour average background/house NH_3 and CO_2 concentration, 24 hour average indoor/outdoor temperature, 24 hour average, wind speed and direction and ventilation rate, number, weight and CO_2-production from adult mink and offspring. 24 hour average, weight, number og mink and calculated 24 hour emission of NH_3, reduction in percentage between technology and reference and P-value.

Table 10 shows dates of the measurements, 24 hour average background/house NH_3 and CO_2 concentration, 24 hour average indoor/outdoor temperature, 24 hour average, wind speed and direction and ventilation rate, number, weight and CO_2-production from adult mink and offspring. 24 hour average, weight, number og mink and calculated 24 hour emission of NH_3 in gNH_3/d/kg mink, Kh NH3/year/LU and g NH3/year/animal, reduction in percentage between technology and reference and P-value.

	Farm	Tech.	Date	Outdoor Temp, °C	Wind direction	wind speed	Air flow m3/h	Bitches/female Offspring Number	Bitches/female Offspring weight, kg.	Bitches/female Offspring CO2 prod. m3/h	Offspring Number	Offspring weight, kg.	Offspring CO2 prod. m3/h	Emission NH3 g/d/kg mink	kg NH3 year-1 LU-1	g NH3 year-1 animal-1	N	Effect, %	P-value
Period 1	Barrit	Reference	21-5 2019	12,5	W	2,3	400722	996	1,85	1,73	6550	0,14	4,71	1,33	242,1	177,5	24	-18,9	0,303
			22-5 2019	13,0	W	3,6	1347339	996	1,85	1,73	6543	0,15	4,86	0,88	159,9	120,7	24		
			23-5 2019	12,5	W	3,7	628634	996	1,84	1,72	6535	0,17	5,00	1,70	310,6	241,8	24		
			24-5 2019	10,8	W	4,1	1052573	996	1,84	1,72	6526	0,18	5,13	1,14	208,5	167,4	24		
			25-5 2019	12,8	W	4,3	1327402	996	1,83	1,72	6515	0,20	5,26	0,94	172,0	142,5	24		
			Average	12,3			951334							1,2	218,6	170,0			
			Std Dev											0,3	60,7	45,8			
		SmartScrape	30-5 2019	11,1	W	4,8	540421	996	1,81	1,71	6440	0,28	5,86	1,38	251,7	243,9	24		
			31-5 2019	13,9	W	2,2	521920	996	1,80	1,71	6421	0,30	5,97	1,22	222,3	222,2	24		
			1-6 2019	17,9	W	4,2	868593	996	1,80	1,71	6400	0,32	6,07	1,04	189,3	195,2	24		
			2-6 2019	21,9	W	2,9	189726	958	1,79	1,64	6378	0,33	6,17	1,81	330,0	346,7	24		
			3-6 2019	22,1	W	3,0	279238	922	1,79	1,58	6355	0,35	6,27	1,68	306,8	328,9	14		
			Average	17,4			479980							1,4	260,0	267,4			
			Std Dev											0,3	58,3	66,8			
	Sønderso	Reference	6-6 2019	17,1	S	4,2	100033	404	1,36	0,63	3816	0,16	2,87	2,47	451,2	247,5	16	50,9	0,000
			7-6 2019	17,2	E	2,9	101529	404	1,37	0,63	3782	0,20	3,09	2,32	422,8	266,6	24		
			8-6 2019	16,8	S	6,1	136935	404	1,37	0,63	3749	0,25	3,27	2,70	493,1	350,8	24		
			9-6 2019	16,1	W	5,2	113901	404	1,38	0,63	3715	0,29	3,42	2,25	410,3	324,7	24		
			12-6 2019	15,8	E	3,1	78161	404	1,41	0,64	3613	0,41	3,76	1,79	327,2	335,5	24		
			13-6 2019	15,6	E	3,4	66738	404	1,42	0,64	3580	0,45	3,84	1,63	297,3	327,3	23		
			Average	16,4			99549							2,2	400,3	308,7			
			Std Dev											0,4	78,5	32,1			
		SmartScrape	15-6 2019	15,8	E	3,2	100215	404	1,43	0,64	3512	0,53	3,98	0,91	166,2	207,6	24		
			16-6 2019	16,5	W	4,2	112932	404	1,44	0,64	3478	0,57	4,04	1,32	241,7	319,6	24		
			17-6 2019	17,2	W	3,0	81476	404	1,45	0,64	3444	0,61	4,09	1,15	210,0	292,7	24		
			18-6 2019	19,6	S	3,3	122743	404	1,46	0,65	3410	0,65	4,13	1,19	216,3	316,8	24		
			19-6 2019	18,6	E	2,5	63921	404	1,46	0,65	3377	0,68	4,17	0,81	148,1	227,1	12		
			Average	17,5			96257							1,1	196,5	272,7			
			Std Dev											0,2	38,4	52,1			
Period 2	Barrit	Reference	23-06 2019	20,6	E	2,1	213530	538	1,69	0,91	5599	0,82	7,36	1,59	290,1	326,4	24	31,3	0,246
			24-06 2019	22,6	E	3,2	205438	536	1,69	0,90	5547	0,85	7,37	1,66	302,2	465,2	24		
			25-06 2019	20,2	E	2,9	392756	536	1,68	0,90	5493	0,88	7,38	1,02	186,0	417,7	24		
			Average	18,5			270574							1,4	259,4	403,1			
			Std Dev											0,4	63,9	70,5			
		SmartScrap	01-07 2019	16,4	W	4,4	296251	568	1,66	0,95	5142	1,04	7,34	1,20	218,8	465,2	15		
			02-07 2019	16,0	W	4,8	190928	579	1,65	0,97	5079	1,07	7,31	0,75	137,7	466,2	14		
			Average	16,2			243590							1,0	178,3	465,7			
			Std Dev											0,3	57,3	0,7			
	Sønderso	Reference	03-07 2019	12,6	W	5,5	174882	404	1,58	0,66	2903	1,15	4,28	1,17	212,9	465,2	14	59,6	0,001
			04-07 2019	12,4	W	5,9	151152	404	1,58	0,66	2870	1,18	4,26	0,83	150,7	466,2	24		
			05-07 2019	15,0	W	5,1	124832	404	1,59	0,67	2836	1,20	4,25	1,03	187,2	467,2	24		
			06-07 2019	13,9	W	5,4	121425	404	1,60	0,67	2802	1,23	4,23	1,18	215,1	468,2	24		
			09-07 2019	13,3	W	6,0	102377	404	1,62	0,67	2700	1,31	4,17	1,05	191,0	469,2	24		
			Average	13,4			134934							1,0	191,4	467,2			
			Std Dev											0,1	26,0	1,6			
		SmartScrape	10-07 2019	15,4	W	3,9	73669	404	1,63	0,67	2667	1,34	4,14	0,55	100,3	465,2	24		
			11-07 2019	14,7	S	2,1	45731	404	1,64	0,67	2633	1,36	4,11	0,40	72,8	466,2	24		
			12-07 2019	16,9	E	1,8	37071	404	1,65	0,67	2599	1,39	4,09	0,42	77,3	467,2	24		
			Average	15,7			52157							0,5	83,4	466,2			
			Std Dev											0,1	14,8	1,0			

Period	Farm	Tech.	Date	Background NH3, ppb	Background CO2, ppm	House NH3, ppb	House CO2, ppm	Indoor Temp, °C	Outdoor Temp, °C	Wind direction	wind speed	Air flow m3/h	Bitches/female Offspring Number	Bitches/female Offspring weight, kg.	Bitches/female Offspring CO2 prod. m3/h	Offspring Number	Offspring weight, kg.	Offspring CO2 prod. m3/h	Emission NH3 g/d/kg mink	kg NH3 year-1 LU-1	g NH3 year-1 animal-1	N	Effect, %	P-value
Period 3	Barrit	R	07-08 2019	113	401	3097	493	10,9	8,3	S	2,5	122033	1992	1,56	3,26	1992	2,19	3,66	0,46	84,0	471,2	24		
			Average	276		4790		11,1	9,6			146905							0,8	141,2	468,2			
			Std Dev																0,3	54,7	2,2			
		SmartScrape	08-08 2019	698	453	567	413	18,2	15,7	W	3,2	295523	1992	1,57	3,27	1992	2,22	3,68	0,18	32,2	465,2	24		
			09-08 2019	1130	463	690	412	19,6	17,0	S	2,4	145676	1992	1,58	3,28	1992	2,25	3,69	0,22	40,6	466,2	24		
			10-08 2019	1017	456	575	409	18,5	18,3	S	4,4	272409	1992	1,60	3,28	1992	2,28	3,71	0,23	42,2	467,2	24		
			11-08 2019	260	414	488	403	18,3	18,2	W	5,8	509583	1992	1,61	3,29	1992	2,31	3,73	0,16	29,4	468,2	24		
			12-08 2019	533	438	427	407	17,7	16,6	W	4,4	371350	1992	1,62	3,30	1992	2,35	3,75	0,18	32,8	469,2	24		
			13-08 2019	1320	494	725	426	14,1	13,7	W	2,5	157793	1992	1,63	3,31	1992	2,38	3,76	0,13	23,1	470,2	13		
			Average	826		579		17,7	16,6			292056							0,2	31,9	468,7			
			Std Dev																0,0	7,9	1,3			
	Sønderse	Reference	14-08 2019	195	395	5021	500	18,0	14,3	W	3,8	65079	400	1,89	0,70	2430	1,91	4,26	0,78	141,8	465,2	14	30,1	0,000
			15-08 2019	465	413	5183	521	19,3	15,5	S	3,3	64993	400	1,90	0,70	2430	1,91	4,26	0,70	127,2	466,2	24		
			16-08 2019	272	404	5875	528	18,0	16,2	W	3,7	55605	400	1,90	0,70	2430	1,92	4,27	0,79	144,1	467,2	24		
			17-08 2019	551	413	4952	506	17,8	16,5	S	4,6	88314	400	1,91	0,70	2430	1,93	4,27	0,74	134,8	468,2	24		
			18-08 2019	401	426	8504	599	18,5	15,2	S	2,5	32522	400	1,92	0,70	2430	1,93	4,28	0,77	140,0	469,2	24		
			19-08 2019	248	401	6936	533	19,5	15,9	W	4,2	48163	400	1,92	0,70	2430	1,94	4,28	0,85	155,4	470,2	24		
			20-08 2019	272	404	7571	548	18,7	16,2	W	4,1	48913	400	1,93	0,70	2430	1,94	4,28	0,86	157,7	471,2	24		
			Average	343		6292		18,5	15,7			57655							0,8	143,0	468,2			
			Std Dev																0,1	10,8	2,2			
		SmartScrape	23-08 2019	181	406	4540	533	22,0	18,3	W	4,0	51033	400	1,95	0,71	2430	1,95	4,29	0,57	103,8	466,2	24		
			24-08 2019	461	443	4845	586	24,1	17,6	E	2,0	51429	400	1,96	0,71	2430	1,95	4,29	0,53	96,4	467,2	24		
			25-08 2019	564	415	3712	508	25,2	20,5	E	2,5	67149	400	1,97	0,71	2430	1,95	4,29	0,54	98,7	468,2	24		
			26-08 2019	638	410	3527	494	23,6	15,7	E	3,3	88434	400	1,97	0,71	2430	1,95	4,29	0,56	102,5	469,2	24		
			27-08 2019	689	413	3699	482	22,6	13,8	E	3,0	62377	400	1,98	0,71	2430	1,95	4,29	0,54	98,5	470,2	18		
			Average	506		4064		23,5	17,2			64084							0,5	100,0	468,2			
			Std Dev																0,0	3,1	1,6			
Period 4	Barrit	Reference	28-08 2019	291	413	5382	522	29,5	28,7	E	1,8	92707	1991	1,79	3,41	1990	2,82	3,99	0,67	122,1	466,2	14	56,7	0,004
			29-08 2019	112	411	2224	481	21,5	18,5	W	1,7	175148	1991	1,79	3,42	1990	2,85	4,00	0,49	89,4	467,2	24		
			30-08 2019	106	416	4201	537	18,8	15,5	S	2,2	118388	1991	1,80	3,42	1990	2,88	4,01	0,52	94,2	468,2	24		
			31-08 2019	552	414	8598	561	23,0	19,0	E	2,3	65766	1991	1,81	3,43	1990	2,90	4,02	0,87	159,0	469,2	24		
			01-09 2019	145	408	2755	487	18,1	15,8	W	2,2	193715	1990	1,82	3,43	1990	2,93	4,04	0,45	82,3	470,2	23		
			Average	241		4632		22,2	19,5			129145							0,6	109,4	468,2			
			Std Dev																0,2	31,6	1,6			
		SmartScrape	06-09 2019	114	403	1853	494	12,2	12,7	S	1,9	143621	1990	1,86	3,46	1990	3,06	4,10	0,22	40,0	466,2	24		
			07-09 2019	299	417	3489	536	11,7	12,0	E	1,2	75318	1990	1,87	3,46	1990	3,09	4,11	0,25	45,1	467,2	24		
			08-09 2019	225	418	3818	561	15,7	12,0	W	0,7	77474	1990	1,88	3,47	1990	3,11	4,12	0,37	68,0	468,2	24		
			09-09 2019	102	402	321	424	12,2	11,9	W	3,0	376724	1990	1,88	3,47	1989	3,14	4,13	0,31	57,3	469,2	24		
			10-09 2019	336	400	4223	481	14,2	13,0	W	3,8	89947	1990	1,89	3,48	1989	3,16	4,14	0,14	26,3	470,2	13		
			Average	215		2741		13,2	12,3			152617							0,3	47,3	468,2			
			Std Dev	191		2872													0,1	16,0	1,6			
	Sønderse	Reference	11-09 2019	336	400	4223	481	29,5	13,9	W	5,1	64082	400	2,08	0,72	2430	2,57	4,71	0,62	112,3	469,2	14	40,9	0,000
			12-09 2019	302	401	5601	518	21,5	15,2	W	4,7	67298	400	2,08	0,72	2430	2,59	4,73	0,66	121,2	470,2	24		
			13-09 2019	118	396	3092	465	18,8	14,7	W	5,6	103747	400	2,09	0,72	2430	2,62	4,75	0,60	110,3	471,2	24		
			14-09 2019	236	408	4394	527	23,0	12,8	W	4,4	64883	400	2,10	0,72	2430	2,65	4,76	0,53	97,6	472,2	24		
			15-09 2019	181	397	2431	446	18,1	14,1	W	7,6	132280	400	2,11	0,73	2430	2,68	4,78	0,59	107,1	473,2	24		
			16-09 2019	94	396	1829	444	15,3	12,2	W	6,0	131865	400	2,11	0,73	2430	2,69	4,79	0,50	91,3	474,2	24		
			17-09 2019	88	397	1654	445	16,3	10,2	W	6,1	144445	400	2,12	0,73	2430	2,72	4,80	0,45	82,9	475,2	24		
			18-09 2019	54	395	1182	429	16,4	10,4	W	6,6	165074	400	2,12	0,73	2430	2,74	4,82	0,43	78,0	476,2	14		
			Average	176		3051		19,9	12,9			109209							0,5	100,1	472,7			
			Std Dev																0,1	15,2	2,4			
		SmartScrape	19-09 2019	59	397	1968	494	14,7	10,7	W	3,3	59723	400	2,13	0,73	2430	2,76	4,83	0,24	43,8	473,2	24		
			20-09 2019	79	400	1984	482	16,8	12,8	W	4,4	93064	400	2,14	0,73	2430	2,78	4,84	0,29	53,7	474,2	24		
			21-09 2019	177	415	4252	553	14,8	13,7	W	2,6	50260	400	2,14	0,73	2430	2,79	4,85	0,36	65,4	475,2	24		
			22-09 2019	511	441	4086	570	13,2	13,9	E	2,5	50343	400	2,15	0,73	2430	2,81	4,86	0,35	63,6	476,2	24		
			23-09 2019	299	405	1733	454	15,0	14,6	E	6,2	121323	400	2,15	0,73	2430	2,83	4,87	0,36	66,6	477,2	24		
			24-09 2019	366	414	5736	600	14,5	14,4	E	1,8	28616	400	2,16	0,73	2430	2,84	4,88	0,34	61,7	478,2	15		
			Average	249		3293		14,8	13,4			67221							0,3	59,1	475,7			
			Std Dev																0,0	8,8	1,9			

There is a statistically significant reduction at each farm location found with a P value of 0,001 for location Barrit and 0,005 for location Søndersø, when we don't account period 1 af Barrit. The overall efficiency is calculated as the average efficiency between the two locations and is found to be 37.3 %. The mean emission for the reference was found to be 142.9 and 168.3 kg NH_3 $year^{-1}$ LU^{-1} and 100.7 and 94.4 kg NH_3 $year^{-1}$ LU^{-1} using SmartScrape at Barrit and Søndersøg, respectively. The average reduction for the two locations is calculated as the ratio between the average emission with the technology and the average emission without the technology for example (1-(97.5/155.6)) kg NH_3 $year^{-1}$ LU^{-1} /100 = 37,3 %. There was a significant difference between case and control for each pair of units except location Barrit period 1 and 2. In period 1 the minks were very small and very small amount of slurry landed in the gutters and therefore the low or negative reduction is not surprising. The same pattern is seen for odour, where we saw a small negative reduction but not significant. The number of days where data were collected for calculation of ammonia emission varies from 5-7 for the reference and 3-5 for the technology period depending on the setup time and moving time as well as the time for changing from reference stage to technology stage including cleaning. The reference period could maximum include 7 full 24 hours days and the test period maximum 5 full 24 hours days. Only in 3 periods out of 12 periods, sample days have been removed due to technical problems with the measuring system (Period 2 Barrit), and early shift from reference state to technology state due to limited time before slaughter. See more 5.2.3 Deviations and 5.2.4 Amendments.
The animal occupation in percent of the permitted area per kg of mink in relation to the actual area per kg mink varies from 24-35 in the start of et first period to 97-98 % in the end of the 6. Period.
At the farm in Barrit bitches / female offspring is reduced from 996 to 538 between the first and second period because some of the mother animals are taken out. The number of offspring is also decreased as they grow. For the 3. period they are down to approx. 2000 from 6500 in the beginning. At the farm in Søndersø the farmer has a different practice and moves almost no bitches out of the house, but only around in the house, hence the constant number.

5.4.2 Odour

Tabel 11 Odour concentration, temperature, flow and calculated odour emission from the two test farms in six periods. Red numbers are outliers and is not included in the calculations. Orange numbers are odour concentrations during pumping and cleaning in the reference houses. Because this event is only occurring once per week (2% of the time) these numbers are not included.

Farm	Tech	Period	Date	Time	[Odour], OUE/m3			Mean	Indoor Temp. °C	Outdoor Temp. °C	Flow m3/LU/s	Emission OU/LU/s	Reduction %
Barrit	Smartscrape	1	03-06-2019	12.00-13.30	42	30	70	47	36.0	20	18.0	850	
		2	02-07-2019	12.00-13.30	15	19	16	17	17.0	16	35.0	584	
		3	13-08-2019	12.00-13.30	34	20	20	25	27.0	19.2	9.4	232	
		4	10-09-2019	12.00-13.30	17	23	27	22	20.0	14.4	10.7	238	
		5	08-10-2019	12.00-13.30	21	28	23	24	24.5	14	4.5	107	
		6	05-11-2019	12.00-13.30	22	21	50	31	21.5	6.2	3.3	101	
		Average									13,5	352	
	Reference	1	21-05-2019	12.00-13.30	50	24	23	37	15.6	12.5	20.5	759	-10.7
		2	20-06-2019	12.00-13.30	38	30	682	34	24.6	18.6	11.3	386	-51.4
		3	31-07-2019	12.00-13.30	273	209	2356	241	26	23	1.4	336	30.9
		4	28-08-2019	12.00-13.30	70	110	2889	90	36	32.2	2.7	240	1.0
		5	25-09-2019	12.00-13.30	98	110	17805	104	18	15.6	2.6	270	60.2
		6	23-10-2019	12.00-13.30	63	38	1579	51	16	13.7	2.9	146	30.9
		Average									6,9	356	1
Søndersø	Smartscrape	1	19-06-2019	12.00-13.30	36	40	63	46	24.6	19	5.8	271	
		2	16-07-2019	12.00-13.30	42	32	50	41	20	19	5.1	212	
		3	27-08-2019	12.00-13.30	93	47	42	61	32	30	3.1	188	
		4	24-09-2019	12.00-13.30	243	173	155	190	20	18	0.6	116	
		5	22-10-2019	12.00-13.30	79	45	30	51	16	13.5	1.3	66	
		6	19-11-2019	12.00-13.30	56	40	56	51	13.1	9	1.4	69	
		Average									2,9	154	
	Reference	1	06-06-2019	12.00-13.30	217	110	383	164	31	29.5	10.1	1.644	83.5
		2	03-07-2019	12.00-13.30	110	53	230	82	26	25	5.4	440	51.8
		3	14-08-2019	12.00-13.30	117	74	273	96	20.5	20	2.6	249	24.5
		4	11-09-2019	12.00-13.30	117	66	721	92	19	19	1.9	178	34.9
		5	09-10-2019	12.00-13.30	164	110	1411	137	15	15	1.0	140	53.1
		6	11-11-2019	12.00-13.30	45	45	854	45	10	9	1.5	69	0.2
		Average									3.8	453	66
Mean reference												405	
Mean SmartScrape												253	37.5

There is no statistically significant reduction at any farm location according to a P-value of 0,98 for location Barrit and 0,25 for location Søndersø. If the threshold for outliers was set differently like

Q3+5*IQR, and all other data was included, then the odour reduction would have been significant for both locations. The overall efficiency is calculated as the average between the two locations efficiencies and is found to be 37.5 %. The overall mean emission for the reference was found to be 405 OU S^{-1} LU^{-1} and 253 OU S^{-1} LU^{-1} using SmartScrape. The five odour concentrations in red were removed from the odour emission calculation in this dataset as an outlier because the value was larger than: Q3+3*IQR
IRQ is the interquartile range being equal to the difference between 75th and 25th percentiles or between upper and lower quartiles ($IQR=Q_3-Q_1$). Q3+3*IQR was 2196 in the Barrit reference and 800 in the Søndersø reference.

5.4.3 Energy consumption

Tabel 12 Energy consumption from the 2 test farms with and without Smartscrape.

	Smart Scrape Barrit	Smart Scrape Søndersø	Smart Scrape Average	Reference Barrit	Reference Søndersø	Reference Average
	Wh/mink/ 30 weeks production					
Pumps	38	32	35	107	84	96
Scraping	30	28	29	manual	manual	manual
Total	68	59	63	107	84	95.6
Reduction %						33.7

From the energy consumption it is seen that normal operation with manual scraping consumes one tried more energy than SmartScrape manly because the pump is less active.

5.4.4 Reference data

In this section reference data for ammonia and CO2 is reported. Ammonia is sampled with the impinger principle and compared with CRDS (Picarro) and CO2 is sampled in TEDLAR bags and analysed with CG-TCD and compared with CRDS (Picarro).The reference samples has sampled during the hole period of one week with the technology off and a hole week with the technology on. This means that it has buffer periods between on/off and periods with scraping failures was not removed. System failures was only detected when the sample bags were not filled. A flow of about 179 ml/h is obviously very hard to control, which is why the reference data comes out with a very high uncertainty.

Tabel 13 reference data for NH3 and CO2 where impinger and GC measurements are compared with data obtained with a Picaro G2508

Period	Farm	Teknology	Location	[NH3] Pi-carro ppm	[CO2] Pi-carro ppm	[NH3] gas bublers ppm	[CO2] GC ppm	% devia-tion NH3	% devia-tion CO2
Period 1	**Søndersø**	Reference	mink barn	2.823	463	5.27	471	46	2
			background	0.369	411	2.06	420	82	2
	Barrit	Reference	mink barn	0.487	416	3.21	412	85	-1
			background	0.097	403	0.23	397	58	-2
		SmartScrape	mink barn	1.495	437	4.12	429	64	-2
			background	0.153	407	0.69	408	78	0
Period 2	**Søndersø**	Reference	mink barn	2.179	449		450		0
			background	0.104	400		410		2
	Barrit	SmartScrape	mink barn	0.742	442	1.14	462	35	4
			background	0.066	406	1.60	409	96	1
Period 3	**Søndersø**	Reference	mink barn	6.004	538	4.58	530	-24	-2
			background	0.348	411	0.41	413	16	0
		SmartScrape	mink barn	3.917	518	4.35	496	10	-4
			background	0.408	416	0.46	414	11	0
	Barrit	Reference	mink barn	4.49	506	3.55	480	-21	-5
			background	0.26	409	0.25	415	-3	1
		SmartScrape	mink barn	0.785	449	0.46	438	-42	-3
			background	0.088	396	0.21	399	57	1
Period 4	**Søndersø**	SmartScrape	mink barn	7.55	555	2.75	543	-64	-2
			background	0.137	404	0.69	406	80	0
Period 5	**Barrit**	Reference	mink barn	3.271	460		449		-2
			background	1.133	413		421		2
		SmartScrape	mink barn	2.483	523	1.14	502	-54	-4
			background	0.212	415	0.23	405	7	-2
Period 6	**Søndersø**	Reference	mink barn	4.185	506	7.78	490	46	-3
			background	0.975	444	2.52	452	61	2
		SmartScrape	mink barn	2.495	497	5.31	478	53	-4
			background	0.488	431	0.96	426	49	-1
		SmartScrape	mink barn	2.495	497	6.87		64	
			background	0.488	431	1.28		62	
Deviation mean %								30	-1

Around half of all measuring campaigns are represented in the above table where measurements from the Picarro analyzer and the reference measurements can be compared. Ammonia concentration measured with impingers is on average 30 % higher than when measured with the Picarro analyzer but only 17 % higher if we subtract the first measuring period there the flow is controlled with a simple vacuum pump. In the later periods an automated syringe pump was installed. The ammonia liquid analysis has an uncertainty of 16 %. The CO2 concentration measured with GC is on average 1 % higher than measured with the Picarro analyzer. There is a lot of deviation when comparing single measurements and that might be because they are sampled at different times during each hour, and because the pumping system was unstable and at times leaky. Due to the extreme low flow, only a small leak has a big impact. More air could have been pumped through the impinger than we thought leading to an overestimation of the ammonia concentration but not the CO2 concentration, because the ammonia concentration was calculated from the air volume collected in the bag. The majority of the CO2 samples shows concentration differences under 20% which is considered acceptable given the difference in sampling time within one hour. Most of the missing data was due to breakdown of syringe pump. In conclusion the sample strategy for the reference samples cannot be recommended because the big risk of system failure. I would have been better to have made spot samples for one hour, where the system could have been supervised. The Picarro data are more solid than the impinger reference. The CRDS Picarro system was checked for linearity and precision just before period 1 and found to linear and within 10 % from the standard gas concentration, se appendix 9.

5.4.5 Operational stability

The operating stability of the system has been good during the entire testing period. There have been 6 incidents where the farmer has manual overridden the system and activated the scraping in a reference period. In the appendix 8, Operation log, a full list of all actions is described. The stability of the system has been successfully tested. The uptime of the system during the test period was 100 %.

5.5 Recommendations for the Statement of Verification

It is recommended that a Statement of Verification is issued with a presentation of the results of the verification.

6. Quality assurance

The staff and the experts responsible for quality assurance as well as the different quality assurance tasks are presented in Table 14.

Table 14 Plan for quality assurance of the SmartScrape verification.

	Verification body (ETA-Danmark)		Proposer (Columbus Aqua)	External expert
Initials	**PF**	**ARNH**	**Lars Fisker**	**(MELT)**
Tasks				
Specific verification protocol	Review	Write	Review	Review
Test plan	Approve	Review	Review + approve	
Test system audit at test site	Audit			
Test performance audit		Audit		
Test report	Approve	Review	Review	
Verification report	Review	Write	Review	Review

A test system audit was conducted following general audit procedures by a certified auditor (Peter Fritzel) from the verification body, ETA-Danmark.

6.1 Test system control

The stability of the test equipment will be controlled by supervision and recording of data. Procedures for ensuring that test facilities and equipment are calibrated and fit for the purposes are described in the QA-system for DTI-Agrotech.

The primary performance parameter ammonia was measured by CRDS analyzer, which was validated on-site using standard ammonia gas, prescribed by the Danish Technological Institutes QA -system – "Procedure for gasmålinger".
The test did general follow the Danish Technology Institutes QA-systems guidelines.
The test plan was external reviewed by technical expert assigned to this verification task.

6.2 Data integrity check procedures

All transfers of data from printed media to digital form and between digital media was checked by spot check undertaken by the test responsible. If errors were found in a spot check, all data transfers from the specific data collection were checked.

6.3 Test report review

The test report has been subject to internal review by the technical experts.

Data storage, transfer and control

Some data were collected and reported at the test site others are collected by electronic means, continuously logged and stored on a server and later transferred to a PC in the TI-AgroTech main office. See Table 7.
Results from external laboratories are sent electronically by email or in paper version by mail. A list of data compilation and storage can be seen in table 15.

Tabel 15 Data compilation and storage summary.

Data type	Data media	Data recorder	Recording of data	Data storage
Test plan and test report	Protected pdf-files.	Test responsible	When approved	Files and archives at TI-AgroTech
Data manually recorded at test site	Data recording forms	Test staff at test site	During collection	Files and archives at TI-AgroTech
Calculations	Excel files	Test responsible,	After conclusion of data sampling	Files and archives at TI-AgroTech
Analytical reports	Paper / pdf-files	Test responsible,	When received	Files and archives at TI-AgroTech

7. References

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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

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, groundwater, 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.

Term	Definition	Comments
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 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

Term	Definition	Comments
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.
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 Quick scan-report is attached to this verification report as a separate pdf-file.

Appendix 3 Proposal
Can be acquired from ETA Denmark

Appendix 4 Specific verification protocol
The VERA protocol is attached to this verification report as a separate pdf-file.

Appendix 5 Amendment and deviation report for verification
See chapter 5.2.3 and 5.2.4

Appendix 6 Test plan
The test plan is attached to this verification report as a separate pdf-file.

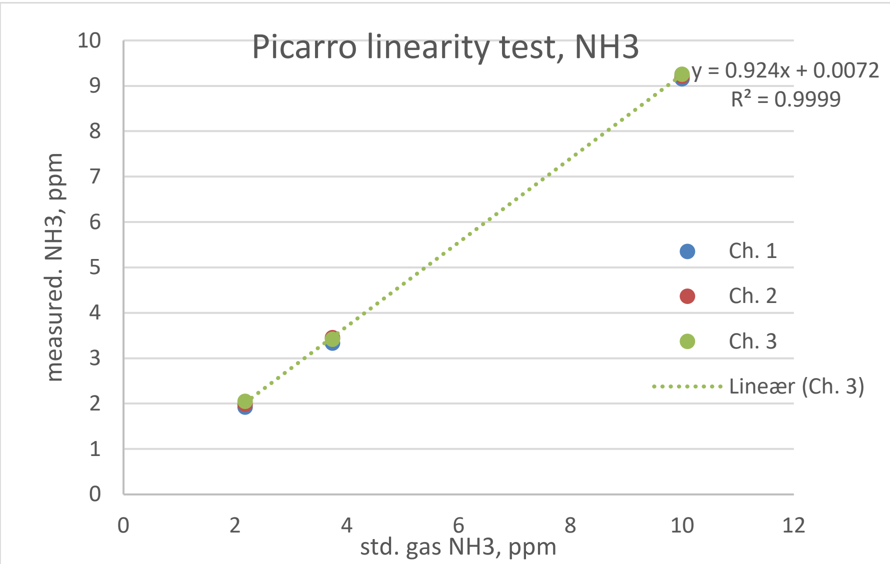
Appendix 7 Test report
The test report is attached to this verification report as a separate pdf-file.

Appendix 8 Operation log
The test report is attached to this verification report as a separate pdf-file.

Appendix 9 Test system assessment report

Picarro linearity test was conducted just before test start.

NH_3 standard gas	Ch. 1	Ch. 2	Ch. 3	Average	Difference
Concentration [NH3]. ppm					%
2.17	1.93	1.99	2.05	1.99	11
3.74	3.34	3.45	3.42	3.40	11
10.00	9.16	9.21	9.26	9.21	8
Average					10



The linearity test shows excellent linearity with R^2 of 0,9999 and a difference in ammonia concentration between the standard gas and the measured concentration of 10 % on an average which is in the limit of the accuracy of the standard gas.