SyreN

Product guide

2022

"With the known GHG reduction potentials, a full use of SyreN System with 2.5 billion m^3 slurry, may reduce world CO_{2e} with up to 2 %"

Morten Toft – January 2022

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Foreword

Since the start of BioCover in 2009, the focus has been on commercializing research- and development activities around sustainable use of organic liquid fertilizers – slurry – during storage and application to fields. This activity has led BioCover Data to be at the forefront of development and we have received a total of 14 international Awards for innovation and product development. Several with groundbreaking innovations, that have led to many patent opportunities. The ideas have been transformed into commercial products.

This booklet on SyreN System, is an overview of the current product offering.

The core product – SyreN – is the center of the developments. Several of the products are an accessory to SyreN System, designed to enhance the performance of the system. Some can be used together with SyreN but may also be stand-alone products that may be used with all slurry application. All products are loyal to the strategy of creating products for the sustainable use of organic liquid slurry.

SyreN was initiated with focus on reduction of ammonia emission from slurry. As the intensive livestock environmental problems have increased on the political agenda, new focus areas like leaching of nitrate, oversupply of phosphorus and biodiversity protection has become part of the agenda. Lately, they have all been overshadowed by the climate crisis discussions – GHG emissions. Fortunately for SyreN System, the agendas are all covered by the same concept. Not with CO_2, but with CO_{2e} as explained below.

With a realistic implementation of SyreN System, it is our estimate that it can reduce world GHG emission with +2 % and do this in a profitable manner. The total potential is up to 5 %.

We are aware, that this is a massive claim. Below we present the arguments and the solutions.

SyreN System is well positioned to start the scale-up journey to contribute to the sustainable- and circular agenda that ultimately will encompass every aspect of agriculture in the future.

Introduction

The use of nitrogen as we know it is both a blessing and a catastrophe. It is a blessing, because use of synthetic mineral fertilizer has enabled us to increase the world´s population from 2 billion to 7 billion people. It has also enabled a change of diet to be based on meat. Where we used to hold 2 domestic animals pr. person before the use of mineral fertilizer, we now hold 10 domestic animals in comparison. That is an increase from 4 billion to app. 70 billion domestic animals.

This has caused a dramatic increase in the volume of organic fertilizer – slurry. The world has app. +2.5 billion m^3 of slurry to dispose of every year. Slurry is the animal recycled residue of mineral fertilizer, and it contains more than half of the world´s yearly need for nitrogen – now as organic fertilizer.

There is a good understanding and efficiency in use of mineral fertilizer – normally around 80 % Nitrogen Utilization Efficiency (NUE). The mineral nitrogen chemical forms of nitrate and urea are dependable and minimize losses.

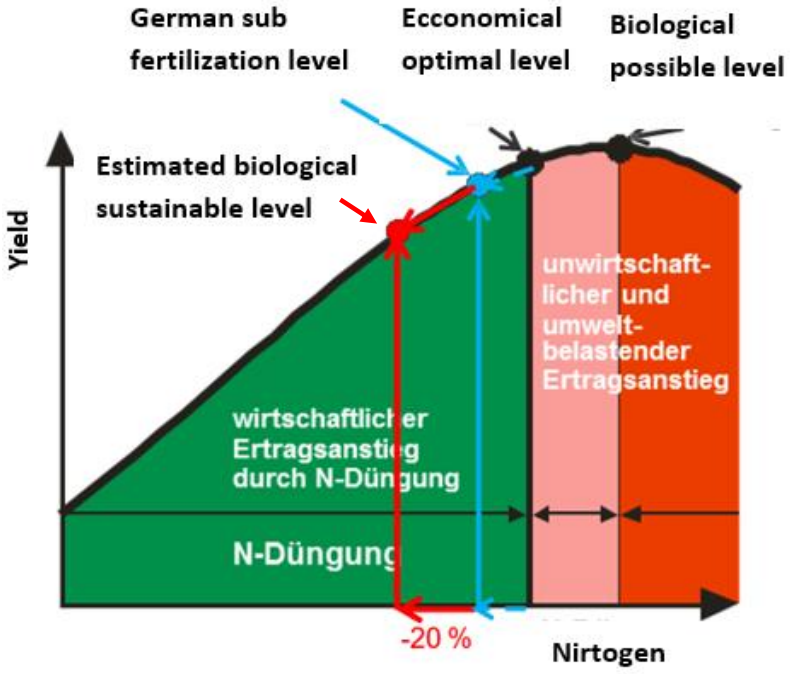
The NUE of slurry is not very efficient. On an average, less than 30 % of the nitrogen is absorbed by plants, so it has a tremendous potential for improvement. It is the nitrogen chemical organic form in the slurry - ammonium – that creates problems. The animal digestion recycles nitrogen as ammonium. It is a chemical form that is very volatile and easily escapes as ammonia gas instead of being captured by the plants as ammonium salt. This is a catastrophe, as it is a primary source of Green House Gas (GHG) emission, eutrophication (pollution with fertilizer salt), air pollution (PM 2.5) and leaching of nitrate to the aquatic environment / ground water.

The pollution problem

Nitrogen as such, is not a pollutant. However, excessive use of nitrogen is. The nitrogen response curves from different crops are well known and they identify an optimal level of nitrogen use pr. ha. An example is below curve in wheat. The curve identifies an economic optimal level of use of nitrogen in relation to yield-response. The curve is not related to an environmental optimal level of nitrogen uptake and that is the problem. It is politically acceptable to have a less than 100 % NUE and the average farm economy depends on that. The environment can absorb some of this excess nitrogen without problems. The average nitrogen loss pr. ha in EU today, is between 70- and 200 kg pr. ha depending on country and that has proven to be too much.

This grey zone between environment and economy has been a political battle ground since the beginning of use of mineral fertilizers. As the science of use of nitrogen and well documented societal cost of the overfertilization have become known, political pressure to reduce the volume of nitrogen has increased.

Recently, the discussions have taken a significantly new direction because of the global agreement to reduce climate gasses because nitrogen has a huge CO_2 footprint. But nitrogen is not only responsible for CO_2 climate gasses. It is the CO_2 compatibles – the CO_{2e} that makes up the bulk of nitrogen problem.

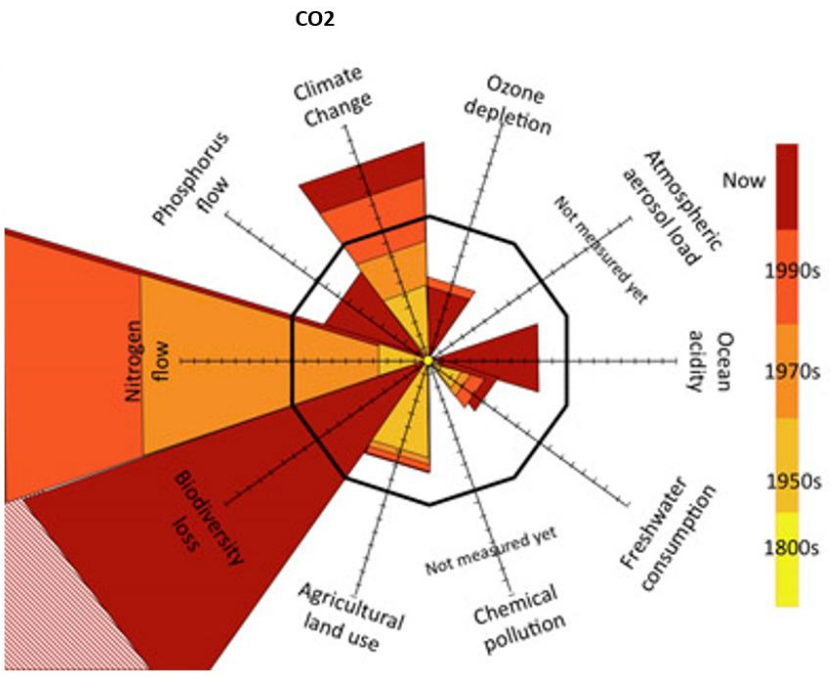


The IPCC has produced a graphic to illustrate the problem:

IPCC climate panel:
The planets sustainability limits

CO2 compatibles:

Methane CH_4 (x40 CO_2 effect)
Produced by methanogenic bacteria in slurry
Nitrous oxide N_2O (x310 CO_2 effect)
By product in breakdown of slurry
NO_X (N_2O_5, N_2O_4, N_2O_3, NO_2, NO)
By product in breakdown of slurry
Ammonia NH3
Indirect contribution to GHG



As can be seen above, the pollution problem is related to a massive increase in the use of synthetic mineral nitrogen. The problem is divided into 4 categories of CO_{2e} that are waste products from the use of nitrogen.
The level of production/use of nitrogen has now exceeded the planetary tolerance limit by x2.5.
The problem with excessive use of nitrogen must be solved if we are to find a solution to the planetary crisis.
This has been a major motivation in the development of the SyreN System portfolio.
This is illustrated in the name SyreN, which is a Danish word game:

SyreN

S = Sulphur

Syre = Acid

reN = clean

N = nitrogen

The short version of SyreN mission is:

Increase of organic Nitrogen Utilization Efficiency - NUE

1 kg. increase in the NUE of organic fertilizer is a direct reduction of 1 kg. of mineral nitrogen fertilizer. The reason is that the two types of fertilizers are use simultaneously.
With efficiency increase in the use of organic slurry, there is less need/use of supplemental mineral nitrogen fertilizer. In other words, 1kg improvement of organic NUE = 2 Kg improvement of total field NUE
A 100 % implementation of SyreN System technologies will result in an app. 5 % reduction in world GHG. It will eliminate problems from +20 % of organic nitrogen and result in a +20 % reduction in use of mineral fertilizer. It is a world impact game changer.
It is a certified- and well documented product, that is easy to scale when the markets is ready to accept responsibility for change and a reduction in pollution.

The problems addressed by SyreN System are:

- CO_{2e} Green House Gas emission
- Loss of biodiversity
- leaching of nitrate
- Air pollution
- Farm profitability

CO_{2e} Green House Gas emissions
GHG from agriculture is a very diffuse problem. It happens everywhere and for a multitude of reasons, so it is not possible to find one technology for its remedy.
The most efficient and agreeable method to stop GHG is to make plants absorb more CO_2. That is what all agriculture wants. Some technologies, that may produce a better yield and thus bind CO_2, are not always preferred as they may represent an investment, or they may be considered difficult- or time consuming to use. In addition, all technologies for improvement of the use of organic NUE are in competition with the price of mineral nitrogen fertilizers.
All farms need to manage their use of nitrogen and because nitrogen is the single largest expense, and it has the highest impact on yield (income). The new addition is to include the losses/emissions in the management thinking and not just the economy. It is the area where most attention should be focused, and accounting of nitrogen losses will become a “license to produce” in the future. The nitrogen loss indicator on e-missioN system is also a visualization of the GHG and the data may be used directly for GHG accounting.
Nitrogen is part of the nitrification- and denitrification processes. This is the soils decomposition of nitrogen. That happens if nitrogen is not absorbed by plants. In Denmark, it is estimated that 40 % of CO_2 from agriculture originates from nitrogen as N_2O – laughter gas – a side effect from nitrification and denitrification processes. Other countries have less surface percentage in agriculture use, but FAO estimates that agriculture is responsible for 17 % of world CO_2 emissions, so this source amounts to app. 2 % of world climate gas emission. Another nitrogen decomposition by-product is nitrous oxides emissions. They take different forms during decomposition and emit as nitrous gasses. The volumes and chemical formular are varied and in addition to GHG_{2e} effect, they are an air pollutant.
Methane GHG_{2e} is related to etheric livestock emission and emissions from slurry storage. SyreN System does not address the etheric emissions, but it may reduce the Methane GHG_{2e} from storage management. This is another 20 % of agricultural $GHG_{2e.}$ The effect of Methane is x40 and emissions from manure management it is equivalent to 1 % of world CO_2 emission.
The production of mineral nitrogen is based on natural gas. This source of GHG is almost 1.5 % of world energy consumption and thus an indirect CO_2 emission of nitrogen.
With the known GHG_{2e} reduction potentials, a full use of SyreN System with 2.5 billion m3 slurry, may reduce world GHG with up to 2 %.

Loss of biodiversity

The excess use of nitrogen is a direct cause of destruction of the aquatic environment. Leaching of nitrogen from fertilizers all over the world is causing algae blooms – including in Denmark. 60 % of the Baltic Sea is dead because of eutrophication or more precisely hypertrophication, which is the depletion of oxygen in a body of water, which kills aquatic animals. It is a marine response to the excess nitrogen nutrients.

Eutrophication is also land based. Airborne ammonia emission from slurry application is a source of nitrogen fertilizer. It is known to change plant growth in nitrogen sensitive habitats. The competition from more nitrogen demanding plants, destroy these habitats, that are breeding ground for special insects and birds.

Leaching of nitrogen

In natural environments, organic material is decomposed all year long and released for plant uptake with different volumes depending on temperature, moisture availability and much more. In the period of plant growth, it will be absorbed by plants and recycled to new organic material. Nitrogen as nitrate, is water soluble and if it becomes plant available in a period without plant growth, or there is too much of it, it will move with the water below the root zone and it will be lost through leaching to the ground water as a pollutant.

Agriculture's dilemma is that the seasons climatic conditions are very dynamic. That makes it difficult to know how much nitrogen volume is correct for a particular season. A 30 % variability in nitrogen uptake between different seasons is normal. That makes dosage management and variable Rate application (VRA) key technologies for reducing leaching of nitrogen by choosing the correct dosage rate of nitrogen and varying the dosage rate according to soil potential.

There is also a choice between different chemical forms of nitrogen, where both ammonium and nitrate are plant available forms. Ammonium has the advantage of a temporal binding to the soil and avoiding leaching, but bacteria will feed on it and reduce it to nitrate. This process can be delayed by use of nitrogen inhibitors. They extend the period of nitrogen as ammonium and avoids leaching through the soils.

Air pollution

Most of the nitrogen in slurry is ammonium. Ammonium and ammonia are in a chemical equilibrium when dissolved in a liquid like slurry. The pH value decides how much of the ammonium is ammonia. The ammonia is a gas form, and it will dissolve into the atmosphere if allowed to do so. App. 40 % of the ammonia gas is lost to the atmosphere, where it will merge with Sulphate or Nitrates, that are by-products from fossil fuel burning. They form ammonium sulfate and ammonium nitrate. Both are fine particles, also called particulate matter PM 2.5

PM 2.5 is a very dangerous air pollutant that has the capability to penetrate through the lungs into the blood stream. The contribution of ammonia to PM 2.5 air pollution is estimated at total of 40 % in EU, where this source is responsible for +120.000 premature death in EU pr. year.

Ammonia is also a direct pollutant to the environment – ref. biodiversity loss and eutrophication.

Farm profitability and market dilemma

The focus for SyreN System is not only on the GHG_{2e}- and the negative environment effects. Any increase in NUE is a monetary benefit for the farmer in both increased yield and savings on purchase of mineral nitrogen.

A major part of the reason for the poor use of organic NUE, is that it has been more expensive to increase the NUE from organic fertilizer than to purchase mineral fertilizer to replace it.

With the focus on the GHG problem and the environmental pressures, many legislative measures to increase the NUE has been introduced. However, the only truly effective one, is to make it profitable to do so!

A significant price increases of natural gas have increased the price on mineral fertilizers. This has created a renewed focus on the NUE from organic nitrogen to replace the mineral nitrogen and it has made the technologies to do so much more profitable / attractive for the farmer.

Historically, slurry has been seen as a waste product suited for deposit as the fertilizer value was unreliable. With SyreN system and other technologies, this is a problem of the past, but there is a need to change the mindset of many farmers. On an EU basis, there is need for education / information on all levels in the stakeholder chain. The missing link, is that the fertilizer industry does not take ownership of the problem with organic slurry. They are keenly aware of the environmental problems, and they all have strategies to improve the NUE of the mineral nitrogen – better formulation, digital agriculture with VRA technology and more, but at the end of the day, it is the organic nitrogen that needs improvement and they do not get involved with that.

There is a real long-term risque for the fertilizer industry in Europe if the problem is not solved and the political- and consumer trend towards ecological farming continues. That will minimize the use of mineral fertilizer and result in an upside for SyreN system technologies.

Long term, it will help to reduce the volume of slurry by shifting to a vegetable human diet, but it is not very realistic. A growing consumption of meat is most likely to be the result of a growing human population although there may be a trend towards a more diverse consumption.

Ownership dilemma

An important segment for application of slurry is contractors / custom applicators.

In Denmark, contractors apply 85 % of all slurry. In Germany, it is estimated at 30- to 40 % and less

in the rest of Europe.

Contractor with 4 SyreN units and 21 slurry tankers

The contractors are normally very rational business partners. They will do what the customers are willing to pay for.
But there are problems with the operational management of the NUE.
Slurry application is often a marginal business. Farmers with excess slurry application capacity often offer this as a service to the market. This makes the market highly competitive for the professional contractor.
The contractor slurry equipment are very expensive machines (+200.000 €) and with a very high output. Their capacity must be used at an optimal level. A contractor carries min. 40.000 m3 and up to 150.000 m3 pr. machine, where a farm machine is typically smaller- or a secondhand machine and they are used from 5.000 - 10.000 m3,
In the peak of the season, their engagement is 24/7 and they will not stop except when bad weather conditions dictate them to do so and sometimes on Sundays – if they can see the end of the season.
To respect a low NUE is bad news for profitability of the slurry spreader. If a law was to enforce the mandatory fertilizer accounting levels of 75 % cow- and 80 % NUE for pig slurry in Denmark, it would require more than x2 capacity for slurry application. This problem is not as pronounced in countries with farmer owned slurry tankers. With farmer owned machines, the problem becomes to give priority to slurry application when the climatic conditions are ideal.
For both groups, the price of modern high technology equipment does require a high output of the machines. The side effect of limiting the capacity of the machine to be use where the climatic conditions are in favor of slurry application, is a negative capacity cost for the contractor that outweighs the positive NUE effects. So, both farmer- and contractor segments have a problem to limit the use of the machine to periods where a high NUE can be guaranteed.
This is one of the situations where SyreN is an ideal technology for a remedy of the problem. Eventually, the market mechanisms will find a way to regulate this.
Restricting the slurry tanker capacity according to NUE, is likely the most single effective GHG emission reduction measurement available in agriculture.

The regulative drivers
The latest EU reform of the common Agricultural policy (CAP), has adopted a strategy to reduce the loss of nutrients with 50 %, resulting in a reduction in use of nitrogen with 20 %. 25 % of the area subsidy is to be withhold. To release the payment, it must be used for sustainability purposes. This corresponds to 12.5 billion € pr. year from 2024. The individual member states decide for which purpose the funds are distributed, but a good guess is, that technologies for reduction in GHG- and loss of nutrients, is top of the list all over Europe.
The structural changes in the market cannot be addressed by SyreN System. However, the remaining volume of slurry, can be certain to be meet with increased regulation for its use to become sustainable.

The German market is the driver for EU by its seize alone. It is the largest animal husbandry market and with its biogas industry, it needs to dispose of 200 Mio m^3 slurry every year. This market has created a specialty problem for itself. By ignoring the EU nitrate- and NEC directives, they have exceeded the limits of leaching of nitrate on 40 % of their area. In addition, the ammonia emission national sealing, has been surpassed by 47 %.
This has caused the EU commission to take Germany to the European high court.
A decision against Germany, has introduced a policy for remedy of the problem by April 2020. If not executed on, the penalty is set at 6 billion € + 850.000 € fine pr. day until executed.
In the policy making, the SyreN technology has a special status as an EU-BAT technology.

For above reason, SyreN technology and open slot slurry injection has been chosen to reduce 16.000-ton ammonia emission by 2025 and 48.000 ton of ammonia emission by 2030. This has been defined in the "Bundesrat Verordnung 216/18" with the decision to subsidize the introduction of the technology with maximum 316 Mio €. A volume estimate to meet this demand, is between 2.000 to 4.000 SyreN Systems. This has so far resulted in an MuP program from 2022 of 3 Mio. €, where 7 Bundesländer will each have up to 3 demonstration machines in a program over 3 years to introduce the technology – a massive fleet of 20 demonstration machines!
To be able to supply and scale-up to this coming demand, BioCover has chosen to enter into a license agreement with Fa. Vogelsang GmbH in Germany. The technology transfer is complete, and the first series has been manufactured in Germany.
BioCover Data continues to be involved in the development of SyreN. Maintenance and development of the software is exclusive to BioCover Data as well as many markets outside of Germany continues to be BioCover Data exclusive.

The SyreN System Technologies
The SyreN technologies addresses the above problems and may contribute up to +50 % improvement in the NUE. On the positive side of the solution to above problems, is that they are existing technologies with a current available- and scalable profile.
The urgent- and most efficient way with which the problems are addressed, is by improving the organic fertilizer NUE. With an increased plant NUE, the nitrogen is not available for decomposition and so the GHG is automatically reduced. The ammonia gas is transformed to ammonium salt and the ammonium is kept available with nitrogen inhibitors. That means that there is far less leaching of nitrogen and up to 40 % less PM 2.5 air pollution. An increase in NUE is also a direct reduction in production- and use of mineral nitrogen.
The pressure on the biodiversity is significantly reduced through much less eutrophication, reduction in ammonia air pollution and leaching of nitrate.

The agricultural machinery industry has so far focused on mechanic solutions for improvement of the NUE. This has been successful, but it is no longer enough. The industry must now look beyond mechanics and implement solutions in addition.
There are 3 technologies available for immediate use:

- Acidification – stabilization of slurry
- NUE – Nitrogen Utilization Efficiency Management
- Nitrogen inhibitors

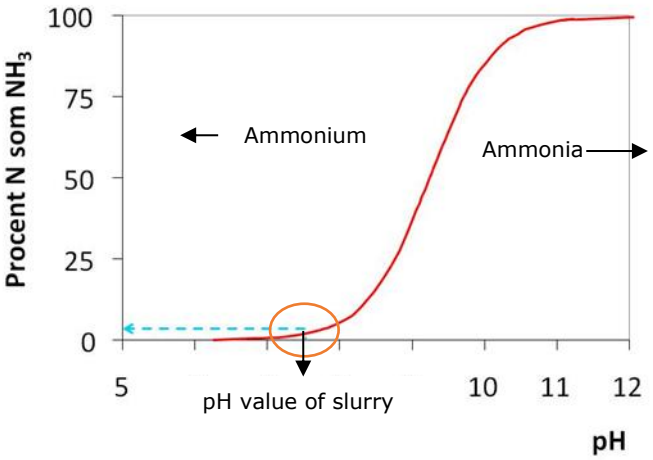
All three technologies are combined in one efficient solution – SyreN technologies. The object is to address all the above problems with one product that contains use of the three different technologies.

This development has been ongoing over a period of 13 years, and it has developed into a series of brands that are all linked to SyreN and makes up the SyreN System.
It may be as an accessory to SyreN or as a separate product that has an option to be integrated into the SyreN System

SyreN

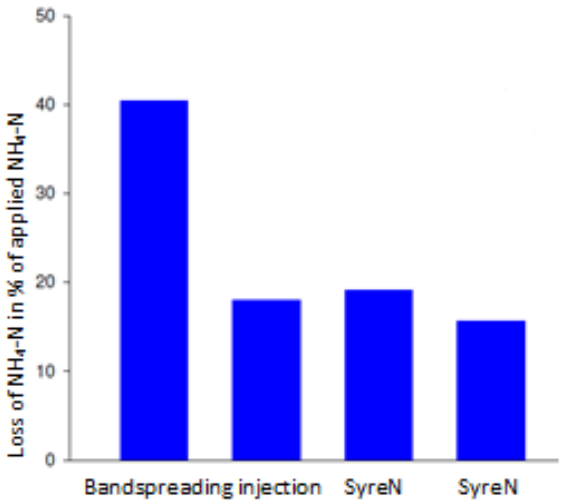
Stabilization of slurry

Ammonia (gas) and ammonium (salt) are in a chemical equilibrium when dissolved in a liquid as slurry. By lowering the pH value, the equilibrium is displaced, and a larger part of the ammonia is to be found as ammonium that cannot evaporate from the slurry. The SyreN system automatically defines and lowers the pH of the slurry. It uses sulphuric acid to lower the pH, as this is 100% environmentally balanced product and the most concentrated and effective acid to lower the pH. The ammonia is thus transformed to ammonium and readily available to the plants after application, when the slurry penetrates the soil. Ammonium is the optimal N fertilizer available to plants and has a minimal loss to the environment as it has a positive charge and binds itself to soils and does leach out.



pH value deciding NH3 or NH4+ (ammonium – ammonia)

A VERA verification done by Aarhus University, has documented a 49 % ammonia emission reduction. In that trail, 2.5-liter sulphuric acid was used at a pH value of 7.8 and a lowering of the pH to 6.4. The volume of acid used, is depending on the slurry pH value and its buffer capacity (Buffer = other chemical reactions than ammonia that consumes acid). In praxis, a very large variation of acid consumption is to be expected, but on average, about 1 liter of acid is used with cow slurry and 1.5 liter with swine slurry. This represents a very good correlation between acid consumption and crop need for Sulphur as fertilizer. There are examples of very high pH values (especially digested slurry) where the acid consumption is +4 liter.



Different income opportunities with SyreN

There are more ways to optimize the use of SyreN system. The chemical process and thus the

Fertilizer effect can be used differently and thus the system is not just part of a better nitrogen utilization Objective.

Effects are:

- Better nitrogen utilization – up to 85 %
- Fertilization with ammonium sulphate – especially in grass and rape
- Addition of nitrogen inhibitor
- 40% increased plant availability of phosphorus
- Reduction in manganese deficiency
- Use of bandspreading instead of open slot injection
- Legislative compliance (EU directives)
- Odor reduction

Extra ammonium nitrogen

By means of the acidification process, ammonia gas is fixed as ammonium salt that cannot evaporate. That means that the volume of ammonium is increased and there is a larger amount of plant available nitrogen. Ammonium is also the best nitrogen fertilizer we know of. This is because the plants are not "force feed" as with water soluble nitrate, but that they absorb what they need when they need it. When the plants absorb ammonium, the shed a H^+ ion, that may help make more phosphorus plant available.
All this leads to increased yield that can be measured in yield trails:

There are a long range of factors that have influence on emissions. This results in a variation between trails and years. Because of this, it is necessary to view yield increases over years. The most influential factors are:

- Volume of slurry
- Amount of ammonia
- Dry matter
- pH value
- Wind speed
- Temperature
- Plant cover
- Soil- and air moisture contend
- Application technology

Yield response following acidification of animal slurry by SyreN technology

Year	No of trials	Yield response Hkg per ha.	pH	Acid use, l/m³ slurry
2010	3	4	6,1	2
2011	4	5	5,9	2
2013	6	3,2	6,3	3,3
2014	4	0,3	6,3	2,6
2015	6	-0,4	6,1	1,9
2016	5	0,7	6,1	1,7
2017	2	6,3	5,8	
Weighted mean	**30**	**2,2**	**6,1**	**2,1**

Martin Nørregaard Hansen, Planteinnovation SEGES

A couple of average effects:

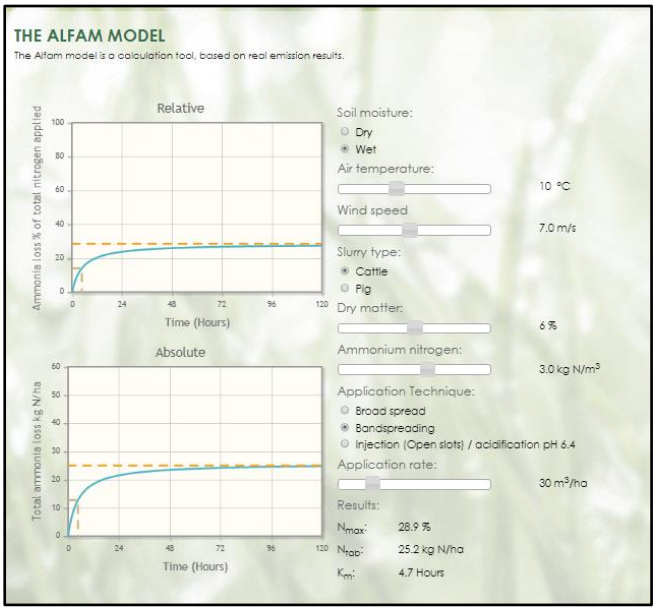
Grass / cow slurry: Emission 18.8% with application in April 30t/Ha = 15 kg ekstra N pr. Ha + 3% yield pr. Ha

Winter wheat / swine slurry: Emission with application in April 24 t/Ha = 10 kg ekstra N pr. Ha + 2.1 Hkg yield pr. Ha

The normal variation can be from 5 kg to 50 kg N pr. Ha depending on climate and above-mentioned conditions. It is possible to estimate the effect of SyreN technology, but it is always important to remember, that it is the conditions on the day that decides. 60- to 80% of emissions happen within the first hour. This is also reflected in the yield trails above from 2010 – 2017, where variations from 0 to 26 % in increased yield were measured and with a yield variation from -0.4 to + 6.3 hkg

The ALPHAM Model

A good help to estimate the ammonia emission on a given day is found in the ALPHAM model. It is a database of +2000 ammonia emission trails. It contains descriptions of which parameters are important and which weight they have in in the estimation and leaves a good overview of how much nitrogen is lost.
On days with wind and high temperatures, emission may total as much as 30-50 % of the total volume of nitrogen. On such days, the economy of using SyreN System may increase a factor x2.
On days with low temperatures and no wind, it may not be feasible to use the system, so there is a lot of good management praxis in optimizing when- and how much to use SyreN system



The ALPHAM model may be found at www.biocover.dk

Fertilization with Sulphur

Sulphuric acid is very well suited to be used as a fertilizer. It contains 577 g Sulphur pr. liter and in the process of lowering the pH, it is converted from H_2SO_4 to SO_4 – sulphate, which is direct plant available. It is thus an excellent fertilizer, inexpensive and easy to dose with the right timing. As there is hardly any plant available Sulphur in slurry, it may well make a mineral NS dosage redundant in grass and rape.
For winter wheat, 0.9 liter of sulphuric acid pr. m3 with an application of 30 ton / Ha is used and for rape 2.1 liter is used with 30 ton / Ha. In the SyreN system terminal, a series of charts identifies the need for different crops depending on crop type, dose rate and soil type. From this list, some typical recommendations can be seen here:

Crop needs for Sulphur

	S-need, kg pr. ha	*Typical amo unt of slurry, ton pr. ha*	*Needed kg S pr. ton*	*Liter H_2SO_4 pr. ton slurry*
Winter wheat, clay soil	15	30	0,5	0.9
Spring barley, sandy soil	10	30	0,3	0.6
Winter rape, clay soil	35	30	1,2	2.1
Silage grass, irrigated sandy soil	30	40	0,8	1.3

(Source: Torkild Birkemose – Videncenter for landbrug)

In the period from 1960 to 2000, agriculture has benefited from a background deposit of Sulphur from coal burning of up to 300 kg S pr. Ha. This deposition is reduced to only 2-3 kg S / Ha today and as a result, Sulphur deficiency is common and may first be visually identified when a +20 % deficiency is a reality. There is a large difference in crop need for S. Both wheat and rape need Sulphur early in the season. To fertilize with Sulphate through slurry may save a passing of the field to compensate for the lack of Sulphur in slurry. Sulphur in slurry is often emitted as hydrogen sulfate (H_2S – rotten eggs). A loss of 20 % is not uncommon and it leads to variable plant availability. Sulphur in digested slurry has been immobilized through the fermentation and what ends up in the gas is cleaned out later in the process.

Sulphate is water soluble and thus exposed to leaching along with nitrate and must be applied every year. The Sulphate in sulphuric acid is price competitive pr. kg compared to other mineral fertilizers and the spreading of it through slurry makes it quickly plant available. A fertilization plan to replace ammonia sulphate could look like this:

Conventional fertilizer strategy:				
Slurry + 80 kg N / Ha - NitroStar (NS 28-5)		90 Euro/ Ha		
Slurry + 80 kg N / Ha – sulphur ammonia (NS 21-24)				109 Euro /Ha
Alternative SyreN acidification:				
Slurry + 80 kg N /Ha - N-34 Svovlsyre 30 m3 - ca. 1.5 liter x 2.50	75 Euro / Ha 10 Euro / Ha	85 Euro / Ha	75 Euro / Ha 10 Euro / Ha	85 Euro / Ha
Difference in cost pr Ha.		+5 Euro / Ha		+24 Euro / Ha
Source: Torben Viuf, Sønderjysk landboforening				

In addition, the strategy of using sulphuric acid as an S fertilizer in slurry has the potential of reducing ammonia emission with 50%, at the same time as being an extremely cost beneficial system and the only known sustainable alternative to injection of slurry into the soil.

Manganese deficiency treatment

Manganese deficiency follows a too high pH value in the soil – often seen as large spots in the field after lime application or inherent to specific parts of a field. To remedy manganese deficiency, ammonium sulphate as fertilizer is often recommended. Addition of sulphuric acid to slurry has an identical effect but for such an application it must be assured that the pH value is lowered to 5.5. A trail test revealed a 26 % yield increase in winter wheat.

Sulphate for rape

Rape is of the species brassica that is known to smell like cabbage or Sulphur. Not surprisingly, it is a crop that needs a lot of Sulphur. Also for rape, sulphuric acid in slurry may substitute price heavy ammonium sulphate, which is often needed to supply the rape with enough sulphate. Since the amount of sulphate is variable with addition of sulphuric acid, it is easy to dose individually. Test have shown that rape often responds with significant yield increases up to 6 liter of sulphuric acid or app. 100 kg S/Ha.

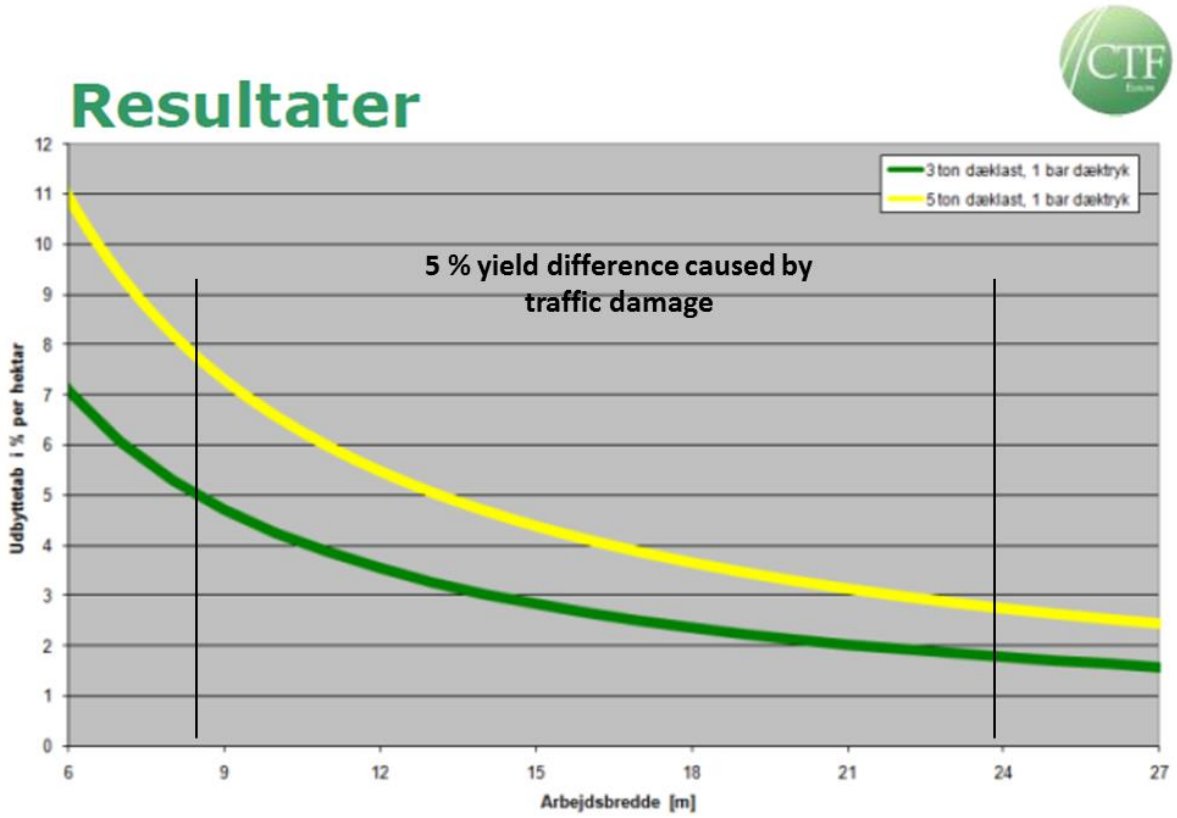
Sulphate for grass

Grass is the crop that responds most favorably to acidification. This is due to a combination of factors, where climate is the main cause. Slurry for grass is often applied after cut in the summertime, where it is warm, dry and without any plant cover. This leads to a significant higher emission in grass than with fertilization of small grains in springtime and thus a higher effect. In addition, grass may consume a larger amount of nitrogen than grains. Grass has a very tight netted and deep root net, so the risqué of leaching of nitrogen is less. Like rape, it has an appetite for sulphate where a dose rate of 40-50 kg S/Ha ensures maximum yield. Acidification has also proven to be very valuable in decomposition of the organic matter following rotation of a field.

Use of bandspreading in lieu of injection

Advantage band spreading with SyreN	Advantage grass injection
• Wider work with gives 50 – 66 % reduction in traffic damage from slurry tanker • 100 % reduction in tine damage in grass • 24 – 36m working with – app. 25 % increased capacity for slurry application • Certain and good operational economy with acidification • Unchanged need for HP power / diesel • Less structural damage because of heavy traffic • Better weight distribution between tractor-slurry tanker • No risqué for drought damage with exposed grass roots • No wear parts with soil exposure • Longer life time for grass fields • Increased window for slurry application (independent of emissions) • Climate gas reduction (no N_2O emission)	• No transport- or storage of sulphuric acid • Reduced risqué of slurry dry matter transport back to barn.

Economic incentives and user advantages are huge when comparing acidification with band spreading to grass open slot injection. Both systems reduce ammonia emission on about the same level but that is where the comparison stops. In general, it can be said that acidification always works, where grass injection does not when the slurry placement is too shallow because of dry soils.



The most significant economic difference is in yield reduction caused by traffic- and tine damage. This effect is because of bandspreading uses 24-36m working with and grass injection with 6-12m

Below is an estimate of the cost between the two technologies:

Band spreading of acidified slurry compared to grass injection, before 1 cut, 25 to slurry pr. Ha			
	Band spreading 24 m SyreN	**Injection 12 m**	**SyreN-injektion Euro pr. Ha.**
Increased cost	2,0 l sulphuric acid pr. m3 cow slurry 25 cent pr. l	0	-21.00
	Application cost 0 cent pr. m3	0	0
S fertilization value	25 kg / 0.33 cent pr. kg	0	+ 8.25
Traffic damage	175 Fe pr. Ha 0.14 cent	350 Fe pr. Ha 0.14 cent	+ 25.70
Crop damage	0 Fe pr. Ha	480 Fe pr. Ha	+ 70.40
Difference			+ 83.35
(*Flemming Hedegaard, Byggeri og teknik*)			

More plant available phosphorus – use of slurry to replace start fertilizer for maize.

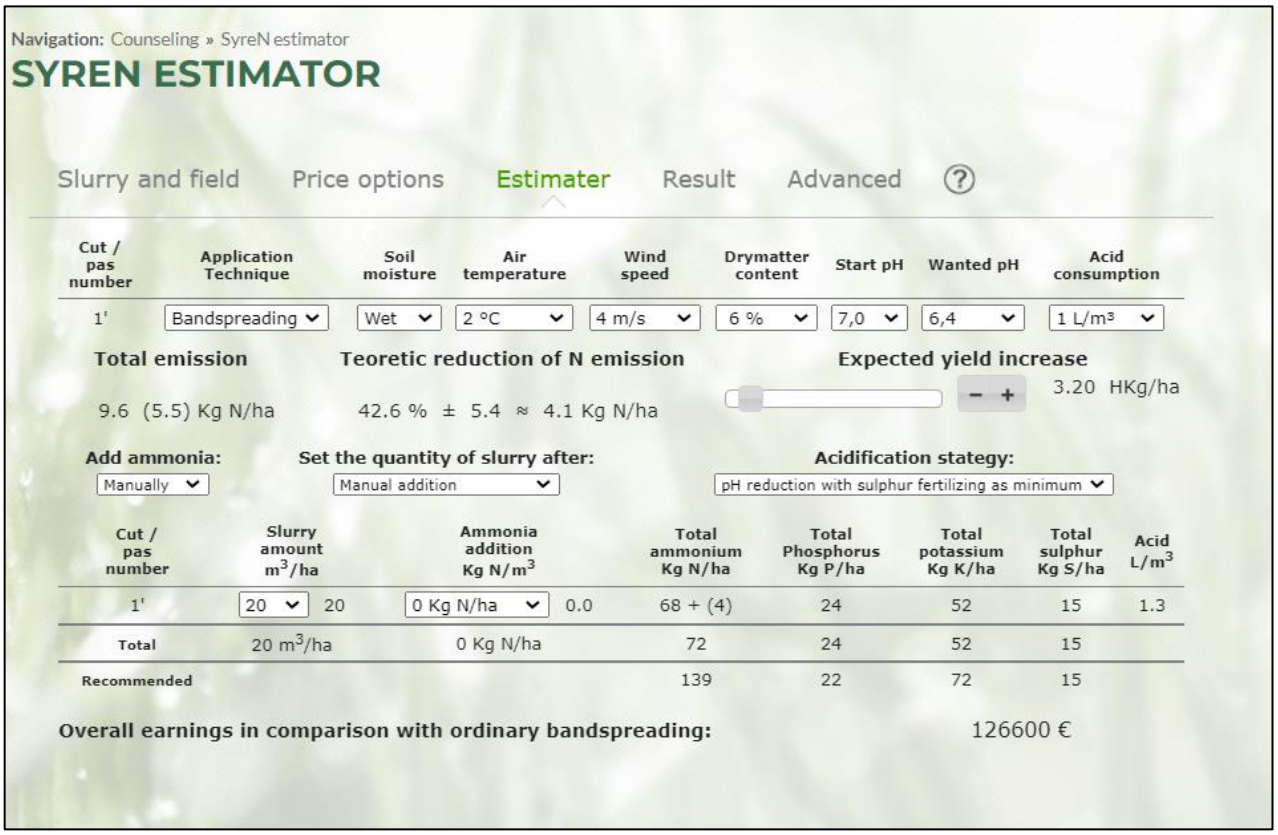
Slurry analysis has showed up to 40% more plant available phosphorus with acidification. Maize is a crop that requires a lot of phosphorus. Normally, there is plenty of phosphorus in slurry, but it is not immediately plant available and therefore mineral phosphorus is added as a starting fertilizer during sowing. Because of the higher plant availability, the starter fertilizer can now be replaced by acidified slurry. A number of studies have shown that acidification of slurry to PH 6.5 is releasing bonding between Calcium and phosphorus and transforms up to 40% more phosphorus in slurry to plant available phosphorus. The slurry application must be guided with RTK GPS and the maize seeds sown at a distance of 5 cm from the slurry approximately one week later. This makes sure that the large quantity of liquid in the slurry does not inhibit the germination of the seed.

Use of Lime with acidification

The use of acid can affect the Soil's pH buffer. Studies have not been able to measure a change in the soil pH buffer when using sulphuric acid, but theoretically 1 liter of sulphuric acid will consume app. 1 kg of lime. The Soil´s natural pH must be below 7 for lime use to be relevant and acidification can also be used to purposely lower the soil pH in the event of a high soil pH.
With digested slurry where the pH is above 8, the lowering of the pH is regarded as an advantage for the soil pH as this level is too high for soil ion exchange.

SyreN economy

Much of the above is difficult to summarize in an economy calculation. There are a great many variable parameters that needs to be identified to know before it is possible to create an overview for each individual farm. Biocover has therefore made an economy calculator based on the above ALFAM model and the financial parameters to be added / estimated before a statement of earnings. In the internet based program, default values have been inserted, meaning that standard values have been entered that can be used if no budget figure / knowledge is at hand. An example thereof is the amount of nitrogen in the slurry. If there is no slurry analysis available, the norm for each barn type/livestock can be used by clicking on the type of barn at hand. This results in values being entered automatically.

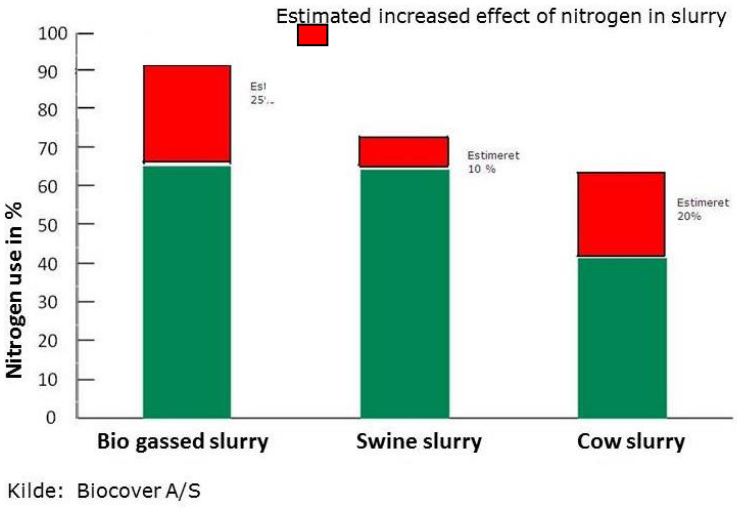


Example of earnings of 200 Ha of silo maize by lowering PH to 6.4 and using 1.5 liters of sulphuric acid

Estimater can be found at Http://www.biocover.dk/radgivning/syren-estimater

Part of the SyreN Systems impact does not relate directly to the farm but to societal impacts of slurry application. Therefore, specific legal framework conditions for the use of the SyreN System implemented in many countries. In Denmark for instance, injection or acidification has been made mandatory on grass and black soils and it is also expected to become mandatory in Germany from 2025. It is difficult to estimate a value on biodiversity loss or increased leaching of nitrate, less CO_2 emission or environmental planning permit. The Estimater program is therefore based on the factors that apply to all farms – added yield and value of Sulphur as fertilizer. The framework conditions may be the factor that creates a decision on the use of the system, but the scope of use should always be the subject of an analysis of costs vs. earnings. It is important for estimator, that correct budget values are entered – especially volume of slurry, value of crop and volume of increased yield are key figures.

Environmental legislation.



Kilde: Biocover A/S

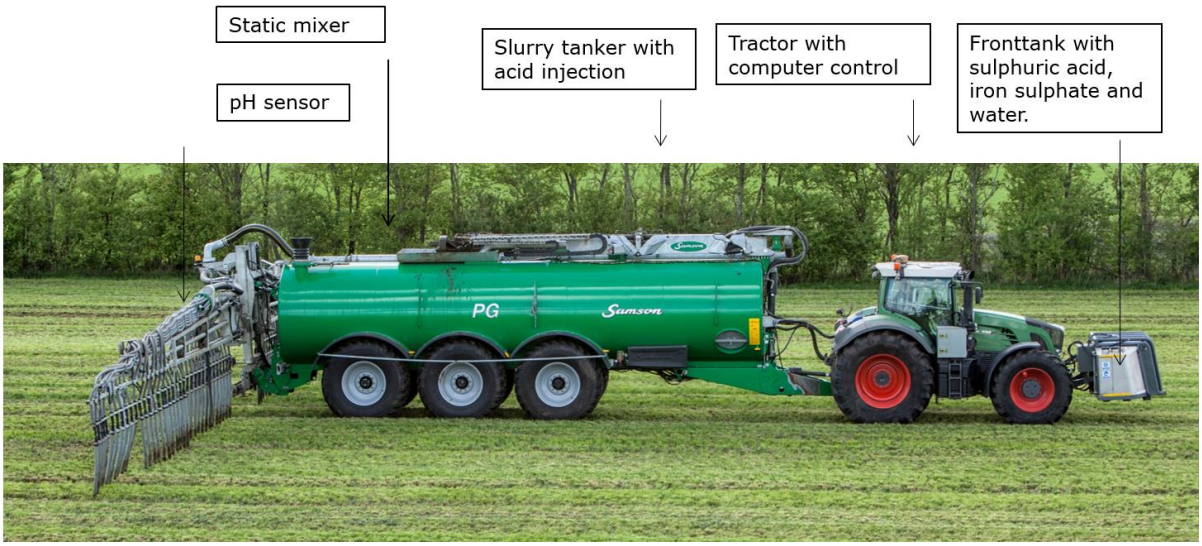
All EU member states are required to reduce ammonium emissions through the NEC (National Emission Ceiling)

The NEC directive aims at reducing air pollution. When ammonia escapes into the atmosphere as gas, it is part of forming Particulate Matter ($PM_{2.5}$ and PM_{10}). Those particles are allergy- and cancer forming and the cause of a range of respiratory illness. The EU estimates that air pollution is causing 460.000 premature death pr. year and PM pollution is responsible for +40 % of the health-related costs of particulate pollutants, which make a negative contribution to the Danish economy of 170 million DKK pr. year.

The nitrates directive limits the amount of nitrate leaching to groundwater, lakes and rivers. One of the important limits is a max dosage rate of 170 kg nitrogen per ha / year from organic fertilizer. A higher utilization rate of nitrogen in slurry is therefore a necessity for many farm / biogas digesters in need of finding farms / fields for application of slurry. This is caused by the receiver of the slurry needs to be certain of the effect when it is recorded into the farm fertilizer accounting. In addition to the acidification effect, SyreN System enables the use of nitrogen inhibitor that creates an average less leaching into the groundwater of app. 3 kg N/ha pr. Year.

SyreN Product:

The SyreN System is constructed for mounting on all types of new or existing slurry tankers. The system is designed with the highest safety standards in mind and that the operation of the process does not encompass a risk from its use and while the function and effect can be documented to authorities.
Installation and use of the components does not interfere with the operation of existing products, nor does it add much in terms of operation of the slurry tanker.



The SyreN System in front of the tractor contains tanks for sulphuric acid, additive and water. The System has a hydraulic drive for the acid pump and electric drive for the additive system. I tis constructed around the use of an IBC tank for transport of sulphuric acid. This "cassette system" ' insures that there is no overfilling of acid from a storage system – which can be a dangerous and time-consuming operation. Instead, the operator placed inside the cab of the tractor, operates the tractor with the SyreN front unit and pick up the IBC tank and thus avoid any danger with filling of the IBC tank. In addition, this is a very quick way to refill the system for continued operation. It should take no more than 4 minutes to change the tank. The coupling of the IBC tank to the SyreN System is made via a dry coupler with no exposure to contact with acid. When the IBC tanks needs to be refilled, the sulphuric acid is ordered from distribution tankers with IBC tank filling equipment. That means the IBC tanks becomes a storage facility where there are no residues as any remains in a tank are simply part of the replenishment of the tank.
When detaching the system from the tractor, the system is fitted with dry couplers and operators are instructed to use water from the water tank with the last load before detachment so that the system is filled with water when it is detached and left for storage

Transport legislation

Sulphuric acid is registered as dangerous goods. That means it must be transported according to the international ADR convention. However, agriculture has an exemption to the ADR regulation. In general, when a tractor is operated in combination with an implement - like a slurry tanker - it is a work operation and that is exempt from ADR, so in principle anybody with a driver's license may operate the SyreN System. They may not transport the IBC containers on a trailer as this is a transport operation which is subject to ADR regulation.
A complete set of ADR safety equipment is available as an accessory for countries where ADR is an issue.
The transport legislation has different restrictions to be observed in each country as well as safety precautions for storage of the IBC tanks. This is a comprehensive list, and it must be observed in the user manuals which list the individual requirements or each country.

Courses and training

BioCover organizes training in use of the SyreN System and the agronomics behind the effects of using the system. This is normally a 2-day course with one part specific to health and safety of using sulphuric acid and the other part with focus on fertilization, use of sulphuric acid as a fertilizer and the effect of the system in relation to different climate conditions.

Fitting a system to a slurry tanker

The delivery and fitting of the SyreN System to a slurry tanker does require some minor modification to the slurry tanker, which can be undertaken by 2 fitters in a two-day operation. The hoses or the slurry tanker must be ordered when the slurry tanker has been identified, as the

individual length of the hoses for acids and additives may differ considerably. Depending on tractor model, trays for protection of the hoses under the tractor may have to be constructed individually.

Research and plot trail work

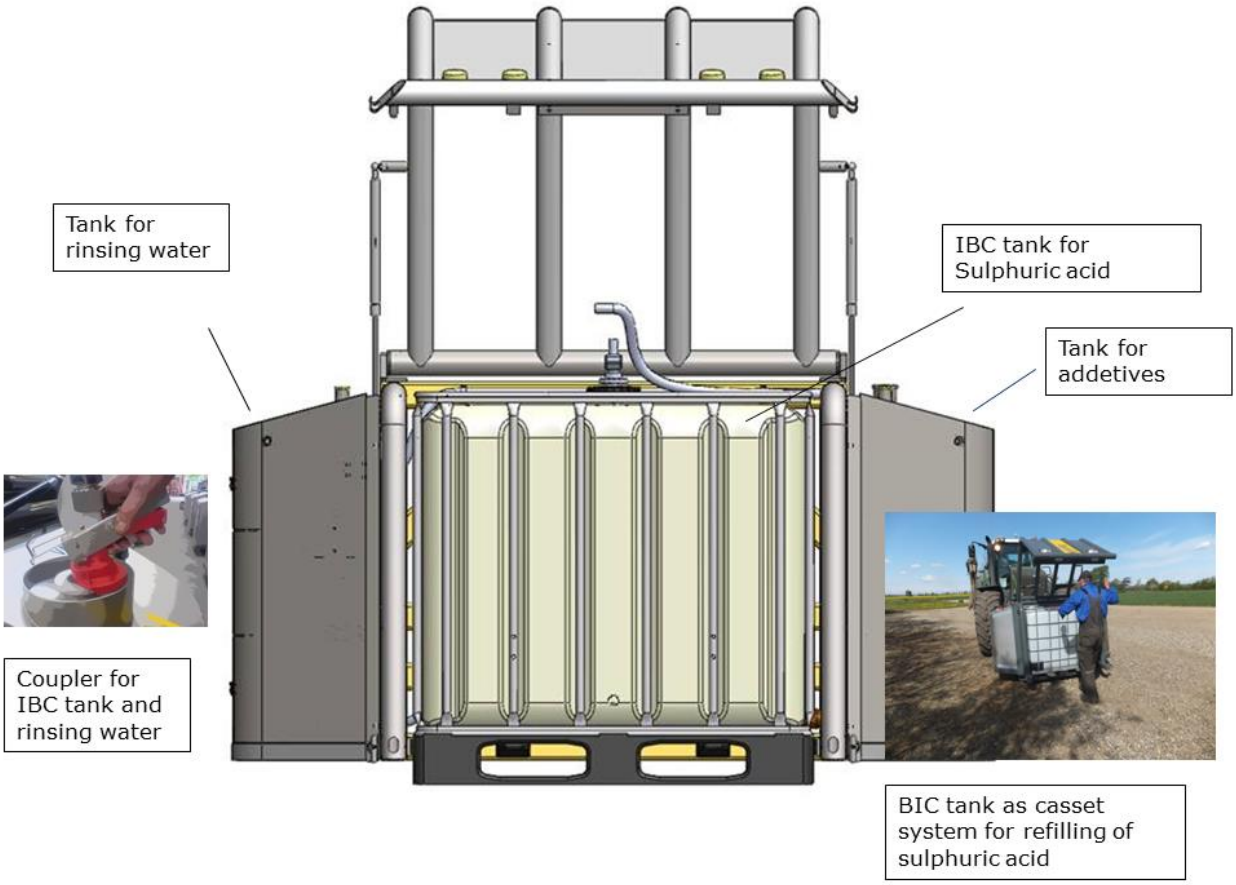
SyreN System has safety measures build into the operating system. It cannot add acid unless it has:

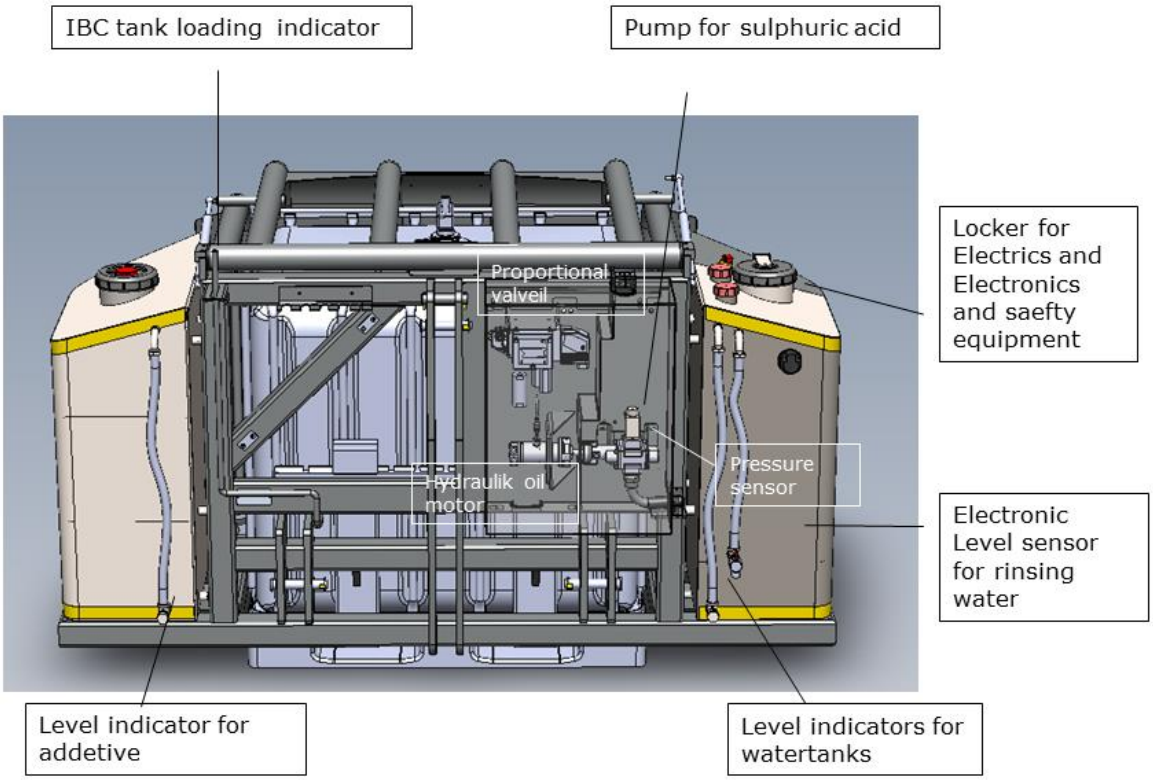
1. Speed
2. There are min 2 m3 volumes in the flow sensor
3. The three-way valve is set to empty tank. This makes it difficult to use as a plot trail system.

There is a special software version of SyreN available for research- and trail work. Please see separate brochure.

Front Tank

Strong gas pressure cylinders hold the door in place when changing the Pallet tank and a fixed extra coupler shoe, eliminates the possibility of acid spillage- or contact.
The Front linkage system is constructed with extra safety dimensions and thus is collision-proof.
The operating system is an Isobus system, and the operation is therefore integrated into the Tractor's own functions such as turn signals, traffic lights and working light. The control is operated through the Tractor's integrated terminal. Alternatively, the SyreN system can use a separate Isobus terminal.





Sulphuric acid Pump

Pump is a displacement pump in Stainless Steel 316 L with internal components of special sulphuric acid suitable alloys and plastics. The displacement pump is selected because of a wide range of Variable Flow and good self-priming ability. It is powered by a Danfoss hydraulic oil motor with PVG valve and has a capacity of 25-liter oil pr. minute.

Addition of sulphuric acid

Sulfuric acid can foam very strongly by the addition of sulphuric acid – especially biogas slurry

Two strategies for adding sulfur are used:

- Sulphuric acid as Fertilizer
- Sulphuric acid for lowering PH value

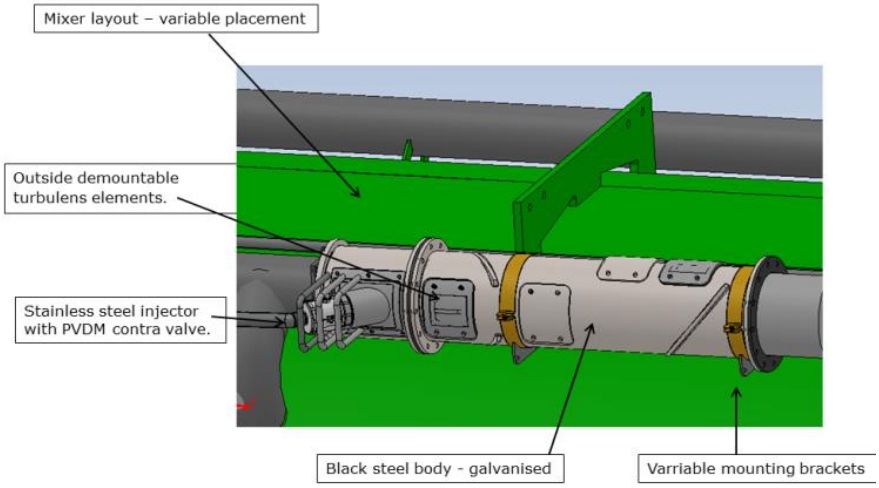
When sulphuric acid is used as fertilizer, the liter/m3 must be entered into the control Program. The SyreN System management program contains tables where it is possible to determine the quantity of acid needed in relation to the crop, number of m3 and soil type. The amount is automatically translated into rotational speed of the oil engine, thus allows the pump to dose the required amount of acid per cubic meters. The system continuously measures the amount of slurry through the flow meter or the slurry pump of the slurry tank and automatically adjusts the acid volume after m3 slurry pr. minute.

Sulphuric acid can also be added according to pH value of the liquid. A dose rate, like VERA recommended pH 6.4 must be entered into the program. By start of a new job, the system will

apply a variable rate from 1-5 m3 without adding acid. During this process, it reads the current pH in the liquid and locks this into the memory. Following, acid is added gradually until the target value has been reached. The equivalent amount of acid to the pH, is then added as long as the job is active.

The automatic determination of dose rate according to pH is ideal for reducing ammonia emission, thereby adding an extra amount of ammonia nitrogen to the crop. This is also the ultimate method of reducing eutrophication of nitrogen sensitive nature. The lower the pH, the less emission. The pH level 6.4 is an economical optimum with app. 50% reduction. The reduction increases all the way down to pH 5.5, where emissions are almost nonexistent.

Sulphuric acid Injector



The Sulphuric acid injector is placed at the rear of the slurry tanker. It is made of heavy dimensions because of the powerful reaction caused by the dissolution of the acid with the liquid. It is very important to get the acid mixed into the full amount of slurry very quickly, because the liquid is split into two directions only milliseconds after injection and because the acidity of the acid must be eliminated before the liquid reaches the ground. After injection, turbulence in the liquid slurry and the slurry distributers make sure the acid is evenly mixed between the band hoses/applicators. Injecting acid into the slurry tanker is not possible because the many chemical reactions that takes place, produces foaming and pressure. This makes control of volume of slurry impossible as well as pumping a foaming liquid is not possible.

PH sensor

The PH Sensor is an important part of the system. This provider assurance of the effect of the addition of acid and provides the documentation often requested by authorities. When using the program part to target a PH value, it is a key part of the process to identify the right amount of sulphuric acid. The PH sensor is located after the distributors to measures the slurry after addition of acid and shortly before application to the field. It is important that the PH sensor is always immersed in a liquid. Otherwise, there is a risk of drying out, thereby losing its precision. For this reason, the pH sensor is therefore located in a specially designed box that allows the sensor to measure in the slurry flow during application and at the same time be immersed in liquid when no slurry flows through the system. The PH sensor head lifetime is limited to 1 year and must be replaced each year.

Slurry Sump with PH sensor

Safety

Every imaginable precaution has been taken to create a 100% safe system. An important element of safety is good operating routines, starting with a 2-day course for users.
There are 3 step requirements to activate any injection of acid

- A job and name must be entered and activated
- There must be speed on the tractor
- A min. flow of 2 M3 must be measured in the flow sensor
- Three-way valve for slurry direction must be left on empty
- PTO sensor shall display revolutions (Isobus systems)

This safety combination for injection of slurry has made sure that we have never seen any damage from acid. To prevent anyone from getting in contact acid while changing an IBC tank, a dry coupler handle together with a coupler shoe welded to the IBC tank has been chosen. A second coupler shoe is situated on the side of the IBC tank with direct access to the water tank. When the IBC tank is removed from the SyreN system, the coupler handle is simply parked at the second dry coupler shoe and the IBC tank can be safely removed from the SyreN system. If the SyreN system itself is being detached, the coupler handle must be attached to the parking shoe. A Flushing Program is then activated on the terminal in the tractor cab during the last load of slurry application. The acid pump will then be activated at the highest speed for 1 minute, injecting water from the water tank. This ensures that the system is completely emptied of acid and any residual amount is neutralized with water. Thus, the system can be safely detached from the tractor using the stainless-steel dry couplers between SyreN system and the tractor.
In addition, protective gloves, glasses, and safety aprons are mandatory to use in all interaction with the system and the equipment are in the safety locker on the side of the front tank.

Figure Side cabinet on SyreN with electronics and safety equipment

Terminal Control Unit/Software

The SyreN control system is developed according to the standard of communication between tractor and implement – Isobus. Isobus enables SyreN System to utilize a lot of the existing electronic equipment on the tractor, like the tractor terminal and several of the tractor sensors. This means a very good integration of the controls into the tractor cabin and less wiring. If the tractor does not use the Isobus standard, a second terminal is then installed to operate the SyreN system.

John Deer touch screen with SyreN software uploaded

Data acquisition-GPS/GSM

A perpetual source of problems is the collection of data for documentation. This function is optimally solved with SyreN System. The system has an integrated mobile phone with a built-in GSM transmitter. This includes a GPS and it is connected to all information via the Isobus. It logs a large number of data every 10 seconds and send them online to a server. This is a large amount of data, among others:

- Name of Customer and field
- Quantity of slurry delivered per job
- PH value before application and during application
- Amount of sulphuric acid consumed
- Hour

Map with slurry tanker tracks easily identified

The position of the slurry spreader can also be monitored online on the internet while it is spreading slurry in the field. With the included log-in, data such as the position of the slurry tank and various operational information can be monitored continuous.
When a job is reported as finished on the slurry tanker terminal, the job data are available as a data file or a report for download on the server. The data acquisition system is an optional extra on most markets – Ref. e-missioN product page 44.

Field size	98,64ha
Applied slurry	3085,4m3
Avg	25,5 m3/ha
Applied N	80,9 kg N/ha
Emission kg NH3	10,5 kg N/ha

SyreN Light

SyreN for smaller slurry tankers

SyreN Light is built by the same components and technologies as SyreN

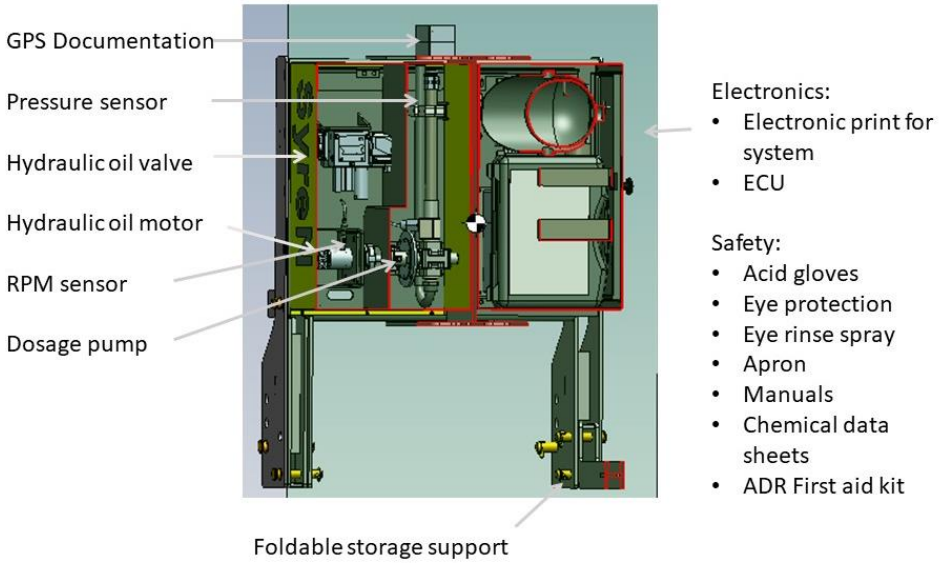
The SyreN Light is designed to be used by smaller slurry tankers from 8- to 12.000 m3. They are typically use on smaller farms or in regions where the field seize, or road accessibility does not allow large seize and high weight equipment.

In addition, the combined weight of SyreN and acid positioned in the front lift of a smaller tractor, cannot be sustained, so there is a market need for a SyreN version, where the weight can be shifted to the rear of the tractor and the acid positioned on the slurry tanker.

SyreN light has been designed to make stabilization of slurry available for all slurry tankers in the market,

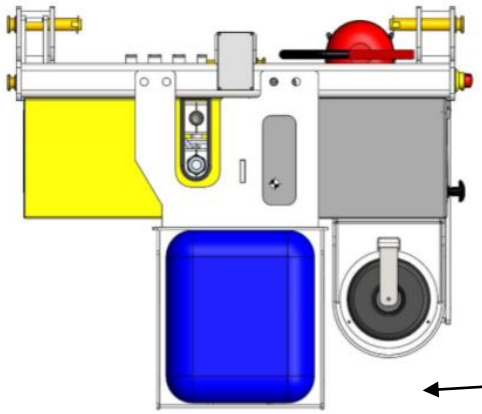
SyreN Light in use by an 8.000 m3 slurry tanker

The SyreN Light is only different from SyreN by the layout of the components. It is positioned in the three-point link in the rear of the tractor, which is available when the tractor is pulling a slurry tanker. The standard design of a slurry tanker does not allow the slurry tanker to carry a large IBC tank, so a smaller 200 l drum is used. As they have a much smaller daily capacity for slurry application, this is often enough for a daily capacity.



Transparent cut of SyreN Light System

A very important feature of SyreN Light, is that it is a closed system where no direct contact with the acid is possible. Easy accessibility to safety equipment will ensure that it is used.



Top View of SyreN Light

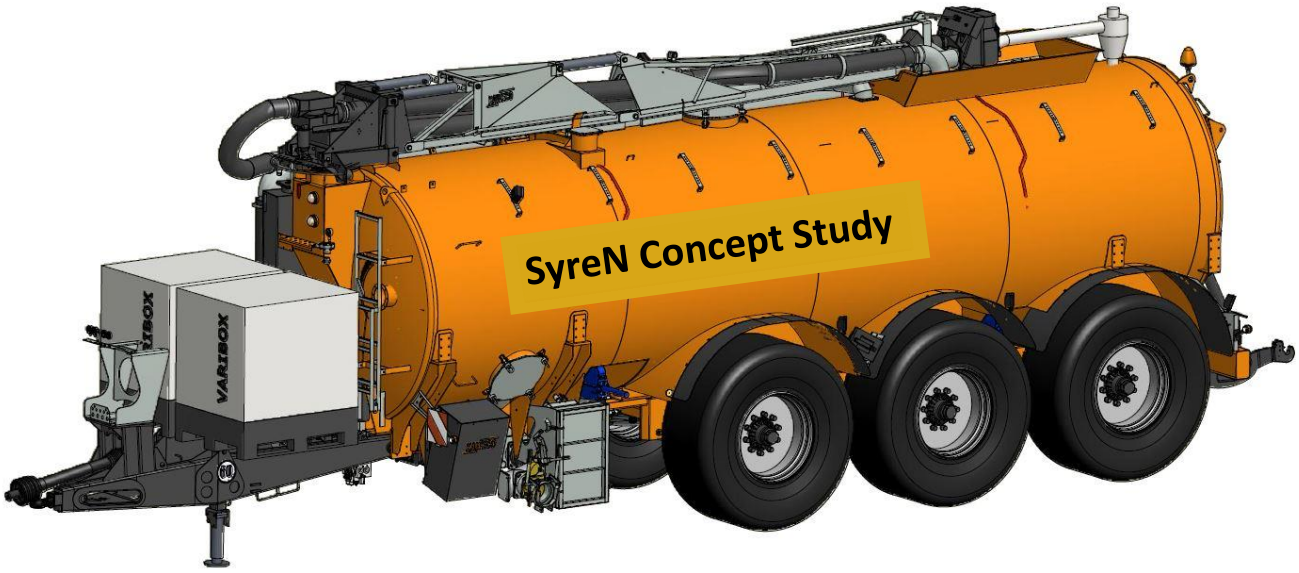
Cabinet for safety equipment, electrics, and electronics

Holder for acid hose coupler

Canister for sulphuric acid

SyreN Light integrated in larger slurry tankers

SyreN Light is the first step in designing and integrated system for all slurry tankers. The SyreN position of the acid in the front of the tractor, is the ideal position for the IBC tank, but it has its limit in acid holding capacity. With SyreN Light, it can be integrated into the slurry tanker, and it can be used by all small- or larger tanker systems. Especially where there is a need for a larger reservoir of acid.



Concept study of integration of SyreN light in a larger slurry tanker

SyreN Research

Research systems

It is important for SyreN to develop precise documentation for the effect of the use of acid and the volumes needed. The trail plots used by research to measure the effect from SyreN, is done at trail plots with a working with of 3 m.

This is the seize of a trail plot and the plot application need to be performed in replicas and often with a varied volume of acid. This is not possible with a standard SyreN light version. The volumes of acid used, are considerably less than a normal slurry tanker and that means it must be fitted with a different pump and a modified software. It also needs to have a more precise measurement of the acid volume.

SyreN Light may be adapted to fit different systems. The components can be modified in the attachments and relocated to a position where the fit it is more convenient for trail purposes.

Process advantages using slurry in-field stabilization

A most noticeable feature of stabilization of slurry is foaming. When sulphuric acid is added to slurry, the slurry will foam. This is a question of the slurry chemistry, and it cannot be avoided. As a minimum, the small bladder in the slurry creates a noticeable discoloring of the slurry, depending on the amount of sulphuric acid used and the buffer of the slurry. When heavy foaming takes place, 100 % of the slurry is transformed into foam.

In digested slurry, the reaction can be almost explosive

0.02 % acid in digested slurry doubles the volume

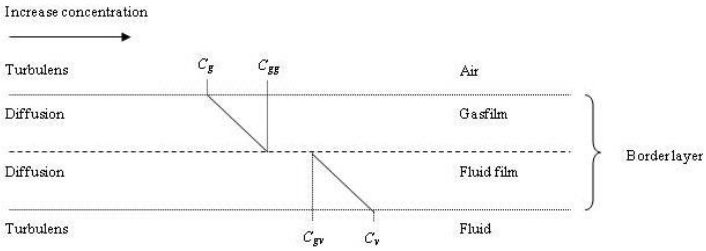
If the acid is added to the slurry in a container before the application, it may cause the slurry pump to cavitate, making pumping or field application impossible until the foam settles again. This may take up to 48 hours. With barn- and storage stabilization, the foam is a regular nuisance, but with in-field application, it is a benefit. Since the acid is added after the pumping, it does not influence the slurry pumping ability and it adds pressure in the pipe and thus accuracy to the flow. In the field, the foam is an advantage because it stops any movement of the slurry. Especially digested slurry has a very low viscosity. It takes a very small inclination for the slurry liquid and thus the nutrients, to move significantly within the field. It may shift so much during application in the field, that it is the cause of significant yield variations. This results in harvest difficulties, and it has a very negative influence on the economy and the environment.

This makes it impossible to simulate in-field stabilization by adding acid to slurry in a container before application. The difference in the volume of slurry applied between the container stabilized slurry and the in-field stabilized slurry, will distort any comparison between the two stabilized slurries – even though the same amount of acid may be used. The container stabilized slurry must rest up to 48 hours before it has returned to a comparable viscosity to the in-field stabilized slurry. In this period, the efficiency of the acid will be reduced significantly, ending all comparison between the slurries.

The foam itself is also a barrier to emissions from slurry. The further away the ammonia is from the surface turbulence, the less likely is emission. Elevating the surface distance through foaming is thus a very efficient method of reducing emissions. The lack of foaming in the field with barn- or storage stabilization reduces the efficiency of the technology and increases the need for acid.

This is described in the formula:

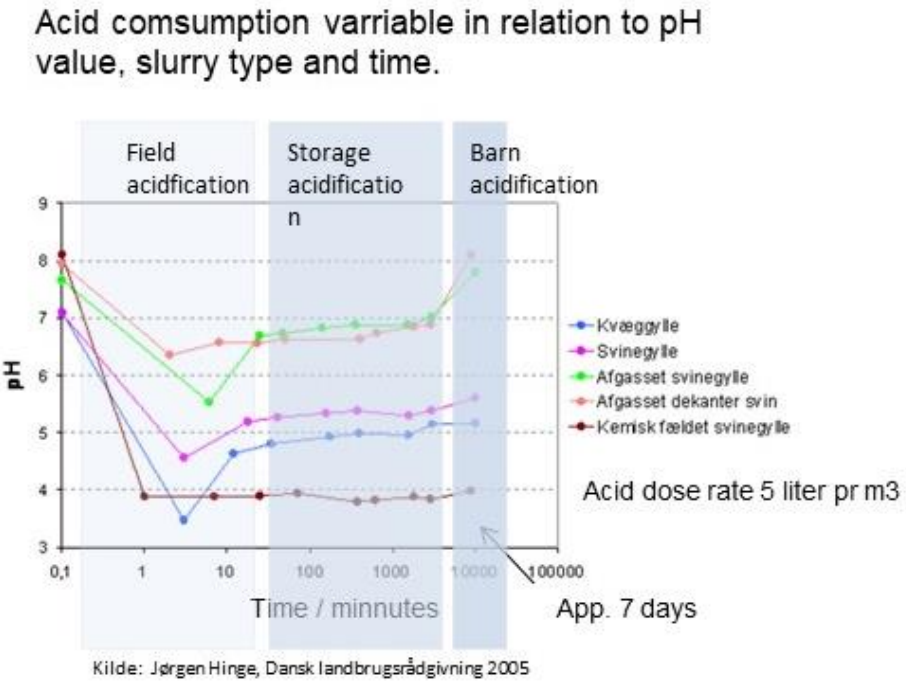
The use of foam to reduce emissions is well documented and it is part of elevating the emission reduction effect from using in-field acidification



Injection of sulphuric acid to slurry reacts with heavy foaming

Time vs. effect

Even if the foam has disappeared from the slurry, it will be non-comparable because some of the acid effect will disappear in the storage period. With ref. To below graphic, there is a significant pH lowering of the slurry in the first 5 minutes, after which pH recovers to a higher value. This low pH period represents almost 25 % of the time in which the



Kilde: Jørgen Hinge, Dansk landbrugsrådgivning 2005

slurry is exposed direct to the atmosphere and where it has the highest level of emission.

If in-field stabilization is to be monitored, there is no option but to use an in-field acidification system.

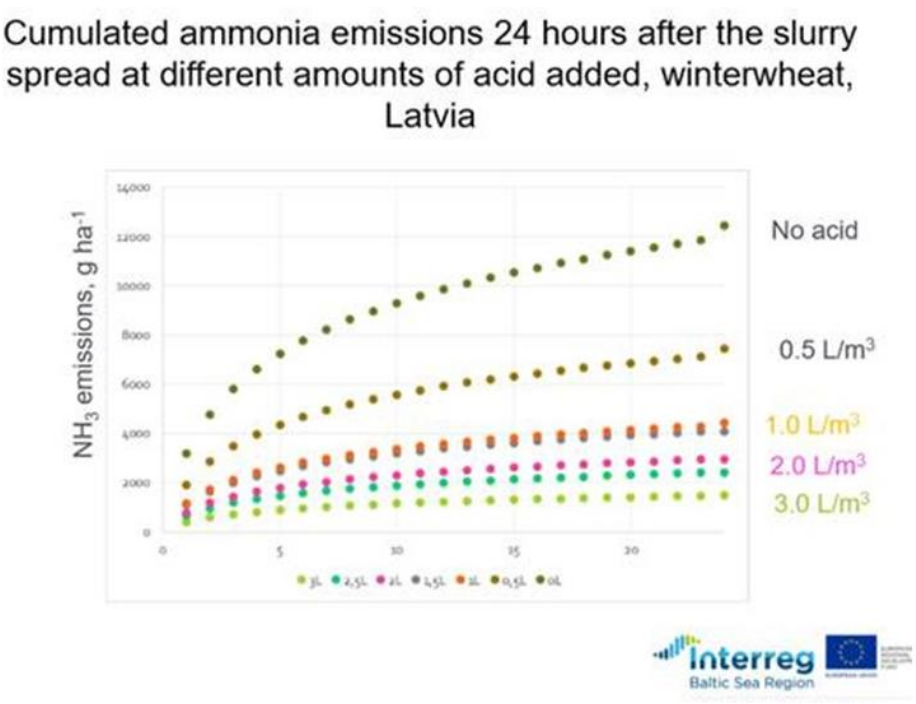
Amount of sulphuric acid used

As a part of the slurry buffer, the dry matter in the slurry influences the consumption of acid. The liquid reacts instantaneous to the acid with a pH change, but the dry matter is slow to react. Thus, the longer the liquid is in contact with the dry matter, the two will even out the pH difference and the collective pH will increase. This leads to an increased consumption of acid. The short time exposure of in-field stabilization will have less acid consumption than barn- or storage stabilization.

Flexibility of pH

A most difficult issue is how much the pH should be lowered? SyreN Light offers the flexibility to individually decide on the pH level depending on slurry, climatic or soil features. A stable pH in the slurry is not a requirement like in a storage situation and the SyreN Light VERA verification has documented a 49 % emission reduction from cow slurry, using 2.7 liter of acid pr. m^3 at pH 6.4

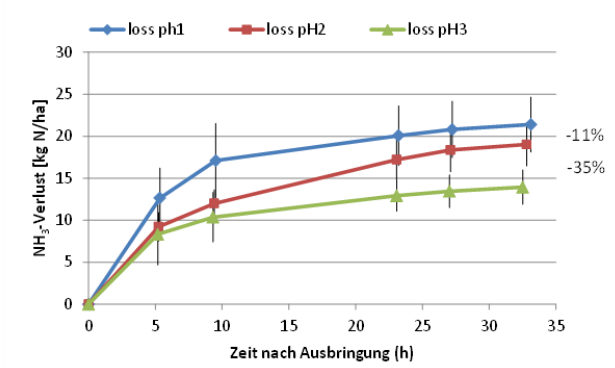
The acid / emission g/ha consumption graphic gives a clear indication that the emission reduction effect is reduced with increase rate of acid injection.

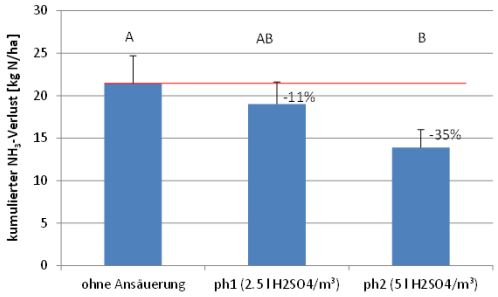


The price of sulphuric acid is the most important cost factor. There is an "international commodity" price with a local variation around 0.30 Euro cent pr. liter. It is instinctively attractive for farmers to save money on the consumption of acid, but it is also imperative that the pH threshold is not compromised. Thus, if research / extensions services set the pH target too low, it will not be respected because of cost. In Denmark, a dosage rate of 1.5 liter with 30 m^3 slurry is often chosen because it is close to the plant need of Sulphur and it corresponds well to the consumption of one IBC tank of acid pr. day. This gives a convenient logistic. However, each slurry has an individual buffer. That makes it important to communicate the message of reaching the pH target value despite a difference in economics and logistic. Considering the economic and logistic factors, a pH target of 6.4 is often the economic optimal level and lowering pH below 6.0 is negative for economy and logistics.

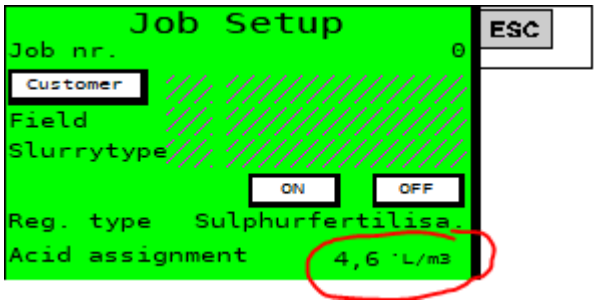
With digested slurry, where the pH and the buffer are very high, failing to consider the amount of acid, may render the technology unsuitable because of logistical problems with an acid consumption above 5 liters. Such a situation has been tested with Lüneburg university, where

lowering a digested slurry from pH 8.4 to pH 6.0 had a consumption of 13-liter acid. However, reducing pH to only 7.0 yielded a 34 % emission reduction with a 5-liter acid consumption.

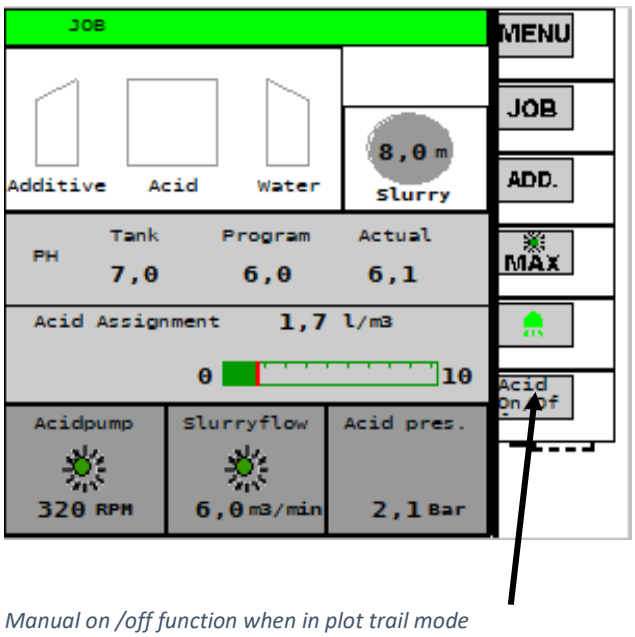




With SyreN light, it is possible to adjust the pH on the fly to test different acid dose rates and decide on the economical optimal level of acid / effect combination.



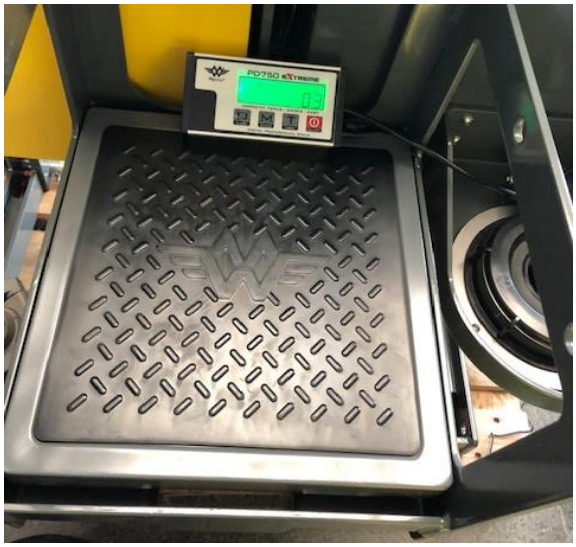
The setup for l / m^3 is easy – simply enter the volume in the system



Manual on /off function when in plot trail mode

The system is operated by using the trail plot function as a simple on / off switch.

NB! Normally, SyreN System stops automatically when the flow sensor impulse is below 2 m^3, PTO stops, or 3-way valve sensor is in return slurry– or stop mode. In the trail plot mode, SyreN System has no automatic cut-off function other than the manual on/off. This mode can only be used with a code that is exclusively available for SyreN Light when used as a trail plot application system and it leaves a lot of responsibility for safety on the pilot.

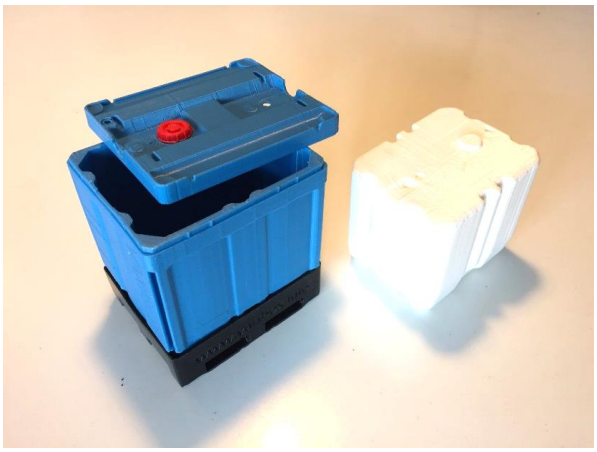


Scale weight for acid consumption recording

As the start/stop is manual, it is important to monitor the precise dose rate of each of the trail plots. This can be monitored on a weigh cell scale, that can be delivered with a wire connection or via a Bluetooth connection. A small printer can be added. The dosage pump may also be used to monitor the acid consumption, but the acid volume must be above 0.5 liter / min to be precise.

As an important feature of the system, SyreN can fill smaller cannisters from a large IBC tank. The hose that normally feeds the slurry tanker mixer, is simply re-positioned to the IBC tank and the slurry tanker hose is positioned on the cannister. In this configuration, the cannister is filled from the IBC.

NB! In this mode SyreN System is operated with a manual on / off function only. Visual inspection and monitoring from the scale weight are a must to prevent overflow when filling. The pump must be operated at low- to medium speed. It is possible to fit an audible sensor as a filling alarm, but the cut off is still manual.



SyreN System uses either a standard IBC tank or a double walled IBC tank. Although the double walled is more expensive, the extra cost is easily justified by the ease of storage as the double wall feature excludes the IBC from having to be stored at a waste containment area and potential rainwater filling of containment area (indoor storage). In addition, it is a lot safer, as it is much less subject to damage from a lift handling

The pH sensor monitors the slurry after the injection of sulphuric acid. The sensor is individually positioned depending on the slurry tanker and application system, but it must be after the slurry distributer and as close to the application site as possible. The sensor head has a normal lifespan of 1 year and must be changed every season. A Bluetooth connection between sensor and sensor head facilitates changing it and protect the plug elements from the harsh environment. The pH reaction in the slurry is instantaneous and can be monitored on the screen as the system operates. However, the pH reaction continues up to 2 minutes after acid injection, so the final pH value can only be monitored after a few minutes. It normally corresponds well to the on-line monitoring, but with trail plot work, it should be checked that the acid dose rate also reaches the target pH value. The pH sensor is positioned in a flow box, where it is always kept moist. Checking the pH value against the target pH value is simply to wait a few minutes after application and monitor the screen to see if there is any change to the pH value in the box.

Bluetooth wireless contact connection and digital chip for quick pH monitoring

Both couplers on the system are equipped with a safety check valve and with a very powerful closing mechanism to prevent any dripping from the repositioning of the couplers.

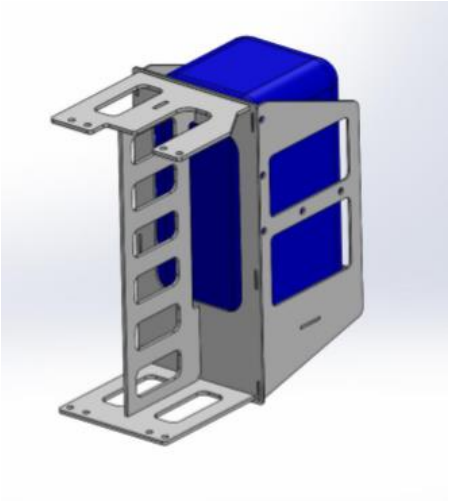
The system is the same design as is used on a pressurized draft beer system and it is very robustly built. Made from glass poly propenyl and Viton, they are lifetime approved with sulphuric acid with a UN 1830 certification

When not in use, the couplers are positioned in a special drip protection holder that locks the coupler and protect it from any physical objects during transport. Any potential acid droplets will be collected in the stainless-steel holder, that has a protective lid when not in use.

Rear- or front position

SyreN Light may be equipped with one-or two 60 l cannisters holders to match the research station needs. There may be slurry tankers that does not allow the cannisters to be positioned in the tractor rear three-point link because of slurry pump position etc. In such an event, the correct position for the cannister is identified and an individual holder- as well as hose length is manufactured individually.

Alternatively, the system can be positioned in the front tree point link, where hoses must be permeant installed underneath the tractor.



Holder for one 60 l Cannister

Individual holder for cannister

SyreN Light installed in the front hitch

SyreN Transporter

SyreN transporter with a slurry feeder tanker

SyreN Transporter

The transport of sulphuric acid from storage to field, has different requirements for road safety. With a SyreN Light system, most needs are covered below the 333 liters. This relieves the driver from having a dangerous goods certificate (ADR) but the transport must still be signposted as ADR groupage. The containers must be UN 1830 approved.

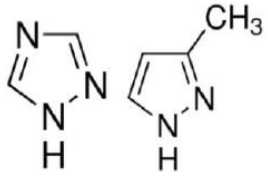
With a 1000-liter IBC tank, the transport is subject to ADR and the system must be equipped with the needed safety equipment and warning tables. For this purpose, BioCover offers the SyreN transporter system, which is a de-spec SyreN front system. This fulfills all the ADR regulations and enables safe- and easy transport of an IBC tank with a tractor.

SyreN Additiv

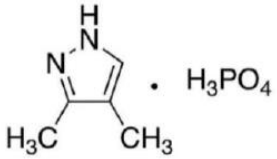
Injection of additives

Nitrogen inhibitors

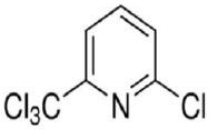
Nitrogen inhibitors have been used for a long time and have a well-documented effect on reduction of nitrate leaching. All of them can postpone the nitrification and denitrification process with use of ammonium fertilizer – slurry. This awards the plants a longer period in which the ammonium is plant available and thus to increase the NUE – Nitrogen Utilization Efficiency.
There are currently 3 Nitrogen inhibitors in the trade with an active ingredient:



1,2,4-triazol og 3-metyl pyrazol
(Piadin)



3,4-dimetyl pyrazol phosphat
(Vizura/Entec/DMPP)



2-chlor-6-trichlormetyl pyridin
(N-lock/N-serve)

When there is a prolonged plant up-take of the ammonium fertilizer, nitrogen inhibitors will reduce the ammonium conversion to nitrate through nitrification- and denitrification processes in the soil. As ammonium, the nitrogen bind itself to the soil and does not leach out. As nitrate, it is water soluble and may leach out with rain.
Nitrogen inhibitors may decrease the ammonia emission by avoiding ammonium returning to ammonia gas form. This is especially important with Maize on sandy soils and in years with a high precipitation, but it may apply to all crops and soils. The effect is well documented. In years with high precipitation in the window between planting / fertilization and plant uptake of nitrogen, the effect may be a reduction of +30 kg nitrate leaching pr. ha. There is also a substantial effect on GHG_{2e} as N_2O emissions through denitrification is reduced.

The use of nitrogen inhibitors with slurry needs specialty equipment. The chemical formular does not accept dissolvement in slurry for more than a few days before losing its effect, so it must be injected into the slurry during application and mixed into the slurry when the slurry tanker is being filled. In contact with soil, the effect remains constant, but it is subject to decomposition with increasing soil temperatures.

The SyreN System is designed to inject nitrogen inhibitor into the slurry. On the front tank, there is a 150-l tank that is in liquid communication with the slurry. When the tanker is filling itself, the chosen dosage rate is injected into the slurry, ensuring a good mixing with the slurry.
The use of nitrogen inhibitor may be documented by the SyreN System through measurement of the dose rate that is defined by liters pr. m3 slurry or liters pr. ha

As the effect from inhibitors are seasonally very variable, it is necessary to evaluate the effect as an average over min. 5 years. An effect of reduced leaching of 5 kg / ha pr. year can be expected in high precipitation areas.

Iron Sulphate Fe^{3+}

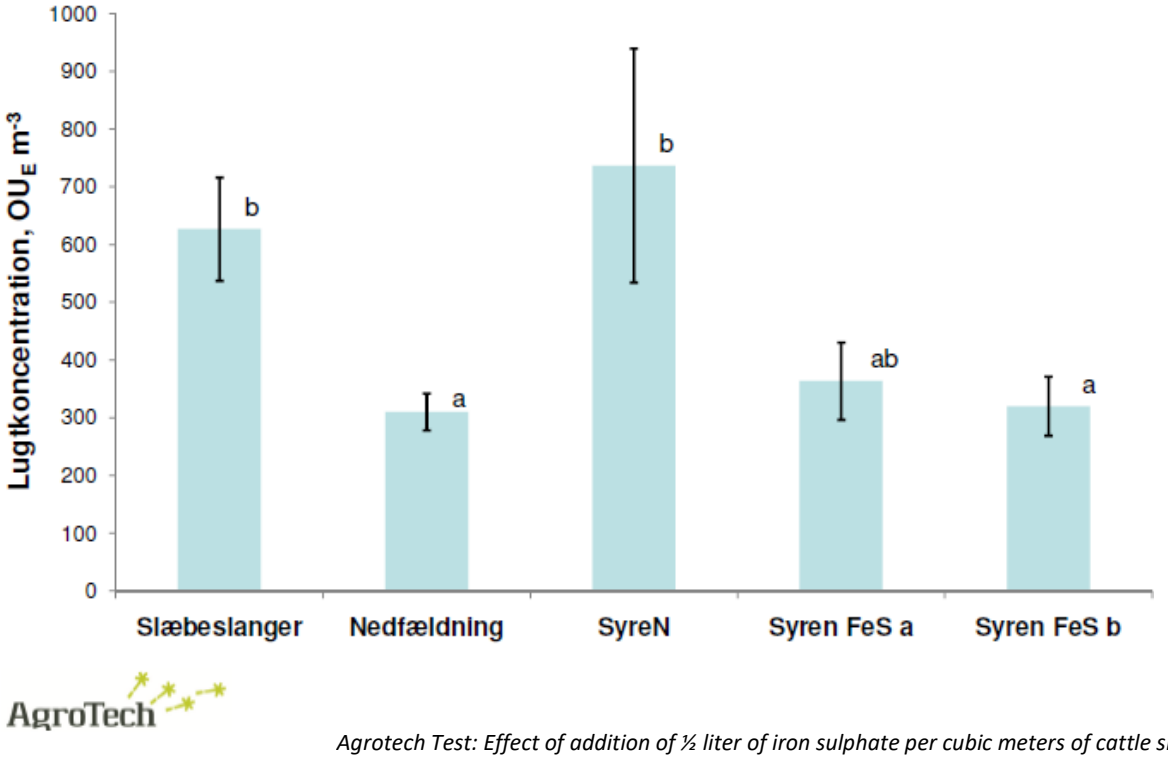
The use of Iron Sulphate is a known technology for eliminating odor from hydrogen sulfide, known for a very characteristic odor of the rotten eggs. It is used as standard in sewage treatment plants with good effect.
Iron sulphate is added to the slurry during filling of the slurry tanker. This is important since the volumes of iron sulphate is small – typically 0.5 - to 1 liter pr. m^3 . – and because it takes about 10 minutes from the addition to the optimum effect.

Iron sulphate works by splitting hydrogen sulphide:

$$FeSO_4 + H_2S \leftrightharpoons FeS + SO_4^{2-} + 2H^+ = No\ odor$$

Sulfuric acid is also very much instrumental in reducing odors. When adding sulphuric acid during application, ammonium is bound as ammonium:

$$H^+ + NH_3 \leftrightharpoons NH_4^+ = No\ odor$$



Agrotech Test: Effect of addition of ½ liter of iron sulphate per cubic meters of cattle slurry

The addition of sulphuric acid means that several odors change in character and thus may have an altered odor.

The effect of odor reduction is very variable. In some slurry types, outstanding results can be achieved, while in others, it may only achieve a modest reduction. This is caused by a different content of hydrogen sulphide and the chemical composition of the slurry origin (pig, dairy, digested). A good advice is to ask neighbors to participate in an odor assessment, since it is often because of the neighboring interest that we want an odor reduction. In relation to neighbors, wind direction and distance to slurry odor is very important. It is known that it is not possible to smell against the wind, but there are fewer who think about the effect of odor reduction due to dilution over the distance to the neighbor. That means that an odor reduction effect will be increasing the further away you are positioned from the Odor source. Neighbors can therefore experience a very significant odor reduction with the use of iron sulphate during slurry application, without this necessarily applying to those who are involved with the slurry application.

Manganese Nitrate

Manganese Nitrate is well known as a remedy for Manganese deficiency. In areas – fields – where manganese deficiency occurs, manganese nitrate is often added together with pesticides when treatment during the early growing season has not delivered sufficient effect. Thus, Manganese nitrate can advantageously be added together with slurry, as the effect is prompt when dissolved in a large amount of liquid that has immediate soil/root contact.

Addition of Additives to the slurry

The SyreN additive is designed to inject additives into the slurry. On the SyreN front tank, there is a 150-l tank that is in liquid communication with the slurry. When the tanker is filling itself, the chosen dosage rate is injected into the slurry, ensuring a good mixing with the slurry.
The use of nitrogen inhibitor may be documented by the SyreN System through measurement of the dose rate that is defined by liters pr. m3 slurry or liters pr. ha
The use of nitrogen inhibitors with slurry needs specialty equipment. The chemical formular does not accept dissolvement in slurry for more than a few days before losing its effect, so it must be injected into the slurry during application and mixed into the slurry when the slurry tanker is being filled. In contact with soil, the effect remains constant, but it is subject to decomposition with increasing soil temperatures.
As the effect from inhibitors are seasonally very variable, it is necessary to evaluate the effect as an average over min. 5 years.
An effect of reduced leaching of 5 kg / ha pr. year can be expected in high precipitation areas.

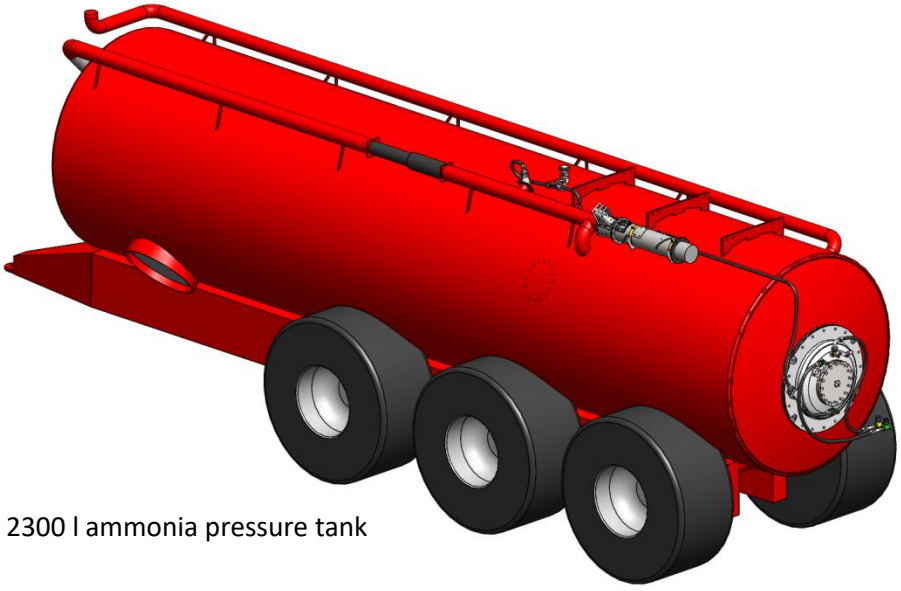
Sustainable one pass fertilisation with slurry

Perspective for SyreN+

When farmers use slurry as plant nutrition source, the plant need for macro nutrition is normally covered except for nitrogen and sulphur. Normally additional fertilizer is therefore applied through a second application of fossil-based N and S fertilizer. With the SyreN-system, it is possible to add sulphur to the slurry through dosing sulphuric acid direct into the slurry during application. Normally 1-3 litres of acid are used pr. m3 slurry, which covers the plant need for sulphur. This reduces the slurry pH value and results in a 40-60% reduced ammonia emission from the slurry. With use of the SyreN system, plants need only a reduced amount of nitrogen as a second application.

It is thus, a huge advantage to be able to adjust the nitrogen contend of the slurry, so a second spreading with a conventional fertilizer spreader can be avoided. Equipment for such adjustments of nitrogen contend in slurry is called SyreN+. A traditional slurry tanker is not equipped to include conventional fertilizer and the tanker must be redesigned (figure 1). An obvious choice for nitrogen is liquid ammonia, as it is very concentrated. However, it must be stored in a pressure tank.

Ammonia injection valves



2300 l ammonia pressure tank

Anhydrous ammonia pressure tank

SyreN+ has an integrated ammonia pressure tank in the slurry tank. It is a very safe positioning of the pressure tank and very easily accessible for refilling. The ammonia pressure tank is inserted into a sleave in the slurry tank and can easily be taken out for yearly inspection. The insertion sleave is supported inside the slurry tank and bolted on to the rear of the slurry tanker. This design makes it possible to completely demount the SyreN+ system if the slurry tanker is to be used without SyreN+ for a period. The ammonia pressure tank can be of different size dependant on slurry tanker and use. The dose rate of ammonia is controlled from the SyreN ISOBus software system that integrates itself into the tractor terminal. A dose rate of 1 – 3 kg pr. m3 anhydrous ammonia fulfils the plant need for additional nitrogen fertilizer. The injector is placed in the slurry tanker return system.

installing sleave for protection of pressure tank

Ammonia pressure tank integrated in slurry tanker

Filling of ammonia pressure tank

Designer slurry – accurate and flexible formula for plant fertilizers.

The SyreN+ system is the first system ever to achieve the ability to create “designer slurry”. This is defined as a system for injection of ammonia, sulphuric acid and other fertilizers to create a one pass fertilization with slurry during application.

Application of slurry and commercial fertilizers have until now been seen as separate operations. A traditional slurry tanker consists of only one big tank for storage of slurry. With the SyreN+ system, the slurry tanker is re-designed so it may hold both slurry and commercial fertilizers. The slurry tanker evolves to a fertilizer formulation system rather than just transport and application of slurry.

The mixing of slurry and fertilizers are individual functions, which in the right sequence create a unique process control system. Mixing of base and acid products is potentially very dangerous. With SyreN+, this problem has been solved optimal with the use of the different functions on the slurry tanker. Ammonia (base) is added when the slurry tanker is being filled / agitated and sulphuric acid (acid) is added during application to a field.

If the slurry is injected into the soil, both ammonia and sulphuric acid dose rates are based on their fertilizer values. If a surface band spreader is used, the sulphuric acid is used to control the slurry pH so there is no ammonia emission. The combination of acid and base in SyreN+ means that the different properties of the chemicals are used to eliminate the negative aspects of the individual fertilizer. It can be argued that the slurry has been turned into a media for surface application of

ammonia as ammonium nitrogen and the sulphur in sulphuric acid is used to optimise the plant available nitrogen through eliminating ammonia emission.

Use of ammonia as a fertilizer without injection

The use of ammonia together with surface application of slurry is new. Traditional use of ammonia requires injection teeth that limits the working with and has high fuel consumption. In addition, the application takes place in an existing operation, which together with a more attractive price on ammonia will potentially give a reduction of 20-30% on purchase of fertilizer.

A solution for phosphorus

The SyreN+ system has the potential to significantly improve the value chain for application of phosphorus.

If all animal slurry in Denmark was applied according to plant phosphorus need, there would be no need for import of phosphorus as commercial fertilizer. This would correspond to an import reduction of 12-14.000-ton phosphorus and a corresponding reduction in the pressure on world phosphorous resources. It would also be an additional saving on purchase of fertilizers of 150 million DKK pr. year.

This vision is within reach with SyreN+ system. All slurry application volumes can be adjusted to the plant need for phosphorous. This can be achieved by using either a lower volume slurry pr. Ha and inject nitrogen or by separation of slurry, which effectively reduces the amount of phosphor in the slurry. The slurry fibre must be transported to biogas digester for degassing. The downside of separation is an increase in cost and increase in emissions from the process.

Regardless of using a lower slurry application dosage rate or a separation technique, the slurry can be adjusted for the N and S value to match the P value with the SyreN+ system. The slurry will have a much higher fertilizer value at a more attractive price.

In this new value chain for slurry, a much more sustainable fertilizer product is available for both livestock- and arable farmers alike. As this system also ends the problem with eutrophication from ammonia emission.

SyreN+ is an ideal management system for application of slurry. Through a unique process control, the addition of N, P, K and S can be managed automatic and individual on the fly, resulting in a unique fertilizer formula pr. field and crop. The new slurry application chain has the potential to make all slurry application sustainable.

Summed up, the farmer will realise a net saving on fertilizer purchases and operational expense in fertilizer application cost. The environment is protected from ammonia emissions, whereby especially biodiversity and the aquatic environment benefits. Reduction in emissions of climate gasses is achieved through an optimisation of the organic fertilizers and thus, reduced production and use of mineral fertilizers. Also, a considerable amount of CO_2 is captured and stored as increased yield. Air particle pollution is reduced with a potential corresponding to the collective emission from all road traffic. Leaching of nutrients to the ground water is seriously reduced as well as pathogen from slurry. A new value-added chain for slurry, may eliminate the need for import of phosphorus to agriculture in Denmark.

Advantages with SyreN+:

- One pass fertilization with slurry, adjusted with N, P and S
- Acidification effect with sulphuric acid
- Quick plant response to fluid dissolved fertilizers
- Very precise spreading
- Flexible combination of fertilizer formulas
- Reduction in field traffic
- Cost reduction on fertilizer purchase
- Use of liquid ammonium fertilizer without injection
- Ammonium nitrogen is soil reactive – less leaching
- Precise dosage of micronutrients
- Preventive use against manganese deficiencies
- Lenient treatment of microclimate in soil
- Possible addition of nitrogen inhibitors to slurry

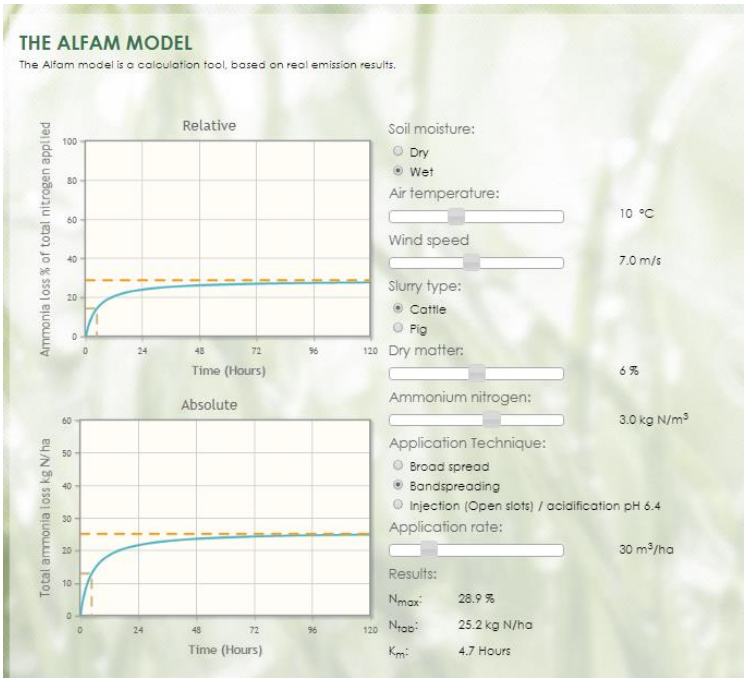
SyreN e-missioN

The digital management for slurry NUE optimization

The e-missioN system is a new technology for liquid organic slurry application. The core of the technology is a database of more than 10.000 ammonia emission trails in all EU countries and North America. The origin of the database was to harmonize the ammonia emission reporting from the EU members to the EU commission. At each trail, the ammonia emission is measured, including all the factors that influences the emissions. The nitrogen emissions are very variable and can be from 20 % and up to 100 % utilization. In EU, this translates from 34 kg up to 170 kg pr. ha efficiency with the same slurry depending on use.
This database has now found a new use for measurement of Nitrogen Utilization Efficiency- NUE – in the e-missioN System.
Being able to measure the NUE – Nitrogen Utilization Efficiency - is a fundamental change to all fertilization strategy with slurry.

The Best Available Technology (BAT) to date is using a normative value for deciding volume of nitrogen fertilizer to be used in combination with slurry.
It is well known, that the NUE of slurry is very variable, so it is customary to decide on a high mineral fertilizer dose rate in combination with slurry to avoid potential sub fertilization. Simply to reduce the mineral dose rate is taking a risque with the economy, so to measure the NUE to establish the optimal mineral fertilizer dose rate will become the new BAT.

Knowledge of the NUE can be used for different purposes – on board the slurry tanker and after the application. The functions can be divided into 4 groups:

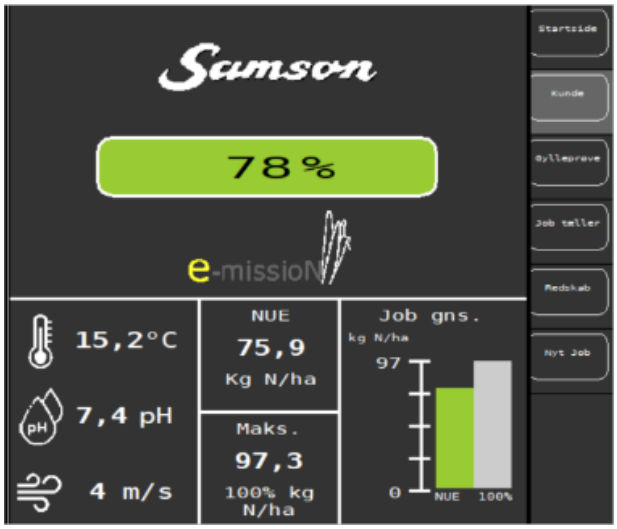


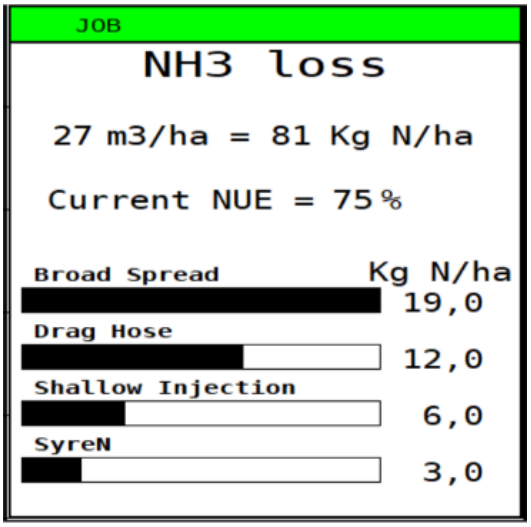
The database can be used on www.biocover.dk

- A nitrogen loss-monitor for a slurry tanker
- Dose rate decision for mineral nitrogen use
- Automatic fertilizer accounting
- Documentation for sustainable use of slurry / mineral fertilizer

A nitrogen loss-monitor for a slurry tanker

During application of slurry, the e-missioN sensor system on the slurry tanker measures all the parameters that causes the volatility of the slurry. The database is built into the slurry tanker terminal, and it responds to the sensor inputs by calculating a value that matches the current set of conditions. This is the NUE, and it is presented as a nitrogen % loss or in kg nitrogen loss.





Different screen shots from the tractor terminal when used with e-missioN.

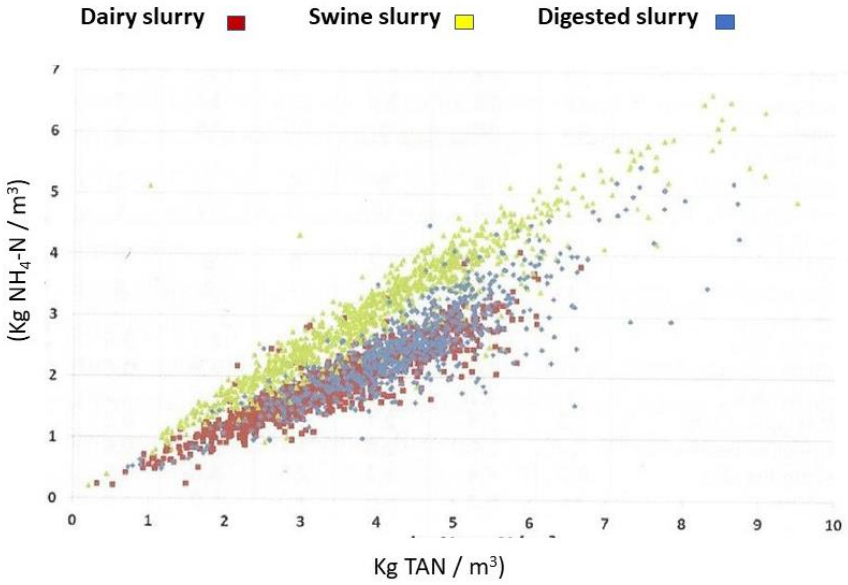
The e-missioN front screen in the tractor has a “traffic light” on the top of the screen. It illustrates the ammonia emission % loss and indicate to the driver when the ammonia losses are no longer acceptable as a green-yellow-red indication.
There is also a calculator to compare current NUE with 100 % NUE. This indicate the overall efficiency of the job and can be compared to different days / jobs as a learning process. e-missioN also displays the NUE using different technologies. This is especially important as a decision support system when using acidification. In above example, the extra volume of nitrogen between acidification to pH to 6.4 and use of drag hose, will yield 9 kg extra nitrogen. This facilitates the decision of when to use acidification.

The ammonium nitrogen in slurry is known to be very volatile. This has caused slurry to be seen as an unreliable source for fertilization for decades. The volatility from the slurry is subject to a significant number of parameters. They can be grouped into three different categories:

- Slurry characteristics
- Application technologies
- Climatic variations

Slurry characteristics
The variability from slurry characteristics is mainly due to volume of nitrogen, pH and dry matter. As can be seen from the below graphic, there is a significant variation of nitrogen in slurry.

This means that the e-missioN system is depending on an accurate input of the volume of ammonium nitrogen in the slurry. This can be entered into the terminal manually from a slurry analysis or from an on board NIR sensor system, that measures the nitrogen contend during filling of the slurry tanker and during application. As ammonium is water soluble, there is limited variation pr. tanker application, but nitrogen in the dry matter may vary.
The use of normative figures will introduce a source of error in the NUE, but it will be a better information than the normative figure alone, as it will disclose the losses and give a better indication of the NUE.



Volume of nitrogen in different slurries

The pH regulates the chemical equilibrium between ammonium and ammonia. The average pH in slurry is 7.2. This level of pH causes the ammonia in the slurry to leave the slurry as ammonia gas during application. In theory, If the pH is below 6.3, all ammonia gas is transformed to ammonium salt that does not evaporate. In practice, the pH is also variable in contact with soils so if all emissions are to be minimized, the pH must be around pH 5.5. A pH between 6.4 and 6.0 is seen as the economical optimal level.

The volume of dry matter in the slurry is also a significant factor. The nitrogen value is referred to the following year as it needs to decompose to be plant available. The dry matter has a surface tension that retains moisture, so it prevents the ammonium from reaching the soil surface and bind itself. The ammonia in this moisture is certain to evaporate as ammonia if it does not get any soil contact and it will be lost as emission to the atmosphere

Application techniques
Different application technologies have a major influence on the NUE. The larger and more exposed the surface of the slurry is to the atmosphere – the higher is the risque of nitrogen loss as emission. The e-missioN system operates with 4 categories of application technologies:

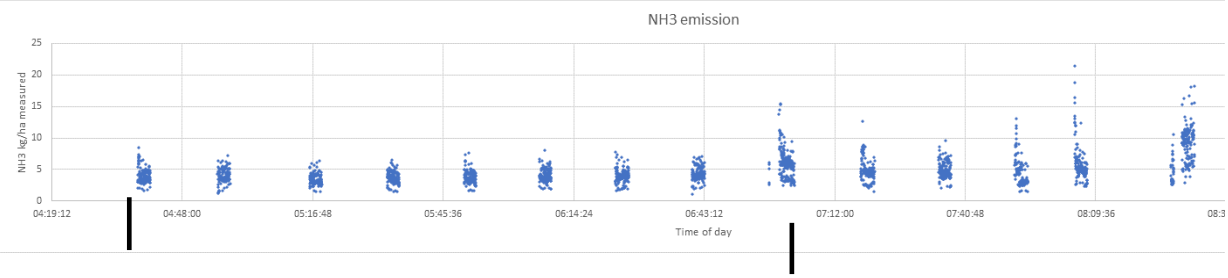
- Broad casting / splash plate application — High exposure
- Band spreading — Medium exposure
- Open slot injection / grass injection — Low exposure
- Black soil injection (+12 cm) — No exposure
- Acidification — Low risque of emission by exposure

The first four technologies are described in the e-missioN system database and the acidification technology is used in combination with one of the first four technologies. With acidification technology involved, the exposure risque factor is reduced with 50 – 70 %. With digested slurry, the effect is depending on the slurry pH that is often x10 higher than conventional slurry.

Climate variations

Ideal slurry application climate conditions are described as cold, moist and with no wind. This says a lot about the climate influence.

The temperature is highly influential on ammonias ability to escape from the slurry as can be seen in below graphic. There is a 5 Kg difference between night and day.



Application Start 4.00 am – 5 Kg loss Sun-up 6.30 am – 10 Kg loss

The wind speed creates a turbulence above the slurry, that "draws" out the ammonia of the slurry. This is because the air holds less ammonia gas than the slurry and this imbalance will always try to equalize.

High moisture contend has the opposite effect. This is caused by ammonia being water soluble. If it rains- or a very high moisture content, the ammonia gas cannot escape to the atmosphere.

The nitrogen loss monitor function on board the slurry tanker is to alert the driver / management of the level of ammonia loss during application. An important feature is to measure against current minimum utilization legislation, which varies from country to country.

The ammonia loss also represents a monetary loss for the farmer. The e-missioN system can quantify the loss in kg nitrogen pr. Ha. This facilitates the decision of when to stop with the application – either because the price pr. Ha in nitrogen value is too high or because the needed for min. nitrogen application utilization efficiency is not meet (quota restrictions). Slurry application with a high nitrogen loss rate may result in significant less yield and thus - economic losses for the farmer. There is an urgent danger of this happening if the loss level is not known to the driver.

Dose rate decision support for mineral nitrogen use

Traditionally, the fertilizer planning takes place in December / January, and it involves considerations of soil history, soil type, type of crop, previous slurry applications, expected yield and many more parameters. The dose-rate is established as a recommended maximum.

The application is split between mineral fertilizers and organic – slurry. Mineral fertilizers are often split into two or three applications, where the first application is very early in the season to start the crop, and the second and third follows slurry application.

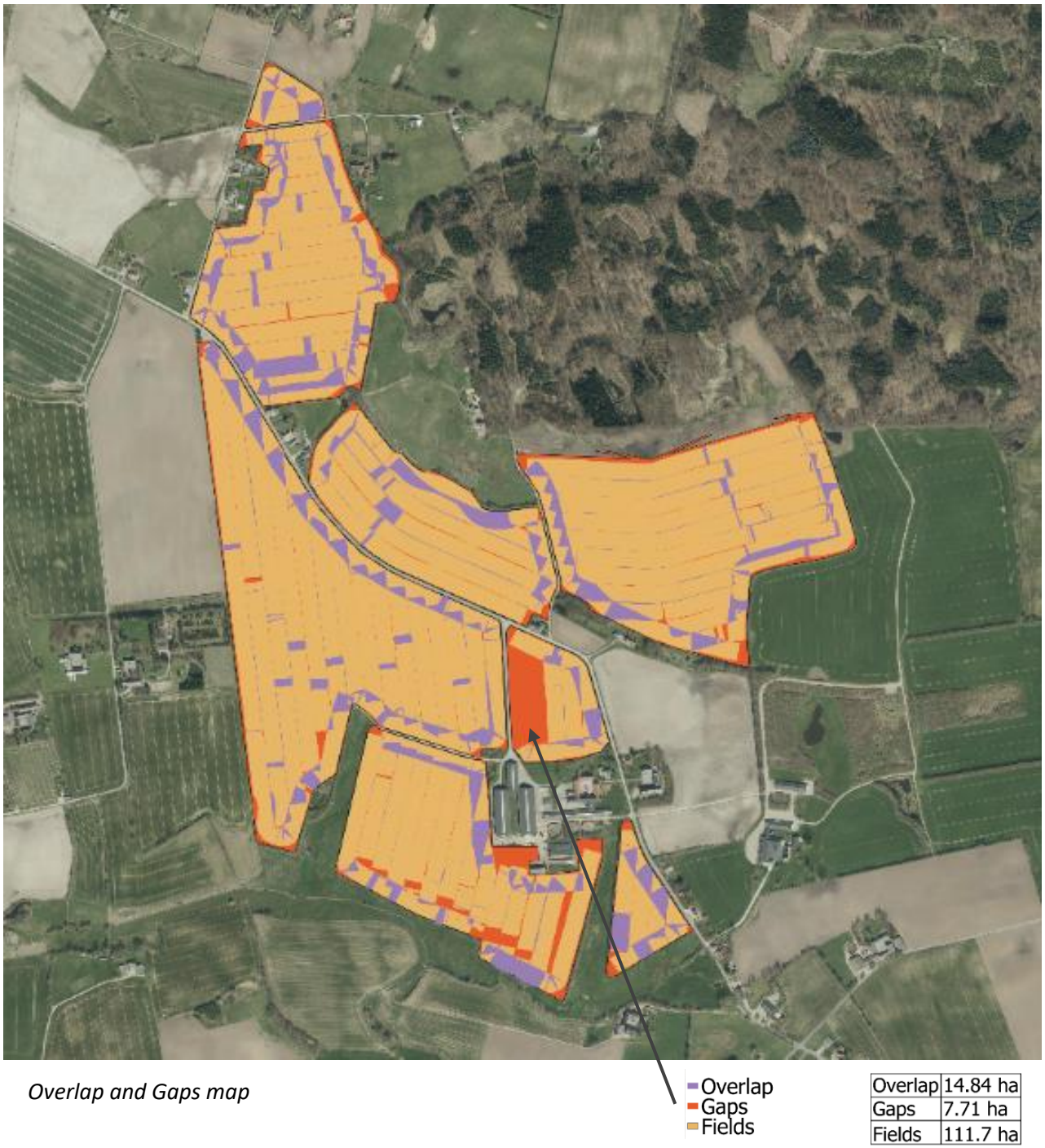
Without knowledge of the NUE, the management has little choice but to use the theoretically based mineral fertilizer application recommendations.

With knowledge of the NUE – the situation is changes with adjustments during the season.

The standard maps from e-missioN System consists of 4 maps and statistics:

- Gaps- and overlap map
- As-applied map with kg nitrogen pr. Ha
- NUE map with Nitrogen utilization Efficiency in kg nitrogen pr. Ha
- VRA map with application recommendations
- Histograms with average dose-rate pr. Ha

The overlap- and gaps with slurry application is between 5- to 15 % depending on the size and shape of the field. They are very accurately monitored by RTK GPS, including the volume of nitrogen lost.
This is also a signature of a professional job. Should any part of the mosaic in the field be missed, it can be identified and later corrected by use of a VRA map with extra dosage rate of mineral fertilizer. The overlap map exposes such an area of 2 Ha.

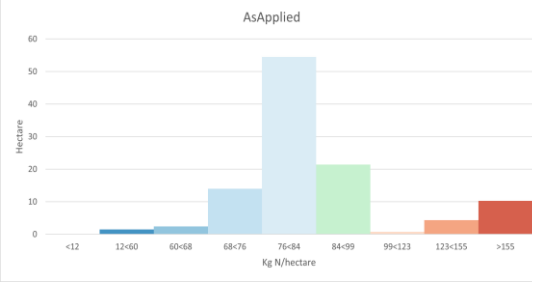


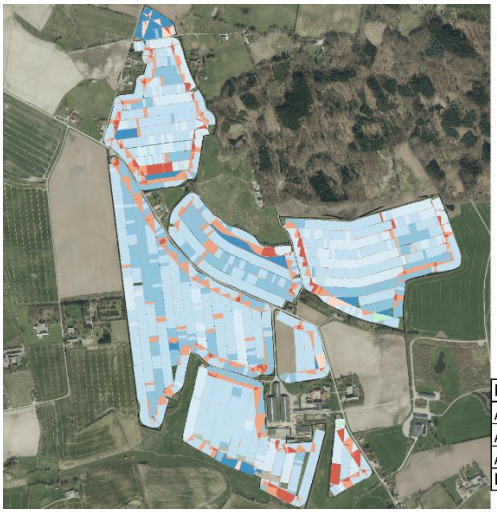
Overlap	14.84 ha
Gaps	7.71 ha
Fields	111.7 ha

Overlap and Gaps map

Field size	98,64ha
Applied slurry	3085,4r
Avg	25,5 m3
Applied N	80,9 kg
Emission kg NH3	10,5 kg

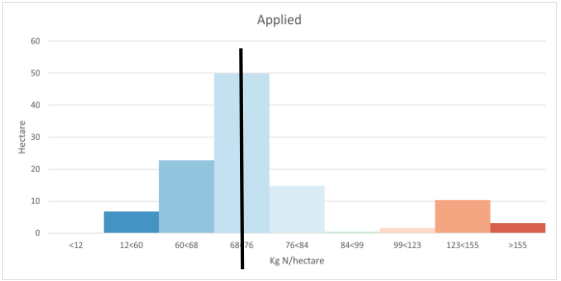
The As Applied map reflects how many m^3 slurry has been delivered pr. ha.
Variations can be caused by mechanical reasons, field topography, soil conditions and many more





Field size	98,64ha
Applied slurry	3085,4m3
Avg	25,5 m3/ha
Applied N	80,9 kg N/ha
Emission kg NH3	10,5 kg N/ha

The Applied map details the NUE – how many kg nitrogen pr. ha is plant available – after overlap- and emission losses.
The average nitrogen dosage rate pr. ha replaces the normative calculated dosage

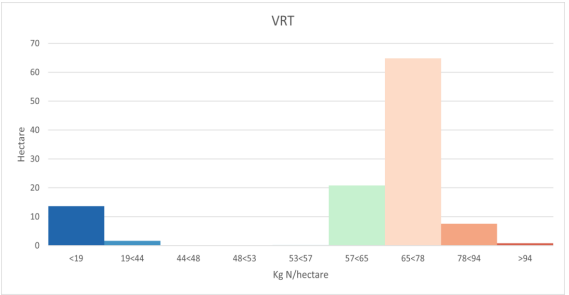


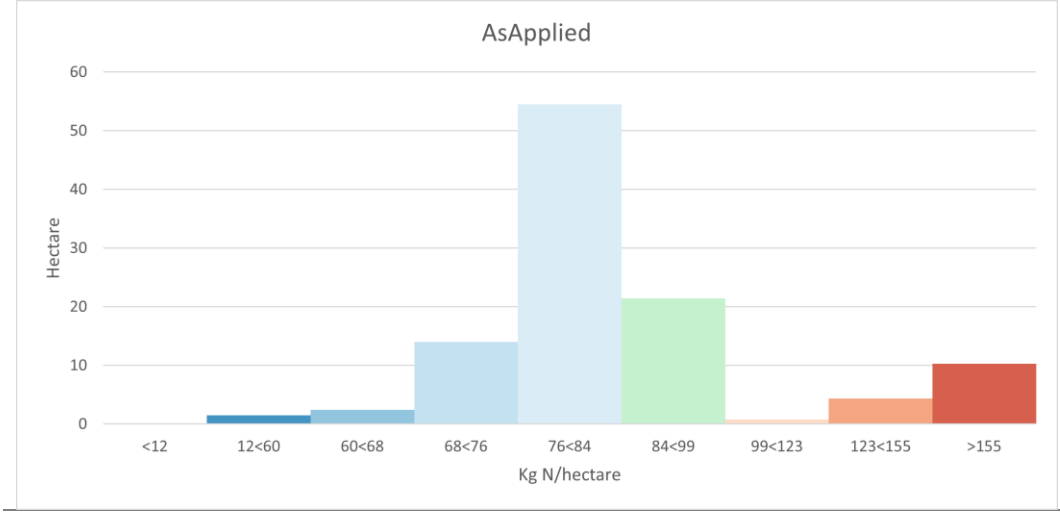
rate

Average nitrogen dosage rate

Field size	98,64ha
Applied slurry	3085,4m3
Avg	25,5 m3/ha
Fertilizer W.Avg	66,9 kg N/ha

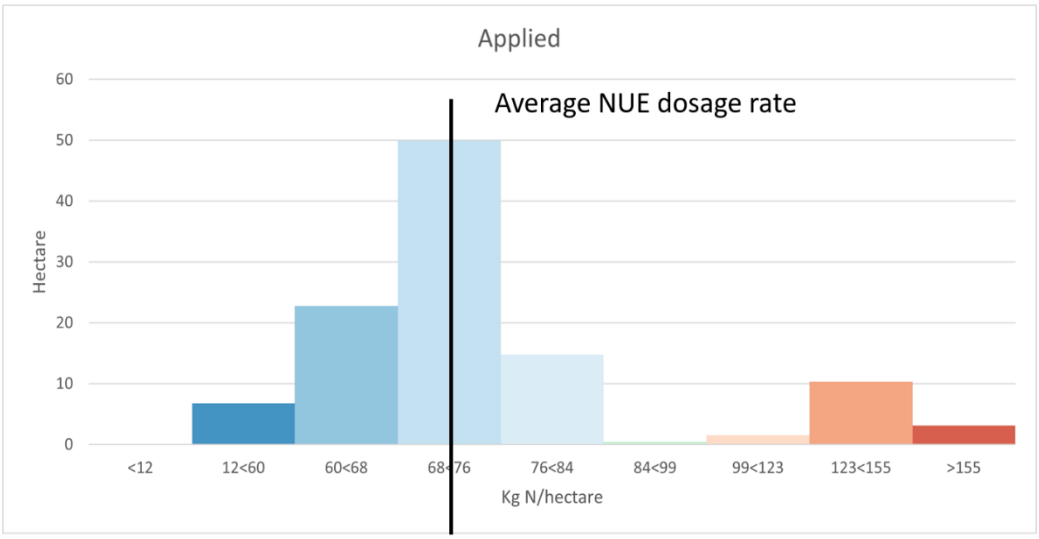
The VRA map reflects the additional need for nitrogen pr. area unit in relation to the planned dose rate pr. ha. of 140 Kg N
The variations caused by slurry volume variations and emission losses have been deducted





As Applied histogram is the volume of slurry pr. m3

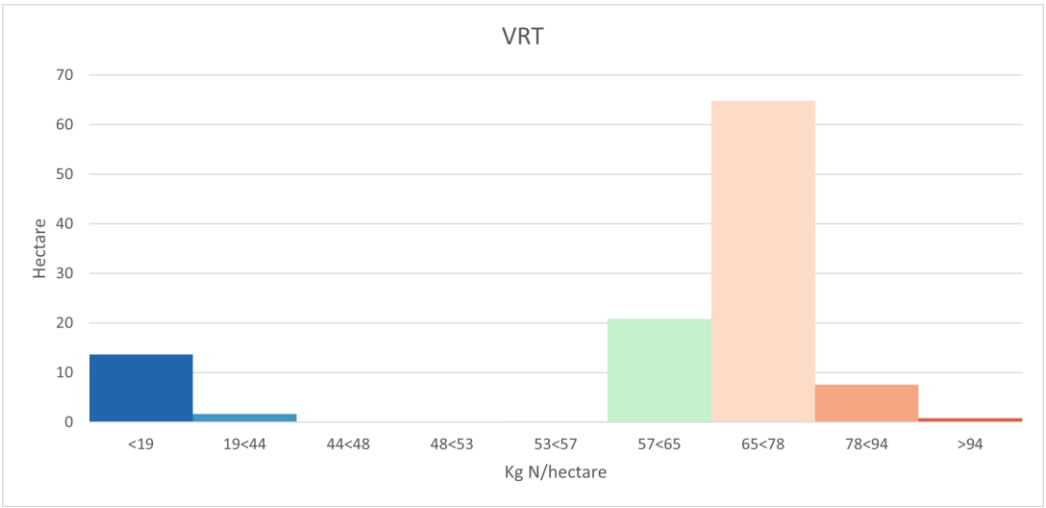
The red area reflects overlaps



The Applied histogram shows the average kg nitrogen pr. ha. after losses.

This is used to identify the average dosage rate of the following mineral

fertilizer



The VRA histogram shows the needed nitrogen to reach a planned average dosage rate of 140 kg

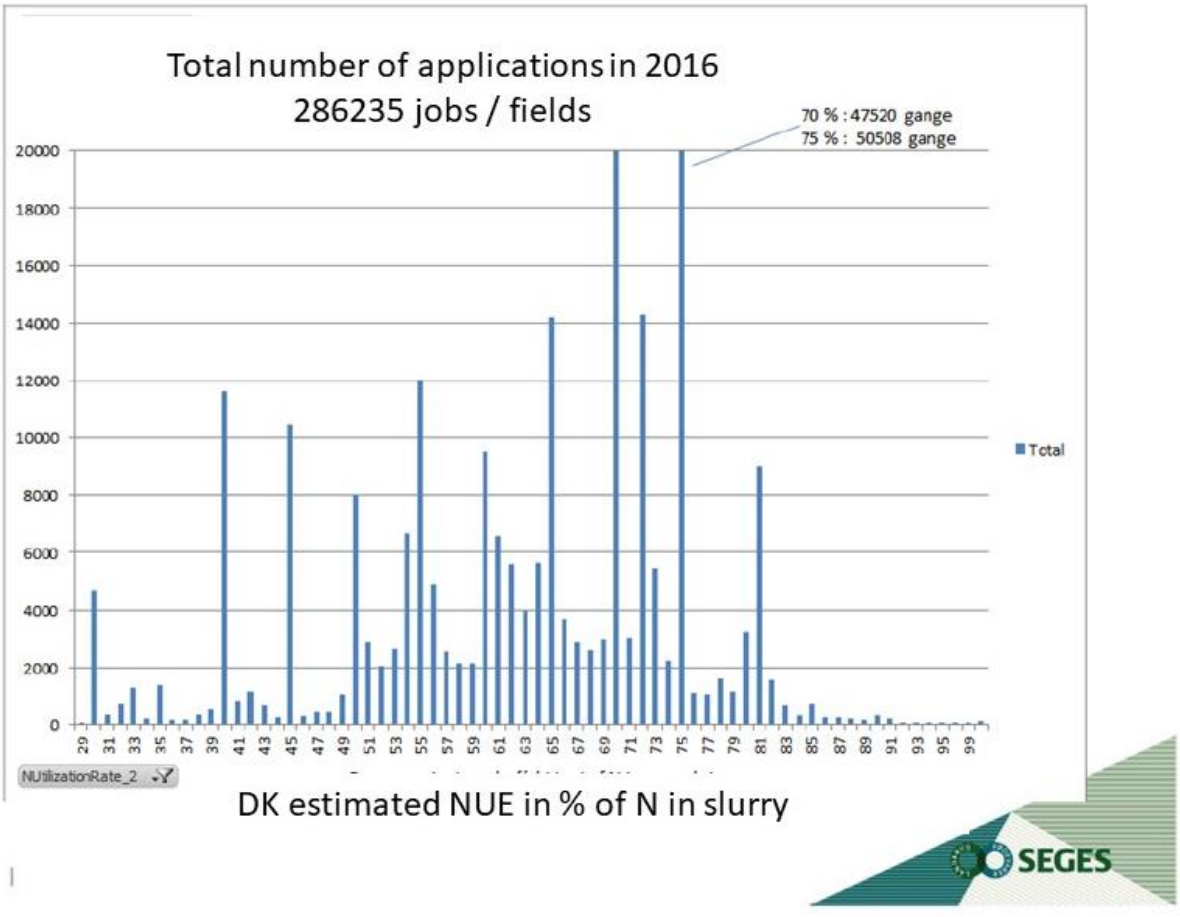
Economics of using e-missioN system
Depending on the outcome of the slurry application, management may decide to change the mineral fertilizer application rate according to the achieved average NUE, which may vary considerably from the planned dosage-rate.
With knowledge of the average NUE, it is possible for management to optimize the planned mineral fertilizer dosage-rates, so the overall nitrogen application rate is met - without any risque of sub- or overfertilization due to slurry variability.

The above histograms show very clearly what NUE the farmer has achieved from his slurry application.
The As Applied map has a 76-84 kg as an average pr ha from the slurry and it is reduced to 68-76 kg pr. ha after the emission loss – the NUE Applied map – a loss of 10.5 kg nitrogen pr. ha.
The variations may be from 2-3 kg up to 80 kg!

This is a revolution for the use of slurry!

This is the first time a commercial system can measure the losses from ammonia emissions, overlaps and gaps and display a map / statistic of the NUE – Nitrogen Utilization Efficiency.

The first step to use this new technology is simple. Slurry is almost always used in combination with mineral fertilizer. But without the knowledge of the average NUE from the slurry, it is difficult to estimate a correct volume / dosage rate of mineral nitrogen. Consequently, legislative values for the NUE are often used by the extension services:



Above statistics of Danish fertilization with slurry, shows that 60 % of slurry fertilizer accounting was based on the legal requirement to obtain min 70 % or 75 % NUE for dairy- and pig slurry. The remaining 40 % are relate to the applied NUE, but it is impossible to know in advance of any application.

The consequence is an inaccuracy when deciding on the mineral fertilizer dosage rate in combination with slurry.

Above example:

		Kg N/need ha
Normative figures:		
Applied 80 kg N at expected efficiency of 75 %		60 / 80
NUE calculation:		
e-missioN Applied NUE		72 / 68
Difference		- 12
Value of saving on 98 ha	3 € pr. Kg N x 1.2 t =	**3.600 €**

The additional volume of nitrogen can now be accurately defined based on an NUE of 72 kg. In above example, it will be 12 kg mineral nitrogen less pr. ha than with the use of normative figures because the NUE average was above the theoretical 75 %.
Based on the above profitability on 98 ha, a 2000 ha us of the e-missioN has a potential income of 73.500 €.
With an average price of e-missioN System of 14.000 €, the ROI X5 pr. season.

Depending on the many variable parameters described above, the NUE calculation may be negative and show an increase in need for nitrogen. In such a situation, there is a need for prioritization of the available mineral fertilizer to reach the ideal application level and to compensate for the lack of slurry NUE. This will lead to an increase in yield, which potentially is a significantly larger increase in profitability compared to a saving on purchase of mineral fertilizer. Such yield increases are not as easy to document, but just 1 % yield increase in winter wheat on 2000 ha, is +50.000 €.
With the high variability of the NUE in slurry, knowledge of the NUE is a win-win situation regardless of the potential being a saving- or yield increase.

Dosage rate decision via VRA map
The e-missioN system also supplies a Variable Technology Application (VRA) map.
Because the slurry application is often both at night- and daytime and during climate conditions that may vary considerably over the time of application, there are often significant differences within a single field.
e-missioN system delivers a VRA map in shape file format that is compatible with most fertilizer spreaders. With the data inserted into the mineral fertilizer spreader control system, it will spread the mineral nitrogen according to the variable dosage-rates identified by the NUE map.

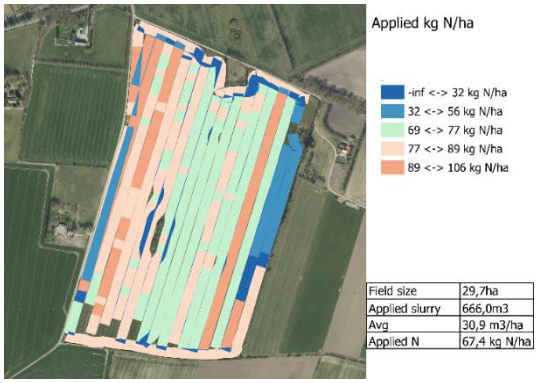
Even without large variations – like in above situation, the use of VRA map may be a good idea. In the example, app. 30 % of the area deviates from the average and there is a Gap of 2 Ha.

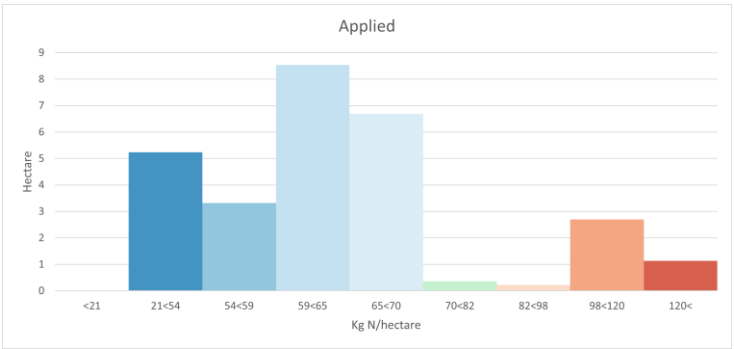
Management- or advisory services may add / change the recommendations according to the available field data and reach an even more optimized dosage rate.
It is important to remember that the application method of mineral fertilizers does not offer the same precision as slurry application.
In the below example, only the larger gap area of 2 % can be corrected with an increase in mineral fertilizer dosage rate. This will reduce the saving on fertilizer with 230 kg / 690 €, but it will likely increase yield with 50 % on the 2 % area or an income of +/- 1.500 €. At the same time, there is and an optimization where 8 Ha receive 10 Kg less and 25 % receives 10 % more, leading to an estimated 1 % yield increase on the 25 %. In this manner, the mineral fertilizer will be distributed from an overapplication area to a sub application area with +10 kg ha.

Example with a 140 kg total pr ha:

	Kg N/need	**Area %/ ha**	**Total 98 ha**
Normative figures:			
Applied 80 kg N at 75 % NUE	60 / 80	100 % / 98	5.880 kg N
VRT calculation:			
Overlap area	0 / 0	0 %	0 kg N
GAPS	0 / 115	2 % / 2	230 Kg N
Low NUE 80 kg N at 80 % NUE	62 / 78	25 % / 24,5	1.570 Kg N
Middle NUE 80 N at 90 % NUE	72 / 68	65 % / 63,7	4.580 Kg N
High NUE 80 Kg N at 100 % NUE	80 / 60	8 % / 7,8	624 Kg N
Total			6.770 Kg N
Difference		100 %/ 98	890 Kg N
Value of saving	3 € pr. Kg N x 890 Kg N =		2.670 €
Sub fertilization area mineral fertilizer cost			-690 €
Sub fertilized area Yield increases 2 % area			1.500 €
Optimization + 10 kg on 25 % area – 1 % yield increase			700 €
Total			**4.180 €**

The above calculation does not take overall yield increases into account because of better targeted fertilizer dosage rate. This is not easy to quantify, but all agronomic know-how says it will improve yields, where overfertilization is a waste and sub fertilization is a reduction in yield.
The need for VRA is very varied. If the application is divided between more days or there are rain showers during application, the need for VRA can be very significant. Different soil types and history are also very important factors.





Example of ”streched” slurry application

There are many examples of the slurry being “stretched” so the slurry tanker travels only once through the field. This will cause deliberate nitrogen variations but with e-missioN VRA application, it may not lead to yield variations, when the missing NUE has been corrected and it has received the minimum average dosage rate.

The ideal e-missioN application combination

The e-missioN method may be used in many different combinations and the above are just examples compared to using normative dosage rate or VRA. There are many more systems that use from 2 to 4 applications depending on crop, winter- or spring sown, climate zone etc. One of the more advanced is use of satellite biomass maps or crop scanners looking at the biomass. This may also be combined with e-missioN.
In above example, the planning for 153 Kg N would look like this:

1st application – 25 Kg N early growth mineral application in February
2nd application – 80 Kg N with slurry in Marts - April
3rd application – +/- 60 kg VRA mineral nitrogen following slurry application
4th application – 13 Kg N +/- with mineral nitrogen - before 1st June according to the biomass map / sensor

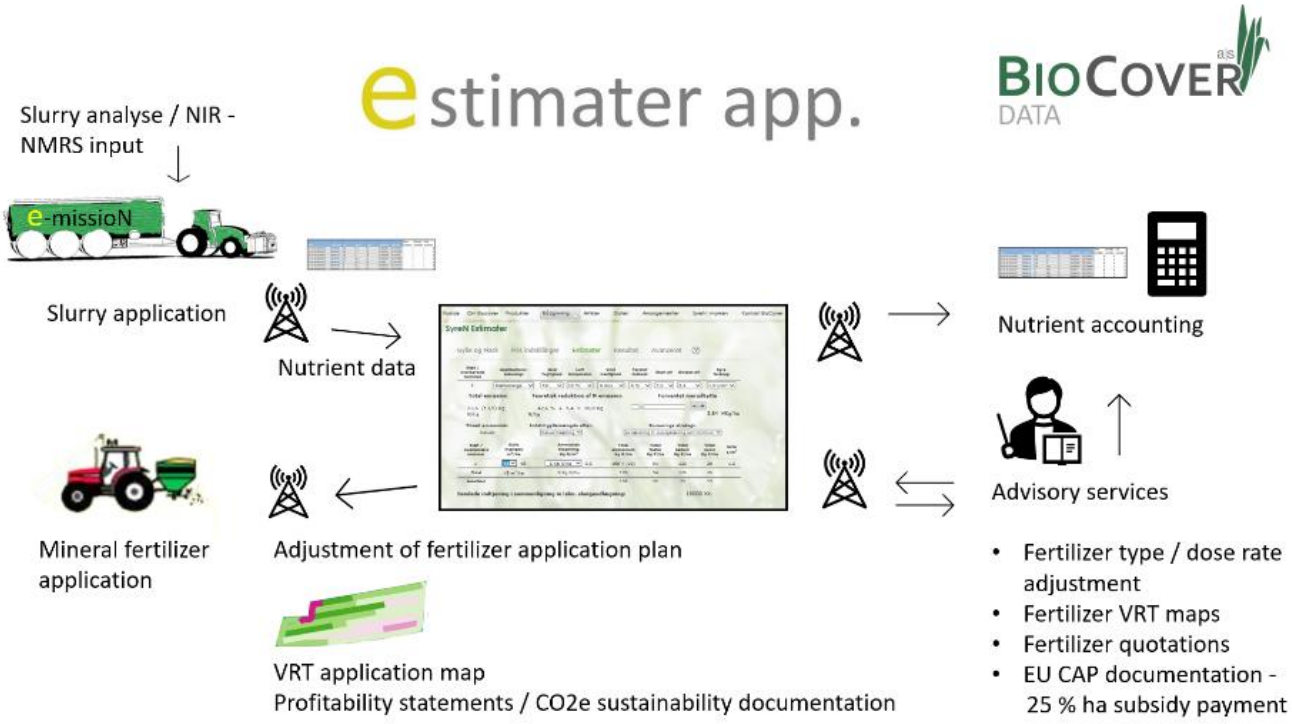
The target dose rate for the field is established in the pre-season fertilization plan.
The 4th application is with the use of on-line sensors or VRA maps based on satellite biomass with the target to apply the final mineral fertilizer according to plant nitrogen uptake. It is recommended to use the “Robin Hood” method – To redistribute from areas with a high biomass to areas with a low biomass.

The e-missioN technology is new. Examples of better management though targeted application volumes of fertilizer will be numerous and a great asset for the system. It enables reduction in the use of nitrogen without the need / risque of reducing yield

Automatic fertilizer accounting

The e-missioN system is depending on accurate data input. It is possible to incorporate a NIR (Near Infra Read) nutrient sensor system that automatically delivers highly accurate nutrient data to the tractor terminal /ECU. There is also a manual function where slurry analysis data from slurry samples may be entered. Normative figures may be used, but without a high accuracy of the entered data, the e-missioN system NUE recommendations may be compromised.

The data flow for e-missioN:
When a job on the slurry tanker is executed, an e-mail containing the above documentation is send to the owner of the system / slurry tanker. In the data transfer set-up, other stakeholders may be added. It is possible to re-route the data to the field management and / or advisory services that delivers nutrient accounting as a service. It is important for the owner to ensure proper management og GDPR before data transfer. There is also the option to re-route the data from the server via Agri-router to a specified account.
When the mineral fertilizer spreader is also part of the system, no further action from management is needed for nutrient accounting and the documentation of the applied levels of fertilizer is delivered automatically.



Data flow from e-missioN

Documentation for sustainable use of slurry / mineral fertilizer

The ability to document the sustainable use of fertilizers – organic and mineral - is likely to become subsidized or even to become mandatory.
The EU Green Deal is part of the agreed EU reform of the CAP. It is policy from 2023 and its focus is a reduction in loss of nutrients with 50 %, leading to a reduction in use of mineral nitrogen of 20 %. Fertilization with knowledge of the NUE, is the only way to significantly reduce the use of nitrogen without consequences for farm economy.

Reduce **nutrient losses** by at least 50% while ensuring no deterioration in soil fertility; this will reduce use of **fertilisers** by at least 20 % by 2030

EU Green Deal strategy from 2023

In Denmark, there is an existing possibility of a 10 % reduced area of catch crops when VRA is used Improvements in the NUE will reduce GHG, eutrophication and leaching of nitrate and reduce loss of biodiversity. BioCover Data will seek to become certified and hopefully the GHG emission reduction can be quantified as a carbon credit and potentially enable a new source of income for agriculture.
Calculation of CO_2 from nitrogen is based on the IPCC norm which is 0.01 kg N_2O pr kg N x factor 300 = 3 Kg CO_2 pr. kg lost Nitrogen. The average loss of nitrogen pr. Ha is app 70 Kg pr. Ha and with 175 Mio Ha under agricultural utilization in EU, this amounts to +35-million-ton CO_2 emission.
Future framework conditions are likely to require accounting of the GHG and the e-missioN System is thus a significant contribution where the As Applied map and Applied NUE maps may serve as documentation.

e-missioN sensor system

It is easy to start with e-missioN. The sensors are already being used on slurry tankers in varied volumes, so it is already tested equipment. That means that there are variations in price, depending on which equipment has been fitted as standard. The list below, is of needed equipment when none of the sensors are available as standard. If e-missioN is to be retrofitted to an existing slurry tanker, a consultation with an individual quotation is needed.
Some sensors can be left out, provided that the information is available and is entered into the system manually.
There are two configurations:

Basic: Use as a nitrogen loss monitor
Advanced: Use as support for dose rate decisions and documentation

The full version of the sensor package contains:

Isobus terminal

An Isobus terminal is standard on large tractors today, so it is not a requirement. Some customers want the e-missioN system kept separate from the tractor controls and if so, a separate terminal for the e-missioN system can be installed. The terminal is connected to the tractor Isobus and uses many of the tractor signals and communicates with the ECU via the Isobus CAN

Slurry flow sensor

Many slurry tankers have a slurry flow sensor installed but some manufactures use the pump to calculate the volume of slurry. The pump calculations may lead to errors in the volume calculations, so although the pump signal can be used for estimating the volume, a separate slurry flow sensor is recommended if it is not standard.

Telemetric system

If the e-missioN system is only used as a nitrogen loss monitor, there is no need for the telemetric system. When used for dosage rate decisions and documentation, the telemetric system is standard.
The telemetric system has a yearly fee for the transfer of the data. The datasets are automatically transferred to the account holder e-mail address as a PDF file for each job started on the terminal. If the account holder is a contractor, he is responsible for transfer of the data to the farmer / advisor

Mobile weather station

The weather station must be on board the slurry tanker. There are significant changes to the climate conditions in wind shaded areas because of trees or topography. Summer showers can be very local and create significant differences.
The mobile weather station comes in two versions – with- or without a rain sensor. It is ideally positioned between the tractor and slurry tanker, but it is subject to individual possibilities

pH sensor

The pH sensor needs to be inserted in a position where it will remain moist and with a flow of slurry. The lifespan of the sensor head is max. 2 years, after which it must be changed. If there is no opportunity available for installing the pH sensor, a separate box can be supplied, which fitted to the boom, serves to keep the pH sensor moist and with a flow of slurry.

ECU / Junction box

The ECU is the controller of the e-missioN system, and it has the database installed in the computer. With e-missioN as an OEM system or with the SyreN System, it is integrated in the host system. As a retrofit, it is integrated in the junction box and with a wiring harness included.

NIR sensor

A NIR (Near Infra Read) sensor may be added to e-missioN to enable on-line measurement of the nutrients in the Slurry. This includes mapping of phosphorus, potash, and dry matter. The addition of e-missioN to the NIR is important because the accurate measurement of ammonium in the slurry is not the same as the NUE. The combination of NIR and e-missioN is thus the ideal system for an accurate estimate of the NUE

Existing- or new equipment

As a retrofit system, e-missioN may be fitted to all slurry application technologies. There may be some duplication of sensors if existing sensors does not match the isobus standard. As an OEM system, this problem is eliminated through a factory build in.

The emission product is a Logic extension of all professional slurry application. It is a signature of a professional contractor / farmer, that are under constant pressure to deliver increased efficiency. It is a system that connects all stakeholders in the application decision chain, and it adds significant value to farm management and the decision process of fertilization.

It is certain to create a real differentiation between contractors where those who creates the most value for their customers, are also the future winners.

The future

It is not difficult to predict a continued pressure from framework conditions for improvements of the NUE. This can be seen in both EU and national regulations.

That makes it good timing to start integrating the digital world with the use of slurry. A lack of documentation in the future, will mean limits on use- and production rights. It can be predicted that transparency with use of nutrients will become as important as the effect we expect from the nutrients that is applied.

But before all, e-missioN is a profitable new technology that will change our way of thinking of- and working with slurry.

We must make room for the existing volume of slurry. This is easier when we can trust the effects from its use. A reduction in the use of mineral fertilizer is a better operational decision, than a reduction in the volume of slurry / number of animals.

An improvement in the NUE is a win-win situation for contractors, farmers, and the environment.

e-missioN Video link: https://www.youtube.com/watch?v=c24WHZ1Nw_E

SyreN Changes

Reduction of Methane emission from storage of slurry

SyreN can be used in many different configurations. Slurry can also be stabilized in the storage facility.

Stabilization in the tank just before application to fields when the tank is full, has several drawbacks. The most important is the foaming of slurry. There is a need to reduce the volume of slurry in the tank to make room for the foam created by the slurry. This is normally 20 % of the volume that cannot be stabilized. It requires a high volume of acid to reduce the emission. This volume must be supplied by an acid semi-trailer truck and delivered to the slurry in combination with a slurry mixer-tractor combination. The logistics must match the operation. That makes it a two-man operation for 5-7 hours pr. tank operating expensive equipment. This type of stabilization has not gained a market following.

There is a situation where the mixing of acid in the storage tank could be wanted. In the period from emptying the tank in the spring and until autom, the storage of the slurry develops a considerable volume of Methane gas. As the temperatures lowers, the Methane bacteria activity and emission is very low to non-existent during the winter.

Using the SyreN to lower the pH in the storage tank in the summer period, can avoid a considerable volume of Methane gas emission as the Methane bacteria cannot develop in a pH environment below 6. The pH will increase again with the addition of more slurry until application in the spring, but that will be without Methane gas emissioN. The addition of acid during the summer period is not expected to be above 1 m^3 acid pr. mixing, and that makes the SyreN ideal, where 1 person can fulfill the task in under ½ hour. Such a method for control of additional emissions from slurry will increase the use and profitability of the system. The volume requirement of acid at spring application will we much less and aid the logistics of SyreN slurry stabilization during spring field application.

This variation in use of SyreN is well suited for digested slurry without gastight cover of the storage. The digestor increases the pH in the slurry to +8. Although most of the Methane has been extracted in the Digestor reactor, there is still 20-30 % potential Methane gas remaining. With the high increase of Methane bacteria and high temperature, this Methane will be lost as GHG emission. A bigger problem is that the volatility of the slurry – ammonia emission – is significantly increased and a nitrogen loss as ammonia of + 30-50 % in comparison to conventional slurry can be expected. This problem will also be eliminated by the combination of storage- and field stabilization.

Currently, the markets have not been persuaded to use this method. The increased number of operations with SyreN, is an additional cost, that will not be sustained without regulation- or subsidies. However, it is BioCovers point of view, that the increased pressures to reduce the GHG

will result in framework conditions that will require a reduction in emissions from the storage facilities.

The only modification to the system is a re-positioning of the acid hose from the mixer to the crane arm. The acid may then be injected into the crane arm pump. The pump must be fitted with a crane arm mixer, that enables the mixing of slurry and acid. This is standard equipment from most slurry tanker manufactures. The slurry tanker may be replaced by a standard tractor slurry mixer, as the reservoir of acid is in front of the tractor.

The SyreN method of storage acidification, opens the possibility of claiming carbon credits for the reduction in GHG from Methane. Measuring the pH is a key technology for issue of carbon credits, as that may be used for documentation of both Methane- and ammonia emission reduction.

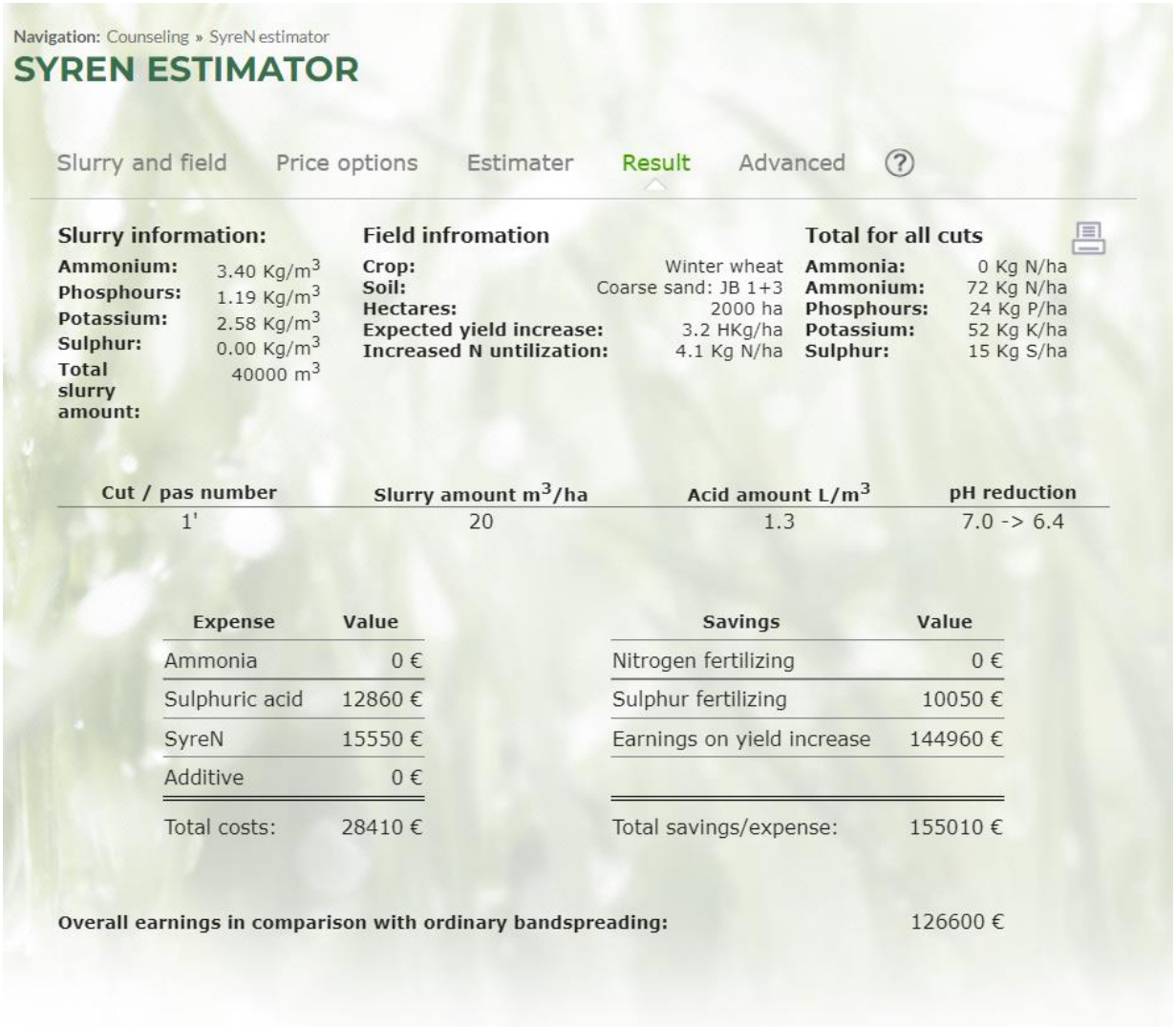
SyreN Estimater

Spreadsheet calculator of profitability

It has proven very difficult to demonstrate the profitability of the SyreN technology to the individual customer because of the many farm variables that influences the profitability of SyreN

For this reason, SyreN Estimator program was developed and made available on the BioCover web site. This is now a program with a following of many advisory services and farmers and it is an important tool for the distribution of SyreN.

By entering the budget figures into the estimator program, the program will calculate the profitability of use for the individual farm conditions. These can be very attractive depending on how much use the conditions can offer the system



Navigation: Counseling » SyreN estimator

SYREN ESTIMATOR

Slurry and field | Price options | Estimater | Result | Advanced

Slurry information:

Ammonium:	3.40 Kg/m^3
Phosphours:	1.19 Kg/m^3
Potassium:	2.58 Kg/m^3
Sulphur:	0.00 Kg/m^3
Total slurry amount:	40000 m^3

Field infromation

Crop:	Winter wheat
Soil:	Coarse sand: JB 1+3
Hectares:	2000 ha
Expected yield increase:	3.2 HKg/ha
Increased N untilization:	4.1 Kg N/ha

Total for all cuts

Ammonia:	0 Kg N/ha
Ammonium:	72 Kg N/ha
Phosphours:	24 Kg P/ha
Potassium:	52 Kg K/ha
Sulphur:	15 Kg S/ha

Cut / pas number	Slurry amount m^3/ha	Acid amount L/m^3	pH reduction
1'	20	1.3	7.0 -> 6.4

Expense	Value
Ammonia	0 €
Sulphuric acid	12860 €
SyreN	15550 €
Additive	0 €
Total costs:	28410 €

Savings	Value
Nitrogen fertilizing	0 €
Sulphur fertilizing	10050 €
Earnings on yield increase	144960 €
Total savings/expense:	155010 €

Overall earnings in comparison with ordinary bandspreading: 126600 €

1SyreN Estimator for calculating the profitability of SyreN

SyreN Patents

BioCover patent and Grant activity

The SyreN products are characterized by a succession of ideation from the continues development since the beginning. The products are first on the market, but that does not always warrant a patent. The innovative nature of the SyreN products have warranted the option of financing a large part of the product development through grants

Patents Awarded:

SyreN System

EP2272316B1

EP2272315B1

SyreN+

EP2514294A1

e-missioN

P25081EP00 – Patent pending

Changes

EP3620439A1 – Patent pending

Grants Awarded:

2009 – 2010 SyreN.
Finansing: Innovationsloven ved FødevareErhverv.
Partners – Aarhus Universitet, Viden center for landbrug, Infarm A/S, BioCover A/S

2012 - 2013 SyreN+.
Finansing: Ministry of research.
Partners – Aarhus universitet, Videncenter for landbrug, A. P. Gyllevogne, Agrodan A/S, Kemira, Agro Business Park, BioCover A/S

2016 - 2019 EU-BAT Status
Finansing: EU Interreg.
Partners: 8 partners from 7 Baltic countries

2021 e-missioN
Finansing: Vækstfonden
Partners: BioCover A/S

SyreN Verification

SyreN Verification

The SyreN System has been extensively tested by several research facilities. Among these are the international accredited VERA Verification and DAN**ETV**

The Verification is for slurry stabilized at:

pH 6.4, 2.7-liter acid and with 49 % ammonia emission reduction

Baltic Slurry Acidification

BioCover initiated the EU Baltic Slurry Acidification – a 3 year project with a budget of 5.4 Mio €. The project was a 365C° study of effect and market readiness. All aspects of the technology have been scientifically reviewed. SyreN was chosen by 6 out of 7 user projects and homologated in 7 EU member states. SyreN received an EU- BAT status and is legal for sale in all EU countries.

http://balticslurry.eu.

SyreN for Sustainability

Direct positive

Indirect positive

SyreN has been awarded as contributing to 9 out of 17 world sustainable goals by Stockholm University

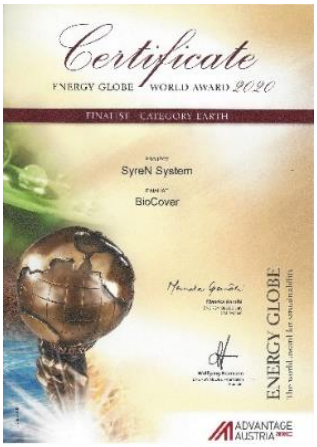
SyreN Awards

Awards

SyreN System has won 11 international awards. The flexibility of the system to match all farm requirements for both storage- and in-field stabilizing of slurry is unmatched.

Awards

- **Agromek prisen 2008**
- **Agromek prisen 2010**
- **Miljøministeriets CSR Award 2012**
- **Baltic Manure Award 2012**
- **EU-CSR Award environment 2013**
- **EU Award program Scale-up finalist 2018**
- **Solar Impulse Efficient solution SyreN 2019**
- **Solar Impulse Efficient Solution Changes 2020**
- **Energy Globe National Award 2020**
- **Solar Impulse Efficient solution e-missioN 2021**
- **Energy Globe International Award 2021**



SyreN

Changes

e-missioN