MINISTERIAL DECISION REPORT

Why the Netherlands Should Authorise SyreN

A verified, measurable and economically proportionate contribution to the Dutch nitrogen strategy

SyreN in-field acidification: verified ammonia mitigation combined with wide-boom application and digital documentation.

12% TAN	15.8 kt	€240m	5 years
proposed interim factor	central annual NH_3 reduction	national technology capital	phased national rollout

Prepared for the Minister of Agriculture, Fisheries, Food Security and Nature
Government of the Netherlands

Prepared by BioCover A/S | Version 1.0 | 28 August 2026

Ministerial decision summary

DECISION REQUESTED

Grant controlled Dutch authorisation for SyreN now, based on VERA and DANETV/ETV verification, the German GülleBest/Thünen evidence, the MuD Säure+ programme and the broader international evidence base. Couple authorisation to continuous pH and application documentation and continue targeted Dutch validation in parallel.

Why a decision can be taken now

- The commercial SyreN system has product-specific third-party verification under VERA and DANETV/ETV. The verified tests establish both ammonia reduction and operational control during field application.
- Two TAN-based German comparisons support a conservative Dutch interim factor. GülleBest/ten Huf reported 12.2% of TAN for acidification versus 17.8% for injection; Seidel reported 4.4% versus 5.5%.
- A provisional factor of 12% of TAN for cattle slurry on grassland, conditional on continuously measured final pH ≤6.0, is conservative relative to the strongest paired evidence and can be reviewed after Dutch trials.
- Remaining uncertainty concerns calibration under specific Dutch soil and weather conditions. It does not justify treating the verified ammonia-reduction mechanism as unproven.

Recommended authorisation conditions

1. Recognise SyreN as an authorised low-emission application technology with a provisional emission factor of 12% of TAN for cattle slurry on grassland at continuously documented final pH ≤6.0.
2. Require secure recording of location, time, slurry volume, final pH, weather and machine state through e-missioN or an equivalent auditable system.
3. Begin with priority deployment in Natura 2000 buffer zones and demonstration farms, while allowing broader voluntary adoption and a five-year national rollout.
4. Commission paired Dutch validation on low- and high-pH soils with untreated trailing hose/shoe as the primary reference and injection as a secondary reference.
5. Review the provisional factor when the Dutch dataset is complete; do not suspend market access while calibration work proceeds.

49%	37%	31%	12% TAN
VERA cattle-slurry reduction vs untreated	VERA pig-slurry reduction vs untreated	GülleBest advantage vs injection	recommended interim factor

The decision in one page

Question	Evidence-based answer
Does SyreN reduce ammonia?	Yes. The mechanism is established and commercial SyreN was tested under VERA/DANETV. Multiple independent field programmes confirm material reductions.
Is the evidence identical to Dutch Annex 3?	No. Some international studies lack every Dutch reporting field, particularly TAN. That limits exact Dutch factor derivation but does not invalidate the observations.
Can an interim factor be defended?	Yes. A conditional 12% TAN factor at pH ≤6.0 is supported by paired German TAN data and is more conservative than several observed outcomes.
Should further Dutch trials continue?	Yes. They should calibrate soil, weather and implementation effects, using untreated slurry as the indispensable reference.
Is waiting cost-free?	No. Delay prolongs emissions, buy-out exposure, farm uncertainty and technology lock-in around injection.
How can compliance be controlled?	Through e-missioN: machine, pH, position, volume, weather, estimated loss and NPA records with permission-based audit access.

Political character of the decision

The scientific record is sufficient for controlled authorisation, but it cannot compel a minister to choose one regulatory pathway. The remaining choice is therefore political in the proper sense: whether to accept a reversible, monitored technology pathway while evidence is refined, or to continue relying on farm closures and a mechanically prescriptive application system. A controlled authorisation is proportionate because its conditions can be tightened, revised or withdrawn; closure of viable farms is difficult to reverse.

RECOMMENDED WORDING

The available verification and scientific evidence is sufficient to justify controlled authorisation of SyreN in the Netherlands. Remaining uncertainties concern calibration of a Dutch emission factor under specific soil and weather conditions—not whether in-field acidification reduces ammonia emissions.

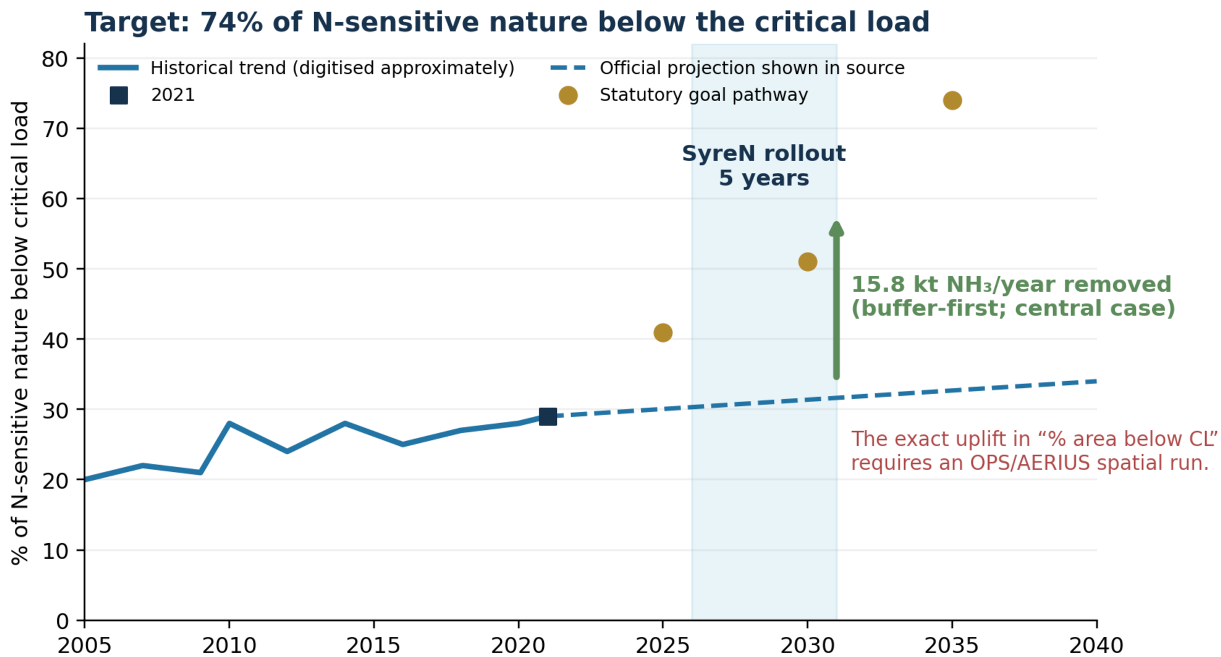
Contents and reading guide

The first three pages are designed to support a ministerial decision. Parts I-VI provide the integrated policy case. The appendices retain the detailed evidence and calculation trails so that LVVN, CDM and technical reviewers can audit the basis without overloading the ministerial narrative.

Part I — The decision facing the Netherlands

1. The Dutch nitrogen challenge

The Netherlands must reduce nitrogen deposition on sensitive nature while preserving a viable agricultural and food-production cluster. Existing projections leave a substantial gap between the share of nitrogen-sensitive nature expected to fall below critical load and the policy ambition of 74%. No single technology can close that gap, but slurry application is a large, addressable ammonia source and reductions close to Natura 2000 can carry disproportionate ecological value.



SyreN as a technology wedge in the trajectory toward 74% of nitrogen-sensitive nature below critical load. The exact nature response requires OPS/AERIUS modelling.

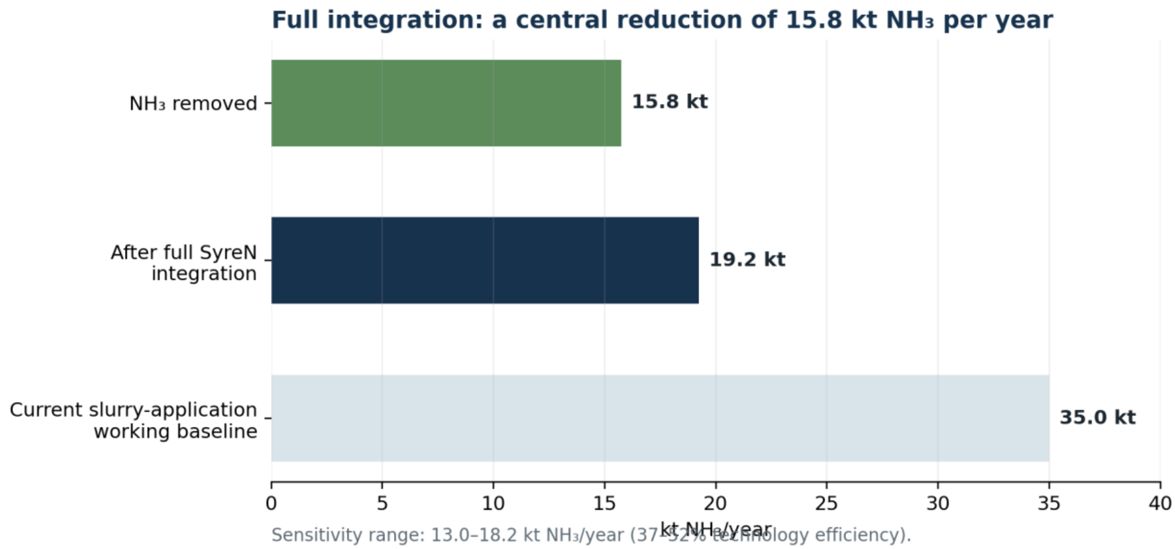
2. The requested policy decision

The request is not for an unconditional permanent factor. It is for controlled market access and an interim regulatory credit based on verified performance, continuous documentation and a defined review process. This separates two questions that CDM's narrow treatment tends to combine: whether SyreN works, and what exact factor the Netherlands should assign under every operating condition.

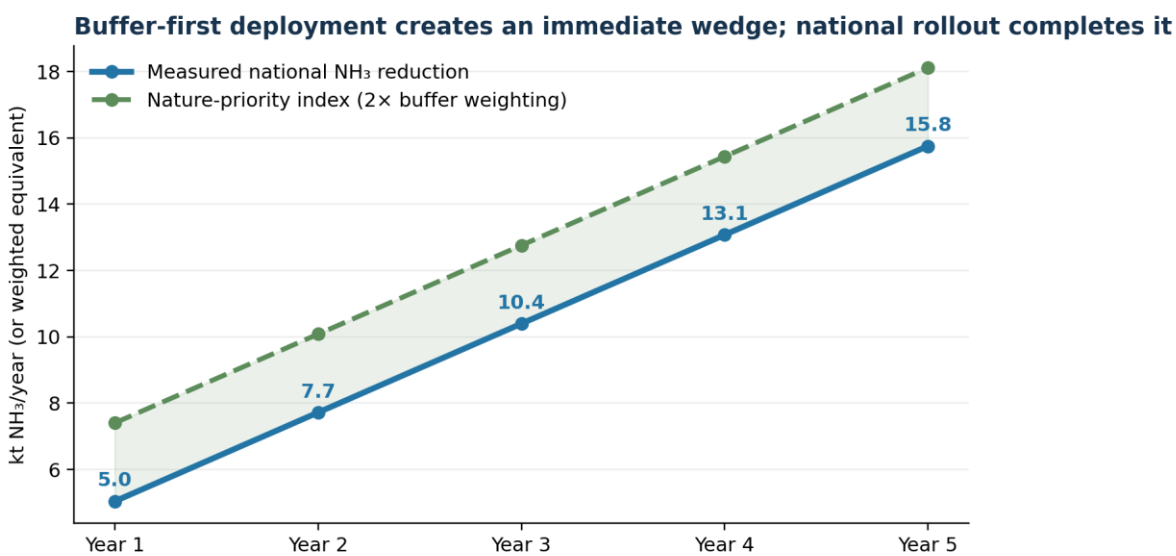
> **PROPORTIONALITY**
> A requirement for additional Dutch calibration can coexist with immediate conditional authorisation. Calibration uncertainty is a reason for conservative credit and monitoring—not for treating all existing verification as if it did not exist.

3. National ammonia and buffer-zone potential

The central national scenario treats 40 million m^3 of slurry, assumes 2,667 systems at 15,000 m^3 per system and phases national adoption over five years. It produces an estimated 15.8 kt NH_3 annual reduction, with a sensitivity range of 13.0-18.2 kt. These are scenario outputs, not a statutory emission factor.



Central scenario: the 15.8 kt NH_3 reduction is shown against current slurry-application emissions and the post-SyreN remainder.



Buffer-first deployment creates an immediate reduction wedge before national rollout is complete.

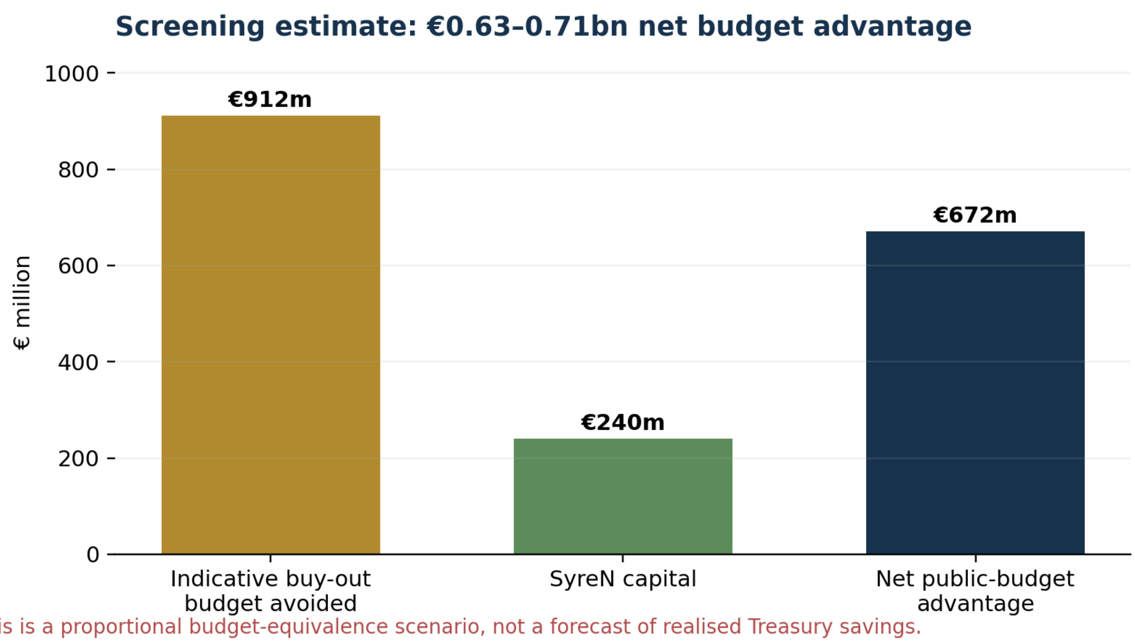
Location-specific value

National tonnes do not translate one-for-one into percentage points of nature below critical load. Dispersion, source height, distance, background deposition and habitat sensitivity matter. For this reason, the report treats buffer-zone weighting as an illustrative policy sensitivity and calls for OPS/AERIUS verification. The robust conclusion is directional: reductions delivered close to sensitive nature should be prioritised.

4. Economic and social proportionality

2,667	€240m	€0.63-0.71bn	15.5%
systems for 40m m^3	gross capital	indicative net budget advantage	of agricultural NH_3

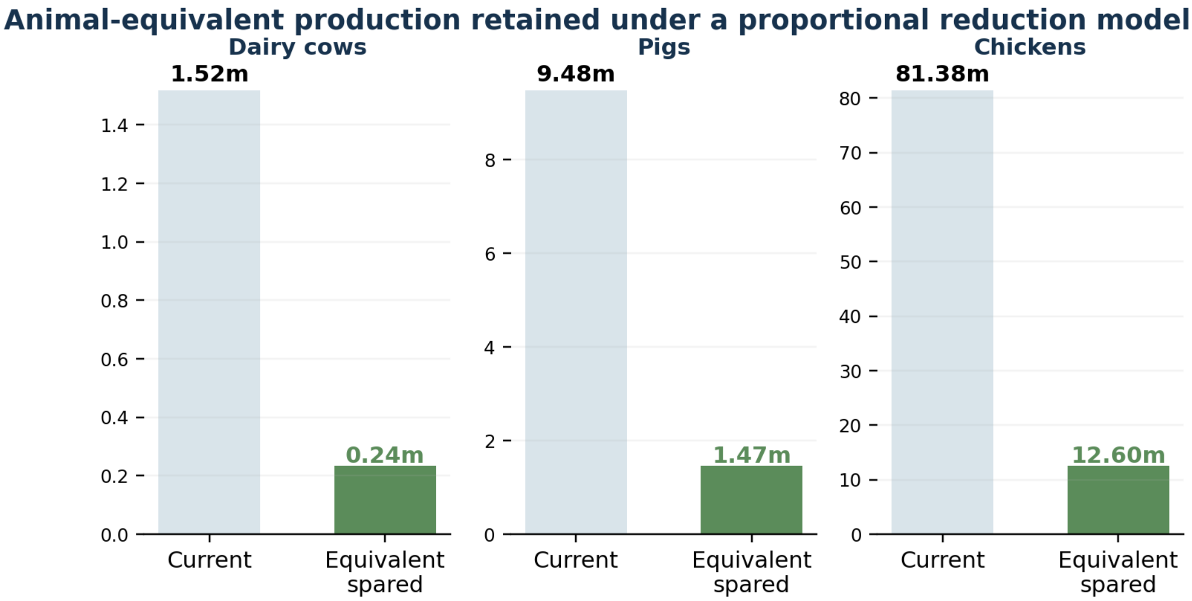
At €90,000 per system, national capital expenditure is approximately €240 million. The economic screening compares this with the €2.75 billion voluntary closure and relocation frame and the broader €20 billion nitrogen package. It does not claim that every euro of theoretical buy-out equivalence becomes a Treasury saving. It shows order of magnitude and opportunity cost.



Indicative buy-out-equivalent budget comparison after deducting SyreN capital expenditure.

Livestock-production equivalents

The central ammonia wedge is equivalent to approximately 235,000 dairy cows, 1.47 million pigs or 12.6 million chickens under proportional emission assumptions. These are alternative illustrations of the same reduction; they must not be added together. Their purpose is to show the scale of productive capacity that technology may protect.



Alternative livestock-equivalent illustrations of the same ammonia reduction. Categories are not additive.

Wider Dutch value

- Preserved farm succession, skills and contractor capacity in rural regions.
- Reduced disruption to dairy, meat, feed, machinery, logistics and food-processing networks.
- A technology-and-data export position in results-based environmental regulation.
- A reversible investment pathway compared with irreversible closure of productive holdings.

Part II — Technology and implementation

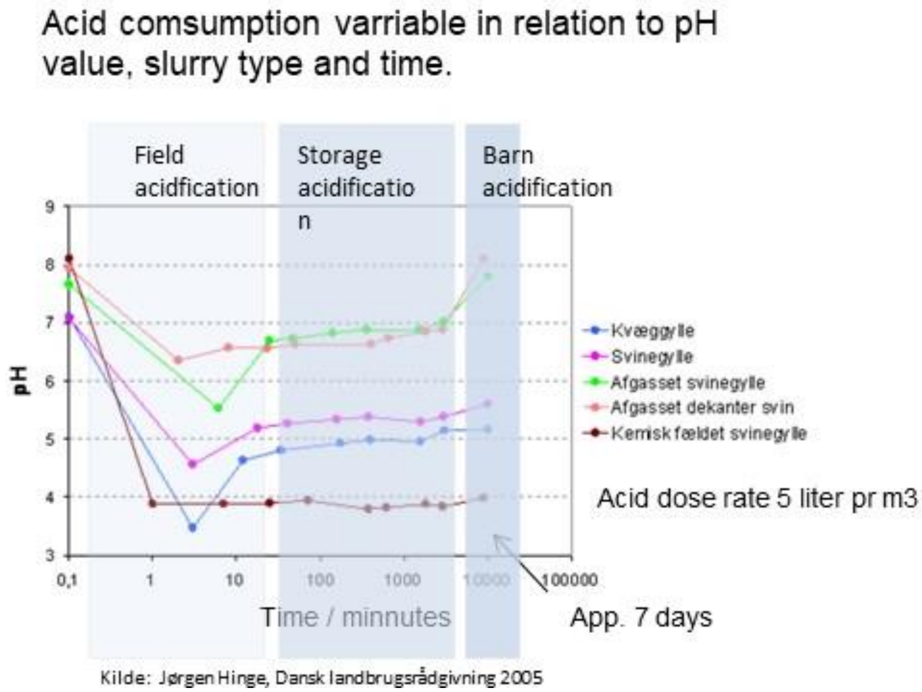
5. How SyreN works

SyreN injects sulphuric acid into the liquid slurry stream immediately before field application. Lower pH shifts dissolved ammoniacal nitrogen from volatile NH_3 toward non-volatile NH_4^+. The system regulates dosing against measured pH, mixes rapidly and records operation data. Adding acid during spreading minimises the interval between treatment and exposure of a large slurry surface on the field.

Commercial SyreN process: acid is injected and mixed immediately before the slurry is distributed.

Why timing matters

When acid is added minutes before application, slurry pH can begin to rebound before spreading. The supplied pH-time graphic shows that the largest initial pH depression occurs immediately after dosing and stabilises over roughly 5-10 minutes. A test without the commercial machine can still validly test acidification, but delayed application may understate the practical inline effect.



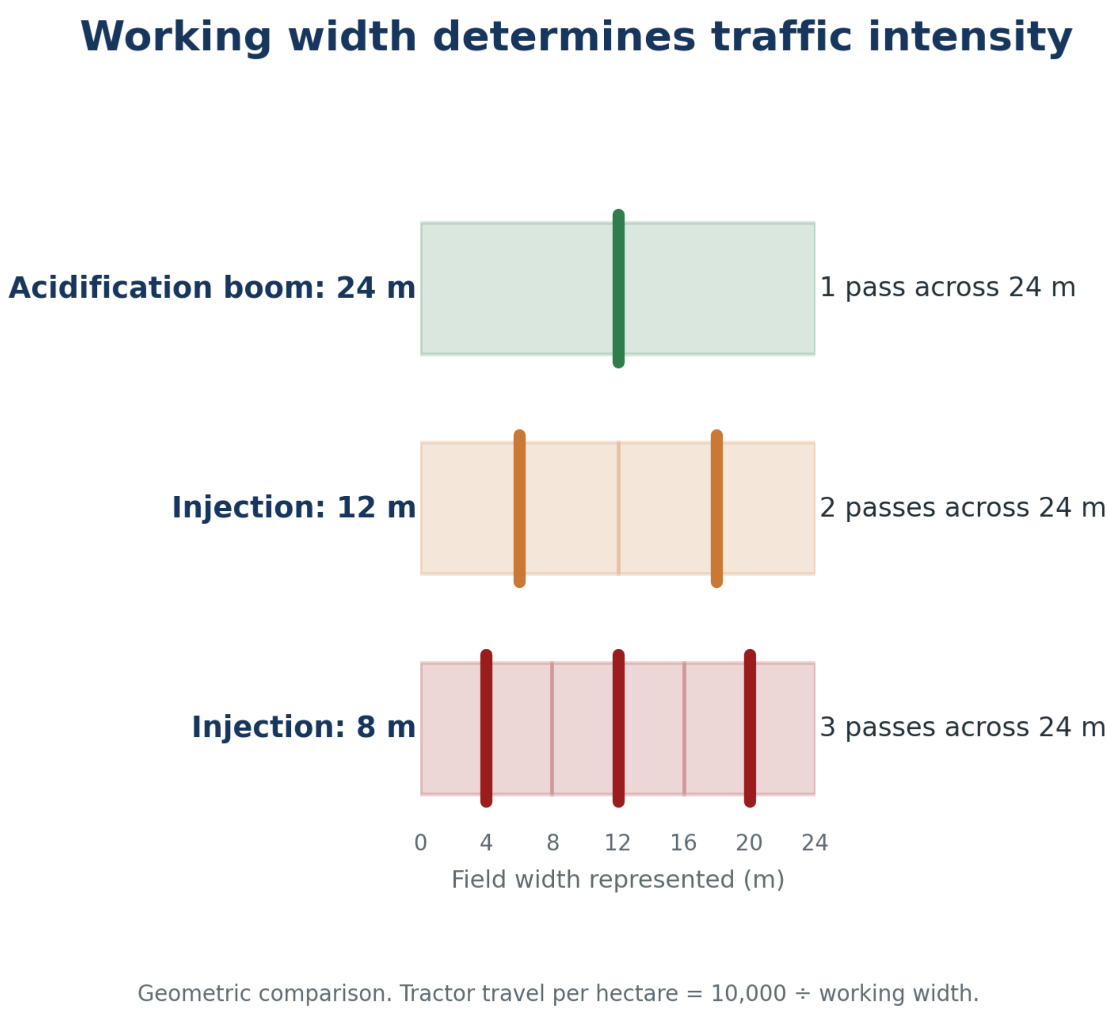
Illustrative pH response after acid addition: the immediate minimum is followed by partial rebound and stabilisation.

Nutrient effects

Retained ammonium and added sulphate increase the fertiliser value of slurry. Lower pH can also alter solubility and cation exchange, potentially increasing short-term availability of phosphorus and selected micronutrients. These secondary effects depend on soil chemistry and should not be converted into universal percentage claims without site-specific evidence.

6. Injection versus in-field acidification

Dimension	Injection	SyreN with boom
Primary mechanism	Mechanical placement below or into soil	Chemical conversion of NH_3 to NH_4^+ before surface exposure
Typical working width	Approximately 6-12 m	Approximately 12-24 m
Traffic intensity	More passes at narrow width	Fewer passes at wider width
Soil interaction	Cuts or disturbs soil; higher draft	No injection slots; lower draft demand
Fuel and capacity	Higher pulling power and lower field capacity	Higher field capacity and lower mechanical resistance
Emission control	Depends on placement quality, soil and weather	Depends on pH, dose, mixing and weather
Verification potential	Usually normative or equipment-class based	Machine-specific pH and application record can be audited



Working width determines the number of passes and traffic intensity per hectare.

At 20-25 cm tine spacing, injection mechanically opens approximately 40-50 km of slots per hectare. This is a geometric description of soil disturbance, not proof of permanent damage. The policy relevance is that ammonia mitigation choices also affect fuel, capacity, soil traffic and greenhouse-gas exposure.

7. BioCover implementation platform

Product	Function	Principal effect
SyreN	Commercial pH-controlled in-field acidification	Verified reduction of ammonia during slurry application
SyreN Light	Compact trial and OEM-ready dosing platform	Applies the same chemistry; effect must be specified by achieved treatment conditions
e-missioN	Application, loss, NPA and VRA documentation	Supports lower mineral-N use, audit and doelsturing
SyreN Changes	Low-dose warm-period storage treatment	Aims to inhibit methanogenesis; performance is being validated in pilots

BioCover reports 170 produced SyreN systems across Denmark, Sweden, Finland, Estonia, Lithuania, Germany and France. Ongoing programmes include Arla methane pilots in Sweden, Denmark and England, a Swedish project with Jordbruksverket, and the German MuD Säure+ programme with eight machines in eight federal states through 2027.

170	7	8	2027
SyreN systems	European markets	German demo units	MuD extension

Part III — Verification and scientific evidence

8. Verification basis

Framework	What it establishes	Relevance
VERA	Product-specific field testing of commercial SyreN with cattle and pig slurry, including ammonia reduction and operation	Core evidence that the system and acidification process work in field application
DANETV / ETV	Independent test, verification statement and traceable reporting	Supports cross-jurisdictional technology assessment and operational credibility
EU BAT	Recognition of slurry acidification within best-available-techniques work	Confirms regulatory relevance; not a product-specific Dutch sales authorisation by itself

VERA reported a 49% average reduction for cattle slurry and 37% for pig slurry relative to untreated application in the verified series. These relative reductions are not the same metric as a Dutch absolute emission factor expressed as percentage of TAN. The distinction must remain explicit throughout the decision.

METRIC DISCIPLINE

49% below untreated, 12% of TAN emitted and a 31% advantage over injection describe different denominators. They can all be correct simultaneously.

9. International evidence and weight of evidence

The international record includes controlled emission measurements, paired technology comparisons, multi-year demonstrations and agronomic trials. Not all studies have equal regulatory weight. A defensible assessment grades them rather than excluding all material that does not reproduce every field in Annex 3.

Evidence tier	Examples	Use in decision
Tier 1 — product verification	VERA / DANETV commercial SyreN test	Direct evidence of product operation and relative ammonia mitigation
Tier 2 — TAN-based paired comparisons	GülleBest/ten Huf; Seidel	Strongest basis for translation into a Dutch TAN factor
Tier 3 — multi-year field programmes	Thünen / GülleBest programme; MuD Säure+	Transferability, operational robustness and agronomic consistency
Tier 4 — broader studies	27-study international review and yield datasets	Mechanistic consistency, boundary conditions and secondary benefits

Thünen confirms the GülleBest programme and should not be double-counted as a separate independent TAN dataset. It remains relevant for interpretation, methodology and multi-year operational consistency.

10. Translating evidence into percentage of TAN

Dataset	Acidification	Injection / reference	Interpretation
GülleBest / ten Huf	12.2% of TAN	17.8% of TAN injection	5.6 percentage points lower; approximately 31% below injection
Seidel	4.4% of TAN	5.5% of TAN injection	1.1 percentage points lower; approximately 20% below injection
VERA cattle slurry	21% observed TAN emission at pH about 6.4-6.5	Untreated reference	49% relative reduction in the verified series
Proposed Dutch interim factor	12% of TAN at final pH ≤6.0	17% TAN benchmark	Approximately 29-30% credit against the benchmark

The recommended 12% factor is not derived by simply subtracting 49% from the Dutch 17% factor. It is supported primarily by direct TAN-based comparisons and bounded by product-specific VERA evidence. Continuous final-pH documentation provides an enforceable operating condition and makes the interim factor more conservative than a technology-name-only approval.

11. Thünen, GülleBest and the machine question

CDM noted that acid was not applied with the commercial SyreN machine in parts of the Thünen/GülleBest work. That observation limits claims about the machine's complete operational system; it does not invalidate measured ammonia differences caused by acidification. Indeed, pre-acidifying slurry and waiting before application removes an important feature of SyreN: the strongest immediate pH reduction occurs while the freshly spread slurry has maximum exposed surface area.

> **SCIENTIFIC CONCLUSION**
> Absence of the commercial machine is a scope limitation, not a validity failure. It may bias the test conservatively against inline SyreN, but the size of that bias requires a paired experiment and should not be invented.

High-pH and low-pH soils

Further Dutch tests should stratify low- and high-pH soils. Rain after application on high-pH soil may reduce observed differences in some events by accelerating infiltration or changing exchange processes. The same weather interaction affects all surface-applied slurry and should be treated as a boundary condition—not as a technology-specific disqualification. Untreated trailing hose or trailing shoe must therefore remain the primary reference in every soil class.

Part IV — Assessment of the CDM opinion

12. Limitations in scope and interpretation

CDM's responsibility is to protect the integrity of Dutch emission factors. Its caution about Annex 3, TAN reporting, direct comparability and transferability is legitimate. The problem arises when evidentiary imperfections are treated as reasons not to evaluate the material at all, rather than reasons to assign different evidentiary weight and conservative conditions.

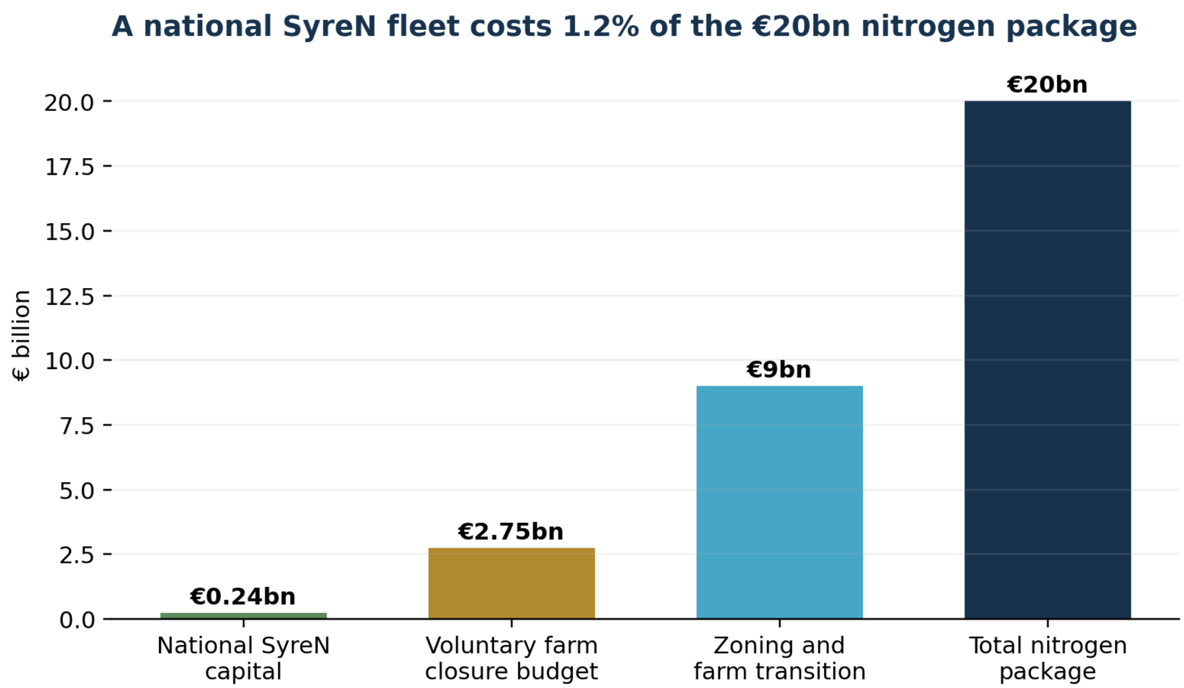
- Conflation of two standards: evidence that a technology reduces ammonia versus evidence sufficient to set an unconditional permanent Dutch factor.
- Underweighting of product-specific VERA/DANETV verification and paired relative evidence.
- Exclusion of trials lacking TAN instead of using them for mechanism, robustness, boundary conditions and relative comparisons.
- Insufficient engagement with GülleBest, Thünen and MuD Säure+ as a connected German evidence programme.
- Failure to examine whether pre-acidification may understate the inline commercial configuration.
- Limited system comparison with injection, including width, fuel, soil disturbance, capacity and digital control.
- Insufficient integration of e-missioN as a solution to monitoring, enforcement and doelsturing.
- No explicit proportionality assessment of the economic and social cost of waiting.

INSTITUTIONAL FRAMING

The criticism is not that CDM should lower scientific standards. It is that the same standards can support a conservative, monitored interim decision while the remaining Dutch calibration work is completed.

13. The cost of waiting for perfect evidence

Waiting does not preserve a neutral baseline. Emissions continue, investment decisions are postponed, farm closures proceed and the Netherlands remains dependent on a mechanically prescriptive technology pathway. Meanwhile, the knowledge that CDM requests can be generated faster after controlled deployment because real operating data and representative machines become available.



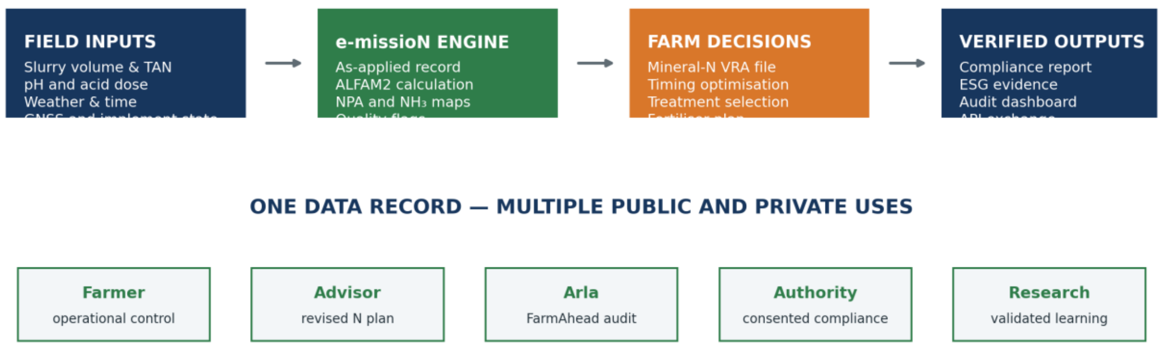
Scale comparison: national SyreN capital is small relative to the total nitrogen package and other public budget frames.

Pathway	Reversibility	Main risk
Controlled authorisation	High: factor, pH threshold, geography and audit rules can be revised	Performance below provisional credit in some conditions
Continued non-authorisation	Medium: future approval remains possible, but deployment and learning are delayed	Continued emissions, buy-outs and lost transition time
Farm closure / buy-out	Low: production capacity and social structure are difficult to restore	Irreversible loss of businesses, jobs and food-cluster value

Part V — e-missioN and doelsturing

14. Digital monitoring and verification

e-missioN is not an optional accessory to the policy case. It is the digital infrastructure that converts a performance-based approval from an aspiration into an auditable system. It links field inputs, the ALFAM2 calculation engine, farm decisions and permission-based outputs.

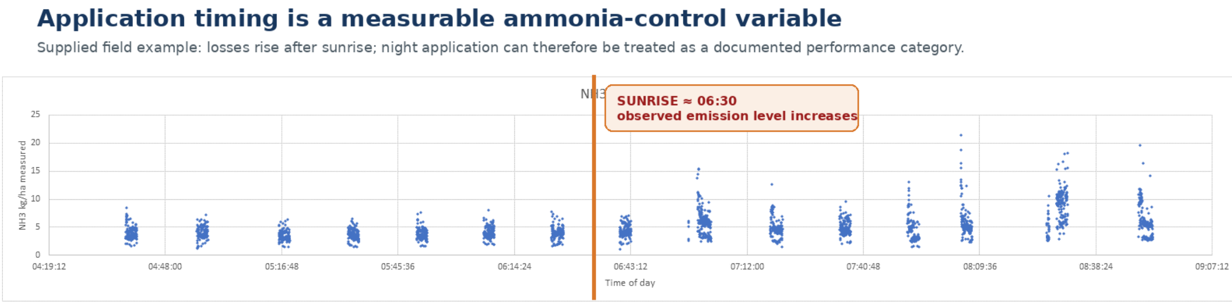


One application record can serve farm management, dairy audit, advisory work and authority oversight under defined permissions.

Recorded or calculated item	Policy use
Location, time and treated area	Confirms where and when a claimed mitigation activity occurred
Slurry volume and machine state	Supports completeness and plausibility checks
Inlet/final pH and acid dose	Demonstrates compliance with the approved operating envelope
Weather and application conditions	Supports calculated ammonia loss and boundary-condition analysis
NPA and estimated N loss	Enables doelsturing and subsequent mineral-N adjustment
As-applied, N-loss, NPA and VRA maps	Provides field-level evidence for farm, auditor and regulator

15. Application timing and night spreading

Sunrise, temperature, humidity and wind influence volatilisation. e-missioN makes application timing a measurable mitigation variable rather than an unverifiable claim. A future Dutch framework could award additional credit when night application is documented and modelled NPA exceeds a defined threshold.



Application timing and sunrise can be treated as a distinct, documented ammonia-control category.

Denmark is developing an approach in which farmers may avoid mandatory injection or acidification when e-missioN documents NPA above 80%, commonly during favourable night conditions. The Netherlands can test the same principle through a controlled pilot without presupposing the final threshold or credit.

16. Arla FarmAhead and private incentives

Results-based public regulation becomes stronger when market incentives point in the same direction. The Arla FarmAhead framework can reward SyreN, e-missioN and SyreN Changes because they address ammonia, mineral-N efficiency and storage methane. BioCover's current model presents five points in total: one for SyreN, one for e-missioN and three for SyreN Changes.

Illustrative five-point FarmAhead package for a dairy farm using the full BioCover platform.

For an illustrative 1,000-cow farm producing 10,333 kg milk per cow, five points at €0.0003 per kg milk per point correspond to €15,500 per year. This is a programme illustration, not a guaranteed payment. Pilots in Sweden, Denmark and England are important because they connect measured environmental change to dairy-chain audit and farmer income.

Part VI — Recommended Dutch approval pathway

17. Immediate conditional authorisation

Element	Recommended condition
Technology	Commercial SyreN in-field acidification or an approved equivalent meeting the same control requirements
Interim factor	12% of TAN for cattle slurry on grassland
Operating condition	Continuously measured final pH ≤6.0, with complete application record
Initial priority	Natura 2000 buffer zones and monitored demonstration farms
Data	Secure e-missioN or equivalent record available for audit under farmer permission and GDPR
Review	Formal review after completion of targeted Dutch paired trials
Safeguard	Authority may revise credit where validated evidence shows systematic underperformance

This pathway does not require the minister to declare all scientific questions closed. It recognises that controlled implementation is itself a means of generating representative Dutch evidence while achieving immediate reductions.

18. Proposed Dutch continuation trials

6. Stratify sites by low and high soil pH and document soil chemistry.
7. Use the same homogenised slurry across treatments and report TAN, total N, dry matter, pH and buffer capacity.
8. Include untreated trailing hose or trailing shoe as the mandatory primary reference.
9. Include injection as a secondary technology reference where feasible.
10. Apply acid inline with the commercial SyreN machine and record inlet pH, final pH, dose and mixing interval.
11. Measure emissions with a recognised method under pre-defined weather and replication requirements.
12. Include rain/no-rain events and document infiltration and surface conditions.
13. Store raw machine and e-missioN data with an independent audit trail.
14. Pre-register the statistical analysis and publish positive, neutral and negative results.
15. Use the dataset to calibrate, not retrospectively redefine, the interim authorisation conditions.

REFERENCE PRINCIPLE

Any claim that rain or high-pH soil reduces the additional SyreN benefit must be tested against untreated slurry under the same event. A smaller treatment difference in one condition is not evidence that SyreN should be disqualified from that soil class.

19. Ministerial conclusion

The Netherlands has enough evidence to make a controlled decision now. VERA and DANETV/ETV verify the commercial system; GülleBest and Seidel provide TAN-based paired evidence; Thünen and MuD Säure+ show operational transferability; and e-missioN provides a practical route to monitoring and doelsturing. The evidence is not perfectly aligned with every Dutch Annex 3 reporting requirement, but the remaining gaps are manageable through a conservative factor, continuous pH documentation and targeted trials.

RECOMMENDED RESOLUTION

Authorise SyreN with a provisional factor of 12% of TAN for cattle slurry on grassland at continuously documented final pH ≤6.0; prioritise Natura 2000 buffer zones; require auditable digital records; and commission a paired Dutch validation programme without delaying market access.

Implementation timetable

Timing	Action
0-3 months	Issue controlled authorisation; approve data fields and audit protocol; identify buffer-zone pilots
Year 1	Mandatory or prioritised buffer-zone deployment; launch low-/high-pH paired trials
Years 2-4	Expand voluntary national adoption; publish annual verified performance and implementation reports
Year 5	Complete national rollout scenario; review interim factor using Dutch and international evidence

The decision is scientifically defensible, economically proportionate and administratively controllable. It does not replace Dutch research; it gives that research a practical policy framework and prevents the search for perfect evidence from becoming a reason for inaction.

Appendix A — Proposed Dutch interim emission factor

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

MINISTERIAL TECHNICAL NOTE

Proposed Dutch emission factor for the SyreN system

Translation of two CDM-identified field studies into percentage of Total Ammoniacal Nitrogen (TAN)

1. Decision requested

BioCover asks the Minister to permit controlled implementation of SyreN using a conservative provisional Dutch emission factor derived from the two studies identified by CDM as capable of translation into the Dutch TAN metric. The factor can apply while a confirmatory Dutch head-to-head programme is completed.

- Provisional SyreN emission factor: 12.2% of applied TAN.
- Equivalent reduction relative to 17% TAN: 28.2%.
- Operating condition: sulphuric-acid treatment to a measured final slurry pH of 6.0 or below.
- Verification condition: automatic recording of slurry volume, acid dose, inlet and outlet pH, time and position, with an auditable e-missioN report.

2. Why these two studies matter

Most international studies report a relative reduction against an untreated reference. The Dutch regulatory system requires an absolute emission factor expressed as ammonia loss relative to TAN. Seidel et al. and ten Huf et al. contain sufficient information to express both acidification and injection directly in this unit.

3. Calculation from Seidel et al.

The grassland study compared untreated band spreading, two slot-injection configurations and cattle slurry acidified to pH 6.5 or pH 6.0. The untreated cumulative loss was 14.0% of NH_4-N/TAN. Reported mitigation percentages can therefore be translated into absolute TAN emission factors.

Injection at 35 cm: 14.0% × (1 − 0.606) = 5.52% TAN

Rounded to 5.5% TAN.

Advantage of acidification: (5.52 − 4.40) ÷ 5.52 × 100 = 20.3%

At pH 6.0, acidification emitted approximately one fifth less ammonia than the best injection configuration tested.

4. Calculation from ten Huf et al. / GülleBest

The German GülleBest programme was a newer multi-site comparison conducted under practical field conditions. The absolute results allow a direct comparison in the same TAN unit without applying a Dutch baseline assumption.

Absolute advantage: 17.8% − 12.2% = 5.6 TAN percentage points

Relative advantage: (17.8 − 12.2) ÷ 17.8 × 100 = 31.5%

Acidification emitted 31.5% less ammonia than open-slot injection under the tested conditions.

Reduction relative to a 17% TAN benchmark: (17.0 − 12.2) ÷ 17.0 × 100 = 28.2%

This is the proposed conservative Dutch reduction credit.

5. Derivation of the proposed factor

The two acidification results are 4.4% and 12.2% TAN. BioCover does not recommend taking their simple arithmetic mean. The trials differ in reference emission, site structure, slurry characteristics, weather and application configuration. Averaging them would imply a statistical comparability that has not been demonstrated.

6. Recommended regulatory formulation

BioCover proposes the following wording for a temporary or conditional recognition:

7. Monitoring, verification and enforcement

A performance-based factor is credible only if the operating condition is verifiable. SyreN and e-missioN can turn the condition from a design assumption into an auditable application record.

8. Scientific and regulatory limitations

- The two studies support a provisional evidence-based factor; they do not by themselves constitute a complete Dutch Annex 3 approval dossier.
- The Seidel source is reported as an abstract-level study in the submitted 27-study analysis; full experimental appendices should be supplied where available.
- GülleBest is the preferable anchor because it is newer, multi-site and provides the more conservative acidification result.
- The factor should not be extended to other slurry types, target pH values or application settings without supporting evidence.
- A Dutch head-to-head programme should compare SyreN and the recognised Dutch injection reference under matched conditions, while retaining the provisional controlled-use route.

9. Conclusion

The two studies selected by CDM show that in-field acidification to approximately pH 6.0 can be expressed directly in the Dutch metric and produced lower ammonia emissions than the investigated injection techniques. Seidel reported 4.4% TAN for acidification compared with approximately 5.5% TAN for the best injection treatment. ten Huf/GülleBest reported 12.2% TAN for acidification compared with 17.8% TAN for injection.

A provisional factor of 12.2% TAN is therefore transparent, conservative and supported by direct field evidence. Relative to a 17% TAN benchmark, it justifies a reduction credit of 28.2%. Conditional recognition with pH control, e-missioN documentation and Dutch confirmatory validation offers a proportionate path between immediate rejection and unconditional final approval.

References and calculation basis

16. Seidel, A. et al. (2012–2013). Ammonia loss reduction from cattle slurry by acidification and injection. Kiel University and Aarhus University; abstract-level results reproduced in BioCover's Analysis of 27 International Scientific Studies of In-Field Acidification (2010–2024), Version 3.
17. ten Huf, M. et al. (2023). Effects of Liquid Manure Application Techniques on Ammonia Emission and Yield. Agronomy, 13, Article 472; GülleBest multi-site field programme (2019–2020).
18. BioCover A/S. Analysis of 27 International Scientific Studies of In-Field Acidification from 2010 to 2024, Version 3.
19. VERA Verification Statement 001 and DANETV verification material for the SyreN slurry application system. These materials independently link controlled sulphuric-acid dosing, pH regulation and data logging to the commercial SyreN technology; the proposed numeric factor in this note is derived from the two CDM-identified TAN-convertible studies above.

Calculation definitions

TAN means Total Ammoniacal Nitrogen. An emission factor of 12.2% TAN means that 12.2% of the TAN applied in the slurry is estimated to be emitted as ammonia under the defined application conditions. A relative reduction percentage always requires a stated reference and must not be confused with the absolute TAN emission factor.

Table A.1

To	The Minister of Agriculture, Fisheries, Food Security and Nature (LVVN), the Netherlands
From	BioCover A/S

To	The Minister of Agriculture, Fisheries, Food Security and Nature (LVVN), the Netherlands
Date	25 August 2026
Subject	A transparent evidence basis for a provisional SyreN emission factor
Status	Technical proposal for ministerial consideration

Table A.2

RECOMMENDATION Recognise a provisional emission factor of 12.2% of TAN for SyreN in-field acidification on grassland when slurry is acidified to pH 6.0 or below and compliance is digitally documented. This equals a 28.2% reduction relative to a 17% TAN benchmark.

Table A.3

Study	Untreated reference	Injection	Acidification	Direct result
Seidel et al. (2012–2013)	14.0% TAN	5.5% TAN (35 cm)	4.4% TAN at pH 6.0	20.3% below injection
ten Huf et al. / GülleBest (2019–2020)	22.6% TAN	17.8% TAN	12.2% TAN at approx. pH 6.0	31.5% below injection

Table A.4

Treatment	Reduction vs untreated	Calculation	Emission factor
Untreated band spreading	0%	14.0 × 1.000	14.0% TAN
Injection, 17.5 cm	31.4%	14.0 × 0.686	9.6% TAN
Injection, 35 cm	60.6%	14.0 × 0.394	5.5% TAN
Acidification, pH 6.5	42.2%	14.0 × 0.578	8.1% TAN
Acidification, pH 6.0	68.9%	Reported lowest loss	4.4% TAN

Table A.5

INTERPRETATION Seidel establishes a low-end emission factor of 4.4% TAN. It also shows why final pH must be part of the regulatory condition: pH 6.0 clearly outperformed pH 6.5.

Table A.6

Application method	Measured emission	Difference from untreated	Remaining emission
Untreated surface application	22.6% TAN	Reference	100.0%
Open-slot injection	17.8% TAN	4.8 TAN percentage points lower	78.8%
Acidification to approx. pH 6.0	12.2% TAN	10.4 TAN percentage points lower	54.0%

Table A.7

Possible approach	Result	Assessment
Use the lower measured factor	4.4% TAN	Scientifically observed, but too ambitious for provisional transfer.
Simple mean	8.3% TAN	Not recommended; ignores different designs and uncertainty.
Use the higher measured factor	12.2% TAN	Recommended conservative factor; directly measured in the newer multi-site programme.
Use Dutch benchmark only	17.0% TAN	Provides no recognition of the demonstrated additional performance.

Table A.8

PROPOSED REGULATORY VALUE 12.2% TAN is conservative because it selects the higher of the two measured acidification factors. It does not extrapolate below the evidence and remains 4.8 TAN percentage points below a 17% TAN benchmark.

Table A.9

DRAFT PROVISION For in-field acidification of cattle slurry on grassland using the SyreN system, an ammonia emission factor of 12.2% of applied TAN may be used where the slurry is acidified with sulphuric acid to a verified final pH of 6.0 or lower during application. Each application must be digitally documented and auditable. The provisional factor shall be reviewed following completion of a Dutch confirmatory validation programme.

Table A.10

Required record	Purpose
Slurry volume and flow	Confirms the treated quantity and application rate.
Acid consumption and dose	Confirms that treatment occurred and supports mass balance.
Inlet and outlet pH	Confirms achievement of the pH ≤ 6.0 condition.
Time, GPS position and treated area	Links compliance to the field and application event.
Weather and operational data	Supports quality control and later validation.
e-missioN application report and API access	Enables farmer evidence, authority audit and enforcement.

Appendix B — Translation of German and VERA results into percentage of TAN

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

TECHNICAL POLICY NOTE

To: Ministry of Agriculture, Fisheries, Food Security and Nature (LVVN), The Netherlands

From: BioCover A/S

Subject: Conversion of German GülleBest results into a Dutch TAN-based emission factor

Status: Evidence-based proposal for independent regulatory assessment

1. Purpose and decision requested

This note explains how relative ammonia reduction percentages from the German GülleBest programme can be translated into the Dutch convention of expressing field ammonia emission as a percentage of total ammoniacal nitrogen (TAN) applied. It also provides a transparent recommendation for the value that should be evaluated for SyreN in the Netherlands.

BioCover requests that the Ministry and its scientific advisers assess 12.2% TAN as the evidence-based provisional factor for SyreN on grassland, pending confirmation through an independent Dutch validation or formal recognition of the German evidence.

2. Evidence base

The GülleBest programme compared cattle slurry application by trailing shoe/band application, open-slot injection and slurry acidification under the same field conditions. Acidification was carried out with sulphuric acid to pH 6. The programme included multiple German sites and measurement cases, thereby reducing the risk that the comparison is determined by one farm, one soil or one weather situation.

The peer-reviewed synthesis reports mean TAN-related NH_3 emissions of 22.6% for trailing shoe application, 17.8% for open-slot injection and 12.2% for acidification. The project brief expresses the same result as relative reductions of approximately 22% for injection and 46% for acidification compared with the trailing shoe reference.

Source: Nyameasem et al. (2022) and the GülleBest project brief. Values are rounded; small differences arise from rounding.

3. Translation from relative reduction to % TAN

3.1 Why 46% versus 22% is not a 24% comparison

Both reduction percentages use trailing shoe application as the common reference. The difference of 24 percentage points therefore describes the additional reduction against that reference; it is not the relative reduction of SyreN compared directly with injection.

Residual emission after injection = 100% - 22% = 78% of the reference

Residual emission after acidification = 100% - 46% = 54% of the reference

Additional reduction vs. injection = (78 - 54) / 78 = 30.8%

Using the unrounded absolute TAN values gives the more precise result:

(17.8 - 12.2) / 17.8 = 31.5% lower NH_3 emission than open-slot injection

3.2 Direct Dutch-format result

No conversion of units is required. The German scientific publication already reports emission as NH_3 loss in percent of TAN applied, which is the format used in Dutch field-emission assessments. The direct measured comparison is therefore:

4. Recommended Dutch factor

The recommendation is deliberately tied to defined operating conditions. It should not be applied to any product described generically as "acidification". Eligibility should require documented achievement of the approved treatment conditions.

4.1 Recommended eligibility conditions

- Cattle slurry applied on permanent grassland by band application or an equivalent surface-placement method.
- Acidification with sulphuric acid to a verified treatment target of pH 6, following the protocol adopted for recognition.
- Continuous recording of slurry flow, acid dosage, treatment status, time and position.
- Farm- and field-level documentation through e-missioN or an equivalent auditable system.
- Traceable calibration and maintenance records for the dosage and measurement equipment.
- Clear separation between the approved emission factor, the recorded operating data and any model-based field-specific estimate.

4.2 Scaling formula if the Netherlands applies another injection factor

If the Ministry chooses to anchor SyreN to an existing Dutch factor for open-slot or shallow injection rather than adopt the directly measured German mean, the trial-derived ratio can be applied transparently:

SyreN factor = Dutch injection factor × (12.2 / 17.8) = Dutch injection factor × 0.685

This scaling preserves the experimentally observed 31.5% advantage over injection. It should be used only if the selected Dutch injection factor represents comparable grassland, slurry and application conditions.

5. Practical meaning

For every 100 kg TAN applied per hectare, the German measurements imply the following average losses:

Expressed as ammonia rather than ammonia-nitrogen, 5.6 kg NH_3-N corresponds to approximately 6.8 kg NH_3 avoided per hectare for each 100 kg TAN applied:

5.6 kg NH_3-N × 17/14 = 6.8 kg NH_3

6. Scientific interpretation and limitations

The recommended factor is supported by a direct, contemporaneous comparison under common field conditions, which is stronger for comparing technologies than combining unrelated national averages. Nevertheless, the following limitations should be explicit:

- Weather, soil, slurry composition and application conditions cause substantial variation in NH_3 emissions.
- The ± values presented in the project brief describe dispersion in reduction performance and should not be treated as simple regulatory confidence intervals.
- The project brief refers to measurement years 2019 and 2020; the wider project ran from 2018 to 2022. It should not be described as three full measurement years without confirmation from the underlying dataset.
- The factor applies to the tested treatment concept: acidification to pH 6 with band application of cattle slurry on grassland.
- Formal Dutch adoption may require protocol review, data access and a confirmatory national trial.

7. Verification and performance-based regulation

A fixed national factor and field-specific documentation serve different functions. The national factor supports inventories, permits and standard compliance. e-missioN provides the operating evidence needed to show that the recognised treatment was actually performed and can support future performance-based regulation.

20. The approved factor defines the standard expected performance of the technology.
21. SyreN records the physical intervention and operating parameters.
22. e-missioN creates the traceable farm-, field- and operation-level evidence record.
23. Authorities or authorised parties can audit eligibility without relying solely on equipment ownership or operator declarations.
24. Field-specific modelling may supplement the standard factor but should remain distinguishable from the regulatory default.

8. Proposed conclusion for the Ministry

References

Nyameasem, J.K. et al. (2022). Impact of cattle slurry application methods on ammonia losses and grassland nitrogen use efficiency. Environmental Pollution 315, 120302. https://doi.org/10.1016/j.envpol.2022.120302

Buchen-Tschiskale, C. et al. (2022). GülleBest: Mit welcher Technik lassen sich Gülle und Gärreste emissionsarm ausbringen? Project brief 2022/41, Thünen Institute. DOI: 10.3220/PB1668515904000.

Huijsmans, J.F.M. et al. (2015). Application of acidified manure with a trailing shoe machine on grassland: ammonia emissions and crop yield. Proeftuin Natura 2000 Overijssel.

Goedhart, P.W. et al. (2019). Estimating ammonia emission after field application of manure by the integrated horizontal flux method. Wageningen University & Research. Used as background for the Dutch TAN-based measurement convention.

Table B.1

RECOMMENDATION BioCover recommends an interim SyreN emission factor of 12.2% of applied TAN for cattle slurry acidified to pH 6 and band-applied on permanent grassland. For administrative presentation this may be rounded to 12% TAN. The factor is the directly measured German multi-site mean. It represents 5.6 percentage points less TAN loss, or approximately 31% lower ammonia emission, than open-slot injection measured in the same trials.

Table B.2

Technique	Measured NH_3 emission (% of TAN)	Reduction vs. trailing shoe
Trailing shoe / band application	22.6%	Reference
Open-slot injection	17.8%	21-22%
Acidification to pH 6 (SyreN principle)	12.2%	46%

Table B.3

Metric	Open-slot injection	SyreN acidification	SyreN advantage
Emission factor	17.8% TAN	12.2% TAN	5.6 TAN percentage points
Relative remaining emission	100%	68.5%	31.5% lower emission

Table B.4

RECOMMENDED VALUE 12.2% of applied TAN for cattle slurry acidified to pH 6 and band-applied on permanent grassland. An administrative rounded value of 12% TAN is consistent with the measured mean. A higher provisional value, such as 13% TAN, would constitute an additional policy safety margin rather than the measured central estimate.

Table B.5

Assumed Dutch injection factor	Calculated SyreN factor	Absolute improvement
16% TAN	11.0% TAN	5.0 percentage points
17% TAN	11.6% TAN	5.4 percentage points
18% TAN	12.3% TAN	5.7 percentage points
20% TAN	13.7% TAN	6.3 percentage points

Table B.6

Technique	NH_3-N loss per 100 kg TAN	Difference vs. injection
Open-slot injection	17.8 kg NH_3-N	Reference
SyreN acidification	12.2 kg NH_3-N	5.6 kg NH_3-N avoided

Table B.7

INTERPRETIVE BOUNDARY 12.2% TAN is the measured German mean and the recommended evidence-based provisional Dutch factor. It is not presented as a guaranteed value for every individual field operation. Field-level performance should be documented separately through e-missioN.

Table B.8

PROPOSED REGULATORY CONCLUSION The German GülleBest evidence supports a provisional ammonia emission factor of 12.2% of applied TAN for SyreN acidification to pH 6 on permanent grassland. This is 5.6 TAN percentage points and approximately 31% lower than the 17.8% TAN measured for open-slot injection in the same trials. BioCover recommends that this factor be admitted for independent Dutch assessment and confirmatory validation, with e-missioN used to document compliance with the approved operating conditions.

Appendix C — Comparative German, Danish and Dutch trial summary

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

TECHNICAL POLICY SUMMARY

To: Ministry of Agriculture, Fisheries, Food Security and Nature (LVVN), The Netherlands

From: BioCover A/S

Subject: Comparative evidence for SyreN and injection expressed as % of TAN

Status: Evidence synthesis for regulatory assessment

1. The question this evidence must answer

The relevant policy question is not whether acidification reduces ammonia relative to untreated surface application; all three evidence streams support that conclusion. The more demanding question is whether SyreN can produce lower ammonia emissions than injection on grassland, and whether the difference can be expressed in the Dutch unit of percent of applied TAN.

2. Side-by-side evidence overview

All absolute ammonia values are expressed as NH_3-N loss in percent of applied NH_4-N/TAN. This common unit makes the measured values numerically comparable, while differences in design and conditions still require interpretation.

3. German trials - the strongest direct comparison

The German GülleBest programme directly compared trailing shoe application, open-slot injection and acidification to pH 6. The treatments were evaluated within a common experimental programme across sites and measurement cases. This makes it the most relevant evidence for quantifying the difference between the technologies.

3.1 Direct advantage over injection

Absolute advantage = 17.8 - 12.2 = 5.6 TAN percentage points

Relative advantage = (17.8 - 12.2) / 17.8 = 31.5% lower emission

4. Danish VERA trials - independent product verification

VERA verified SyreN as a product-specific environmental technology. Cattle slurry was applied to grassland at pH 6.4-6.5 using 2.3-2.9 L sulphuric acid per tonne. The VERA statement reports a mean reduction of 49% against untreated trailing-hose application, with standard deviation 11% and a range of 34-61%.

4.1 What the Danish result means

- The Danish trials independently confirm a substantial and verified SyreN effect.
- In this specific dataset, injection was three TAN percentage points lower than SyreN: 18% versus 21%.
- The verification was designed to establish SyreN performance against untreated application, not to establish a universal ranking against injection.
- The result demonstrates why a technology comparison should rely on multi-site evidence and common treatment optimisation rather than one absolute value from one location.

5. Dutch Proeftuin - useful but not a technology comparison

The Proeftuin Natura 2000 study measured untreated trailing-shoe application and acidification at nominal dosages of 2 and 4 L/m^3. It reported average emissions of 35%, 33% and 27% TAN respectively. Injection was included in the crop-yield component, but not in the ammonia-emission comparison.

5.1 Why the Dutch study cannot answer the comparison

- No injection treatment was measured for ammonia in parallel with the acidification treatments.
- The study therefore cannot show whether acidification was better or worse than injection.
- BioCover's machine-data analysis indicates that actual acid delivery may have been materially below the nominal 2 and 4 L/m^3 settings.
- Large variation in pH, slurry characteristics, rainfall and reported soil conditions limits transferability.
- The Dutch result is evidence of effect under those test conditions, not a definitive verification of correctly operated SyreN.

6. Why the results differ

7. Evidence weighting

The studies should not be pooled by taking a simple arithmetic average. They differ in purpose, number of sites, treatment target and reference emissions. A transparent evidence hierarchy is more appropriate:

8. Recommended ministerial interpretation

- Recognise that the German evidence directly demonstrates lower emission from acidification than from open-slot injection on grassland.
- Use 31% lower emission as the central comparative estimate, expressed as a 5.6 TAN percentage-point advantage in the German measurements.
- Use the Danish VERA result as independent confirmation that SyreN is a verified ammonia-reduction technology, while disclosing the 21% versus 18% TAN result.
- Do not use Proeftuin to rank SyreN against injection because that comparison was not measured.
- Commission an independent Dutch validation designed specifically to compare optimised SyreN and compliant injection under the same conditions.
- Require e-missioN documentation of pH, flow, acid consumption, time and position so every qualifying operation is auditable.

9. Proposed statement to the Ministry

References

Nyameasem, J.K. et al. (2022). Impact of cattle slurry application methods on ammonia losses and grassland nitrogen use efficiency. Environmental Pollution 315, 120302. Mean TAN emissions: trailing shoe 22.6%, acidification 12.2%, open-slot injection 17.8%.

Buchen-Tschiskale, C. et al. (2022). GülleBest project brief 2022/41. Grassland reduction: acidification 46% ± 29%; open-slot injection 22% ± 22%.

VERA Verification Statement No. 002. SyreN verification under the VERA protocol for gaseous emissions from land-applied manure. Cattle-slurry reduction: 49%; SD 11%; range 34-61%.

DANETV / AgroTech Verification Centre. ETV Verification Statement: SyreN slurry application technology. Cattle slurry on grassland: untreated 41%, shallow injection 18%, SyreN 21% of applied NH_4-N.

Aarhus University / AgroTech (2010). Background data for SyreN VERA verification.

Huijsmans, J.F.M. et al. (2015). Proeftuin Natura 2000: untreated trailing shoe 35%, nominal 2 L/m^3 acid 33%, nominal 4 L/m^3 acid 27% of applied NH_4-N; no injection NH_3 comparator.

Table C.1

MAIN CONCLUSION The German GülleBest trials provide the strongest direct multi-site comparison of acidification and open-slot injection on permanent grassland. They measured 12.2% TAN for acidification and 17.8% TAN for injection. SyreN-type acidification therefore emitted 5.6 TAN percentage points less ammonia, equivalent to approximately 31% lower emission than injection. The Danish VERA trials independently verify SyreN's ammonia-reduction mechanism, while the Dutch Proeftuin study cannot determine superiority over injection because injection was not included in its ammonia-emission comparison.

Table C.2

ANSWER IN ONE LINE The best direct comparative estimate is 31% lower ammonia emission for SyreN acidification than for open-slot injection, based on the German multi-site grassland trials.

Table C.3

Evidence	Setting and design	Untreated reference	Injection	SyreN / acidification	Can it rank SyreN vs. injection?
Germany - GülleBest / Nyameasem 2022	Multi-site grassland cases; acidification to pH 6 and open-slot injection measured under common conditions	22.6% TAN	17.8% TAN	12.2% TAN	Yes - direct comparison
Denmark - VERA / DANETV 2010	Product verification at Foulum; cattle slurry on cut grass; micrometeorological measurement	41% TAN	18% TAN	21% TAN; verified 49% reduction vs. untreated	Limited - injection was a secondary reference
Netherlands - Proeftuin 2014/2015	Trailing-shoe acidification at nominal 2 and 4 L/m^3; four measurement series	35% TAN	Not measured for NH_3	33% TAN at 2 L/m^3; 27% TAN at 4 L/m^3	No - no injection NH_3 comparator

Table C.4

Technique	Measured emission	Reduction vs. trailing shoe	Remaining emission
Trailing shoe	22.6% TAN	Reference	100%
Open-slot injection	17.8% TAN	Approximately 22%	78.8%
Acidification to pH 6	12.2% TAN	Approximately 46%	54.0%

Table C.5

GERMAN CONCLUSION Under the tested grassland conditions, acidification produced approximately 31% less ammonia emission than open-slot injection. This is the principal quantitative answer to the Ministry's comparison question.

Table C.6

Technique	Measured emission	Difference vs. untreated
Untreated trailing hoses	41% TAN	Reference
Shallow injection	18% TAN	23 percentage points lower
SyreN	21% TAN	20 percentage points lower; 49% verified

Table C.7

TRANSPARENCY POINT The Danish value must not be omitted. It does not invalidate the German result; it shows that absolute performance and technology ranking vary with conditions. The German programme is more directly suited to estimating the average difference between optimised acidification and injection.

Table C.8

Treatment in Dutch ammonia trials	Average emission	Reduction vs. untreated
Untreated trailing shoe	35% TAN	Reference
Nominal 2 L/m^3 acid	33% TAN	7%
Nominal 4 L/m^3 acid	27% TAN	24%

Table C.9

DUTCH EVIDENTIARY CONCLUSION The Proeftuin study should not be used to claim that injection outperforms SyreN. It did not measure that comparison.

Table C.10

Driver	Effect on the comparison
Treatment target and dosage	German acidification was controlled to pH 6. Danish VERA reached pH 6.4-6.5. Dutch nominal dosage did not consistently achieve the intended pH.
Reference emission level	Untreated references ranged from 22.6% TAN in Germany to 41% TAN in Denmark, showing strong environmental influence.
Soil and weather	Temperature, wind, humidity, rainfall, soil infiltration and soil pH affect both surface application and injection.
Injection quality	Slot depth, closure, soil moisture and machine performance determine how much slurry remains exposed.

Driver	Effect on the comparison
Study objective	Germany directly compared techniques; Denmark verified a product claim; the Netherlands tested acid dosage without an injection NH_3 comparator.
Data assurance	Actual treatment delivery, pH, flow and dosage must be documented to interpret performance.

Table C.11

Question	Most relevant evidence	Reason
Does SyreN reduce NH_3?	Danish VERA	Independent product-specific verification of 49% reduction.
How much better can SyreN be than injection?	German GülleBest	Direct multi-site comparison under common conditions: 31.5% lower emission.
What happened in the previous Dutch test?	Dutch Proeftuin plus machine data	Shows a Dutch acidification effect but cannot rank against injection; operational uncertainties require review.
How should compliance be shown in practice?	VERA operating envelope plus e-missioN	Links verified technology performance with auditable field operation.

Table C.12

PROPOSED CONCLUSION Across the available evidence, SyreN is consistently shown to reduce ammonia emissions relative to untreated band application. The strongest direct comparison with injection is the German GülleBest programme, where acidification emitted 12.2% of applied TAN compared with 17.8% for open-slot injection. This corresponds to 5.6 TAN percentage points and approximately 31% lower ammonia emission. The Danish VERA trials independently verify SyreN's reduction performance, while the Dutch Proeftuin study did not measure injection as an ammonia comparator and therefore cannot contradict the German finding. A Dutch head-to-head validation with auditable e-missioN data is the appropriate next step.

Appendix D — Scientific validity of the Thünen acidification trials

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

TECHNICAL NOTE

Executive conclusion

The scientifically proportionate interpretation is:

- Use the Thünen trials as evidence for the causal treatment: lowering slurry pH with sulphuric acid to a stated target and measuring field emissions against relevant application methods.
- Use separate SyreN/VERA documentation to establish machine-specific matters such as dosing control, mixing, safety, logging and operational repeatability.
- Treat any delay between acid addition and field discharge as a potential conservative bias, because slurry pH can rebound while the highest volatilisation risk begins immediately after surface exposure.
- Do not assign a numerical "inline advantage" without a paired field trial. The chemistry supports the direction of bias; the exact field magnitude must be measured.

1. The correct scientific question

CDM's observation is relevant to scope, but not to validity. A field trial can validly test the efficacy of an acidification treatment without using one particular commercial delivery machine, provided the treatment is adequately characterised: acid type and dose, initial and application-time pH, slurry properties, application method, timing, weather and the emission measurement method.

Interpretive matrix. The distinction between treatment efficacy and product conformity is the central methodological point.

2. What the Thünen/GülleBest programme actually demonstrates

The official GülleBest project brief describes field comparisons at four German sites and explicitly lists "acidification of slurry/digestate during application with trailing hose/shoe". It reports a clear reduction in NH_3 emissions when sulphuric acid was used to reach pH 6, and states that an NH_3 emission factor for acidified cattle slurry and digestate could be derived for Germany. The peer-reviewed grassland analysis compared band-spread cattle slurry acidified to pH 6.5 and pH 6.0 with band spreading and open-slot injection; acidification to pH 6.0 had the lowest ammonia loss in that dataset.

Consequence: the study is direct evidence of the acidification treatment under German field conditions. It should not be represented as a complete certification of SyreN hardware unless the machine itself was part of the protocol.

3. Timing of acid addition is a material test parameter

The supplied time-series figure illustrates a well-known buffering response: after a fixed sulphuric-acid dose, slurry pH can fall sharply and then move upward as carbonate/bicarbonate buffering, gas exchange and other acid-consuming reactions proceed. In several curves, much of the early rebound occurs within approximately 5–10 minutes, although longer-term development continues and varies by slurry type.

Figure 1. pH development after a fixed acid dose (5 L m^{-3}), by slurry type and elapsed time. Source shown in the supplied slide: Jørgen Hinge, Danish Agricultural Advisory Service, 2005. The figure is explanatory and is not a substitute for application-time pH measurements in the Thünen protocol.

4. Quantifying the chemical importance of pH rebound

For the aqueous ammonium–ammonia equilibrium, the un-ionised NH_3 fraction can be approximated by:

$f(NH_3) = 1 / [1 + 10^{(pK_a - pH)}]$

At pH values well below the ammonium pK_a (approximately 9.25 at 25 °C; temperature dependent), a rise of one pH unit increases the equilibrium fraction of un-ionised NH_3 by approximately tenfold. This does not mean field flux rises tenfold: volatilisation also depends on TAN, temperature, infiltration, wind, exposed area and mass transfer. It does show why application-time pH is not a minor procedural detail.

Calculated from 10^ΔpH in the low-pH approximation. These are chemical-equilibrium ratios, not claimed emission multipliers.

5. The first exposure period is disproportionately important

Surface-applied slurry has its highest emission rate immediately after application. The ALFAM2 database and model describe NH_3 emission dynamically from field-applied slurry, and reviews of field measurements report that a substantial share of total loss occurs within the first hours. The practical implication is straightforward: preserving the lowest pH at discharge is especially relevant because it coincides with the period of maximum exposed surface area and maximum initial emission rate.

Therefore, if the Thünen treatment was prepared sufficiently in advance for pH rebound to occur, the likely direction of bias is conservative for SyreN. The trial may understate the performance of immediate inline acidification. This is a testable hypothesis—not a licence to add an unmeasured bonus to the reported reduction.

6. Nutrient and cation-exchange effects: relevant, but secondary

Acidification changes more than the NH_4^+/NH_3 equilibrium. Added H^+ can displace base cations from exchange surfaces into solution, while reduced pH changes mineral dissolution and precipitation. Two defensible examples are:

- Phosphorus: peer-reviewed slurry work found that sulphuric-acid treatment promoted initial phosphorus solubilisation. In storage, part of that effect was reversed over time—another reason why treatment-to-application timing matters.
- Micronutrients and alkaline soils: lowering pH can increase the solubility of Fe, Mn and Zn and can reduce calcium-phosphate precipitation, potentially increasing short-term availability where high pH constrains these nutrients.

Important qualification: acidification does not universally improve nutrient availability. On already acidic soils, additional acidity can increase Al or Mn solubility, reduce base saturation and promote Ca, Mg or K leaching. These effects should be treated as soil- and dose-specific co-benefits or risks, not as part of the ammonia reduction factor unless measured.

7. Recommended regulatory interpretation

8. Proposed wording for the ministerial file

Limitations and evidence status

- The supplied 2005 pH figure provides mechanistic and illustrative support; the underlying raw dataset and measurement uncertainty were not supplied with the slide.
- The exact Thünen acid-addition apparatus and delay must be confirmed from the full site protocols before quantifying a timing penalty.
- The pH-equilibrium calculations quantify chemical potential only; they do not replace measured field emission.
- Soil nutrient effects are context dependent and should not be incorporated into an ammonia quota without dedicated measurements.

References and source links

1. Buchen-Tschiskale et al. (2022), GülleBest project brief, Thünen Institute. Source link

2. Nyameasem et al. (2022), Impact of cattle slurry application methods on ammonia losses and grassland nitrogen use efficiency, Environmental Pollution 315, 120302. Source link

3. Hafner et al., ALFAM2 database and dynamic model, Aarhus University project page. Source link

4. Sommer & Hutchings (2001), Ammonia emission from field applied manure and its reduction, European Journal of Agronomy 15, 1–15. Source link

5. Regueiro, Coutinho & Fangueiro (2016), Alternatives to sulfuric acid for slurry acidification, Journal of Cleaner Production 131, 296–307. Source link

6. Overmeyer et al. (2021), One-Time Acidification of Slurry, Agronomy 11, 1319. Source link

7. Supplied figure: Jørgen Hinge, Danish Agricultural Advisory Service (2005), "Acid consumption variable in relation to pH value, slurry type and time."

Table D.1

To	The Minister of Agriculture, Fisheries, Food Security and Nature, the Netherlands
From	BioCover A/S
Date	26 August 2026
Subject	Scientific interpretation of Thünen/GülleBest field data
Purpose	Response to the CDM observation concerning the absence of a SyreN machine

Table D.2

RECOMMENDED MINISTERIAL FINDING The Thünen results remain valid evidence for the ammonia-mitigation effect of sulphuric-acid slurry acidification. They are not, by themselves, a verification of the commercial SyreN machine. Rejecting the emission data merely because the commercial machine was not used confuses treatment efficacy with equipment conformity. If acid was added and mixed before spreading rather than dosed inline immediately before discharge, the design is more likely to have reduced—not exaggerated—the advantage achievable with SyreN during the emission-critical opening period.

Table D.3

Question tested	What Thünen-type data can show	What requires SyreN-specific verification
Does sulphuric-acid pH reduction mitigate NH_3?	Yes—when the acidification treatment and emissions are measured.	Not necessary for the causal chemistry.
Does inline dosing preserve the intended pH at discharge?	Only if dosing-to-discharge timing and pH were recorded.	Yes—this is a system-performance question.
Are dosing, mixing, safety and data logging reliable?	No; a research setup does not certify the commercial machine.	Yes—machine and control-system evidence is required.
Can the emission result be discarded because SyreN was absent?	No. Absence limits product-specific claims; it does not erase treatment evidence.	Machine evidence complements rather than replaces field treatment evidence.

Table D.4

WHY INLINE DOSING MATTERS SyreN adds acid into the slurry flow immediately before discharge. This reduces the interval in which buffering can raise pH before the slurry is exposed as narrow surface bands. A batch or pre-treatment method with a waiting period can therefore test acidification validly while still failing to capture the most favourable pH trajectory achievable at the moment of application.

Table D.5

Illustrative pH rebound	Equilibrium NH_3 fraction ratio	Interpretation
0.5 pH unit	≈ 3.2×	Material increase in volatilisation potential
1.0 pH unit	≈ 10×	Order-of-magnitude change in chemical potential

Illustrative pH rebound	Equilibrium NH_3 fraction ratio	Interpretation
1.5 pH units	≈ 31.6×	Very large chemical change; field flux still requires measurement

Table D.6

No.	Recommendation	Reason
1	Reject the categorical invalidity claim	A missing commercial machine limits product-specific conformity claims, but does not invalidate a properly characterised acidification treatment or its measured emissions.
2	Retain Thünen as independent efficacy evidence	The work tests sulphuric-acid pH reduction under field conditions and compares relevant application techniques.
3	Pair it with SyreN/VERA system evidence	This covers dosing, mixing, safety, pH control, documentation and repeatability of the commercial implementation.
4	Require application-time pH and timing metadata	Record pH immediately before acid addition, after mixing, at discharge and after 5–10 minutes; record the exact acid-to-discharge delay.
5	Run a compact Dutch paired confirmation	On the same slurry and day, compare pre-acidified batch treatment with SyreN inline dosing at identical target discharge pH and application method. Measure high-resolution early flux and cumulative % TAN loss.
6	Do not award an unmeasured uplift	Until paired measurements exist, use Thünen's observed result without a numerical machine bonus; describe the inline advantage as a plausible conservative-bias mechanism.

Table D.7

PROPOSED TEXT “The absence of a commercial SyreN unit in an experimental treatment does not, in itself, invalidate measured ammonia-emission data where sulphuric-acid treatment, target pH, application technique and measurement procedures are adequately documented. Such data demonstrate treatment efficacy, while separate evidence is required for machine-specific performance. Where acid was mixed before application, any delay and pH rebound should be treated as a potentially conservative methodological difference relative to immediate inline dosing. Application-time pH and treatment-to-discharge time shall therefore be reported in future Dutch verification trials.”

Appendix E — Technology comparison: injection versus in-field acidification

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

TECHNOLOGY DECISION BRIEF

Left: injection creates open slots and places slurry below the surface. Right: SyreN acidifies slurry inline and applies it through a wide surface boom. Images: Danish EPA evaluation report and BioCover/Arla presentation.

Scope. Crop-yield comparisons are deliberately excluded because they are documented separately. Historical Danish figures are used to quantify physical mechanisms; they are not proposed as Dutch emission factors.

Executive comparison

Table 1. Whole-system comparison. Working-width ranges reflect the supplied material and current SyreN boom configurations; individual machines vary.

1. Two different control principles

Injection: control by physical placement

Injection opens or presses a slot in the soil and places slurry into it. The emission result depends on how much slurry is actually contained below the surrounding surface. The Danish EPA evaluation found that highly effective injection reduced ammonia loss substantially, while less effective placement—where slurry remained exposed or overflowed—delivered much smaller reductions. Hard, dry or stony soil can prevent consistent depth and slot capacity.

SyreN: control by chemistry at the point of application

SyreN adds sulphuric acid inline immediately before the slurry reaches the boom. Lowering pH shifts the ammonia/ammonium equilibrium toward non-volatile ammonium. Because mitigation is achieved chemically, the slurry can be applied with a wide trailing-hose or trailing-shoe boom without cutting the soil. The VERA verification reported a 49% NH_3 reduction for cattle slurry at approximately 2.7 L acid/m^3 in the verified test conditions. The German GülleBest programme reported the greatest NH_3 mitigation from acidification and derived a German emission factor for acidified cattle slurry and digestate.

Figure 1. The technologies act on different control variables: soil placement versus controlled pH at discharge.

2. Working width changes the complete field system

Working width is not a minor productivity parameter. It determines tractor travel per hectare, the number of passes, the share of the field exposed to wheel traffic and whether existing controlled-traffic lanes can be respected. Injection draft limits practical width; the supplied Danish evaluation describes typical injection widths of 6–9 m and wide surface booms of 18–24 m. For the present comparison, the broader equipment ranges 6–12 m and 12–24 m are used.

Figure 2. Across the same 24 m strip, a 24 m boom requires one pass, a 12 m injector two passes and an 8 m injector three passes. Derived geometrically; headland manoeuvres and overlap are excluded.

Table 2. Calculated as 10,000 m^2 divided by working width. This is a transparent traffic-intensity indicator, not a fuel model.

3. Soil loading and mechanical disturbance

Figure 3. Wheel stress propagates below the visible track, and narrower equipment increases the frequency of tracks. Source: Ole Green, Aarhus University; field image from Danish EPA evaluation report.

Ole Green's work illustrates that wheel loading extends below the surface and becomes deeper with higher axle load. Width affects how often this stress footprint is repeated. Injection adds a second mechanism: the coulters or discs mechanically open the soil across the full implement width.

Why this matters

- Wet or weak soils: additional passes increase compaction and rutting risk outside established tramlines.
- Dry or hard soils: penetration and containment can decline while draft and wear rise.

- Stony soils: coulter lift, wear and breakdown can leave slurry on the surface and reduce mitigation consistency.
- Low-lying and peat/polder soils: repeated traffic and disturbance deserve specific research because soil structure, drainage and subsidence sensitivity are nationally important. The supplied studies do not quantify a Dutch subsidence effect.

4. Energy use, fuel and greenhouse-gas trade-offs

The Danish EPA evaluation quantified the additional draft created by injection. Compared with surface application, grassland injection increased fuel consumption by 1.8–4.7 L/ha, corresponding in that report to 5.6–14.5 kg CO_2/ha. The report also explains that higher draft limits working width, so fuel and traffic effects reinforce one another.

Table 3. GHG pathways. This document does not monetise carbon and does not include yield effects.

5. Capacity, timing and operational resilience

Narrow working width and the need for acceptable slot formation reduce effective capacity. In the Danish EPA example—1,000 m transport distance, 7 km/h, 24 m surface boom and 12 m injector—calculated throughput was approximately 60 t/h for surface application and 49 t/h for injection. The same report estimated 35 probable spring application days for hose application versus 14 for injection in winter cereals. These are historical Danish assumptions, but they demonstrate the direction and scale of the operational mechanism.

Capital and maintenance profile

Injection equipment has many soil-engaging components and wear parts; the Danish evaluation reported substantially higher acquisition and maintenance expectations than a surface boom. SyreN adds an acid tank, dosing, mixing and control system to a boom-based platform. It shifts complexity from heavy mechanical soil engagement to chemical handling, calibration and control. Current supplier quotations—not historical prices—should be used for a Dutch cost comparison.

6. From prescribed equipment to verified performance

The central policy difference is observability. A rule can prescribe that an injector is present, but the actual result still depends on depth, slot volume, soil condition and overflow. SyreN can combine a defined acidification treatment with digital evidence from e-missioN. This supports Dutch doelsturing: the regulated outcome becomes documented performance rather than the ownership of one mechanical implement.

7. Recommended conclusion

For ammonia regulation, injection and in-field acidification should be treated as alternative mitigation systems—not as interchangeable pieces of hardware. Injection can perform well where soil and operating conditions support effective containment. SyreN can deliver comparable or stronger mitigation evidence while preserving wide-boom application and enabling auditable digital documentation. The preferred system should be selected on total environmental and operational performance.

Recommended decision criteria for Dutch assessment

- NH_3 loss expressed consistently as % of TAN under Dutch reference conditions.
- Robustness across soil moisture, hardness, stones, slope and slurry type.
- Working width, tractor travel and traffic outside controlled lanes.
- Fuel use and the complete GHG balance, including N_2O risk and acid life-cycle impacts.
- Field capacity and the number of practically available application days.
- Safety, maintenance, calibration and operator requirements.
- Digital monitoring, auditability and enforceability through e-missioN.
- A dedicated Dutch paired programme comparing open-slot injection and inline acidification on the same slurry, field, date and measurement system.

Evidence boundaries

- No crop-yield evidence is included in this brief.

- Historical Danish operating figures are transparent evidence of physical mechanisms, not current Dutch cost or emission factors.
- The 40–50 km slot-length estimate is geometry based; permanent soil damage and subsidence require dedicated Dutch research.
- The precise NH_3 quota for SyreN is addressed in separate technical recommendations.

Sources

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2. Danish Environmental Protection Agency, Environmental Project No. 1345 (2010), “Injection of slurry in winter cereals – an evaluation report”.

3. Bastholm et al., “Slurry injection in grass and winter wheat: user experience and quantification of traffic damage”, supplied report.

4. Ole Green, Aarhus University, “Controlled traffic in forage crops – grass and maize”, supplied presentation, 2008 experimental/simulation material.

5. DANETV/VERA, Verification Statement for the SyreN Slurry Application System, supplied verification documents.

6. Buchen-Tschiskale et al. (2022), GülleBest project brief; Nyameasem et al. (2022), Environmental Pollution 315, 120302.

Table E.1

Injection	SyreN acidification with wide boom

Table E.2

CORE FINDING Injection is a mechanical ammonia-control technology that trades lower exposed slurry area for greater draft, narrower working width and soil disturbance. SyreN is a chemical control technology that preserves the operational advantages of a wide boom and can add digital, field-level verification through e-missioN. A policy comparison should therefore assess the complete system—not ammonia reduction alone.

Table E.3

Decision criterion	Injection	SyreN acidification + wide boom
Primary mechanism	Reduces air contact by placing slurry in mechanically opened slots.	Lowers pH and shifts TAN from volatile NH_3 toward NH_4^+ immediately before application.
Typical working width	6–12 m, constrained by draft, weight and tool geometry.	12–24 m with a trailing-hose/shoe boom; 18–24 m is common for wide-boom operation.
Soil interaction	Cuts or presses slots; repeated mechanical disturbance.	No injection slot; slurry is applied at the surface in bands.
NH_3 performance driver	Depth, slot volume, soil condition, overflow and closure.	Discharge pH, acid dose, slurry buffering, weather and application pattern.
Fuel and draft	Higher draft; Danish evaluation: +1.8–4.7 L diesel/ha versus surface application.	Boom application avoids injection draft; acid-system energy demand is comparatively small.

Decision criterion	Injection	SyreN acidification + wide boom
N_2O consideration	Concentrated slurry bands can create anaerobic microsites; evidence is variable.	GülleBest reported no N_2O increase from acidification in its trials.
Operational window	More sensitive to wet, hard, frozen, stony or sloping soils.	Wider operational window, subject to normal trafficability and acid-handling requirements.
Documentation	Activity can be logged, but actual performance is difficult to infer from machine presence alone.	e-missioN can document location, dose, pH-related inputs, weather, overlap and estimated NPA/NH_3 performance.
Key residual risk	Mechanical performance may vary even when equipment is present.	Requires engineered acid safety, calibration and auditable control data.

Table E.5

REGULATORY CONSEQUENCE Equipment identity is not the same as verified performance. Injection requires assurance that depth and containment were achieved. Acidification requires assurance that dose, mixing and pH-related performance were achieved. A performance-based framework should verify the result of either technology.

Table E.6

Working width	Pass distance/ha	Relative to 24 m	Operational meaning
24 m	417 m	1.0×	Wide boom reference
18 m	556 m	1.33×	Wide-boom operation
12 m	833 m	2.0×	Wide injector / narrow boom
8 m	1,250 m	3.0×	Common narrow-injection comparison
6 m	1,667 m	4.0×	Narrow injection

Table E.8

TRANSPARENT GEOMETRIC ESTIMATE At 20–25 cm coulter spacing, injection creates approximately 40–50 km of slot per hectare per application (10,000 m^2 ÷ 0.20–0.25 m). With 3–5 annual applications, this is approximately 120–250 km of mechanically opened slot per hectare per year. The figure quantifies disturbance length; it does not claim that every metre causes permanent damage.

Table E.9

GHG pathway	Injection	Acidification with boom
Traction fuel	Higher due to soil-engaging tools; documented +1.8–4.7 L/ha versus surface application.	Avoids injection draft; normal boom and pumping demand remains.
Traffic-related soil effects	More pass distance at narrower width; greater exposure outside wide tramlines.	Wider boom can reduce pass distance and align with existing tramlines.

GHG pathway	Injection	Acidification with boom
N_2O after application	Potential increase where concentrated slurry bands create wet, oxygen-limited microsites; results vary.	GülleBest did not observe an acidification-related N_2O increase in its field programme.
Acid production/use	None.	Embodied emissions and logistics of sulphuric acid must be included in a complete life-cycle assessment.
Avoided mineral N	Both can retain more slurry N by reducing NH_3 loss.	Both can retain more slurry N; e-missioN can quantify the field-level NPA outcome.

Table E.10

BALANCED INTERPRETATION The older literature identifies an N_2O risk from injection, not a universal outcome. More recent GülleBest trials did not find an increase from open-slot injection under their conditions. Regulation should therefore avoid fixed assumptions where field evidence and monitoring can distinguish performance.

Table E.11

Constraint	Injection response	Wide-boom acidification response
Wet soil	Higher risk of rutting and poor trafficability outside tramlines.	Still requires trafficability, but no penetration requirement.
Hard/dry soil	Higher draft; shallow or inconsistent slots; overflow risk.	Chemical control is not dependent on coulter penetration.
Frozen soil	Mechanical penetration may be impossible.	Application remains subject to legal and agronomic conditions, not injection penetration.
Stones	Wear, lifting and breakdown risk.	No soil-engaging distribution elements.
Slopes	Open/glazed slots may channel slurry or overflow.	Surface bands also require runoff management; wide boom does not remove slope risk.
Time-critical logistics	Lower field capacity and fewer suitable days increase peak machinery demand.	Higher field coverage supports timely application and weather-based optimisation.

Table E.12

Audit question	Injection-only equipment check	SyreN + e-missioN
Where was slurry applied?	May require separate telematics.	GNSS field record and application map.
Was treatment active?	Machine presence does not prove depth or containment.	Dose and system-state records can document active acidification.

Audit question	Injection-only equipment check	SyreN + e-missioN
Were overlaps/gaps controlled?	Possible with separate precision-farming system.	Overlap/gap and applied-volume mapping.
What weather governed risk?	Normally not part of implement compliance.	Weather can be linked to the field application record.
What was the estimated N outcome?	Not inherent in equipment inspection.	NPA/NH_3 estimate and auditable report using the e-missioN/ALFAM2 framework.
Can Arla/authority audit remotely?	Only if compatible data services are added.	API-based access can support customer and authority audit workflows.

Table E.13

POLICY DESIGN Recognise both technologies on measured performance, but require technology-specific evidence: placement quality for injection; dose, mixing and pH-related control for acidification. Use e-missioN as the monitoring, reporting and verification layer for field-level implementation and enforcement.

Table E.14

PROPOSED MINISTERIAL MESSAGE A transition from mandatory injection to performance-based recognition of verified acidification can reduce ammonia without requiring widespread mechanical disturbance of Dutch soils. Wide-boom SyreN application should therefore be assessed as a complete mitigation-and-documentation system, with e-missioN providing the monitoring layer required for credible doelsturing.

Appendix F — e-missioN and doelsturing technical and business dossier

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

POLICY AND IMPLEMENTATION BRIEF

Figure 1. e-missioN converts one application record into operational decisions, environmental documentation and independently accessible audit evidence.

Executive summary

- Doelsturing requires measurable outcomes, farm-specific accountability, traceable data, independent verification, enforceability and freedom for the farmer to choose the method. e-missioN is designed around those functions.
- The current Dutch policy direction establishes farm-specific ammonia norms for housing and storage, while the June 2026 government letter states that manure application is not yet included. e-missioN can close that material boundary gap.
- At field level, e-missioN combines as-applied data, weather, slurry characteristics, pH, time and position with the ALFAM2 framework. It outputs ammonia-loss and NPA maps rather than relying only on equipment presence.
- NPA—Nitrogen Plant Availability—is the share of applied slurry nitrogen expected to remain plant-available after ammonia loss. It creates a direct bridge from air-emission control to mineral-fertiliser adjustment and reduced nitrogen surplus.
- Timing becomes auditable. Night application under favourable conditions can be recognised as a separate performance category when the farmer documents the actual result; the supplied sunrise example shows a clear increase after sunrise.
- SyreN Changes extends the platform from field ammonia to methane inhibition in slurry storage. Pilots planned with Arla-linked partners in Sweden, Denmark and the United Kingdom can build the evidence needed for FarmAhead and public accounting.
- Arla's FarmAhead Incentive proves that a major dairy processor is prepared to pay for digitally documented sustainability action. At €0.0003/kg milk per point, five points equal approximately €15,500/year for a 1,000-cow example producing 10,333 kg milk/cow.
- The strategic value is the combination: SyreN treatment, e-missioN measurement, Changes storage mitigation, VRA nitrogen decisions and a common audit interface.

1. What Doelsturing requires—and how e-missioN responds

Table 1. Doelsturing design criteria derived from Dutch government and WUR descriptions of farm-specific outcome control, monitoring and assurance. "Operational" does not mean legally approved in the Netherlands.

2. From slurry application to a Digital Nitrogen Twin

The four-map evidence chain

e-missioN creates four connected records. Together they convert slurry from a normative input into a measured nitrogen event:

- As-Applied Map — where and how much slurry nitrogen was applied.
- N-Loss Map — estimated ammonia-N loss under the recorded conditions.
- NPA Map — plant-available slurry nitrogen after ammonia loss.
- VRA Map — the site-specific mineral-N correction required to meet the crop target without blanket over-application.

Figure 2. Four map types generated from one application dataset. Source: BioCover, SEGES presentation, 10 August 2026.

Why this reduces nitrogen losses beyond ammonia

Uniform mineral fertilisation assumes that slurry performed uniformly. Field data show that it did not. A VRA correction reduces over-supply where NPA was high and prevents under-supply where NPA was low. The supplied 729.3 ha case identified 448.4 ha below the 80% operational reference and approximately 1,155 kg N available for redistribution from fields above it. This is precision agriculture based on measured organic-fertiliser performance.

3. A measurable new category: favourable application timing

Ammonia risk changes rapidly with temperature, wind, humidity and solar conditions. Conventional regulation normally credits the implement, not the timing. e-missioN can document the application window and calculate the resulting NPA, allowing favourable night application to become a separate, auditable performance category within doelsturing.

Figure 3. Supplied on-site monitoring example. The source material reports application beginning around 04:00, sunrise around 06:30 and a marked rise in measured loss after sunrise. It also describes 5–15 kg variation between night and day as a typical operational range; this must not be treated as a universal emission factor without a defined denominator and Dutch validation.

Proposed regulatory treatment

- Define minimum data: GNSS, timestamp, slurry flow, TAN/pH input, weather and active technology state.
- Use an approved model version and publish uncertainty/quality flags.
- Credit the documented result—not “night” as a label—because some nights can still be warm or windy.
- Allow higher verified reduction only where the complete data record passes automated and external audit.

4. One platform—four environmental outcome categories

Table 2. Integrated outcome structure. Figures have different evidence status and must not be added without aligned boundaries, baselines and uncertainty treatment.

5. Arla FarmAhead: market demand for verified action

Arla’s FarmAhead Incentive is a practical example of private-sector outcome governance. Arla states that each point triggers €0.0003 per kg of milk and that points are based on digitally registered and documented activities. The model connects climate and environmental action directly to the monthly milk price.

Figure 4. BioCover’s August 2026 working model: 1 point for SyreN, 1 point for e-missioN and 3 points for SyreN Changes, giving five points in total. The calculation uses Arla’s official value of €0.0003/kg milk for each point. Final eligibility and audit rules remain subject to Arla confirmation.

Table 3. Illustrative milk-payment calculation. This is material recurring income, but it is not a substitute for the separate operational value of retained nitrogen or yield.

Arla-linked demonstration pathway

BioCover and Arla have discussed demonstration programmes for storage-methane inhibition and the wider SyreN platform in Sweden, Denmark and the United Kingdom. The Swedish programme is planned with RISE and partners from 2027; Danish and UK programmes are under development. These projects can establish common evidence, implementation and audit rules before wider rollout.

6. External audit, dashboards and lawful data access

Doelsturing is only credible if data can be checked without relying on self-declaration. e-missioN therefore separates data generation, decision support and audit access.

Table 4. Proposed access model. GDPR does not prevent authority access, but access must have a lawful basis, defined purpose, data minimisation, security and transparent governance. Farmer consent can support voluntary Arla and pilot use; statutory enforcement requires an appropriate legal basis.

Minimum assurance package

- Approved hardware and software versions; calibration status; secure user and machine identity.
- Timestamped raw inputs plus the exact model and parameter version used for each result.
- Automated completeness and plausibility checks; flagged manual corrections.
- Independent review procedure, retention period and reproducible export.
- Documented API permissions and a complete access log.

7. Illustrative 1,000-cow dairy-farm value and impact

The example below combines the principal SyreN platform opportunities requested for a dairy farm with 1,000 cows, 10,333 kg milk/cow/year, 10,000 m^3 slurry and approximately 500 ha. It is a portfolio illustration—not a guaranteed forecast. Field-acidification and VRA yield effects can overlap and must be de-duplicated farm by farm.

Figure 5. Illustrative annual value categories based on the supplied BioCover/SEGES assumptions. Error bar shows the supplied VRA net range.

Table 5. Gross portfolio potential: approximately €77,000–85,000/year before de-duplication. Direct incentive/tax-linked value is approximately €18,100/year in the 2030 illustration; operational value represents the larger share.

8. Recommended Dutch implementation

Stage 1 — Recognised pilot and data governance

- Select dairy farms in sensitive areas and pair treated/untreated or recognised reference applications.
- Approve data dictionary, model version, quality flags, consent, audit access and retention rules.
- Include day/night windows but credit actual calculated performance rather than a fixed clock-time factor.
- Run Arla and authority dashboards from the same evidence layer with separate permissions.

Stage 2 — Conditional performance credit

- Publish a conservative standard emission factor for compliant SyreN use.
- Permit a higher field-specific credit when e-missioN passes the defined completeness and uncertainty threshold.
- Use buffer-zone location as a prioritisation variable because a kilogram reduced close to sensitive nature has higher policy relevance.
- Require mineral-N plan adjustment so retained slurry nitrogen does not become excess nitrogen.

Stage 3 — Farm and supply-chain integration

- Aggregate application, housing/storage and nutrient data into farm-specific emission reporting.
- Recognise compatible processor incentives, while preventing the same reduction from being double issued.
- Create APIs for Arla, advisors, equipment platforms and authorities.
- Use verified performance data to update factors and expand technology-neutral compliance.

Key policy safeguard

The June 2026 Dutch policy package explicitly separates farm-specific norms for housing/storage from manure application. A Dutch pilot should therefore be designed as an application-layer extension, coordinated with—not confused with—the housing/storage norm. This makes the system boundary transparent and avoids claiming that current farm norms already credit field application.

Evidence status, assumptions and sources

Evidence status

- Verified/established: Arla's general point value; e-missioN data architecture; SyreN VERA field-ammonia result under its verified conditions.
- Operational case data: four-map outputs, 729.3 ha NPA distribution, 1,155 kg N redistribution and VRA business case from supplied BioCover/SEGES material.
- Pilot/proposed: five specific FarmAhead points for the SyreN portfolio; Changes factor; Sweden/Denmark/UK programme outcomes; Danish >80% NPA exemption pathway.
- Illustrative: dairy portfolio aggregation and Danish tax value. These require farm-specific boundaries, final policy recognition and de-duplication.
- Legal caution: e-missioN data can support compliance, but legal admissibility depends on Dutch approval of methods, calibration, assurance, governance and due process.

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7. BioCover, “SEGES 10.08.26”, supplied PowerPoint: e-missioN maps, NPA/VRA cases, Changes, Arla five-point working model and economic assumptions.

8. BioCover, “Agrometer 17.03.2026”, supplied PowerPoint: sunrise monitoring, NPA system, dashboard and farm examples.

9. DANETV/VERA, Verification Statement for the SyreN Slurry Application System: 49% NH_3 reduction for cattle slurry under verified conditions.

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Table F.1

CENTRAL PROPOSITION The Netherlands is moving from prescribed measures toward farm-specific emission goals. e-missioN provides the missing field-application layer: it documents where, when and how slurry was applied; estimates ammonia loss and Nitrogen Plant Availability; converts the result into a revised mineral-N plan; and can expose consented evidence to processors, advisors and authorities.

Table F.2

RECOMMENDED DUTCH USE CASE Launch a controlled recognition pathway in which e-missioN is used to verify manure-application outcomes, first in sensitive buffer zones and demonstration farms. Establish a standard factor for ordinary compliance, while allowing higher documented performance—such as favourable night application—to be credited under defined data-quality rules.

Table F.3

Doelsturing requirement	Regulatory meaning	e-missioN response	Readiness
Outcome, not equipment	Regulate environmental performance rather than ownership of a prescribed implement.	Reports calculated NH_3 loss, NPA and treatment activity for each application.	Operational
Farm-specific target	Translate sector goals into accountable farm results.	Aggregates field jobs into farm, season and supplier views.	Operational
Time and place	Performance must reflect actual conditions.	GNSS, timestamp, weather and field	Operational

Doelsturing requirement	Regulatory meaning	e-missioN response	Readiness
		boundary are attached to every job.	
Transparent baseline	Credit must be assessed against a declared reference.	Stores untreated/reference assumptions and treatment inputs for comparison.	Configure NL
Measurement quality	Inputs, models and uncertainty must be known.	Uses sensor/machine data and ALFAM2; quality flags and calibration can be exposed.	Validate NL
Independent verification	A third party must reproduce or inspect the claim.	Report, dashboard and API access support advisor, processor and authority review.	Operational
Enforceability	Records must support supervision and sanctions.	Immutable identifiers, timestamps and machine-state logs can form an audit trail.	Governance needed
Technology neutrality	Farmers select the method that reaches the target.	Can document acidification, untreated application, timing and other configured practices.	Expandable
Privacy and consent	Access must be lawful and purpose-limited.	Role-based access and farmer consent can govern Arla, advisor and authority views.	Contract needed
Interoperability	Avoid isolated datasets and duplicate reporting.	API-ready outputs, SHAPE/VRA files and common field identifiers.	Operational
No pollution swapping	NH_3, climate and nitrogen surplus must be considered together.	Links NH_3/NPA, VRA mineral-N decisions and Changes storage CO_2e evidence.	Platform logic
Continuous improvement	The framework must reward verified better performance.	Actual NPA and timing data enable differentiated factors and learning.	Pilot pathway

Table F.4

NPA DEFINITION Nitrogen Plant Availability (NPA) is the share of applied slurry nitrogen expected to remain available to the crop after ammonia volatilisation. In simplified form: available slurry N = applied TAN-N × NPA%. NPA therefore converts an air-emission result into a fertiliser-management value.

Table F.5

DANISH POLICY SIGNAL BioCover's supplied 2026 material describes a Danish regulatory pathway in which injection or acidification may be omitted when e-missioN documents NPA above 80% for the relevant slurry volume. This is a proposal/implementation pathway, not presented here as final enacted law. Its importance is conceptual: measured performance can replace a prescribed technique.

Table F.6

Outcome	Intervention	e-missioN evidence	Illustrative effect	Doelsturing value
Field NH_3	SyreN inline acidification and/or favourable timing.	Dose, pH-related inputs, weather, application map, calculated loss.	VERA: 49% NH_3 reduction for cattle slurry under verified test conditions.	Direct air-emission outcome.
Nitrogen surplus	NPA-based mineral-N VRA correction.	NPA map and revised SHAPE/VRA file.	Supplied case: 1,155 kg N internally redistributed; 61.5% of area below 80% NPA.	Links manure efficiency to water/soil objectives.
Storage methane	SyreN Changes: sulphate-based inhibition of methanogenic archaea—not storage acidification.	Treatment event, volume, date, dose and CO_2e calculation.	Pilot expectation 70–80% methane reduction; final factor requires verification.	Adds climate outcome to the same MRV layer.
Indirect CO_2e	Retained slurry N and better distribution can reduce mineral-N manufacture and N_2O risk.	Mineral-N correction and fertiliser-plan revision.	Supplied 448 ha case: indicative 10–15 tCO_2e direct N_2O and 13–24 t incl. indirect effects.	Prevents single-pollutant optimisation.
Biodiversity	Less NH_3 deposition and reduced excess N.	Spatial field record can be linked to sensitive areas/buffer zones.	Site-specific; no universal percentage proposed here.	Targets high-impact locations.

Table F.7

IMPORTANT TECHNOLOGY DISTINCTION SyreN Changes inhibits methane formation through sulphate-related microbial pathways. It should be introduced and documented as methane inhibition—not as slurry-storage acidification. The treatment and accounting protocol must reflect this distinction.

Table F.8

Calculation	Formula	Annual value
Milk supplied	1,000 cows × 10,333 kg	10,333,000 kg
Value per point	10,333,000 × €0.0003	€3,100
Five-point value	€3,100 × 5	€15,500/year

Table F.9

Actor	Purpose	Permitted view	Control principle
Farmer	Operational control and evidence.	All own field, job, NPA and recommendation data.	Data ownership and correction workflow.
Advisor / SEGES	Revised fertiliser plan and quality assurance.	Consented farm data and exception flags.	Professional review and version control.
Arla	Award and audit FarmAhead points.	Only lever-relevant evidence and compliance status.	Purpose limitation; no unnecessary agronomic detail.
Authority	Verify compliance or performance credit.	Consented or legally authorised evidence, audit trail and model version.	Role-based access, logging and retention rules.
Research / model owner	Validate methods and improve factors.	Anonymised or contractually governed datasets.	Separation of research and enforcement use.

Table F.10

ARLA DASHBOARD A dedicated processor dashboard can show eligible farms, verified treatment events, completeness, exception flags and audit status. It should issue points from a defined rule set and retain the underlying evidence reference. The same architecture can support authorities under a separate permission and governance layer.

Table F.11

Category	Annual value	Associated environmental result	Evidence/status
SyreN field acidification	€36,274	NH_3 reduction; retained N; lower injection traffic.	Supplied 500 ha grass business case.
e-missioN VRA	€21,600–30,600 net	Better spatial N allocation; indicative N_2O/CO_2e benefit.	Supplied 448 ha cereal case; transfer to dairy rotation requires validation.

Category	Annual value	Associated environmental result	Evidence/status
FarmAhead: 5 points	€15,500	Processor-recognised climate/land-use actions.	Contractual value if all five levers are approved and verified.
Mineral-N saving	€1,386	1,155 kg N redistributed × €1.20/kg N.	Direct saving from supplied dataset; avoid double counting within VRA net value.
Changes tax value, 2030	€2,576	161 tCO_2e avoided if 10,000 m^3 × 23 kg baseline × 70%.	Illustrative only: €16/t effective Danish 2030 rate and formal recognition assumed.

Table F.12

MINISTERIAL DECISION MESSAGE e-missioN should be evaluated as public digital infrastructure for manure-application doelsturing: a system that measures performance, guides mineral-N correction, enables remote audit and connects regulation with private incentives. SyreN, Changes and night application then become verifiable interventions within the platform—not isolated technology claims.

Appendix G — Economic case for national SyreN implementation

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

ECONOMIC POLICY BRIEF

Scope: 40 million m^3 slurry; 2,667 SyreN systems; five-year implementation context

Decision message. A fleet of 2,667 SyreN systems represents a one-time equipment value of €240 million. On the stated assumptions, it removes 15.8 kt NH_3 per year and is equivalent to preserving about 15.5% of current livestock production from an otherwise proportional emission-driven contraction. A cautious budget-equivalence model indicates €0.87–0.95 billion of avoided buy-out expenditure and a net public-budget advantage of €0.63–0.71 billion after the equipment investment.

The €20bn package contains non-substitutable expenditure for nature, zones and transition. The chart is budget context—not a claim that SyreN replaces the full package.

1. Executive summary

- National equipment requirement: 40,000,000 m^3 ÷ 15,000 m^3/system = 2,666.7; rounded up to 2,667 systems.
- Capital value: 2,667 × €90,000 = €240.03 million. This equals 1.2% of the current €20bn nitrogen package and 8.7% of the €2.75bn voluntary-closure budget.
- Central ammonia effect: 35 kt NH_3/year application baseline × 45% = 15.75 kt NH_3/year. Evidence sensitivity: 13.0–18.2 kt at 37–52%.
- Relative to 2024 agricultural NH_3 emissions (approximately 101.7 kt), the central SyreN wedge equals 15.5 percentage points; the sensitivity range is 12.7–17.9 points.
- This technology wedge equals approximately 32–35% of the full 42–46% agricultural reduction objective relative to 2019.
- Under a proportional animal-equivalence model, approximately 235,000 dairy cows, 1.47 million pigs or 12.6 million chickens represent the production capacity corresponding to this reduction. These categories are alternative illustrations and must not be added together.
- Operational SyreN use is treated as cost-neutral, as instructed. Agronomic, fertiliser, fuel and yield benefits are therefore excluded from the base case, making the calculation conservative.

2. Current Dutch budget context

On 26 June 2026, the Dutch Government announced a €20bn package to restore licensing, reduce nitrogen pressure and support transition. The published package includes €9bn for targeted zones around vulnerable nature, €2bn for farm adaptations including housing and feed, €2.2bn for nature restoration and management, and €250m for industry and mobility. A separate government information page states that €2.75bn is available through 2035 for voluntary farm closure or relocation. The European Commission approved a further €715m Dutch ammonia-reduction State-aid scheme in July 2026.

3. Technology investment and unit economics

Annualisation is shown only to make capital intensity comparable. The operating case follows the user assumption that SyreN is operationally cost-neutral.

4. How much of the livestock-reduction requirement can SyreN replace?

The Government's 2035 agricultural objective is 42–46% lower ammonia emissions than in 2019. SyreN does not remove emissions from housing or storage; it removes a large part of application emissions. If every verified kilogram is credited under goal-based regulation, the central 15.75 kt wedge equals approximately 32–35% of the total sector reduction task.

Interpretation. The figure is an emission-equivalence calculation, not a prediction that all remaining policy can be replaced. Housing, storage, water quality and site-specific deposition obligations remain separate constraints.

5. Animal-equivalent production retained

The most transparent way to express "animals not needing to be removed" is a proportional equivalence: divide the SyreN reduction by current agricultural NH_3 emissions and apply that percentage to current livestock numbers. This answers how much production capacity corresponds to the same national NH_3 reduction. It does not identify which individual farms or species would otherwise be selected for closure.

CBS December 2025 populations are provisional. Dairy cows are included within all cattle; veal calves are also included within all cattle. Rows are alternative indicators and must not be summed.

What the central case means

- About 235,000 dairy cows represent the milk-production capacity corresponding to the SyreN reduction.
- About 1.47 million pigs represent the pig-production capacity corresponding to the same reduction.
- About 12.6 million chickens is a whole-sector proportional illustration only; most poultry manure is not liquid slurry and is outside the direct 40m m^3 treatment assumption.
- The central wedge preserves 15.5% of current animal-equivalent capacity. Measured against the Government's 2019 baseline, it contributes 14.6 percentage points and reduces a 42–46% proportional reduction requirement to approximately 27.4–31.4%.

6. Avoided farm-closure expenditure

A direct farm-by-farm saving cannot be calculated without the accepted applications, compensation valuations and AERIUS deposition effect of each location. A policy-screening estimate can nevertheless allocate the €2.75bn closure budget in proportion to SyreN's share of the 42–46% agricultural reduction task.

Boundary. This is not a claim that €0.87–0.95bn will automatically return to the Treasury. Closure expenditure is spatially targeted and includes legal, land and transition objectives. The calculation shows the order of magnitude if verified technology reductions substitute proportionally for closure-based ammonia reduction.

7. Value of maintaining a larger livestock sector

The economic value of an animal is not limited to farm-gate output. Dutch livestock supports feed suppliers, contractors, veterinary services, equipment manufacturers, dairy and meat processing, logistics, distribution, research and export capabilities. Wageningen's Agrimatie data place the 2023 value added of the ground-based livestock complex at €12.7bn with 124,000 job-years, and the intensive livestock complex at €9.7bn with almost 76,000 job-years.

The proportional values are exposure indicators, not forecasts of GDP loss. Processing may source alternative inputs, prices can adjust, and some labour and capital can move to other activities.

Social and strategic value

- Continuity of family farms, succession plans and rural communities, particularly around vulnerable nature areas where closure pressure is highest.
- Retention of throughput for dairies, slaughterhouses, feed mills, contractors and logistics networks; these assets depend on sufficient regional production density.
- Preservation of the Netherlands' knowledge and innovation position in dairy, livestock management, manure technology, breeding, veterinary science and food processing.
- Greater food-system resilience: maintaining domestic productive capacity while lowering emissions per unit of production.
- A more credible goal-based policy: farmers can choose verified technology and document results instead of facing closure as the primary compliance route.

8. Policy recommendation

Recommended decision. Create a national SyreN programme for 40 million m^3 of liquid manure, beginning with mandatory deployment in nitrogen-sensitive zones and expanding nationally over five years. Recognise a conservative default emission reduction, while allowing measured performance through e-missioN. Use the €2bn technology envelope and relevant parts of the €9bn zonal package before committing additional farms to permanent closure.

Implementation safeguards

- Credit only verified and auditable reductions; e-missioN should record location, time, slurry volume, untreated and treated pH, acid dosage and calculated emission.

- Use OPS/AERIUS to distinguish national emission reduction from the higher deposition value of reductions close to sensitive nature.
- Differentiate regulatory factors by slurry type and retain the 37–52% evidence range until Dutch validation supports a narrower value.
- Avoid double counting with housing, storage, feed or herd-reduction measures.
- Make contractor fleets eligible so 2,667 systems can serve many farms without requiring every farm to own equipment.

9. Evidence boundaries and next calculation

Before formal use in budget legislation, the Ministry should replace the screening assumptions with: (1) the latest NEMA application-emission baseline for the exact 40m m^3 manure mix; (2) parcel-level buffer-zone volumes; (3) accepted SyreN factors by cattle and pig slurry; (4) current buy-out applicant costs and expected kg NH_3 reduction; and (5) OPS/AERIUS deposition outcomes. This will convert the present order-of-magnitude case into an auditable investment appraisal.

References

1. Government of the Netherlands (26 June 2026), “Kabinet haalt Nederland van het stikstofslot”: €20bn package; €9bn zones; €2bn farm adaptations; €2.2bn nature. https://www.rijksoverheid.nl/actueel/nieuws/2026/06/26/kabinet-haalt-nederland-van-het-stikstofslot-met-stevig-pakket-weer-ruimte-voor-boer-natuur-en-bouw

2. Government of the Netherlands, “Stikstofplannen kabinet voor landbouw en tuinbouw”: €2.75bn for voluntary closure/relocation through 2035. https://www.rijksoverheid.nl/themas/klimaat-milieu-en-natuur/landbouw-en-tuinbouw/stikstofplannen-kabinet-voor-landbouw-en-tuinbouw

3. Government of the Netherlands, “Plannen kabinet voor minder stikstof”: agricultural target of 42–46% lower NH_3 emissions in 2035. https://www.rijksoverheid.nl/themas/bouwen-en-wonen/stikstof/plannen-kabinet-voor-minder-stikstof

4. European Commission (22 July 2026), approval of €715m Dutch State-aid scheme to permanently reduce ammonia emissions.

5. CBS, 2024 ammonia emissions: 113m kg nationally; agriculture 90%. https://www.cbs.nl/nl-nl/dossier/dossier-broeikasgassen/hoe-groot-is-onze-uitstoot-van-luchtverontreinigende-stoffen-

6. CBS, livestock on agricultural holdings, December 2025 provisional figures. https://www.cbs.nl/en-gb/figures/detail/84952ENG

7. Wageningen Economic Research / Agrimatie, livestock-complex value added and employment (2023): ground-based €12.7bn/124,000 job-years; intensive €9.7bn/~76,000 job-years.

8. WUR/CBS, agricultural exports of €128.9bn in 2024. https://www.wur.nl/en/news/strong-growth-dutch-agricultural-exports-driven-european-trade

9. VERA/DANETV SyreN verification: 49% ammonia reduction for cattle slurry and 37% for pig slurry. The 52% high case is retained as sensitivity from the wider test evidence.

10. Scenario inputs supplied by BioCover: 40m m^3 treated; 15,000 m^3/system; €90,000/system; operations treated as cost-neutral.

Table G.1

Budget item	Latest stated amount	Relationship to SyreN
Overall nitrogen package	€20.0bn	SyreN capital equals 1.2%; most package functions remain necessary
Targeted zones and farm transition	€9.0bn	Directly relevant: buffer-zone technology can reduce need for contraction
Farm technology, housing and feed	€2.0bn	Potential funding home for a SyreN rollout
Nature restoration and management	€2.2bn	Not replaced by SyreN

Budget item	Latest stated amount	Relationship to SyreN
Voluntary closure/relocation to 2035	€2.75bn	Reference budget for avoided-closure scenario
National SyreN fleet	€0.240bn	2,667 systems at €90,000

Table G.2

Calculation	Formula	Result
Systems required	40,000,000 ÷ 15,000	2,666.7 → 2,667 systems
Equipment value	2,667 × €90,000	€240.03m
One-time capital per treated m^3	€240.03m ÷ 40m m^3	€6.00/m^3 of annual capacity
Central NH_3 reduction	35 kt × 45%	15.75 kt/year
Reduction per system	15.75m kg ÷ 2,667	≈5,906 kg NH_3/year
Capital per annual kg capacity	€240.03m ÷ 15.75m kg	€15.24 per kg NH_3/year
Annualised cost, 10 y at 5%	€240.03m × 12.95%	≈€31.1m/year
Annualised abatement cost	€31.1m ÷ 15.75m kg	≈€1.98/kg NH_3

Table G.3

Category	2025 population	Low equivalent	Central equivalent	High equivalent
Dairy cows	1.518m	193k	235k	272k
All cattle	3.549m	452k	550k	635k
Veal calves	0.866m	110k	134k	155k
Pigs	9.482m	1,207k	1,468k	1,697k
Chickens	81.379m	10,362k	12,603k	14,563k

Table G.4

Item	Low case	Central presentation	High case
SyreN share of sector target	31.6%	≈33.1%	34.7%
Indicative buy-out budget avoided	€0.87bn	≈€0.91bn	€0.95bn
Less national SyreN capital	€0.24bn	€0.24bn	€0.24bn
Net public-budget advantage	€0.63bn	≈€0.67bn	€0.71bn
Gross avoided budget / SyreN capital	3.6×	≈3.8×	4.0×

Table G.5

Economic indicator	Published base	15.5% proportional exposure
Ground-based livestock complex value added	€12.7bn (2023)	≈€1.97bn/year

Economic indicator	Published base	15.5% proportional exposure
Intensive livestock complex value added	€9.7bn (2023)	≈€1.50bn/year
Combined livestock-complex value added	€22.4bn (2023)	≈€3.47bn/year
Combined employment	≈200,000 job-years	≈31,000 job-years
Milk production value	≈€7.4bn (2024)	≈€1.15bn/year
Total agricultural exports	€128.9bn (2024)	Context only; not multiplied

Appendix H — SyreN contribution to the Dutch nitrogen target

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

POLICY ANALYSIS

Status: Screening-level policy proposal; spatial verification required

Decision message. A buffer-first mandate followed by a five-year national rollout can remove approximately 15.8 kt NH_3 per year in the central case—about 13% of the 2020 Dutch national NH_3 total. The reduction is measurable at field level and is spatially prioritised where it matters most. It cannot, however, be converted honestly into a precise percentage of sensitive nature below the critical load without an OPS/AERIUS source–receptor calculation.

Figure 1. The historical, projection and goal points reproduce the visual logic and approximate values in the supplied PBL presentation (RIVM 2023 data). The SyreN arrow is an emissions wedge, not a calculated habitat-area outcome.

1. Executive summary

- The supplied PBL presentation shows approximately 29% of nitrogen-sensitive nature below the critical load in 2021, an official projection of only about 34% in 2040, and a statutory goal of 74% in 2035.
- SyreN directly addresses ammonia released during slurry application. Using a transparent 35 kt NH_3/year working baseline and 45% central effectiveness, full deployment removes 15.8 kt NH_3/year (range 13.0–18.2 kt at 37–52% effectiveness).
- This is approximately 12.7% of the 2020 national NH_3 total and 14.6% of agricultural NH_3. It is more than three times the <5 kt NH_3 reduction by 2030 attributed in the supplied presentation to livestock buy-out schemes.
- Making SyreN mandatory in buffer zones from the outset front-loads the ecological benefit. In the central model, Year 1 already removes 5.0 kt NH_3/year nationally; an illustrative 2× buffer weighting raises the nature-priority value to 7.4 kt-equivalent.
- The recommended legal architecture is a default verified emission factor plus an optional measured-performance route using e-missioN data, audited and connected to the Dutch calculation system.

What can be claimed now—and what requires modelling

2. Baseline and calculation logic

The calculation deliberately separates technology performance, activity data and spatial impact. This prevents a verified percentage reduction at the slurry outlet from being presented as if it were already a verified percentage reduction in national critical-load exceedance.

Inventory anchor: RIVM Informative Inventory Report 2022 (1990–2020). Technology anchor: VERA Verification Statement 001 / DANETV SyreN verification. Values should be refreshed before formal submission.

Reading the national wedge

- Central case: 35.0 kt NH_3/year × 45% = 15.75 kt NH_3/year removed.
- Evidence range: 35.0 × 37–52% = 13.0–18.2 kt NH_3/year removed.
- National significance: 15.75 / 124.4 = 12.7% of the 2020 Dutch NH_3 inventory, all else equal.
- Comparison in the supplied PBL material: the expected effect of buy-out schemes is stated as less than 5 kt NH_3 by 2030; the central SyreN wedge is therefore more than three times larger.

3. Five-year implementation scenario

Assumption: all slurry application in designated buffer zones uses SyreN from Year 1. Outside the buffers, adoption rises in equal 20-percentage-point steps to full coverage in Year 5. The model counts only ammonia reduction during application; it does not add potential benefits from avoided injection, fertiliser substitution, methane inhibition or improved nitrogen-use efficiency.

The "nature-priority index" applies a 2× weight to reductions in buffers. It is a prioritisation index—not an emission inventory and not a deposition calculation.

4. Why buffer-zone reductions have extra value

Ammonia is a reactive gas with substantial near-source deposition. A kilogram avoided next to nitrogen-sensitive habitat can therefore prevent more deposition on that habitat than a kilogram avoided far away. The effect varies with distance, wind, surface roughness, atmospheric chemistry, season and habitat. Dutch OPS/AERIUS modelling is the appropriate method for quantifying it.

At the central planning assumption that 15% of slurry-application emissions occur in designated buffers, a 2× nature weight gives the same national kilograms 15% more nature-priority value at full rollout. During Year 1, when the buffer mandate is already complete but national adoption is only beginning, the uplift is approximately 47%. This is why sequence matters: a buffer-first mandate delivers disproportionately early protection.

5. Contribution to the 74% critical-load objective

The supplied PBL material identifies a large policy gap: the official projection remains around 34% of sensitive nature below the critical load in 2040, compared with the 74% goal for 2035. SyreN can provide a large, rapidly deployable agricultural ammonia wedge, but the habitat-area response is nonlinear. Some habitat cells are close to their critical load and may cross the threshold after a modest reduction; others remain far above it.

Important evidence boundary. A national percentage of nature below the critical load must not be calculated by multiplying the 74% target by the national emission reduction. The legally robust number must come from a spatial model run using Dutch emission locations, application timing, meteorology, habitat polygons and critical deposition values.

Proposed OPS/AERIUS calculation

6. Recommended Dutch policy package

- Mandate SyreN or an equivalently verified measured-emission technology for slurry application in designated nitrogen-sensitive buffer zones from Year 1.
- Phase in nationwide coverage over five years, preferably through contractor fleets and equipment-neutral retrofit access, so implementation is not limited to one slurry-tanker manufacturer.
- Recognise a conservative default reduction factor in regulation, differentiated by slurry type where needed, while allowing a higher or field-specific value only when measured and audited.
- Use e-missioN as the monitoring, reporting and verification layer: geolocation, application time, slurry volume, pH before and after treatment, acid dose and calculated ammonia loss.
- Commission an independent Dutch OPS/AERIUS scenario before attaching a numeric “% of nature below CL” claim to the policy. Publish assumptions and uncertainty bands.
- Run Dutch field demonstrations across peat/clay and sandy soils, seasons and buffer distances to calibrate model parameters and confirm operational practice.

7. Strategic interpretation

The principal value of SyreN is not that it replaces the entire Dutch nitrogen programme. It is that it converts one of the largest controllable agricultural ammonia sources into a measurable, enforceable and scalable reduction pathway. Unlike structural buy-out programmes, the technology can be introduced through the existing contractor and machinery system while retaining food production.

8. Conclusions

Recommended conclusion for the Minister. Treat SyreN as a national technology wedge: mandatory first in nitrogen-sensitive buffer zones and then rolled out across the Netherlands over five years. On the stated assumptions, full integration removes about 15.8 kt NH_3 per year, with a plausible evidence-based range of 13.0–18.2 kt. The buffer-first sequence gives the earliest and most nature-relevant effect. The Ministry should commission the OPS/AERIUS calculation needed to translate this verified emissions wedge into the official indicator “percentage of N-sensitive nature below the critical load.”

References and source notes

1. PBL Netherlands Environmental Assessment Agency. “Tackling the Dutch nitrogen crisis: Policies and Challenges in Agricultural Nitrogen Reduction” (supplied presentation, June 2024).

2. RIVM. Informative Inventory Report 2022: Emissions of transboundary air pollutants in the Netherlands 1990–2020. RIVM report 2022-0004.

3. VERA / DANETV. Verification Statement 001: SyreN slurry application system. Verified ammonia reduction: 49% for cattle slurry and 37% for pig slurry.

4. RIVM. OPS model documentation. OPS calculates concentration and deposition from spatially specified emissions and is the appropriate framework for the proposed source–receptor assessment.

5. Scenario assumptions introduced in this paper: 35 kt NH_3/year slurry-application baseline, 15% buffer share and 2× buffer priority weighting. These are transparent planning assumptions and must be replaced or validated with current Dutch spatial data.

Table H.1

Claim	Status	Required evidence
SyreN reduces field NH_3 emissions	Verified technology evidence	VERA/DANETV field verification; Dutch acceptance procedure
National full-rollout reduction: 13.0–18.2 kt NH_3/year	Transparent screening calculation	Latest NEMA manure-application baseline and Dutch slurry mix
Buffer-zone reductions have higher nature relevance	Scientifically and spatially plausible	OPS/AERIUS source–receptor calculation by location
Exact increase in % nature below critical load	Not yet established	National spatial run using parcel activity, habitat KDW and meteorology

Table H.2

Parameter	Central value	Sensitivity / note
Dutch national NH_3 emissions (2020)	124.4 kt/year	RIVM inventory; agriculture 87%
Agricultural NH_3 emissions	108.2 kt/year	Calculated as 87% of national total
Slurry-application NH_3 working baseline	35.0 kt/year	Planning assumption; replace with latest NEMA source-category value
SyreN reduction efficiency	45%	37% pig and 49% cattle in VERA; 52% external high case
Buffer share of slurry-application emissions	15%	Planning assumption, not a mapped Dutch result
Buffer nature-priority weighting	2×	Illustration only; test 1.5–3×; replace with OPS/AERIUS

Table H.3

Year	Adoption outside buffers	Total covered activity	NH_3 removed kt/y	Nature-priority index	Share of national NH_3
Year 1	20%	32%	5.0	7.4	4.1%
Year 2	40%	49%	7.7	10.1	6.2%
Year 3	60%	66%	10.4	12.8	8.4%
Year 4	80%	83%	13.1	15.4	10.5%

Year	Adoption outside buffers	Total covered activity	NH_3 removed kt/y	Nature-priority index	Share of national NH_3
Year 5	100%	100%	15.8	18.1	12.7%

Table H.4

Metric	Without additional SyreN policy	Full SyreN scenario	Interpretation
Sensitive nature below CL	≈34% in 2040 projection	To be calculated by OPS/AERIUS	Do not infer directly from kt NH_3
Slurry-application NH_3	35.0 kt/year working baseline	19.3 kt/year residual	15.8 kt/year central reduction
National NH_3	124.4 kt/year inventory anchor	≈108.7 kt/year, all else equal	12.7% national reduction
Agricultural NH_3	108.2 kt/year inventory anchor	≈92.5 kt/year, all else equal	14.6% agricultural reduction
Buffer-zone deployment	No SyreN mandate assumed	100% from Year 1	Local protection front-loaded

Table H.5

Step	Model input	Output
1. Baseline	Latest parcel-level slurry application, technique and NEMA emission factors	Baseline NH_3 grid and deposition
2. Buffer mandate	100% SyreN in defined buffer polygons; verified default efficiency	Immediate local deposition change
3. Five-year rollout	20/40/60/80/100% outside-buffer uptake	Annual national deposition pathway
4. Measured route	e-missioN records: volume, location, time, untreated/treated pH and performance	Auditable realised emissions
5. Nature result	Overlay on N-sensitive habitat and KDW values	% area below CL and average exceedance

Table H.6

Policy criterion	SyreN assessment
Scale	Central screening potential of 15.8 kt NH_3/year at full rollout
Speed	5.0 kt/year already in Year 1 under buffer-first implementation
Spatial precision	High: mandate and measurement can be targeted to buffer parcels

Policy criterion	SyreN assessment
Auditability	High when e-missioN records are required and independently accessible
Production impact	Designed to reduce loss during application rather than remove production capacity
Legal robustness	Strongest when default factors are backed by Dutch tests and realised effects are modelled in OPS/AERIUS

Appendix I — CDM protocol for assessment of low-emission application techniques

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

ASSESSMENT PROTOCOL

Assessment criteria

25. Is a scientific report available that describes the research, including the experimental design, measurement method, conditions and calculation of the emission factor? If not, the system cannot be assessed.
26. Does the manure application system meet the requirements for low-emission manure application techniques for grassland laid down in the Environment and Planning Act? If so, the system does not need to be assessed under this protocol.
27. Are the field trials, soil type, application rate and manure application system - including the reference application method - described in sufficient detail?
28. Is the operation of the new system described in sufficient detail to explain its operating principle - why the technique reduces ammonia emissions - and its differences from existing techniques?
29. Is the experimental design scientifically sound for testing whether the ammonia emission from the application technique is equivalent to that from shallow injection on grassland on sandy soil, or trailing-shoe application of diluted slurry on grassland on clay and peat soil?
30. Is the ammonia-emission measurement method scientifically sound, and does the measurement method comply with the VERA protocol? Have at least three trials been conducted and has an emission factor been established? Three trials are the minimum under the VERA protocol.
31. Are the application method and the relevant conditions - weather, soil, crop and slurry composition - described in sufficient detail to assess the ammonia emission?
32. Were there circumstances that make the measurement results unusable or of limited use, for example because they apply only to a specific situation?
33. Are the uncertainties associated with the measurements described in sufficient detail?
34. A condition for authorising a new technique is that its emission factor is lower than or equal to that of shallow injection or trailing-shoe application of diluted slurry: an emission factor of 17% of the applied total ammoniacal nitrogen (TAN).
35. Final judgement: Does the assessed application technique produce ammonia emissions equivalent to those from shallow injection or trailing-shoe application with slurry dilution?

Questions supporting the final judgement

- If yes, specify whether equivalence applies only under particular conditions.
- If no, does the technique nevertheless have potential?
- If the technique is considered promising, what additional data or research are required for a new assessment?

Source and translation status

This document reproduces only the protocol contained in Appendix 3 of the Dutch CDM opinion dated 11 June 2026. It does not include CDM's application of the criteria to SyreN, its conclusions, or additional BioCover commentary. The Dutch original remains the authoritative text.

Table I.1

Origin and scope. The protocol was originally prepared in 2017 for the assessment of manure application techniques under the SBIR programme 'Reducing ammonia emissions: manure application'. It was updated for the CDM opinion assessing the SyreN system.

Appendix J1 — Yield evidence: injection versus acidification

Integrated technical dossier. Content has been normalised into the report’s common style; the evidence and qualifications remain those of the source document.

EVIDENCE REVIEW

Yield differences between shallow injection and in-field slurry acidification

Assessment of direct comparative trials in grassland and cereals

Purpose: Evidence-based comparison of crop yield and nitrogen uptake

Status: Technical working document

1. Executive summary

- The average yield effects reported across the 27-study review - approximately +17.1% for grass and +4.9% for cereals - are mainly calculated against untreated surface or band spreading. They must not be presented as the yield difference between acidification and injection.
- The strongest direct field evidence is Seidel et al. (Denmark/Germany), Keskinen et al. (Finland) and the Wehnen winter barley trial (Germany).
- Seidel et al. found no statistically significant overall effect on dry-matter yield, but acidification to pH 6.0 produced the highest yields and, in selected site-years, higher crop N uptake.
- Keskinen et al. found no treatment response in 2017. In 2018, acidification increased dry-matter yield by 29% relative to untreated band spreading and was more productive than both untreated and injected slurry. Injection produced no positive yield response in either year.
- At Wehnen in 2018, approximate chart readings indicate 58 dt/ha for acidified trailing hose and 64 dt/ha for acidified trailing shoe, compared with about 54 dt/ha for open-slot injection. The respective estimated differences are +4 dt/ha (+7%) and +10 dt/ha (+19%). Only the latter exceeds the reported LSD of 5.8 dt/ha.
- The GülleBest project brief reports equal nitrogen-use efficiency across application techniques and no yield reduction from spring application into growing crops, but it does not provide treatment-specific yields suitable for calculating an acidification-versus-injection percentage.
- The 2010 Aarhus University note compares ammonia, odour and nitrous oxide emissions. It contains no crop-yield results and should therefore not be cited as yield evidence.

2. Assessment method

A study was treated as a direct comparison only when acidified slurry and untreated slurry applied by injection were included as parallel treatments under the same crop, site, season and experimental design. Results against untreated trailing hose, trailing shoe or broadcast spreading were retained as supporting evidence but were not converted into a yield advantage over injection.

Where numerical values were available only as bars in a presentation, they were read approximately from the graph and labelled as estimates. Statistical conclusions are reported only where the source gives a significance test, grouping or least significant difference (LSD).

3. Evidence matrix

4. Detailed assessment of the new evidence

4.1 Wehnen trial - winter barley, 2018

The Landwirtschaftskammer Niedersachsen presentation describes a winter-barley trial on sandy soil (Ackerzahl 25) with 132 kg total organic N/ha. The organic treatments included trailing hose and trailing shoe, each with and without sulphuric-acid acidification, and open-slot injection. A mineral-N response curve was used to calculate mineral-fertiliser equivalents and N-removal efficiency.

Figure 1. Approximate reconstruction of the untreated organic treatments shown on page 3 of the Wehnen presentation.

The same presentation reports mineral-fertiliser equivalence values of 32.0% for untreated trailing hose, 42.9% for open-slot injection and 44.0% for untreated trailing shoe. Acidification increased the reported equivalence to 45.8% for trailing hose at pH 6.0 and 60.0% for trailing shoe at pH 6.0. These values reinforce the yield result, but represent a single site-year and should not be treated as a general conversion factor.

4.2 GülleBest project brief - Germany, 2019-2020

GülleBest compared trailing hose/shoe, open-slot injection at approximately 5 cm depth, acidification to pH 6.0 and injection with a nitrification inhibitor across four sites in Schleswig-Holstein, Lower Saxony and Baden-Württemberg. The project brief states that acidification and open-slot injection achieved the highest ammonia mitigation, neither technique increased nitrous oxide emissions, and nitrogen-use efficiency was equal among the techniques.

The brief also states that spring application of cattle slurry and digestate into growing crops caused no yield reduction at any site. However, it does not publish treatment-specific crop yields. It therefore supports yield equivalence and operational suitability, but cannot quantify a yield advantage of acidification over injection.

4.3 Aarhus University SyreN note - Denmark, 2010

The Aarhus University note was prepared to assess whether acidification could be considered equivalent to injection for regulatory purposes. It includes direct treatment comparisons for ammonia, odour and greenhouse-gas measurements. Average ammonia reduction was reported as 54% for injection and 42% for SyreN relative to untreated trailing-hose application, with the note observing that a higher acid dose would lower pH and emissions further.

No crop-yield or harvested-N results are reported. The note is therefore relevant to the history of environmental verification, but it adds no evidence to the yield comparison and has been excluded from all yield calculations in this review.

5. Integrated interpretation

5.1 What the trials demonstrate

- Yield parity is well supported: no reviewed direct trial establishes a general yield disadvantage from acidification relative to injection.
- A positive acidification advantage is plausible and observed in individual trials. The most likely mechanism is retention of ammoniacal N without mechanical injury to the crop or grass sward.
- The advantage is conditional. It will be larger when untreated or imperfect injection would otherwise allow substantial ammonia loss, and smaller when weather, rapid infiltration or effective slot closure already limits emissions.
- Acidification supplies sulphate-S. Where sulphur is deficient, part of the yield response may reflect S nutrition as well as conserved N. This must be considered when attributing causality.

5.2 What the trials do not demonstrate

- They do not support applying the review-wide +17.1% grass or +4.9% cereal figures as premiums over injection.
- They do not establish one national yield factor valid for every soil, slurry type, crop and season.
- They do not permit the 2010 AU emission results to be converted into crop yield without a separate agronomic model and explicit assumptions.

6. Recommended wording for external use

For quantitative presentation, the Wehnen result may be shown as a site-specific example: approximately +7% for acidified trailing hose and +19% for acidified trailing shoe relative to open-slot injection. The values must be labelled as approximate graph readings from one site-year, not as general SyreN performance factors.

7. Recommended next step for a defensible pooled estimate

A pooled acidification-versus-injection estimate should be calculated only after retrieving treatment-level yield, variance and replication data from the original studies. The minimum dataset should include crop, site, year, soil type, slurry type and rate, acid dose and achieved pH, injection depth and slot spacing, yield, harvested N, standard error and statistical grouping. Study identity must be reconciled so that conference papers and later journal publications from the same experiment are not counted twice.

Sources reviewed

- BioCover A/S. Analysis of 27 international scientific studies of in-field acidification from 2010 to 2024, Version 3. Umbrella review supplied for this assessment.
- Howind, M. / Landwirtschaftskammer Niedersachsen. Daten Versuchsstation Wehnen, 18 June 2019. Winter barley 2018; pages 2-6.
- Buchen-Tschiskale, C. et al. GülleBest: Mit welcher Technik lassen sich Gülle und Gärreste emissionsarm ausbringen? Project brief 2022/41. Four-site project summary.
- Nyord, T. et al. Notat til Miljøstyrelsen om SYREN-projekt, final version, 2010. Emission comparison; no yield data.
- Seidel, A. et al. (2017). Effects of acidification and injection of pasture applied cattle slurry on ammonia losses, N2O emissions and crop N uptake. Agriculture, Ecosystems & Environment 247, 23-32. Direct grassland comparison.
- Keskinen, R. et al. (2022). Slurry acidification outperformed injection as an ammonia emission-reducing technique in boreal grass cultivation. Nutrient Cycling in Agroecosystems. Direct grassland comparison.
- Schreiber, F. et al. (2023). Impacts of slurry acidification and injection on fertilizer nitrogen fates in grassland. Nutrient Cycling in Agroecosystems. Direct mesocosm comparison.

Table J1.1

Overall finding: Direct comparative trials support the conclusion that acidification produces yields at least equivalent to shallow injection. Some trials show a yield and nitrogen-uptake advantage for acidification, but the available evidence does not justify one universal percentage yield premium across crops, soils and seasons.

Table J1.2

Study	Crop / setting	Direct?	Yield finding	Weight
Seidel et al. 2017	Grass; DK/DE; 2012-13	Yes	No significant overall DM-yield difference. pH 6.0 acidification had highest yield and higher N uptake in selected site-years.	High
Keskinen et al. 2022	Grass ley; Finland; 2017-18	Yes	No response in 2017. In 2018 acidification was more productive than untreated and injected slurry; +29% vs untreated band spreading.	High
Wehnen 2018	Winter barley; sandy soil; Germany	Yes	Approx. 58 dt/ha acidified hose; 64 acidified shoe; 54 injection. Differences vs injection approx. +7% and +19%.	Medium

Study	Crop / setting	Direct?	Yield finding	Weight
Schreiber et al. 2023	Montane grassland mesocosms; Germany	Yes	Acidification increased above-ground biomass and plant N export relative to injection; injection reduced biomass under ambient conditions.	Medium
GülleBest 2019-20	Wheat and permanent grassland; four German sites	Yes, by design	Equal N-use efficiency; no yield reduction from spring application. Brief lacks treatment-specific yield figures.	Medium for equivalence
Bull/Kureck/Ramp 2014	Winter wheat/digestate; Germany	Design includes both	Acidification +4.1 dt/ha vs untreated hose. Injection-specific yield absent from the reviewed summary.	Low for direct difference
AU SyreN note 2010	Grass/winter wheat; Denmark	Techniques included	No crop-yield measurements reported.	Not usable for yield

Table J1.3

Comparison	Approx. difference	Relative difference	Statistical reading
Acidified trailing hose vs injection	+4 dt/ha	+7.4%	Below LSD 5.8 dt/ha; not demonstrated as significant
Acidified trailing shoe vs injection	+10 dt/ha	+18.5%	Exceeds LSD 5.8 dt/ha; indicates a significant advantage if the stated LSD applies to this pairwise comparison
Untreated trailing shoe vs injection	≈0.5 dt/ha	≈1%	Agronomically similar

Table J1.4

Interpretation: Wehnen provides a direct cereal comparison and indicates that acidification can outperform injection. The result is strongest for acidified trailing shoe. Because values are read from a presentation graph and originate from one site-year, they should be described as indicative rather than used as a universal yield coefficient.

Table J1.5

Recommended conclusion: The available direct comparative trials indicate that in-field slurry acidification provides crop yields at least equivalent to shallow injection. Under conditions with significant ammonia-loss potential, acidification can increase dry-matter or grain yield and crop nitrogen uptake relative to injection. Direct field evidence includes a Finnish grassland trial, Danish-German grassland trials and a German winter-barley trial. The evidence supports yield equivalence with a documented potential advantage for acidification, but it does not yet justify one universal percentage yield premium across all farming conditions.

Appendix J2 — Yield evidence: untreated trailing hose/shoe versus acidification

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

EVIDENCE REVIEW

Yield differences between untreated trailing hose/shoe and in-field slurry acidification

Assessment of direct comparative trials in grassland and cereals

Purpose: Evidence-based comparison of crop yield and nitrogen uptake

Status: Technical working document

1. Executive summary

- The three-season Säure+ programme compared acidified and conventional trailing hose/shoe application across about 65 arable fields and about 49 grassland comparisons in seven German federal states. Approximately 60% of the arable comparisons produced a higher yield with acidification; grassland results were predominantly positive and reached about +30% in the strongest cases.
- The Säure+ reference treatments received mineral sulphur according to crop need. The observed differences therefore cannot simply be attributed to sulphur fertilisation and are consistent with improved retention and uptake of slurry nitrogen.
- The 27-study review reports average yield differences of +17.1% for grassland and +4.9% for cereals relative mainly to untreated spreading. These are useful portfolio-level indicators, but the underlying trials differ in design and should not be treated as one formal meta-analysis.
- Direct examples include +29% dry-matter yield in Finnish grassland in 2018; approximately +18% for both acidified hose and acidified shoe at Wehnen; +4.5% in Estonian winter wheat; and mixed German wheat results of +9.4% at Kiel and -6.1% at Hohenheim.
- The long-term Danish dataset of approximately 30 winter-wheat trials reports a weighted average response of +220 kg grain/ha, with annual results from -40 to +630 kg/ha.
- Yield response depends on ammonia-loss potential, crop N response, water availability, soil heterogeneity, acid dose and achieved pH. Neutral and negative individual results must remain visible in external communication.

2. Assessment method

A comparison was included when the same slurry was applied with and without acid under the same crop, site and season using trailing hose, trailing shoe or an equivalent band-spreading reference. Absolute and relative differences were retained as reported. Where a value was derived from a graph, it is labelled approximate.

Evidence was classified as replicated field research, multi-site demonstration comparison, long-term trial series or supporting evidence. Demonstration strips are valuable for showing performance under commercial conditions, but they do not carry the same statistical weight as replicated randomized experiments. Results were not pooled when treatment definitions, crops or reporting units differed.

3. Evidence matrix

4. Detailed assessment

4.1 Säure+ - results after three growing seasons

The German model and demonstration programme established paired strips or demonstration plots with conventional trailing hose/shoe application and the same application with acidification. Seven federal states and seven arable crops were represented, dominated by winter wheat and winter barley. The untreated reference received mineral sulphur according to crop requirement, reducing the risk that an observed response merely reflects extra sulphur in the acidified treatment.

The arable-crop figure contains approximately 65 field comparisons. The source states that around 60% produced a yield increase with acidification. The plotted range is approximately -14% to +12%, and the statistically significant observations are concentrated at both ends of the distribution. This demonstrates real upside but also material site-to-site variation.

The grassland figure contains approximately 49 comparisons and is predominantly positive, with observed differences from approximately -17% to +32%. Some treatments were acidified once, others up to three times, so the observations are not a single uniform dose-response experiment. Several of the largest positive results are reported as significant at $p<0.05$.

4.2 Quantified direct comparisons

Figure 1. Selected site-year comparisons with a quantified untreated reference. No pooled mean is implied.

4.3 Wehnen - paired hose and shoe treatments

At Wehnen, 132 kg total organic N/ha was applied to winter barley on sandy soil. Approximate readings from the source graph give 49 dt/ha for untreated trailing hose and 58 dt/ha after acidification to pH 6.0. The corresponding trailing-shoe values are about 54.5 and 64 dt/ha. The reported LSD (5%) is 5.8 dt/ha; both acidified-versus-untreated differences exceed this threshold if the stated LSD applies to these pairwise comparisons.

Mineral-fertiliser equivalence also increased: from 32.0% to 45.8% for trailing hose and from 44.0% to 60.0% for trailing shoe. This supports the interpretation that acidification improved the fertiliser value of the organic N in this site-year.

4.4 Long-term and supporting datasets

The Danish SyreN winter-wheat series covers approximately 30 trials from 2010 to 2017. It reports a weighted mean yield response of +2.2 hkg/ha (+220 kg/ha), with annual values from -0.4 to +6.3 hkg/ha. This is valuable repeated evidence, although the supplied summary does not provide treatment-level variance or a common untreated baseline yield for conversion to percent.

The Schleswig-Holstein trials report substantial grass responses - +400 to +1,100 kg DM/ha in the first cut and +250 to +750 kg/ha in the second - while winter-wheat responses were neutral or slightly negative. Bull/Kureck/Ramp report +4.1 dt/ha grain, +0.3 percentage point crude protein and +0.7 dt/ha crude-protein yield compared with untreated trailing hose.

5. Integrated interpretation

5.1 What the trials demonstrate

- Grassland has the clearest and largest response because slurry is applied repeatedly, including during warmer periods with high ammonia-loss potential, and grass commonly remains responsive to additional available N.
- Cereal effects are smaller and more variable because early-spring applications often occur under low-emission conditions and the crop may already be near its economic N optimum.
- The effect is primarily consistent with conserved ammoniacal N. Säure+ strengthens this interpretation because the untreated references were supplemented with mineral sulphur according to crop need.
- Protein content and harvested grain N can improve even where grain-yield response is modest. Yield alone therefore understates part of the agronomic value.
- Negative results are credible and expected where water, soil heterogeneity or another factor limits crop response, or where weather already suppresses ammonia loss.

5.2 What the trials do not demonstrate

- The evidence does not establish that every acidified application increases yield.
- The +17.1% grassland and +4.9% cereal values should be described as review-level averages, not statistically weighted meta-analytic effect sizes.
- The Säure+ observations should not be averaged directly with replicated trials without obtaining plot design, replication, variance and treatment-level data.
- Results cannot be transferred unchanged between cattle slurry, pig slurry and digestate or between acid doses and achieved pH values.

6. Recommended wording for external use

For a conservative technical claim, BioCover should lead with documented conditional performance rather than one guaranteed premium: acidification normally protects slurry N, frequently increases yield or protein, and offers the largest agronomic benefit when temperature, wind, radiation and lack of rainfall create high ammonia-loss conditions.

7. Recommended next step for a defensible pooled estimate

A defensible pooled estimate should be calculated after retrieving treatment-level yield, variance and replication data. The minimum dataset should include crop, site, year, spreading method, slurry type and rate, acid dose and achieved pH, mineral-S treatment of the control, yield, quality, harvested N and statistical grouping. Säure+ field identifiers should be linked to weather and application data so that e-missioN can test whether measured yield response follows documented ammonia-loss potential.

Sources reviewed

- Säure+ im Feld. Results and findings after three growing seasons with SyreN, 2026. Paired demonstrations in arable crops and grassland across seven German federal states.
- BioCover A/S. Analysis of 27 international scientific studies of in-field acidification from 2010 to 2024, Version 3. Umbrella review and individual study summaries.
- Howind, M. / Landwirtschaftskammer Niedersachsen. Daten Versuchsstation Wehnen, 18 June 2019. Paired trailing hose and trailing shoe comparison in winter barley.
- SEGES PlanteInnovation / Martin Nørregaard Hansen. Danish SyreN winter-wheat yield trials, 2010-2017. Long-term trial series.
- Keskinen, R. et al. (2022). Slurry acidification outperformed injection as an ammonia emission-reducing technique in boreal grass cultivation. Nutrient Cycling in Agroecosystems. Untreated band spreading versus acidification and injection.
- Estonian Crop Research Institute / Baltic Slurry Acidification project, 2017. Grassland and winter-wheat comparisons.
- Jorissen & Recke (2021). Cost efficiency of acidified cattle slurry - German 2019 field trials. Contrasting winter-wheat results at Kiel and Hohenheim.
- Bull, Kureck & Ramp (2014). Ansäuern und Schlitzen - Was bringen neue Applikationstechniken? Winter-wheat digestate comparison.

Table J2.1

Overall finding: In-field acidification frequently increases yield and crop nitrogen recovery compared with the same slurry applied by untreated trailing hose or trailing shoe. The response is strongest and most consistent in grassland and under high ammonia-loss conditions. Cereal responses are smaller and more variable, so one universal yield premium is not scientifically justified.

Table J2.2

Study	Crop / setting	Paired?	Yield finding	Weight
Säure+; 3 seasons	~65 arable and ~49 grass comparisons; seven German states	Yes	~60% of arable comparisons positive; grass predominantly positive, with the strongest near +30%. Sulphur balanced in controls.	Broad demonstration

Study	Crop / setting	Paired?	Yield finding	Weight
Danish SyreN series	Winter wheat; 2010-17; approx. 30 trials	Yes	Weighted mean +220 kg/ha; annual range -40 to +630 kg/ha.	Strong series
Keskinen et al. 2022	Grass ley; Finland; 2017-18	Yes	2017 no significant effect; 2018 +29% DM yield vs untreated band spreading.	High
Wehnen 2018	Winter barley; sandy soil; Germany	Yes	Approx. +18.4% acidified hose vs hose and +17.4% acidified shoe vs shoe.	Medium
Schleswig-Holstein 2017-18	Grass and winter wheat; cattle slurry/digestate	Yes	Grass +400-1,100 kg DM/ha first cut and +250-750 kg/ha second cut; wheat neutral to slightly negative.	Medium
Estonia 2017	Grass and winter wheat	Yes	Grass -119 kg DM/ha (-2.7%, not significant); wheat +244 kg/ha (+4.5%).	Medium
Kiel / Hohenheim 2019	Winter wheat; digestate	Yes	Kiel +600 kg/ha (+9.4%); Hohenheim -700 kg/ha (-6.1%).	Medium
Bull/Kureck/Ramp 2014	Winter wheat; digestate	Yes	+4.1 dt/ha grain and +0.3 percentage-point crude protein vs untreated hose.	Medium

Table J2.3

Interpretation: Säure+ is the strongest practical evidence that acidification can add yield relative to conventional trailing hose/shoe use under commercial conditions. It should be presented as a distribution of outcomes - not as proof that every application will generate a fixed premium.

Table J2.4

Comparison	Untreated reference	Acidified treatment	Difference
Finland grass, 2018	Band-spread slurry	Band-spread acidified slurry	+29% DM yield
Wehnen winter barley - hose	~49 dt/ha	~58 dt/ha	~+9 dt/ha; +18.4%

Comparison	Untreated reference	Acidified treatment	Difference
Wehnen winter barley - shoe	~54.5 dt/ha	~64 dt/ha	~+9.5 dt/ha; +17.4%
Estonia winter wheat	5,431 kg/ha	5,675 kg/ha	+244 kg/ha; +4.5%
Estonia grass	4,351 kg DM/ha	4,232 kg DM/ha	-119 kg/ha; -2.7%; not significant
Kiel winter wheat	6.4 t/ha	7.0 t/ha	+0.6 t/ha; +9.4%
Hohenheim winter wheat	11.4 t/ha	10.7 t/ha	-0.7 t/ha; -6.1%

Table J2.5

Recommended conclusion: The available European evidence shows that in-field slurry acidification can improve crop yield and nitrogen recovery compared with conventional trailing hose or trailing shoe application of untreated slurry. The response is strongest and most consistent in grassland, while cereal responses are generally smaller and more variable. The three-season German Säure+ programme found higher arable yield in approximately 60% of field comparisons and predominantly positive grassland responses. Across the wider 2010-2024 review, average reported differences were approximately +17.1% for grassland and +4.9% for cereals. These values describe the reviewed portfolio and should not be interpreted as a guaranteed result for every application.

Appendix K — Facts about BioCover and the SyreN System

Integrated technical dossier. Content has been normalised into the report's common style; the evidence and qualifications remain those of the source document.

BIOCOVER

SyreN in-field acidification: pH-controlled treatment during slurry application with a wide distribution boom.

Company and product fact book | Prepared from BioCover source material and public verification records

1. BioCover at a glance

BioCover A/S is a Danish, founder-owned environmental technology company specialising in the sustainable use of livestock slurry. Founded in 2009 and led by founder and CEO Morten Toft, the company combines agricultural machinery, chemistry and digital documentation to reduce emissions while improving the fertiliser value of slurry.

Strategy: one integrated slurry-management platform

BioCover's strategy links three points in the manure-management chain: storage, field application and post-application nutrient decisions. The portfolio is designed so that environmental performance can be delivered by hardware and then documented digitally.

Commercial model

- Scale through OEM, production and distribution partners, including established cooperation with Vogelsang.
- Serve contractors and farms with retrofit and OEM-ready solutions that fit existing slurry logistics.
- Create recurring value through monitoring, reporting, audit access and precision-nitrogen services.
- Use verified emission reduction and operational data to support regulatory acceptance and results-based environmental policy.

2. Product portfolio

SyreN - in-field acidification

SyreN adds sulphuric acid to the liquid slurry stream immediately before spreading. Lowering pH converts volatile ammonia (NH_3) into non-volatile ammonium (NH_4^+), retaining nitrogen in the slurry and simultaneously supplying sulphate sulphur. Automatic pH control, acid dosing and GPS-enabled documentation are integrated into the system.

SyreN process principle: sulphuric acid is injected and mixed into the slurry immediately before field application.

SyreN Light - compact and OEM-ready

SyreN Light is a compact configuration for field trials, smaller installations and flexible OEM integration. It contains the essential dosing, mixing, sensing, safety and GPS-documentation functions. Its environmental effect comes from the same pH-controlled chemistry as SyreN and should be specified by achieved treatment conditions, not a separate unverified fixed percentage.

3. Measurement, precision and methane reduction

e-missioN - from application data to nitrogen decisions

e-missioN combines machine, slurry, position and weather data with the ALFAM2 model to estimate ammonia loss and Nitrogen Plant Availability (NPA) during slurry application. It produces auditable field records and map layers for as-applied volume, estimated N loss, NPA and variable-rate application (VRA).

e-missioN combines slurry and machine sensors, weather information, GPS and telematics in one documented workflow.

- Environmental effect: supports lower ammonia loss through operational feedback and reduces the risk of unnecessary mineral-N application.
- Farm effect: replaces a single normative slurry-N value with field-specific information that can be used for subsequent VRA.
- Audit effect: data can be shared through a permission-based digital dashboard with farmers, dairy companies, advisers and authorities.

SyreN Changes - methane inhibition in slurry storage

SyreN Changes is designed for controlled, low-dose treatment of slurry storage tanks during the warm period. Sulphate inhibits methane-forming microorganisms; the concept is distinct from simply lowering storage pH. Pilot work evaluates timing, dose, durability and farm-scale documentation.

4. Market footprint and current projects

The 170 produced SyreN systems are deployed across Denmark, Sweden, Finland, Estonia, Lithuania, Germany and France. A country-by-country unit split was not included in the source presentations and is therefore not inferred here.

Current and ongoing projects

* e-missioN installation count is taken from BioCover's April 2026 investment presentation.

Why these programmes matter

- They move the technology from controlled verification into auditable, full-scale operations.
- They test performance across countries, climate, slurry types, contractors and regulatory settings.
- They connect environmental results to commercial incentives such as Arla FarmAhead points and future results-based regulation.

5. Verification and regulatory standing

BioCover's market position is built on third-party verification, regulatory recognition and operational data. The terms below are related but not interchangeable: a test protocol verifies performance, while BAT recognition describes a technology's place in an environmental permitting framework.

Core verified chemistry

$NH_3 + H^+ \rightarrow NH_4^+$

volatile gas plant-available, non-volatile ion

6. Awards and recognition

BioCover's source material records 13 international awards and recognitions spanning product innovation, environmental responsibility, scale-up and sustainability.

Agromek Award 2022 for BioCover Data / e-missioN precision-nitrogen documentation.

7. Patent portfolio

The portfolio covers the core SyreN application concept, slurry distribution and safety hardware, methane reduction in storage, and digital monitoring of nitrogen loss. The list below uses published patent-family titles; legal status and territorial scope should be confirmed in the relevant official register before contractual or freedom-to-operate use.

Fact-book summary

Selected sources

BioCover, Presentation for Minister Jaimi van Essen, August 2026.

BioCover, SyreN Light presentation, 2026.

BioCover, Investment presentation, April 2026.

VERA Verification Statement 001 and DANETV verification documentation for the SyreN slurry application system.

BioCover company timeline and product pages: www.biocover.dk/uk.

European Patent Office / Google Patents public family records for the listed publications.

BioCover A/S | Veerst Skovvej 6, 6600 Vejen, Denmark | www.biocover.dk

Table K.1

170 systems produced	7 European markets	13 international awards	3 integrated product platforms

Table K.2

PURPOSE Turn slurry from an environmental liability into a measurable nutrient resource - with solutions that work in normal farm and contractor operations.

Table K.3

Layer	BioCover solution	Strategic role
Storage	SyreN Changes	Reduce methane formation during warm-period storage through controlled, low-dose treatment.
Application	SyreN / SyreN Light	Reduce ammonia loss at the moment slurry is spread and retain nitrogen as ammonium.
Data & decision	e-missioN	Document application, estimate ammonia loss and NPA, and support variable-rate mineral-N adjustment.

Table K.4

DOCUMENTED EFFECT The VERA verification reported an average 49% ammonia reduction for cattle slurry and 37% for pig slurry in the verified test series. Actual performance depends on slurry, target pH, acid dose, weather and application conditions.

Table K.6

EFFECT UNDER EVALUATION BioCover's project material indicates a Danish national mitigation potential of roughly 0.8-1.05 million tonnes CO_2e per year if 35 million m^3 were treated in the warm period. This is a scaled technical potential, not a guaranteed farm result; current Arla and public pilots are intended to verify performance under operating conditions.

Table K.7

170 SyreN systems produced	35 e-missioN installations*	8 German demo machines	2023-27 Säure+ programme

Table K.8

Programme	Geography	Period / scale	Purpose
Arla methane pilots	Sweden, Denmark, England	Ongoing pilots	Validate SyreN Changes and farm-scale methane/CO_2e documentation across different dairy systems.
Jordbruksverket project	Sweden	Ongoing	Swedish pilot and development work for storage treatment and methane inhibition.
MuD Säure+ im Feld	Germany	2023-2027; 8 machines in 8 federal states	Demonstrate in-field acidification under regional farming

Programme	Geography	Period / scale	Purpose
			conditions and build practical implementation evidence.
BMEL preparation	Germany	Linked to MuD programme	Support the evidence, operating framework and market preparation needed for wider German introduction.

Table K.9

Framework	Status	What it establishes	Practical relevance
VERA	Verified	Field testing of SyreN with cattle and pig slurry, including ammonia reduction and operational performance.	Core third-party evidence for the environmental effect of in-field acidification.
DANETV / ETV	Verified statement and test documentation	Independent verification process and reporting for the SyreN slurry application system.	Adds verification traceability and supports technology assessment across jurisdictions.
EU BAT	BAT status referenced since 2017	Recognition of slurry acidification within EU best-available-techniques work for intensive livestock production.	Supports regulatory relevance; it is not a product-specific sales authorisation by itself.

Table K.10

RESPONSIBLE CLAIM Verification supports approval of the verified technology and operating envelope. It should not be presented as proof that every product configuration, dose or field situation delivers the same fixed percentage reduction.

Table K.11

Year	Award / recognition
2008	Agromek Award
2010	Agromek Award
2012	Danish Ministry of the Environment CSR Award
2012	Baltic Manure Handling Award
2013	European CSR Award - Environment
2018	Scale-Up Denmark finalist
2019	Solar Impulse Efficient Solution - SyreN

Year	Award / recognition
2020	Solar Impulse Efficient Solution - SyreN Changes
2020	Energy Globe Award - national winner
2021	Energy Globe International Award
2021	Solar Impulse Efficient Solution - e-missioN
2022	Agromek Award - BioCover Data / e-missioN
2025	RVM Hardenberg recognition

Table K.12

Publication	Published title	Portfolio area
EP2272315B1	A system and apparatus for reducing emission from slurry	SyreN core process and apparatus
EP2272316B1	A mobile system and apparatus for reducing emission and smell from slurry	Mobile SyreN system
EP2514294B1	Improved slurry distribution system	Distribution and application
DK201300076U4 / DE202013004346U1	Intermediate Bulk Container for Hazardous Liquids	Acid-container safety architecture
EP3620439A1	A gas emission reducing system and method for reducing greenhouse gases and/or ammonia emissions from slurry stored in one or more slurry storage tanks	SyreN Changes / storage emissions
EP4005362A1	A nitrogen loss-monitor for a slurry tanker	e-missioN / nitrogen-loss monitoring

Table K.13

BIOCOVER IN ONE SENTENCE A Danish environmental-technology company with a verified field-acidification platform, a digital nitrogen-documentation layer and an emerging methane-reduction solution for slurry storage.

Consolidated source register

This report consolidates the following BioCover ministerial and technical documents. Where figures differ because they use different denominators or scenarios, the main report states the denominator and preserves the relevant qualification.

- Proposed Dutch interim emission factor — Proposed_Dutch_emission_factor_for_SyreN_based_on_two_TAN_trials.docx
- Translation of German and VERA results into percentage of TAN — Translation_of_emission_percent_to_Dutch_percent_of_TAN.docx
- Comparative German, Danish and Dutch trial summary — Comparative_summary_German_Danish_Dutch_SyreN_trials.docx
- Scientific validity of the Thünen acidification trials — Scientific_validity_of_Thuenen_acidification_trials.docx
- Technology comparison: injection versus in-field acidification — Technology_comparison_injection_vs_in_field_acidification.docx
- e-missioN and doelsturing technical and business dossier — e-missioN_and_Doelsturing.docx
- Economic case for national SyreN implementation — Economic_case_for_national_SyreN_implementation_in_the_Netherlands.docx
- SyreN contribution to the Dutch nitrogen target — SyreN_contribution_to_the_Dutch_nitrogen_target.docx
- CDM protocol for assessment of low-emission application techniques — CDM_Protocol_Assessment_of_Low_Emission_Manure_Application_Techniques.docx
- Yield evidence: injection versus acidification — Yield_comparison_injection_vs_acidification.docx
- Yield evidence: untreated trailing hose/shoe versus acidification — Yield_comparison_trailing_hose_shoe_vs_acidification.docx
- Facts about BioCover and the SyreN System — Facts_about_BioCover_and_the_SyreN_System.docx

VERA Verification Statement 001 and DANETV verification report/statement for the SyreN slurry application system.

CDM, Beoordeling nieuwe techniek mesttoediening, and the extracted CDM assessment protocol.

GülleBest project brief and Thünen-related German trial material.

MuD Säure+ im Feld results after three growing seasons.

International review of 27 in-field acidification studies, 2010-2024.

RIVM national emissions inventory and OPS/AERIUS modelling framework, as cited in the underlying policy documents.

BioCover source presentations for the Dutch Minister, SyreN Light, Arla FarmAhead, product history, awards and patents.

USE OF THE REPORT

The document is a consolidated policy and technical submission. Patent status, statutory emission factors, public budgets and programme payment terms should be checked against the relevant official register or scheme before contractual or legal reliance.