Farm Nitrogen Management for a Circular Economy and Cleaner Environment

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Centre for Ecology & Hydrology

Scotland's Biennial Land Use and the Environment Conference XII

Theme 1: What type of environmental public goods should be prioritised for delivery by land managers in the future?

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28th November, 2018

Overview

1. Nitrogen sources & trends
2. Impacts on Environmental Public Goods
3. Key legislation drivers
4. Farm Nitrogen Management & Mitigation Measures
5. Going forwards

Nitrogen sources

NO, NO_2: NOx (nitrogen oxides)

Transport

Gas powered generator

Ammonia NH_3 sources

NH_3 (ammonia)

UK Animal Stats (2015)

27 million layers

110 million broilers

420k sows

3 million fatteners

5.5 million cattle

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Ammonia emission sources

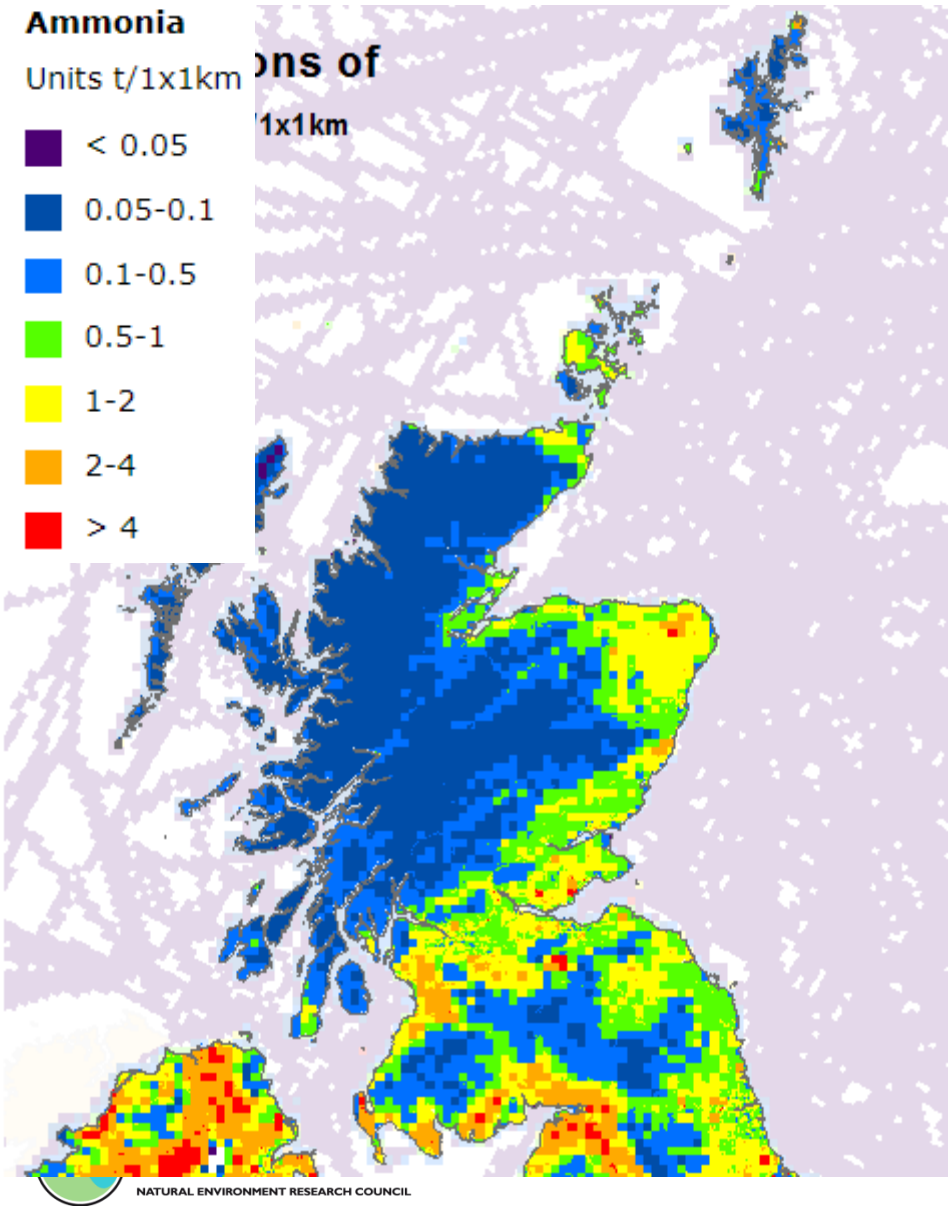
housing

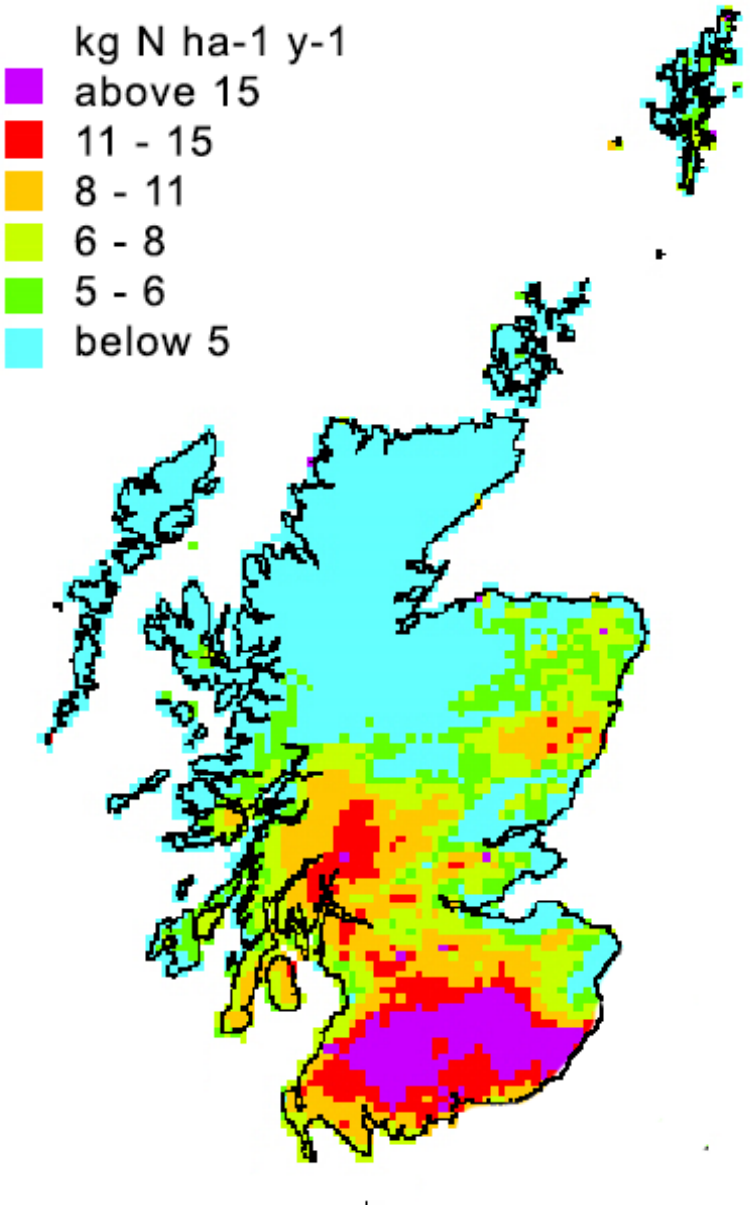
storage

fertilizer application

spreading

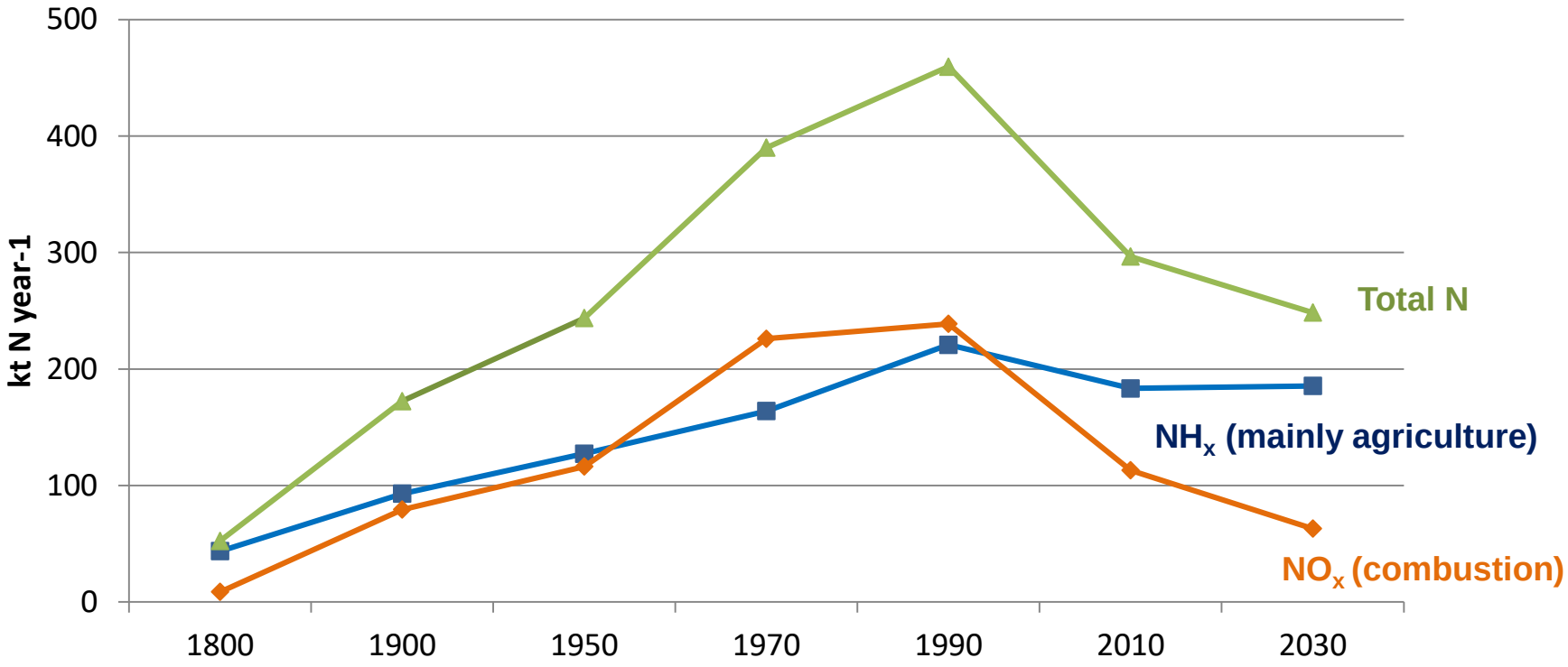
Ammonia Emissions vs N deposition





http://naei.beis.gov.uk/data/map-uk-das?pollutant_id=21&emiss_maps_submit=naei-20181126225141

Nitrogen deposition trends 1800-2030



- **N emissions –** large increase 1800-1990
- **Oxidised N (NO_x) -** emissions reductions from ~1990 mainly due to international legislation (e.g. combustion/catalytic converters)
- **Reduced N (NH_x) –** now largest source of N deposition, largely unchanged & predicted to remain stable.

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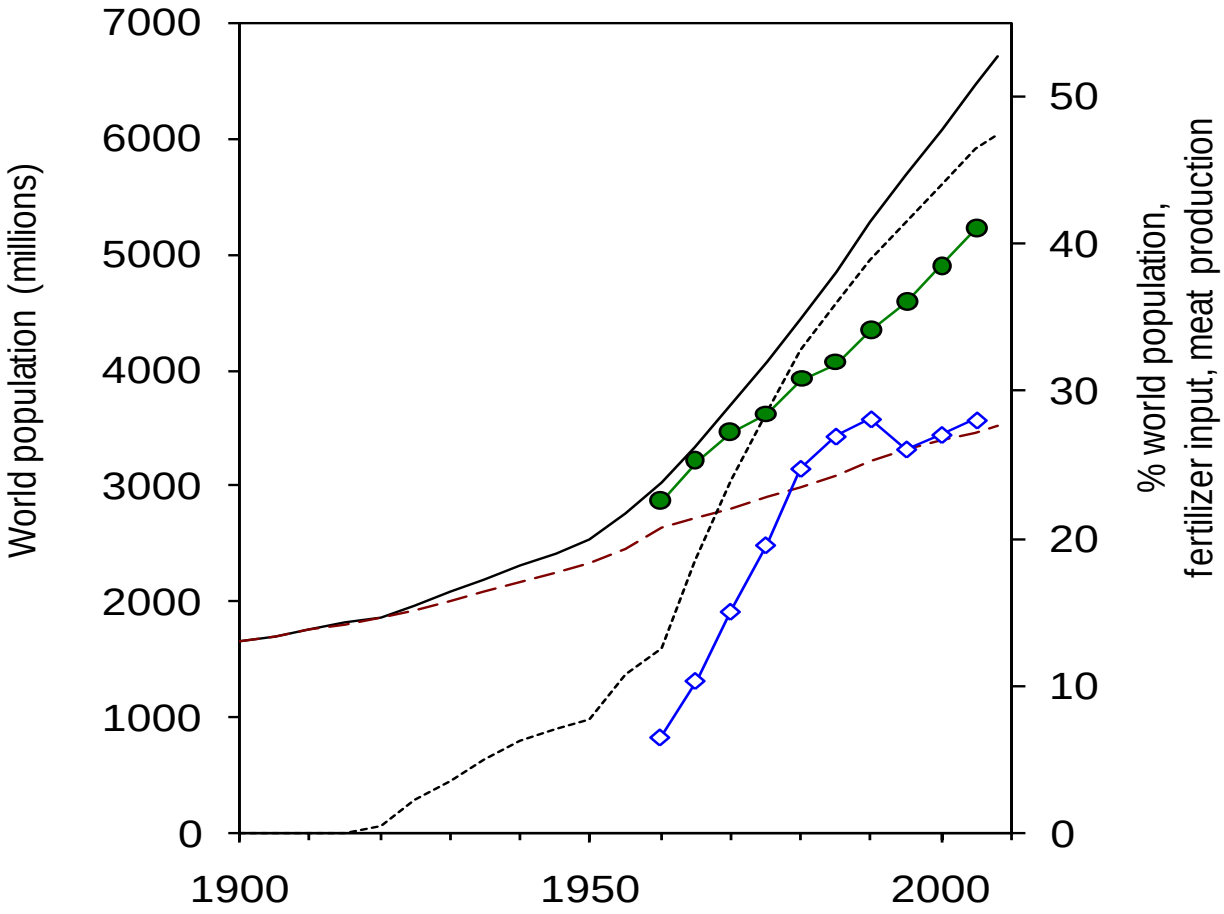
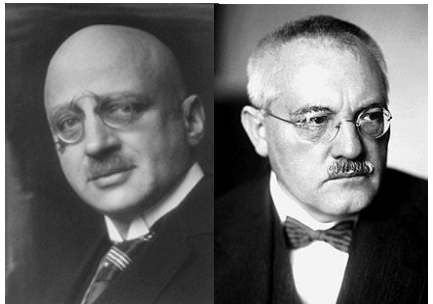
NERC MacroNutrients Programme: CEH Edinburgh contribution to Long-term Large Scale (LTLS) project

Haber-Bosch process



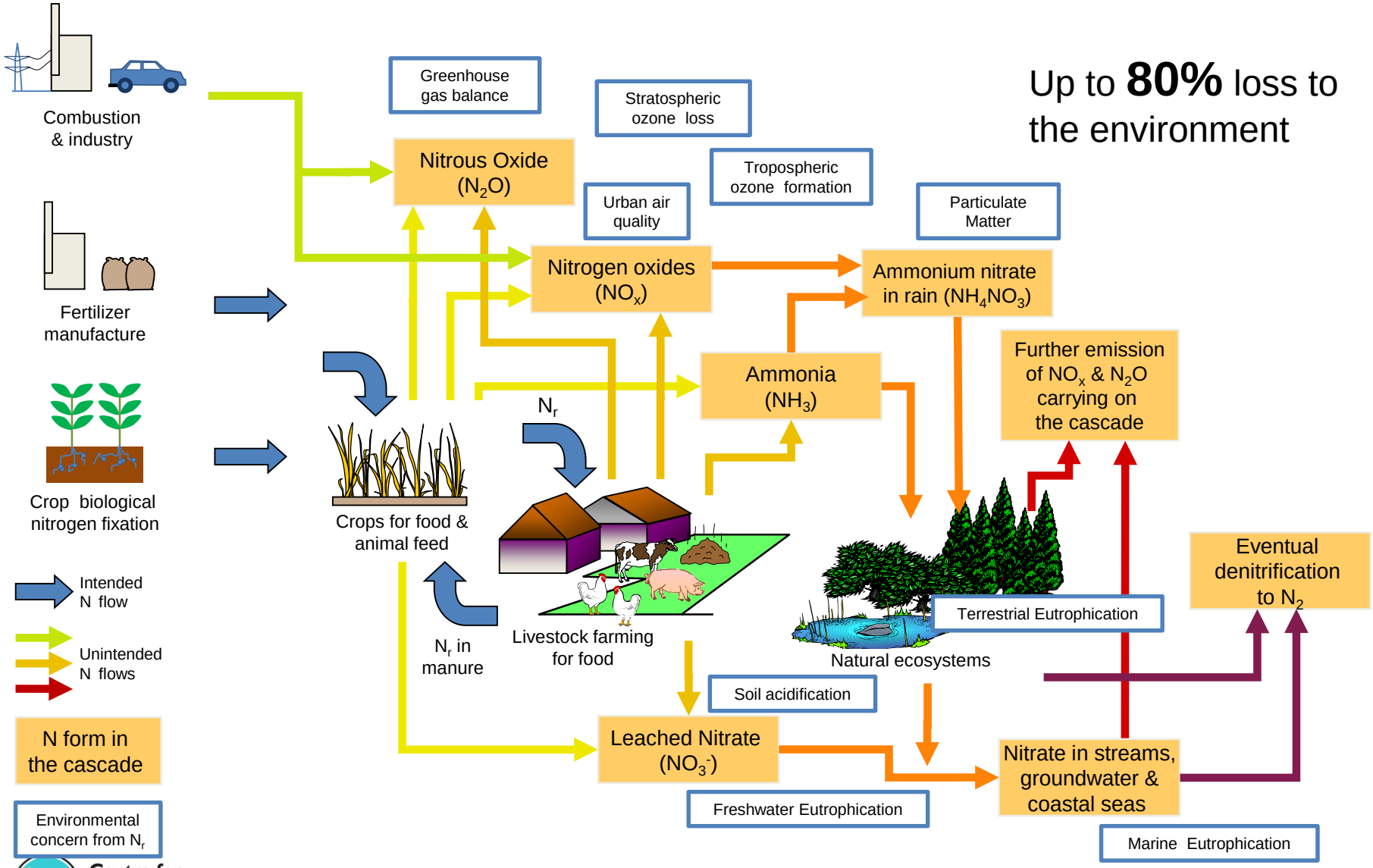


$N_2 + H_2 = NH_3$

Frizt Haber (l) & Carl Bosch (r)

Erisman et al. 2008 Nature GeoScience

Nitrogen Cascade



Up to **80%** loss to the environment

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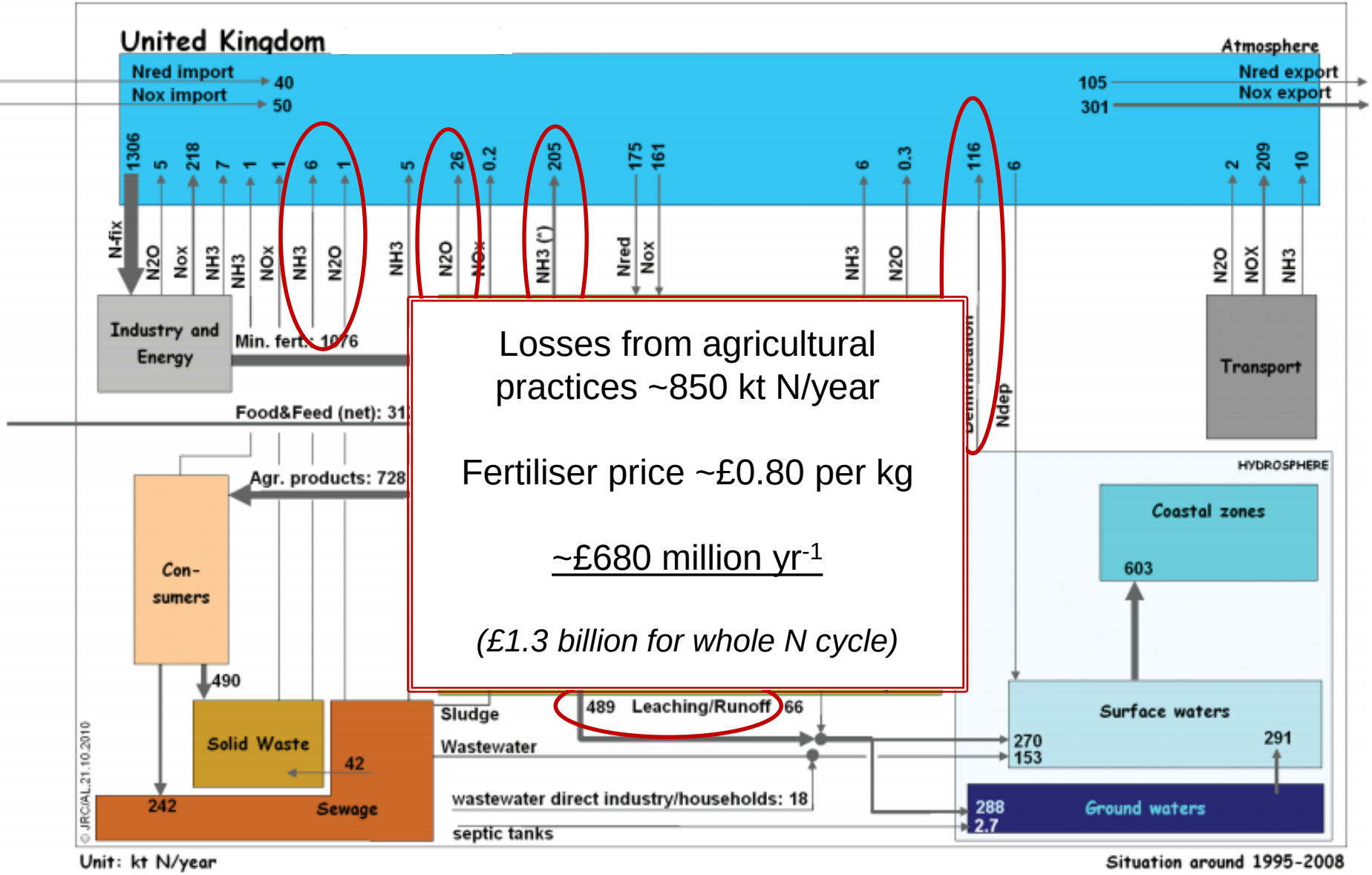
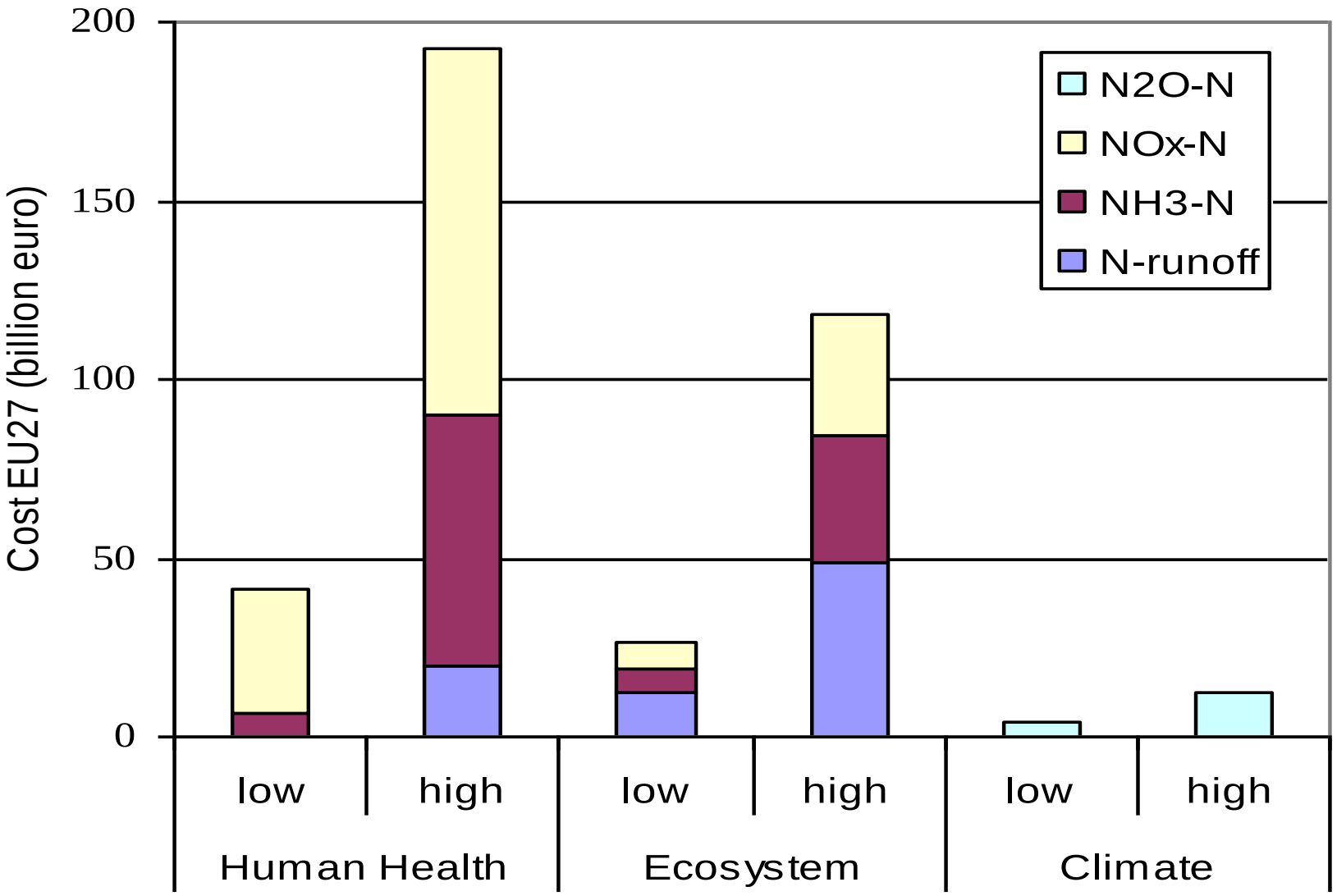
Galloway et al, 2003

UK integrated nitrogen budget



European Nitrogen Assessment (2011)

Social damage of nitrogen pollution in EU27 in 2000



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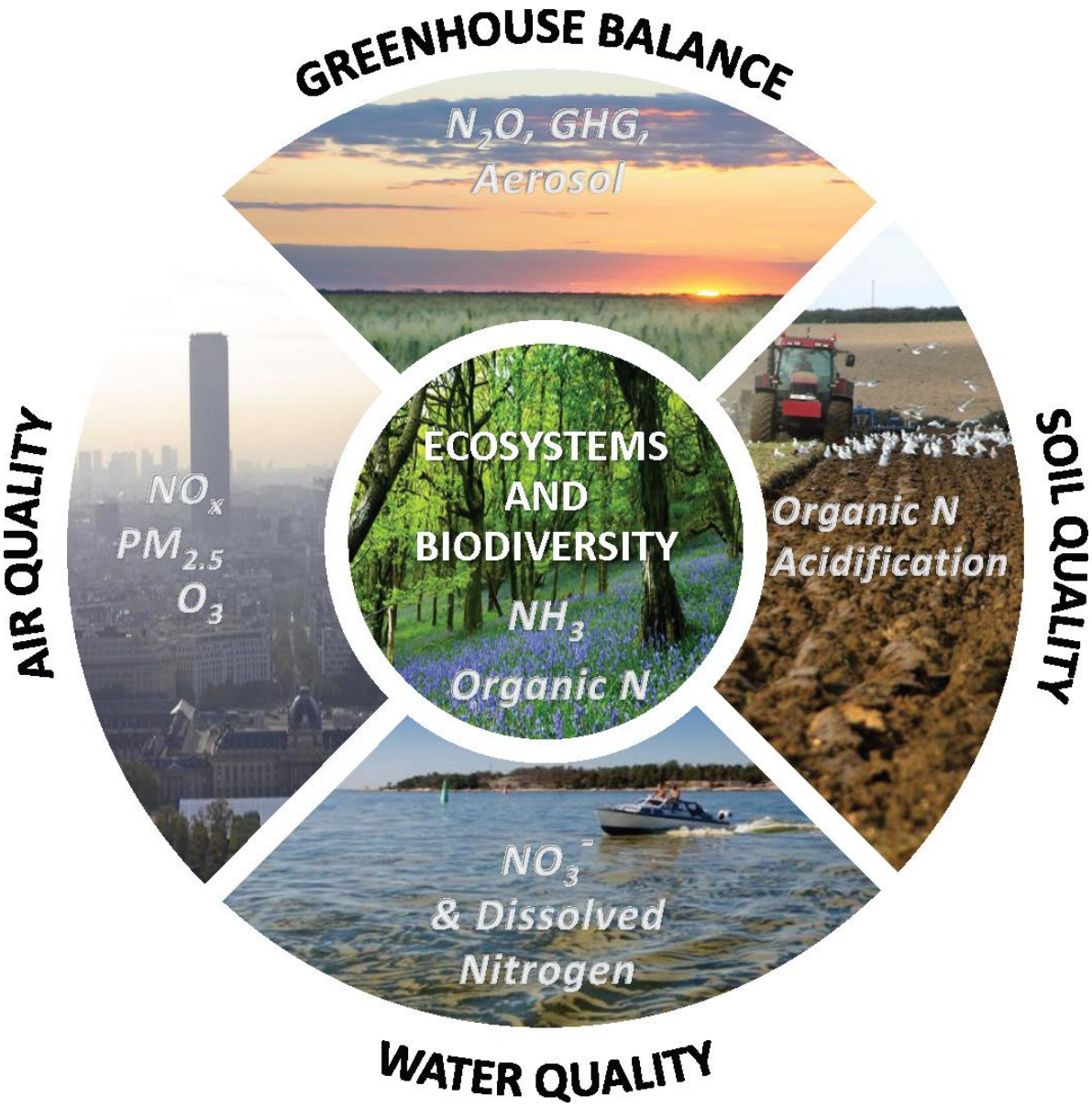
European Nitrogen Assessment (2011)

The five key threats of excess Nitrogen

The WAGES of too much nitrogen

Water quality
Air quality
Greenhouse balance
Ecosystems
Soil quality



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European Nitrogen Assessment (2011)

Environmental Impacts

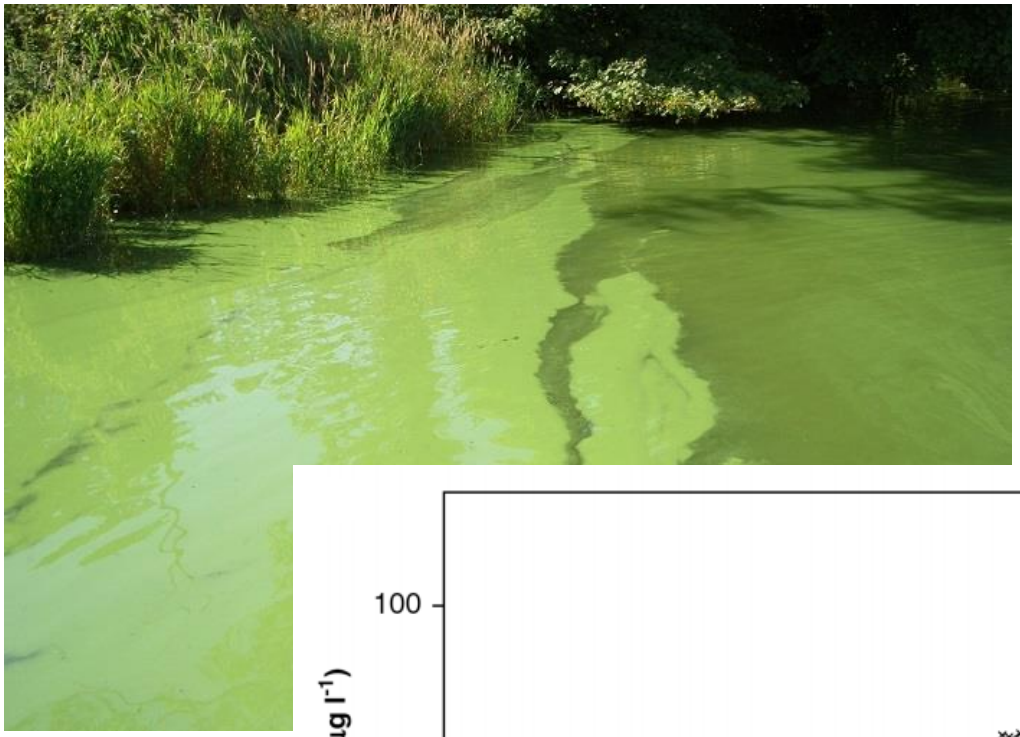
Freshwater & Marine

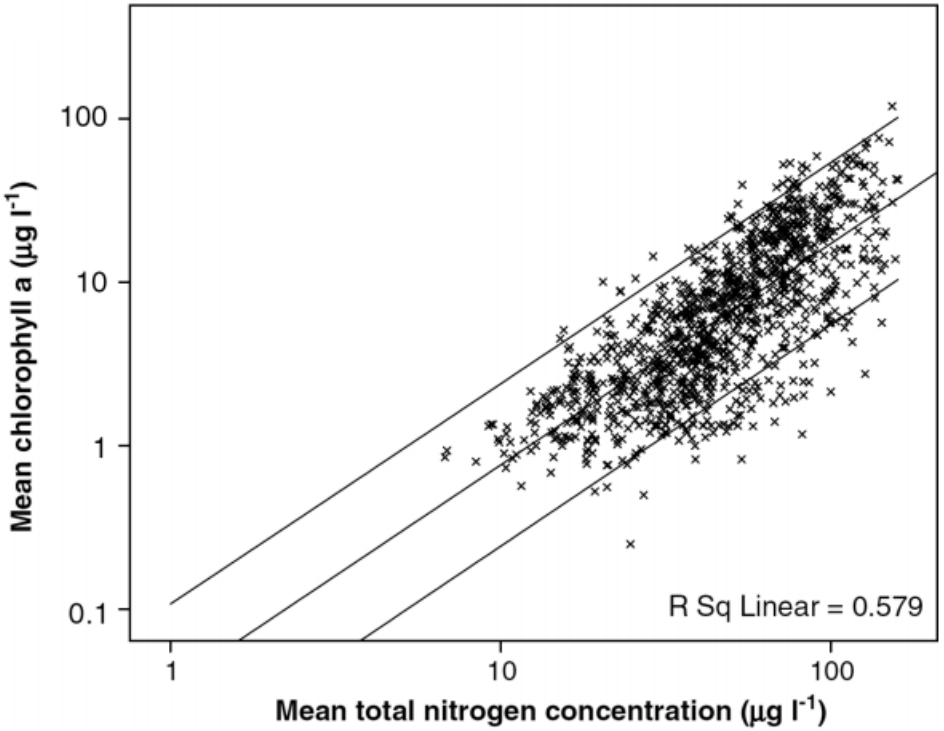
- excessive plant growth and decay, favouring simple algae and plankton over more complicated plants
- reduction in ground water quality
- harmful algal blooms (shellfish toxicity)
- low dissolved oxygen levels (hypoxia)

Terrestrial

- species composition changes (mosses & lichens most sensitive).
- reduced biodiversity
- soil acidification

Water Quality - Agricultural run off and nitrates





Relationship between growing season chlorophyll *a* in phytoplankton (algae) and total N concentrations in over 1000 European lakes (Phillips et al ., 2008).

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Freshwater – Drinking Water

Nitrate in drinking water increases the risk of colorectal cancer

A new study from Aarhus University now shows that there is an increased risk of colon and rectal cancer in connection with nitrate in drinking water. Also at concentrations far below the current drinking water standard. The highest nitrate concentrations are mainly seen in small private water supplies.

2018.02.13 | METTE LOUISE OHANA

The drinking water standard for nitrate in drinking water in Denmark is determined based on recommendations issued by the WHO. The research suggests that the drinking water standard should be reconsidered. Photo: Colourbox

Nitrate in groundwater and drinking water, which primarily comes from fertilisers used in the agricultural production, has not only been subject to decades of environmental awareness – it has also been suspected of increasing the risk of cancer. The largest epidemiological study ever carried out in this area now shows that there is a correlation – also when the amount of nitrate in the drinking water is far below the current drinking water standard. The results have just been published in the scientific journal *International Journal of Cancer*.

Risk of cancer even with small amounts of nitrate

The researchers have calculated how much nitrate Danes have been exposed to where they lived and compared this to information about cancer diagnoses in Denmark. Researchers have managed to follow a total of 2.7 million Danes during the period 1978-2011 and the study is based on nitrate analyses from more than 200,000 drinking water samples, making the study the largest and most detailed in this area.

"Each year, approximately 5,000 Danes contract colorectal cancer, which can have many causes. Our study shows that nitrate in drinking water may be one of them. In the study, people who were exposed to the highest concentration of nitrate in drinking water (above 9.3 mg per litre of water) had a 15 per cent greater risk of getting colorectal cancer compared to those who had least exposure (less than 1.3 mg per litre of water). The current drinking water standard is 50 mg nitrate per litre of water, but the increased risk of cancer could already be seen at concentrations greater than approximately 4 mg nitrate per litre of water," says Jörg Schullehner, PhD from the Department of Public Health at Aarhus University. He is the man behind the research results together with researchers from the Geological Survey of Denmark and Greenland (GEUS) and the National Centre for Register-based Research at Aarhus University.

"In the study, people who were exposed to the highest concentration of nitrate in drinking water (above 9.3 mg per litre of water) had a 15 per cent greater risk of getting colorectal cancer compared to those who had least exposure (less than 1.3 mg per litre of water)…"

↓50 mg/l.

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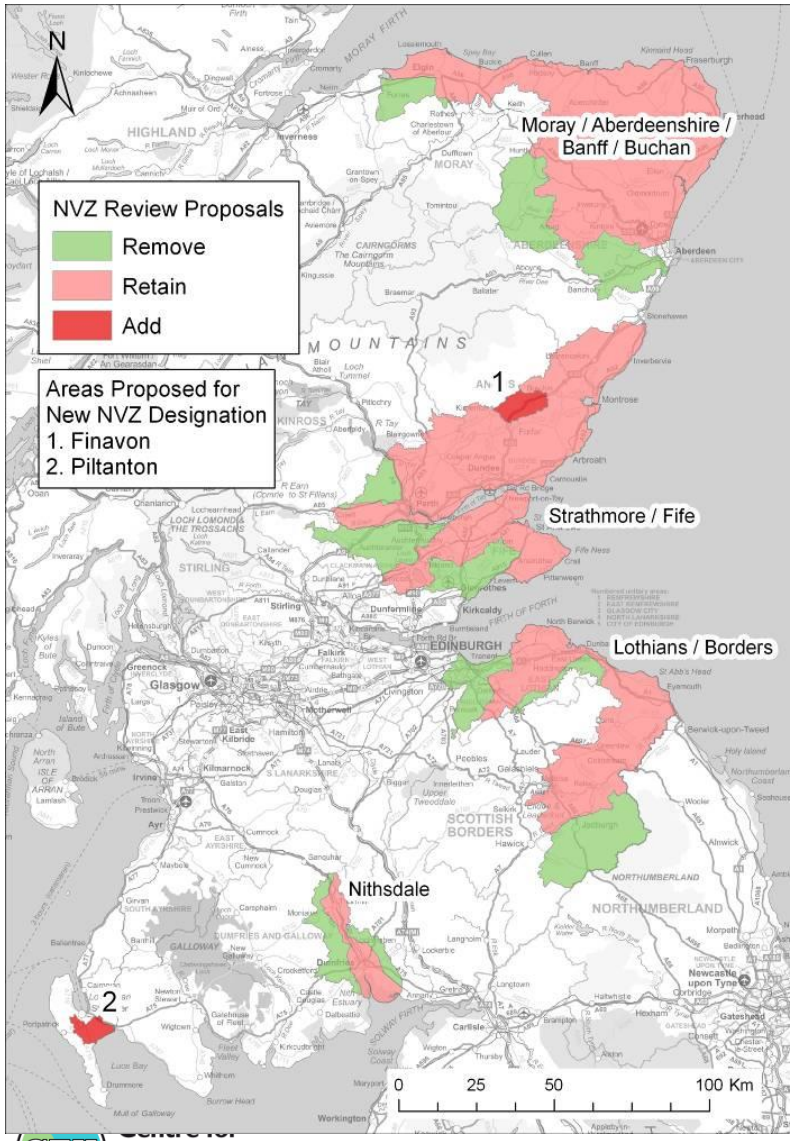
http://newsroom.au.dk/en/news/show/artikel/nitrat-i-drikkevand-oeger-risikoen-for-tarmkraeft/

Nitrate Vulnerable Zones



- closed period for the spreading slurry on soils (other than sandy and shallow soils)
- limits for organic manure is 250 kg N/ha in any 12 month period
- provisions about the placement of field heaps (farmyard manure)

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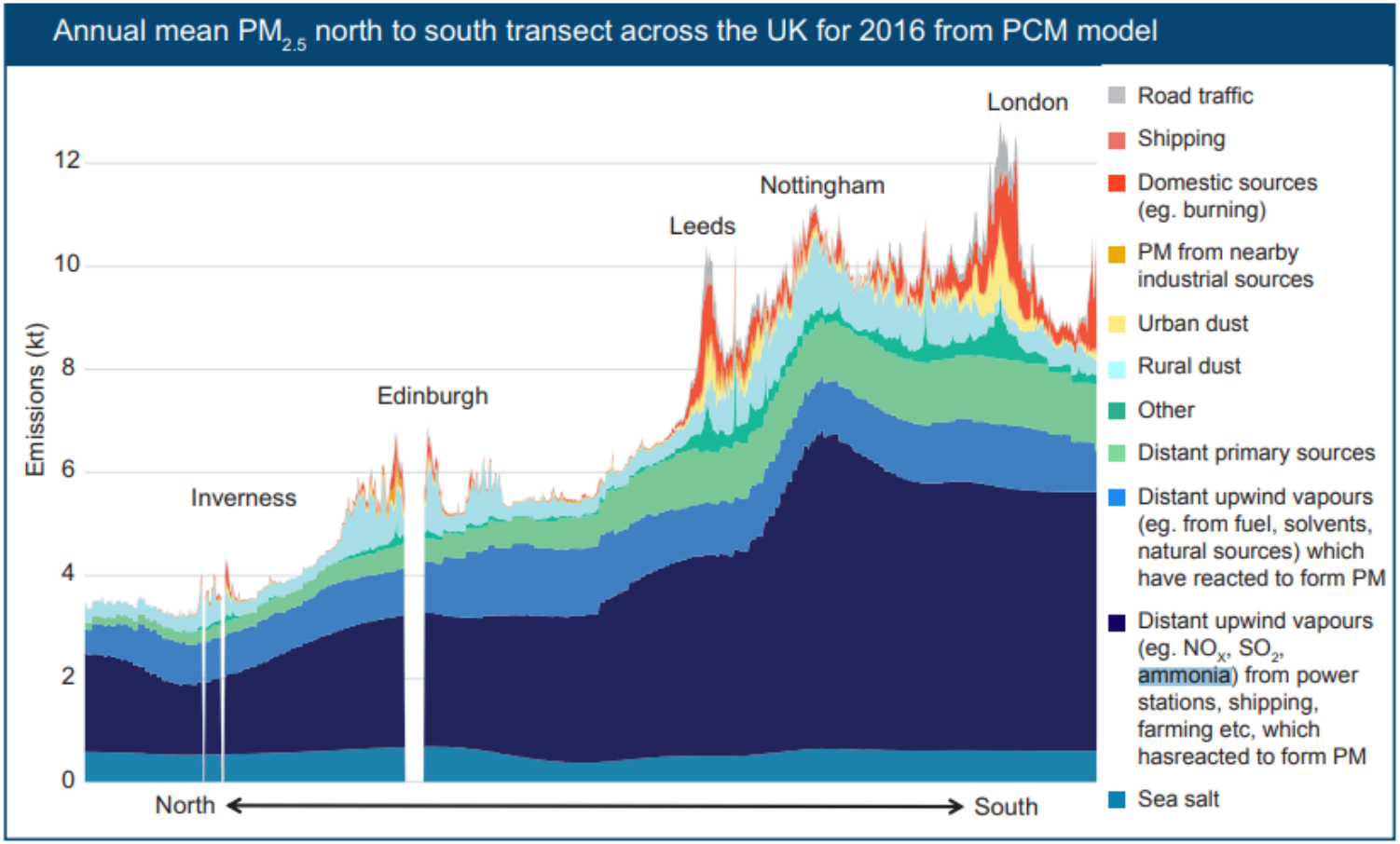
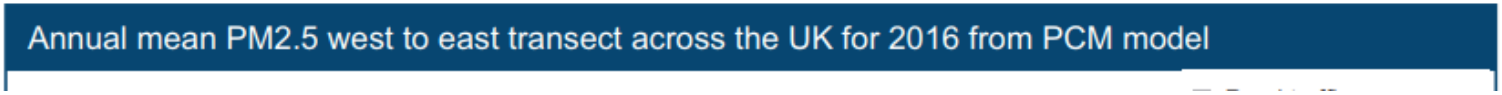
https://www.sepaview.com/2014/11/nitrate-vulnerable-zones-a-new-methodology

Air Quality – formation of $PM_{2.5}$

Ammonia reacts with other pollutants in the atmosphere to produce ammonium sulphate and nitrate. These secondary aerosols make up a large proportion of the total mass of $PM_{2.5}$ in the UK

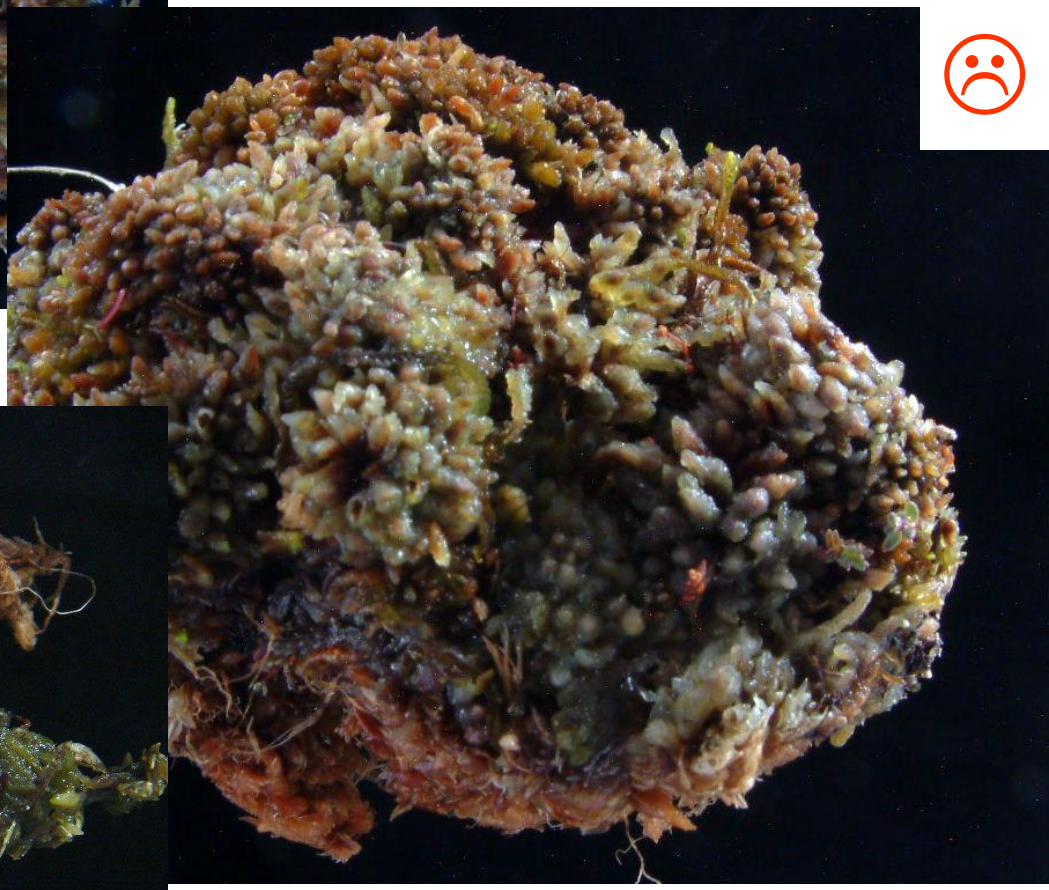


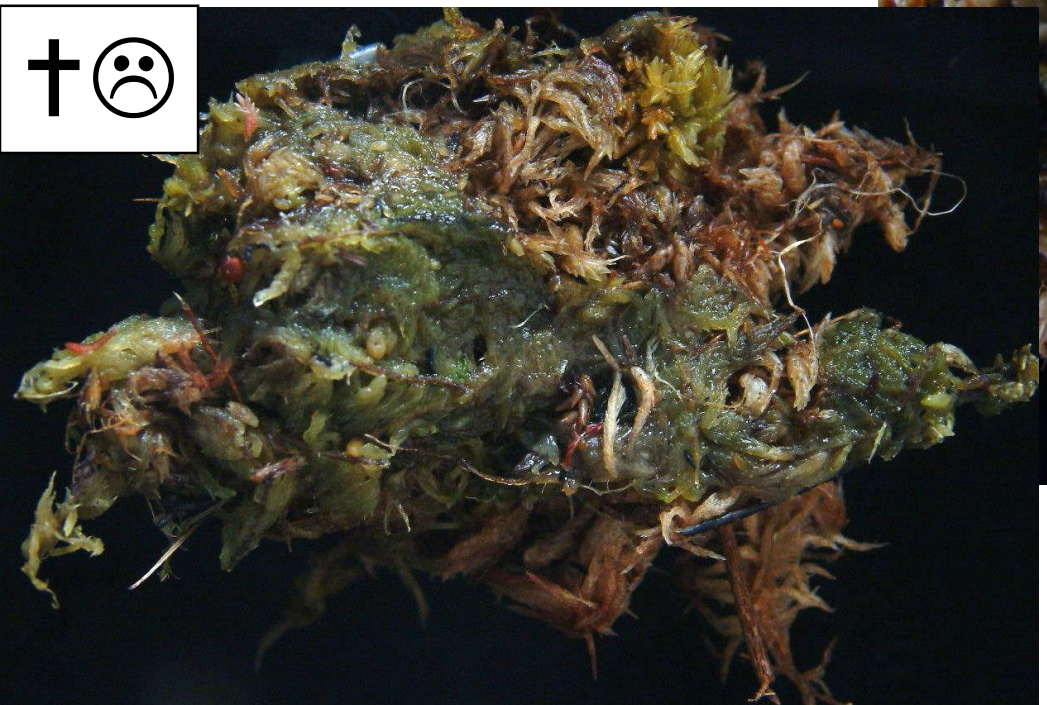


https://consult.defra.gov.uk/environmental-quality/clean-air-strategy-consultation/

Bog moss

Sphagnum imbricatum





Nitrogen Deposition and Plant Community Change

Map of acid grasslands surveyed in the Atlantic

Plant species richness (mean number of species in five 2 by 2 m quadrats per site) against total inorganic N deposition for each of the countries surveyed

Species richness (mean no. of species for five 2x2 m quadrats)

$y = 24.39e^{-0.0244x}$

$R^2 = 0.40$

Total inorganic N deposition (kg N ha^{-1} yr^{-1})

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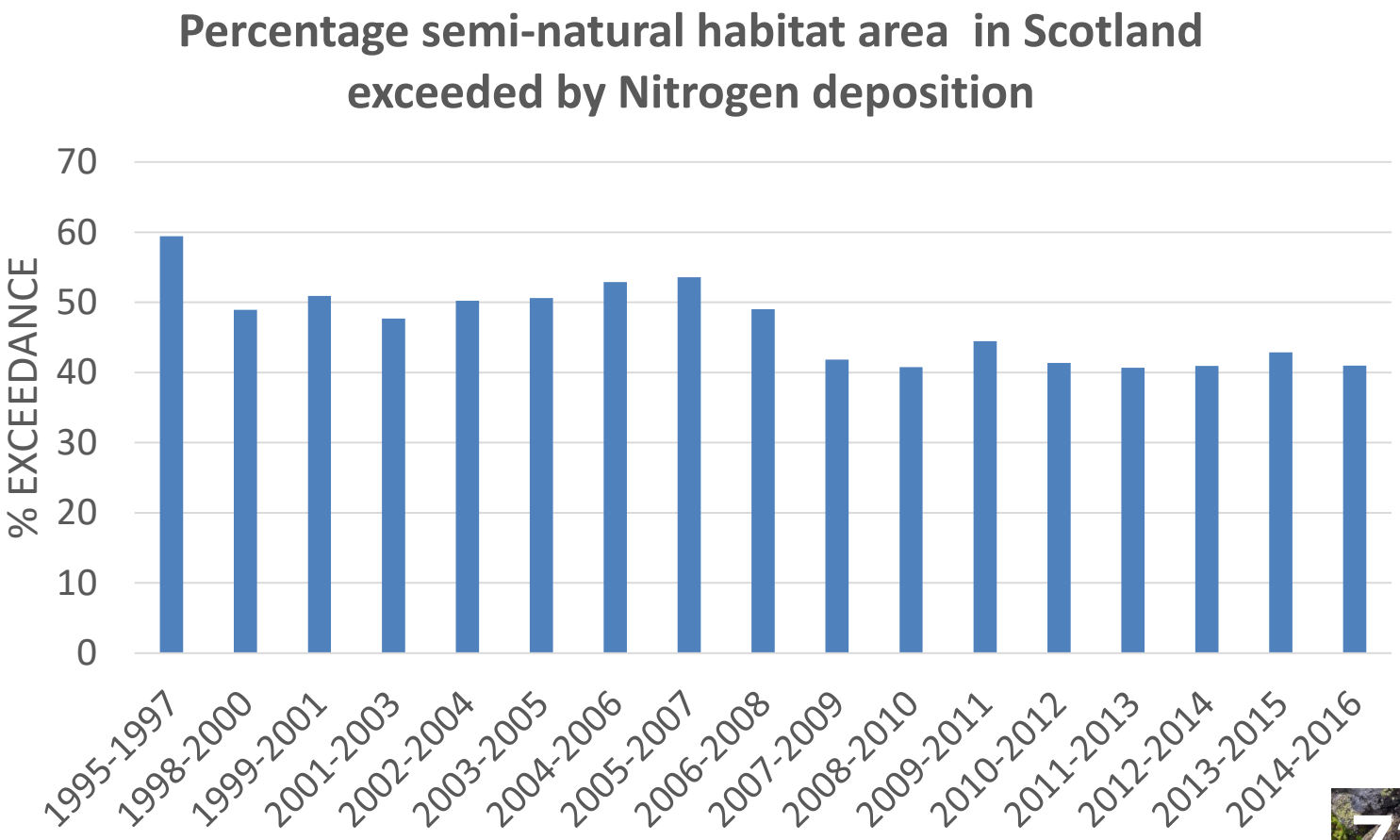
Stevens et al., 2010 Environmental Pollution. 158, 9, p. 2940-2945

Critical load exceedance nutrient nitrogen - Scotland



Total area 43,200 km^2 ● 13 semi-natural habitat classifications

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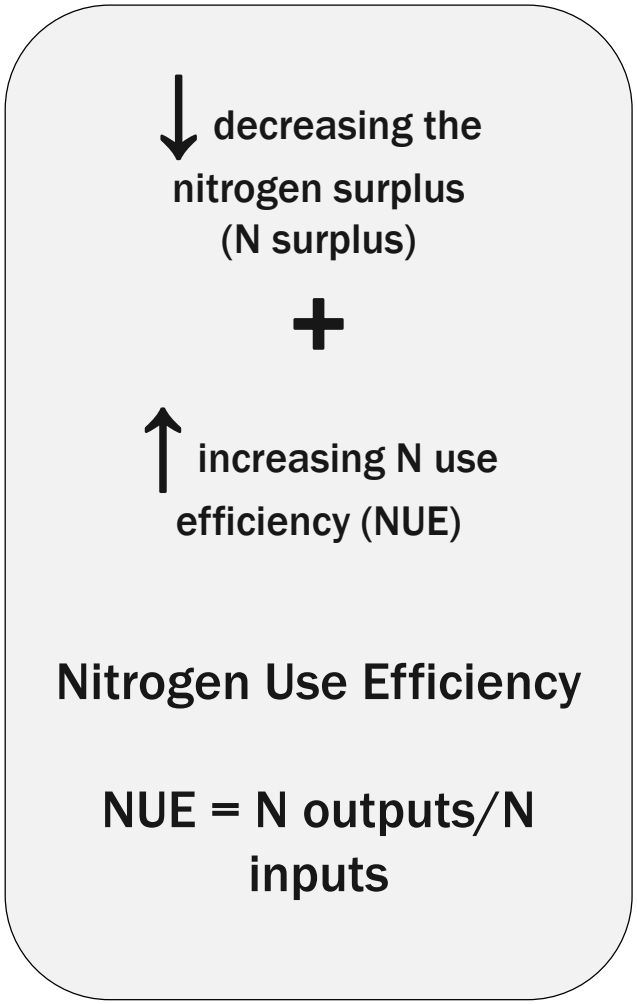
Key legislation drivers for nitrogen

- UNECE Air Convention: to Abate Acidification, Eutrophication and Ground-level Ozone.
- Industrial Emissions Directive – regulation of pig & poultry
- Nitrates Directive – NVZs
- Habitats Directive – protection of Natura 2000 network
- National Emissions Ceiling Directive
- Cross-compliance - requirements & standards to receive support scheme payments

Farm Nitrogen Management

It involves implementing an iterative set of common management activities:

- analysis – N sources, various N demands by crops. Soil testing to help better plan nutrient applications.
- decision making - assessing impacts and selecting the best option that achieves both agronomic and environmental targets
- planning of the actual plan to allocate available nutrients and working out the when and where and the how and how much
- execution in putting the management plan into practice
- monitoring and control of the input-output balance sheet, by collecting data on yield and N contents; calculating N surplus and NUE.



Mitigation - Housing floor systems

Cattle shed and grooved slurry scrapers

Partly slatted floors covering 50% of floor, especially if the slats are metal or plastic-coated. It is also animal-friendly and anti-slip.

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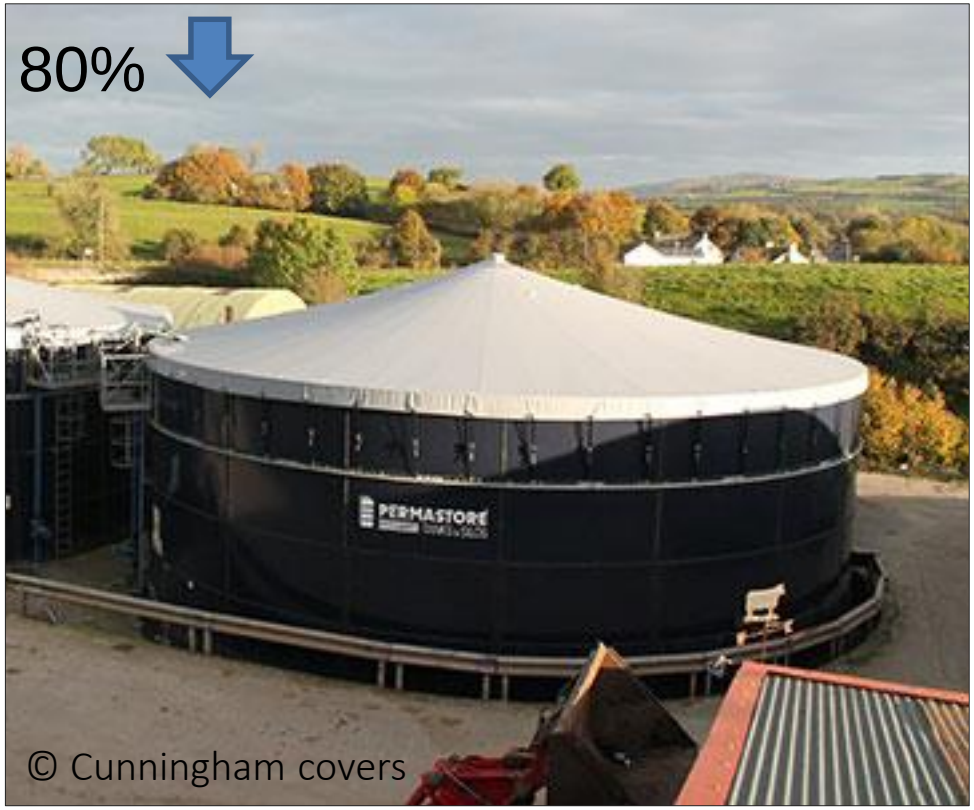
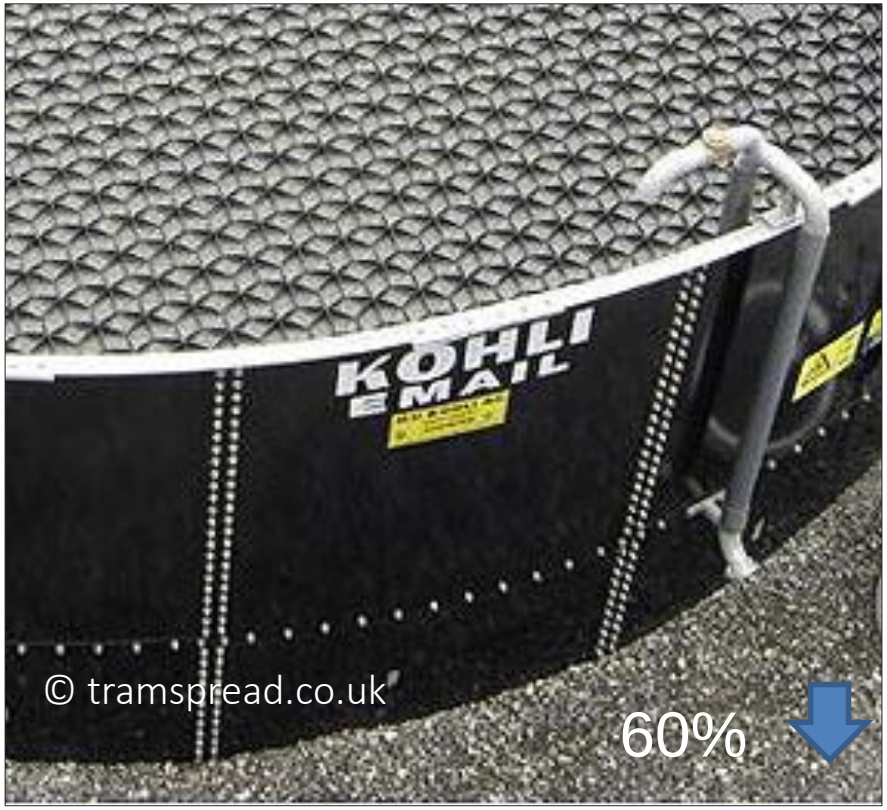
Storage systems



Tight lid cover is the best proven and most practicable method to reduce emissions from slurry stored in tanks or silos. Can be retro-fitted.



Hexa floating Cover

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Low-protein animal feed

5%– 15% ↓

Low-protein animal feeding also decreases N_2O emissions, and increases the efficiency of N use in animal production. Moreover, there are no animal health and animal welfare implications as long as the requirements for all amino acids are met.

Low-protein animal feeding is one of the most cost-effective and strategic ways of reducing NH_3 emissions. For each per cent (absolute value) decrease in protein content of the animal feed, NH_3 emissions from animal housing, manure storage and the application of animal manure to land are decreased by 5%– 15%,

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http://www.clrtap-tfrn.org/sites/clrtap-tfrn.org/files/documents/AGD_final_file.pdf

Inhibitors while spreading fertilizers

- **Urease inhibitors** - delays the conversion of **urea fertilizer** to ammonium carbonate by directly inhibiting the action of the enzyme urease. This delayed/slower hydrolysis is associated with a much smaller increase in pH around the urea granules and, consequently, a **significantly lower NH_3** emission. >30% ↓
- **Polymer coated urea granules -** provide a slow-release fertilizer that may reduce NH_3 emissions >30% ↓
- **Switching from urea to ammonium nitrate fertilizer -** is a rather easy way to reduce NH_3 emissions, with an effectiveness of around 90%. A possible negative side effect is the potential increase in N_2O, especially when the ammonium-nitrate (NH_4NO_3) based fertilizers are applied to moist or wet soils. up to 90% ↓
- **ATMS** (Application Timing Management Systems)- exploits the variation in NH3 emission potential based on environmental conditions, so as to use management of application timing to reduce overall emissions. Apply under cooler conditions and prior to rainfall (although bearing in mind the need to avoid the associated risk of run-off to water bodies) are associated with lower NH_3 emissions. ?% ↓

Spreading (reference system): splash plate

Reference system - splash plate

7. Spreading systems: trailing shoe

Trailing shoe enables plants to absorb nutrients from slurry faster and reduces leaf contamination.

6. Spreading systems: disc injection

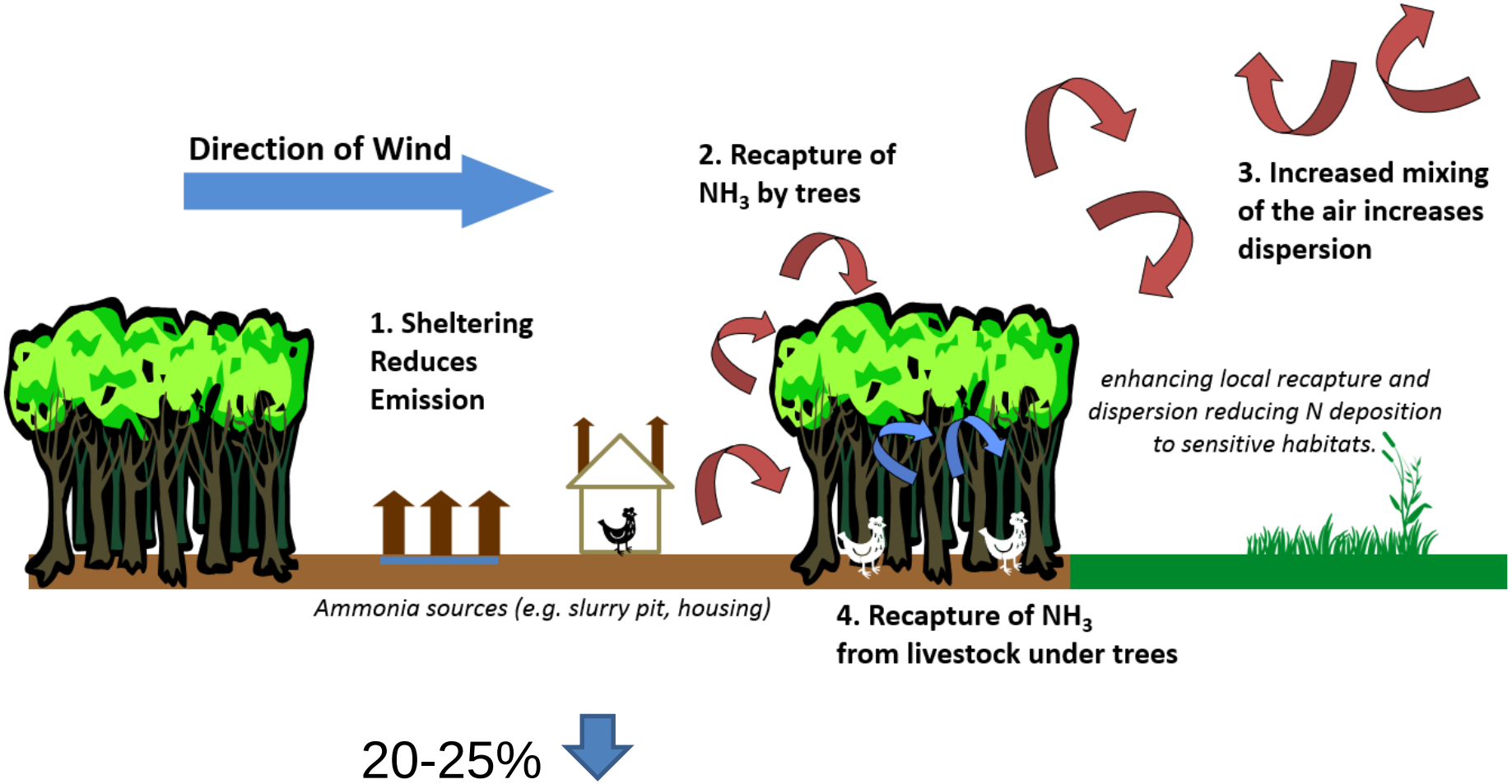
Disc injector

7. Spreading systems: Acidified slurry

The equilibrium between ammonium-N and NH3 in solutions depends on the pH (acidity). High pH favours loss of NH3; low pH favours retention of ammonium-N. Lowering the pH of slurries to a stable level of 6 and less is commonly sufficient to reduce NH_3 emission by 50 per cent or more. The technique of adding sulphuric acid to slurry is now practiced in Denmark, with considerable success.

Farm woodlands for reducing ammonia

Increased grazing and woodland effect



20-25%

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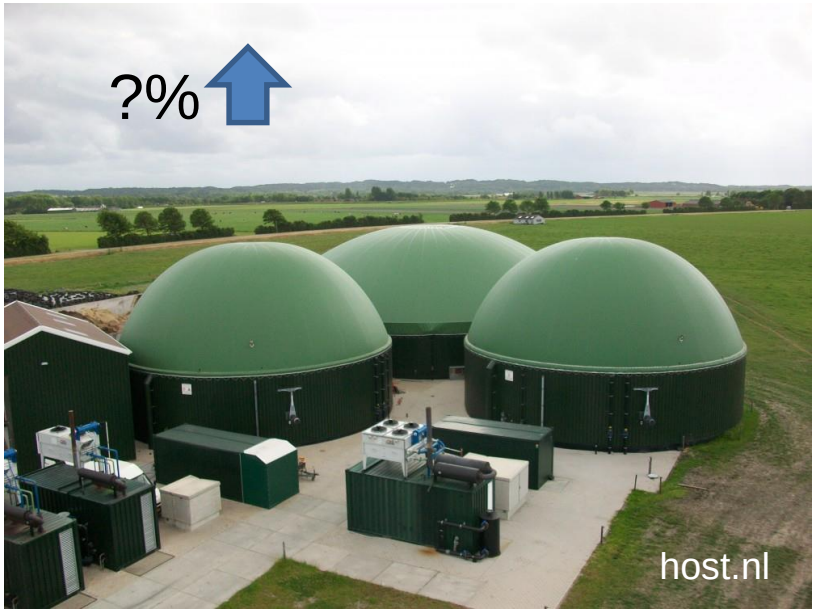
Anaerobic Digestion - Circular Economy

- Biogas can be used directly in engines for Combined Heat and Power
- Digestate as a nitrogen rich fertiliser
- Increasing the ammonium content of the digestate
- Competing factors
  (-) greater available N for NH_3 loss
  (-) higher pH encouraging NH_3 loss
  (+) lower total solids encouraging more rapid infiltration
- On balance increases ammonia emissions?



But all is not lost!

We can:

- Disc-injection spreading
- Add an acid to reduce the pH on spreading

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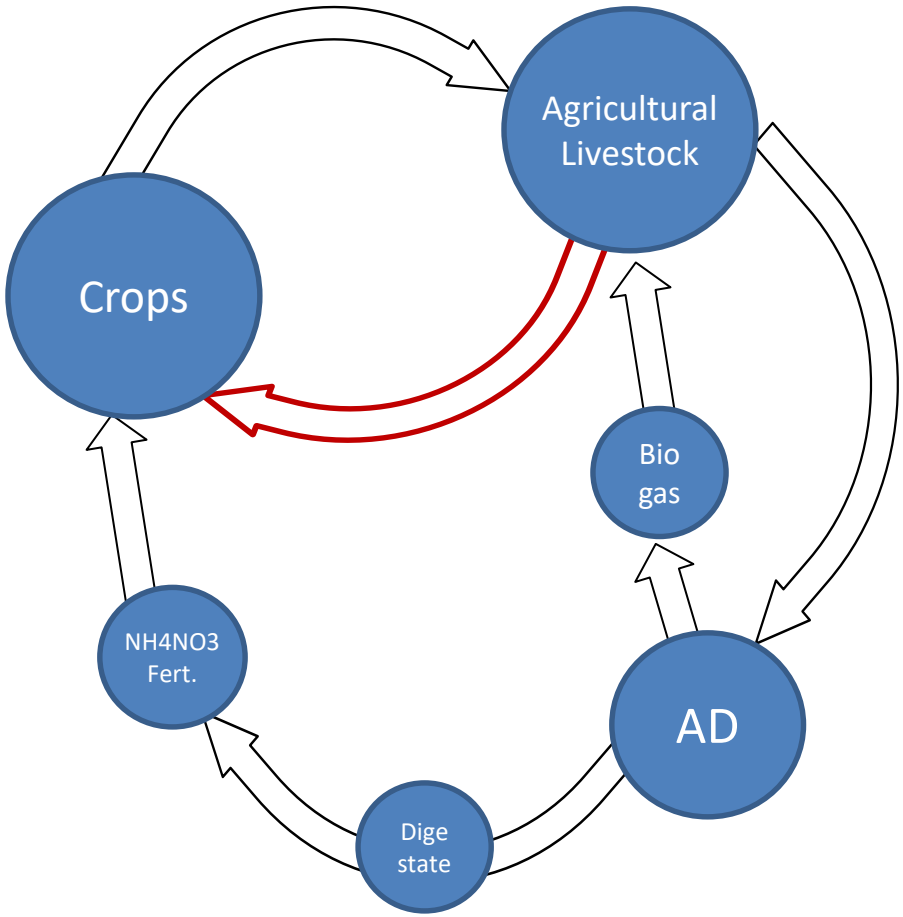
Circular Economy – recycling manures & slurries



Ammonia stripping

- pass high pH digestate liquor over a membrane –>
- Degas the NH_3 ->
- add an acid to create ammonium nitrate or ammonium sulphate fertiliser

• Use it or sell it back to fertiliser company!

Going Forwards

- Nitrogen management plans
- Know your soil nutrient content
- Integrated nitrogen policy

  "Better alignment needs to ensure that regulations and regulators are fully joined up across agriculture"
- Regulation of large dairy farms (>150 animals)
- Raft of mitigation measures - start with injection spreading to gain a 30% reduction across Scotland
  - grants & incentives
- Nitrogen budget for Scotland
- Invest in new technologies for Circular Economy and Recycling of manures/slurries