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dNmark
The solution scenarios

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Solution scenarios

- New production chains with more efficient use and recycling of N
  - This scenario focuses on reducing losses through more efficient crop uptake of N (perennial crops, cover crops), efficient use of N in livestock production, technologies for reducing losses through the production (e.g. within crop and livestock production systems), technologies for capturing and recycling N for fertilisation.
- Geographically differentiated N-measures based on landscape planning and management
  - N flows and emissions have substantially different effects depending on the location of the emissions relative to vulnerable ecosystems, depending on N retention (uptake and reduction) during the low path. Measures here focus on optimising N retention through local planning.
- Changed consumption patterns driving land use change and reducing N use
  - Changes in consumption patterns can involve changes in organic food consumption (e.g. extensive grassland farming), more or less meat consumption (more or less livestock), new demands and productions through bioenergy crops, biorefineries etc. that lead to more perennial cropping for food, feed and bioenergy.

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Selected specific scenarios

- **New production chains with a more efficient use and recycling of N**
  - Biogas
  - Biorefinery
  - New dairy farming
- **Geographically differentiated N-measures**
  - Spatially differentiated regulation
- **Changed consumption patterns driving land use change and reducing N use**
  - Changed demand for global consumption
  - Changed demand for local consumption
  - Expanded organic farming

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New production chains with a more efficient use and recycling of N

Biogas	Biorefinery	New dairy farming
The recycling of manure and other residues through biogas is maximized by combining manure with other energy (and nitrogen sources)	The current import of soya is replaced with protein from Danish grown grass or grass-clover that is processed to protein feed in a biorefinery	New technologies (Best Available Technologies, BAT) in the livestock housing, manure storage and crop rotations are used to maximize N use and reduce emissions.
Biogas of manure, possibly coupled with acidification of the digested manure. Addition of household waste, straw and beet to the manure.	Biorefineries that use grass-clover to produce protein feed for monogastrics (pig, poultry productions) and the remaining product are used for cattle feed. Grass and grass-clover replaces cereals.	Change and use of BAT in the livestock house and manure storage N leaching losses from crops are reduced by changes in crop rotations replacing rotational grass-maize.
From 7 to 70% of manure being treated as biogas. Use of 50% of household waste for biogas. 20% of straw for biogas. 40.000 ha of beet grown for additional biomass.	Cultivation of highly productive fertilized grass or grass-clover at a rate that would allow production of protein feed to substitute current soys import	No rotational grass-land (i.e. permanent grass). Silage maize should have effective catch crops or be replaced by fodder beet
Climate change mitigation, beets increase biodiversity	Climate change mitigation, reduced P surplus	Climate change mitigation

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Changed consumption patterns driving land use change and reducing N use

Changed demand for global consumption	Changed demand for local consumption	Expanded organic farming
Agricultural production is intensified for export with as small an N footprint as possible. Meat and milk production is maximized for export.	Agricultural production is extensified and especially the meat consumption is reduced in size leading to changed land use. All livestock should either be grazing or have access to outdoor areas to maximize animal welfare. Nature areas are grazed at sustainable rates to maximize biodiversity.	Organic agriculture is expanded so that all milk and cattle meat production is organic. The current national milk production is maintained, but converted to organic.
All livestock is kept in house (no grazing except on nature land). Biogas and other BAT are used to maximize N use of manure. Grasslands are used for protein and feed production through biorefining, such that there is no import of protein feed for livestock.	Livestock density is reduced to a level where all cattle graze permanent pastures and cattle for meat production only graze nature areas. All monogastric animals (pigs and poultry) also have access to outdoor areas integrated with perennial cropping (agroforestry).	Conversion of conventional dairy farming to organic dairy farming using current crop rotation systems. Conversion of pig and arable farming to organic dairy farming so that total milk production is maintained.
Aim is to achieve maximum livestock production from national feed sources whilst minimising gaseous N emissions and nitrate leaching.	No animals are kept indoor and all nature areas are grazed at low livestock densities to maintain biodiversity.	Expansion of organic farmed area from currently 7% to approximately 50% based on dairy farming, primarily for export of milk and meat.
May serve as a green growth model for developing new marketable technologies	Many other values, public partnerships, food citizenship, etc.	Nature, new organic products and jobs

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Geographically differentiated N-measures based on landscape planning and management

Alternative local and geographical differentiated regulation of N according to vulnerability of the aquatic environment as loading levels of individual parts of the landscape supplements and/or replaces the general regulation of N.
The measures that can be targeted spatially include wetlands, fertilisation rate, and use of catch crops, crop choice (in particular perennial or crops with long growing season), set-aside and conversion to nature. Also downstream measures such as small constructed wetlands can be used.
Three different versions of regulatory instruments are considered in prioritised order (although the order of priority may be debated): 1) Crop rotation and land use is used as a regulatory mechanism to move the land use type to where it maximise production and minimises N loading to the environment. This also includes down-stream measures such as constructed wetlands. 2) Some of the more vulnerable areas are taken out of production for permanent grass (nature) or forestry. 3) Perennial crops (energy crops, crops for biogas and biorefinery etc) are grown in the vulnerable areas in order to minimize N loading but maintain production. The incentives for achieving this may involve mandatory combination of measures according to efficiency, subsidised conversion of agricultural land combined with land substitution measures, and subsidised production of perennial energy crops on areas with high risk of N loadings.
Focus on reducing N loadings to vulnerable coastal and groundwater reservoirs depending on vulnerability of recipients and on N reduction along the flow path from the root zone to the recipient. The premise of this scenario is that the new reduction requirements (WFD objectives) must be met and observed in every River Basin District.
Promote nature, forestry, climate change mitigation

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Challenges in implementing geographically differentiated measures

At national scale this is a complex analysis:

› N load requirements depend on receipients (coastal waters and groundwater)

› Each ID15 has separate N reduction potentials

› How to combine requirements from different ID15 that have the same recepients?

› There are many different measures, which should be given priority?

At local scale this needs to address different opportunities:

› Farm structure, possibilites to change land with other farmers

› Possibilities for landscape measures (wetlands, constructed wetlands, mussels farming)

› Possibilities of changing land use (e.g. to perennial cropping, nature or forests)

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Methods for scenario analyses in dNmark of geographically differentiated measures

At national scale:

› For each ID15 identify the need for N loading reduction

› Use current land use and management map to identify sources of N leaching

› Implement effects of increasing N fertilisation rates to economically optimum using N response in N-LES4

› Use different combination of measures to reduce N leaching to tolerable levels with effects from Virkemiddelkatalog and N-response from N-LES4

At local scale:

› Clarify which opportunities are at farm scale at which at landscape scale

› Model what the N loading would at economically optimal N rate.

› Model effects of implementing options at either farm scale or landscape scale

› Use different combination of measures to reduce N leaching to tolerable levels with effects from Virkemiddelkatalog and N-response from N-LES4

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Main categories of efficient measures

Agricultural land use:

› Changing fertilisation rate (avoiding over-fertilisation – dairy farms!)

› Catch crops

› Crops with greater N-uptake (grass, beet)

› Avoid tillage in some periods, early sowing of winter cereals

Land use change

› Perennial energy crops

› Afforestation

› Set-a-side, and buffer zones along rivers and streams

Downstream:

› Wetlands and constructed wetlands

› Mussel and sea-weed farming

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Measures in Virkemiddelkatalog

Virkemiddel	Referencepraksis/ kommentar	Årlig N-effekt [1]	Sikkerhed ift. N-effekt	Budget-økonomisk omkostning kr./kg N [2]	Velfærds-økonomisk omkostning kr./kg N [2]
Efterafgrøder	Jord uden efterafgrøde	12-45 kg N ha^{-1} [3]	***	5 - 19 157 - 236 [4]	6 - 25 209 - 311 [4]
Mellemafgrøder	Vintersæd uden mellemafgrøder	9-13 kg N ha^{-1}	**	30 - 36	39 - 48
Afgrøder med høj N-optagelse: > Sukkerroer > Græs og frøgræs > Foderroer	 Jord uden efterafgrøde Jord uden efterafgrøde (Mangler data)	 12-45 kg N ha^{-1} >12-45 kg N ha^{-1} -	 ** (samlet bedøm-melse)	 -114 – (-156) IV IV	 -152 – (-206) IV IV
Tidlig såning af vinter-hvede (7. september)	Normal såning af vinter-hvede (23. september)	5-8 kg N ha^{-1}	**	-80 - 54	-106 - 72
Flerårige energiafgrøder	Kornrige sædskifter under den nuværende regulering	34-51 kg N ha^{-1} [3]	***	-45 - 107	-60-142
Brak (ikke permanent udtagning)	Jord i omdrift	35-58 kg N ha^{-1} [3]	*	28 - 190	37 - 253
Permanent udtagning	Jord i omdrift	50 kg N ha^{-1}	**	69-83	91-130 [5]
Randzoner	Jord i omdrift og varig græs	37-74 kg N ha^{-1}	*	47-93	62-123 [7]
Fjernelse af biomasse i randzoner og engarealer	Ingen fjernelse af biomasse	Pt. ikke datagrundlag	IV	IV	IV
Skovrejsning	Jord i omdrift	50 kg N ha^{-1}	**	50-153 [6]	66-203 [6]
Forbud mod jordbear-bejdning i visse perioder	Jord der bearbejdes	10 kg N ha^{-1}	**	1	1-2

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Measures in Virkemiddelkatalog

Virkemiddel	Referencepraksis/ kommentar	Årlig N-effekt [1)]	Sikkerhed ift. N-effekt	Budget-økonomisk omkostning kr./kg N [2)]	Velfærds-økonomisk omkostning kr./kg N [2)]
Forbud mod omlægning af fodergræs om efteråret	Intet forbud mod omlægning om efteråret	36 kg N ha^{-1}	*	14	18
Reduceret jordbearbejdning	Konventionel jordbearbejdning	0 [8)]	**	IV	IV
Nedmuldning af halm før vintersæd	Fjernelse af halm før vintersæd	0 [8)]	**	IV	IV
Biochar	Ingen biochar produktion og tilsætning	0 [8)]	IV	IV	IV
Positionsbestemt tilførsel af gødning	Bredspredning af handelsgødning	1-2 kg N ha^{-1}	**	IV	IV
Ændret udbringningsperiode for husdyrgødning om efteråret	Husdyrgødningen kan gemmes til næste forår, alternativt udbringes inden 1. september	Samlet effekt: 1850 t N	**	12	15
Afbrænding af husdyrgødning	Antages kun at være aktuelt for biogasbehandlet gylle	Svinegylle: 5 kg N DE^{-1} Kvæggylle: 8 kg N DE^{-1} Fjerkrædybstr.: 20 kg N DE^{-1}	**	IV	IV
Kontrolleret dræning	Almindelig dræning	Pt. ikke datagrundlag	*	IV	IV

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Measures in Virkemiddelkatalog

Virkemiddel	Referencepraksis/ kommentar	Årlig N-effekt [1]	Sikkerhed ift. N-effekt	Budget-økonomisk omkostning kr./kg N [2]	Velfærds-økonomisk omkostning kr./kg N [2]
Konstr. mini-vådområder med over-fladisk afstrømning	Er målrettet drænrans-port; virker uden for markfladen	5-20 kg N ha^{-1} opland; 500-3500 kg N ha^{-1} anlæg	**	21 - 173	27 - 232
Konstr. minivådområ-der med filtermatrice	Er målrettet drænrans-port; virker uden for markfladen	5-35 kg N ha^{-1} opland; 500-7000 kg N ha^{-1} anlæg	**	IV	IV
Vådområder	Jord i omdrift	120-190 kg N ha^{-1} [9]	***	31-33	41-44
Marine virkemidler					
Muslingeopdræt	IR	600-900 kg N ha^{-1} [10]	**	70-97	93-129 [11]
Tangdyrkning	IR	16 kg N ha^{-1} [10]	**	575-805	762-1068 [12]
Udplantning af ålegræs	IR	IV	IV	IV	IV
Stenrev	IR	IV	IV	IV	IV

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Challenges now in dNmark

› Scenarios have been developed

› Their consequences will now be assessed at national scale, with the needed assumptions

› Their applicability at local and regional scale also needs to be assessed and discussed with stakeholders

› Need to draft a plan for publication of the scenario studies that also integrates the other studies in dNmark