DNMARK: Danish Nitrogen Mitigation Assessment: Research and Know-how for a sustainable, low-Nitrogen food production (Strategic Research Alliance 2013-2017)

B1 Summary

Agricultural food and biomass production are the main sources of reactive nitrogen (N) pollution, causing N concentrations in air and water exceeding critical levels for eutrophication, significant greenhouse gas emissions, landscape and biodiversity deterioration, and severe human health impairments. In parallel, N is the main limiting factor to increased agricultural productivity. Many research-based N mitigation measures have already been implemented in Danish agriculture, yet N pollution and the related costs for society and the food sector remain unacceptably high. Future societal development will require N pollution to be significantly reduced while increasing the food and biomass production. Thus, innovative, cross-sectoral solutions to reduce N losses and ally public and private stakeholders are crucial for the development of a sustainable biobased economy. The DNMARK cross-disciplinary research alliance will identify barriers and develop research-based solutions to meet this N challenge, emphasizing both costs and benefits of different development pathways. In an integrated project with core private and public partners we will focus on three main solution scenarios: i) New production chains with a more efficient use and recycling of N, ii) Geographically differentiated N-measures based on intelligent planning and management of agricultural landscapes, and iii) Changed consumption patterns driving land use change and reducing N use. For the first time, a consistent Danish framework for N flows will be set up, along with landscape study sites and economic evaluation models. PhD research studies will focus on critical N issues of relevance to the participating private and public stakeholders, and the project management and dissemination activities will ensure the results are synthesized and disseminated nationally and internationally.

B2 Objective of the project

Allying key research groups and private and public stakeholders, the overall objective is to identify pathways to significantly reduced N pollution and increased N efficiency, thus making Denmark leader in resource efficient agriculture and the mitigation of N-derived impacts from agricultural production on the environment, climate, public health and the economy. The aim is to:

- Develop new methods to analyse time series of national N flows, and the effect of innovative mitigation scenarios on future agricultural production and food/biomass consumption (RC1).
- Assess the potentials to locally targeted landscape-scale N mitigation measures by analysing and modelling 3 study areas with extensive spatial data coverage (RC2).
- Provide policy-relevant knowledge about catchment scale policy implementation, and hereby extend the research on cost-effectiveness and implementation of N measures (RC3).
- Enhance the collaboration between the individual Danish N research environments via PhD and post-doc research education on high-impact topics affecting N mitigation (RC4).
- Synthesize results, and communicate with farmers, consumers and the wider public how the detrimental effects of N can be reduced via changes in the management of N in the whole chain from production to consumption of food and bioenergy (RC5, RC6).

B3 The main results of the project

Table 1. Main DNMARK results and relevance to selected private or public stakeholders (listed in brackets, with bold abbreviations taken from Table 4). See also appendices A and E.

Output	Relevance to stakeholders
Solution scenarios to increased N efficiency, and significantly reduced N-footprint	It is recognized by Danish agriculture (**VFL, VSP**) and major agribusinesses (**ARLA, Danish Crown, YARA**) that significant improvements in N utilization is crucial for the further development of the sector. The Danish government (**MAFF, MEM**) needs to comply with EU directives and international treaties, and development of a targeted strategy to reduce N-pollution is demanded by green thinktanks (e.g. **CONCITO**).
The first full, dynamic model for N flows in Denmark	It is attractive for international research institutions (**IASA, JRC, ALTERRA**) to test new N-models in Denmark, and develop world leading agro-environmental databases (**EEA, DKSTAT, EUROSTAT**). This is also important for documenting effects of national N-mitigation initiatives (**MEM**).

Landscape platforms to test effects of local N mitigation initiatives	Locally adapted N-mitigation solutions are important to municipalities' (**Varde, Skive, Odsherred** etc.) mandatory spatial planning and sustainable development strategies. New planning tools are needed (**ALECTIA, CONTERRA**), to integrate the full range of ecosystems services and the comparative, often disparate, advantages for local agribusinesses and rural development (**DAAS, ADVICE, MEM, MAFF**).
Models to assess cost-effectiveness of targeted and voluntary N measures	The societal costs of Danish N pollution amounts to billions of DKK yr^{-1} (Brink et al. 2011), and cost-effectiveness analyses and modeling of N measures are of high priority to **MEM, MAFF**. Especially the development of models for more efficient, location-specific instruments, including voluntary actions and improved collaboration between agents, is required (**DORS, MEM-Nature**) to develop the bioeconomy.
New insights from 5 post-docs and 6 PhD studies in high-impact N topics	High-priority areas for further N research include the development of new urban-rural N recycling technologies (in collaboration with **HEDEDK, ORGREST**), water policy cost-benefit analyses (**MEM-Nature, DORS**), sustainable food consumption and healthy lifestyles (**Horsens, WHO**), agricultural watershed management and optimal N use (**DAAS, YARA**), Ecosystem Services Assessment (**EEA**), and public health effects of air (**MEM-EPA**) and water N pollution (**OfficeDoctors, WaterAalborg**).
Dissemination and synthesis of knowledge	Via significant co-funding the Danish farm advisory services (**DAAS**) and agroindustry (**YARA, VSP**) intend to integrate project results into new, more holistic local advisory services (**ADVICE**) for the sustainable development of farming and food production in Denmark. Similarly, **ARLA** develops a "closer to nature" strategy, with improved N utilization and lower greenhouse gas emissions, and overall recommendations of the project are disseminated via **Farm4you, ANI-HUB, EXPERI** and the University PR offices as well as documented in peer-reviewed publications.

B4 Background and hypothesis of the project

The availability of industrial N fertilisers led to a large expansion of agricultural production (including livestock) and a reliable reactive N supply remains essential for the yield and stability of the agricultural production (Jensen et al. 2011). However, large losses of reactive N species, primarily from agricultural systems, have considerable adverse effects on the environment and human health. The European Nitrogen Assessment (Sutton 2011a, b) estimated the cost of reactive N emissions in Europe to €70-320 billion per year, which outweighs the direct economic benefits of reactive N in agriculture. The highest costs were associated with reductions in air and water quality, and related health and nature effects, though these estimates are still associated with large uncertainties. The benefits of reducing N loading to improve water quality to comply with the Water Framework Directive have been estimated in Danish case studies (Hasler et al. 2010), indicating a positive benefit-cost ratio for many but not all catchments. Achieving cost-efficient mitigation of N losses is therefore highly sensitive to spatial targeting, the choice of policy instruments and farmers' responses to these (Beharry-Borg et al. 2012).

There are many different forms of reactive nitrogen (e.g. NH_3, NO_3, NO, N_2O and NO_X) that move through biogeochemical processes. This implies that one atom of N may take part in many environmental processes before it is immobilised or finally converted back to N_2. Referred to as the nitrogen cascade (Galloway et al. 2003), it explains why policy measures targeting one N species (e.g. nitrate or ammonia) may have large positive or negative effects on other species (e.g. nitrous oxide). These strong inter-linkages require a holistic approach to solve problems related to excess reactive N (Rygnestad et al., 2002).

Denmark has already implemented a number of measures to reduce losses of reactive N to the environment (Kronvang et al. 2008) but there is still a need to make substantial further reductions. If major further reductions are to be achieved cost-effectively, it is essential to include measures that control the flows of N between agriculture and society (including urban waste) and between agriculture and other ecosystems (including the harvesting of biomass for bioenergy use). Since the flows of reactive N display large spatial variations, such measures will also

need a landscape or catchment approach in order to maximise their efficiency. However, since the Danish Environmental Research Program 1992-2004 (info.au.dk/smp), there have been no resources for concerted research on these issues in Denmark. This means we lack a mechanism for exploiting the significant expertise that exists within the diverse research groups and adopt a coherent interdisciplinary approach to solving the challenge of closing the Danish N cycle.
Our fundamental hypothesis is that the cycling of reactive N can be significantly improved through targeted measures at national, landscape and farm management scales, and that the design of policies to promote such measures requires a comprehensive understanding of the cycling of reactive N and its holistic impact on ecosystems and socio-economy at national and landscape scales. A clear understanding of the effectiveness of the incentive structures used to implement measures as well as the influence of the social and institutional context of regulation is crucial. The development and use of this knowledge will help prioritise new, innovative measures and technologies for dealing with the N problem, thereby minimizing the costs and maximizing the benefits. We thereby hypothesize significantly higher cost-effectiveness of targeted regulation taking into account the local areas' vulnerability to the specific N pollution. In the DNMARK alliance we believe that interdisciplinary research and the integration of the whole range of public and private stakeholders into the research chain, and the two-way communication of research results to be tested in the real world, are key to the identification of solution pathways for a more sustainable N management and utilization. It is in particular in this area that we think DNMARK can move the frontier of interdisciplinary research, and facilitate the improvements needed in N management for a sustainable bioeconomy development.
Recently, the European N Assessment (Sutton et al., 2011b), the most extensive assessment ever made of N flows and impacts in a large multinational region, was published by the EU FP7 NitroEurope project. This exceptionally productive international collaboration, in which 17 Danish university researchers played a central role, has been continued in several cross-European research initiatives, funded by a range of EU instruments (EU-FP7, FACCE-JPI, COST and ESF), together involving more than 200 researchers worldwide, and supported by the Aarhus University IDEAS program (2012-2014). With the Danish N Mitigation Assessment (DNMARK), we aim to develop further Denmark's strong international position in this area, and bring together ten small, but strong, Danish research environments, dealing with the N problem in the production and consumption chains of food and bioenergy. More than 20 public and private stakeholder partners and key international partners are actively involved (see app. A, Table 1, 4), and will contribute to the fruitful process of building the alliance and creating innovative research.
Policy targets and solution scenarios will be used in the DNMARK project to structure discussion with stakeholders and promote collaboration between the constituent Research Components. The three policy targets will be to reduce losses of: 1) NO_3^- to comply with the EU Water Framework Directive, 2) NH_3 to comply with the Clean Air for Europe nature and health targets, 3) N_2O by 50%, to contribute to national and international commitments for GHG emissions. We will focus on three contrasting solution scenarios:

i) New production chains with more efficient use and recycling of N,
ii) Geographically differentiated N-measures based on intelligent planning and management of agricultural landscapes, and
iii) Changed consumption patterns driving land use change and reducing N use.

The development of these scenarios in workshops between researchers and stakeholders (Figure 1, B6) will be the main mechanism for ensuring the delivery of policy-relevant results. To drive this process effectively, the organisation of these workshops has been integrated with the project management in a separate research component (RC6).

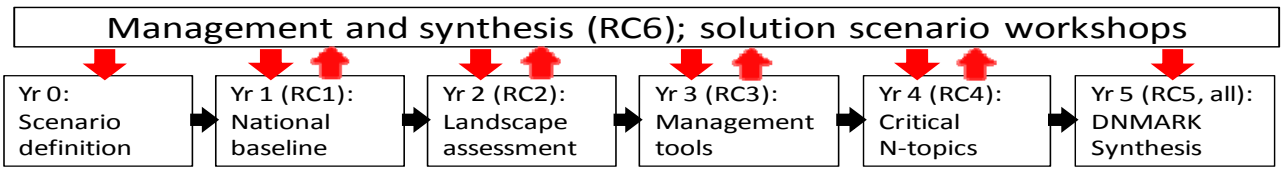

Figure 1. Development of solution scenarios during the series of annual project meetings organized by RC6 as a cross cutting activity for stakeholder involvement, research activity coordination, and dissemination of results (co-organised by the RC's mentioned in brackets).

B5 Innovative value, impact and relevance of the project

Scientific knowledge base: Integrating agronomic, economic, natural, social and health sciences the interdisciplinary research alliance imply substantial improvements to the knowledge base on sustainable N management, and enhance the scientific basis for sound policy formulation for reducing detrimental effects of N on human and ecosystem health (Dalgaard et al. 2003). The project will result in the formulation of the first full and dynamic national N budget for Denmark. This will provide an opportunity to evaluate effects of introducing changes in N fluxes at any scale from local to regional and national, such as the recycling of organic waste.

Policy formulation: The project will establish the first landscape research observatories to study the effects of changes in agricultural technologies and practices, landscape changes, and alternative policies and mechanisms on the entire N budget and the economic impacts. This will significantly improve policy formulation (EC 2011). After 25 years of intensive regulatory measures (Kronvang et al. 2008), which in many respects have proven insufficient (Windolf et al. 2012), the project will help in the design of the additional or alternative measures required.

Business opportunities: As indicated in Table 1, and with the extensive commitment of both large and small companies (Table 4, Appendix A), the project will support important innovations in business and industries, with new opportunities for the agri-tech sector, advisory services and the food industries. This includes the development of new public-private partnerships (for example between universities, municipalities and the consultancy sector), and the promotion of green farm technologies (for example new types of N fertilization and recycling), new advisory services (for example for watershed management), sustainable food production chains (for example 'closer to nature' strategies for dairy production with a smaller N footprint and greenhouse gas emission), and technologies for a cleaner and healthier water and air environment. Finally, the extension service and the private partners will also benefit from the dissemination of the results.

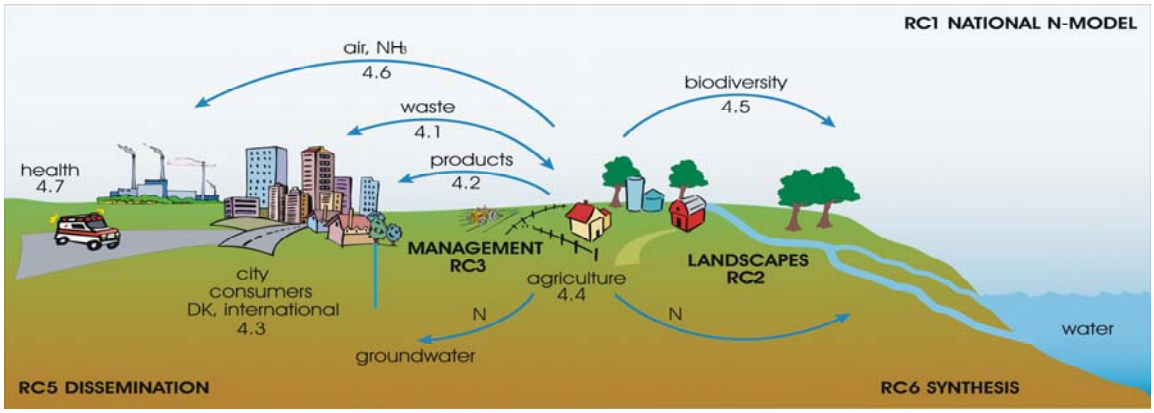

Figure 2. Focus areas for the DNMARK Research Compo-nents RC1- RC6.

B6 Project's methodology and results

As illustrated in Figure 2, the development of methodologies for sustainable N management will be divided into the five Research Components (RC1-RC5), and a coordination component (RC6), divided into subtasks as specified in the following (with main contributors in brackets):

RC1: National N-model *(Lead: N Hutchings; Co-lead: W de Vries)*

1.1 (ALTERRA, AGRO, JRC, IIASA) Prior to the first stakeholder workshop, we will construct a prototype national Danish N model (inputs, outputs and losses) for the period 1990-2010. The model will quantify all major terrestrial and aquatic flows (Leip 2011) using the top-down method developed during the European N Assessment. The model will subsequently be refined in response to stakeholder comments, knowledge gained in task 1.2 and the consequences of solution scenarios. Based on data from 2.1, an alternative national scale model for the agricultural sector will be developed using a bottom-up approach based on farm-scale data and an existing farm N model (Happe et al., 2011), to allow a robust comparison with the top-down approach. Revised national N budgets for 1990-2010 and future national N budgets reflecting the consequences of solution scenarios will be included in the Danish N Assessment (RC6).

1.2 (AGRO, ALTERRA, DKSTAT/EUROSTAT) The national N budget for agriculture will be disaggregated to a range of spatial units, using the INTEGRATOR model (Reinds 2012), spatially disaggregated data and GIS techniques. Initial results at the NUTS2 scale will be available for the first stakeholder workshop. The modelling will be progressively refined, taking advantage of detailed spatial information already available concerning e.g. the NO_3^- transport to aquatic ecosystems and the atmospheric transport of NH_3. Methods to account for the consequences of solution scenarios will be included. The revised model will be included in the Danish N Assessment.
1.3 (AGRO, FOI, CONTERRA) The consequences of implementing the solution scenarios developed in the RC6 stakeholder workshops will be modelled for the period 2010-2030, taking the greening of the EU CAP into account (Uthes et al., 2009). The consequences of all solution scenarios will be quantified at the national scale. For the agricultural sector, the effect on the spatial distribution of N flows will be predicted for the same period, including losses of NO_3^-, NH_3 and N_2O. It will be investigated how the general N balance is affected by consumption trends, international trade, policy interventions addressing food demand etc., and results will be synthesized in the form of time-series (Hansen et al. 2011). First results will be presented at the 2nd stakeholder workshop and revised for subsequent workshops and the final N Assessment.

RC2: DNMARK Landscapes *(Lead: H Vejre, Co-lead: T Dalgaard)*

2.1 (AGRO, MUNICIPAL, ADVICE, GEO, BIO, CONTERRA) In collaboration with local municipalities and farmers' unions two case landscapes with a low NO_3^- retention (Skive and Odsherred) and one with a high retention (Varde) are inventoried with farm and landscape data in GIS (Dalgaard et al. 2011b). A detailed N budget is constructed using inputs from RC1 and more detailed local data. N retention, load and N-budgets output to RC3.
2.2 (GEO, ALECTIA, CONTERRA, MUNICIPAL, AGRO) Local scenarios for the case landscapes are formulated where N reduction effects of various changes in landscape, agricultural practice and technical installations are modelled. Forecasting scenarios allow the prediction of effects of changes on open trajectories, whereas backcasting scenarios allow optimization of landscape and farm management tools with fixed aims in terms of N loss reduction (Bende-Michl et al., 2011). The scenarios are formulated with stakeholders and in an iterative process with RC3, RC4.1-4.7 and RC5, ensured by a sequence of scenario-building followed by local workshops.
2.3 (ALECTIA, EEA, GEO, AGRO) In the last part of the RC we will evaluate the extent of other externalities brought about by the various N mitigation efforts which are simulated in 2.2. Selected ecosystem services (wildlife habitats, flood control, cultural heritage, recreation etc.) will be mapped in the baseline scenario of step 1, and the development in the provision of services will be assessed for each scenario of step 2 (Stubkjær et al., 2012). The assessment will require development of new methodologies, in close collaboration with RC3, RC4.5, RC5 and municipal stakeholders, and include assessments of the global effect of local land use change.

RC3: Management strategies *(Lead: B Hasler, Co-lead: B Jacobsen)*

3.1 (ENVS, FOI, MEM-Nature, BIO) Scenarios for cost-effective N reductions to allowable loads for freshwater and marine waters will be formulated with input data from RC1 and RC2, and in coordination with RC4.2 and 4.4. Furthermore, cost-effective spatial distribution of measures to achieve the N load reductions will be modelled by applying existing cost minimization models at national level and at case study catchment level (Konrad et al. 2012).
3.2 (ENVS, BIO, AGRO, DORS, MEM) A comprehensive spatial model framework is developed to study alternative regulatory mechanisms (subsidies, taxes, quotas, spatial zoning, production or environmental legislation), modelling farm behavior as individual optimizing firms (Hansen & Hansen 2012). The model outcomes will be tested and refined using experimental data (Beharry-Borg et al. 2012) to test the extent to which the model output mimics behavioural outcomes using alternative economic assumptions and approaches.
3.3 (ENVS, MEM-NatureAalborg, DORS) Building on 3.2, Task 3.3 studies implementation of measures that require cooperation between agents, as their effectiveness is dependent on scale and spatial adjacency. Spatially defined subsidy schemes and agglomeration bonus schemes will be investigated in a Payment for Ecosystem Services (PES) modelling framework. There will be special focus on construction of wetlands, buffer strips and watercourse maintenance, which needs collaboration between farmers at subcatchment level. We will use a heuristic optimization approach building on agent-based modelling frameworks (Touza et al. 2012). Promising PES schemes are evaluated using experiments in workshops (Beharry-Borg et al. 2012) where farmers evaluate the potential for implementing such schemes in the agri-environmental policy mix. This RC3.3 part is linked to RC2+5. The result will be compared to results from real cases

where such payment schemes have been implemented, e.g. the Swiss example where farmers receive bonus payments when their fields are part of habitat networks (Wätzold et al. 2011).

RC4: Critical N impact issues *(Lead: LS Jensen, Co-lead: O Hertel)*

This RC focuses on gaps in our current N knowledge, and comprises in-depth studies of critical N issues in relation to a sustainable agriculture and food production. These issues have been identified by the alliance partners as of key importance to the quantification of N flows or to the mitigation of N losses in DK, and were also prioritized in the European N Assessment report as research needs. Moreover, each of these research education projects adds to the core competences of the research alliance members supervising the projects (see appendix A):

4.1 Urban-rural N recycling from waste (AGEC, HEDEDK, ORGREST) There is scope for increased recycling of N in urban waste residuals (WR) from new emerging technologies for municipal solid waste and waste water treatment, e.g. biosolids, composts, struvite precipitates, digestate (Svirejeva 2011). We will screen a range of WR together with the industry (HEDEDK) and for a subset quantify fertilizer value, improvement options, medium to long-term effects on soil quality and emissions (lab+field testing in long-term trial at AGEC). Outcomes and innovation needs will be discussed with stakeholder network (ORGREST) and contribute to scenarios in RC1.3+6.1.

4.2 Cost benefits of N measures to improve surface water quality (FOI, MEM, MAFF, ENVS) The aim is to bridge costs analyses and benefit analyses in order to answers questions like: What is the optimal water quality in a given catchment from a cost-benefit viewpoint? How to proceed to cover the whole country, where local benefit analyses are not possible? How much can the costs of implementation be reduced if on site specific N-reduction potential can be obtained (Jensen et al., 2012) There will be strong links with RC3 and exchange of data with RC1-3.

4.3 Sustainable, low N food consumption (ARTS, WHO, Horsens, AGRO, FOI). We will investigate whether the dual aims of reducing environmental N loss and reducing the protein share of healthy diets are congruent or conflicting, and on which scale. The work will estimate food demand component of the N map nationally and selected local areas (coord. with RC2), determine trends and drivers for consumption of Danish food products – nationally and internationally and analyse alternative interventions to change food demand behavior at the local level. Two case-studies from EU Healthy Cities Network, Horsens (DK) and Belfast (IE), will be included.

4.4 Watershed N Management (DAAS, AGRO, ARLA, ADVICE, YARA, MUNICIPAL) Going from farm to watershed based N management shows significant potentials for increased productivity combined with lower N-losses (Dalgaard et al., 2011b). Areas vulnerable to N-losses are selected from RC2, and new watershed management concepts are developed together with RC5 and local farm advisory services, incl. the extensive drainage water data provided by DAAS.

4.5 N mitigation, Ecosystems Services mapping and biodiversity management (BIO, AGRO, EEA, ALECTIA) We focus on how composition and distribution of ecosystem services (ES) correlates with N mitigation options, N vulnerable areas, and agricultural production, to quantify synergy effects between N mitigation and biodiversity protection (Dise 2011). Together with RC2.3 we analyse the spatial distribution of the proposed ES and N management using the method of Turner et al. (2012) and compare the effects in different scenarios (RC1+2) on energy budgets, N-leaching, displacement of agricultural and forestry production etc. Outputs to RC2 and RC3.

4.6 Agricultural airborne N-pollution, particle pollution and public health effects (ENVS, HEALTH, MEM-EPA, OfficeDoctors, ALLERGY, LUNG, DK-HEALTH) The aim is to assess the contribution from agricultural N-emissions to negative health effects from ambient air particle exposure of the Danish population This will be based on state-of-the-art source apportionments and exposure assessment will be used as basis for an epidemiological study with health register data (from CIRRAU), using a GIS approach. The integrated system approach based on impact-pathway will be adjusted to assess the health-related economic externalities of agricultural air pollution (Brandt et al. 2011) based on a refined DNMARK dataset. Outputs to be used in RC6.

4.7 Groundwater N-pollution and public health effects (GEUS, HEALTH, AGRO, OfficeDoctors, MEM-Nature, WaterAalborg) The aim is to assess the contribution from N polluted groundwater to negative health effects on the Danish population. This will be based on an epidemiological study of people exposed to nitrate containing drinking water and assess the incidence of cancer (e.g. colon cancers; van Grinsven et al. 2010) by combining drinking water quality data (Hansen et al., 2011) with health register data using a GIS approach. The unique Danish CIRRAU registers (see 4.6) combined with the JUPITER groundwater quality data hosted at GEUS enables this new research opportunity. Outcomes to RC6, similarly to RC4.6.

RC5: Dissemination *(Lead: IA Wiborg, Co-lead: C Kjeldsen)*

5.1 (DAAS, AGRO) A communication strategy will be developed including the construction of a www.DNMARK.dk website to host the Danish N Assessment results, and links to partner websites. Throughout the lifetime of the project, the websites will be iteratively revised, with project results visualized and communicated in films, animations and exhibitions (RC5.3), with the solution scenarios of RC6.1 as the central input.

5.2 (DAAS, ARLA, YARA, ADVICE, MUNICIPAL) Local dissemination of the DNMARK results and task 6.1 solution scenarios will be developed and tested in the local landscapes of RC2. Here, the development project "Closer to nature", initiated by ARLA will be of inspiration. ARLA and local farmer groups will meet on 40-50 planned farm meetings, where the agenda is to identify measures at farm level that might improve resource efficiency and climate change adaptation, including C and N footprint. Through the utilization of cognitive mapping, and the facilitation of learning processes between the multiple stakeholders at local development workshops, RC5.2 will produce action plans for sustainable N-management strategies at local and regional level, and successful results will be disseminated through the national advisory services (DAAS).

5.3 (AGRO, ANI-HUB, Farm4You, DAAS) For dissemination at national level, visual narration of the solution scenarios will be developed, and this will be carried out in collaboration with ANI-HUB and hand-picked collaborators from the media sector. Dissemination at national scale will also be with input from other research partners as well as stakeholders on new initiatives improving resource efficiency or climate change mitigation. An important element is the 'scaling-up' of the work in local workshops (including relevant representatives from the stakeholder network of Table 4), where the knowledge from lessons learned locally is synthesized, and fed into the RC6 solution scenario workshops.

5.4 (AGRO, all research and International partners; PRP and IntP in Table 4) International publication and dissemination is closely coordinated with RC6 and include the organization of an international conference together with the final synthesis scenario workshop (Figure 1).

RC6: Management and synthesis *(Lead: T Dalgaard, Co-lead: JE Olesen and J Schjørring)*

The project management consists of 1) A management committee headed by Tommy Dalgaard, including all RC leaders and co-leaders. 2) An alliance board with official representatives from all partner institutions (PRP and PIPs in Table 4), and the three RC6 project managers. 3) A research advisory committee comprising national and international peers. The coordination of DNMARK by the Department of Agroecology ensures a close relationship to AU's formal role of providing research-based policy advice in relation to N and food production. Research management will focus on the coordination of DNMARK RCs and the ongoing national and international project portfolio of the institutions involved. This includes the following tasks:

6.1 (AGRO, all PRPs, PIPs, private and public stakeholders of Table 4): The annual solution scenarios workshops of Figure 1 are used to facilitate stakeholder integration and crosscutting research and dissemination activities. The general solution scenario pathways are defined during the inception phase (yr 0) and form the basis for the work in RC1-RC5. The national scale baseline and preliminary scenario results (yr1) feed into more specific landscape scenarios (yr 2), management mitigation options to be quantified and discussed in yr 3, and the effects of the RC4 specific key N-topics to be synthesized in yr 4. These workshops and the specified RC deliveries ensure that results feed-back to the final yr 5 synthesis scenarios to be developed both at landscape and national scales in the final DNMARK assessment (RC6.3), and the continuous dissemination of results (RC5).

6.2 (AGRO, PRPs) Biannual project meetings, and status reporting to the research council.

6.3 (AGRO, AGEC, PRPs and PIPs) Based on the RC6.1 scenario results, the publications delivered during the project, and the continuously updated www.DNMARK.dk RC5.1 homepage, a full Danish Nitrogen Assessment anthology with invited paper chapters is compiled.

B7 Project plan

It is expected that the contracts and work programs of the alliance will be agreed by Dec 2012, and that the project will be launched at a meeting Jan 2013 (Table 2). The initiation of activities in the RCs will depend on the time taken to recruit the planned post-docs and PhD students; hence it is expected that the duration of the project will be four and a half years, with three months for the start-up phase and a yr to complete the final Danish N Assessment. For most post-docs and PhDs we have competent candidates, suggesting a short recruitment process.

Table 2. Gantt diagram: workplan, timeline and milestones (M) for the Research Component RC1-RC6 activities. The RCs and subtask durations are indicated with green and grey shading.

			2013				2014				2015				2016				2017	
RC	**Tasks:**		**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**
1	**National N-model**																			
1.1	National N-budget			M1.1						M 1.4			M 1.6							
1.2	Agr. N-budget disaagregation			M1.2								M 1.5								
1.3	National scenarios							M1.3								M 1.7				
2	**Landscapes**																			
2.1	Landscape inventory					M2.1														
2.2	Local scenarios						M2.2	M2.3				M2.4								
2.3	Ecosystem service externalities								M2.5					M2.6		M2.7				
3	**Management strategies**																			
3.1	Cost-effectivess scenarioes					M3.1														
3.2	Spatial model framework						M3.2	M3.3	M3.4											
3.3	Subsidy scheme evaluation									M3.5	M3.6			M3.7						
4	**Critical N impact issues**																			
4.1	Urban-rural waste N-cycling					M4.1				M4.8						M4.21				
4.2	Cost benefits of N measures					M4.2				M4.9				M4.15		M4.22	D4.2			
4.3	Sustainable food consumption					M4.3				M4.10				M4.16		M4.23	D4.3			
4.4	Watershed N Management					M4.4				M4.11				M4.17		M4.24	D4.4			
4.5	N mitigation & Ecosyst Services					M4.5				M4.12				M4.18		M4.25	D4.5			
4.6	Air N pollution & public health					M4.6				M4.13				M4.19		M4.26	D4.6			
4.7	Groundwater N pollut & health					M4.7				M4.14				M4.20		M4.27	D4.7			
5	**Dissemination**																			
5.1	Communication Strategy	M 5.1		M 5.2				M 5.3				M 5.4				M 5.5			M 5.6	
5.2	Local dissemination		M5.7				M5.8				M5.9				M5.10			M5.11		
5.3	National dissemination		M5.1		M5.13				M5.14				M5.15				M5.16		M5.17	
5.4	International dissemination						M5.18				M5.19				M5.20			M5.21	M5.22	
6	**Proj. management & synthesis**																			
6.1	Solution Scenario workshops	M6.1		M6.2				M6.3				M6.4				M6.5			M6.6	
6.2	Project meetings and reporting		M6.7	M6.8, M6.18		M6.9, M6.23		M6.10, M6.19		M6.11, M6.24		M6.12, M6.20		M6.13, M6.25		M6.14, M6.21		M6.15, M6.26	M6.16, M6.22	M6.17, M6.27
6.3	Danish Nitrogen Assessment															M6.28				M6.29

M 1.1 Prototype national N model completed to be presented at the M6.2 stakeholder workshop
M 1.2 Preliminary disaggregated agricultural N budget completed to be presented at the M6.2 stakeholder workshop
M 1.3 First implementation of solution scenarios at national scale to be presented at the M6.3 stakeholder workshop
M 1.4 Bottom-up agricultural N model completed
M 1.5 Final disaggregated agricultural N budget completed to be presented at the M6.4 stakeholder workshop
M 1.6 Final national N model completed
M 1.7 Final implementation of solution scenarios at national scale to be presented at the M6.5 stakeholder workshop
M 2.1 Landscapes baseline conditions reported and ready for scenario building.
M 2.2 Scenario workshops with local stakeholders in the landscapes (together with task 5.2)
M 2.3 First generation scenarios formulated in all case landscapes to be presented at the M6.3 stakeholder workshop
M 2.4 Second generation scenarios formulated in all case landscapes to be presented at the M6.4 stakeholder workshop
M 2.5 Conceptual framework for ecosystem service assessment agreed
M 2.6 First generation ecosystem service assessment ready
M 2.7 Second generation ecosystem service assessment ready to be presented at the M6.5 stakeholder workshop
M3.1 Cost-effective spatial distribution of measures to obtain the N load reductions
M3.2 Spatial model framework developed
M3.3 Study of alternative regulatory mechanisms reported
M3.4 Experiments and tests of model performed
M3.5 The Payment for Ecosystem Services (PES) agent based modeling framework established and described
M3.6 Analysis of collaboration schemes published
M3.7 Scenario analysis of cost-effectiveness and implementation finished
M4.1-M4.7 Post-doc and PhD candidates recruited and projects plans presented during the M6.9 project meeting
M4.8-M4.20 Post-doc and PhD results and publications presented at the M6.11 and M6.13 project meetings
M4.21-M4.27 Post-doc and PhD solution scenario results presented at the M6.5 stakeholder workshop
M5.1 Establishment of an iteratively updated www.DNMARK.dk homepage with newsfeed and intranet function
M5.2-M5.6 Communication strategy to be discussed and approved at the annual project meeting, together with homepage updates
M5.7 50-60 local ARLA farmers group meetings on potentials to improve ressource efficiency and reduce N- and C footprint
M5.8-M5.11 Local development workshops and sustianable N-management action plans (M5.7 together with task 2.2)
M5.12 Advisory board for national dessimination established during start-up project meeting M6.7
M5.13-M5.17 Dessimination of workshop result (M5.7-M5.11 and M6.1-6.6) to the wider public, together with communication partners
M5.18-M5.21 International papers results from the project synthesised in newsletters
M5.22 Final international conference (together with M6.29)
M6.1-M6.6 Solution scenario workshop with stakeholders (See Figure 1).
M6.7 Start-up meeting together with first scenario workshop (M6.1) quickly after project start
M6.8-M6.17 Bi-annual project meeting
M6.18-M6.22 Half-annual report, M6.23-M6.26 Annual report, and M6.27 Final report
M6.28 Plan for the final DNMARK anthology presented and approved during the M6.14 project meeting
M6.29 Final Danish Nitrogen Assessment and DNMARK anthology (together with M5.22)

The main deliverables from the project will, apart from the outputs of relevance to stakeholders specified in Table 1 and the dissemination activities of RC5.1-RC5.3, be in the form of refereed international publications. Two papers will be delivered per year of post-doc activity in RC1-4, and each of the RC4.2-RC4.7 PhDs is expected to deliver at least one paper per year of activity (see success criteria in B10) . Subsequently, the final Danish Nitrogen Assessment will be reported in the form of a common DNMARK anthology and a number of supporting papers, synthesizing the overall results from the research components RC1-5.
The following approximate resources will be deployed for each of the RCs [including estimated man hours for the committed Principal Innovation Partners in brackets]:

- **RC1**: 16-month post-doc (AGRO), and 12+6+2 months scientific staff from AGRO, ALTERRA and FOI [+500 hours from PIPs]
- **RC2**: 24-month post-doc (GEO) and 7+8+2 from GEO, AGRO, BIO [+800 hours from PIPs]
- **RC3**: 18 month post-doc (ENVS), and 7+2+2+4 months scientific staff from ENVS, FOI, AGRO and BIO [+400 hours from PIPs]
- **RC4**: 26-month post-doc (from AGEC and ENVS), 6 PhD projects (see Table 3), in total about 20 months from the supervision partners of Table 3. [+800 hours from PIPs]
- **RC5**: 12+6 months from DAAS and AGRO [+600 hours from PIPs]
- **RC6**: 14 months from AGRO (+6 month secretary), and in total 15 months from other principal partners [+800 hours from PIPs]

However, this list only describes the main efforts of the partners in each RC and does not encompass minor activities in other RCs. In addition, significant activities will be carried out by the International Partners and the Stakeholder Network Partners (IntP and sNet in Table 4). Table 3 shows in more detail partner responsibilities for the planned PhD and post-doc projects, and the involvement of stakeholders and international experts. They will be responsible for the specific workplans for each PhD and post-doc, and crosscutting activities to other RCs.

B8 Project's international dimension

The importance of reactive N in both food production and environmental pollution is acknowledged as a global issue. In response, the scientific community has gathered in the International Nitrogen Initiative (INI; http://initrogen.org/) to coordinate and disseminate global N research. A key recent activity of the European INI centre was the European Nitrogen Assessment, to which nine Danish and international participants in the DNMARK proposal contributed. A similar number of DNMARK participants are also active in either the UN Task Force on Reactive Nitrogen (TFRN; www.clrtap-tfrn.org/) or the UN Task Force on Emissions, Inventories and Projections (TFEIP; www.tfeip-secretariat.org/) and associated expert panels. International project partner and policy advice collaborations are further described in section B11. Moreover, the DNMARK PhD and post-doc connections to key international research partners and stakeholders are shown in Table 3, and Table 4 show the inclusion of international partners in the project.

Table 3. PhDs and post-docs/sabbatical contacts to stakeholders and international partners.

RC	PhD/post-doc/Sabb.	Affiliation	Supervisor/ Training officer	Co-supervisor/ main contact	Core Stakeholder	Institute to be visited
1	Post-doc	AGRO	N Hutchings/ T Dalgaard	Prof. W de Vries Dr.A Leip/ Winiwarter	DKSTAT EUROSTAT	Alterra JRC/IIASA
2	Post-doc	GEO	H Vejre	Prof. F Müller	MEM-Nature,	Uni-Kiel
3	Post-doc	ENVS	B Hasler	B Jacobsen and M Termansen	DORS	Uni-Leeds
4.1	Post-doc	AGEC	LS Jensen	JK Schjørring	HEDEDK	Alterra
4.2	PhD	FOI	B Jacobsen	B Hasler	MAFF-Dept	Uni-E. Anglia
4.3	PhD	ARTS	S Brock	J Devlin	Horsens	WHO-Europe
4.4	PhD	DAASAGRO	T Dalgaard	I Wiborg	ARLA	JHI
4.5	PhD	BIO/AGRO	T Dalgaard	JC Svenning	MEM-Nature	EEA
4.6	PhD	ENVS	O Hertel	T Sigsgaard	MEM-EPA	USDA-ARS
4.7	PhD	GEUS	B Hansen	T Sigsgaard	OfficeDoctors	Uni. Maastricht
6	Sabbatical	AGRO	T Dalgaard	JE Olesen	EEA,FAO,MAFF	Uni-Lincoln

B9 Legal and ethical aspects, etc.

Capital work proposed in this project does not include experiments with living animals, or empirical experimentation which might pose a threat to the health or safety of humans or ecosystems. Existing data of a personal or commercially confidential nature that may be collected in connection with the project, or data of this nature that will be collected during the project, will be managed in accordance with the current legislation of the state in which the data has been or will be collected. For the data relating to persons within the jurisdiction of Denmark, the relevant legislation is the Law on the Management of Personal Data (*Lov om behandling af personoplysninger*) from year 2000. DNMARK co-chair Jørgen E Olesen is appointed member of The Danish Council of Ethics, with the possibility of introducing relevant ethical issues for discussion in DNMARK and vice versa.

B10 Publication and promotional strategy and exploitation of results

The major success criteria of the project are delivery of the main outputs lined up in Table 1. The project team has a strong publication track record, and at least 25 peer reviewed publications are planned, together with the 6 PhD theses and the 5 post-docs. Communication with and to the project stakeholders and business partners is strongly emphasized, and the project will not hold any patent, so the knowledge generated will be freely accessible to everyone. In total more than 30 workshops and project days are planned, and will be reported (M6.18-M6.27 in Table 2), together with in total 10 popular science magazine publications, and a large number of conference presentations. Each year, the alliance will organize a workshop with the participation of the network and of stakeholders, where results will be presented and discussed (Figure 1). Feedback from the workshop will help ensure that the developed RC1-RC3 platforms fulfill the needs of the end-users, including the other DNMARK components and the final DNMARK synthesis. Furthermore, the alliance will organize an international symposium in the final project year, where the special topics of the Danish N Assessment will be presented, and the alliance will organize an international workshop in 2013 jointly with the www.macsur.eu project. During this workshop we will discuss the implications of the scenarios offering alternative, innovative and science-based solutions to the N problem. The results of the alliance will be shared with stakeholders at different levels (Figure 2) via the following activities:

- A www.DNMARK.dk website will be established with intra/extranet and in collaboration with the professional communication architects (connected to Animation Hub).
- Open access to the stakeholder network, PhD courses and workshops will be organised.
- Collaboration with Researcher-For-A-Day activities that reach out to more than 3000 students in secondary and 1800 students in tertiary education per year (Farm4you).
- Each involved institute will publish at least two popular articles about their results for a Danish audience, and present their results at national meetings and symposia. The list of contributions will be collated on the DNMARK website.
- Results from DNMARK will be incorporated into textbooks authored by DNMARK partners.

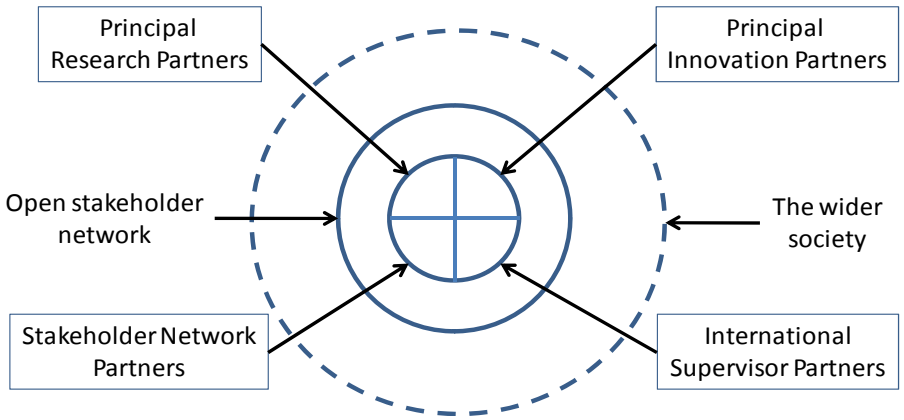

Figure 2. The involvement of partners and stakeholders in the project. The core consists of the Principal Research Partners (PRP, responsible for the Research Components of the project), the affiliated Principal Innovation Partners (PIP, responsible for specific innovation tasks; for

example development of ARLA's "Closer to Nature" strategy, advisory services developed by ALECTIA, or new planning forms developed with the municipalities), the International Partners (IntP, responsible for supervision) and the Stakeholder Network Partners (SNet) who have already confirmed their contribution to specific tasks in the alliance. An open stakeholder network will be developed during the project, as will communication to the wider society.

B11 The participating parties, project management and the alliance centre function

The alliance consists of Principal Research Partners, Principal Innovation Partners, International supervision Partners, Stakeholder Network partners included from the beginning of the project (Table 4), and an open stakeholder network for new partners to join during the project (see Figure 2, and Appendix C and E for more information).

Table 4. List of partners from the beginning of the alliance, and their contribution to the project.

Abbreviation	Role	Partner name	Contribution
AGRO	COOR PRP	Aarhus University (AU), Department of Agroecology (T Dalgaard, JE Olesen, N Hutchings, C Kjeldsen)	RC1-RC6
AGEC	PRP	University of Copenhagen (KU), Department of Agriculture and Ecology (LS Jensen, JK Schjørring)	RC4, RC6
GEO	PRP	KU, Department of Geoscience, Natural Resources and Planning (H Vejre, P Gundersen)	RC2, RC6
FOI	PRP	KU, Institute of Food and Resource Economics (B Jacobsen, J Dejgaard)	RC1, RC3, RC4.2, RC6
ENVS	PRP	AU, Department of Environmental Sciences (O Hertel, B Hasler, M Termansen, LB Hansen, R Peel)	RC3, RC4, RC6.
ARTS	PRP	AU, Department of Culture and Society, Arts (S Brock).	RC4.3, RC6
ALTERRA	PRP	Alterra, Wageningen, NL (W de Vries, G Reinds, H Kroes)	RC1, RC6
BIO	PRP	AU, Bioscience (JC Svenning, B Kronvang, HE Andersen)	RC2, RC3, RC6
HEALTH	PRP	AU, Department of Public Health (Torben Sigsgaard)	RC4.6, RC4.7, RC6
GEUS	PRP	Ministry of Climate and Energy, Geological Survey of Denmark and Greenland (Birgitte Hansen)	RC4.7, RC6
DAAS	PRP	The Knowledge Centre for Agriculture, Danish Agricultural Advisory Service (Irene Wiborg, Leif Knudsen).	RC4.4, RC5, RC6, RC2.1
ARLA	PIP	ARLA Foods a.m.b.a. (Anna Flysjö, Peter Enemark, Jan D. Johannesen, Jens Christian Flye).	RC1, RC4.4, RC5, RC6
HEDEDK	PIP	HedeDanmark A/S. One of the major entrepreneurs in the organic waste business (SA Sckerl and E Ervolder Olesen)	RC4.1, RC6
ALECTIA	PIP	Leading Danish Consulting Engineer in Sustainable development and restoration of the natural environment (www.alectia.com/eng, C Vesterager and JCS Jensen)	RC2, RC6
CONTERRA	PIP	Conterra Analyses and mapping; (Poul E Larsen) (SME developing landscape models and scenarios for use in planning and administration)	RC1, RC2, RC6
Horsens	PIP	Horsens Municipality (Inge Kristiansen)	RC4.3, RC6
MUNICIPAL	PIP	Varde, Skive, Jammerbugt and Odsherred municipalities	RC2, RC5, RC6
ORGREST	PIP	Brancheforeningen for Organiske Restprodukter (JR Schrøder) Industry organization representing all major companies in the organic waste recycling industry	RC4.1, RC6
YARA	PIP	YARA Danmark Fertilisers A/S (JJ Ulnitz)	RC4.4, RC5, RC6
VSP	PIP	Danish Pig Research Centre (BI Hansen and P Tybirk).	RC5, RC6
JRC	IntP	EU Joint Research Centre, Ispra, Italy (A Leip, F Bouraoui)	RC1
IIASA	IntP	Inst. of Applied Systems Analysis, Austria (W Viniwarter)	RC1
JHI	IntP	The James Hutton Institute, Scotland (M Stutter)	RC2, RC3, RC4.4
Uni-Kiel	IntP	University of Kiel, Germany (F Müller)	RC2
Uni-Leeds	IntP	University of Leeds, Geography Department, UK	RC3
Uni-E.Anglia	IntP	University of East Anglia, UK	RC4.2
WHO-Europe	IntP	WHO Europe, Healthy City Coordinator, Belfast (J Devlin)	RC4.3
USDA-ARS	IntP	United Nations, Beltsville, MD (Laura L. McConnell)	RC4.6
ReUseWaste	IntP	Marie Curie Training Network: Recovery and Use of Nutrients, Energy and Organic Matter from Animal Waste	RC4, RC5
CONCITO	SNet	Denmark's green thinktank (Thomas Færgeman)	RC6
DanishCrown	SNet	Danish Crown meat company (K Ch Møller)	RC6
NatureAalborg	PIP	The Danish Nature Agency, Aalborg	RC2, RC6

DHI	SNet	Danish Hydraulic Institute (A Erichsen and R Poulsen)	RC6
Experi	SNet	Experimentarium.dk, Hellerup (Morten Busch)	RC5
ANI-HUB	SNet	The Animation Workshop, Viborg (VJ Jensen), and Kollision Communication, Aarhus (A Lykke-Olsen)	RC5
Farm4you	SNet	Researcher for a day, Agro-Business Park, Foulum	RC5
EEA	SNet	EU Environmental Agency (J Martin and P Kristensen)	RC1, RC4
ADVICE	SNet	Local farm advisory centres: LandboNord, Gefion, Jydsk.	RC2, RC5
OfficeDoctors	SNet	Danish Health and medicines authority (Helene Bavnhøj Hansen, Public Health Medical Officers of Mid Jutland)	RC4.7
WaterAalborg	SNet	Aalborg Waterworks (Per Grønvald)	RC2, RC4.7
DTU-Food	SNet	Fødevareinstituttet, Danish Techn University (Gitte Gross)	RC4.3, RC6
DORS	SNet	Danish Economic Councils, The Environmental Economic Council (Jesper S. Schou)	RC3, RC6
DKSTAT/ EUROSTAT	SNet	Statistics Denmark (K Hjulsager, O Olsen), EUROSTAT (J Selenius)	RC1, RC6
CIRRAU	SNet	Nat. Centre for Register-Based Research (PB Mortensen)	RC2, RC4
BIOALL	SNet	BioRefinery Alliance (AG Holmsgaard)	RC6
ALLERGY	SNet	Danish Asthma and Allergy Society (J Sommer)	RC4.6
LUNG	SNet	Danish Lung Association (A Brandt)	RC4.6
DK-HEALTH	SNet	Danish Health Agency (L Keiding)	RC4.6, RC4.7
MEM-EPA	SNet	Danish Ministry of Env, Env. Protection Agency (CL Fogh)	RC4.6, RC6
MEM-Nature	SNet	Danish Ministry of Environment, Nature Agency	RC3, RC4, RC6
MAFF-Dept	SNet	Danish Ministry of Food, Agriculture and Fisheries (Regulator and administration of agriculture)	RC1, RC6
MAFF-Nature	SNet	Danish Ministry of Food, Agriculture and Fisheries, (Nature management in agricultural areas)	RC2, RC4, RC6

Alliance management

The management structure of the DNMARK Alliance will consist of an alliance board, an alliance coordinator and six RC coordinators (Figure 3).

DNMARK alliance board: This will be the forum for overall decision-making. Tommy Dalgaard will be the scientific and administrative coordinator of the alliance and chairman of the board. Professor Jørgen E Olesen will act as co-chair. A secretariat at AU-Agro will support the work of the coordinator and of the management board. A coordinator for each RC has been identified and will be a member of the board, together with selected members representing the business and stakeholder partners. DAAS is already represented on the board, and three more representatives from the Figure 2 DNMARK network will be elected at the beginning of the alliance. Both male and female representatives are thereby ensured. Moreover, a representative from one international institute will be elected and the PhD students and post-docs appointed within the project will also elect a representative amongst them for the alliance board. The alliance will be in close contact with a network of public institutions and private companies (see above).

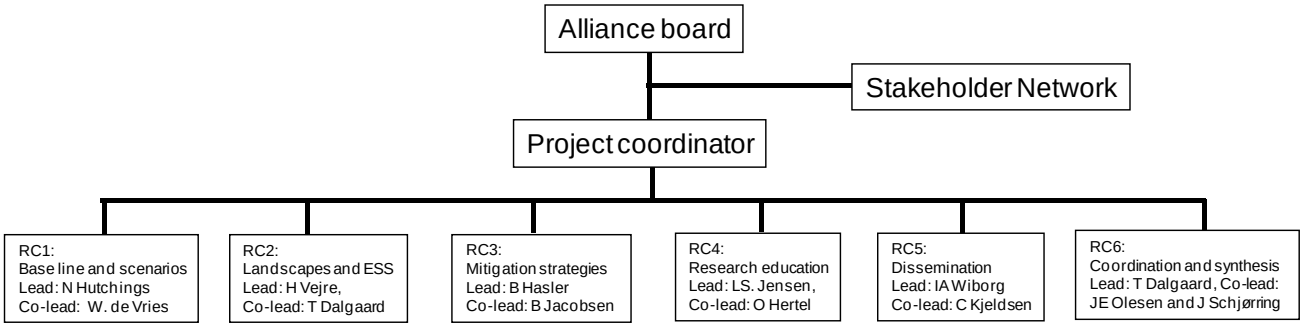

Figure 3. Organisational diagram.

The alliance will be constituted by the establishment of the board (see above), which will form the forum for decision-making for the overall research alliance strategy, contractual matters, procedural matters, etc. The board will also ensure that other ongoing and related R&D activities of the partners are coordinated and integrated into the alliance and ensure efficient

collation and dissemination of results. At the first meeting, the board will set up a detailed Work and Dissemination Monitoring Manual, which will be confirmed by all participants at the first workshop. The board will meet at intervals of three months and assess progress in relation to milestones and the work and dissemination monitoring manual. For the benefit of the international member, the board will mostly meet via videolink/Skype. At least once a year, there will be a physical meeting of the board, immediately following an alliance workshop.
Alliance coordinator: Tommy Dalgaard has proven through his leading roles in national and EU-funded research and from seven years of leading a research group of more than 20 people, that he can efficiently manage research with many involved partners from different countries and institutions. This has, for example, included the role of landscape component A1 activity leader in NitroEurope (www.nitroeurope.eu). The alliance coordinator will maintain a detailed work and time schedule to be approved by the board and will be responsible for implementing board decisions. The coordinator will prepare the status report and the final report, together with the RC leaders. The responsibility also includes the contact with The Danish Council for Strategic Research.
The RC leaders: will have the responsibility of identifying opportunities for collaboration between members of their RC, for attracting new members to the Network and for reporting on progress within the RC to the alliance coordinator.
Progress monitoring and risk contingency: The release of funds will depend on the achievements in relation to the Work and Dissemination Monitoring Manual. The DNMARK coordinator will collate inputs from RCs and prepare a half-yearly progress report describing current achievements, plans for the next period, and difficulties and their possible solution; decisions will be taken on the basis of these reports. AU AGRO will maintain regular contact with all partners and key experts involved to ensure timely commitment to the research alliance tasks, a uniform and high quality of the deliverables, and to guarantee good links between all contributions. The risk caused by dependency between RCs and subsequent deliverables is reduced via the inclusion of ALTERRA and JRC/IAASA, basing RC1 on existing model frameworks with low risk of failure or delay. The risk from problems with recruitement of PhDs and post-docs is met, making the whole project independent on single PhD projects, and via the attachment of more than one experienced researcher to each post-doc, PhD-project and RC coordination task. The web-based file and information system Sharepoint, hosted at the DNMARK intranet webpage server, will be used to transfer information smoothly and efficiently between partners. This is important because of the different geographic locations of the institutes and stakeholders both inside and outside Denmark.
DNMARK Secretariat: will be staffed by Lene Kirkegaard (secretary) and Jytte Christensen (IT and web-design), both AGRO. Together with Inge Harbo (project accounts, audits etc.) they will form the daily management team, and organize workshops, write minutes, and ensure timely receipts of contributions to deliverables and timely contributions to documents. Auditor Inge Harbo will be responsible for the audit of the project accounts and follow up to ensure timely receipt of payment and financial reports.
National and international relations: To consolidate the contacts with international alliance partners and encourage international institutions to join the network of the alliance, the alliance coordinator will visit a number of leading international institutions involved in N budgeting and N management at landscape and national scales. The visits will include at least two international DNMARK partners and will commence after the initial workshop. The duration of the visits will vary but may be of an extended nature (e.g. to provide time to analyse data and draft a scientific paper). During these periods, the alliance coordinator will be in contact with alliance participants through regular electronic contact. Otherwise, the alliance will be represented by co-chair professor Jørgen E Olesen. The research partners will link to and draw upon a network of existing national and international projects, centres and alliances with which they are involved. The principal function of these links is to enable the DNMARK alliance to identify and quantify the major nitrogen flows at a range of scales, and how these may be managed to increase nitrogen use efficiency and reduce losses of nitrogen to the environment. Nationally, these links include among others the following:

- The DSF-funded *Centre for Regional change in the Earth System (cres-centre.net)*; better understanding of the interaction between climate change and natural processes, incl. N cycling, and the implications of this interaction for the need for adaptive responses in a wide range of human activities.
- The DSF-funded strategic research alliance *CLEANWASTE (www.cleanwaste.dk)*; development of high-tech methods for the treatment of animal manure and the application of a systems approach to the management of nutrients in animal manure.
- The Danish Research Council for Technology and Production-funded *Foliar nitrogen fertilization of wheat crops;* investigating the possibilities for reducing risks of leaf burning and increasing nitrogen use efficiency**.**
- The *Centre for Sustainable Agriculture and Forestry Systems (safor.ku.dk)*; a platform for partnership between university, industry and authorities, to utilize research on sustainable and acceptable use of natural resources in agriculture and forestry.

Internationally, these links include the following:

- The EU Joint Programming Initiative project on Climate Change Risk Assessment for European Agriculture and Food Security (www.macsur.eu).
- The EU FP7 project *LegumeFutures*; the aim of this project is to develop and assess legume-supported cropping systems that raise the economic and environmental performance of European agriculture.
- The EU FP7 project *SMARTSOIL*; effect of farming practices on soil organic matter in general and carbon sequestration in particular. The project includes a study of the long-term soil and crop management in different farming systems on both C and N cycling.
- The EU Marie Curie Initial Training Network *ReUseWaste - Recovery and Use of Nutrients, Energy and Organic Matter from Animal Waste;* development of manure management systems and new technology for sustainable utilization of valuable organic matter, energy and nutrient resources.
- The NMR-funded project *Developing and applying a high spatial and temporal resolution ammonia emission inventory for the EMEP model* The aim is to extend the high resolution NH_3 emission inventory developed for Denmark
- The EU FP7 project INEMAD; concentrates on innovative strategies to reconnect livestock and crop production farming systems. New flows of energy and materials within the agricultural sector (or linked to the agricultural sector) for re-thinking the relation between crop and livestock production

Links to international policy advice will be made via the international Stakeholder Partners. In particular, the alliance will inform and will receive feedback from the UN Task Force on Reactive Nitrogen (TFRN) and the UN Task Force on Emission Inventories and Projections (TFEIP). Both these task forces are established under the UN Convention on Long-Range Transboundary Air Pollution (CLRTAP) but the TFRN relates also to the EU Nitrates Directive and both have close links to the EU National Emissions Ceilings Directive. More specifically, this alliance will use the participation of a number of its members in the Expert Panels of the task forces – the Expert Panels on Nitrogen Budgets and Mitigation of Agricultural Nitrogen under TFRN and the Agriculture and Nature Expert Panel under TFEIP.

The coordination of DNMARK from AGRO ensures a close relationship to Aarhus University's research-based policy advice in relation to nitrogen and food production, which is hosted in the department (and the newly established Danish Centre for Food and Agriculture, DCA). AGRO's role in this centre includes special coordination roles within the areas of plant production, agriculture and environment, bioenergy, organic farming, climate, natural resource management. Moreover, Tommy Dalgaard is acting head of the MSc education programme in Agro-Environmental Management at AU and is thus in close contact with university education in Denmark – highly relevant to DNMARK. Finally, Jørgen E Olesen chairs the Food and Agriculture group of CONCITO (Denmark's green think tank), and is member of the current Danish Commission on Nature and Agriculture (http://www.naturoglandbrug.dk/) giving access to key policy stakeholders in the area.

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