Urban Europe and NSFC

Europe – China joint call on Sustainable Urbanisation in the Context of Economic Transformation and Climate Change: Sustainable and Liveable Cities and Urban Areas

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UNCNET

Urban nitrogen cycles: new economy thinking to master the challenges of climate change

Combined report on the Final Stakeholder workshop, covering:

D8/2: Final workshop recommendations & report
D8/3: N budgets for urban planning &
Report (meeting transcript) of experience obtained from the respective approaches
D8/4: Report on practitioner interaction

Due date of deliverable: **01/08/2022** Actual submission date: **02/07/2022**

Start Date of Project: **01/04/2019** Duration: **35+6 months**

Organisation name of co-chairs for this deliverable:
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Dissemination Level		
PU	Public	☒
PP	Restricted to other programme participants (including funding agencies)	☐
RE	Restricted to a group specified by the consortium (including funding agencies)	☐
CO	Confidential, only for members of the consortium (including funding agencies)	☐

1. Executive Summary

An important aspect of the project is the applicability of the results in practice. For this reason, it is important to involve stakeholders and potential users at an early stage in the process in order to jointly develop practical approaches. In connection with the elaboration of nitrogen budgets a dialogue process with relevant stakeholders was started in the city of Vienna and the small town of Klagenfurt in Carinthia. In both cities / regions stakeholders have been identified during an intense stakeholder mapping process.

The first two workshops were held virtually in November 2020 using the communication platform Zoom and the virtual whiteboard Miro. At this stage of the project, primarily the background and objectives of the project as well as first project results were presented and discussed. In addition, it was important to identify the stakeholders' requirements for the project.

Based on the results of two workshops, the next workshop series took place on October 11 in Klagenfurt and on October 14 in Vienna. In addition to a review of the already further developed nitrogen budgets, approaches for practical implementation were primarily identified and further elaborated.

On May 31. all results have been compiled in an international conference in Vienna. To this event, the stakeholders who were already involved in the process during the previous workshops were invited in the first place. However, some new stakeholders also participated. In addition, scientists from the Expert Panel on Nitrogen Budgets under the UNECE Air Convention who had a meeting in Vienna the next day also took part. Especially this mixture of practitioners and scientists led to interesting results.

At the conference the promising outcomes of the UNCNET project were presented. In particular, the comparison between the Viennese nitrogen budget with those of Zielona Góra in Poland and the cities of Shijiazhuang and Beijing in China provided much material for discussion.

In a fishbowl discussion, the project results were jointly analysed and discussed. In the process, existing approaches to practical implementation were further developed and new ideas and solutions were identified. In general, the stakeholders were very interested in the project and showed a high willingness to actively participate.

2. Objectives of WP8:

- Identification of relevant stakeholders in Vienna and Klagenfurt (Austria)
- Preparation of scientific (interim) results and information for stakeholders
- Obtaining feedback from stakeholders on the project and first results in order to optimise the further course of the project

- Development of ideas, approaches for possible implementation projects/programmes and a possible applicability in practice
- Identification of further research needs and the necessary prerequisites to advance the topics further
- Elaboration of a final report with recommendations for next steps

3. Method and activities:

3.1 Stakeholder mapping

In coordination with the project management two stakeholder maps for Vienna and Klagenfurt were prepared, in order to identify the relevant stakeholders. According to the project structure stakeholders were selected from the areas agriculture and nutrition, waste and sewage water, clean air and climate protection, soil and biodiversity. Based on the mapping, about 50 to 100 stakeholders have been invited to the four Stakeholder Workshops in Vienna and Klagenfurt in November 2020 and October 2021.

With regard to the final stakeholder conference the existing stakeholder maps have been further developed. Especially companies and stakeholders from the surrounding areas of the cities were added. Finally, about 200 stakeholders from Vienna, Klagenfurt have been invited to the Stakeholder conference, which took place on May 31, 2022.

3.2 Information materials

In order to familiarize stakeholders with the issues covered in UNCNET, a specific document has been created (as a flyer posted at www.uncnet.org, Public Project Repository). Originally in German language, the flyer has been translated into English and will be made available also in Polish and Chinese to appropriately address the local interest groups.

To reach not only stakeholders, but also broad sections of the population, it is also important to disseminate information in a low-threshold and unconventional way. Therefore, a set of post-cards with project-specific and, above all, topic-specific information and results has been created. This set was distributed to the participants of the different workshops and is also available at www.uncnet.org.

3.3 Stakeholder Workshops

Stakeholder involvement in the UNCNET project took place primarily within the framework of three rounds of workshops, which pursued different objectives, depending on the progress of the project.

3.3.1 Workshops series 1

The first two workshops were held in November 2020. One – the pilot study – in Klagenfurt and the other one in Vienna. Due to the prevalent situation of the COVID-19 pandemic, the project partners decided to switch to a virtual workshop format. This format allowed a virtual workshop room to be opened via the Zoom. In parallel, the participants worked with the virtual whiteboard Miro.

At this stage of the project, primarily the background and objectives of the project as well as first project results were presented and discussed. In addition, it was important to identify the stakeholders' requirements for the project.

Procedure: After the presentation of the project and the first research results, the participants split into two breakout sessions (Agro-Food-Chain & Combustion-Chain). The following questions were addressed:

- Are there any questions of understanding?
- Is something missing from your point of view?
- What results in what form do I expect from the nitrogen balance?
- Are there any points of reference for my work practice?
- What (which data) can I contribute?

The results of the working group were then presented in the plenum, discussed together and summarized again.

3.3.2 Workshops series 2

Based on the results of the first two workshops, the next workshop series took take place in fall 2021, on October 11 in Klagenfurt and on October 14 in Vienna. In addition to a review of the already further developed nitrogen budgets, approaches for practical implementation were primarily identified and further elaborated.

Procedure: In contrast to the first stakeholder workshops held virtually, the second workshop for experts and decision-makers took place on-site in Vienna and Klagenfurt. A plenary discussion and in the meantime small group discussions were conducted. Guiding question:

- General impression of the graphics?
- Are the numbers realistic?
- Where are the biggest accumulations/problems?
- What can be done to close loops?
- Are the topics about which information is provided appropriate?
- Are the slogans appealing?
- What information should still be developed?
- What are the biggest challenges of the future regarding nitrogen?

- How can nitrogen be communicated in an appealing way?

3.3.3 Stakeholder conference

On May 31. 2022 all results have been compiled in an international stakeholder conference in Vienna. It was a hybrid event with the possibility to participate both online and in person. A total of 49 people participated in the conference, 21 of them via Zoom.

To this event, the stakeholders who were already involved in the process during the previous workshops were invited in the first place. However, some new stakeholders also participated. In addition, scientists from the Expert Panel on Nitrogen Budgets under the UNECE Air Convention who had a meeting in Vienna the next day also took part. Especially this mixture of practitioners and scientists led to interesting results.

Procedure: At the beginning of the conference the promising outcomes of the UNCNET project were presented. In particular, the comparison between the Viennese nitrogen budget with those of Zielona Góra in Poland and the cities of Shijiazhuang and Beijing in China provided much material for discussion.

In a fishbowl discussion, the project results were then jointly analysed and discussed. In the process, existing approaches to practical implementation were further developed and new ideas and solutions were identified. In general, the stakeholders were very interested in the project and showed a high willingness to actively participate.

4. Results:

4.2 Stakeholder structure

In the course of the stakeholder mapping, attention was paid to a balanced distribution of stakeholders both thematically (agriculture, waste management, energy, mobility, etc.) and structurally (authorities, NGOs, companies, etc.). A total of 104 people participated in the stakeholder workshops with the following distribution among the different stakeholder groups:

- Authorities (23 persons): primarily from city, state and federal environmental and agricultural departments.
- NGOs (12 people): mainly environmental NGOs from the climate protection sector.
- Research and science (48 persons): universities and research institutes worldwide. However, this high number is mainly due to the participation of the Expert Panel on Nitrogen Budgets at the conference.
- Companies (9 persons): companies from the water, energy and chemical sector (fertilizers)
- Stakeholder organisations (7 persons): mainly from agriculture and industry
- Urban planners (5 persons): number includes traffic planners

It can be seen that scientists and authorities in particular have the strongest connection to the topic of nitrogen and were therefore recruited in greater numbers for the stakeholder process.

The rather low number (compared to the invitations) of companies that came to the workshops is striking. Only companies where nitrogen plays a role in the core business, such as the wastewater treatment plant operator of the City of Vienna or the fertilizer manufacturer Borealis seemed sufficiently interested in the topic. It is therefore also important to make other companies with a strong connection to nitrogen, for example in the area of energy production or mobility, more aware of the topic, for example by better highlighting problems and correlations. A business circle in cooperation with an economic interest group could be a suitable measure.

4.3 Stakeholders' demands on the project

The majority of stakeholders were impressed by the idea and implementation of nitrogen budgets. Especially in the first two workshops (both in Klagenfurt and in Vienna), the stakeholders formulated their wishes and demands on the project, which could partly be considered in the project elaboration. Here is a selection of the contributions and suggestions:

- In the context of material cycles, such as the nitrogen cycle, holistic considerations / approaches are necessary: It is very much welcomed that sectoral approaches can be merged through the elaboration of nitrogen budgets.
- The results are awaited eagerly by the City of Vienna. Particularly in the area of waste management, it is hoped that data, facts and arguments will help to better tackle the problem of food waste, for example.
- Urban mining from sewage sludge is a major topic and is currently being implemented as part of a pilot project in Vienna. Perhaps the nitrogen balances can provide new inputs and impulses in the direction of N-recycling.
- Important (from the Viennese point of view): Establish context to the Viennese situation, to "Viennese possibilities for action".
- Findings on "Which greenhouse gas emissions are caused in Vienna" would be interesting. What is our responsibility in this respect, consumption etc.?
- Establish value / shares for the Viennese greenhouse gas balance. Differentiate production-based and consumer-based emissions (the latter referring to emissions caused by consumers but occurring in distant areas)
- Think cross-sectoral, consider systemic approach
- As solid as possible, updated balance in coordination with the balance of the city of Vienna (Emi-Kat). Provide "action items", an action-oriented summary
- While OMV -refinery, as situated in the surrounding area of Vienna, is not included in the Vienna emission inventory, it needs to be covered in the modelling; data of OMV are accessible in the electronic data management.

- What conclusions can be drawn from this? Where do we have to start in concrete terms? Results would therefore be interesting for strategy processes
- Move away from Vienna-centrism: which findings can be drawn also for smaller cities that have other infrastructure than Vienna.
- Choose new perspectives: This representation allows a new level of observation. In this way, connections or problems can be recognized and analyzed from one perspective.
- Show potential for closing loops: Especially the type of nitrogen is relevant to discuss reuse or recycling; example surrounding area: sewage sludge is treated and reapplied to the field.
- Balance Vienna surrounding area: If the system boundary was extended to all of Lower Austria, the balance would probably look different. Input from animals/dairy significantly greater with greater nitrogen accumulation, as well as leaching or volatilization in this area.

4.4 What practical approaches for Nitrogen Budgets were identified?

An important focus of the stakeholder engagement was the "reality check" of the nitrogen budgets. Therefore, the question should be answered: Can nitrogen budgets be practically applied or support stakeholders in their daily work? Here is a selection of the findings:

- Practical example of N-Recycling is sewage sludge spreading: In some parts of Austria, e.g. in Carinthia it is permitted on agricultural land, regulated by a provincial ordinance - Carinthian sewage sludge and compost ordinance. The problem with sewage sludge is rather in the phosphates than nitrogen.
- In the implementation of N-budgets, the regional approach is of great importance. Create priority regions: e.g. focus on KEMs (climate and energy model regions) or KLARs (climate change adaptation regions) or e5 (energy regions); cross-border consideration is necessary.
- N-budgets would make a valuable contribution to biodiversity management. Information on N-release and N-input via air plays an important role for certain ecosystems. Input of N into ecosystems often shifts the species spectrum. For example, in the Danube National Park, grassland is a priority-habitat very sensitive to nitrogen inputs.
- Importance of food waste prevention Action (Food Plan) - data and results would be underpinning the work of Vienna's municipal departments
- Nitrogen Budgets could deliver meaningful information for the Austrian climate council, especially in the field of waste management and circular economy
- For strategy development in other municipalities/cities, the further development into a user tool as a basis for the elaboration of measures or prioritization of them would be interesting.
- There are already national nitrogen footprints existing. But nitrogen budgets show different things than footprints. Budget shows where N release happens and where pollutants are. What remains open is what environmental impacts to estimate at various points. 1t of nitrogen can be well recycled or lead to overturning of water bodies depending on where it is found, so there is a dependence on location.

- Composting and organic waste: The assumption is that a lot of private composting is done. In Carinthia, residual waste ends up in the organic waste container, so composting is usually not done well. However, green waste is collected. If you have a garden, you are obliged to compost, but residents often do not. A lot of compost is carried into the forest (no data on this) or composted incorrectly. Actually, the municipality would be responsible to control this. Some is also thrown into the toilet. The EU regulation states that no organic waste may be fed to animals. Regulations are aimed at mass animal operations.
- Phosphorus and nitrogen must be seen together to describe eutrophication. Example: Baltic Sea Helsinki Commission for the Protection of the Baltic Sea (HELCOM) governs the international convention to deal with pollution of the Baltic Sea; for this purpose, national nitrogen balances are also a useful tool.
- INMAP (Integrated Nutrient Management Action Plan) serves as a tool for the EU to achieve the goals of the Farm to Fork Strategy and the Biodiversity Strategy. The plan makes use of nitrogen budget data.
- Comparable with nitrogen budgets, the global accounting of nitrous oxide shows that the sources and sinks fit well and that the understanding of the processes may be better than previously thought. Nitrous oxide (N_2O) is a relatively stable gas that remains in the atmosphere for a long time, similar to CO_2.Although primarily from agricultural sources, industrial releases are also of interest, especially because favourable measures could be taken here (but have not been implemented due to lack of legislation). For example, the production of adipic acid (needed to make nylon) accounts for 1-2% of global emissions; Visp, Switzerland, is home to a chemical plant that, at least until last year, released nitrous oxide equivalent to 1% of total Swiss greenhouse gas emissions – a fact that was only detected by accident.
- Possible indicators based on nitrogen budgets: Imports per inhabitant (polluter pays principle) or inputs per unit area (impact). Questions to be considered in the comparison: is a city's contribution greater or less than another city? Or than the global average?
- Compliance with emission ceilings: For nitrogen oxides and ammonia, there are significant exceedances in many countries; this can also be broken down to regions and cities. Nitrogen budgets are a useful tool to illustrate this and evaluate the benefits of measures.
- Impacts on sensitive terrestrial ecosystems: Nitrogen balances provide important information here. For example, for the critical loads of nitrogen oxides and ammonia. What quantity is still acceptable here? There are significant contributions in this area also by the Austrian Federal Environment Agency.
- Recovery of reactive nitrogen: today we are still far from reactivating the usable components in Wastewater - big hygienic, sanitary problems; big need for research.
- As long as cheap natural gas is available, with low CO_2 tax, it is more attractive to extract nitrogen from the air than to rely on recycling.
- Urban fluxes of nitrogen: Urban nitrogen budgets could also be used to validate emission inventories.
- Comparison of nitrogen problem & climate crisis, both exceeding the planetary boundaries: If no new reactive nitrogen were introduced by humans, the nitrogen problem would be

solved relatively quickly by natural degradation processes. In contrast to the climate crisis, even if CO_2 emissions were to be completely stopped, greenhouse gases (CO_2) would continue to persist in the atmosphere and continue to cause increased temperatures - which would lead, for example, to the continuous melting of glaciers. The magnitude and impact of the climate crisis will be increasingly felt in the coming decades, especially if emissions continue.

- Awareness raising: The nitrogen problem is hardly perceived as a threat potential by the population, but also not by politicians. This is despite well-known major negative effects on health and the environment negative aspects, such as water eutrophication, overfertilization; ammonia emissions (source of particulate matter). The main task here is to create awareness and sensitize people, for example through campaigns, public relations work or educational measures. Microplastics can serve as a successful example for raising awareness.
- Image problem of agriculture: Awareness-raising measures should also help agriculture to get out of its defensive position. Above all, research is challenged to offer solutions to agriculture, but also agriculture to understand its own activities in such a way that they become part of an environmentally sound solution.
- Climate and energy regions with a focus on the circular economy: The results of the project should definitely be made available to the climate and energy regions so that they can be inspired to do something about the issue of nitrogen. The question should also be clarified: how can the regions profit from the results? And with which measures can one produce which effect.
- Role of the authorities: The present project can only offer starting points for concrete activities of authorities. Political activities (ordinances, laws) are only realistic if authorities themselves commission studies. On the one hand, this would highlight the problem and lay a foundation for further planning and action.
- International initiatives: Germany, Sweden, Estonia, Latvia, Denmark and Switzerland have all provided national N budgets already, at least for some sectors. In general, not so many countries are involved yet, and there is no public discourse.
- Look at the big picture: Measures must be well thought out, otherwise there is only a shift of problems from one area to another. In the agricultural sector in particular, nitrogen must be used in a targeted and effective manner to minimize waste. Here, too, awareness must prevail that nitrogen is a valuable resource.
- Closing loops: Currently, it is mainly end-of-pipe solutions that are successful. It is therefore more important to close the loops and to recycle or reuse reactive nitrogen. However, there are still many open questions and a great need for research, especially for the recycling of nitrogen.
- Cooperation with agriculture: The topic must be brought into the agricultural sector. Currently, there is already 25% organic farming in Lower Austria. It is also extremely important to cooperate with the educational sector (especially BOKU – University of Natural Resources and Life Sciences, Vienna and University of Applied Sciences Wieselburg).

4.5 Challenge of digital stakeholder engagement in times of Covid 19

Due to the Covid-19 pandemic, two stakeholder workshops (Workshop series 1) were held online using the communication software Zoom and the Miro whiteboard. Although the final stakeholder conference was held as a hybrid event. Only Workshop series 2 workshops could be conducted with the physical presence of the participants in a classical manner.

Holding digital meetings and workshops has several advantages:

- Low time requirements and the elimination of travel to and from the meeting usually means that more participants are present.
- Participants can attend from anywhere (including home office).
- People with reservations about physical contact (e.g. Covid 19) can participate.
- The chat function allows moderators and participants to communicate effectively, even if, for example, a presentation is in progress.
- After a training session, participants can operate the online tools. In addition to the newly gained skills, there is often a certain fun factor.
- Certain moderation tools, such as assessments or queries, can be made very effective online.
- In the course of breakout sessions, smaller rounds with greater interaction between participants are also possible

On the other hand, digital events also bring challenges:

- Due to less commitment, there is a high cancellation and drop out rate.
- Interpersonal communication (small talk), especially during breaks, is eliminated. In practice many contacts require such informal settings.
- Conversations / presentations / communication with a counterpart leave a stronger impression.
- Certain formats (like fishbowl or world cafe) only work in physical meetings.
- Especially in larger meetings, not all participants can be reached or involved throughout. Facilitators do not have the opportunity to react to non-verbal signals.
- Different settings, movements in the room etc. encourage interaction and creativity. This is only possible to a limited extent online.
- Technical disruptions or deficits often lead to delays and irritations.

In summary, the involvement of stakeholders in the form of online meetings and workshops using special tools such as Miro or Menti works well, but also has its limits.

Especially in a smaller context, when the participants come from one region or city, it makes sense to hold at least the kick-off event physically. The advantages, especially in terms of variety of methods and interpersonal interaction, clearly outweigh the disadvantages here.

Hybrid meetings are a good option for larger, supra-regional or international events. Ideally with a joint introductory part and differentiated interaction tools between the physical participants and the online community. At the end of the event, both groups can present their results to each other.

5. List of Documents/Annexes:

Minutes Workshop I and II Klagenfurt (see deliverables D8/1a and D8/1b)

Minutes Workshop I and II Vienna (see deliverables D8/1a and D8/1b)

Minutes Stakeholder conference Vienna (Annex 1)

Postcards – Awareness rising tool (Annex 2)

Annex I

Minutes Stakeholder conference Vienna

Stakeholder Conference Vienna

Urbane nitrogen cycles:

Innovative approaches,

to meet the climate crisis

Minutes

Location: The Vault Vienna, Schadekgasse 5/6, 1060 Vienn

Date: 31.05.2022

Financed: JPI Urban Europe

Moderation:

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Project title	UNCNET Stakeholder Conference
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Participants via Zoom	Susanne Schmidt (The University of Queensland) Barbara Amon (Leibniz-Institut für Agrartechnik und Bioökonomie) Anna Bazan (University of Zielona Góra) Bill Bealey (UK Centre for Ecology & Hydrology) Shabtai Bittman (Agriculture and Agri-Food Canada) Boris Boincean (Selectia Research Institute of Field Crops, Moldavia) Ulli Dragosits (UK Centre for Ecology & Hydrology) Xiangwen Fan (Chinese Academy of Sciences, Center for Agricultural Resources Research) Andrzej Greinert (University of Zielona Góra) Kentaro Hayashi (Research Institute for Humanity and Nature, Japan) Natalia Kozlova (IEEP – branch of FSAC VIM, St. Petersburg) Allison Leach (University of New Hampshire) Hanna Malchykhina (Institute for nature management National Academy of science of Belarus) Cristina Martin Hernandez (UK Centre for Ecology & Hydrology) Filip Moldan (IVL, Gothenburg) Mark Sutton (UK Centre for Ecology & Hydrology) Audric Vigier (UK Centre for Ecology & Hydrology) Lin Zhang (Peking University) Feng Zhou (Peking University) Anne Kasper-Giebl (TU Wien) Isaura Rabago (CIEMAT)
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1 Introduction

1.1 Executive project summary

Along with climate change and biodiversity loss, nitrogen is one of the three most important issues for our planetary boundaries. We have already crossed these three boundaries and the negative impacts are difficult to reverse.

The project Urban Nitrogen Cycles: New Approaches to Address the Climate Crisis (UNCNET) addresses this acute issue and is coordinated by the International Institute for Applied Systems Analysis (IIASA, Laxenburg). Project partners are the Chinese Academy of Sciences (China), Peking University (China), the University of Zielona Góra (Poland), brainbows informationsmanagement in Vienna and E.C.O. Institute for Ecology in Klagenfurt.

UNCNET investigates and compares nitrogen cycles in four cities - Vienna, Zielona Góra in Poland, and Shijiazhuang and Beijing in China. Especially in urban areas, the accumulation of nitrogen compounds leads to major problems. Ammonia and nitrate from imported food or nitrogen oxides from traffic and industry pollute air and water, accelerate climate change, impair biodiversity and endanger health. Especially in cities, many people are directly affected. On the other hand, it is precisely here that a better understanding of the interrelationships can help to make sustainable decisions and significantly improve the effectiveness of measures.

Further information: https://www.uncnet.org/

1.2 Stakeholder involvement in the project

An important aspect of the project is the applicability of the results in practice. For this reason, it is important to involve stakeholders and potential users at an early stage in the process in order to jointly develop practical approaches. In connection with the elaboration of nitrogen budgets a dialogue process with relevant stakeholders was started in the city of Vienna and the small town of Klagenfurt in Carinthia. In both cities / regions stakeholders have been identified during an intense stakeholder mapping process.

The first two workshops were held virtual in November 2020 using the communication platform Zoom and the virtual whiteboard Miro. At this stage of the project, primarily the background and objectives of the project as well as first project results were presented and discussed. In addition, it was important to identify the stakeholders' requirements for the project.

Based on the results of the first two workshops, the next workshop series took take place on October 11 in Klagenfurt and on October 14 in Vienna. In addition to a review of the already further developed nitrogen budgets, approaches for practical implementation were primarily identified and further elaborated.

On May 31. all results have been compiled in an international conference in Vienna. To this event, the stakeholders who were already involved in the process during the previous workshops were invited in the first place. However, some new stakeholders also participated. In addition, scientists from the Expert Panel on Nitrogen Budgets under the UNECE Air Convention who had a meeting in Vienna the next day also took part. Especially this mixture of practitioners and scientists led to interesting results.

1.3 Agenda of the Conference

9:00 to 10:00	Arrival of guests with coffee and cake
10:00 to 10:10	(4 pm Beijing time) Welcome
10:10 to 10:40	Keynote & discussion: Mark Sutton, UK Centre for Ecology & Hydrology
10:40 to 11:00	Keynote & discussion: Ika Djukic, Austrian Federal Environmental Agency
11:00 to 12:00	(5 to 6 pm Beijing time): Urban Nitrogen Cycles: new economy thinking to master the challenges of climate change, Wilfried Winiwarter and UNCNET project team in interaction with the audience
12:00 to 13:00	Lunch break
13:00 to 14:50	Knowledge café with working groups
14:50 to 15:00	(9pm Beijing time) Closing ceremony

1.4 Objectives

At the beginning of the conference the promising outcomes of the UNCNET project were presented. In particular, the comparison between the Viennese nitrogen budget with those of Zielona Góra in Poland and the cities of Shijiazhuang and Beijing in China provided much material for discussion.

In a fishbowl discussion, the project results were then jointly analysed and discussed. In the process, existing approaches to practical implementation were further developed and new ideas and solutions were identified. In general, the stakeholders were very interested in the project and showed a high willingness to actively participate.

The following objectives were pursued at the workshop:

- Information about the results and findings of the UNCNET project
- Discussion of the results. Where are the starting points for implementation in practice (climate protection programs, air pollution control plans, biodiversity programs, etc.)?
- Identifying solutions and approaches: Where are the biggest problems according to N at the moment? How can (urban) nitrogen budgets contribute to solving the problem? What do we need to master the challenges?
- Exchange of experience: different cities have different conditions and approaches. What can we learn from each other?
- Obtaining feedback and expectations of the stakeholders on the project.

1.5 Workshop method

Primarily, stakeholders who were already involved in the process during the previous workshops were invited to the conference. However, some new stakeholders also participated. In addition, scientists from the Expert Panel on Nitrogen Budgets under the UNECE Air Convention who had a meeting in Vienna the next day also took part. Especially this mixture of practitioners and scientists led to interesting results.

At the beginning of the conference the outcomes of the UNCNET project were presented. In particular, the comparison between the Viennese nitrogen budget with those of Zielona Góra in Poland and the cities of Shijiazhuang and Beijing in China provided material for discussion.

In a fishbowl discussion, the project results were then jointly analysed and discussed. Fishbowl is a method to efficiently discuss a topic in a large group.

The name of the event format comes from the seating arrangement of the participants. An inner circle of 3-6 discussing participants - the 'fish' - form the 'goldfish bowl', the fishbowl. Around this, spectators sit or stand in a larger circle. They observe the fish in the fishbowl.

Each observer can decide to participate briefly in the discussion. If, for example, they think that the discussion has come to a standstill and that their argumentation would bring fresh air into the discussion, he may leave his place in the leave his seat in the outer circle. He then takes a seat on the free chair in the inner circle and participates in the discussion. Afterwards, he leaves the inner circle again, returns to his observer's seat, thus giving another observer the opportunity to participate in the discussion.

The discussion is recorded in the form of bullet points for all to see (flipchart, wallpaper) and presented at the end of the event in the form of a summary.

The fishbowl method allows a large number of people to actively participate in a conversation. The technique thus promotes controversial and multi-layered discussion of one or more topics.

2 Results

2.1 Presentation UNCNET

After a keynote of Mark Sutton (UK Centre for Ecology & Hydrology) and Ika Djukic (Austrian Federal Environmental Agency) the UNCNET team presented the results of the project. The following presentations were made:

- Introduction The UNCNET project /concept (Wilfried Winiwarter)
- Results Urban Agriculture (Xiangwen Fan, Chinese Academy of Sciences) via zoom
- Results Waste and Wastewater (Monika Suchowska-Kisielewicz, University of Zilona Gora)
- Results Atmospheric transport (Lin Zhang. Peking University) via zoom
- Results Leaching and N effects (Feng Zhou, Chinese Academy of Sciences) via zoom
- Comparing cities, indicators (Katrin Kaltenegger, IASA)

2.2 Results “fishbowl discussion”

The fishbowl discussion started with the following persons in the inner circle:

- Christoph Resch (facilitation)
- Wilfried Winiwarter (IIASA)
- Katrin Kaltenegger (IIASA)
- Ika Djukic (Environment Agency Austria)
- Markus Geupel (German Environmental Agency)

About 30 observers sat in the outer circle. The free chair in the inner circle was very soon occupied and there was a lively exchange of discussants.
In particular, the following questions were discussed:

- Are we suffocating from nitrogen? Has the cycle gone off the rails? Where are the biggest problems at the moment?
- Especially in cities the accumulation of nitrogen compounds causes big problems. How can (urban) nitrogen budgets contribute to solving the problem?
- Different cities have different conditions and approaches. What can we learn from each other?

- Saving, recycling, smart technologies? What do we need to master the challenges?

Here is a summary of the discussion points:

Can we compare the Problem with the N-Cycle (too much reactive N) with the global warming problem (too much greenhouse gas)?

- Fortunately not, because the N-Cycle is not so much accumulating. This means that if we now stop to bind the nitrogen from the air, the cycle would become stable again in a few years. The situation is different with greenhouse gases: Carbon dioxide, for example, is broken down very slowly by the natural physical and biogeochemical processes in the Earth system. After 1,000 years, about 15 to 40 percent of it remains in the atmosphere.

Has the cycle gone off the rails? Where are the biggest problems at the moment?

- The current strategy – technical fixation of N through the Haber Bosch-method on the one hand, and conversion of fixed nitrogen back to molecular nitrogen such as in wastewater treatment on the other hand – is in total an inefficient process, as requiring energy and effort at two processes for a net zero effect. The challenge is to recover nitrogen at different points and thus close loops.
- Due to too much nitrogen compounds, we have global effects, but almost always need local solutions.
- Understanding of background nitrogen deposition / concentrations is necessary, to develop effective programs of measures.
- Agriculture has the largest impact (mineral fertilizers, methane emissions, etc.), followed by households and transport.
- At the moment only 8 percent of our income need to be spent on food (average for Netherlands, may be extrapolated to the European Union). This is only possible with a lot of technology (Haber Bosch method) and a lot of impacts (climate crises, water pollution etc.) > therefore tackle the problem at the source.
- We have a big lack of circular economy, especially in the Agro Food Chain.
- Phosphorous and Nitrogen Recycling are linked – at the moment technologies are being tested to recover both.
- Nitrogen Budgets can contribute significantly to the UN Sustainable Development Goals, the SDGs (targeting e.g. hunger, poverty, clean energy, climate change, water, biodiversity etc.)

Different cities have different conditions and approaches. What can we learn from each other?

- Comparison between cities (e.g., Vienna and Bejing) show different results from different productions etc. But we must take into account indirect emissions and consumer patterns → maybe then budgets will be more comparable.

Are there any other comparable nitrogen budgets?

- At the moment no other such evaluations of individual cities are known. But some countries work on national budgets. Beside the Austrian N-budget (see also presentation of Ika Djukic), there is a similar balancing system (N-budget) for Germany existing, as well as for a handful of other countries.
- Also consider: is the place of emission identical to the place of consumption?

Success Factor Awareness Raising

- We need more knowledge and more sensitivity in the general population about the nitrogen problem and the interrelationships.
- Important to point out: what are the direct threats? focus on pollution and health effects. Key message: “High N-Concentrations in the Environment are a major problem – also for our health”. Make it personal “it´s personal!”

Different approaches to make people aware of the topic

- N-Footprint of citizen could be good tool. But it could also be too much information for consumers because there are already different footprints existing. Are we asking too much from consumers? Putting in responsibility?
- N-Budgets to make people aware of its effects: applying → potential identification (eg. Wastewater…)
- SDGs are good tool to get people attention, make use of them to reach policy makers!
- Integrating SDGs into N-Budgets / impacts & footprints is a work in progress.
- Communication of N-topic → develop adapted communication measures for the different stakeholder groups (farmers, consumers, administration, etc.)

Game Chancer Pricing?

- At the moments prices (especially for energy) are rising rapidly. Especially the costs for agriculture / fertilisers are a big challenge → Therefore, we need a change process for farmers to a clever N-Use Management,
- Farmer will be a key factor to reduce N-emissions → awareness raising is needed

- Prices are an important tool to reduce the N-Emissions, but high pressure from retailers exists to maintain intensive agriculture.

Last round of questions for discussants / speaker

- **What is your Personal issue with N?**
- Jobwise
- Being a Vegetarian
- Fascinated by Haber Bosch method
- Relationship to waste management and biodiversity

What is your key message for multiplicators?

- N causes health problems and pollution (Nitrate, PM10…)
- N accelerates climate change
- N affects and changes ecosystems
- Live more ecologically and consume less
- We need to support farmers to develop best practise
- Eat no (or: less) meat
- We accumulate too much – also Nitrogen. That's not good for our health and our environment

2.3 Project output

The project results will be published as scientific results (paper), project reports and a summary of the results or sent to the experts.

Literature

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., De Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson. L.M., Ramanathan V., Reyers, B. & S. Sörlin (2015): Planetary boundaries Guiding human development on a changing planet. In: Science Vol 347/6223. [DOI: 10.1126/science.1259855]

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Winiwarter, W., Amon, B., Bai, Z., Greinert, A., Kaltenegger, K., Ma, L., Myszograj, S., Nohel, C., Schneidergruber, M., Suchowska-Kisielewicz, M., Wolf, L., Zhang, L. & F. Zhou (2020): Urban nitrogen budgets: flows and stock changes of potentially polluting nitrogen compounds in cities and their surroundings – a review. Journal of Integrative Environmental Sciences (NENS), Online Publication. [DOI: 10.1080/1943815X.2020.1841241]

3 APPENDIX

3.1 Presentation slides Keynote Mark Sutton

3.2 Presentation slides Keynote Ika Djukic

3.3 Presentation slides Introduction The UNCNET project /concept (Wilfried Winiwarter

3.4 Presentation slides Results Urban Agriculture (Xiangwen Fan, Chinese Academy of Sciences)

3.5 Presentation slides Results Waste and Wastewater (Monika Suchowska-Kisielewicz, University of Zielona Góra)

3.6 Presentation slides Results Atmospheric transport (Lin Zhang. Peking University)

3.7 Presentation slides Results Leaching and N effects (Feng Zhou, Chinese Academy of Sciences)

3.8 Presentation slides Comparing cities**,** indicators (Katrin Kaltenegger, IIASA)

Recent advances in international nitrogen governance

Mark Sutton
UK Centre for Ecology & Hydrology

Vienna Workshop 31 May 2022

@MarkNitrogen

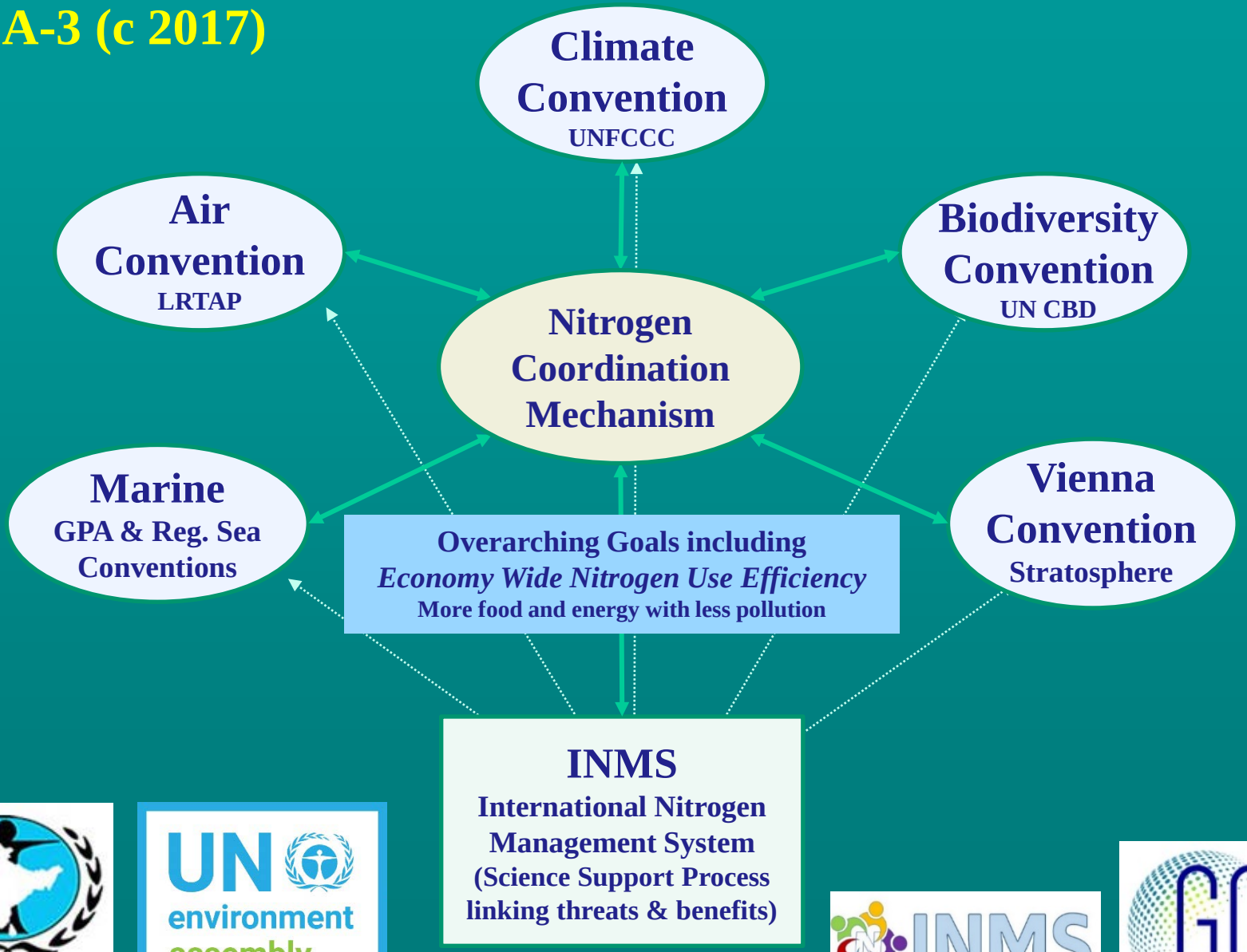
International Nitrogen Management System

A huge activity with significance progress….

- International Nitrogen Management System established (2016)
- GCRF South Asian Nitrogen Hub established (March 2019)
  - Regional championship for global transformation
- Resolution 4/14 on Sustainable Nitrogen Management adopted at 4th UN Environment Assembly (March 2019)
- Launch of UN Nitrogen Campaign ‘Nitrogen for Life’ under lead of President of Sri Lanka (October 2019)
  - Colombo Declaration agrees to work on national roadmaps with “ambition to halve nitrogen waste by 2030”, preparing for UNEA-5
  - First Nitro-Innovation Exhibition
  - Premiere of the Nitrogen Song with Grammy® winner Ricky Kej
- First e-briefing of the UNEP Nitrogen Working Group, developing the concept of a Inter-convention Nitrogen Coordination Mechanism (June 2020)
  - Formation of NWG Task Team on INCOM options
  - Review of INA progress
- COP26 *Redisovering Nitrogen* event with Sri Lanka and Maldives presidents
- UNEA5.2 – Accelerating action with the new nitrogen resolution…

Towards Regional & Global Nitrogen Coordination

View from UNEA-3 (c 2017)



SACEP

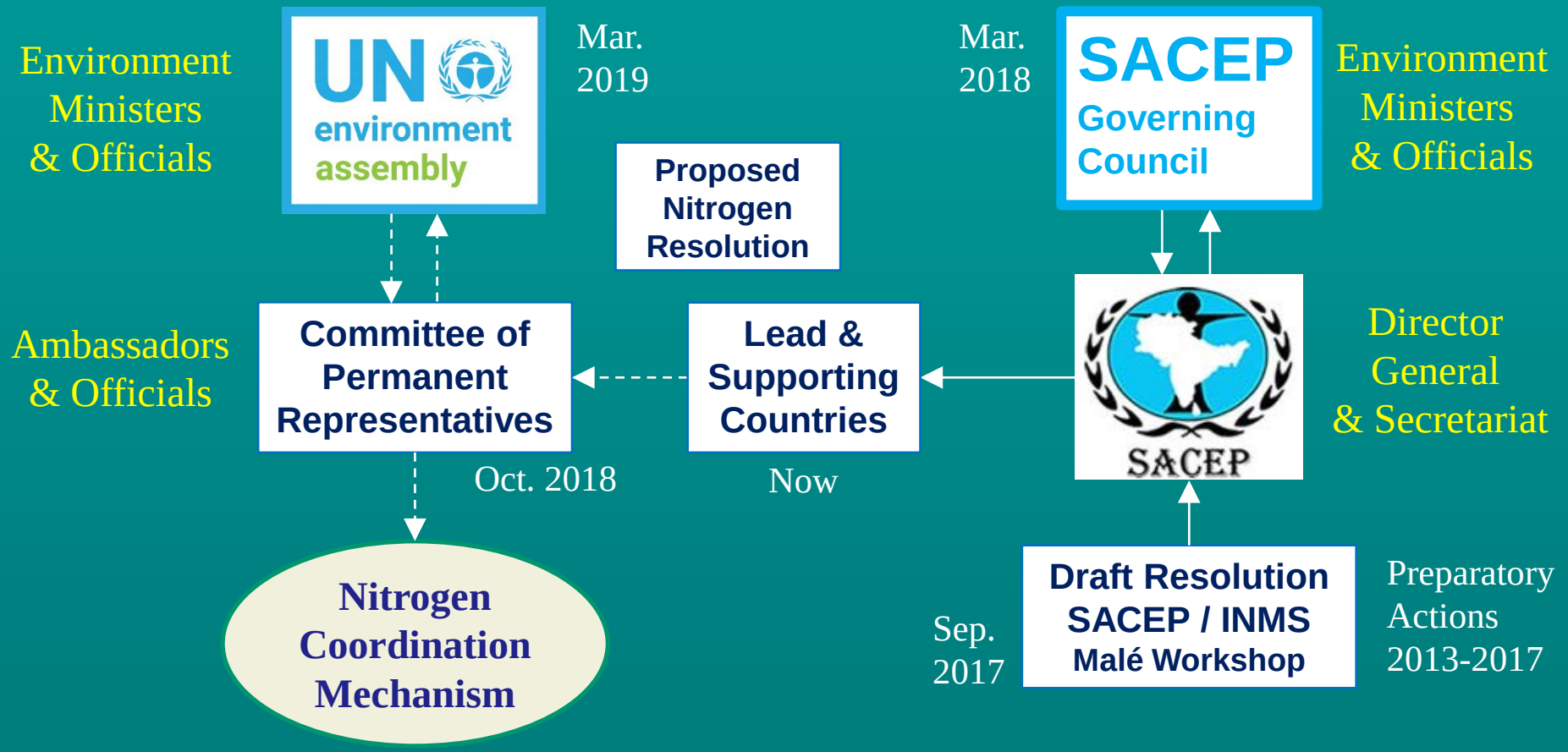
UN environment assembly

INMS

GCRF
Global Challenges Research Fund

Nitrogen Champions

Pathways from South Asia to the World



UNEP/EA.4/L.16
Distr.: Limited
9 March 2019
Original: English

United Nations Environment Assembly of the United Nations Environment Programme

Resolution UNEP/EA.4/L.16 agreed UNEP/EA.4/Res.14 final

United Nations Environment Assembly of the United Nations Environment Programme
Fourth session
Nairobi, 11–15 March 2019

Sustainable nitrogen management*

The United Nations Environment Assembly,

Recognizing the multiple pollution threats resulting from anthropogenic reactive nitrogen, with adverse effects on the terrestrial, freshwater and marine environments, contributing to air pollution and greenhouse gas emissions, while acknowledging the benefits of nitrogen use for food and energy production,

Recognizing also that global crop production in the world and the world's food security is dependent on nutrients, including nitrogen and phosphorus resource use,

Calls on the Executive Director of the United Nations Environment Programme to:

(a) Consider the options to facilitate better coordination of policies across the global nitrogen cycle at the national, regional and global levels, including consideration of the case to establish an intergovernmental coordination mechanism on nitrogen policies, based primarily on existing networks and platforms and consider the case for developing an integrated nitrogen policy, which could enhance the gravity of common cause between multiple policy domains,

We, the
Ceremoni
'Nitrogen

Recognizi
Ministries
stakehold

1. Endorse the proposed Roadmap for Action on Sustainable Nitrogen Management 2020-2022, including its activities as one of the instruments to establish an Inter-convention Nitrogen Coordination Mechanism and secretariat to better facilitate communication and coherence across nitrogen policies, consistent with mandates of existing conventions and MEAs,

2. Call upon UN agencies and other international organizations, development partners, philanthropic agencies, academic and civil society organizations, to support the implementation of this Declaration, through the establishment of mechanisms of cooperation to mobilize human, financial and technical resources, including capacity building and transfer of know-how and technology, for this purpose;

3. Agree that countries should consider, in line with their national circumstances and where relevant, to:

   3.1 Develop and implement comprehensive policies on Sustainable Nitrogen Management;

   3.2 Develop national roadmaps for sustainable nitrogen management, with an ambition to halve nitrogen waste by 2030;

   3.3 Conduct comprehensive assessments on quantitative and qualitative nitrogen cycling covering scientific aspects, policy, regulation and implementation;

   3.4 Promote innovation on anthropogenic nitrogen use and recycling, emphasizing the opportunities for the circular economy;

   3.5 Sensitize the citizens to understand the natural nitrogen cycle and how anthropogenic activities alter its balance;

   3.6 Identify the best of descended traditional agricultural wisdom and assess the opportunities offered for nitrogen management, where appropriate mainstreaming it through policy, implementation and regulatory channels;

   3.7 Cooperate to submit a joint resolution to the Fifth Session of the United Nations Environment Assembly; and

Confusing terminology of multiple Roadmaps

- The UN-wide process to follow up UNEA 4/14 resolution
  - *"Roadmap for Action on Sustainable Nitrogen Management 2020-2022"* (presented to CPR Oct 2019 and endorsed by CD-SNM)
- Sustainable Nitrogen Action Plans at national scale
  - CD-SNM: *"national roadmaps"*
  - UNEA 5/2 resolution: *"Member States to share information on national action plans…"*

Title of this meeting… Roadmaps or Action Plans…

Evolving narratives for nitrogen action

Stage 1: Reduce nitrogen pollutants

- Fragmentation across N forms (N_2O, NO_x, NH_3, NO_3…)
- Missing critical synergies that can motivate action

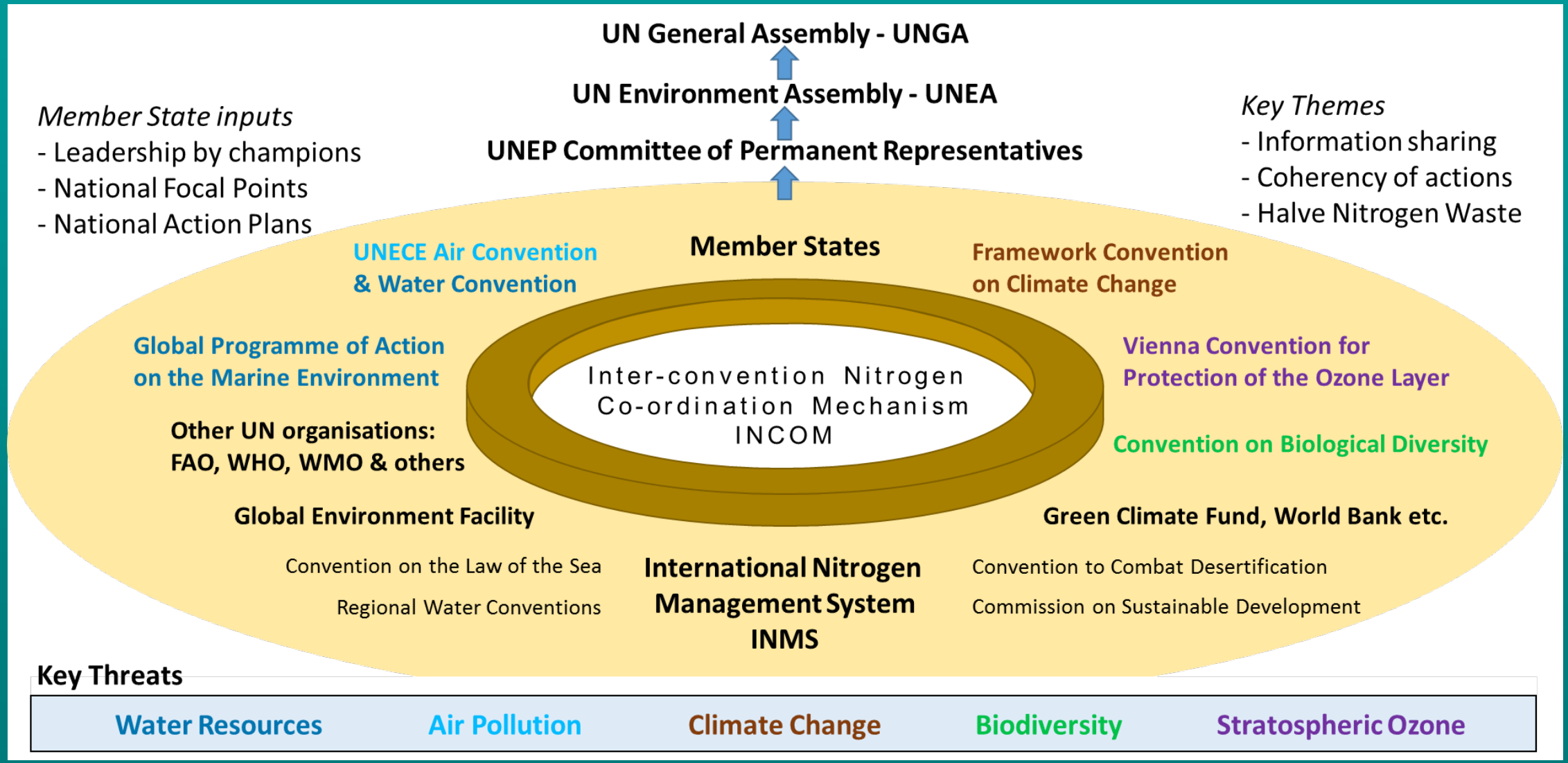
Stage 2: Increase nitrogen use efficiency

- A positive approach with economy-wide potential, but hard to set shared goals

Stage 3: Reduce wasted nitrogen resources

- Sums losses of all N forms, including denitrification to N_2
- Allows equitable shared goals, fosters circular economy

Establishing an intergovernmental process on nitrogen



Sutton et al. The Nitrogen Decade *One Earth*, January 2021

What do we really mean by waste?

PHYTOLOGIA;

OR THE

PHILOSOPHY

OF

AGRICULTURE

AND

GARDENING.

WITH THE THEORY OF DRAINING MORASSES,

AND WITH AN

IMPROVED CONSTRUCTION OF THE DRILL PLOUGH.

By *ERASMUS DARWIN, M.D. F.R.S.*

AUTHOR OF ZOONOMIA, AND OF THE BOTANIC GARDEN.

LONDON:

PRINTED FOR J. JOHNSON, ST. PAUL'S CHURCH-YARD;

BY T. BENSLEY, BOLT COURT, FLEET STREET.

1800.

3. A third queſtion here preſents itſelf, if the recrements of vegetable and animal bodies buried a few inches beneath the ſoil undergo the ſame decompoſition, as when laid on heaps in farm-yards.

Defining ‘nitrogen waste’ :

Guidance Document on Integrated Sustainable Nitrogen Management

- Summary for Policy Makers
  “A distinction is made between unreactive atmospheric dinitrogen (N_2) and reactive nitrogen forms (N_r), which represent valuable resources. Around 80 per cent of anthropogenic N_r production is ***wasted*** *as air and water pollution and through denitrification back to N_2.”*
- Para 78: *“Although emission of gaseous N_2 does not lead directly to adverse environmental effects, its release can be considered as a waste of the energy used to produce N_r, as well as a lost resource of useful nitrogen, indicating the need for N_2 emissions to also be addressed.”*
- Para 113, Box III.1 on Metrics *“**total ‘nitrogen waste’, this being the sum of all nitrogen losses to the environment (including N_2 and all N_r forms)”**.*

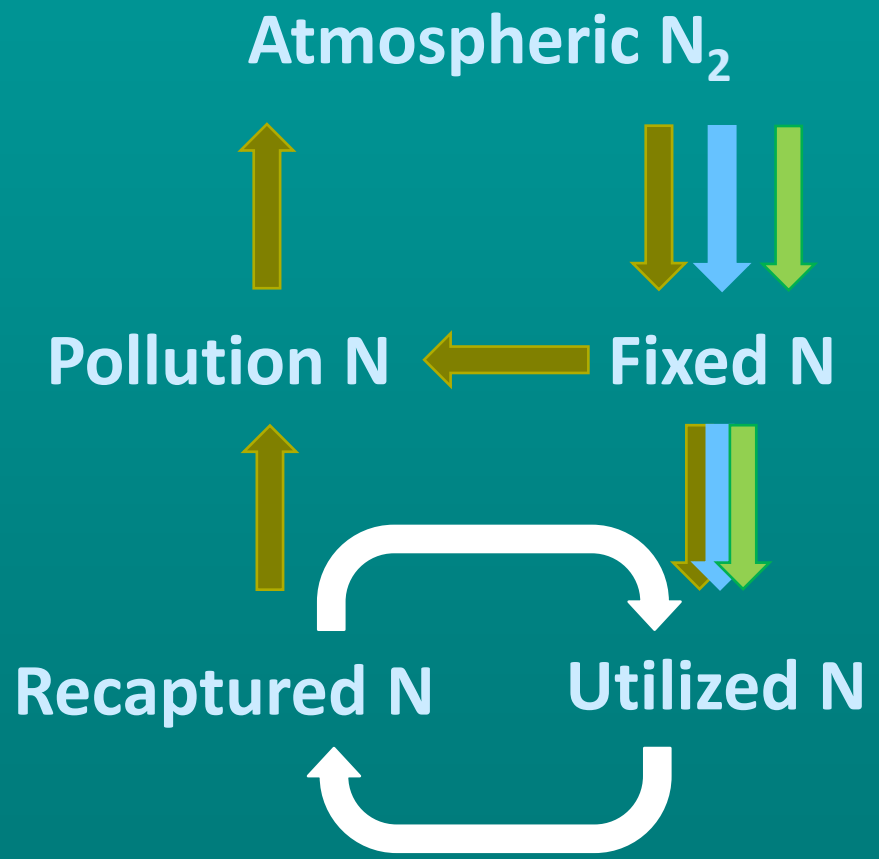
$$\text{Reduction in total N waste} = \frac{(\text{Reference N waste} - \text{Revised N waste})}{\text{Reference N waste}} \quad \text{(percentage)}$$

ECE/EB.AIR/149 Adopted Dec 2020

UNECE Task Force on Reactive Nitrogen

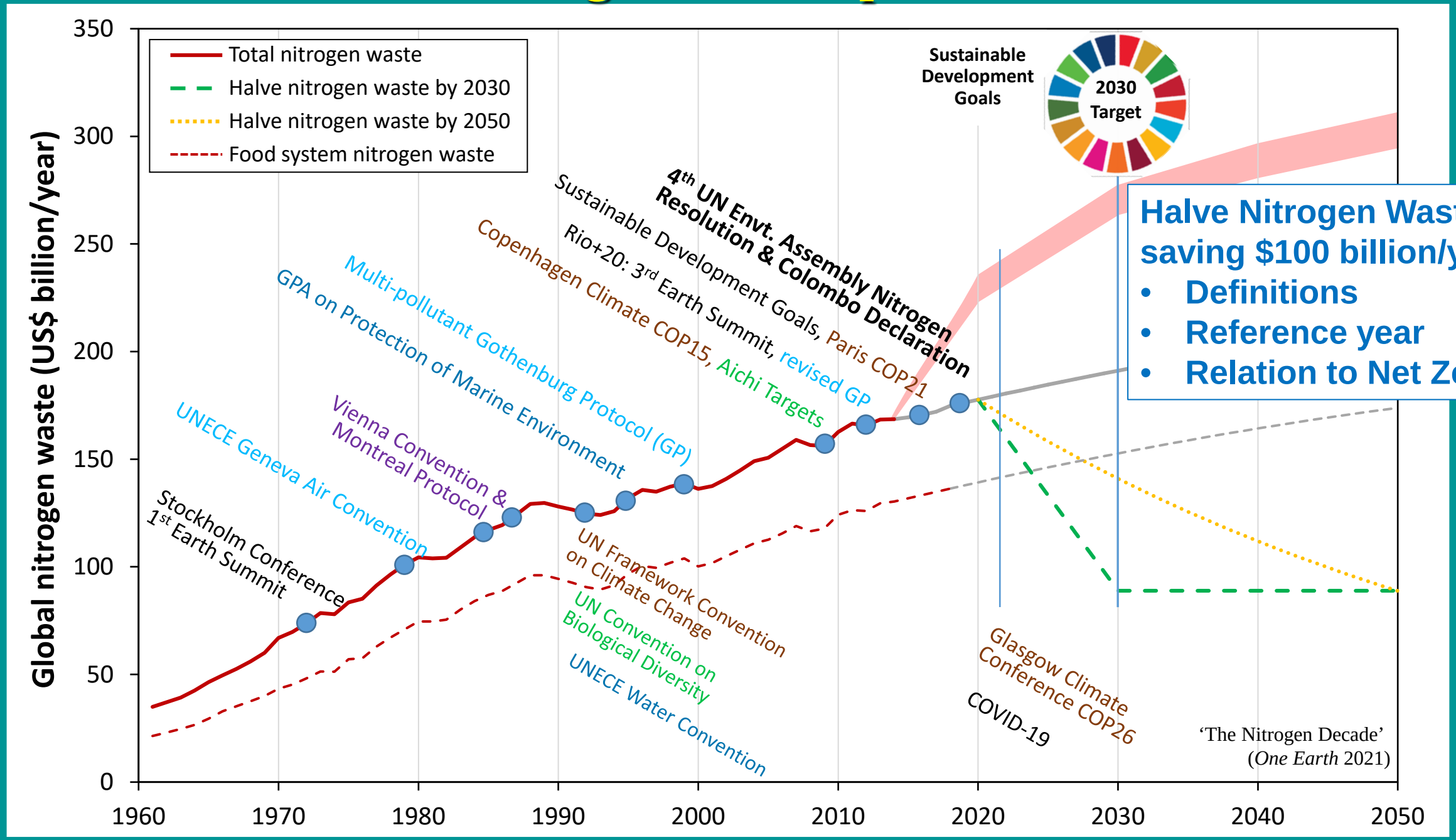
Nitrogen innovation for the circular economy

- **Agriculture** Less nitrogen waste means more available for food production, allowing inputs to be reduced
- **Industry** Gaseous nitrogen recovery for cleaner air & circular economy
- **Wastewater** Nutrient recovery & recycling for innovative products – future fertilizer factories
- **Landscapes** designed for C & N co-benefits (water, air, climate, nature, resilience…)
- **Reduced Food-Prints** for healthy & sustainable diets



A new opportunity for '**white ammonia**'

Global nitrogen waste – past & future



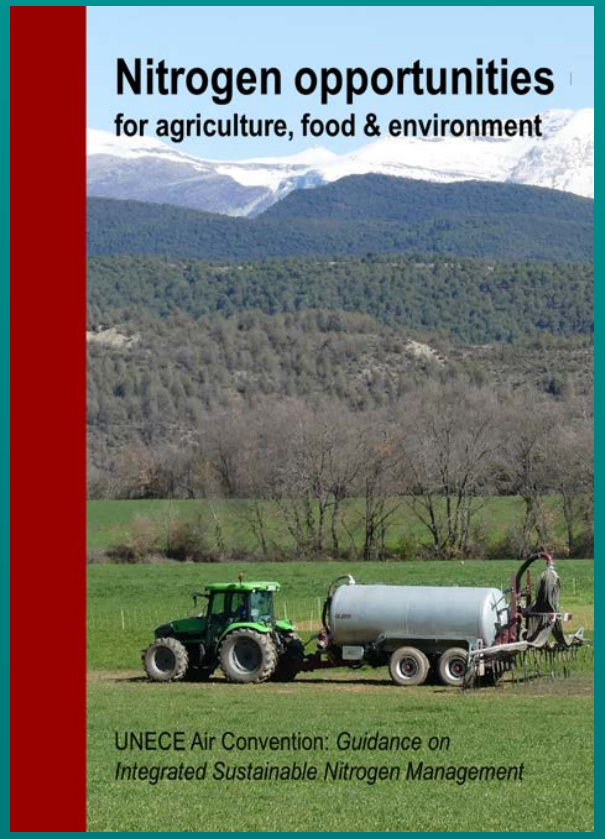
Next Steps: Conventions and Programmes

UNECE Gothenburg Protocol

- **UNECE Air Convention:** Gothenburg Protocol review underway, possible protocol revision process starting in 2023
- Task Force on Reactive Nitrogen key tasks 2022-2023
  - Dissemination of the UNECE Guidance Document on Integrated Sustainable Nitrogen Management
  - Report on methane – ammonia interactions (joint with TFEIP)
  - Review of Parties implementation of Annex IX on ammonia (synthesizing questionnaire results)
  - Revision of the UNECE Ammonia Guidance Document (later the Ammonia Framework Code)
  - Completion of the Appetite for Change report on mobilizing action on dietary change
  - Publication of the UNECE Guidance Document on National Nitrogen Budgets (updated and finalized in partnership with INMS (need agree date for submission to enable adoption by UNECE).
  - Establishment of INMS Portal for National Nitrogen Budgets, for UNECE region and globally
  - Options for parties to inform possible revision of Annex IX on ammonia, inc nitrogen dimension

UNECE Guidance Document on Integrated Sustainable Nitrogen Management

- 24 principles; 76 measures
- Adopted by UN Air Convention (Dec 2020)



ECE/EB.AIR/149

UNECE Task Force on Reactive Nitrogen

INMS

Dietary Measure 5: Adapt protein intake in diet (poultry)

Housing Measure 1: Immediate segregation of urine and faeces (cattle)

Manure Measure 2: Covered storage of slurry (natural crust & impermeable base)

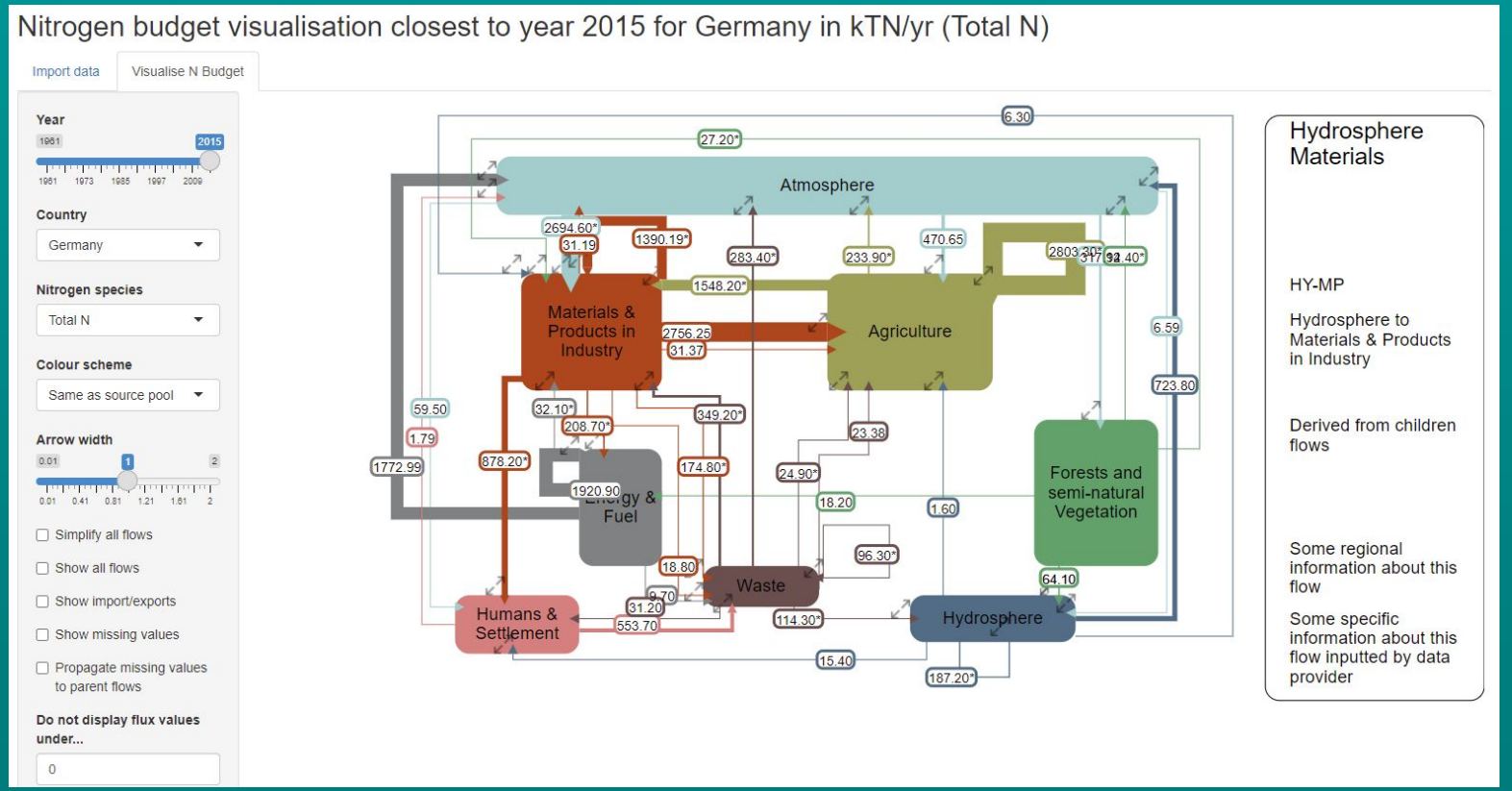
Nutrient Recovery Measure 5: Ammonia stripping and recovery

Field Measure 14: Nitrification inhibitors (with inorganic fertilizers)

Landscape measure 8: Drainage management

Global Reporting and Dissemination of National Nitrogen Budgets

- A developing tool under GEF/UNEP ‘Towards INMS’ project
- Testing and mobilization phase: looking for pilot countries
- Further development as part of future GEF/UNEP ‘Mobilizing INMS’ project.



Nitrogen budget visualisation closest to year 2015 for Germany in kTN/yr (Total N)

Import data | Visualise N Budget

Year
1961 — 2015
1961 1973 1985 1997 2009

Country
Germany

Nitrogen species
Total N

Colour scheme
Same as source pool

Arrow width
0.01 — 1 — 2
0.01 0.41 0.81 1.21 1.61 2

- [ ] Simplify all flows
- [ ] Show all flows
- [ ] Show import/exports
- [ ] Show missing values
- [ ] Propagate missing values to parent flows

Do not display flux values under...
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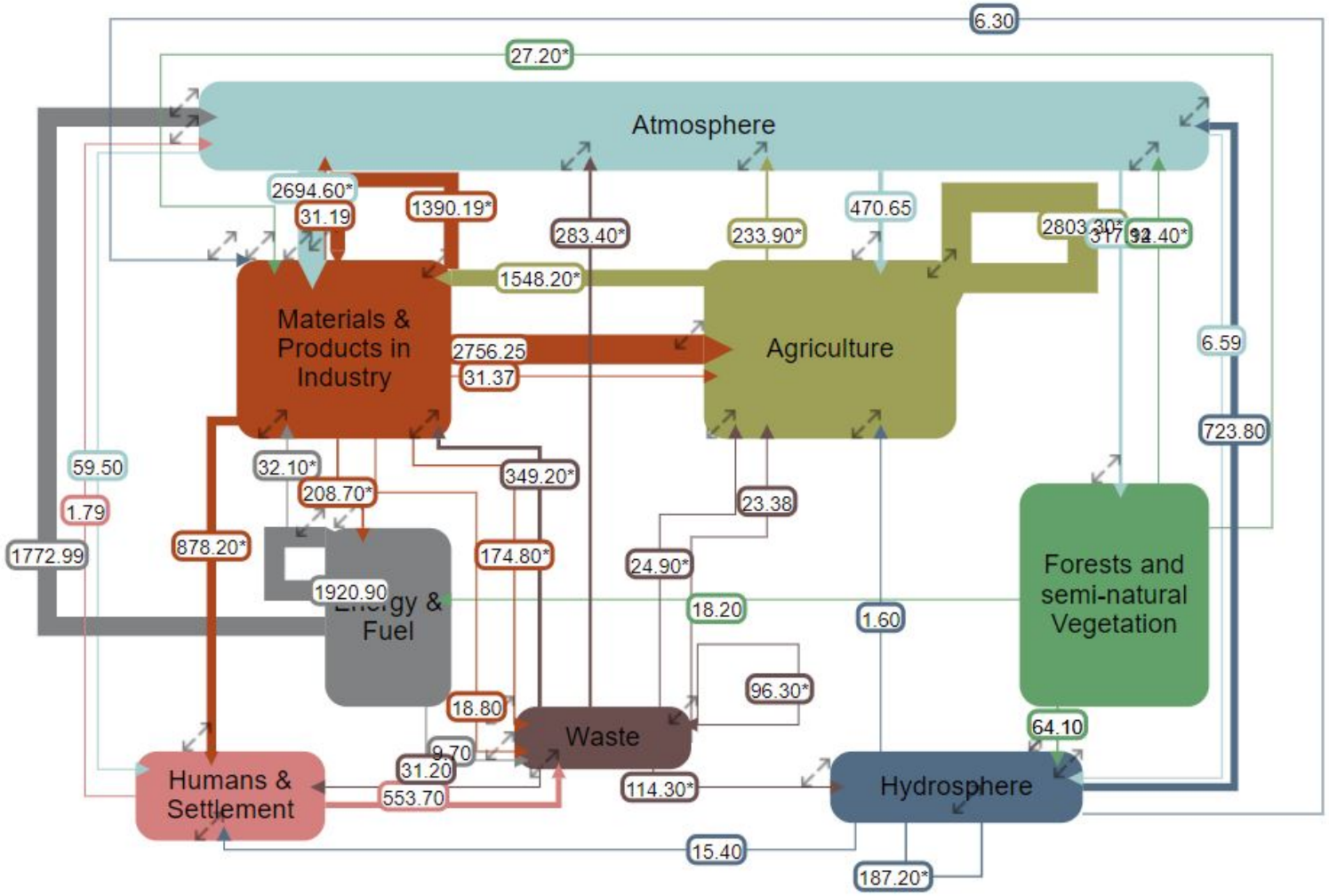


Hydrosphere Materials

HY-MP

Hydrosphere to Materials & Products in Industry

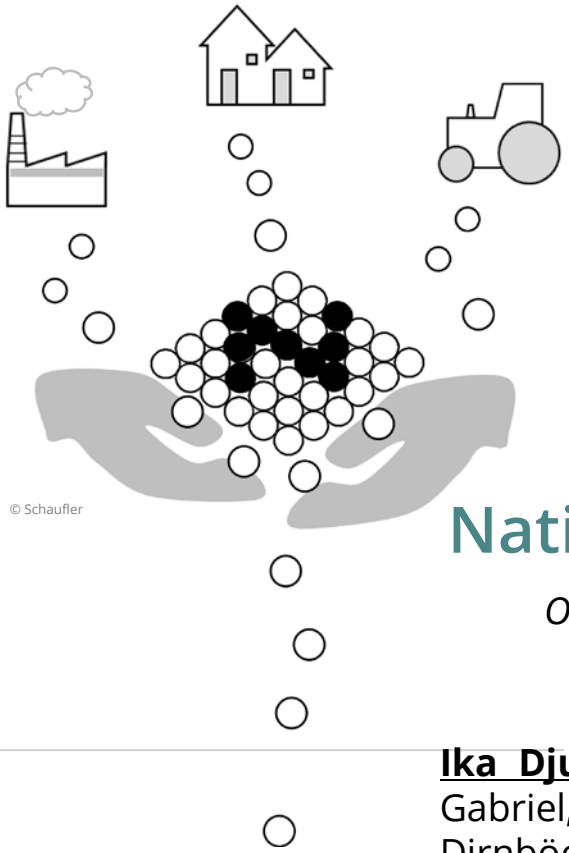
Derived from children flows

Some regional information about this flow

Some specific information about this flow inputted by data provider

Next Steps: Conventions and Programmes
UNEP Nitrogen Working Group (NWG)

- **June 2022 Next meeting of Task Team for INCOM.** To agree draft report on options for NWG
- **July 2022 NWG-2.** National Focal Points (NFPs) to consider options report from Task Team & provide feedback.
- **Sept 2022 WG-3 in person** (2-day hybrid) meeting at UNEP in Nairobi. Papers in advance (inc on INCOM related options, National Action Plans, INA, UN Nitrogen Campaign.
- **29 Sept 2022 CPR-159, in person** (hybrid) at UNEP in Nairobi. Developing consenus on INCOM options/modalities with Parties. Agreement on next steps and meetings in run up to UNEA-6
- **Spring 2023** next NWG meeting. Discussion on UNEA resolution
- **Autumn 2023** Proposed INA launch to member states at CPR.
- **Feb 2024** UNEA-6 with new resolution on sustainable nitrogen management.



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National N-Budget – an Austrian Case Study

On behalf of Federal Ministry Republic Austria (BMK): V/9 Sustainable development and awareness raising

Ika Djukic, Harald Loishandl-Weisz, Carina Broneder, Julia Tanzer, Oliver Gabriel, Bettina Schwarzl, Simone Mayer, Nicole Mandl, Peter Weiss, Thomas Dirnböck, Stephan Poupa, Christoph Lampert

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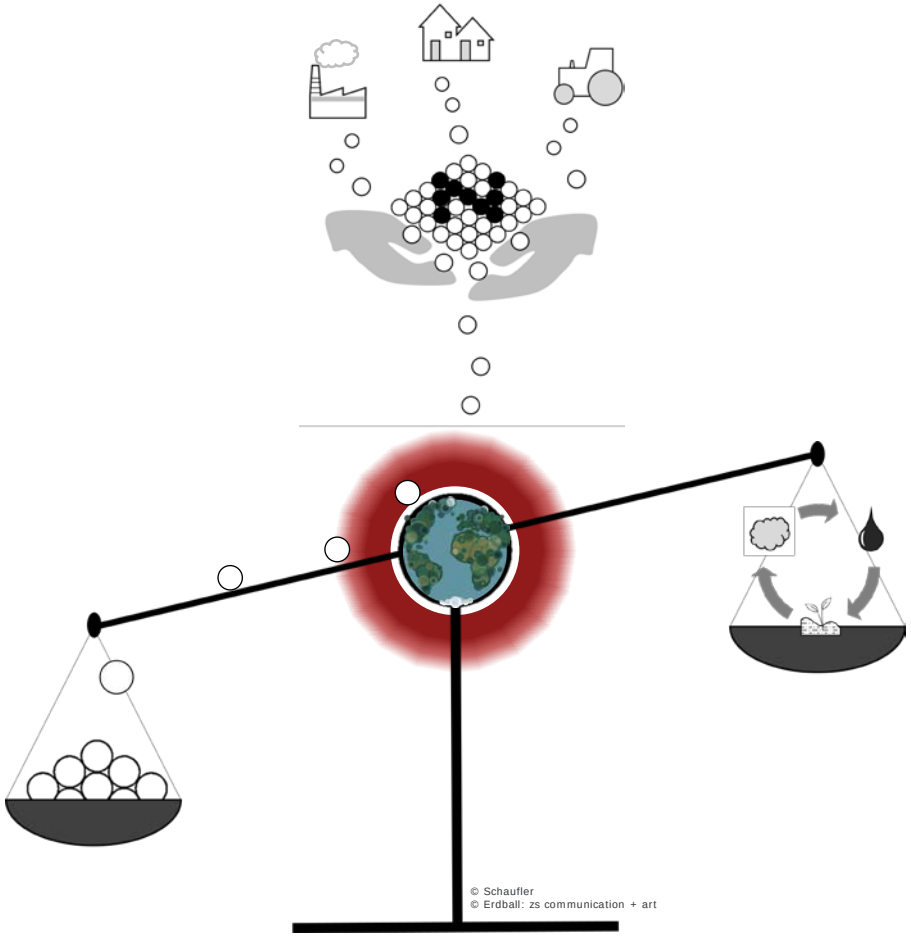

N reactive species:

- Ammonium (NH_4^+)
- Nitrate (NO_3^-)
- Nitrite (NO_2^-)
- Ammonia (NH_3)
- Nitric oxide (NO)
- Nitrogen dioxide (NO_2)
- Nitrous oxide (N_2O)

PLANETARY BOUNDARIES

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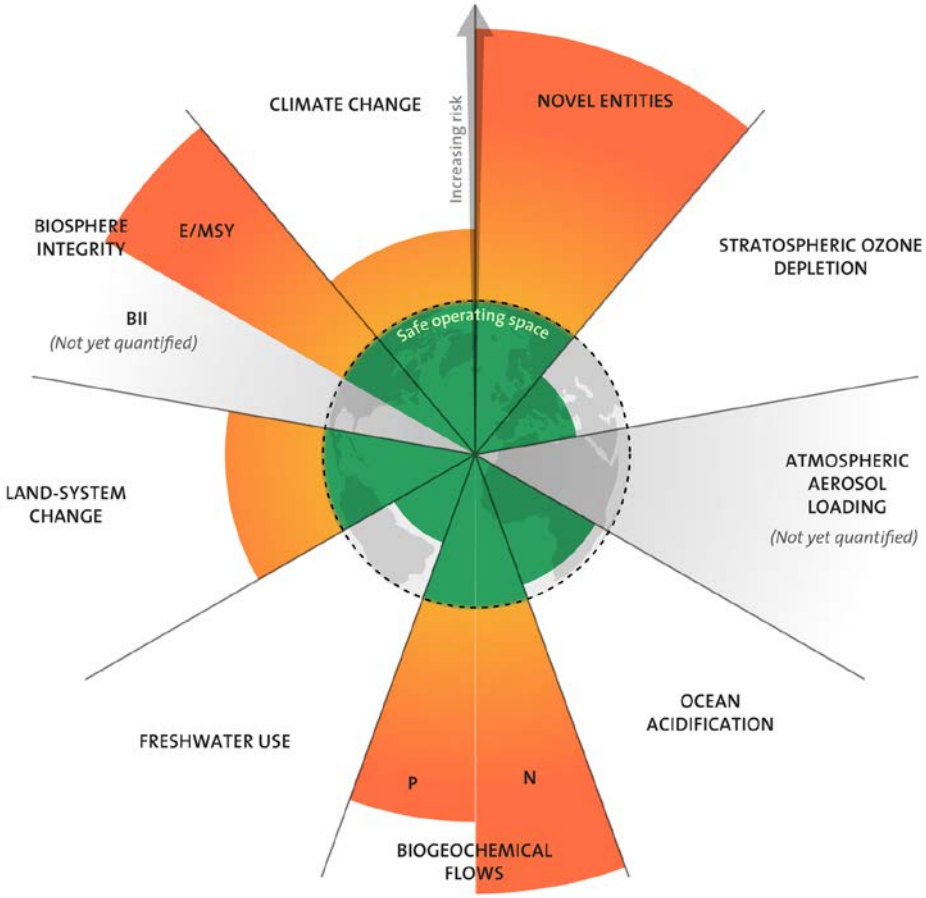

© Designed by Azote for Stockholm Resilience Centre, based on analysis in Persson et al 2022 and Steffen et al 2015

INTEGRATED N-MANAGEMENT

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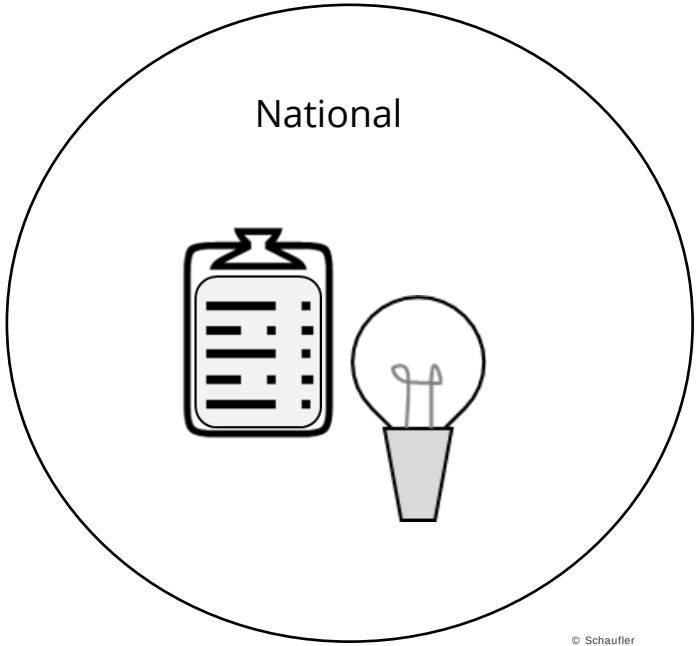

- Quantifying fluxes
- Understanding of the system
- Identifying needs for action
- Evaluating measures & achievement of sectoral goals
- Identifying synergies of actions
- Communication tool

INTEGRATED N-MANAGEMENT

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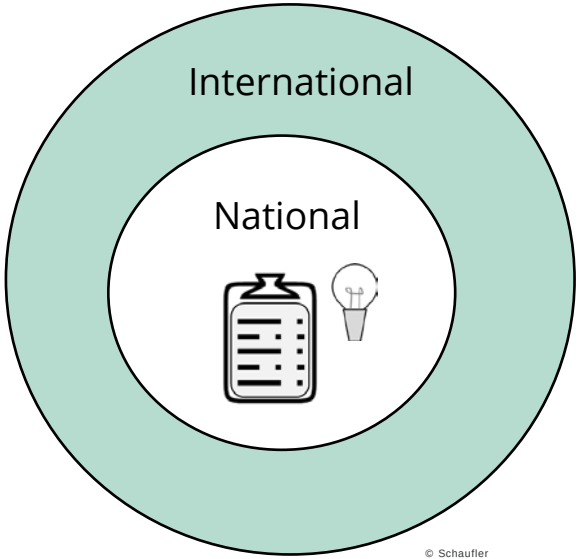

- Cross-border challenge
- Planetary boundaries
- Data comparability (EPNB-Guidance)
- Benefit for various activities:
  - UNECE/LRTAP – Gothenburg protocol
  - EU NEC-D
  - Critical loads
  - UN SDGs
  - EU biodiversity strategy
  - EU soil strategy
  - EU green deal
  - EU common agricultural policy (CAP)

METHODOLOGY

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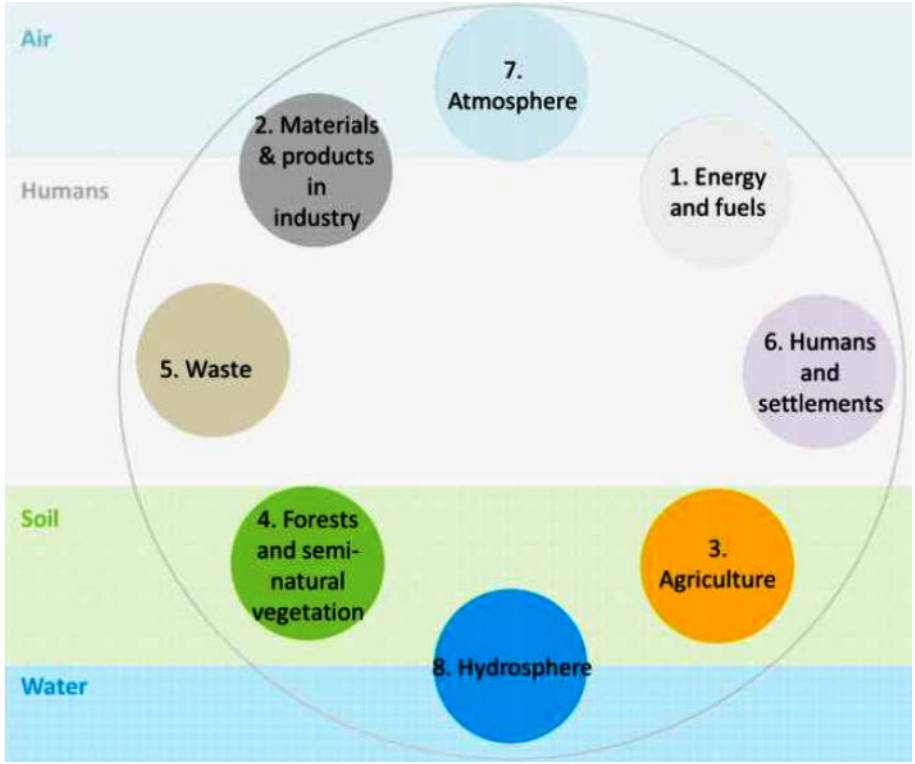
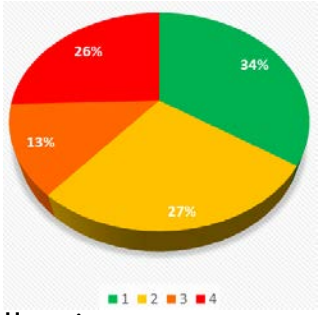


http://www.clrtap-tfrn.org/epnb

Austrian N-Budget according to EPNB-Guidance Document

- 8 sectors:
  - 128 flows (182 flows if diverse N species considered)
  - 6 pools with stock changes
- Flow threshold:1kt N/yr
- Presented data: mean values 2015-2019
- Data sources/uncertainties:
  - 1: official statistics / measured data (10%)
  - 2: expert estimates (33%)
  - 3: assumptions (50%)
  - 4: calculation based on assumptions (75%)



- DESTINO template for data collection
- STAN model-material flow analysis

$$\Delta_{Nbudget} = \sum N_{inflows} + \sum N_{sources} = \sum N_{outflows} + \sum N_{sink} + \sum N_{stockchanges}$$

AUSTRIAN N-BUDGET

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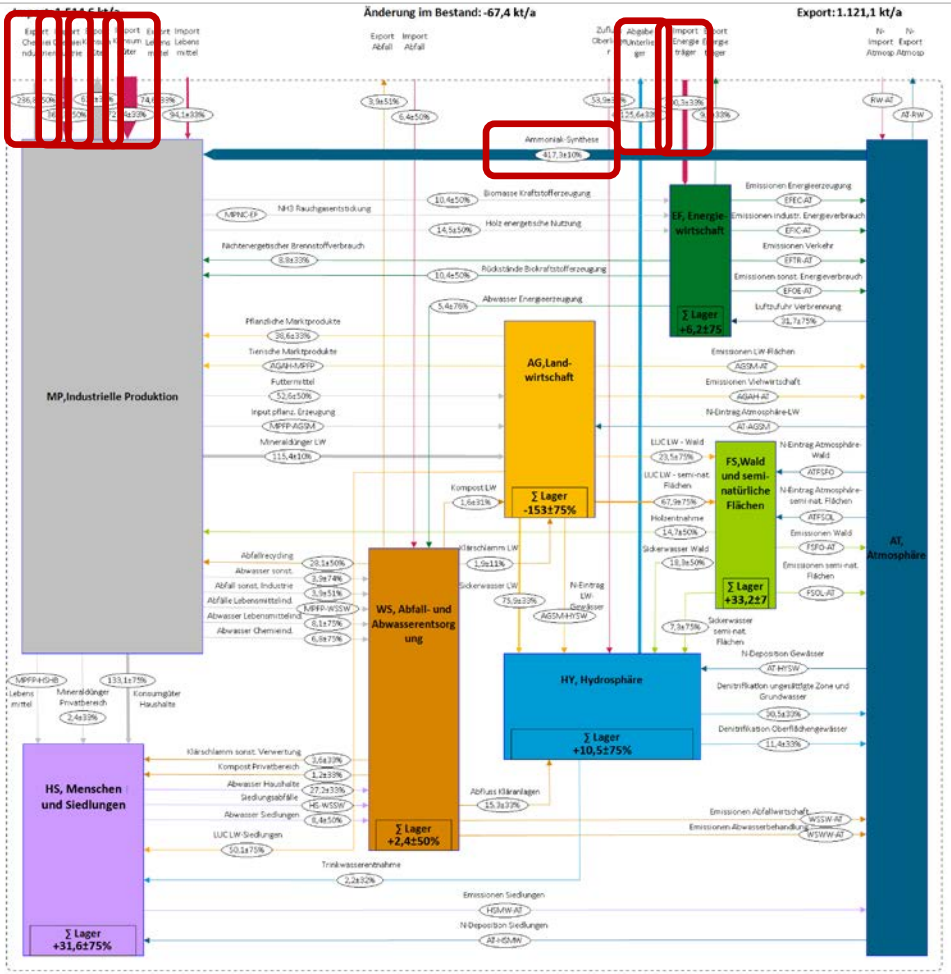


Sources and Sinks

- N-Import: 1 514 kt N/a
  - Import consumer goods industry: 727 kt N/a (± 33%)
  - Ammonia synthesis: 417 kt N/a (± 10%)
  - Import chemical products: 368 kt N/a (± 50%)
  - Import raw materials: 200 kt N/a (± 33%)
  - Deposition & N fixation: ca. 133.7 kt N/a
- N-Export: 1 221 kt N/a
  - Export consumer goods industry : 612 kt N/a (± 33%)
  - Export chemical products: 236 kt N/a (± 50%)
  - Export via downstream: 125 kt N/a (± 33%)
  - N_2 from combustion-energy sector: 72 kt N/a (± 50%)
  - Emissions into atmosphere (without N_2): ca 136 kt N/a

Stock change: -67.4 kt N /a

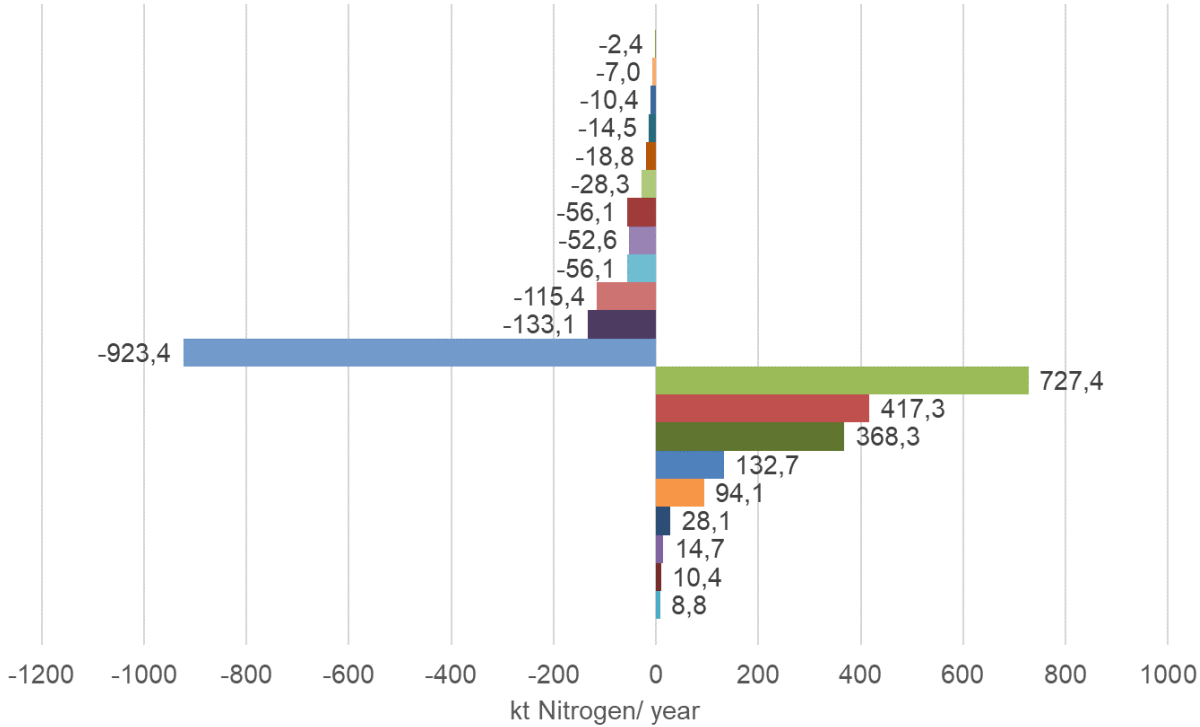
Surplus: 226 kt N /a

POOL MATERIAL & PRODUCTS IN INDUSTRY

Export: 1362 kt N/a

Import: 1801.8 kt N/a

Stock changes: 0 kt N/a



Surplus: 439 kt N/a

POOL AGRICULTURE

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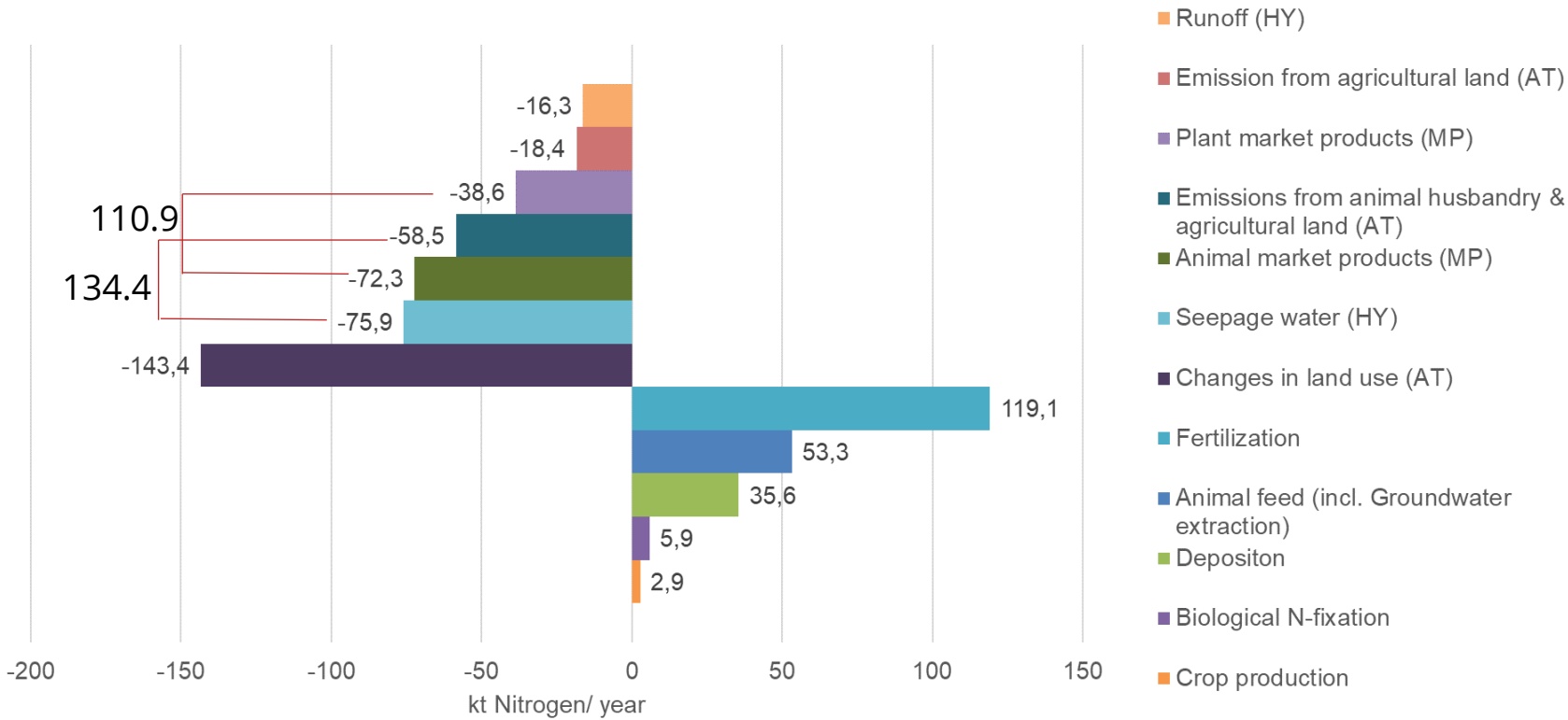
PROMAN

Export: 423.4 kt N/a

Import: 216.5 kt N/a

Stock changes: -153.0 kt N/a



Deficit: 64 kt N/a

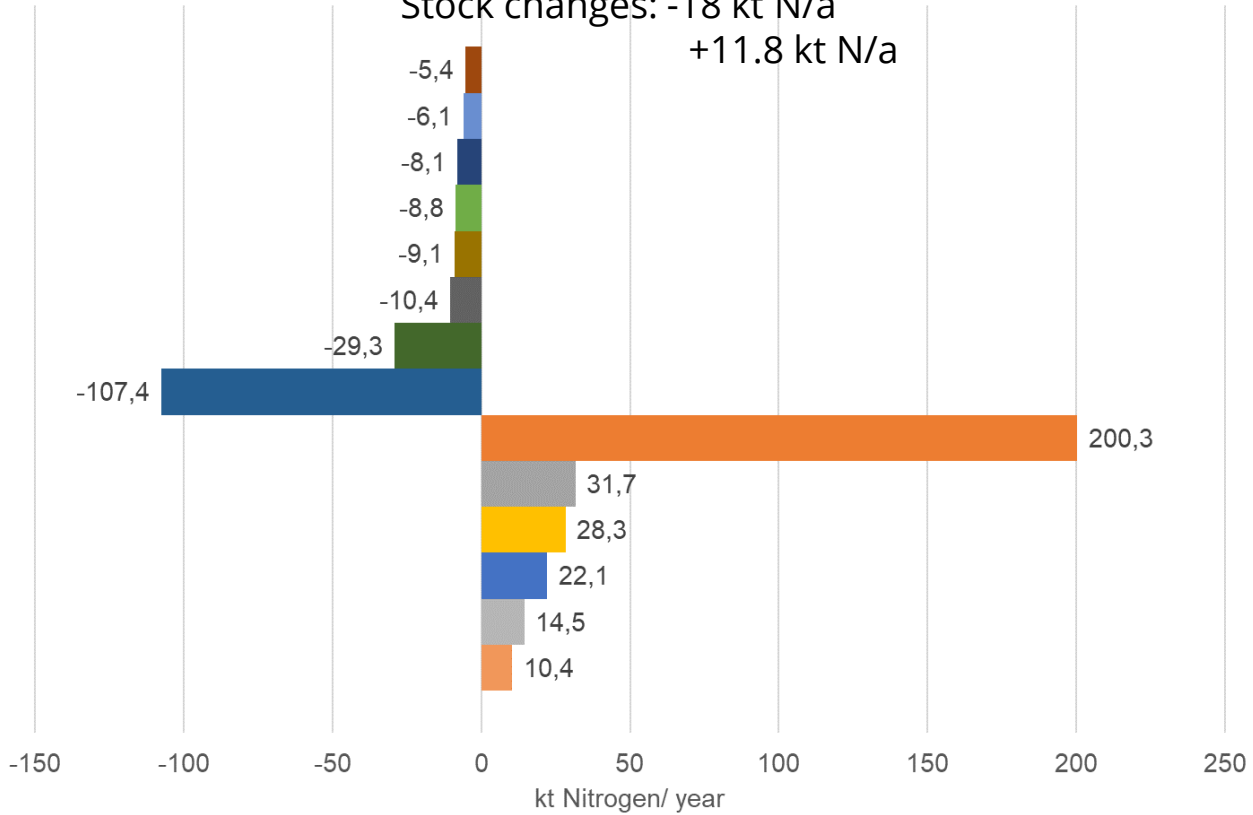
POOL ENERGY & FUEL

Export: 184.6 kt N/a

Import: 307.3 kt N/a

Stock changes: -18 kt N/a

+11.8 kt N/a



- Waste water (WS)
- Emissions other energy use (AT)
- Emissions industrial energy use (AT)
- Not-energetic fuel use (MP)
- Export energy source (RW)
- Rresidue fuel production (MP)
- Emissions traffic (AT)
- Emissions energy production (AT)
- Import of energy and fuel sources (RW)
- Air supply for combustion
- NH3 for flue gas denitrification (waste & AdBlue)
- Energy sources inland
- Wood for energetic use
- Biomass for fuel production

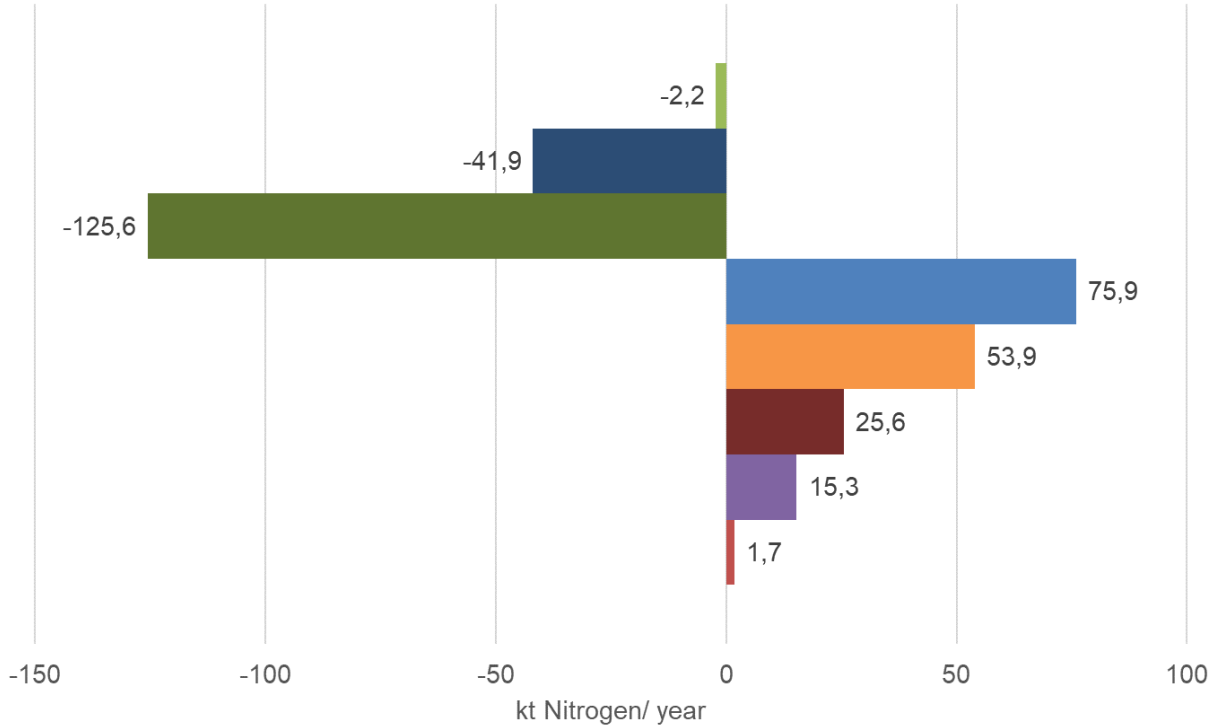
Surplus: 116.5 kt N/a

POOL HYDROSPHERE

Export: 169.7 kt N/a

Import: 198.4 kt N/a

Stock changes: +10.5 kt N/a



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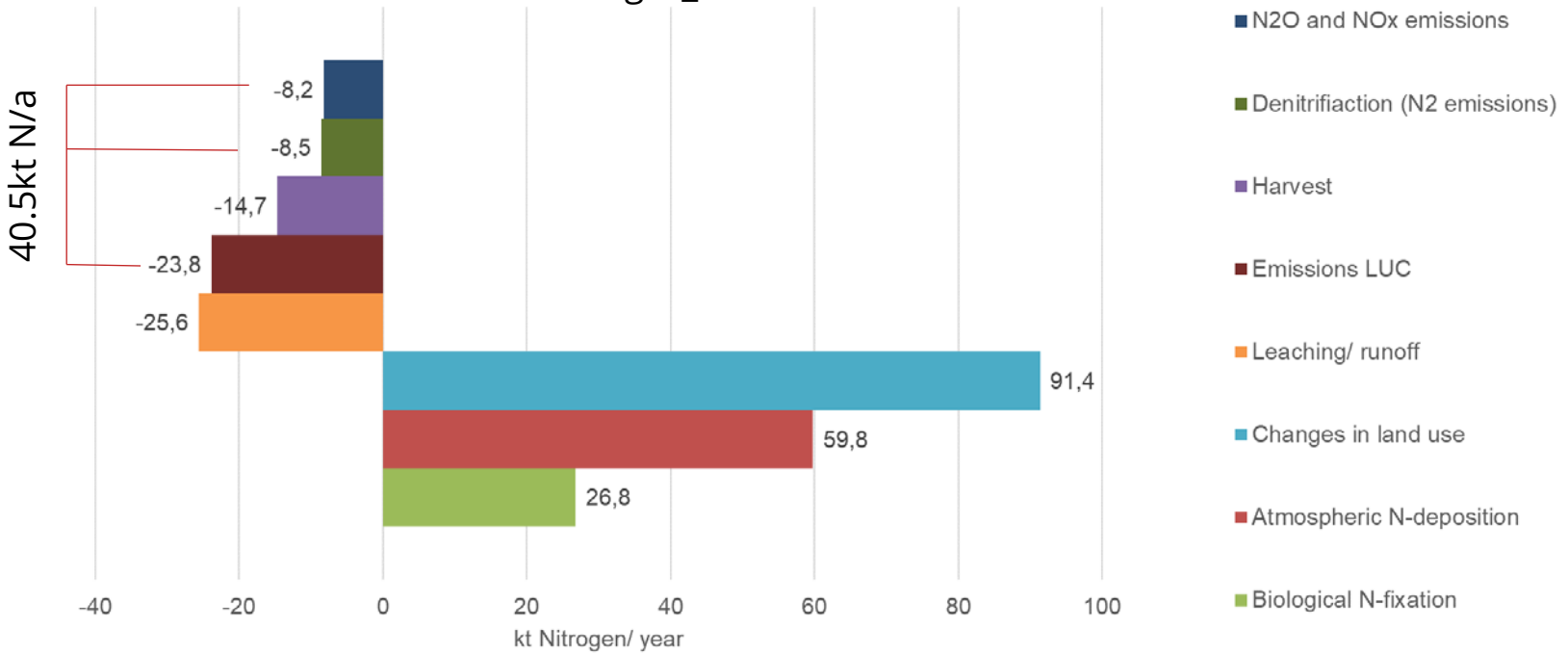
ENVIRONMENT AGENCY AUSTRIA
PROMAN

POOL FOREST & SEMI-NATURAL VEGETATION

Export: 80.8 kt N/a

Stock changes_Soil: -2.7 kt N/a
Stock changes_FS:+35.9 kt N/a

Import: 178.0 kt N/a



Surplus: 64 kt N/a

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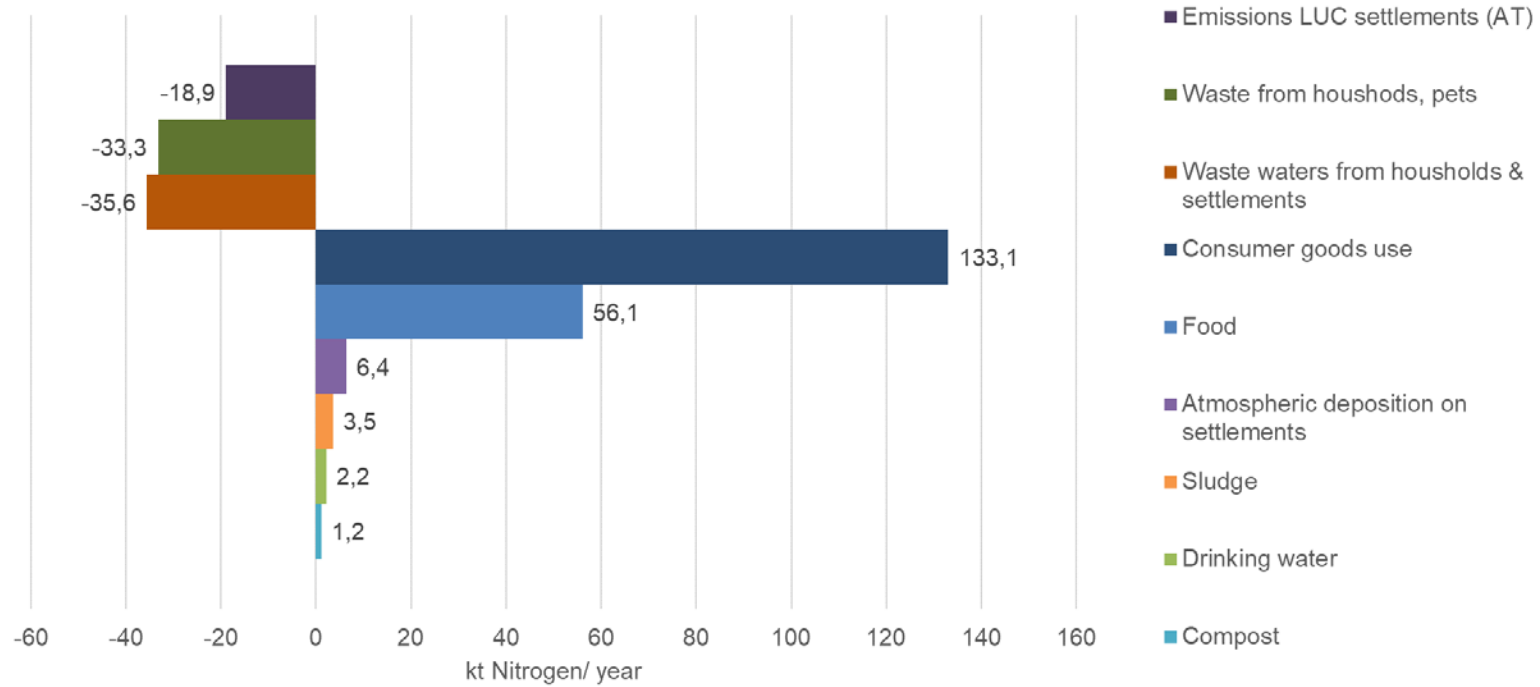
ENVIRONMENT AGENCY AUSTRIA
PROMAN

POOL HUMANS & SETTELMENTS

Export: 87.8 kt N/a

Import: 202.5 kt N/a

Stock changes: -31.6 kt N/a



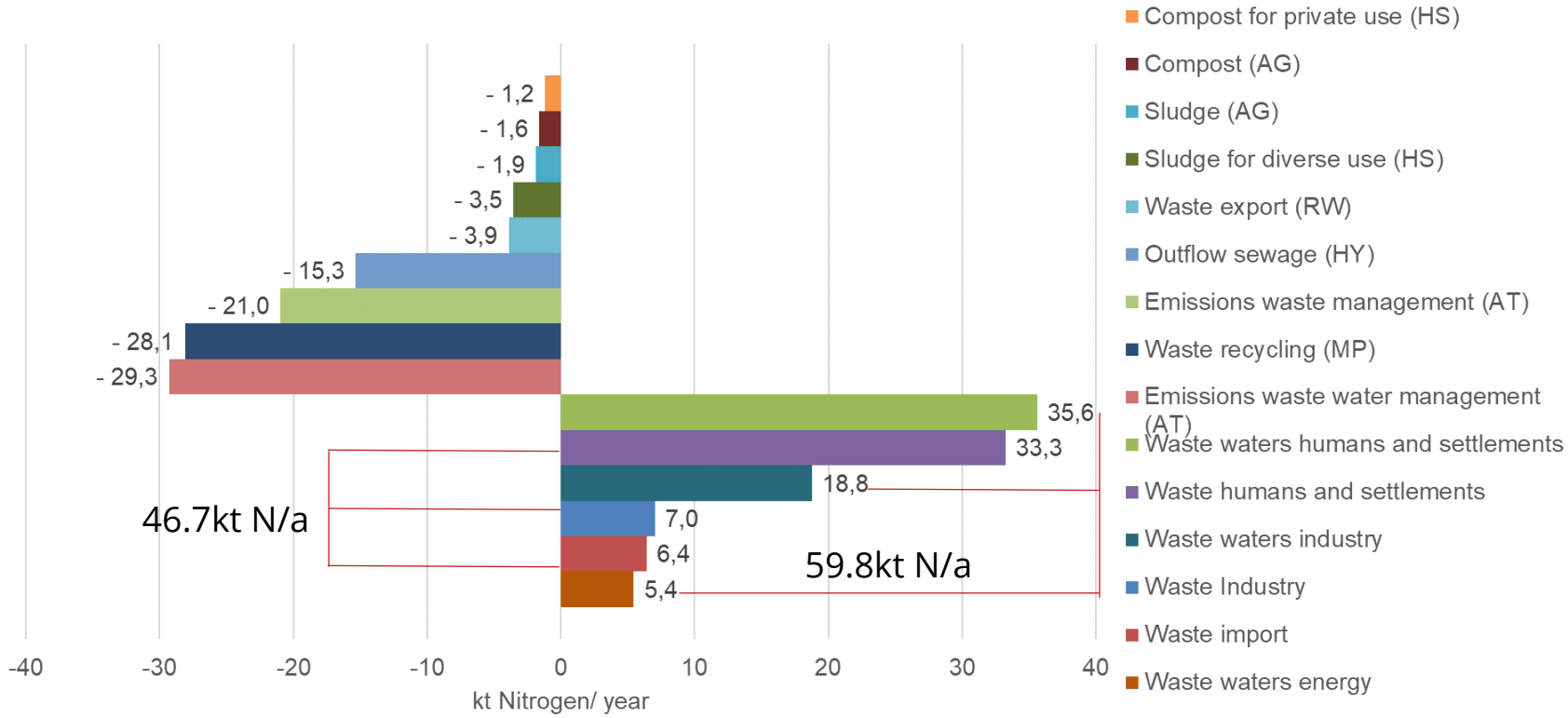
Surplus: 83.1 kt N/a

POOL WASTE

Export: 105.8 kt N/a

Import: 106.5 kt N/a

Stock changes: +2.4 kt N/a



POOL ATMOSPHERE

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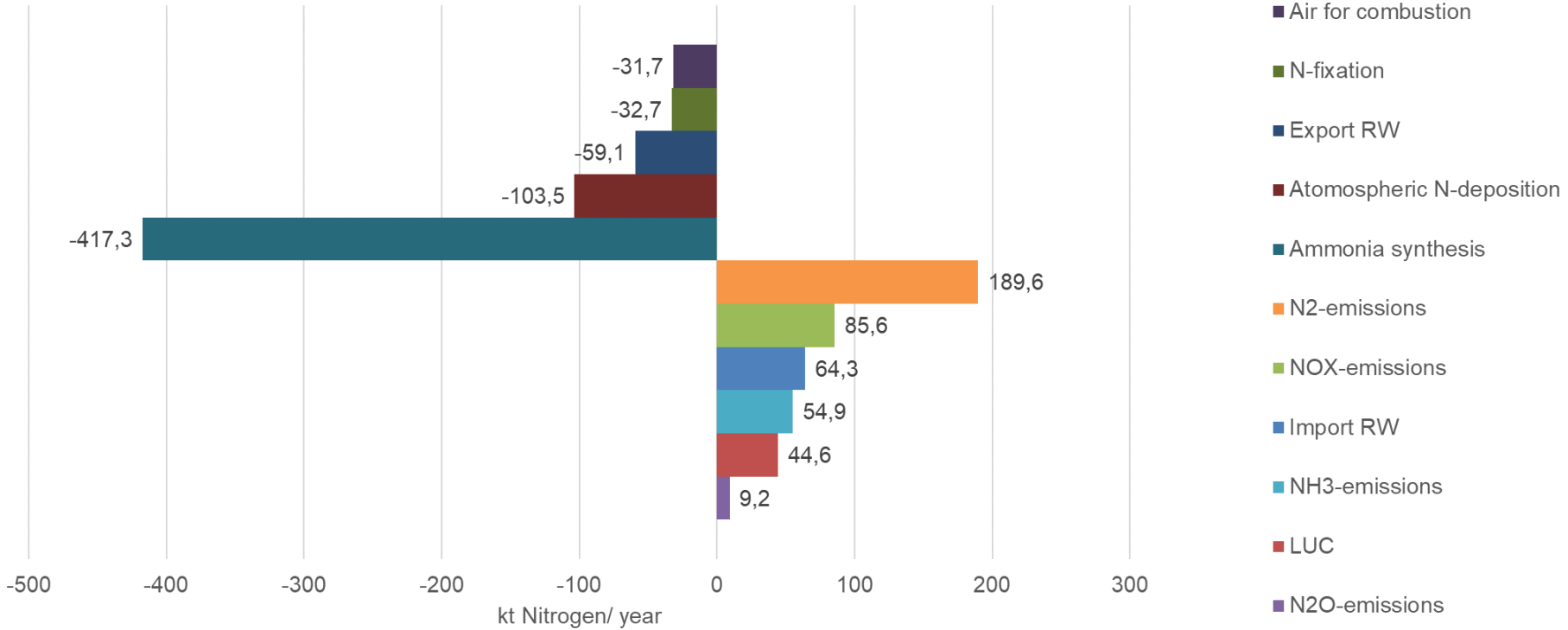
ENVIRONMENT AGENCY AUSTRIA

PROMAN

Export: 644.3 kt N/a

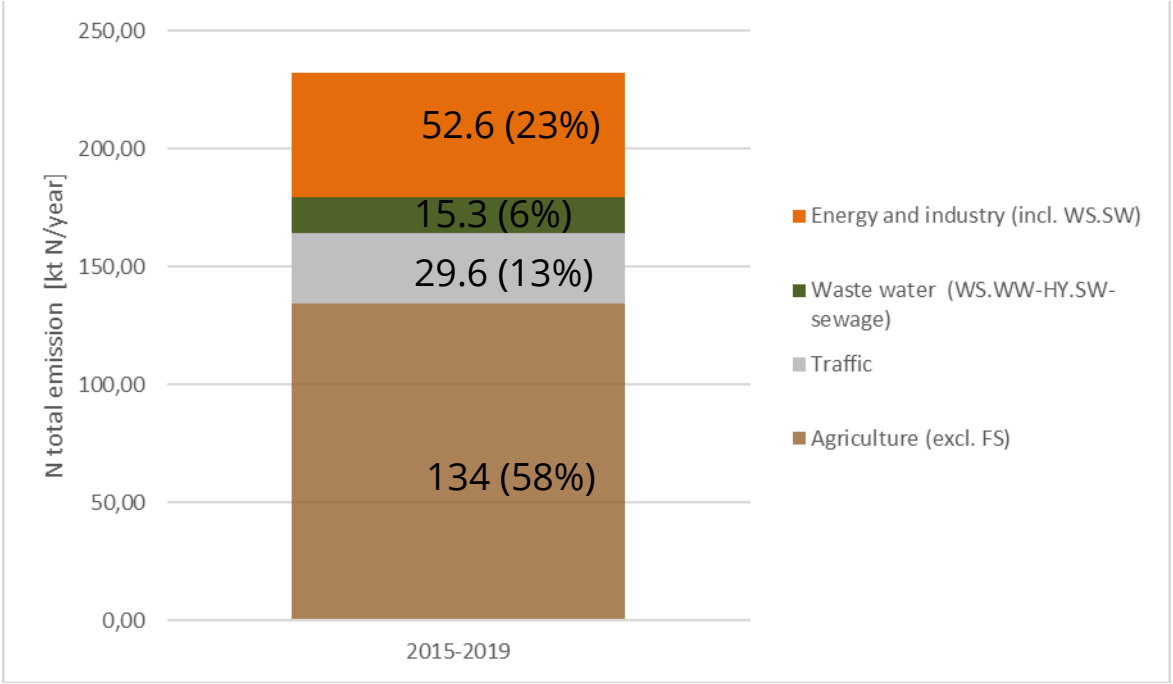
Import: 455.5 kt N/a

Stock changes: 0 kt N/a



Deficit: 196.9 kt N/a

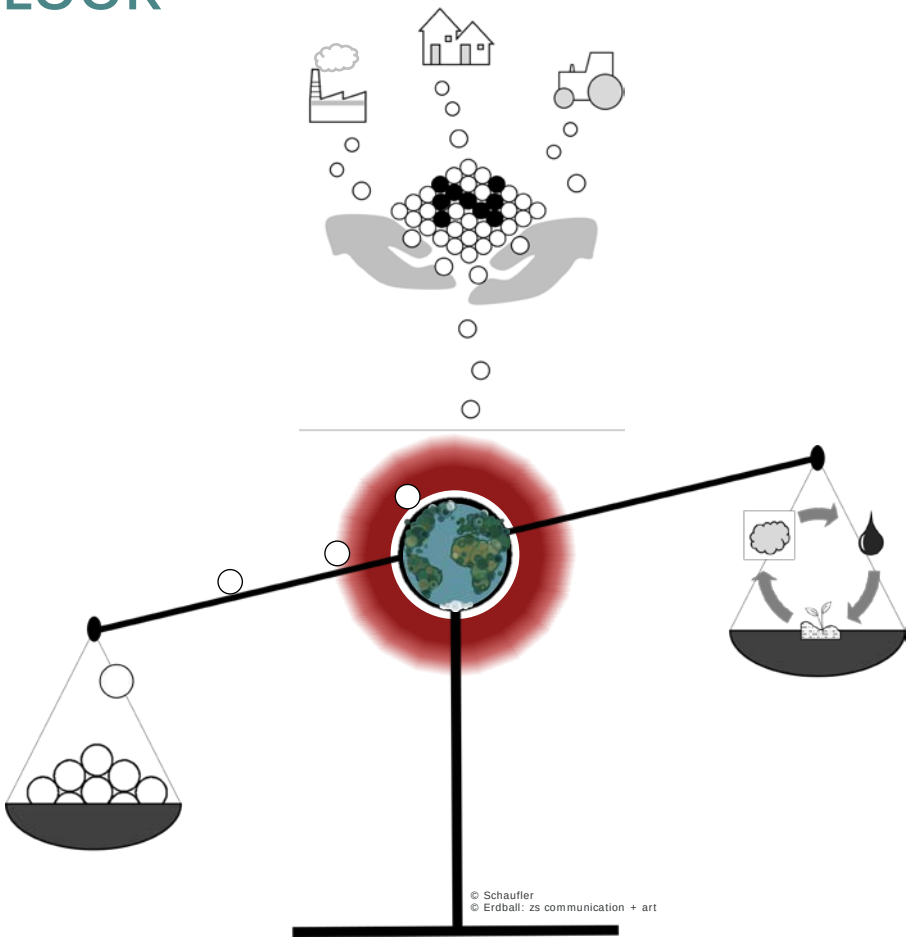
MEAN ANNUAL N-INPUT IN THE ENVIRONMENT



OUTLOOK

umweltbundesamt
ENVIRONMENT AGENCY AUSTRIA

PROMAN



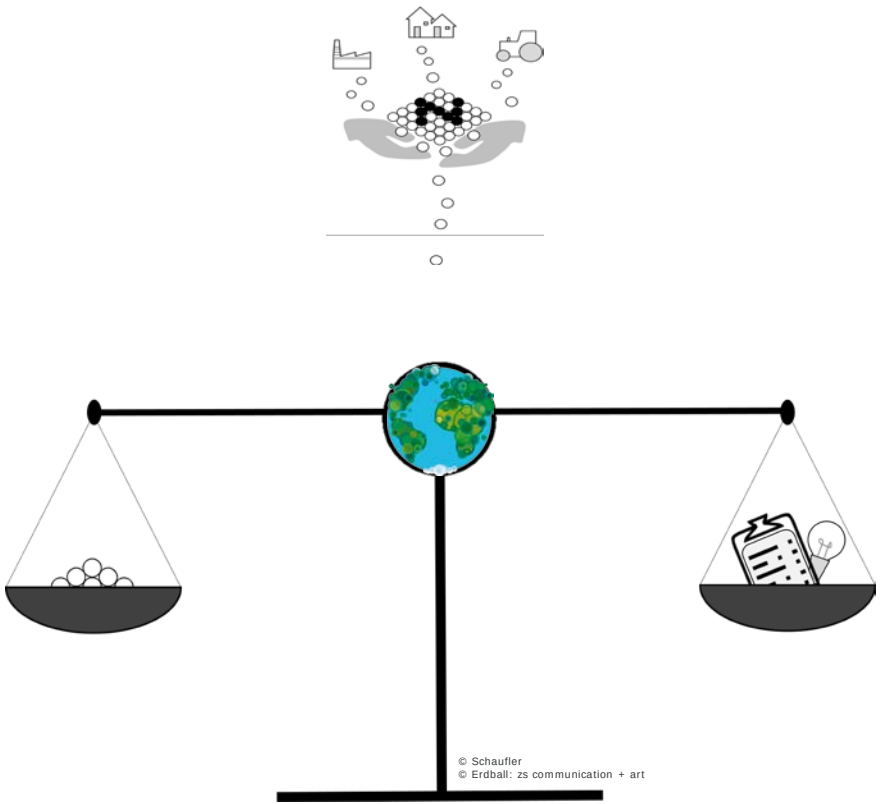
National N Budget

National N indicator

OUTLOOK

umweltbundesamt
ENVIRONMENT AGENCY AUSTRIA

PROMAN

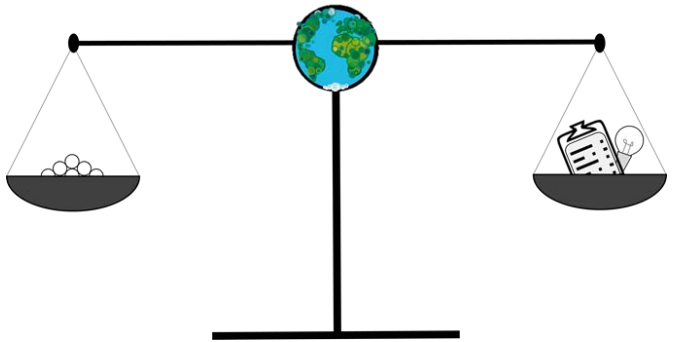


National N Budget

National N indicator

Integrated N strategy

Ika DJUKIC
Environment Agency Austria
+43 (1) 31304-3432
ika.djukic@umweltbundesamt.at



Urban Nitrogen Cycles: Are we suffocating in nitrogen?

Vienna, May 2022

Urban Nitrogen Budgets – UNCNET

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UNIWERSYTET ZIELONOGÓRSKI

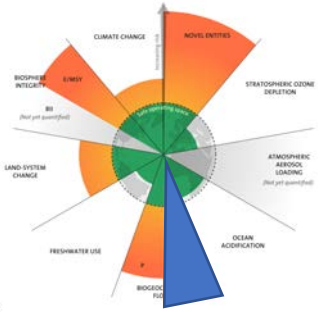
E.C.O. Institut für Ökologie

PEKING UNIVERSITY 1898

brainflows

Project background

- Planetary boundary concept: N threshold exceeding

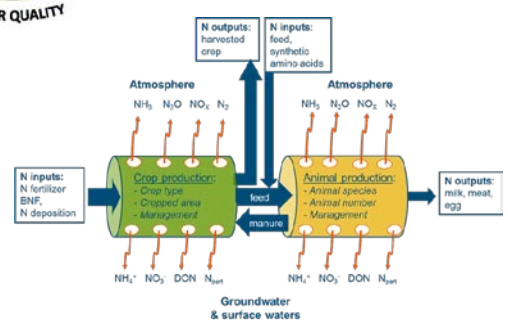


Persson et al., 2022

- N is responsible for multiple environmental effects

Sutton et al., 2012

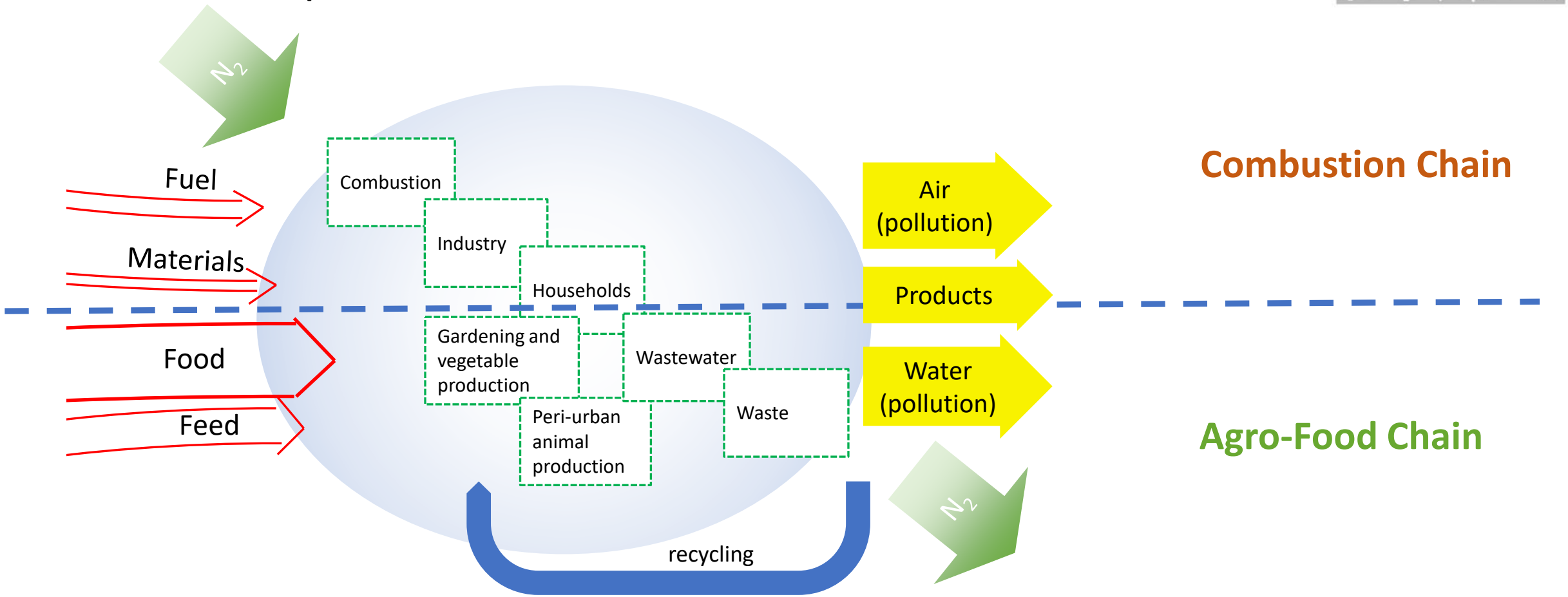
- N represents interaction between measures, processes, effects



Oenema et al., 2009

- Relevance of N in an urban environment?

Urban N pools and fluxes



Winiwarter et al., 2020

Project team and expertise

Coordination
Concept and data integration
Industry and energy

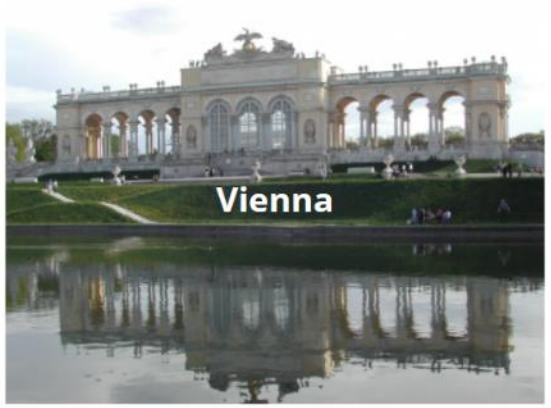
Agriculture
Soils

Coordination China
Atmosphere
Hydrosphere and soils

Waste
Wastewater

stakeholders
dissemination

Test cities



Klagenfurt

Collaboration and context

- Funding

- Related project activities

  Expert Panel on Nitrogen Budgets

- Support and acknowledgments: MA22 (Vienna), Abt. Anlagentechnik (NÖ) BOKU Institute of Meteorology and Climatology
- See all details at www.uncnet.org

Atmospheric emissions and impacts

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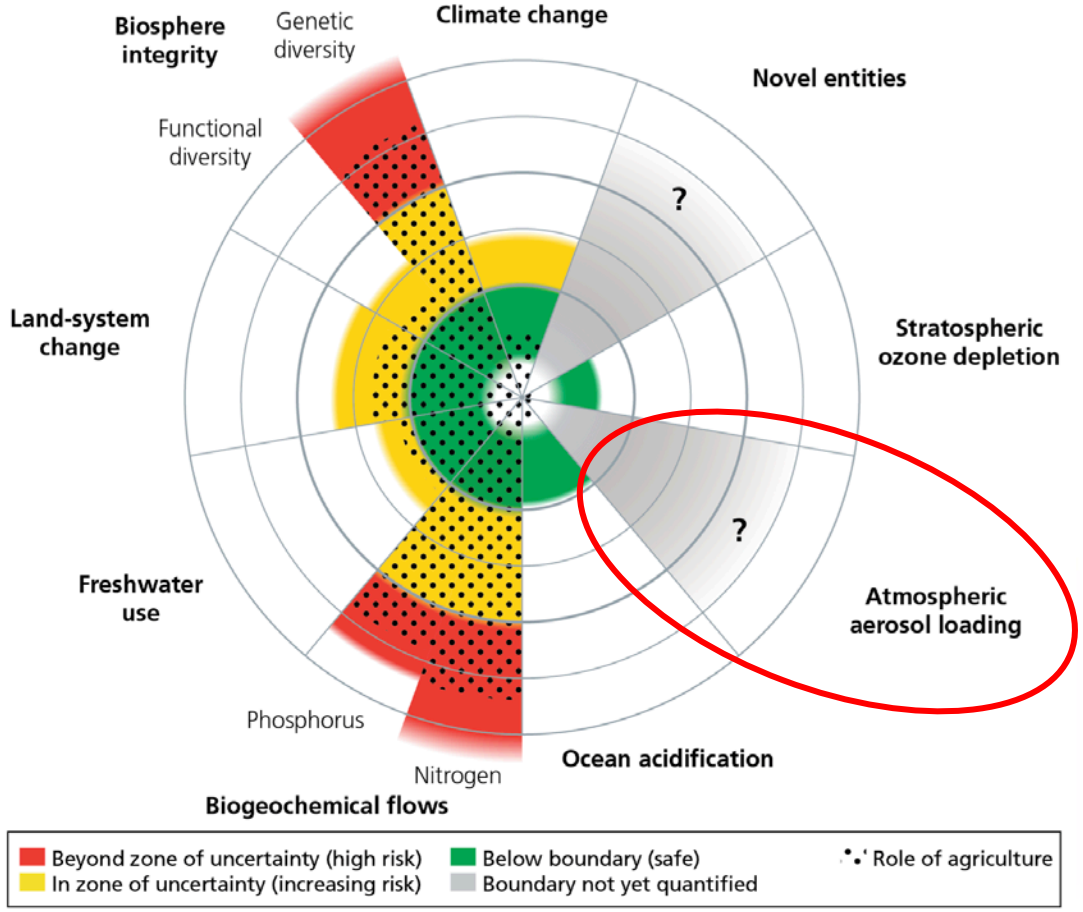
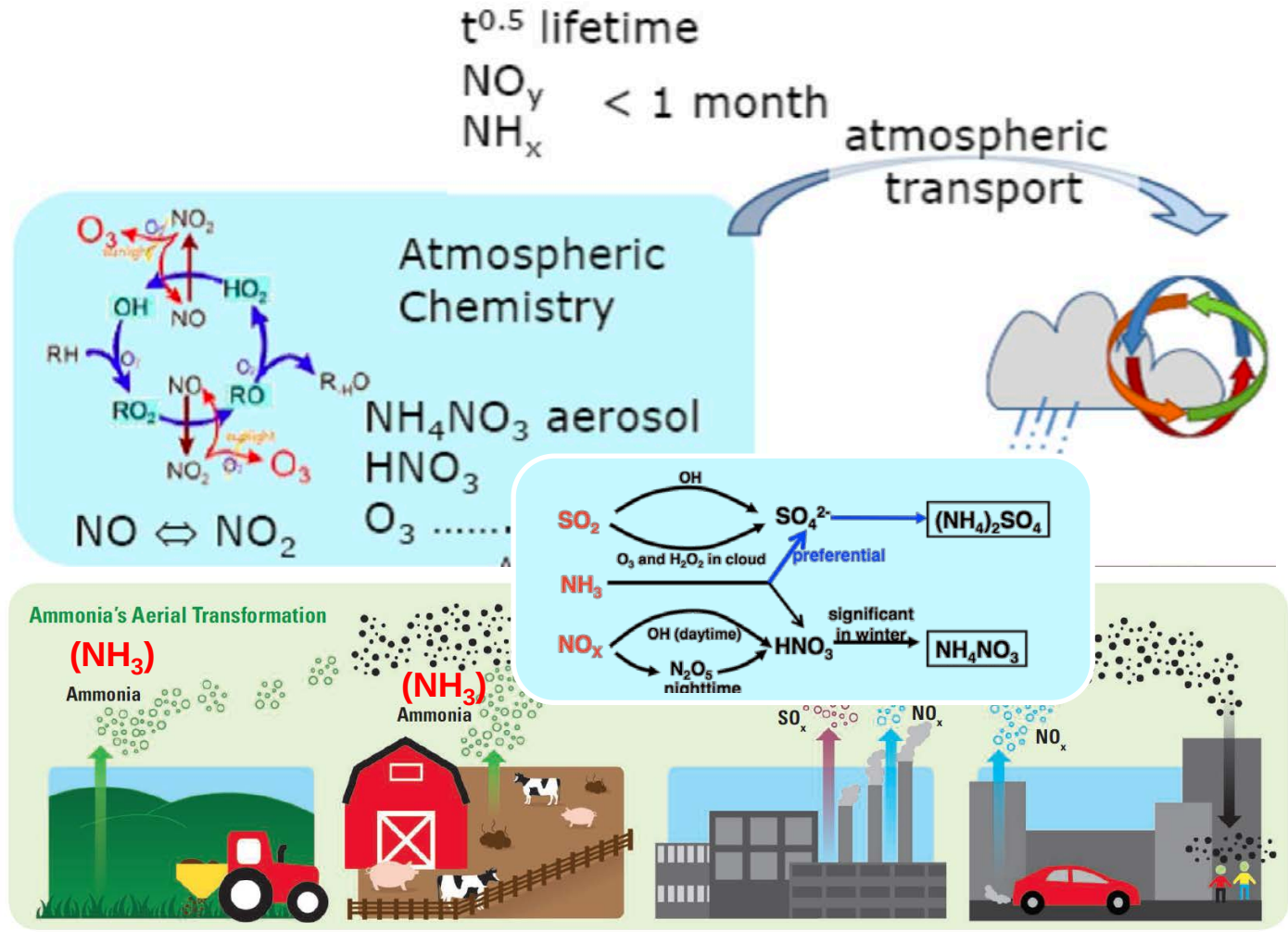
brainbows

Agriculture largely drives the Earth system exceeding safe planetary boundaries



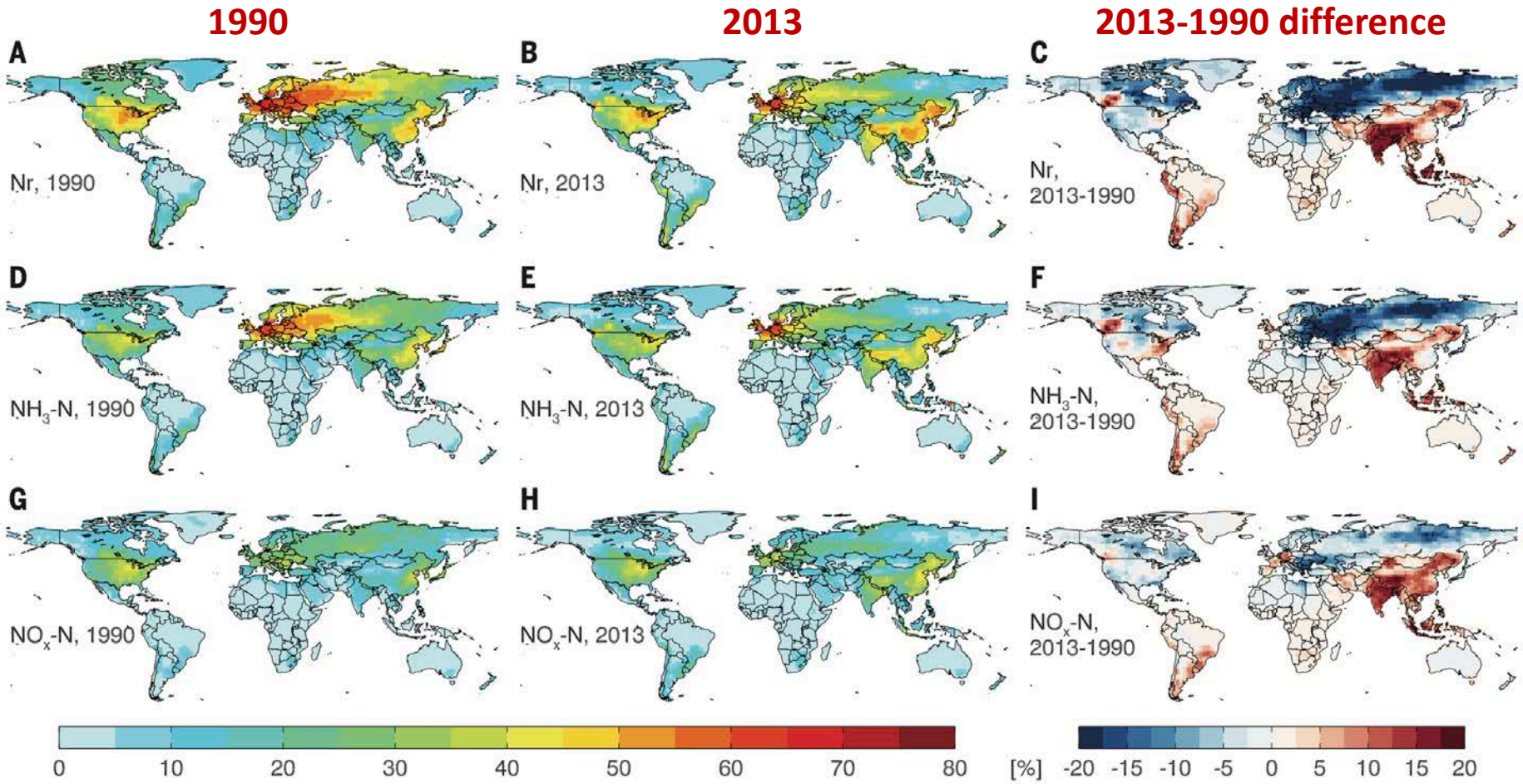
[Steffen et al., Science 2015; Campbell et al. E&S 2017]



[Erik Stokstad, 2014; Fowler et al. 2015]

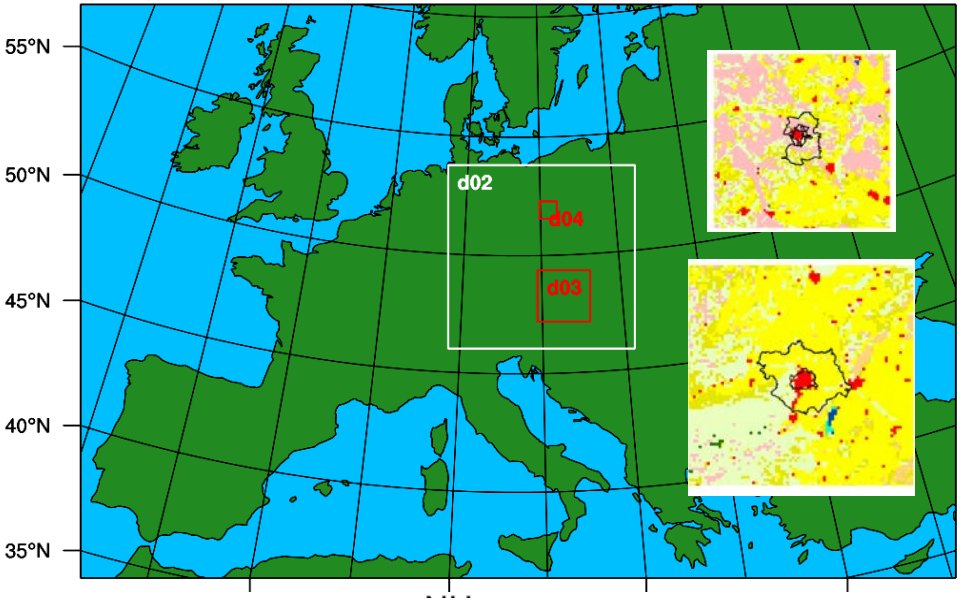
N-shares of $PM_{2.5}$ pollution and their 1990-2013 changes

- Global Nr-share of $PM_{2.5}$ pollution increased from 30% in 1990 to 39% in 2013
- NH_3-share increased from 25% in 1990 to 32% in 2013
- Large increases in Asia, South America; decreases in Europe and North America
- YYL caused by Nr emissions increased from **19.5 to 23.3 million years**.

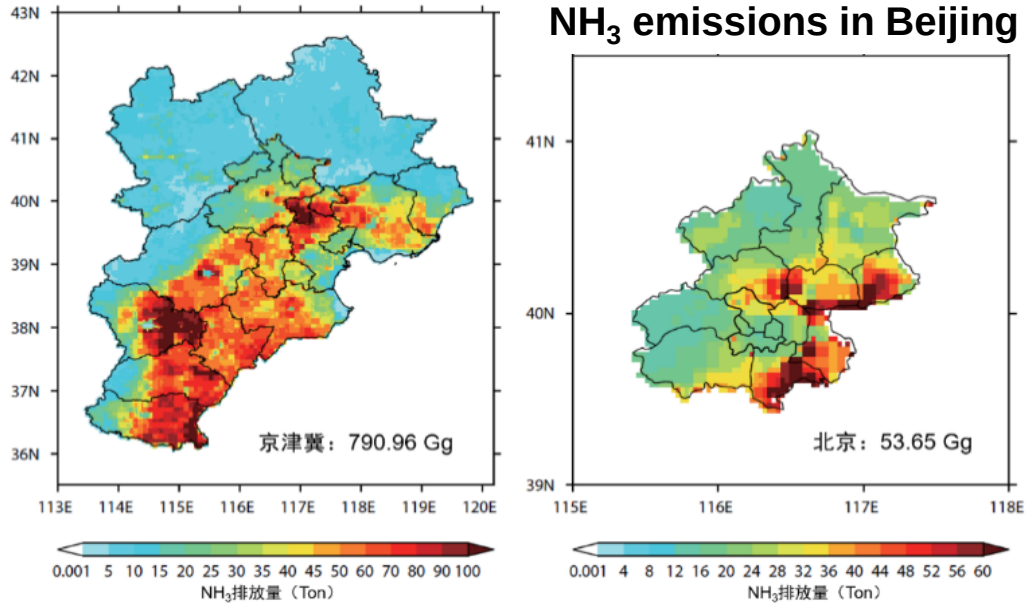


[Gu*, Zhang*, … Sutton*, *Science*, 2021]

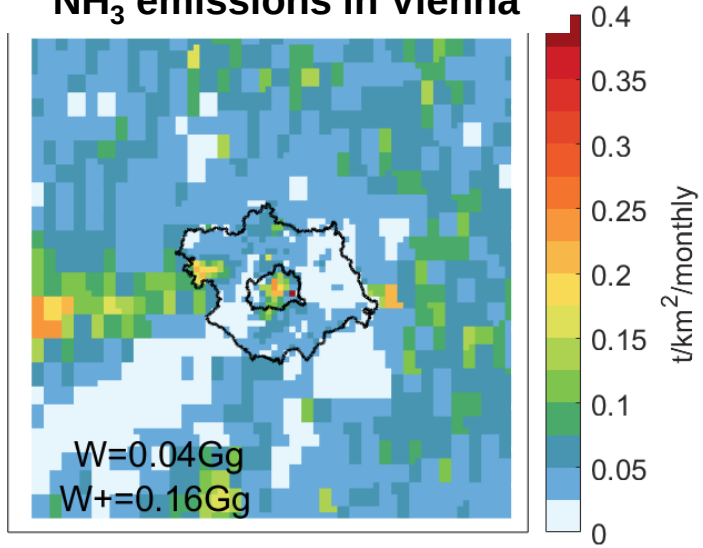
Air quality modeling covering the Chinese and European cities



NH_3 emissions in Beijing

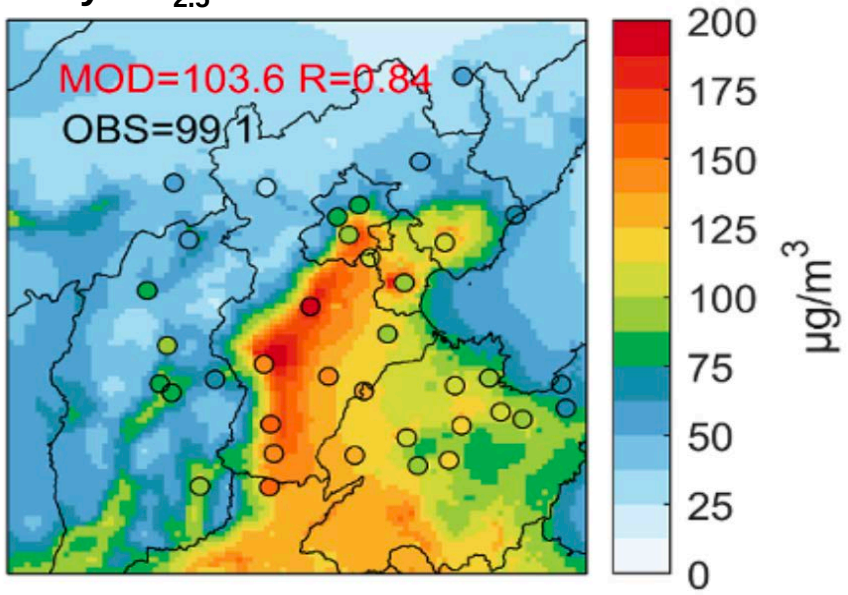


NH_3 emissions in Vienna

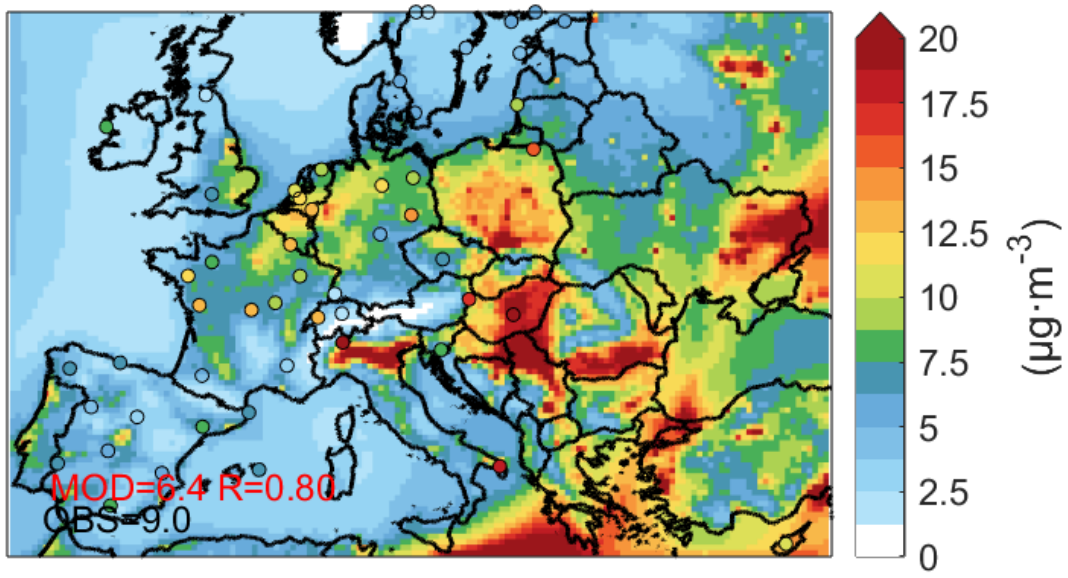


Observed and simulated January $PM_{2.5}$ air pollution

January $PM_{2.5}$ level over North China



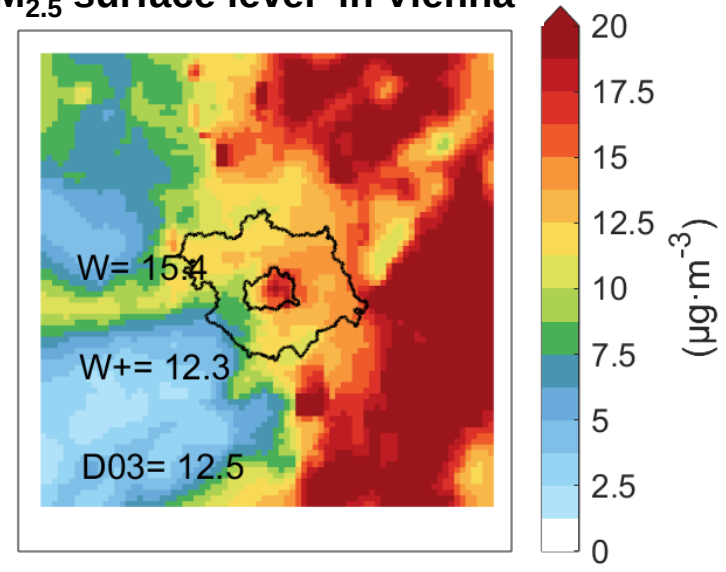
January $PM_{2.5}$ level over Europe



January 2015:

Beijing 85 ug/m³ vs. Vienna 15 ug/m³!

$PM_{2.5}$ surface level in Vienna

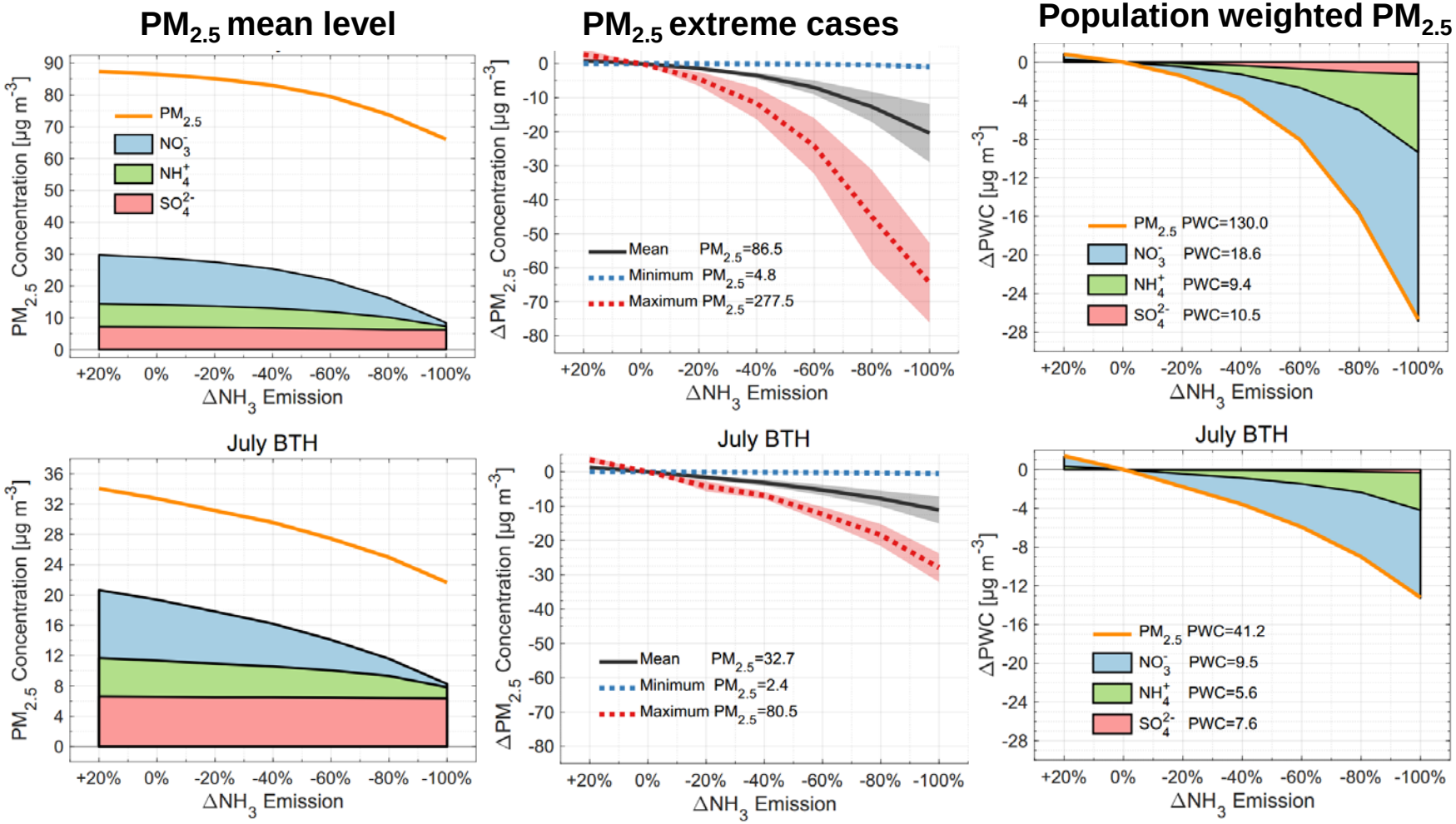


Impacts of NH_3 emission reductions on $PM_{2.5}$ air pollution – North China

Reduce NH_3 emissions over North China by 20%-100%

January 2015

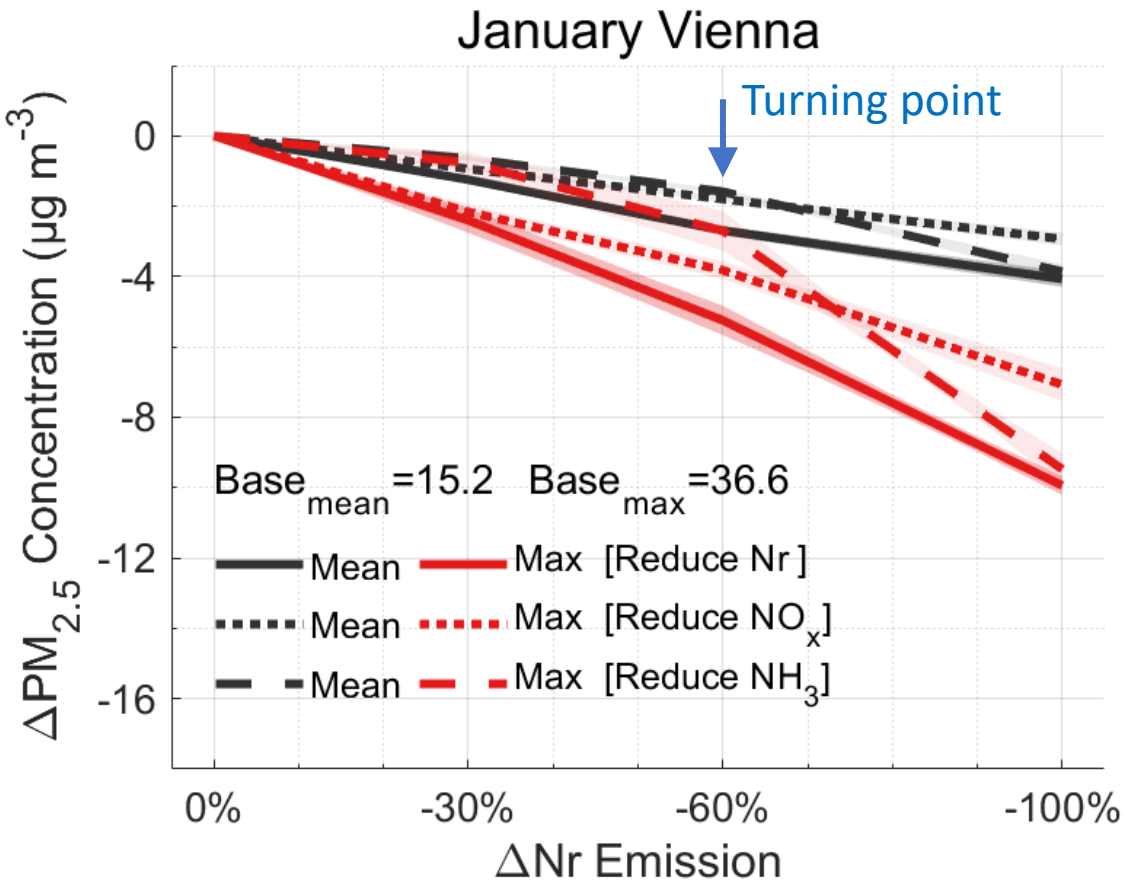
July 2015

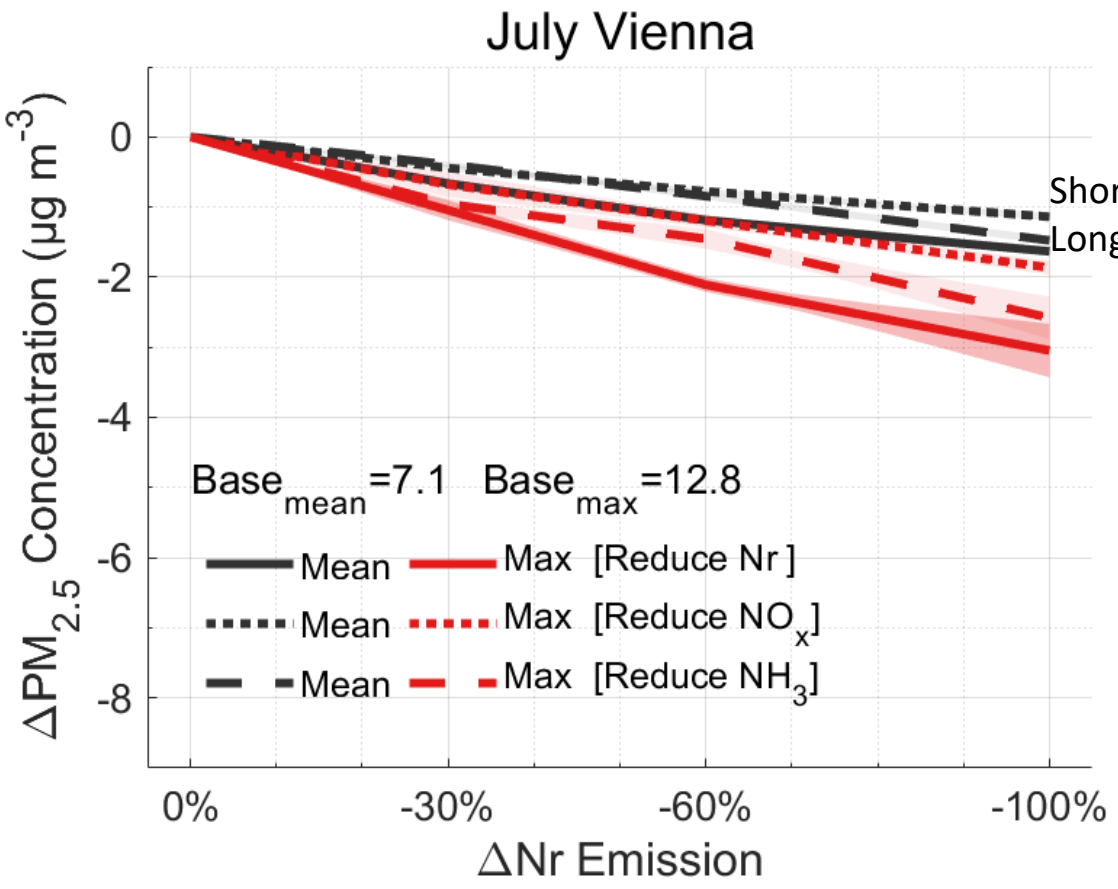


- Strong nonlinear responses of $PM_{2.5}$ concentrations to NH_3 emission reductions;
- Increasing effectiveness with larger reductions

[Liu et al., *Environ. Res. Lett.*, 2021]

Impacts of Nr emission reductions on $PM_{2.5}$ air pollution – Vienna





Short dash: NOx
Long dash: NH3

For $PM_{2.5}$ air quality improvements in Vienna

- NH_3 emission controls become more effective than NO_x emission controls when the emission reduction percentage is higher than ~60% in January;
- always similar or more effective in July.

Measures to reduce agricultural NH_3 emissions

Scenario		Measures	North China 2015 emission [Gg]	Reduction %
Baseline		No mitigation measures	**639.7**	**/**
Manure	Feeding	**Use suitable feed for pigs and poultry**	**594.4**	**7.1%**
	Housing	**Floor management of the farm house**	**524.0**	**18.1%**
	Storage	**Use cover materials and change the pH for slurry; Use compaction, static piling and covering for solid**	**631.7**	**1.3%**
	Field application	**Band spreading, injection, incorporation digestate, and solid-liquid separate**	**560.6**	**12.4%**
Chemical fertilizer	Reduce application rate	**Optimize nitrogen use rate**	**600.7**	**6.0%**
	Improved application methods	**Change spreading to deep fertilization**	**548.2**	**14.3%**
	Addition	**Use urease inhibitor (LIMUS)**	**551.4**	**13.8%**
Combine		**All measures above**	**279.6**	**56.3%**

NSFC-EU Project – stakeholder conference

WP4–Soil N leaching, impacts, & mitigations

Feng Zhou, Wulahati Adalibieke, Wenjun Jiang
College of Urban and Environmental Sciences, Peking University

May 31, 2022, online

Objective and tasks of WP4

Objective

We will quantify regional-scale N leaching from agricultural soils at high spatial resolution, as well as to optimize agricultural management practices to mitigate groundwater and air N pollution.

Key tasks

Task 1. Development of high-resolution N inputs and irrigation datasets

Task 2. Land surface modeling simulation of N leaching and the associated N flow in aquifer groundwater under different agricultural management and climate change

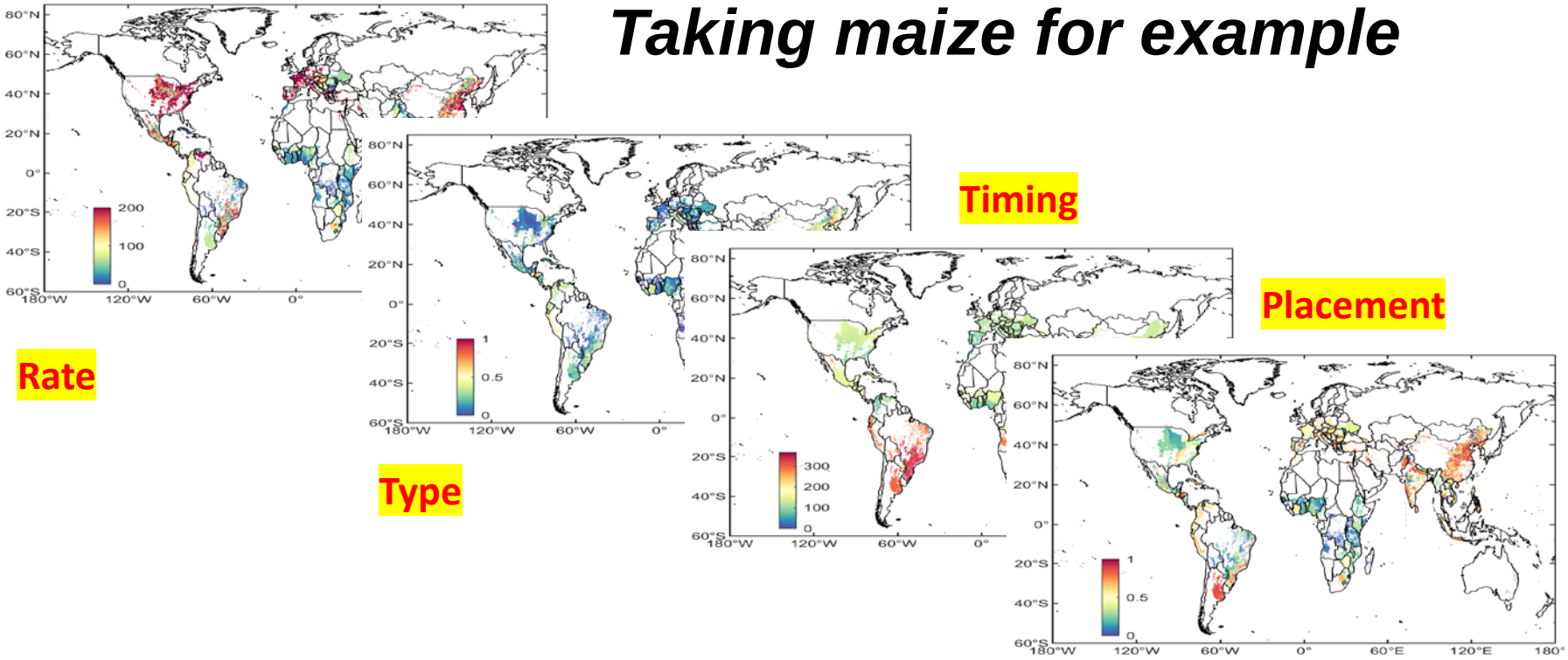
Task 3. Optimization of urban agriculture management to mitigate groundwater N pollution under different climate changes

WP4 Task 1

Global high-resolution vegetation-specific N-fertilizer application dataset (1961-2017, annual, 5-arc-minute, NetCDF file)

The N inputs are defined as the annual quantity of chemical fertilizers, manure, crop residues, and human excreta applied to soils.

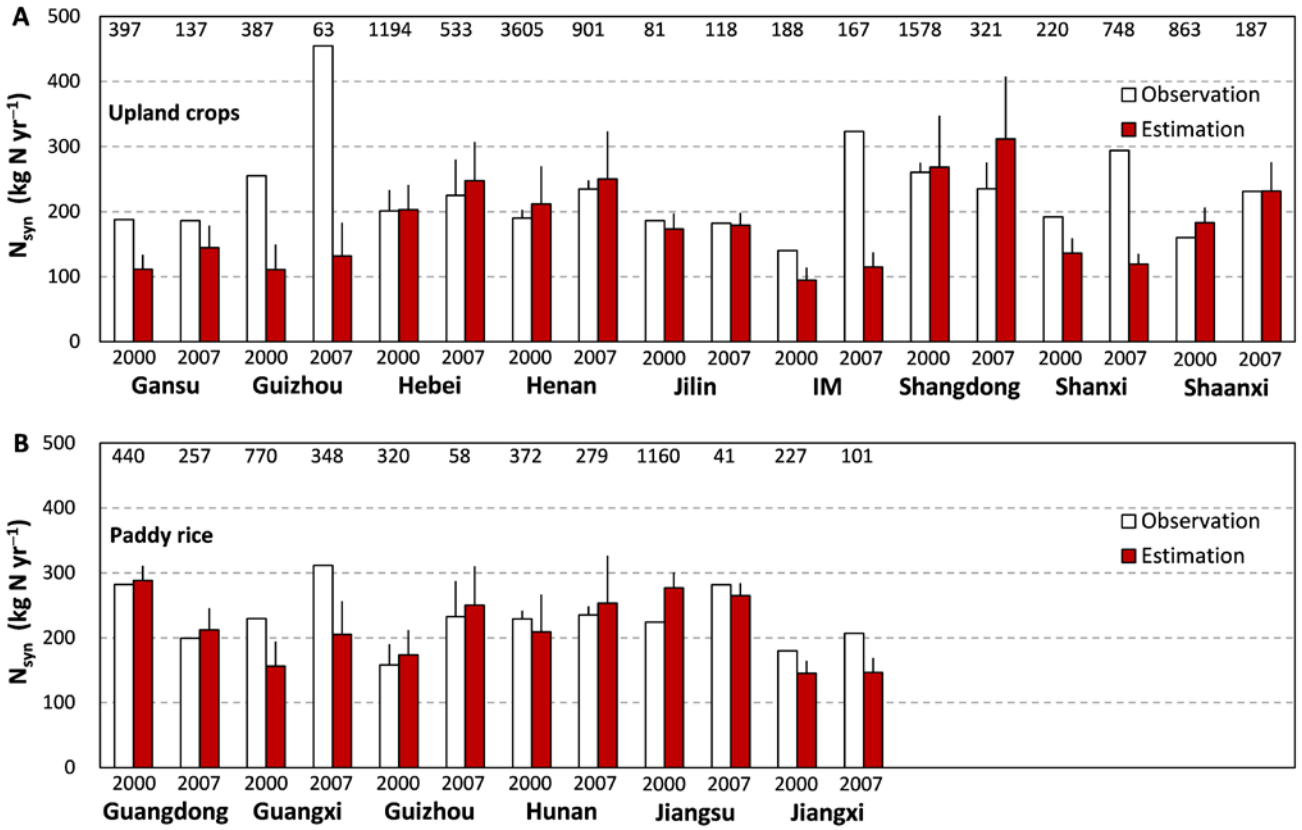
Taking maize for example



WP4 Task 1

Global high-resolution vegetation-specific N-fertilizer application dataset (1990-2017, annual, 5-arc-minute, NetCDF file)

The N inputs are defined as the annual quantity of chemical fertilizers, manure, crop residues, and human excreta applied to soils.

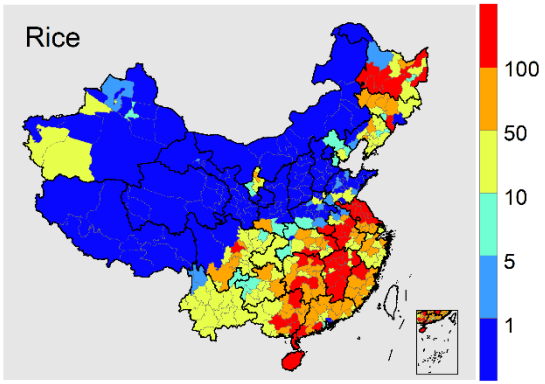


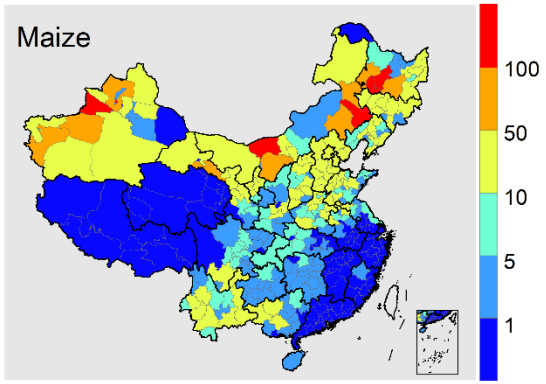
WP4 Task 1

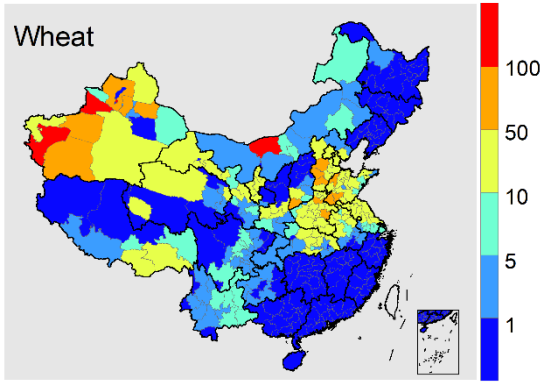
China's high-resolution crop-specific irrigation water use dataset

(1990-2017, annual, municipality, Excel file)

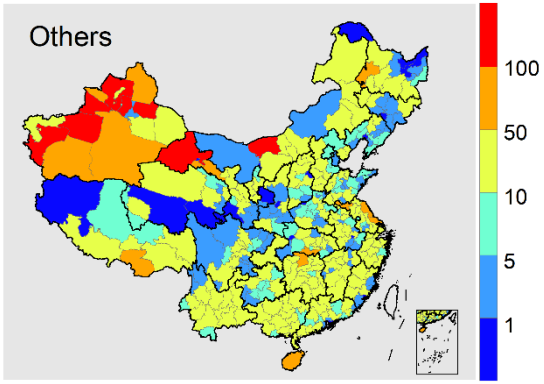
Irrigation water inputs are defined as the annual quantity of water withdrawn for irrigation including the losses during conveyance and field application.

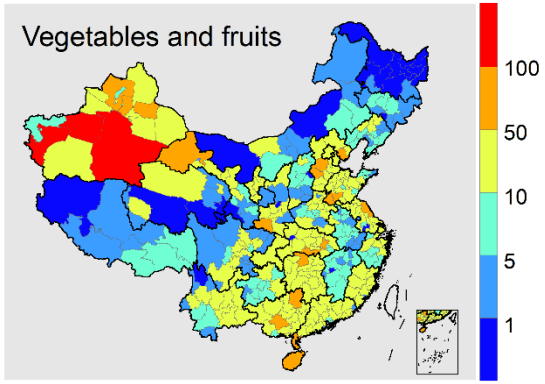




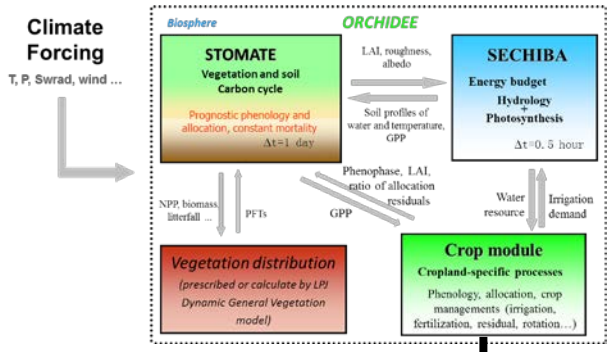


Unit:
million m3

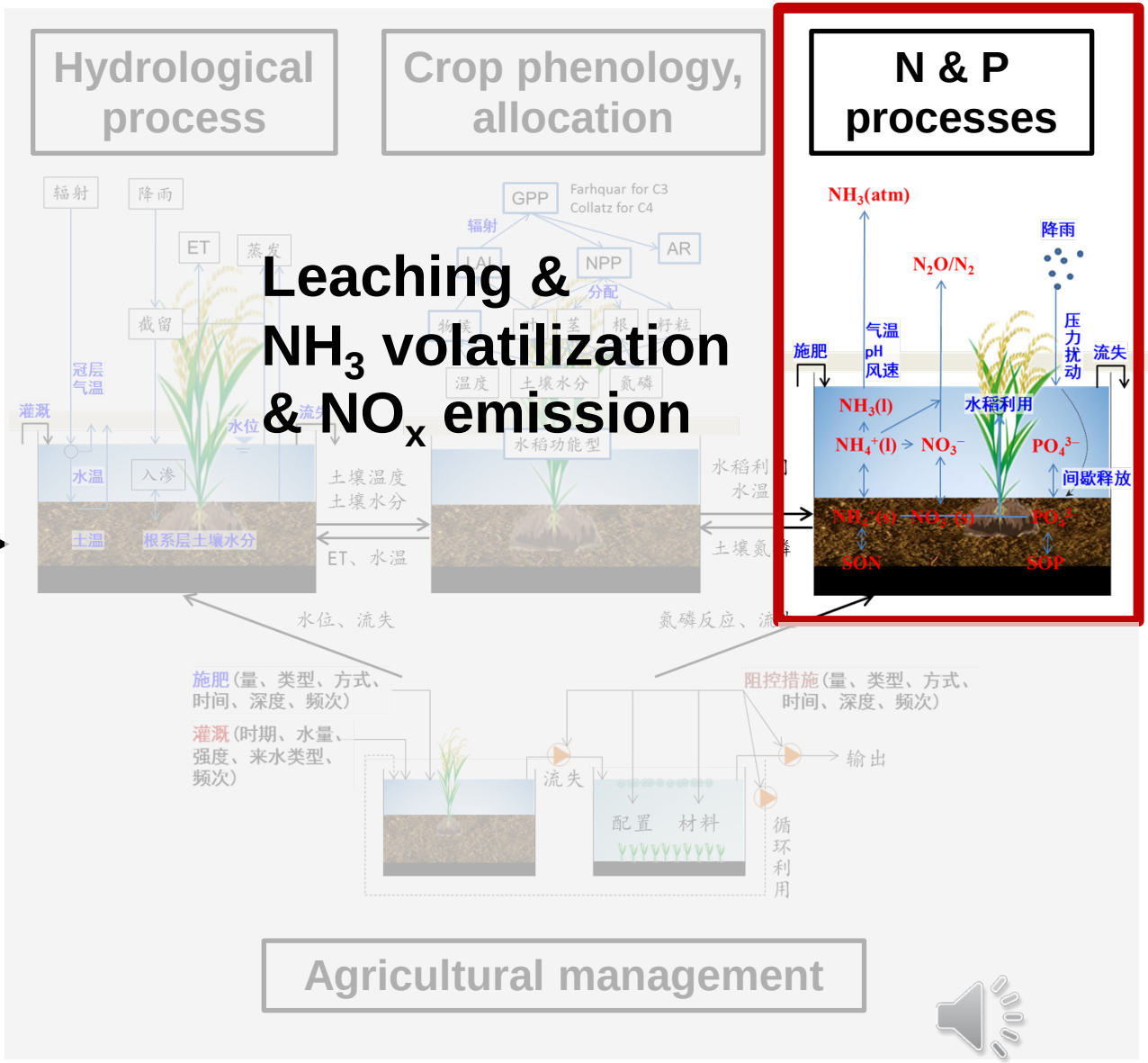




WP4 Task 2 – Modeling



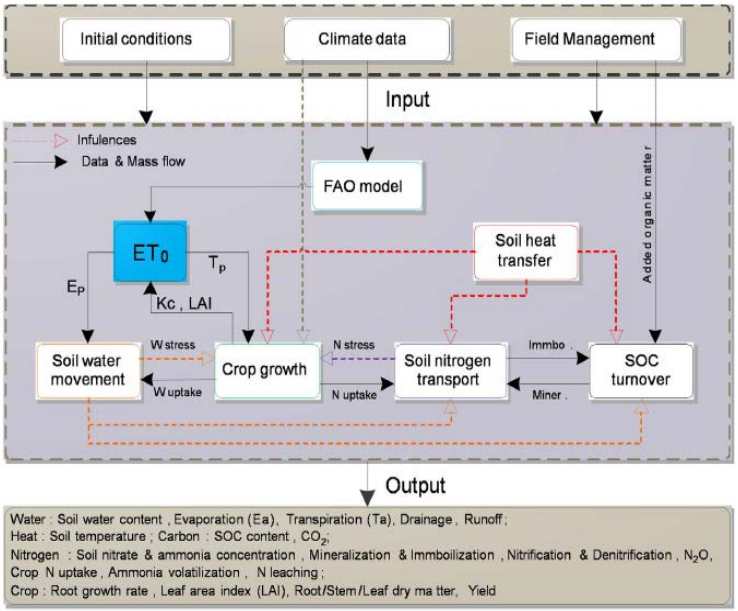
Rice paddies module



D4/2: Land surface modeling simulation of N leaching (PKU)

Jiang et al. 2021

WP4 Task 2 – Modeling



Soil water infiltration

$$f = K_s\left(1 + \frac{h_f \triangle \theta}{F}\right)$$ Green-Ampt equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[k(h)\left(\frac{\partial h}{\partial z} + 1\right)\right] - S_w$$ Richard's equation

Soil solute transport of NH_4^+-N and NO_3^--N

$$\frac{\partial C_1}{\partial t} = \mathrm{D}\frac{\partial^2 C_1}{\partial z^2} - v\frac{\partial C_1}{\partial z} + K_n C_2 - K_{den} C_1 - K_{bio}$$

The initial conditions:

$$C_1 = C_{10}(z), \qquad (0 \le z \le \infty,\ t = 0)$$
$$C_2 = C_{20}(z), \qquad (0 \le z \le \infty,\ t = 0)$$

Boundary conditions:

$$D\frac{\partial C_{01}}{\partial z} = 0 \quad (z = 0, t \ge 0); \quad C_1 = C_{11}(t)\ (z \to \infty, t \ge 0)$$

$$\left(1 + \frac{\rho}{\theta}K_d\right)\frac{\partial C_2}{\partial t} = \mathrm{D}\frac{\partial^2 C_2}{\partial z^2} - v\frac{\partial C_2}{\partial z} + K_{min} - K_n C_2$$

$$D\frac{\partial C_{02}}{\partial z} = 0 \quad (z = 0, t \ge 0); \quad C_2 = C_{12}(t)\ \ (z \to \infty, t \ge 0)$$

Jiang et al. 2021, Environ. Pollut.

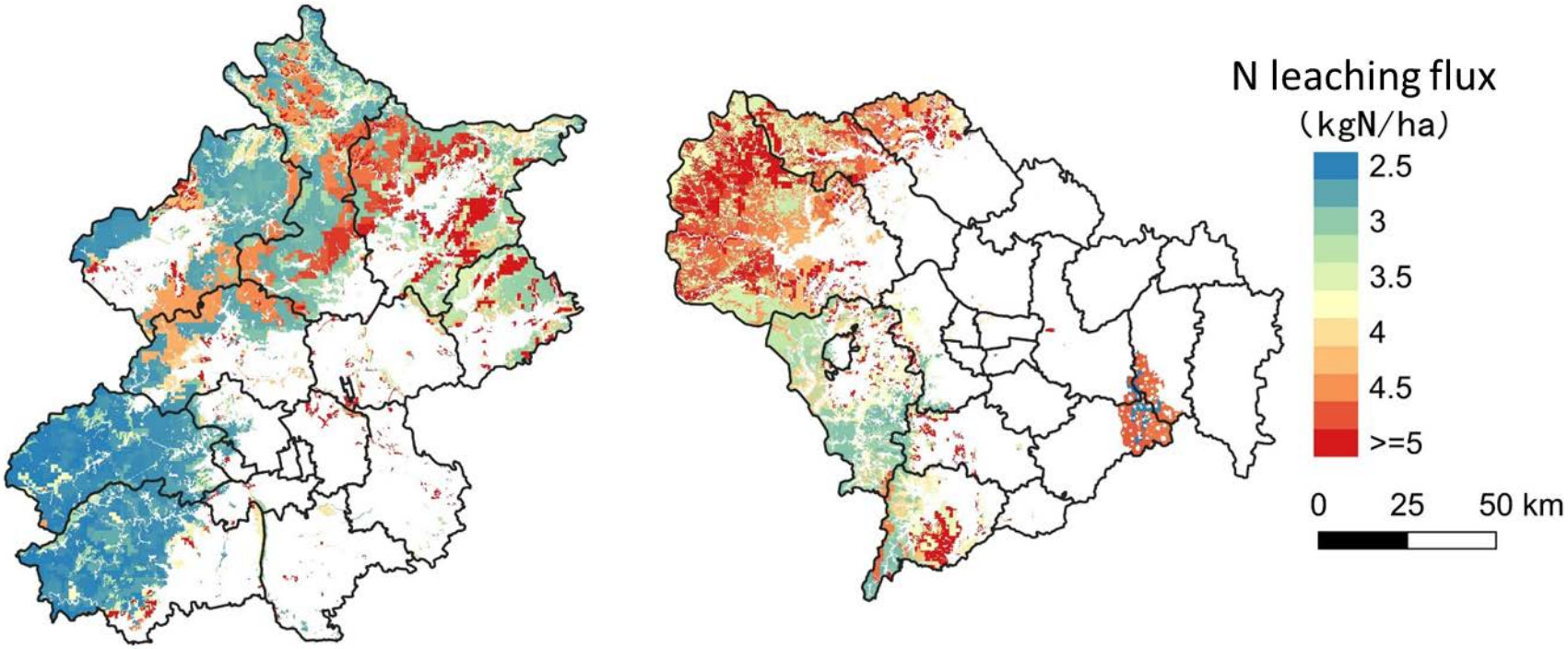
Field experiments (6 sites) for model validation

- running from May 2017 to Sept. 2019
- Indicators: climate, soil, crop growth, all budget fluxes of water and nitrogen (including N leaching)
- Resolution: daily

WP4 Task 2 – applications

N leaching flux over forest and grassland in Beijing

N leaching flux over forest and grassland in Shijiazhuang



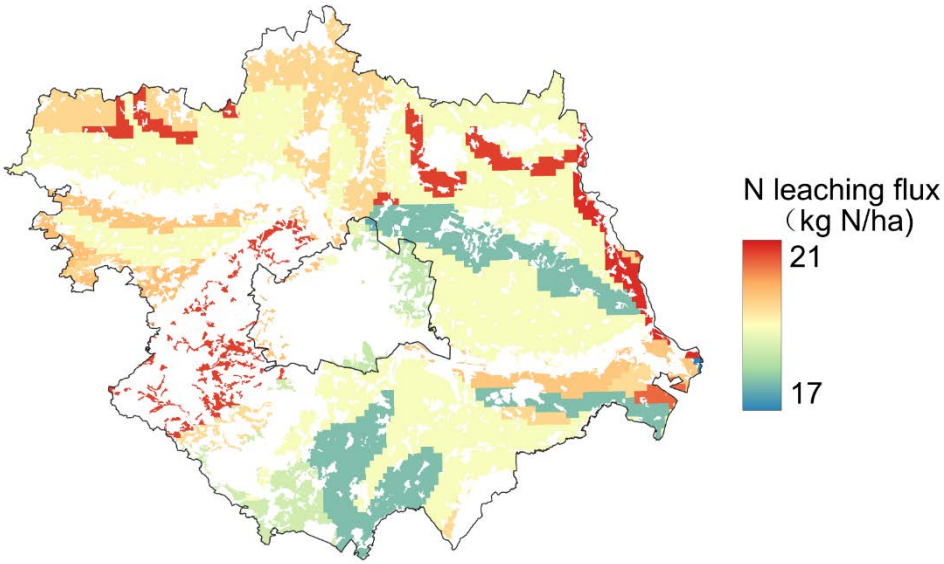
Mean: 3.4 kgN/ha

Mean: 4.4 kgN/ha

Threshold of N leaching: 22.6 kgN/ha (De Vries et al., 2013)

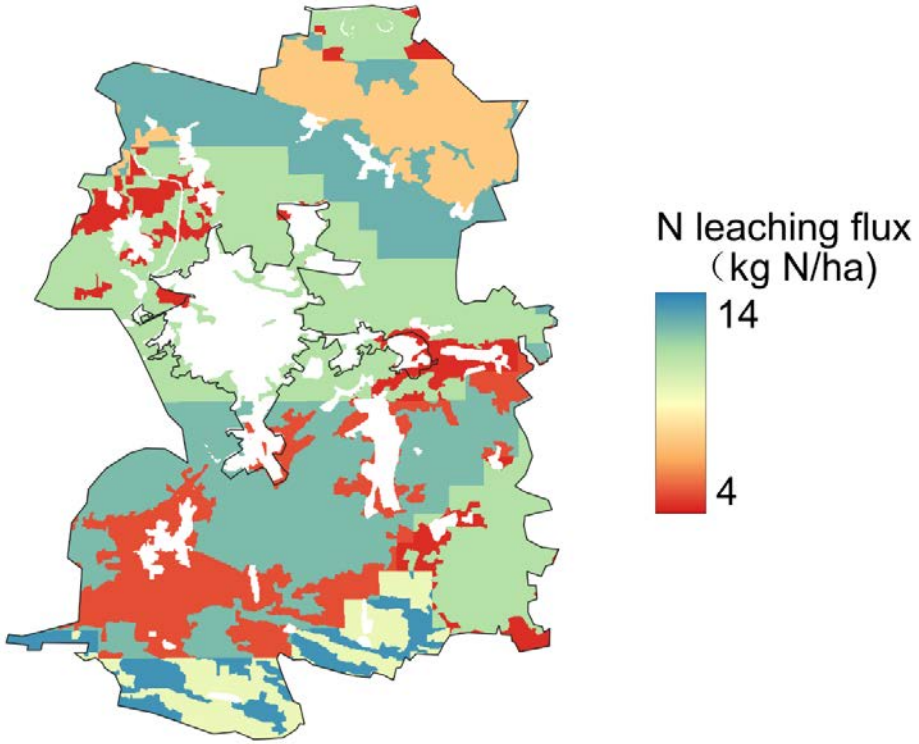
WP4 Task 2 – applications

Vienna



Total N leaching flux (kg N/ha):
Vienna core area: 18.54
Vienna surrounding area:19.0012
Total: 18.9978

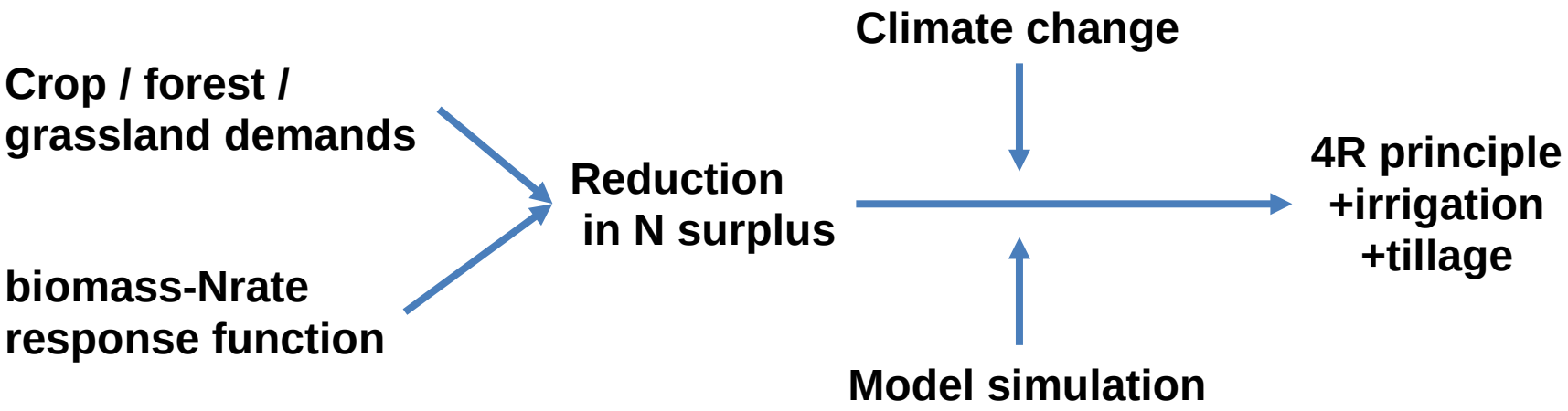
Zielona Góra



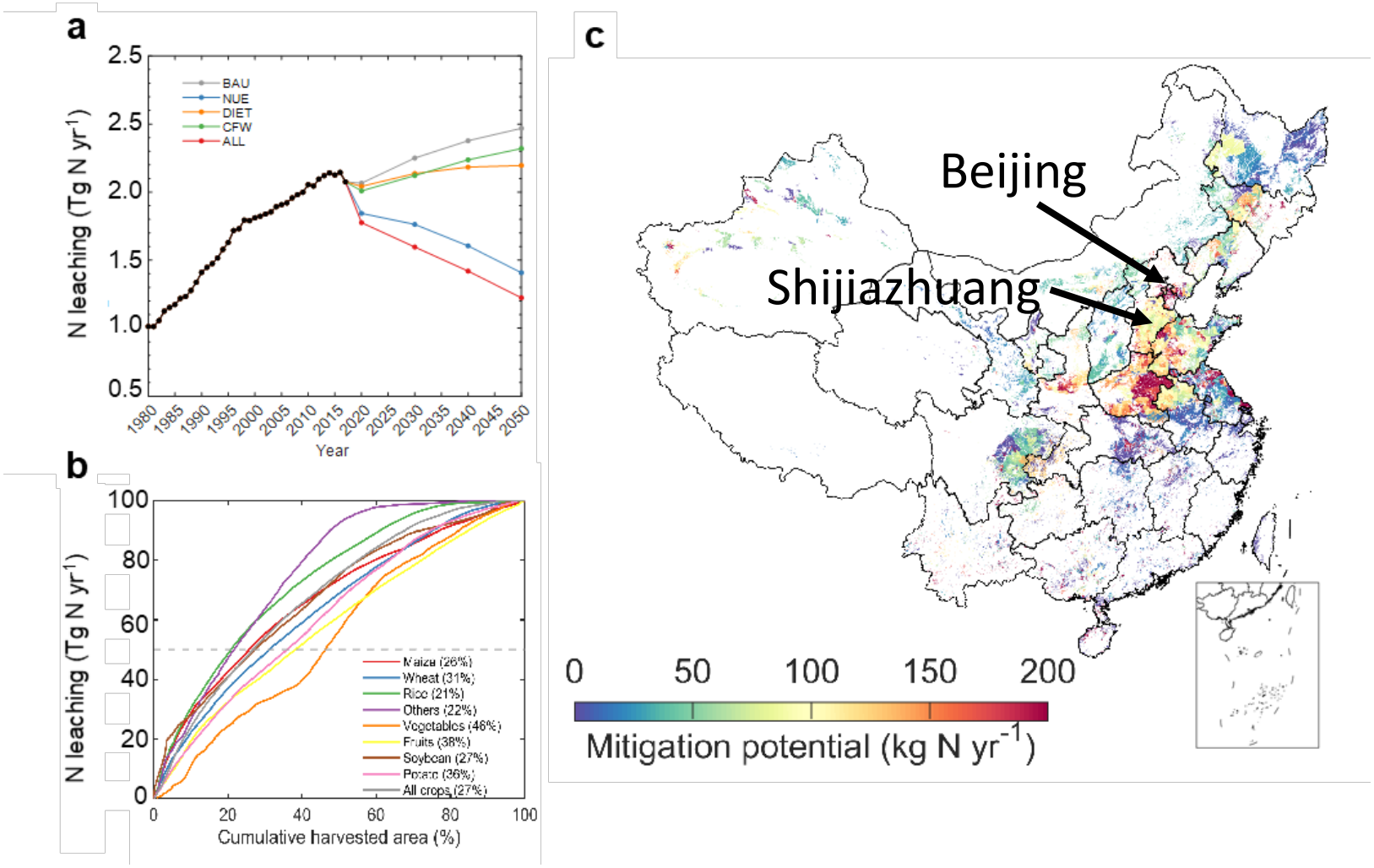
Total N leaching flux of 2018 (kg N/ha):
Zielona Góra City: 7.14
Zielona Góra New District:8.00
Total: 7.89

WP4 Task 3 – Optimization

D4/3: Optimization of urban agriculture management to mitigate groundwater and air N pollution under different climate changes (PKU) **(Month 30)**

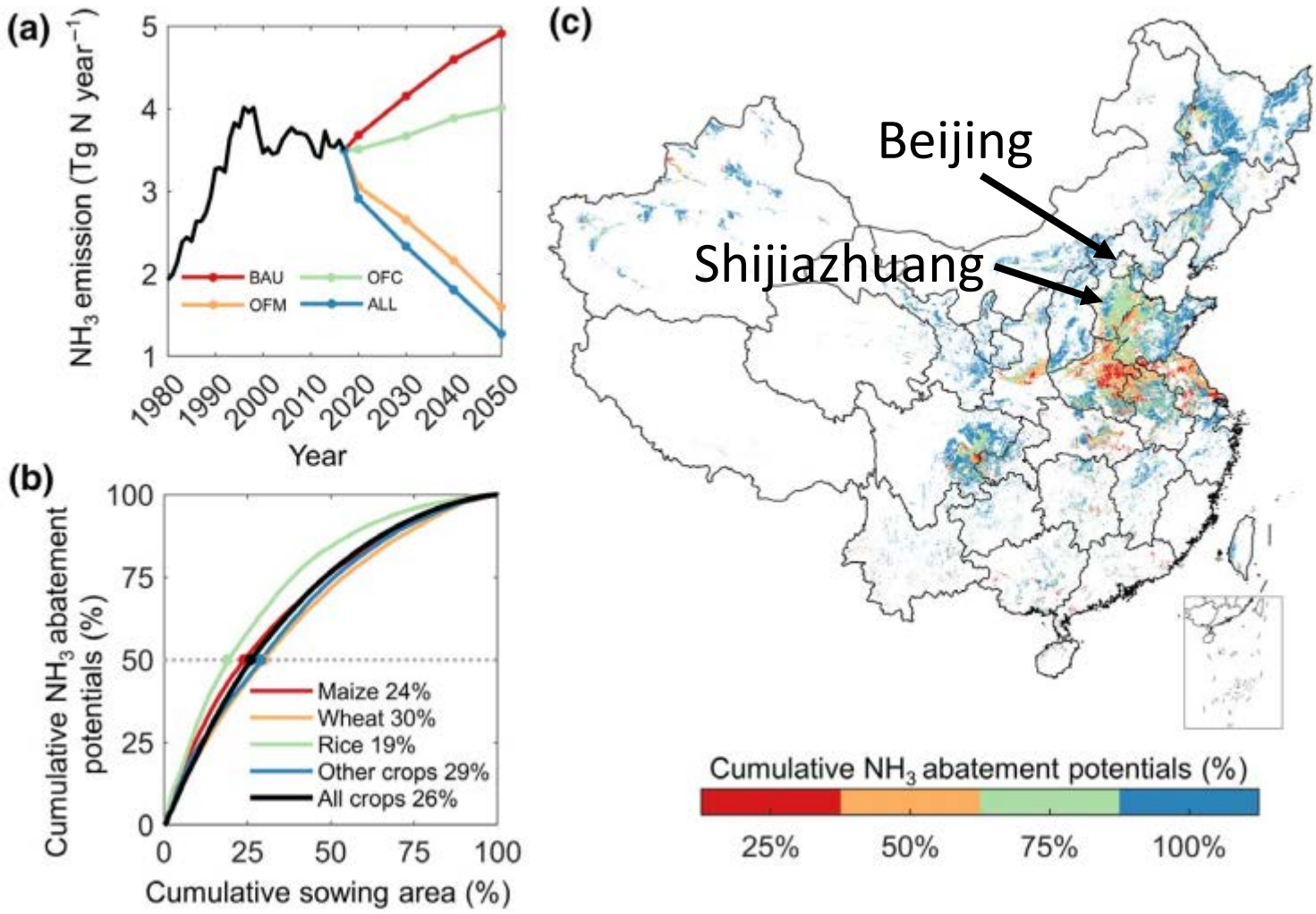


WP4 Task 3 – Optimization



China's cropland N leaching mitigation potentials

WP4 Task 3 – Optimization



China's cropland-NH_3 mitigation potentials.

Thanks for your attention!

1. **Zhou, F.*** et al. (2020) Deceleration of China's human water use and its key drivers. *Proceedings of the National Academy of Sciences* 117, 7702-7711
2. Cui, X.[#]; **Zhou, F.***; et al., Global mapping of crop-specific emission factors highlights hotspots of nitrous oxide mitigation. *Nature Food*. 2021, 2, 886-893.
3. Adalibieke, W.[#]; Zhan, X.[#]; ..., **Zhou, F.***, Decoupling between ammonia emission and crop production in China due to policy interventions. *Global Change Biology*. 2021, 27(22): 5877-5888.
4. Zhan, X.[#]; Adalibieke, W.[#]; …, **Zhou, F.***, Improved estimates of ammonia emissions from global croplands. *ES&T*. 2021, 55(2): 1329-1338.
5. Jiang, W.[#]; Huang, W.[#]; …, **Zhou, F.***, Is rice field a nitrogen source or sink for the environment? *Environmental Pollution*. 2021, 283: 117122.

Urban Agricultural Model and Nitrogen flow characteristics

Xiangwen Fan, Zhaohai Bai, Lin Ma

Center for Agricultural Resources Research, IGDB, CAS

Content

- Background
- Methodology and aim
- Model construction
- Result
- Conclusion

Content

- Background
- Methodology and aim
- Model construction
- Result
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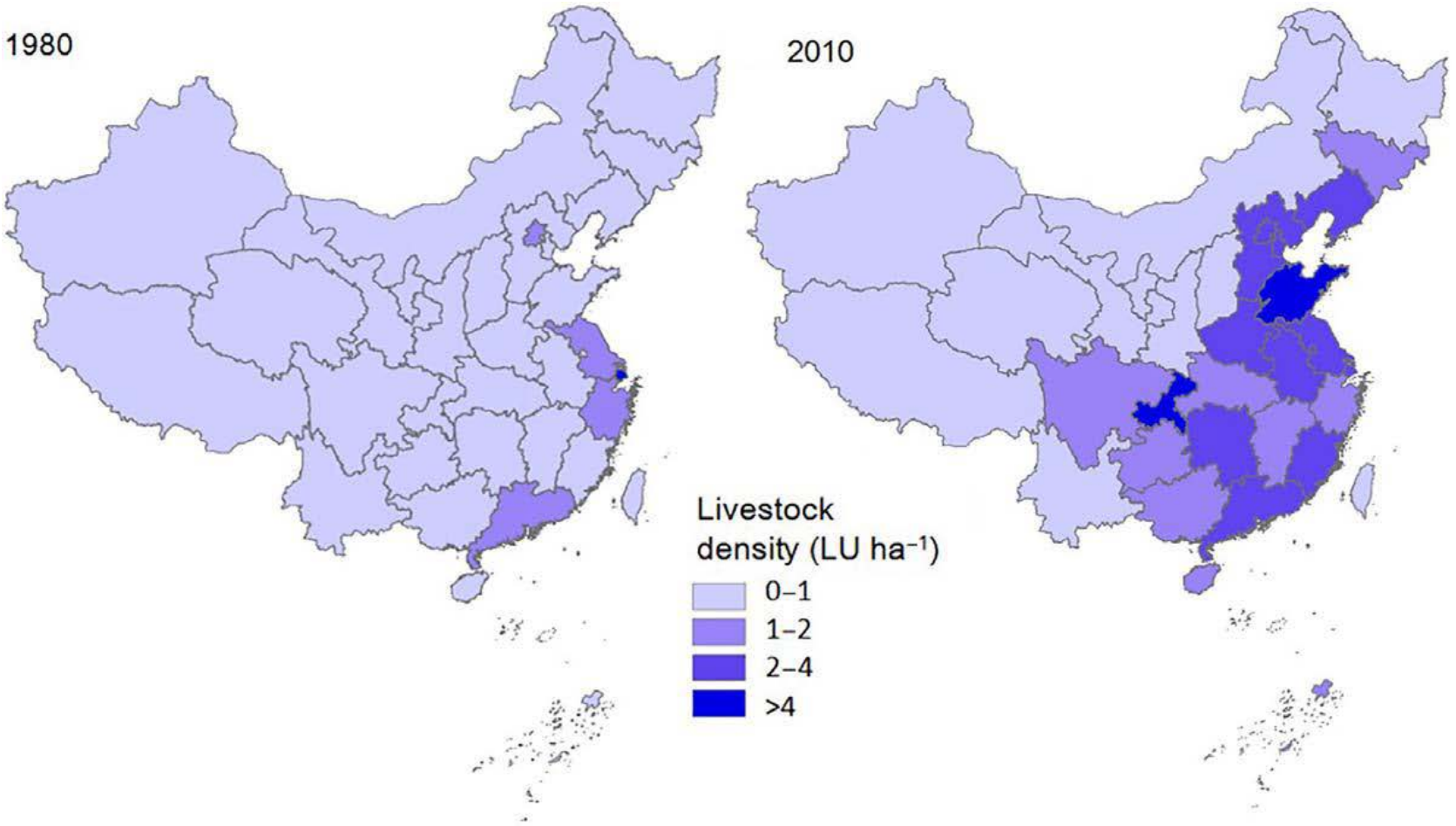
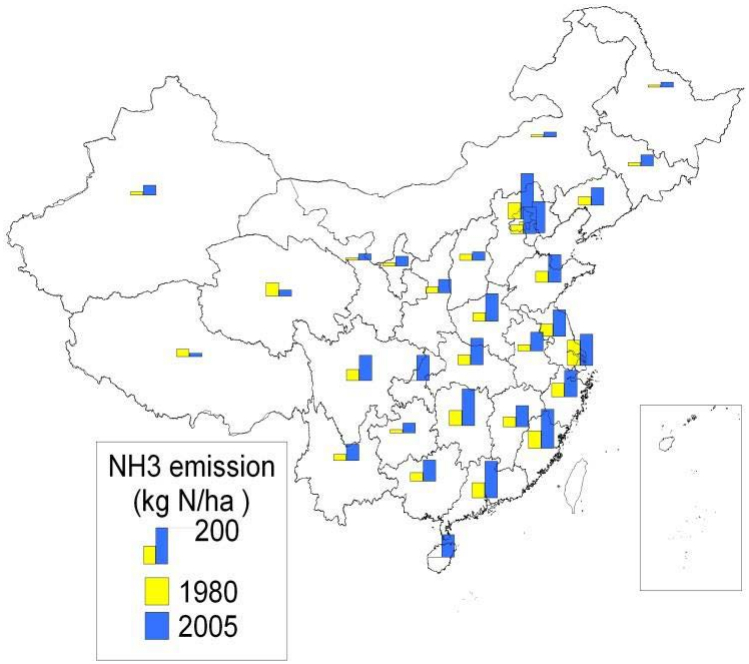
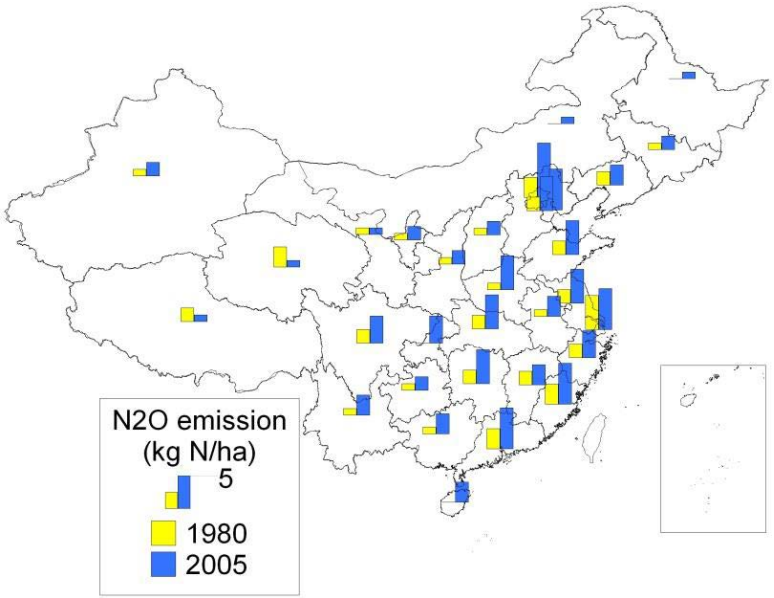
Uneven distribution of livestock production across China, especially in metro cities

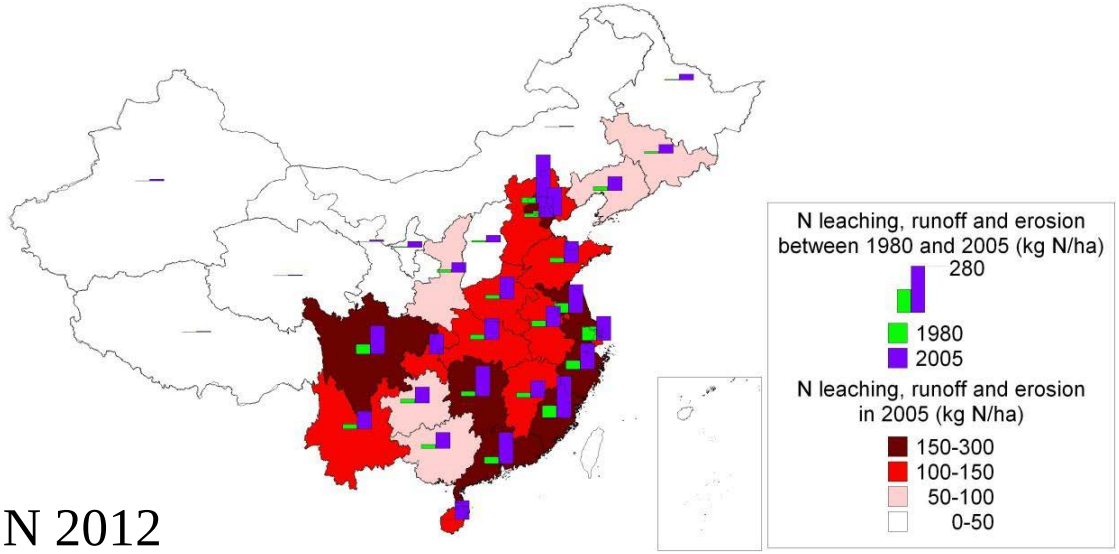


Bai et al.,2018 Science Advances

High nitrogen losses occurred in metropolitan

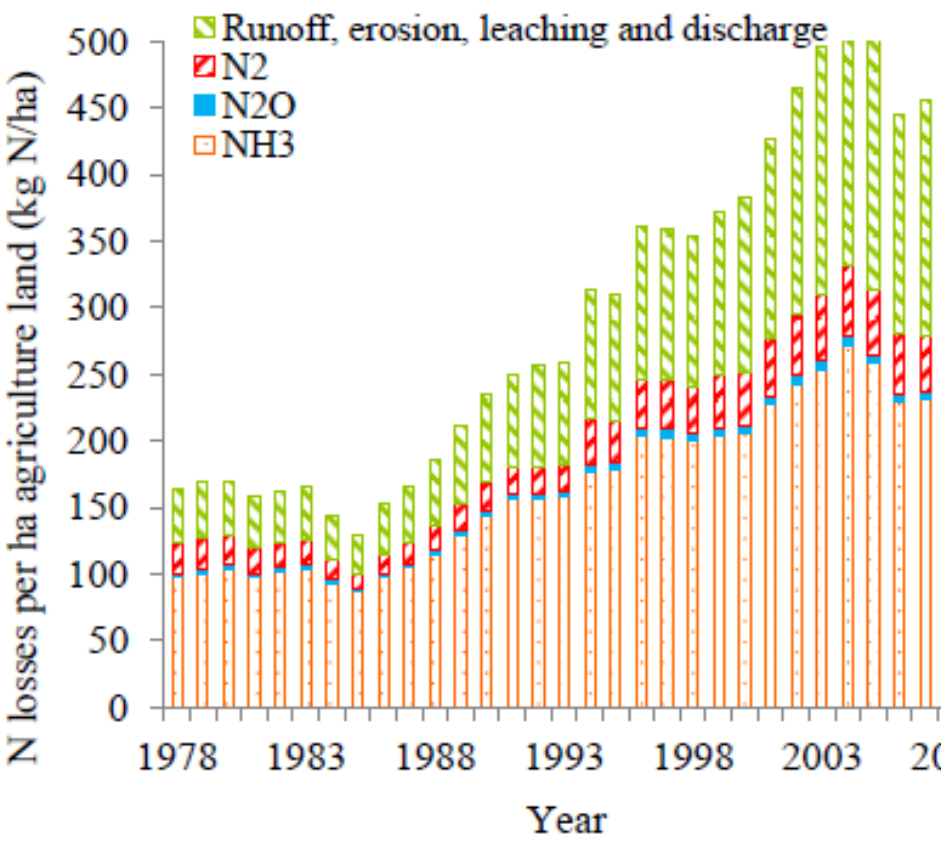


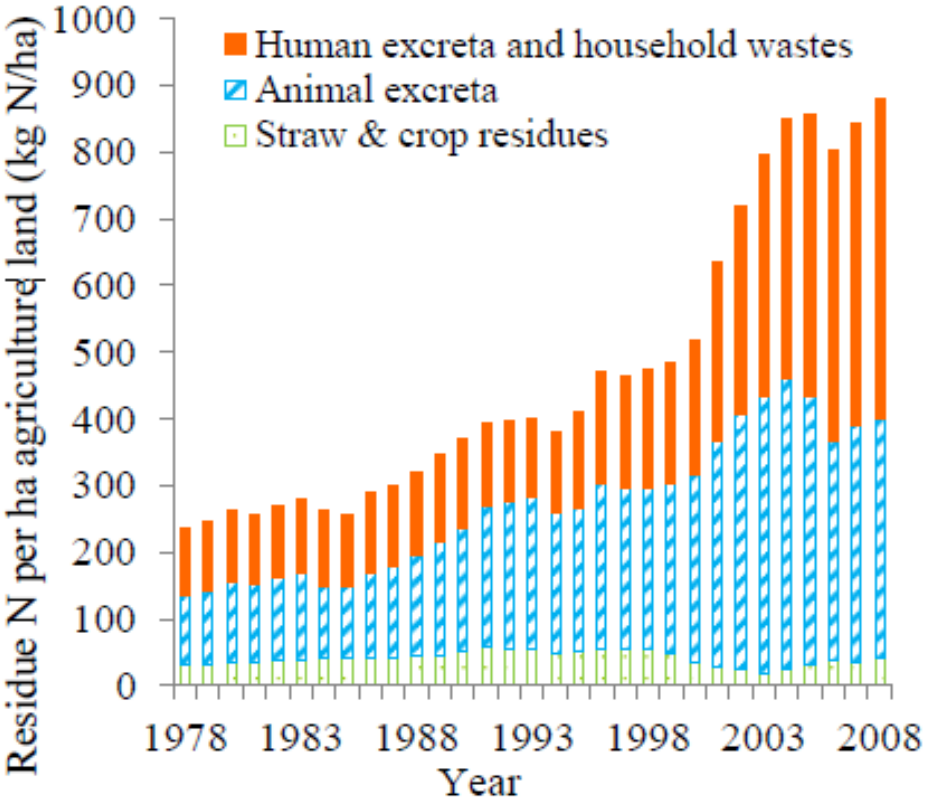




Ma et al., STOTEN 2012

Urban expansion increased N losses and residues in city





Ma et al., GEC 2014

Content

- Background
- Methodology and aim
- Model construction
- Result
- Conclusion

Methodology and aim

Collect data

Extend NUFER model

Export

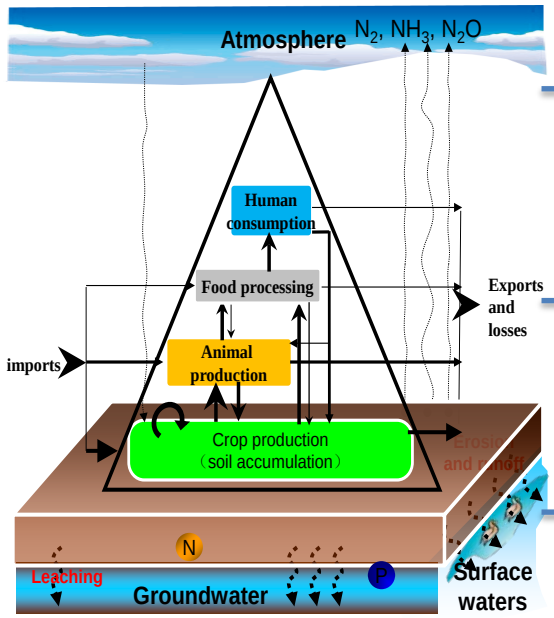
Cropland system

Livestock system

Pet system

Greenland system

Horticultural system



Pet

Greenland

Horticultural

NH_3 N_2 N_2O

Manure export

Product export

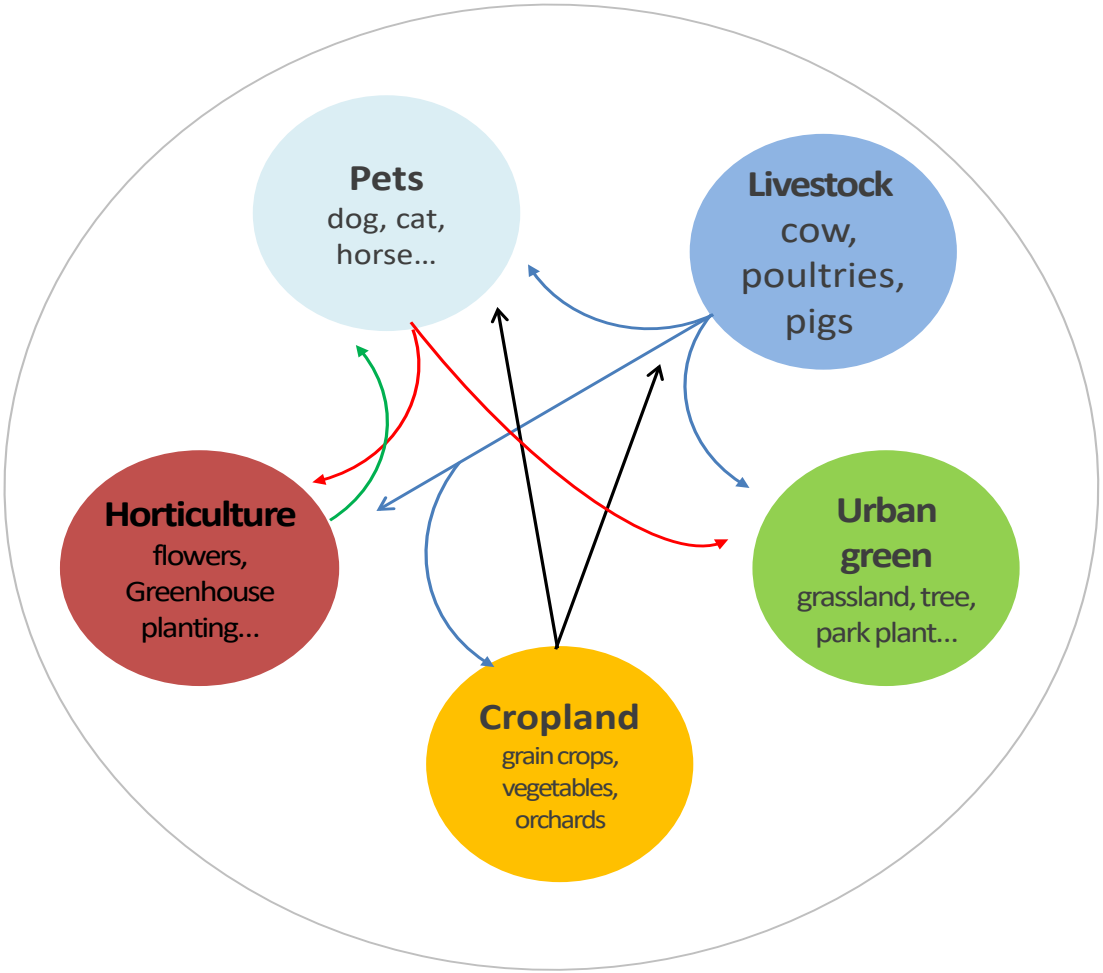
Runoff erosion

Detailed urban agricultural N flow

Content

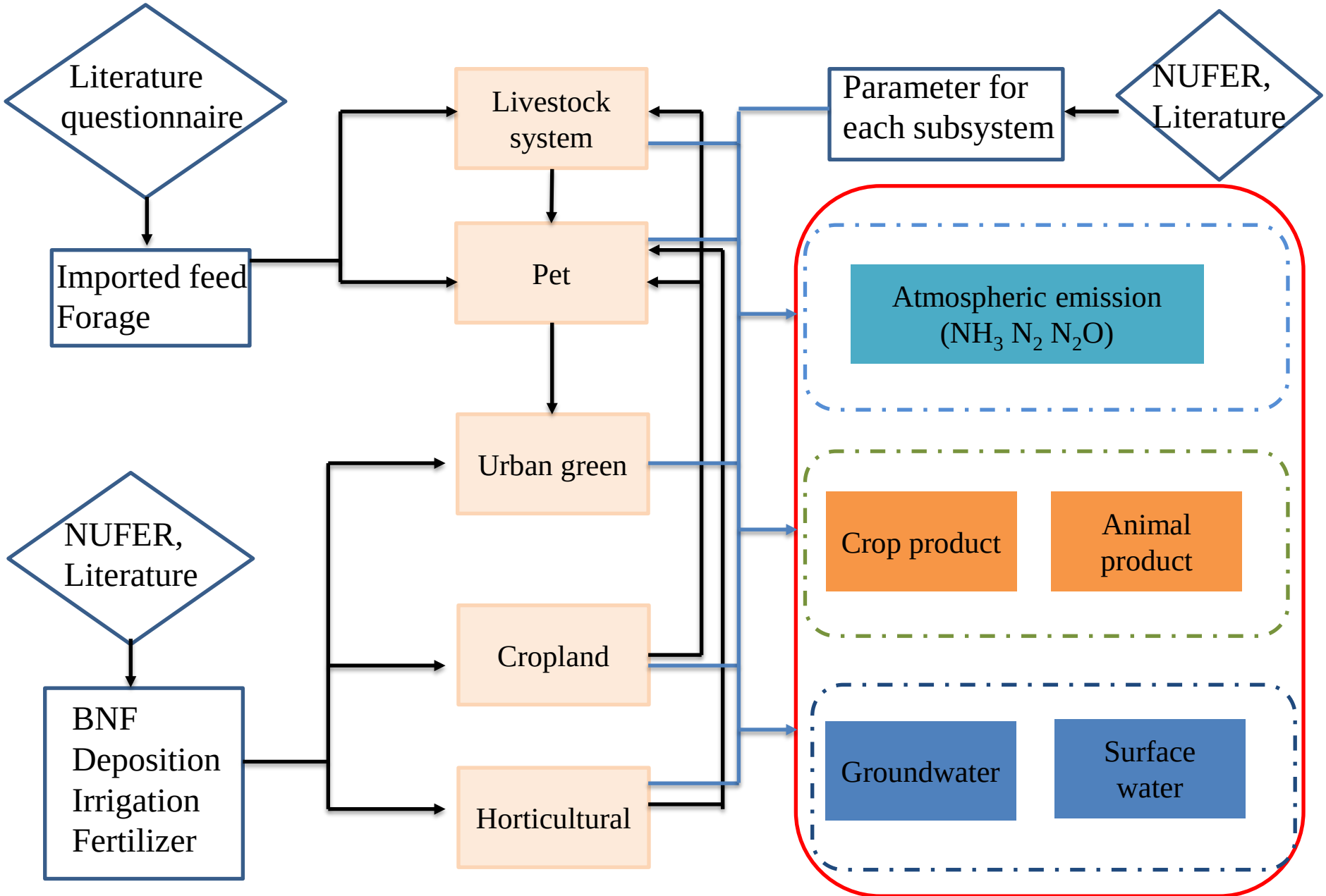
- Background
- Methodology and aim
- Model construction
- Result
- Conclusion

Build the detailed urban agricultural N flow



Concept of nitrogen flows in urban agriculture

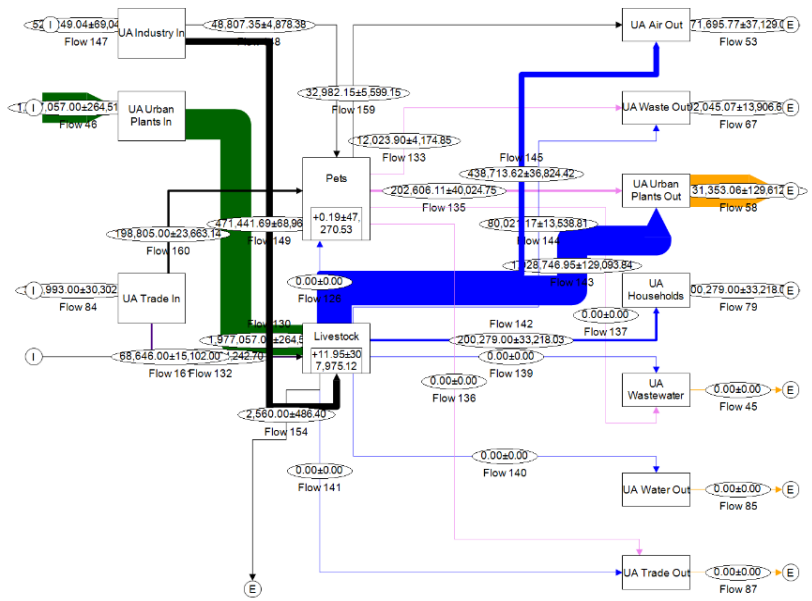
Build the detailed urban agricultural N flow

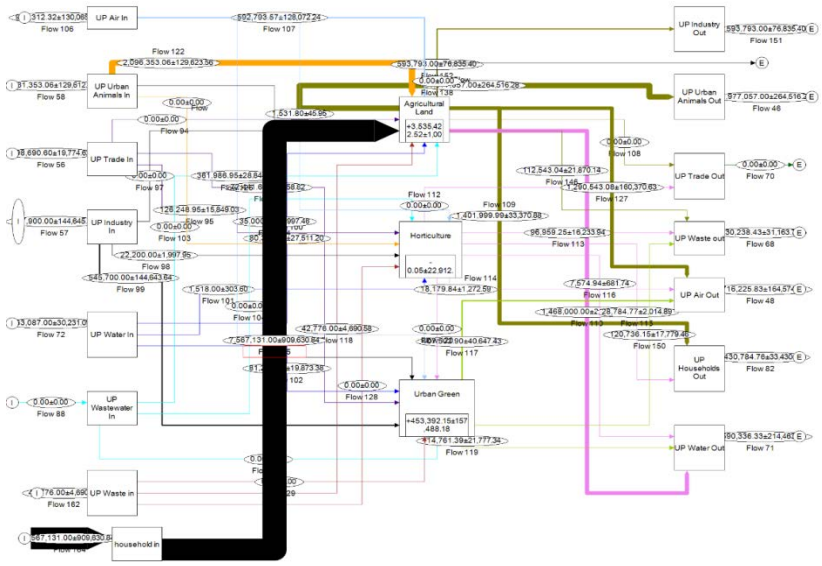


Content

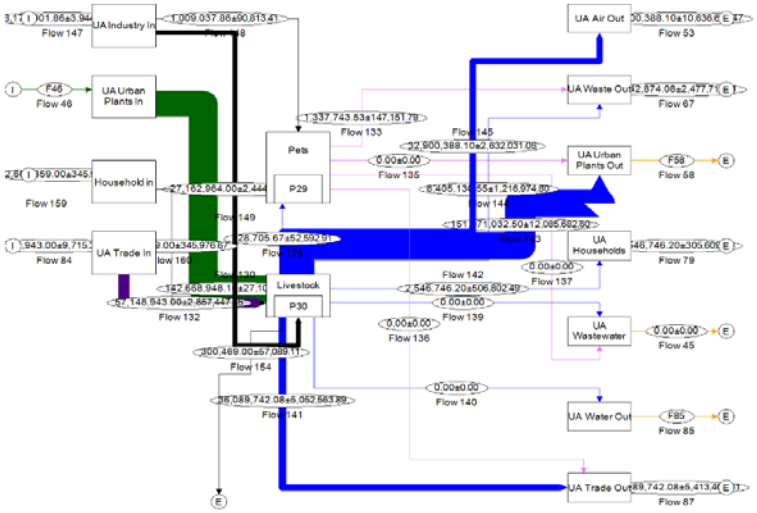
- Background
- Methodology and aim
- Model construction
- Result
- Conclusion

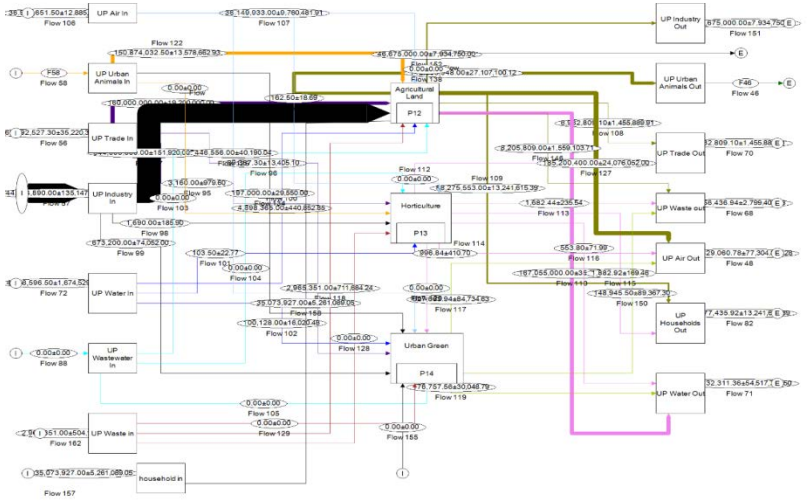
Simulation of urban agriculture flows in Shijiazhuang





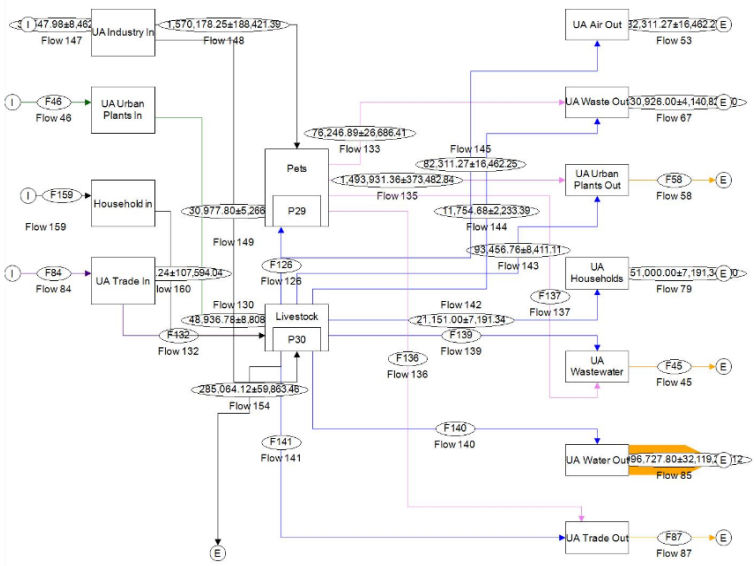
Agricultural N flow in Shijiazhuang city

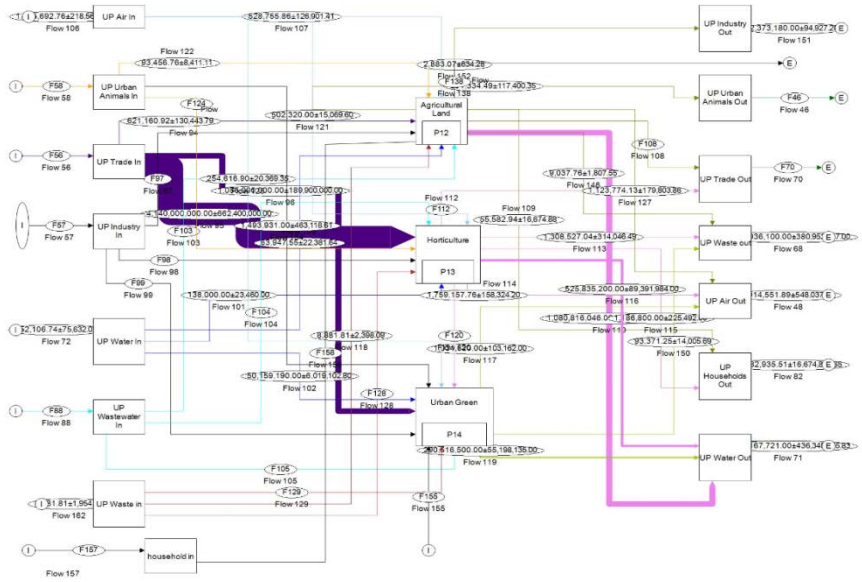




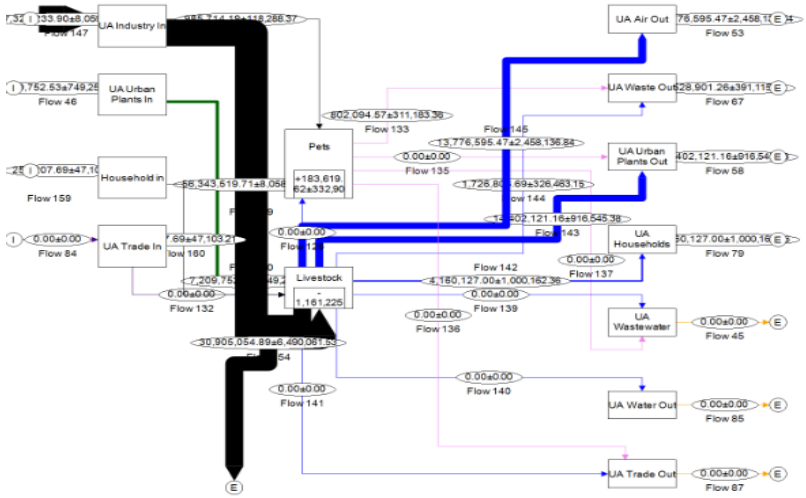
Agricultural N flow in Shijiazhuang surrounding area

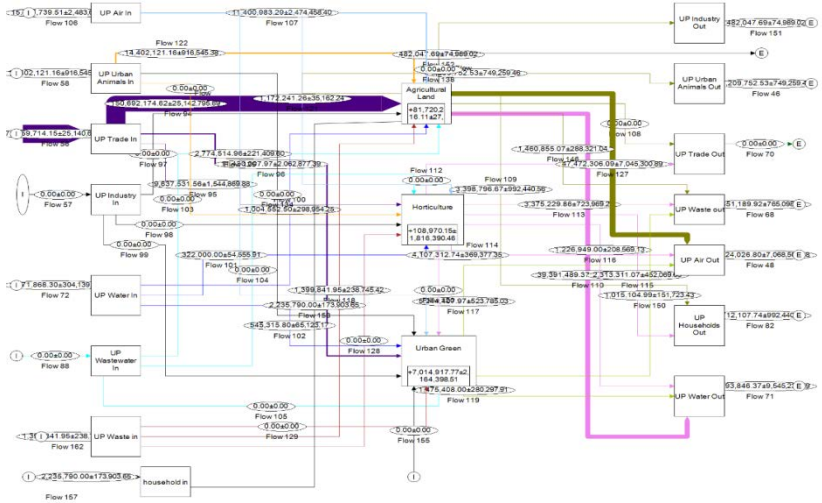
Simulation of urban agriculture flows in Beijing





Agricultural N flow in Beijing city





Agricultural N flow in Beijing surrounding area

Characteristics of agricultural N flow

1. The NUE of urban area is higher than surrounding area;

2. Due to high agricultural production in surrounding area, the plant products self-sufficiency, fodder self-sufficiency and livestock products self-sufficiency are higher in surrounding area;

3. Coupling rate of crop and livestock and ratio of annual manure N excretion to annual crop N uptake both are low in city and surrounding area;

4. Share of N in food and feed imports in city are higher than surrounding areas in order to meet high population needed.

Content

- Background
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Conclusion

1.Greatly increased total N input to agricultural system to meet high population may caused high losses of ammonia and N_2O to air and N to groundwater and surface waters;

2. Optimizing livestock diet and on-farm manure management in livestock systems can serve as a powerful instrument to tackle N pollution ;

3. Increased coupling rate of crop and livestock and manure applied to field can reduce N imported and N losses.

Thank you!

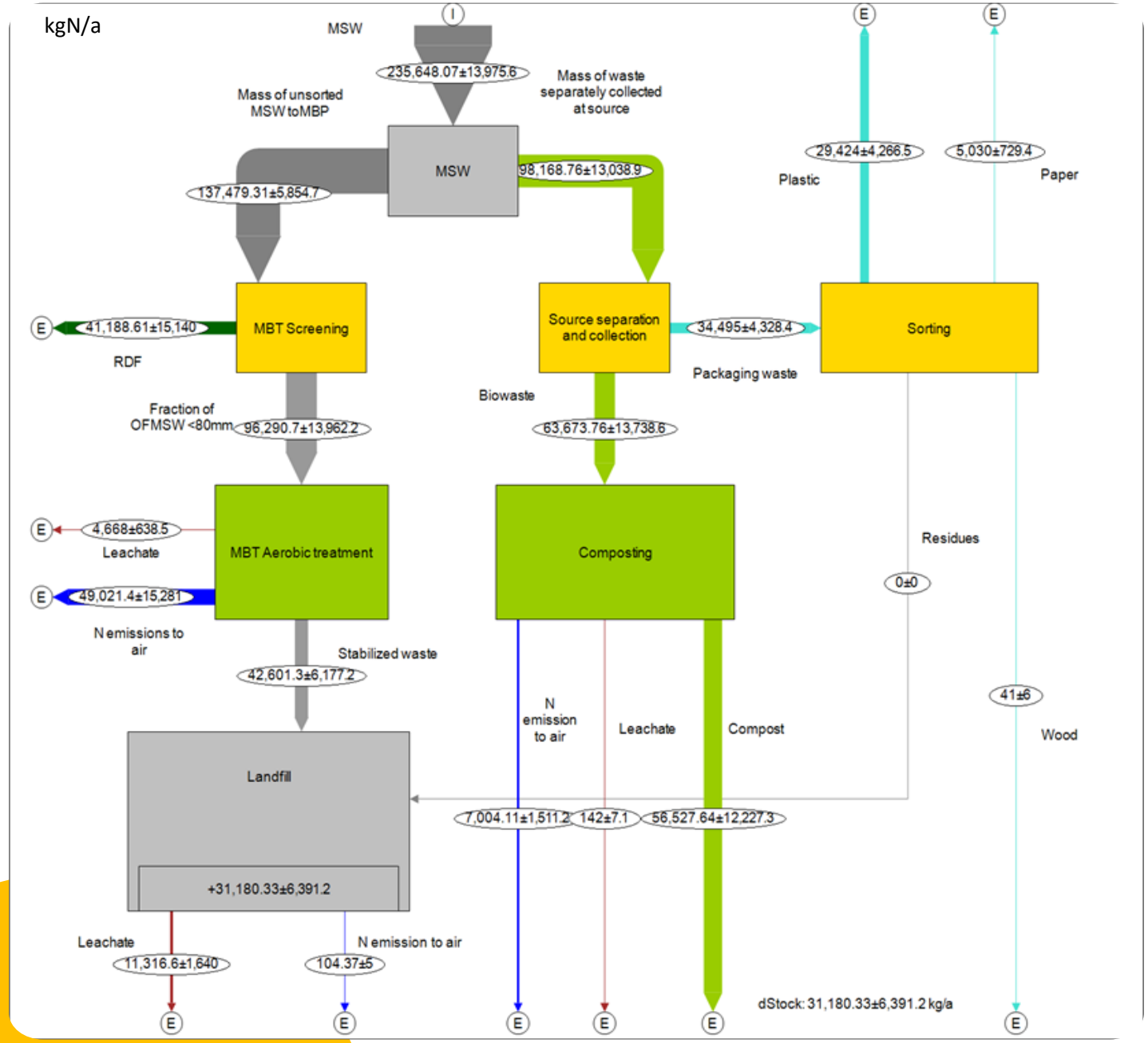
Urban Nitrogen Cycles: New Economic Thinking to master the challenges of climate change

Nr emissions from wastewater and waste in cities

Nr emissions from wastewater and waste in cities

- The rate of nitrogen emissions from wastewater and waste is significantly correlated with the **dynamics of changes in the number of people living in urban areas**, producing waste/wastewater, and on their physical and chemical composition.
- The physical and chemical components of waste/wastewater and their mass depend on: **eating habits, standard of living, degree of commercial activity, season, dynamics of economic development, cultural conditions, technical and sanitary equipment, type of industry and its efficiency**, etc.
- The type of waste and wastewater **treatment technology** used, how it is collected and transported, and **the amount of nitrogen recovery and reuse** have a significant impact on nitrogen emissions.

100,000 inhabitants

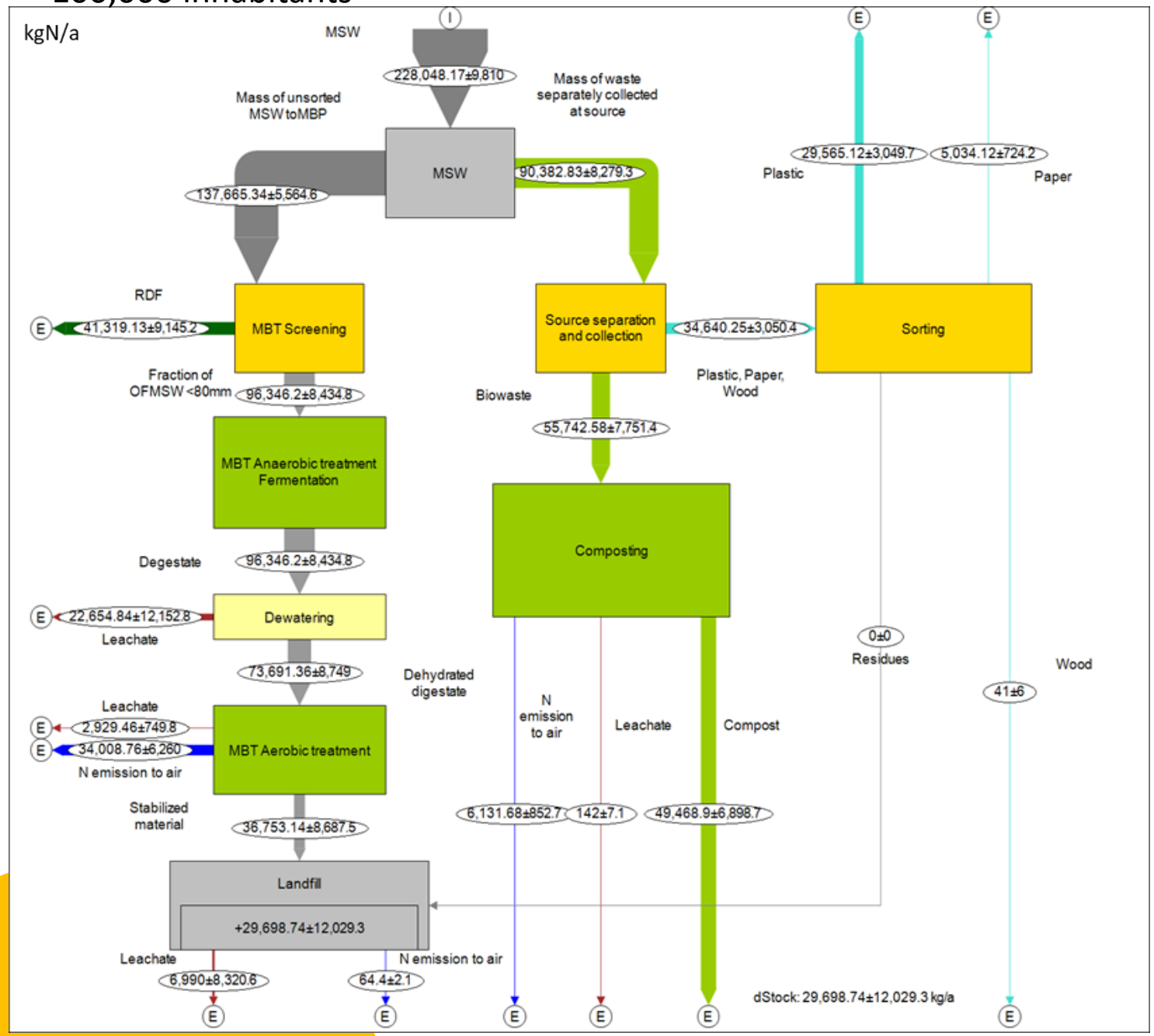


Mechanical-biological treatment of waste

Typical waste management in cities is carried out in mechanical-biological waste treatment plants which aim to:

- **biologically stabilize the biodegradable fraction of municipal waste,**
- **reduce the waste deposited in landfills,**
- **recover materials.**

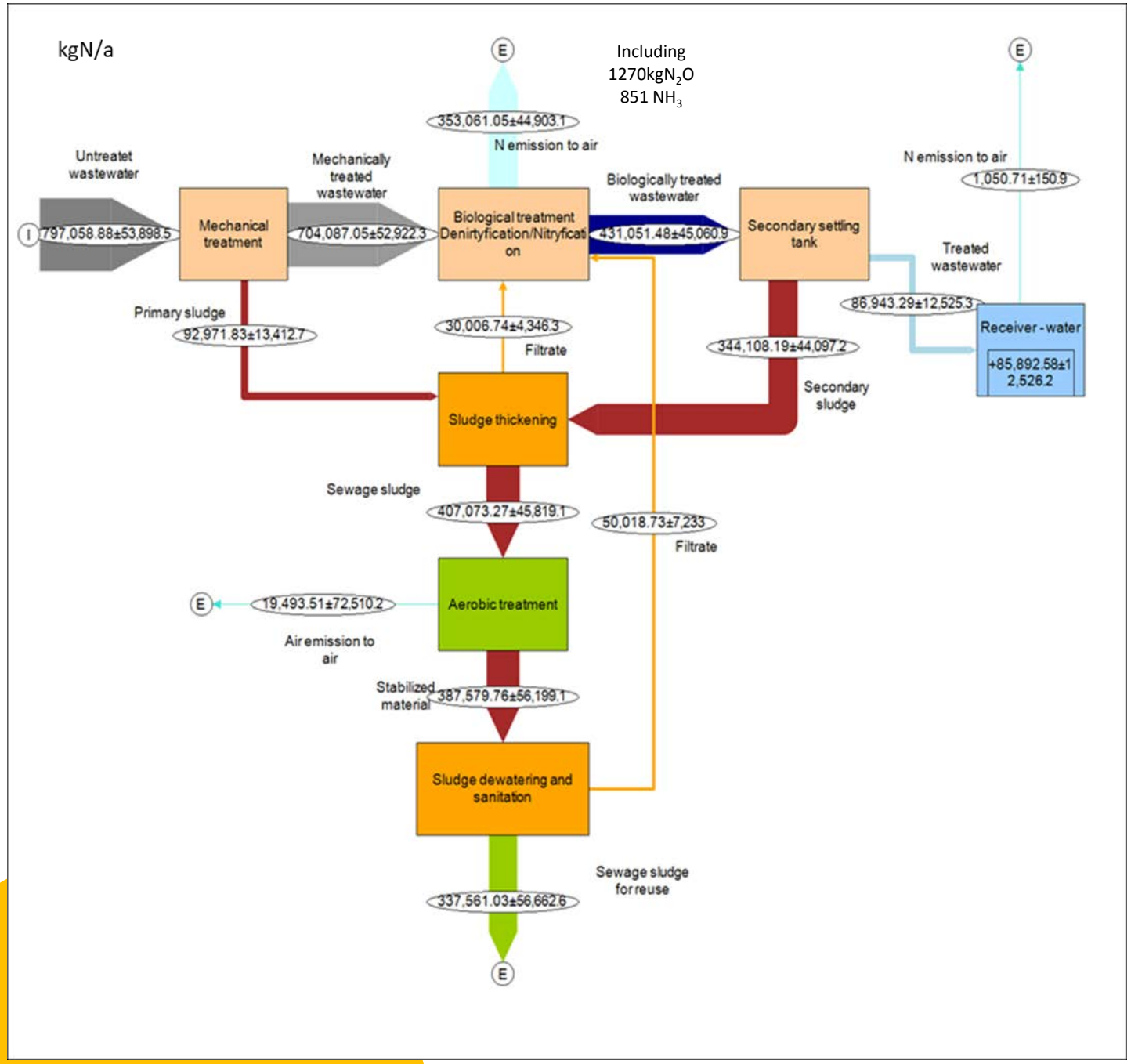
100,000 inhabitants



Mechanical-biological treatment of waste

- Biological stabilization of MSW and collected at source bio-waste can be carried out by aerobic and anaerobic methods. In anaerobic method there is additional energy recovery. And in case of bio-waste there is no emission of Nr to air.

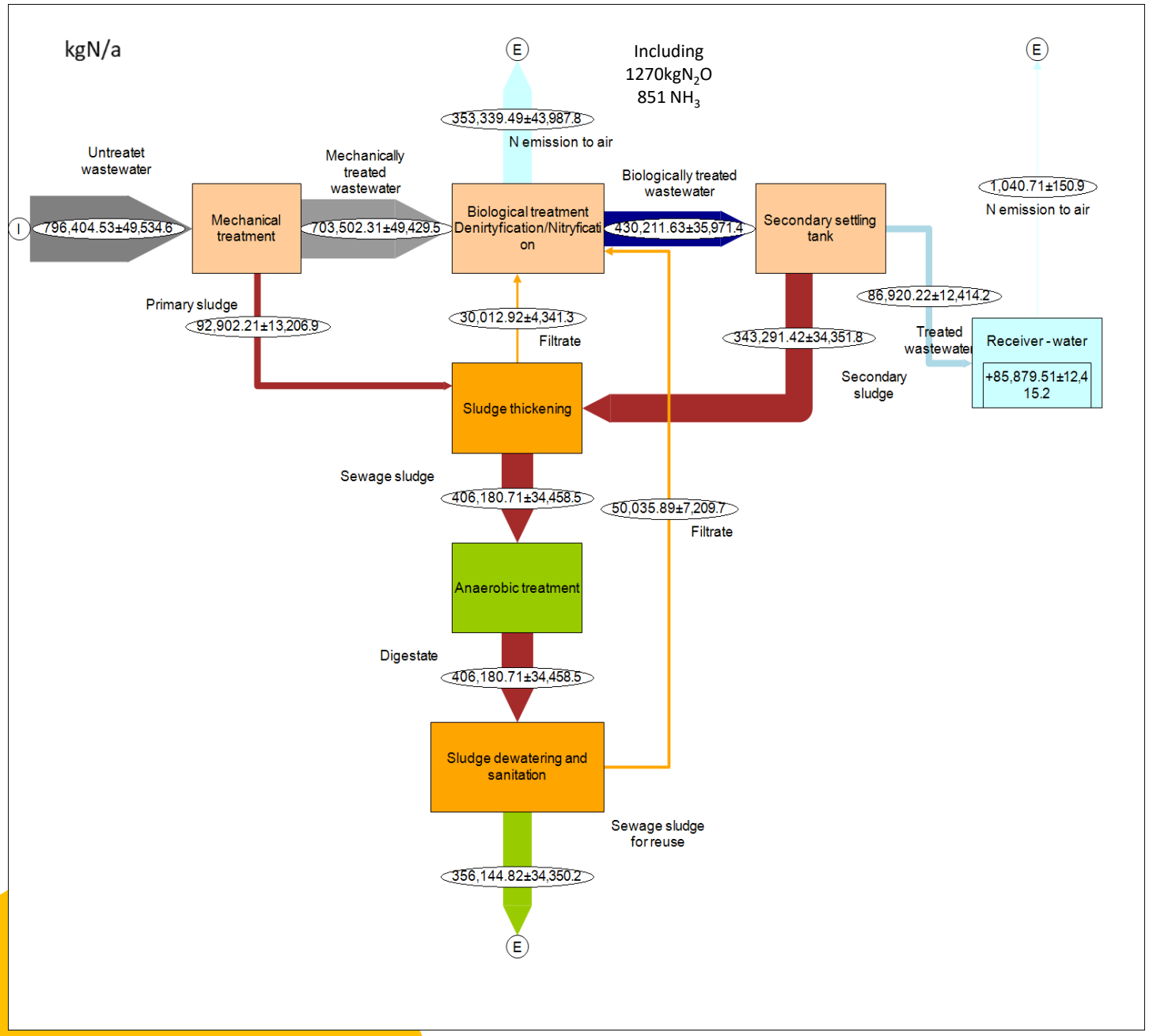
100,000 inhabitants



Wastewater treatment plant

- Typical wastewater treatment is mechanical-biological treatment in activated sludge plants. The main nitrogen emissions during the process occur during the biological nitrogen removal process, nitrification and denitrification. Most of the gaseous nitrogen is emitted during the process, while emissions of nitrous oxide and ammonia are much smaller.
- The main nitrogen stream to be managed is in sewage sludge and treated wastewater. Sewage sludge can be treated under aerobic and anaerobic conditions and these processes result in a product that can be used for nature or agriculture.

100,000 inhabitants



Nitrogen reuse and recovery from wastewater and sewage

A popular method Nr recovery is the production of struvite (ammonium-magnesium phosphate) - mineral fertilizer from sedimentary liquid by precipitation reactions.

Other methods which are at the stage of research and implementation are:

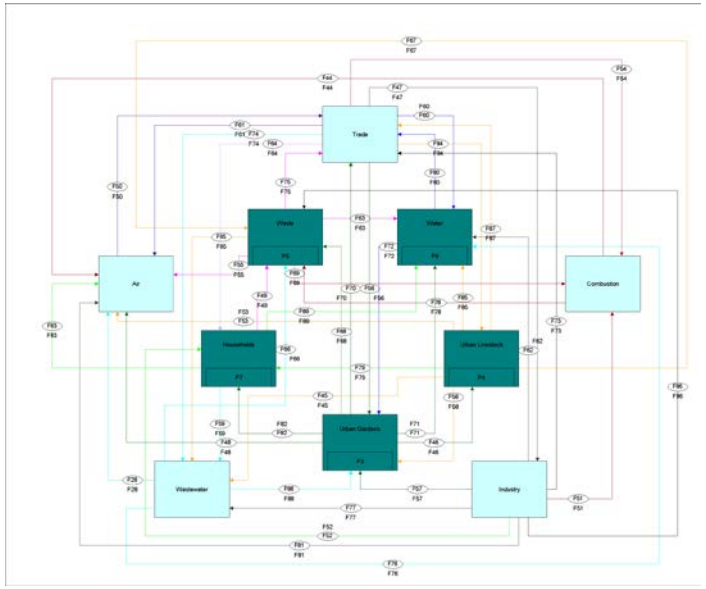
- **recovery of ammonia from wastewater and digestion liquids in membrane technologies**
- **stripping of ammonia in stripping towers with recovery of concentrated solution of ammonium sulfate, ammonium nitrate or ammonia water**
- **use of urea from wastewater as a catalyst in hydrogen generators**
- **use of microbial fuel cells (MFC)**

How to reduce the amount of nitrogen emitted to the environment

- **Increase nitrogen recovery and/or reuse**
- **Use highly efficient methods to treat nitrogen from wastewater (the higher the efficiency, the lower the N_2O emissions)**
- **Reuse of treated wastewater**
- **Increase separate collection of packaging waste and biowaste**
- **Use anaerobic digestion processes for waste and sludge**

Urban Nitrogen Budgets Comparison and Indicators

Methodology & Purpose

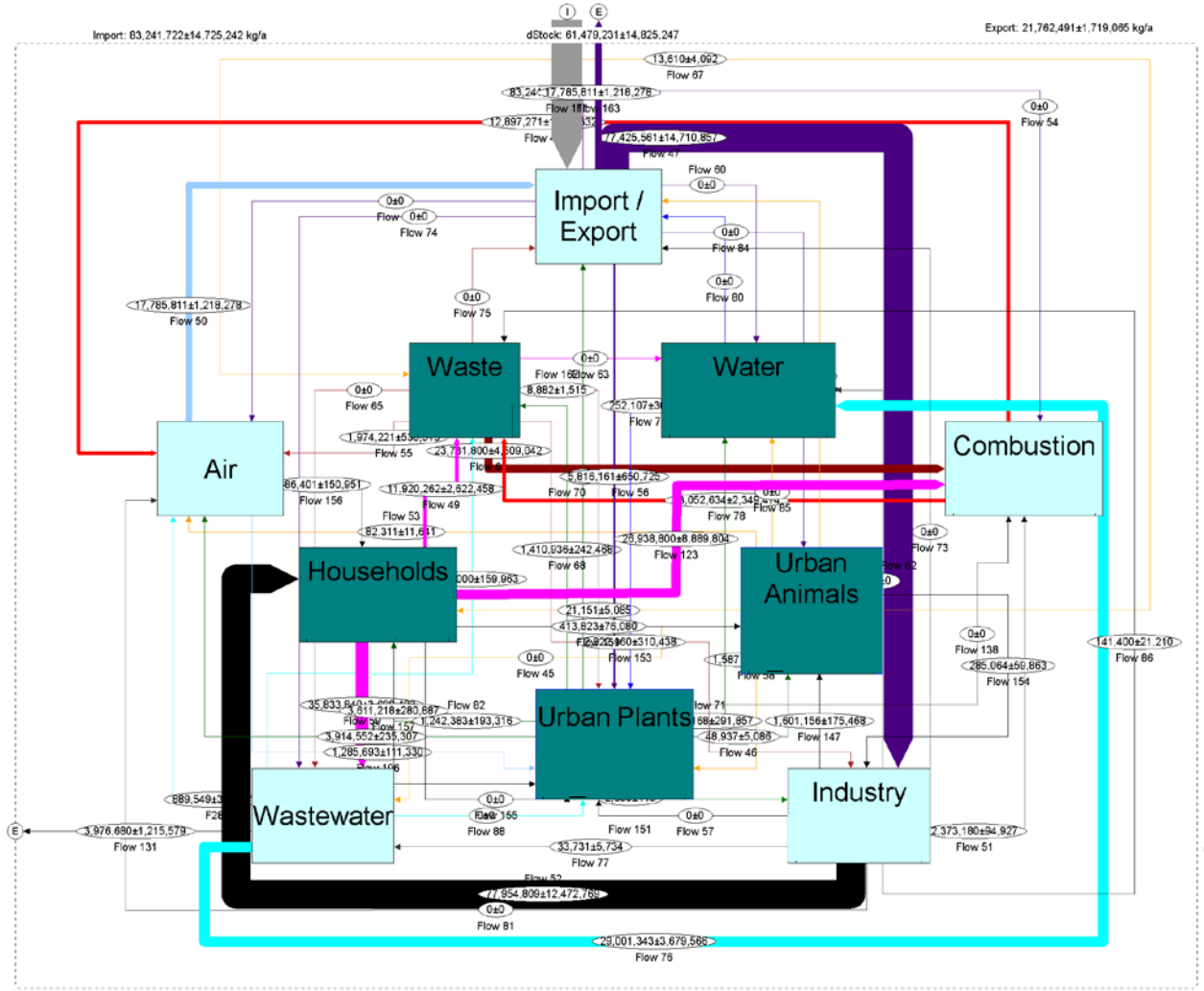


- Characterize system & find patterns
  - Biggest flows per pool and in overall budget
  - Identification of N sinks and sources
  - Flows per capita & per area where relevant

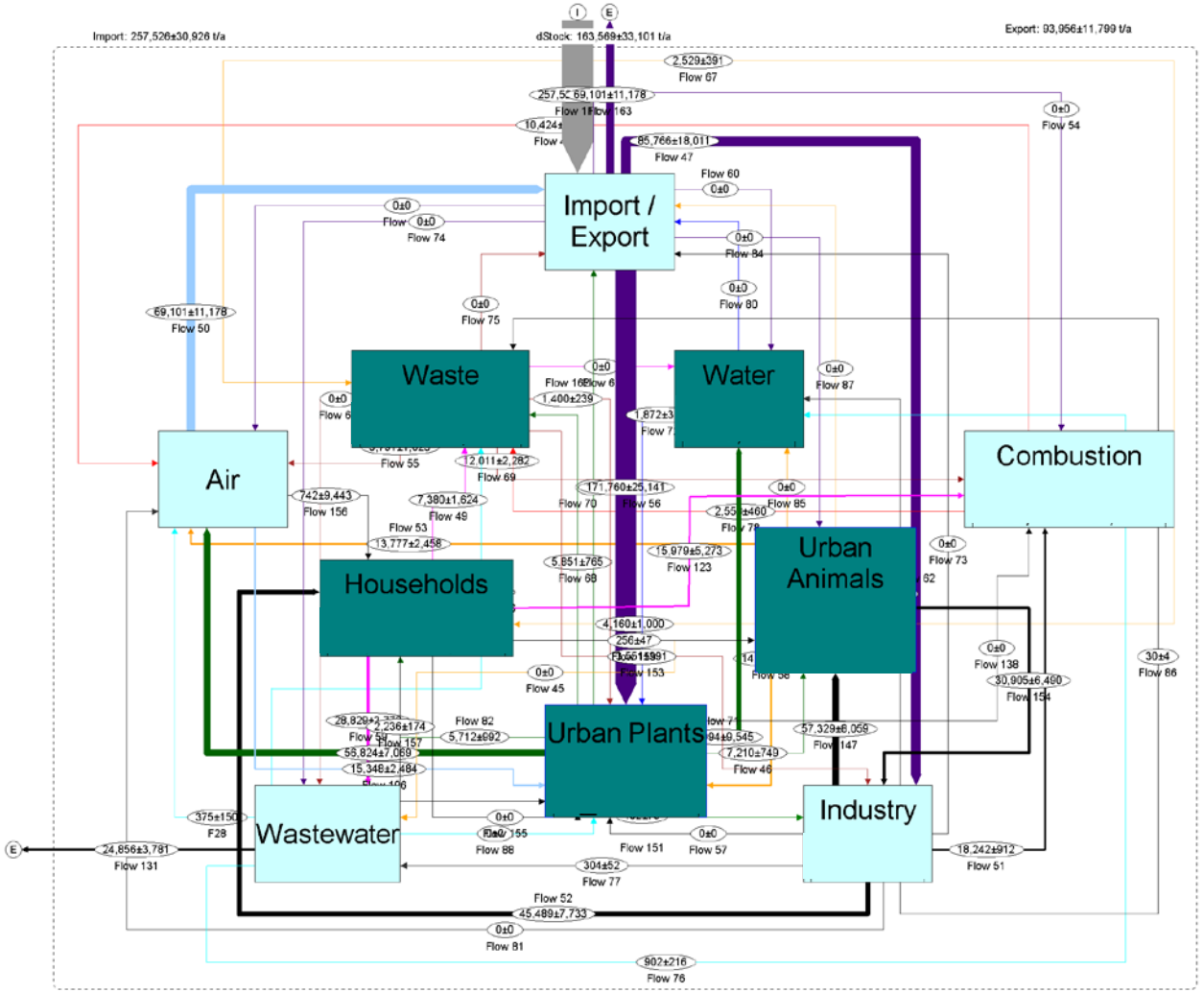
- Evaluate (environmental) impacts
  - Using indicators: NUE, N surplus - planetary boundaries, SDGs

- Evaluate potentials/solutions supporting the development of a circular economy
  - Recycling rate

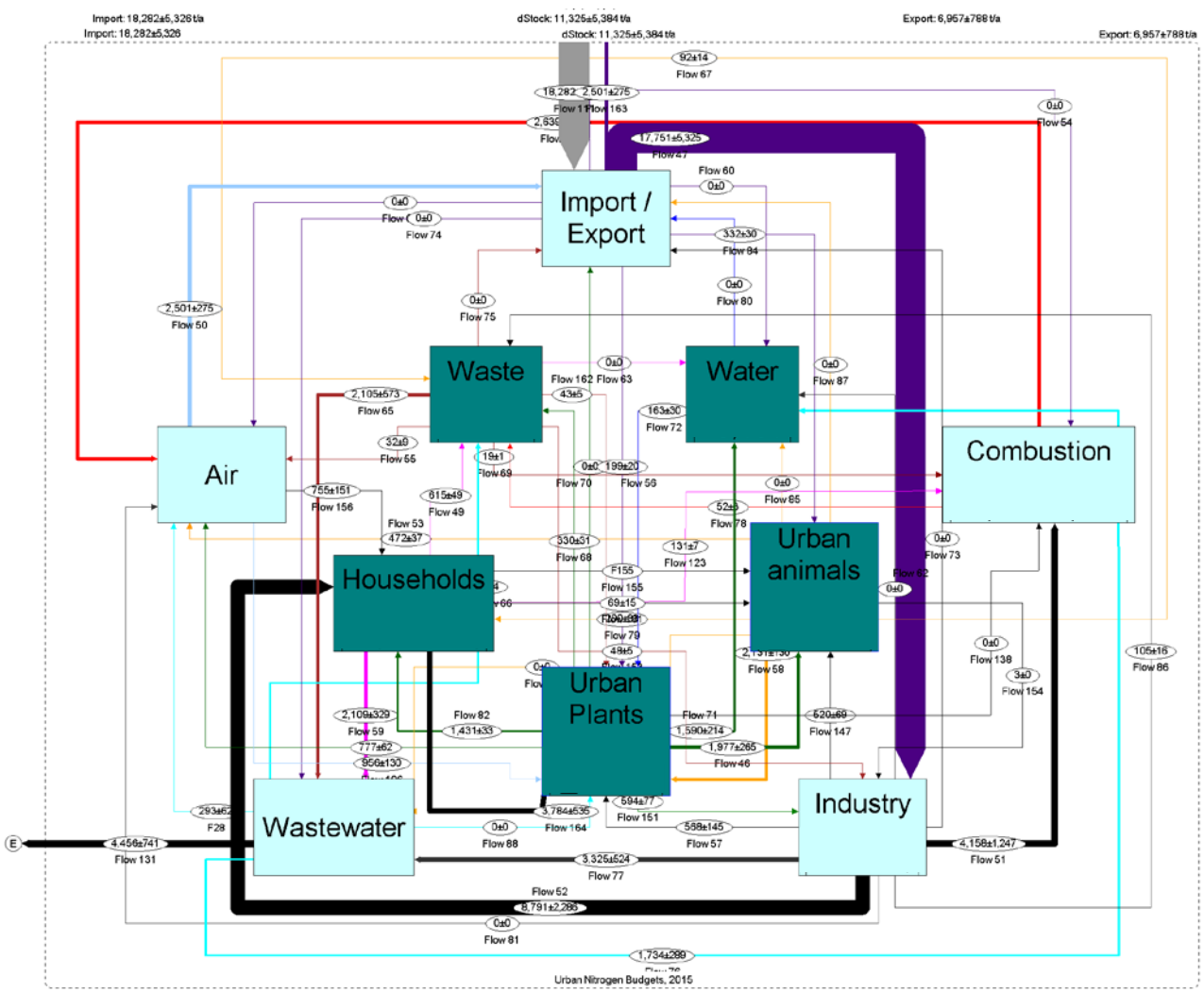
Beijing



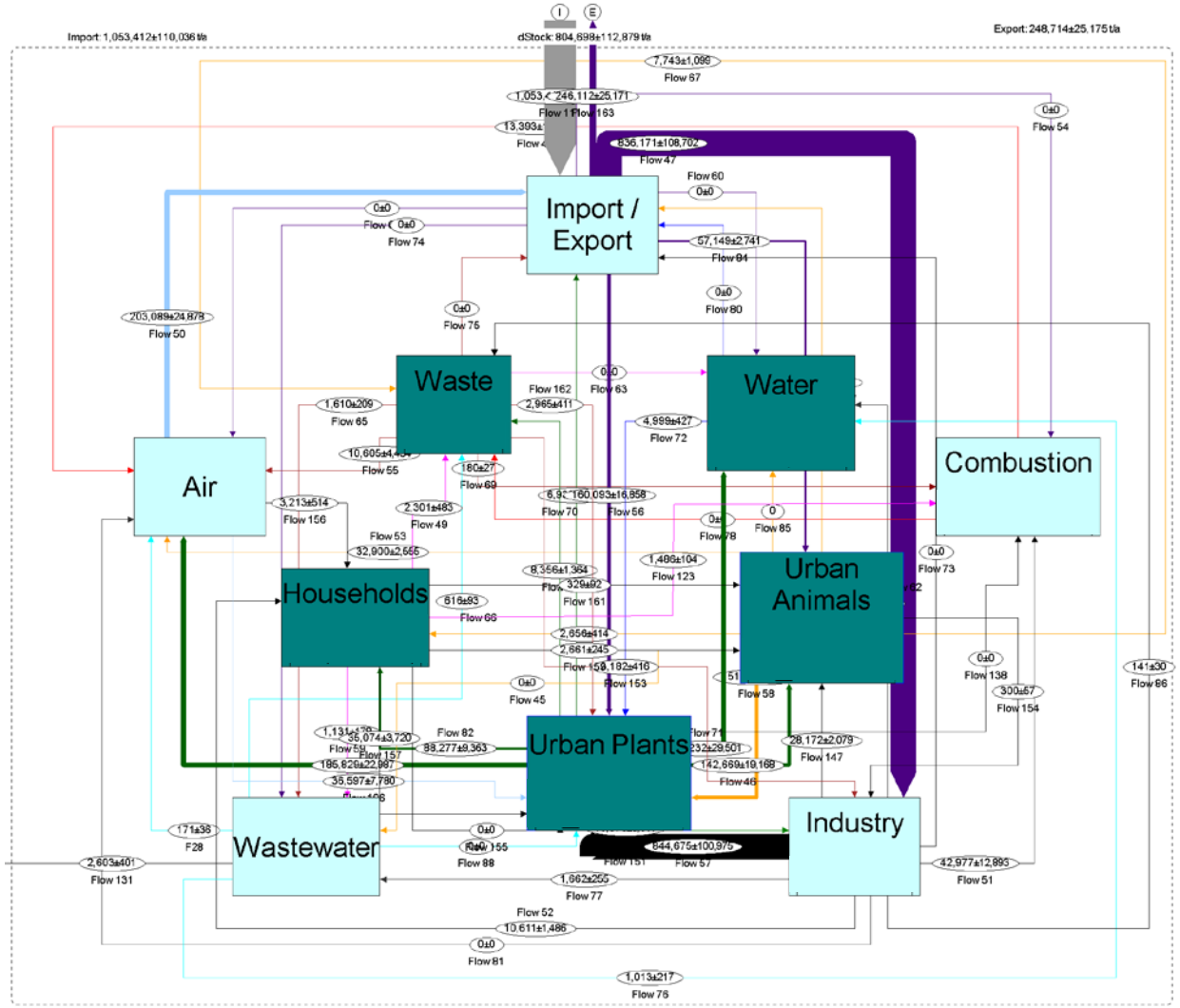
Beijing Surrounding

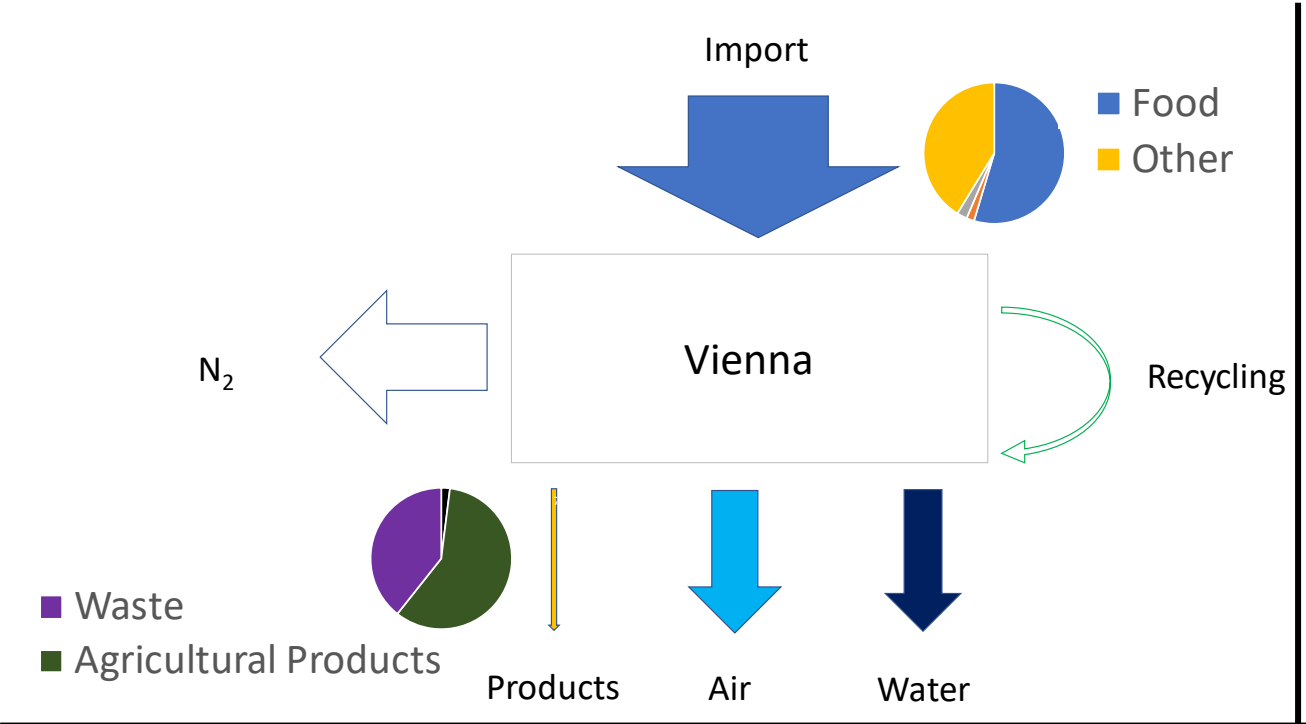


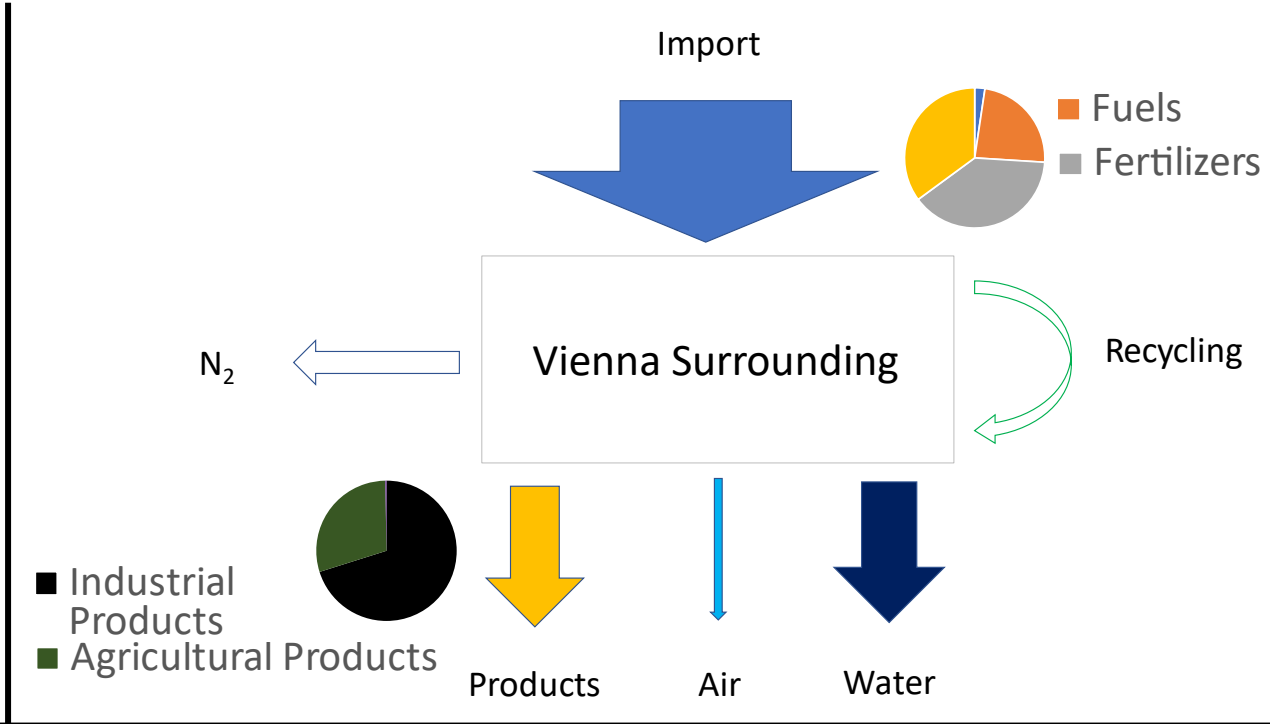
Shijiazhuang

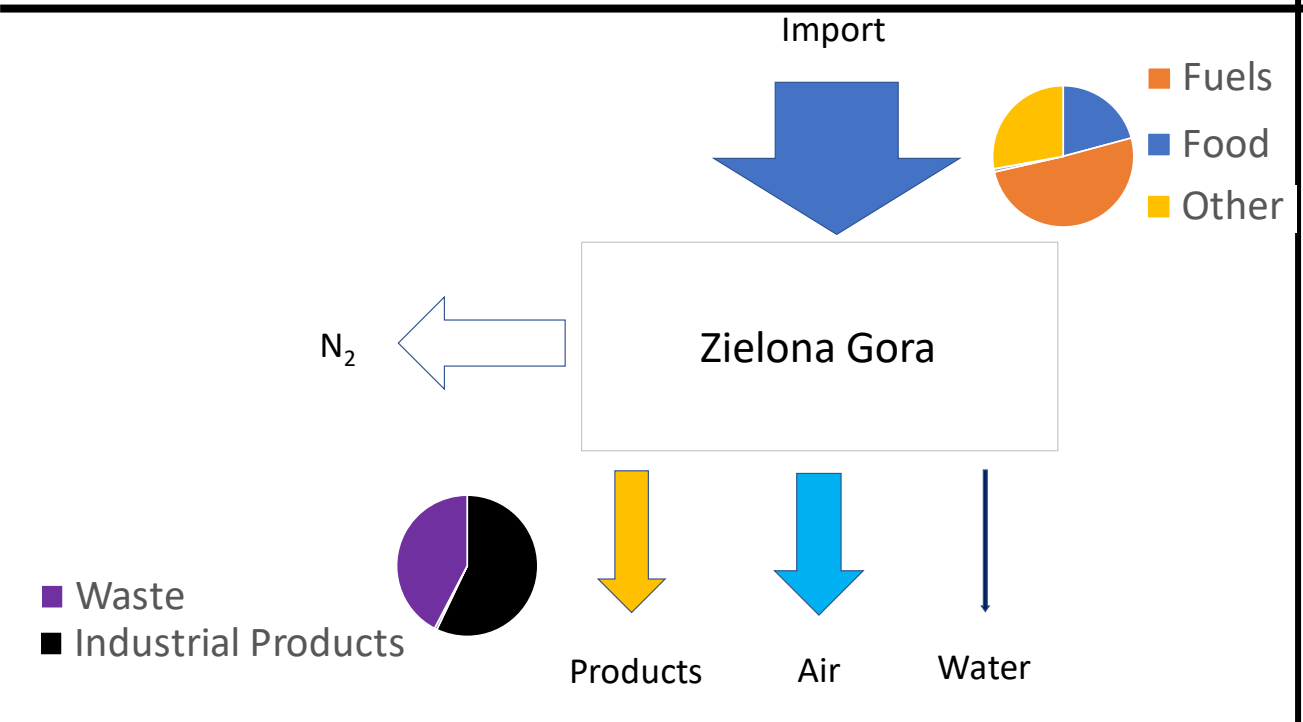


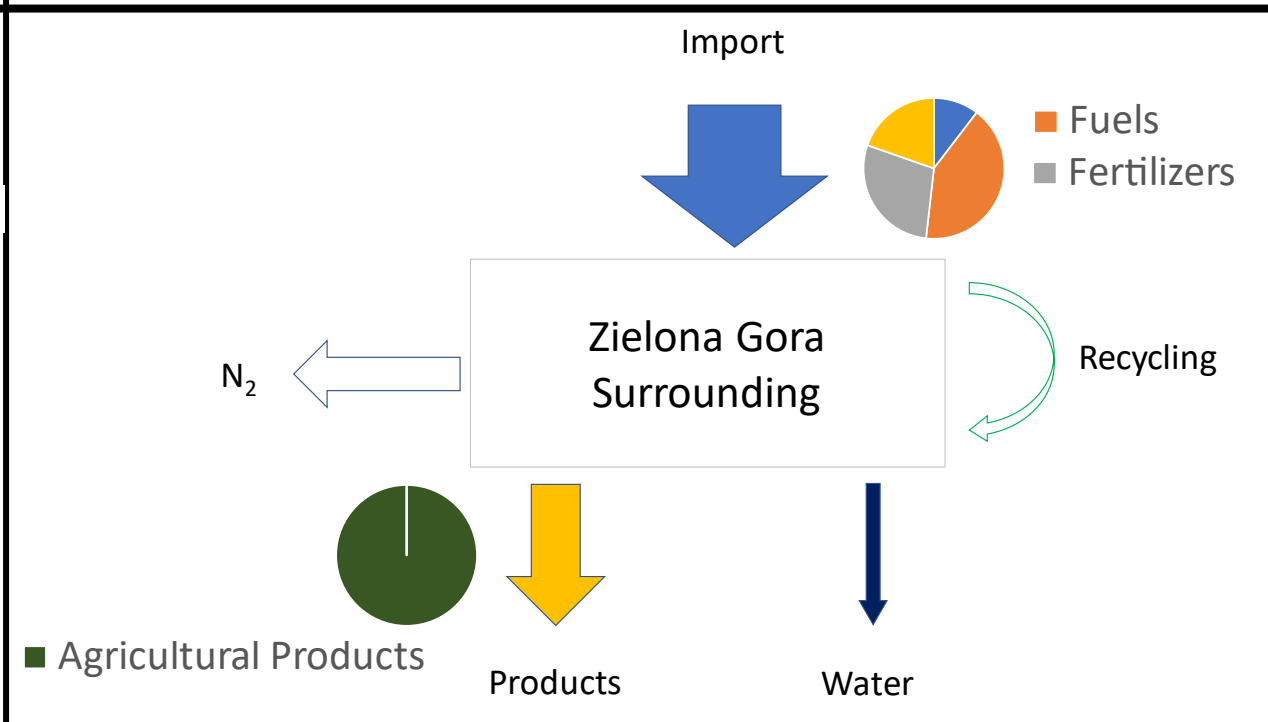
Shijiazhuang Surrounding




Import
Food
Other
N_2
Vienna
Recycling
Waste
Agricultural Products
Products
Air
Water


Import
Fuels
Fertilizers
N_2
Vienna Surrounding
Recycling
Industrial Products
Agricultural Products
Products
Air
Water

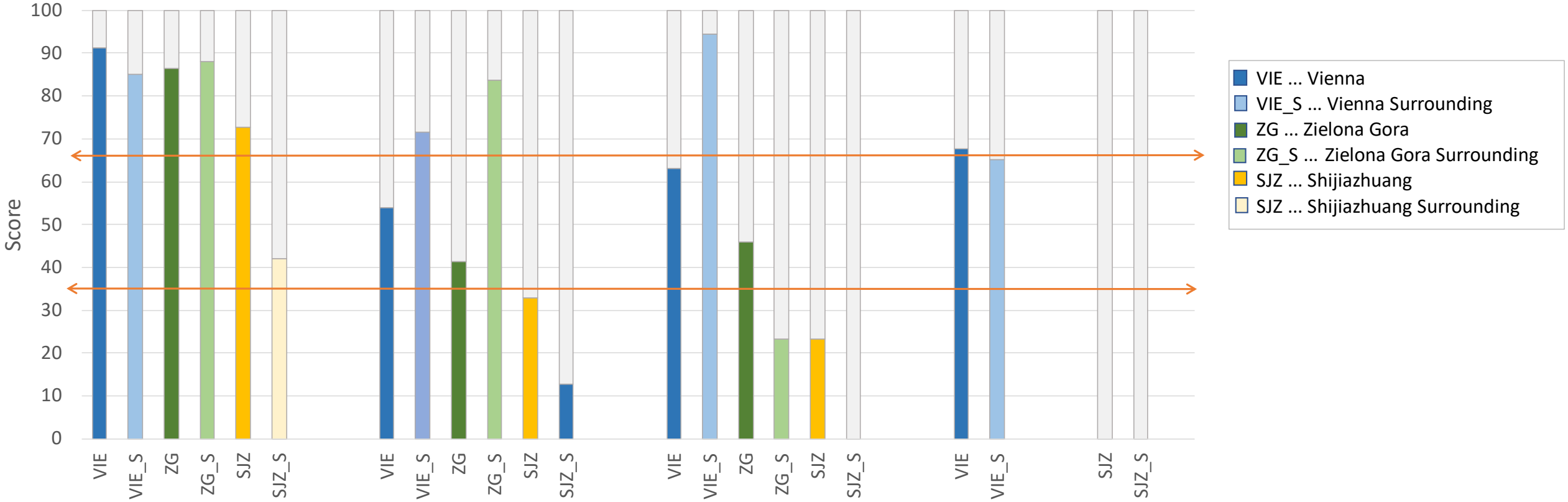

Import
Fuels
Food
Other
N_2
Zielona Gora
Waste
Industrial Products
Products
Air
Water


Import
Fuels
Fertilizers
N_2
Zielona Gora Surrounding
Recycling
Agricultural Products
Products
Water

Analysis and Indicators

	Vienna	Vienna Surrounding	Zielona Gora	Zielona Gora Surrounding	Shijiazhuang	Shijiazhuang Surrounding	Beijing	Beijing Surrounding
General								
Recycling (% of import)	4%	6%	0%	13%	32%	19%	8%	8%
Agri-Food Chain								
Self-sufficiency Plant Food	3%	317%	9%	66%	59%	69%	25%	28%
Self-sufficiency Livestock Products	0%	38%	0%	65%	41%	84%	37%	48%
Self-sufficiency Feed	728%	276%	0%	49%	48%	88%	13%	20%
NUE on agricultural land	58%	73%	49%	82%	42%	26%	45%	31%
N surplus [kgN/ha]	53.39	36.55	62.36	20.44	74.00	117.00	65.00	93.00
Emissions (including Combustion Chain)								
N deposition per hectare [kgN/ha]	16.60	12.84	15.78	16.78	24.00	26.00	32.71	47.32
Emission per hectare [kgN/ha]	110.13	15.68	207.39	7.24	40.00	22.00	133.84	15.59
Livestock (% of total emissions)	0%	6%	0%	11%	10%	14%	0%	16%
Agricultural Land (% of total emissions)	1%	21%	0%	25%	8%	76%	6%	56%
Combustion (% of total emissions)	89%	52%	94%	62%	63%	6%	65%	12%
Waste (% of total emissions)	8%	11%	5%	0%	1%	4%	10%	4%
Wastewater (% of total emissions)	1%		0%	0%	7%	0%	5%	0%
Urban Greens (% of total emissions)	1%	10%	0%	2%	10%	0%	5%	6%
Horticulture (% of total emissions)	0%	0%	0%	0%	0%	0%	9%	5%

Urban Nitrogen Budgets and Sustainable Development Goal Scores



NH3 Emissions from Agriculture

NUE

N Surplus

N Losses to Surface

Annex II

Postcards – Awareness rising tool

‘Waiting until we near some suggested limit for nitrogen deposition and other pollutions will just permit us to continue to a point where it is too late.’

William Schlesinger, biogeochemist

Foto: StadtPresse Klagenfurt | Franz Gerdl

Urban Nitrogen Cycles

https://www.uncnet.org/

- Nitrogen is the main component of air, accounting for 78 %
- It is a common element in the universe, estimated at about seventh in total abundance in the Milky Way and the Solar System.
- Global atmospheric nitrous oxide (N_2O) mole fractions have increased from a pre-industrial value of ~270 nmol/mol to ~319 nmol/mol in 2005
- Human activities account for over one-third of N_2O emissions, most of which are due to the agricultural sector.
- Nitrogen occurs in all organisms, primarily in amino acids (and thus proteins), in the nucleic acids (DNA and RNA) and in the energy transfer molecule adenosine triphosphate.
- The human body contains about 3 % nitrogen by mass, the fourth most abundant element in the body after oxygen, carbon, and hydrogen.

Project title: Urban Nitrogen Cycles: new economy thinking (UNCNET) to master the challenges of climate change

Project coordinator: International Institute for Applied Systems Analysis (IIASA)

Project funding: Urban Europe (Sustainable and Liveable Cities and Urban Areas)

Project partners: 6 (Austria, China, Poland)

Project duration: 03/2019–02/2022

‘Nature does not waste nitrogen.’

Wilfried Winiwarter (UNCNET)

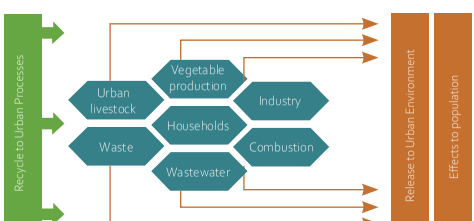
Foto: Stadt Presse Klagenfurt

Urban nitrogen metabolism

https://www.uncnet.org/

More atmospheric nitrogen (N_2) is now converted to reactive forms by human activities **than by all terrestrial processes on Earth combined**. This makes it difficult for both organisms and industry to convert N2 into useful compounds, but at the same time means that large amounts of often useful energy are released when nitrogen compounds are burned, exploded or decomposed to form nitrogen gas.

UNCNET studied and compared the nitrogen cycles in four cities – Vienna, Zielona Góra in Poland, and Shijiazhuang and Beijing in China. Klagenfurt played a special role here, as it served as a pilot region for the large cities.



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Project partners: 6 (Austria, China, Poland)

Project duration: 03/2019–02/2022

‘Ammonia is contributing to health-damaging fine particles in cities. Measures against ammonia emissions have many times greater benefits than their implementation costs.’

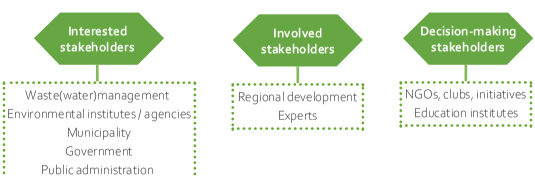
UNCNET

Foto: Stadtpresse Klagenfurt, Ingo Pauer

Stakeholder process

https://www.uncnet.org/

Especially in urban areas, the accumulation of nitrogen compounds leads to major problems. Ammonia and nitrate from imported food or nitrogen oxides from traffic and industry pollute air and water, accelerate climate change, impair biodiversity and endanger health. Particularly in cities, many people are directly affected. On the other hand, it is precisely here that a better understanding of the interrelationships can help to make sustainable decisions and significantly improve the effectiveness of measures.



During several workshops with different stakeholders, the project results could be discussed, coordinated and reflected with different decision-makers and stakeholders. For political decisions, it is essential to understand what makes stakeholders tick and how robust a scientific statement is.

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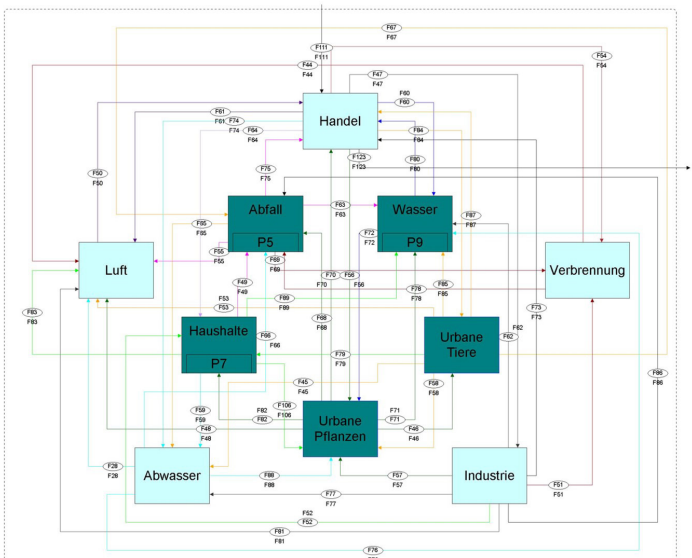
‘Nitrogen is life.’

Wim de Fris

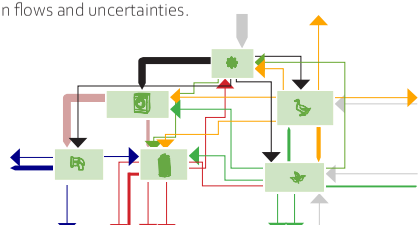


Period under review: 2015

Substance Flow Analysis

https://www.uncnet.org/

The complex nitrogen cycles and flows in cities were analysed during the project using different data. The STAN (subSTance flow ANalysis) model, developed by TU Wien, is a model for material flow analysis. It allowed not only the representation of the different processes, their deposits and the flows within the urban system boundaries, but also the calculation of unknown flows and uncertainties.



Data can be imported from an Excel file into the model as well as exported as an Excel file. The finished graph can be exported as an image. The representation of the flows is done in Sankey style, a graphical representation of quantity flows. This allows the arrow width to be shown in proportion to the flow size. The model is freely accessible to everyone: stan2web.net

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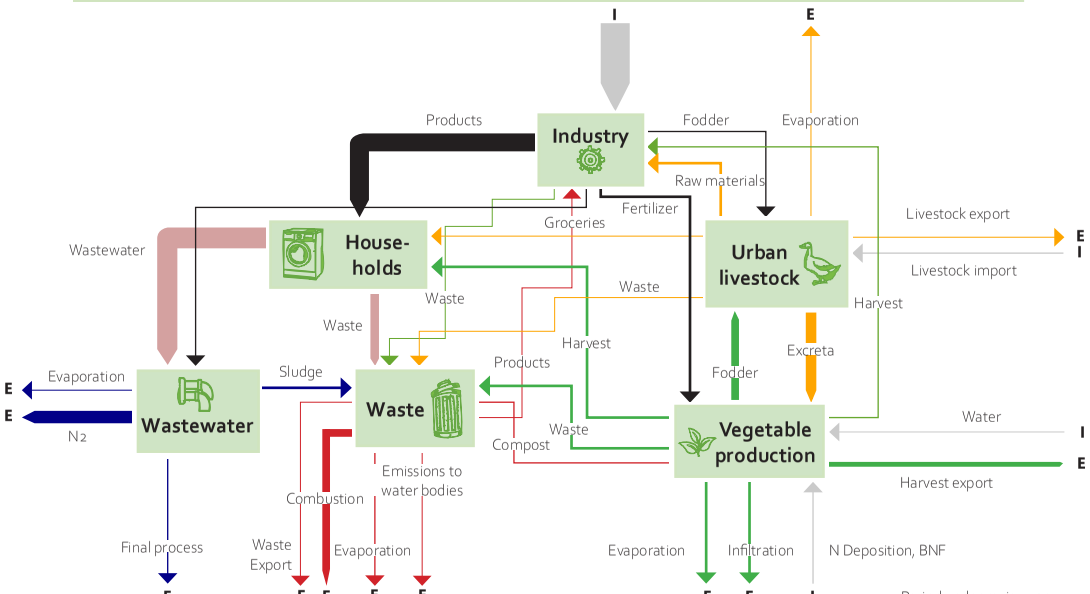
‘Saving nitrogen fertiliser would not jeopardise food security.’

UNCNET



Agriculture and food security

The importance of agriculture in urban areas can be considerable: the Chinese urban province of Beijing produces more milk than it consumes. Although milk consumption in China is generally much lower than in Europe, for example, it is remarkable that urban agricultural production requires local exports.

If we shut down the Haber-Bosch plants today, the nitrogen overabundance in the biosphere would decrease again in a few years. This is in contrast to the climate problem, where the atmosphere stores greenhouse gases such as CO_2 in the long term (even after the end of emissions, the effects of global warming remain in the long term). The question is whether we really need so much mineral fertiliser; the Haber-Bosch process is often cited; there are considerations on how to produce artificial fertiliser with hydrogen, but we need a lot of energy for this, our own wind farms; the advantage would be to bring back something that is already in the cycle so that we don't have to produce it separately.

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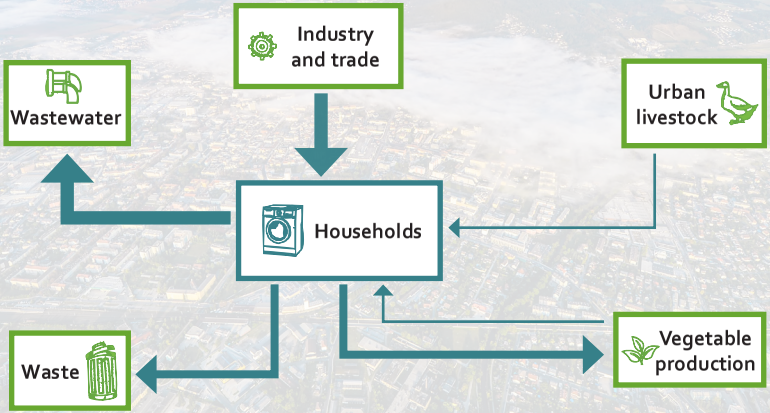
‘According to a new report, air pollution shortens the lives of billions of people by up to six years, making it a far bigger killer than smoking, car accidents or HIV/Aids.’

The Guardian



Period under review: 2015
Unit: t N / a

Foto: StadtPresse Klagenfurt | Helge Bauer

Households

Households refer to consumers. For a household, the nitrogen pools are calculated based on all products stored in the households (e.g. clothing, furniture, etc.).

The inflows to the household pool currently include the inflows from these pools: industry and trade, urban livestock and urban vegetable production. Industrial products also include commercial products, such as small retailers or supermarkets. Other important N fluxes here relate to consumed livestock products, harvested plants, flowers and garden fruits / vegetables and household waste. All types of waste are considered, which means that the waste composition is included in the calculations. With regard to households, the N discharged by the population into domestic wastewater, e.g. via excreta and household chemicals, is also taken into account.

Thus, the total amount of transported nitrogen can be properly assessed.

In addition, one can still calculate the N fluxes between households and combustion. These include all N emissions (NO_x, NO_2, NH_3 and N_2O) from the private transport and heating sectors as well as from other household appliances that emit N.

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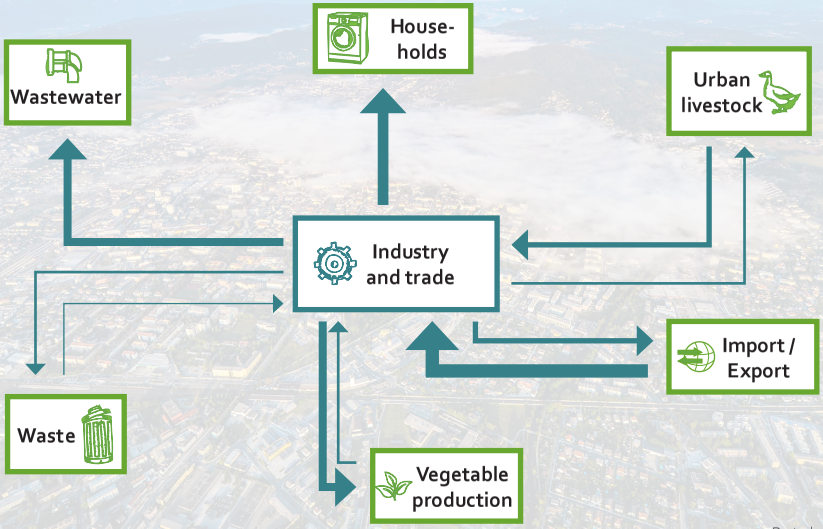
‘The chemical industry used to fix nitrogen requires about 1.3 % of global energy, mostly using fossil fuels.’

Wilfried Winiwarter



Period under review: 2015
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Foto: StadtPresse Klagenfurt | Helge Bauer

Industry and trade

Nitrogen is used as a starting material for the synthesis of a wide variety of compounds, such as nitrites, ammonia or nitric acid. It is used primarily in the production of fertilizers, but also in the electrical and metal industries. Nitrogen is suitable as a filler gas for incandescent lamps, a propellant in sprays, and as a diluent. In the food and pharmaceutical industries, as well as in medicine, liquid nitrogen is used because it is suitable for shock freezing or freeze drying, for example for preserving tissue, blood, vaccines and medicines, as well as sausage and fresh poultry products. The accumulation of nitrogen compounds is not always directly relevant to the environment, but may indicate a potential for later release, for example when things are sent to landfills or groundwater and substances are released there.

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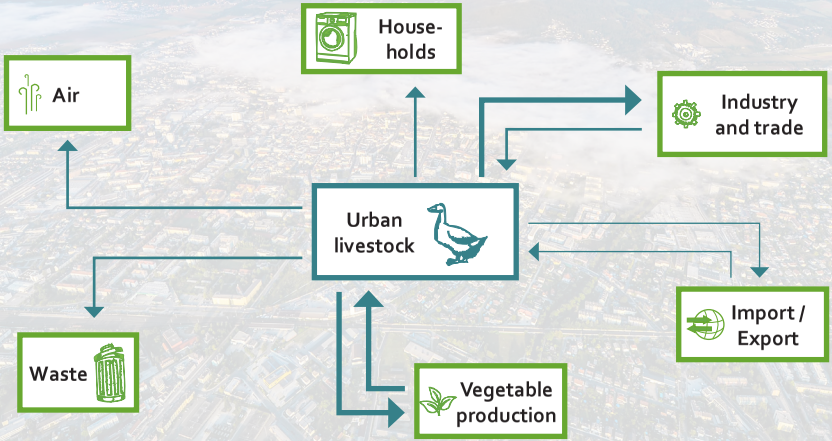
‘The death of thousands of fish in the “Warme Fischa” River in the district of Wiener Neustadt is due to a lack of oxygen and excessive nitrate pollution.’

ORF



Period under review: 2015
Unit: t N / a

Foto: StadtPresse Klagenfurt | Helge Bauer

Urban livestock

Animal husbandry also plays a role in the budgeting of nitrogen fluxes in urban areas. Here, one refers to farm animals and domestic animals in cities. A combination of different statistics is used. First, one looks at the animal population and the associated feed requirements as well as the excreta.

In the N-pool of urban livestock, one also includes the number of slaughterings. This results in the meat production. Another statistic provides information about live animal transports from or to the respective cities.

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‘NO_2 makes plants stunt, age faster, it turns their leaves yellow. It overfertilizes and acidifies soils and waters.’

Falter

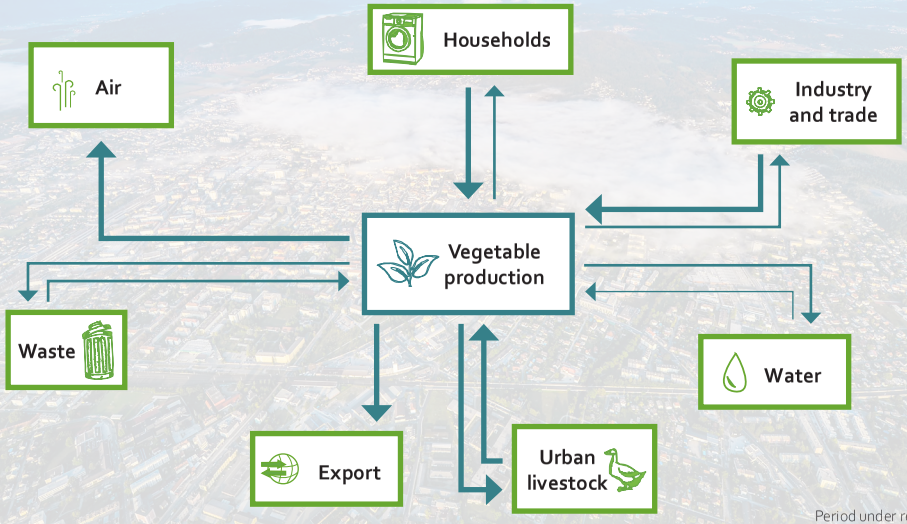

Foto: StadtPresse Klagenfurt | Helge Bauer

Vegetable production

Plants need nitrogen to synthesize proteins, such as enzymes, and DNA – nitrogen is therefore essential for metabolism. A lot of energy is needed to convert atmospheric nitrogen into chemical compounds that are also available to plants (illustrated figuratively: nitrogen oxides are formed from atmospheric nitrogen and atmospheric oxygen during a lightning strike).

The addition of nitrogen as fertilizer is essential for plant growth. However, in Europe only about 60-70% of the available nitrogen fertilizer is absorbed (globally even much less). The rest may leach to groundwater or run off to surface waters. Accurate quantification is difficult, depends on local conditions (soil texture, slope, precipitation).

This pool contains three sub-pools: agricultural land, horticultural land, and urban green space. Agricultural land includes cropland and grassland. Urban green includes public parks, private gardens, backyards, forests, and greenbelts. Horticulture includes horticultural land according to the respective national definition.

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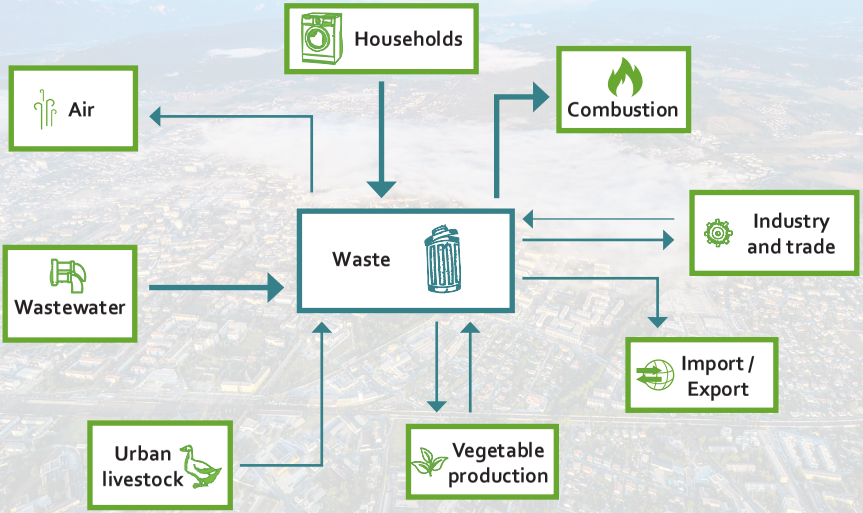
‘The planet is suffocating in nitrogen.’

Wilfried Winiwarter



Period under review: 2015
Unit: t N / a

Foto: StadtPresse Klagenfurt | Helge Bauer

Waste

Technically, the reduction of nitrogen oxide emissions has been solved. With the help of catalytic converters in vehicles, or even without catalytic converters in denox plants of power plants, emissions can be reduced by up to 95%.

Nevertheless, nitrogen compounds such as nitrous oxide (N_2O) are released into the atmosphere and the air. Households transfer nitrogen to landfills and wastewater through their garbage and sewage. Nitrogen is also passed directly through landfills via wastewater.

Appropriate limits help to make this problem largely a thing of the past. Emission ceilings (according to EU regulations) also exist for sulfur dioxide, particulate matter, and volatile organic compounds. Each EU country may only emit a certain amount, because emissions also influence the respective neighboring EU countries.

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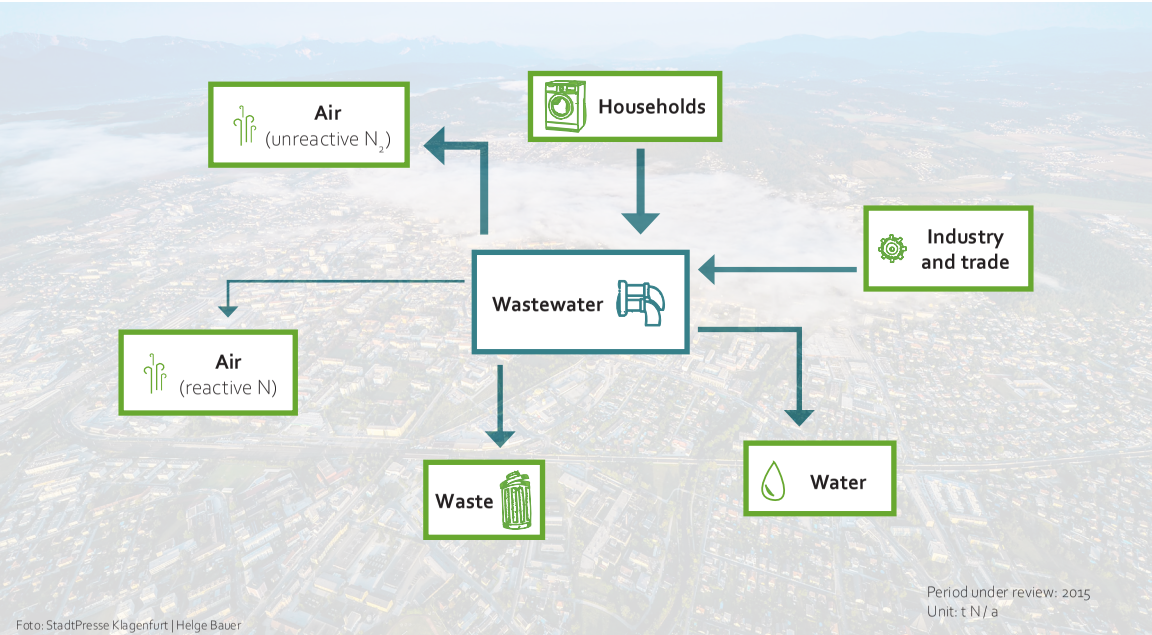
‘Nature does not waste nitrogen.’

UNCNET



Period under review: 2015
Unit: t N / a

Foto: StadtPresse Klagenfurt | Helge Bauer

Waste water

Wastewater treatment plants are often the last link in the chain in terms of nitrogen flows. Elemental nitrogen is released from them and beyond the system boundaries. The largest proportion escapes into the air and volatilizes as nitrous oxide (N_2O) and thus as a greenhouse gas. What is surprising is that a great deal is released into the air. ¾ of the nitrogen in wastewater is removed at the wastewater treatment plant, with the remainder going into streams (not groundwater). N_2 that re-enters the air through the biological processes is not problematic. This should be considered as an energetic loss, because there would be potential here for further use of the nitrogen.

Specifically, one must ask whether we are consuming more than we need. What can be reduced in terms of waste? What nitrogen consumption and excretion do we get per person?

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