GHG emissions from agriculture and food

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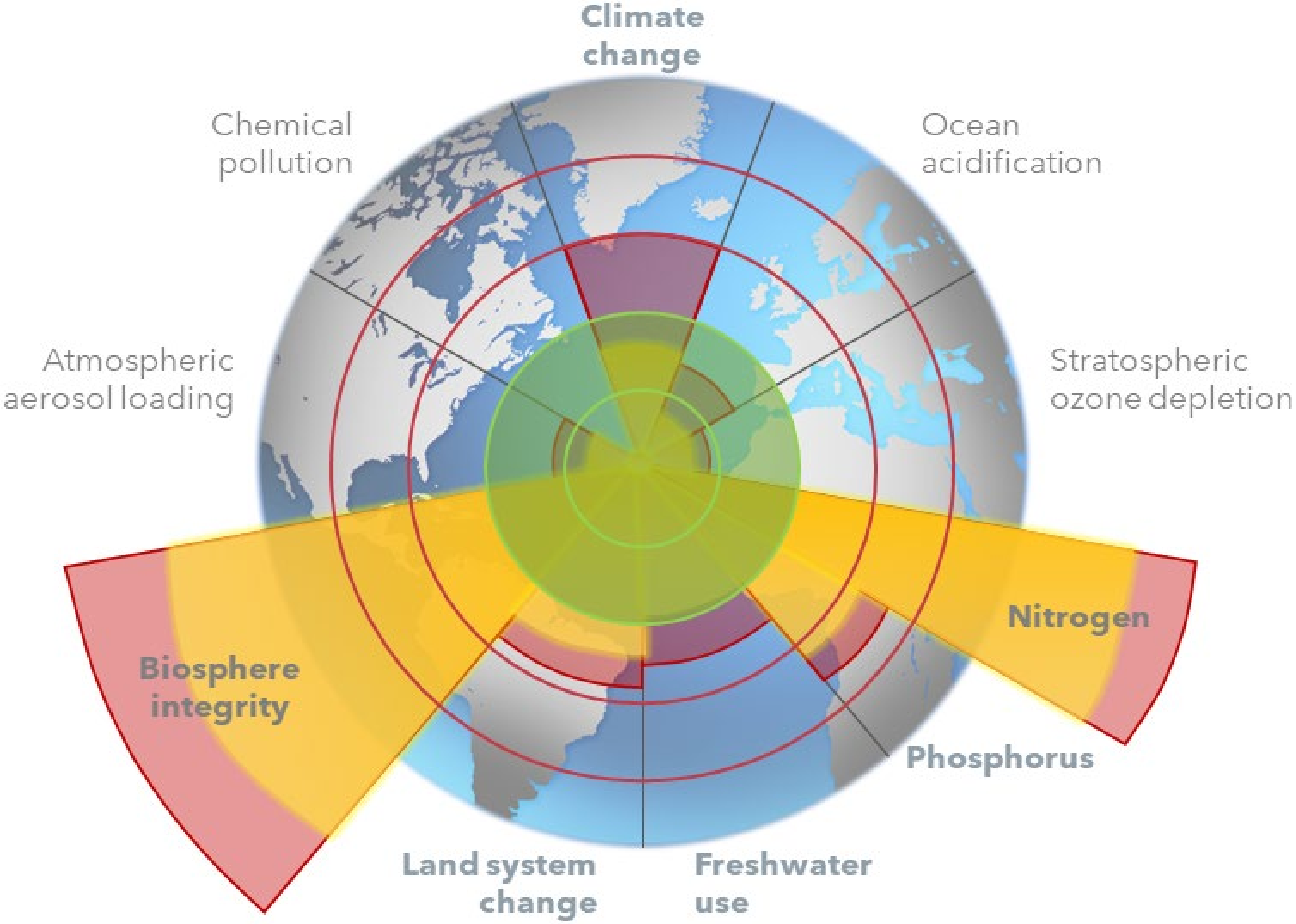
Agriculture is critical to planetary boundaries

Agriculture contributes to
- Food
- Bioenergy
- Biomaterials

Agriculture also contributes to
- Nutrient pollution
- Greenhouse gases
- Biodiversity decline
- Declining freshwater
- Soil degradation



Global food consumption

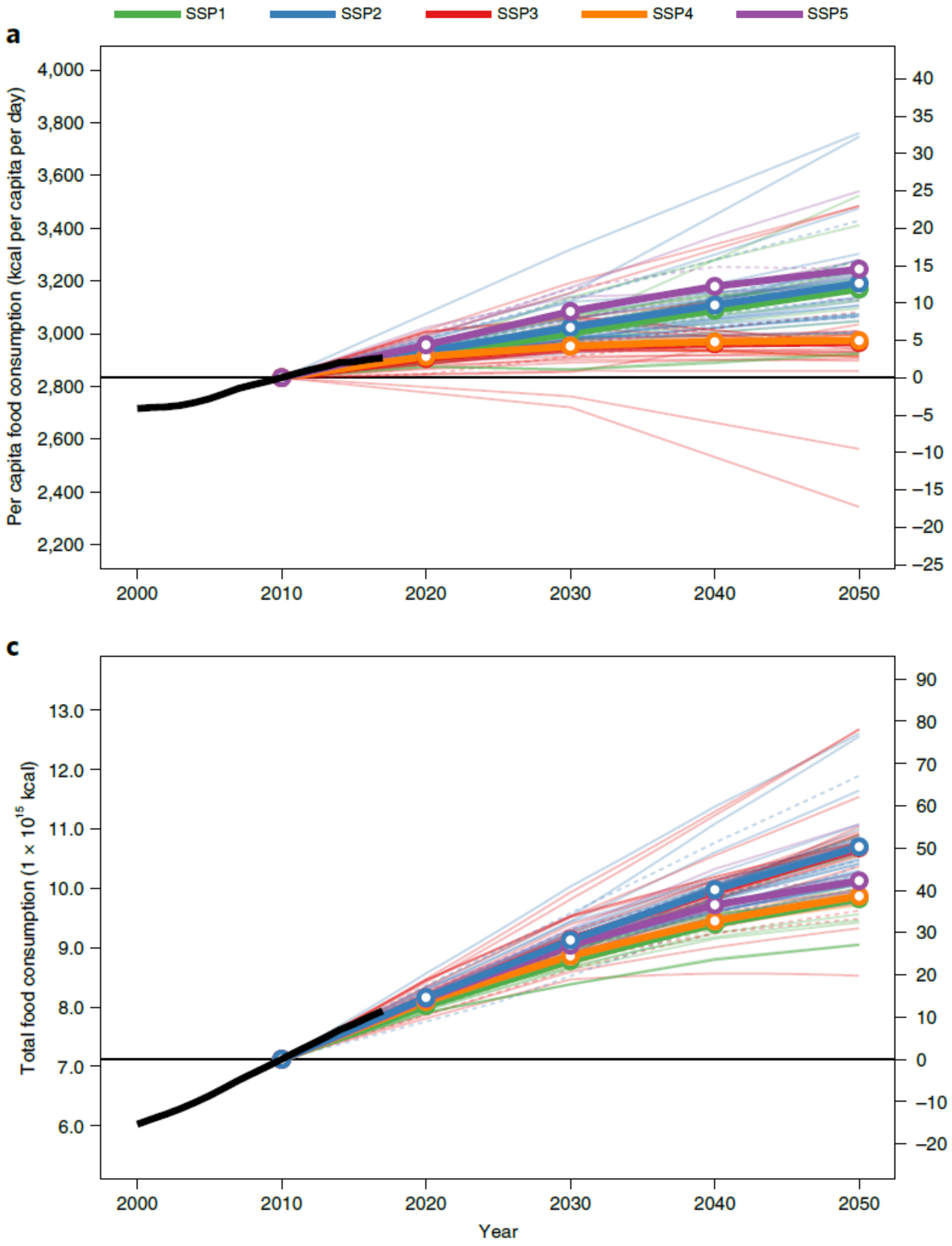
- Food consumption er capita is increasing
- Global population also increases
- Total food consumption is expected to increase by about 45% until 2050

- Global meat and milk production increases more than grain production thus worsening impacts

A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050

Michiel van Dijk[1,2], Tom Morley[1], Marie Luise Rau[1] and Yashar Saghai[3,4]

NATURE FOOD | VOL 2 | JULY 2021 | 494–501 |



ARTICLES
https://doi.org/10.1038/s43016-021-00225-9
nature food

Food systems are responsible for a third of global anthropogenic GHG emissions

M. Crippa[1]✉, E. Solazzo[1], D. Guizzardi[1], F. Monforti-Ferrario[1], F. N. Tubiello[2] and A. Leip[1]✉

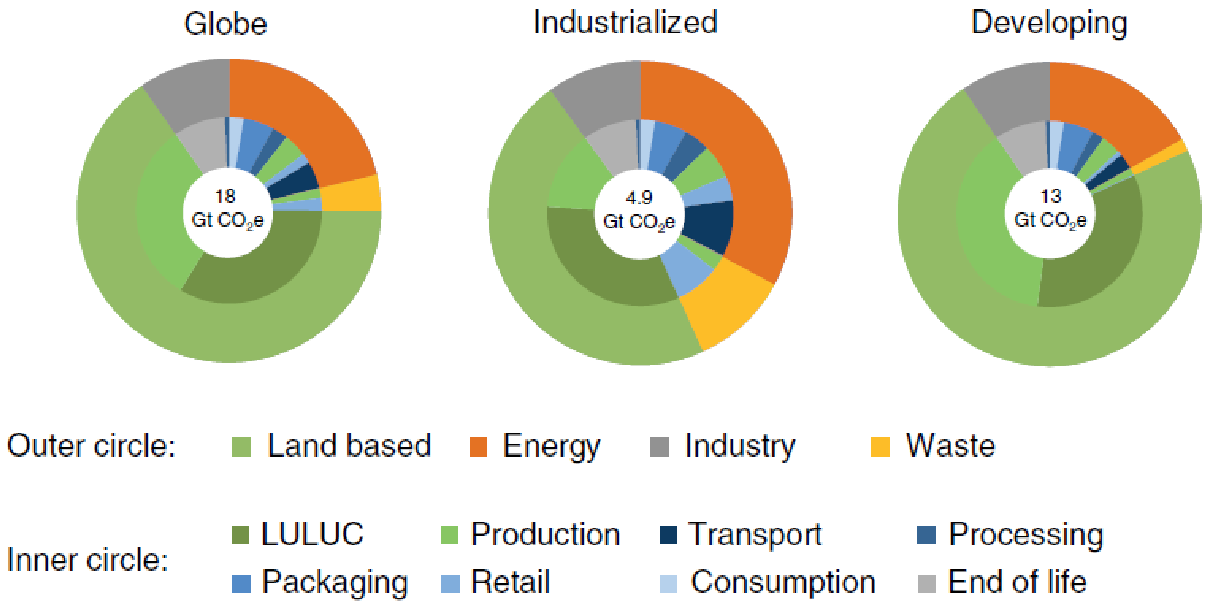


Fig. 1 | GHG emissions from the food system in different sectors in 2015. Total GHG emissions (including CO_2, CH_4, N_2O and F-gases) are expressed as CO_2e calculated using the GWP100 values used in the IPCC AR5, with a value of 28 for CH_4 and 265 for N_2O.

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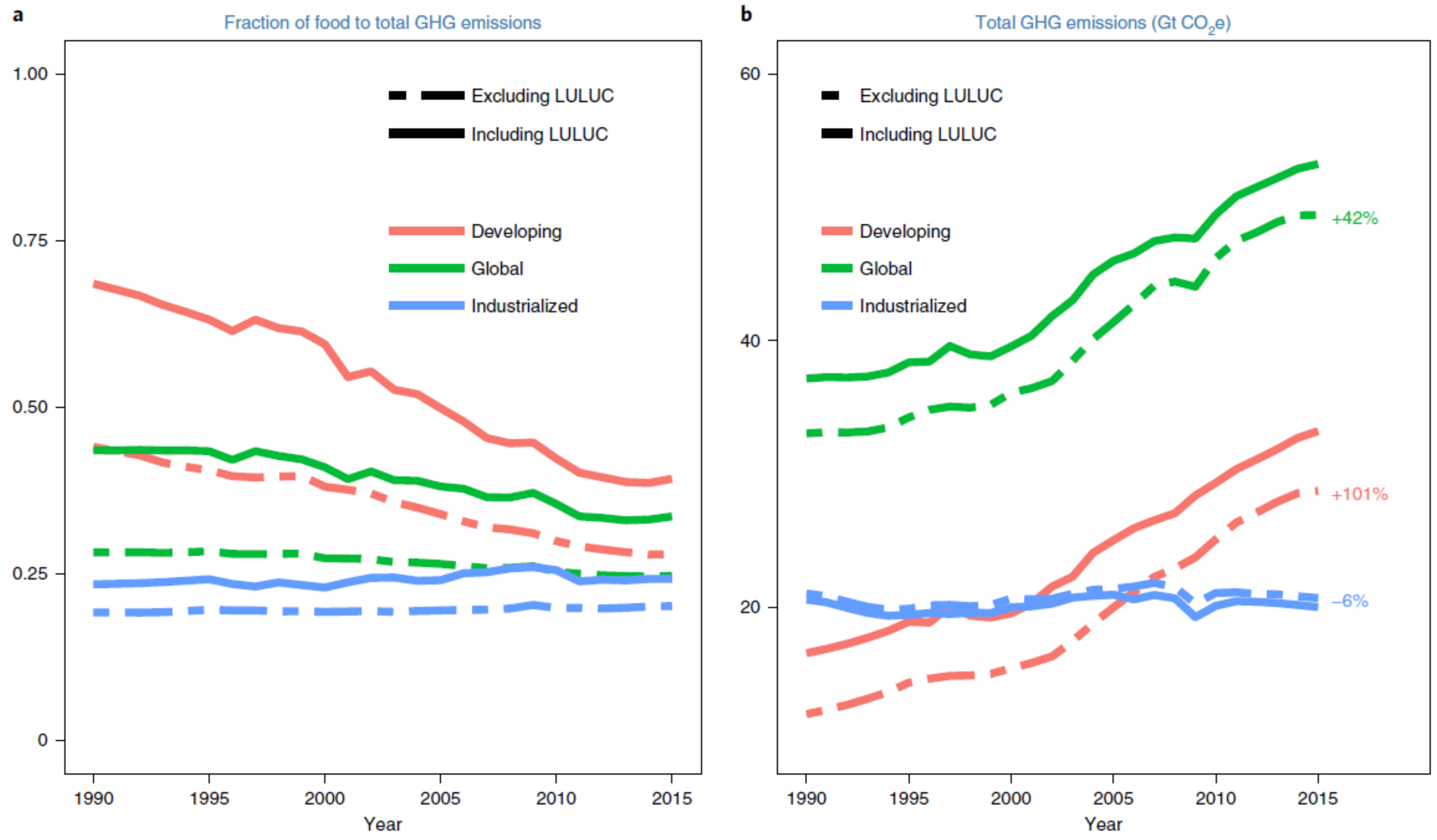

Fig. 2 | Total GHG emissions and food-system data globally, and in developing and industrialized countries. a,b Fraction of food to total GHG emissions (**a**) and total GHG emissions from the food system (**b**) globally, in developing and industrialized countries. Non-CO_2 GHG emissions (CH_4, N_2O and F-gases) are expressed as CO_2 equivalent (CO_2e) calculated using the GWP100 values used in the IPCC AR5, with a value of 28 for CH_4 and 265 for N_2O.

Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods

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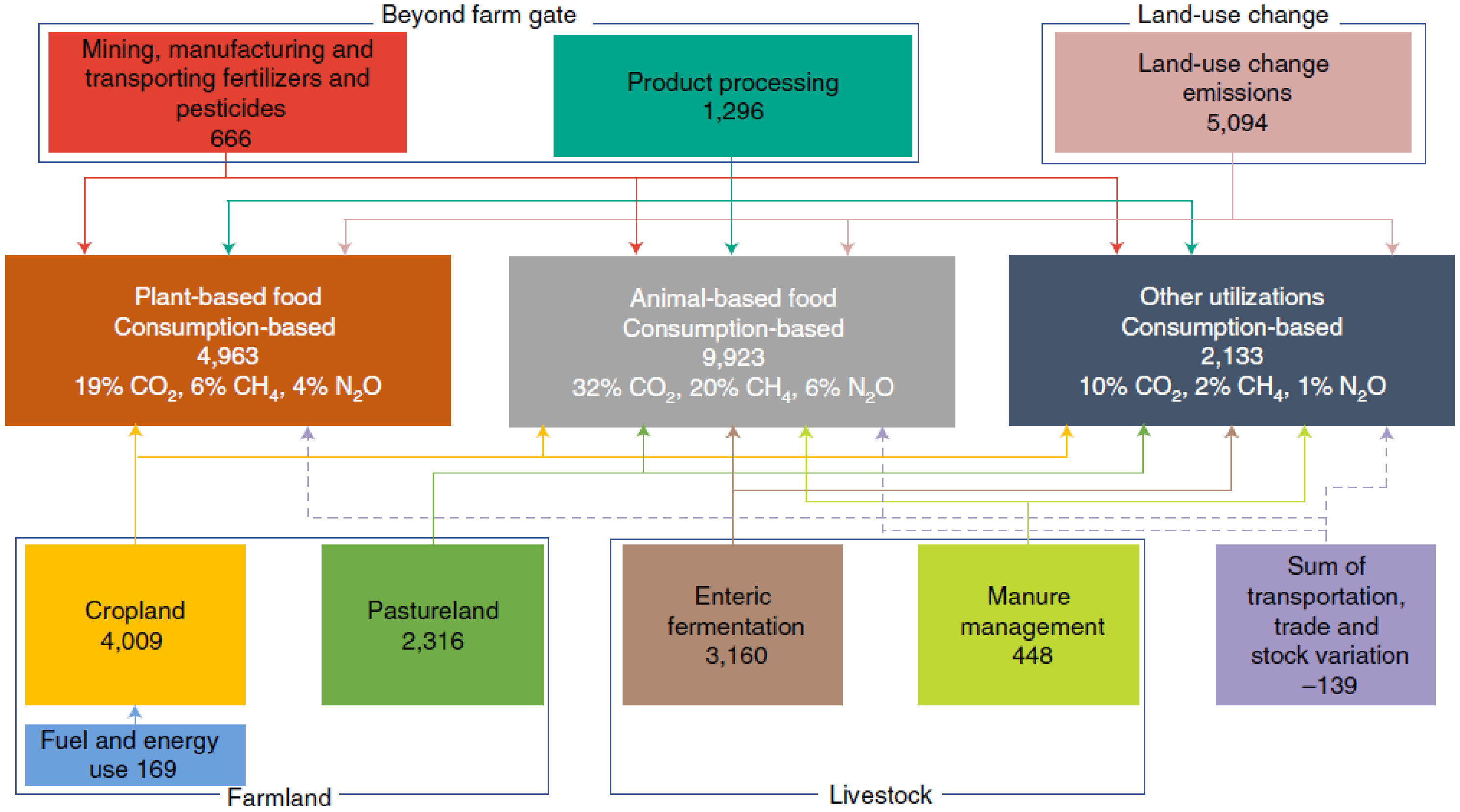

Fig. 1 | GHG emissions from different subsectors of plant- and animal-based food production/consumption. The contributions of individual GHGs provided are the percentage of the total emissions. Solid arrows indicate production-based emissions, and solid and dashed arrows combined are consumption-based emissions. The values in the boxes are mean values for 2007–2013, which may slightly differ from the median values of 10,000 Monte Carlo simulations in the text. Values are expressed in $TgCO_2eq$.

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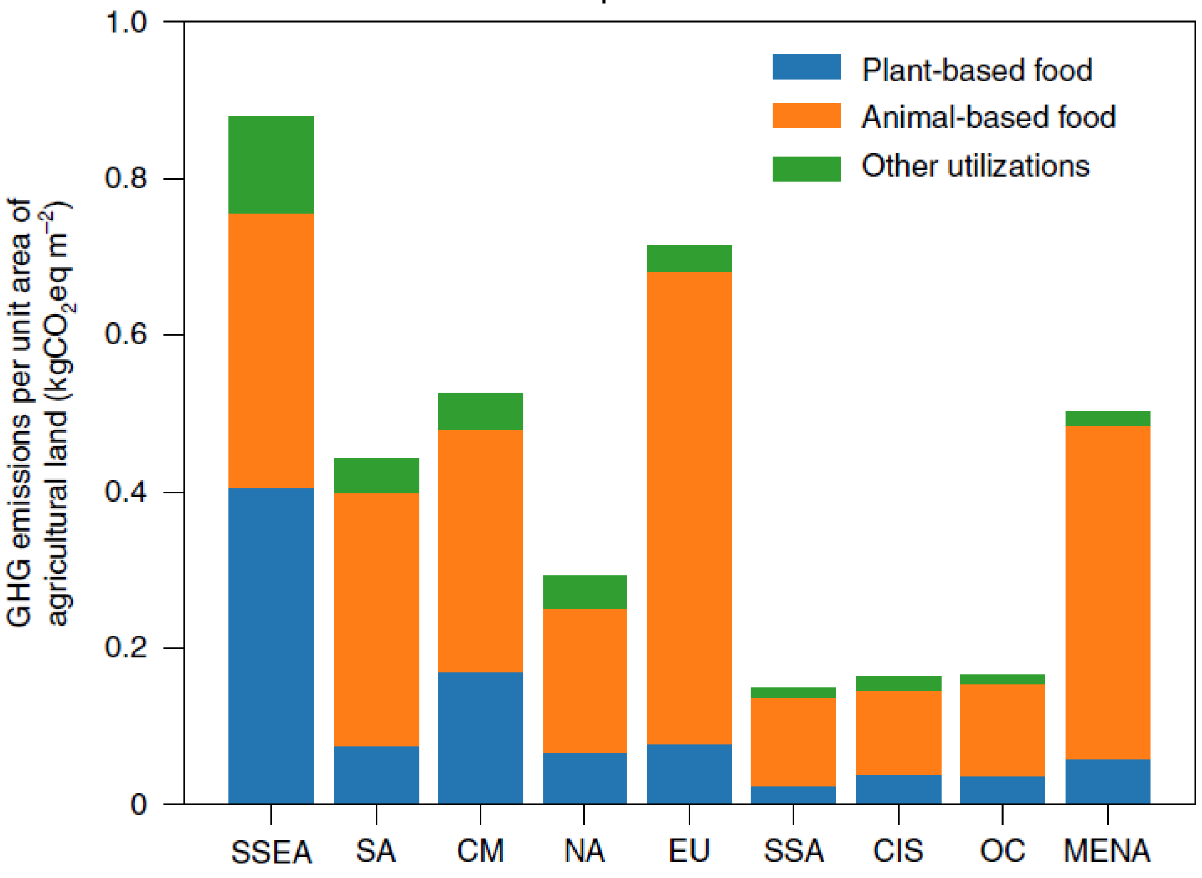
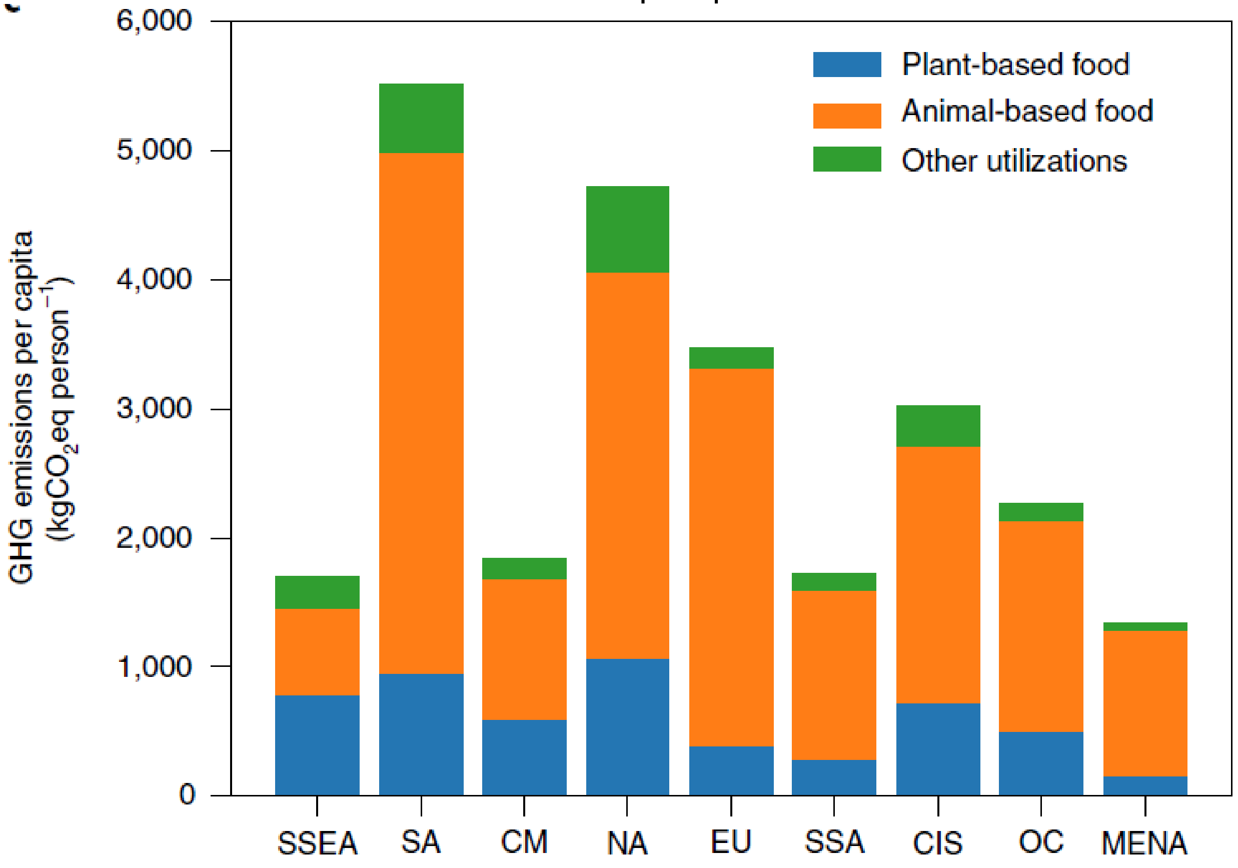
GHG per area



GHG per person



NA, North America; SA, South America; EU, European Union; MENA, Middle East and North Africa; SSA, sub-Saharan Africa; CIS, Commonwealth of Independent States; CM, China and Mongolia; SSEA, South and Southeast Asia; OC, Oceania and other East Asia

Food system changes are required to constrain climate change

- Food systems currently contribute one-third to global warming
- Many different changes in both food demand, production and processing are required to meet targets

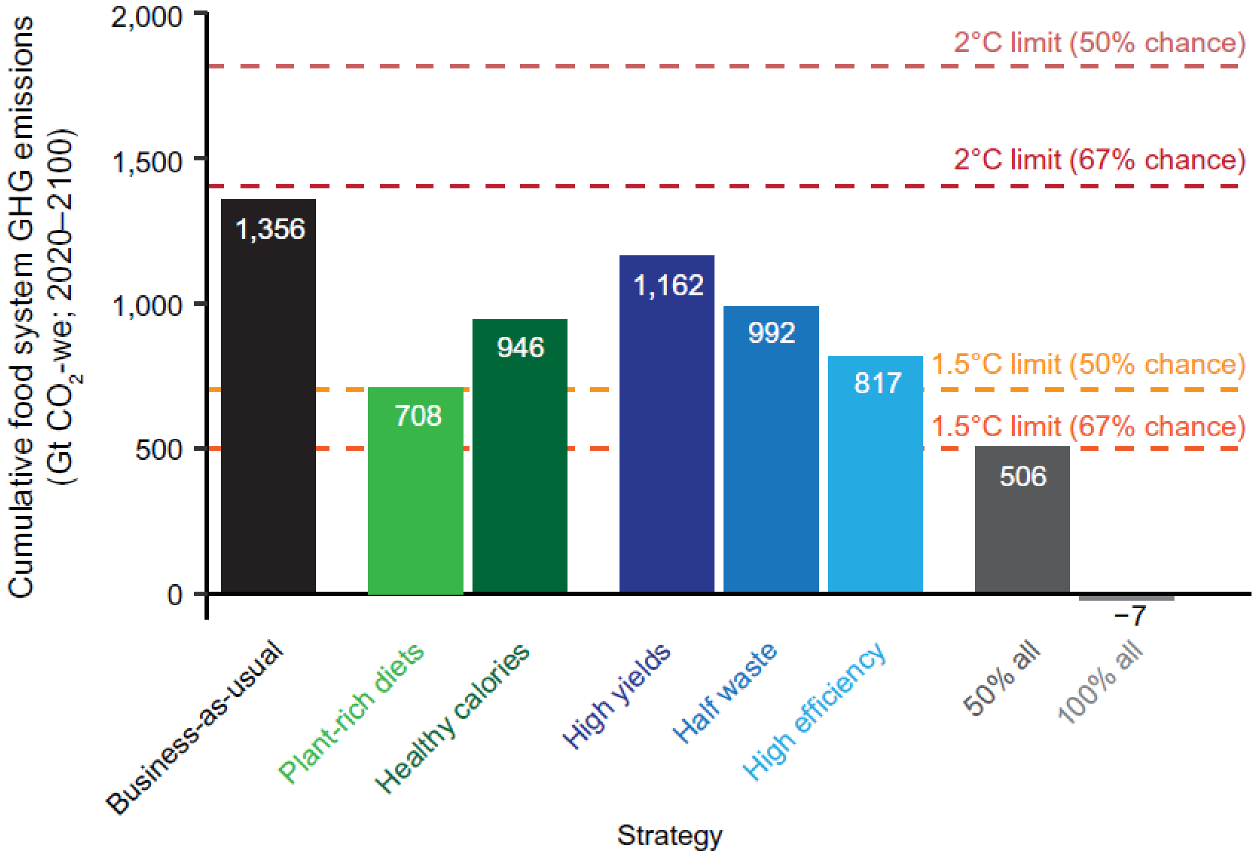


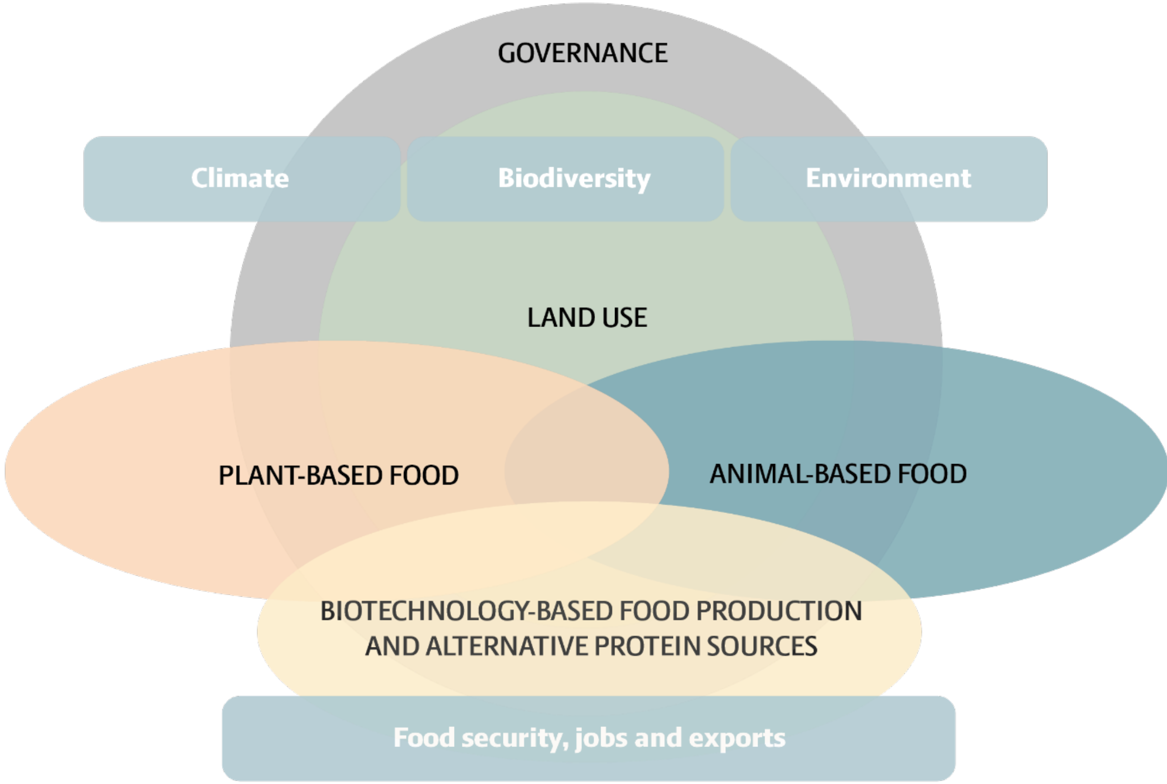
Fig. 1. Projected cumulative 2020 to 2100 GHG emissions solely from the global food system for business-as-usual emissions and for various food system changes that lead to emission reductions.

Clark et al. (2020) Science

There a many sustainability challenges

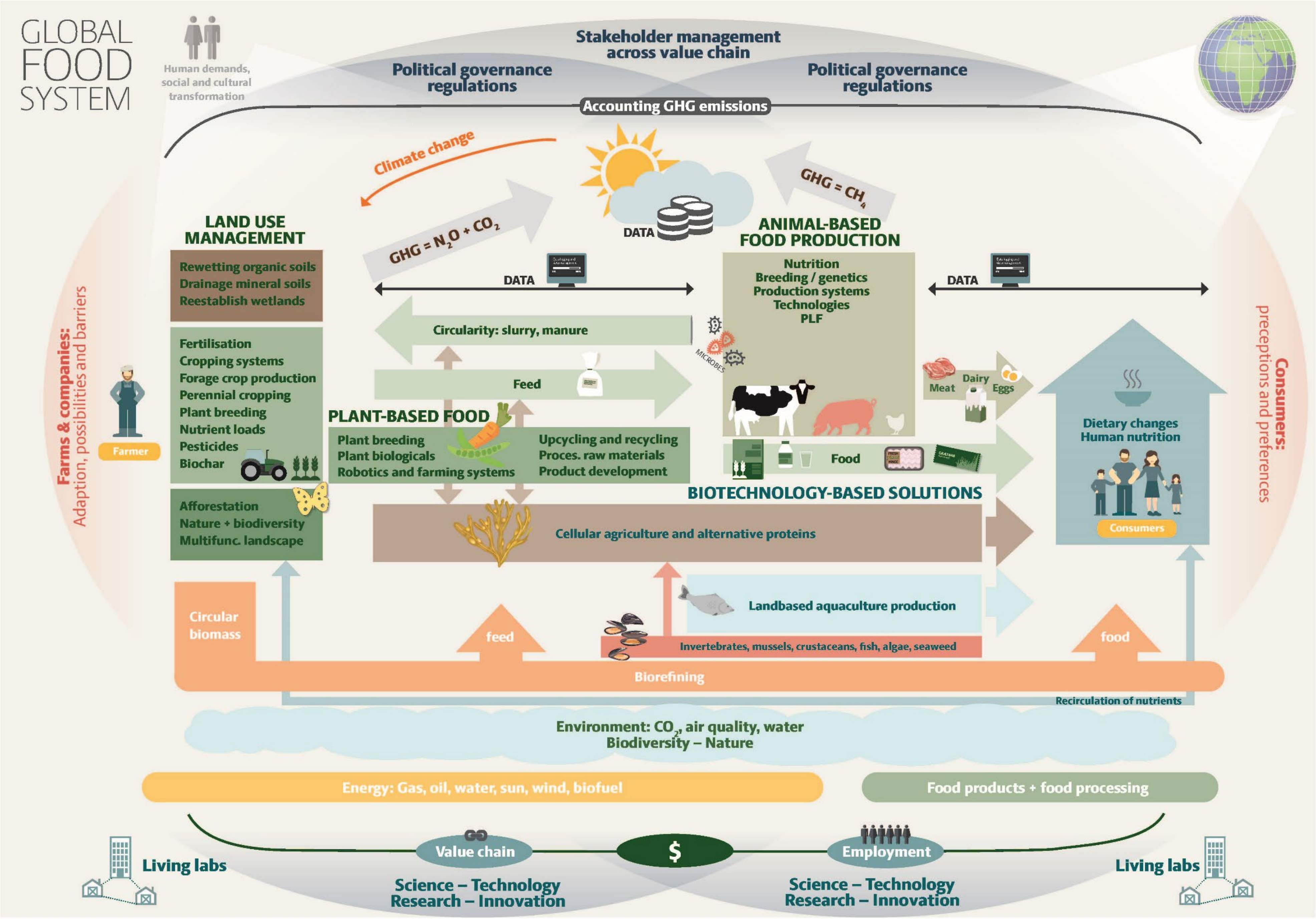
- Lower GHG and environmental footprint
- Enhance biodiversity (inside and outside farming)
- Less pesticide use
- Land area for other purposes (infrastructure, nature, recreation, climate change adaptation)
- Increased production of
  - Food (globally +45% by 2050)
  - Bioenergy
  - Biomaterials
- Jobs and growth outside cities

AgriFoodTure roadmap

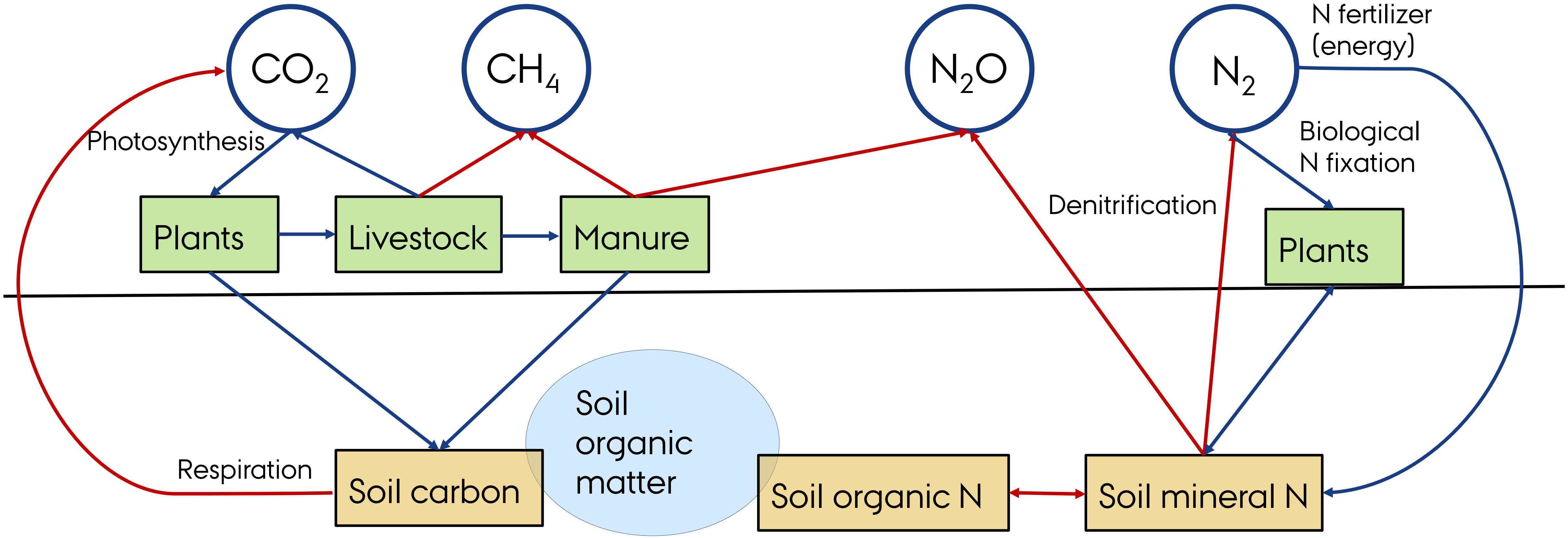


Roadmap developed by universities and agroindustry in Denmark

It is complex



GHGs associated with the carbon and nitrogen cycle



CO_2, CH_4 and N_2O emissions are driven by microbiological processes

Methane from livestock

Changed feeding for ruminants

- More fat (5%)
- Extended lactation (<5%)
- Changing / breeding fodder crops (?)

Additives (effects are not additive)

- Nitrate (10%)
- 3NOP (Bovaer) (30%)
- Seaweed and others (?)

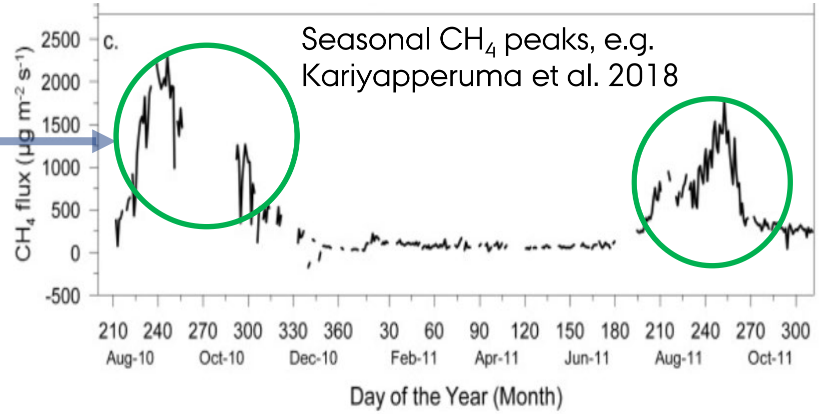
Breeding

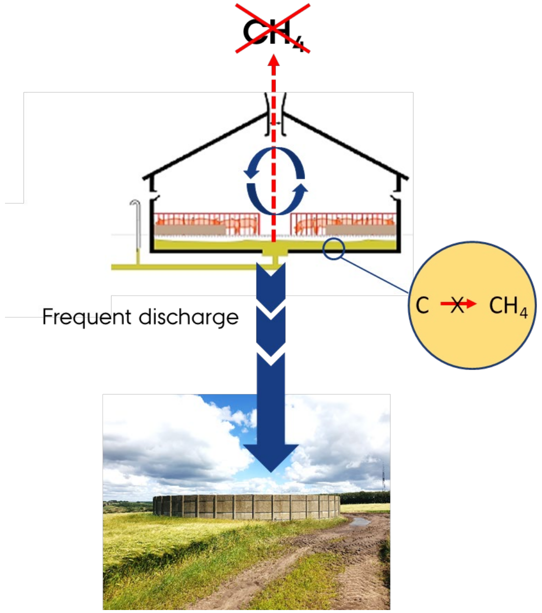
- Breeding for livestock with low methane (10%)

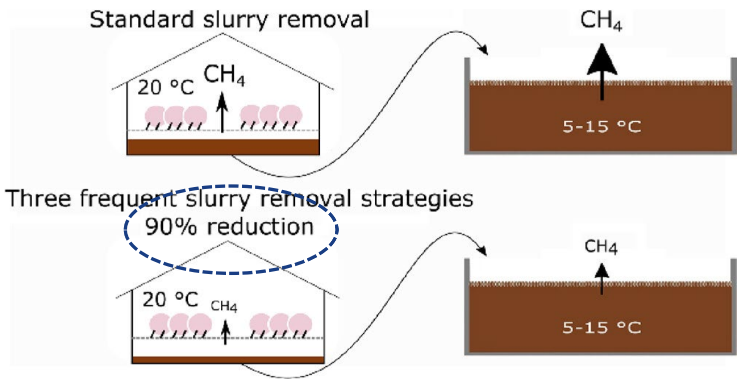
Collecting (and removing) methane (?)

Mitigation of manure methane

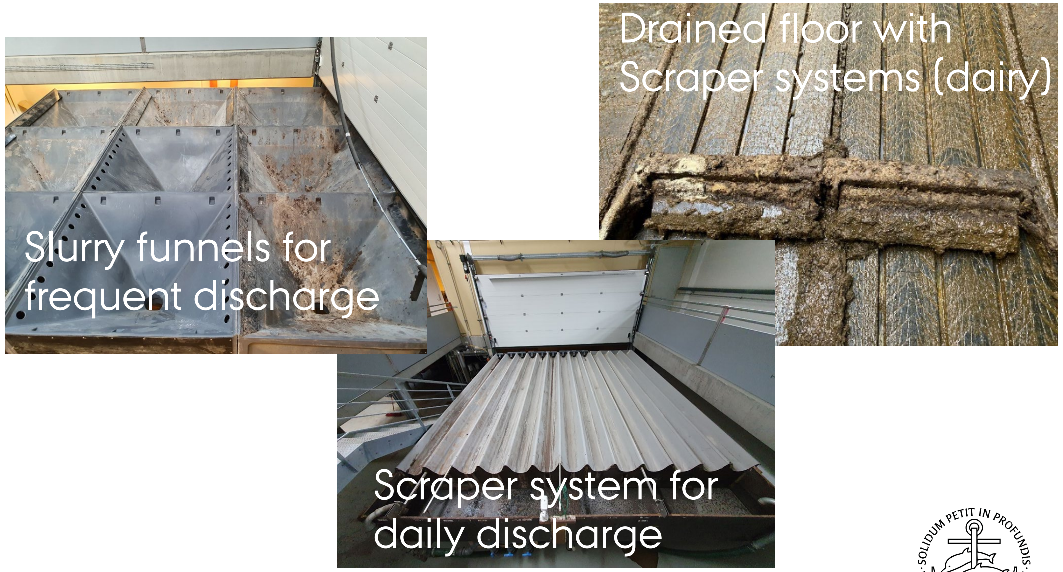
1. **~~Frequent~~ discharge** (at least weekly)
2. **Treatment in storage** – target summer peak
3. **Integrate carbon management** (e.g. biogas)



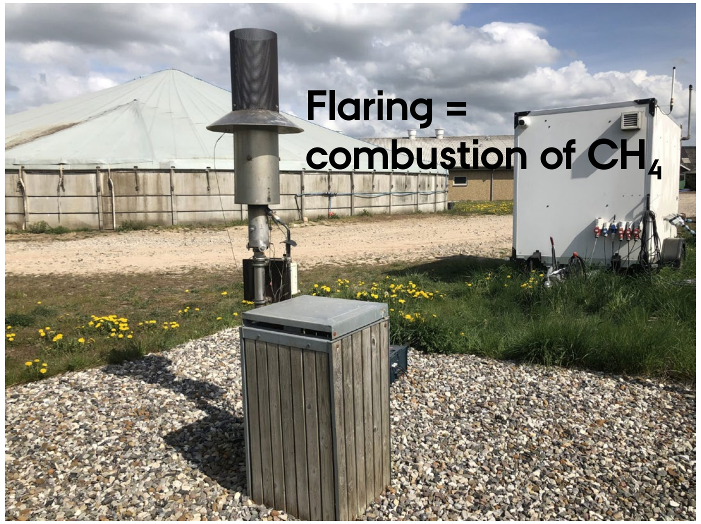


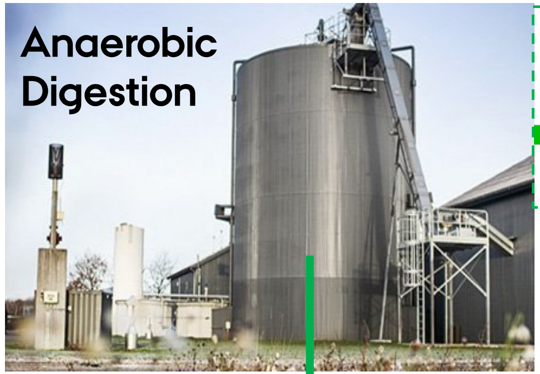


Dalby et al. ES&T 2023



Technologies with high mitigation potential





Biogas

CH_4
CO_2

Heat and power

Digestate treatment

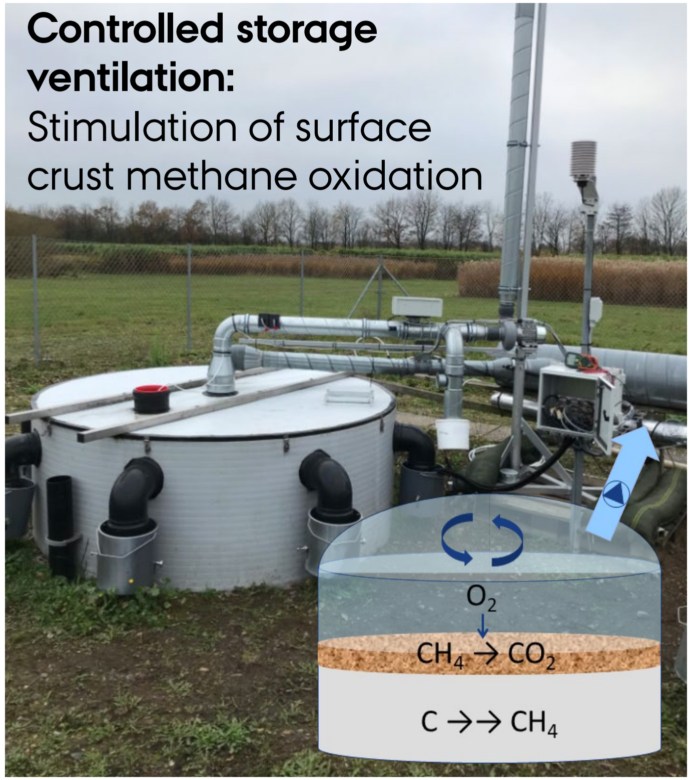
Combined with frequent discharge:

Overall CH_4 mitigation potential (barns + storage):

~50-80%

NH_3 mitigation: added value

Other CH_4 mitigation technologies under development



Field level options (in particular for N_2O)

Improved fertilisation strategies

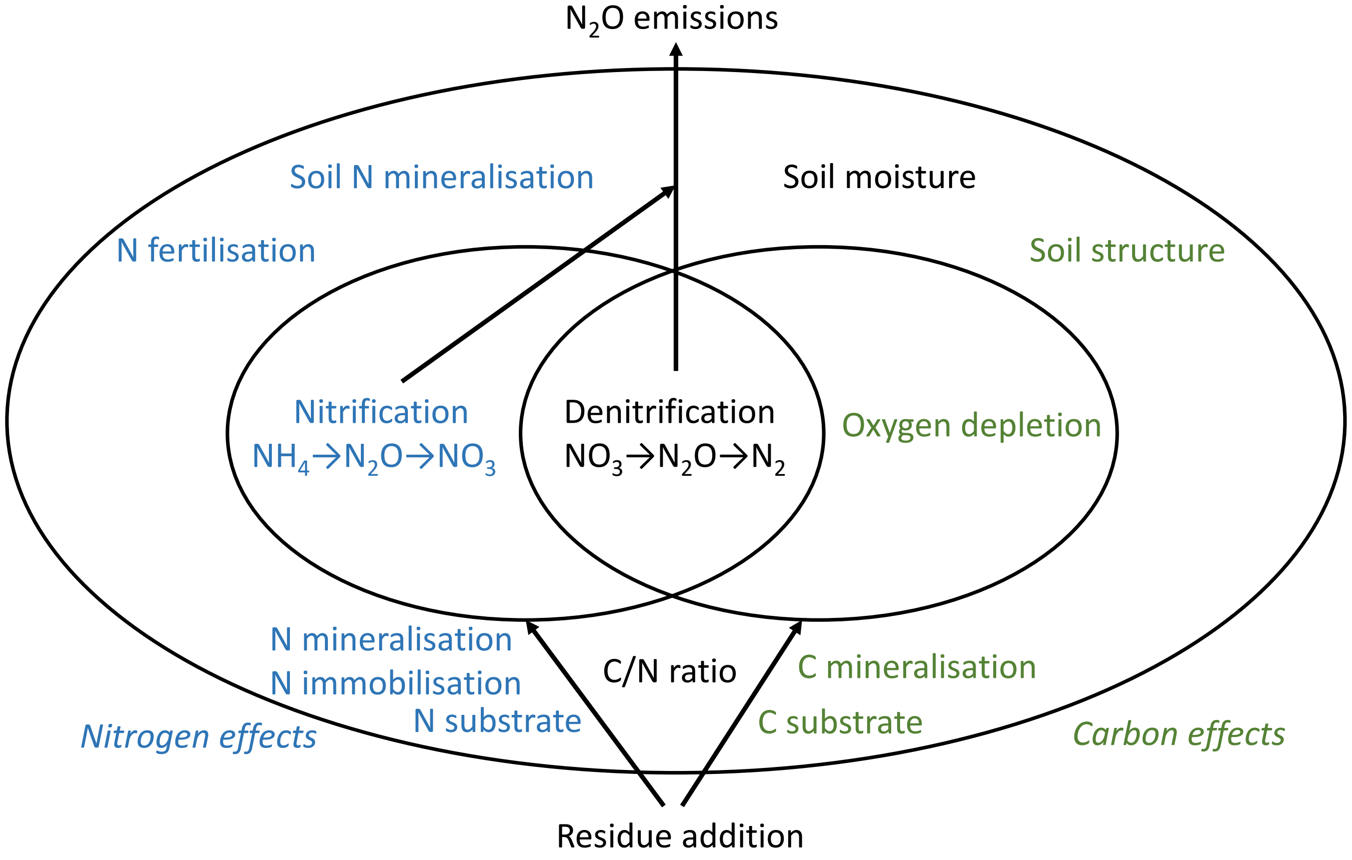
- Nitrification inhibitors
- Precision fertilization
- Leaf fertilization
- Manure treatments (e.g., separation)

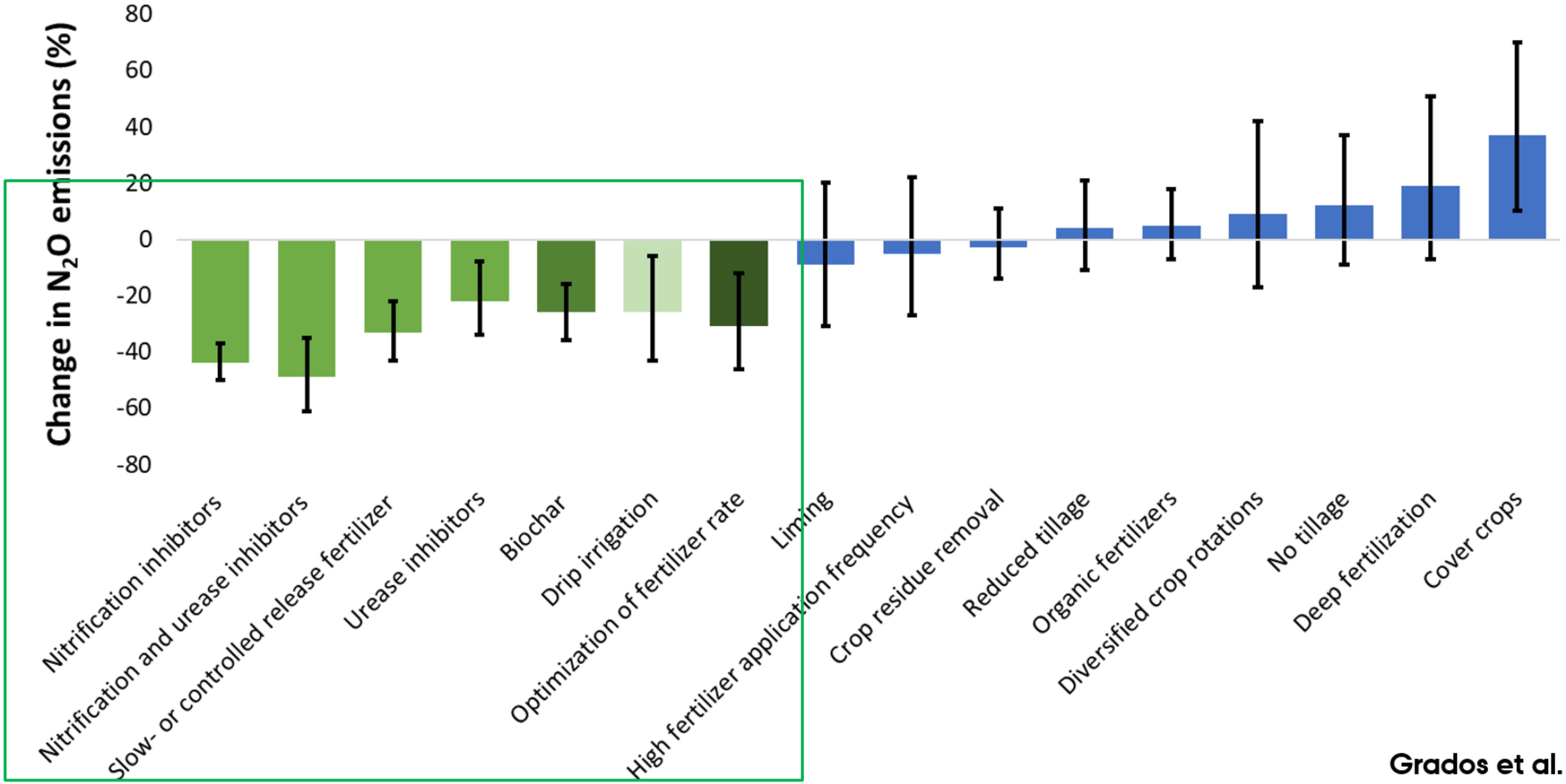
Water management

- Improved drainage
- Improved irrigation (timing)

Cropping systems

- Conservation agriculture
- Controlled traffic
- Residue removal (in particular green residues)
- Perennial crops (e.g., grassland)





Grados et al. (2022)

Technology-driven solutions (e.g., inhibitors, biochar, drip irrigation) and optimization of fertilizer rate have considerable mitigation potential (30-50%)

Soil carbon storage

Increase carbon through cropping systems

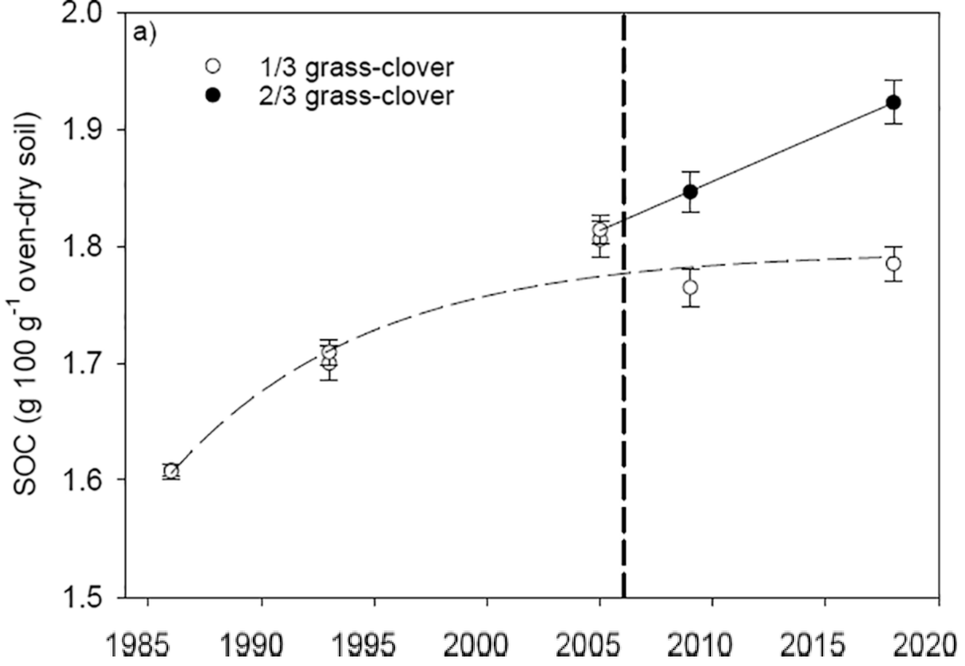
- Perennial crops (in particular grass)
- Biochar

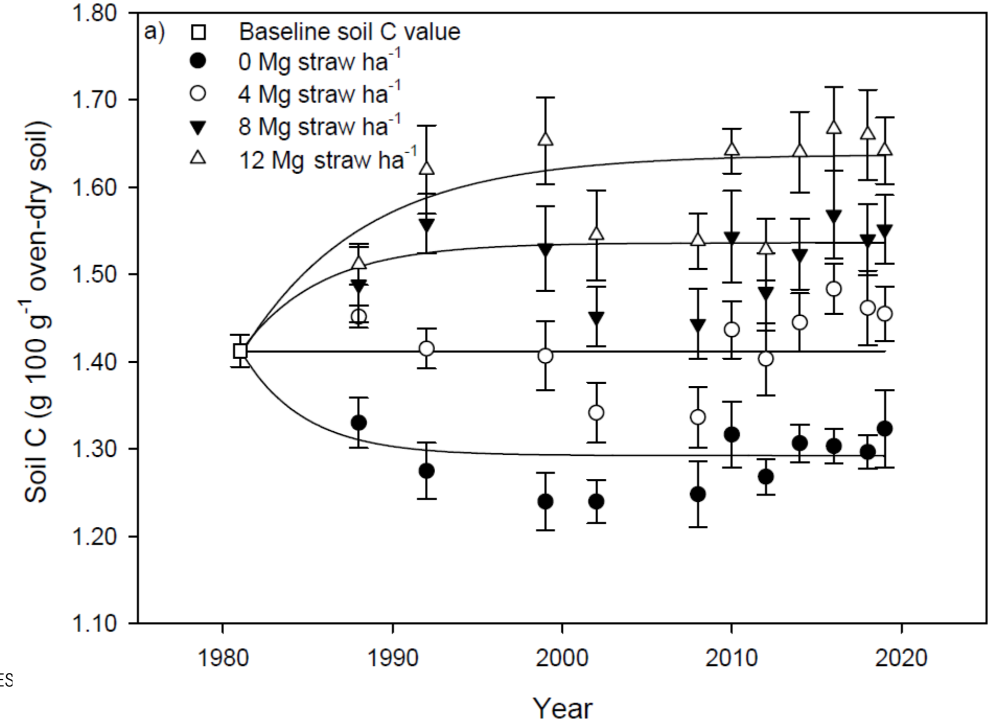
Requires changes in production systems

- Biorefining (of grass for feed, food, fibre and energy)
- Biochar of straw, woodchips and manure (pyrolysis)

Other less efficient measures

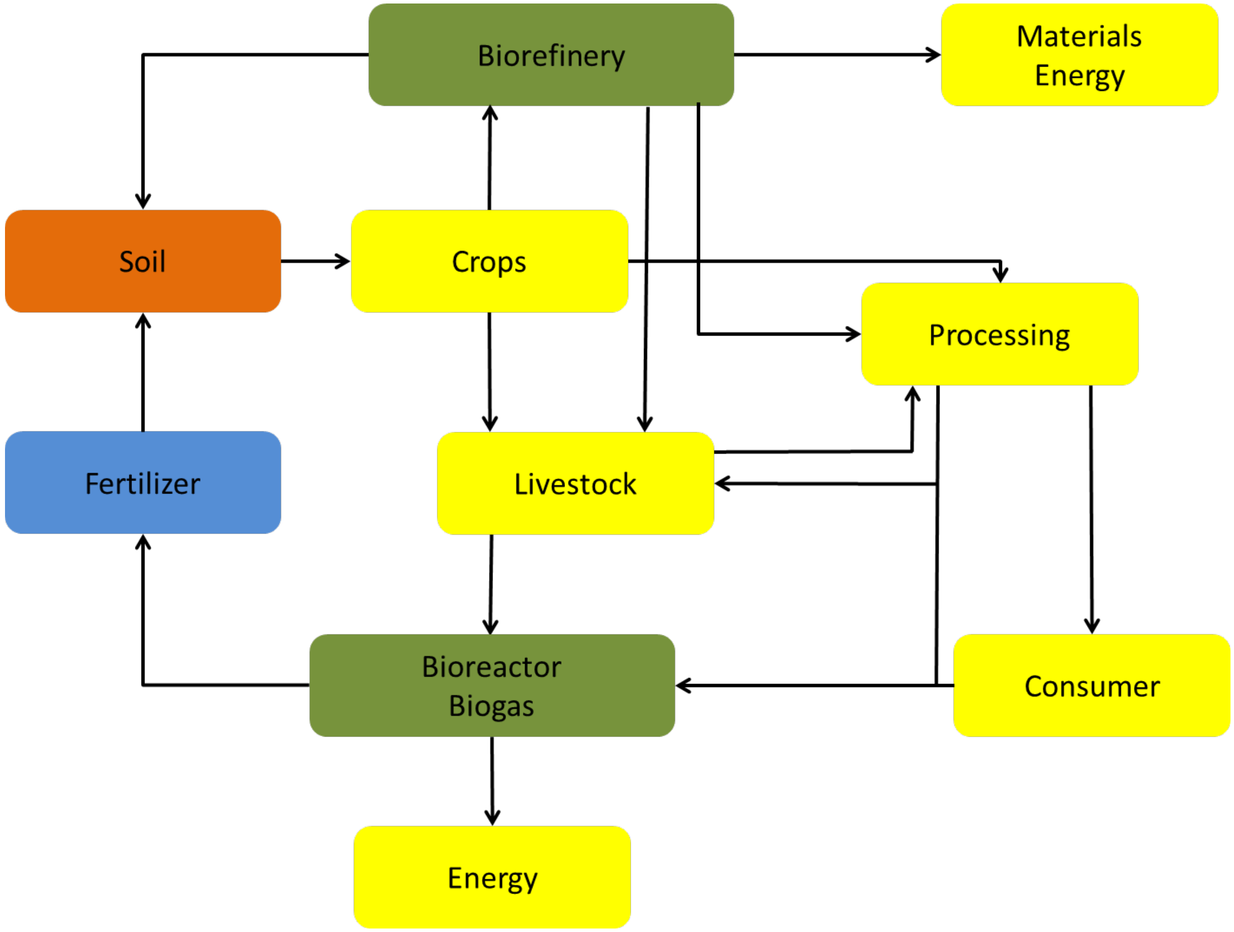
- Cover crops
- Straw





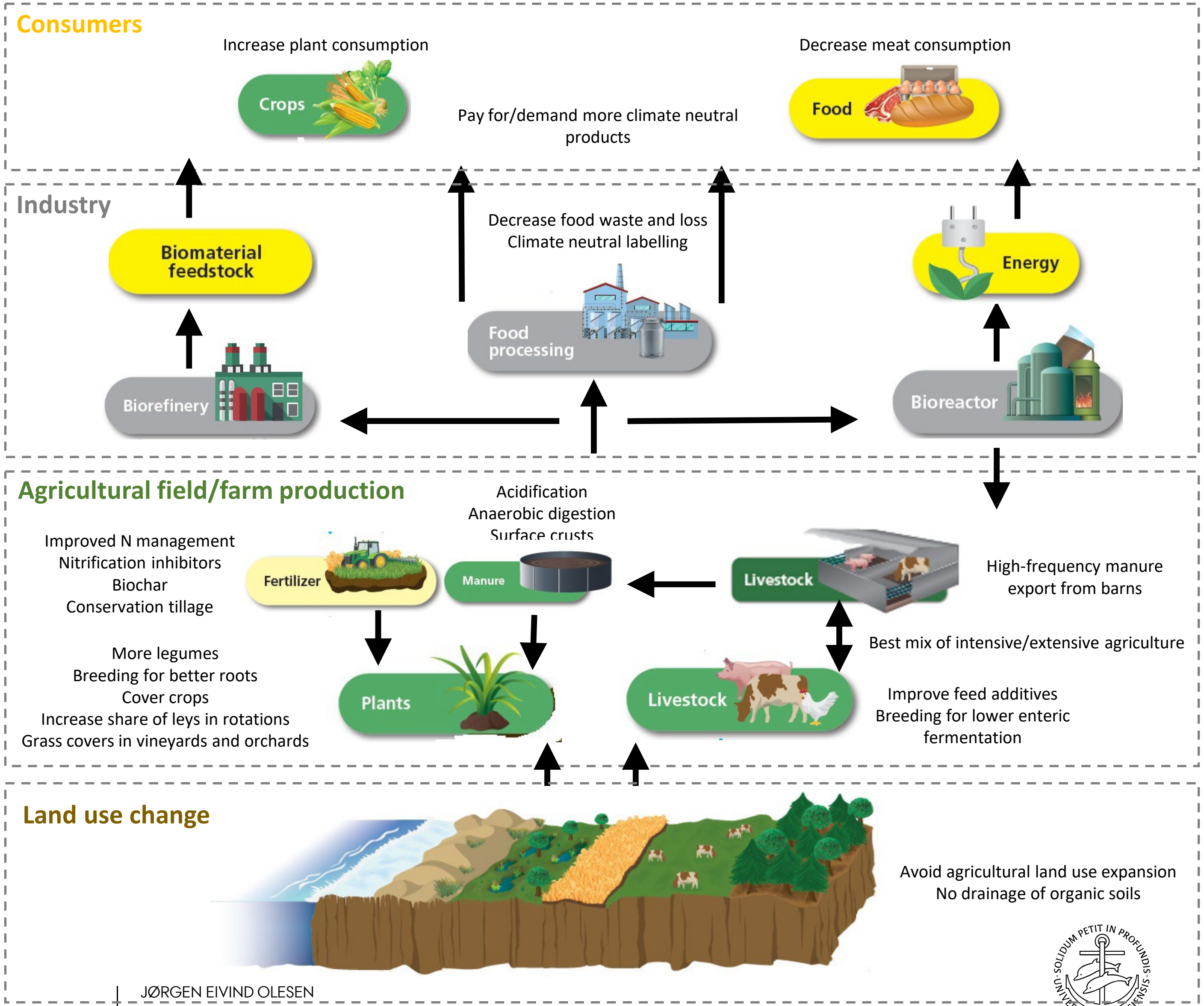
Circularity is part of all topic areas

- Recycling of biomass and nutrients with use of side streams and bioenergy production enable
  - Lower external inputs
  - Higher production efficiency
  - Lower emissions through less waste
  - Energy production (e.g., biogas)
- New biorefining technologies enable
  - Cultivation of highly productive crops with low environmental and GHG as biomass for biorefining
  - Replacement of traditional feed crops, ingredients for food industry and biomaterials



Technology needs for all parts of the food system

- Technologies are essential for sustainable systems, but need direction
- Technologies should support the green transition (not only productivity)
- Technologies include, e.g.,
  - Landscape engineering
  - Biomass production systems
  - Biorefining
  - Nutrient recycling and retention
  - Biochemical engineering
  - Microbial manipulations
  - Genomic selection (plants, animals)
  - New Genomic Techniques (CRISPR)
  - Precision farming (sensors, robots)



Cross-cutting issues and investments

Issues

- Improved GHG accounting
- Data-driven agri-food system
- Regulation and incentives from farm to fork

Vast investment needs for the transition

- Research and innovation capacity
- Establish R&I partnerships
- Funding the transition
  - Research and technology development
  - Demonstration and implementation
  - Commercialization and entrepreneurship
  - Required about 10 billion DKK annually

Incentives

There are many barriers:

- Technology
- Financial, investments
- Environment and health
- Regulation

Farm level accounting

- Basis for future public regulations
- Basis for product carbon labelling

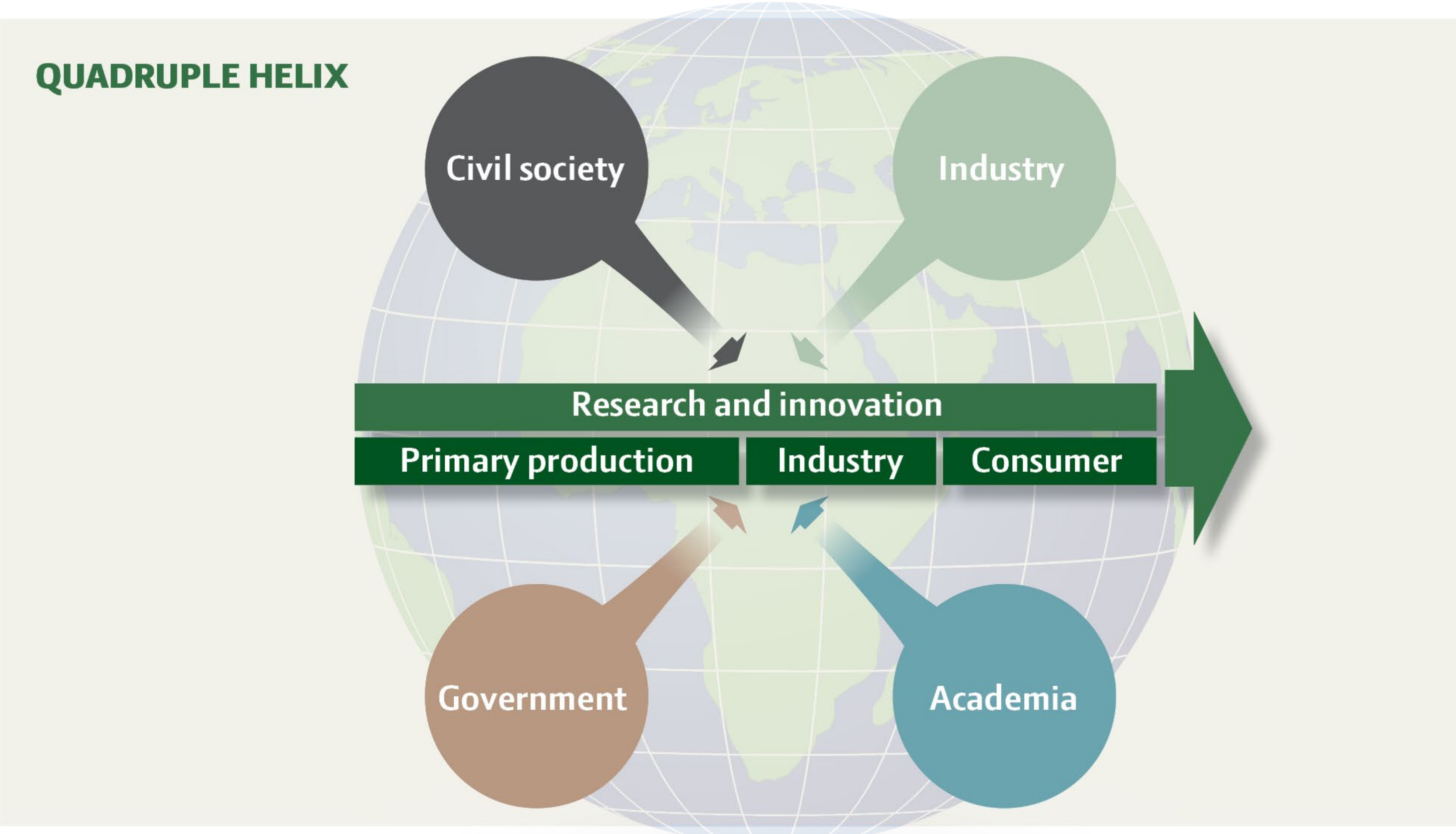
Need to speed up processes:

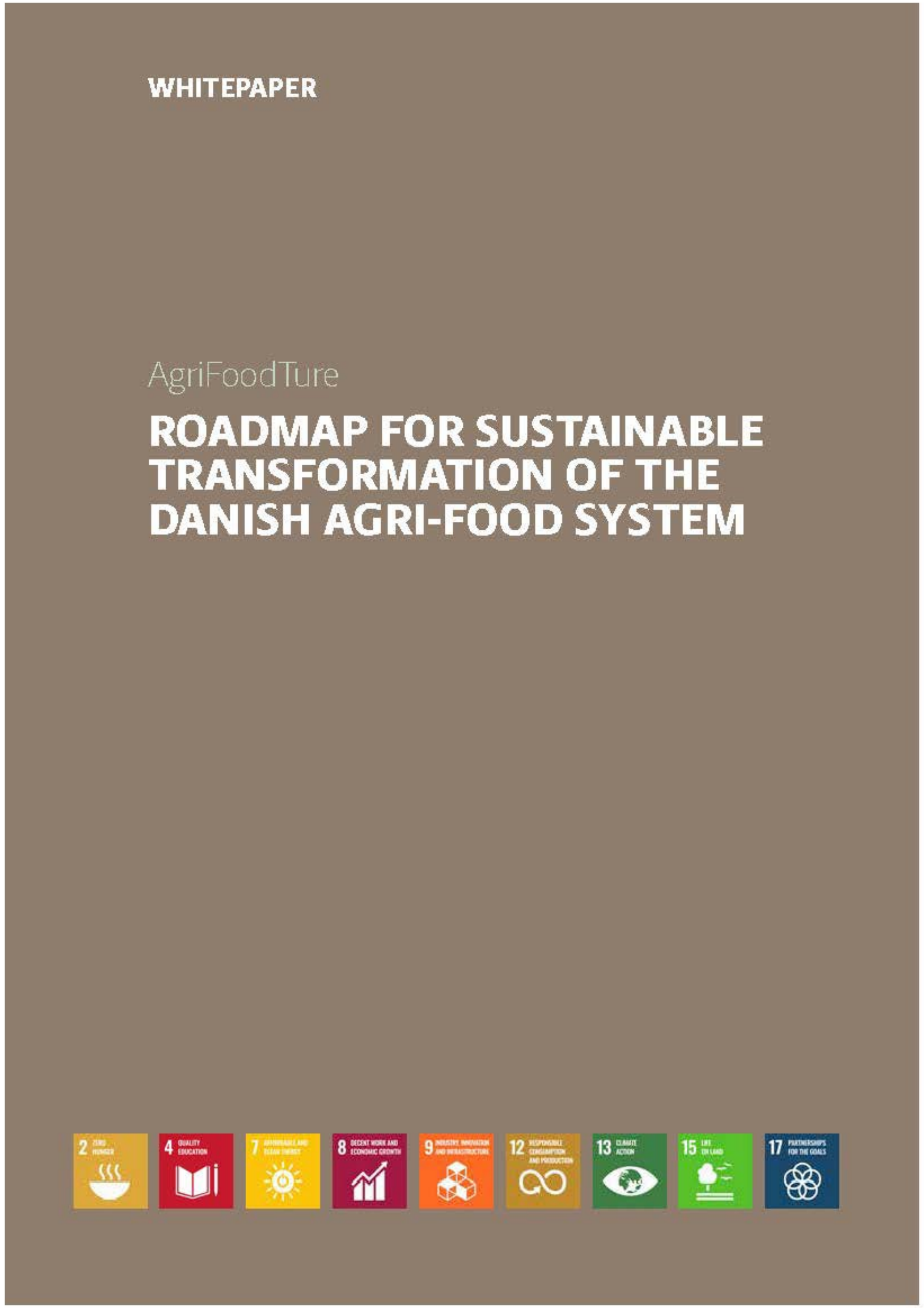
- Authority approval of new activities
- New facilities (biorefining, biogas, pyrolysis)
- Partnerships
- Demonstration

GreenLab Skive

The AgriFoodTure innovation partnership

- The overall vision of the AgriFoodTure partnership is to position Denmark as the leading country in innovative and disruptive green transition of the agri-food system.
- 60 partners
- Driven by a roadmap developed by 300 researchers across universities and innovation centers





WHITEPAPER

- Whitepaper: extended version of Roadmap submitted for the Innovation Fund Denmark
- Where: www.agrifoodture.com (under About)
- Background document used by policy makers (including in Parliament to secure funding for research, innovation and pilot scaling)

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