Current efforts of lowering GHG emissions in Danish agriculture and beyond

Professor Jørgen E. Olesen

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

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

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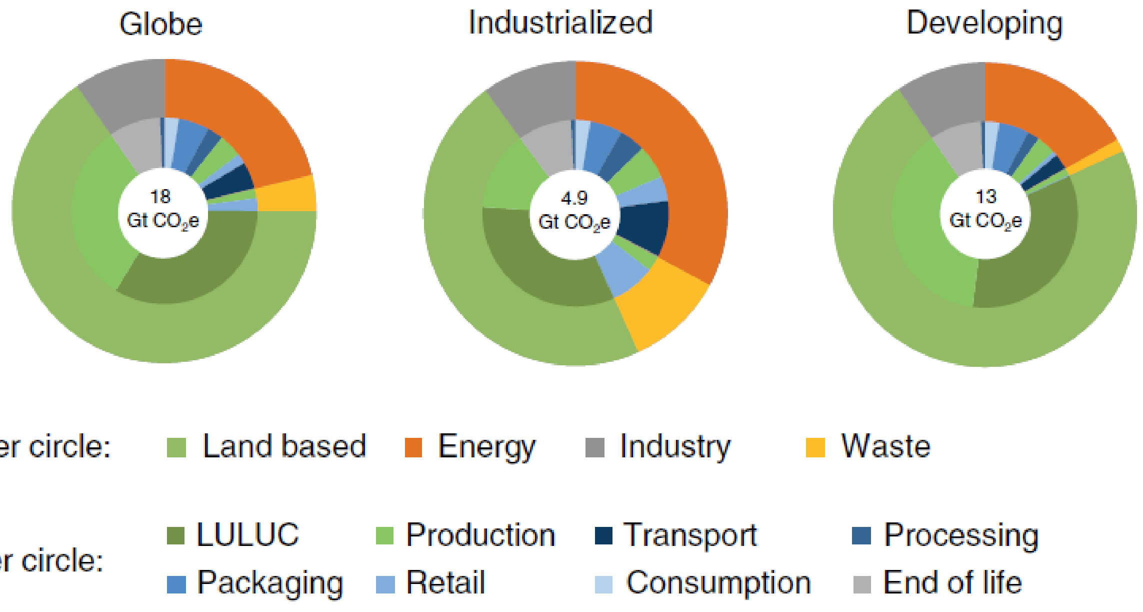

Fig. 1 | GHG emissions from the food system in different sectors in 2015. Total GHG emissions (including CO_2, CH_4, N_2O and F-gases) are expressed as CO_2e calculated using the GWP100 values used in the IPCC AR5, with a value of 28 for CH_4 and 265 for N_2O.

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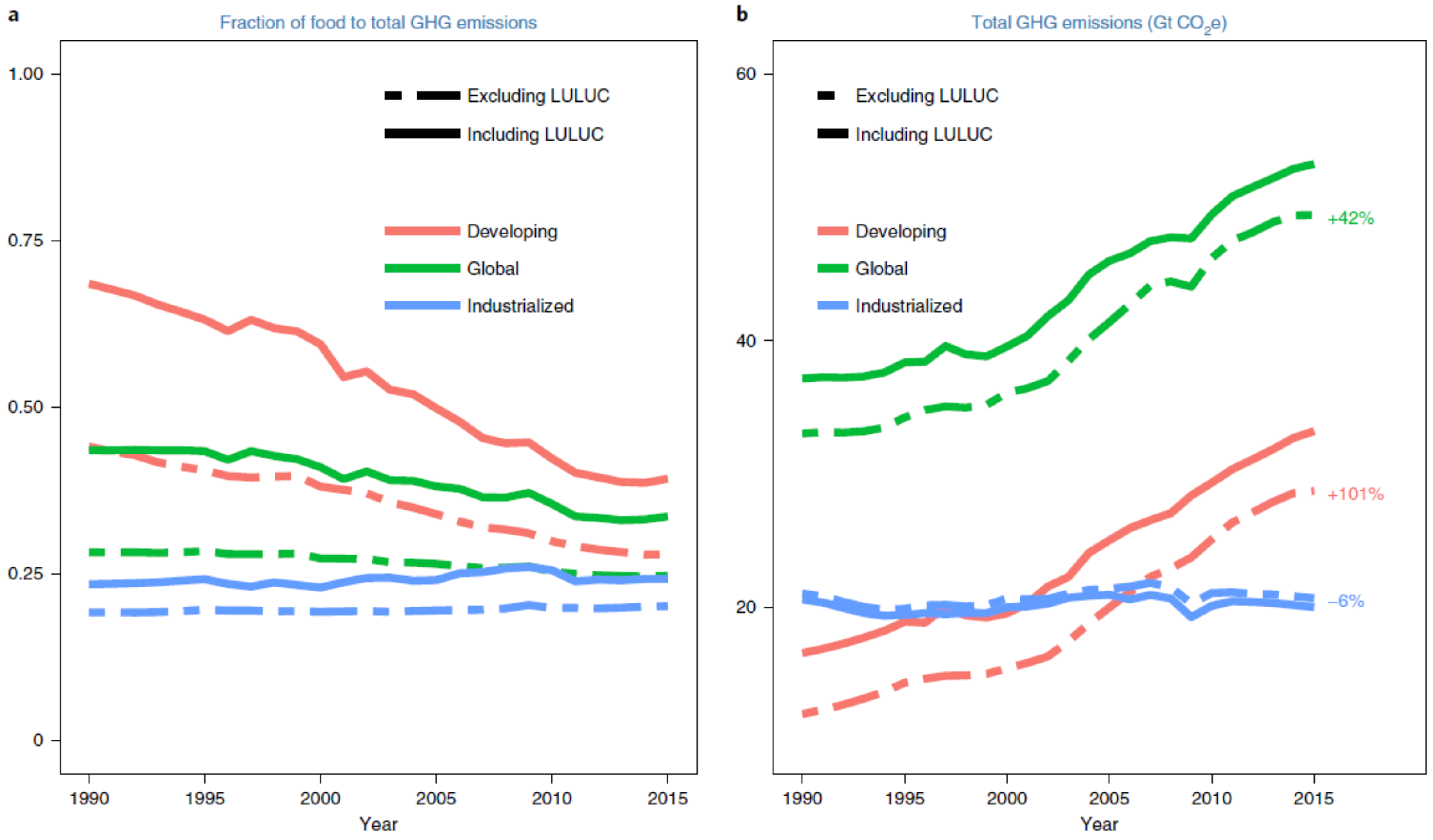

Fig. 2 | Total GHG emissions and food-system data globally, and in developing and industrialized countries. a,b Fraction of food to total GHG emissions (**a**) and total GHG emissions from the food system (**b**) globally, in developing and industrialized countries. Non-CO_2 GHG emissions (CH_4, N_2O 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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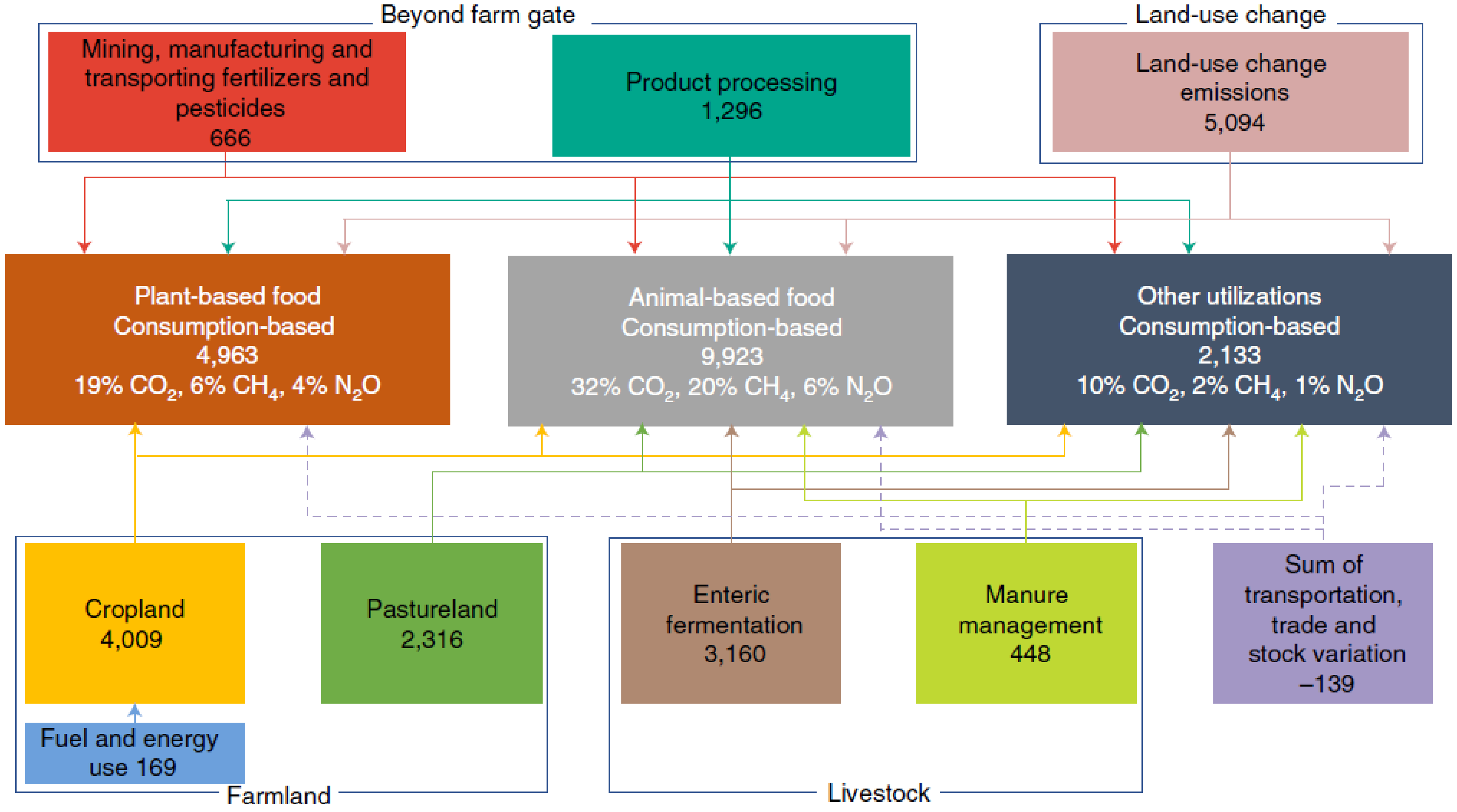

Fig. 1 | GHG emissions from different subsectors of plant- and animal-based food production/consumption. The contributions of individual GHGs provided are the percentage of the total emissions. Solid arrows indicate production-based emissions, and solid and dashed arrows combined are consumption-based 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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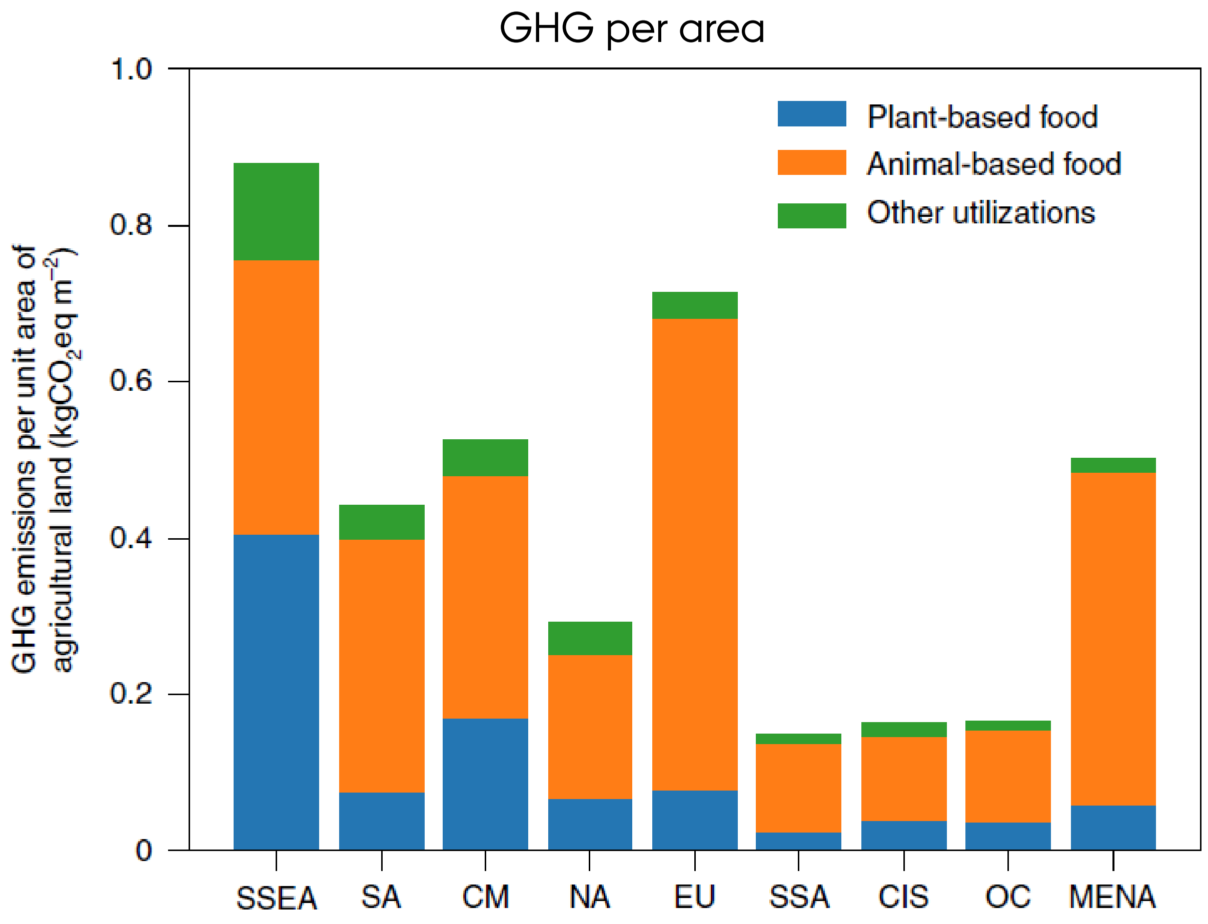
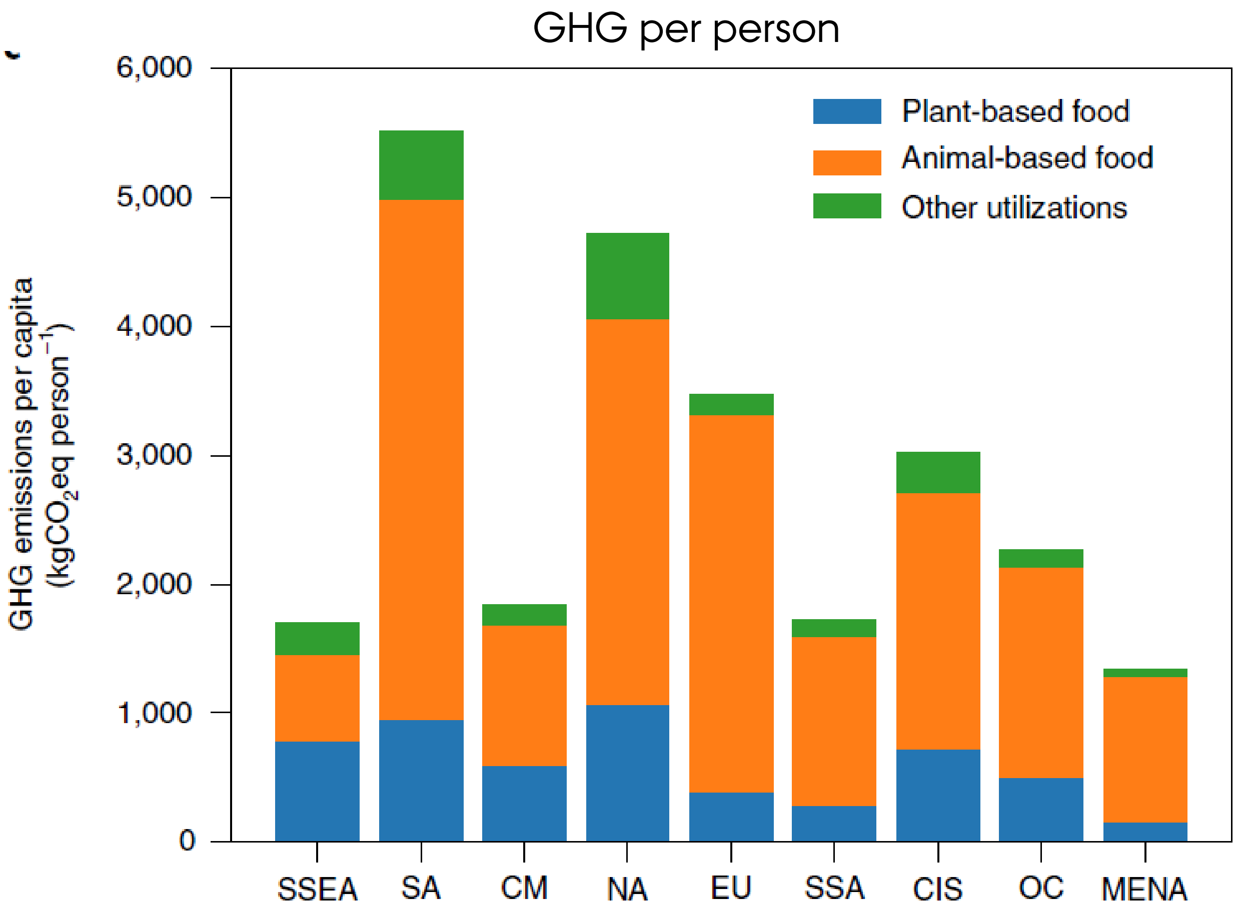




NA, North America; SA, South America; EU, European Union; MENA, Middle East and North Africa; SSA, sub-Saharan Africa; CIS, Commonwealth of Independent States; CM, China and Mongolia; SSEA, South and Southeast Asia; OC, Oceania and other East Asia

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

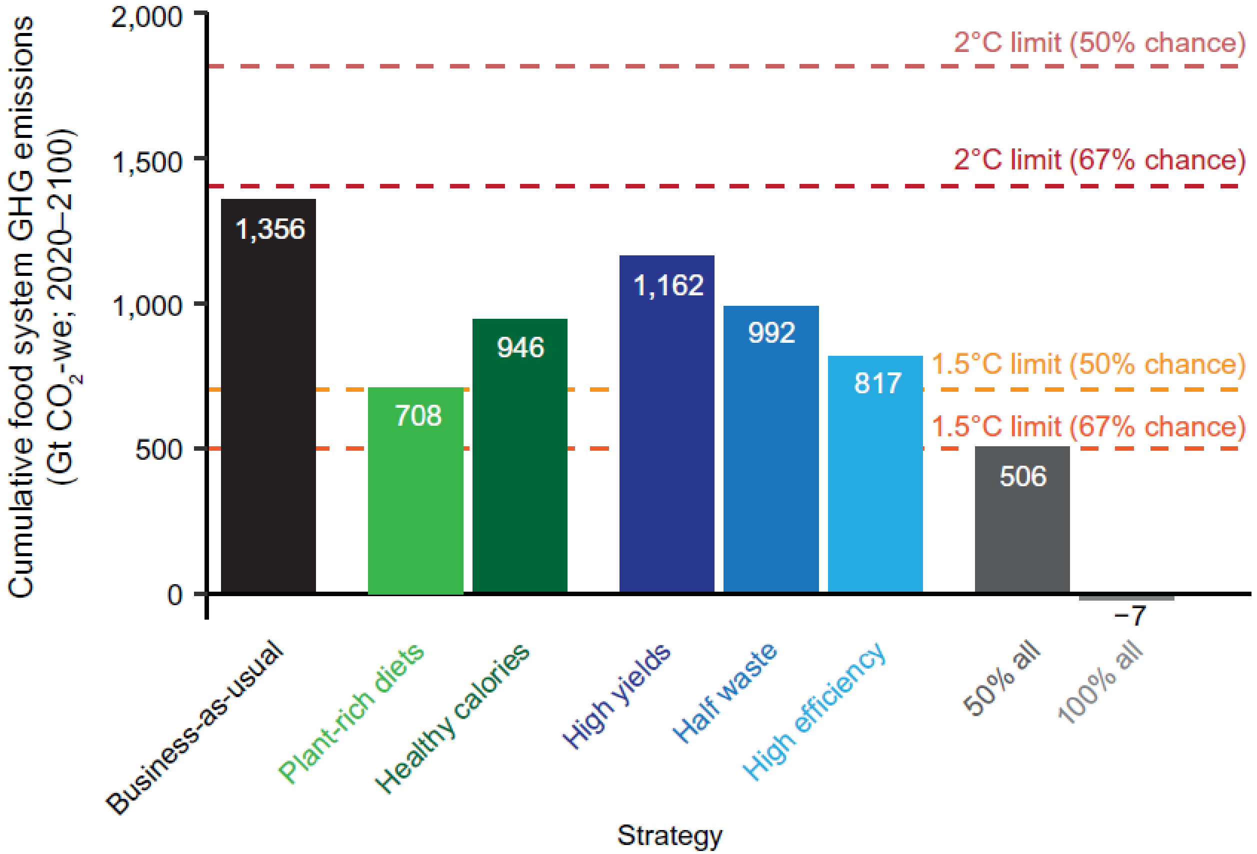


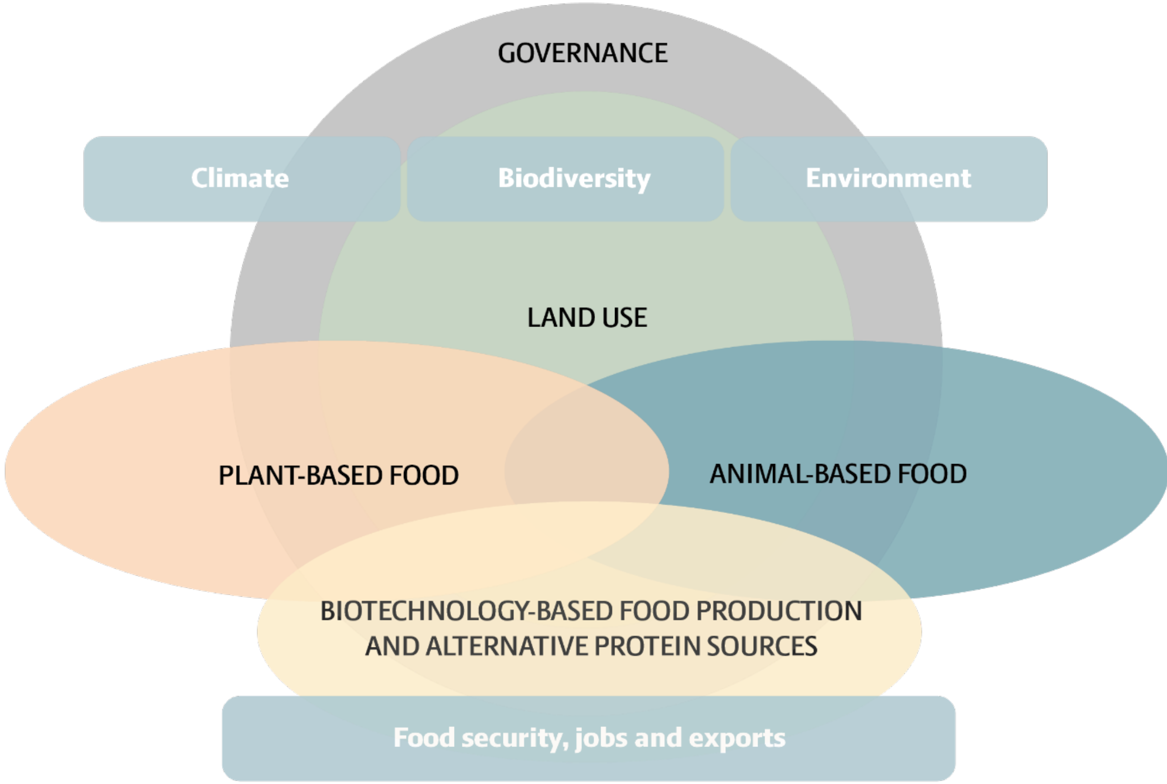
Fig. 1. Projected cumulative 2020 to 2100 GHG emissions solely from the global food system for business-as-usual emissions and for various food system changes that lead to emission reductions.

Clark et al. (2020) Science

There a many sustainability challenges

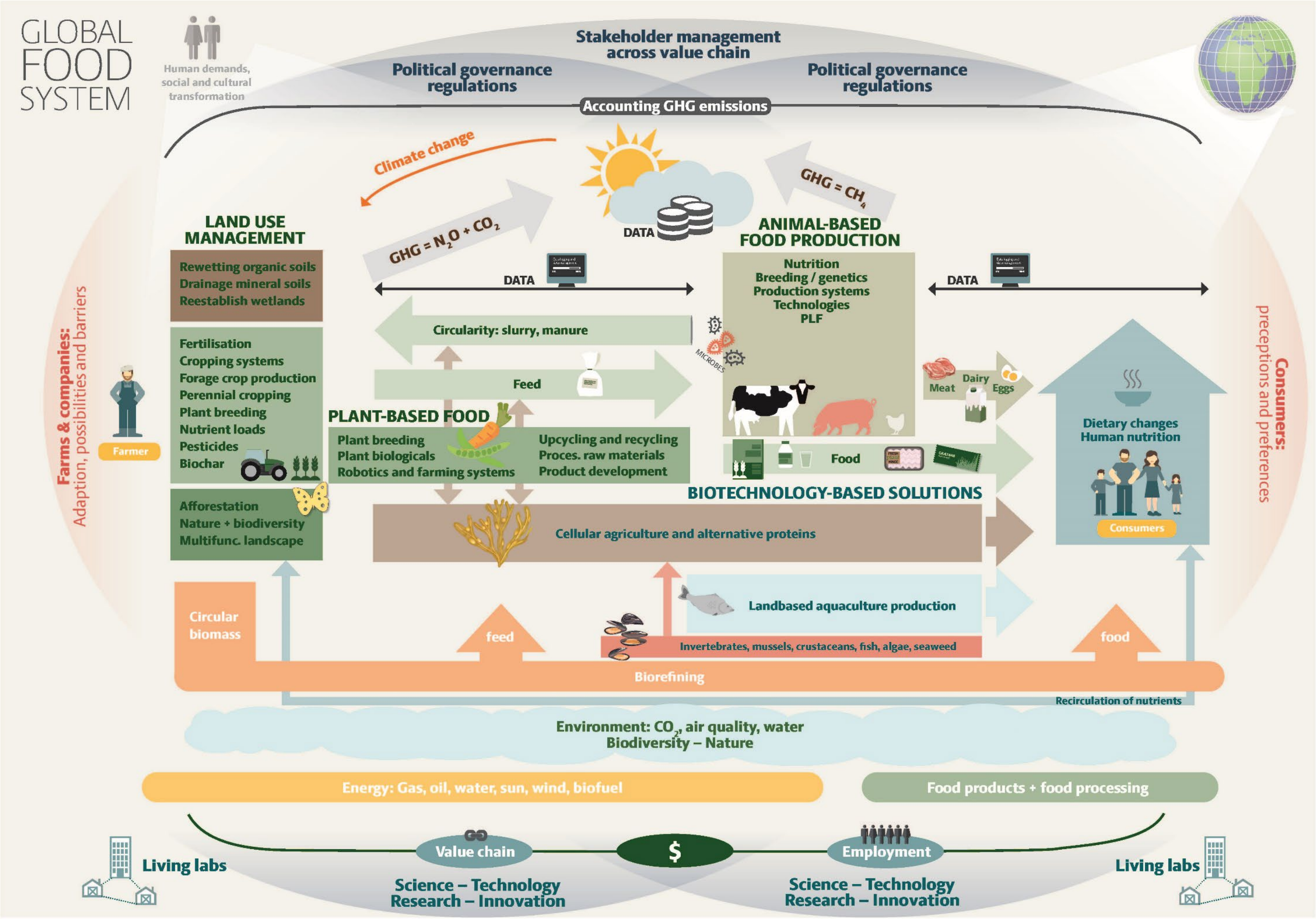
- Lower GHG and environmental footprint
- Enhance biodiversity (inside and outside farming)
- Less pesticide use
- Land area for other purposes (infrastructure, nature, recreation, climate change adaptation)
- Increased production of
  - Food (globally +45% by 2050)
  - Bioenergy
  - Biomaterials
- Jobs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

AgriFoodTure roadmap



Roadmap developed by universities and agroindustry in Denmark

It is complex



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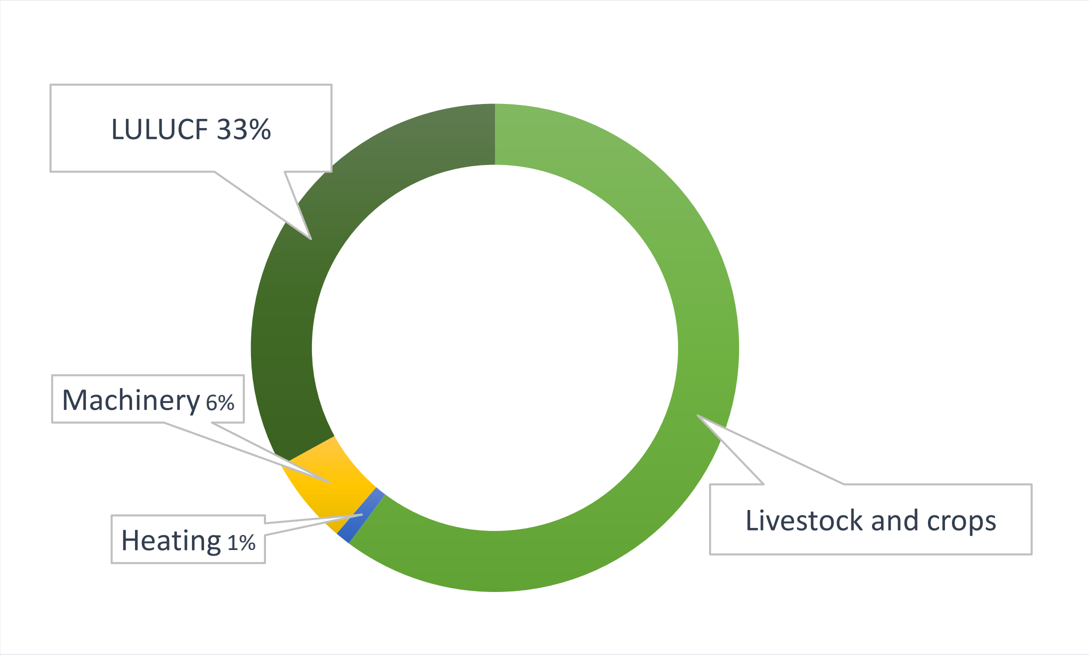
Greenhouse gases from Danish agriculture

Agriculture accounts for 35% of national emissions

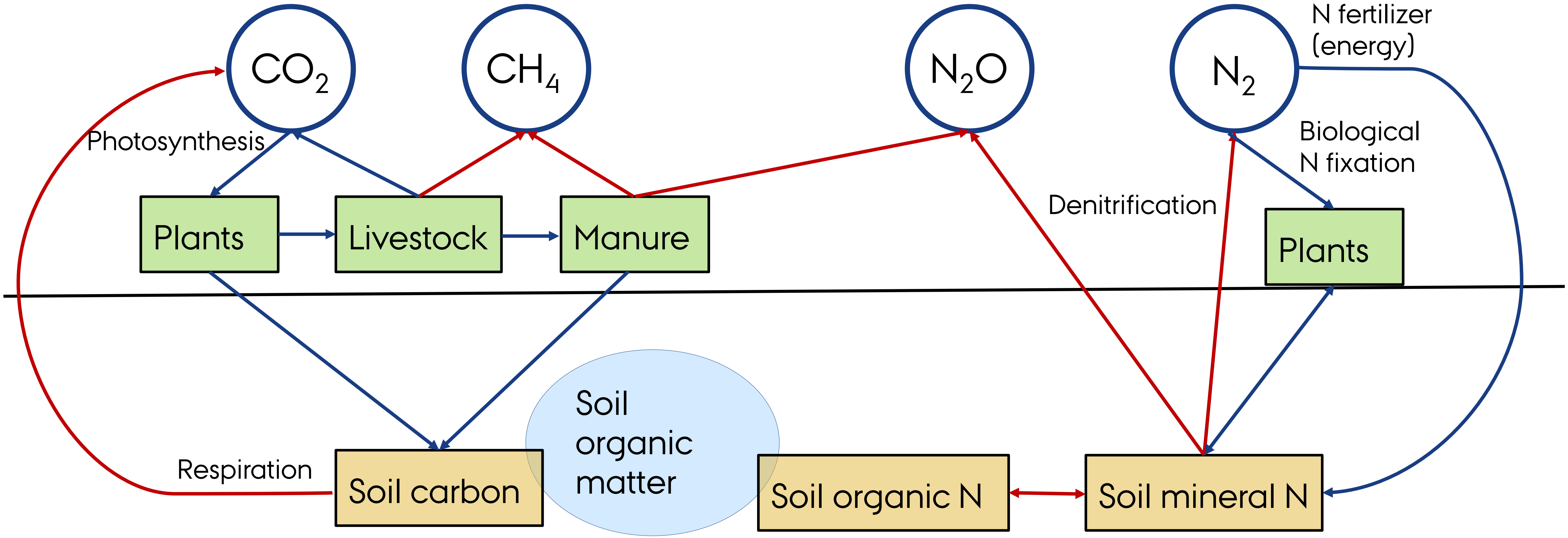
Agricultural emissions (territorial basis)

- Enteric fermentation (CH_4 from ruminants, cattle)
- Manure management (primarily CH_4 from slurry)
- Soil (N_2O from fertilizers, manures, crop residues etc.)
- Energy (primarily fuels)
- LULUCF (primarily drained peatlands)

- **Landbrug + LULUCF**: 17.5 mill. t CO_2-ækv
- Reduced by about 15% since 1990
- 70% reduction will require additional reductions of about 10 mill. t CO_2-eq.



GHGs associated with the carbon and nitrogen cycle



CO_2, CH_4 and N_2O losses are mostly driven by microbiological processes

Measures for reducing GHG emissions (2030)

- Changed feeding of cattle (CH_4)
- Feed additives for cattle (CH_4)
- Biogas (CH_4)
- Acidification of slurry/manure (CH_4)
- Covers on slurry tanks (CH_4)
- Nitrification inhibitors (N_2O)
- Better use of N in manures (N_2O)
- Rewetting drained peatlands (CO_2, N_2O, CH_4)
- Set-a-side of agricultural land (CO_2, N_2O)
- Perennial energy crops (CO_2, N_2O)
- Cover crops (CO_2, N_2O)

These measures reduce emissions by 18% and compensate 11% by soil carbon storage
I total: 2.7 mill. ton CO_2-eq.

Autumn 2021

Danish parliament political agreement on nitrogen load reductions (WFD) by 2027 and GHG reductions by 2030

Reduktionseffekter

	Mio. t. CO_2e		Kvælstof (t. N)
Nye indsatser	***2025***	***2030***	**2027**
Reduktionskrav for husdyrenes fordøjelse	0,17	0,16	0
Hyppigere udslusning af gylle	0,15	0,17	0
Reform af EU's landbrugspolitik	0,38	0,38	1.550
Udtagning af 22.000 ha lavbundsjorder	0,04	0,33	700
Privat skovrejsning	0,00	0,05	50
Ekstensivering	0,10	0,10	400
Kvælstofindsats	0,31	0,64	8.000
Midlertidig reduceret hugst i skove	-	0,07	-
I alt (reduktioner)	***1,2***	***1,9***	***10.800***
Allerede besluttede			
Udtagning af lavbundsjorder (FL20-FL21)	-	0,3	-
Øvrige tiltag	-	0,2	-
I alt allerede besluttede		***2,4***	
Udviklingstiltag			
Brun bioraffinering	-	2,0	-
Gyllehåndtering[1)]	-	1,0	-
Fodertilsætning	-	1,0	-
Fordobling af økologi	-	0,5	-
Udvidet lavbundspotentiale	-	0,5	-
I alt (udviklingstiltag)	-	***5,0***	-
I alt (reduktioner + udviklingstiltag)	-	**7,4**	

Stipulated GHG reduction for carbon neutrality

Source	Baseline ($Mt\ CO_2eq$) 2018	Reduction (%) 2030	Reduction (%) 2050	Reduction ($Mt\ CO_2eq$) 2030	Reduction ($Mt\ CO_2eq$) 2050
Enteric fermentation (CH_4)	3.77	40	70	1.51	2.64
Manure management (CH_4, N_2O)	2.81	50	90	1,41	2.53
Fertilization (N_2O)	2.83	40	70	0.91	1.60
Crop residues (N_2O)	0.61	10	40	0.06	0.24
Ammonia volatilization (N_2O)	0.34	20	40	0.07	0.13
Nitrate leaching (N_2O)	0.33	10	30	0.03	0.10
Liming (CO_2)	0.24	10	20	0.02	0.05
Energy use (CO_2)	1.25	50	100	0.62	1.25
Organic soils (CO_2, N_2O)	5.75	30	80	1.73	4.60
Soil carbon (CO_2)	-	-	-	1.80	4.30
Total	17.37	48	100	8.16	17.44

Targets are extremely ambitious, but feasible with extraordinary large and coordinated efforts

Organic soils in cultivation in Denmark

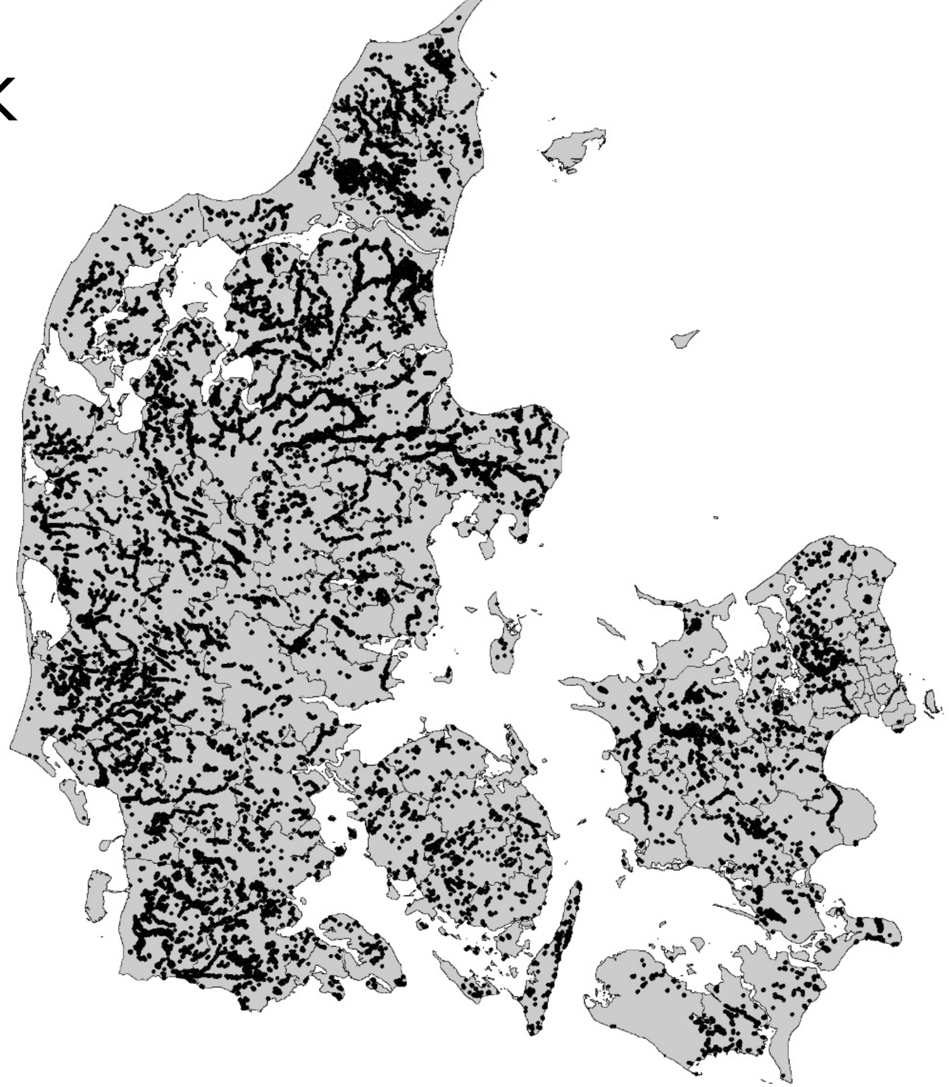
› Cultivated fields with more than 6% C (international 12%C)

› Soils with less than 6% C also contribute to emissions

Kulstof (%C)	Areal (ha)	Potentiel CO_2 udledning (mio. ton CO_2)
3-6	62.960	24.0
6-12	98.080	69.2
>12	73.523	64.5
I alt	234.563	157.6

› Annual emissions in 2017: 5.8 Mt CO_2-eq.

› Rewetting all organic soils will reduce by 4.4 Mt CO_2-eq. (76%)



Marker med organisk jord
I alt ca. 171.000 ha med over 6 %C

Methane from livestock

Changed feeding for ruminants

- More fat
- Extended lactation
- Breeding fodder crops

Additives

- Nitrate
- 3NOP (Bovaer)
- The ”X” compound
- Seaweed and others

Breeding

- Breeding for livestock with low methane

Collecting methane

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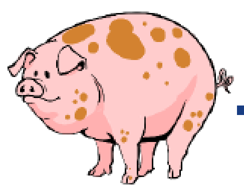
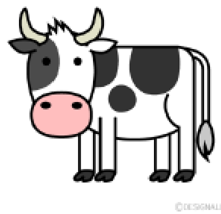
HEAD OF DEPARTMENT, PROFESSOR

Manure management





Staldteknologi og management:
- Ugentlig udslusning
- Nye gyllesystemer (tragte/skrabere)

\+ Supplerende tiltag:
- Behandling af restgylle (fx syre)
- Robot-tømning
- Nye additiver til restgylle
- Gyllekøling
- …

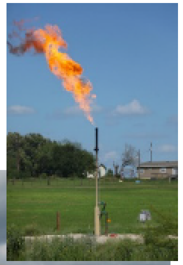
Kulstofkontrol:
- Biogas
- Separation
- Separation + biogas af fiberfraktion
- Separation + pyrolyse → Biochar
- Biogas + separation + pyrolyse (fiber) → Biochar
- …

Mere omsætteligt kulstof i lager

Rest-kulstof

N_2O NH_3 Lugt

Lager-teknologi:
- "Målrettet" lagerforsuring
- Kontrolleret oxidation i flydelag
- Ventilering og metanoxidation
  - Kemisk
  - Biologisk
- Ventilering og afbrænding
- …



Field level options (in particular for N_2O)

Improved fertilisation strategies

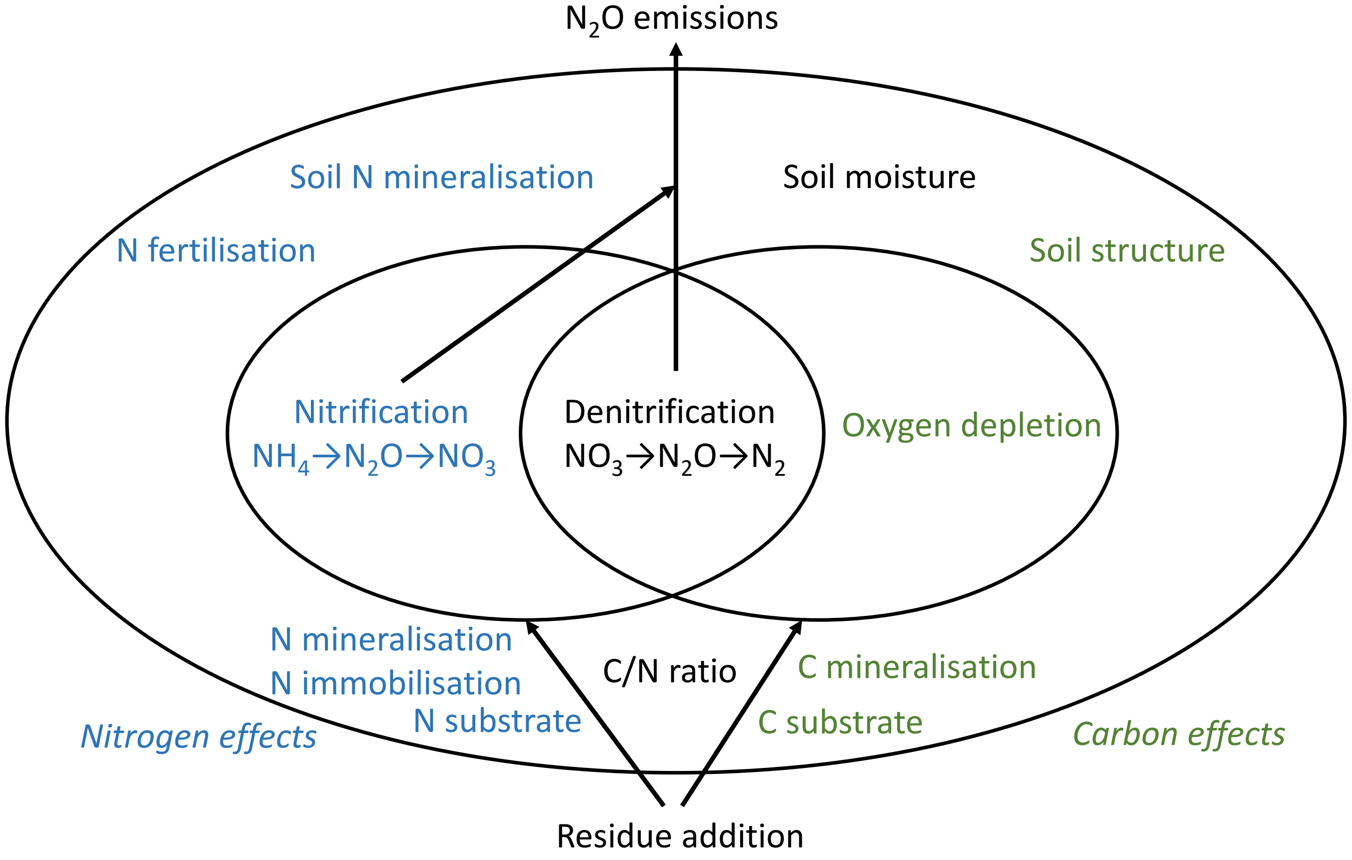
- Nitrification inhibitors
- Precision fertilization
- Leaf fertilization
- Manure treatments (e.g., separation)

Water management

- Improved drainage
- Improved irrigation (timing)

Cropping systems

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



Can agricultural soils store more carbon?

Sufficient measures to enhance soil organic carbon (SOC)?

- Soil carbon is primarily (solely?) enhanced through higher organic matter inputs.
- Competition with demands for biomass (food, feed, fibre, biofuels).

Permanence of soil carbon?

- Existing high carbon pools in peatland soils should be preserved through high water table.
- Measures to maintain C stocks in mineral soils needs to be sustained.

Global warming increases soil carbon decomposition

- Higher temperatures enhance SOC decomposition. A 1 °C increase is estimated to reduce global SOC by 1.6 Gt C/yr.

Overall assessment

- The possibilities for enhancing SOC depends on the balance between enhanced C inputs and enhanced SOC decomposition.
- It will likely be challenging just to maintain current SOC levels.

Soil carbon storage

Increase carbon through cropping systems

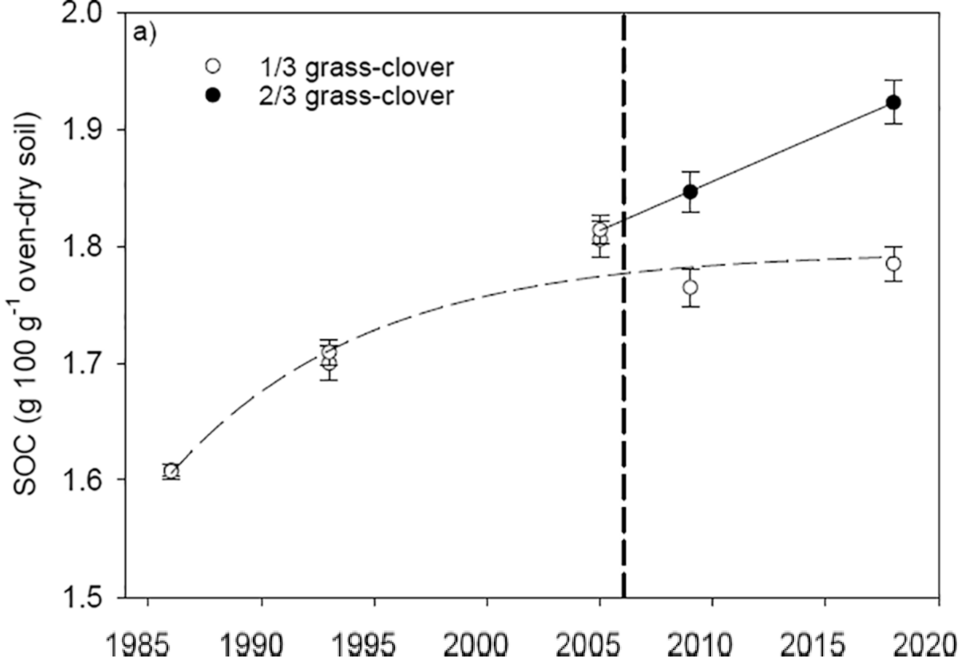
- Perennial crops (in particular grass)
- Biochar

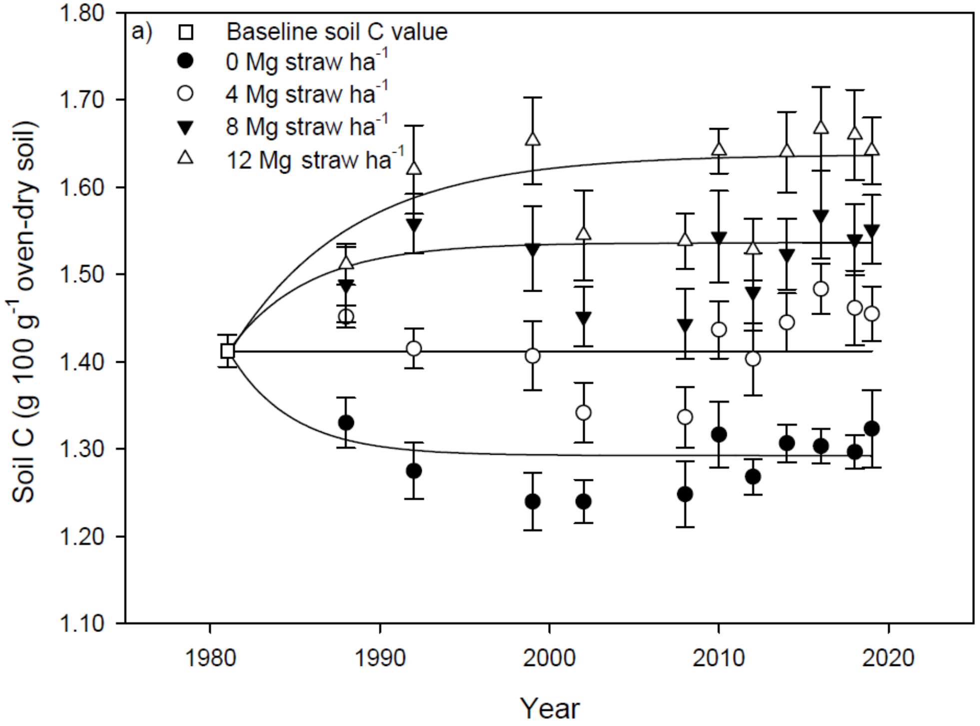
Requires changes in production systems

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

Other less efficient measures

- Cover crops
- Straw





No-till changes vertical distribution of carbon in soils

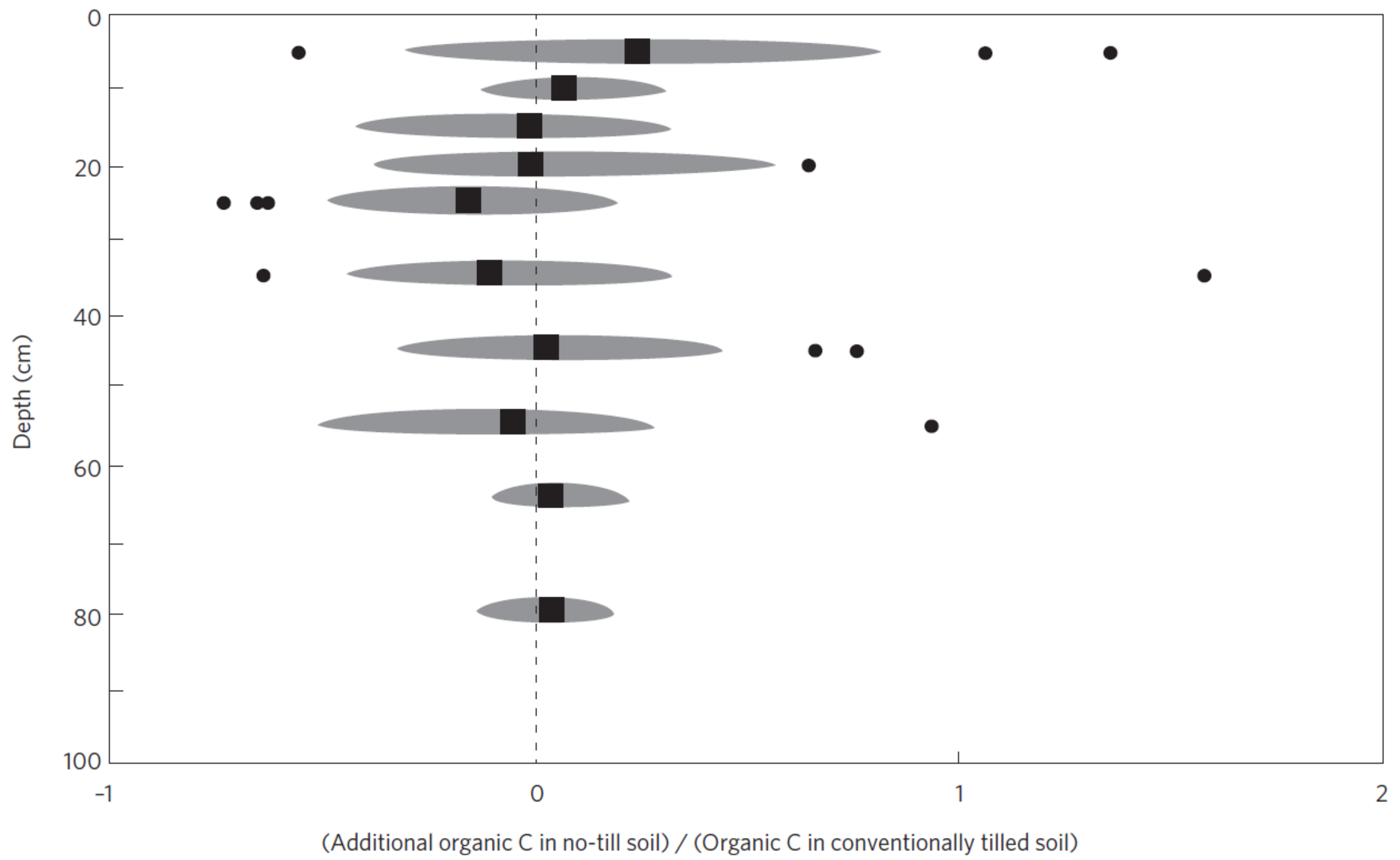
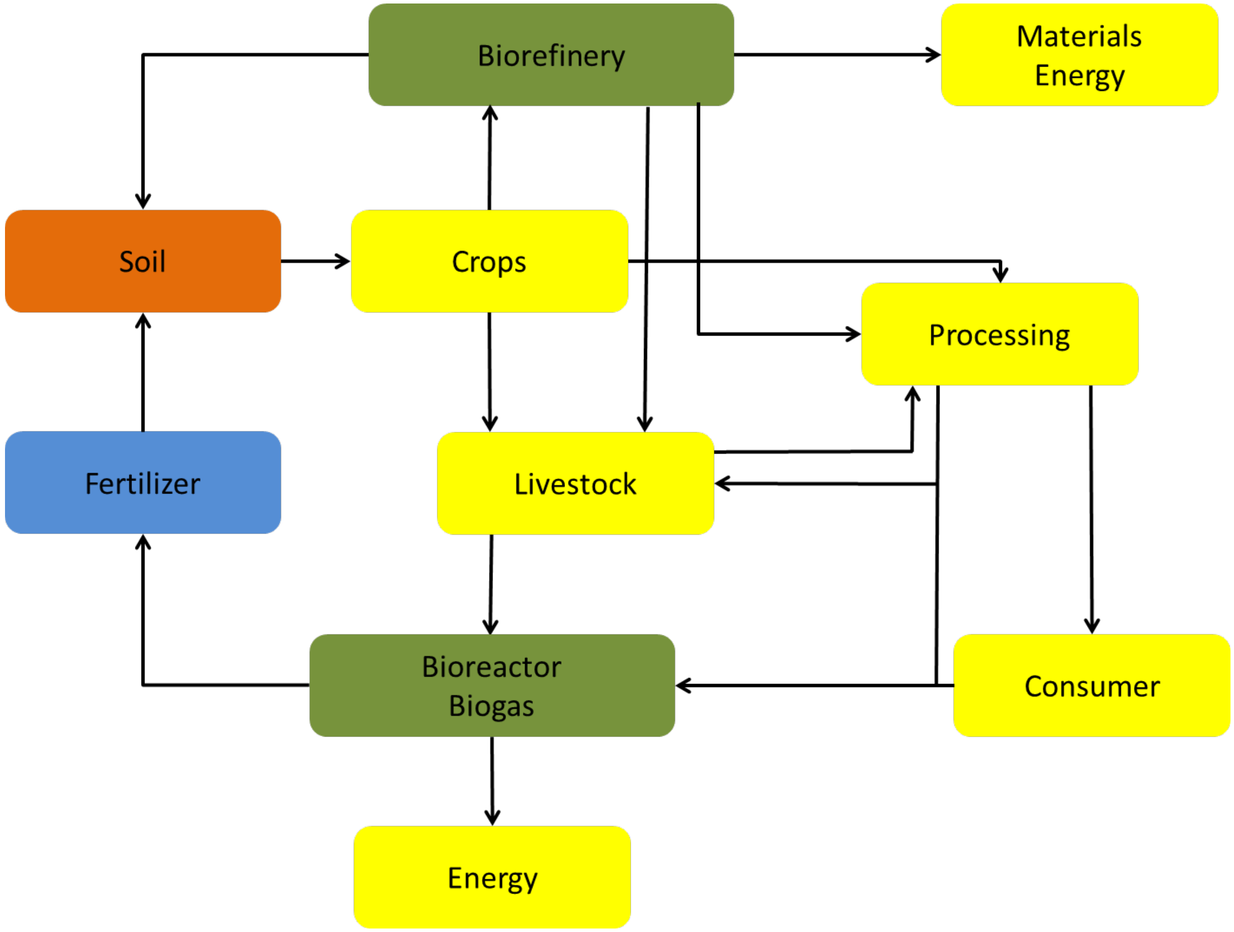


Figure 2 | Changes in soil organic carbon (SOC) content in soil under no-till compared to conventional tillage. Based on a meta-analysis of data from 43 sites where the two tillage systems had been applied for at least 5 years, and in many cases for more than 15 years. Large filled squares are

Powlson et al. (2014)

Circular food and material chains

- Cycling and recycling of biomass and nutrients with collection of GHGs (e.g. methane) enable
  - Lower external inputs
  - Higher efficiency of primary production
  - Lower emissions through less waste
  - Energy production (primarily biogas)
- New biorefinery technologies enable
  - Growing highly productive crops with low environmental impact for feedstocks to biorefining
  - Substitution of traditional feed crops for livestoc, ingredients for food industry and for biomaterials



Incentives

There are many barriers:

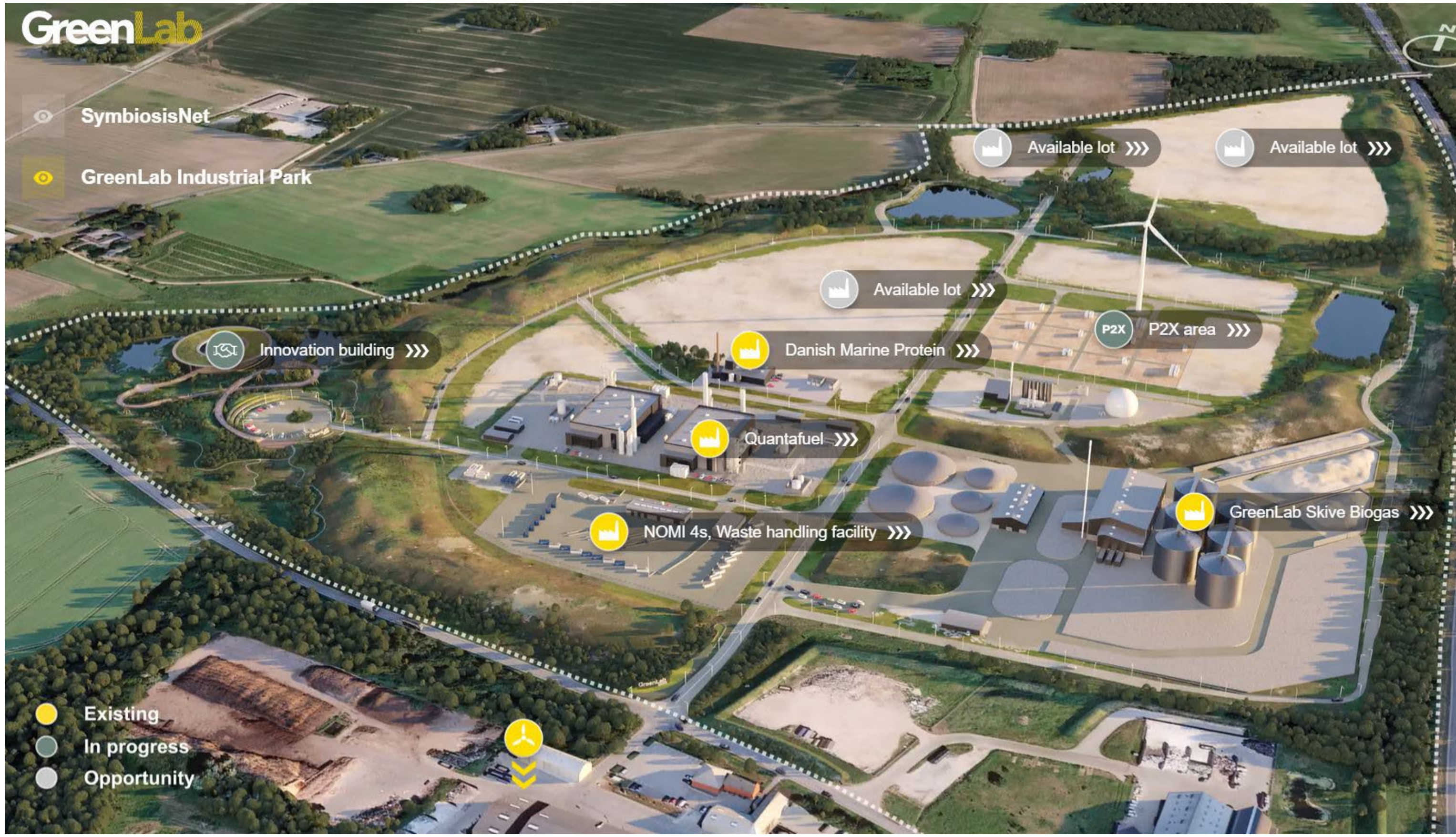
- Technology
- Financial, investments
- Environment and health
- Regulation

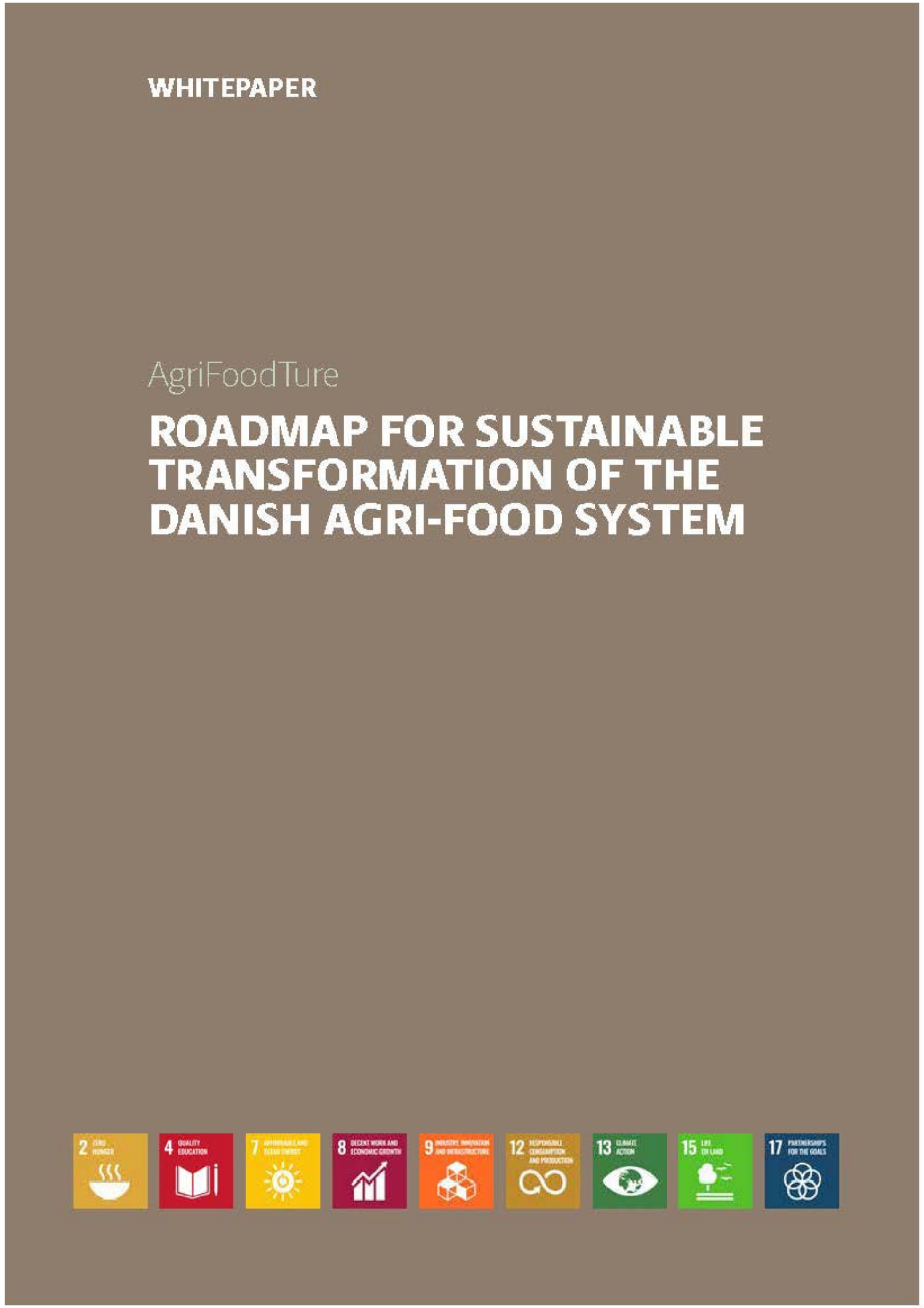
Farm level accounting

- 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




WHITEPAPER

AgriFoodTure

ROADMAP FOR SUSTAINABLE TRANSFORMATION OF THE DANISH AGRI-FOOD SYSTEM

MORE INFORMATION

- Whitepaper: https://pure.au.dk/portal/files/219295609/Climate_roadmap_white_paper_06.07.2021_final_version.pdf
- Partnership: agrifoodture.com

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