FABLE Scenathon 2023: Pathways for food and land-use systems in Denmark

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CONSORTIUM

About FABLE
The Food, Agriculture, Biodiversity, Land-Use, and Energy (FABLE) Consortium is a collaborative initiative to support the development of globally consistent mid-century national food and land-use pathways that could inform policies towards greater sustainability. The Consortium brings together teams of researchers from 24 countries and international partners from the UN Sustainable Development Solutions Network (SDSN), the International Institute for Applied Systems Analysis (IIASA), the Alliance of Bioversity International and CIAT, and the Potsdam Institute for Climate Impact Research (PIK). https://www.fableconsortium.org/

About the authors
The pathways for food and land-use systems in Denmark were developed by Simone Højte (CONCITO - sih@concito.dk), Regitze Skou Fertin (CONCITO - rf@concito.dk), Emil Fraas Tavs Nyord (CONCITO - tn@concito.dk).

National context Denmark

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Our food and land-use systems are critical for staying within our planetary boundaries and the Earth's system resilience. Among the six Transformations required to achieve the Sustainable Development Goals (SDGs), the fourth Transformation—focusing on food, land, and water—is crucial. This Transformation is key to achieving SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land). Moreover, it significantly supports the remaining SDGs, underscoring its crucial role in fostering a sustainable future.

In this document, we present the results of the 2023 'Scenathon', a modelling exercise by the FABLE Consortium exploring three alternative futures for national and regional food and land-use systems. The term 'Scenathon' stands for 'a marathon of scenarios' and refers to FABLE's iterative process for ensuring that national and regional pathways have coherent trade assumptions and align with global sustainability targets (see the 2024 Sustainable Development Report for more information).

Through these long-term pathways, we can identify trade-offs and synergies between different goals and see the impact of various actions, as well as key levers for guiding sustainable development policies through 2030 and 2050. These results, together with our modelling tools and methods, are designed to support decision-making and the development of better policies and targets to drive the transformation of our food and land-use systems.

Figure 1. Historical share of GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) to total AFOLU emissions and removals by source in 2020
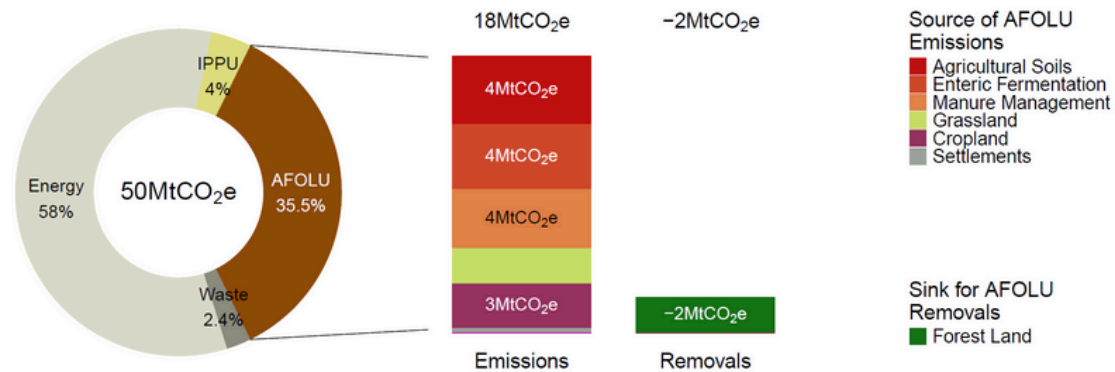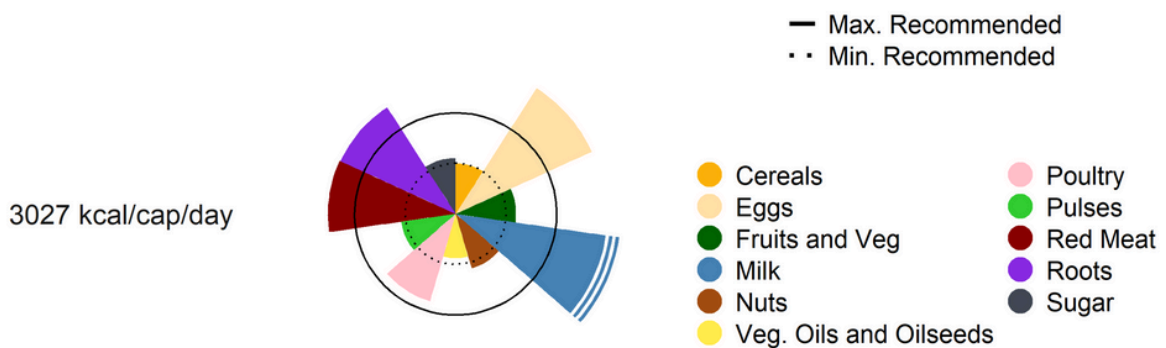

Figure 2. Daily average kilocalorie intake per capital per food category in 2020

National context

Denmark

This table summarizes national targets for food and land use, derived from national commitments, policies, and strategies. It provides an overview of the country's current ambitions to transform its food and land-use systems. Where countries lacked quantitative national targets, we have estimated targets based on qualitative pledges.

SDG	Indicator	National Target
2 ZERO HUNGER	Undernourishment	Eliminate undernourishment entirely by 2050
	Other food-related targets	Reducing the use of antimicrobials in farmed animals and aquaculture by 50% by 2030
13 CLIMATE ACTION	Total GHG emissions reduction	70% reduction by 2030 compared to the level in 1990. Achieve net zero in 2045. 110% reduction by 2050.
	Land use and land use change GHG emissions reduction	Extraction of 100,000 ha peat land by 2030
	Agriculture GHG emissions reduction	55%-65% reduction in the AFOLU sector, which equals 6,1- 8,0 million tons of CO2e in 2030
	Reduce or halt deforestation	Reduce logging in Danish forests by 20% in 2026-2031. All global forest and agricultural value chains are deforestation-free, without compromising other natural ecosystems.
	Other climate mitigation related targets	CCS: 430,000-ton biogenic CO2 (Ørsted). Reduce emissions from livestock digestion by 0.17 tons CO2e by 2025- and 0.16 tons CO2e by 2030 and manure by 0.17 tons CO2e by 2030. Increase carbon storage to 2 million tons by 2030 with biochar. 25,000 ha of approx. agricultural land for solar panels by 2030 target.
15 LIFE ON LAND	Promote afforestation	20-25% of Denmark should be forest before the end of the 21st century.
	Expand protected areas or 'Other effective area-based conservation measures'	Achieve 25,000 ha of natural national parks by 2024.
	Reduce or halt use of agrochemicals and other agricultural practices that harm biodiversity	Reduce the sale of pesticides by 40% compared to the level in 2011. Further reduce by 27%. 2026.
	Expand cropland area under agroecological practices	Doubling the organic agricultural area (today 310,000 ha) by 2030.
14 LIFE BELOW WATER	Limit nitrogen use	Reduce N discharge from agriculture to the environment by 10,800 tons in 2027.
	Limit phosphorous use	Reduce P discharge from agricultural soils to aquatic environments by 2027

Model

Using the open-access <u>FABLE Calculator</u> and the FABLE decentralized modelling infrastructure, we have developed three alternative pathways —Current Trends, National Commitments, and Sustainable Pathway— to explore the impact of various practices and policies on achieving sustainability targets through 2050. We compare our results with targets across food security and nutrition, GHG emissions reduction, forest and biodiversity conservation, and sustainable use of water, nitrogen, and phosphorus.

For each of these pathways, we have established various assumptions regarding the evolution of several model parameters. These parameters include population growth, dietary patterns, food waste, food import and export levels, crop and livestock productivity, agricultural expansion, afforestation, livestock density, protected areas expansion, post-harvest losses, biofuel demand, urban expansion, agricultural practice coverage, and irrigation area expansion. These assumptions detail the extent to which these factors will drive changes in food and land systems from 2020 to 2050.

Pathway narratives

Current Trends: We will have the same growth in productivity (crops) as seen in 2000-2010, and only a slightly smaller agricultural area. Afforestation will be slightly increasing, and peatlands will not be taken out of production on a large scale. However, 25,000 ha of agricultural land will be transformed into parks with solar panels. There will be no increase in protected areas.

National Commitments: The agricultural area will decrease; 100,000 ha of peatlands will no longer be used for agriculture, increased rate of afforestation etc. The diets will change according to the national dietary guidelines. This should lead to the fulfilment of the Danish Climate Act stating a 70% reduction of GHGs in 2030 compared to the level in 1990, Net zero in 2045 and 110% in 2050.

Global Sustainability: Denmark increases its crop productivity, so we can produce the same amount (or more) on less land. This ensures that we can convert agricultural land into forest and other protected areas which is good for biodiversity. Danes' diet will follow the EAT-*Lancet* guidelines and the intake of meat and dairy products will be markedly reduced. To ensure negative emissions we have a bigger production of non-food biomass which is used for biochar.

Figure 3. Assumptions on the levers for change in each pathway

Relative change between 2020 and 2050 (2020=0)
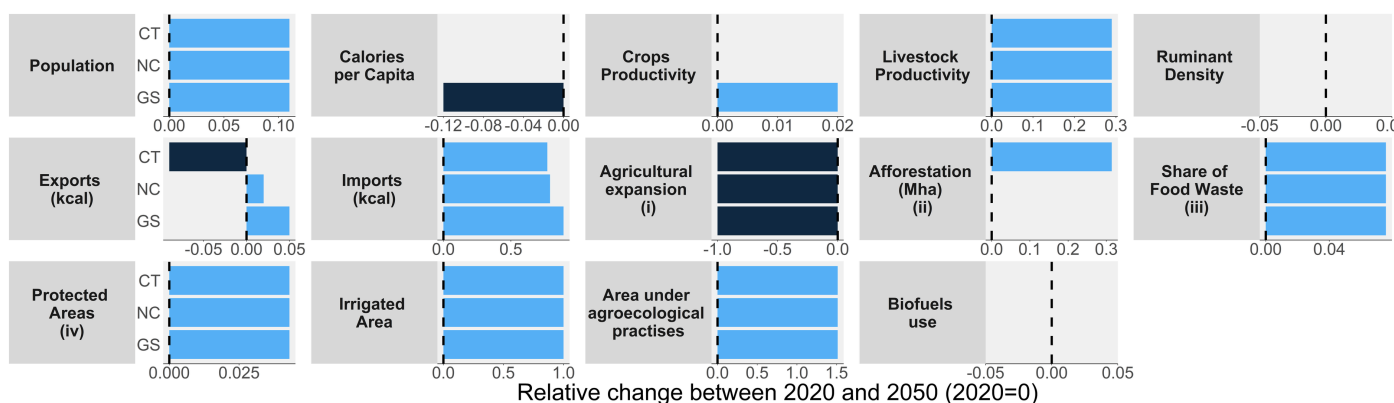
Notes: (i) Results are expressed in code, taking the value 1 for 'Free expansion scenario', -0.5 for 'No deforestation' and -1 for 'No Agricultural expansion'.
(ii) Results are expressed in a net increase rather than relative change.
(iii) Results are expressed % of consumption that is wasted.
(iv) Results are expressed in % of total land in 2050.

Figure 4. Computed daily average intake per capita over 2000-2050

Current Trends · **National Commitments** · **Global Sustainability**

Legend:
- Alcohol
- Animal Fat
- Beverages and Spices
- Cereals
- Eggs
- Fruits and Vegetables
- Milk
- Nuts
- Oilseeds and Veg. Oils
- Other
- Pork
- Poultry
- Pulses
- Beef, Goat and Lamb
- Roots and Tubers
- Sugar and Sugar Crops
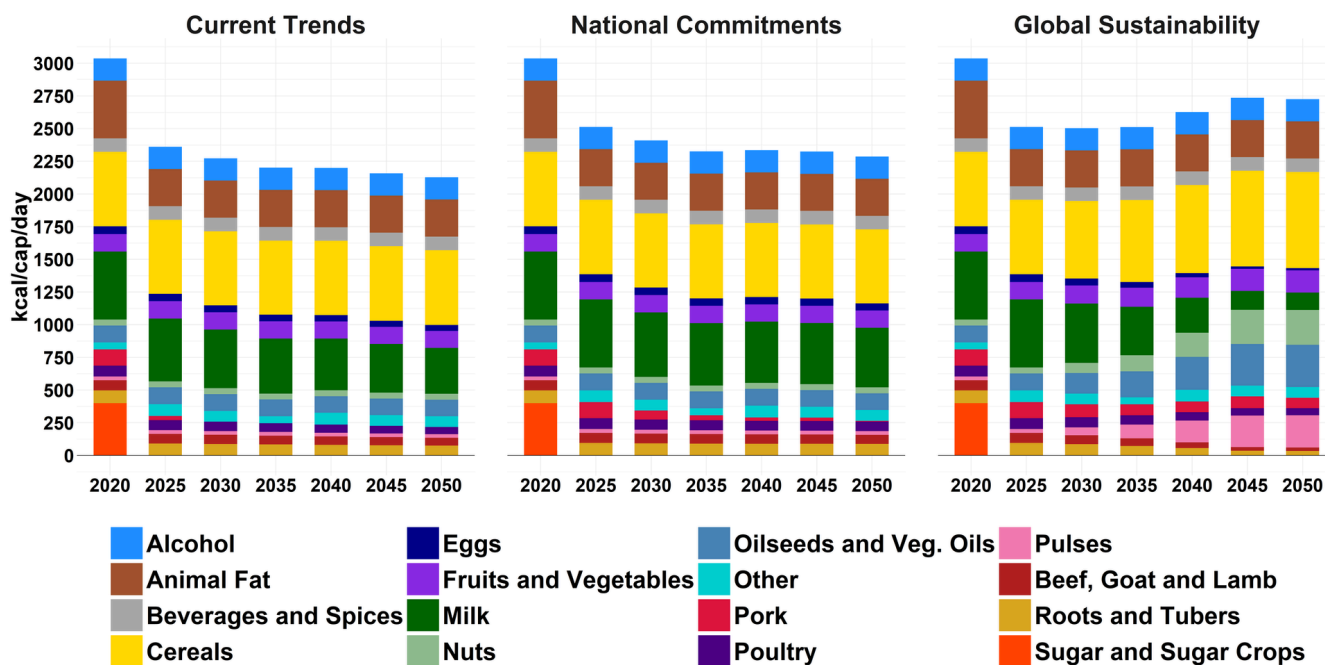
Figure 5. Comparison of the computed daily average kilocalorie intake per capital per food category across the three pathways and the prevalence of undernourishment in 2050

	Current Trends	National Commitments	Global Sustainability
PoU	25.2%	<2.5%	7.8%
kcal/cap/day	2415	2595	2805

Legend: Cereals, Eggs, Fruits and Veg, Milk, Nuts, Veg. Oils and Oilseeds, Poultry, Pulses, Red Meat, Roots, Sugar. — Max. Recommended, ·· Min. Recommended
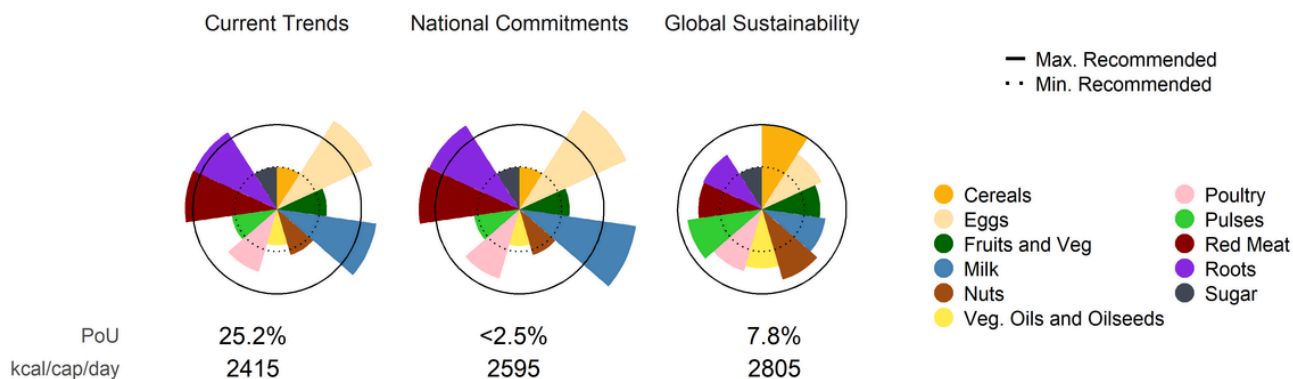
Figure 6. Evolution of land cover 2000-2050

Current Trends   **National Commitments**   **Global Sustainability**

- Protected Areas

Cropland   Forest   Urban   New Forest
Pasture   Other Land   New Other Land
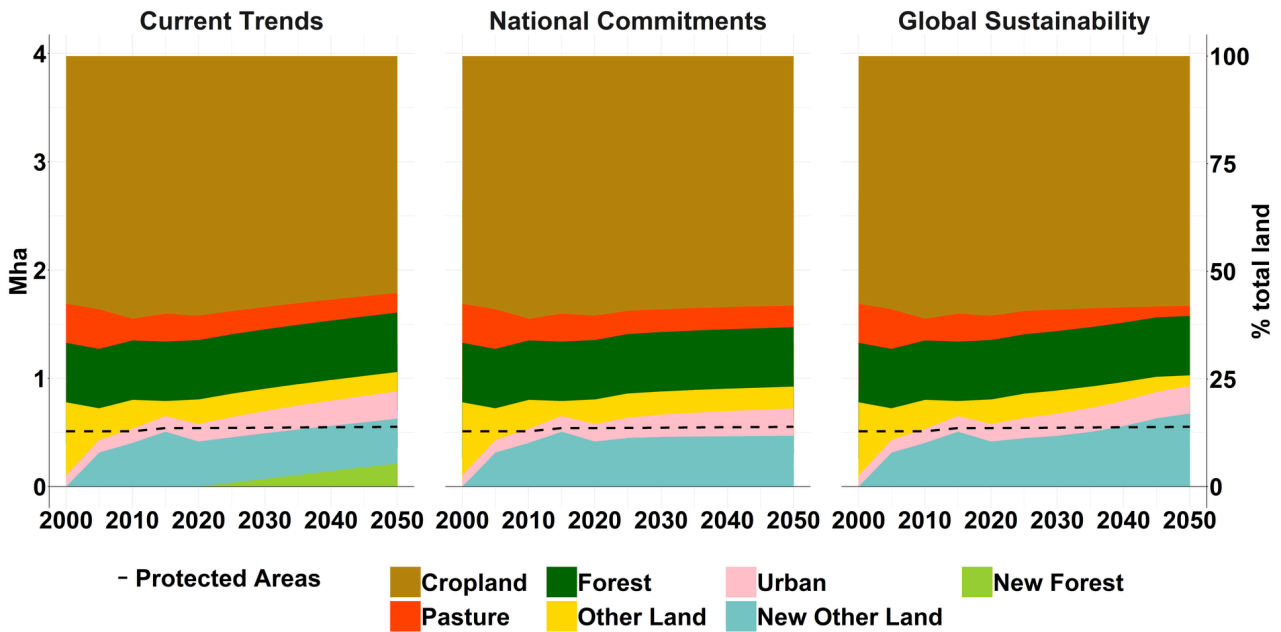
Figure 7. Evolution of the cropland composition 2000-2050

Current Trends   **National Commitments**   **Global Sustainability**

Barley   Rapeseed   Oats
Wheat   Rye   Rest of cropland

Figure 8. Projected AFOLU emissions and removals between 2020 and 2050 by main sources and sinks across pathways

Legend:
- N2O Livestock
- CH4 Livestock
- N2O Crop
- CH4 Crop
- CO2 from Farm
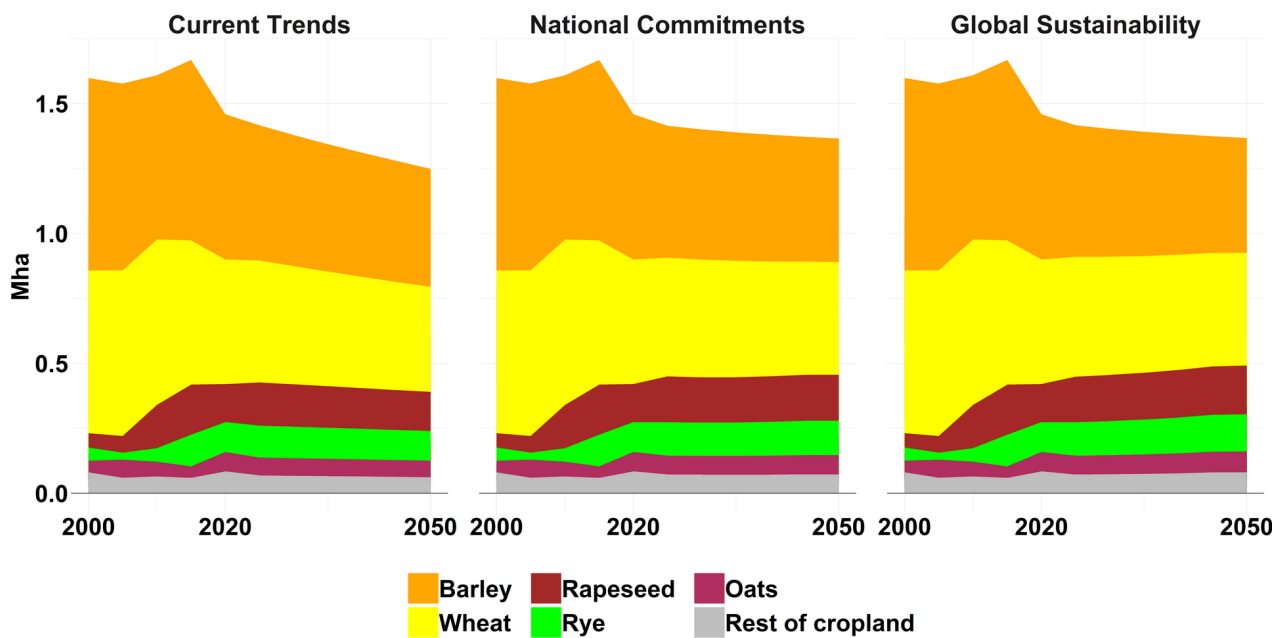- CO2 Deforestation
- CO2 Other Land Use
- CO2 Abandoned Agr. Land
- CO2 Afforestation
- CO2 Peatland
- Savings from Biofuels
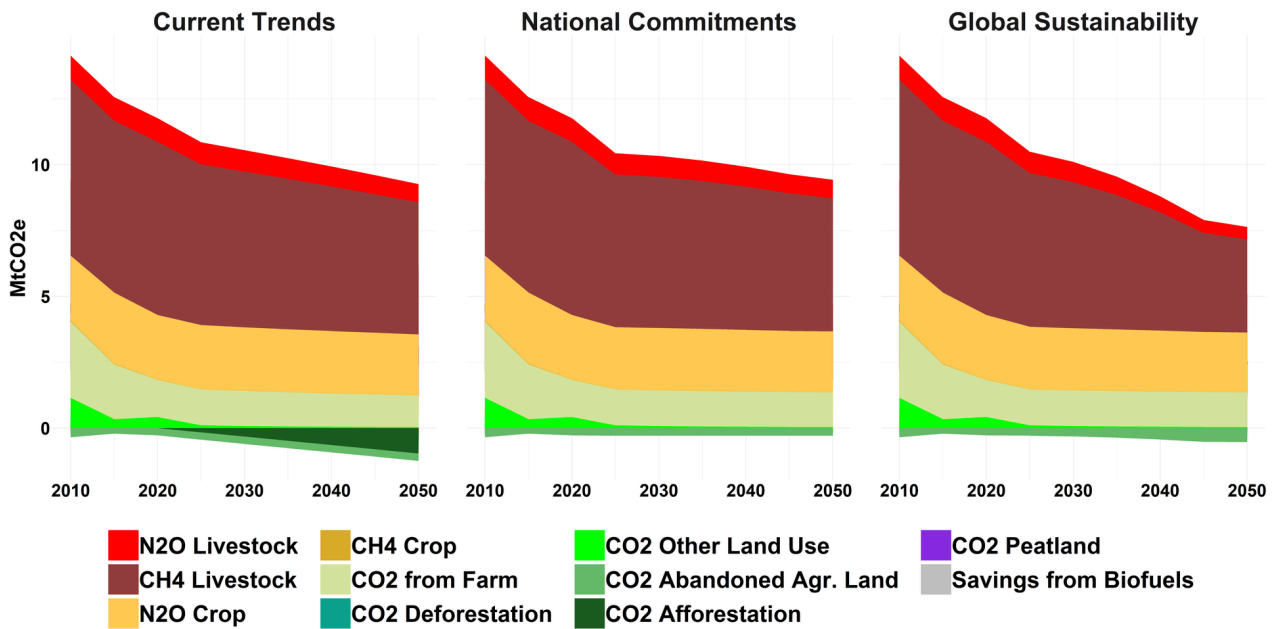
Figure 9. Share of cropland under agroecological practices

Agroecological practices included: Cover crops, cultivar mixtures, diversified farming systems, embedded natural, organic farming, no/minimal tillage.
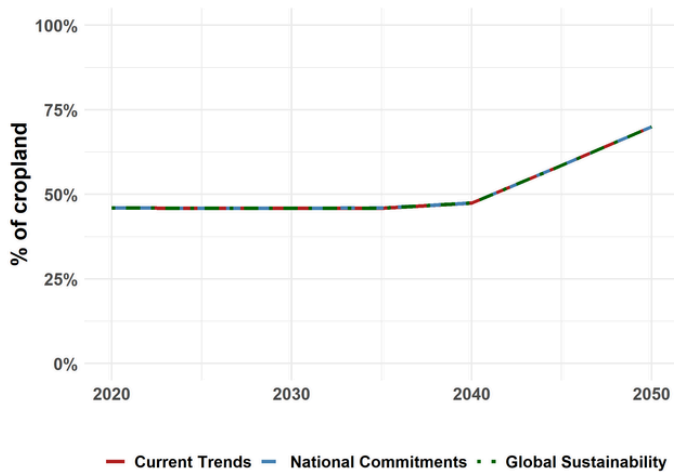
Figure 10. Total area of land where natural processes predominate (LNPP)

Legend:
- LNPP in mature forests
- LNPP in mature other natural lands
- LNPP in new forest
- LNPP in new other natural land

Figure 11. Nitrogen application

Current Trends **National Commitments** **Global Sustainability**

1000 t N

2030 2050 2030 2050 2030 2050

- N left on pasture
- Org. N applied to cropland
- Synth. N applied to cropland

Figure 12. On-farm production costs

Current Trends **National Commitments** **Global Sustainability**

million USD — workers FTE

2030 2050 2030 2050 2030 2050

- Diesel
- Fertilizer
- Labour
- ◆ Workers FTE
- Machinery Running
- Pesticide

FTE: Full-time equivalent

For more detailed results and visual data, visit www.scenathon.org

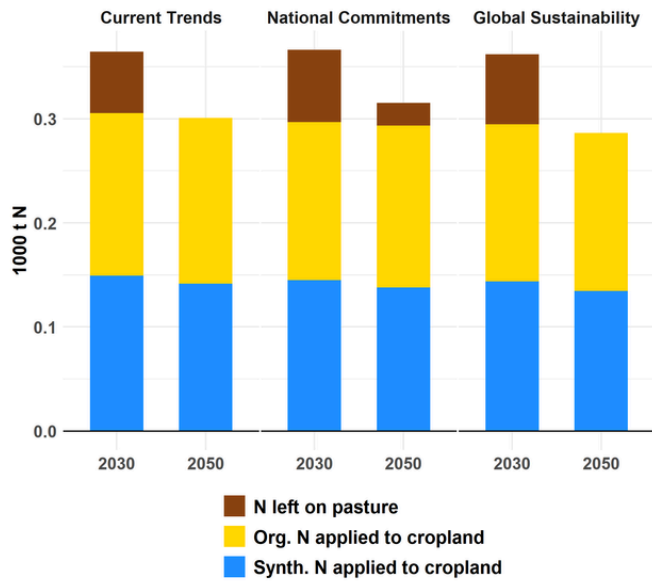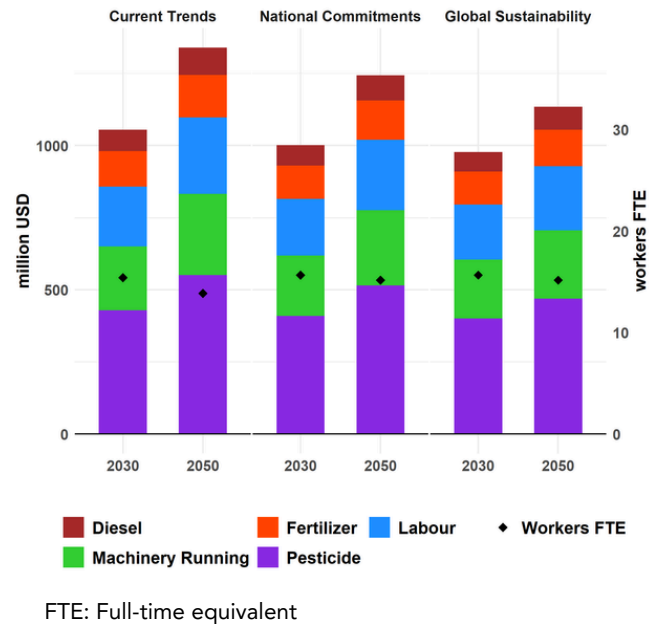**1. Promote sustainable dietary shifts**

Implement national dietary guidelines emphasizing increased consumption of fruits, vegetables, legumes, and plant-based proteins. This can be promoted through public awareness campaigns aimed at educating citizens on sustainable diets, and the health and environmental benefits of sustainable diets. Food service companies and public canteens also play a central role; they can help normalize sustainable diets by introducing new dishes and inspiring new plant-rich food cultures with new flavours and textures.

2. Land use strategy

Creating a more sustainable, climate-neutral, and climate-resilient land use strategy requires a complex and coordinated effort. The significant land demands for climate adaptation, food production, and biodiversity protection only amplify this challenge. Therefore, a comprehensive land use strategy is essential to achieve national green goals while ensuring sufficient food production and enhancing the well-being of citizens in both rural and urban areas.

3. Support land-efficient and sustainable production

It is central to achieve the highest possible output of food production per land area, tailored to what local conditions allow, while minimizing greenhouse gas emissions and other environmentally harmful impacts associated with production. There is a crucial need to emphasize land efficiency within agricultural and environmental policy to avoid well-intentioned policies inadvertently contributing to an increase in global environmental impacts.

4. Stronger agricultural policies

The primary agricultural policy in Denmark is the EU Common Agricultural Policy (CAP). Currently, this policy incentivizes production on marginal lands and disproportionately supports animal production, practices that do not necessarily promote a more sustainable food system. Agricultural policies should integrate a strategic long-term vision for the sector, integrating stringent, targeted measures which promote more sustainable agricultural practices. Ongoing impact evaluations and adjustments are essential to maintain efficient policies that both provide sufficient food and enhance environmental and climate outcomes.

Scenarios and assumptions

		A) CURRENT TRENDS	B) NATIONAL COMMITMENTS	C) GLOBAL SUSTAINABILITY	Justification
1. Macroeconomics	**1.1)** GDP per capita	68,008 US$ (2021)	1,4 % (SSP3)	1,4 % (SSP3)	1,4 (SSP3)
	1.2) Population	5,941,388	UN_medium 6,3 mio people	UN_medium 6,3 mio people	UN_medium 6,3 mio people
	1.3) Inflation	+5.3% (April 2022-April 2023)	Not able to implement in calculator and cannot find data	Not able to implement in calculator and cannot find data	Not able to implement in calculator and cannot find data
	1.4) Inequalities	8% of the differences in income are due to inequality in possibilities	BAU from 2021 to 2050 an increase of 25 %	BAU from 2021 to 2050 an increase of 25 %	BAU from 2021 to 2050 an increase of 25 %
2. Land	**2.1)** Constraints on agricultural expansion/deforestation	Reduce emissions from the agricultural sector by 1.9 mio. Tons CO2e	No expansion of agricultural land Constraints: 25,000 ha of approx. agricultural land for solar panels (2030 target).	No expansion of agricultural land Constraints: 25,000 ha of approx. agricultural land for solar panels (2030 target). 100,000 ha of peatland out of agricultural production. Only due to afforestation: 265.000 ha agricultural land out of production.	No expansion of agricultural land Constraints: 25,000 ha of approx. rural land for solar panels (2030 target). 100,000 ha of peatland out of agricultural production. Only due to afforestation: 265.000 ha agricultural land out of production.
	2.2) Afforestation, and forest plantations targets	13.3% (11% is production forest)	38.000 more ha of forest compared to 2023. All planted forest.	265.000 ha more forest than in 2023	265.000 ha more forest than in 2023
	2.3) Urban and settlements area	14% (Buildings 8% and roads etc. 5%)	18% increase between 1989 and 2050	18% increase between 1989 and 2050	12% increase between 1989 and 2050
	2.4) Protected areas	9 % (nature 2000 areas)	9 % of DK area – 310.000 ha (Natura 2000 areas) EPA data	9 % if DK area – 310.000 ha (Natura 2000 areas) EPA data	12% of DK area – 515,200 ha protect agricultural and forest area

Scenarios and assumptions

		A) CURRENT TRENDS	B) NATIONAL COMMITMENTS	C) GLOBAL SUSTAINABILITY	Justification
3. Productivity and management	**3.1)** Crop productivity for the key crops	Key crops: Top 3 in 2022: Vårbyg (68 hkg/ha), vinterhvede (87 hkg/ha) og vinterraps (45 hkg/ha)	Low growth: "At least 30% closure of yield gap"	No growth	High growth
	3.2) Cropland under agroecological practices	Key crops: Top 3 in 2022: Vårbyg (68 hkg/ha), vinterhvede (87 hkg/ha) og vinterraps (45 hkg/ha)	25 % more than in 2010	50 % more than 2010	75 % more than in 2010
	3.3) Livestock productivity for the key livestock products	Cattle: 11.1 mio. Ton (March 2023), Pork: 144.1 mio. Ton (March 2023), Egg: 80 mio. Tons (2021), Milk (that leaves the farms and gets weighed at the dairy): 5.721,87 mio kg (2021)	BAU: Same productivity growth as over 2000-2010	No growth	BAU: Same productivity growth as over 2000-2010
	3.4) Pasture stocking rate		NoGrowth	NoGrowth	NoGrowth
	3.5) Forest management	Naturnær skovdrift: Måldiameterhugst (de største træer fældes og ikke alle på en gang). Fældes sjældent store, sammenhængende arealer. Vedvarende skovdække. Reducere hugst med 20% i 2026-31.	Close-to-nature forest management in public forests (2approx. 1/4 of all Danish forests), more "untouched"/"wild" forest. More uncertainty in the private forests – maybe more logging due to increased demand	In 2040, 10% of the Danish forests must have nature and biodiversity as their primary purpose.	Approx. 75 % of all forest is highly protected
4. Trade	**4.1)** Share of consumption which is imported for key imported products (%)		Reduced import of oil seeds and protein crops. Slow rise in imports of beef.	Reduced import of oil seeds and protein crops. Slow rise in imports of beef.	Reduced imports of oil seeds and protein crops. Slow rise in imports of beef.
	4.2) Evolution of exports for key exported products (1000 tons)		Increase of exports of dairy products, decrease of pig meat exports.	Increase of exports of dairy products, decrease of pig meat exports.	Increase of exports of dairy products and decrease of pig meat exports.

Scenarios and assumptions

		A) CURRENT TRENDS	B) NATIONAL COMMITMENTS	C) GLOBAL SUSTAINABILITY	Justification
5. Food	**5.1)** Average dietary composition	Current dietary habits, including a high intake of meat as well as sweet, salty and fatty foods, and a low intake of legumes may be a major challenge. The dietary habits have to change significantly to apply to the **Food Based Dietary Guidelines.** **Food Based Dietary Guidelines**: constituting a healthy diet from a sustainable food system. By following these Food Based Dietary Guidelines the **climate food print of food consumption can be reduced with more than 1/3**.	SSP2	SSP2	We assume the EAT-*Lancet* diet which is close to the DK official dietary guidelines: 75 g wholegrain pr day, 600 g fruit and vegetables (50% must be vegetables) pr day, 100 g legumes (prepared) pr day, 350 g meat (pr week) (reduce the intake of beef and lamb), 30 g nuts pr day, 350 g fish pr week, low-fat dairy products 250 ml milk and 20 g cheese pr day, less sweets and salty products
	5.2) Share of food consumption which is wasted at household level	36%	36%	EU reduction target on food waste: 50%	SDG: Reduce food waste pr person by 50%
6. Biofuels	**6.1)** Targets on biofuel and/or other bioenergy use	Energistatistik 2021	Biomass for heating is projected to decrease from 48 pct in 2020 to 29 pct. by 2035. The consumption of biofuels is more or less projected to stay stable until 2025. Biogas production is expected to increase from 2022-2035 by 25%.	Energy crops is phase down in biogas production to a level of 4 % by 2026/27 of the biomass weight percent	Consumption of bio resources is expected to be 29 GJ pr capita

Scenarios and assumptions

		A) CURRENT TRENDS	B) NATIONAL COMMITMENTS	C) GLOBAL SUSTAINABILITY	Justification
	6.2) Targets on other non-food use		24,298 hectares used to production of Christmas trees; 9,010 hectares used to production of seeds for grass to lawns = 1.3% of the total agricultural land	24,298 hectares used to production of Christmas trees; 9,010 hectares used to production of seeds for grass to lawns = 1.3% of the total agricultural land	4.8 mio ton extra biomass in dry matter to use for biochar to spread on agricultural soils - result in negative emissions of 3 mio. ton in 2040. Bigger use of non-food biomass production is needed but does not affect food production as a lot of it would come from higher straw yields.
7.Water	**7.1)** Irrigated crop area	17% in 2012 - 500.000 m3 of groundwater allowed every year - FAOAQUASTAT: avrg: 231.000 ha	Stable. Irrigation is allowed on 17% of Denmark's arable land (465,000 ha)	Stable	Reduce to 15 % of arable land