



By Denmark

WHITE PAPERS
for solutions of tomorrow

CLIMATE

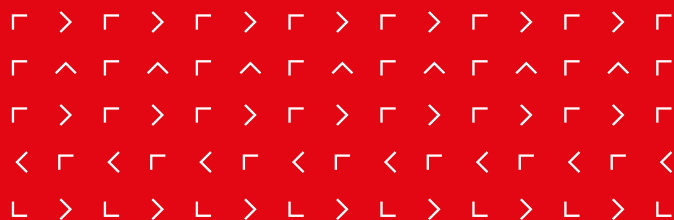
DRIVING THE TRANSITION
TO CARBON-NEUTRAL FOOD
AND AGRICULTURE

INSIDE THIS WHITE PAPER:

- Crop cultivation with respect for resources
- Efficient livestock for a world of growing demand
- Food processing towards a carbon-neutral future



Solutions of tomorrow
By Denmark



Climate

Driving the transition to carbon-neutral food and agriculture

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EXECUTIVE SUMMARY

A relentless focus on efficiency, productivity and cross-sector collaboration is driving the Danish food and agriculture industry towards the national goal of climate neutrality by 2045. Through the continuous development of new practices and innovative technology, progress is being made. The ambition is to put climate solutions to work in Denmark and globally by being a trustworthy partner for international export markets.

In the primary sector, arable farmers are benefiting from climate-resilient seeds, smart crop management and other tools that maximise yields while reducing greenhouse gas (GHG) emissions and nutrient losses from agricultural land. Within livestock farming, innovative approaches to animal genetics, feed efficiency and manure management are turning climate issues into sustainable opportunities to meet the world's demand for animal-derived foods.

A long tradition for research and innovation and strong private-public partnerships make Denmark a leading player in the green transition of food, agriculture and land use

The decarbonisation of energy-intensive food processing is also picking up pace. Danish food, ingredient and biosolution companies are working to maximise raw material utilisation as part of their effort to reduce land use for agriculture – a primary source of GHG emissions from the global food system. Inside food processing plants, Danish equipment suppliers are enabling the move to efficient, fossil-free production through heat recovery, electrification and alternative processing technologies.

A long tradition for research and innovation and strong private-public partnerships make Denmark a leading player in the green transition of food, agriculture and land use. Farm-to-fork collaboration accelerates the development and implementation of solutions to today's climate challenges.

This Food Nation white paper provides an overview of the Danish food and agriculture sector's climate journey so far and the next steps on the horizon. Although climate impact is closely linked with other environmental parameters such as water quality, nutrient loadings, pesticide use and biodiversity preservation, these are outside the scope of this publication.

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Supporting the SDGs

How does Denmark contribute?

Denmark's food and agriculture sector can contribute significantly to a future global food supply with a low climate impact. The UN's sustainable development goals (SDGs) are key to setting the direction for best practices and innovation targets in collaboration with academia and authorities. Innovation that improves the efficiency and sustainability of food production contributes to all 17 goals, either directly or indirectly.

Activities in support of **Goal 13 Take urgent action to combat climate change and its impacts** are the specific focus of this white paper. Others goals where Denmark can make a direct impact include **Goal 2 End hunger, achieve food security and improved nutrition, and promote sustainable agriculture**, **Goal 12 Ensure sustainable consumption and production patterns** and



Goal 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Achieving the ambitious goals of the 2030 agenda requires global support and partnerships. In Denmark, extensive cross-sector collaboration accelerates the progress of

national and international initiatives and directly contributes to **Goal 17 Strengthen the means of implementation and revitalize the global partnership for sustainable development.**

FOREWORD



Photo: Steen Brogaard

High levels of greenhouse gas emissions from food and agricultural production are a global concern. In Denmark, we recognise the sectors contribution to climate change and the looming boomerang effect on world capabilities to produce sufficient safe and healthy food.

The Danish government has set ambitious goals for the green transition of the food and agriculture sector in Denmark. By 2030, the target is a 55 to 65 percent reduction in greenhouse gas emissions, compared to emission levels in 1990, achieved through the implementation of new and improved agricultural practices and technological innovations. Key initiatives include a strategy for green proteins and a new Fund for Plant-based Foods.

Achieving these ambitions requires partnerships, where specialists from the entire food value chain come together to share knowledge and drive innovation forward.

Generations of cooperation

Denmark has a long tradition for cooperation and partnerships. Over generations, our farmers, food manufacturers and technology suppliers have partnered with universities, specialised knowledge centres and authorities to generate solutions that improve

efficiency and yield while reducing resource consumption and related emissions.

Today, these joint efforts continue to develop innovative new tools, such as precision agriculture technologies, new feed additives and circular manure management systems.

Novel approaches to the ancient art of fermentation are among the emerging bio-solutions. In addition to extracting value from food production side-streams, fermentation is a promising means to meeting the world's protein needs with a low climate footprint.

Enabling positive change

At government level, we have noted a growing desire among Danish consumers to know more about the climate impact of their food choices. In 2021, the publication of Denmark's revised official dietary guidelines responded to this need by putting climate considerations on the menu.

Denmark has also initiated the development of a national, voluntary climate label on food – as one of the first countries in the world – to guide consumer purchases and facilitate the production of foods with a lower carbon footprint. At the same time, we work hard to reduce food loss and waste, for example, through public private partnerships and voluntary agreements. These initiatives are all steps towards the UN sustainable development goals.

As a nation, Denmark is committed to supporting the international effort to combat climate change. The insights shared in this white paper are one contribution.

A handwritten signature in blue ink that reads "Jacob Jensen".

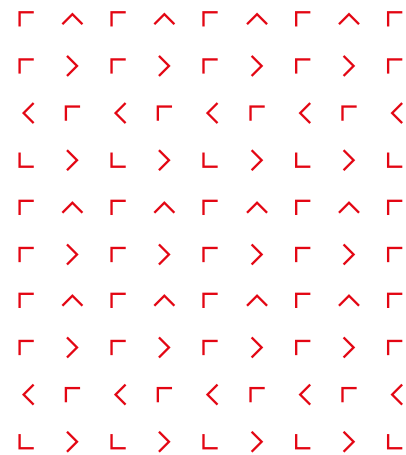
Jacob Jensen
Minister for Food, Agriculture and Fisheries



CHAPTER 1

THE COLLABORATIVE HEART OF CLIMATE INNOVATION

A FOOD AND FARMING NATION BUILT ON
MAKING MORE WITH LESS



The Danish food and agriculture industry has an unrelenting focus on efficiency, productivity and cross-sector collaboration. This is the culture that will drive progress towards climate goals.

Denmark has an ambition to be climate neutral by 2045. Within the Danish food and agriculture sector, there is a broad recognition of the work that must be done to achieve this goal. The continued development and adoption of efficient practices and innovative technology are the clear way forward.

A long tradition for making the best use of limited resources has already brought Denmark part of the way. In recent years, public and private partners across the Danish food and agriculture industry have stepped up their efforts, declaring commitment to the Paris Agreement goals, adopted at the UN Climate Change Conference in 2015. Climate targets aligned with the Science-Based Targets Initiative are high on the agenda.

Denmark's food production has grown almost a third since 1990 – with 16 percent fewer emissions

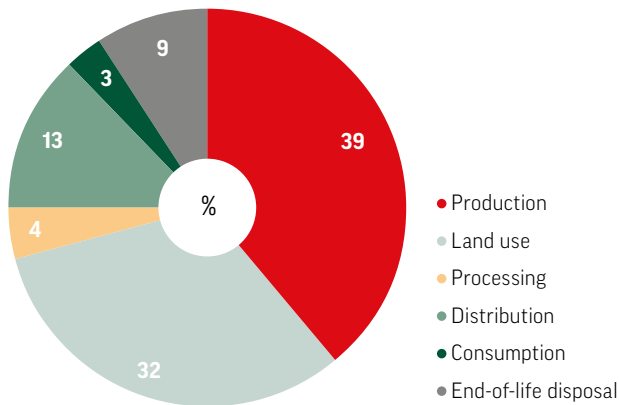
contributing to a climate-neutral future both in Denmark and in international markets. Partnerships at home and abroad are accelerating progress.

Productivity with emissions in focus

Following decades of environmental regulation, the Danish food and agriculture sector has become experienced in implementing efficient solutions that reduce emissions while increasing productivity. Production volumes have consequently grown by almost a third since 1990, accompanied by a 16 percent decline in emissions over the same period.

The ability to produce more food with fewer emissions per hectare of cultivated farmland is essential to secure the global food supply. However, it is not the only strategy. In Denmark, innovation is increasingly focused on a holistic approach that explores conventional, organic and other new approaches to agriculture and food production. The purpose is to shape a circular, climate-resilient future where the needs of a growing global population are balanced with a healthy and biodiverse planet.

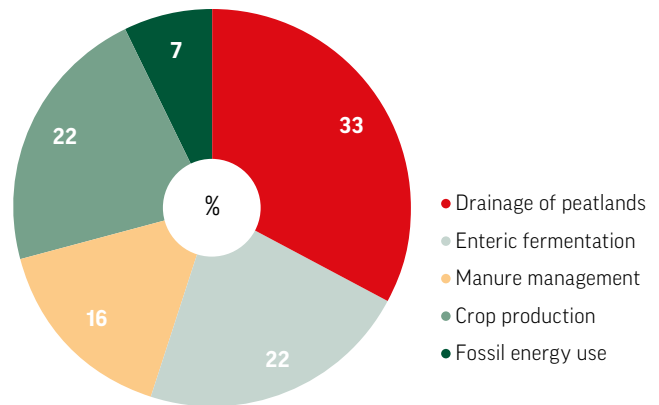
The fact that the global food system accounts for a third of greenhouse gas (GHG) emissions is a strong motivator for change. Today, new Danish approaches to crop and livestock farming and food processing are



Greenhouse gas emissions from the global food system

Production, including agriculture and fisheries, is responsible for the largest share of GHG emissions from the global food system. In second place are land use activities, mainly related to carbon losses from deforestation and degradation of organic soils, including peatlands.

Source: Global food emissions database (EDGAR-FOOD)



Greenhouse gas emissions from agricultural activities in Denmark

There are five key sources of GHG emissions in the Danish primary sector. All are the target of technological innovation to reduce the carbon footprint of agriculture.

Source: Roadmap for sustainable transformation of the Danish agri-food system (AgriFoodTure)

Climate solutions driven by science and data

Agriculture and land use account for the biggest share of the GHG emissions generated by global food production. Danish science and knowhow mitigate emissions from a broad spectrum of farming activities, enabling farmers to grow crops with a low carbon footprint, raise dairy cattle that emit less methane and optimise the efficiency of animal feed.

Well-defined milestones and high-quality data are essential to measure progress towards climate neutrality and incentivise emission reductions. This is where Denmark's data-driven operations stand out, providing a traceable overview of what goes into production processes and what comes out. Decades of data collection to minimise on-farm losses have resulted in vast databases that can support future emissions reduction in many agricultural fields.

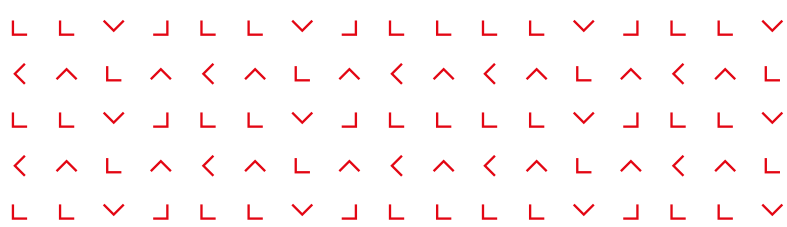
Digital tools developed by the agricultural research and development organisation SEGES Innovation enable farmers to harvest data and gain a rapid overview of crop and livestock performance. Supporting informed decision-making about productivity improvements, such tools are in great demand all over the world. For SEGES Innovation, collaboration with Danish and international researchers and companies is a priority to share new knowledge about data-driven solutions.

Collaboration – the key to innovative power

Cross-sector collaboration is all part of the Danish agrifood tradition – combining the knowhow of food producers, universities and research institutes, authorities and other organisations and interest groups. The power of pooling resources in this way is long proven, starting with the farmers who found a shorter route to new markets by forming the first cooperatives in the late 19th century.

Partners at all levels of the food value chain benefit from working together in a spirit of openness and mutual trust. Danish farmers, for example, are closely involved in new technological developments, where they frequently perform the role of living lab. Their rapid feedback on pilot trials is key to fast implementation of the latest methods and practices.

The Danish food and agriculture sector continues to invest in partnerships that deliver sustainable solutions to global challenges. For international business partners, this gives access to an entire ecosystem, rich in knowledge and innovative strength. The following chapters will showcase innovation that specifically targets production on farms and in food processing plants – with mutual benefits for the planet and business.



CASE / Danish Crown

FARM DATA ENABLES EFFECTIVE EMISSION REDUCTION

More than 90 percent of GHG emissions in the meat production business comes from the farms. As one of the world's largest pork exporters and a top-five beef producer in Europe, Danish Crown has agreed carbon reduction targets with its farmers, who strive to be role models for resource-efficient production towards shared climate goals.

To help farmers on the way, the global food company has established the sustainability programme, the Climate Track.



Photo: Danish Crown

Data enables Danish Crown to implement group-level emission reduction initiatives with a measurable impact

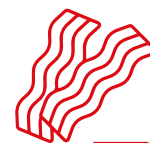
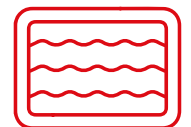
Farmers on the Climate Track cooperate with Danish Crown in four major areas – climate, animal welfare, social responsibility and biodiversity. Parameters vary depending on the country and animal breed.

In return for sharing livestock production data and sustainability information, farmers receive individual feedback on their sustainability performance against a Danish Crown national average. This includes a mapping of where their GHG emissions come from and

suggestions for reduction initiatives. Danish pig farmers who report on feed use and daily weight gain also receive a reporting premium.

The collection of individual farm-level data enables Danish Crown to implement group-level emission reduction initiatives with a measurable impact. The data is also used in lifecycle assessments that calculate carbon footprint per kilo of selected products, providing clear documentation of the carbon footprint for customers and consumers.

Minced beef / **21.20**



Bacon / **5.93**

CO₂e per kg product (A-LCA)

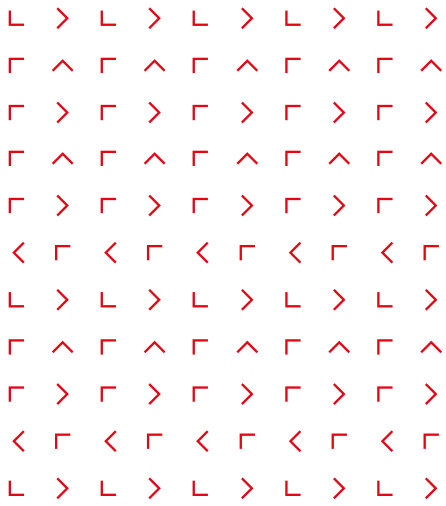
Calculation of carbon footprint based on data from Danish pigs for bacon and Danish cattle for minced beef.



CHAPTER 2

CROP CULTIVATION WITH RESPECT FOR RESOURCES

STRATEGIES FOR HIGHER YIELD
AND CLIMATE PROTECTION



Danish knowhow is pioneering new approaches to arable farming that are reducing greenhouse gas emissions and improving climate resilience from seed to harvest.

As a small agricultural nation, Denmark depends on farmers to maximise yields while protecting natural resources. Many Danish companies have grown out of this need. Specialised in plant breeding, farm machinery and smart crop management, they play a major part in reducing GHG emissions and nutrient losses from agricultural land. Farmers all over the world benefit from these ongoing improvements.

Fertiliser knowhow for fields in balance

Nitrous oxide is the primary GHG released through crop cultivation and nearly 300 times¹ more potent than carbon dioxide. According to recognised calculation standards for GHG emissions², an estimated one percent of the nitrogen in fertilisers is converted into nitrous oxide.

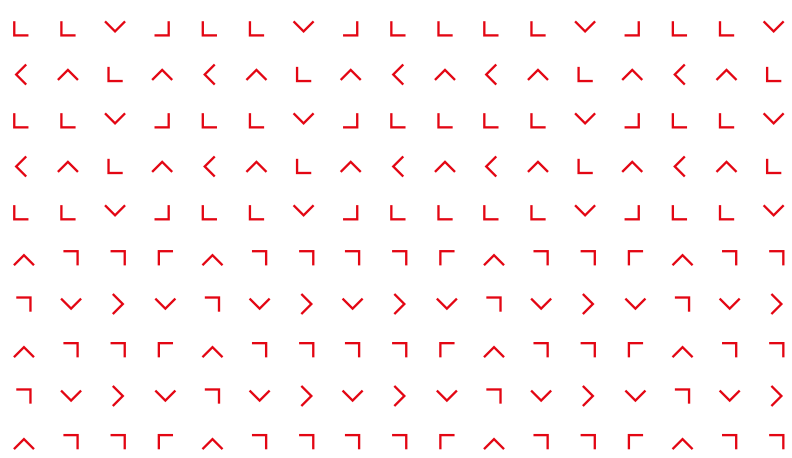
Danish environmental regulations have led to a considerable reduction in nitrogen loss from agriculture over the last three decades. To secure regulatory compliance, Danish farmers have made important advances in manure handling and fertiliser strategies. The objective is to ensure just the right amount of nitrogen is added to the soil, minimising leaching of surplus nitrogen into the environment.

New crop varieties withstand the impact of climate change

In addition to improved manure and fertiliser management, farmers are adopting precision farming technologies that employ satellites, drones and advanced GPS systems to steer agricultural equipment with centimetre accuracy. Real-time observations of soil and crop variability can then be used to optimise fertilisation.

Other measures include earlier sowing of winter cereals to increase nitrogen uptake, improved cover crops that minimise nitrate leaching and perennial crops, which are productive throughout the growing season and retain nutrients within the soil-plant system. Grass and clover are examples of perennials that reduce the need for fertilisers and, at the same time, support biodiversity and act as 'carbon sinks' by capturing and storing carbon dioxide. Danish biosolution companies provide additional tools that reduce fertilisation needs by releasing nutrients bound in the soil – Novonesis' microorganism inoculants are one example.

¹⁾ <https://www.soilassociation.org/causes-campaigns/fixing-nitrogen-the-challenge-for-climate-nature-and-health/the-impacts-of-nitrogen-pollution/>
²⁾ <https://www.sciencedirect.com/science/article/pii/S0269749111001953>



Climate-efficient seeds for high-yield crops

Around the world, extreme weather conditions and temperature changes are an increasing challenge for crop farmers. Within the Danish seed industry, efforts are ongoing to develop resilient new varieties that can withstand the effects of climate change. Farmers around the world already benefit from climate-efficient Danish grass, clover and beet seeds. High-quality seeds for grain and feed crops are also exported all over Europe.

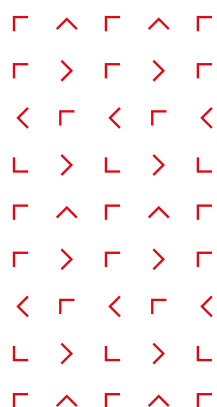
Yield improvement is a necessity for reducing the climate impact of crop production. This is where Denmark's two large grain and feed producers – DLG and Danish Agro – make a difference through the development of high-yield seeds and solutions for digital field management. Climate declaration labels on feed products enable farmers to document their climate impact and identify further opportunities to drive their production in a more sustainable and productive direction.

National investment in local green protein

In Europe, local production of protein sources is the subject of growing interest to reduce reliance on long-distance soya imports. Here, Danish universities, research institutes and agricultural companies, such as DLG, Danish Agro and DLF, are collaborating to develop

biorefining techniques for extracting high-quality protein from grass and clover grass. A key objective of this work is to reduce land use for crop production.

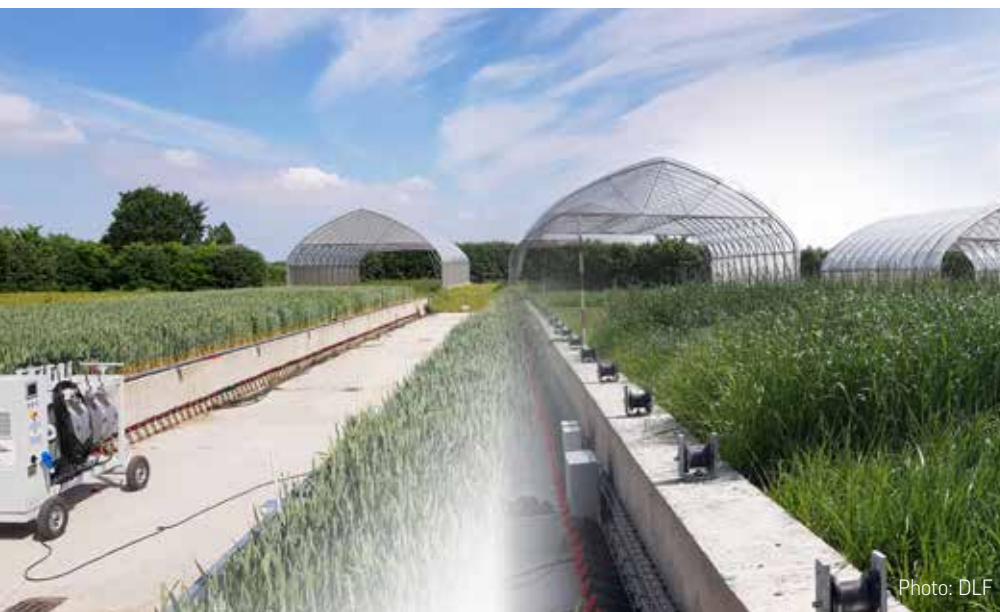
With a dry matter content of up to 25 percent protein and a balanced composition of amino acids, these perennial crops have great potential. Results from feeding trials show that grass and clover protein is an efficient alternative to soya meal in pig and poultry feed. Denmark's first biorefineries for the production of organic green protein are today in operation. The Danish government is investing a considerable sum in further biorefinery development.





CASE / DLF

DEEP ROOTS HOLD THE SECRET TO DROUGHT-RESILIENT CROPS



increased nitrogen uptake. Other climate benefits include a natural ability to bind carbon in the soil and minimise nitrogen leaching. The clover varieties among DLF's solutions reduce the need for synthetic fertilisers due to nitrogen fixation from the air.

New forage varieties have 30 percent deeper root biomass, higher drought tolerance and increased nitrogen uptake

All varieties produce high-quality feed that is easy to digest and improves the milk yield of dairy cattle, for example.

Droughts are growing in frequency and severity as global temperatures rise. For farmers, the impact on crop yields can be devastating, with knock-on consequences for feed and food supplies.

Today, farmers around the world look to Danish seed company DLF for a solution. Specialised in breeding seeds for temperate climate zones, DLF has a reputation for staying ahead. So, when climate change hit the global agenda, long-rooted plant varieties were already in the product portfolio.

A strategic investment in the world's largest and most advanced root-screening facility – RadiMax – has helped accelerate the development of new climate-resilient plant varieties. Initiated by DLF in partnership with Danish universities and other breeders, the facility enables researchers to follow plant root growth under increasing drought stress.

DLF has used the results to select new forage varieties with 30 percent deeper root biomass, higher drought tolerance and

Drought, flooding and disease are continuously changing factors in crop production. Through dedicated plant breeding, DLF's breeders are on a mission to deliver solutions for sustainable land use with high yields.

CASE / Agrometer

PRECISION MANURE MANAGEMENT AT MINIMAL COST

Liquid manure disposal is an expensive necessity in livestock production and a significant contributor to GHG emissions, particularly when traditional spreaders spray slurry onto fields. In Denmark, an innovative machinery supplier has come up with solutions that cut the costs for farmers and the climate.

Agrometer has developed an approach that takes slurry tankers off the road and directly pumps the slurry into a nurse tank next to the fields, ready for easy connection to a slurry spreader. By eliminating the need for transport and distribution, emissions associated with energy consumption are reduced by around 60 percent.

Emissions associated with energy consumption are reduced by around 60 percent

In the field, Agrometer helps farmers maximise the value of liquid manure while minimising the climate impact. Their self-propelled, lightweight spreaders are equipped with GPS technology, so slurry can be distributed according to the precise nutrient requirements of the soil. By giving farmers a clear understanding of nitrogen usage efficiency, the technology may reduce or even eliminate the need for artificial fertilisers.



Photo: Agrometer

The estimated carbon emission savings from optimised slurry handling and reduced fertiliser usage are 85 percent and 75 percent respectively. As new CO₂ duties are introduced in Denmark and around the world, slurry-handling solutions from Agrometer are gaining ground as a cost-efficient choice.

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CASE / Carlsberg Group

BARLEY COLLABORATION CUTS THE FOOTPRINT OF BEER

Malted barley may be the backbone of many a good beer, but it is also responsible for a large share of the carbon emissions from international brands. At Carlsberg Group, an estimated 27 percent of overall value chain emissions come directly from agricultural products.

Through partnerships with suppliers and experts, farmer collaborations and research into new barley varieties, the Danish brewery group is taking action to turn the situation around.

Novel malting barley uses 25 percent less energy during wort boiling

Partner farmers that deliver barley to Carlsberg companies in Denmark, Finland, France and the UK have kicked off by adopting new barley cultivation practices that prioritise soil health, supporting natural carbon capture, promoting biodiversity and regenerating the farmland.

In France, for example, 20 percent of the malt used to brew Kronenbourg 1664 Blonde beer is being sourced from farms using sustainable practices, with full traceability enabled by a new blockchain solution.

Scientists at the Carlsberg Research Laboratory are strengthening these efforts by using selective breeding to develop new barley types that reduce the energy and synthetic input requirements – and related carbon emissions – of the malting and brewing processes.

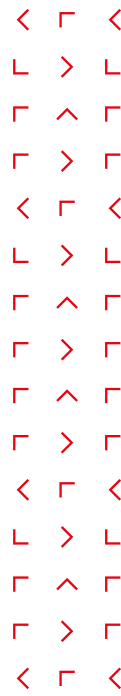
Early trials with a novel malting barley have demonstrated an up to 25 percent reduction in energy use during wort boiling. Carlsberg is today rolling out the variety to markets in Europe and aims to make it available to other brewing companies.

As part of a broader commitment to supporting the development of regenerative agriculture around the world, Carlsberg became a member of the cross-industry Sustainable Agriculture Initiative Platform in 2022.

If all goes to plan, 30 percent of Carlsberg's global agricultural raw materials will be sustainably sourced and grown using regenerative practices by 2030, increasing to 100 percent in 2040.



Photo: Carlsberg Group



CASE / DLG

COOPS INVEST IN GREEN FERTILISER POWERED BY THE WIND

Commercial fertilisers derived from natural gas are a major source of the carbon emissions from plant production – but maybe not for much longer. Four farmer-owned Danish cooperatives have joined forces to develop a greener fertiliser based on wind power.

DLG, Danish Agro, Arla and Danish Crown have founded a new company – Green Fertilizer Denmark – to drive this game-changing initiative. If successful, the investment could reduce Danish CO₂ emissions from commercial fertiliser use by 750,000 tons a year – equivalent to the emissions from an estimated 250,000 diesel cars.

Green fertiliser could reduce Danish CO₂ emissions by 750,000 tons a year



A feasibility study is currently underway for a green fertiliser plant with sufficient capacity to meet the needs of farmers in Denmark and commence sales to local export markets.

The ambition is to replace conventional fossil-based fertiliser with fertiliser based on green ammonia, which is produced by electrolysis of surplus wind power from the North Sea. Copenhagen Infrastructure Partners is driving the development of the wind farm and production facilities that will deliver the green ammonia.

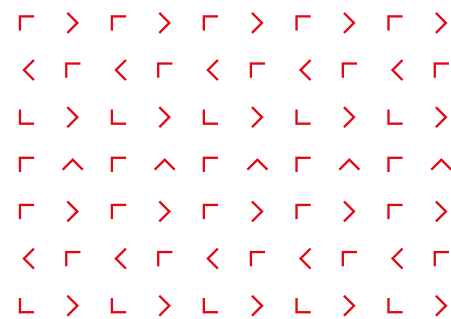
Fertiliser is an absolute necessity to meet the global population's growing need for food. Green Fertilizer Denmark represents a new opportunity to satisfy that need sustainably.

A photograph of two cows in a metal stall, eating hay. The cow on the left is black and white, and the cow on the right is white with black spots. They are both wearing collars. The stall has metal bars and a wooden base. The floor is covered with yellow hay.

CHAPTER 3

EFFICIENT LIVESTOCK FOR A WORLD OF GROWING DEMAND

**SPOTLIGHT ON CLIMATE
ACTIONS IN ANIMAL-BASED
PRODUCTION**



Improvements in animal genetics, feed efficiency and manure management are key to producing livestock with less carbon emissions. Denmark is a technology leader.

Livestock production is responsible for a major share of agricultural GHG emissions. Cattle, feed and manure are primary culprits. In Denmark, innovative enterprises are tackling the issues through targeted breeding, feed efficiency improvements and new technologies for manure management and biogas production. By driving down the climate impact of meat, dairy and egg production, they are creating sustainable opportunities to meet the global demand for animal-based foods.

Better performance from animals and feed

Enteric methane from rumen fermentation is the biggest emission challenge for cattle farmers, with a warming potential 28 times higher than carbon dioxide on a 100-year timescale. In chicken and pig production, much of the carbon footprint stems from the consumption of feed. Denmark's prominent breeding organisations and feed industry are making significant progress in their efforts to relieve these challenges.

Animal genetics reduce GHG and nutrient loads in livestock production

Advances in animal genetics today make it possible to breed dairy cattle that produce more milk and pigs that convert feed more efficiently and have bigger litters. Such improvements are key factors in reducing GHG and nutrient loads per production unit while

safeguarding animal welfare and economic performance.

At the same time, animal microbiome studies have contributed to new feed processing technologies and additives that enable livestock to digest more of the nutrients in feed – optimising their productivity and health while reducing methane emissions and nitrogen excretion.

Manure management with high potential

While manure is a major source of GHG emissions, its management has outstanding potential to reduce emissions from animal-based food production. Technologies related to manure management technologies contribute to fossil-free energy production and optimised nutrient utilisation and recycling.

Danish universities and research institutions are recognised leaders in manure management and go-to partners in the international research community. Danish farmers participate in the development of manure management systems and technologies for cooling, acidification, covering slurry stores and methane oxidation. Farm trials ensure minimum methane formation during handling and storage and enhanced methane yield in integrated biogas systems. Rapid removal of manure from livestock housing is essential to all measures.

Denmark is also home to specialised companies that design energy-efficient livestock housing solutions to minimise environmental pollution. Advanced systems from KJ

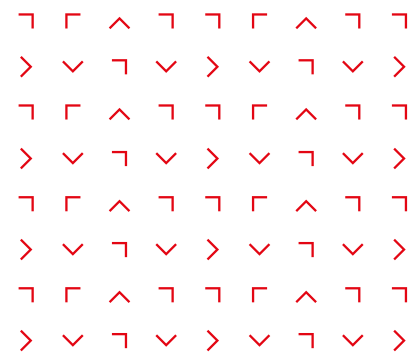
Klimateknik, for example, eliminate up to 91 percent of ammonia by automatic slurry removal and air purification in pig and cattle housing.

From organic waste to renewable energy

The Danish biogas industry is well established. Large-scale plants treat manure and other organic waste streams from food production and households to produce a renewable alternative to fossil fuels.

Research shows that manure both increases biogas production and boosts the availability of nitrogen in the degassed biomass, which is reused as a low-odour fertiliser³. The risk of nitrate leakages from degassed manure into the aquatic environment is correspondingly low. Advantages like these underline how the synergistic links between biogas and agriculture contribute to the green transition of the energy sector and to the circular bioeconomy in general.

³ <https://agro.au.dk/en/current-news/news/show/artikel/low-availability-of-sulphur-in-degassed-fertilisers>



CASE / Arla Foods

ARLA INCENTIVE SCHEME AIMS TO SPEED UP CLIMATE ACTION

Ambitious climate strategies are a must in the global dairy industry. At Arla Foods, the farmer owners are taking proactive steps to reduce GHG emissions. A broad focus on efficiency has cut emissions from their milk production by nine percent a kilo since 2015.

Now a new sustainability incentive is helping to accelerate progress towards the goal of a 30 percent reduction in GHG emissions by 2030, with 2015 as the baseline. For the farmers, it brings an opportunity to earn up to 2.4 eurocents more per kilo of milk, rising to 3 eurocents when the scheme is fully implemented.

Arla has based the incentive model on data obtained from its comprehensive Climate Check tool. For the latest Climate Check report, close to 8,000 farms across Denmark and six other European countries used the tool to submit data about their climate footprint – a contribution already rewarded with an extra eurocent per kilo.

A broad focus on efficiency has cut GHG emissions by nine percent

Analysis of this huge dataset has revealed the 'Big Five', which are the primary levers of the sustainability incentive's point-based system. These are the main drivers of the differences between low and high-performing farms and represent the greatest opportunities to cut GHG emissions while increasing efficiency and profitability.

For each action in these areas, farmers can score points that translate into an additional payment. The bigger the improvement potential for climate and nature, the more points can be collected. Categories include feed, fertiliser and protein efficiency, land use, animal robustness, manure handling, biodiversity, carbon farming, sustainable feed and renewable electricity.

The Arla Big 5 farm management areas with greatest climate impact



FEED EFFICIENCY

More milk per feed input



PROTEIN EFFICIENCY

Reduce protein surplus in feed rations



ANIMAL ROBUSTNESS

Healthy cows with longer life expectancy



FERTILISER USE

Reduce nitrogen surplus from feed production



LAND USE

Efficient use of land for milk production

CASE / VikingGenetics

BIG DATA LEADS THE WAY TO LOW-EMISSION CATTLE

Breeding cows that produce less methane is a promising scenario in the effort to reduce the climate impact of milk production. Since scientists discovered that some cows are genetically inclined to convert more feed into milk and less into methane, this possibility is coming closer to reality.

The Danish cattle breeding company VikingGenetics – owned by Nordic dairy and beef farmers – is playing a lead role in that development by enabling farmers to breed the healthy and efficient cows of the future.

The patented Cattle Feed Intake System (CFIT) is one of the company's key tools. A smart solution based on 3D cameras and artificial intelligence, CFIT is designed to monitor the feed intake and weight of each cow in commercial herds throughout the lactation period.

Genetic selection for better feed efficiency could cut 20% of GHG emissions

VikingGenetics registers the data in the Nordic Saved Feed Index, which describes the genetic ability of each cow to turn feed into milk. The amount of methane produced – varying from two to 12 percent of the feed's

energy content – is closely linked to feed-to-milk efficiency.

Farmers can then use this overview of genetic potential to select the breeding bulls that will pass high feed efficiency and other desirable traits onto the next generation.

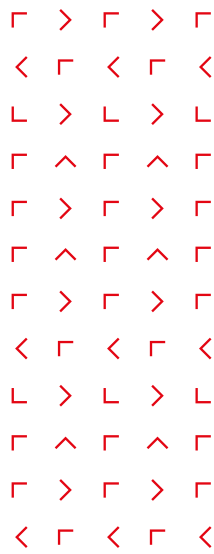
Today, CFIT monitors 12,500 cows across 25 commercial farms. By 2025, further planned installations will bring the number of cows up to 30,000. The collection of data from a larger number of herds in different production

systems will speed up the breeding of highly productive, feed-efficient and low-emission cows that also stand out for their good health.

According to a new study based on CFIT data, genetic selection for improved feed efficiency could reduce GHG emissions from dairy cattle in VikingGenetics' home markets by 20 percent in 2050. In a country like India, for example, the improvement potential is even higher. Here a dairy farmer may reduce methane emissions by 33 percent per litre of milk using Nordic genetics.



Photo: VikingGenetics



CASE / SKOV

SMART VENTILATION CUTS ENERGY USE IN THE POULTRY HOUSE



Photo: SKOV

SKOV replaced the existing fans in one of the houses with the new BF 50 BlueFan. Due to the higher ventilation capacity, the number of fans could be reduced from 16 to 13. Comparative tests were then run over five broiler batches.

The results were clear. With its stepless control, the BF 50 reduced energy consumption for ventilation by 35 to 50 percent. Conditions inside the house remained optimal throughout.

Such an energy-saving improvement means the return-on-investment time can be as little as two years, depending on electricity prices, climatic conditions and other producer-specific factors. The overall rewards are lower energy costs and reduced carbon emissions into the environment.

Round-the-clock air conditioning is indispensable in large poultry houses. Even a small variation in the temperature and humidity level can compromise healthy growth from day-old chicken to slaughter. So a lot of energy goes in to maintaining the perfect indoor climate – particularly in countries where outdoor conditions reach the extremes.

That is why Danish ventilation system supplier SKOV decided to test the energy-saving capacity of a new fan on a broiler farm

just outside Brisbane, Australia where the summers are both hot and humid. The farm belongs to a long-standing customer with a series of identical houses, each one containing the same poultry breed and employing the same feed and management tools.

BF 50 BlueFan reduced energy consumption for ventilation by up to 50 percent

CASE / LJM

CUTTING POLLUTION WITH CLEANER BARN

Livestock manure is a primary source of ammonia and methane emissions, leading to a poor indoor climate for pigs and cattle and pollution of the surrounding environment.

Danish farm machinery supplier Lind Jensen Maskinfabrik (LJM) develops and refines manure removal systems to minimise these emissions. As growing environmental legislation drives innovation, farmers can rely on LJM systems to help them comply with the most stringent requirements.

Frequent manure removal reduces methane emissions by up to 90 percent



Photo: LJM

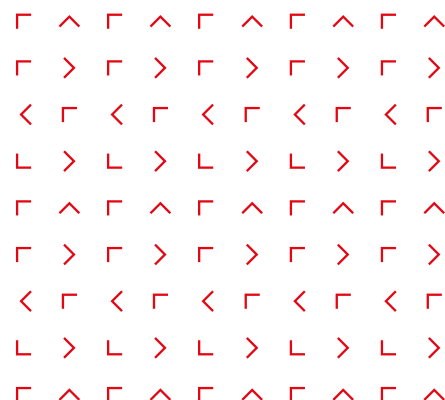
Significant improvements have been made. Although Danish law only requires weekly emptying of the slurry pits under the floor slats in pig barns, LJM's mechanical scrapers make it easy to empty the pits daily. For cattle barns, LJM has designed an automated scraper system to remove manure from solid floors fast and efficiently 12 times a day.

Frequent manure removal reduces methane emissions by up to 90 percent. In cattle barns where manure is scraped from a solid drained floor, a recent study has also found

a 23 percent reduction in ammonia evaporation compared to barns with a slatted floor and slurry pit.

LJM has an ongoing collaboration with the agricultural research and development organisation Seges Innovation to evaluate and optimise its systems to ensure they deliver the best possible climate benefits at minimum cost.

As barns have grown in size over the years, LJM has developed scraper systems for barn floors up to 250 metres in length.





CHAPTER 4

NEW ROUTES TO LOW-CARBON FOODS

THE CIRCULAR VISION OF
MAXIMUM VALUE

Danish food and ingredient technology reduces climate pressures by preventing waste and exploring new opportunities in plant-based innovation.

Danish food, ingredient and biosolution companies are skilled in making the very best use of raw materials, often producing high-value products from side streams or through the use of sustainable processing technologies. Maximum raw material utilisation leads to higher yields and less land use for agriculture – both key to reducing GHG emissions from the global food system.

Attention on plant-based foods and proteins

In recent years, more Danish food and ingredient companies have turned their attention to developing plant-based foods and proteins as an alternative or supplement to animal-based foodstuffs. These products are a response to the world's growing need for protein. National dietary guidelines are also pushing food consumption in a more sustainable direction, where plants have a bigger share of the plate.

Fermentation technology unlocks the protein in local cereal crops

The movement has inspired a wave of innovative start-ups to launch convenient plant-based versions of popular meat dishes and organic textured vegetable proteins for meat substitution. Within the biosolutions sector, fermentation technology unlocks the protein content of locally grown oats and other cereal crops. Such developments enable the production of sustainable foods and beverages with appealing tastes and textures and high nutritional value.

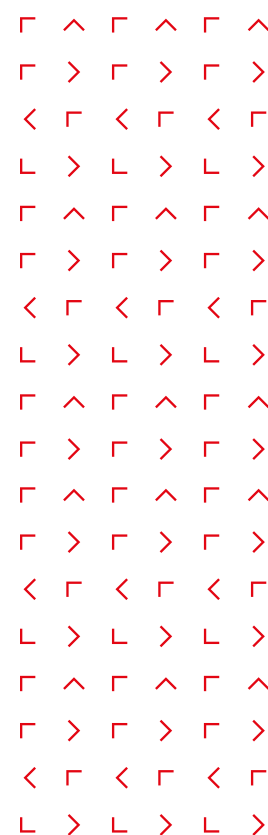
Experts in the value cascade

A number of Danish companies have established an international business by utilising food production side streams, such as whey from cheese processing or trimmings from fish and meat production. By extracting value components from other manufacturers' waste, these companies bring high-quality feed and food ingredients to the circular economy.

Remaining components that cannot be used in food products are used in livestock feed, biogas production, or natural fertilisers that return the remaining nutrients to the soil. In this way, raw materials are used to maximum value over multiple lifetimes, reducing the demand for virgin materials and the subsequent pressure on climate-challenged ecosystems.

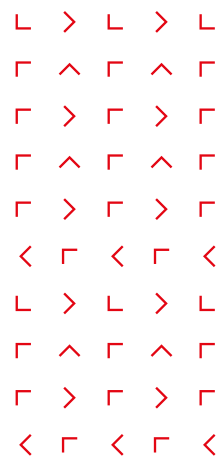
Reducing waste of processed food

Food loss and waste accounts for an estimated eight to ten percent⁴ of global GHG emissions. Denmark's ingredient industry delivers solutions to help food manufacturers reduce their waste and related climate impact. Bakery enzymes, for example, can slow the staling process, so bread keeps its soft, fresh feel right down to the last slice. Natural cultures can extend yoghurt shelf life by at least seven days by reducing the risk of yeast and mould spoilage, while antioxidants delay the onset of rancidity in products such as cooking oil, margarine and snacks. Such solutions reduce the volumes of food discarded at consumer level, where food waste has the highest carbon footprint⁵.



⁴ <https://www.unep.org/resources/report/unep-food-waste-index-report-2021>

⁵ https://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/FWF_and_climate_change.pdf



CASE / Novonesis

PRECISION FERMENTATION TARGETS THE GLOBAL PROTEIN NEED



Photo: Novonesis

percent lower. Water consumption and land use could also be reduced by 90 percent.

At the same time, the strictly controlled process promises to deliver a reliable protein supply, independent of climate change, harvest variations or zoonotic epidemics.

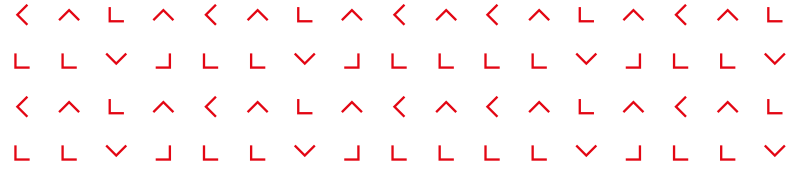
Novonesis has extensive fermentation knowledge to draw on when encoding microorganisms, such as yeast or filamentous fungi, for protein production. The goal is to develop specialised proteins with an optimised amino acid composition or improved taste – meeting the dietary needs of distinct consumer groups or optimising the protein content of a food or beverage brand.

Global demand for protein is expected to double by 2050 due to population growth and rising incomes. Within the food industry, pioneering research is developing new low-carbon protein sources to meet this need without burdening the planet.

For Danish biotech company Novonesis, precision fermentation was the obvious starting point for innovation. Used for decades to produce functional enzymes for food and beverages, the technology is now at the heart of the company's advanced protein solutions.

The outcome is new protein ingredients of similar nutritional quality to the proteins in meat and milk. Because they are produced by microorganisms in a tank of sugar and water, carbon emissions may be up to 90

Carbon emissions from new protein ingredients may be up to 90 percent lower



CASE / Novonesis

LESS YOGHURT WASTE WITH BIOPROTECTION

Short product shelf life is a major sustainability problem for the dairy industry. Once purchased by consumers, a large proportion of fermented products such as yoghurt, sour cream and cottage cheese end up as household waste. The challenge many manufacturers face is how to keep products fresh for longer without resorting to unwanted additives.

Bioprotective cultures from the Danish ingredient company Novonesis are an effective solution. Comprising specially selected strains, the cultures protect fermented dairy products from spoilage caused by yeast and mould – even when storage and cold chain conditions are difficult.

The extended shelf life not only reduces the climate impact of dairy production by minimising waste. It also supports the manufacturer's reputation as a supplier of consistent, high-quality products.

A longer shelf life minimises waste and climate impact



Ten years after the initial market launch, Novonesis introduced a new generation of bioprotective cultures that offer even better stability at high distribution temperatures and a better sensory fit, so taste and texture are always at their best.

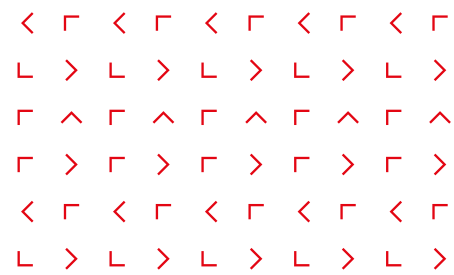
Novonesis has more than 50,000 microbial strains in its collection – an excellent starting point for finding the right strain for every trend, need and sustainability hurdle.

A close-up photograph of industrial food processing equipment. A circular pressure gauge with a white face and black markings is mounted on a stainless steel pipe. The gauge has a needle pointing to approximately 0.15 MPa. To the left of the gauge is a vertical glass tube containing a yellowish liquid. The background is a blurred stainless steel surface.

CHAPTER 5

FOOD PROCESSING TOWARDS A CARBON-NEUTRAL FUTURE

**ELECTRIFYING AN ENERGY-
INTENSIVE BUSINESS**



The decarbonisation of food processing is a work in progress. Danish manufacturers and equipment suppliers work together to fine-tune processes and prepare the ground for electrification.

Food and beverage processing is an energy-intensive business, where thermal treatments and sterilisation processes are key to securing high standards of quality and food safety. In Denmark, the transition to super-efficient production lines driven by fossil-free energy is well underway. Heat recovery, electrification and alternative processing technologies are paving the way to climate neutrality.

Heat recovery and reuse is a key lever for improving energy efficiency

Optimising energy efficiency

Since 2000, the Danish food processing

industry has increased production by close to 43 percent and cut energy consumption by 25 percent. The use of renewable energy has increased more than sevenfold during the same period. Denmark's equipment suppliers support food manufacturers in fine-tuning processes to run at full capacity with less energy use. Cleaning in place (CIP) systems, with their high heat requirements, are one area of focus. Maintaining the highest food safety standards with fewer resources is the priority.

Recovery of surplus heat

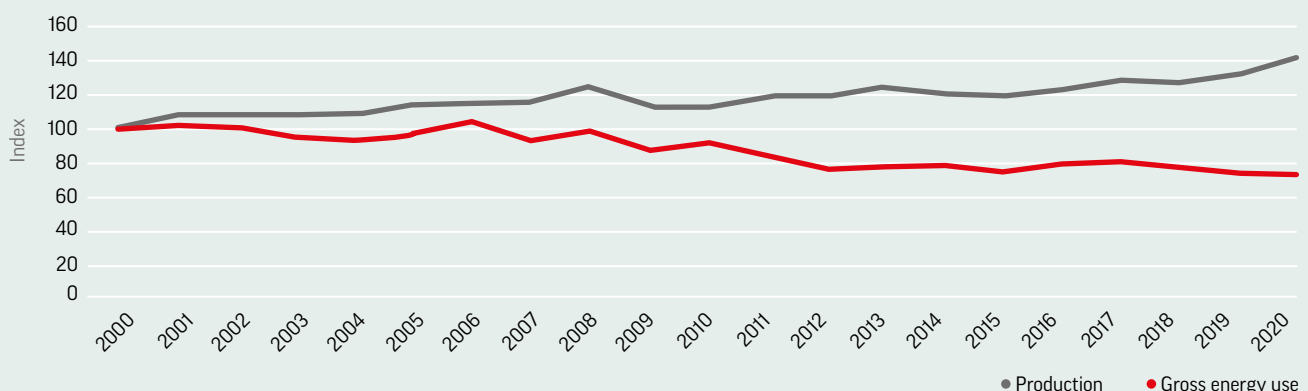
Heat recovery and reuse is a key lever for improving energy efficiency. Across the Danish food industry alone, surplus heat generation is equivalent to the heating requirements of an estimated 150,000 homes⁶. Many companies have recognised this potential. Arla

Foods Ingredients, for instance, has made significant carbon savings by investing in systems that repurpose surplus heat from various processes in the production of dairy-based powder ingredients.

The move to fossil-free electrification

The ultimate decarbonisation of the food industry depends on electrification. This also supports shorter processing times and better process control, which can enhance product quality. In one major collaboration project – SuPrHeat – Danish food companies are working closely with technology suppliers and researchers to develop high-temperature heat pumps that can replace gas-fired boilers. Industrial heat pumps of this kind both facilitate the move to renewable energy and offer great possibilities to reduce energy consumption overall.

Production value versus energy use in the Danish food, drink and tobacco sector



Source: Statistics Denmark

⁶ https://ddfi.dk/sites/default/files/udgivelser/DDFI/DDFI_2018/viegand_maagoe.pdf

CASE / Royal Unibrew

RENEWABLE ENERGY IS SOUND BREWERY BUSINESS

The need to replace fossil fuels with renewable energy sources became even more pressing when the war in Ukraine put Europe's natural gas supplies at risk. At Royal Unibrew, the volatile situation was a fresh reminder that the transition to carbon-neutral production was the right policy for the planet and business.

A New solar park covers 40 percent of plant energy needs

As a leading multi-beverage company with 19 production sites in nine markets, Royal Unibrew has focused on reducing its climate impact for many years. From 2015 to 2021, for example, energy efficiency improvements cut CO₂ emissions per hectolitre by 28% while production volumes grew 32%.

In 2023, the group achieved three important milestones.

- > At the largest production site in Denmark, construction of a solar park was complete, delivering sufficient renewable energy to cover 40 percent of plant needs.
- > A second project at the site involved the installation of a heat pump to utilise surplus heat from process cooling systems. The outcome is a 30 percent reduction in heat consumption.
- > Thirdly, a bioreactor established at Royal Unibrew's second largest site in Finland, has enabled the conversion from fossil-based to bio-based fuel for heating. The bioreactor runs on production by-products, supported by locally produced biogas.

Additional energy efficiency and renewable energy projects are planned at all other Royal Unibrew sites. The group goal is to become 100 percent carbon-neutral by 2025.



Photo: Royal Unibrew

CASE / GEA

HEAT PUMPS DELIVER AN ENERGY-SAVING MILESTONE

Spray drying accounts for up to 70 percent of the energy requirements in milk powder processing. Until recently, all the heat that goes into the process was released as low-temperature waste. Now GEA has come up with a solution to utilise this heat, reducing fuel consumption and related carbon emissions by more than 50 percent.

One of the world's largest food system suppliers, GEA has based its business unit for powder and thermal separation technologies in Denmark. Here, the specialised design team has developed the new air heating system – GEA AddCool – to recover low-temperature waste heat from exhaust air and cooling processes.

Air heating system cuts fuel consumption and emissions by more than 50 percent

GEA AddCool uses high-temperature heat pumps to capture and upgrade the heat, which is then used to pre-warm air to 120°C before it is fed into the spray-drying process. Because it is an add-on system, retrofitting to existing spray dryers is simple. Production throughput and powder quality are unchanged.

GEA's patent-pending solution is the result of a five-year collaborative development project involving experts in engineering, heat pumps, spray drying and powder processing. For powder manufacturers, GEA AddCool is an energy-saving milestone that cuts heating needs, costs and carbon footprint.

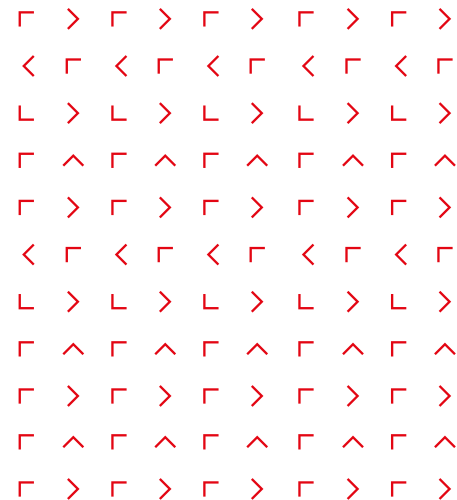


Photo: GEA

A woman with long, wavy, light brown hair, wearing a white lab coat, is looking up at several tall, vertical glass tubes. Each tube contains a green plant, likely a grass, growing from a small pot at the bottom. The tubes are arranged in a row, and the background shows a greenhouse structure with wooden frames and translucent panels. The lighting is bright and even.

CHAPTER 6

TURNING DISRUPTIVE IDEAS INTO CLIMATE SOLUTIONS

IMPACTFUL INNOVATION THROUGH
BROAD COLLABORATION

Denmark is a hub for food and agriculture research to solve the climate challenges of global food production. From farmers to food processors and involving universities, research organisations and NGOs, collaboration accelerates change.

A long tradition for research and innovation and strong private-public partnerships make Denmark a leading player in the green transition of food, agriculture and land use. Cross-sector efforts continue to contribute solutions to today's overarching challenge – the need to secure enough safe and healthy food for a growing human population while reducing the climate impact of food and agricultural production systems.

Four tracks to the climate goals

In 2021, 300 researchers and experts from Danish universities, companies, research organisations and NGOs developed the AgriFoodTure roadmap. This sets out four primary tracks which describe the pathway to developing innovative solutions for reaching the national goal of a 70 percent reduction in GHG emissions by 2030 and further reductions in global GHG emissions towards 2050.

Five Danish foundations are financing research into pioneering solutions for agriculture

AgriFoodTure was subsequently established as a research and innovation partnership. Today, it numbers around 50 partners from the public and private sector and has 11 projects in progress, with more on the way. Strong collaboration between researchers, organisations and companies is necessary

to achieve climate and other sustainability targets. The AgriFoodTure partnership is open to all interested parties.

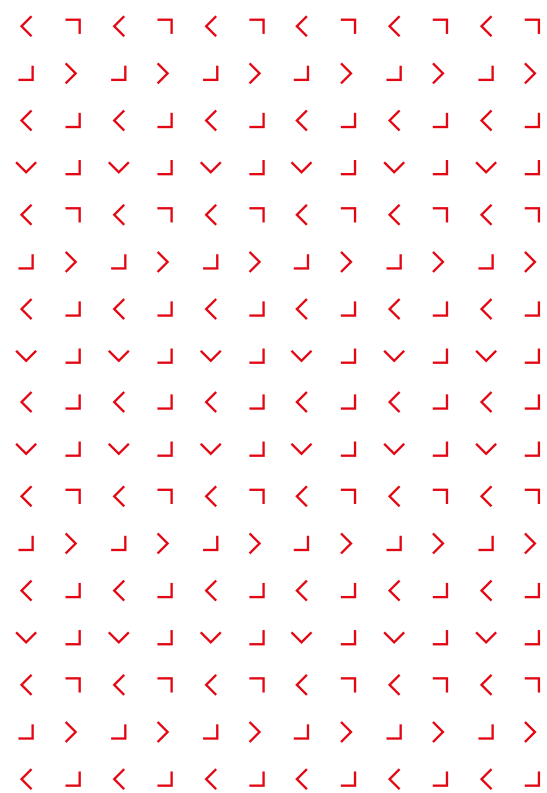
Dedicated research funding

Within livestock and crop farming, decades of optimisation provide an excellent foundation for further progress. In 2022, five of Denmark's largest foundations came together to finance the Land-CRAFT centre – part of a national initiative to drive dedicated research in key areas. Pioneering science-based solutions for climate change mitigation and adaptation in agriculture is a primary aim.

Thanks to major research investments of this kind, new improvement opportunities continue to be revealed, whether in animal genetics, feed efficiency and manure management or through the development of novel fertilisation systems and precision technologies. Such solutions support the increasing circularity of agricultural resources and the recapture of carbon in the soil.

Accelerating the transition

Novel research initiatives are also underway to accelerate the transition to more sustainable diets. Funded by the Novo Nordisk Foundation, Plant2Food is a new collaboration platform aimed at solving complex issues when turning crops into plant-based foods. All the results achieved by academic and industry partners will be publicly available, benefiting further innovation work to develop consumer products.



Another avenue of exploration focuses on cell-based production of meat and milk to reduce reliance on livestock. Again, the Novo Nordisk Foundation is lead investor in research to find a sustainable and more affordable alternative to the animal-based growth medium that is currently used. Nutrients from yeast and algae will provide the basis for the new culturing method. Aarhus University, the Technical University of Denmark and several international researchers are involved in the project.

Innovative ideas and disruptive thinking are fundamental to the decarbonised future of food and agriculture. Denmark is making a vital contribution.

AgriFoodTure tracks and workstreams



Land use and management

- Rewetting of organic soils, reducing emissions from drained peatlands
- Fertilisation management for lower nitrous oxide and nitrate leaching, including green fertiliser
- Perennial crops with greater productivity
- Targeted plant breeding
- Biochar as soil amendment, increasing carbon sequestration



Animal-based food production

- Improved feed efficiency and optimised herd management
- Targeted livestock breeding
- Feed additives to reduce methane and ammonia emissions from livestock
- New manure technologies to capture methane and ammonia in buildings and systems



Plant-based food production

- Holistic approaches to trigger a shift in consumer diets
- New food crops and farming systems to ensure reliable sourcing of suitable raw materials
- Enzymes and fermentation technologies for gentler raw material processing and improved functionality, structure, taste and nutritional value
- Upcycling and recycling technologies for extracting food grade ingredients from waste materials



Biotechnology-based food production

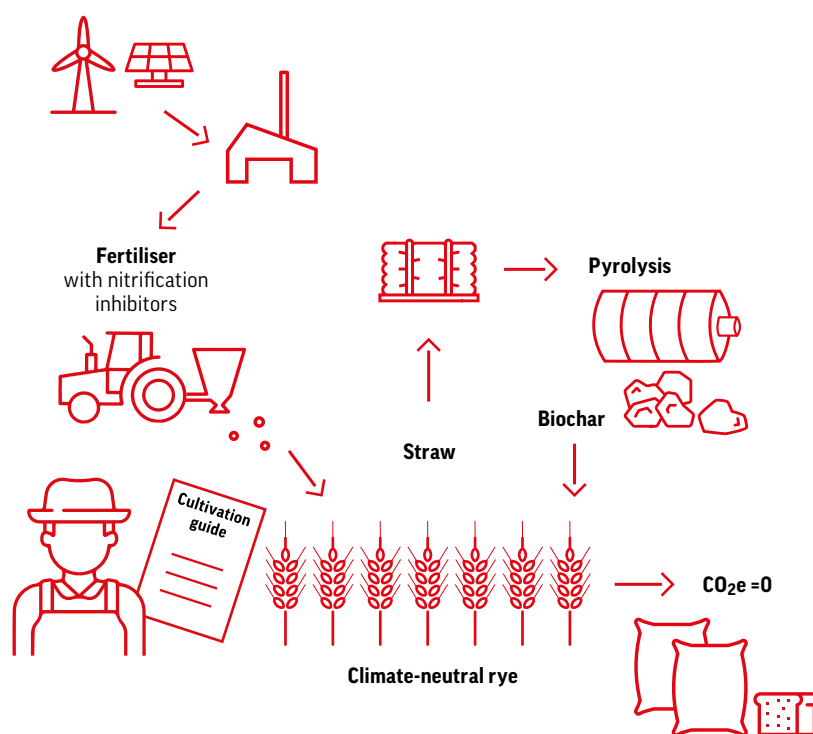
- Novel microorganisms and animal cell-based alternatives to animal-based food
- Alternative proteins and other food ingredients from e.g. insects and blue biomasses
- Microbial and enzymatic upgrades of side stream components
- Functional food ingredients, cultures and additives
- Biorefining of green plants to extract proteins for feed and food

CASE / Project Zero

COLLABORATION WILL BAKE THE FIRST CLIMATE-NEUTRAL BREAD

Danish consumers could become the first to buy climate-neutral oats and ryebread when the results of a cross-sector project arrive in supermarkets in a few years' time. Led by SEGES Innovation and involving partners from the entire food value chain, Project Zero is combining existing technologies to bring climate-neutral food products from farm to table⁷.

One of the key objectives is to demonstrate that climate neutrality and profitability can go hand in hand in food production.



Project Zero combines existing technologies to bring climate-neutral foods from farm to table

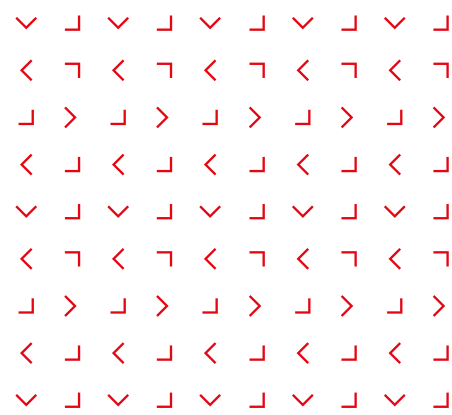
The three-year project has three primary tools in focus – biochar, green ammonia and nitrification inhibitors. Biochar will be produced from oat and rye straw by pyrolysis,

providing a stable carbon source when returned to the soil. Green ammonia, produced from wind and solar energy, will serve as a nitrogen fertiliser, while nitrification inhibitors will be used to suppress emissions of nitrous oxide, reducing the climate impact of fertilisation.

Life cycle assessments of the oats and rye-bread will verify their climate neutrality.

In addition to SEGES Innovation, the project partners are COOP, Kohberg, Valsemøllen, Aarhus University, Stiesdal SkyClean, Skovgaard Energy, BASF, Bureau Veritas, Fjordland and Innovation Centre for Organic Farming. The Green Development and Demonstration Program under the Danish Agricultural Agency has provided funding for the project, which runs until December 2025.

⁷ Source: https://www.seges.dk/da-dk/nyheder/klimaneutralt_rugbrod



CASE / MABICOW

PIONEERING FEED ADDITIVE TO REDUCE METHANE FROM COWS



Photo: MABICOW

The ultimate test of the bioactive compounds will be a controlled feeding trial with dairy cows, measuring the impact on methane generation alongside milk production, health and other key parameters.

The plan is to patent and commercialise the additive within five years of the project's completion in August 2025. As no additive for effective methane reduction is currently available, market demand is expected to be high.

The other partners in the project are Danish Technological Institute, Ocean Rainforest, Lactobio, Novonesis, Vilofoss and DLG.

Can bioactive compounds in Nordic macroalgae be used to limit methane production in cow stomachs? Danish researchers are investigating the possibility in a project to pioneer a new methane-reducing additive for cattle feed⁸.

Initial findings suggest there could be potential to cut cow methane emissions by at least 45 percent with no negative consequences for productivity, animal health or food safety.

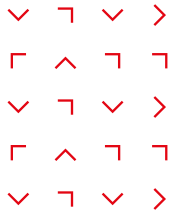
Aarhus University is leading the partnership project, which started out by harvesting and cultivating macroalgae species with known anti-methanogenic properties. From them, a handful of promising compounds are being identified through in vitro simulation.

Macroalgae could cut cow methane emissions by 45 percent

⁸) Source: <https://agrifoodture.com/projects/mabicow/>

CASE / KLIMINI

FERTILISER ADDITIVE SHOWS POTENTIAL AS A CLIMATE CHANGE TOOL



Many farmers benefit from the use of nitrification inhibitors (NI) to maximise nitrogen availability for sustaining crop growth and reducing nitrate leaching. International studies have also documented the ability of NI to reduce the production of nitrous oxide – a primary source of GHG emissions from agriculture.

Now a research team from Denmark is investigating another important question: the precise climate and environmental effects of NI under Danish conditions.

types and the practices of the individual farmer. There is similarly little data about the side effects of NI on soil microorganisms and the risk of leaching into surface and ground water.

This is all necessary knowledge before policy-makers decide whether to promote NI as a sustainable tool for reducing GHG emissions in Denmark.

Aarhus University, University of Copenhagen and SEGES Innovation are partners in

the project which will provide the basis for recommendations to the agricultural industry on NI use. Funding has been provided by the Climate Research Programme under the Danish Agricultural Agency.

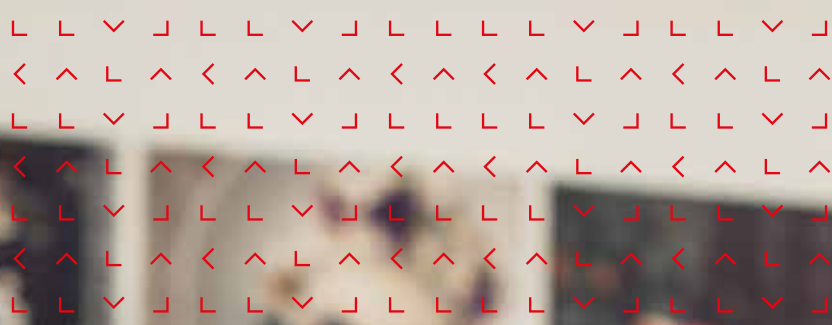
NI research will provide basis for national recommendations

The objective is to document whether NI can support Danish farmers in reaching their climate goals. Based on initial calculations, potential exists to cut nitrous oxide emissions by at least 400 kt CO₂ equivalents a year.

However, little is currently known about how NI are affected by different soil types, weather patterns, fertiliser and manure



Photo: KLIMINI



ABOUT FOOD NATION



Interested in hearing more about Denmark's strengths as a centre for agrifood innovation? Contact Food Nation.

Food Nation is a non-profit partnership established by the Danish government and leading private organisations and companies. It is your gateway to information about the Danish food cluster and knowhow that can accelerate the growth of international businesses through better solutions, innovative products and trusting cooperation.

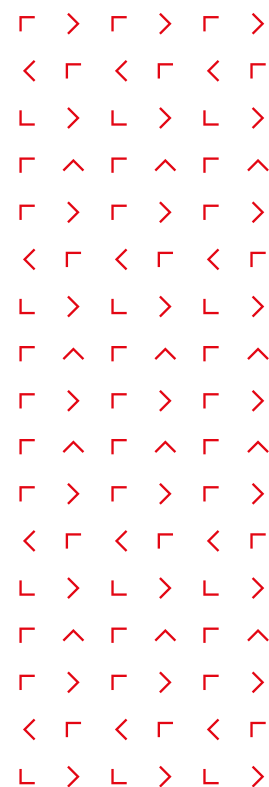
The Danish food cluster encompasses everything from primary production in agriculture and the fishing industry to the food products consumers buy in stores. Companies, universities, research institutes, local and national authorities and other private and public organisations belong to the extensive, collaborative network. Together, they work hand-in-hand with international partners to maintain and improve food quality and safety along the value chain.

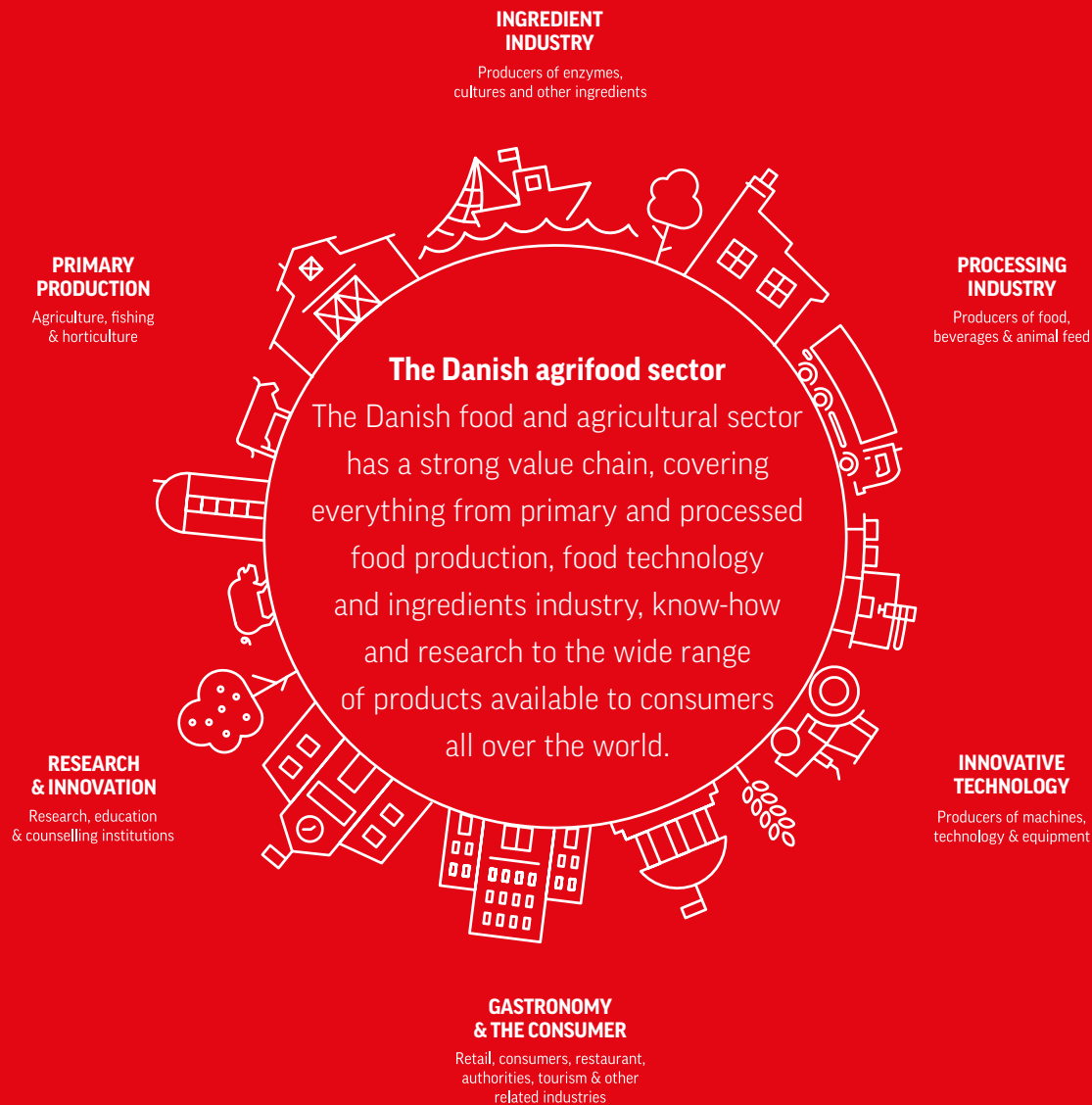
Take an interactive tour

Food Nation's Visitor Centre in central Copenhagen and in Agro Food Park in Aarhus welcomes international delegations, providing them with an introduction to Danish capabilities within food and agriculture. An interactive installation at the centre gives visitors an up-to-date overview of the food value chain based on their individual interests. It is the ideal starting point before visiting Danish food producers and production facilities.

An inspiring preview is also available from the Food Nation digital universe. Here, inspirational publications, webinars, videos and talks provide insights into how Denmark can contribute to the green transition. Visit the digital platform at **foodnation.virtualhive.live**, register as a user and take a browse.

Food Nation is a great place to start learning about how Denmark support sustainable development through collaboration. Find out more about our services, the Danish food arena and arranging a visit to the Food Nation visitor centre at **foodnationdenmark.com**





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