Think Denmark

White papers for a green transition

PRODUCING MORE WITH LESS

The Danish transition to a bio-based society with resource-efficient production

INSIDE THIS WHITE PAPER

Solutions and technologies that secure sustainable agricultural production

Reusing and upcycling residual and by-products across the value chain

Specific examples of resource-efficient practices from a number of industries

State of Green

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PRODUCING MORE WITH LESS
The Danish transition to a bio-based society with resource-efficient production
Version 2.0
Printed July 2018

Front page photo
Photo: Peter Prik Larsen, Petri & Betz

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This White Paper was developed and produced in collaboration by:

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Danish Agriculture & Food Council

Ministry of Environment and Food of Denmark

AGRO BUSINESS PARK

NORDIC ECOLABEL

EXECUTIVE SUMMARY

The aim of the white paper is to share some of Denmark's solutions and experiences from our ongoing transition to a sustainable agriculture and food cluster that is based on renewable biological resources and ultra resource-efficient production. We believe that by doing so, we can make a tangible contribution to achieving progress on the global sustainability goals and inspire others to do the same.

We have gathered a selection of cases, which provide specific examples of how the agriculture and food cluster in Denmark reuses, recycles and upcycles residual and by-products to create new forms of food and feed, materials, new products and even energy. The selected cases also include examples of how maximum value can be extracted from resources, thus reducing overproduction and overconsumption. The cases are supplemented with perspectives from a number of actors in Denmark that work to drive progress in this area.

This White Paper provides insights and guidance on how sustainable production in the agriculture and food cluster can be achieved, by way of concrete and ready-to-be-implemented Danish technologies and solutions. The examples contained in this publication can be implemented in a number of contexts and are sustainable in all senses of the word – not only economically, but also environmentally.

We hope that you will be inspired.

The UN Sustainable Development Goals (SDGs) are a group of 17 goals that entered into force as of January 1, 2016. Part of the 2030 Sustainable Development Agenda and universally applicable, the goals seek to spur action to end poverty, protect the planet and secure peace and prosperity for all. Interconnected in nature, achieving progress on one goal will often involve tackling challenges related to another. This white paper primarily addresses goals 2, 6, 7 and 12, but also includes cases that are relevant for the attainment of goals 1, 8, 13, 14 and 15.

SUSTAINABLE DEVELOPMENT IN A BIOECONOMY

The bioeconomy entails utilising our biological resources in a new way to match the production conditions of the future.

By Jakob Ellemann-Jensen, Minister for the Environment and Food of Denmark

By 2050, the world's population will hit 10 billion. That is three billion more than today. Therefore, it is imperative we change our linear thinking, where we produce, consume and throw away. Instead, we need to adopt a circular approach and adjust our production, so that what was previously considered waste is now considered a resource. Furthermore, we need to explore a myriad of new sustainable biological sources such as mussels, seaweed, perennial grasses, single-cell proteins and insects, and we need to develop innovative technological solutions to process these into a variety of valuable products and services.

The bioeconomy means sustainable use of the planet's resources

A true bioeconomy includes the sustainable production and harvest of renewable resources and the conversion of these resources into new products and value streams such as food, feed, bio-based products and bioenergy. A bioeconomy stimulates the production of sustainable biomass and its efficient use, reducing overall pressure on the environment and the climate. The bioeconomy can thus contribute to continued economic growth in a way that uses the planet's resources in a sustainable manner. The UN's 17 Sustainable Development Goals will lead the world in a more sustainable direction. The bioeconomy is an integrated part of the solution.

Danish companies are embarking on the journey to a bioeconomy

Many companies in Denmark excel at utilising microorganisms and enzymes in mass production of food, pharma and chemicals, and in plant breeding. The agriculture and food cluster is experimenting with alternative proteins in order to meet the growing global demand for meat, but also to provide proteins to meet the increasing demand for plant-based food. It is common practice in Denmark to recirculate the nutrients into the soil, as well as to ensure all of the meat from swine and beef production is utilised so that nothing is left. In turn, food products, bioenergy and valuable proteins are created. Other companies utilise biological resources – even side streams from other productions - to produce more sustainable new building materials, textiles or chemicals. The spectrum is broad and the possibilities enormous. But it requires collaboration – and very often unusual partnerships – to make this happen. Fortunately, companies, governmental authorities, research institutions and non-governmental organisations are working together to develop, test and bring new solutions and products on the market, supported by regulatory frameworks that promote and enhance collaboration and innovation.

I am pleased to share with you this white paper about the Danish agriculture and food cluster's ongoing transition to a bioeconomy.

I hope you will be inspired.

THE DANISH AGRICULTURE AND FOOD CLUSTER'S CONTRIBUTION TO THE SUSTAINABLE DEVELOPMENT AGENDA

From a global perspective, Denmark has one of the most efficient agricultural sectors in the world. In this white paper, 'Producing more with less', we seek to underline how sustainable production is embedded in the DNA of the Danish agriculture and food cluster. Although today's production levels are higher than ever before, each unit of production requires dramatically less water and energy consumption, thus creating substantially fewer CO_2 emissions.

By Karen Hækkerup, CEO of the Danish Agriculture and Food Council

Decoupling agricultural production from resource consumption
The Danish agriculture and food cluster is advancing the 2030 sustainable development agenda via concrete, proven examples that can achieve considerable progress within areas such as responsible consumption and production, hunger, energy and water. Greenhouse gas emissions from the sector continue to decline – and the same goes overall for other environmental parameters, such as water usage, where increased food production has gone hand in hand with reduced water consumption.

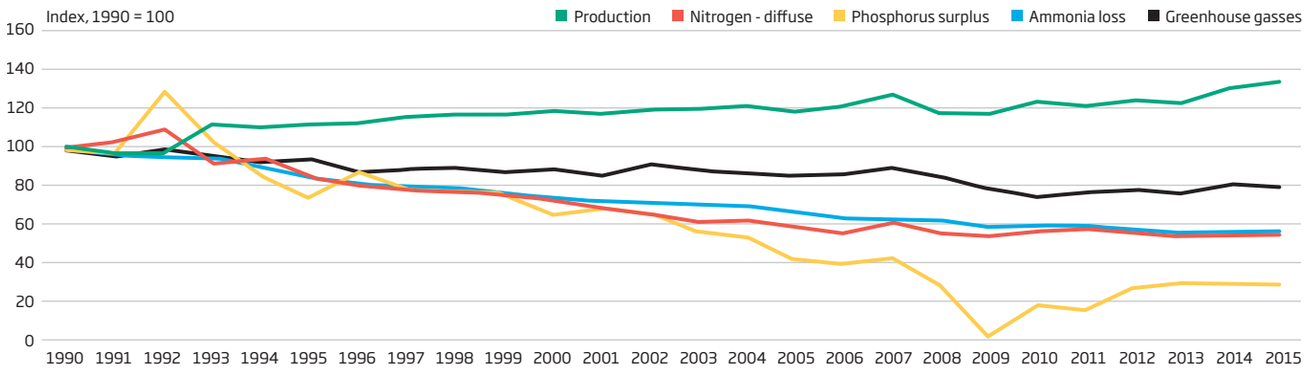
How has this been achieved? A small island nation with modest natural resources, Danish farmers and companies have been compelled to adopt a life cycle approach, where the entire value chain is exploited to maximise results and resource consumption optimised for minimal impact on the environment and finances. This is anchored in a strong public-private partnership culture, close integration throughout the food chain from farm to end-consumer and cutting edge research and innovation. Ensuring each unit of production consumes less water and energy, resulting in fewer CO_2 emissions, is always a factor in the design process.

Moving towards a circular economy
To secure sustainable food production that can nourish a growing world, the Danish agriculture and food cluster also utilises by-products to create new and higher value products. One example is the use of whey - a side stream from cheese production - to extract protein for human consumption. The sector is also pioneering the use of biomass sourced from agriculture and food production in the form of straw, manure, energy crops, animal by-products and other residues from food production to create bioenergy, thus limiting the use of fossil fuels and ending energy poverty in rural areas. We will continue to develop new high-value and innovative products from our waste streams as we can see it makes financial and environmental sense.

Proven and tested case examples that make a tangible contribution to the sustainable development agenda
As the sector with the largest export, the Danish agriculture and food cluster has a key role to play in solving global challenges. We aim to adress a growing population's need for food, water and energy in a sustainable manner. This paper presents examples that primarily support Sustainable Development Goal #2 to end hunger and promote sustainable agriculture, goal #6 clean water and sanitation, goal #7 affordable and clean energy and goal #12 to ensure sustainable consumption and production patterns.

Highlighting state-of-the-art case examples from Denmark, this white paper acts as a blueprint; demonstrating how to maximise the potentials in sustainable intensive production and how we support the transition to a bio-based economy.

I hope you will be inspired.



Denmark is among the world leaders in sustainable intensive food production and innovative solutions in the bioeconomy. We have reduced overall climate and environmental footprint, enhanced and increased our production and are on the way to optimise the production's side stream to high-value products.

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PROTEINS FOR THE FUTURE

- Recommendations from the Danish Bioeconomy Panel.

The Danish Bioeconomy Panel is established by the Danish government with the aim to harvest potentials of the bioeconomy, to the benefit of future earnings, the environment and climate. The Panel consists of scientists from leading universities and representatives from commercial interests.

By Asbjørn Børsting, Chairman of the Danish Bioeconomy Panel

The Danish Bioeconomy Panel provides recommendations to the government on a variety of different aspects of the bioeconomy. The bioeconomy is an agenda for innovation, growth and sustainability. More value can be added to existing resource utilisation, by using biorefining technologies to existing sources of raw material – both virgin material and side streams - and the co-production of bio-based products such as food, feed, materials, chemicals and pharmaceuticals.

In June 2018, the panel launched its recommendations to the Danish government on new value chains for proteins, "Proteins for the Future".

Denmark is a net importer of proteins for feed purposes. Approximately one million tonnes of protein for feed is imported. The consumption of animal protein is expected to increase by 70 per cent by 2030. This is coupled with increasing demand in Denmark and Europe as a whole for new protein sources, which are produced locally, are non-GM and/or are organic. Finally, a growing share of consumers are demanding plant based alternatives to animal proteins.

The key message from the Danish Bioeconomy Panel is that within a five-year timeframe, new protein sources will be capable of competing with existing protein sources, both in terms of price and quality. Furthermore, it will be possible to substitute as much as one third of the proteins imported today from third countries with more sustainable local alternatives, which will generate positive environmental and climate impacts. In order to achieve this, the panel has composed 15 key recommendations to the Danish government on how to improve framework conditions, support research & development initiatives and secure coherency within and between new protein value chains.

The main part of the new proteins will come from well-known agricultural crops such as grass-clover and legumes. These crops are known for their high content of protein with an attractive amino acid composition. The challenge that has to be overcome is to refine the protein content in grass and grass-clover into a competitive and effective feed product that can be benchmarked with other protein products on the market.

Grass and clover are not only attractive sources of protein for feed purposes. These agriculture crops have positive effects on the climate and the environment, due to low levels of nitrogen leaching and greenhouse gas emissions. They may also be beneficial from a health and nutrition perspective.

The Danish Bioeconomy Panel will now embark on its next topic; new value chains for biomaterials. The Danish government will receive the recommendations early spring 2019.

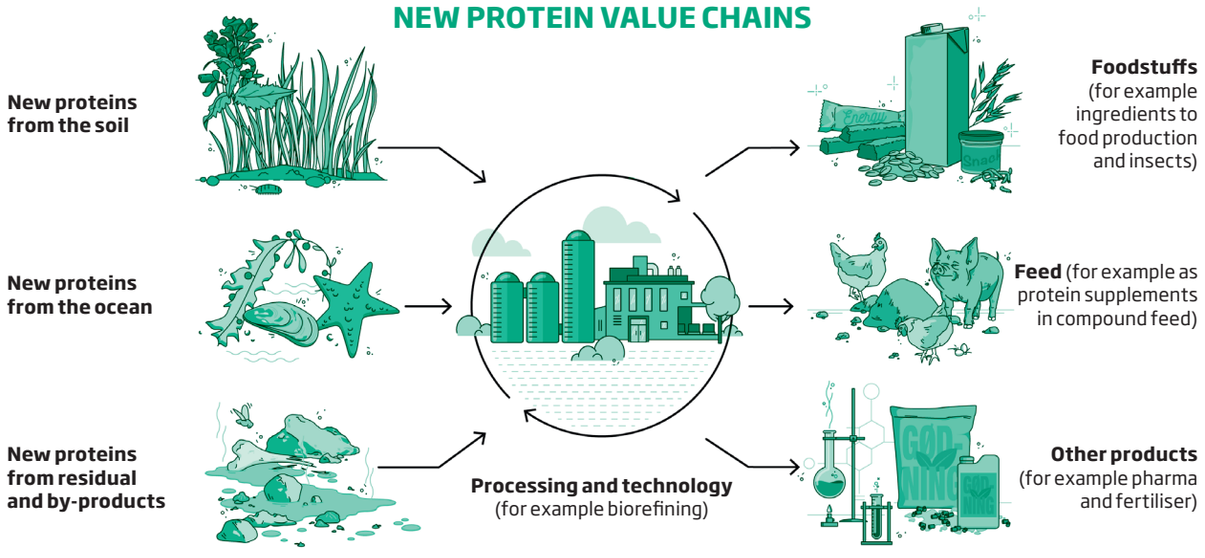


Illustration: Kontrapunkt

STRENGTHS IN THE DANISH AGRICULTURE AND FOOD CLUSTER

Denmark is a leading food nation and has a long history of food production with low environmental footprint.

Even though our own agricultural area is relatively modest, Danish food production feeds three times our own population. Today, the Danish food cluster accounts for more than 25 per cent of the total Danish export of goods and exports to more than 200 countries around the globe.

Mie Ole Lauritzen, Senior Project Manager, Food Nation

Denmark is a food producing country and has optimised production at every single step of the value chain - this includes everything from cattle breeding to transportation. As a result, Denmark now has ultra environmentally friendly production. For instance, the Danish food cluster produces milk that has the lowest CO_2 emissions per litre of milk out of all EU28-countries. Ingredients from Danish companies can extend the lifetime of food products and thus minimise food waste. Danish food processing facilities are initiating programmes that reduce electricity and water usage. Seen as a whole, it means that when you buy Danish food, you can be certain that the environmental footprint is kept to a minimum. Photo: Food Nation

Denmark is the place to look to if you want to experience sustainable and environmentally friendly food production. When doing business with the Danish food industry, you will find a wealth of experience and know-how within resource efficiency and discover how to produce more with less – while actually saving money. Throughout the Danish food production chain, you can find innovative, new solutions for a world that soon has to feed nine billion people. Dating back to the 1960s, Danish food production has long been known for making products with minimal pollution, high resource efficiency and a small carbon footprint. This is something Denmark constantly strives to do better. Since 1990, the Danish agricultural sector has succeeded in increasing output and reducing pollution. Food producers have continuously optimised production processes; investing in new production equipment that makes it possible to consume less water and energy, thus saving money in the long-term. Actions such as these have made Denmark front-runners in the European Union (EU) in various studies on sustainable production. Denmark has the lowest ammonia emission levels in the EU; Danish milk, meat and egg producers are more resource efficient than other EU countries and the Danish retail market has the largest number of organic products on the shelves in the world.

Denmark's unique market position as one the greenest food producers comes from the high level of collaboration that takes place at every step of the value chain. Farmers harvest their products in the most sustainable way, small-scale fisheries cooperate with companies to source fish from shallow waters, thus leaving the seabed untouched and using less fuel, which results in fish that is fresher. The transportation of goods is via HGVs (Heavy Goods Vehicles) that are required by law to drive with particle filters, thus reducing pollution – and even supermarkets have developed new, innovative ways of cutting down on energy usage when cooling dairy products. Altogether, this means that when you buy Danish food products, every possible action has been taken to reduce the load on the planet.

Food Nation is a public-private partnership established by the Danish government and leading private organisations and companies. Food Nation aims to create awareness of Denmark as a frontrunner within innovative, sustainable and effective food production. Food Nation is a gateway for international stakeholders seeking information about Danish food solutions, products and cooperation.

REDUCING FOOD WASTE WITH NATURE'S OWN RESOURCES

How bioprotection can reduce dairy waste.

Bioprotection is nature's own way to keep food fresh and safe for longer. With the potential to reduce yogurt waste by 30 per cent it helps to address the global food waste issue.

Annemarie Meisling, Sustainability Director, Chr. Hansen

Reducing food waste - a global issue
Reducing food waste has been identified by the UN as a Global Goal for Sustainable Development. Although consumer awareness of the impact of food waste is growing, a study published in 2016 showed that only 53 per cent of US consumers* were aware that food waste is a problem – even though they throw away approximately 36 billion kilos of food every year. Up to one third of all food is wasted, according to the Food and Agricultural Organization (FAO) and 17 per cent of all yogurt goes to waste every year in the EU, which equals a total of 1.5 million tonnes of yogurt.

Consumers worldwide are demanding food that is less processed and made without artificial ingredients. So a key dilemma for food manufacturers is how to help keep food fresh and safe for longer while keeping products and ingredient lists attractive to the modern consumer? Global bioscience company, Chr. Hansen, recently launched a new generation of natural dairy cultures to help dairy manufacturers – and consumers – tackle the food waste dilemma.

Innovating to make a world of difference
With the recent launch of a new generation of bioprotective food cultures, global bioscience company, Chr. Hansen, is empowering food manufacturers and consumers to tackle food waste. Bioprotection uses nature's own good bacteria to delay spoilage from contaminants, such as yeast and mould in dairy products, to extend shelf life. With a conservative seven days extension, this equates to as much as 30 per cent of yogurt waste which equates to a reduction in EU CO_2 emissions by 520,000 tonnes annually.

Benefiting the entire value chain
With fresher products and longer shelf life, dairy manufacturers can also differentiate their brands, retailers can reduce the risk of waste and customers waste less and save money.

"Consumer awareness of food waste is on the rise – and no one likes to throw away unopened products. Our goal with the new FreshQ® cultures is to help dairy producers around the world to offer longer lasting and great tasting products to their consumers – without compromising their product label," says Peter Thoeysen, Director for Dairy Bioprotection at Chr. Hansen

Chr. Hansen offers bioprotective cultures that keep food fresh and safe for dairy, meat, smoked salmon and ready-to-eat salad.

*Household Food Waste: Multivariate Regression and Principal Components Analyses of Awareness and Attitudes among U.S. Consumers - PLOS research article - Published: July 21, 2016

Innovating to help consumers reduce dairy waste
17 per cent of all European yogurt production goes to waste. 80 per cent of the waste is related to the sell-by date – to products that expire in the supply chain or in the consumer's fridge. The R&D teams at Chr. Hansen have identified food cultures that have the ability to delay the growth of yeast and mould in dairy products. Known as bioprotection, this natural solution can help dairy products stay fresh for longer and embrace the clean label demand. An impact study, conducted for Chr. Hansen, found that extending the shelf life by a mere seven days – a very conservative estimate of the potential with these food cultures – can reduce yogurt waste by as much as 30 per cent in Europe.

Photo: Chr. Hansen

INSECTS AS A SUSTAINABLE PROTEIN SOURCE

Upcycling biowaste and reducing CO_2 with Black Soldier Fly larvae.

Creating value from low value biomass is essential in the bioeconomy. By converting waste with larvae from the Black Soldier Fly, otherwise unused or downgraded resources are transformed into high value protein, oil and fertiliser.

Lasse Hinrichsen, Chief Development Officer, ENORM

By 2050 there will be more than nine billion people on the planet. This will place immense pressure on the planet's resources. The demand for sustainable food production is therefore higher than ever before.

ENORM's mission is to create a food and feed revolution that will lead to consumers eating in a more environmentally friendly manner. Insects are a known sustainable source of protein, and the Black Soldier Fly has the potential to make a sizeable impact. The fly larvae have a short life cycle and are highly effective in converting biowaste into valuable products. At the same time, they can be fed on wet substrates, which means that they can utilise a wide range of available waste products from the food and feed industry. The Black Soldier Fly is therefore superior to other insects that are raised for food and feed.

We are developing the production of an environmentally friendly substitute to other animal proteins and high-quality vegetable proteins, such as fishmeal and soy. In 2022 we will be producing 30 metric tonnes of larvae per day, where most of it will be processed into fish feed and a smaller part of it will be used for food ingredients. From this, three main outputs will arise: insect meal (dried and defatted larvae with 60 per cent protein), insect oil (fat derived from the dried larvae) and fertiliser (larvae manure).

We already have a range of food products with insects on the Danish market that are sold in some of the largest Danish supermarkets. This way, we are successfully nudging the consumer towards accepting insects as food and other production animals fed on insects. We are in the process of automating and scaling up the production of insects for feed.

We have long-term global ambitions, but Northern Europe is our initial target market for the fish feed. Our ambitions mean that we are on the lookout for international partners and international collaboration.

Scientists and the Food and Agriculture Organisation of the United Nations envisage a bright future for insects in the world's food production. The insect industry is presenting a viable solution to many of the Sustainable Development Goals, such as Climate Action, Zero Hunger and Life on Land.

The Black Soldier Fly naturally originates from South America. It has a total lifespan of around 52 days: 2 days as an egg, 18 days as larvae, 12 days as prepupae, 10 days as pupae and 10 days as a fly.

- *It only takes 1.4 kg of feed to produce 1 kg of larvae.*
- *The production of 1 kg of protein from Black Soldier Fly Larvae emits around 100 times less greenhouse gasses than the production of 1 kg protein from beef.*
- *It only takes 1/10 of the space to produce 1 kg of insects compared with beef.*
- *They can be fed on organic waste streams from the food and feed industry.*

Photo: ENORM

GREEN PROTEINS

Upcycling biomass to secure sustainable dairy production.

Increasing the local supply of high-quality protein feed for dairy cows can replace imported feed and create environmental benefits. The BioValue project exemplifies how collaboration can drive sustainability in Danish agriculture.

Anna-Karin Modin-Edman, CSR Sustainability Manager, PhD, Arla Foods

Arla Foods has engaged in the BioValue project with the objective of improving local supplies of high quality protein feed for dairy cows. There is a potential to provide both valuable roughage and green proteins that can be used to replace imported feeds such as soybean meal.

The BioValue project is part of a research and innovation platform that aims to develop the entire biomass value chain with 15 public and private collaborating partners. In this specific project, technologies are developed to separate biomass into components that are either used directly (e.g. proteins) or that can be decomposed into building blocks (e.g. sugar molecules) with subsequent conversion into new products.

The project has developed a method to extract green proteins of different qualities derived from locally grown crops such as grass, clover and Lucerne. The growing conditions for these crops are good in Denmark, the protein delivery per hectare is substantial and they are also beneficial from an environmental perspective. Diversifying crop rotations by using more grass and clover can improve organic content and reduce nutrient losses.

Feed quality is essential in dairy production to secure high yielding and healthy cows. The nutritional qualities of the different fractions of feed in the BioValue project have been assessed and the palatability of the feed seems to be pleasing, which is a critical factor in ensuring the dairy cows consume a high level of feed. The results are promising with regard to maintaining and increasing milk yield when replacing other feed sources with the green protein feeds.

The multiple benefits of locally produced green proteins assist Arla Foods in delivering on the company's sustainable dairy farming strategy, with healthy cows, high resource efficiency, and low negative environmental and climate impacts. Being able to demonstrate a high sustainability performance forms part of our competitive advantages and allows us to gain the trust of customers and consumers both in Denmark and abroad.

Headed up by Aarhus University, the project is scaling up to further assess performance. The pilot plant has increased capacity as well as improved efficiency, which are important qualities to deliver sufficient volumes for the market at competitive prices.

To Arla Foods, the broad partnership with two universities, Agro Business Park and Region Midt and three other large Danish agribusinesses, where Aarhus University is in the driver's seat adds collaborative value, strength and credibility. This project is one of the many solutions needed in the transition to a bio-based society.

Arla Foods is involved in a project which aims to produce more feed protein sourced from home grown grass. The project, which is managed by Aarhus University, can create significant environmental, climate and economic gains. Photo: Aarhus University

Photo: Arla Foods

OBTAINING FOOD SECURITY, IMPROVED NUTRITION AND ENERGY EFFICIENCY VIA FISHMEAL AND FISH OIL

Making full use of the ocean´s resources: increased use of by-products.

The demand for food will grow dramatically by the middle of this century. How can we meet this demand with the lowest impact on the planet? The answer could be hidden in the depths of the ocean.

Anne Mette Bæk, Managing director, Marine Ingredients Denmark

In 2015, global aquaculture production reached 106 million tonnes, achieving an average annual growth rate of 6.6 per cent since 1995. This positive trend is projected to continue; consequently, the aquaculture sector is expected to play a significantly greater role in contributing to food security and economic development in fishing communities.

Marine ingredients are needed to produce healthy fish rich in omega 3. Access to fishmeal and fish oil is therefore essential for further development in global aquaculture production.

More than 30 per cent of contemporary global fishmeal and fish oil production is based on offcuts from fish that is processed for human consumption. In the process of filleting, up to 60 per cent of the fresh fish can be discarded as waste. These by-products contain valuable fish protein and oils, and when used for fishmeal and fish oil, full use is made of the natural resources. The industry thus adds value to this otherwise unused raw material and provides a conduit to transport nutrients from the ocean to the human food chain.

Health benefits

Fishmeal and fish oil provide all essential amino acids, minerals, phospholipids and omega 3 fatty acids (DHA and EPA) and bring those into the human diet.

EPA and DHA are central components in all cell membranes – particularly important for the development of the brain and vision early in life. EPA and DHA contributes to the function of the heart, blood system and immune system.

- Reduces blood pressure
- Reduces risk of cardiac attack
- Reduces inflammation and formation of blood clots

Furthermore, marine fish are also reliant on marine omega 3 fatty acids to varying degrees and fishmeal and fish oil are by far the most valuable ingredients in diets for aquaculture and many land-farmed animals.

The composition of micronutrients in fishmeal, including amino acids, vitamins and minerals, support growth and optimal physiological function of animals and farmed fish. This makes fishmeal and fish oil indispensable feed ingredients.

Energy efficiency

Production of fishmeal and fish oil requires energy. A dedicated effort by the industry has reduced energy consumption effectively. At the same time, surplus heat from the production is efficiently transferred to local heating systems. In Skagen, at the very northern tip of Denmark, the local fishmeal factory provides approximately 25 per cent of the community´s heating, saving the local community considerable cost and making best use of resources.

Aquaculture has been the fastest growing protein sector for several decades and fishmeal and fish oil are important strategic ingredients, bringing the essential omega 3 fatty acids EPA and DHA into the human food chain via farmed fish and fish oil supplements. Photo: Marine Ingredients Denmark

With a yearly production of 150,000 tonnes of fishmeal and 50.000 tonnes of fish oil and exports totaling DKK 3 billion (approximately EUR 402 million), Denmark is Europe's leading producer of fishmeal and fish oil. On a global level, Denmark is the seventh largest producer of fishmeal and the fifth largest producer of fish oil. Production is based partly on fresh landings of small, oily, short-lived fish with no or very little demand for direct human consumption, partly trimmings (leftovers) from the fish processing industry. Photo: Marine Ingredients Denmark

SINGLE CELL PROTEIN (SCP)

Decoupling protein production from farming and fishing.

Transforming biogas - derived from agriculture or food waste - into feed proteins through a fermentation process is a huge challenge. However, an even greater challenge facing humankind is how to adequately nourish a fast-growing global population with food.

Michael Jensen, Group Chief Commercial Officer, Unibio Group

The megatrends speak for themselves; the world is in urgent need of sustainable solutions to overcome contemporary food challenges. Namely, how can a growing world population be fed when agricultural land per capita is decreasing? How can we produce more protein in a sustainable way without destroying the planet?

Unibio's main focus is to deliver solutions to the protein scarcity challenge in an eco-friendly way that reduces environmental issues such as overfishing, deforestation, use of pesticides and fertilisers and depletion of farmlands and water resources. Therefore, as an answer to the challenges mentioned above, Unibio has developed the unique U-Loop® technology and the UniProtein® product. This allows Unibio to produce an ultra-scalable protein variant with the help of a game-changing bio industrial technology that converts methane (biogas) into a highly concentrated Single Cell Protein ("SCP").

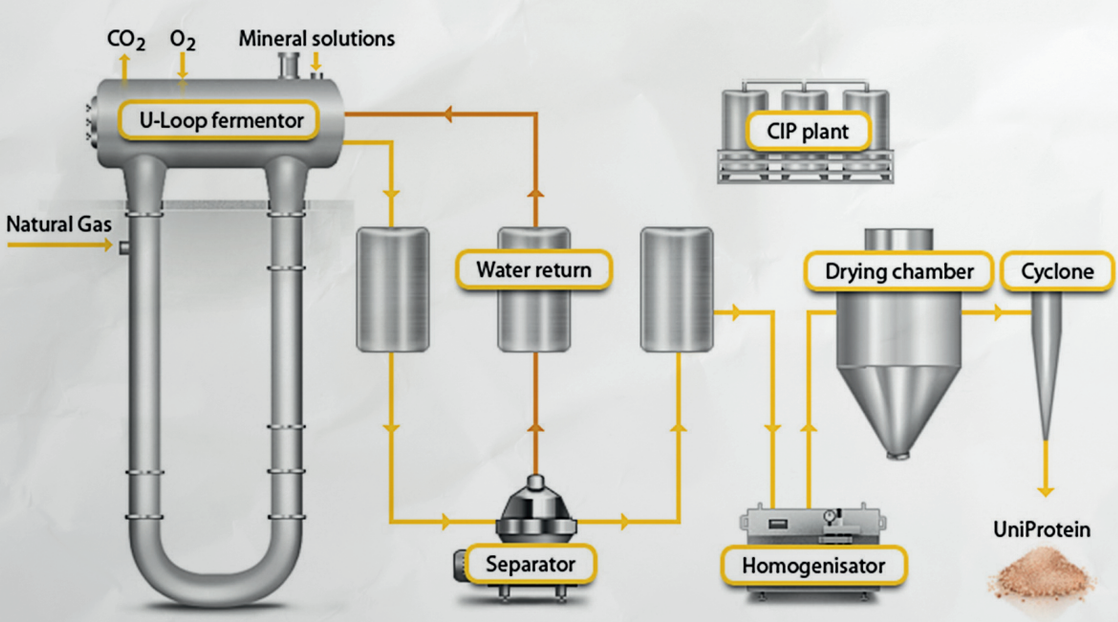
In the process, which is illustrated in the accompanying diagram, biogas is converted into a highly concentrated protein product, suitable as a protein ingredient for animals.

Unibio's bioindustrial innovations make it possible to save energy and water in a manner that is highly sustainable, while simultaneously decoupling protein production from the volatile agricultural sector and stressed fishing industries.

Unibio's work highlights how proteins can be produced by the bio industry. In doing so, Unibio is contributing to disruption of the protein value chain and setting new standards for responsible protein production. By decoupling protein production from fishing and farming, Unibio provides sufficient food for animals without needing to use arable land or limited water resources to produce it.

Unibio's game-changing green technology has been developed in collaboration with the Technical University of Denmark (DTU). The concept is based on converting natural gas or biogas into a highly concentrated protein product, the UniProtein® product, by bacterial fermentation. UniProtein® can be used as a direct supplement in feed for all animals, including fish. A joint venture has recently been established in Nigeria to do so, utilising the country's gas resources.

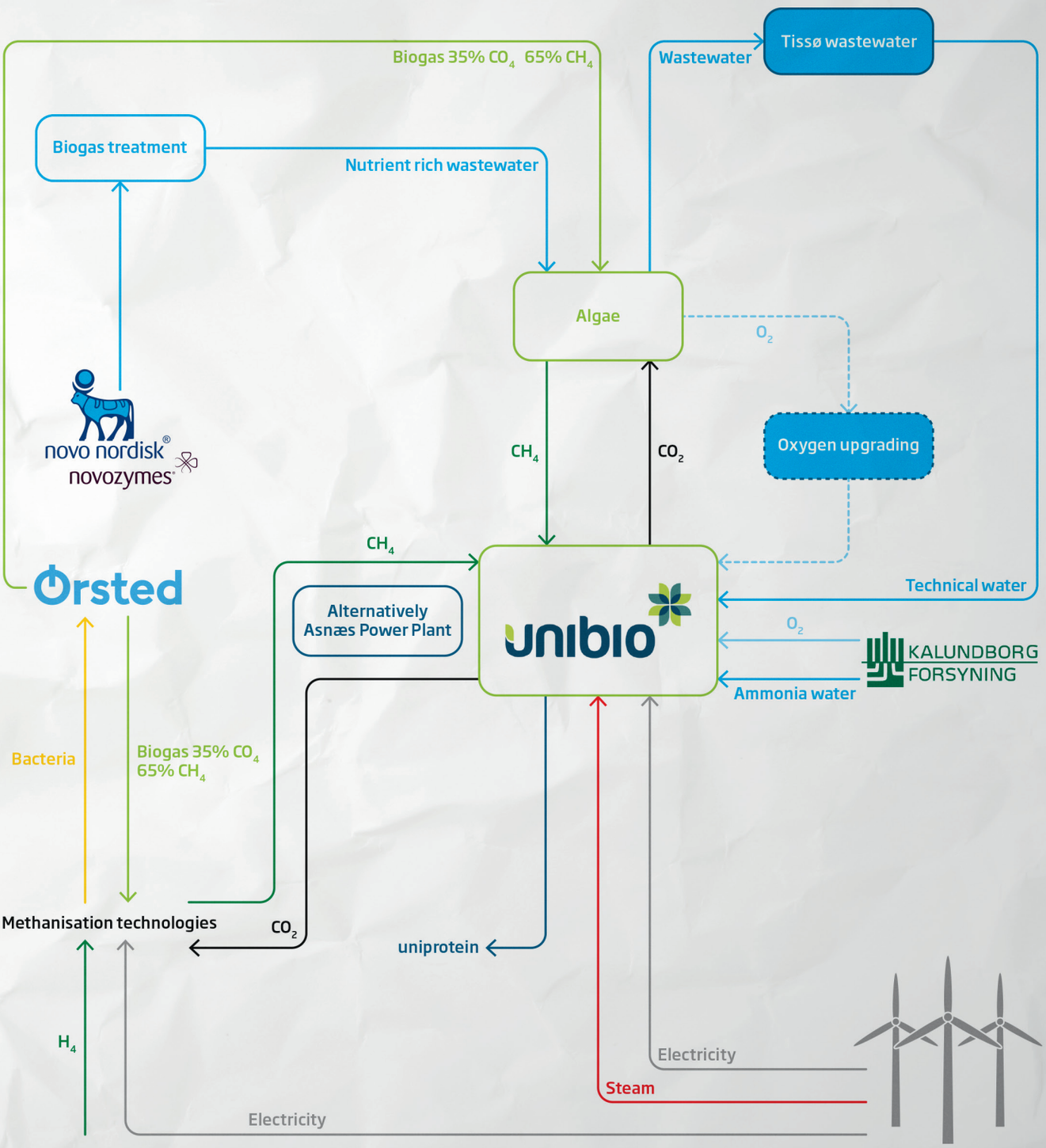
The fermentation technology itself constitutes an economically solid business model with significant growth in predictable and recurring revenue. The patented U-Loop® fermentor facilitates the conversion of bacteria into a protein broth (UniProtein®) with an attractive amino acid profile, especially in terms of essential amino acids. UniProtein® is thus very suitable to replace high-protein feed ingredients such as premium fishmeal in feed recipes for household animals.



The concept of the U-Loop fermentation technology and the subsequent downstream process to provide the UniProtein® product

UNIBIO IN KALUNDBORG, DENMARK

- the sustainable wheels of the setup in Kalundborg, Denmark.



Credit: Unibio

THE ACRE STUDY

Harnessing the power of biotech to produce more feed and energy from one acre of arable land.

The demand for agricultural output is increasing rapidly. The UN projects that in the next 40 years farmers will need to produce more food than they have in the past 10,000 years combined. Via the use of bio-based solutions, Novozymes is reducing greenhouse gas (GHG) emissions while generating additional feed and bioenergy from the same agricultural land base.

Jesper Hedal Kløverpris, Senior Sustainability Specialist, Novozymes

Take one acre of farmland planted with corn/maize, and see how much you can increase productivity. A new report from Novozymes estimates the additional value that can be generated using bio solutions in the agricultural value chain (crop production, livestock production and bioenergy). Using a life cycle analysis, the study begins by looking at an average one-acre U.S. cornfield, which, when using conventional farming methods, produces 153 bushels of corn used to feed 900 chickens.

How much can one acre of corn produce?

Today, one acre of US cropland can provide feed for the production of approximately 900 chickens. The present study indicates that by adding biology to the value chain (enzymes and microbes), continued production of 900 chickens would result and, at the same time, provide 13 US gallons of biodiesel, 3 US gallons of starch-based ethanol, 32 pounds of protein-rich animal feed, 100 US gallons of cellulosic ethanol and 230 kWh of electricity. This extra production was possible with 12 pounds less pure phosphorus in the chicken feed. In addition, the resource savings and the bioenergy production (among other things) leads to a total reduction in greenhouse gas (GHG) emissions of 1.1 metric ton CO_2 equivalents (CO_2e) per acre.

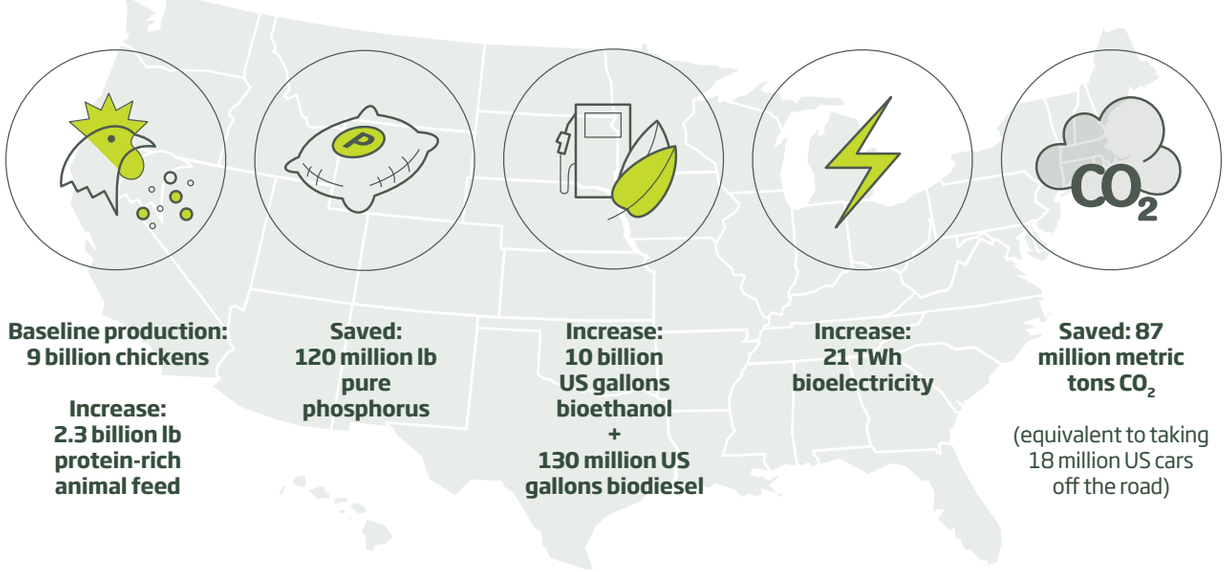
More feed, more energy and reduced greenhouse gas emissions

These results, for just one acre, become substantial when extrapolated to the U.S. national level. If these same bio solutions were applied to all US corn fields and in all of the US's chicken production, it could result in 130 million extra US gallons of biodiesel, more than 10 billion extra US gallons of bioethanol (primarily cellulosic), 2.3 billion extra pounds of protein-rich animal feed, 21 TWh of bioelectricity, 120 million pounds of pure phosphorus saved and total GHG saving of almost 90 million metric tons (equivalent to taking 18 million US passenger cars off the road). This is while maintaining current chicken production on the existing agricultural land base.

Novozymes advances the sustainable use of resources in agricultural production as part of our actions in accelerating progress towards achieving the UN Sustainable Development Goals. Implementing biotech solutions across the agricultural value chain can contribute to climate action (SDG 13), renewable energy (SDG 7), no hunger (SDG 2), no poverty (SDG 1) and good jobs and economic growth (SDG 8).

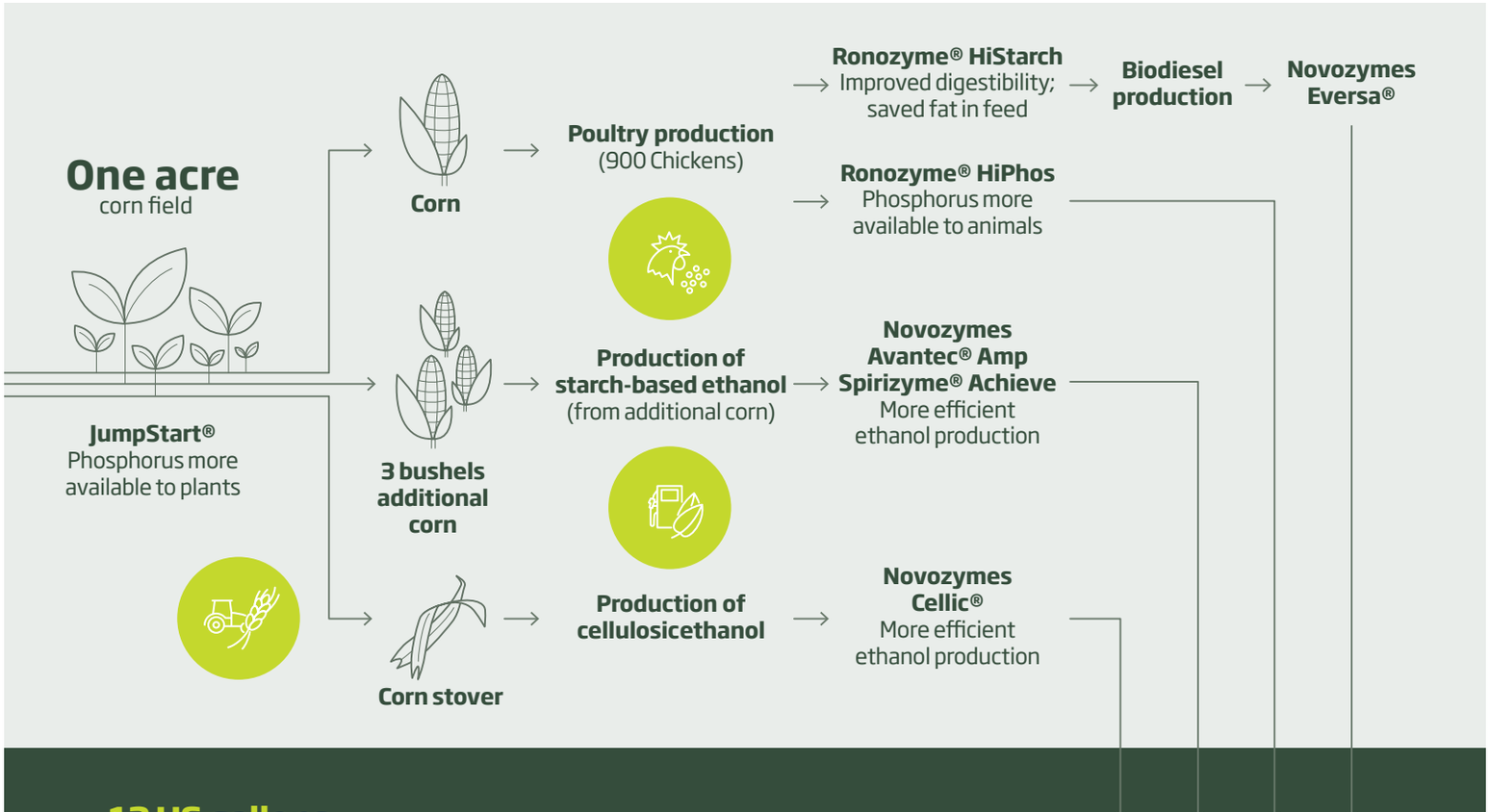
Now let's take it to a bigger scale

What if enzymes were used in all US chicken feed, microbial yield-enhancers were applied to all US corn fields, and biofuels were produced from all the additional corn, freed-up fat, and 30 per cent of US corn stover?



Here's how much more we could get from one acre of corn

Imagine you take one acre of corn, and see how you can increase productivity. New report from Novozymes measures how much more value can be generated using biosolutions in ethanol, crop and poultry production. The results? More feed, food and energy, less CO_2 emissions.



13 US gallons
biodiesel

12 pounds
pure phosphorus saved, reduced feed costs

3 US gallons
starch-based ethanol*

32 pounds
more protein-rich animal feed**

100 US gallons
cellulosic ethanol

230 kWh
electricity

Avoid
1.1 metric tons
of CO_2 emissions

**The three extra gallons of ethanol come from the additional corn obtained with JumpStart® after subtracting the additional corn used in the poultry production caused by the Ronozyme® HiStarch application. **The 32 pounds of protein-rich animal feed includes distillers grains with solubles (DGS) and soybean meal (SBM) saved in poultry production through use of Ronozyme® HiStarch.*

BIO-BASED CHEMICALS BREAK THE BARRIER

The shift from fossil-based to bio-based chemicals has moved closer.

Haldor Topsoe's MOSAIK™ technology produces chemicals from biomass at a cost that competes with that of traditional oil-based chemicals. As demand for sustainable plastics and materials increase, this can be a turning point for bio-based chemicals.

Lars Storm Pedersen, Director Strategic Projects and Asset Management, Haldor Topsoe

Cost often puts an end to the desire of lawmakers, industry, and consumers to replace oil with sustainable raw materials, such as biomass. Market mechanisms make it hard or even impossible to replace low-cost commodity chemicals made from oil with a more sustainable alternative. Today's technologies for producing chemicals and polymers from biomass are simply too expensive. However, new technology can change that.

Haldor Topsoe researchers have devised a novel process that produces several chemicals from biomass – at an attractive cost that can compete directly with similar oil-based chemicals.

A sweet deal from sugar

Topsoe's MOSAIK™ technology converts concentrated sugars into an oxygen-rich intermediary product that is further processed to a number of chemicals with a wide range of applications. Sugars constitute 75 per cent of all biomass and can be obtained from many different sources such as cane, beet, corn and even wood and straw. In fact, there is an abundance of sugars in the world.

One of the chemicals that MOSAIK™ can produce from sugars at a low cost is monoethylene glycol or MEG. It is a very common chemical that is used for PET plastic bottles, food wrapping, polyester fabrics, and many more products. Topsoe and Braskem, a leading producer of thermoplastic resins in the Americas, are currently working on a demonstration plant to further develop, test, and validate the process. The overall goal of the partnership is the start-up of a commercial plant in 2023.

But MOSAIK™ also has the potential to deliver completely new bio-based "building blocks" that can revolutionise industrial processes, lead to new products or improve existing products. Methyl vinyl glycolate (MVG) is an example of a new and highly versatile molecule for use within plastics. It can replace existing materials and also allow for new formulations. All at a price that makes it a commercially interesting option.

Can biomass replace oil?

Not all chemicals can be made efficiently from biomass. In other cases, biomass can not only replace oil – it can be a better option. Biomass offers a lot of "chemical functions" that can be reused or slightly altered. This can reduce the number of steps in the production, which leads to a more effective process and lower cost compared to oil-based production.

MOSAIK™ now shows how to produce a number of bio-based chemicals ranging from well-known commodities to new specialty chemicals in a commercially attractive way.

The global production of bio-based polymers is expected to more than triple from 5.7 million tonnes in 2014 to approximately 17 million tonnes in 2020, which represents a four per cent share of the global polymer production. The demand for sustainable materials for packaging and furniture is the main driver behind the growth and will create a market for e.g. bio-based plastics that can be sold at prices close to those of plastics made from oil. Although the market share for bio-based polymers will remain small compared to oil-based polymers for years to come, the anticipated growth rates are far higher than those seen for conventional polymers. Photo: Haldor Topsoe

Photo: Haldor Topsoe

ADVANCED SUBSTRATE TECHNOLOGY: BIOENERGY AND FOOD PRODUCTION IN THE CIRCULAR BIOECONOMY

High quality mushroom substrate produced using biogas residues.

The Danish company Advanced Substrate Technology transforms residues from biogas production to high quality substrate for mushroom cultivation. After being used for mushroom cultivation, the substrate from the food production can be re-used in a biogas reactor.

Svend Hoff, Director, Advanced Substrate Technologies

Mushrooms are an integral part of the daily intake in many regions around the world. It is expected that the consumption of conventional and more exotic mushrooms in Europe will grow by five per cent per year. This growth in demand calls for sustainable solutions to decrease the environmental impact of this intensive food production. Advanced Substrate Technology (AST) has developed a concept where mushroom cultivation becomes a part of the transition to a circular bioeconomy.

Mushroom substrate
In a biogas reactor, biomass is converted into energy and fertilisers by decomposition of protein, cellulose and hemi-cellulose - but not lignin. From the digestate, a fibre fraction that is rich in organic material can be removed and dried and compacted in a new process. This gives a fibre substrate that is highly suitable for mushroom cultivation.

The circle closes
During the growth process, the mushrooms by enzymatic activities break down the lignin so after cultivation, the spent mushroom substrate becomes a valuable input to the biogas reactor. The overall result is enhanced exploitation of the energy and nutrients' potential in the biomass and sustainable mushroom production without the creation of new waste streams. This concept benefits all stakeholders in the Food Waste - Food Production - Bioenergy value chain, creating added value and has the potential to create new jobs in rural areas.

Proven technologies in a new context
The New Substrate process is based on technologies used in industries where Denmark has a stronghold. The Danish biogas industry has developed through public regulations that promote proper nutrient management and the Danish food sector is widely considered to be among the most effective and innovative in the world. Using AST's concept and technology, nutrient management, bioenergy production and sustainable food production go hand in hand.

Advanced Substrate Technology has received support from Agro Business Park from the very beginning and AST has opened their office in Agro Business Park to continue this cooperation. Agro Business Park is Denmark's only science park specialising in knowledge based innovation and entrepreneurship within agriculture, bioenergy, environmental technologies and food processing.
For more information, please visit www.agropark.dk

By creating a value chain between biogas production, mushroom production and energy and nutrient recovery, it is possible to:

- *Generate high value growth media that is the basis for high value food production*
- *Increase the feasibility of mushroom production by using an easy to store and transport, ready to use advanced substrate*
- *Increase the feasibility of biogas production by re-entering the spent mushroom substrate back into biogas production*
- *Increase energy efficiency from existing 50-55 per cent to 80-85 per cent of biomass in biogas production*
- *Recover nutrients from biogas production*

WHERE BIOGASMEANS BUSINESS

Transforming waste into biogas and fertiliser.

For many, Denmark is synonymous with wind turbines, but bioenergy actually represents approximately two-thirds of the total renewable energy production. Biogas plays a bigger and bigger role: The total biogas production during the last three years is higher than the production the 30 years before that.

Claus Mortensen, Project Manager, Agro Business Park and The Danish Innovation Network for Biomass (INBIOM)

Since the previous Energy Agreement was signed by a majority of political parties in the Danish Parliament in 2012, Denmark has seen a large increase in the number of biogas plants and the production of biogas. Driving this expansion is a €15.3/GJ subsidy plus other support schemes on biogas production that make biogas investments an attractive business proposition. The stable policies have particularly helped stimulate investment in large and professionally run biogas plants that are built to handle waste resources such as livestock manure, thus reducing greenhouse gas emissions while recycling important resources such as phosphorous.

Waste to value in a local circular economy

Biogas production is a good example of the circular economy in practice. In addition to producing renewable energy, thereby reducing greenhouse gases and creating blue collar jobs in rural areas, biogas enables the recirculation of nutrients from different types of waste. This eliminates the dependency on imported fertiliser. Livestock manure and industrial food waste are currently the primary biomass resources, but it is expected that more and more of the organic fraction from household waste will go into Danish biogas plants. This is due to the fact that the Danish parliament has set a target that aims to use 50 per cent of the organic fraction in municipal waste for biogas and fertiliser production rather than going to waste incineration by 2022. Although it is expected that the production of biogas will continue to increase and more plants are being constructed, it will largely be 2nd generation biomass that will be used. Figures from the Danish Energy Agency reveal that the Danish biogas model is based on waste, rather than food: Only 2.4 per cent of the total input in tonnes going into Danish biogas plants were energy crops in 2016. In the same year, it was legal to use up to 25 per cent energy crops in the plant. In the beginning of 2018, this limit was reduced to 12 per cent.

100 per cent biomethane in the gas grid by 2035?

The interest group Green Gas Denmark predicts that Denmark is able to become 100 per cent independent from fossil fuel natural gas. If Denmark succeeds, it would be the first European country to do so. In order to make this a reality, continuous process optimisation needs to take place and large investments need to be made. According to Aarhus University, the green transition will still be sustainable if we use already available straw, household waste and livestock manure in the process.

The high subsidy for biogas has not acted as a sleeping pill. Never has the Danish biogas industry invested so much in the development of new technologies such as pre-treatment of lignin-based biomasses and household waste, gas conditioning, power-to-gas and big data in biogas. Global companies also acknowledge biogas as a key technology in the green transition and Denmark as one of the most advanced countries when it comes to anaerobic digestion; in 2016 Aarhus University signed a cooperation agreement with Apple. The purpose of the collaboration between Apple and Aarhus University is to supply the nearby Apple data centre to run solely on renewable energy including biogas.

Photo: Aarhus University R&D Biogas Plant in Foulum.

AN ENERGY SOLUTION FOR AFRICA

How a high-tech/low-cost mindset brought a Danish company to Africa.

By combining advanced process knowledge from Denmark, cheap manufacturing capabilities from India and a unique, humanitarian business case in a Kenyan refugee camp, MASH Biotech has found a viable solution for powering the African continent.

Jakob Axel Bejbro Andersen, CEO, PhD, MASH Biotech

The energy challenges of the future will disproportionately affect growing populations in the developing world, where lack of infrastructure and capital has historically stifled the development of utility power as it is known in the Western world. Luckily, it is also in the developing world we find the regions with the most biomass to energy potential – central Africa being the clear example. In MASH Biotech, we have set out to exploit this massive resource and at the same time help improve the livelihoods of impoverished populations in Africa and other developing regions.

In MASH Biotech, we realised the potential of addressing both energy-related and humanitarian problems on a grand scale while visiting the remote refugee camp Kakuma in Kenya. Here, more than 150,000 refugees live at the mercy of diesel gensets, requiring massive support via humanitarian aid and adding little value besides electricity to the local population. In MASH, we saw that the gensets could be avoided entirely if our solutions were tailored to produce electricity from the local, widespread, invasive plant species, Prosopis. This would create thousands of local jobs and also result in the production of a valuable by-product "biochar" – a soil amendment material, which could, in time, enable the farming of otherwise arid lands around the camp.

In short, such a solution could contribute substantially to the overall UNHCR goal of creating self-sustaining settlements, instead of camps requiring massive support from the global community.

After realising the humanitarian and commercial potential of using our technology in Kakuma, we set out to develop and perfect a unique, decentralised gasifier in collaboration with our partners in India. Today, the solution is ready for the market in the form of our MB-G100C gasifier. The MB-G100C can provide both baseload and peak load power at unprecedented low cost – enabling payback times of less than three years. Furthermore, it can be set to output a large quantity of biochar for use in enabling /increasing yields from local farmland. MASH Biotech is working with the Kenyan Red Cross in realising the potential of the solution in the country.

However, the potential goes far beyond Kenya. In surveying the biomass availability in countries such as Malawi, Tanzania, Uganda, South Africa and Mozambique, we are beginning to realise that the MASH solution really has the potential to form the backbone of Africa's future power grid.

African rural populations base their livelihoods on farming to a large extent. However, desertification, poor soil quality, conflicts, energy price inflation, fertiliser costs and many other factors mean that this source of livelihood is a precarious one. In MASH Biotech, we have developed a solution, which leverages a local biomass resource in providing sustainable and dependable electricity and soil amendment products, thereby directly supporting the farmer and greatly decreasing exposure to the factors mentioned.

Photo: MASH Biotech

Forest and agricultural lignocellulosic residues are very large potential biofuel resources if available for conversion to biofuels. One critical aspect of such biomasses is the fact that they are distributed in the open rural landscape and therefore must be collected, stored and transported before final use. The key to any bioenergy project is therefore to ensure the raw material supply and its quality. We provide that key through local preprocessing and compression into high density briquettes.

We simply unlock the technical biofuel potential of the vast resources of lignocellulosic biomass that otherwise would have been lost. The biomass can now be converted to fuels such as bioethanol and biomethane or incinerated for heat and power.

One record estimates that one third of all European transportation fuels potentially can be met by biofuels; which is a very significant - and everlasting - fraction.

Local satellite stations situated at the origin of the various residues provide an opportunity for foresters, farmers and landowners to operate their own station or to supply their excess residues to a briquetting station. From the local station, the densified biomass can be distributed to a central facility or to consumers.

Biogas is one dominating biofuel in Europe; with addition of briquetted cereal straw, any biogas plant can more than double its methane output. Also, the lignocellulosic raw material is in stable supply and can be contracted for several years. With known biogas output, costs, and prices, any business case can be calculated and ensured. Hence, the ground is prepared for rapid expansion of biofuel production.

We provide mechanical presses for any purpose and at virtually any capacity. We preprocess and compress the material at the lowest possible energy and maintenance cost as compared to alternative technologies for densification of woods or cereal straws. Keeping the processing cost minimal is key to rendering potential biomasses available for actual bioenergy use.

Our energy cost is no more than about 75 kWh per tonne of material and maintenance cost is generally no more than about 5 Euros per tonne. This is unparalleled by any other technology.

Kinetic BioFuel A/S
C. F. Nielsen A/S
BioFuel Technology A/S
Aarhus University
Danish Governmental R&D funding (EUDP)

Gemidan has since 2012, supported by the Danish Market Development Fund, worked with the purpose of developing a new pre-treatment technology to process source separated food waste and producing a high-quality pulp for anaerobic digestion (AD) plants. For the past six years, the Gemidan facility in Holsted, Denmark has been testing and refining its ECOGI pulping system. During the last five years, the facility has also operated at commercial scale.

Gemidan Ecogi has now installed a 24,000 tonnes per year facility to process waste collected from six municipalities in South Zealand. The plant will produce a high-quality, pulp-based substrate which will be distributed to local AD facilities. The site benefits from an on-site energy from waste operation and a supply of process water from a nearby water treatment plant. Pulp from the new facility will mainly be used to generate biogas for upgrade and injection into the Danish natural gas grid.

By extracting value from the resources hidden in rubbish bins, Gemidan is supporting the transtition to a bio-based, circular economy.

Gemidan Ecogi A/S
Lars Ravn Nielsen

WATER-EFFICIENT POULTRY PRODUCTION

How a simple step can reduce water usage by 50 per cent.

The Danish company HKScan has an ambition of reducing its overall water usage by up to 10 per cent in its poultry abattoir business. It can do so by directing the water it uses to rinse the chickens' feet against the current. This surprisingly simple method allows for water reductions of 100m³ per day.

Hanne Skov Bengaard, Partnership Manager, DRIP

Water, energy and food production are intextricably linked. Agriculture is the largest consumer of the word's freshwater resources and one quarter of global energy usage is expended on food production. At the same time, while population growth is slowing, an additional one billion people will be added to the globe by 2030. Providing sustenance for these additional citizens without further straining water supplies or increasing energy consumption will be of paramount importance.

In the small Danish town of Vinderup, with its approximately 3,200 inhabitants, poultry plays a key role, so much so that the there even is an annual chicken festival. The town is home to HKScan, which processes and prepares poultry for export. In recent years, HKScan has experienced increased demand for its products and has therefore expanded production. Although the company had already reduced water consumption by 20 per cent, it wanted to do more.

Simple solution = Large water savings

Chicken feet are one of HKScan's business lines. Before the feet can be packaged and exported, they are exposed to a lot of water – not only to soften them so the skin can be removed, but also to cool them down. In all steps of the process, clean water is used and then sent to the factory's wastewater treatment facility. In the new process, water is pumped counter-clockwise, so the water is moved from the clean processes in the cooling to the previously dirty processes. In this way, only clean water must be added to the last part of the process. It reduces both water consumption and produces less wastewater. Furthermore, the water temperature in the disposal process can be reduced from 55 to 35 degrees without affecting either hygiene or product quality, thus leading to energy savings.

Realising both water reductions and energy savings

With the new method, HKScan will be able to save 50 per cent of its daily water usage in its food production. This amounts to approximately seven per cent of the factory's overall water consumption and saves almost EUR 100 per day in energy expanded on heating the water that cleans the chicken feet.

Resource and water-efficient industrial food production

The company HK Scan is part of DRIP – the Danish partnership for resource and water efficient industrial food production. DRIP is a public-private partnership focused on water efficiency in the food industry, one of the largest water consuming industries in Denmark and globally. The partnership consists of 14 food companies and five research organisations. DRIP seeks to develop new sustainable water and production technology solutions that can reduce water consumption in industrial food production by 15-30 per cent - without compromising on food safety or quality.

Photo: HKScan

DISCOVER THE SECRETS TO DENMARK'S PATH TO A CIRCULAR BIOECONOMY

Connecting, inspiring and sharing Danish know-how within the bioeconomy and resource-efficient production.

The concept of producing energy based on biogas and biofuels is relatively well established. Less well known is the possibility to utilise renewable biological resources from both land and sea to produce food and animal feed, materials, energy and high-value products. Known as the bioeconomy, Danish companies, governmental authorities and civil society organisations are engaged in making this a reality.

Finn Mortensen, Executive Director, State of Green

The global reliance on fossil fuels and linear production and consumption models cannot continue if we are to sustain our growing population. We require a new economic paradigm that can reduce environmental degradation and eliminate waste. Known as circular bieconomy, it entails the use of biomass in industries such as food, pulp and paper, as well as chemical, biotechnological and energy industries and in primary production, such as agriculture, forestry, fisheries and aquaculture. Agriculture in particular is key to a successful transition to a circular, bio-based economy, where fossil fuels are replaced by agricultural biomass sources.

Doing so will help achieve a low-carbon society that practises sustainable agriculture, ensures food security, and simultaneously preserves biodiversity, protects the environment, as well as making sense from an economic perspective.

Agricultural biomass for resource-efficient production

Approximately 66 per cent of land use in Denmark is devoted to agricultural and food production. An early pioneer of the so-called triple helix approach, the country has a strong track record of developing partnerships between research institutions, governmental authorities and industry to develop solutions that allow for responsible production and consumption. Danish governmental agencies, scientists, companies and farmers are forging ahead with the development of new and innovative methods to refine agricultural biomass from residual straw, wood and algae and organic waste to create end-products such as energy, biofuels, feed protein, food ingredients, chemicals, building materials, bioplastics and medicines.

Tap into Danish competencies to secure resource-efficient, sustainable agricultural and food production

State of Green is a not-for-profit, public-private partnership from Denmark. We facilitate relations with international stakeholders and are your one-point entry to all leading Danish actors working to drive the global transition to a sustainable, low-carbon, resource-efficient society.

Our web portal, www.stateofgreen.com, allows you to access Danish solutions and competencies from public and private actors alike, free of charge. It provides a window into Danish competencies with the circular bioeconomy and resource-efficient production, including facts, news and a green database where you can search for partners and learn more about their technologies.

By accessing www.stateofgreen.com, you can learn more about, for instance, how Denmark has achieved leading competences in plant breeding and has the world's highest utilisation of residual products from agriculture – and delve into the 1,400 plus cases, R&D projects, policy initiatives, products and services we feature on our site.

ABOUT STATE OF GREEN

State of Green is a public-private partnership founded by the Danish Government, the Confederation of Danish Industry, the Danish Energy Association, the Danish Agriculture & Food Council and the Danish Wind Industry Association. H.R.H. Crown Prince Frederik of Denmark is patron of State of Green.

Connect through: **www.stateofgreen.com**

Learn more about Danish bioeconomy and resource-efficient solutions, find more cases from around the world and connect with Danish expertise at:

stateofgreen.com

State of Green facilitates relations between Danish and international stakeholders seeking to drive the global transition to a sustainable, low-carbon, resource-efficient society. We are a not-for-profit, public-private partnership founded by:

Confederation of Danish Industry

DANISH ENERGY ASSOCIATION

Danish Agriculture & Food Council

DANISH WIND INDUSTRY ASSOCIATION

Ministry of Industry, Business and Financial Affairs

Danish Ministry of Energy, Utilities and Climate

Ministry of Environment and Food of Denmark

Ministry of Foreign Affairs of Denmark