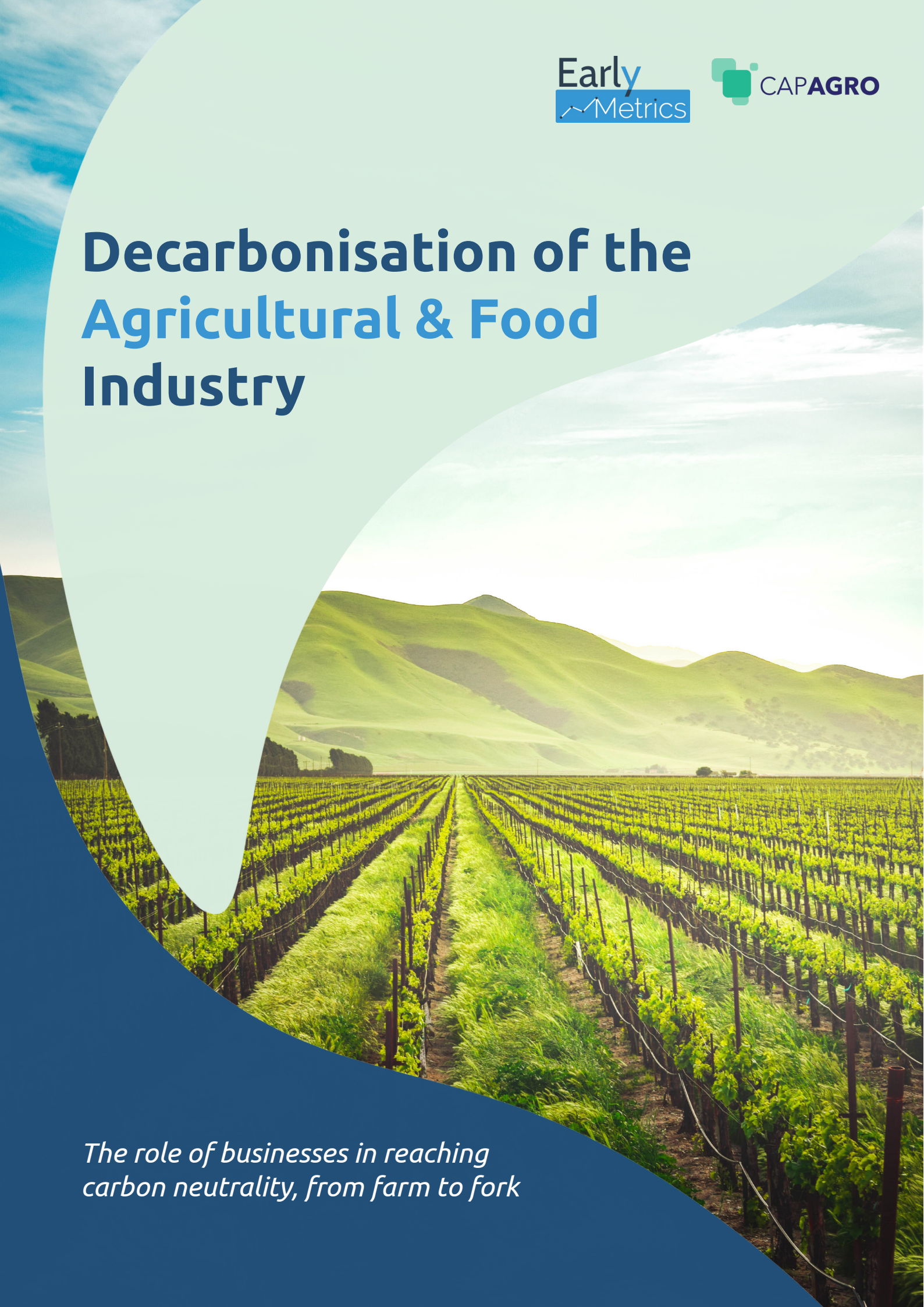
Decarbonisation of the Agricultural & Food Industry



The role of businesses in reaching carbon neutrality, from farm to fork

“Decarbonisation of the agricultural and food industry”
was produced in partnership by Capagro and Early Metrics.

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Foreword

Tackling climate change is one of the biggest challenges faced by humanity. Reducing the amount of carbon dioxide and greenhouse gas emissions is paramount to address global warming and preserve the planet. In recent years, a growing number of businesses in the agricultural and food sector have expressed their commitment to reducing their carbon emissions. However, decarbonising such a large and globalised industry requires complex measures throughout the value chain.

Early Metrics, the international startup rating and research agency, and Capagro, the French leading venture capital fund dedicated to the Food and Ag industries, have partnered to help players in this sector accelerate their decarbonisation. In this white paper, they have highlighted some of the key innovations and resources that can enable carbon footprint reduction at all stages of the agriculture and food value chain.

The insights found in this paper have been collected through an in-depth review of the available literature, recent policies and news relating to the decarbonisation of the food and beverage sector. Moreover, the authors interviewed several entrepreneurs, public sector representatives and senior professionals from large companies. Some of the case studies were identified via Capagro's portfolio of startups and Early Metrics' database of rated startups.

Both Early Metrics and Capagro have experienced first-hand how startups can bring game-changing approaches, tools and solutions to market. The case studies presented in this white paper are not meant to be exhaustive, but rather provide inspiration for concrete steps that could be taken to address different sources of carbon emissions.

The authors share the belief that collaboration between public institutions, large industry players and startups is essential to bring about meaningful and sustainable change. Hence, they hope that this white paper will encourage further collaborations in the agricultural and food industry.

PACKAGING

PRODUCTION

PROCESSING

DISTRIBUTION

Introduction

The food industry is facing two major challenges: **ensuring global food security for a growing population and reducing its carbon footprint to preserve the planet**. The world's population grows at an average of 83 million people per year and, in 2020, 690 million people or 8.9% of the global population suffered from severe food insecurity (FAO). Meanwhile, about 1.3 billion tonnes of food, representing nearly one third of all food produced, goes to waste each year. This not only constitutes an economic and social disaster, but also an environmental one: it is estimated that if total global food waste was a country it would be the third worst emitter of greenhouse gases (FAO, WRI).

Aside from waste, food production has a significant carbon footprint with emissions sources at all stages of the value chain:

- Production (synthetic fertilisers, soil degradation, enteric fermentation, deforestation…)
- Processing (heat treatment, refrigeration, waste mismanagement…)
- Packaging (non-biodegradable and/or non-recyclable materials…)
- Distribution (transportation, post-consumption waste…)

The intergovernmental panel on climate change (IPCC) found that **Agriculture, Forestry and Land use directly accounts for 23% of global greenhouse gas (GHG) emissions**. The food system as a whole – including refrigeration, food processing, packaging, and transport – is estimated to represent 21 to 37% of GHG emissions (IPCC). In the European Union (EU), agriculture accounts for about 10% of the region's carbon emissions (Eurostat, 2018).

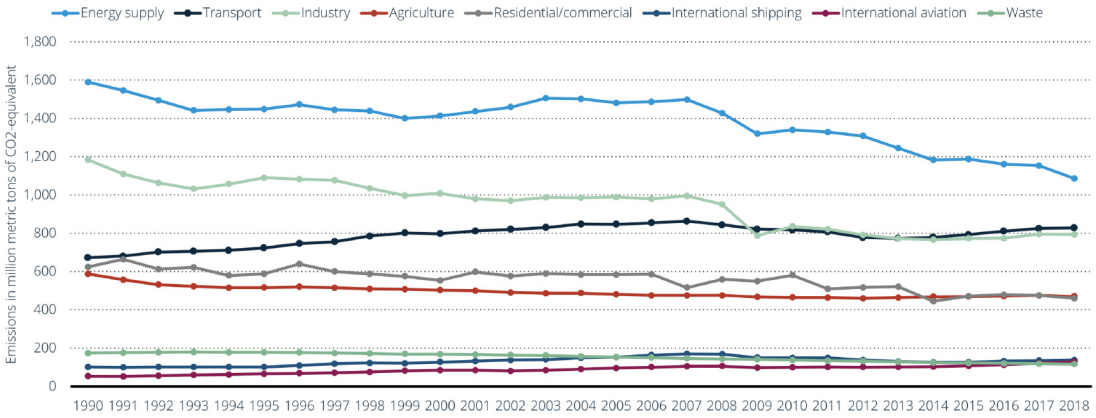
To meet global targets for both food security and carbon emissions, the agricultural and food industry has to change its processes and adopt decarbonisation strategies. Indeed, **governments across the world have committed to ambitious goals to tackle climate change**. Since 2016, 191 countries have signed the Paris Agreement, a legally binding United Nations (UN) treaty which aims to limit global warming to well below 2 degrees Celsius compared to the pre-industrial average. In April 2021, the EU set itself a target to reduce carbon emissions by at least 55% by 2030, compared to 1990 emission levels. The EU also aims to reach carbon neutrality by 2050. Moreover, the European Green Deal was introduced in 2019 to "boost the efficient use of resources by moving to a clean, circular economy" and "restore biodiversity and cut pollution" (European Commission). The **Farm to Fork strategy** is one of the cornerstones of the deal and it entails among other things:

- the introduction of legally binding targets for food waste reduction by 2023
- the development of a sustainable food-labelling framework
- the promotion of organic farming, with the goal of 25 % of total farmland being used for organic farming by 2030
- €10 billion under Horizon Europe to be invested in R&I related to food, bioeconomy, natural resources, agriculture, fisheries, aquaculture and the environment.

The Green New Deal is supported by the Common Agricultural Policy (CAP), as it was announced in May 2020 that 40% of the CAP budget would go towards climate-relevant initiatives. Through the CAP, farmers from Member states can also receive advisory services on how to best implement carbon reduction strategies.

For these ambitious targets to be realistic, it is assumed that industry players will enact comprehensive changes to their activities in order to cut down GHG emissions. Recent data and research suggest that drastic reductions in carbon emissions are yet to be seen. The graph on the right shows that annual **GHG emissions in the EU from most industries have remained fairly stable between 2009 and 2018**, with the exception of the energy sector which has seen a stronger decline in emissions. While agriculture is not the most polluting sector, its emissions have been declining at a very slow pace. It is difficult to ascertain the evolution of emissions coming from other parts of the food and beverage value chain, such as processing and distribution, as they fall under the wider categories of industry, transport or shipping. We should acknowledge that 2020 saw global GHG

Annual greenhouse gas emissions in the European Union from 1990 to 2018, by sector (in million metric tons of CO2-equivalent)



Note(s): EU; 1990 to 2018
Source(s): Statista, EEA; ID 1171183

emissions fall by 6.4%, or 2.3 billion tonnes due to the Covid-19 pandemic shuttering a vast portion of the global economy. Nevertheless, **experts do not expect 2021 to follow the same trend**, as business as usual gradually resumes. Furthermore, aside from hospitality providers, and compared to other sectors, the food and beverage sector was only mildly impacted by the pandemic.

Several industry leaders have announced decarbonisation targets and initiatives which are aligned with the EU's guidelines. Anecdotal evidence points towards a sharp rise in awareness of the climate crisis among businesses and an acceleration of related actions in the past four years, particularly following the emergence of social movements such as the climate strikes and Extinction Rebellion. Among the examples of actions taken by large companies, we can cite Danone's baby formula production site in Wexford (Ireland) which became carbon neutral in 2020 through the use of 100% renewable energy, a zero-waste to landfill strategy, and digital technologies to address inefficiencies. This milestone fits within its €2 billion climate acceleration plan to fund the transformation of its agriculture, energy and operations, packaging and digital capabilities between 2020 and 2022. Both Nestlé and PepsiCo, on the other hand, have outlined decarbonisation strategies centred around sustainable sourcing of raw materials (e.g. regenerative farming, deforestation-free supply chain...). As part of its sustainability pledges, the Irish food manufacturer Greencore announced in November 2020 that it was developing a fully recyclable sandwich skillet and that it would donate all surplus products to local communities by 2022. The dairy producer Groupe Bel is also deploying several programs including "Water Saving at Bel" and "Energy Saving at Bel" to curb its consumption of water and energy.

While writing this white paper, we reached out to several European leaders in the food and beverage sector to find out more about the specific decarbonisation actions they planned to take. Many preferred not to comment, with some citing confidentiality concerns over their strategic plans; others stated that their decarbonisation actions were at too early a stage to share. Another blocker seemed to lie in the difficulty of finding the right spokesperson within their group who would have a comprehensive view of their company-wide decarbonisation efforts. Indeed, as we will detail in the following pages, a wide range of departments and activities need to be addressed in order to reduce carbon emissions on a group level. Our exchanges with industry professionals highlighted that not all food and beverage companies have the same level of maturity, and that **most are in fact only in their early days of implementing decarbonisation solutions**.

Meanwhile, **the European startup ecosystem is seeing a growing number of innovative solutions arise in the food and agriculture space**, some of which could reduce the industry's carbon footprint. There are also signs of growing investment appetite for Foodtech and Agtech solutions. In 2020, European Foodtech unicorn companies reached a combined value of €92bn according to Dealroom and European Foodtech startups raised €2.7bn according to DigitalFoodLab. Of course, not all of these startups address decarbonisation, but some do offer relevant solutions. In the following chapters we will highlight a selection of the most promising startup technologies which could be leveraged within a decarbonisation strategy.

The role of public institutions

Public regulations and incentives can have a strong impact on the pace of industrial and environmental change. As mentioned earlier, European governments have set up ambitious targets for carbon emission reductions accompanied by policies, frameworks and funding plans. Here we take a closer look at how the three biggest economies in Europe (Germany, France and the UK) are addressing the decarbonisation of the agricultural and food sector.

France

France is home to some of the largest agriculture and food players in Europe and the French government has put in place several funding schemes and resources to help them accelerate their decarbonisation.

Many of these initiatives have been and continue to be carried out by its **public investment bank, Bpifrance**. Most recently, as part of the country's Covid-19 Industrial Recovery Plan ("Plan de relance pour l'industrie"), the bank has been issuing grants to companies wishing to lead projects with strong social and environmental impact. By the end of 2020, over **1000 companies in several sectors had benefited from this scheme**, including Groupe Lesaffre, the world's largest yeast manufacturer. Bpifrance also provides advice for agriculture and food companies to build and implement sustainability strategies, through Diag Eco-Flux for instance.

Speaking to **Ariane Voyatzakis, Head of the Agrifood sector at Bpifrance, and Benoît Calatayud, Managing specialist - Energy transition at Bpifrance**, it transpired that their view of the government is that of a facilitator of the decarbonisation of the industry. "Public bodies provide the frame, in the shape of laws and incentives, while private companies make the picture," said Calatayud. "So public frameworks are essential because they complement private efforts, especially public economic incentives which allow to bridge the gap in terms of market demand or private initiatives." **For Voyatzakis, most industry players have now realised that their environmental and business issues are interlinked**: "Energy is a significant source of expenditure for large agrifood groups, hence improving their energetic efficiency is aligned with both their sustainability and profitability goals, not to mention their consumers' demand for more eco-friendly products."

Voyatzakis and Calatayud share the opinion that synergies between startups and corporates are needed to meet decarbonisation goals. Startups can offer corporates new perspectives and solutions, while corporates can enable startups to scale, they said. According to Voyatzakis, carrying out more precise carbon tracking and more educational initiatives would enable industrial players to speed up their decarbonisation.

United Kingdom

In 2019, the UK became **the first European country to pass net-zero emissions into law**. Since then, the government has introduced increasingly stringent regulations to monitor and reduce the agriculture and food industry's carbon footprint. For example, supermarkets and food businesses with more than 250 employees and £36m in annual turnover are now required to report on direct and indirect emissions under the government's Streamlined Energy and Carbon Reporting policy, to help the country become carbon neutral by 2050.

Aside from regulations, the British government is also launching new schemes to incentivise sustainable farming and food production. For instance, in 2021 the Department for Environment, Food and Rural Affairs (Defra) announced the creation of the **Sustainable Farming Incentive** which will be launched mid-2022. The Food and Drink Federation also runs the FDF Awards which, among other things, rewards environmental leadership and sustainable packaging innovation.

The **Knowledge Transfer Network** or KTN (Innovate UK's network partner) is yet another public institution which helps British startups and corporates connect to bring about pioneering innovations, including in the food and drink sector. **David Telford PhD, Head of AgriFood at KTN** stated: "Startups play a very important role in the reduction of the food industry's carbon footprint, as they will lead on the development of a lot of the technologies that the wider industry will later adopt."

Germany

Similarly to France and the UK, the German government has shown its commitment to decarbonisation through new regulations and various funding schemes for innovation. A significant proportion of public initiatives are centred around **clean energy and energy efficiency**. At the start of 2021, the federal government introduced CO2 pricing on fossil fuels for heating and transport at 25 euros per ton of CO2, as part of its climate package. Meanwhile, the public investment and development bank **KfW provides several loan and grant schemes** for private projects relating to renewable energy, energy efficiency and climate protection.

Alexandra Khripko, Senior Expert in Start-ups in Renewable Energies and Mobility at dena (the German energy agency) commented: "Without the full participation of the food industry, much of our global net-zero goals would not be met. This is why new innovations, especially from the energy sector, can support industries in reducing their emissions and reaching their decarbonisation goals." Among the initiatives carried out by dena to support such innovations, the Start Up Energy Transition (SET) Award and Platform help connect innovative newcomers in the clean energy and mobility space with industry leaders.

Regarding the agricultural and food sector, in April 2019, the Conference of Agricultural Ministers adopted the **Agenda for Climate-change Adaptation in Agriculture, Forestry, Fisheries and Aquaculture**. This agenda includes many measures to guide companies in the reduction of their carbon footprint. In November 2020, Germany also became the first country to invest in the **World Bank's Food Systems 2030 Trust Fund**, with the aim to promote new agriculture and food models on a global scale that simultaneously improve the health of people and of the environment by 2030.

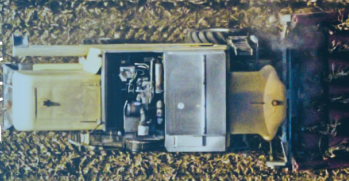
PRODUCTION

Farmers have been pressured to meet growing demand while keeping their prices competitive and their costs low. This has led many to prioritise yield optimisation over sustainability, adopting practices that have negative effects on soil nutrients, biodiversity and GHG emissions. Several large food and drink manufacters have in fact identified unsustainable raw material production as one of their biggest carbon emission sources.

European policies and new consumer expectations are now leading agriculture players to reconsider their traditional ways. Thankfully, the startup ecosystem is emerging as a valuable source of solutions to help agriculture shift towards greater sustainability.

In the following section, we will look at several of these innovative solutions aimed at reducing carbon emissions at the production stage. We will analyse innovations relating to:

- Alternative agricultures
- Inputs
- Animal feed
- Alternative proteins
- Cellular agriculture
- Robotics



CASE STUDY: CleanGreens

CleanGreens Solutions SA (formerly CombaGroup SA) provides an innovative **mobile aeroponic solution** to grow fresh, environmentally friendly, and nutrient-rich leafy greens. CleanGreens offers its clients a solution that aims to bring production closer to consumption centres.

"This mobile aeroponic solution uses less water, increases yield and extends the shelf life of leafy greens."

CleanGreens system is exceptionally efficient, with **97% less water use than traditional agriculture and 30% less than hydroponics**. Aeroponics' main advantages are an unlimited amount of oxygen available to the roots and the non-propagation of pathogens since each plant is independent of each other.

As a critical enabler, CleanGreens' systems address many environmental and social challenges: soil depletion, water scarcity, pesticide residue contamination, population growth, social pressure for transparency in the food chain and increasing urbanisation. Through its unique growing system, CleanGreens strives to achieve sustainable improvements in two main focuses: locally grown high-quality produce and profitable production.

In terms of agronomy, quality and product size, mobile aeroponic irrigation systems allow to produce large heads of leafy greens and plants with a high level of consistency and quality. This brings benefits to processors and the foodservice industry, as it increases yields (less waste) and extends shelf life (fresher, more resistant leaves).

As a scale-up company, CleanGreens' vision is to create long-term value while preserving the environment. To this end, the company strives to reduce its footprint and control its social impact. Through collaborative efforts with other innovating startups and large companies, CleanGreens pursues opportunities in the fields of energy efficiency, robotisation of operations and decarbonisation, including projects of circular economy with companies like Air Liquide and Nestlé.

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Alternative agricultures

- **Novel farming systems accounted for 5% of total Agritech investments in 2020**, which corresponds to 99 deals or $1.3bn.
- **A fully agro-ecological Europe could sustainably feed 530 million Europeans by 2050 and lead to a 40% reduction in GHG emissions.** (Institute for Sustainable Development and International Relations)

Traditional agricultural practices can release CO2 trapped in soils and often imply unefficient use of resources, such as water and fuel. Certain fertilisers and pesticides can also have negative effects on human health and biodiversity.

The first answer to using less resources and producing healthier food is to adopt **nature-inspired practices** such as no-till, cover crops, agroecology and so on.

This way of producing food is a holistic approach based on several principles like using renewable resources and relying on biodiversity to provide ecosystem services and resilience. It is also in line with a **current social movement defending small scale and family farming.**

New ways of farming, such as vertical farming, indoor farming, aquaponics and hydroponics also aim at making a better use of resources. While it is not always clear whether these practices result in reduced carbon emissions, they have clear advantages like using less water, less soil, less pesticides and herbicides. They often are a solution for **growing food closer to the consumer**, which in turn reduces transportation emissions and potentially limits waste.

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Opportunities:

- With many vacant spaces, especially on rooftops, **cities have an underutilized productive capacity**. Integrated into buildings, greenhouses can produce food in the heart of urban centers, create employment opportunities, improve urban aesthetics and biodiversity. They also make it possible to benefit from unused resources (surplus energy, carbon dioxide capture, water carbon dioxide, rainwater harvesting, etc.) while reducing the ecological footprint of the buildings themselves.

- Efficiency will keep on improving energy-wise, and there is a wide opportunity to integrate **alternative energy sources**. Growers are already using alternative approaches such as cogeneration, geothermal sources, and waste heat networks. H2Orto tomatoes are grown in greenhouses heated with biogas-generated hot water. Gotham Greens uses 100% renewable electricity-powered greenhouses, and Nordic Harvest will be running Europe's largest indoor farm using wind power only.

- The next innovation layer will be about **crop optimisation, going towards autonomous control of the growing environment**. This trend will be enabled by multiple technologies such as imaging and sensor platforms (Ecoation, iUNU, 30MHz...), data analysis, machine learning and artificial intelligence. Startups like the Blue Radix Crop Controller and Priva's Plantonomy, that create autonomous growing innovations, promise to extend and enhance the reach of available grower expertise, particularly in large and multi-site operations.

- The recent public offering and **$3 billion market cap of AppHarvest** also clearly raised awareness. Other high-profile and expanding greenhouse growers, including BrightFarms and Gotham Greens, have attracted large investments.

Challenges:

- Transitioning from a conventional to an agroecological or even organic farm is a long and tedious process. Adapting the soil, farming practices and still achieving good yields represents **a huge investment in time and money** for the farmer, who often finds it difficult to support all the costs.

- **Vertical and indoor farming have also struggled with financial viability** and this has consequently limited what can be grown this way. The cost of energy can be significant, and some crops are much more expensive than others. The challenge is to recreate the soil, light and nutrition conditions of indoor plants in a small space. Vegetable gardens are generally self-managed and offer a variety of seeds. Thus, the modules are highly technological and include connected sensors for resource management. In addition, growth rates need to be accelerated, which makes resource management more complex.

Inputs

- **The market value of conventional crop nutrition was $155bn in 2018** (Sofiprotéol)
- **The green crop nutrition market was worth $18.5bn in 2018**, and is expected to grow by 10% (CAGR) between 2011 and 2021 (Sofiprotéol)
- **10% is the expected CAGR of the global green chemicals market** from 2019 to 2023 (Bloomberg)

Traditional practices and chemical inputs like N,P,K are responsible for a large part of the agriculture's greenhouse gas emissions. **40% of the emissions of the agricultural sector are due to nitrogen fertilizers.** In France for example, the manufacture of one ton of ammonia emits an average of 2 t eq CO2 (Réseau action climat).

It is now commonly agreed that management practices which increase carbon storage in soils and biomass should be widely developed.

Biocontrol brings many solutions when trying to lower agriculture's carbon emissions, in addition to reducing the toxicity of crop protection and nutrition products for humans and the environment. **Biocontrol is a set of plant protection methods based on the use of natural mechanisms.** Alone or combined with other means of plant protection, these techniques are based on the mechanisms and interactions that govern the relationships between species in the natural environment. Thus, the principle of biocontrol is based on the management of the balance of populations of aggressors rather than their eradication.

Biocontrol products include in particular macro-organisms and plant protection products that are composed of microorganisms, chemical mediators such as pheromones and kairomones, or natural substances of plant, animal or mineral origin.

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Opportunities:

- While some startups are focusing on **plant extracts**, like Antofénol or Axioma, others are specialised in **microorganisms**, like Biolevel, Biome makes, Boost Biomes, Growcentia. Some are developing innovative **discovery platforms** to develop a wide range of new active compounds like Plant Response or Micropep.

- **Investment is increasing in the field**, with examples like DuPont and BASF who invested $36.5m in Provivi in 2018. The startup using pheromones to protect crops from major damaging insects. We can also cite the Joyn Bio joint venture founded In 2017 by Bayer and Ginkgo Bioworks to develop probiotics for plants, which has raised $200m in total.

- **Agriculture has a great potential to be a carbon sink** when farming practices are sustainable and also when soils are healthy. A new generation of companies are focusing on regenerative agriculture and soil health. French startup Greenback, for example, is the first worldwide agency for soil health rating. According the the USFRA association, more than 150 companies currently support digital data collection, analysis and sharing for climate-smart soil agriculture. By 2025, widespread adoption of climate-smart agriculture practices could reduce U.S. agriculture's contribution to total U.S. GHG emissions by more than half, from 9.9% to 3.8%

Challenges:

- Users expect biocontrol products to be as effective as conventional solutions. But they often point out irregular efficiency and a high price. However, as research advances, products show more and more performance, with a deeper and deeper understanding of their mechanism of action. Their application might be different from conventional products, as well as the whole crop management strategy, which means the farmers need to change their habits and learn new methods.

CASE STUDY: Gaïago

Gaïago helps farmers and agricultural distributors in their agroecological transition. One of the tools developed by the startup is a soil prebiotic that significantly accelerates carbon sequestration in soils. If correctly applied, it allows an average storage of 3 to 5 t CO2e / ha / year, and these results are measurable from the second year of application. The first measurements confirm that **the revitalisation of soils is a powerful lever to decarbonise not only the agrifood chain, but also the whole economy**.

Gaïago has dedicated a significant R&D budget to the implemention of agronomic trials, to study the mode of action and to measure the results in fields. They have also involved key partners to try to develop decarbonisation projects as fast as possible. These partenrs include universities (Unilasalle, Gembloux, Sayens-INRAE), startups (Greenback, AgBiome), clients (cooperatives), a network of farmers and other initiatives (Pour une Agriculture du Vivant, CDA, La Note Globale...). **For Gaïago, the challenge goes way beyond having traditional measures to reduce emissions or decrease impact; it is about operating a real drawdown**: what actions, solutions, initiatives should we implement to sequester carbon on the long run, to restore biodiversity, to clean soils and water.

Animal feed

- **45% of greenhouse gas emissions from livestock production is attributable to feed production** (FAO)
- **$1.39bn is the predicted value of the global insect feed market by 2024** (Research and Markets)
- **3m tonnes is the estimated decline in fishmeal availability by 2025**

Livestock producers have to face increasing regulatory pressure to demonstrate concrete actions to reduce and limit their carbon footprint. The demand for low-carbon animal feed is bound to grow as a result, fuelling the market for innovative feed alternatives.

Traditional feed ingredients account for a large part of carbon emissions in livestock production. In November 2020, the Global Feed LCA Institute (GFLI) published its first database showing the environmental impact of different livestock and fish farm feed ingredients, from cradle-to-gate. In terms of global warming contribution (kg CO2 eq / ton product) including land change use, **the most polluting ingredients in feed are**:

- Processed livestock by-products, such as fat and blood meal
- Soybean oil
- Peanut meal
- Palm oil.

These products all require **extensive, energy intensive processing** to be turned into viable feed ingredients. Moreover, soybean and palm oils are associated with **high carbon emissions due to long-distance distribution and deforestation** for land change. Oil palm trees grow fast and have a higher than average carbon sequestration rate, but the carbon emissions from forest conversion are so high that an oil plantation will store 50-90% less carbon over 20 years than the original forest.

When it comes to soybean, **consumer behaviour changes may be aggravating the rate of deforestation**. Indeed, reports by Greenpeace show that British consumers are replacing red meat in their diet in part by chicken, due to health and environmental concerns. To keep up with demand, UK-based supermarkets have ramped up their use of industrial feed of which soybean imported from South America is a large component. Over one billion chickens are slaughtered in the UK every year, 95% of which are intensively farmed. Meeting the UK's annual demand for soybeans requires 1.4 million hectares of land – an area larger than Northern Ireland - and contributes to the destruction of natural habitats such as the Brazilian Cerrado (Greenpeace, 2020).

The decrease in availability of fishmeal, considered to be the gold standard of animal nutrition, is also a concern for agricultural players and especially for those in aquaculture. The depletion of this type of feed is mainly due to overfishing resulting in lower stocks and higher prices of raw ingredients (mainly sardines, anchovies, capelin, sand eels). Finding alternatives which can be equally nutritious but more sustainable and cost effective is a key challenge that innovative startups are attempting to address.

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Opportunities:

- **Insect-based feed holds great promise.** For instance, the startup **The Bug Picture** has found a sustainable way of addressing both livestock feed demand and the locust plagues affecting Kenya, as it collects and grinds locusts for feed and fertiliser. Another up-and-coming startup is **Better Origin** which produces container-sized fly farms for chicken feed. The farms can be fuelled by food waste, therefore contributing to the circular economy. After launching in May 2020, the British startup has already raised $3 million. But perhaps the most well-known startup in this space is **Ÿnsect, having raised a total of $425 million to date**. The French startup produces meal and oil from mealworm beetle larvae (Molitor) intended for the farming of fish and shellfish.

- Alternative feed production can also be **coupled with carbon capture and recycling technologies.** That's the case in Deep Branch's solutions (rated by Early Metrics in 2018). The startup captures CO2 from industrial sites and turns it into Proton™, a single-cell protein optimised for animal feed, via a proprietary gas fermentation process. According to the startup, the production of Proton™ emits 90% less carbon than traditional feed proteins. Moreover, the costs of inputs are lower than for other single-cell proteins which use sugar or methane as feedstock. Deep Branch also raised €8m in March 2021.

- As part of waste reduction strategies, **food producers and supermarkets are increasingly trying to sell their surplus to farmers as animal feed**. For instance, Arla Foods' largest factory, which is also the largest dairy processor in the UK, partnered with the sustainability charity WRAP to convert 100% of its food surplus into animal feed. This practice represents a source of high-quality feed for livestock farmers as well as a revenue stream for food producers and supermarkets.

Challenges:

- Livestock farmers require a consistent, large scale supply of high-quality feed to maintain their fast pace of production. **Cost-efficiency and scalability are therefore key challenges that alternative feed startups fac**e and/or that may make agricultural players wary of unconventional alternatives. Concerns over the nutritional value and the impact of feed alternatives on animal gut microbiota, which could then affect their health, are also considerable hurdles to adoption.

- **EU regulation limits the development of alternative feeds** derived from food waste, mainly to prevent pathogen transmission. While EU regulation should remain stringent on safety, it could evolve to be more in line with Japan, Taiwan or South Korea's approaches which encourage food waste usage in feedstock with clear policies on biosafety and processing. If food waste is to be used in animal feed it must undergo adequate thermal treatment, which itself can be energy intensive and therefore risks undermining its environmental benefits. Regulations should then take energetic efficiency into consideration.

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Alternative proteins

- **$14.32 bn expected value of the global plant-based protein market by 2025** (Statista/ Meticulous Research)
- **99.5 kg est. amount of CO2 emitted per kilogram of beef produced** (Statista)
- **$2.2 bn total sum raised by alternative protein startups** between November 2019 and November 2020 (CBInsights)

Meat and dairy account for around 14.5% of global greenhouse gas emissions, according to the UN's Food and Agricultural Organization (FAO). Researchers at the University of Oxford found that not eating meat and dairy products can reduce a person's carbon footprint by up to 73%. The need for a change in diet toward vegetarianism is considered essential to meet the targets set out by the EU on carbon footprint reduction and temperature rise limits. However, this dietary shift is partly dependent on the availability and diversity of alternatives to meat and dairy.

Thankfully Europe has seen a strong increase in demand and adoption of plant protein and meat-free alternatives. The main drivers of this behaviour are rising concerns surrounding the impact of meat and dairy on health, animal welfare and climate change. Indeed, though aggregate consumption of meat-based protein worldwide is increasing, the overall pace of growth is expected to slow down sharply in upcoming years.

Currently the **key sources of alternative proteins** on the market are:

- Soya
- Grain
- Vegetable plants (e.g. peas)
- Single cell organisms (e.g. fungi and microalgae)

While it's true that traditional European cuisines are still very reliant on meat and dairy, there are signs of growing acceptance of alternatives within different cultures. In January 2021, ONA became the first French vegan restaurant to receive a Michelin star. On top of this, the prestigious guide awarded a green star to the restaurant to recognise its ethical practices. This sends a strong message regarding the place that meat-free, ethical foods can have in countries with strong culinary traditions such as France.

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Opportunities:

- **Plant-based protein meets new consumer demands** in terms of accessing foods that have a low carbon impact and that are healthier than meat. Indeed, plant protein has a lower content of essential amino acids than animal protein and lowering the intake of amino acids can prevent cardiovascular diseases. Provided they are not overly processed, plant-based alternatives to meat-based dishes could not only **contribute to decarbonisation, but also address the SDG 3 - good health and wellbeing.**

- **Fermentation is opening the door to further innovation** in the development of low carbon protein. Microbial fermentation processes have the potential to increase the efficiency of alternative protein production (thanks to the microbial biomass) as well as enhance their taste and nutritional value. Quorn is perhaps the most well known and oldest company to have harnessed fermentation for its mycoprotein-based meat substitutes. But newcomers are pushing this ancient foodtech to new frontiers. **Perfect Day is the biggest success story** in this area having managed to harness precision fermentation to produce milk proteins at scale for dairy alternatives. The Californian startup has so far raised $360m, including a $160m top up to its Series C in July 2020.

- **Investors have clearly recognised the potential of the alternative protein market.** Perfect Day was not the only startup to complete a mega-round in 2020, as the Swedish oat-drink Oatly and the American plant-based burger Impossible Foods both secured $200m. Looking further back at 2019, Beyond Meat's successful IPO represented a milestone for the alternative protein market. Overall protein alternative startups attracted over $2.2bn in investments worldwide in 2020. While U.S. based startups have so far taken centre stage, there is room for European players to grow.

Challenges:

- Various **cultural and socio-economic factors represent barriers to adoption** of plant-based alternatives to meat. For example, a survey conducted among Finnish people highlighted that young people in rural areas might be less aware of plant-based alternatives. Other participants also cited food enjoyment and difficulty of meal preparation among the blockers to a plant-based diet.

- **Lobbying from the dairy and meat industry** is a major hurdle for the growth of alternative protein players. In the U.S., meat substitute startups were attacked by the lobbyist group Centre for Consumer Freedom through several ad campaigns, claiming those alternatives could be harmful to consumers' health. Meanwhile, Oatly's "milk made for humans" ad campaign was banned in Sweden following backlash from dairy producers. The EU has been pressured by lobbyists to ban meat and dairy-related terms on vegan alternatives, a limitation that could prevent startups from successfully marketing their products to new consumers.

- **All alternative proteins are not made equal**; this stands both on the nutritional side and on the environmental side. Let's take the example of soya, which is currently the key ingredient in most meat substitutes. To keep up with the booming demand for soya, some countries (like Brazil) have resorted to **widespread deforestation**. The effects of deforestation are compounded by the carbon footprint of long distance distribution. From an importer perspective, the European Union showed the largest carbon footprint per unit of imported soya between 2010 and 2015 (0.77 $tCO_2e\ t^{-1}$) as most of it came from Brazil. Although the research is not conclusive, soya has been found to include endocrine disruptors which could increase susceptibility to certain cancers.

Decarbonisation of the agricultural and food industry. 2021.

Cellular agriculture

- **€163m was the total sum invested in lab-grown foods in 2019 globally**
- **The expected value of the cell-based meat market in 2025 is €214m**
- **The average cost of cell based meat could reach €4,75 per kilo by 2030** (GFI studies), down from around €180 in 2019 (Alcimed)

Cultivating meat directly from cells could be a solution to produce meat with fewer resources and a smaller environmental impact.

Some studies point out that in comparison to conventional beef, **cultivated beef reduces greenhouse gas emissions by 75%** (The Good Food Institute). Other advantages include reduction of land use, although pasture areas within extensive breeding can also be interesting carbon sequestration solutions. Another key advantage is that cultivated meat does not require the use of antibiotics, which is a growing public health concern.

The first cultivated burger was produced in 2013 by Professor Mak Post, at a cost of €2m per kg (Alcimed). There are now more than **50 active companies worldwide dedicated to the development of lab-grown foods** including chicken, beef, salmon and foie gras.

Most of them are already able to produce meat, while more and more startups focus on resolving bottlenecks limiting these new technologies, like growth media production.

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Opportunities:

- Several startups are innovating in the **cultivated meat and fish** space. For companies such as Memphis Meats, Aleph Farms, Future Meat, and so on, it all begins with sampling and banking stem cells from an animal. These cells are then grown in bioreactors at high densities and volumes, using a culture media in which the cells will be able to develop themselves. Changes in the medium composition trigger immature cells to differentiate into the skeletal muscle, fat, and connective tissues that make up meat. The meat-like texture can be obtained through filling/mixing, 3D printing, or using a scaffold structure. This process is expected to take between 2-8 weeks, depending on what kind of meat is being cultivated. Some companies are pursuing a similar strategy to create milk and other dairy products using cells from mammary glands, such as Biomilq or TurtleTree Labs, or foie gras using liver cells such as Gourmey.

- We are also seeing the emergence of **startups focusing on the production of media and cells** for this new type of agriculture. The cells need to be grown in an oxygen-rich cell culture media made up of basic nutrients such as amino acids, glucose, vitamins, and inorganic salts, and supplemented with proteins and other growth factors. The goal of startups producing this media, such as ORF Genetics or Multus Media, is to create a scalable, safe and bovine serum-free product.

- **Plant molecular farming** is an exciting new branch of plant biotechnology, where plants are engineered to produce recombinant pharmaceutical and industrial proteins in large quantities. Soybeans for example would be grown for the harvest of animal or milk proteins, as demonstrated by companies such as Fantastic Farms, Moolec or Mozza Foods.

Challenges:

- **The regulatory aspect** of cellular agriculture is one of the key obstacles faced by players in this sector. Some countries like Singapore, Hong Kong and Japan are very advanced in the process of creating a legal framework and approving cell-based foods for mass consumption. This process will probably take much longer in the U.S. and Europe.

- **Consumer acceptance** is also challenging: pre-millennials are quite skeptical of anything new and hard to understand when it comes to food. Millennials are more open to testing new products, such as plant-based alternatives, but are also watchful of the health benefits and risks of new foods. We can assume that most European consumers will be distrustful of cell-based meat, which can be compared to cloning, and that they will be more willing to try products issued from fermentation, which is a more familiar concept. Companies will need to out efforts into **educating the customer**. If they are able to create their products without using any animal products, they will also gather more consumer approval (bovine serum-free media, cell line banks, etc).

- **Scaling up the productions at an affordable cost remains the biggest challenge for cellular agriculture.** In 2020, production costs averaged around €184 per kg, an impressive decrease compared to 2013, when they amounted to €2m per kg. The cost of production is expected to continue shrinking, with a prediction of €80 per kg in 2021 (Alcimed). Nonetheless, it is still expensive, given that regular meat and dairy cost €3-6 per kilo to produce.

Robotics

- **The agricultural robots market is projected to grow from $4.6bn in 2020 to $20.3bn by 2025, at a CAGR of 34.5%** (MarketsAndMarkets)
- **The global autonomous mobile robots market size was valued at $1.9bn** in 2019 and is expected to grow at a CAGR of 19.6% from 2020 to 2027 (Grand View Research)

Agricultural machinery is responsible for most part of direct emissions from agriculture.

A new generation of robots are on their way to replace heavy, soil-damaging tractors and to allow a decrease of synthetic chemicals in the fields.

New agricultural robots intend to **replace the current concept of large machines** that can work in large landholdings, with economies of scale being the only way to make such an investment profitable. They offer a new concept where fleets of smaller, specialised machines (autonomous or not) can cover individual tasks in a more efficient way and provide better accuracy, while being suitable to environmental, social and economic conditions.

New robot designs are **flexible, scalable and allow the interconnection with other machines**, sensors or vehicles. They should be able to tailor their performance to the farm and land level, adapting to the characteristics of the field.

Challenges:

- The new generation of agricultural robotics needs to overcome a series of challenges. Operating and understanding how they work from the farmer's perspective is key. **Infrastructure is a very important challenge** as well : the need for new networks for IT connections, the technology's dependence on electricity and batteries to power the equipment or adequate hardware and software for their operation can be a burden. Other challenges, such as data ownership, efficient business models, adequacy of crop management, adaptation to the local conditions and so forth will add to the complex process that leads to a successful adoption.

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CASE STUDIES

EcoRobotix develops, produces and sells innovative farming machines that require low energy and that reduce the negative ecological impact of modern agriculture, while keeping costs competitive.

EcoRobotix' technology can reduce up to 95% the quantity of synthetic chemicals used for crop weeding, which are oil-based and therefore highly carbon intensive. In addition to being able to be deployed by a tractor, this technology can be applied to autonomous solar-powered robots, thus avoiding the use of energy-intensive tractors. For example, the startup works with Nestlé Waters to help farmers regarding their water catchment, using less chemistry with their technology.

Ecorobotix strongly believes that AI/ machine learning, robotics and data will play a key role and will be the next big changes in agriculture in the upcoming years. In addition to its core mission, Ecorobotix has adopted a number of measures to reduce the company's carbon footprint : offset of company transport emissions (plane, car, train), subsidizing employee public transportation, home office, renting low energy facilities using renewable energy, waste management, as well as pro-bono environment protection activities.

Naïo Technologies is a leader in the realm of agricultural robotics and autonomous guidance systems. Its co-founders Aymeric Barthes and Gaëtan Séverac were inspired to build there technologies after speaking to many farmers who struggled to find enough labour to support their operations.

Meeting the demand for food of a growing global population while making food production sustainable is a complex problem. Any progress will require taking a multifaceted approach. Barthes and Séverac comment: "One of the issues of past agriculture is that we tried too much to simplify the system, and we are stuck in a non-sustainable system. If we want a sustainable system, we need to be able to manage that complexity."

Robotics can help the agriculture sector meet its rapidly increasing production goals. Not only do autonomous machines give farmers the gifts of accuracy, efficiency and better decision-making, they do so without sacrificing natural ecosystems or fertile farmland. Robots also enable data collection in the field, so farmers can better understand the soil conditions, crop conditions, monitor diseases, and so on. Once the information is gathered and analysed, farmers are able to make smarter agronomic decisions. This enables operations, for example, to reduce their herbicide usage and limit the emission of greenhouse gases and particles.

"Our robot will help to bring the right crop management inputs to the right place at the right moment," the founders say. "It is all about more accurate farming, more accurate data collection and more accurate decision making. Altogether, you have a more efficient system."

PROCESSING

A significant part of the carbon footprint of the food and drink sector is attributed to the processing and manufacturing phase.

While a stronger attention to food safety and hygiene has been overall positive for human health, it has also entailed the wide adoption of energy-hungry and polluting heat processes. Carbon emissions from refrigeration and transportation have increased as the industry became globalised and the supply chains became longer.

Consumption trends have further aggravated the sector's environmental impact, particularly the demand for convenience foods in urban areas such as ready-made meals, which demand lengthy processing.

Addressing these emission sources generally implies costly infrastructure changes, which constitute a hurdle to adoption for many producers. However, the growing availability and cost-efficiency of renewable energy sources could enable drastic reductions in energy-related carbon emissions.

In this section, we will focus on three particular aspects of the processing stage which can benefit from innovation:

- Energetic efficiency: optimising energy use, transitioning to renewable energy sources and to leveraging circular processes.
- Waste management: finding new ways to prevent, reuse and recycling organic waste issued at the manufacturing stage.
- Carbon Capture: preventing carbon emissions from reaching the atmosphere and giving value to the CO2 produced.

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CASE STUDY: Avril

"Decarbonisation is above all a matter of energy management"

Founded in 1983 on the initiative of the agricultural world to ensure sustainable outlets for French production, Avril is a leading industrial and financial player in the vegetable oil and protein sectors.

Avril is currently working on making structural commitments that will give concrete expression to its role in the agricultural, energy and food transitions. A work of framing these commitments is in progress based on the assessment of their GHG emissions carried out in 2020, and modelling of a multi-year reduction trajectory. The Avril Group also has **a CSR program called Spring**, which is connected to the 10 SDGs to which Avril contributes. It complements the 2019-2023 strategic plan and enables short-term management of the Group's sustainable development objectives and actions.

In terms of Avril's industrial activities, decarbonisation is above all a matter of energy management, an area where the Group has direct leverage to act. The new roadmap of the Group's energy department reflects this vision. The aim is to continue the long-standing efforts to **improve the energy efficiency of operations** (measurement systems, training, sharing of best practices, etc.) and to **accelerate the Group's energy transition**. This roadmap includes a focus on "innovating for decarbonisation". In this context, the use of electricity from renewable sources via the setting up of PPA (Power Purchase Agreement) projects is an option currently under study. The introduction of an internal carbon price for industrial investment projects is also being considered in the short term.

Beyond its own operations, **Avril is focusing on developing low-carbon solutions for its suppliers and customers**. Alongside the production of the rapeseed-based fuel Oleo100, Avril is developing specialty biodiesels with a high reduction in greenhouse gases (70 to 80% vs. fossil diesel) to meet the demand of certain countries such as Germany and the Scandinavian region. The challenge for Avril is to develop French supply chains to increase this production, with the aim of purchasing 300 kt of seeds per year within a few years. This is the ambition of OleoZE, a digital solution created by the Group that allows farmers and collecting organisations to **add value to their sustainably produced rapeseed and sunflower seeds**. OleoZE remunerates oilseeds above market prices with a bonus linked to producers' efforts to reduce GHG emissions and store carbon in the soil on their farms.

Avril has also been involved for several years in research programs on **advanced biofuels from lignocellulosic biomass** (agricultural and forestry residues). The BioTfuel partnership project (Axens, CEA, IFP Énergies nouvelles, Avril, ThyssenKrupp Industrial Solutions, Total) launched 10 years ago succeeded in demonstrating the technological feasibility of the entire chain in 2020.

Energetic efficency

- By 2025, **the share of renewables in total electricity generation is expected to be 33%** (International Energy Agency, 2020)
- **The food sector consumes globally about 200 EJ per year** (FAO, 2017; EIA, 2017)
- Food production, from farm to fork, accounted for about **17 % of the EU's gross energy consumption** in 2013 (European Commission JRC)

Food processing can entail significant energy consumption for storage, sterilisation, preparation (mechanical energy), cooking and other electrochemical processes. Research shows instant coffee, milk powder, French fries, crisps and bread are among the most energy intensive foods, mainly due to the thermal processes they undergo. It is estimated that **a third of energy consumption in food manufacturing plants comes from boiler systems**. Bringing changes to these boiler systems (through electrification or low carbon fuels) is essential for the decarbonisation of food and drink processing.

Reducing the carbon footprint of food processing is therefore a significant challenge. Thankfully **the availability of clean energy is growing** in the European market. A report released by the International Energy Agency in November 2020 highlighted that the economic slowdown derived from the Covid-19 pandemic did slow down the pace of growth of the global renewable energy market too. However it did not halt it, which is evidence of the clean energy sector's resilience.

Wind and hydropower are currently the most used renewable energy sources in Europe (EurObserv'ER, 2018). Yet, as food processing results in large amounts of organic waste and byproducts, biogas appears as a logical alternative to fossil fuels in the food industry.

Biogas plants in the food and beverage industry are also interesting because they provide the following advantages:

- possibilities for more efficient energy use and self-sufficiency
- cost-effective energy and waste management
- competitive advantages and quality improvement in the production of organic fertilisers.

Aside from sourcing renewable energy, food and beverage companies could benefit from more **precise monitoring of their energy consumption**, to spot inefficiencies and then implement concrete solutions more easily. Technologies that combine IoT, cloud computing and predictive AI represent valuable tools to optimise energy use. Furthermore, alternative methods to traditional energy-hungry heating and cooling processes for food storage are also emerging from the startup ecosystem.

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Opportunities:

- A large number of startups are developing solutions to **make biofuel production and use more attractive**, both in terms of cost and energy efficiency. Some companies, such as Cryo Pur and EnviTec Biogas, have developed modules to upgrade biogas derived from organic waste into biomethane and fuel, which can then be used in natural gas vehicles among other applications. NULIFE GreenTech has also developed a hydrodeoxygenation (HDO) catalyst to process organic waste into advanced biofuels and bio-carbon. Other notable examples of innovative companies include Antaco, Renergon and C-Green (see p.29).

- New startup solutions are emerging to **recover and reuse energy**. The Swedish startup Enjay, for instance, has created the Lepido heat exchanger for restaurant and food factory ventilation. Its two proprietary patents, the aerodynamic configuration called Particle Repellent Geometry and the recovery coil cooling protocol called Automatic Phase Change, prevent grease and soot particles from getting stuck in the heat exchanger. The recovered energy can then be used for heating and cooling processes within the food manufacturing site. Enjay counts Burger King as one of its early clients.

- Some startups are innovating to **make food transformation and storage more energy efficient**. For example, the Indian startup S4S Technologies has devised an award winning solar-powered and electricity-free dehydrator that's highly efficient and increases the shelf life of a variety of crops by about 6 months.

Challenges:

- **Stricter hygiene standards have led to increased use of heat processes** in the meat and dairy industries, which also contributed to increased energy consumption. Moreover, rising customer demand for convenience foods also entail further energy-hungry steps in the production of these highly processed products. The electrification of these sanitation and transformation processes is key to reduce their carbon footprint.

- Reducing the carbon footprint of food production from energy consumption is dependent on **the overall greening of national energy infrastructures**. The decarbonisation of natural gas and hydrogen production, the stabilisation of renewable energy prices, the implementation of smart grids are but a few ongoing trends in the energy sector which impact the potential for decarbonisation in food processing.

- It can be costly and complex to adapt infrastructure to cleaner energy and/or install on-site biofuel production. When it comes to biogas from organic waste, the level of usage and the regulatory frameworks vary widely throughout the EU, with Germany and Italy currently ahead. **Christin Schmidt, Expert in Bioenergy at dena** (Deutsche Energie-Agentur Gmbh, the German energy agency), pointed out: "The energy demand cannot currently be covered by the energy produced by the biogas plants and there is a lack of incentives for the sale and the feeding of energy into the grid. **Some countries do not offer adequate regulation, funding or subsidies for biogas plants.**" She also noted that there is generally a perception on the side of food and beverage companies that commercial biogas plants are too large. The seasonality of raw materials and the multitude of technologies that can be used to produce biogas add a layer of complexity, which might slow down adoption. Still, Schmidt sees great potential in biogenergy in this sector. She explained that "the food and beverage industry in Germany produces around 52 million tons of waste annually of which more than half are biogenic residues that would be suitable for fermentation in biogas plants".

Reducing and upcycling waste

- **32% of global food waste happens at the post-harvest handling and processing stages**, which accounts for 30% of the sector's carbon footprint (FAO)
- **3.3bn tonnes of greenhouse gases are emitted yearly due to wasted food** (FAO)

Food and beverage players recognise that **preventing, reducing and reusing waste** is important to increase their internal efficiency, reduce costs and decrease their carbon footprint. Many European corporates, of the likes of Nestlé, Arla Foods and Fazer, have in fact announced to be working towards "zero to landfill" waste management strategies.

Preventing food waste from happening in the first place is somewhat seen as the holy grail. While it is difficult, it can be done through **more precise demand prediction for accurate raw material purchasing**. This could be enabled by predictive software that can learn from past market data and then combine these historical trends with real-time data collection and analysis. The emergence of **artificial intelligence and machine learning** make the prospect of resilient and accurate supply chains increasingly realistic. Moreover, **industrial internet of things (IoT)** sensors could be used to detect inefficiencies and improve processes in food manufacturing facilities. IoT could also be applied to the storage monitoring of raw materials (humidity, temperature, oxygen concentration...) to prevent spoilage.

Reducing waste is generally recommended over reusing or recycling, as the latter may involve more processing. Two main paths are available to reduce waste: donations for human consumption or selling to farmers as livestock feed. The short shelf life of organic waste and the associated hygiene concerns are major hurdles to the adoption of such reduction practices.

On the other hand, there are a variety of ways in which food and beverage manufacturers can **reuse and upcycle waste**. By implementing anaerobic digestion on-site, they can turn organic waste (including wastewater sludge) into **biogas** which can then power the processing plant directly, therefore forming a circular process. The digestate resulting from anaerobic digestion can also be turned into **biofertiliser to enrich agricultural soils**. Other composting methods and direct land application can be used for land enhancement.

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Opportunities:

- We are seeing the rapid development of fermentation-based innovation to produce proteins for human and animal consumption (see p.19). Food waste can be used as a raw material to feed microorganisms for these fermentation processes. Startups such as Mycorena and Bonumose are among the newcomers adding valuing food waste for this purpose.

- It can be challenging to recycle and reuse solid wet waste due to its high water concentration which makes it heavy to transport, energy intensive to dry and prone to GHG emissions and pathogen development when stored outside. The Swedish startup C-Green is addressing this with its OxyPower HTC™ technology. By combining wet oxidation and hydrothermal carbonisation (HTC) **the startup sterilises organic wet waste and transforms it into renewable energy and useful products** (HTC biocoal, phosphorus and nitrogen). C-Green claims that its technology can prevent the emission of up to 200 kg CO_2-eq/ton of sludge saved from storage and composting. Other startups, such as Antaco, are using HTC to turn wet but also dry organic waste into biocoal.

Challenges:

- There are a number of barriers to food donation in EU legislation. This includes for example the waste hierarchy of the Waste Framework Directive which has not been adapted to the specificities of food. The EU could follow the example of Italy which implemented a national law on food donations in 2016. In addition to providing definitions for important terms (food operators, donators, food leftover…), the Italian law establishes incentives for free food leftover to charity organisations. Moreover, the law allows municipalities to establish tax exemptions for food donors, encouraging further waste reduction.

- While there are an increasingly vast number of solutions to turn food waste into value-added products, the cost of the required infrastructure changes is still a major barrier to adoption for food and beverage manufacturers, especially for small to mid-sized players. Moreover, some food wastes are more difficult to recycle and reuse than others.

CASE STUDY: Bonumose

"We believe in – and pursue – the circular economy principles of eliminating waste."

Ed Rogers, CEO at Bonumose

Starch is the primary feedstock for producing Bonumose's low-cost healthy "rare sugars" (tagatose, allulose and others). The startup seeks out waste starch from other food production processes, such as pea starch leftover from pea protein production, and potato starch leftover from cutting potatoes for French fries. For a variety of reasons, these low-volume starch sources do not have a good "home" in the food industry, but they are suitable and attractive for their process.

Bonumose's rare sugar production process results in a small amount of by-product syrup consisting of glucose, maltose and other simple sugars. They have several strategies for upcycling this syrup, including using it as the feedstock in enzyme production, enzymes which are then used to convert more starch into rare sugars. As an added benefit, the startup's tagatose is healthier and more energy efficient than sucrose (often used in processed foods), as it requires lower temperatures to caramelise. Bonumose's growth potential was highlighted by Early Metrics' rating in 2018, which ranked it among the top 10% of rated startups.

Carbon capture

- Only **40 million metric tons of CO_2 are captured** from power and industrial facilities each year (Global CCS Institute)
- **$27bn were invested in 16 CCS projects globally since 2017** (International Energy Agency)

In 2018, the National Academies of Sciences, Engineering and Medicine reported that "negative emissions technologies" — techniques for removing carbon from the atmosphere, rather than simply reducing emissions — are needed to stabilise global warming below 2 degrees Celsius, the level which scientists believe could be catastrophic. Hence, it's important to **promote natural and artificial ways to capture carbon** and reduce the quantity of CO2 released in the atmosphere.

Agricultural fields can be natural carbon sinks if managed sustainably. This means implementing farming practices that minimise tillage and other soil disturbances, to prevent releasing carbon trapped in the soil. There are also carbon capture and storage (CCS) solutions to address emissions at the processing stage. Different methods allow for the capturing of carbon at the pre-combustion stage, post-combustion stage or through oxy-fuel combustion.

Capturing carbon from industrial plants and storing it underground is not a new idea. However, **its adoption has been low in the food and beverage industry**. A report by the British Food and Drink Federation and SRL Consulting stated that CCS was currently not a cost effective decarbonisation method for food companies as they often don't produce large enough amounts of carbon dioxide.

Still, new technologies are emerging to **reuse and give value to the captured carbon**, as an energy source, for example. These technologies could in turn make carbon capture solutions more attractive for food and beverage players.

New policies are likely to be introduced in the near future to reward companies that implement CCS practices. Indeed, the European Commission has announced that it would support carbon farming through the Common Agricultural Polici (CAP) and that it is developing a regulatory framework for certifying carbon removals, as part of its Circular Economy Action Plan.

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Opportunities:

- So far, captured carbon has mainly been stored in geological formations or sold to oil companies for enhanced oil recovery. But carbon can also be **recycled into new energy** (such as hydrogen) or turned into **sustainable by-products for other industries**, which can bring additional revenues. For example, Cambridge Capture Carbon developed a mineralisation process that permanently locks the sequestered CO2 in rock form. This material can then be utilised across a range of industries, including as an eco-friendly alternative to concrete fillers, blocks and plasterboard.

- **Carbon dioxide already has many uses in the food and beverage sector.** Popular use cases include fizzy drinks and dry ice for food storage. Sourcing CO2 from industrial plants can be difficult as it must be cleaned from impurities to meet food-grade standards; nevertheless, it is feasible and could contribute to the circular economy. Air Liquide is among the key players innovating in this space. Some startups are also recycling carbon for new applications. As mentioned previously (see p.17), Deep Branch uses microbes to convert carbon dioxide from industrial emissions into **sustainable animal feed**.

- In January 2021, **Elon Musk, CEO at Tesla and Space X, announced he would donate $100m to the best CCS solution** through a contest run by the XPRIZE Foundation. While the initiative is not focused on the food and beverage sector, it might foster useful technological advances in this domain. Moreover, Musk's involvement might encourage other influential figures and institutions to invest in the improvement of CCS technologies.

Challenges:

- **The CCS industry is still in its infancy** and primarily targets oil and gas companies and heavy industry. According to the Global CCS Institute, there are 51 large-scale CCS facilities in development globally but only 19 in operation. Large investments are needed to install such infrastructures and because CCS projects are in their early stages, companies are not going to see a financial return in the short-term. Consequently, investors impose higher risk premiums, which further increases the private cost of the necessary capital.

- **Additional energy is required for CO2 capture and it may have a negative impact on air quality**, as the type and amount of air pollutants released depend on the CCS technology used. The deployment of CCS at processing plants may influence local and transboundary air pollution, i.e. the emission of key atmospheric emissions such as SO2, NOX, NH3, Volatile Organic Compounds (VOC), and Particulate Matter (PM2.5 and PM10).

- **There are also safety concerns surrounding the long-term storage of CO2.** Leakage of CO2 could negate the initial environmental benefits of capturing and storing carbon emissions and may also have harmful effects on human health. Two types of CO2 leakages may occur: abrupt leakage through injection well failure or from an abandoned well; and gradual leakage, through undetected faults, fractures or wells. Moreover, pressure built up by injected CO2 could trigger small seismic events. It has been suggested that CO2 storage sites may become potential terrorist targets or that seal failure could result in catastrophic release. Greenpeace points out that concentration of CO2 greater than 7-10% by volume in the air puts the health and lives of people in the vicinity in immediate danger.

PACKAGING

Plastic is a very handy material for food packaging: it's durable, it can be heat and cold resistant, it can be flexible and hard, it can keep products safe from moisture, it's light to transport... And while many plastic containers are now recyclable, virgin plastics are still the go to for most packaged goods. Over-reliance on this non-biodegradable material is an issue that concerns all industries, but the food and drinks sector in particular could do better.

As consumers have become aware of the carbon footprint of plastic and the impact of plastic pollution, the demand for glass containers has increased. Indeed, many consumers are yet to realise that the energy and heat-hungry processes needed to produce glass packaging has a significant carbon footprint too, not to mention their heavyness which leads to higher fuel consumption for transportation.

Thankfully new technologies are emerging to provide better alternatives to traditional packaging materials. In this section we look at the different ways in which both traditional materials and more unusual ones can be used to produce more sustainable packaging. We will look in particular at:

- Innovations in paper and plant pulp
- Bioplastics
- Seaweed-based materials
- Milk protein-based materials
- Bulk packaging

Decarbonisation of the agricultural and food industry. 2021.

Paper and pulp

- **About 420m metric tonnes of cardboard and paper are produced annually worldwide**, equivalent to USD 349bn (Statista)
- **The value of the pulp and paper packaging market estimated at US 280bn globally** (Resources Information System Inc.)
- **The carbon footprint of cellulosic fiber-based materials is on average below 1.5 kg CO2eq/kg** (Science Direct)

Choosing paper and wood pulp-based packaging over plastic may not sound like a ground-breaking idea. Yet, several companies are innovating to improve such materials and make them viable for new use cases, such as drink bottles. The major advantage of pulp and paper packaging lies in the fact that **the supplies chains are already in place and operational for the raw materials**. In particular, primary packaging (food contact) can benefit from the development of new coating technologies. This enables the production of **recyclable and compostable packaging materials** with a very large source of procurement. Responsible forestry and other sustainable pulp sourcing are essential to make such packaging truly effective in the decarbonisation of this industry area.

Opportunities:

- As packaging demand is shifting towards more sustainable solutions at an increasing rate, **the world's biggest companies are working on wood and paper-based alternatives**. For example, in 2018 Kellogg's pledged that they will work towards 100% reusable, recyclable, or compostable packaging by the end of 2025. McDonald's has committed to sourcing all of their guest packaging from renewable or recyclable sources by 2025. More and more companies are focusing on technologies using **grassland and hay as raw material**, to reduce the impact of using trees and forests in an intensive way.
- On the startup side, many companies are emerging to bring new solutions to the table. **Creapaper makes paper and cardboard from grass**, claiming a 75% reduction of CO2 emissions, and already has contracts with major players. Colombier has been recognised for its sustainable cup material, using a water based, recyclable and compostable coating to replace the usual plastic part providing grease and water resistant properties to the cup. Papkot developed a technology directly treating the surface of paper through a **cellulose molecular coating** giving to the paper hydrophobicity, lipophobicity, fire-resistance and other properties to the packaging.

Challenges:

- The development of technologies adding strong value to packaging (such as sustainable food preservation technologies, gas and water barrier properties for bio-based packaging...) are still at a quite **early stage of research**.
- Manufacturers have to deal with the **high volatility of recycled and new paper fiber prices**.

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Bioplastics

- **1% of the 368 million tonnes of plastic produced in 2019 were bioplastics** (Plastics Europe)
- **The global bioplastics market is expected to experience a CAGR of 16.1% from 2020 to 2027** (Grand View Research)
- **Switching from traditional plastic to corn-based PLA would cut U.S. greenhouse gas emissions by approximately 25%.**

Bioplastics are polymers produced from plants and other natural **raw materials that are not petroleum**.

There are two main types of bioplastics, those made from sugars and those derived from microorganisms. In the former type, sugars extracted from sugarcane, corn and cassava are turned into **polylactic acids (PLA)**. In the latter, microorganisms are deprived of nutrients and fed extra carbon to produce **polyhydroxyalkanoate (PHA)**. Both PLA and PHA have similar chemical and mechanical properties to traditional plastic and can therefore be used in a variety of food packaging formats, includings solid containers and protective film.

New biorecycling processes have also emerged in recent years to **turn organic waste into plastics**. This includes end-consumption waste but also crop waste and residue. Coupled with renewable energy, polymers derived from biorecycling represent a more viable solution for the decarbonisation of food packaging than virgin bioplastics and fossil fuel plastics.

Decarbonisation of the agricultural and food industry. 2021.

Opportunities:

- In the right conditions, **bioplastics are biodegradable** and therefore less harmful to the planet than petroleum-based materials. Moreover, bioplastics are **less toxic than petroleum-based ones** as they do not contain the hormonal disruptor bisphenol A (BPA). They are thus healthier for humans exposed to the packaging through their food and less harmful to other animal species if they land in natural environments.

- There are already **many European startups developing bioplastics**. For instance, Lyspackaging transforms bagasse, the dried fibrous residue left after extracting the juice from sugar cane, into pellets through a proprietary process to obtain a material with similar manufacturing and usage properties to plastic, that is entirely plant-based, biodegradable and compostable. The startup was ranked by Early Metrics among the top 20% of 3000 rated startups in 2019 for its growth potential.

- Most major food and beverage companies are looking to **increase their use of recycled materials in their packaging**. For example, Nestlé committed to using 50% of recycled materials for its packaging in the US by 2025. Some have also joined together to support innovation in this space. In 2019, Nestlé Waters, along with PepsiCo, Suntory Food and Beverages Europe and L'Oréal formed a consortium to help the startup Carbios develop its enzymatic biorecycling technology.

Challenges:

- While bioplastics sound sustainable on paper, a 2010 study from the University of Pittsburgh showed bioplastic processes could have negative effects. Certain virgin plant-based bioplastics could be worse in terms of greenhouse gas emissions than fossil fuel plastics, due to **the impact of fertilisers and land use** needed to grow the necessary crops. That is especially true of PLA materials based on crops that are also needed for human consumption (corn and sugarcane mostly). Critics have said such **bioplastics could threaten food security** and are therefore not suitable candidates to replace petroleum-based materials in the long term. This reinforces the need to **prioritise biorecycled materials**.

- **Bioplastics need to be composted in specific environments to safely decompose.** Most need to be heated at high temperatures to enable biodegradation, which can be an energy-hungry process and requires specialised infrastructure that is not commonly available. If they are discarded in landfills, bioplastics risk releasing methane and will not biodegrade. A separate recycling stream is needed for these materials as they may contaminate other petroleum-based recyclable plastics (PET) if they are not disposed of correctly. Moreover, if they land in water ways, they have the potential to break down into microparticles which could find their way into the food chain and harm natural ecosystems.

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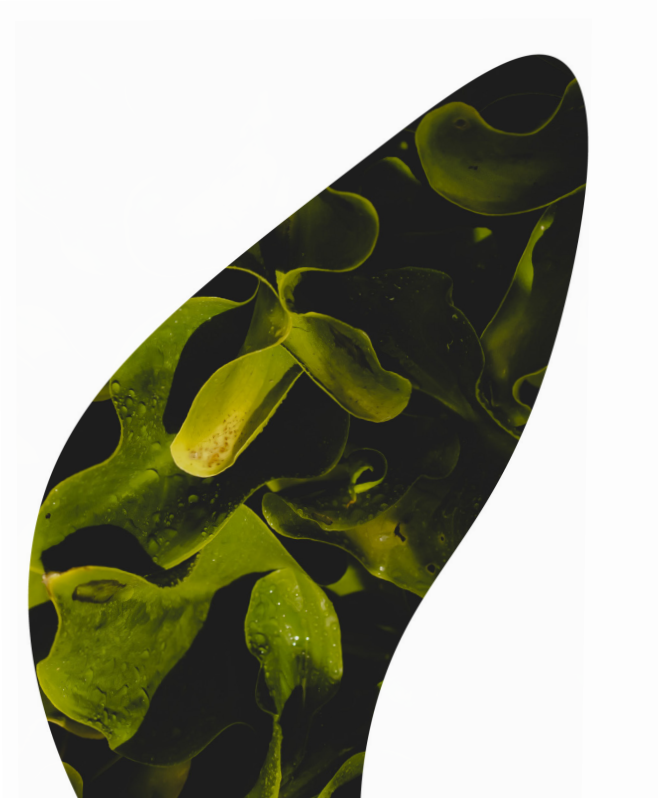
Seaweed-based materials

- **296k tonnes of CO2e emissions could be saved annually** by replacing plastic packaging with seaweed-based packaging (Seaweed for Europe)
- **99% of global seaweed production was done in Asia in 2018** (FAO)
- **115,000 jobs could be created in Europe** by the seaweed industry by 2030 (Seaweed for Europe)

While replacing fossil fuel-based plastics by bioplastics is a good step towards more sustainable packaging, **edible and fully-biodegradable materials** hold the potential to bring a more drastic reduction in carbon footprint. For the moment, seaweed is the raw material of choice for such edible packaging.

Seaweed doesn't need fresh water irrigation or fertilizers to grow and has a high carbon capture potential (estimated at 1 tonne per hectare a year by the World Bank). **Seaweed is also highly versatile**: it can be turned into film, sachets, straws and bottle-like containers. Each type of algae has its own mechanical and chemical properties that can lend it to be more suited for certain types of packaging.



Aside from its potential in packaging, it's of course in high demand as a source of food for animals and humans but also can be a source of biofuel, biostimulant and additives. As the end-material is safe to eat and it rapidly biogrades if left in landfills or even if it lands in nature, **it doesn't have any damaging effects on natural ecosystems unlike other biopolymers** (e.g. cornstarch, sugarcane...).

Currently Asia, and most particularly China, are far ahead in the industrialisation and valorisation of seaweed, albeit primarily for human consumption. Europe has the potential to become a global player in this market too. Indeed, there are plenty of viable sites to set up aquaculture for seaweed farming in Europe and recent regulations such as the Green New Deal are supportive of the development of this market. The Seaweed for Europe coalition estimated that the Old Continent could scale its production from 300k tonnes fresh weight currently produced to 8m trillion tonnes by 2030, which would also bring **the potential value of the European seaweed market to €9.3bn by 2030**.

Startups are blossoming in this space, bringing new innovations to the market to optimise the farming and processing of the material. They represent a valuable source of solutions to scale the production of seaweed-based packaging, expand the use cases and ultimately help Europe reach its full potential in this market.

Opportunities:

- The **EU's Single Use Plastic Directive** entails that a range of plastic packaging will be banned from July 2021. This includes takeaway containers, straws and certain beverage bottles. Seaweed-based materials will therefore represent a viable alternative to replace these.

- While the market is still young, **there are a number of startups turning seaweed into packaging for the food industry**. Among the most visible: Loliware (USA), Evoware (Indonisia), Margarita Talep (Chile), Algopack (France) and Notpla (UK). Further innovation is also being developed through **university-led projects**, such as the Mak Pak material developed by the Alfred Wegener institute for the German fast food chain Nordsee. Another interesting collaboration is that of the Finnish green chemistry player Brightplus and Origin By Ocean who are currently working to test new seaweed refinery processes. Corporates should seek the opportunity to foster this new market, creating synergies with academic bodies and startups.

- Seaweed-based edible packaging can be used as a way to reduce carbon emissions but also as **a marketing tool**. Consumers are intrigued by the novelty of eating their packaging. **The Glenlivet, a whisky maker, went viral** in 2019 thanks to its partnership with Notpla, when it served a selection of cocktails encapsulated in the startup's Ooho edible pods. These seaweed pods are also being trialled by Just Eat for ketchup samples and other condiments, which have a **68% lower carbon footprint than regular sachets**. Notpla had in fact received a strong score for its market positioning and potential, when it was rated by Early Metrics in 2018.

Photo: The Glenlivet/Notpla

Challenges:

- The vast majority of European seaweed production is concentrated in wild harvesting, which can be harmful to the natural ecosystem if overdone, is subject to climate fluctuations and is difficult to scale. **Sustainable harvesting through aquaculture** (which can be done off-shore, near-shore, in co-location with wind farms...) needs to be ramped up to allow for mass production of seaweed-based packaging. **Lack of investment, infrastructure, value chain integration and awareness** of these practices are among the major hurdles to aquaculture. Complex licensing processes have also been identified as a challenge.

- Due to its sensitivity to moisture and heat, which can lead to rapid decomposition, seaweed-based food packaging can present **storage and transportation challenges**. Indeed, some edible seaweed-based wrappings have a shelf life of only a few days. The use cases are therefore still limited to fast consumption foods, for instance, for takeaways and festivals.

- All edible packaging, including those made of seaweed, raise **hygiene questions**. If the consumer is expected to be able to eat the material then it needs to be protected from dust and germs, which would then call for an outer wrapping. This would in turn decrease the sustainability of the material, as it would potentially involve two layers of packaging.

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Milk protein

- **The global water dissolvable packaging market is expected to grow from USD 2.86 billion in 2019 to USD 4.87 billion by 2027**, at a CAGR of 6.9% during the forecast period 2020-2027 (Fior Markets)

In the edible packaging area, seaweed has received the most attention so far. However, it is not the only raw material to hold potential in this space. Casein is a protein in cow milk precipitated by the enzyme rennin and which can be turned into **water soluble, biodegradable and potentially safe to eat packaging**.

Casein-based materials are not new. In fact, casein was used in tempera paint in ancient Egypt, in glue since the Middle Ages and in one of the first plastics ever to be developed from the end of the 19th century. Casein plastics were mainly used in the 1920s and 1930s to produce a variety of items such as buttons and straws. The material fell out of fashion due to the emergence of petroleum-based plastics post World War II, which were easier to manufacture.

Now some **startups and academic institutions are striving to create more efficient processes to bring back casein-based materials** and replace petroleum plastics in food packaging. For instance, in 2016, researchers at the United States Department of Agriculture found that by combining casein with glycerol and citrus pectin, a soft but structurally sound bio-polymer could be formed. This could then be used as a film to replace traditional non-recyclable wrapping and protect food from light, oxygen, and humidity.

Opportunities:

- Using soluble casein pouches instead of paper or plastic could **enable a significant reduction in waste**. Dehydrated soup and risottos are ideal use cases as the casein packet could be fully immersed in boiling water and add to the nutritional content of the food as it dissolves.

- **Casein is an underutilised material** nowadays and very few private players are currently exploring its potential for food packaging. **The French startup Lactips** is one of the only startups that is doing so, having gathered support from the public and private sector. Indeed, in May 2020, in the midst of the first Covid-19 wave, it managed to secure €13m from Bpifrance's SPI (Société de Projet Industriel) fund and Diamond Edge Ventures (DEV), the innovation investment arm of Mitsubishi Chemical Holdings Corporation (MCHC). Therefore, there is market appetite for this kind of innovation and room for more players to enter the casein-based packaging industry.

- Casein might seem like an odd choice of material from a carbon emission standpoint, as cow milk is a polluting industry. But the emergence of **synthetic casein** could turn this into a far more sustainable material than petroleum-based plastic. As mentioned in the alternative proteins segment (see p.19), the startup Perfect Day has indeed created a process to produce casein without using cow milk, thanks to **precision fermentation**.

Challenges:

- The current processes known to produce casein-based films and plastics are still not as efficient as for regular plastics. Casein-based films have also been shown to be less effective at protecting food from humidity than traditional plastic film. Therefore **more research needs to be done to optimise these materials** to make them a viable alternative to petroleum plastics at scale.

Zero-Packaging (bulk)

- **€1.2bn is the expected value of the EU market for bulk goods in 2030** (Réseau Vrac)
- **5,500 tonnes of packaging could be prevented** from entering circulation in the EU in 2023 as a result of packaging free shops

Zero waste is a lifestyle trend that is experiencing significant growth worldwide. The impact of plastic pollution is a highly publicised subject, and it is increasingly easy to act daily by limiting the consumption of products overpackaged with plastics.

In France, bulk distribution is divided among specialty stores (5%), led by the world's only dedicated bulk franchise, the Day by Day network (59 stores); organic stores (45%), 88% of which have a bulk department; and food superstores, which account for the remaining 50%. **The market is still very niche**, and only represented 0,75% in market shares (excluding fresh products) in France in 2020 (Terre-net).

Opportunities:

- **Fully disposable, single-use packaging is no longer in keeping with the times.** Aurore Market raised €1.5m in April 2020 to launch its returnable metal packaging system, along its online sale of organic and solidarity products. French startup Castalie raised €13.5m in 2020 to roll out its system for purifying and filtering water fountains, designed to eliminate plastic bottles. The Drive tout nu, launched in 2018 near Toulouse, intends to quickly develop its concept mixing drive and bulk in franchise thanks to the €500k raised in February. Their business exploded during the lockdown and the startup plans to raise further funds in 2021. Meanwhile, the American startup Loop has been growing its presence in Europe signing partnerships with large local supermarket chains, including Tesco and Carrefour.
- Recycling is tremendously changing its image. Waste prevention took precedence, with **strong growth in dry bulk** over the last years. Formerly reserved for associations, solidarity economy funds are now financing companies that have switched to a virtuous model.

Challenges:

- **Product hygiene and traceability** (ingredients, expiration dates, etc.) can generate fears in the minds of consumers. Some products with PDOs cannot be sold in bulk in Europe to guarantee the origin of the product.
- **The whole supply chain needs to be rethought** in order for distributors to offer bulk products. Not only the final form of the product is different but its conditioning from the factory or producer and its transport has to guarantee a reduced packaging while avoiding waste and sanitary risks.

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In this last chapter we look at the final stages of this industry's value chain: the distribution and consumption of food products.

While this may not be the most polluting part of the value chain, it could benefit from innovative solutions to further decrease the carbon footprint of the industry.

The focus here is primarily on providing end consumers with the insights and options to make informed, sustainable purchasing decisions. We look also at how recent trends, such as fast at-home delivery and short distribution circuits, may be at odds with sustainability goals. Lastly, we explore how more and more startups are tackling the scourge of post-purchase food waste.

CASE STUDY: Groupement les Mousquetaires

"The Groupement les Mousquetaires aims to valorise 100% of its waste by 2025."

The Groupement les Mousquetaires counts more than 4000 points of sales in France and Europe. The company is taking decisive action to expand its low carbon strategy. Their stores already developed a responsible range of products, in particular with their label "Producteurs d'ici", promoting organic, zero pesticide residues and HEV (high environmental value) labelled products. 90% of Intermarché branded products are made in France.

Hand in hand with ADEME, the group is putting in place new objectives for 2030 : **a 55% reduction in carbon emissions and a 40% decrease in energy consumption**, as well as making sustainable products account for the majority of products on sale. The group is working towards recycling all packaging, with an objective to valorise 100% of its waste by 2025.

The Groupement les Mousquetaires expects five main areas of transformation in food distribution in the coming years:

- Goods transportation should transition to **natural gas vehicles**.
- The nature of food products will shift towards **alternative, bulk, local and plant-based offers**, along with efforts to educate customers on the impact of their food purchases.
- There might also be **a revolution in coupon practices**, which generate huge amounts of paper waste.
- Finally, waste is going to disappear thanks to **recycling practices**. The way stores are designed will also change to **prevent heavy light pollution**.

Short distribution circuits

- **5% of the average American household food footprint was attributable to transport in 2020** (Our World in Data)

For most products, transport accounts for less than 10% of carbon emissions of the product and it might be as low as 0,5% for the largest greenhouse gas emitters like beef (Our World in Data). However, while the carbon footprint of short distribution circuits depends on numerous factors, they can in some situations help cut food product emissions. Furthermore, they have a **positive social impact** by contributing to territorial cohesion, sustainability and local socio-economic dynamism. They can help **preserve small farming and artisanal food processing** as well as improving diets with easier access to fresh food, less preservatives, more variety. Short circuits often mean less packaging and less food waste. They can be a great tool to preserve products that are traditional and based on local agro-biodiversity.

Opportunities:

- Since 2011, La Ruche qui dit Oui! has grown into the most well-known short circuit network in France. Their "hives" (1,500 points of sale in Europe) offer products purchased directly from local producers. Other players address the "eating local" trend with **innovative business models**: farmer's markets, on-farm selling, box delivery subscriptions, catering... Both producers and consumers can expect economic benefits and better value for money.

- **The Covid-19 crisis has highlighted the growing demand for local products**, thus increasing the visibility and practicality of short circuits. Startups focused on proximity such as Kelbongoo, a pioneer of short circuits in Paris, or Rutabago and its organic meal baskets, which raised €1.8m in 2020, have gone beyond their pre-pandemic projections.

- Big players start to turn to these solutions as well, like **Carrefour which acquired Potager City in 2020**. Potager City offers different formulas of fruit and vegetable boxes, delivered in relay points or in companies and accompanied by recipes. The company has a unique network of more than 750 local producers, market gardeners and arboriculturists, selected for the quality of their produce, their know-how and their commitment to responsible production.

Challenges:

- **Inadequate means of transport, insufficiently optimised logistics and certain consumer behaviours can have a negative impact** on greenhouse gas emissions from local products. To offer all types of products locally, not taking into account **natural crop cycles and seasonality** in a given environment, producers might use energy intensive production methods or refrigeration and other preservation methods to store foods during several months. In those cases, importing foods has a lower carbon footprint. In order to limit emissions, short circuit players should give priority to the types of food they can grow locally and sustainably. If conditions are optimised, then short proximity circuits have an interesting potential in terms of reducing greenhouse gas emissions. It is therefore advisable to support initiatives and share best practices to optimise the environmental gains of the sector. Furthermore, **the risks in terms of food safety are higher** than in conventional distribution because of a reduced number of controls.

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Last mile delivery

- **The global Last Mile Delivery market size is projected to reach $66bn by 2026**, from USD 39,570 Million in 2020, at a CAGR of 8.9% during 2021-2026. (Valuates Reports)
- **70 percent of consumers will do their grocery shopping online by 2024** (Nielsen)
- Urban last-mile delivery emissions are on track to **increase by over 30 percent by 2030 in the top 100 cities globally**

Last-mile delivery is the last leg of the outbound logistics process, which involves the movement of goods from a fulfilment centre (where goods are received, packaged and shipped) to the final destination – usually the consumer's doorstep. The distance can range from a few blocks to 50 miles. Today it is on the front line of the shopping experience as **demand for fast and convenient delivery increases**.

Last-mile delivery plays a major part in **customer satisfaction and loyalty**. 55% of consumers say that a two-hour delivery option would increase their loyalty and 61% say the same for same-day delivery. But when delivery moves out to three days or more, only 30% say this will increase their loyalty (Capgemini study). At the same time, consumers are increasingly eco-conscious and want to adopt a sustainable way of life.

Logistics players are thus faced with a crucial conundrum. They currently use road transportation which, coupled with dense traffic and congestion, is responsible for significant CO2 emissions. They must find a more sustainable way to bring products from distribution hubs (often located in the suburbs of major cities) to the consumer's home.

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Opportunities:

- The demand for deliveries has boomed and the growth e-commerce industry has accelerated in the wake of Covid-19. **During lockdowns, consumers turned to online grocery shopping** in fear of contracting the virus or because they were in isolation. Consumers want to avoid crowded supermarkets and online shopping allows them to select their products at a leisurely pace, from the comfort and safety of their home. The demand for delivery services is growing mainly in cities, as most people do not own a car. So there is the potential for **synergies between urban smart mobility startups, food delivery startups and supermarkets**.

- There is an increasing **demand for local products**, involving fewer intermediaries. More local farmer markets, organised by towns or by startups (La Ruche qui dit oui), are reaching end consumers directly. Producers get organised and pool resources for deliveries: one producer collects all orders from neighbouring producers and brings them to a pick-up point near the final consumer's home. This **removes the need for storage** and ensures a higher quality and freshness of products (often with no packaging).

- Innovative technologies can **increase efficiency and therefore reduce last mile delivery carbon emissions**. Some companies are starting to automate deliveries using mobile robots, drones, and autonomous vehicles (such as Nuro, pictured on the right), which can be powered by renewable energies. Drones hold particular promise as they could free up road space by delivering by air routes. Startups are also developing software with AI algorithms that can optimise delivery route planning. Moreover, GPS technology and IoT sensors can be used to track delivery remotely or control the cold chain during transportation, which can help prevent food damage and waste.

Photo: Nuro

Challenges:

- Last-mile delivery **brings more vehicles in cities**, which are already struggling with congestion issues and pollution. Delivery services must find a way to reduce the number of vehicles in use without impacting the quality of service. Electric vehicles and scooters could be an option, but they have a limited autonomy to date and require specific charging infrastructure (which do not exist in all cities). Drone deliveries could also be a solution as they can be powered by sustainable energy, but they are still associated with safety issues. Some companies in the US have received the authorisation from the FAA to test drone-operated solutions, but it's still at a very early stage.

Carbon tracking

- **67% of Western consumers support carbon labelling on food products** (YouGov/ Carbon Trust)
- **30% of British farmers had completed a carbon audit in 2020** (Clydesdale and Yorkshire Bank)

As Peter Drucker famously said: "if you can't measure it, you can't improve it". While his quote wasn't originally directed at the decarbonisation of the food industry, it certainly applies to it. Being able to measure and showcase the carbon footprint of particular food practices or products is **a powerful driver for change for both consumers and industry players**. Or at least it can be, if carbon auditing methods are standardised and clearly communicated.

Lately there has been a push from the consumer side to introduce **carbon footprint labels on food products**. A YouGov survey conducted in 2020 with 10,000 consumers from France, Germany, Italy, the Netherlands, Spain, Sweden, the UK and the U.S. found that two in three support carbon labelling. From this survey, the three most supportive countries appeared to be France, Italy and Spain. Whether it would make a significant difference or not in consumer behaviour is still under debate. A Belgian study did find that consumers exposed to carbon footprint labels in supermarkets made buying choices that **reduced their CO2 impact by 5.3% compared to the average shopper**.

Some brands, including Quorn and Oatly, have taken the initiative themselves to integrate an indication of their carbon impact on their packaging; but few other companies have followed suit so far. The British supermarket chain Tesco had actually attempted to introduce carbon labelling on its products back in 2011, but decided to roll back the initiative because it was **too labour-intensive and consumers found the labels confusing**.

The main framework used to audit the carbon footprint of a business, regardless of its sector, is the **Greenhouse Gas Protocol** (GHG Protocol). This standardised framework encompasses three categories or scopes:

- Scope 1: Direct emissions
- Scope 2: Indirect emissions from the energy purchased and used
- Scope 3: All other indirect emissions including raw material sourcing, transportation, waste generated and end-of-life treatment of sold goods

How the emissions are calculated within each scope is of course highly dependent on the nature of the business, scope 3 being the hardest to measure. **Processed food producers** can find it particularly difficult to gather, analyse and display their carbon footprint. This is due to the seasonality of raw foods, the different cooking and storage methods used as well as the multiplicity of raw material suppliers (for seasonings especially).

Decarbonisation of the agricultural and food industry. 2021.

Opportunities:

- **Traceability technologies**, such as IoT coupled with blockchain and automated data analytics, could enable more precise calculations of carbon emissions throughout the supply chain. The startup ecosystem is rich in these solutions that combine multiple technologies to make data more readily available and actionable.

- **Smartphones** have become key enablers for collecting consumption and behavioural data, and by extension could be used for carbon tracking and displaying. So far, many startups have mainly taken advantage of smartphones' ability to scan barcodes and QR codes to provide further nutritional information on products. Some are now extending this concept to carbon footprint, such as the applications Karbon and Open Food Facts. In December 2020 the president of France, Emmanuel Macron, expressed his support for the development of a "Yuka-style app" for carbon scoring. Well, Yuka didn't miss this opportunity: in February 2020 it released alongside eight other organisations **an independent "eco score" available through scanning a food item's barcode with a mobile app**.

Challenges:

- Among the blockers to the adoption of carbon auditing and labelling is **the difficulty in aggregating all the carbon emission data throughout the supply chain**. Benchmarking that data for different types of products is also a hurdle. More companies in the food industry will need to pool their product carbon footprint data to produce more representative and efficient standards and benchmarks.

- **Carbon emission units are difficult to read and contextualise** for the average consumer. So carbon auditors need to find equivalencies and visual representations that can clearly convey what the level of CO2 emitted means for the wellbeing of society and the planet. Without this, carbon auditing and labelling could fail in driving sustainable consumption change.

CASE STUDY: Doconomy

"Our journey towards reduced carbon emissions starts with understanding our consumption."

Doconomy has developed tools and indexes to promote sustainable consumption. Its DO credit card shows the carbon footprint of each purchase in real-time and even caps spending based on carbon thresholds. It has also created the Åland Index, which enables financial service providers and corporates to deliver personalized ESG data to their consumers so that they can see the footprint of their purchases.

The startup explained about its index: "The Åland Index currently functions on a sector level such that any consumer can see what impact their purchase has had, given any given industry's footprint at large. As product level data is not yet available, our Climate Profiles will function as the best-practice interim solution we can feasibly bring to market given the current data climate. We are already seeing impressive and early efforts towards this end, but we still have ways to go before each product consumers can pick off the shelf are valued not just by its price, but also by its footprint." By calculating and visualising carbon footprint, Doconomy aims to help consumers understand the consequences of their lifestyle choices and catalyse a worldwide movement of drastic carbon reduction. Concretely, their two main goals are to enable 500 million users to understand their impact and prevent 2 billion tonnes of CO2 from being emitted.

Consumption waste reduction

- **Nearly one billion tons of food are wasted each year in the world,** representing 20% of the food produced (UN)
- In France, **a third of the national food waste happens at the consumption stage** (ADEME)
- The UN considers that **if global food waste was a country, it would be the 3rd largest emitter of greenhouse gases.**

Post-consumption food waste is an important issue in all Western societies. The greenhouse gas emissions from the production, processing and transportation of such wasted food products are compounded with their emissions once they reach the landfill.

Beyond the carbon impact, food waste has several negative effects linked to food production: waste of water, fertilisers, land, work time... If we look further, we can see that the waste of arable land is catastrophic for the climate. Indeed, agriculture is a major cause of deforestation and therefore is responsible for the loss of carbon sinks. It is estimated that every year we use an area the size of Mexico to produce foodstuffs that end up in landfills.

Educating consumers is key to tackle this growing problem. But there are also an array of solutions emerging to help food distributors reduce food waste. Logistics optimisation through SaaS, mobile applications, IoT, use-by-date management can help to better adapt production and purchasing to demand. Enhancing food conservation conditions and technologies can also prevent food waste. Finally, more and more initiatives and businesses are being launched to enable a better use of unsold products.

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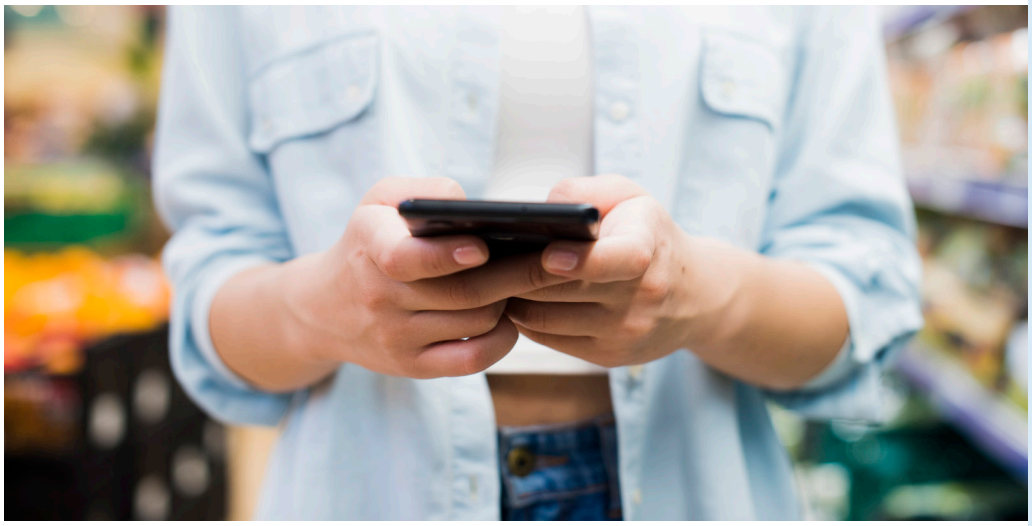
Opportunities:

- **Food waste represents a cost for distributors**, hence they have economic motivations to find solutions to better prevent and manage waste. This makes for an ideal market for startups to emerge in.

- There are now several **app-based marketplaces that allow consumers to buy unsold products** from cafes, restaurants and grocery stores at a discounted price. Too Good To Go is perhaps the most successful European player with this business model. According to the Danish startup, it is active in 15 countries, has raised over $45m and saved 50 million meals since its foundation in 2015. The Swedish startup Karma has a very similar offering to Too Good To Go but the British startup OLIO has taken a slightly different approach: with a C2C model, its app allows individuals to donate their surplus food to their neighbours.

- Many supermarkets, especially in the UK, **only sell fruits and vegetables that fit their standards** in terms of size and appearance. This means that post-production food waste also happens unbeknownst to the consumer. UK-based Oddbox aims to address this issue by purchasing produce not deemed fit to sell by traditional distributors, and then reselling them to consumers via a box subscription model.



Challenges:

- **Solid business models supporting these solutions can be hard to build**, making it difficult for companies to scale such solutions and reach profitability.

- **Regulatory frameworks are not harmonised between countries**, hindering the international development of waste prevention and reduction initiatives. The implementation of innovative solutions among industrial and commercial players, mainly driven by regulatory constraints, remains slow.

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CASE STUDY: Phenix

"Phenix saved 44 million meals in 2020 alone, which represents 22,000 tons of food and 99,000 tons of CO2 avoided."

From field to fork, Phenix helps professionals reduce food waste by giving value to their unsold products. Today, Phenix is the only player working on the entire value chain : producer, wholesaler, industrialist, collective catering, distributor, food retailer, consumer. The company even goes beyond the purely operational aspect with a Research and Consulting division for strategic support to both public and private players.

Phenix has created four tech tools for food distributors. Firstly, Phenix Date, which informs them of products with short shelf life that are still present on their shelves. The store teams will be able to take these products off the shelves and offer them to charities thanks to the B2B marketplace. They will also be able to sell them at a reduced price in store thanks to their smart sticker tool. In addition, their mobile application allows distributors to sell the remaining products in the form of surprise baskets, while attracting new customers in store. The startup has also developed an electronic signature system that allows the entire food donation certification process to be digitised.

The company believes in the complementarity of solutions to achieve zero food waste. A model already tested in 20 French hypermarkets under the Leclerc, Intermarché, Carrefour and Système U brands.

Founded in France, Phenix is now present in Spain and Portugal with plans to expand into Italy and Belgium in 2021. It has saved over 110 million meals since its inception in 2014. The acceleration of the last few years has allowed the company to save 44 million meals in 2020 alone, which represents 22,000 tons of food and 99,000 tons of CO2 avoided. In 2021, they are on an average rate of 120,000 meals saved daily from destruction. This is the equivalent of 60 tons of food every day.

Phenix sees many improvements to come in the future. Their vision is that waste will be increasingly reduced upstream of the chain. The rise of big data and its processing via artificial intelligence is undoubtedly one of the most promising expected changes: the intelligent processing of correctly collected data allows for crucial optimisations at each link of the value chain. In addition, the development of IoT, which is gradually taking hold in farms and factories should be highlighted. Its potential in terms of energy optimisation and predictive maintenance is attractive. Waste is largely a logistical problem but according to the startup, logistics will be dramatically optimised in the next few years thanks to technology.

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Conclusion

In this white paper, we attempted to give an overview of the innovations and companies enabling the decarbonisation of the agricultural and food industry.

Our first finding is that there is a gap between the environmental goals set out by European governments and the actions taken towards these goals. Based on their public communications, stakeholders from all sides (from the public and private sectors) seem to appreciate the importance of tackling the industry's carbon footprint. Indeed, the EU and several large food and beverage producers have set themselves ambitious targets for carbon emission reductions. However, when we reached out to leading companies in the industry, few wished to communicate on their initiatives. Some declined to comment due to the lack of maturity of their decarbonisation projects, while others deemed theirs too confidential to share. These factors make the need for knowledge sharing and collaboration between large players and innovative newcomers all the more pressing.

Our second finding is that the startup ecosystem is a valuable source of solutions for the decarbonisation of the sector. For every part of the value chain we analysed (production, processing, packaging and distribution), we found a wide variety of startups and innovations tackling different issues related to decarbonisation. The volume and maturity of these innovative offers do vary depending on the subject matter. For instance, solutions addressing energetic efficiency are available in greater numbers and at a bigger scale than those for carbon capture storage and use.

This leads us to our third finding: startups and corporations working towards the decarbonisation of this industry face multiple challenges. Regulatory hurdles can impede the development of certain innovations, such as synthetic meat and meat-free proteins. Many startup solutions require significant infrastructure investments to make their implementation possible (e.g. on-site waste treatment or feed production) which can slow down the rate of adoption from large industry players. Certain areas of innovation, such as the electrification of distribution fleets, are equally slowed down by the lack of suitable public infrastructure. Scalability is also a key concern for corporates considering a startup solution, as most innovative companies in this field are still in their early days and therefore lack the track record of large-scale deployments.

Financial incentives and investments from private and public funds are needed to bring the European Agritech and Foodtech ecosystems up to speed, compared to North American and Asian markets. Moreover, health and safety concerns, taste and quality assurance as well as some consumer demand trends (e.g. fast home delivery) can be at odds with the carbon reduction goals of the sector.

Lastly, we have to recognise the complexity of decarbonising such a large and globalised industry. There are a multitude of carbon emission sources throughout the whole agricultural and food value chain. Hence, it can be difficult for industry players to measure, track and address all these emission sources, which can be direct and indirect. Carbon tracking and auditing is slowly but surely becoming widespread. Having a clear picture of their carbon footprint will allow large companies to better prioritise which decarbonisation solutions to adopt. In turn, it will accelerate the pace of change in the sector.

Large groups could also benefit from reconsidering their internal organisation. Indeed, several of the large companies that did not wish to comment for this paper struggled to find a person internally that had a comprehensive understanding of all the initiatives taken throughout their group. We recommend that agriculture and food leaders build stronger bridges between their heads of innovation, of CSR and of relevant business units to create a group-wide decarbonisation strategy.

All in all, we can say that startups, corporates and public institutions are generally willing to collaborate to help achieve carbon neutrality in agriculture and food production. More and more industry leaders (Avril, Groupement Les Mousquetaires, Coca-Cola, Nestlé…) are launching pilots with innovative newcomers. European governments are providing more and more financial incentives and strategic frameworks to facilitate collaboration and technology adoption. As consumers become increasingly aware of the climate crisis, we believe the demand for environmentally-sound food and beverages will continue to grow in Europe, further fuelling the decarbonisation of the secor.

About

The report “Decarbonisation of the agricultural and food industry” is brought to you by Capagro and Early Metrics.

EARLY METRICS

Early Metrics specialises in startup ratings and emerging technology research. As an independent agency, it has developed a scientific methodology to identify emerging tech players and assess their growth potential. It therefore provides the right tools for decision-makers from funds and corporates to discover, qualify and engage with startups. To date, Early Metrics has rated over 3500 startups in Europe and worldwide on behalf of 280 corporates and funds.

For further information, visit www.earlymetrics.com or contact Pierre-Louis Martinie at: pierre-louis@earlymetrics.com

CAPAGRO

Capagro is the French leading venture capital fund dedicated to the Food and Ag industries. It was created in 2014 and has 124 M€ under management. Feeding a sustainable planet and maximizing value creation across the entire agri-food chain is its core focus. Capagro invests to accelerate the development of European FoodTech and AgTech companies and facilitates the adoption of innovative solutions for stakeholders in those sectors. Capagro’s team of seasoned investors is unique in combining strong sector expertise with a wide range of international experience.

For further information, visit www.capagro.fr or contact Léa Louvat at: lea.louvat@capagro.fr

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