Whitepaper

How can we find **a new protein mix for 2050?**

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How can we feed 10 billion people in a healthy and sustainable way?

We will need new sources of protein.

The world's population is expected to reach 10 billion by 2050, and our current food system will not be capable of feeding them in a way that does not harm the planet or our health. Meat-based diets are key contributors to both environmental and public health crises, and it's vital that we make a large-scale shift to sustainable, alternative protein sources.

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It's estimated that by 2050 there will be nearly 10 billion people on earth. How to feed this growing population in a healthy and sustainable way is one of the greatest challenges we now face. It will require 56% more food crop calories than were needed a decade ago[1], and currently two thirds of our food calories come from just four crops – soy, corn (maize), rice and wheat. Around 70% of the soy and maize produced, meanwhile, is currently being used for animal feed.

It's not just the number of people that's increasing – middle class populations in the developing world are growing rapidly[2], which means more and more demand for meat. Meat production is a major driver of climate change, biodiversity loss and freshwater depletion, with the agri-food sector accounting for 25% of all greenhouse gas emissions, largely as a result of shifts in land use from forest land to pasture or cropland for livestock. While changes in land use are promoting climate change, the knock-on effects of this are, in turn, putting crop yields at risk. Just a 1°C increase in temperature can potentially reduce soy and rice yields by 3% and those for wheat and maize by 6-7%.[3]

Agriculture also accounts for 71% of fresh water use, while runoffs from agrochemicals and manure disrupt our aquatic systems. To grow 1 kilogram (kg) of cereal takes up to 3 tonnes of water, while 1 kg of beef needs up to 15 tonnes – this means that the daily food intake of just one person requires between 2,000 and 5,000 liters of water.[4] Growing demand for seafood is also leading to depletion of fish stocks, with more than 30% of stocks now overfished.[5] A frequently underestimated driver of our growing protein demand, meanwhile, is companion animals. Pet food is thought to be responsible for a quarter of the overall environmental impact of meat, as we increasingly feed our pets human-grade food.[6]

All of this means that today's food system is already operating outside of our 'planetary boundaries'.[7] The last 50 years have seen the environmental degradation of our planet grow exponentially, with increased food production one of the major causes. Despite all of this, the UN estimates that – almost 20 years into the 21st century – 820 million people are still going hungry[8], while at the same time, a third of all food is being lost or wasted across the value chain.

From a consumer perspective, poor diet is also the cause of 11 million deaths per year through cardiovascular diseases, diabetes and cancers.[9] Intensive livestock farming, meanwhile, is associated with a rising number of serious food-borne illnesses as well as the emergence of deadly antimicrobial-resistant bacteria through overuse of antibiotics. Clearly, scaling our current protein supply to nourish more people is not an option given the high risk of catastrophic environmental and health consequences. The question is how will we be able to feed 10 billion people without further extending arable land use and while also cutting harmful

emissions? How can we provide healthy and sustainable protein that people will want to eat? In short, what would the sustainable protein mix for 2050 look like?

Uncovering new protein sources

A genuinely sustainable food system will need to increase the diversity of protein sources, as well as reducing losses and waste. It will also need to make sure that healthier options are not only available but are attractive to the consumer. What options exist for more sustainable protein sources for food and animal feed? One currently under-used resource is pulses. Despite having high protein content, production rates for pulses worldwide are still far lower than for corn, wheat or rice. Pulses in combination with cereals like wheat improve the overall nutritional value and can be processed into products such as pasta, snacks or baked goods.

Interest in older, traditional grains such as quinoa, sorghum, and teff is also increasing as they are nutritious and can help to fill yield gaps in arid regions. Nuts are another valuable protein source, while many current industry side streams such as seed oil press cake and cereal bran are also rich in proteins.

Considering arable land restrictions and need for km zero solutions, single cell protein, such as microbial protein is another viable protein source, with potential to meet up to 20% of conventional crop-based animal feed protein demand by 2050[10], which could significantly reduce the environmental impact of the sector. Likewise, food ingredients from fermentation of fungal cultures are a valuable source of protein.

Another highly promising source of single cell protein is microalgae. In nature, the number of microalgae species is estimated between 200,000 and 800,000.[11] Over 20 species are currently used in food or feed applications[12], but with some microalgae containing up to 70% protein, along with essential amino acids, the potential is enormous. There are still hurdles to overcome, however.

The standard way to grow microalgae is the photoautotrophic method using sunlight, CO2 and fertilizer. “It’s a single cell system so it’s quite efficient, but if you’re not close to the equator then light and temperature are a problem,” says Alexander Mathys, Professor at the Institute of Food, Nutrition and Health, and Assistant Professor in Sustainable Food Processing at ETH Zurich. This means compensating via resource-intensive technology, with attendant costs in energy, materials and infrastructure. Another method is heterotrophic cultivation – using organic carbon sources instead of light as energy – in a dark fermenter. “These facilities already exist so you don’t need to invest in new infrastructure, but you need to understand the system and you need all the biotechnological know-how,” Mathys explains. “So there are constraints, but there’s great potential because we could have up to 70% of protein in dry matter in microalgae that we already cultivate on a large scale, such as photoautotrophic Arthrospira platensis or ‘Spirulina’.”

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>
> **Alexander Mathys,**
> Professor in the Institute of Food, Nutrition and Health, ETH

An additional benefit is that microalgae require very little space. “We’ve used almost of all our arable land, so microalgae are very interesting,” he says. “We can grow them on non-arable land, in urban areas where we can use roofs and other spaces, even in deserts.”

Reduce environmental impact with insects

Another promising alternative protein source for the animal feed and pet food markets, meanwhile, is insects. Again they require relatively little space and essentially up-cycle existing food waste, quickly turning it into body mass. “Insect protein has the potential to address a new resource of food by-products and food waste, and upgrade that into high quality protein,” says CEO of insect protein and nutrition company Protix, Kees Aarts. “At the moment that’s either lost, land-filled, digested or composted. But if you upgrade that to high quality proteins that can be used in fish feed, chicken feed and even human food, then all of a sudden you can drive the footprint reduction of the entire food system.”

For every kg of fish eaten by humans, for example, 2-3 kg is currently fished from the ocean. “This is where the impact can be significant,” says Kees Aarts. “We can feed fish without fishmeal or chickens without soy.

That would drive a huge reduction in land use, carbon dioxide, water use, and impact biodiversity. At the moment, the amount of protein in the total amount of food waste is about the same as the total amount of protein used in global animal feed. From the perspective of unlocking a new resource, the potential is enormous.”

Conclusion

— We are in the midst of an environmental and public health crisis.

— Our current protein system is in no way sustainable.

— Pulses, insects and microalgae are promising sources of sustainable protein.

— Science and technology can make these scalable and cost-efficient.

— Consumers have to be convinced by tasty protein foods with a low footprint.

Rethinking food

Attitudes to food, and to our food system, are changing. Younger generations are more and more health conscious and increasingly concerned about issues such as animal welfare, as is shown by the growing popularity of flexitarian, vegetarian, and vegan diets.

One possible way of providing meat products without the need to raise and slaughter animals via a system that's having profound environmental consequences and is increasingly regarded as inhumane is 'cultured meat' – the in-vitro cultivation of meat from animal cells. This remains a nascent sector, however – there are significant issues in terms of scaling, and there are also likely to be significant regulatory and consumer acceptance aspects that will need to be addressed.

In the meantime, plant-based meat alternatives and protein-rich drinks like soy milk are seeing strong market growth, but to enjoy real success in the long-term products such as these will need to win over consumers by making sure they pay attention, above all, to taste. Here texturized plant protein products as meat substitutes have been leading the way for more than 15 years, and while they represent "a huge opportunity" to reduce meat consumption they should really be regarded as a short-term solution, says Alexander Mathys. "Many young people want to eat less meat – vegetarianism is cool, flexitarian is a new consumer group. This arena is popular, so it's a very good move to go in this direction and improve these products even more. However, in the long term we should think about what else can we do with plant raw materials rather than just copying meat. We should come up with entirely new plant-based, protein-rich categories," he explains.

Producers also need to think about how they get messages about the huge environmental benefits of non-meat products across to consumers. "The reduction of meat consumption is mainly a social topic," says Mathys. "There is no scientific reason why I should eat a lot of meat – there's only an emotional, subjective reason. People want to do the right thing, and we have all the information available in terms of sustainability performance. We have to motivate – we need good marketing and communication. People need to be convinced."

There is vast potential in pulses, microalgae and insects as alternative sources of protein, but while the insect industry is developing at a rapid pace, significant and inevitable challenges remain. "There's one thing I always bring in and it's that this is not a software business," says Kees Aarts. "It's operations, it's biology, and we need to be realistic. The food system is enormous, so yes the insect sector will have fast growth, but it's also production-limited. Assets need to be built, production capacity needs to be ramped up, companies need to run their operations."

Diversity equals resilience

Microalgae represent a vast untapped resource and an under-developed value chain. While this means it is hugely promising, the lack of development means it also has a "low technology readiness level," says Mathys. "There are some highly optimized large-scale production facilities, but compared to plant protein sources such as soy or even pea, it's niche – the scale is not comparable at all. Methods are currently being developed to grow microalgae in more effective ways, however, along with new technologies to make them more competitive. As with pulses, insects and perhaps even cultured meat, responsibility lies with producers to seize the opportunity offered by changing consumer attitudes and maximize their potential. It's clear that the cost of not doing so would be far too high. "We won't replace all existing crops with microalgae," Mathys explains. "Diversity is a benefit, because it is more resilient. The future will be diverse. It must be diverse."

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Alexander Mathys is a Professor in the Institute of Food, Nutrition and Health at the Swiss Federal Institute of Technology (ETH) in Zurich. A food technologist, he received his doctoral degree in Food Processing in 2008. He has held the post of Assistant Professor in Sustainable Food Processing at ETH since 2015, where he focuses on driving sustainability in food and feed value chains. He is the author of more than 70 publications and was selected “Young Researcher” of the 60th Meeting of Nobel Laureates 2010, ICEF “Young Food Engineer” Award winner 2008, and “Einstein Young Scholar 2010” at the Falling Walls conference.

Kees Aarts

Chief Executive Officer, Protix

Kees Aarts is founder and CEO of leading insect company Protix. He started his career as an advisor at McKinsey on R&D innovation and business development, before founding Protix with a partner in 2009. Protix aims to contribute to a sustainable food system by developing ingredients from insects, and is a highly technological and data-driven producer with automated breeding and rearing processes. The company has turned insect production into a commercial success by serving the animal feed industry while also developing food applications for consumers, and is a recipient of the Technology Pioneer award from the World Economic Forum.

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Béatrice Conde-Petit holds the position of Group Expert Food Science & Technology at Bühler. She drives strategic innovation projects at the interface between science, technology, and business around the world. She is responsible for the Future of Food Program with a focus on sustainable food processing, leveraging collaborative innovation with customers, academia, startups, and suppliers. Conde-Petit holds a Diploma and PhD in Food Science & Technology from ETH Zurich. Before joining Bühler in 2008, she worked at ETH Zurich for 20 years as researcher, lecturer, and consultant to the international food industry.

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