Protein pathways

Accelerating sustainable food system transformation through business innovation

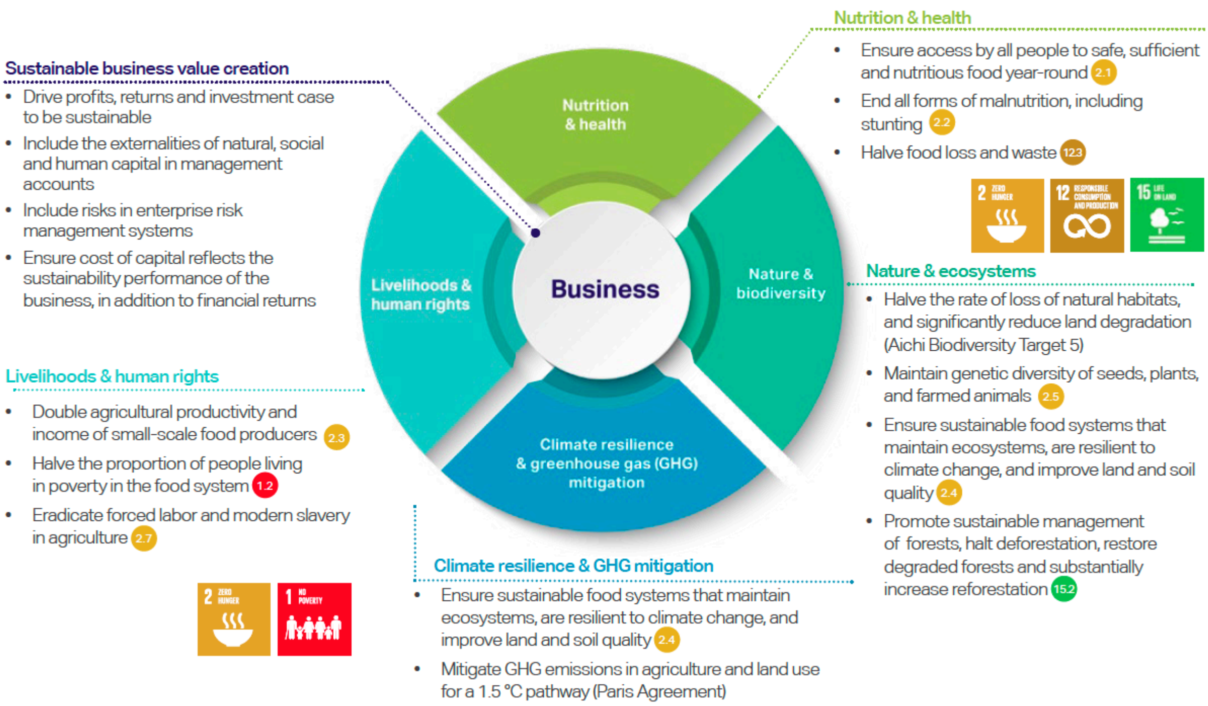
Table of contents

Why focus on protein transformation?

Achieving our Healthy People, Healthy Planet vision requires unprecedented global collaboration on several levers of system transformation at the same time. Business action is necessary on diets as they connect to all aspects of the food system. This paper discusses the complex issue of protein transformation and actions business leaders are taking and must take to respond to this challenge.

Proteins are at the heart of fierce arguments within the food system because of their environmental impacts and because of the continuing debate about how best to balance them in human diets. As such, they have to align, at a similar pace if not faster, with the targets established in the WBCSD CEO Guide to Food System Transformation (Figure 1).

Figure 1: Food system transformation goals, grounded in science and aiming to deliver against the Sustainable Development Goals, Paris Agreement and developing biodiversity targets[1]

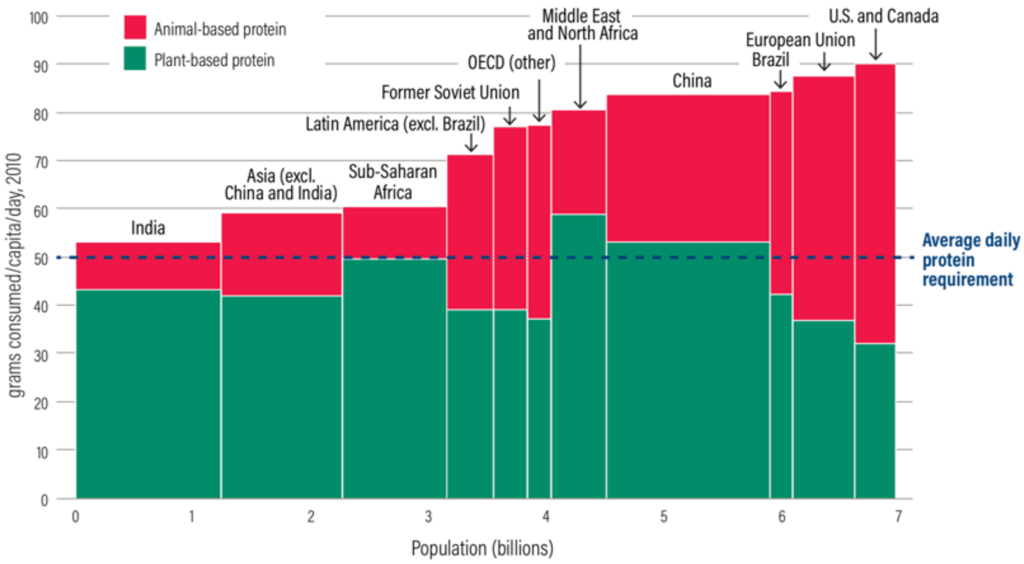


The importance of proteins for humans

Fact 1: Proteins are an essential part of human diets, yet they are over-consumed overall

Everyone needs 50-70 grams of protein a day. Protein is essential to producing muscle, hormones, enzymes and antibodies in human immune systems. While an increasing number of people eat too much protein, especially animal protein, many people in developing countries still lack sufficient access to animal protein for nutrition and health (Figure 2). A critical health objective is therefore to reach adequate protein intake in terms of quantity and quality for everyone, while rebalancing animal and plant protein consumption.

Figure 2: Average daily protein consumption by region[2]



The importance of proteins for the environment

Fact 2: Proteins have a significant impact on the environment, with recognized negative effects depending on protein sources

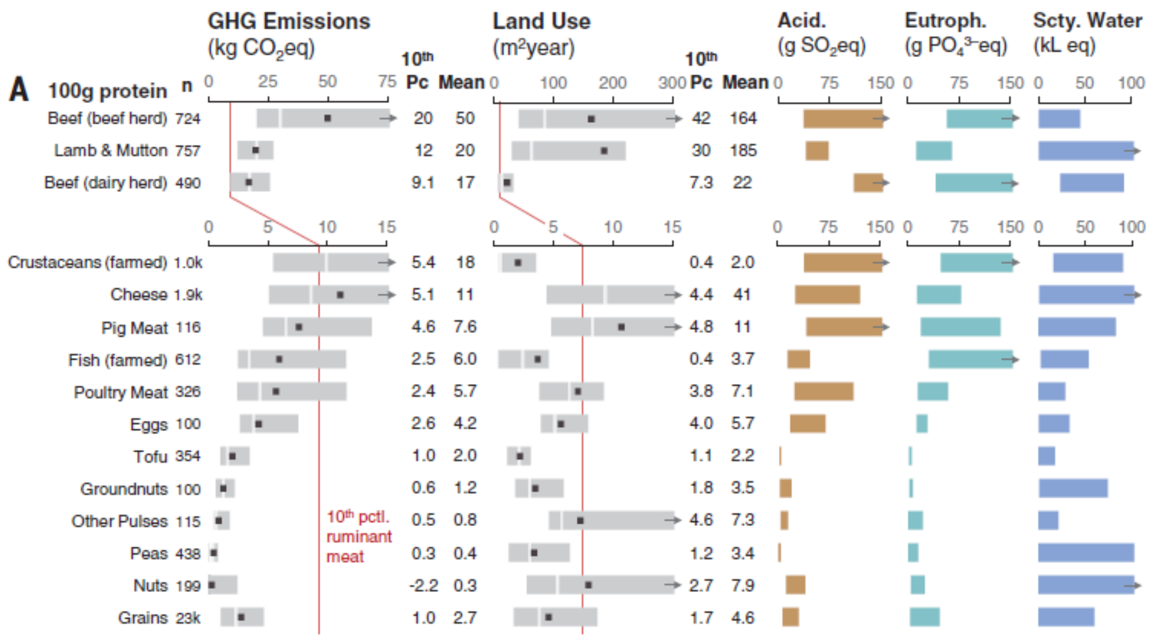
The FReSH 2018 "People, Planet, Protein - What's the Plan?" Science to Solutions Dialogue recognized that globally, and given current rates and means of production, livestock have a significant impact on the environment.

Greenhouse gases (GHG): The livestock sector is a major emitter of greenhouse gases, generating 7.1 Gt CO_2e and representing 14.5% of all human-induced emissions. Beef and milk production are responsible for 60% of the livestock sector's emissions.[3] However, the global GHG values are still subject to discussion, as the Intergovernmental Panel on Climate Change (IPCC) keeps revising the conversion factor of methane (and of nitrous oxide) into CO_2e. Milk production has less of an impact in terms of GHG emissions than meat production (four to six times less per gram of protein per serving).

Land use: Food production has a major impact on global land use, at it covers 32% of arable land globally. Of this area, the livestock sector uses 62%. This includes land to grow feedstocks for animals as well as native grasslands to graze animals.[4] The negative impact of livestock production on land use varies considerably according to regions and land management practices.

Water use: Beef production is also water intensive, having a water footprint six times larger than that of pulses.[5]

Figure 3: Estimated global impact range in GHG emissions, land use, terrestrial acidification, eutrophication and freshwater withdrawals of major food categories[6]



However, animal proteins show high variability in terms of their environmental impacts[7]. This variability corresponds to a variety of practices that offer opportunities for more sustainable management.

But protein also have positive effects

Greenhouse gases: First and foremost, the commonly cited 7.1 Gt CO_2e figure does not factor in the carbon sequestration potential of grazed cattle. Estimates suggest that grazing systems could sequester anywhere from 250 $MtCO_2$ to 3.5 $GtCO_2e$ per year; thus, lowering the net amount of emissions.[8]

Land use: Similarly, the livestock land-use narrative often stresses the area occupied by cattle and feed crops, rather than highlighting the ecosystem services provided in certain production systems. For example, in grassland biomes, livestock can play ecological roles similar to livestock native to these systems or farmers can manage them using methods that are compatible with grassland biodiversity (birds, mammals, reptiles). Land use also plays a role in remote or poor areas in the transformation of grass that humans cannot consume into nutrient-rich food, bringing economic value to these areas.

Biodiversity: A recent analysis found that holistic rangeland management systems could contribute to biodiversity conservation, reduced soil erosion and improved water quality without compromising yield.[9] Even when raised on non-grass biomes, farmers can use silvopastoral systems to create habitat and connectivity for biodiversity that can reduce some of these impacts.

"From the livestock sector, two improved grazing pathways (Optimal Intensity and Legumes) increase soil carbon, while two others (Improve Feed and Animal Management) reduce methane emissions."
Griscom et al., 2017 "Natural Climate Solutions"[10]

Why is it urgent to "bend the curve"?

Fact 3: The animal protein sector is a significant contributor to climate change

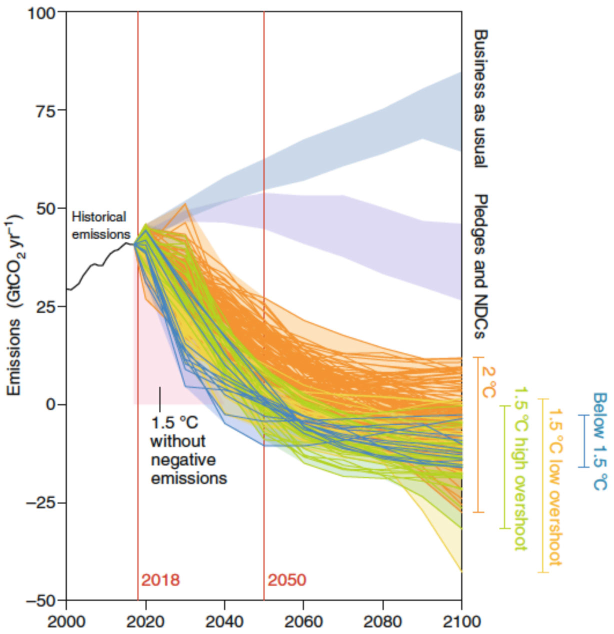
Representing 14.5% of GHG emissions (and up to 30% in 2050 under business-as-usual (BAU) scenarios), the animal protein production sector must act even faster than other sectors. Otherwise, growing demand for animal protein will keep emissions growing despite efforts to reduce emissions per unit produced.

According to the IPCC Special Report on 1.5°C, net global CO_2 emissions must reach zero to stabilize global temperatures, whether at +2°C, +3°C or any other level. The best chance to avoid the worst impacts of climate change is to limit temperature increases to 1.5°C by halving emissions by 2030 and dropping them to net zero by 2050 (see Figure 4).[11]

For the business sector, including for the food sector, this translates as reaching net zero emissions from operations, products and supply chains within this timeframe. WBCSD's work on climate smart agriculture[12] has clearly shown how challenging it is to reduce total emissions in the food sector despite the abatement of per unit emissions reductions.

Figure 4: Global net anthropogenic CO_2 emission pathways in BAU, NDCs (nationally determined contributions), 2° C and 1.5° C model scenarios[13]

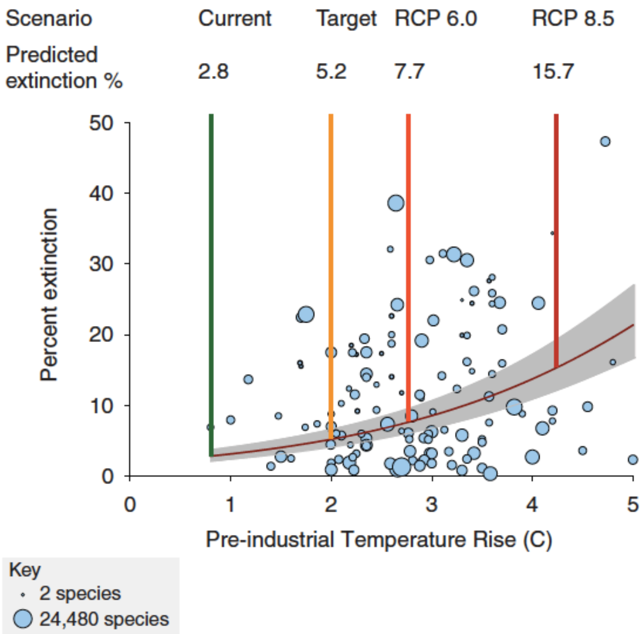
> *"Reaching the Paris Agreement goal will be challenging and require an 'agrarian revolution', where our food system becomes part of a global roadmap for rapid decarbonization."*
> Johan Rockström, EAT Food Forum, State of People and the Planet, 2017



Fact 4: The agricultural sector impacts biodiversity extensively

The same urgency applies to biodiversity impact, be it directly or indirectly (e.g., through climate change). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has recently reported that land use change is one of the largest drivers of biodiversity loss, with agriculture as the largest contributor.[14]

Figure 5: Predicted extinction risks from climate change accelerate with global temperature rise (extinction rate for four scenarios are: the current temperature rise of 8°C, the policy target of 2°C, and IPCC's Representative Concentration Pathway (RCP) 6.0 and 8.5)



"Current food and land use systems (...) are the leading cause of the continuing conversion of the world's tropical forests, grasslands, wetlands, and other remaining natural habitats – and thus the main culprit of the ongoing 'sixth extinction' of biodiversity."
The Food and Land Use Coalition[15]

Navigating science and business controversies on proteins

Debates and challenges

On top of political debates about protein transformation, with consumers concerned that governments will take away their burgers or will ruin livestock farmers, the most crucial challenge in connecting science with business is the issue of consensus itself. A lack of consensus on a scientific result does not help decision-makers identify pathways to solving the challenges at the base of the issue. Business and governments will take their own views in this situation, ranging from complete buy-in to outright denial.

On protein, the most debated issue is health, as shown by the flurry of reactions from health scientists in the months following the publication of the EAT-Lancet report[16] arguing the current health debate is based on "old science". Indeed, there is not yet full scientific consensus on the positive and negative effects of animal and plant-based proteins on human health due to their ramifications. And planetary boundaries such as biodiversity, nitrogen and phosphorus remain insufficiently understood to support enough targeted action.

Yet ways to move forward

The complexity of the agri-food sector and how it impacts planetary and social issues has led WBCSD and its members and partners to innovate in this engagement between business and science.

As an example, our FReSH Science to Solutions Dialogues (SSD), conducted with EAT in 2018, helped the food sector prepare actions and transformation that resulted in the publication of the 2019 EAT-Lancet report on Food in the Anthropocene. A Science to Solutions Dialogue is a one- to three-day event designed as a safe space for detailed conversations between science and business focused on defining specific solutions embedded in a long-term commitment to developing and implementing purpose-driven business solutions.

Based on FReSH's 2018 Science to Solutions Dialogue on "People, Planet, Protein – What's the plan?" outcomes,[17] we decided to focus our protein transformation pathways on their impacts on climate, land expansion and biodiversity as there is sufficient consensus in these areas to define a common ambition.

Our objectives

We aim to identify and quantify the business ambition elements to achieve a global protein transformation by:

- Comparing the sustainable pathways[18] considered as "realistic scenarios" from 18 countries, using the EAT-Lancet Planetary Health Diet and respective environmental impacts by 2050;
- Demonstrating how the industry can accelerate the protein transition between now and 2030; and
- Calling for action on business protein transformation.

Some few limitations and caveats are (see next section for those related to the FABLE calculator):

- We do not consider fish and neither does FABLE, as reliable data on fish remain insufficient to date at global and country levels.
- The FABLE impact assessment in 2019 only took GHG emissions, land and biodiversity into account; further iterations will include nitrogen, phosphorus and water.
- This is therefore a living document that we will update in 2020 once FABLE has completed another round of country scenarios.

The scope of solutions

The FABLE Calculator

Introduction

The FABLE Calculator is a framework for governments, businesses, civil society organizations and the scientific community to achieve country-specific changes and global sustainable land-use and food systems. This Excel modelling tool quantifies regional future food demand and the resulting global food security and environmental impacts (food security, GHG emissions, land-use changes and biodiversity).

The strengths of the FABLE model are:

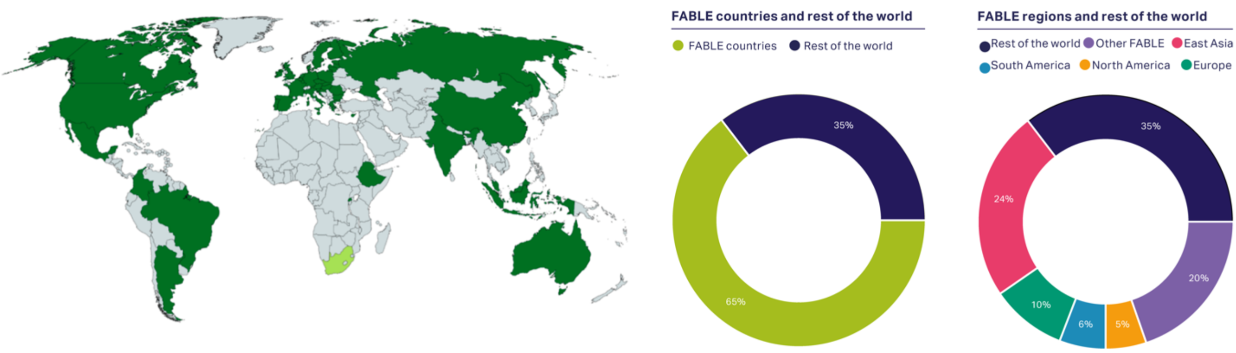
(1) Capacity to consider the **role of trade** between several countries;

(2) National strategies and long-term pathways to sustainable land-use and food systems designed by **individual country teams**, illustrating national policy objectives as closely as possible.

FABLE countries

FABLE's models are based on data from 18 countries plus the European Union. The countries that are part of the FABLE Consortium represented 65% of the world population in 2010 (62% in 2030, 59% in 2050), thus illustrating a global scenario (see Figure 6). FABLE's ability to mobilize country-based research teams, has to date two major caveats: Africa is under-represented and Middle Eastern countries are missing. Therefore, there are not further considered.

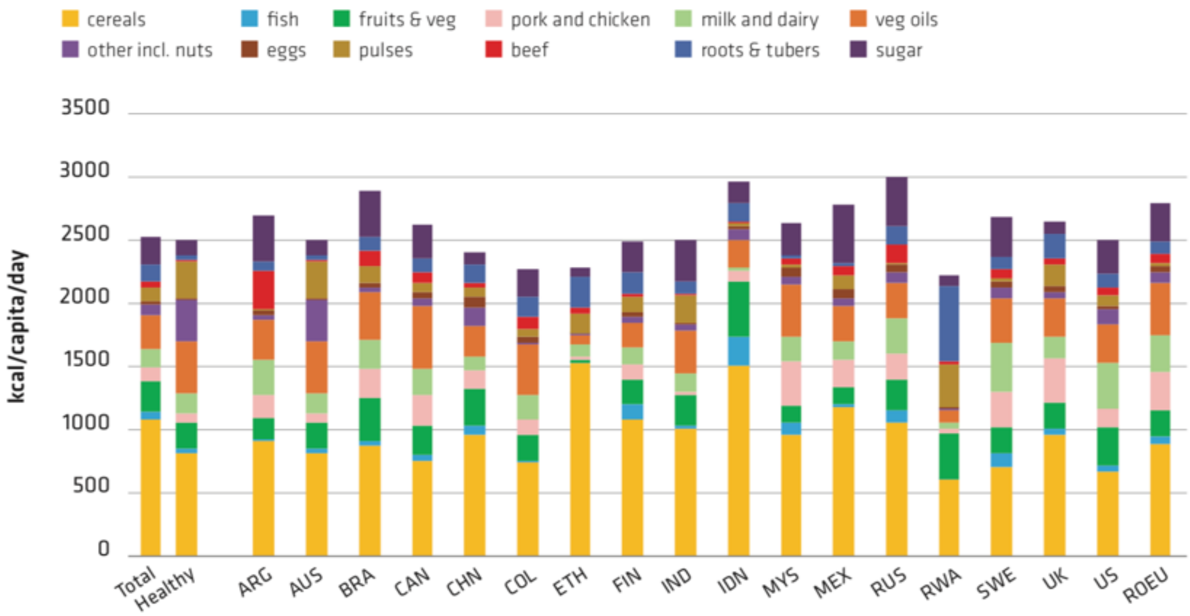
Figure 6: FABLE countries, regions and their present population



The assumptions of FABLE countries' dietary choices reflect local traditions, customs and resource endowments, as well as the feasibility and desirability of changes. While dietary patterns vary by country, all FABLE countries aim to reach food security (average daily kcal consumption higher than the average minimum daily energy intake). The choice of diets is one element as the countries aim to reach land-use and food system sustainability. Some countries (e.g., Australia, Finland) consider diets as a key element of their sustainable pathway, while others (e.g., Latin American countries) focus predominantly on the combination of zero deforestation policies and high productivity.

The dietary choices are one of the levers that country teams can activate to collectively meet the global targets: zero net deforestation, half Earth's terrestrial land supporting biodiversity, GHG emissions compatible with keeping rise in average global temperatures below 1.5°C.

Figure 7: Assumptions on average diet composition in 2050 by FABLE country[19] ("Total" is a weighted average of FABLE countries and rest of world assumed diets by 2050; "healthy" is a diet based on the EAT-Lancet report[20]) - See Annexes for the list of country abbreviations.



The characteristics and assumptions above have led us to retain the FABLE Calculator as a consistent, comprehensive and realistic tool to estimate future trends in sustainable protein consumption around the world. The different scenarios made available through the FABLE Calculator also allow us to estimate what the accelerating effect of a fast and sustainable transition led by business could be.

Methodology limitations

Food security and healthy diets: Illustrated as the average energy intake. The FABLE analysis does not yet cover quality of diets (providing nutritious diets) to all.

Biodiversity conservation and restoration: The FABLE Calculator does not consider carbon sequestration in managed forests. It also does not account for carbon in dead organic matter and soil organic carbon.

Efficient and resilient agricultural systems: The FABLE Calculator only reduces GHG emissions from agriculture by lowering production volumes or increasing productivity. It does not yet include improved rice management, animal feed supplements, fertilization techniques or anaerobic digesters.

Horizon 2050: Projected protein consumption

This section compares protein consumption in 2050 in key FABLE regions between: (i) a Food and Agriculture Organization (FAO) of the United Nations business-as-usual (BAU) scenario (with food consumption based on economic and population growth): (ii) what FABLE countries project with their own sustainable scenarios; and (iii) the EAT-Lancet Planetary Health Diet.

We present regional projections first as they strongly shape what the global projection will look like.

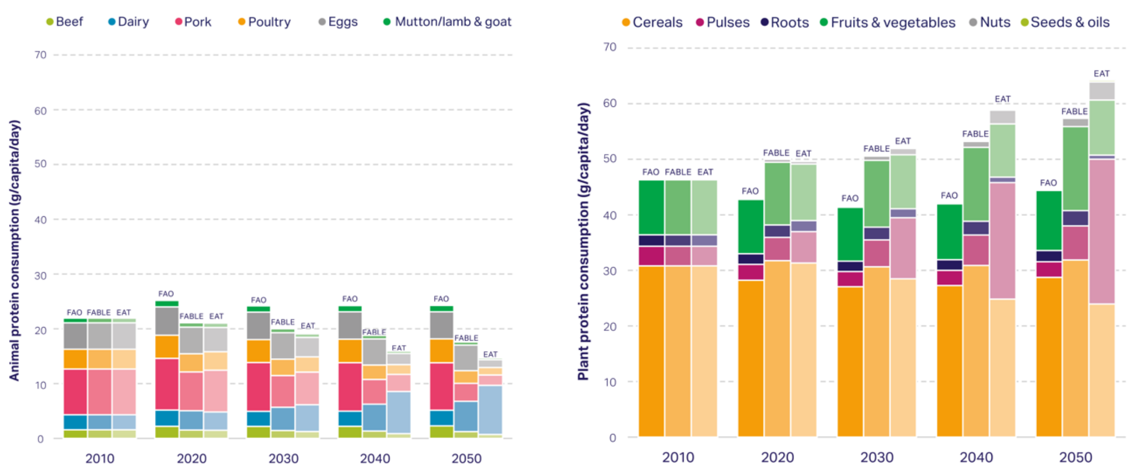
Note: In Figures 8 to 13:

- *The darkest tone bars show the protein consumption if all FABLE countries were to follow the FAO BAU for their dietary pattern;*
- *The intermediate tone bars show protein consumption under FABLE country dietary choices;*
- *The lightest tone bars show the protein consumption if all FABLE countries were to follow the EAT-Lancet Planetary Health Diet.*

Regional trends driving the global evolution

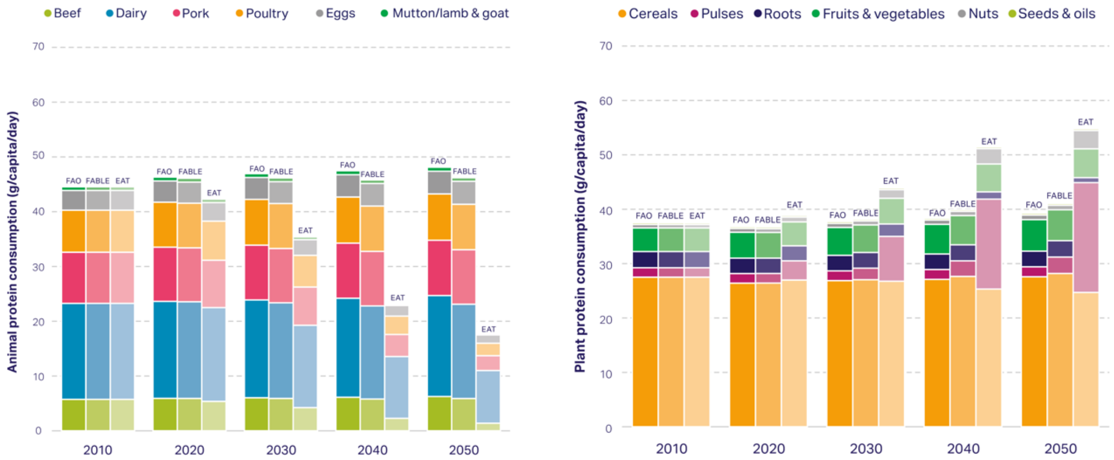
East Asia: Protein consumption projections for East Asian FABLE countries show a substitution of pork protein with milk protein under the sustainable countries scenario. A large increase in protein from pulses, fruits and vegetables, and nuts compensates for the slight decrease in animal protein. China largely influences these projections, due to its large population.

Figure 8: Animal and plant protein consumption in East Asian FABLE countries (China, Indonesia and Malaysia)



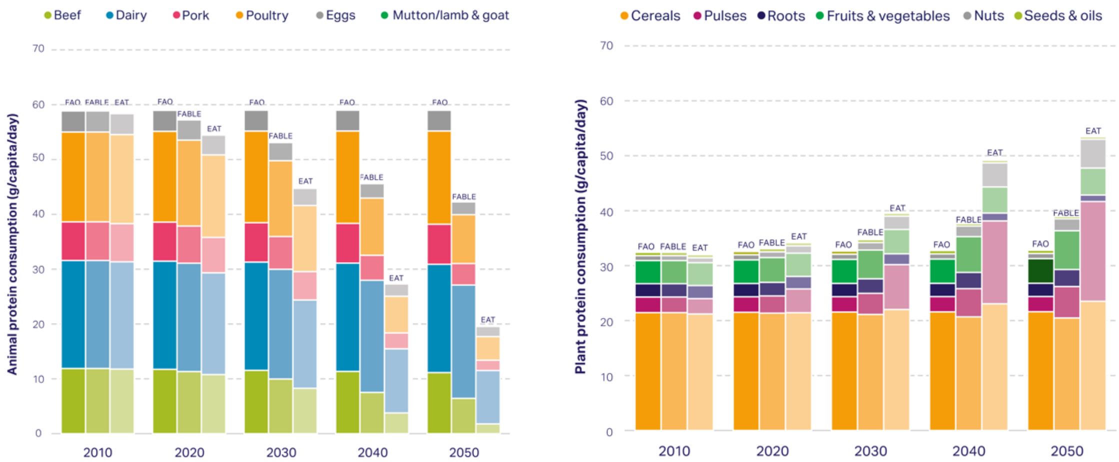
Europe: Protein consumption projections for European FABLE countries remain fairly constant under the FABLE sustainable countries scenario. Cereals are the major source of protein, followed by dairy and other animal-based foods. We expect a slight increase in pulses.

Figure 9: Animal and plant protein consumption in European FABLE countries (Finland, Russia, Sweden, United Kingdom and rest of the EU)



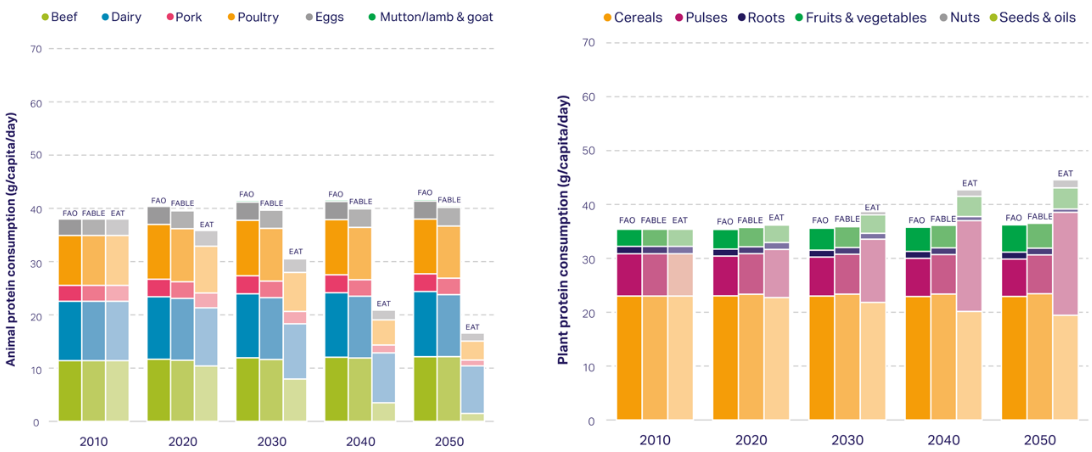
North America: Protein consumption projections for North American FABLE countries indicate a shift in dietary patterns compared to today's diet. We expect the substitution of pork, poultry and beef proteins by dairy and plant-based protein. Protein consumption from pulses, nuts, and fruits and vegetables show a considerable increase.

Figure 10: Animal and plant protein consumption in North American FABLE countries (Canada and USA)



Latin America: Protein consumption projections for Latin American FABLE countries indicate a slight increase in animal protein consumption. The intake in protein from plant-based sources remains constant. Fruits and vegetables are the only category showing an increase.

Figure 11: Animal and plant protein consumption in Latin American FABLE countries (Argentina, Brazil, Colombia and Mexico)



Evolution of global consumption

Here, we compare protein consumption in 2050 in key FABLE regions between: (i) an FAO BAU scenario (with food consumption based on economic and population growth); (ii) what FABLE countries project with their own sustainable scenarios; and (iii) the EAT-Lancet Planetary Health Diet.

We first consider the individual consumption of animal and plant proteins in FABLE countries, which shows a significant decrease in animal protein consumption, especially for pork protein, compensated by in pulses, roots and fruits and vegetables (see Figure 12). China largely influences this global trend, as observed previously (see Figure 8).

Figure 12: Global individual animal and plant protein consumption for the 18 FABLE countries

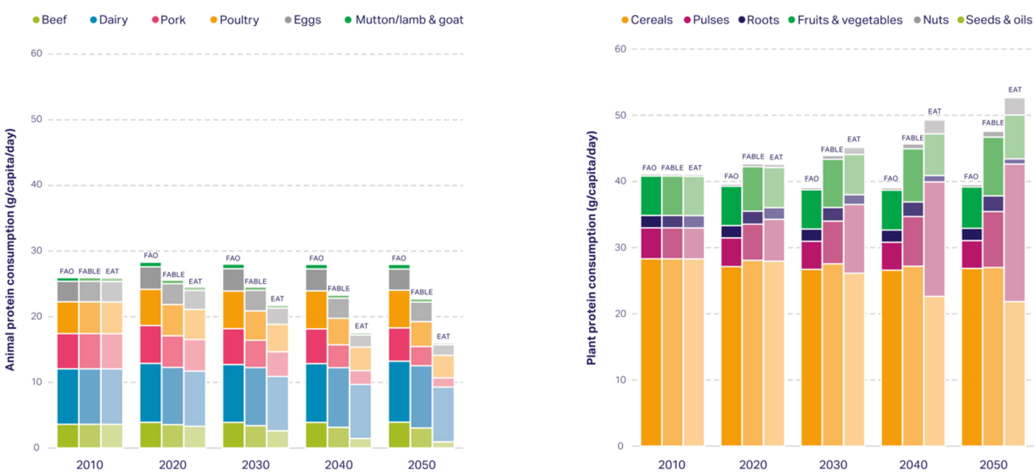


Figure 13: Global individual animal, plant protein consumption for the 18 FABLE countries

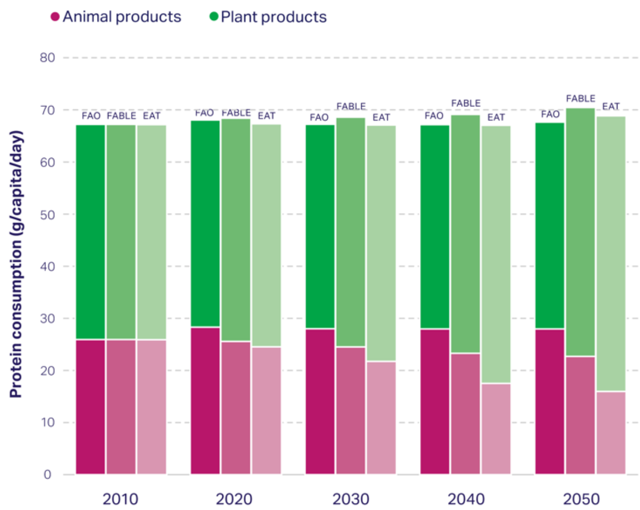


Figure 13 confirms those projected evolution and replacement of animal proteins by plant proteins. Note that a possible overestimation of protein from fruits and vegetables in East Asia has amplified the observed increase in total protein consumption with the FABLE scenarios as compared with the BAU scenario.

Horizon 2030: Pathways for business-driven acceleration

Business-driven acceleration: Why and how?

What if business accelerated solutions to reduce the environmental impact of proteins? What could be the impact of protein production in 2030 on GHG emissions, land and biodiversity? These are the questions this section tries to answer, benefitting from important input from WBCSD members, who provided the data used to estimate how industries can help reduce the environmental impact of proteins while sustaining future demand for animal and plant protein:

- **Objective**: Demonstrate how the industry can accelerate the protein transition between now and 2030;
- **How**: Using the FABLE Calculator to estimate the maximum potential impact of business solutions; using business data to assess the realistic impact of business acceleration.
- **Impact:** Climate, land and biodiversity. Impact on nitrogen, phosphorous and water are not assessed due to FABLE's current limitations.

Quantifying the impacts

- **GHG emissions**: The FABLE Calculator accounts for emissions from: (1) crop cultivation, rice cultivation, synthetic fertilizers, energy use in crop fields; (2) livestock production, ruminant enteric fermentation and manure; and (3) land-use change due to the expansion of cropland, pasture and urban areas into forests and other natural land. We account for carbon sequestration in afforested land and in abandoned agricultural land.
- **Biodiversity**: Biodiversity is defined as the share of the total terrestrial land surface that can support biodiversity conservation. This refers to the sum of land covered by forest, other natural land classes defined at the national level, as well as afforested or abandoned agricultural land. Cropland, pastureland and urban land are not considered in support of biodiversity. This definition is significantly limited by the fact that natural land categories can be heterogenous (e.g., including degraded land, desert areas, etc.), thus poorly reflecting the extent to which they can support biodiversity. Moreover, the model does not yet consider agroforestry or regenerative agriculture as an opportunity for biodiversity conservation.

Solution spaces and their impacts

The following table and figures present the various solution spaces identified through a Business Dialogue held in Paris on 25 November 2019 with WBCSD members and representatives from FABLE, EAT and the World Economic Forum.

For each solution space, the business leadership role, the quantified ambition, and the recommended government action to achieve the ambition by 2030 are described. Figure 14 and Figure 15 show the possible impact on GHG emissions and biodiversity by 2030 if the business solutions described are implemented at the defined levels of ambition.

Table 1: Solutions spaces, quantified impacts, and proposed business and governments roles

Solution spaces	Definition	Business leadership	Quantified business. ambition 2030	Policy recommendation
Zero land expansion	Global commitment to no further land expansion as compared to land surface of 2010	(1) Supply chain agreements for zero deforestation (2) No planting of oil palm on peatland	Compared to 2010 FAO values, this translates as: • 98 million hectare decrease in pastureland* • 17 million hectare increase in cropland	Regulations and policy regarding land-use, defined land area for conservation, limit deforestation, and further land for agriculture use
Afforestation	Country commitments to afforestation, reforestation target	Compensate emissions through plantations	Compared to 2010 FAO values, this translates as: • 116 million hectares of afforested land • 8 million hectare net increase in forests	(1) Commitment to afforestation, reforestation target (2) Incentives to promote afforestation or agroforestry production systems
Dietary shifts	FABLE countries adopt their chosen sustainable diets fully by 2030	(1) Lead changes in consumer demand (2) Communicate and advertise healthy and sustainable diets with a balanced and reduced (high income) mix of animal and plant protein consumption (3) Engage with retailers, esp. on a selection of products, placement (4) Innovative products with positive nutritional and sustainability profiles – creating product appeal and options (5) Revaluing the perception of soy and transition from feed to food	Compared to 2010 FAO global individual protein consumption (g protein per capita per day), this translates as the following multipliers (see Figure 2): (1) 0.94 increase in animal-based protein consumption (0.94 beef, 1.05 dairy, 0.92 poultry, 1.0 eggs, 0.77 pork and 0.91 mutton/lamb) (2) 1.1 increase in plant-based protein consumption (0.99 cereals, 0.98 seeds and oils, 1.12 roots, 1.25 fruits and vegetables, 1.37 pulses, 1.95 nuts)	(1) Encourage consumer changes (2) Create national nutrition guidelines (3) Labeling – nutrition and sustainability scores (4) Set the right product incentive (e.g., halt subsidies for unhealthy food production) (5) Support and incentivize the animal-based value chain to transition
Food waste	As FABLE only considers food waste at consumption level, food losses not factored in	(1) Improve packaging and portions (2) Extend shelf life and consumer communication e.g., on best before dates (3) Rethink retail system on selection of products, promotions, placement (4) Better reflect the true value of food in market prices	Halve food waste, in line with Sustainable Development Goal (SDG) 12.3	(1) Labeling (2) Education (3) Circular economy: provide structure to recycle and reuse food waste (4) Implement true value of food

* Note a possible trade-off here as this could release carbon from soil and counter pasture soil carbon sequestration (see "insetting" below).

Solution spaces	Definition	Business leadership	Quantified business ambition 2030	Policy recommendation
Crop productivity	Crop yield per hectare, as regularly increased by improved practices, esp. in smallholder agriculture	(1) Improve irrigation systems (2) More precise, lower fertilizer application (3) Regenerative agriculture (improve soil health and natural fertility, reduce chemicals) (4) More drought-resistant staple crops (1) (5) Increase ratio of grains per total plant biomass (short corn, etc.)	Compared to 2010:* • 50% increase in crop yield for smallholder agriculture (in line with SDG 2.3) • Increase crop yields by 30% in industrial agriculture (ca. 1% per year)	(1) Generalize safety nets for smallholders (minimum income for all food producers) (2) Support development of crop and transition insurance schemes (3) Support development of payment for environmental services (4) Invest in farming education to attract the next generation
Livestock productivity **(1) Ruminant productivity**	Meat, milk and/or eggs production per animal	Ruminant productivity:** (1) Improve farming practices§ (2) Improve animal breeding (3) Improve basic feed quality	Productivity improved by 25% for ruminants. Resulting in: (1) GHG reduction values of: • 198 MtCO_2e† from dairy improvement • 539 MtCO_2e from beef improvement • Negligible from monogastric improvement (2) Decrease in agricultural land by: • 0.119 Mha from Dairy Improvement • 0.119 Mha from Beef Improvement (3) And increase the share of land supporting biodiversity by: • 1.0 % for dairy • 1.0 % for beef[21]	(1) Generalize safety nets for smallholders (minimum income for all food producers) (2) Support development of crop and livestock insurance schemes (3) Support development of payment for environmental services (4) Invest in farming education to attract the next generation

* Being aware of possible trade-offs for nitrogen, phosphorus and water, plus biodiversity in the land area considered as supporting biodiversity conservation (see FABLE definition p. 16).
** Depends considerably on bringing inefficient systems to the average level.
§ Being aware of possible trade-offs on animal welfare, which consumers are increasingly sensitive to. Important to improve transparency and traceability.
†Significantly lower than the value predicted by the FAO's Global Livestock Environmental Assessment Model (GLEAM) – 540 Mt – as reported in the 2018 Global Dairy Platform Report.[22] We, however, decided to keep the GHG reduction value as predicted by FABLE to remain consistent with other assumptions. We recognize there is scope for further improvement of the FABLE Calculator on the GHG reduction impact of improved dairy productivity.

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Solution spaces	Definition	Business leadership	Quantified business ambition 2030	Policy recommendation
Livestock productivity **(2) Animal feed practices, feed additives**	Meat, milk and/or egg production per animal	Animal precision feeding:* (1) Improve digestibility of crops, crop residues, and crop and food processing by-products (2) Improve animal health by supplementing essential amino acids and vitamins to meet animals' nutritional needs (3) Reduce inclusion of protein meals in feed to reduce metabolic stress, improve gut health, and reduce animal's exposure to manure and ammonia emissions (4) Improve implementation of "phase feeding" to suit specific animal needs in their respective stage of life (5) Better alignment between animal genetics, animal nutrition and farming practices to achieve higher feed conversion into meat, milk and eggs (6) Source feed only from production with limited environment impact (land, nitrogen, water) (7) Implement a framework for sustainable feeding practices along the entire value chain	Animal precision feeding:* (1) Further GHG reduction values of: • 148 $MtCO_2e$** from dairy improvement • 162 $MtCO_2e$ from beef improvement • 320 $MtCO_2$ from monogastric improvement (2) Decrease in agricultural land by: • 0.104 Mha from dairy improvement • 0.042 Mha from beef improvement (3) And increase the share of land supporting biodiversity by: • 0.9% for dairy • 0.4% for beef[23]	Animal precision feeding:* (1) Improve digestibility of crops, crop residues, and crop and food processing by-products (2) Improve animal health by supplementing essential amino acids and vitamins to meet animals' nutritional needs

* With the possible trade-off that the price of raw materials is too low, hence it is often better to overfeed animals than to work with feed additives.
** Significantly lower than the value predicted by the FAO's Global Livestock Environmental Assessment Model (GLEAM) – 540 Mt – as reported in the 2018 Global Dairy Platform Report.[24] We, however, decided to keep the GHG reduction value as predicted by FABLE to remain consistent with other assumptions. We recognize there is scope for further improvement of the FABLE Calculator on the GHG reduction impact of improved dairy productivity.

Solution spaces	Definition	Business leadership	Quantified business ambition 2030	Government action
Arable Land regenerative practices: soil organic carbon sequestration **In-field insetting***	Soil organic carbon (SOC) sequestered via regenerative agriculture practices	(1) Agricultural practices that increase soil and plant biomass (carbon) through practices such as no-till, agroforestry, living-hedges (2) Use of legumes either as an intercrop, cover crop or part of a crop rotation to decrease farm inputs, such as fertilizers and pesticides, and increase or maintain soil carbon	210 Mt SOC stored equivalent to 770 $MtCO_2$ (medium scenario from Sommer & Bossio[25]) Increase the share of land supporting biodiversity by 1.63 %	(1) Support development of payment for environmental services (2) Develop soil carbon markets
Pasture land regenerative practices: soil organic carbon sequestration **"In-field insetting"**	Soil organic carbon sequestered via regenerative grazing practices	(1) Management of livestock on pastures to increase soil carbon sequestration (2) Use of legumes to enrich pastures in soil carbon (3) Livestock manure reused as fertilizer to increase productivity and soil carbon	140 Mt SOC stored equivalent to 513 $MtCO_2$ (medium scenario from Sommer & Bossio[26]) Increase the share of land supporting biodiversity by 1.63 %	(1) Support development of payment for environmental services (2) Develop soil carbon markets
Reducing ruminant enteric fermentation **"On-farm insetting"**	Reducing the methane emitted from the stomachs of ruminants (cattle, buffalo, goats and sheep)	(1) Develop vaccines to improve the microbiomes of animals' guts (2) Select animal breeds that naturally produce fewer emissions (3) Incorporate special feeds or supplements into animal diets	GHG emissions reductions: • 71 $MtCO_2e$** from dairy improvements • 102 $MtCO_2e$ from beef improvements	(1) Support research and development (2) Support dissemination of new technologies to farmers
Biogas & biofuel production **"On-farm insetting"**	Recycling livestock manure through biodigesters and produce biogas for local use or injection into wider gas network	(1) Develop affordable biodigesters to produce biogas on farm, as a renewable energy source for heat and electricity (2) Cover manure pits and thermal use of collected methane (3) Use fat residues from animals for biodiesel production	GHG emissions mitigation estimated by the industry sector to be around 200 $MtCO_2e$ with: • 90 $MtCO_2e$ from dairy • 50 $MtCO_2e$ from pork • 60 $MtCO_2e$ from poultry	(1) Foster biogas collection from farms through infrastructure and rewarding gas prices to enable investment into purification technology (2) Incentivize electricity supply from biogas operated combined heat & power facilities to make investment attractive

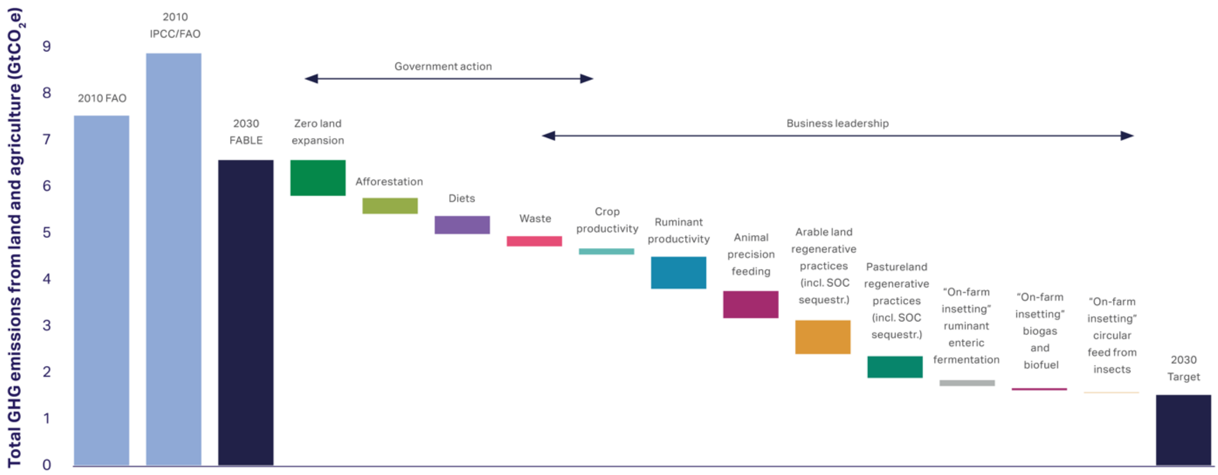
* This solution space and the following ones refers to "insetting" measures, i.e., measures to locally remove or compensate for GHG emissions. They therefore have no measurable impact neither on net forest change nor on biodiversity using the FABLE Calculator. However, field insetting, i.e., soil organic carbon sequestration, is known to also improve soil biodiversity, whose quantitative impact on global biodiversity remains insufficiently studied so far.

** Significantly lower than the value predicted by the FAO's Global Livestock Environmental Assessment Model (GLEAM) – 540Mt – as reported in the 2018 Global Dairy Platform Report.[27] We, however, decided to keep the GHG reduction value as predicted by FABLE to remain consistent with other assumptions. We recognize there is scope for further improvement of the FABLE Calculator on the GHG reduction impact of improved dairy productivity.

Solution spaces	Definition	Business leadership	Quantified business ambition 2030	Government action
Circular feed from insects **"On-farm insetting"**	Using insects to upscale by-products as feed for poultry and fish	• Reuse materials • Decrease land use • Low water use • Zero emissions • Expand application to poultry	Insect companies and university assessing potential. Replacement of fishmeal and soy could mitigate GHG emissions in range of 2-5 $MtCO_2e$[28]	Support enabling regulations on low-grade food and agricultural waste streams as inputs

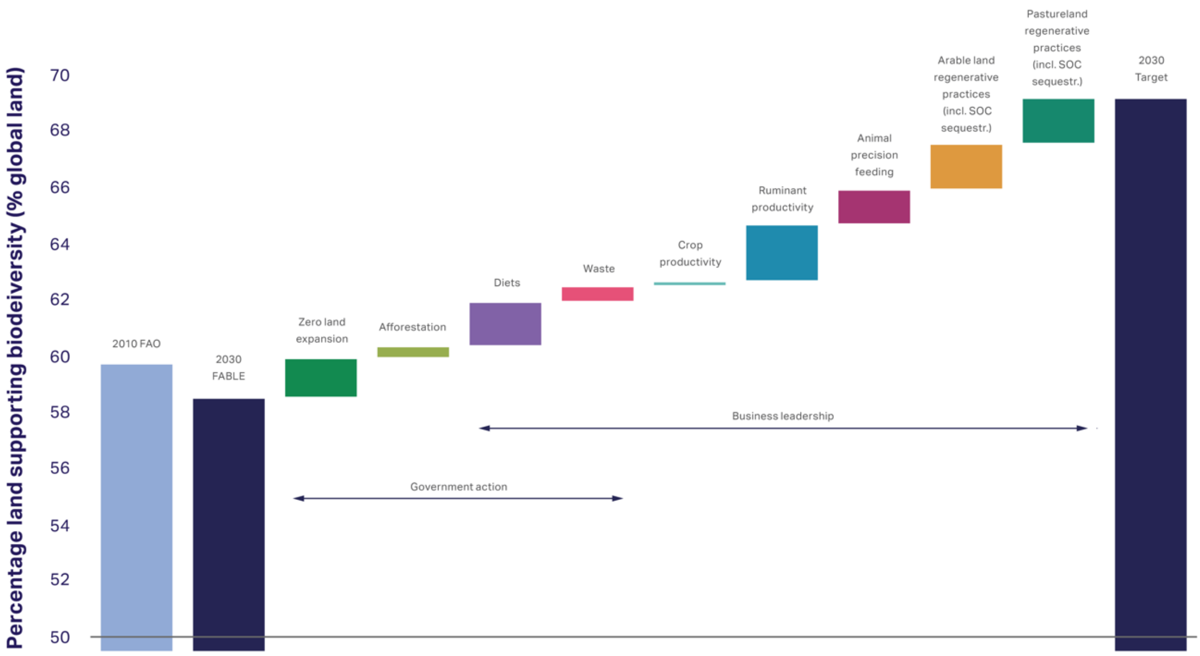
Figure 14 and Figure 15 below show the respective impacts of the business solutions presented Table 1 to mitigate GHG emissions from land-use and agriculture, and to protect land that supports biodiversity. The next section comments on implementation conditions and trade-offs.

Figure 14: Mitigation potential of business solutions on land and agriculture GHG emissions



Note: See Table 1 for description of solutions.
Arrows indicate who, between government and business, can drive the solutions.

Figure 15: Potential of business solutions to protect



Note: See Table 1 for description of solutions. We have calculated arable land and pasture soil carbon sequestration but there are not enough elements to quantify the possible impact. Arrows indicate who, between government and business, can drive the solutions.

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Recommendations and call to action

The estimations made with the FABLE Calculator and ambitious business scenarios applied to the protein sector show that**, by 2030, GHG emissions from agriculture could go down by more than 50% and the global area supporting biodiversity could increase by 20%.**

In other terms, **the protein sector could drive the agricultural sector to reach net-zero by 2050 and play a positive role in biodiversity restoration, helping to stop the halt and reverse biodiversity loss**.

Prioritizing business solutions along the value chain

Table 2 presents the business solutions spaces described above, ranked along their combined contribution to GHG emissions reduction and supporting biodiversity:

- Even if the impacts on biodiversity from soil organic carbon sequestration have not been quantified, we have ranked this solution space ahead of afforestation and dietary changes as it is known to restore soil biodiversity, thereby supporting wider biodiversity;
- One critical aspect not accounted for here is the possible trade-offs of both components on livestock productivity with animal welfare and farmer income: traceability along the value chain and proper incentives (recognizing the true value of food) will be key to ensuring such solutions can thrive;
- WBCSD members have recognized circular feed for insects as a promising solution space but with probably limited penetration in the coming years. It could gain more traction beyond 2030 whereby the global amount of food waste and byproducts is 1.5 billion tons with a recovery potential of >50 million tons of proteins and a GHG reduction potential of over 0.75 $GtCO_2e$.

Table 2: Ranked business solutions spaces by their contribution to GHG emissions reductions and supporting biodiversity

Solution spaces	GHG emissions reduction ($GtCO_2e$)	Additional share of land supporting biodiversity
Arable land regenerative practices incl. soil organic carbon sequestration	-0.77 Gt	1.6%
Livestock productivity - (1) Ruminant productivity	-0.74 Gt	2.0%
Livestock productivity - (2) Animal feed practices	-0.63 Gt	1.2%
Pasture land regenerative practices incl. soil organic carbon sequestration	-0.51 Gt	1.6%
Dietary shifts	-0.43 Gt	1.6%
Food waste	-0.27 Gt	0.6%

Crop productivity	-0.18 Gt	0.2%
Reducing ruminant enteric fermentation	-0.17 Gt	-
Biogas & biofuel production	-0.09 Gt	-
Circular feed from insects	-0.005 Gt	N/A

Policy recommendations

Table 3 shows the policy actions that will enable business acceleration along the proposed solution spaces. Crop and livestock productivity, enteric fermentation reduction, biogas and biofuel production and circular feed from insects are the most relevant and specific to the protein sector. Others are more generic for whole food system transformation.

Table 3: Policy recommendations to enable business acceleration along the proposed solution spaces

Solution spaces	Policy commitments	Regulation	Incentives
Zero land expansion		Regulations and policy regarding land use; define land area for conservation, limit deforestation and further land for agriculture use	
Afforestation	Commitment to afforestation, reforestation target		Incentives to promote afforestation or agroforestry production systems
Dietary shifts	Encourage consumer changes Create sustainable national dietary guidelines	Labeling – nutrition and sustainability scores	Set the right product incentives (e.g., halt subsidies for unhealthy/unsustainable food production) Support and incentivize the animal-based value chain to transition
Food waste	Education Circular economy: provide structure to recycle and reuse food waste	Labeling	Implement true value of food

Crop productivity & livestock productivity **(1) Ruminant productivity**	Support development of payment for environmental services Invest in farming education to attract the next generation		Generalize safety nets for smallholders (minimum income for all food producers) Support development of crop and transition insurance schemes
Livestock productivity **(2) Animal feed practices**	Support research and development Support dissemination of new technologies to farmers	Support product labeling for "sustainably produced"	Ban subsidies for low-quality feed crops
Arable land & pasture regenerative practices incl. soil organic carbon sequestration	Support development of payments for environmental services, and of regenerative agriculture		Develop soil carbon markets
Reducing ruminant enteric fermentation	Support research and development Support dissemination of new technologies to farmers		
Biogas & biofuel production	Foster biogas collection from farms through infrastructure and rewarding gas prices to enable investment into purification technology		Incentivize electricity supply from biogas-operated combined heat & power facilities to make investment attractive
Circular feed from insects		Support enabling regulations on low-grade food and agricultural waste streams as inputs	

Addressing nitrogen, phosphorus and water

In the recently published FOLU report[29], health aspects related to food consumption and food production dominate externalities (see Figure 16). However, environmental aspects related to biochemical flows of phosphorous and nitrogen exceeding planet boundaries surpass the externalities associated with greenhouse gas emissions.

Figure 16: Hidden costs of global food and land use systems[30]

WBCSD members are developing animal feed solutions (especially pork and poultry, including egg production) to drastically reduce nitrogen externalities, at an estimated reduction of 10 million tonnes of nitrogen, which would bring nitrogen emissions from food systems (presently at 130 million tonnes per year) closer to the target proposed by the EAT-Lancet report of 90 million tonnes[31], and even below the one at 121.5 million tonnes per year proposed by Steffen et al.[32] They are also developing water-related solutions whose impact should be further quantified.

We therefore recommend that FABLE explore those environmental variables in its 2020 Scenathon with countries.

Call to action

The business dialogue that supported this paper's development concluded with a call to action for CEOs in line with the WBCSD CEO Guide to Food System Transformation, so as to achieve the immense positive impacts proposed:

Internal actions

1. **Understand your company's link to food system challenges and its role and aspirations in the CEO Guide to Food System Transformation's transformational pathways**: Create strong internal policies and mechanisms to limit the sourcing of materials with unacceptable footprints, which implies strengthening supply chains' traceability.
2. **Set robust science-based targets that reflect the true financial value of externalities**: Assess risks and materiality for the whole business, including supply chains, define priority areas for improvement and environmental impact life cycle analysis for scopes 1, 2, 3.
3. **Develop and implement scalable solutions and new business models to achieve the targets** for each environmental impact and priority area, involving suppliers, customers, investors and external stakeholders.

External actions

4. **Lead your industry to accelerate the adoption of solutions**: Adopt new business practices and relationships with key suppliers to make the necessary investments and improvements throughout the supply chain; create programs and mechanisms to drive the adoption of the solutions, technologies and best practices highlighted in this paper.
5. **Bring a leading voice to global events as a champion of food system transformation**: Report on annual progress and create internal incentives and programs to drive change; communicate transparently about successes and failures; make bold, public commitments; drive policy change within your industry and countries of focus, including on redirecting subsidies to animal protein production practices that are proven sustainable.
6. **Cooperate across the industry to deliver at scale:** Join or adopt existing industry-wide and multilateral initiatives, roundtables and certifications focus on tackling environmental footprints and improving the overall sustainability of animal and vegetable production while maintaining high levels of animal welfare; involve and enklist support from other players and stakeholders, such as input suppliers, non-governmental organizations and universities.

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Annexes

FABLE countries

Country	Country Abb.	Regions
Argentina	ARG	South America
Brazil	BRA	
Columbia	COL	
Mexico	MEX	
Canada	CAN	North America
USA	US	
China	CHN	East Asia
Indonesia	IND	
Malaysia	MYS	
Ethiopia	ETH	Africa
Rwanda	RWA	
Finland	FIN	Europe
Russia	RUS	
Sweden	SWE	
United Kingdom	UK	
Rest of European Union	ROEU	
Australia	AUS	
India	IND	

FABLE food categories

Category	Food category	Food items
Animal	Beef	Beef
	Poultry	Chicken, duck, turkey, goose
	Dairy	Milk (dairy cows, dairy sheep & goats)
	Pork	Pork
	Eggs	Eggs
Plant	Cereals	Corn, rice, oat, rye, barley, millet, sorghum, wheat, other
	Pulses	Pea, bean, groundnut, soybean, other
	Roots	Yam, cassava, potato, sweet potato, tuber, other
	Fruits & vegetables	Apple, banana, coconut, date, grapefruit, grape, lemon, onion, orange, pineapple, plantain, other citrus, other fruit, other vegetable
	Nuts	Nuts
	Seeds & oils	Rapeseed, sesame, sunflower, olive, cotton, palm oil, palm kern oil, oil palm fruit, coco oil, cotton oil, groundnut oil, olive oil, rapeseed oil, soy oil, sunflower oil, sesame oil, other oil, other seed oil

FABLE pathway design summary

FABLE targets

The table below presents the FABLE global targets for sustainable land-use and food system.

Table 1 *Proposed global targets for sustainable land-use and food systems. Select references included in the table.*

AREA	GLOBAL TARGET	JUSTIFICATION
Food security	**Zero hunger** *Average daily energy intake per capita higher than the minimum requirement in all countries by 2030*	Based on SDG 2 and literature review (Springmann et al., 2016; Laborde et al., 2016)
	Low dietary disease risk *Diet composition to achieve premature diet related mortality below 5%*	EAT-Lancet and Global Burden of Disease Collaboration reports (Afshin et al., 2019; Willett et al., 2019)
Greenhouse gas emissions	**Greenhouse gas emissions from crops and livestock compatible with keeping the rise in average global temperatures to below 1.5°C** *Below 4 $GtCO_2e\ yr^{-1}$ by 2050*	Based on literature review: 3.9 Gt for non-CO_2 emissions and 0.1 for CO_2 emissions (Hadjikakou et al., in preparation)
	Greenhouse gas emissions and removals from Land-Use, Land-Use Change, and Forestry (LULUCF) compatible with keeping the rise in average global temperatures to below 1.5°C *Negative global greenhouse gas emissions from LULUCF by 2050*	Based on literature review (Griscom et al., 2017; Rogelj et al., 2018; Popp et al., 2017). Due to large uncertainties and lack of clarity on the sources of LULUCF emissions/removals which are accounting for in the different articles, we prefer not using precise number at this stage.
Biodiversity and ecosystem services	**A minimum share of earth's terrestrial land supports biodiversity conservation** *At least 50% of global terrestrial area by 2050*	(Dinerstein et al., 2017; Noss et al., 2012; Wilson, 2016)
	A minimum share of earth's terrestrial land is within protected areas *At least 17% of global terrestrial area by 2030*	Aichi Target 11 and Maron et al. (2018)
Forests	**Zero net deforestation** *Forest gain should at least compensate for the forest loss at the global level by 2030*	Aichi Target 5; SDG 15; New York Declaration on Forests
Freshwater	**Water use in agriculture within the limits of internally renewable water resources, taking account of other human water uses and environmental water flows** *Blue water use for irrigation <2453 km^3yr^{-1} (670-4044 km^3yr^{-1}) given future possible range (61-90%) in other competing water uses*	Based on literature review (Hadjikakou et al., in preparation)
Nitrogen	**Nitrogen release from agriculture within environmental limits** *N use <69 Tg N yr^{-1} total Industrial and agricultural biological fixation (52-113 Tg N yr^{-1}) and N loss from agricultural land <90 Tg N yr^{-1} (50-146 Tg N yr^{-1}) by 2050*	Based on literature review (Hadjikakou et al., in preparation)
Phosphorous	**Phosphorous release from agriculture within environmental limits** *P use <16 Tg P yr^{-1} flow from fertilizers to erodible soils (6.2-17 Tg P yr^{-1}) and P loss from ag soils & human excretion <8.69 Tg P yr^{-1} flow from freshwater systems into ocean by 2050*	Based on literature review (Hadjikakou et al., in preparation)

FABLE pathways

The assumptions of FABLE countries' dietary choices reflect local traditions, customs and resource endowments, as well as the feasibility and desirability of changes.

While FABLE country dietary patterns vary, they all aim to reach sustainable land-use and food system targets. The choice of the diets thus aligns with a supply in daily energy per capita that is higher than the minimum recommended requirement and that lowers the risk of premature mortality linked to diet composition.

Collectively, country dietary choices aim to meet the goals for sustainable land-use and food systems: zero net deforestation, half Earth's terrestrial land supporting biodiversity, GHG emissions compatible with keeping rise in average global temperatures to below 1.5° C.

FAO projection horizon 2050	Own country policy diets
Argentina	Australia: EAT-Lancet Diet
Brazil, Columbia	Canada: Canada Food Guide
Ethiopia, Indonesia	China: Chinese Healthy Diet
Malaysia, Mexico	Finland: Low Carbon Diet
Russia, Sweden	India: CurPlus Diet India*
Rest of the European Union	Rwanda: Cur Plus Diet**
Rest of the world	UK: Eat-Well Diet
	USA: Healthy Diet – USDA

*CurPlus Diet India: Increases average calorie consumption to 2,453, with a 26% milk increase, 74% other food increase and 16% cereal decrease)
**CurPlus Diet Rwanda: Diet based on the current diet, but with an increase in cereals and livestock production.

Population
The world population is expected to increase by 30% between 2015 and 2050, reaching 9.2 billion by 2050. This is in between the low variant and medium variant estimates of United Nations (UN) Population Division projections. Some 44% of this increase occurs in Asia, 37% in Africa, and 7% in the Middle East. Total population projection from FABLE is only 4% higher than the UN medium variant.

Dietary shifts
Lower animal-based calorie intake between 2015 and 2050 expected in Australia, China, Finland, the United Kingdom, and the United States. Increase in per capita consumption of animal-based proteins through to 2050 expected in Ethiopia, India, Indonesia and Malaysia.

Increase global average daily caloric intake by 5% between 2015 and 2050. Large increases in consumption of nuts, fish, pulses, fruits and vegetables at the aggregated level projected.

Food loss and waste

FABLE Calculator splits food losses into two categories: post-harvest losses and consumption losses. The FABLE Scenario targets only food consumption waste. The share of the production lost after harvest by crop and by country assumed constant at 2010 levels (based on FAOSTAT statistics).

In total, 11 out of 18 FABLE countries project a fall in food losses at the household level by 2050 compared to 2015 levels.

The World Resources Institute (WRI) highlights the underestimates in food losses and waste by the Food and Agriculture Organization (FAO) of the United Nations and the discrepancy between FAO data and people's survey data on food consumption. This leads to an excessive food consumption assumption by FAO.

Crop and livestock productivity

(1) Total agricultural land productivity projected to increase by 56% between 2010 and 2050, corresponding to an annual compound growth rate of 1.1%
(2) Australia, Russia and the United Kingdom assume more than a doubling of total productivity between 2010 and 2050.
(3) Productivity growth measured in calories per hectare.
(4) Large, ambitious yield increases assumed for corn, rapeseed, soybean, sugarcane, wheat and oil palm fruit in several countries.

Land-use, land-cover change

(1) Argentina, Brazil and Colombia project zero deforestation beyond 2030.
(2) 105 million hectares of land projected afforested by 2030 and 191 million hectares by 2050 across all FABLE countries.
(3) Only China has set up a formal constraint to avoid cropland area reductions over the 2015-2050 period.
(4) India and Mexico assume no further expansion of agricultural land beyond the area covered in 2010.

Agricultural trade

All FABLE countries assume an increase in their agricultural exports. Except for China, Colombia, Russia and the rest of the EU, FABLE countries assume higher total imports for many products,

About FReSH

Food Reform for Sustainability and Health (FReSH) is a key World Business Council for Sustainable Development (WBCSD) Food & Nature Program project. FReSH facilitates the pre-competitive collaboration of over 30 member companies to accelerate transformational change in the food system in order to reach healthy, enjoyable diets for all, produced responsibly within planetary boundaries. We focus on areas where business can have the most impact, along four transformational goals:

- Healthy and Sustainable, from Fork to Farm;
- Food Loss and Waste;
- True Value of Food; and
- Policy and Advocacy.

The Healthy and Sustainable, from Fork to Farm workstream accelerates the development of business-led solutions with the biggest positive health and environmental impacts. We do this by focusing on the following topics:

- Accelerating the delivery of positive nutrition by the food industry;
- Scaling-up healthy and sustainable protein production and consumption;
- Stimulating the healthy and sustainable production and consumption of a diversity of nutrient-rich plants.

In January 2020 at the WEF Annual Meeting in Davos, FReSH will launch two protein white papers: the 'Protein Pathways: Accelerating sustainable transformation through business innovation' and the 'Plant Proteins: a main lever for accelerating food system transformation'. The aim of these publications is to raise awareness among the business community and beyond about the need to take bold action on protein transformation in order to deliver healthy, enjoyable diets for all, produced responsibly within planetary boundaries.

We will complement these documents later this year with a FReSH Roadmap containing a concrete action plan for positive nutrition, protein and plants.

Disclaimer

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- Carlos M Saviani, Global Sustainability Lead, DSM
- Caroline Chesneau-Guillemont, Nutrition Manager, Bel Group
- Christine Debeuf, Danone Group
- Elselina Battenberg, Head of Communication, Protix
- Gabriela Burian, Global Director, Sustainable Food Systems, Bayer
- Henk Bosch, Sustainability Manager, DSM
- Jacobine Das Gupta, Director, Sustainability and Lead, Nutrition, DSM
- Karolien Bytterbier, Sustainability Coordinator, DuPont
- Michael Binder, Director, Sustainability Development, Evonik
- Ralf Kelle, Sustainable Development, Evonik
- Sonia Huppert, Global Marketing Lead, Plant-Based Health & Meal Solutions, DuPont
- Stefan Tempel, Head of Market & Competitive Intelligence, Bayer
- Yaw Sasu-Boakye, Climate Lead, Food & Agriculture, Inter IKEA Group

Partners

- Aline Mosnier, Scientific Director, UN Sustainable Development Solutions Network (UNSDSN)
- Fabrice DeClerck, Science Director, EAT
- Gaëlle Espinosa, Senior Analyst, UN Sustainable Development Solutions Network (UNSDSN)
- Lisa Sweet, Head Business Strategy and Engagement, World Economic Forum (WEF)

FReSH representatives

- Alain Vidal, Director, Food & Nature Science and Partnerships, WBCSD
- Aude Vuilliomenet, Intern, WBCSD
- Camilla De Nardi, Associate, WBCSD
- Emeline Fellus, Director, FReSH, WBCSD

Member companies that actively contributed to this white paper include:

Partners that also actively contributed to this white paper include:

World Business Council
for Sustainable Development

Maison de la Paix
Chemin Eugène-Rigot 2B
CP 2075, 1211 Geneva 1
Switzerland
www.wbcsd.org