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The Carbon Footprint of Food and Sustainable Solutions

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This is the first part of a two-part series on the sustainable food sector that will cover (i) sustainable solutions for the food sector, thereafter (ii) focusing on the alternative proteins subsector.

1. Key takeaways

This report covers the GHG emissions from the food sector across food types and countries, and potential growing trends for sustainable solutions in this space. To note,

- **Investors can play a key role in deploying capital** to catalyse the trends in the food sector alongside the sustainability revolution.
- **Smart solutions for digital agriculture and circular-based solutions** that address food loss and waste throughout the entire supply chain are likely to expand.
- **Consumers can expect corporates and governments to focus on health and sustainability moving forward**, influencing the change to healthier diets (e.g. reducing consumption of animal-based protein) and more sustainable products.

2. The carbon footprint of food

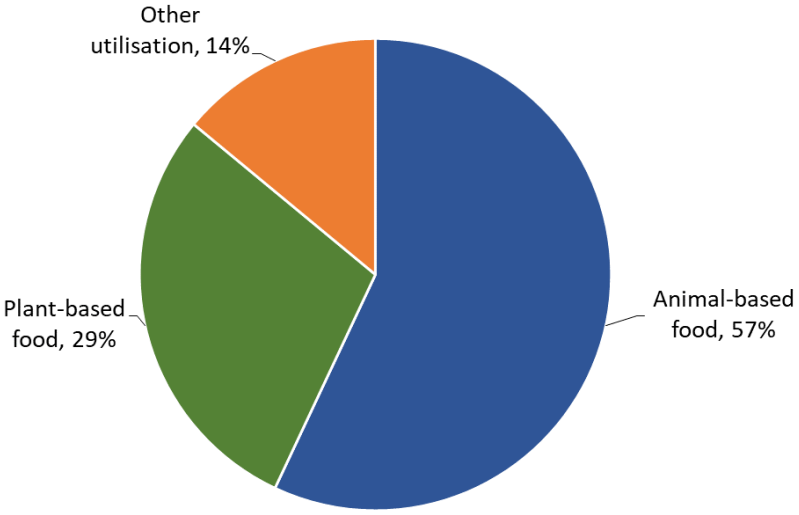
2.1 Breakdown of GHG emissions from the food sector

The food sector is estimated to produce ~17.3 bil metric tons of CO_2 per year. Food production and consumption account for over a third (35%) of global man-made greenhouse gas (GHG) emissions, and half of the world's habitable land is used for agriculture. Therefore, the food sector has an important role to play in tackling climate change through measures such as the reduction of emissions and restoration of land.

The production of animal-based food (i.e. meat, poultry, dairy and growing of crops to feed livestock and provide pastures for grazing) account for more than half (57%) of food-related GHG emissions. Plant-based food for human consumption contributes 29% of GHG emissions, while the remaining 14%

comes from products not used for human consumption or animal feed e.g. cotton and rubber (Figure 1).

Figure 1: Breakdown of GHG emissions for the food sector

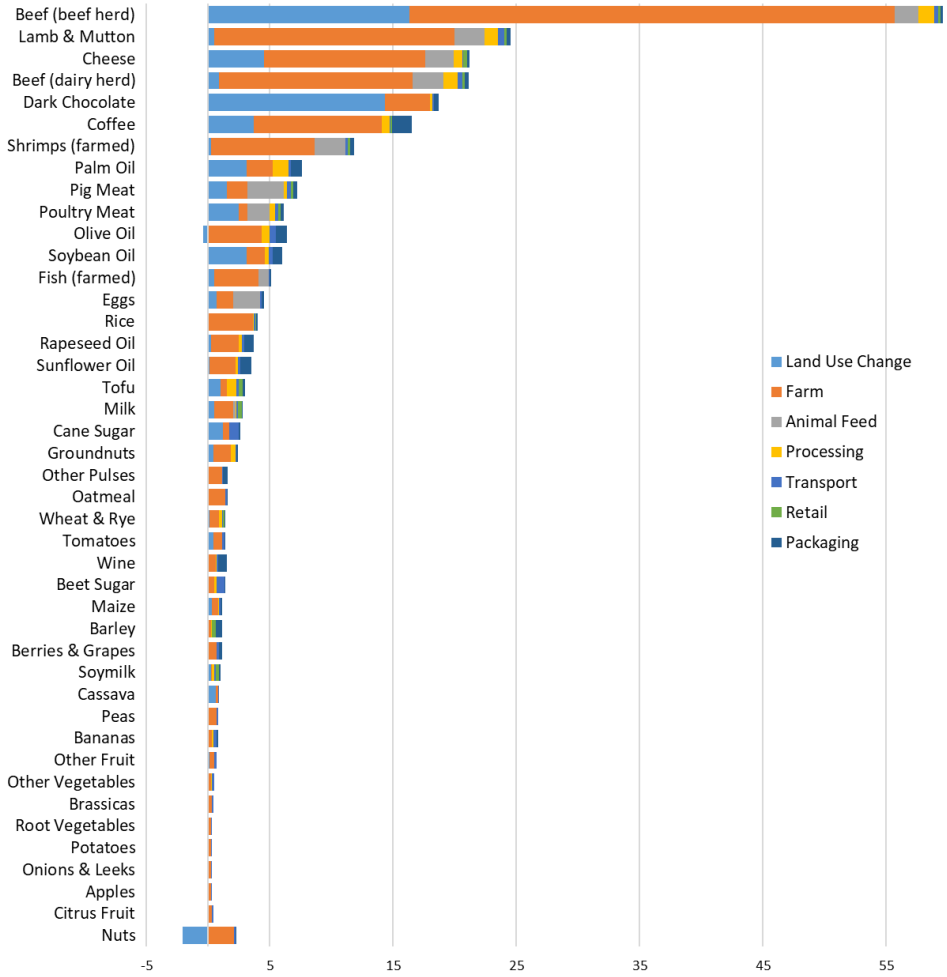


Source: Nature Food (Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods, 2020), OCBC

Figure 2 shows the breakdown of GHG emissions across food types. Beef products are the most emissions-intensive as cows require high land use for grazing and produce high volumes of methane, resulting in a high carbon footprint.

The emissions from most plant-based products, such as cane sugar and peas, are lower than most animal-based products. This can explain why a reduction in animal-based products and transitioning toward a plant-based diet is recognised as a key factor in curbing GHG emissions and meeting long-term climate change goals.

Figure 2: GHG emissions across food types and by source (kg CO2 equivalent per kg of product)



Source: Science (Reducing food's environmental impacts through producers and consumers, 2018), OCBC

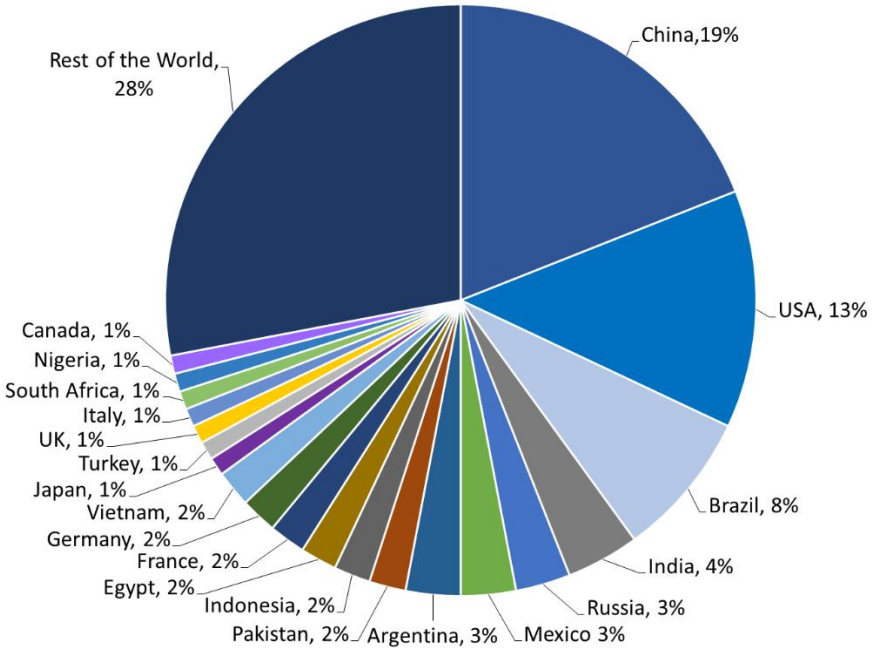
2.2 Emission-intensive regions and countries

South and Southeast Asia produce the most GHG emissions (23% of global total) related to food production among regions, as rice is a staple in Asian diets and is the largest emissions contributor among plant-based food. It is the only region where emissions from plant-based food are more than that from animal-based food. South America is the second largest emitter at 20%, with the largest emissions from animal-based food due to the prevalence of ranching.

Figure 3 shows the breakdown of global GHG emissions for the food sector by country, with China and the US as the highest emitters. Table 1 shows the

countries with the highest GHG emissions from (i) plant-based and (ii) animal-based food production. China has the highest GHG emissions for both plant-based food production and animal-based food production, at 7% and 8% of global food-related GHG emissions respectively. For plant-based food, rice, flour and wheat flour are responsible for the greatest carbon emissions in the Chinese diet. As China is the leading consumer and producer in the pork industry, pork is likely the greatest contributor to China's emissions for animal-based food.

Figure 3: GHG emissions for the food sector by country



Source: Food and Agriculture Organisation of the United Nations (FAO), World Bank, Science (Reducing food's environmental impacts through producers and consumers, 2018), OCBC

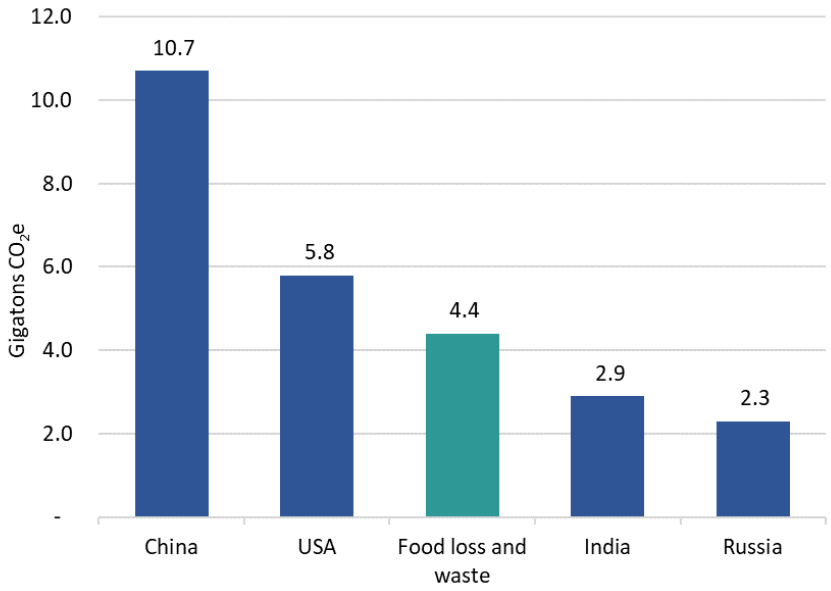
Table 1: Countries with leading food-related GHG emissions

Country	Proportion of global food-related emissions
Plant-based food	
China	7%
India	4%
Indonesia	2%
Animal-based food	
China	8%
Brazil	6%
USA	5%
India	4%

2.3 Food loss and waste

The impact of GHG emissions on the environment are exacerbated by food loss and waste. The economic, environmental and social costs associated with food waste are estimated by the FAO to be $2.6 trillion. Approximately 50% of food loss happens in the production/handling phase, while 45% occurs in the distribution/consumption phase and the remaining 5% in the processing phase. To put the GHG emissions from food loss and waste in context, it would be the third-largest GHG emitter globally if compared against major emitters (Figure 4). This highlights the need for circular-based solutions to address food loss and waste throughout the supply chain.

Figure 4: Food wastage footprint compared to major GHG emitters



Source: CAIT (2015), FAO (2015), OCBC

3. Sustainable solutions and industry trends

All 17 UN Sustainable Development Goals are likely to benefit from a sustainable food system (Annex A). Some sustainable solutions to reduce the carbon footprint of the food sector and reduce food waste are elaborated on in the paragraphs below.

3.1 Change in diet

Moving to a plant-based diet can provide health and environmental benefits. The transition toward a plant-based diet and reduction in the consumption of animal-based food can contribute to the reduction of food-related GHG emissions. It can also support a healthier diet with decreased consumption of unhealthy saturated fats found in some meats and dairy products. However, consumer acceptance of some plant-based or alternative products

is still developing as some consumers are more accustomed to traditional animal-based protein compared to the plant-based or cell-cultured equivalent.

There is likely a strong growth potential for alternative animal-protein products, with the market for alternative meat and dairy estimated to grow to $1.4 trillion by 2050. There has been growing consumer interest in veganism in recent years, and more sustainable food observed to be consumed by better educated and above-average earners. Sustainable food is currently consumed more by higher earners as some are sold at a premium compared to conventionally-marketed products in some countries e.g. oat milk priced higher than dairy milk (Annex B).

3.2 Smart agriculture

To cater to continued population growth and declining arable land, increasing productivity across the food supply chain to meet consumer demand can be achieved through innovation and new technologies.

Annex C shows how some technologies can transform different parts of the food value chain. Some of these technologies are still nascent and require more time to mature and commercialise e.g. nanopesticides, nanofertilisers. However, other technologies are already available (e.g. vertical agriculture) and if implemented globally, can improve the sustainability of the global food sector. Below are some technologies that are of interest:

- **Vertical agriculture and high-tech cultivation methods**: For areas with farmland scarcity, vertical farming with controlled environmental factors (e.g. light, humidity) can produce greater volumes and varieties of crops. Other cultivation methods to replace soils have been developed, such as aeroponics and hydroponics.

- **Precision farming** through innovations like artificial intelligence, drones and satellite technologies can allow farmers to better manage their crops through real-time data on soil and weather conditions. Computer algorithms are able to differentiate between crops and weeds, and selectively spray herbicides on only the weeds. This can lead to a reduction in herbicide use and increase farmers' profitability through better monitoring and plant management. Precision agriculture companies anticipate that customers will increasingly adopt these technologies to help profitability in the long run.

- **Autonomous machinery** has been gaining consumer and investor interest recently. Agricultural machinery could benefit from this as deploying autonomous machinery can increase efficiency by freeing up resources and reducing human error.

The agricultural industry could add $500 billion to global GDP by 2030, with the largest potential attributed to East Asia and the Pacific (~50%). Across different technologies, smart-crop monitoring is anticipated to unlock the largest potential of $130-175 billion by 2030. Drone usage could contribute ~$85-115 billion and smart-livestock monitoring is estimated to grow by $70-90 billion.

3.3 Circular economy and smart/alternative packaging

Reducing food loss or waste through circular solutions can promote a more sustainable food sector. An initiative in Singapore aimed at minimising food waste is the 'Treatsure' app, that works by connecting consumers with hotel buffet restaurants and F&B merchants with excess food. A similar initiative is 'Makan Rescue' that connects staff and students in university communities with surplus catered food from events for free. Further along the food value chain, technologies also exist for waste to be sent to advanced water treatment facilities to be transformed into energy or fertiliser.

Smart packaging solutions are being developed to improve production yields and reduce waste across the entire supply chain. Using recycled materials, recycling agricultural films used to protect and incubate crops, and using bio-based organic materials are solutions that can reduce the carbon footprint of packaging.

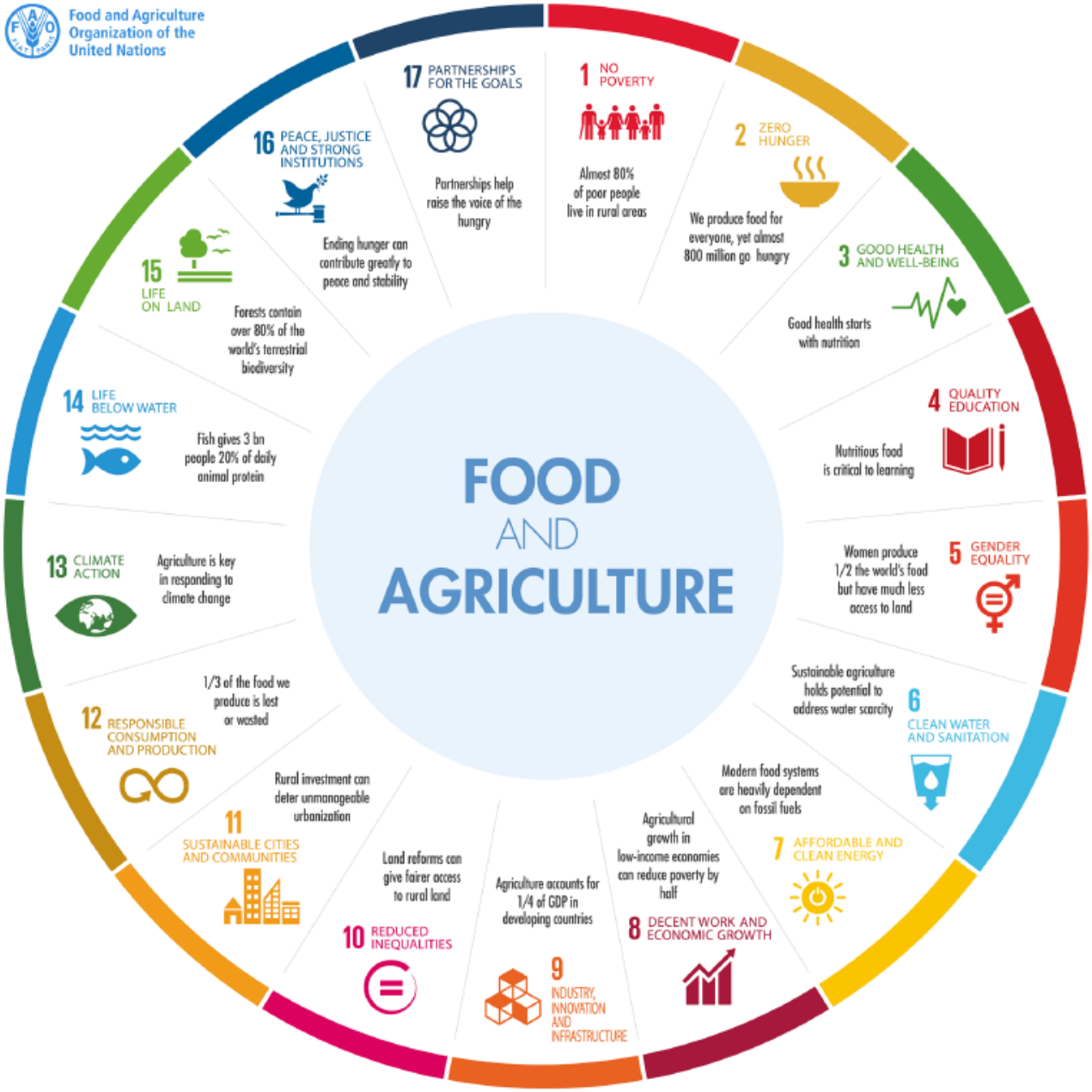
The market for plant-based plastic alternatives for packaging is also growing. This is led by demand from US and European corporates, and increased consumer awareness of the long lifespan of plastic products and its detrimental environmental impacts. Demand from Asia for plastic alternatives is also expected to increase in the next few years.

4. Summary

The food sector's contribution to global GHG emissions is substantial (35%), exacerbated by the impact of food waste across the supply chain. This sector presents great potential to reduce GHG emissions, with consumers increasingly incorporating more sustainable choices into their lives (e.g. plant-based diets and choosing sustainable packaging).

There is strong growth potential for sustainable solutions in the food sector, including cell-based/plant-based products, smart agriculture technologies and sustainable packaging. This is driven by growing consumer awareness of environmental issues, pressure on corporates to support the green transition, as well as governments focusing on sustainability, food and health. Investors play an important role in catalysing these trends through capital, with investment opportunities in growing markets that support sustainable solutions in the food sector.

Annex A: The food system and its relevance to the UN Sustainable Development Goals



Source: FAO (2020)

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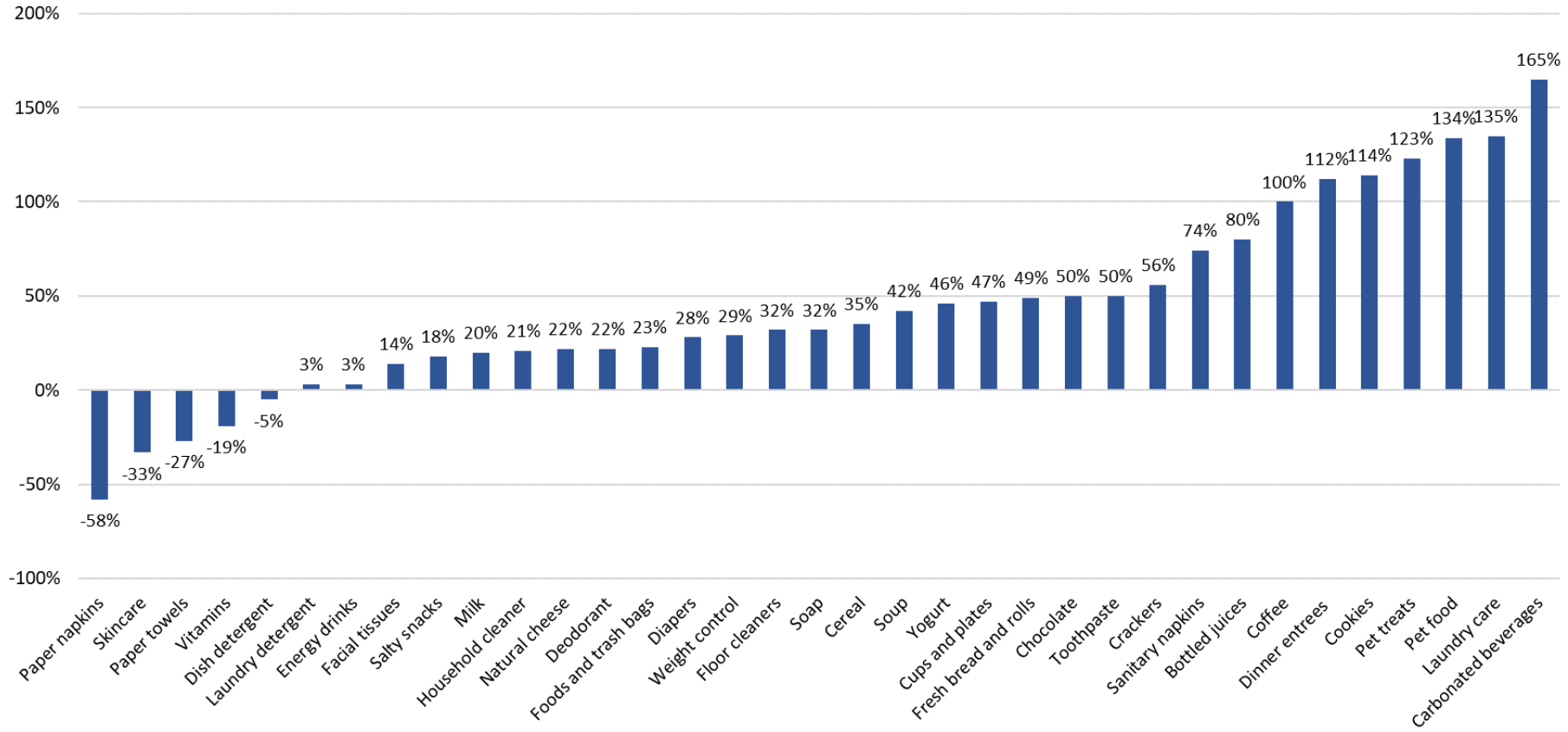
Annex B: Sustainability-marketed products' price premium/discount (2018)



Note: Products with negative values indicate that sustainability-marketed products are priced lower than its conventionally-marketed products, while products with positive values indicate that the sustainability-marketed products are priced higher compared to its conventionally-marketed products.

Source: NYU Stern CSB Sustainable Market Share Index (2020), OCBC

Annex C: Future technologies with transformation potential across the food system and their position in the value chain

	Production	Processing	Packaging	Distribution	Consumption	Waste
Cellular agriculture						
Artificial meat/fish	■	■			■	
Artificial products	■	■			■	
Molecular printing	■	■	■	■	■	■
Digital agriculture						
Advanced sensors		■	■	■	■	■
Artificial intelligence	■	■	■	■	■	■
Disease/pests early warning	■					■
Drones	■			■	■	■
Intelligent food packaging		■	■	■		■
Pest control robotics	■					■
Sensors for soil	■					■
Food processing and safety						
Biodegradable coatings			■	■		■
Micro-organisms coating			■	■		■
Sustainable processing technologies		■	■	■		■
Gene technology						
Biofortified crops	■				■	
Disease/pest resistance	■					■
Genome editing	■					
Genomic selection	■					
Novel nitrogen-fixing crops	■					■
Weed-competitive crops	■					■
Inputs						
Enhanced efficiency fertilisers	■					■
Nanoenhancers	■					■
Nanofertilisers	■					■
Nanopesticides	■					■
Soil additives	■					■
Intensification						
Electro-culture	■					
Irrigation expansion	■					■
Vertical agriculture	■			■		
Replacement food/feed						
Dietary additives for livestock	■					■
Innovative aquaculture feed	■	■				■
Insects for food	■	■			■	■
Livestock/seafood substitutes	■	■			■	■
Microbial algae and cyanobacteria for food	■	■			■	■
Microbial protein	■	■			■	■
Seaweed for food/feed	■	■			■	■
Resource use efficiency						
Circular economy	■	■	■	■	■	■

Source: Nature Food, (Innovation can accelerate the transition towards a sustainable food system, 2020), OCBC

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