CHARTING ASIA'S PROTEIN JOURNEY

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ARE ASIA RESEARCH & ENGAGEMENT

CHARTING ASIA'S PROTEIN JOURNEY

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Published September 2018

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AUTHOR'S NOTE

We are grateful for the support of ADM Capital's CIBUS fund and ADM Capital Foundation in commissioning this report. It is not possible to solve the world's sustainability challenges without addressing the implications of the growing demand for protein in Asia. We hope that this report contributes to finding solutions by setting out a business-as-usual (BAU) scenario for meat and seafood and highlighting the dangers inherent in the current course. We welcome feedback on the report and assumptions. We also look forward to working with many parties to prioritise and implement the solutions necessary to feed Asia while managing the undesirable environmental and social side effects.

Ben McCarron
Founder and Managing Director, ARE

FOREWORD

Asia's rapidly growing middle class is fuelling an increase in protein consumption, yet the environmental consequences of this trend are not adequately considered. We know, for example, that the production of animal protein is responsible for a significant share of global greenhouse gas emissions. Asia Research & Engagement (ARE) in its new report has examined the impact of this dietary shift and provided analysis to illuminate Asia's protein journey.

After almost two decades investing in Asia and observing the rapid growth in the region, I started to think harder about how we produce our food globally and saw opportunity to help reformulate protein production with investment as well as the risk of business-as-usual (BAU). The Cibus Fund strategy was, to a great extent, developed on the premise that domestic production of animal protein, especially in Asia, is increasingly difficult due to reduced availability of natural resources, particularly land and water. The result of this is increased reliance on imports to the region, making it unlikely that the environmental impact will be borne entirely by Asia.

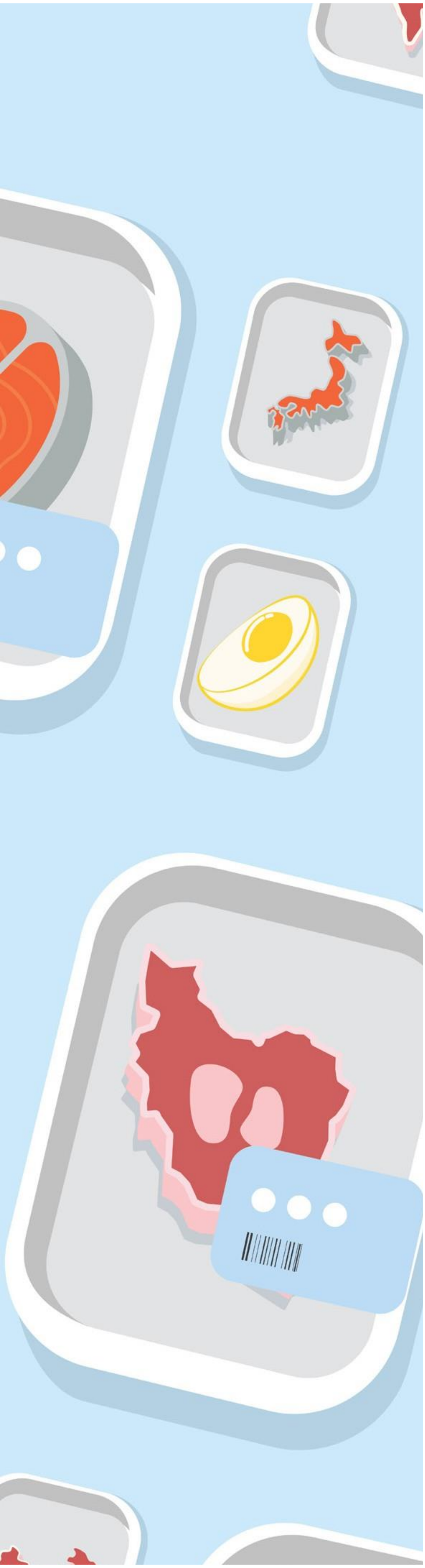
An interesting landscape has developed as countries without adequate resources at home to feed their populations have turned their attention to domestic food security. This focus manifests itself in cross-border purchases of agribusiness companies in countries with sufficient resources at their disposal, and the ability to produce foods destined for export. China has executed this strategy through global acquisitions, for example Shanghai CRED's third-time-lucky bid in 2016 for the massive Australian integrated beef concern, Kidman property, which boasts 185,000 head of cattle.

This global strategy to achieve food security acknowledges the significant increase in protein consumption with population growth and affluence, as well as the associated negative externalities addressed in this report. Whilst we encounter many food companies that may disrupt this sector and bring improvements in emissions, diets are changing and, without action by governments to protect against excessive and polluting resource use, our ecosystems and climate will suffer.

This excellent report sheds light on the GHG emissions associated with a BAU scenario and the excessive and damaging use of antibiotics with concurrent health consequences, offering many reasons to improve the sustainability of protein production in Asia.

I would like to thank ARE and the ADM Capital Foundation for their seminal report on the impacts of protein consumption patterns in Asia. We believe this will help to build understanding of the changing global trade flows as well as the challenges we face that are pivotal to feeding our future.

Robert Appleby
Founder and Partner, ADM Capital



CONTENTS

1

EXECUTIVE SUMMARY

CHARTING ASIA'S PROTEIN JOURNEY

- Growing wealth and urbanisation rates are driving increasing demand for meat and seafood across Asia
- This growth is causing significant knock-on environmental and social impacts, such as greenhouse gas emissions, water use, land use, and antimicrobial use
- An understanding of the current trajectory can help policy-makers, producers, and investors to identify priorities for developing a sustainable food system in Asia

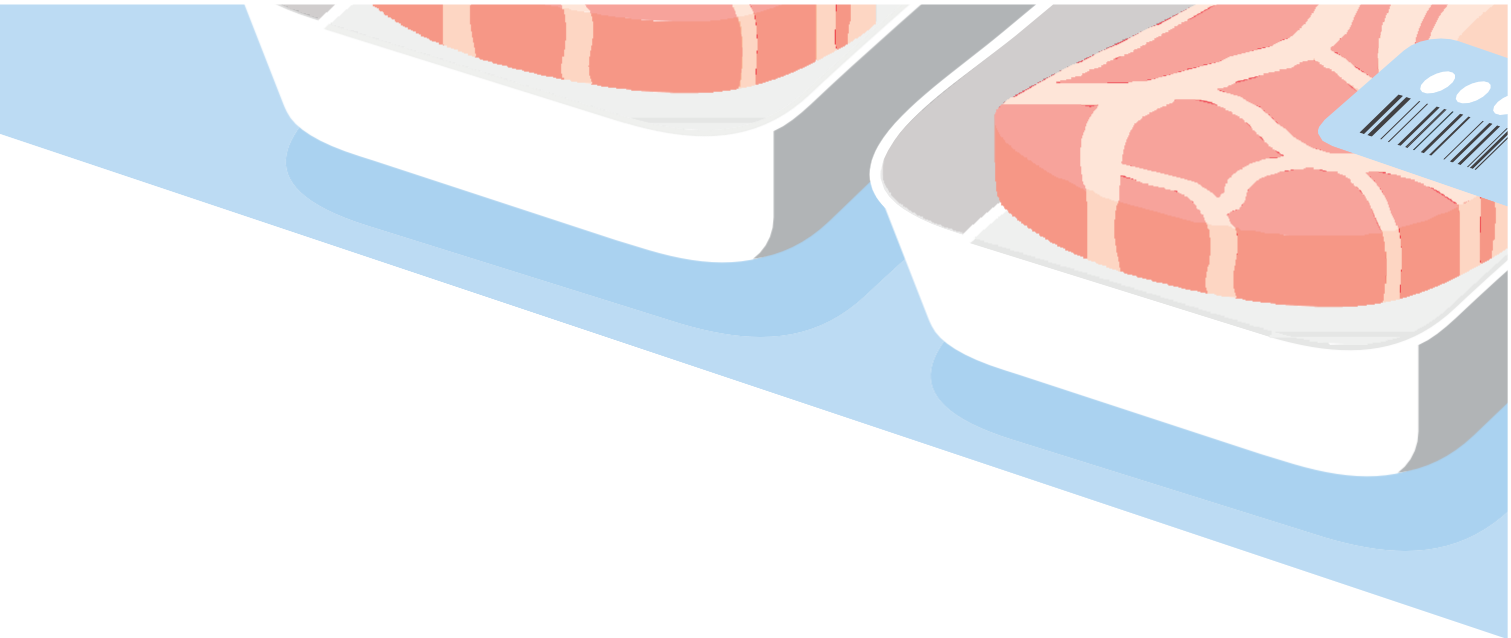
Wealth growth to drive 78% higher meat and seafood consumption in Asia by 2050

Economic growth and rising incomes have driven Asia's appetite for meat and seafood. The business-as-usual (BAU) scenario presented here by Asia Research & Engagement (ARE) indicates that Asia's meat and seafood consumption will increase 33% by 2030 and 78% from 2017 to 2050,[1] on the back of higher urbanisation rates and growing wealth in emerging Asian countries. The purpose of presenting this scenario is to quantify the impacts so as to provide some context for the challenge of transitioning to a sustainable food system. Without proper management, the unconstrained growth in consumption of meat and seafood will have significant negative environmental and social consequences.

The consumption projections described here are more conservative than the Food and Agriculture Organisation's (FAO) findings as reported in its working paper, "Mapping supply and demand for animal-source foods to 2030". [2]

1 The study modelled Bangladesh, China, India, Indonesia, Japan, and South Korea individually and projected values for the Rest of Asia (RoA) — defined as the weighted aggregate of the following countries: Cambodia, Laos, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam.

2 T.P. Robinson & F. Pozzi, "Mapping supply and demand for animal-source foods to 2030", Animal Production and Health Working Paper, No. 2, FAO, 2011.



Demand growth projections for meat products can vary depending on economic growth rates and changes in dietary habits. These are in turn influenced by factors such as relative changes in price, ageing population, cultural considerations, and concerns over the impacts of meat on health, the environment, and animals.

The overall growth creates major environmental and social risks

The continued pursuit of meat as a protein source will have numerous knock-on effects on the environment and social well-being. These include food safety, nutritional challenges, growing viral and bacterial epidemic risks, rising greenhouse gas (GHG) emissions, increased water use and pollution, growing land use, and impacts on the welfare of animals and workers across the meat and seafood industries. We have modelled three critical environmental factors (greenhouse gas, land use and water use) and also the growth in antimicrobial use for this report.

Greenhouse gas

With GHG emissions near doubling…

The production of feed, the clearing of land to produce feed, and digestion processes of animals emit greenhouse gases. ARE estimates that in a BAU scenario GHG emissions from meat and seafood consumption in Asia will grow almost 90% from 2.9 billion tonnes carbon dioxide equivalent (CO_2e) to 5.4 billion tonnes CO_2e from 2017 to 2050. The first figure represents about 6% of total 2012 global GHG emissions, while the growth is equivalent to adding about 40% of the 2012 US emissions figure. (Refer to Appendix 3.1 for more information.)

Land and water use

…and a heavy impact on available land and water resources

The land and water requirements to produce livestock place significant strains on the environment. In the BAU scenario, an additional 81% of land, representing 3.2 million km2, will be required to meet consumption growth between 2017 and 2050 (refer to Figure 19). Large tracts of land are required to produce feed, for grazing, and for production or intensive farming facilities. Without dramatic improvements in efficiency, there could be increasing land-use challenges including deforestation, degradation through over-grazing, pollution, and conflicts with other land users. (Refer to Appendix 3.4 for more information.)

The raising of livestock is also water intensive. The BAU scenario requires 83% more water (an increase of 477 billion m3). Pollution is a major concern from animal wastes and, in cropland areas, through chemical or fertiliser run-off. (Refer to Appendix 3.2 for more information.)

Antimicrobial use

Antimicrobials are frequently used in meat and seafood production, particularly pig and poultry, to ward off disease and to promote growth, regardless of whether there is any medical need. This prophylactic use of antimicrobials is contributing to an increase in antibiotic resistant strains of bacteria in humans. This has alarmed the scientific community. WHO states that antibiotic resistance is one of the greatest threats to global health today.

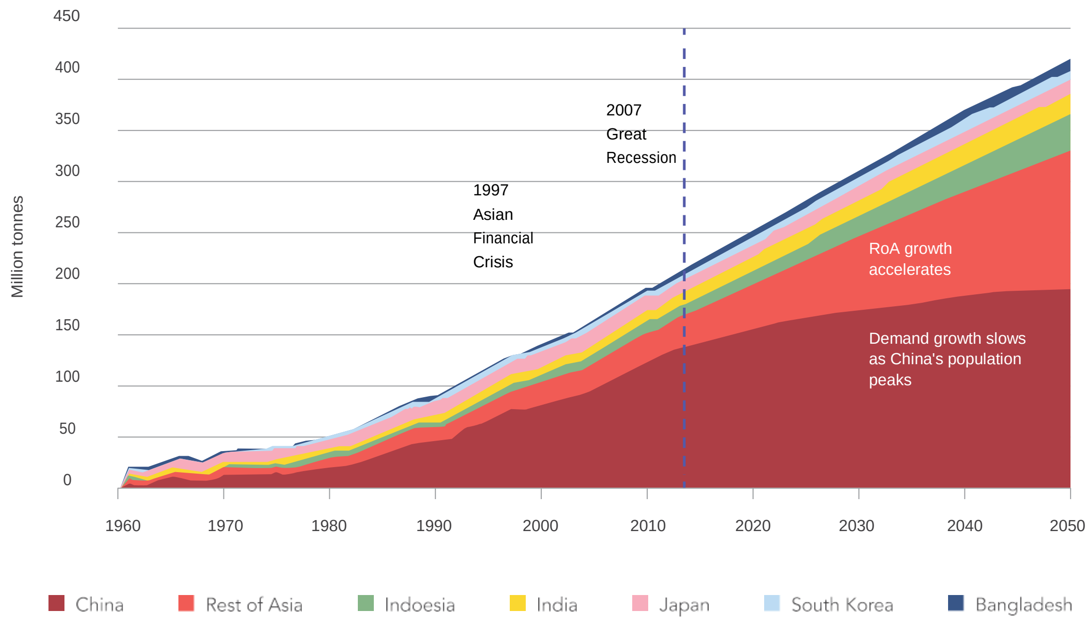
ARE estimates antimicrobial usage in meat and seafood production will grow 44% by 2050. China, as the largest producer of pork and poultry in the region, will account for more than 91% of antibiotic use in food animal production in Asia. However, the Rest of Asia, Indonesia and Bangladesh will record the fastest growth of antimicrobial usage from 2017 to 2050 at 258%, 207% and 109% respectively based on current estimated antimicrobial dosages. These numbers may even increase faster if production shifts to more intensive farming practices, where close proximity of animals increases disease risk. (Refer to Appendix 3.3 for more information.)

Different growth & differing market maturities

Countries have very different growth rates

The above challenges will present themselves in different countries in different ways. China's meat and seafood consumption growth is predicted to be moderate in the coming decades as the effects of increasing affluence fade and population growth slows. Instead, the growth mantle will pass to the Rest of Asia, including Pakistan, the Philippines, and Myanmar, which will see accelerating meat and seafood consumption as affluence increases there. These different projected growth rates and differing market maturities create varying contexts for the development of each market.

Figure 1: Asia's projected meat and seafood consumption growth, 1961-2050



NOTE: Historic figures till 2013; projection figures thereafter

Sources: FAO Statdata (1961 – 2013) [3] *, World Bank, OECD, ARE estimates (2013 onwards)*

[3] Food and Agriculture Organization, FAOSTAT Data, 2017

Figure 2: Asia's projected meat and seafood GHG and resource use

	2017	2030	2050	Growth from 2017-0	Growth from 2017-50
GHG (billion tonnes CO_{2e})	2.9	3.9	5.4	34%	88%
Water (billion m^3)	577	777	1,054	35%	83%
Antimicrobials (thousand tonnes)	27	33	39	22%	44%
Land (million km^2)	3.9	5.2	7.1	33%	81%

Source: ARE estimates

Charting a new course

In this report, we have provided a BAU scenario for demand growth for meat and seafood and quantified some of the environmental and social impacts. The next question is how to move away from this undesirable scenario and find a favourable future, one in which Asia charts a course to a sustainable food system.

Fortunately, there are already many potential solutions. We discuss some of these in the fourth chapter in three groups: supply side responses, where producers improve their processes; demand side responses, where consumers and large customers change their buying patterns; and external actors, such as regulators or investors, that may work across the value chain.

There are many parties that will need to come together to implement these solutions, which will vary among countries and across the stages of production. The BAU scenario presented in this report can help readers prioritise efforts for a sustainable food future.

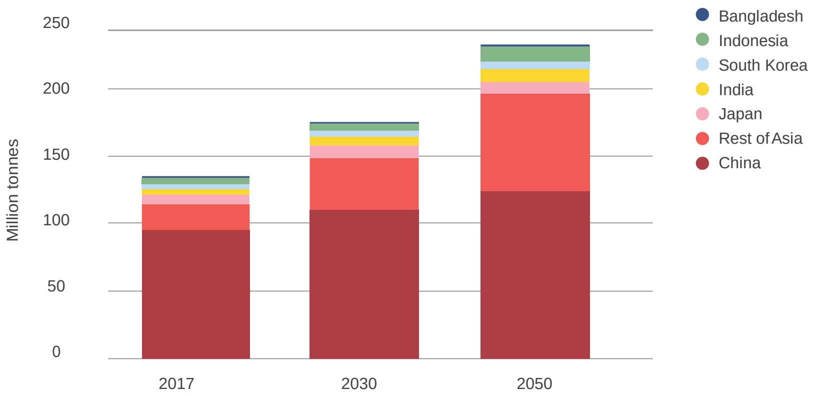
2

DEMAND PROJECTIONS

Total meat and fish consumption in Asia will grow 78% by 2050, according to our BAU scenario (refer to Figure 1, Figure 3 shows projection for meat only). While China currently represents over 70% of the region's consumption, the proportion will diminish to only 54% by 2050 as other emerging and frontier markets will be the main contributors to additional meat and fish demand. (Refer to Appendix 2 for more information).

China will only account for 54% of meat and seafood demand by 2050

Figure 3: Total meat consumption by country



Sources: FAO Statdata (1961 – 2013), World Bank [4], OECD [5], ARE estimates (refer to Appendix 1)

Pakistan, Philippines and Vietnam set to lead demand growth for rest of Asia

The aggregate for the Rest of Asia includes 13 regions with significant differences in size and stage of economic development, and consequently varying trends in meat and seafood consumption. Although we projected future consumption for the aggregate only, the pattern is visibly skewed by the four most populated countries, which account for over 70% of the group — Pakistan, the Philippines, Vietnam and Thailand. In particular, the UN's population projections indicate a faster population growth in Pakistan, leading its relative weight in the group to increase to approximately 36% by 2050 from 30% at present.

[4] World Bank Group, World Bank Open Data, 2017

[5] Organisation for Economic Co-operation and Development, OECD Statistics, 2017

Taiwan and Mongolia have seen declines in per capita meat and seafood consumption

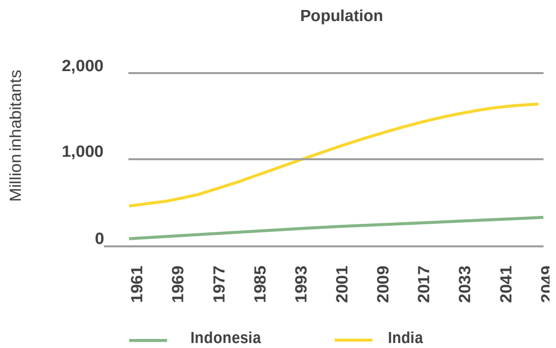
Conversely, some of the markets with slowing or declining trends are too small to make a difference to the Asia totals. With about 24 million inhabitants (or 3% of Rest of Asia population), Taiwan has already shown a flattening and then decline in per capita meat consumption, likely related to increasing health awareness among higher income groups. Mongolia, which has only three million inhabitants, has seen its per capita meat consumption steadily declining for the past few decades, though for very different reasons: meat represented a basic food staple to a country of nomad herders, but new economic opportunities accompanied migration to the capital Ulaanbaatar, with urbanisation and international trade bringing wider access to new food resources other than meat.

Indonesia's meat and seafood consumption will overtake India's within two decades

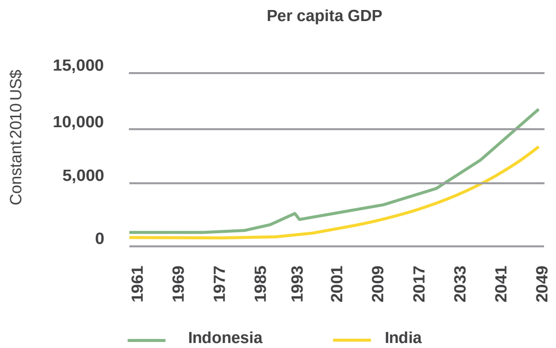
Changes in consumption preferences can outweigh population size as a factor in total meat and seafood consumption. In our projections, Indonesia's total meat and seafood supply will grow by nearly three times between 2018 and 2050 — a much faster pace than the 60% expected for India over the same period (refer to Figure 4). This faster pace will result in Indonesia's meat consumption overtaking India's by 2036 at around 7.5 million tonnes, despite India's per capita GDP increasing at a faster pace and India being home to a population five times that of Indonesia over the forecast period.

The different trends follow from a cultural aversion towards meat consumption in India, which has the highest proportion of vegetarians in the world at 38% of the country's population [6], and greater per capita income levels in Indonesia.

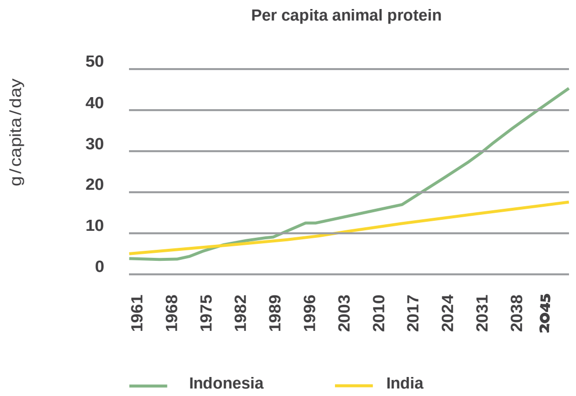
Figure 4: Meat and seafood consumption drivers in Indonesia and India



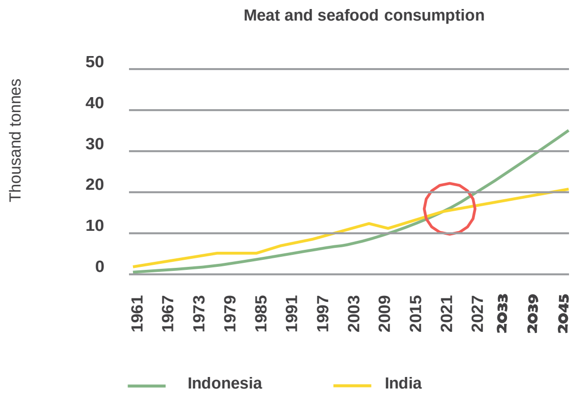
India's population stays at around 5 times that of Indonesia, with both countries growing over 20% by 2050…



…but Indonesia's income level grows 2.5 times compared to 1.5 times for India over the same period



Higher income levels enable a stronger shift towards higher consumption of discretionary food…



...leading to Indonesia's total meat and seafood consumption overtaking India's by 2026

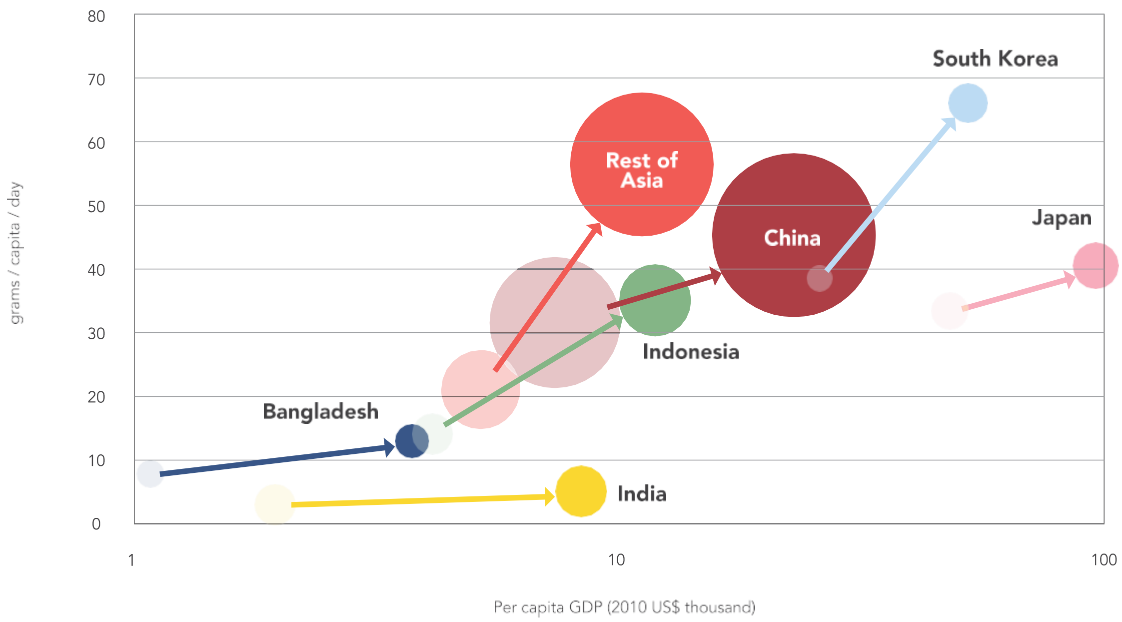
Sources: FAO Statdata (1961 – 2013), World Bank, OECD, ARE estimates (2013 onwards)

[6] B.E. Sawe, "Countries With The Highest Rates Of Vegetarianism" WorldAtlas.com

Changing dietary trends

Changes in per capita demand and population growth drive total consumption. As shown in Figure 5, there is a strong correlation between percentage change in income and protein consumption levels. Human intake eventually levels off, but this will not necessarily occur in many Asian countries over the next three to four decades. In Asia, continued growth in disposable incomes will lead to more regular access to meat and seafood meals that were previously unaffordable.

Figure 5: Protein consumption, 2017-2050

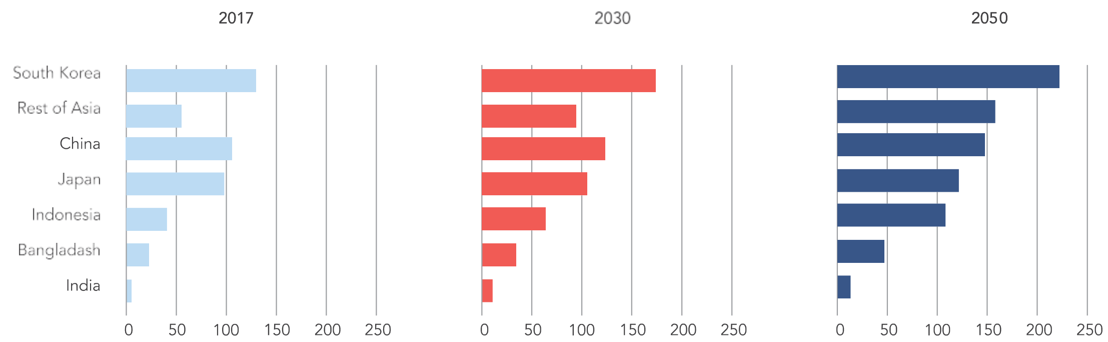


NOTE: The relative size of each circle represents the total protein consumption of each country. Protein consumption refers to nutrient weight that only forms only a small portion of meat and seafood products.

Sources: FAO Statdata (1961 – 2013), World Bank, OECD, ARE estimates

We believe emerging and frontier economies will lead per capita meat and seafood consumption, with the Rest of Asia leaping ahead of China and Indonesia and nearly reaching Japan levels by 2050 (refer to Figure 6).

Figure 6: Meat and seafood consumption (kg / capita / year)



Sources: FAO Statdata (1961 – 2013), World Bank, OECD, ARE estimates

Culinary preferences generally persist across generations

There is variation in the consumption of meats among the different Asian countries. The major reason is religious restrictions and related culinary habits that often persist in secularised portions of the population. The notable examples are the low consumption of pork in Muslim communities and the low consumption of meat, particularly beef, in Hindu India.

Relative prices can explain shift in preferences between meat types over time

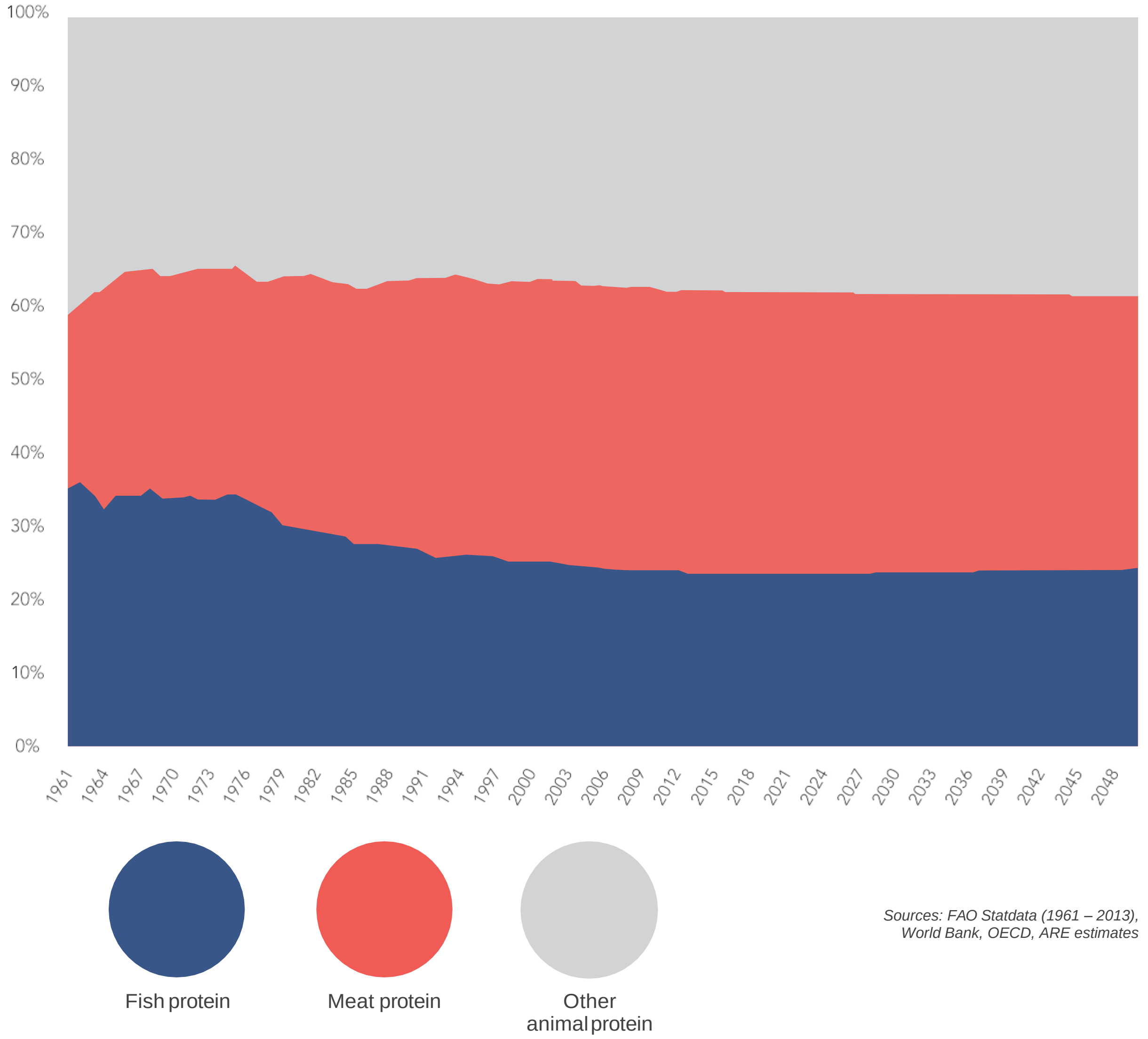
The shares of seafood and different meats consumed within each market show some variation across time. Reasons include the relative pricing of the different products and availability of different meats; and other changes in taste or cultural disposition.

In general, we have not sought to explicitly model changes in preference among different types of meat. Rather we have assumed that past culinary and cultural meat preferences will hold into the future — i.e. that the proportions of different meats will remain similar to the current proportions. We made exceptions where there were clearly changing consumer trends in place. These included the increasing proportion of poultry consumed in India; the decreasing proportion of fish in Japan; and the decreasing proportion of bovine meats in Bangladesh.

Similarly, shares of seafood, meat and other animal protein such as eggs, milk and butter show limited variation over time in Asia on an aggregate basis. This is significant for modelling, as meat and seafood have different impacts. Generally, we did not model a change in proportions, unless there was a clear shift in consumption patterns already taking place.

The proportion of seafood consumed on an aggregate basis across Asia declined from the 1960s to the 1990s. Since then, the proportion of meat relative to seafood and other proteins consumed has remained relative constant. This masks the underlying changes that have occurred within each country. Seafood consumption as a proportion of protein consumed declined for countries such as Japan, Korea, and Rest of Asia, with the trend forecast to continue over time. A notable change in preferences is in Japan, which is discussed later in this chapter. Indonesia and Bangladesh have particularly high shares of seafood as a proportion of protein consumption.

Figure 7: Split between meat, fish and seafood and other protein products of animal origin



Sources: FAO Statdata (1961 – 2013), World Bank, OECD, ARE estimates

Poultry is most preferred in Bangladesh, India and Indonesia

We expect largely Muslim Bangladesh to continue consuming negligible amounts of pork throughout the forecast period and increase instead chicken and mutton consumption by about 78% by 2050. In Indonesia, preference for poultry has clearly taken the lead throughout the last two decades, but pork will still represent about 23% of total meat consumption due to the presence of Christian minorities and different ethnic groups.

In India, consumers have gradually switched from bovine meat to poultry over the past two to three decades, a trend that we project to continue in the medium term, with an increase in beef and water buffalo exports to higher earning countries.

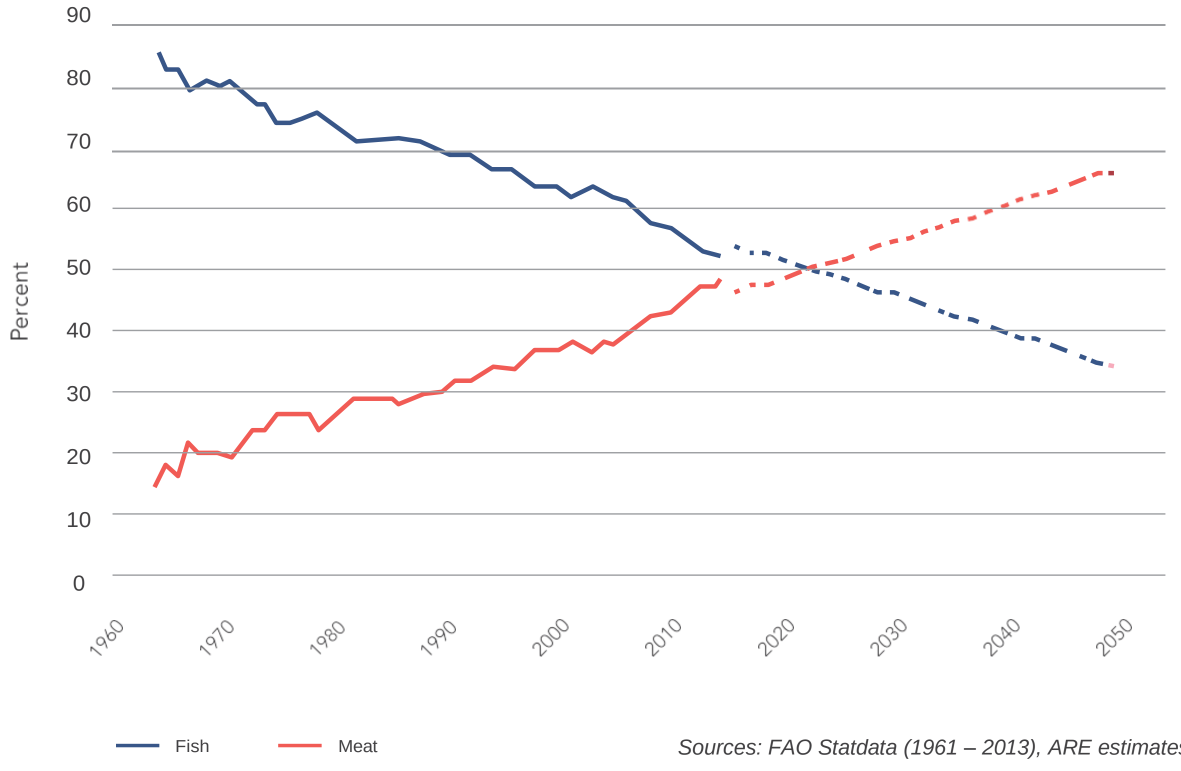
East Asian countries favour pork

East Asia typically favours pork over other types of meat, accounting for about 63% of total meat consumption (excluding fish) in China and 52% in Korea — respectively about three and two times the amount of the second meat type consumed. Japan's meat preferences are more balanced, with pork consumption representing 42% of the total (excluding fish), followed by poultry at 39%. These proportions have remained relatively stable through time.

Traditional seafood diet in Japan gradually shifts as domestic meat consumption increases

One notable change in preferences is in Japan. There, fish consumption has steadily declined in relative terms, falling from nearly 70% of total animal protein consumption (including animal-derived products such as dairy and eggs) in the early 1960s to about 38% in 2014. At this pace of change, meat protein will match fish protein consumption by the end of the decade (refer to Figure 8).

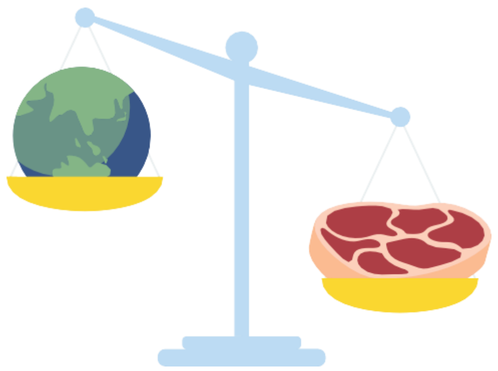
Figure 8: Changing shares of meat and seafood in Japan



Sources: FAO Statdata (1961 – 2013), ARE estimates

3

IMPACT



Meat and seafood production have significant environmental footprints as compared to other forms of food such as grains and vegetables. With environmental pollution, food security, and climate change mitigation among the major challenges many countries in Asia face, there is an increased focus on the environmental impacts of diets.

In this study, we examine the environmental footprint and antimicrobial dosage associated with the production of livestock and seafood. Through quantifying the impact, we hope to highlight the need for measures to ensure that food demand can be met with sustainable production, emission reduction and other mitigation strategies.

3.1 Greenhouse Gas

GHG emissions of meat and seafood accounts for 15% of total GHG emissions in Asia

We estimate the total GHG emissions related to supplying Asian meat and seafood demand at 2.9 billion tonnes CO_2e. This is approximately 15% of the latest available CO_2 equivalent emissions for the aggregate of Asian countries in our study. For reference, the Intergovernmental Panel for Climate Change estimates global agriculture sector emissions at 11.3% of total GHG emissions.[7] The FAO's Global Livestock Environmental Assessment Model (GLEAM)[8] estimates emissions from the Asian livestock sector at 3.1 billion tonnes CO_2e based on 2010 figures. This number differs in scope from our calculation in several important ways. The FAO numbers include eggs and dairy, exclude seafood, and are based on production emissions. Our calculations have estimated emissions associated with supplying consumption, the effect of this is that our figures include the emissions associated with meat imports.

GHG emission from Indonesia and Rest of Asia will grow the fastest

We project that GHG emissions in Asia will increase 34% by 2030 and increase 88% by 2050 based on our projections of Asian demand for meat and seafood at current rates of emissions. The Rest of Asia will almost double GHG emissions by 2030 and increase 3.5 times by 2050. Indonesia and Bangladesh will record the next fastest rate of GHG emissions arising from meat and seafood consumption of more than three times by 2050.

At the other end of the spectrum, India's GHG emissions will decrease marginally by 2030 before increasing 21% by 2050 due to the changing mix of consumption – with lower proportion of bovine meats that have high associated greenhouse gas emissions. The growth in demand for the type of meat or seafood can have a significant impact on the overall GHG emissions growth as ruminants have a much higher GHG footprint than other meats or seafood due to their digestion processes. Ruminant proportion is the dominant aspect for country level differences. Countries with a higher proportion of beef consumption will correspondingly have a larger greenhouse gas footprint. Emission intensity can vary greatly among producers due to different farming practices, farming technology, environmental conditions and supply chain management practices (refer to Appendix A3.1).

[7] European Environment Agency, "Sectoral greenhouse gas emissions by IPCC sector", 2018

[8] Food and Agriculture Organization of the United Nations, "Global Livestock Environmental Assessment Model (GLEAM)", 2018

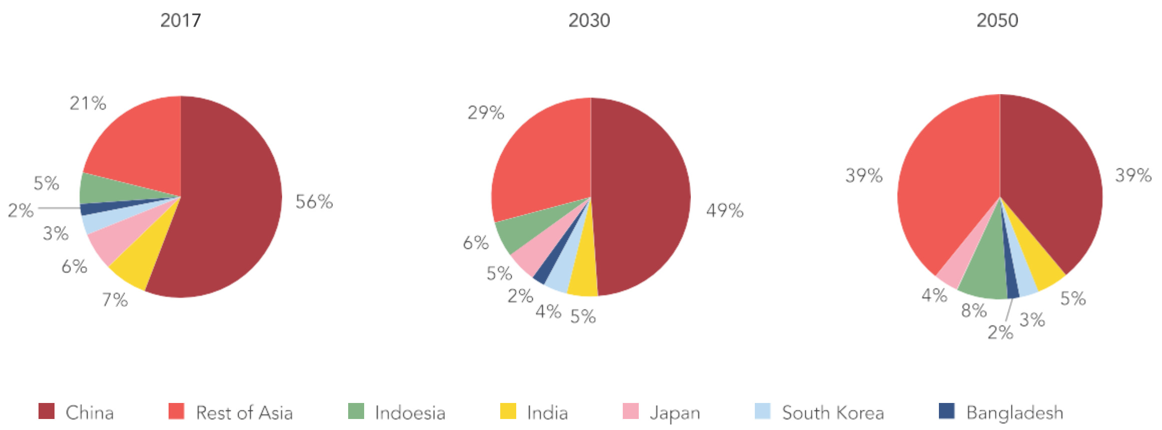
Figure 9: Meat and seafood-related GHG emissions and growth by country (million tonnes CO_2e)

Country	2017	2030	2050	Growth from 2017-30	Growth from 2017-50
China	1,603	1,898	2,131	18%	33%
India	205	194	248	-5%	21%
Japan	187	195	203	4%	9%
Korea	97	132	161	36%	66%
Bangladesh	58	83	118	43%	101%
Indonesia	137	238	420	74%	208%
Rest of Asia	591	1,129	2,114	91%	258%
Total Asia	2,877	3,869	5,395	34%	88%

Source: ARE estimates

In 1961, Japan accounted for a quarter of GHG emissions from meat and seafood consumption in Asia. Fast forward to today, China accounts for more than half of GHG emissions from meat consumption while Japan represents just 6% (refer to Figure 10). This is expected to change in the coming years as developing countries in Asia becomes wealthier. By 2050, China and Rest of Asia will each account for 39% of GHG emissions from meat and seafood consumption. Countries with the fastest growth in per capita GDP and population, the key drivers of meat consumption growth, will see the fastest growth in GHG emissions.

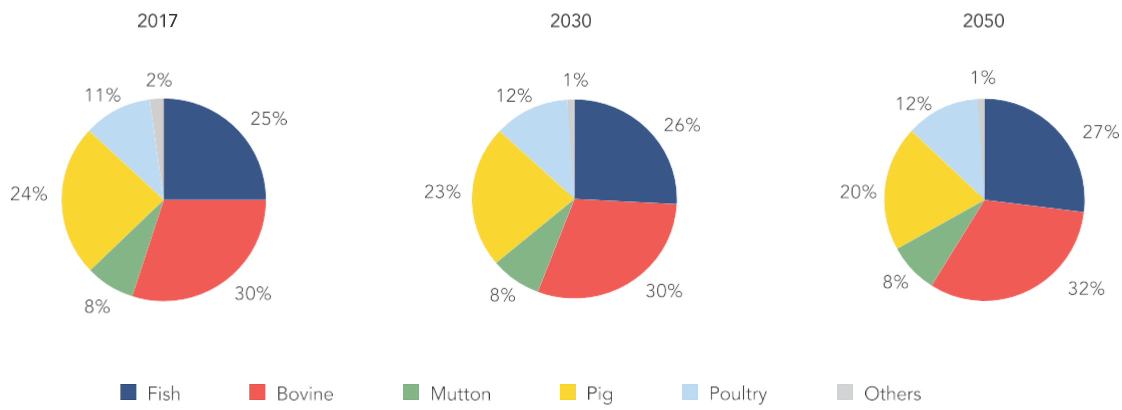
Figure 10: Contribution to GHG emission from meat and seafood consumption in Asia by country



Source: ARE estimates

Unlike GHG emissions by country, emissions by meat type remain relatively unchanged over the next few decades, primarily as the proportions of different meats consumed are relatively stable (refer to Figure 11). Reality could differ from this if there were interventions, such as widespread investment in methane capture from cattle.

Figure 11: Contribution by animal type to Asia's GHG emission from meat and seafood consumption



Source: ARE estimates

3.2 Water Footprint

Water footprint related to meat and seafood demand is 13% of total water footprint

We estimate the total water footprint related to supplying Asian meat and seafood demand will increase 35% by 2030 and 83% by 2050. The meat and seafood water footprint in Asia of 480,939 million m³ in 2011 represents 13% of the total water footprint in Asia based on statistics published by the National water footprint explorer[9] by the Water Footprint Network. Estimates based on the explorer tool also show that meat production accounts for 22% of water footprint globally. There are multiple possible reasons for differences between global and Asia-level statistics for meats' share of water use. Notably, our estimates do not include the water footprint associated with post-farm processes such as slaughtering, processing and transport.

The majority of water use is indirectly in agriculture-related activities such as the production of grains and oil grains for use as feed (refer to Appendix 3.2). Increases in water demand associated with the direct footprint of meat and seafood production will be especially significant in areas that are water stressed.

China's demand for meat and fish, and the resulting water footprint is the largest in the region, dwarfing the second largest region, Rest of Asia. China's water footprint growth of 18% from 2017 to 2030 and 33% to 2050 is the second lowest in the region after Japan. This is largely due to slowing population growth in the coming decades. At the same time, pork consumption, which accounts for 50% of protein consumption from meat and fish sources in China, has favourable water footprint measurements compared to other meat types. Beef has the highest water footprint, followed by pig and poultry. Aquaculture has an approximate water footprint half that of pig and poultry. (refer to Appendices 1 and 3).

Emerging Asian countries such as Bangladesh and Indonesia will face the highest growth in water demand. This is associated with an increase in fish and poultry consumption in Indonesia and higher fish consumption in Bangladesh.

[9] Asia total water footprint is estimated to be 3,674,365 million m³ in 2011, using stats from National Water Footprint explorer, a tool from the Water Footprint Network.

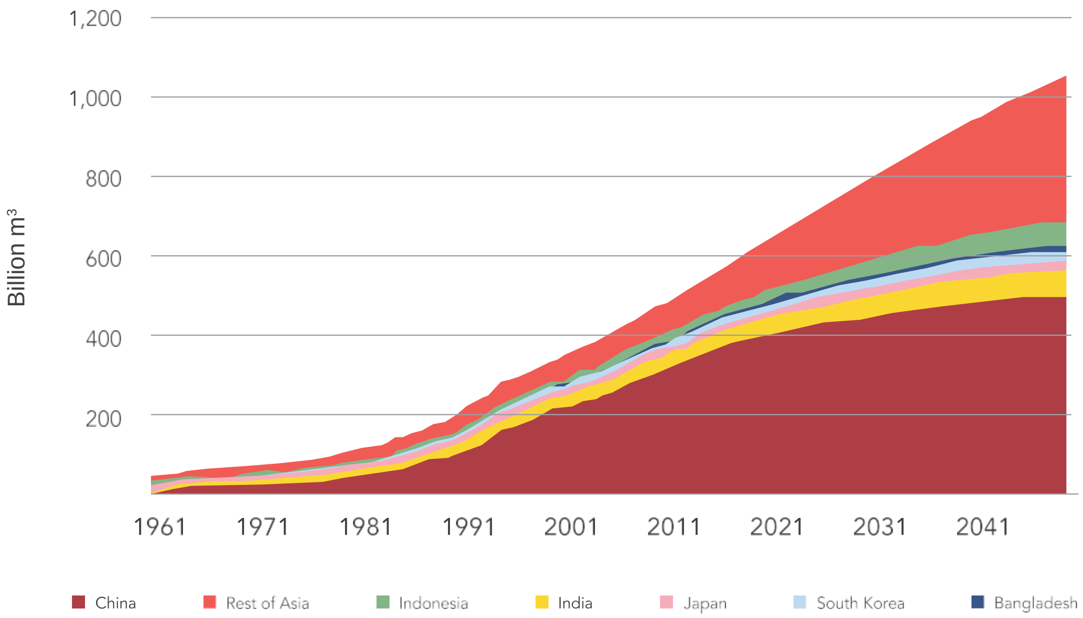
We project that the water footprint from supplying India's meat and seafood demand will increase 63% by 2050. Although India is the second most populous country in the region, its water footprint is less than one-tenth that of China (refer to Figure 12). This is primarily because meat consumption per capita in India is the lowest in Asia due to cultural factors and lower income levels. However, India's water footprint per kilogram for pig and poultry is the highest in Asia, possibly due to inefficient production.

Figure 12: Water footprint of meat and seafood consumption in Asia (billion m³)

Country	2017	2030	2050	Growth from 2017-30	Growth from 2017-50
China	378	448	203	18%	33%
India	38	50	62	31%	63%
Japan	17	20	23	15%	36%
Korea	15	20	24	36%	66%
Bangladesh	7	10	14	46%	106%
Indonesia	20	35	61	74%	207%
Rest of Asia	102	196	366	91%	258%
Total Asia	577	777	1,054	35%	83%

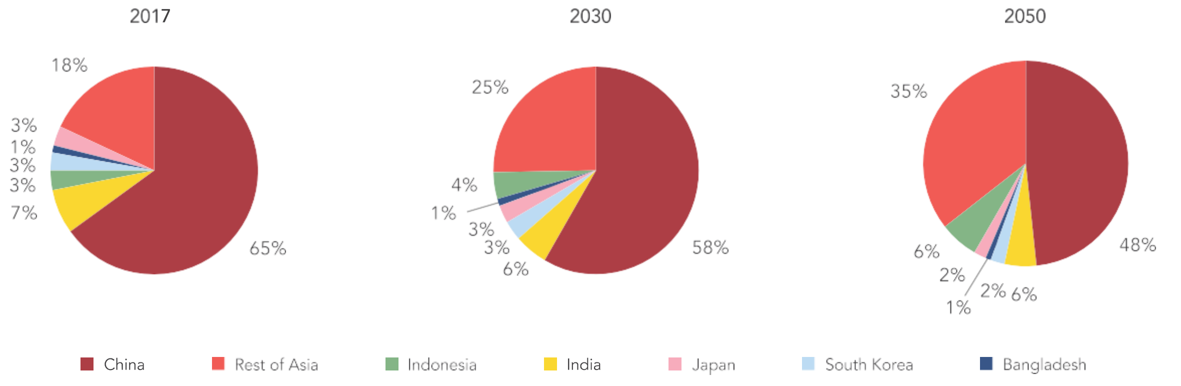
Source: ARE estimates

Figure 13: Water footprint of meat and seafood consumption



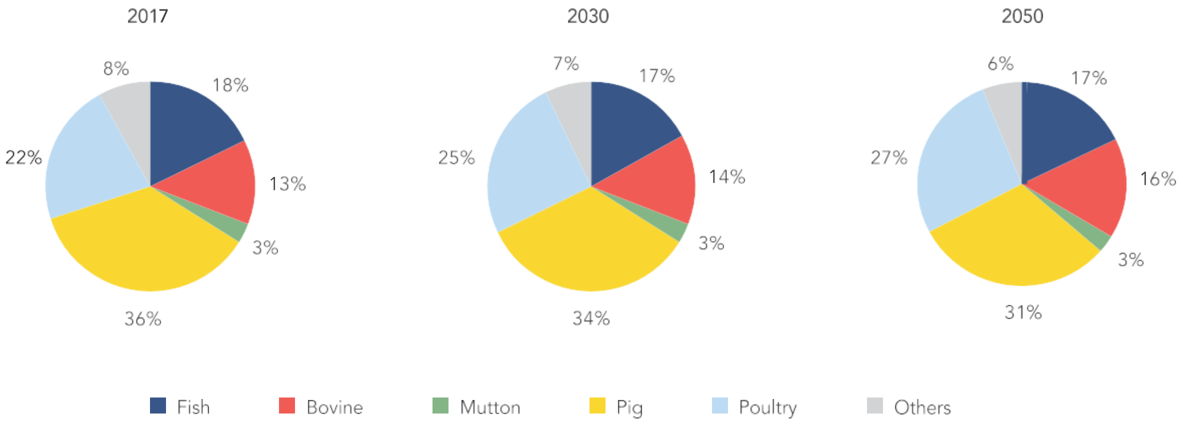
China's water footprint from meat and seafood consumption increased from 26% of Asia's total estimates in 1961 to 65% of the total in 2017 (refer to Figure 14). Its contribution to the total water footprint is expected to peak and gradually decline to account for half of Asia's water footprint from meat and seafood consumption by 2050. China's falling proportion is due to a rapid increase in water footprint from meat and seafood consumption in Rest of Asia. These two regions will collectively account for around 80% of Asia's water footprint from meat and seafood consumption in the decades to come.

Figure 14: Contribution to water footprint from meat and seafood consumption in Asia by country



Source: ARE estimates

Figure 15: Contribution to water footprint from meat and seafood consumption in Asia by meat type



Source: ARE estimates

3.3 Land Use Intensity

Additional meat and seafood demand in Asia will require land equivalent to 70% of China

The production of livestock to meet Asia's meat demand comes with corresponding demand for arable land. The land footprint required to meet Asia's appetite for meat and seafood will increase 81% to 7 million km^2 by 2050 under the BAU scenario (refer to Figure 16). This increase is almost equivalent to 70% of the size of China.

Rest of Asia will see the largest growth in land use. In all, 1.8 million km^2 of land will be required to support additional meat consumption in these countries. This represents 56% of the increase in Asia's land requirement.

[9] Asia total water footprint is estimated to be 3,674,365 million m^3 in 2011, using stats from National Water Footprint explorer, a tool from the Water Footprint Network.

The land required to produce bovine meats is large (refer to Figure 18). In India, decreasing domestic beef consumption leads to an 8% decline in land demand by 2030 before increasing 18% by 2050.

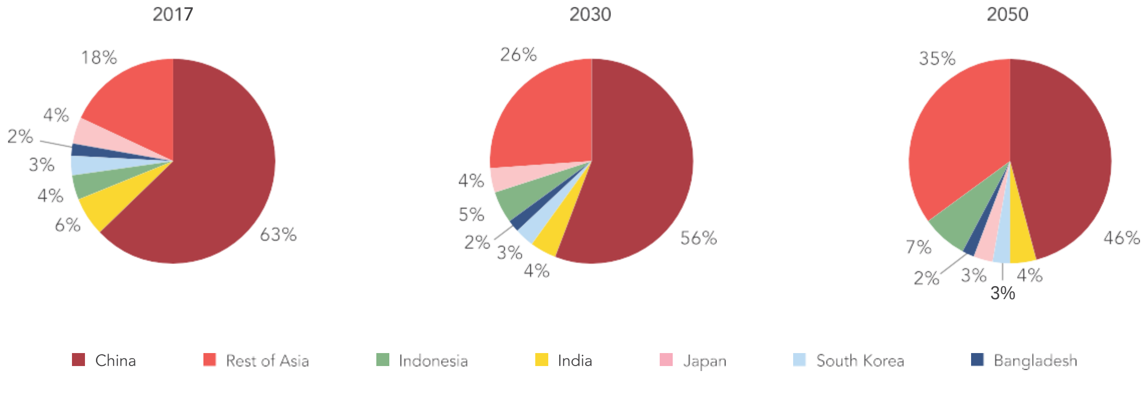
Figure 16: Land demand (thousand km²)

Country	2017	2030	2050	Growth from 2017-30	Growth from 2017-50
China	2,484	2,942	3,303	18%	33%
India	232	214	274	-8%	18%
Japan	171	196	230	14%	34%
Korea	114	155	190	36%	66%
Bangladesh	63	89	126	41%	99%
Indonesia	153	267	473	74%	208%
Rest of Asia	703	1,342	2,513	91%	258%
Total Asia	3,921	5,206	7,108	33%	81%

Source: ARE estimates

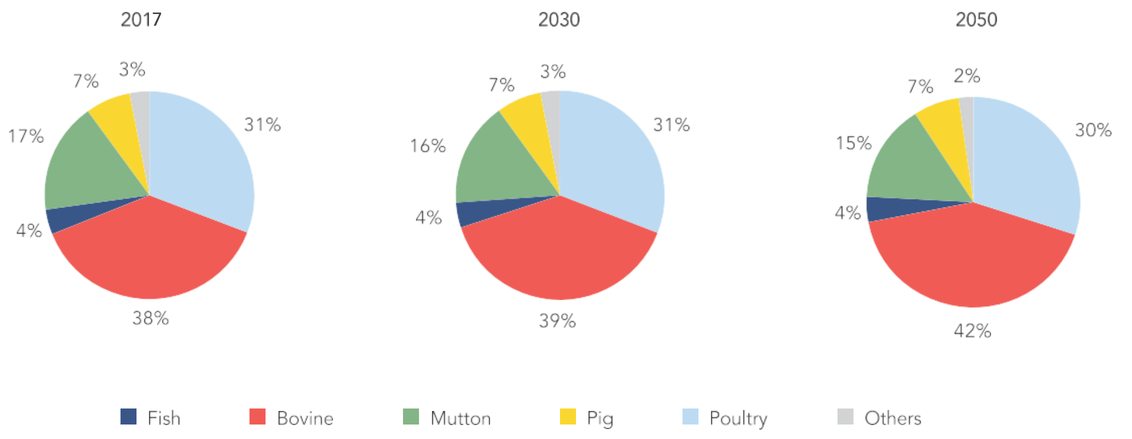
China, which accounts for 63% of land demand from meat consumption, will continue to dominate land requirements in Asia (refer to Figure 17).

Figure 17: Land demand from meat and seafood consumption in Asia by country



Source: ARE estimates

Figure 18: Contribution to land demand from meat and seafood consumption in Asia by meat type



Source: ARE estimates

3.4 Antimicrobial Use

Antimicrobials are frequently used in meat and seafood such as pig and poultry production to ward off disease and to promote growth, even when there is no medical need. The prophylactic use of antimicrobials is contributing to an increase in antibiotic resistant strains of bacteria in humans. An FAO[10] study found high levels of resistance to specific antibiotics for salmonella spp. samples isolated from poultry meat. More than half of the samples from Bangladesh and Thailand had resistance to Tetracycline, a broad spectrum antibiotic.

Asia accounts for 18% of global anti-microbial demand for food animals

An updated 2017 study[11] estimated that 131 thousand tonnes of antimicrobials were used in the production of food animals globally in 2013. We estimate[12] that Asia required 24 thousand tonnes of antimicrobials in 2013 to produce meat and seafood. Based on ARE's estimates that year, Asia accounted for 18% of global antimicrobial demand for food animals.

We estimate antimicrobial usage in meat and seafood production will grow 44% by 2050. The growth is lower than other impacts as it is dominated by Chinese pork consumption and the high antimicrobial usage for production in China. However, Chinese pork consumption levels off, restraining the overall Asian growth of antimicrobial use. Rest of Asia, Indonesia and Bangladesh will record the fastest growth of antimicrobial usage from 2017 to 2050 at 258%, 207% and 109% respectively, if production increases at current antimicrobial dosages. These numbers may even increase faster if production shifts to more intensive farming practices where crowding of animals increases disease risk.

[10] J Otte, et al, 'Antimicrobial Use in Livestock Production and Antimicrobial Resistance in the Asia-Pacific Region' APHCA Research Brief No. 12-10

[11] Van Boeckel, T. P. et al., 2017. Reducing antimicrobial use in food animals. Science, 357(6358), pp. 1350-1352.

[12] Country figures were extracted from "ResistanceMap - Animal Use", Center for Disease Dynamics, Economics & Policy website ARE assumes from the underlying data that total consumption in the article is provided in metric tonnes.

Figure 19: Antimicrobial usage (tonnes/year)

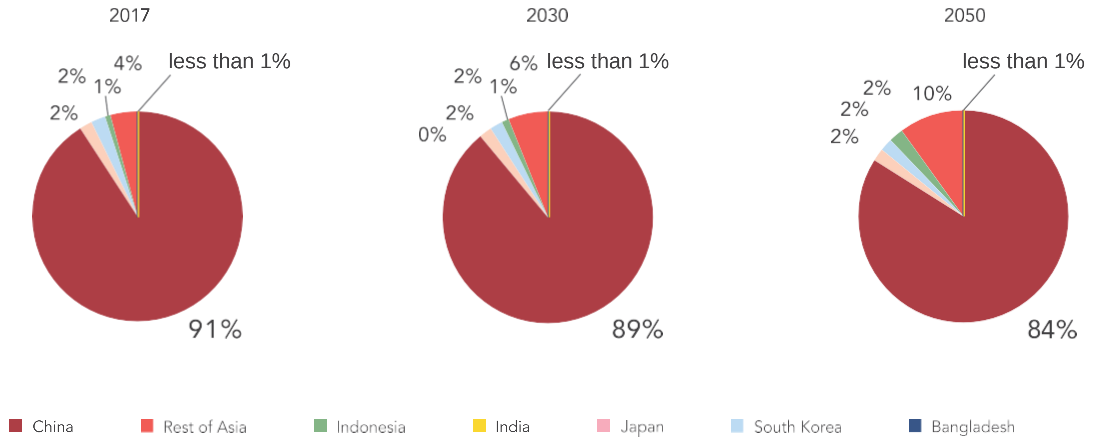
Country	2017	2030	2050	Growth from 2017-30	Growth from 2017-50
China	24,821	29,396	32,994	18%	33%
India	0.3	0.4	0.5	41%	75%
Japan	415	483	580	16%	40%
Korea	551	748	915	36%	66%
Bangladesh	72	107	151	48%	109%
Indonesia	233	404	715	74%	207%
Rest of Asia	1,034	1,979	3,707	91%	258%
Total Asia	27,126	33,118	39,062	22%	44%

Source: ARE estimates

China, as the largest producer of pork and poultry in the region will account for more than 91% of antimicrobial use for food animal production in Asia (refer to Figure 20). China's usage of antimicrobials in meat and seafood dwarfs that of any other country globally at 319mg/PCU[13]. Korea, which has the second highest dosage globally, uses 188mg/PCU, 40% less than China. The growth rates could possibly slow. Efforts by authorities to limit antimicrobial use, such as national action plans in both India and China, may prevail and reduce growth rates or usage levels.

[13] PCU refers to 'population correction unit' and considers the animal population and estimated weight of each particular animal at the time of treatment with antibiotics. It is a unit of measurement developed by the European Medicines Agency to monitor antibiotic use and sales across Europe.

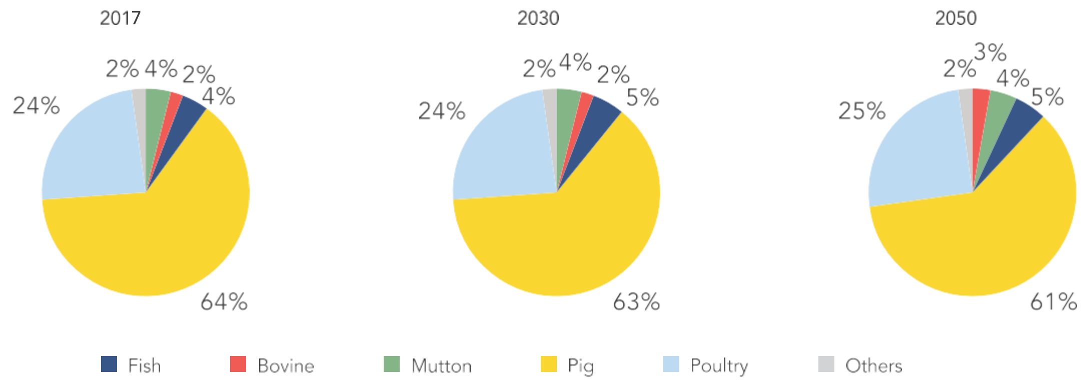
Figure 20: Contribution to antimicrobial consumption in meat and seafood production in Asia by Country



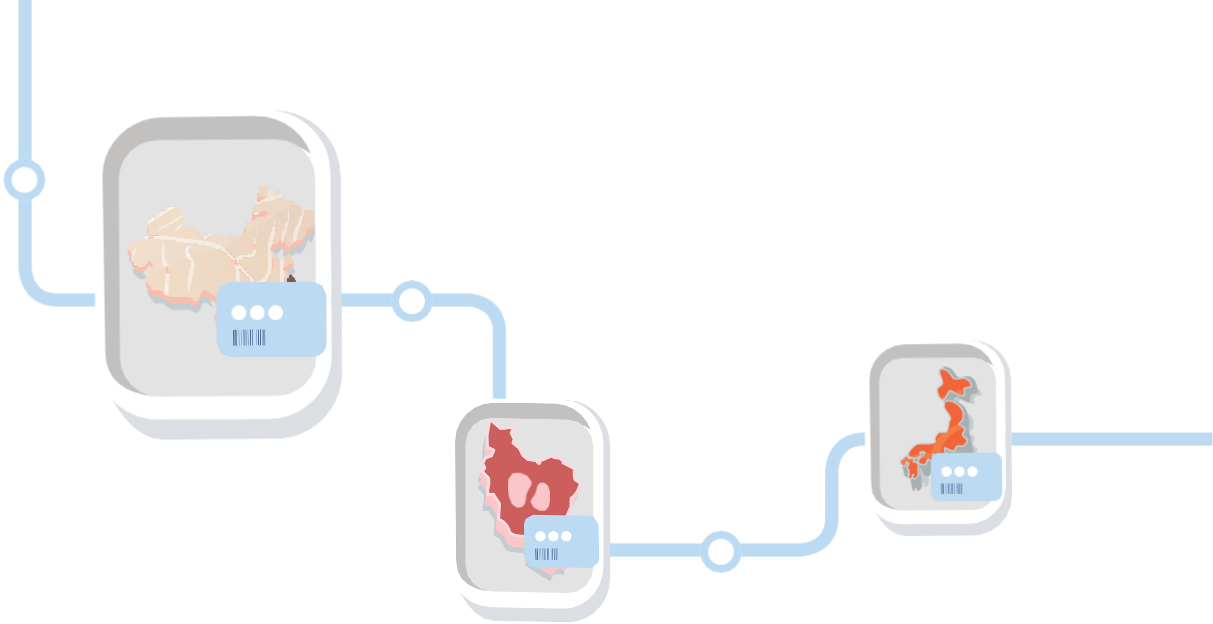
Source: ARE estimates

The split by meat type shows that pork, mainly from China, will drive overall antimicrobial usage growth until 2050. Pork production accounted for 64% of antimicrobial usage in 2017 and will decrease to 61% of total Asian consumption in 2050 (refer to Figure 21).

Figure 21: Contribution to antimicrobial consumption in meat and seafood production in Asia by meat type



Source: ARE estimates



4

THE ROAD TO SUSTAINABLE PROTEIN

There are multiple solutions required to mitigate the environmental and social impacts of livestock production. We have grouped these into: supply side responses, where producers improve their processes; demand side responses, where consumers and large customers change their buying patterns; and external actors, such as regulators or investors, that may work across the value chain. Together, these groups can bring about the changes required to transition to a sustainable food system.

Producers – supply side

- Producers can improve farm technology, introduce sustainable farming practices, and rationalise the production industry

Consumers/ customers – demand side

- Multinational food corporations are already changing their sustainability requirements through world-wide commitments
- Consumers are already changing their behaviour, particularly in developed markets, and this will need to continue

External actors

- Regulators use carrots and sticks to shift the balance in the food system
- Investors and banks are increasingly considering the implications of environmental and social impacts in their activities. This can create signals that spur change at protein production companies

While the steps that all these actors are taking are clearly positive, serious challenges remain. Not least of these is the question of how to define sustainable protein production. Many of the solutions improve one factor but then increase problems elsewhere.

Organic chicken can illustrate the challenges. The term organic only has a defined meaning in markets where there is a standard setter — for example, the USDA in the US or the Soil Association in the UK. In such markets, organic chicken supply chains should have much lower associated pollution from synthetic chemicals and the chickens should have higher welfare. However, as organic chickens are able to move around, they burn more energy and require higher feed for the meat produced. This in turn implies higher crop inputs and associated GHG emissions, and land and water intensity.

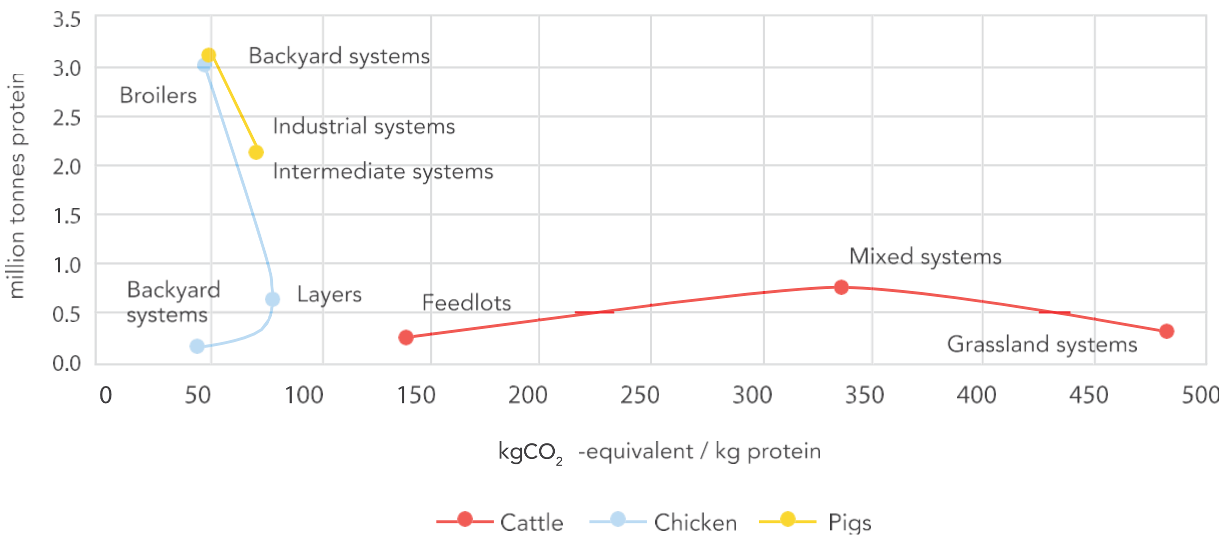
These trade-offs are both complex to identify and understand. In many cases there are clashes between different value systems. One of the most significant clashes is between large scale industry and smallholder farming. Industry is associated with claims that increasingly industrialised agriculture is the only way to increase yields and address the challenge of increasing production. But smallholders may claim that the large agricultural systems prioritise the interests of supermarket chains for urban buyers, while creating large monocultures with little resilience to changing conditions. On this view, smallholder systems offer more sustainable options and a more resilient food system.

There are many areas for innovation that present clear wins without needing to take sides.

Producers – supply side

Production systems can be a large determinant factor in GHG emissions intensity, and land and water use. Figure 22 below illustrates the range of GHG emissions intensities for different livestock in different production systems. Typically, backyard systems emit the least, while mixed production systems are the most GHG intensive. The large difference in emission intensity, particularly for beef, implies that a 30% GHG emission reduction is possible by changing from grassland to mixed production systems. (In grassland systems, nitrogen, phosphorus, and potassium fertilisers are added on pastures, and there are also no methane capture systems.) The ability to make such changes may depend on the type and cost of land in the production areas.

Figure 22: Production to GHG emission intensity in East and Southeast Asia

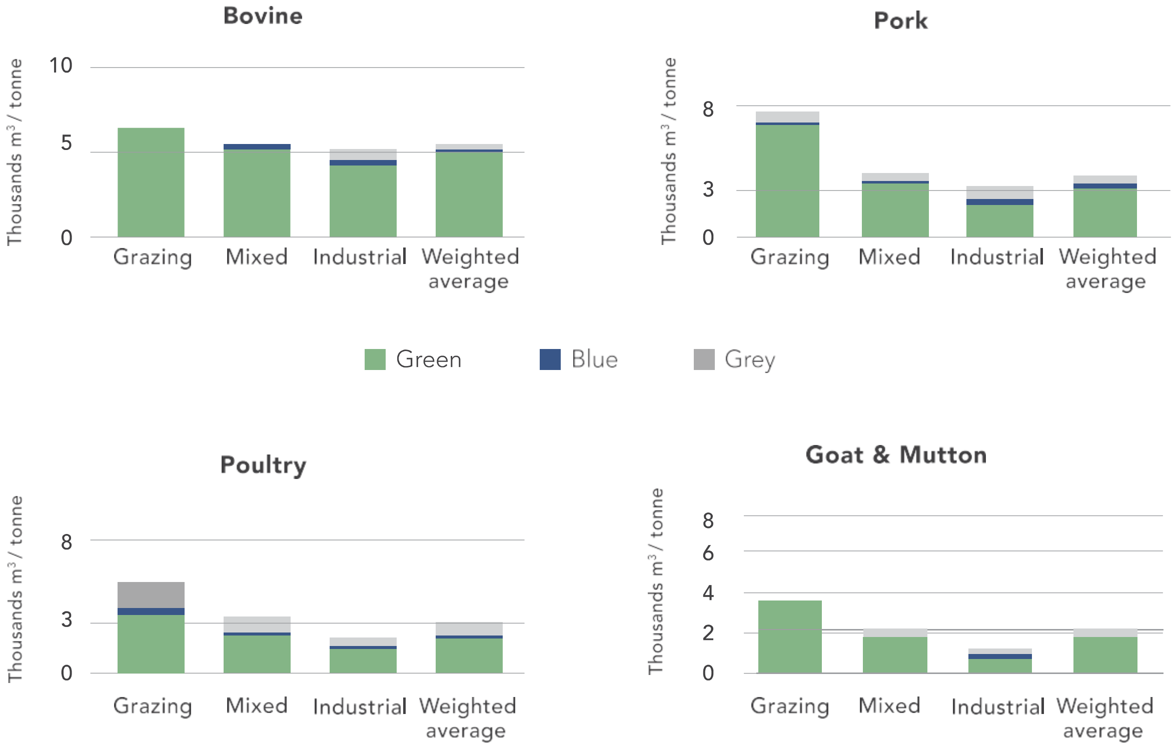


Sources: GLEAM[14], ARE estimates

[14] Food and Agriculture Organization of the United Nations, "Global Livestock Environmental Assessment Model (GLEAM)", 2018

Similarly, changing production systems from grazing to industrial could reduce the water footprint of pork and poultry by 22% and 30% respectively. The water footprint depends on feed conversion efficiencies — that is the amount of feed required to produce an equivalent amount of meat; the type or composition of feed; and the origin of feed. The change of production system from grazing to industrial improves feed efficiency. However, it is not only the change in production systems to an industrial setting but the availability of appropriate equipment to reduce resource use that results in the improvements.

Figure 23: Water footprint of main meat types decreases as production shifts to industrial systems



Note: The green water footprint refers to the consumption of rainwater that would otherwise become runoff. Blue water footprint refers to the consumption of surface and groundwater along the supply chain of the product and the pollution of surface groundwater. The grey water footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards.

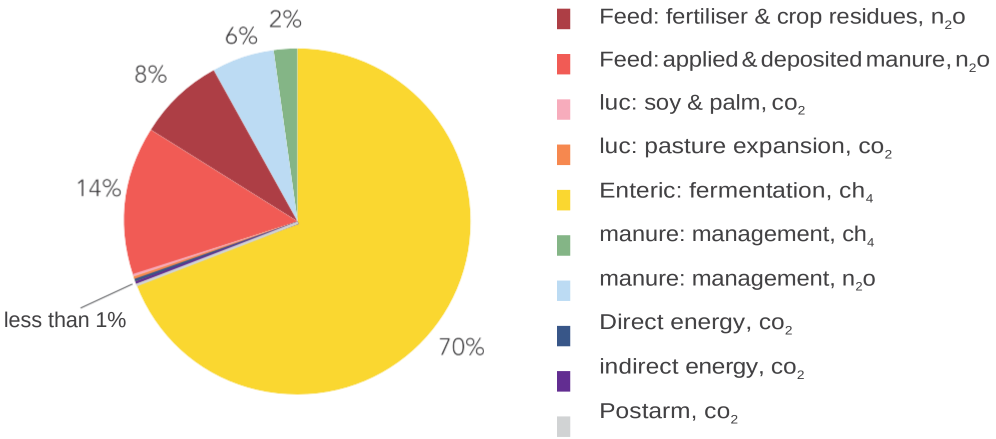
Source: Water Footprint Network[15] *, ARE estimates*

Bio-digesters, supplements can reduce GHG emissions

Improvements in technology and additives can further reduce GHG emissions. Examples include bio-digesters in sewerage treatment or supplements, such as types of seaweed, added to feed for ruminants that reduce enteric methane emissions. The installation of energy saving devices across production processes would also reduce GHG emissions. Such tools, plus improvements in animal genetics, have resulted in up to 50 times less carbon footprint in the developed world without compromising animal welfare.

[15] Water Footprint Network, “National water footprint explorer”, 2018

Figure 24: Source of GHG emission of cattle in East Asia and Southeast Asia

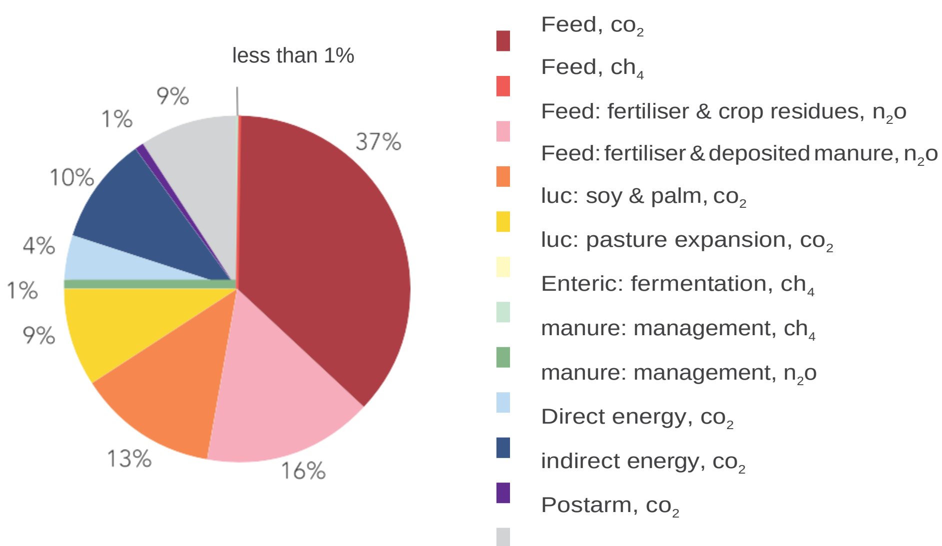


Source: GLEAM, ARE estimates

Feed, a large component of environmental footprints, has many opportunities for reduction

Another example is in feed, which accounts for almost a third of GHG emissions for poultry. Improvements in crop yields and fuel efficiency in the production and transport of feed resources provide a significant opportunity to reduce emissions.

Figure 25: Source of GHG emission of poultry in South Asia



Source: GLEAM, ARE estimates

Aside from emissions reduction, yield increases in grains and improved feed conversion ratios through better farming practices can reduce land use. Spared land can potentially be used for environmental benefits and for conservation.

Examples of methods to reduce meat environmental (water, CO_2e, antimicrobial) footprint

- Increase crop yields
- Reduce packaging material
- Installation of grey water recycling equipment
- Less fuel use to produce required feed sources
- Improvements in packing plant water efficiency
- Improving animal digestion/ uptake of nutrients to maximise feed-to-grain ratio [16]
- Use of biogas capture
- Optimisations to reduce packaging and reduce pre-chain water use
- Installation of covered lagoons
- Biogas conversion by packing plants
- Use of wet-distillers grain

Source: BASF Beef sustainability report website, ARE

Consumers/ customers – demand side

Global commitments to no-antibiotics meat increasing

In April 2017, KFC announced that the company will not serve chicken with antibiotics by end 2018. McDonald's followed soon after, announcing in August 2017 that it will phase out antibiotics from chickens globally within 10 years and is working to limit the use of antibiotics in beef and pork. Other fast food companies have made similar commitments as the implications of the over use of antibiotics on society has become more apparent.

Treatment of animals is moving up the agenda

In another trend, consumers are increasingly preferring higher-welfare labelled products, and welfare is becoming a greater concern for major buyers and suppliers. For instance, McDonald's has timebound commitments to shift to cage free egg and gestation crate free pork supplies. The objective for pork in the US is crate free by 2022 and McDonalds has stated that it will not source from suppliers without a commitment to phase out gestation crates.

Plant-based diets on the rise

The growing awareness of the environmental impact of meat consumption, recognition of animal rights and the perception of plant-based meals as healthier is leading to dietary change. This is reflected in populations eating a greater number of vegetarian meals as well as increased adoption of vegetarian and vegan diets.

Leading to investments in meat replacement companies

In Asia, vegetarian diets have historically been closely related to Hinduism and Buddhism — soy-based mock meats are commonly eaten by vegetarians in some Asian countries. However, a new secular trend appears to be emerging. A 2017 Mintel study revealed a 140% rise in vegetarian claims on new food and drink product launches in Southeast Asia between 2012 and 2016 and a 440% rise in vegan claims over the same period. [17] We infer from the increased provision of information about vegan and vegetarian products that food companies are responding to increasing demand.

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[16] The feed to gain ratio (F:G) is a key measure of efficiency. Also known as the feed conversion ratio (FCR), F:G is a measure of an animal's efficiency in converting feed nutrients into increased body mass. F:G is an important variable in the cost to finish an animal. (http://www.beefresearch.ca/research-topic.cfm/optimizing-feedlot-feed-efficiency-8)

[17] Food Industry Asia, "A Look at Food and Drink Trends in Southeast Asia", 2017

External actors - Investors & Banks

In line with these trends, the growing interest in alternative meat or protein products has led to prominent Asia-based investors such as Temasek, the sovereign wealth fund of Singapore, Li Ka-Shing, Hong Kong's richest man, and UBS Wealth Management in Asia to invest in Impossible Foods, a Californian alternative protein company [18]. Even Tyson Foods, the largest meat processor in the USA raised its stake above 5% in Beyond Meat [19], a plant-based alternative protein company, and in 2018 invested in Memphis Meat, a cell-cultured meat producer in response to the rapidly growing global trend [20].

Dietary shifts towards plant-based proteins and away from red meats in particular may become deep rooted enough to change the top line meat and fish consumption numbers, reducing the consequent impacts. This also presents significant new opportunities and risks for companies at multiple points of food supply in Asia.

External actors – Regulators

Governments in the region are coming under increasing pressure to act on social and environmental issues and are increasingly aware of the related impacts of meeting demand for protein. Governments can adopt a multi-faceted approach to this challenge. The promotion of healthier diets will reduce the corresponding environmental footprint and possibly health-care expenditure. This is probably the most effective action in high per capita consumption countries such as South Korea, Japan and urban China.

Regulators can also increase penalties for environmental pollution, an approach that China has adopted, with stronger monitoring and enforcement. There is also a push to encourage governments to incentivise investment in solutions.

Land use is one area that needs regulatory support. Only local regulators and planners are in a position to decide, incentivise, and approve limits to land expansion for food security in balance with environmental considerations. One approach would be to ensure that approvals for the conversion of arable land should only be allowed following environmental impact studies. Another would be to require undertakings by companies to use efficient production technologies. Monitoring and enforcement are also typically necessary to ensure land is used in line with long term plans.

Dietary guidelines

Regulations and policies in China aims at reducing water footprint, antimicrobial usage and meat intake

Many countries publish national dietary or nutritional guidelines as a basis for public food and nutrition, health and agricultural policies and nutrition education programmes. These guidelines provide advice on foods, food groups and dietary patterns to the general public to promote overall health and prevent chronic diseases [21]. These could be used to change protein habits.

In China's case, a 2016 revision of the guidelines included a downward revision of the lower end of its meat consumption range [22]. In Singapore, the nutritional guidance states that vegetarian diets bring health benefits, where they are well-balanced [23]. Governments can address over-consumption of meat in this fashion, by forming

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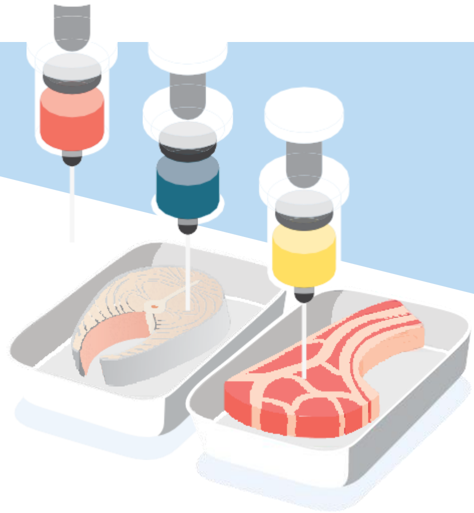
[18] P. Ambler, "A Veggie Burger Could Be The Solution To Asia's Food Security Dilemma", Forbes, 2017

[19] Reuters, "Tyson Foods raises stake in plant-based protein maker Beyond", 2017 Meat

[20] C. Purdy, "The world's biggest meat companies are betting on cell-cultured meat", Quartz, 2018

[21] Food and Agriculture Organization of the United Nations, "Food-based dietary guidelines", 2018



an understanding of the science linking meat to undesirable outcomes and then communicating this to the public at large.

Antimicrobial

Antimicrobial action plan should reduce usage inproduction of meat

We are relatively more optimistic on the use of antimicrobial medicines in livestock production and believe that actual consumption could be below our projections. This is because regulators in both India and China have put national action plans in place to address antimicrobial use. In China's case, the country announced its national action plan to contain microbial resistance in August 2016 [24]. The plan sets out multiple steps for managing the use of anti-bacterial agents, including the gradual withdrawal of antibacterial agents used on animals that easily produce cross-resistance. However, there is rapid growth, industrialisation and concentration of livestock production in the Rest of Asia where standards are currently lower. There will need to be a focus on antimicrobial management in these countries.

Figure 26: Regulation of antimicrobial use in livestock for growth promotion

Country	Ban for growth promotion	Prescription required
Europe	Yes – 2006	Yes
United States	No	No
Australia	Partial ban – 2013	In most cases
Japan	No	Yes
New Zealand	Yes	Yes
South Korea	Yes – 2011	Yes
India	No	No

Source: OECD [25]

[22] L. Luo, "The new Chinese dietary guidelines – what do they really say on meat consumption and sustainability?", Food Climate Research Network (FCRN), 2016

[23] Singapore Health Promotion Board (HPB), "A Vegetarian's Guide to Eating Right", 2015

[24] Y. Xiao, "A National Action Plan to Contain Antimicrobial Resistance in China: Contents, Actions and Expectations", 2017

[25] Organisation for Economic Co-operation and Development, "Antimicrobial Resistance: the use of antimicrobials in the livestock sector", 2017

External actors – Investors & Banks

Investors and banks can make more informed investment decisions with regards to protein demand growth in Asia. In public equity markets, investors can establish a dialogue with large listed companies, addressing strategic options as well as improving environmental disclosures. Engaged investors can help companies determine what actions may be taken to address and improve on clear shortcomings in meat and fish supply, including mitigation measures and the longer-term path towards transitioning into lower-impact product lines.

In the private equity and bank financing space, there is significant potential for business models that will help transition Asia's food system. These include upgrading production facilities, such as with manure processing technology as well as developing healthy restaurant concepts, with a lower level of meat. Alternatively, there are potential businesses based on stronger traceability standards and creating a stronger link between consumers and their food sources. In the venture capital space there is growing attention paid to longer term solutions, such as competing approaches to create lab-grown meat with a low environmental impact.

Industry

The meat and seafood producers are already starting to respond to the increased demands from the different parties, whether customers, consumers, regulators or banks and investors. The question is whether these tentative steps will accelerate to deliver a more sustainable food system.

The food industry can take concrete and direct steps to improve the food sustainability landscape. Some actions, such as improved transparency and traceability, will require multiple actors across the value chain.

- Feed producers are critical. They can focus on gradually replacing high-impact sources by assessing the environmental imprint of their sources. They can also look at how ingredients improve conversion efficiency in livestock operations.
- The producers can focus on improving and aligning their operations to be more environmentally efficient, to transition away from antimicrobials and provide higher welfare to the animals and workers.
- Manufacturers have the opportunity to invest in alternative meats, improved standards and labelling systems.
- Industry has a role to help educate consumers on sustainable choice.
- Retailers and restaurateurs can play a significant role by increasing their offerings of plant-based meals and offering product lines that avoids more unsustainable options.

Larger companies can introduce management systems, policies, standards, and greater transparency as part of their approach to these issues. If left unmanaged, the meat industry may face increasing and erratic regulation or consumers switching to substitute products.

5

CONCLUSION

This report has presented a BAU scenario for the food system in Asia, focussing on the highest impact protein sectors of meat and seafood. It highlights how undesirable and potentially impossible the environmental and social consequences of supplying the growth in Asian demand will be. In doing so, it provides a baseline against which to consider solutions that must be found to progress to a sustainable food system and to meet global environmental challenges, particularly climate change.

There are three obvious next steps for this work. First, to socialise it with decision makers among the key stakeholders identified in Chapter 4 — producers, consumers, regulators, investors, and banks and entrepreneurs that seek solutions through innovation.

Next, the BAU model itself needs refining. One of the critical assumptions is the split between seafood and meat consumption. We have used BAU assumptions based on protein, rather than the underlying food types. This results in a very high absolute growth in seafood consumption in the markets that comprise Rest of Asia. However, potential challenges in growing the quantity of seafood[26] and increasing prices for seafood at the same time as growth in concentrated livestock feeding operations may result in an increasing overall share for meats. This would likely increase the environmental impacts.

Finally, and critically, the BAU model can serve as a basis for prioritising efforts to find solutions, both technological and behavioural, towards a more sustainable food system.

We look forward to working with multiple parties to address the issues raised in this report and welcome comments in relation to it.

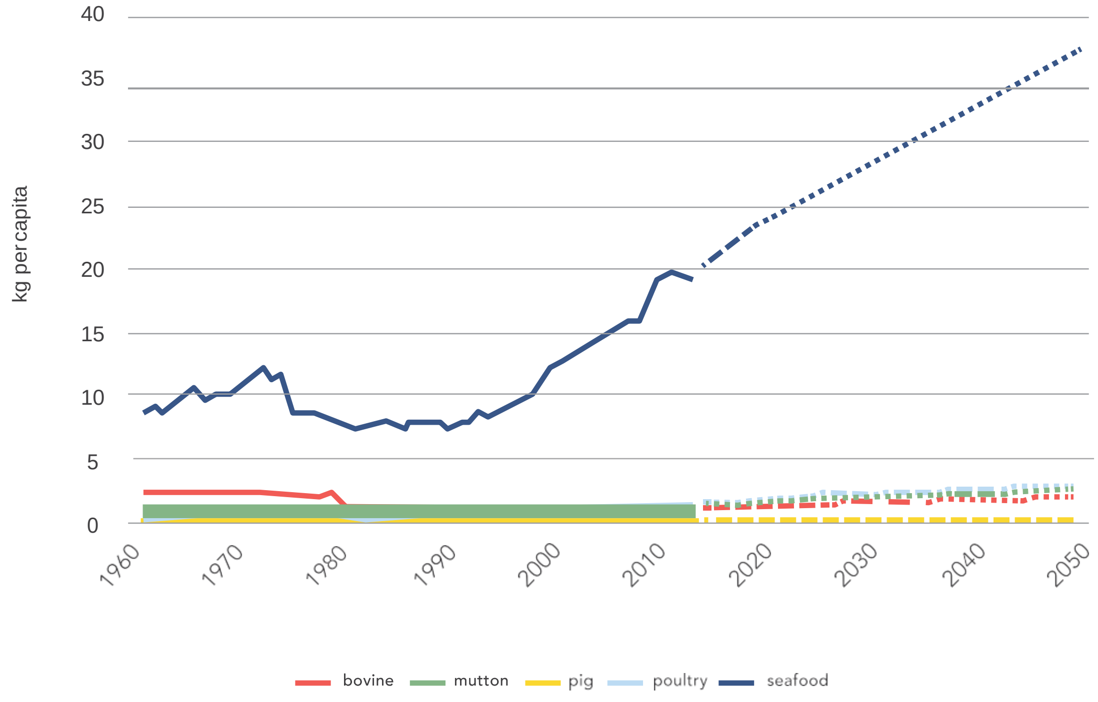
[26] McCarron, B, "Empty Nets: How overfishing risks leaving investors stranded, Fish Tracker Initiative", 2017

APPENDIX 1 COUNTRY TABLES

BANGLADESH

Consumption in 2050	Bovine	Mutton	Pork	Poultry	Fish
Total food consumption (million tonnes)	0.4	0.6	-	0.6	7.6
Per capita food consumption (kilograms per capita)	2.0	2.8	-	3.0	37.5

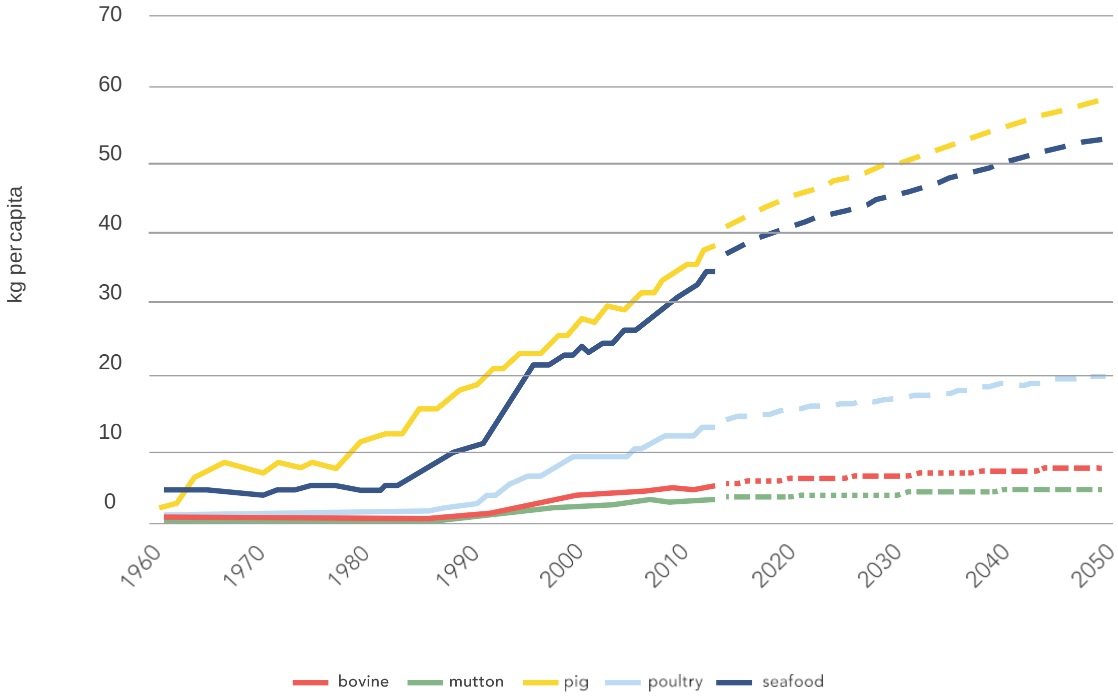
	2017	2030	2050	CAGR 2017-30	CAGR 2030-50
Total meat & fish consumption (million tonnes)	4.4	6.5	9.2	3.0%	1.7%
Per capita meat & fish consumption (kilograms per capita)	27.0	35.1	45.5	2.0%	1.3%
Total GHG emissions (billion CO_2-equivalent kilograms)	58	83	118	2.8%	1.7%
Antimicrobial use (tonnes)	72	107	151	3.1%	1.7%
Water footprint (billion m^3)	7	10	14	3.0%	1.7%
Land use intensity (billion m^2)	63	89	126	2.7%	1.7%



CHINA

Consumption in 2050	Bovine	Mutton	Pork	Poultry	Fish
Total food consumption (million tonnes)	10.4	6.4	78.3	27.1	71.2
Per capita food consumption (kilograms per capita)	7.8	4.8	58.5	20.3	53.2

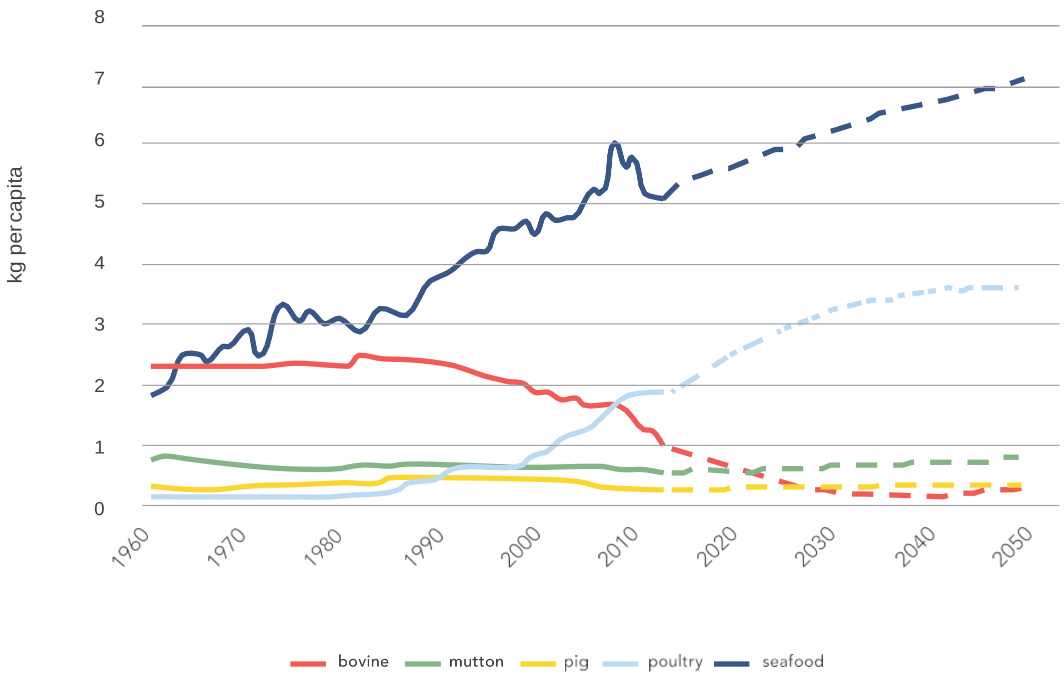
	2017	2030	2050	CAGR 2017-30	CAGR 2030-50
Total meat & fish consumption (million tonnes)	149.5	175.4	195.9	1.2%	0.6%
Per capita meat & fish consumption (kilograms per capita)	108.1	124.6	146.4	1.1%	0.8%
Total GHG emissions (billion CO_2-equivalent kilograms)	1,603	1,898	2,131	1.3%	0.6%
Antimicrobial use (tonnes)	24,821	29,396	32,994	1.3%	0.6%
Water footprint (billion m^3)	378	448	503	1.3%	0.6%
Land use intensity (billion m^2)	2,484	2,942	3,303	1.3%	0.6%



INDIA

Consumption in 2050	Bovine	Mutton	Pork	Poultry	Fish
Total food consumption (million tonnes)	0.5	1.3	0.6	6.0	11.7
Per capita food consumption (kilograms per capita)	0.3	0.8	0.4	3.6	7.0

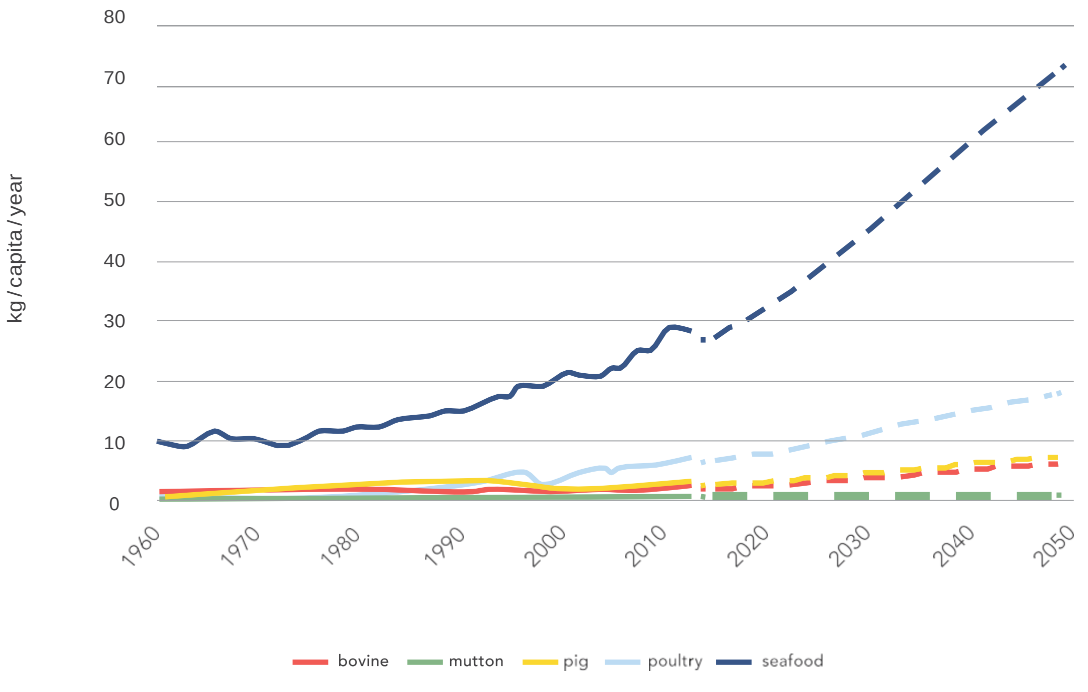
	2017	2030	2050	CAGR 2017-30	CAGR 2030-50
Total meat & fish consumption (million tonnes)	12.7	16.4	20.4	1.9%	1.1%
Per capita meat & fish consumption (kilograms per capita)	9.5	10.8	12.3	1.0%	0.7%
Total GHG emissions (billion CO_2-equivalent kilograms)	205	194	248	-0.4%	1.2%
Antimicrobial use (tonnes)	0.3	0.4	0.5	2.7%	1.1%
Water footprint (billion m^3)	38	50	62	2.1%	1.1%
Land use intensity (billion m^2)	232	214	274	-0.6%	1.2%



INDONESIA

Consumption in 2050	Bovine	Mutton	Pork	Poultry	Fish
Total food consumption (million tonnes)	2.0	0.4	2.5	5.9	23.4
Per capita food consumption (kilograms per capita)	6.4	1.2	7.6	18.3	72.8

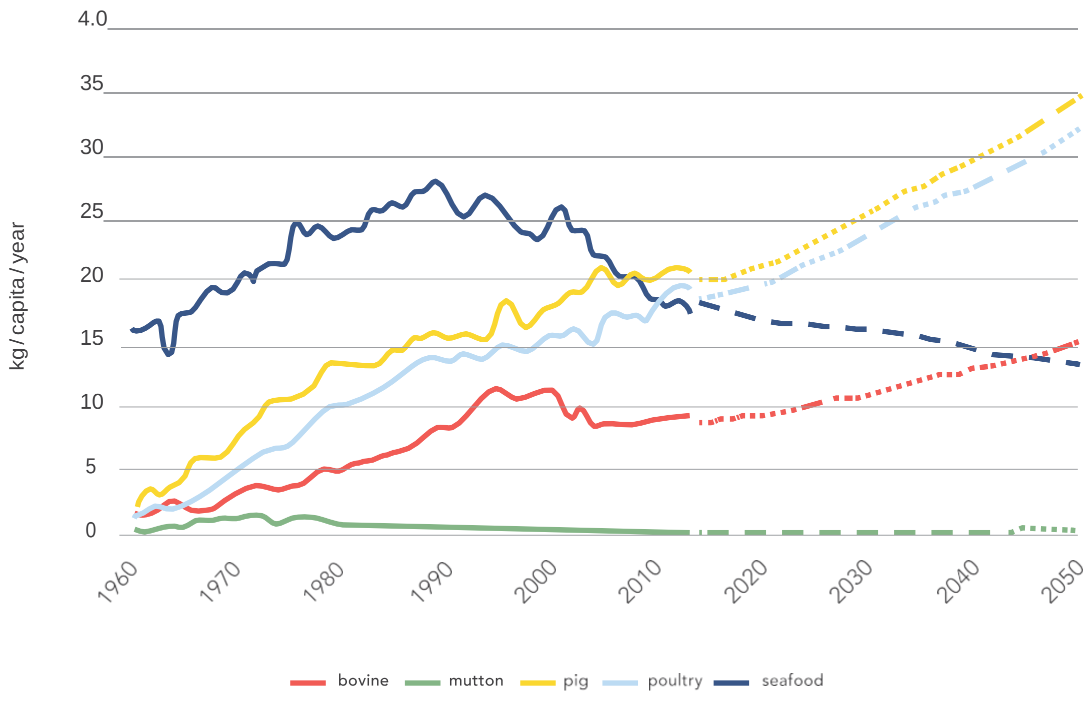
	2017	2030	2050	CAGR 2017-30	CAGR 2030-50
Total meat & fish consumption (million tonnes)	11.1	19.3	34.2	4.4%	2.9%
Per capita meat & fish consumption (kilograms per capita)	42.1	65.4	106.3	3.4%	2.5%
Total GHG emissions (billion CO_2-equivalent kilograms)	137	238	420	4.4%	2.9%
Antimicrobial use (tonnes)	233	404	715	4.3%	2.9%
Water footprint (billion m^3)	20	35	61	4.3%	2.9%
Land use intensity (billion m^2)	153	267	473	4.4%	2.9%



JAPAN

Consumption in 2050	Bovine	Mutton	Pork	Poultry	Fish
Total food consumption (million tonnes)	1.6	0.0	3.7	3.5	4.1
Per capita food consumption (kilograms per capita)	15.2	0.2	34.5	32.1	37.7

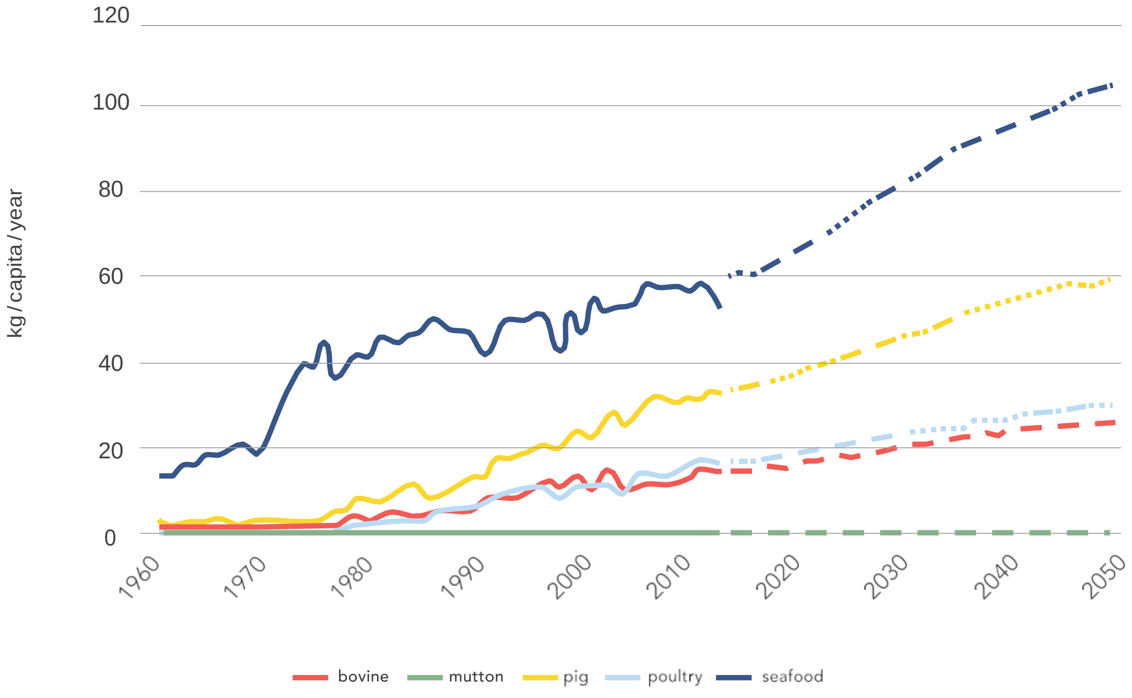
	2017	2030	2050	CAGR 2017-30	CAGR 2030-50
Total meat & fish consumption (million tonnes)	12.4	12.8	13.0	0.2%	0.1%
Per capita meat & fish consumption (kilograms per capita)	98.1	106.2	120.0	0.6%	0.6%
Total GHG emissions (billion CO_2-equivalent kilograms)	187	195	203	0.3%	0.2%
Antimicrobial use (tonnes)	415	483	580	1.2%	0.9%
Water footprint (billion m³)	17	20	23	1.1%	0.8%
Land use intensity (billion m²)	171	196	230	1.0%	0.8%



SOUTH KOREA

Consumption in 2050	Bovine	Mutton	Pork	Poultry	Fish
Total food consumption (million tonnes)	1.3	0.0	3.0	1.5	5.3
Per capita food consumption (kilograms per capita)	25.9	0.3	59.9	29.9	105.8

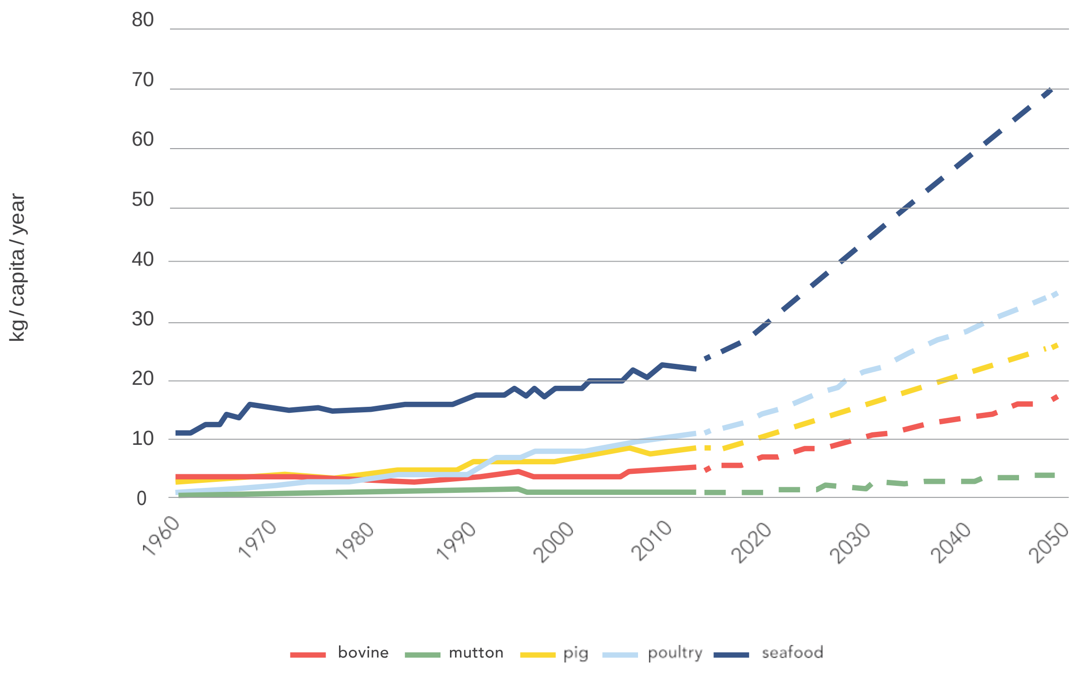
	2017	2030	2050	CAGR 2017-30	CAGR 2030-50
Total meat & fish consumption (million tonnes)	6.7	9.2	11.2	2.4%	1.0%
Per capita meat & fish consumption (kilograms per capita)	131.1	172.4	222.1	2.1%	1.3%
Total GHG emissions (billion CO_2-equivalent kilograms)	97	132	161	2.4%	1.0%
Antimicrobial use (tonnes)	551	748	915	2.4%	1.0%
Water footprint (billion m^3)	15	20	24	2.4%	1.0%
Land use intensity (billion m^2)	114	155	190	2.4%	1.0%



REST OF ASIA

Consumption in 2050	Bovine	Mutton	Pork	Poultry	Fish
Total food consumption (million tonnes)	15.1	3.5	23.0	30.6	61.7
Per capita food consumption (kilograms per capita)	17.6	4.1	26.8	35.6	71.7

	2017	2030	2050	CAGR 2017-30	CAGR 2030-50
Total meat & fish consumption (million tonnes)	37.5	71.7	134.3	5.1%	3.2%
Per capita meat & fish consumption (kilograms per capita)	57.2	95.1	156.2	4.0%	2.5%
Total GHG emissions (billion CO_2-equivalent kilograms)	591	1,129	2,114	5.1%	3.2%
Antimicrobial use (tonnes)	1,034	1,979	3,707	5.1%	3.2%
Water footprint (billion m^3)	102	196	366	5.1%	3.2%
Land use intensity (billion m^2)	703	1,342	2,513	5.1%	3.2%



APPENDIX 2 METHODOLOGY

We estimated meat and seafood consumption through 2050 by projecting animal protein use, converting data on meat and seafood protein into equivalent meat and seafood consumption and then determining consumption for each meat type according to observed trends in relative preferences. In this exercise we estimated individual data for six main countries of interest (Bangladesh, China, India, Indonesia, Japan and South Korea) and for an aggregate of another 13 countries to represent the Rest of Asia (Cambodia, Laos, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam).

We first obtained historical data from 1961 on per-capita animal protein and food supply from the UN Food and Agriculture Organization (FAO). Food supply is the quantity available for human consumption, estimated as production minus net exports, stock changes and other adjustments.

We then estimated animal protein consumption for the main six countries through simple regression on per capita GDP and — when possible — other proxy variables such as the share of the bottom wealth quintile in the population and the share of senior population. Data on the dependent variables were derived from United Nations (UN) raw data and estimates and from the Organisation for Economic Co-operation and Development (OECD) long term projections. We also formulated hypotheses on the trends for other proxy variables and where necessary interpolated the limited data points available to construct a full series through 2050. For the remaining 13 countries, we weighted the values by population size and performed one estimate for the whole group.

From the obtained animal protein series, we converted the values into equivalent amounts of annual per capita food supply assuming an adjustment factor based on the average previous five years historical data available.

Finally, we broke the protein estimates down into the main meat types and seafood. For each country and for the aggregate Rest of Asia, we measured the historical proportion between fish and meat protein as well as the proportions of each meat type. We then generated hypotheses on future preferences based on observed trends, or projected a recent historical average if no change in trend was clearly visible. We then used these projected proportions to obtain annual per capita consumption in kilograms and yearly country totals by multiplying per capita figures by the corresponding population.

These figures form the basis for projecting the magnitude of protein consumption's environmental and social impacts.

APPENDIX 3 ASSUMPTIONS

A3.1

Greenhouse Gas Emissions Assumptions by Commodity

The estimates for greenhouse gases are obtained using FAO's GLEAM Global greenhouse gas (GHG) emissions from livestock summary data (2017). It provides estimates for cattle, sheep, goats, buffaloes, pigs and chicken based on different production systems such as mixed, grazing, and feedlot systems for cattle and ruminants, and backyard, industrial and intermediate for pig and chicken production. The aggregate average emission is then calculated for each animal species in each of the regions (East Asia, Southeast Asia and South Asia). As detailed information on the production system for each country is not available, the aggregate data is used to estimate greenhouse gas emissions. A simple average emission intensity is taken for the "other" type of proteins category as there are no detailed breakdowns of the types of protein in the "other" category. These includes meat such as quail, duck, goose, rabbit, buffaloes etc. Details of the assumptions used in the estimates of GHG emissions can be found in Table 1 below.

The emission intensity includes GHG emissions arising from feed, fertiliser applied to feed crops, decomposition of crop residues, land use change due to expansion of cropland for feed production (soybean and corn), pasture expansion, enteric fermentation, manure management, direct energy use on farm, indirect energy used during the production of materials for farm buildings and equipment, and post farm processing and transport of livestock. Therefore, the estimated emission number is a global GHG emission resulting from the consumption of the animal protein.

These figures form the basis for projecting the magnitude of protein consumption's environmental and social impacts.

The GHG intensity from fish are not available from the same study. We use the average of a recent study on Asian Aquaculture in the estimates as presented in Figure 28. We inferred GHG intensity for wild capture fish by assessing studies with total seafood production emissions and reducing the aquaculture production component. Figure 29 serves as a comparison to the Asian GHG emission studies that we use for the modelling estimates.

Figure 27: Aggregate greenhouse gas (GHG) emission intensity by animal species and region (2017)

Region	Animal species	Emission intensity kg CO_2-eq·kg protein	Production thousand tonnes protein
East Asia and Southeast Asia	Cattle	331.90	1,252
East Asia and Southeast Asia	Buffaloes	554.81	114
East Asia and Southeast Asia	Sheep	214.04	126
East Asia and Southeast Asia	Goats	161.62	277
East Asia and Southeast Asia	Pigs	62.79	7,292
East Asia and Southeast Asia	Chicken	52.78	3,712
South Asia	Cattle	529.10	687
South Asia	Buffaloes	378.56	421
South Asia	Sheep	302.84	106
South Asia	Goats	231.42	190
South Asia	Pigs	75.91	123
South Asia	Chicken	37.47	1,303
Average Asia	Cattle	401.76	1,939
Average Asia	Buffaloes	416.08	535
Average Asia	Sheep	254.56	232
Average Asia	Goats	190.03	467
Average Asia	Pigs	63.01	7,415
Average Asia	Chicken	48.80	5,015

Note: Average Asia is calculated by taking the weighted average of emission intensity of East Asia and Southeast Asia and South Asia.

Source: FAO Global Livestock Environmental Assessment Model 2.0 (GLEAM)

Figure 28: GHG emission intensity of Asian Aquaculture

Asian Aquaculture Emission intensity	kg co_2-equivalent / kg of live-weight
Bangladesh Nile Tilapia	1.58
India Major Cars	1.84
Vietnam Striped Catfish	1.36
Average	1.59

Source: FAO, Robb et al, Greenhouse gas emissions from aquaculture a life cycle assessment of three Asian systems, 2017

Figure 29: Comparison of different studies of fish globally (kg CO_2-eq/kg)

	Study Calculations	Winther et al 2009 (NO)	Ziegler 2002 (SE)	Ayer & Tyedmers 2008 (CA)	Pelletier et al 2009 (NO)	Average
Cod at harbour	1.78	1.6	2.45	-	-	1.94
Mackerel at harbour	0.32	0.4	-	-	-	0.36
Herring at harbour	0.47	0.4	-	-	-	0.44
Cod at supermarket	5.25	-	5.83	-	-	5.54
Salmon at fish farm	2.05	2	-	2.07	1.79	1.98
Average	1.974	1.1	4.14	2.07	1.79	0.91

Source: Bushspies et al, Life Cycle Assessment of High-Sea Fish and Salmon Aquaculture

A3.2

Water Intensity Assumptions

The estimates for water intensity of farmed animal products are obtained from The Water Footprint Network, which is based on research by Mekonnen and Hoekstra et.al. The green, blue, and grey water footprints are determined for different production systems such as grazing, mixed, and industrial in each of the countries in Asia. The weighted average water footprint is based on the proportion of each production system used in each country in the study.

Country-based water footprint[27] estimates for fish are not available. The estimates for the water footprint of fish are based on the same research by Mekonnen and Hoekstra et.al. Aquaculture production is approximately twice as water intense as wild capture fishery. Different fish species have different water footprints due to different feed requirements. For example, water footprints of carnivores generally tend to be lower than those of omnivores, planktivores and herbivores due to a larger share of fish meal and fresh fish meat their diet.

The water footprint of fish does not include water evaporated from the system in pond aquaculture, nor the pollution of freshwater resources due to effluents from aquaculture systems, which would add an average 5200m^3/ton.

[27] The green water footprint refers to the consumption of rainwater that would otherwise become runoff. Blue water footprint refers to the consumption of surface and groundwater along the supply chain of the product and the pollution of surface groundwater. The grey water footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards.

Figure 30: Water footprint of animal products (m^3/ton and m^3/kg), 1996-2005

Country	Protein	Green (m^3/ton)	Blue (m^3/ton)	Grey (m^3/ton)	Total (m^3/kg)
Bangladesh	Bovine	6117	186	2	6
Bangladesh	Fish	1629	179	166	1.1
Bangladesh	Mutton & Goat	2826	290	2	3
Bangladesh	Other	212	12	12	0
Bangladesh	Pig	0	0	0	-
Bangladesh	Poultry	4237	238	240	5
China	Bovine	4981	184	155	5.3
China	Fish	1629	179	166	1.4
China	Mutton & Goat	1960	167	3	2.1
China	Other	19212	329	583	20
China	Pig	3234	241	415	3.9
China	Poultry	2212	209	666	3.1
India	Bovine	6644	299	123	7.1
India	Fish	1629	179	166	1
India	Mutton & Goat	3158	250	81	3.5
India	Other	27419	862	383	29
India	Pig	3206	688	328	4.2
India	Poultry	5246	671	599	6.5
Indonesia	Bovine	7616	205	202	8.0
Indonesia	Fish	1629	179	166	0.8
Indonesia	Mutton & Goat	3519	221	1	3.7
Indonesia	Other	21606	366	197	22
Indonesia	Pig	3406	357	226	4.0
Indonesia	Poultry	3926	269	399	4.6

Country	Protein	Green (m³/ton)	Blue (m³/ton)	Grey (m³/ton)	Total (m³/kg)
Japan	Bovine	4644	179	524	5.3
Japan	Fish	1629	179	166	0.3
Japan	Mutton & Goat	1646	137	56	1.8
Japan	Other	13745	649	773	15
Japan	Pig	2698	298	358	3.4
Japan	Poultry	1660	114	215	2.0
Korea	Bovine	8588	145	186	8.9
Korea	Fish	1629	179	166	0.4
Korea	Mutton & Goat	2191	240	95	2.5
Korea	Other	17116	440	758	18
Korea	Pig	3108	346	416	3.9
Korea	Poultry	2834	206	459	3.5
ROA	Bovine	9822	166	71	10
ROA	Fish	1629	179	166	0.8
ROA	Mutton & Goat	2916	162	16	3
ROA	Other	17010	482	237	18
ROA	Pig	2931	239	142	3
ROA	Poultry	4498	306	349	5

Source: Mekonnen, M.M. and Hoekstra, A.Y.[28]; and Pahlow et al [29]

[28] Mekonnen, M.M. and Hoekstra, A.Y., "A global assessment of the water footprint of farm animal products, Ecosystems", 2012

[29] Pahlow et al, "Increasing pressure on freshwater resources due to terrestrial feed ingredients for aquaculture production", 2015

A3.3

Antimicrobial Assumptions

There is no quantitative measurement of antimicrobial consumption by livestock globally. Research published by the US National Academy of Sciences[30] is frequently cited and is used in this study.

The research estimates that the global average annual consumption of antimicrobials per kilogram of animal produced is 45mg/kg for cattle, 148mg/kg for chicken and 172 mg/kg for pigs. These estimates were obtained through a Bayesian statistical model that combines livestock density, economic projections of demand and current estimates of antimicrobial consumption in higher income countries. The research used estimates of overall antimicrobial consumption that are published by OECD countries to estimate the consumption for each type of livestock in intensive production systems. Subsequently, the level was adjusted according to the distribution of production systems.

While total estimates of antimicrobial consumption per kilogram of animal are published in addition to country specific breakdowns of antimicrobial use by animal type, the country specific figures for consumption per kilogram of animal are not published. We estimated the latter figure by using the estimate antimicrobial usage per kilogram of animal and its respective proportion of livestock production in each country. Implicit in this methodology is that all animal protein consumed is produced in the same country.

Figure 31: Adjusted antimicrobial consumption (mg/PCU)

Country	Fish	Bovine	Mutton	Pig	Poultry	Other	Total
Bangladesh	13.4	17	46	64	55	46	40.0
Indonesia	9.3	19	52	74	64	52	57.0
China	17.0	94	254	359	309	254	319.0
India	11.9	16	43	61	52	43	43.0
Korea	5.1	62	167	237	204	167	188.0
Japan	3.6	25	68	97	83	68	78.0
ROA	9.5	18	48	68	59	48	52.9
Study's average	**23.4**	**45**	**122**	**172**	**148**	**122**	

Sources: Van Boeckel et al.; and ARE calculations

We have performed a coarse estimate breakdown of antimicrobial consumption by animal for each region by calibrating global animal values and country total averages by the regional proportions of food supply for each meat type. This again ignores the effects of trade but offers a reference value for the equivalent antimicrobial consumption if all meat supply were provided within the country.

[30] Van Boeckel et al., The Center For Disease Dynamics Economics & Policy, 2017

A3.4

Land Use Assumptions

Life-cycle analysis is used by researchers to determine the environmental impacts across the value chain in producing the livestock. These includes the food chain inputs such as land for feed production, seed production, fertiliser production, land manure management and farm infrastructure. Such life-cycle analyses can also be applied to fully quantify all the inputs necessary to produce meat or fish.

The production of animal feed and fertiliser will have a large land footprint as compared to the actual farm activity and may not originate in the country of animal production. As such, even though different countries utilise different dominant production systems, country-based assumptions for land use are not available.

We compared a number of different studies to determine a suitable basis for estimates for this report. We found there is a reasonably narrow range of estimates for pig and poultry production. However, land use estimates for bovine have a wide range largely due to pasture land availability. For this report, the average land use estimate per kilogram of product is used as shown in Figure 4.

Figure 32: Summary of land use assumptions by different studies

Type of Protein		Bovine			Mutton and Goat			Pig			Poultry		
Study	**Remark**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**
Clark and Tilman (2017)	Per kg of protein	-	1024.3	-	-	1024.3	-	-	129.9	-	-	75.1	-
Swain, Nijdam (2012)	Per kg of protein	15.0	158.0	420.0	-	-	-	8.0	-	15.0	5.0	-	8.0
Elferink and Nonhebel (2007)	Per kg of protein	23.7	29.0	43.6	-	-	-	8.5	10.3	16.9	6.6	7.7	13.6
deVries and deBoer (2010)	Per kg of protein	27.0		49.0	-	-	-	8.9	-	12.1	8.1		9.9
Costello, Xue, Howarth (2015)	Per kg of protein	114.1	-	165.1	-	-	-	8.3	-	22.8	2.1	-	11.9
Flachowsky, Meyer and Sudekum (2017)	Per kg of protein	7.0	286.0	420.0	20.0	-	33.0	8.0	-	15.0	5.0	-	8.0
	Average	**37.4**	**157.7**	**219.5**	**20.0**	**-**	**33.0**	**8.3**	**10.3**	**16.4**	**5.4**	**7.7**	**10.3**
	Standard Deviation	**43.6**	**128.5**	**189.3**	**-**	**-**	**-**	**0.4**	**-**	**4.0**	**2.2**	**-**	**2.5**

Source: Compiled by ARE

Figure 34: Land intensity of Asian aquaculture

Land use	m²/tonne	m²/kg
Shrimp pond culture, Vietnam	80,594	80.6
Shrimp pond culture, India	14,095	14.1
Milkfish pond culture, Philippines	2,339	2.3
Pangasius pond culture, Vietnam	24.16	0.0
Average	-	24.3

Source: Akvaplan-niva et al [31]

Figure 34: Land intensity of Asian aquaculture

Summary	Land Use Intensity (m² per kg of product)
Bovine	135.2
Mutton & Goat	26.5
Pig	12.2
Poultry	7.8
Fish*	9.8
Others	47.8

*Note: adjusted for aquaculture proportion in Asia

Source: Compiled by ARE

[31] Akvaplan-niva et al, "Resource use and greenhouse gas emissions by aquaculture systems in the case study areas"; Aquaculture Asia.

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