Environmental Impact of Key Food Items in Singapore

October 2019

Executive Summary (1/3)

Study quantifies environmental impact of key food items in Singapore

- Food contributes to **19–29% of global greenhouse gas (GHG) emissions**.
- Singapore **imports more than 90% of our food** while the rest are produced locally. This has a significant effect on the food security of Singapore, which is susceptible to climate and natural resource risks if food supply is disrupted.
- By understanding the environmental impact of the food items in Singapore, stakeholders are able to **focus their sustainability efforts both individually and collectively** to reduce environmental impact.

Life Cycle Assessment (LCA) approach used to assess the environmental impact of 13 key food items

- A Life Cycle Assessment (LCA) approach was adopted, considering **three key environmental impact indicators**: **1) Greenhouse Gas (GHG) emissions, 2) energy consumption** and **3) water consumption.**
- **13 key food items** consumed in Singapore were studied: beef, mutton, pork, chicken, duck, egg, fish, other seafood, fruits, leafy vegetables, other vegetables, rice and wheat.
- Average **food consumption** in Singapore is estimated based on: $\frac{\text{Import quantity} + \text{Locally produced quantity} - \text{Export quantity}}{\text{Population}}$
- The life cycle stages considered for each food item include the **production, process and transportation stages** of food consumed in Singapore. **Food loss** along these stages were also considered.

Environmental impact of food computed based on consumption pattern

- Environmental impact of **meats (specifically pork, mutton and beef)** is the **most severe**, although **rice** has the **highest water consumption** (per kg basis).
- 367 kg of food is consumed per capita annually. This results in **GHG emissions of 954 kg CO_2-eq per capita** for food consumed in Singapore**.**
- Although **red meats** represent **~11% of consumption per capita by weight annually, they contribute ~ 40% of GHG emissions.**
- Notably, while **pork** accounts for **~6% of food** consumed by weight, it accounts for **~28% of food GHG emissions**.

Executive Summary (2/3)

Air transport has significant environmental impact	• Less than **10% of food items** imported are transported into Singapore **by air**. These items are chilled pork, chilled mutton, chilled beef and chilled fish. However, these items contribute to **more than half of the GHG emissions in the transportation stage,** for all 13 food items considered in this study. • For frozen food items **transported by land or sea**, distance from import source **does not significantly impact GHG emissions** due to lower emission of land and sea transportation methods.
Reducing air transportation can reduce environmental impact	• **Chicken and pork:** Due to high consumption of chicken and pork in Singapore, **optimising import strategy** for these two food items will meaningfully reduce environmental impact per capita. • **Transportation:** Sourcing fresh food from **neighbouring countries or producing locally** can meaningfully reduce environmental impact as this means avoiding air transport for import. – For instance, **importing fresh and frozen pork via land or sea** from neighbouring countries results in **significantly less GHG emissions and energy consumption** as compared to importing fresh pork via air. • **Chilled and frozen meats**: Choosing chilled meat from **geographically closer countries**, or choosing frozen meat can reduce environmental impact due to **less air transport** required. • **Local production of fish and leafy vegetables:** Scaling up local production of fish and leafy vegetables can **reduce the need for transportation** and thus, reduce environmental impact.
Sourcing from cleaner energy can reduce environmental impact	• **Energy sources**: Sourcing food from countries with **cleaner and renewable sources of electricity generation** via sea/land transport can meaningfully reduce environmental impact. • For instance, despite being **farther than Malaysia**, **frozen chicken from Brazil** has **15% lower GHG emissions** as Brazil **uses electricity generated from hydropower**, while Malaysia is heavily dependent on fossil fuel-based energy.

Executive Summary (3/3)

Substituting red meats with plant-based meats can reduce environmental impact

- **Plant-based meats:** Incorporating plant-based meats into diet will reduce environmental impact of food.
  - Plant-based meats* has the **lowest GHG emissions** as compared to animal meat, with the exception of chicken
  - Substituting **25% of red meat** (pork, mutton, duck and beef) with plant-based meats could bring a **~7% reduction in GHG emissions per capita** from current business-as-usual (BAU) level.

Future scenario analysis to year 2030

- **BAU scenario:** Locally-produced food **remains at <10%** in year 2030, and population grows to 6.7 million in year 2030.
  - Per capita GHG emissions **remains at 954 kg CO_2-eq per capita** as in year 2018.
  - Absolute GHG emissions for food in Singapore **increases by ~19%** (compared to year 2018 emissions) due to population growth.
- **'30 by 30' scenario**: Producing 30% of Singapore's nutritional needs locally by year 2030.
  - Per capita GHG emissions will **reduce by ~3%** compared to BAU due to less transport required and cleaner energy used in Singapore.
  - Absolute GHG emissions still **increases by ~16%** (compared to year 2018 emissions) due to population growth.
- **Optimal health diet scenario**: Adopting optimal health diet of 50% "Fruits and vegetables", 25% "Grains" and 25% "Meats, eggs and seafood" in addition to the "30 by 30" scenario.
  - Per capita GHG emissions will **reduce by ~16%** compared to BAU due to less meat consumption.
  - Absolute GHG emissions **decreases by ~1%** (compared to year 2018 emissions) despite population growth.
- **Plant-based meats scenarios:** 25% and 50% of red meats consumed are replaced by plant-based meats**,** in addition to the "30 by 30" scenario and the optimal health diet scenario.
  - Replacing 25% and 50% of red meat with plant-based meats will **reduce per capita GHG emissions by ~21% and ~26%** respectively compared to BAU, as plant-based meats have **lower GHG emissions** than red meat.
  - Absolute GHG emissions **decreases by** ~**6% and ~12%** respectively (compared to year 2018 emissions) despite population growth.

* Plant-based meat data is referenced from Beyond Meat and follows the same system boundary as this study.

Contents

1. Motivation of Study

Motivation of study

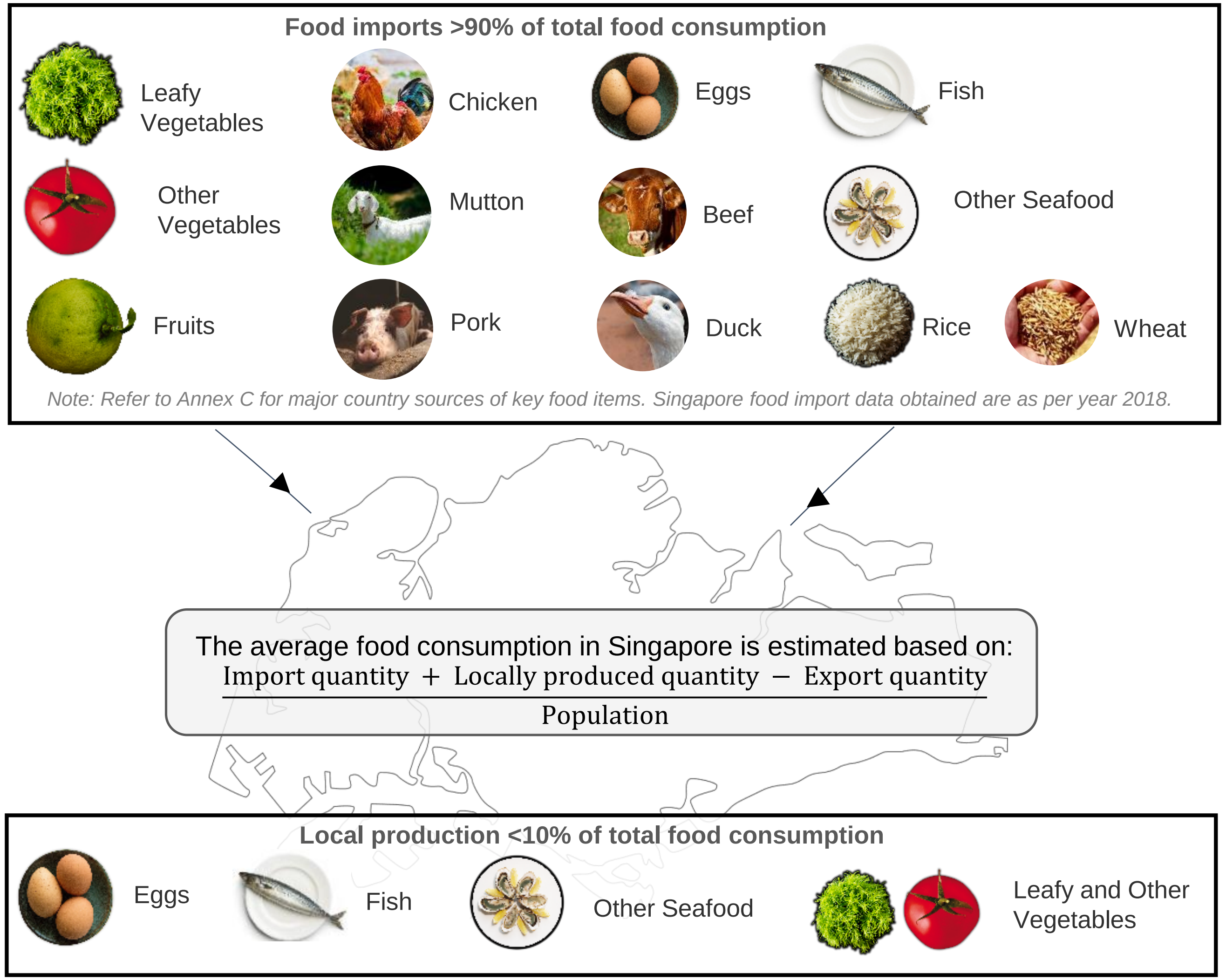
By having a better understanding on the environmental landscape of the food items in Singapore, stakeholders are able to focus their sustainability efforts both individually and collectively to reduce environmental impact.

Why is environmental impact of food important?

- Food contributes 19–29% of global greenhouse gas (GHG) emissions.[1]
- Singapore imports more than 90% of our food while the rest are produced locally.[2]
- This has significant effect on the food security of Singapore, which is susceptible to climate and natural resource risks if food supply is disrupted.

Why do this study?

- Many existing studies are USA or Europe-centric and do not consider unique export-import country pairs, and hence not representative of Singapore's actual emissions.[3,4,5]
- This study provides insights for different stakeholders; policy makers, businesses and consumers.
    - How does a basic necessity like food contribute to climate change?
    - How can our food choices reduce environmental impact?



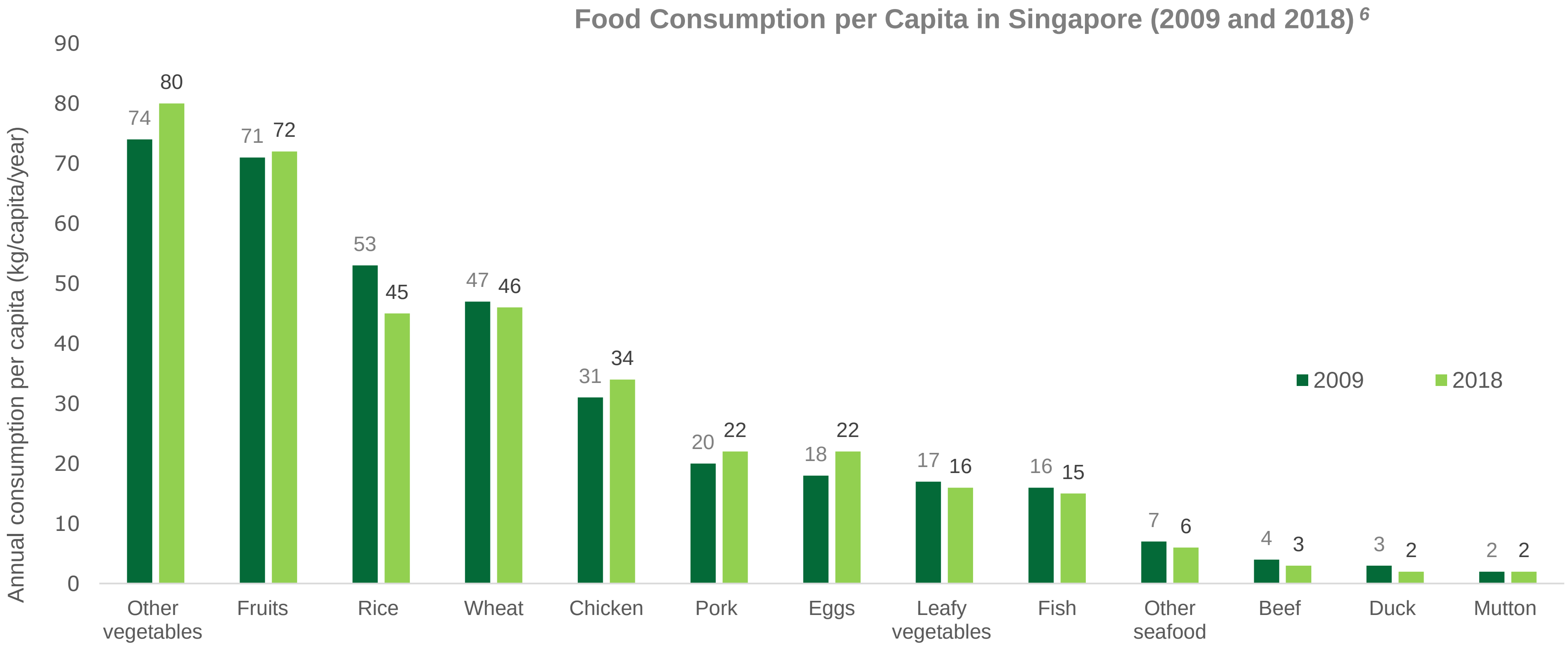
[1] Vermeulen, S. J., Campbell, B. M., Ingram, J.S.I. (2012)
[2] Agri-Food & Veterinary Authority of Singapore (2018)
[3] Natural Resources Institute Finland (2016)
[4] Poore, J., Nemecek. (2018)
[5] Clune, S., Crossin, E., Verghese, K. (2017)

2. Objective and Approach of Study

Objective and approach of study

This study covers 13 key food items which are the 11 items tracked by SFA [6] and 2 staples (rice and wheat). Per capita food consumption has remained relatively consistent over the past 10 years (2009–2018).

Study Objective: Quantify the environmental impact of key food items in Singapore



Breakdown of key food items

Other vegetables:
Tomato, cabbage, carrot, beansprout, onion, potato

Fruits:
Banana, watermelon, papaya, pineapple, orange

Leafy vegetables:
Spinach, lettuce, Chinese cabbage

Fish:
Catfish, salmon, mackerel (includes aquaculture and capture fishing)

Other seafood:
Shrimp, crab, squid

Note: Food items in key food items groups are based on top consumed items by weight.

[6] Singapore Food Agency (2019)

Objective and approach of study: Life cycle assessment methodology

An LCA based on ISO 14040/44[7,8] was performed to quantify the environmental impact of key food items in Singapore. The study has been contextualised to account for production, processing and transportation life cycle stages in Singapore.

Study Objective: Quantify the environmental impact of key food items in Singapore.

Approach

1
Goal and Scope Definition
Setting the system boundary, assumptions, allocation methods

→

2
Life Cycle Inventory Analysis
Collecting data such as amount of feed, energy, water, waste

→

3
Life Cycle Impact Assessment
Evaluating the environmental impact

→

4
Life Cycle Interpretation
Interpreting and distilling insights

The LCA methodology is a systematic and transparent way to provide visibility and insights of the environmental impact across the lifespan of a product. An LCA is conducted in four main phases: 1. Goal and Scope Definition, 2. Life Cycle Inventory Analysis, 3. Life Cycle Impact Assessment, and 4. Life Cycle Interpretation.

[7] *ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework*
[8] *ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines*

Objective and approach of study: System boundary

The system boundary was defined and data on the life cycle processes were collected for identified key food items. The data was analysed based on selected environmental impact indicators.

Study Objective: Quantify the environmental impact of key food items consumed in Singapore, based on per capita consumption

Approach

The scope of study is from '**farm-to-table**'. This means that the system boundary includes the production, processing and transportation stages. All material and resource inputs, as well as waste, by-products and direct emissions output are considered.

Embodied impacts of all materials and resources used in the system are considered. For example, the water and energy used to irrigate feed are included in the environmental impact of beef. **Food loss** along the supply chain is also considered. The figure below shows the full life cycle of food from production to disposal.

System boundary of study

	Production	Processing	Transport	Retail	Cooking and Storage	Waste
(Inputs)	Material, energy, transport	Material, energy, transport	Transport			
Local Production	Local farm activities to produce food for four farm types: egg, leafy vegetables, other vegetables and fish	Washing, packaging and storage of food items	Logistics involved in moving food items to food importers	Distribution of food to retailers, manufacturers and F&B outlets	Food preparation and dining	Disposal of food
Import	Farm activities to produce meat, eggs, vegetables, fruits and seafood	Slaughtering, washing, packaging and storage of food items	Logistics involved in importing food into Singapore	Distribution of food to retailers, manufacturers and F&B outlets	Food preparation and dining	Disposal of food
(Outputs)	Production food loss, emissions, by-products, waste	Processing food loss, emissions, by-products, waste	Transportation food loss, emissions			

Note: Refer to Annex B for system boundaries of key food items.

Objective and approach of study: Environmental Impact Indicators (1/3)

The study quantifies the environmental impact of the production, processing and transportation stages of food in Singapore in terms of GHG emissions, energy consumption and water consumption.

GHG Emissions (kg CO_2-eq per kg of food)

- **Greenhouse gas (GHG) emissions**, or carbon footprint, is an indicator used to measure the amount of GHG gases released into the atmosphere due to human activities. These gases cause the greenhouse effect that leads to global warming. The unit used for this indicator is in term of carbon dioxide equivalent (CO_2-eq).
- GHGs are **naturally occurring and anthropogenic gases** that cause the greenhouse effect, the key drivers behind the global phenomena of climate change.
- Research suggests that the food system contributes to **19–29% of total anthropogenic GHG emissions.**[9]
- Most farm-related GHG emissions come in the form of **methane** (CH_4) and **nitrous oxide** (N_2O).
- **Enteric fermentation from cattle** releases CH_4, and **cattle manure management** together with the addition of natural or synthetic **fertilisers and manure** to soils cause N_2O emission.
- **Electricity generation to power the food system** also contributes to GHG emissions.
- Therefore, GHG emissions is an **important indicator of climate change** to be considered in a life cycle assessment of locally-produced and imported food.
- It provides a **measurable and comparable** unit used in tracking Singapore's climate change targets and carbon abatement goals.
- The GHGs considered in this study include **carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4)**, which are converted and expressed as CO_2-eq.

[9] *Vermeulen, S. J., Campbell, B. M., Ingram, J.S.I. (2012)*

Objective and approach of study: Environmental Impact Indicators (2/3)

The study quantifies the environmental impact of the production, processing and transportation stages of food in Singapore in terms of GHG emissions, energy consumption and water consumption.

Energy Consumption (kWh per kg of food)

- Energy consumption indicator **represents cumulative renewable and non-renewable energy** use which includes energy from biomass, fossil, geothermal, nuclear, primary forest, water, wind, and solar (e.g. photosynthesis and the use of photovoltaics* to capture solar energy).
- In food life cycles, energy consumption is a key environmental impact indicator because it is an **essential resource** needed to power the farms and logistics used throughout the supply chain – **from production to transportation stage**.
- It provides a good **representation of energy needed** in the production, processing and transportation of each food item in Singapore.
- This indicator reflects the **efficiency of using energy resources** and provides comparability for the energy required for different food items should Singapore decide to produce or process any food item locally.
- As Singapore moves towards strengthening the resilience in food supply by adopting technology to increase agriculture productivity, LCA can be used to **track the potential changes in energy consumption**.

** Photovoltaics refers to the conversion of light into electrical energy*

Objective and approach of study: Environmental Impact Indicators (3/3)

The study quantifies the environmental impact of the production, processing and transportation stages of food in Singapore in terms of GHG emissions, energy consumption and water consumption.

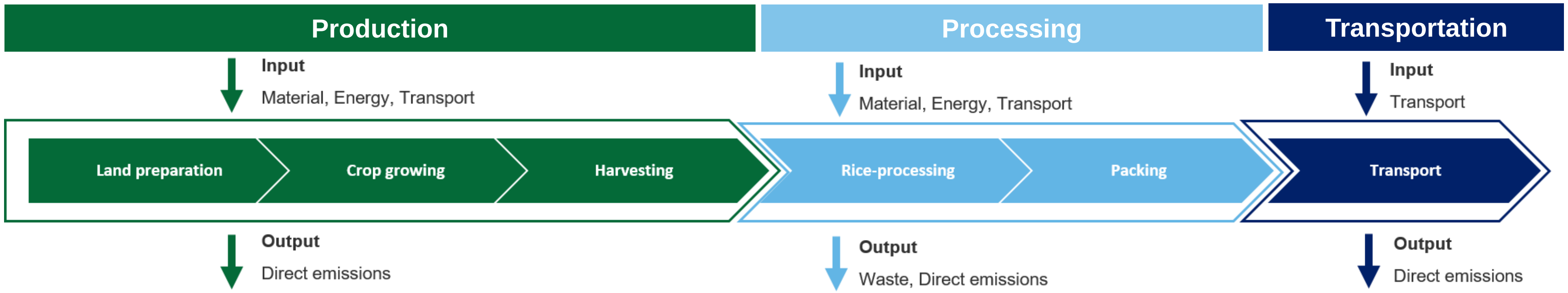
Water Consumption (litres per kg of food)

- The water consumption indicator used in the study **specifically assesses the impact of water depletion**, which can be used to assess impact of water used when coupled with region-specific water scarcity index.
- It represents the total amount of water used **within the system boundary**. This includes water used in food production that is extracted from **reservoirs, lakes, rivers and groundwater.**
- The LCA study computes **water extracted for consumption** across the life cycle of the food item based on the system boundary of **production, processing and transportation.**
- This quantification **differs from the water footprint indicator**, which quantifies the total volume of freshwater used from the environment.[10] Water footprint includes soil moisture, water from water bodies, and water used to dilute/assimilate pollution. The water footprint indicator highlights water use from a global water cycle perspective.
- Water consumption in this study **does not include moisture in the soil**, which contributes significantly to livestock farming (i.e. grazing pastures), and water used to dilute polluted water for safe discharge. This is because the two factors are not representative of how much water would be directly used if a food item was locally produced and processed in Singapore.
- Typical water consumption for meats would consist of **87% soil moisture**, **6% water extracted from water bodies and 7% water used to dilute pollution** [10]. However, only water extracted from water bodies will be considered in this study.
- Water consumption helps to consider **how Singapore's water supply will be stressed** if different food items are produced or processed locally.

[10] Mekonnen, M. M., & Hoekstra, A. Y. (2010)

Objective and approach of study: Case example for 1 kg of rice

Scope



Life Cycle Inventory Analysis

Production

- Irrigation water used to flood the paddy fields.
- CH_4 produced from anaerobic decomposition of organic material in the flooded fields.
- N_2O produced due to fertiliser use and alternate flooding and draining of paddy fields.

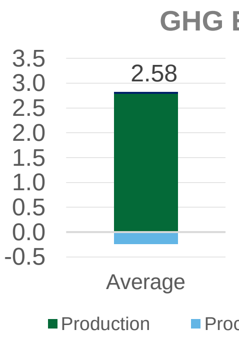
Processing

- Majority of our imported rice uses dry-processing methods.
- Offsets in GHG emissions and energy consumption is due to the rice husks, which are produced at the rice-processing stage, being burned and converted to energy.[12]

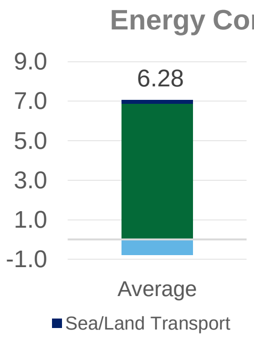
Transportation

- Rice is transported to Singapore by land and sea transport.

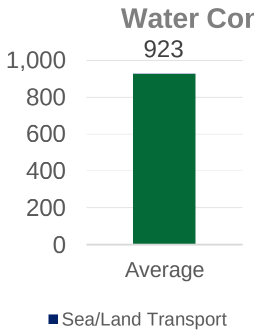
Life Cycle Impact Assessment



Significant GHG emissions at the production stage is due to the release of CH_4 and N_2O during the flooding of rice fields.[11] GHG emissions is offset (negative) at the processing stage. This is as electricity from the burning of rice husks offsets the GHG emissions from standard electricity production.



Energy consumption is offset (negative) during the rice-processing stage as the by-product (rice husk) is used to generate electricity.



Significant amount of water is used to flood the rice fields during the production stage.[11]

Life Cycle Interpretation

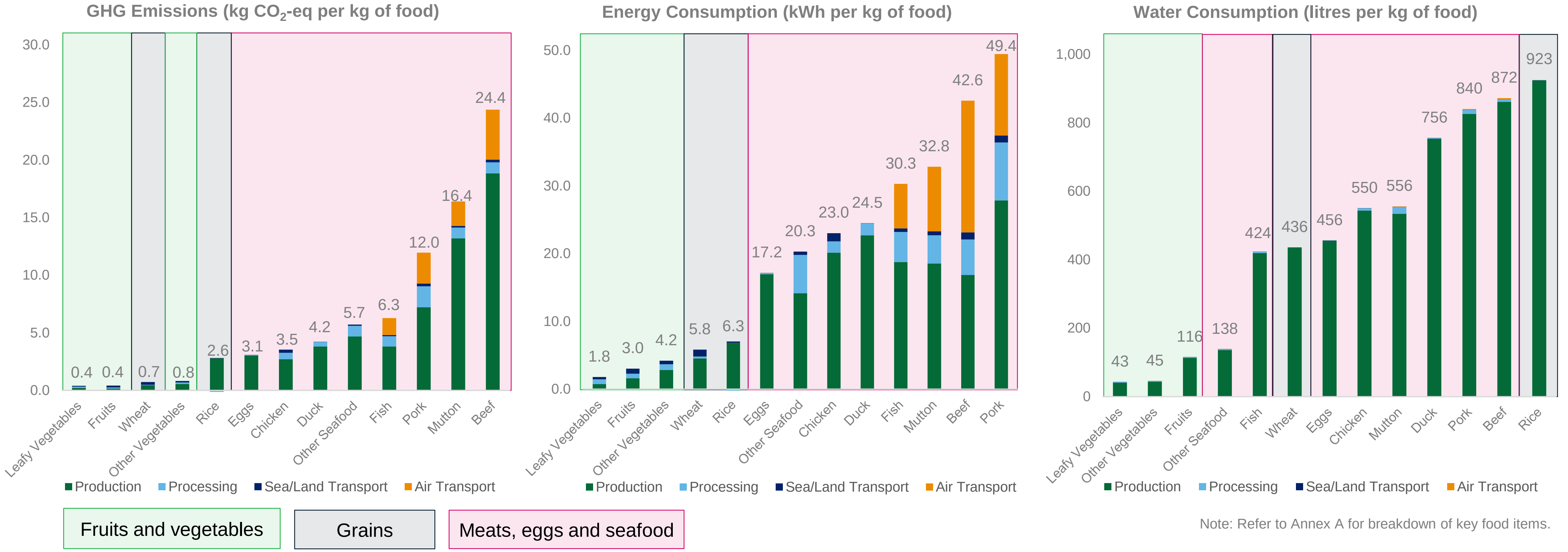
- Direct CH_4 emission is the main contributor to GHG emissions. Rice cultivation techniques that can reduce CH_4 with minimal increase of N_2O production can be considered.
- Importing rice from regions that use non-flooded cultivation techniques can reduce GHG emissions and water consumption.

[11] *Brouwer, C., Prins, K., & Heibloem, M. (1989)*
[12] *Rice Knowledge Bank. (2019)*

3. Findings of Study

Findings of study: Environmental impact of food per kg

Environmental impact of red meats (duck, pork, mutton and beef) is the most severe, although rice has the highest water consumption (per kg basis).

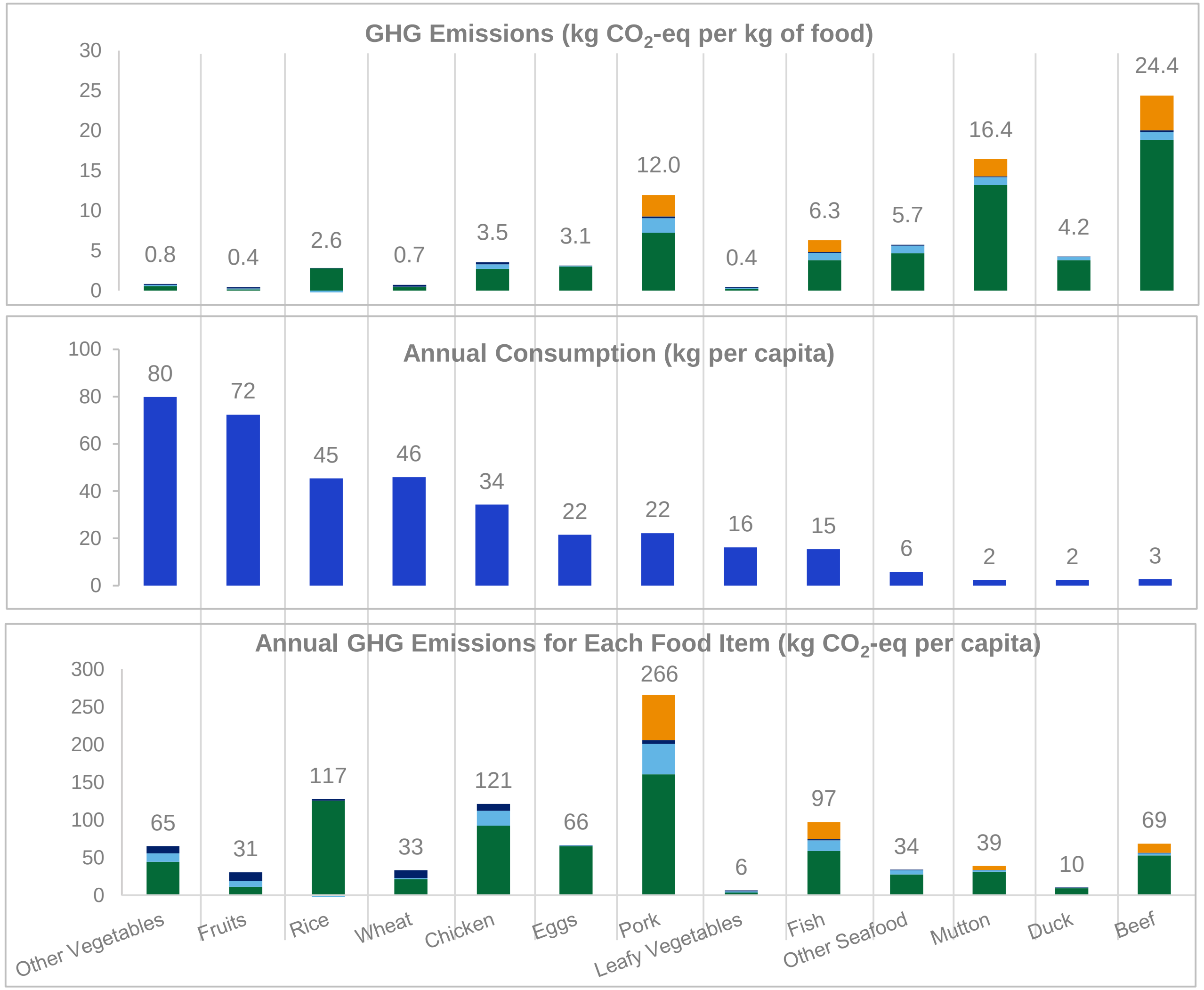


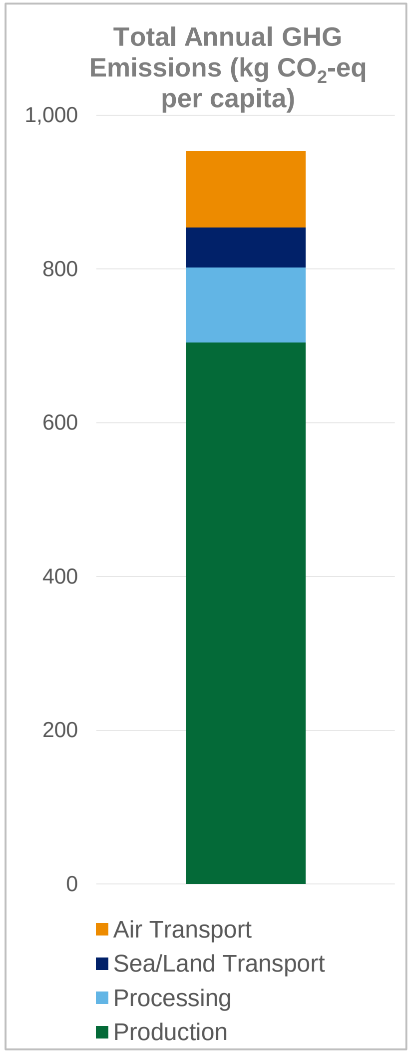
Note: Refer to Annex A for breakdown of key food items.

- While **beef has the highest GHG emissions per kg** due to enteric fermentation from cattle and manure storage that produce methane, **pork has the highest energy consumption per kg** due to air transport, intensive indoor housing and manure management systems.
- The lower energy consumption of beef as compared to pork is due to the fact that **Singapore imports mostly grass-fed beef** from Brazil, Australia and New Zealand. This means that the **cattle spend more time grazing on pastures instead of staying indoors where energy is required** for heating, ventilation and producing the grains to feed the cattle.
- **Rice has the highest water consumption per kg** due to flooding of the paddy fields during the production stage.

Findings of study: Environmental impact of food per capita (1/2)

Despite high GHG emissions of selected food items, consumption patterns significantly affect Singapore-level environmental impact of food. Air transportation of a few food items contribute to more environmental impact than sea and land transport of all food items.





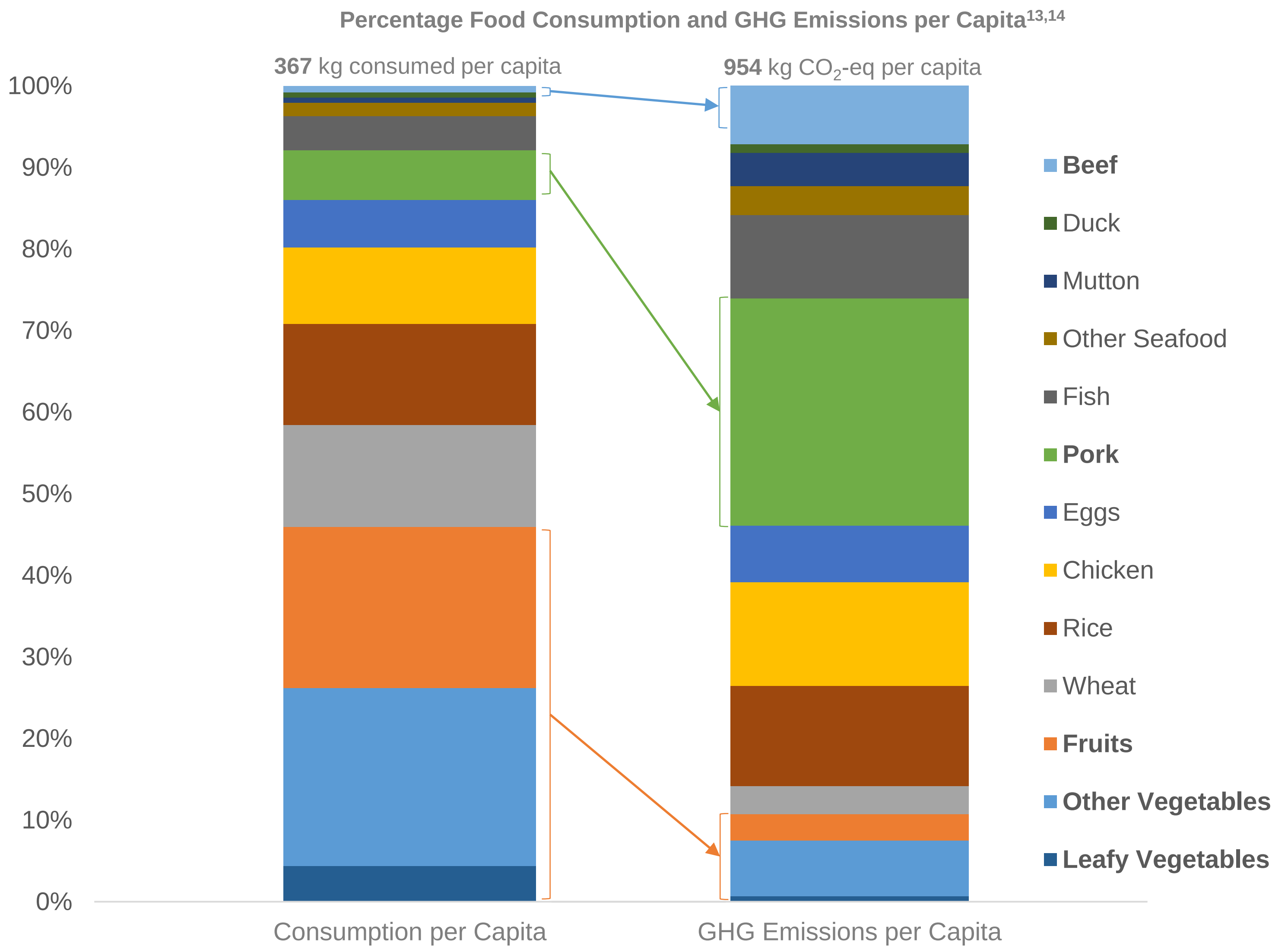
Consumption & Air Transport

- **Beef** has the highest GHG emissions per kg, but has **relatively low GHG emissions on a per capita basis** due to low consumption.
- **Pork** has about half the GHG emissions of beef. However, when considering consumption, pork has the **highest GHG emissions per capita consumption**.
- **Other vegetables and fruits** are the most highly consumed food items. However, their **GHG emissions on per capita basis are relatively low**.
- GHG emissions from **air transporting four key food items** are about **double** that from **transporting the rest of food items by land and sea**.

Note: Per capita values have been rounded to nearest whole number. For purpose of calculation, exact values have been used in aggregate summations and computations.

Findings of study: Environmental impact of food per capita (2/2)

For a select few items, there is a disproportionate difference between the percentage of consumption and their related GHG emissions.



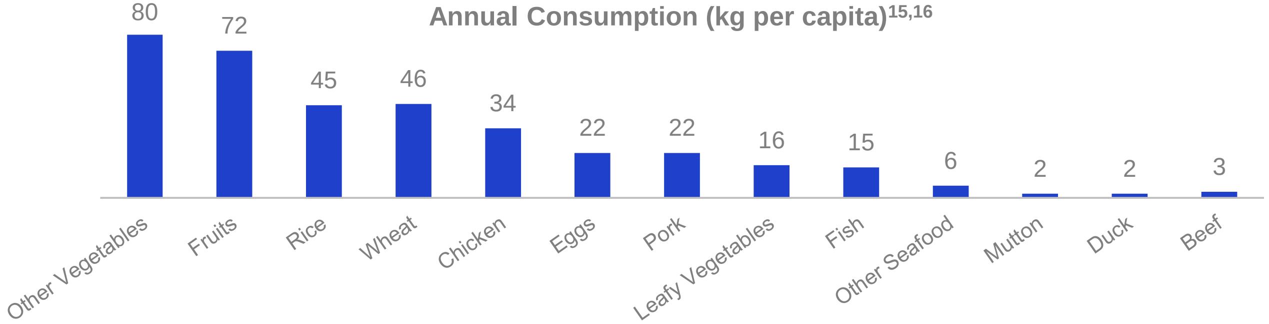
Consumption & GHG emissions

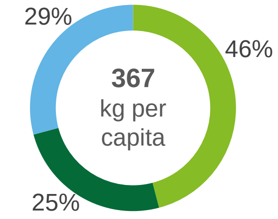
- **Beef** accounts for only **~0.8% of total consumption**, but it contributes to **~7% of total GHG emissions per capita**.
- **Pork** accounts for only **~6% of total consumption**, but it contributes **~28% of total GHG emissions per capita**.
- In contrast, **fruits and vegetables** account for **~46% of total consumption** but only contributes to **~11% of total GHG emissions per capita**.
- This is because of the **significantly higher GHG emissions of beef and pork** as compared to fruits and vegetables **on a per kg basis**.
- Therefore, GHG emissions of food items should be looked at from a **per kg basis as well as from consumption**.

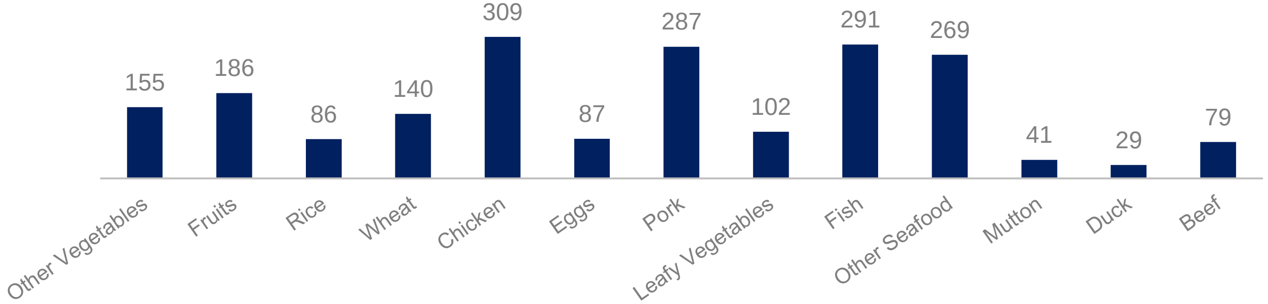
[13] Singapore Food Agency (2019)
[14] Department of Statistics Singapore (2019)

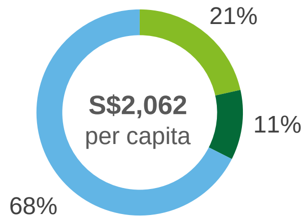
Findings of study: Environmental impact vs expenditure of food per capita

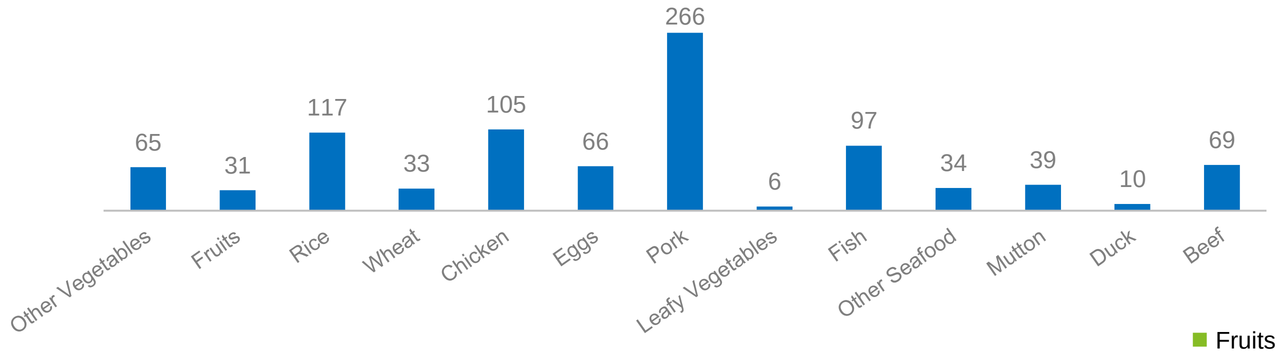
While 'Fruits and vegetables', and 'Grains' represent the largest consumption category per capita (two-thirds of food consumed by weight annually), 'Meats, eggs and seafood' account for more than two-thirds of the expenditure and GHG emissions.

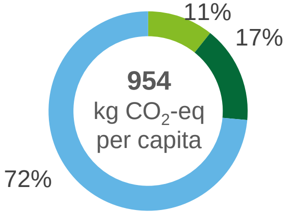












Fruits and vegetables Grains Meats, eggs and seafood

Fruits and vegetables

- Make up **almost half of consumption** but account for **less than a quarter of expenditure** and **about one-tenth of GHG emissions**.

Meats, eggs and seafood

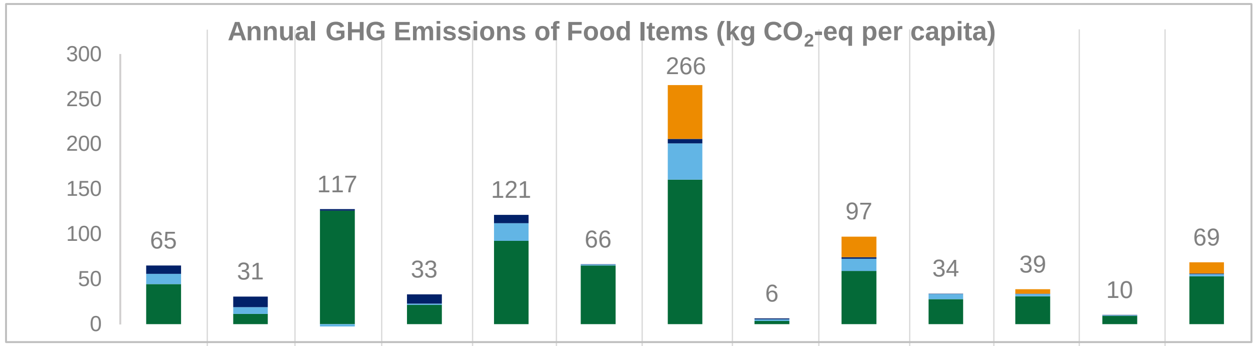
- Make up **less than a third of consumption** but account for **more than two-thirds of expenditure** and **GHG emissions**.
- Consumption of **pork is two-thirds of chicken** but pork has a significantly higher contribution of **2.5 times GHG emissions** compared to chicken.
- Consumers in Singapore are willing to spend on seafood as it accounts for **~27% of food expenditure**.

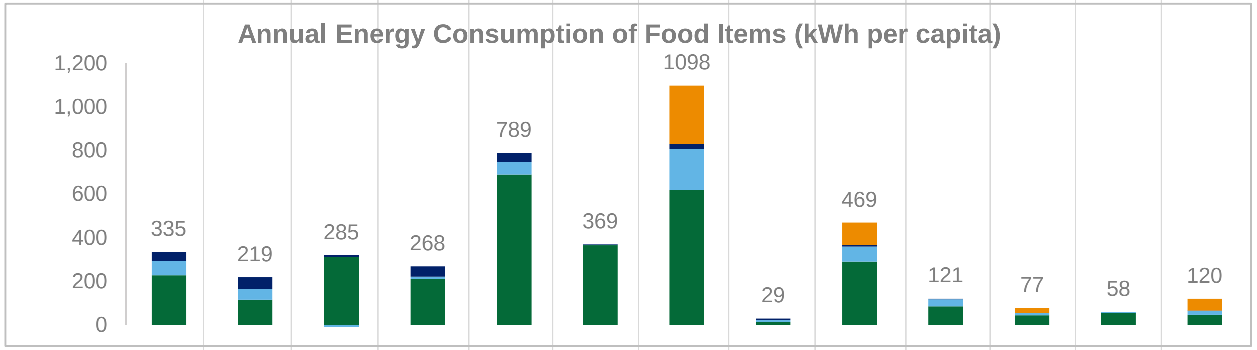
[15] Singapore Food Agency (2019)
[16] Department of Statistics Singapore (2019)
[17] Redmart (2019)

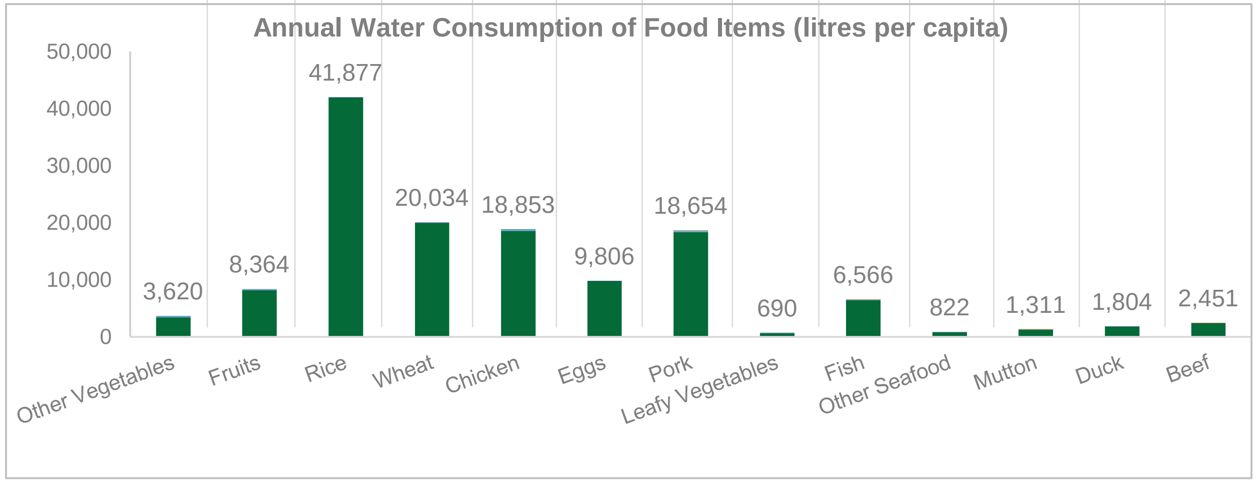
Note: Per capita values have been rounded to nearest whole number. For purpose of calculation, exact values have been used in aggregate summations and computations.

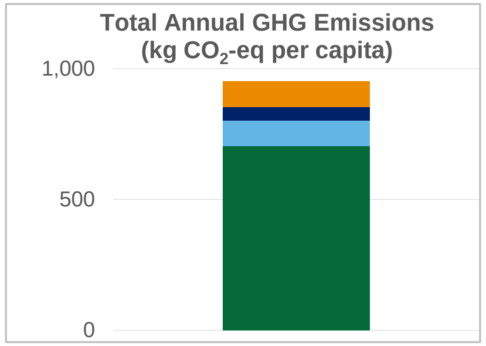
Findings of study: Factors contributing to environmental impact of food

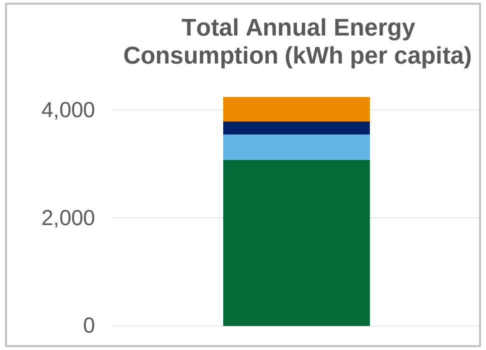
The majority of GHG emissions of food consumption is due to the high amount of energy and water consumed at the production stage.

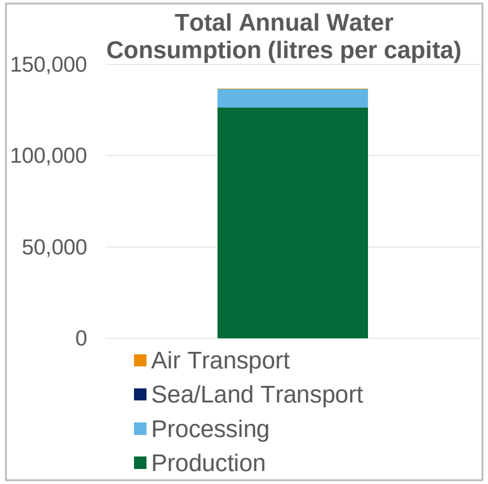












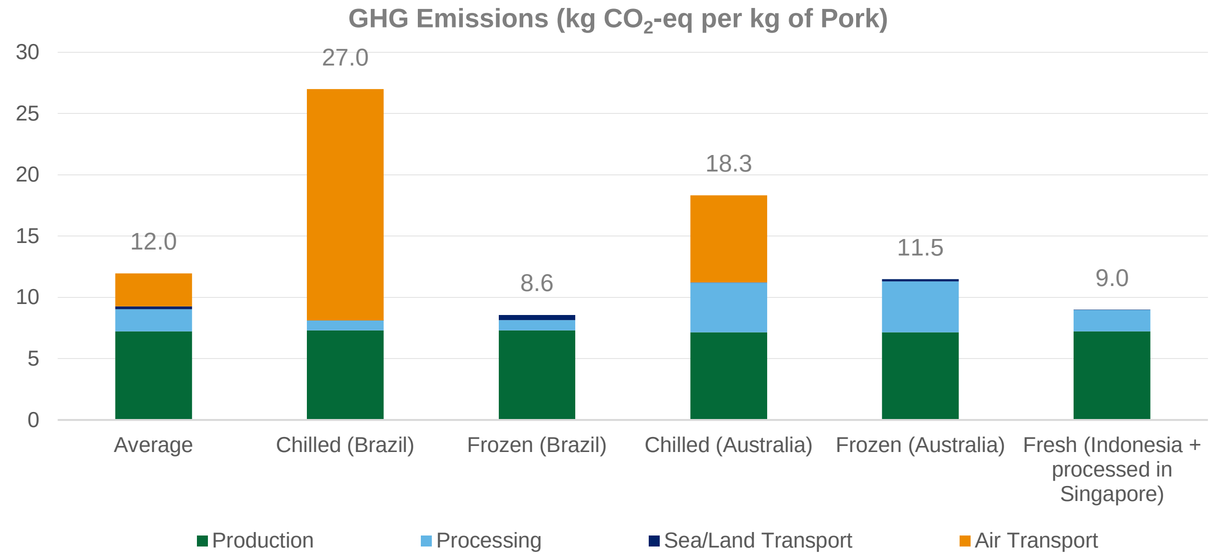
Factors contributing to environmental impact

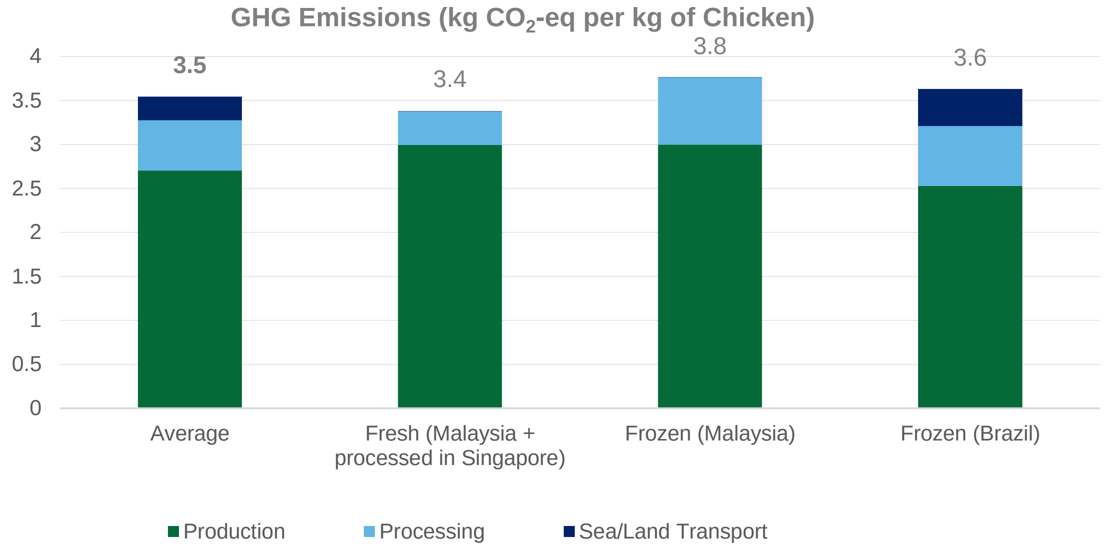
- **Significant amount of water is consumed at the production stage** to grow livestock feed, and for irrigation of rice, wheat, fruits, leafy vegetables and other vegetables.
- However, water consumption is **almost negligible during the transportation stage**.
- **Transportation plays an important role in the GHG emissions and energy consumption** of food as Singapore imports more than 90% of food.
- Chilled air-flown pork, mutton, beef and fish account for only **about 9% of food consumed** but they **contribute to about 65% of the energy used for transporting all food items** to Singapore.

4. Pathways to Environmental Impact Reduction

Pathways to environmental impact reduction: Transport and energy sources

If transported by land or sea, distance of import country does not have a large environmental impact, while transportation by air will greatly increase GHG emissions. Energy source of import country could be more significant than distance in determining GHG emissions when air transport is excluded.





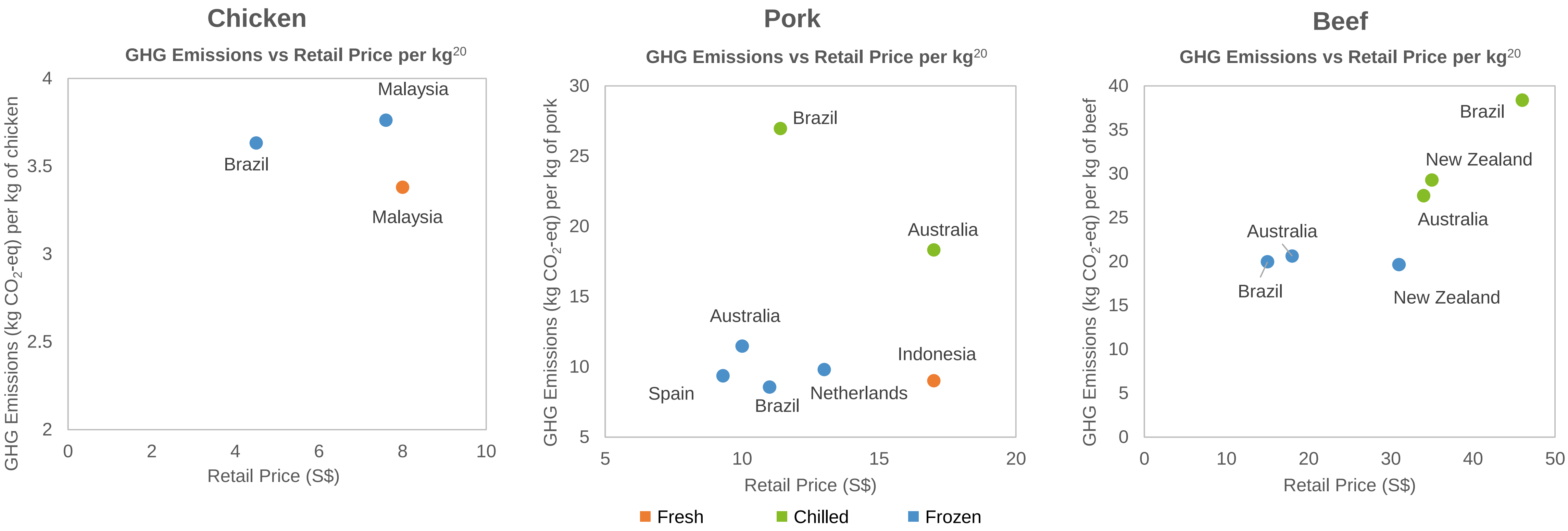
- Importing chilled food items through **air transport can significantly increase GHG emissions.** This is due to air transport being nine times more carbon intensive per tonne-kilometre than land transport and about 50 times that of sea transport.
- GHG emissions from **air transporting chilled pork from Brazil is almost three times the GHG emissions than that of Australia** due to the farther distance travelled to Singapore.
- Fresh pork from Indonesia has lower GHG emission than chilled pork from Brazil and Australis due to the avoidance of air transport. Therefore, sourcing fresh food from **neighbouring countries or producing locally** can meaningfully reduce environmental impact as this means avoiding air transport for import.
- In the case of frozen chicken, **GHG emissions during processing and production** stage for **Brazil** is **15% lower** than that of **Malaysia** as Brazil has **cleaner energy sources for electricity generation** (75% hydropower)[18,19] and therefore has lower GHG emissions.
- Therefore, sourcing food from countries with **cleaner and renewable sources of electricity generation** can meaningfully reduce environmental impact.

Note: Fresh meat refers to animals that are produced overseas, and transported to Singapore for processing. Chilled meat refers to animals that are produced and processed overseas, and transported to Singapore in chilled form. Frozen meat refers to animals that are produced and processed overseas, and transported to Singapore in frozen form.

[18] *Malaysia Energy Information Hub (2011)*
[19] *International Energy Agency (2019)*

Pathways to environmental impact reduction: Chilled and frozen meats, and sources of import

Frozen meat as opposed to chilled or fresh meat, or meat from geographically closer countries, are eco-friendlier alternatives.



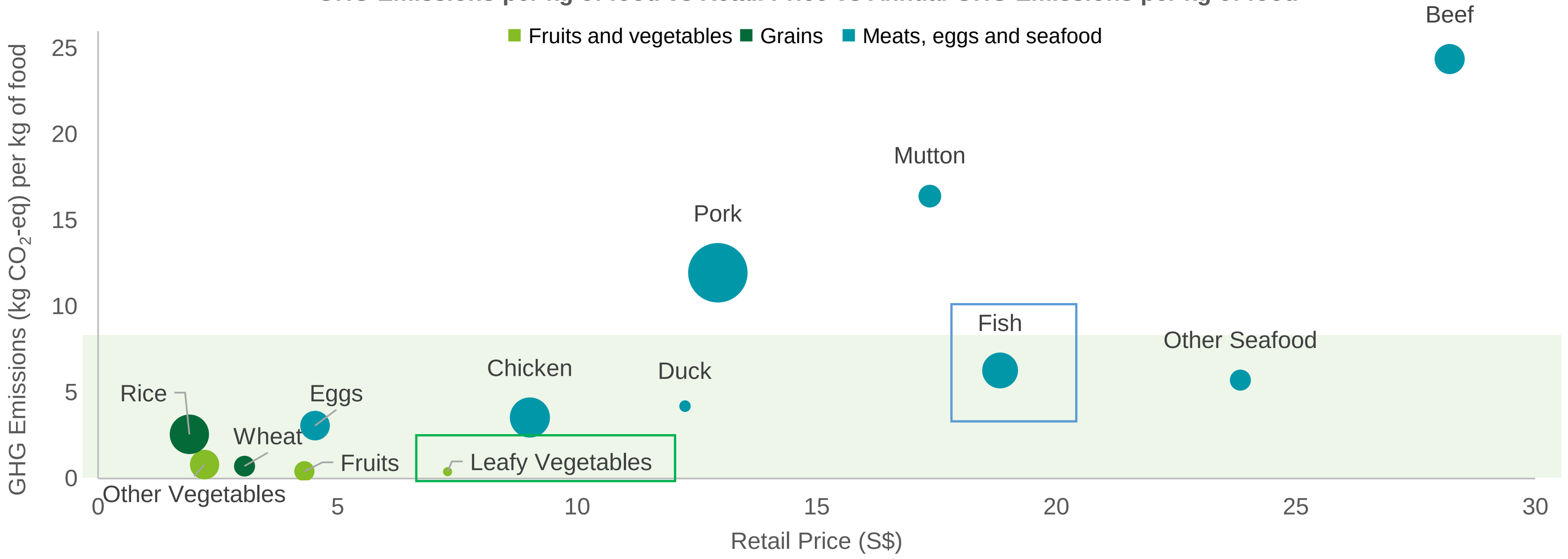
- **Fresh chicken** has the lowest GHG emissions among chicken meat and should be **recommended for its lower environmental impact**. However, **frozen Brazilian chicken could be a good alternative** given its significantly lower price yet marginally higher GHG emissions.
- In the cases of pork and beef, **frozen meat would be the eco-friendlier option** as compared to chilled meat. This is because chilled meat generally has higher GHG emissions as it needs to be air transported due to its shorter shelf-life and to maintain freshness.
- Where chilled or fresh meat is preferred, **source countries closer to Singapore should be favoured** for its lower environmental impact. From the consumer perspective, given a similar price point, **fresh pork from Indonesia would be an eco-friendlier alternative** than chilled pork from Australia due to less transportation required and thus, lower GHG emissions.

[20] *Redmart (2019)*

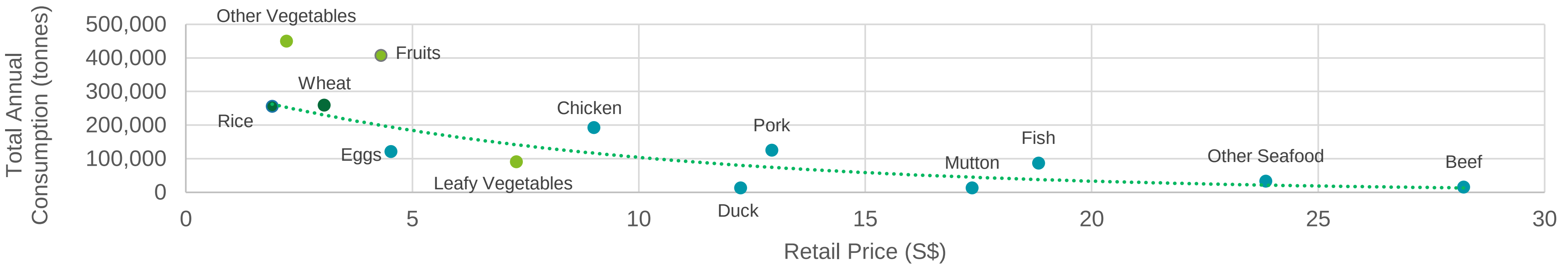
Pathways to environmental impact reduction: Imports vs local produce (1/2)

Food items that have low GHG emissions and are in high demand (indicated by consumption) or high commercial value (indicated by retail price) could be preferentially produced locally.

GHG Emissions per kg of food vs Retail Price vs Annual GHG Emissions per kg of food[21,22]



Size of circle represents ***Annual GHG Emissions*** *per food item*



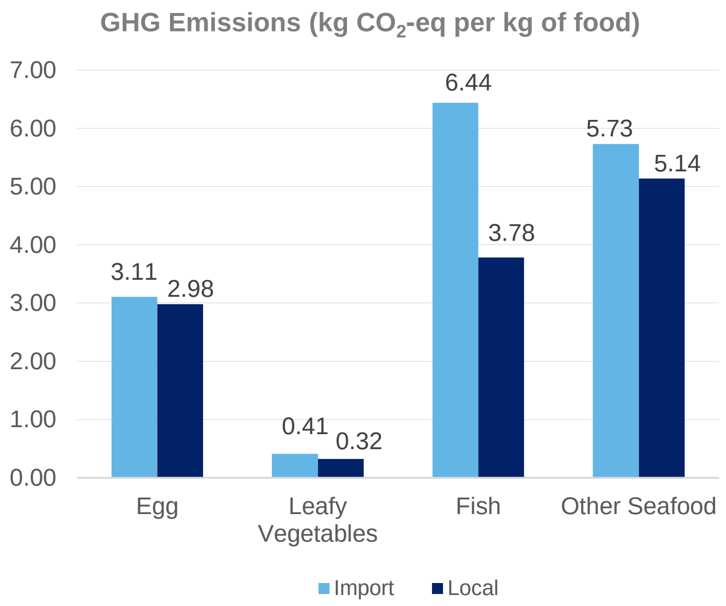
Food items for local production

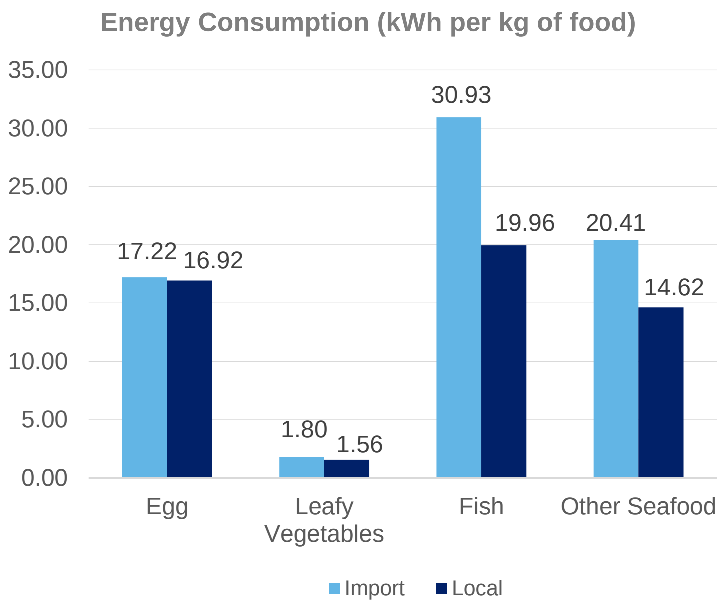
- **Fish and leafy vegetables** have low GHG emissions and high commercial value in their respective categories and **provide a good case for increasing their local production**.
- **Other vegetables** with high local demand or **other seafood** with high commercial value are also **good candidates to be produced locally**, provided there is availability of suitable technology to overcome the current challenge of limited land space.

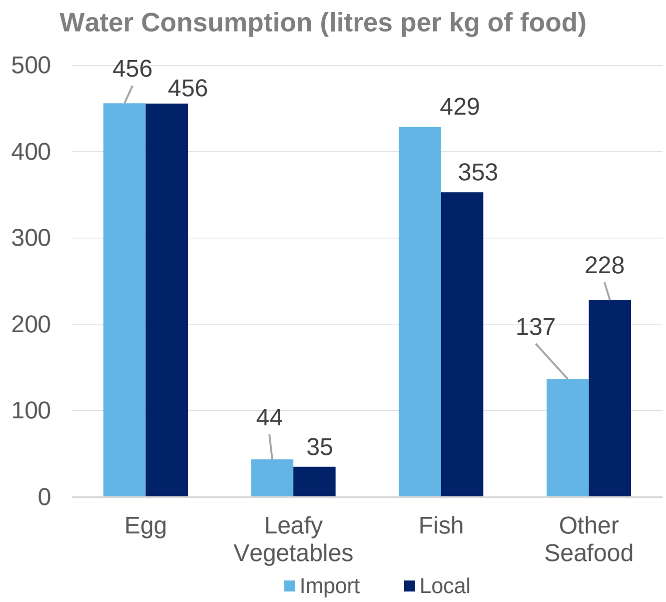
[21] *Singapore Food Agency (2019)*
[22] *Redmart (2019)*

Pathways to environmental impact reduction: Imports vs local produce (2/2)

Of the four key food items produced in Singapore, producing leafy vegetables and fish locally instead of importing them can lower environmental impacts.



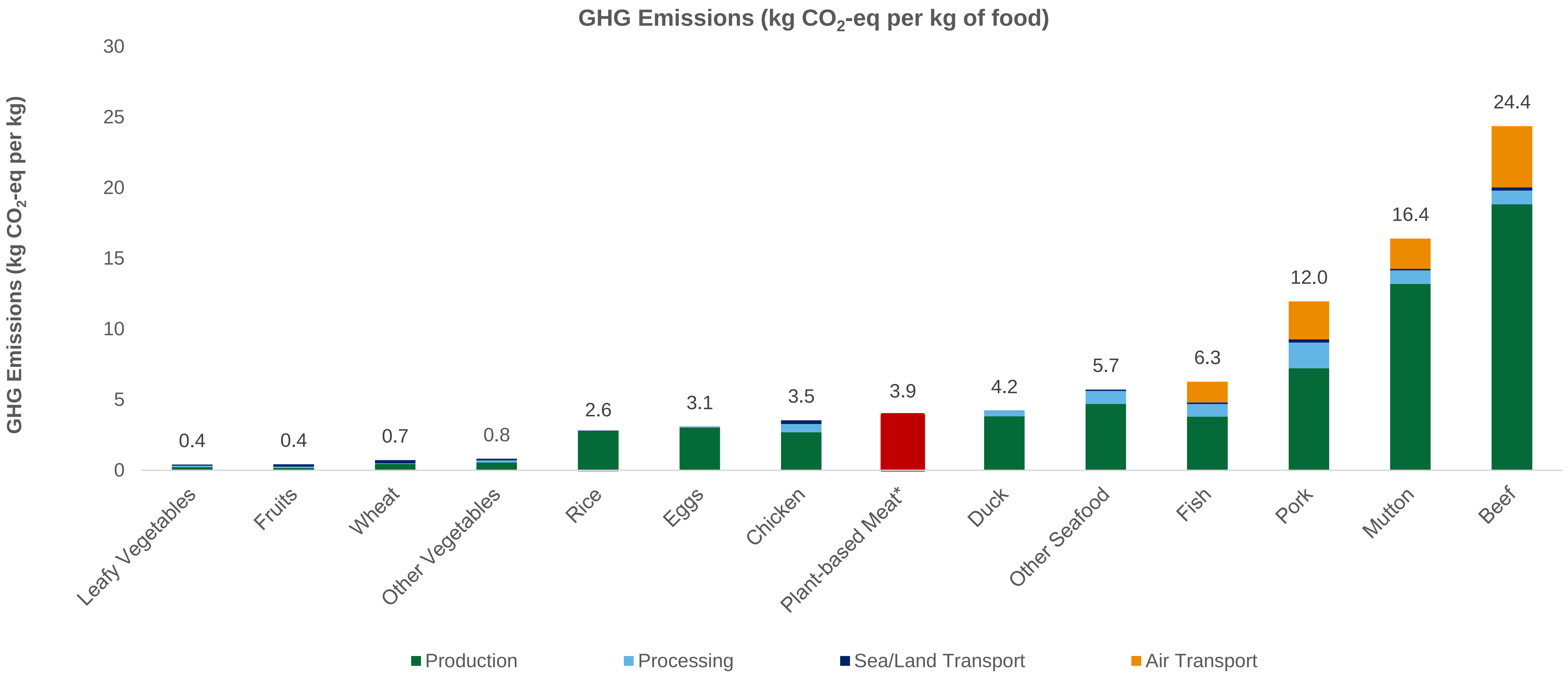




- **Locally-produced leafy vegetables** have ~22% lower GHG emissions, ~13% lower energy consumption and ~20% lower water consumption as compared to imported leafy vegetables. This is due to **reduced transportation requirement and cleaner energy sources in Singapore** (electricity is powered by ~95% natural gas) as compared to Malaysia, Indonesia and China (a significant percentage of electricity in these country is from coal).
- **Locally-produced fish** has **significantly lower environmental footprint** as compared to that of fish imported from overseas for all environmental indicators**.** This is mainly due to reduced transportation requirement.
- **Locally-produced other seafood** is **about 1.7 times more water intensive** than other seafood imported from overseas. This is because **almost all of Singapore's production of other seafood comes from aquaculture** which has higher water consumption as compared to capture fishing that is more commonly practised in the import source countries.
- **Locally-produced eggs** have **slightly better environmental performances** than imported eggs but the **difference is not significant**. This is due to the mature local egg farming industry, where the optimal use of technology is achieved for maximum output.

Pathways to environmental impact reduction: Animal meats vs plant-based meats (1/2)

Plant-based meat* has the lowest GHG emissions as compared to animal meat, with the exception of chicken. This makes plant-based meats a viable option for replacing animal meats to reduce GHG emissions.



* Plant-based meat data is referenced from Beyond Meat[23] and follows the same system boundary as this study.

[23] *Heller, M. C., & Keoleiank, G. A. (2018).*

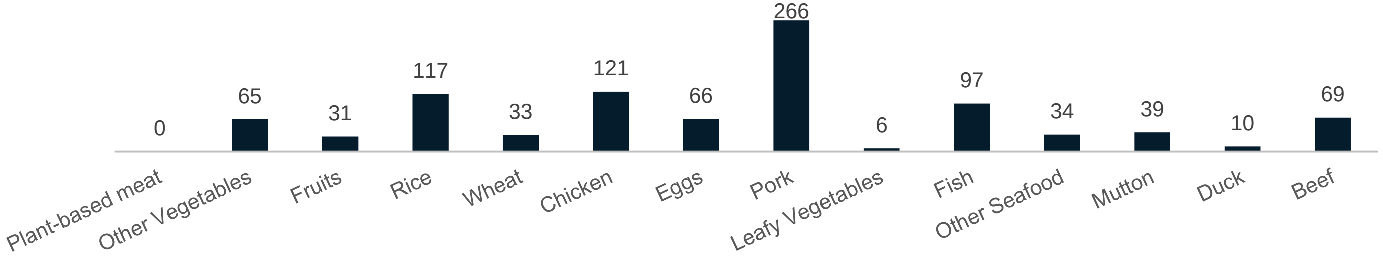
Pathways to environmental impact reduction: Animal meats vs plant-based meats (2/2)

Incorporating plant-based meats will meaningfully reduce environmental impact of food.

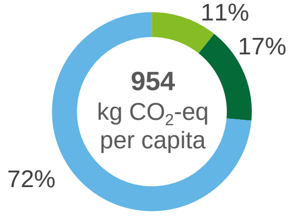
Business as Usual (BAU)

Diet consisting of 46% fruits and vegetables, 26% grains, 28% animal meats

Annual GHG Emissions for BAU Scenario (kg CO_2-eq per capita)



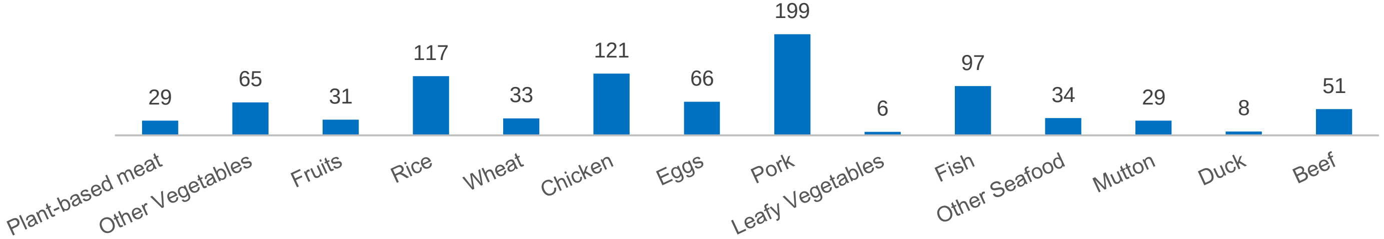
BAU



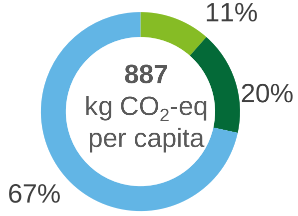
Scenario 1

Replace 25% of red meats (pork, mutton, duck and beef) with plant-based meats

Annual GHG Emissions for Scenario 1 (kg CO_2-eq per capita)



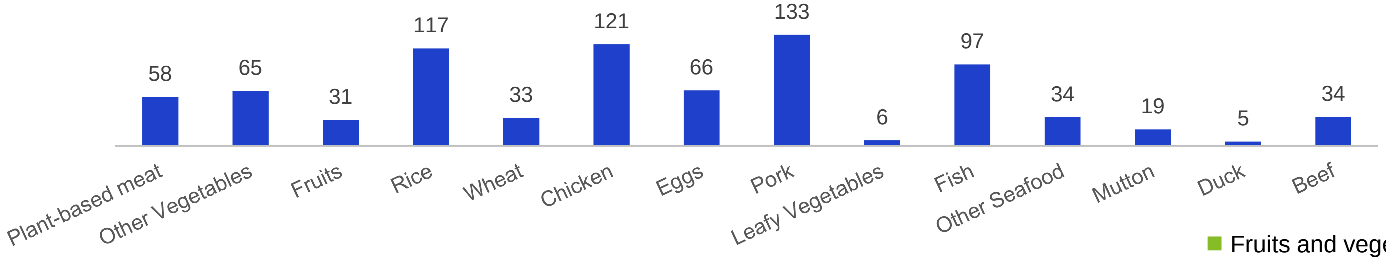
↓7% from BAU



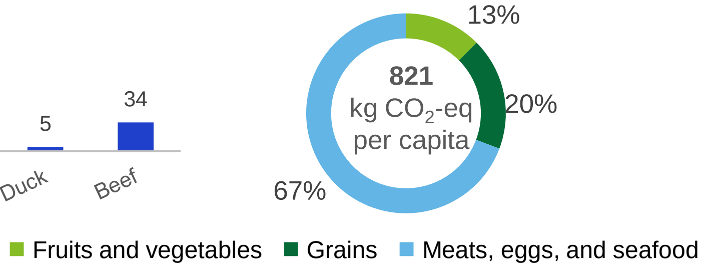
Scenario 2

Replace 50% of red meats (pork, mutton, duck and beef) with plant-based meats

Annual GHG Emissions for Scenario 2 (kg CO_2-eq per capita)



↓14% from BAU



Note: Per capita values have been rounded to nearest whole number. For purpose of calculation, exact values have been used in aggregate summations and computations.

- Presently, **29% of the average Singaporean's diet** consists of **'Meats, eggs and seafood'**. Meat products such as pork have significantly higher GHG emissions than fruits and vegetables, and 'Grains' such as rice and wheat respectively.
- A possible pathway to reduce the environmental impact of our food is by **replacing animal-meats with plant-based meats** or **shifting to a plant-based diet**.

5. Future Scenario Analysis

Future scenario analysis (1/2)

Various scenarios are considered for the reduction of GHG emissions based on the shifts in local production and consumption patterns by 2030.

	Possible Year 2030 Scenarios				
	Business As Usual	**30 by 30**	**Optimal Health**	**Plant-based Meats**	
Food Supply Mix (Imported vs Locally Produced)	Locally-produced food **remains at <10%** in year 2030.	Locally-produced food **increases to 30%** in year 2030, consisting of 20% leafy vegetables, and 10% eggs and fish. This assumption is based on Singapore's goal of producing 30% of its nutritional needs locally by 2030.			
Average Singapore Diet	**46% fruits and vegetables** **26% grains** (rice and wheat) **28% meats, eggs and seafood** (egg, fish, other seafood, chicken, duck, pork, mutton and beef)		↑ **50% fruits and vegetables** ↓ **25% grains** ↓ **25% meats, eggs and seafood** as prescribed by the Health Promotion Board		
Source of Meats (Animal vs plant-based meats)	The consumption of **eggs, fish, other seafood, and meats** (chicken, duck, pork, mutton and beef) in the average Singaporean diet **remains at 28%**.		The consumption of **eggs, fish, other seafood, and meats** in the average Singaporean diet **drops to 25%**.	The consumption of **eggs, fish, other seafood, and meats** in the average Singaporean diet **drops to 25%,** but with **25%** red meats* **being replaced by plant-based meats.**	The consumption of **eggs, fish, other seafood, and meats** in the average Singaporean diet **drops to 25%,** but with **50%** red meats* **being replaced by plant-based meats.**
Population Growth	Singapore population **grows to 6.7 million people**. This assumption is based on the midpoint of 6.5 and 6.9 million people as projected in the Population White Paper[24].				

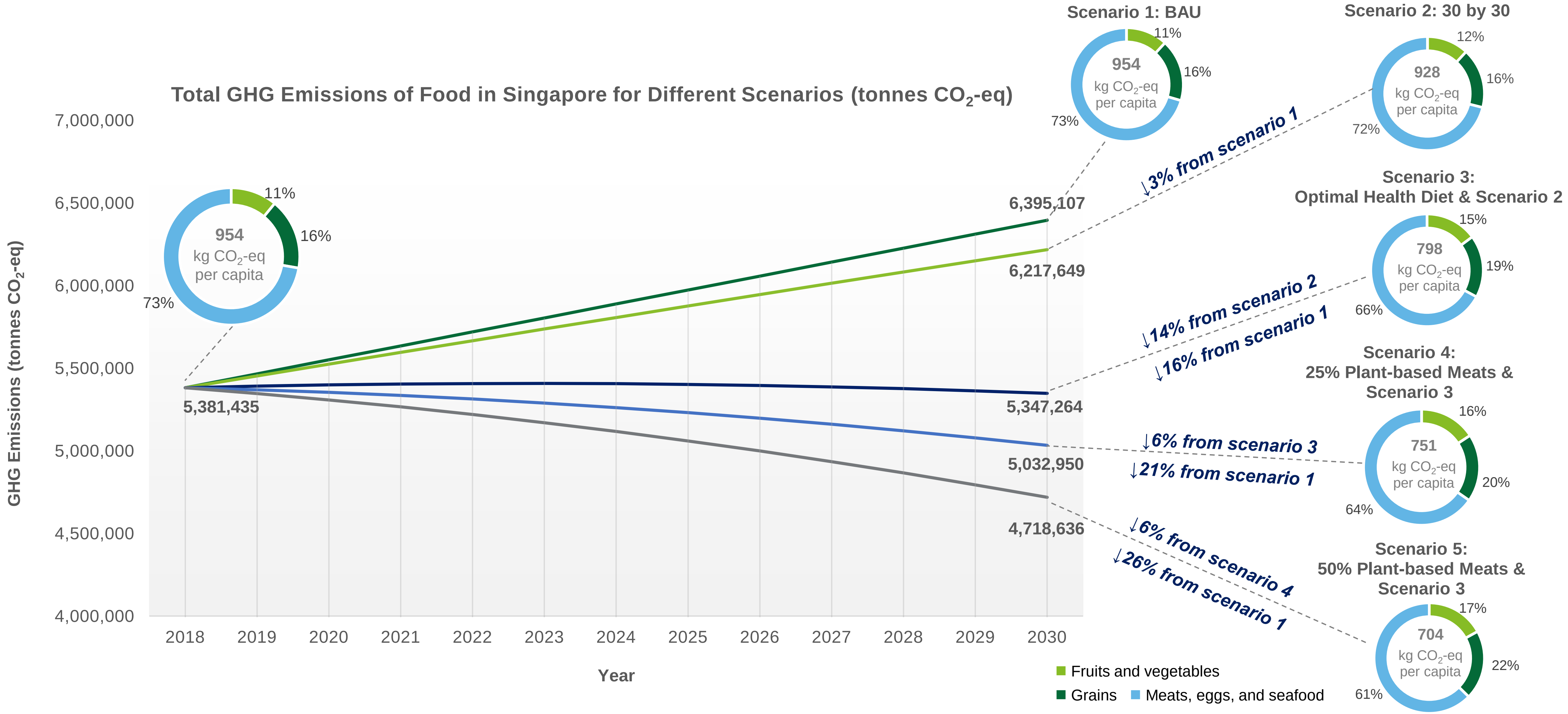
* Refers to duck, pork, mutton and beef

[24] *National Population and Talent Division (2013)*

Note: Refer to Annex D for other optimal health diets.

Future scenario analysis (2/2)

Producing 30% of Singapore's nutritional needs locally by 2030, adopting optimal health diet, and replacing 50% of red meat with plant-based meat will significantly reduce GHG emissions by ~26%.



6. References

References

Ahmed, J., Lorch, J., Ong, L., & Wolfgram, J. (2018). How the global supply landscape for meat protein will evolve.

Aldaya, M. M., Muñoz, G., & Hoekstra, A. Y. (2010). Water footprint of cotton, wheat and rice production in Central Asia. UNESCO-IHE.

Agri-Food & Veterinary Authority of Singapore (2018). 2017/2018 Annual Report. [online] Available at: https://www.sfa.gov.sg/publications

Ariyarathna, S. M. W. T. P. K., Siriwardhana, H. P. D. S. N., & Danthurebandara, M. (2016). Life cycle assessment of rice processing in Sri Lanka: Modern and conventional processing. In 2016 Moratuwa Engineering Research Conference (MERCon) (pp. 297-302). IEEE.

Arunrat, N., & Pumijumnong, N. (2017). Practices for reducing greenhouse gas emissions from rice production in Northeast Thailand. Agriculture, 7(1), 4.

Asem-Hiablie, S., Battagliese, T., Stackhouse-Lawson, K. R., & Rotz, C. A. (2019). A life cycle assessment of the environmental impact of a beef system in the USA. The International Journal of Life Cycle Assessment, 24(3), 441-455.

Asia Research and Engagement (2018). Charting Asia's protein journey.

Australian Government Department of the Environment and Energy (2018). Australian Energy Update 2018

Australian Government. National Health and Medical Research Council. Department of Health and Ageing. (2019) Australian Guide to Health Eating. [online] Available at https://www.eatforhealth.gov.au/sites/default/files/content/The%20Guidelines/n55_agthe_large.pdf [Accessed 27 Sep. 2019]

B.CCH.2072 Final Report – The environmental sustainability of premium Australian beef exported to the USA: A Life Cycle Assessment. Mla.com.au. (2019). [online] Available at: https://www.mla.com.au/download/finalreports?itemId=2904 [Accessed 14 Jun. 2019].

Banerjee Chirantan (2014). Up, up and away! The economics of vertical farming, Journal of Agricultural Studies. 2(1), 40-60.

Biswas, W. K., Barton, L., & Carter, D. (2007). Life cycle global warming potential of wheat production in Western Australia. In International Conference on Climate Change, Hong Kong.

Biswas, W. K., Barton, L., & Carter, D. (2008). GHG Emissions of wheat production in Western Australia: a life cycle assessment. Water and Environment Journal, 22(3), 206-216.

Biswas, W. K., Graham, J., Kelly, K., & John, M. B. (2010). Global warming contributions from wheat, sheep meat and wool production in Victoria, Australia–a life cycle assessment. Journal of Cleaner Production, 18(14), 1386-1392.

Blomeyer R., Goulding, I., Pualy, D., Sanz, A., & Stobberup, K. (2012). The role of China in world fisheries. Directorate general for internal policies, policy department B: structural and cohesion policies.

References

Bosma, R., Anh, P. T., & Potting, J. (2011). Life cycle assessment of intensive striped catfish farming in the Mekong Delta for screening hotspots as input to environmental policy and research agenda. The International Journal of Life Cycle Assessment, 16(9), 903.

Boyd, C. E., McNevin, A. A., Racine, P., Tinh, H. Q., Minh, H. N., Viriyatum, R., ... & Engle, C. (2017). Resource use assessment of shrimp, Litopenaeus vannamei and Penaeus monodon, production in Thailand and Vietnam. Journal of the World Aquaculture Society, 48(2), 201-226.

Brock, P., Madden, P., Schwenke, G., & Herridge, D. (2012). Greenhouse gas emissions profile for 1 tonne of wheat produced in Central Zone (East) New South Wales: a life cycle assessment approach. Crop and Pasture Science, 63(4), 319-329.

Cao, L., Diana, J. S., Keoleian, G. A., & Lai, Q. (2011). Life cycle assessment of Chinese shrimp farming systems targeted for export and domestic sales. Environmental science & technology, 45(15), 6531-6538.

Chungsangunsit, T., Gheewala, S. H., & Patumsawad, S. (2004). Environmental profile of power generation from rice husk in Thailand. In The Joint International Conference on Sustainable Energy and Environment (SEE)(pp. 1-3).

Clune, S., Crossin, E., Verghese, K. (2017) Systematic review of greenhouse gas emissions for different fresh food categories. J. Clean. Prod. 140, 766–783.

Da Silva, V. P., van der Werf, H. M., Soares, S. R., & Corson, M. S. (2014). Environmental impact of French and Brazilian broiler chicken production scenarios: An LCA approach. Journal of environmental management, 133, 222-231.

David Michael. (2011). Life Cycle Assessment: Australian Duck Meat Value Chain

Department of Statistics Singapore (2019). [online] Available at: https://www.singstat.gov.sg/find-data/search-by-theme/population/population-and-population-structure/latest-data [Accessed 14 Jun. 2019].

Fang, Q., Drugan, C. D. J., & Director, A. T. (2018). Chinese Japanese Flying Squid (JFS) Fisheries Improvement Scoping Report.

FAO (Food and Agriculture Organization of the United Nations) (2016). FAOSTAT. [online] Available at: http://www.fao.org/faostat/en/#data/TM [Accessed 14 Jun. 2019].

FAO (Food and Agriculture Organization of the United Nations) (2011). Global food losses and food waste – Extent, causes and prevention. Rome

Food Innvoation Australia Limited (2019). Protein Market: Size of the prize analysis for Australia.

Fréon, P., Durand, H., Avadí, A., Huaranca, S., & Moreyra, R. O. (2017). Life cycle assessment of three Peruvian fishmeal plants: Toward a cleaner production. Journal of cleaner production, 145, 50-63.

Graamansa, L.,Baezab E, Dobbelsteena V.D.A, Tsafarasb I.,Stanghellinib C.(2018). Plant factories versus greenhouses: Comparison of resource use efficiency.

References

González-García, S., Gomez-Fernández, Z., Dias, A. C., Feijoo, G., Moreira, M. T., & Arroja, L. (2014). Life Cycle Assessment of broiler chicken production: a Portuguese case study. Journal of cleaner production, 74, 125-134.

Heller, M. C., & Keoleiank, G. A. (2018). Beyond Meat's Beyond Burger Life Cycle Assessment: A Detailed Comparison between a Plantbased and an Animal-Based Protein Source. CSS18-10.

Henriksson, P. J. G., Zhang, W., Nahid, S. A. A., Newton, R., Phan, L. T., Dao, H. M., ... & Vo, N. S. (2014). Final LCA case study report. Results of LCA studies of Asian aquaculture systems for tilapia, catfish, shrimp, and freshwater prawn. Sustaining Ethical Aquaculture Trade (SEAT) Deliverable Ref: D, 3.

i Canals, L. M., Muñoz, I., Hospido, A., Plassmann, K., McLaren, S., Edwards-Jones, G., & Hounsome, B. (2008). Life Cycle Assessment (LCA) of domestic vs. imported vegetables. Case studies on broccoli, salad crops and green beans. United Kingdom, Cent. Environ. Strateg. Univ. Surrey, 46.

International Energy Agency (2019). [online] Available at: https://www.iea.org/countries/Brazil/ [Accessed 14 Jun. 2019].

IPCC (2006): Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use

IPCC (2014): Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework

ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines

Kaur, S. B. (1994). Comparative Evaluation Of Commercially Grown Lupin And Mung Sprouts.

Laurenti, R., Redwood, M., Puig, R., & Frostell, B. (2017). Measuring the environmental footprint of leather processing technologies. Journal of Industrial Ecology, 21(5), 1180-1187.

Lee, S. Y., & Lee, C. S. (1992). Some factors affecting the production and quality of bean sprouts. MARDI Res. J, 20(1), 85-92.

Lymer, D., Funge-Smith, S., Khemakorn, P., Naruepon, S., & Ubolratana, S. (2008). A review and synthesis of capture fisheries data in Thailand. Large versus small-scale fisheries. FAO.

Malaysia Energy Information Hub (2011). [online] Available at: https://meih.st.gov.my/statistics [Accessed 14 Jun. 2019].

Martinez-Mate, M. A., Martin-Gorriz, B., Martínez-Alvarez, V., Soto-García, M., & Maestre-Valero, J. F. (2018). Hydroponic system and desalinated seawater as an alternative farm-productive proposal in water scarcity areas: Energy and greenhouse gas emissions analysis of lettuce production in southeast Spain. Journal of cleaner production, 172, 1298-1310.

References

Mekonnen, M. M., & Hoekstra, A. Y. (2011). The green, blue and grey water footprint of crops and derived crop products. Hydrology and Earth System Sciences, 15(5), 1577-1600.

Memon, T. A., Harijan, K., Soomro, M. I., Meghwar, S., Valasai, G. D., & Khoharo, H. (2017). Potential of Electricity Generation from Rice Husk-A Case Study of Rice Mill. Sindh University Research Journal-SURJ (Science Series), 49(3), 495-498.

Nagashima, Futa & Suzuki, Toru & Watanabe, Manabu. (2018). Environmental Load of Domestic Squid Distribution with Various Conditions. Journal of Life Cycle Assessment, Japan. 14. 219-227.

National Population and Talent Division. (2013). A sustainable population for a dynamic Singapore: Population white paper.

Natural Resources Institute Finland (2016). [online] Available at: https://www.luke.fi/en/natural-resources/food-and-nutrition/effects-of-food-production-and-consumption-the-environment-and-climate/ [Accessed 21 Jun. 2019].

Nhu, T. T., Schaubroeck, T., De Meester, S., Duyvejonck, M., Sorgeloos, P., & Dewulf, J. (2015). Resource consumption assessment of Pangasius fillet products from Vietnamese aquaculture to European retailers. Journal of Cleaner Production, 100, 170-178.

Nunes, J. V. D., Nóbrega, L. H. P., da Cruz-Silva, C. T. A., & Pacheco, F. P. (2015). Comparison among beans species for food sprouts yield. Bioscience Journal, 31(6).

Pelletier, N., Ibarburu, M., & Xin, H. (2013). A carbon footprint analysis of egg production and processing supply chains in the Midwestern United States. Journal of cleaner production, 54, 108-114.

Poore, J., Nemecek. (2018) Reducing food’s environmental impacts through producers and consumers, Science 360(6392), 987-992.

Poonpolsup, S., Jakrawatana, N., Pattarapremcharoen, M., & Setthapun, W. (2017). Carbon footprint reduction from Bangkok urban home vegetable garden. Journal of Renewable Energy and Smart Grid Technology, 12(2), 75-86.

Popescu, I., & Ogushi, T. (2013). Fisheries in Japan. Directorate general for internal policies, policy department B: structural and cohesion policies

Public Health England. (2018) The Eatwell Guide. [online] Available at: https://www.gov.uk/government/publications/the-eatwell-guide/the-eatwell-guide-how-to-use-in-promotional-material [Accessed 27 Sep. 2019]

Ramos, S., Vázquez-Rowe, I., Artetxe, I., Moreira, M. T., Feijoo, G., & Zufía, J. (2011). Environmental assessment of the Atlantic mackerel (Scomber scombrus) season in the Basque Country. Increasing the timeline delimitation in fishery LCA studies. The International Journal of Life Cycle Assessment, 16(7), 599-610.

Robb, D. H., MacLeod, M., Hasan, M. R., & Soto, D. (2017). Greenhouse gas emissions from aquaculture: a life cycle assessment of three asian systems. FAO Fisheries and Aquaculture Technical Paper, (609).

References

Redmart. (2019). Redmart. [online]. Available at: https://redmart.lazada.sg/#home [Accessed 14 Jun. 2019].

Rice Knowledge Bank. (2019) Using rice husk for energy production. [online] Available at http://www.knowledgebank.irri.org/step-by-step-production/postharvest/rice-by-products/rice-husk/using-rice-husk-for-energy-production. [Accessed 21 Jun. 2019]

Romeo, D., Vea, E. B., & Thomsen, M. (2018). Environmental impact of urban hydroponics in Europe: a case study in Lyon. Procedia CIRP, 69, 540-545.

Rotz, C. A., Asem-Hiablie, S., Place, S., & Thoma, G. (2019). Environmental footprints of beef cattle production in the United States. Agricultural systems, 169, 1-13.

Shepherd, T. A., Zhao, Y., Li, H., Stinn, J. P., Hayes, M. D., & Xin, H. (2015). Environmental assessment of three egg production systems—Part II. Ammonia, greenhouse gas, and particulate matter emissions. Poultry science, 94(3), 534-543.

Sieng, M. (2012). Where to Go From Here? Exploring Shrimp Farming LCA in Thailand.

Singapore Food Agency. (2019). Food Import & Export. [online] Available at: https://www.sfa.gov.sg/food-import-export [Accessed 14 Jun. 2019].

Stoessel, F., Juraske, R., Pfister, S., & Hellweg, S. (2012). Life cycle inventory and carbon and water foodprint of fruits and vegetables: application to a Swiss retailer. Environmental science & technology, 46(6), 3253-3262.

Suffian, S. A., Sidek, A. A., Matsuto, T., Al Hazza, M. H., Yusof, H. M., & Hashim, A. Z. (2018). Greenhouse Gas emissions of Broiler Chicken Production in Malaysia using Life Cycle Assessment Guidelines: A Case Study. International Journal of Engineering Materials and Manufacture, 3(2), 87-97.

Thanawong, K., Perret, S. R., & Basset-Mens, C. (2014). Eco-efficiency of paddy rice production in Northeastern Thailand: a comparison of rain-fed and irrigated cropping systems. Journal of cleaner production, 73, 204-217.

Tridge. (2019). [online] Available at: https://www.tridge.com [Accessed 14 Jun. 2019].

United States Department of Agriculture. Center for Nutrition Policy and Promotion. (2018) What’s my plate all about? [online] Available at https://choosemyplate-prod.azureedge.net/sites/default/files/printablematerials/2013-WhatsMyPlateAllAboutInfographic.pdf [Accessed 27 Sep. 2019]

United Nations Comtrade (2019) International Trade Statistics Database [online] Available at: https://comtrade.un.org/data/ [Accessed 14 Jun. 2019]

Uses.plantnet-project.org. (2019). Brassica rapa Chinese Cabbage (PROSEA) - PlantUse English. [online] Available at: https://uses.plantnet-project.org/en/Brassica_rapa_Chinese_Cabbage_(PROSEA) [Accessed 14 Jun. 2019].

Usubharatana, P., & Phungrassami, H. (2017). Greenhouse gas emissions of one-day-old chick production. Polish Journal of Environmental Studies, 26(3).

Vanham, D., & Bidoglio, G. (2013). A review on the indicator water footprint for the EU28. Ecological indicators, 26, 61-75.

Vázquez-Rowe, I., Moreira, M. T., & Feijoo, G. (2010). Life cycle assessment of horse mackerel fisheries in Galicia (NW Spain): comparative analysis of two major fishing methods. Fisheries Research, 106(3), 517-527.

References

Vermeulen, S. J., Campbell, B. M., Ingram, J.S.I. (2012). Climate Change and Food Systems, Annual Review of Environment and Resources. 37, 195-222.

Verones, F., Bolowich, A. F., Ebata, K., Boutson, A., Arimoto, T., & Ishikawa, S. (2017). A case study of life cycle impact of small-scale fishing techniques in Thailand. Cogent Environmental Science, 3(1), 1387959.

Wang, C., Li, X., Gong, T., & Zhang, H. (2014). Life cycle assessment of wheat-maize rotation system emphasizing high crop yield and high resource use efficiency in Quzhou County. Journal of Cleaner Production, 68, 56-63.

Watanabe, K., Tahara, K., Fujimori, Y., Shimizu, S., & Miura, T. (2006). Life cycle inventory of environmental burden on squid fisheries. Environmental Science (Japan).

Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, B. (2016). The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, 21(9), 1218-1230.

Wiedemann, S. G., & McGahan, E. J. (2011). Environmental assessment of an egg production supply chain using life cycle assessment. Australian Egg Corporation Limited: Sydney.

Wiedemann, S., McGahan, E., Murphy, C., Yan, M. J., Henry, B., Thoma, G., & Ledgard, S. (2015). Environmental impact and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment. Journal of Cleaner Production, 94, 67-75.

Wiedemann, Stephen & J. McGahan, Eugene & M. Murphy, Caoilinn. (2016). Environmental impact and resource use from Australian pork production assessed using life-cycle assessment. 1. Greenhouse gas emissions. Animal Production Science. 56. 10.1071/AN15881.

Wikström, F., Williams, H., Verghese, K., & Clune, S. (2014). The influence of packaging attributes on consumer behaviour in food-packaging life cycle assessment studies-a neglected topic. Journal of Cleaner Production, 73, 100-108.

Winther, U., Ziegler, F., Hognes, E. S., Emanuelsson, A., Sund, V., & Ellingsen, H. (2009). Carbon footprint and energy use of Norwegian seafood products. SINTEF Fisheries and aquaculture, 32.

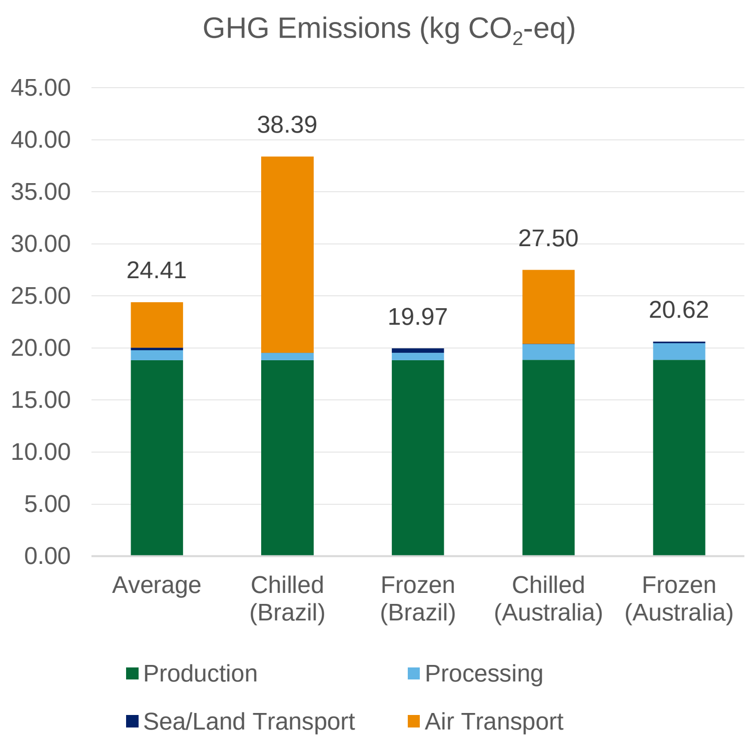
Xiang, Y., Zou, H., Zhang, F., Qiang, S., Wu, Y., Yan, S., ... & Wang, X. (2019). Effect of Irrigation Level and Irrigation Frequency on the Growth of Mini Chinese Cabbage and Residual Soil Nitrate Nitrogen. Sustainability, 11(1), 111.

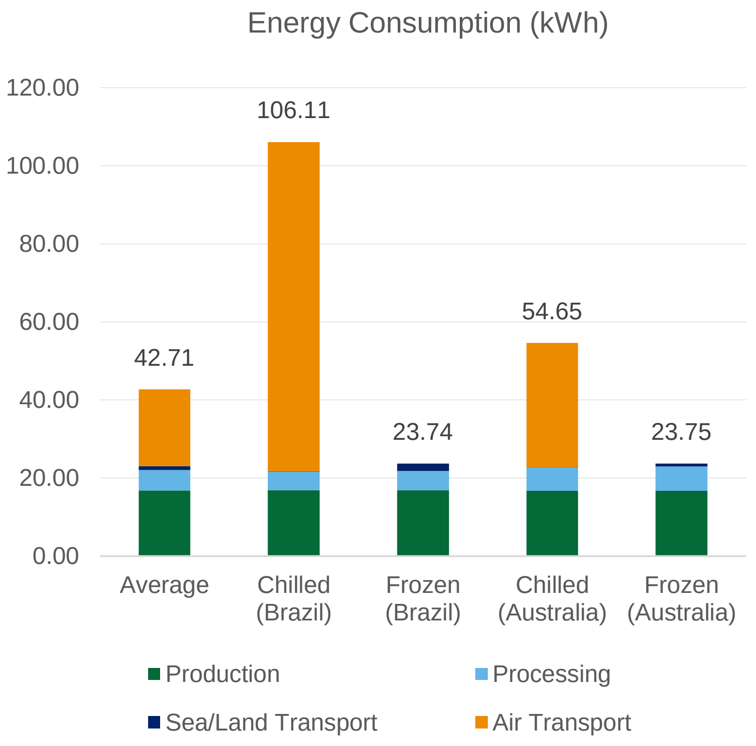
Yodkhum, S., & Sampattagul, S. (2014). Life Cycle Greenhouse Gas Evaluation of Rice Production in Thailand. In Proceedings of the 1st Environment and Natural Resources International Conference, Bangkok, Thailand (pp. 6-7).

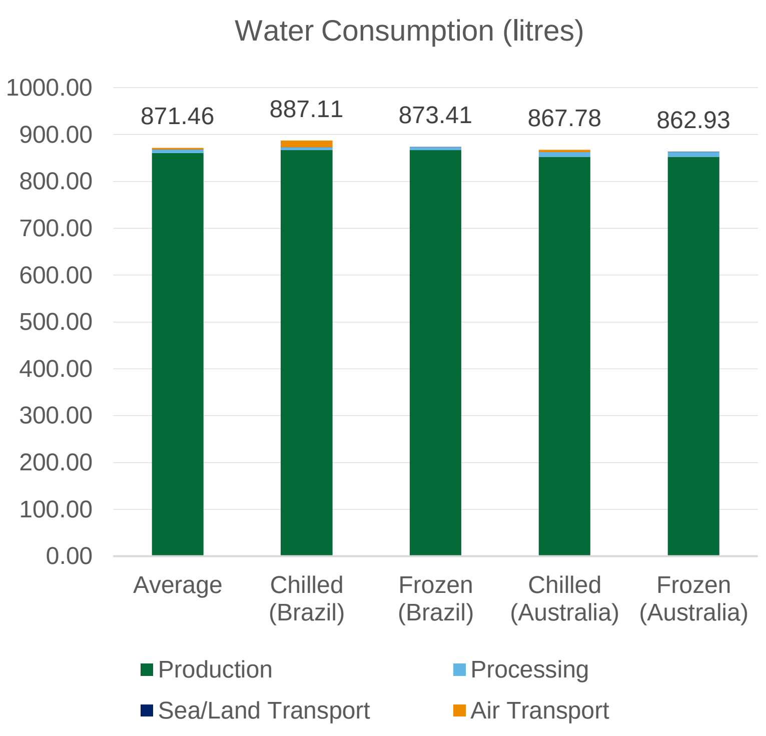
Zabaniotou, A., & Kassidi, E. (2003). Life cycle assessment applied to egg packaging made from polystyrene and recycled paper. Journal of Cleaner Production, 11(5), 549-559.

7. Annex A: Environmental Impact of the 13 Key Food Items

Environmental impact of 1 kg of beef

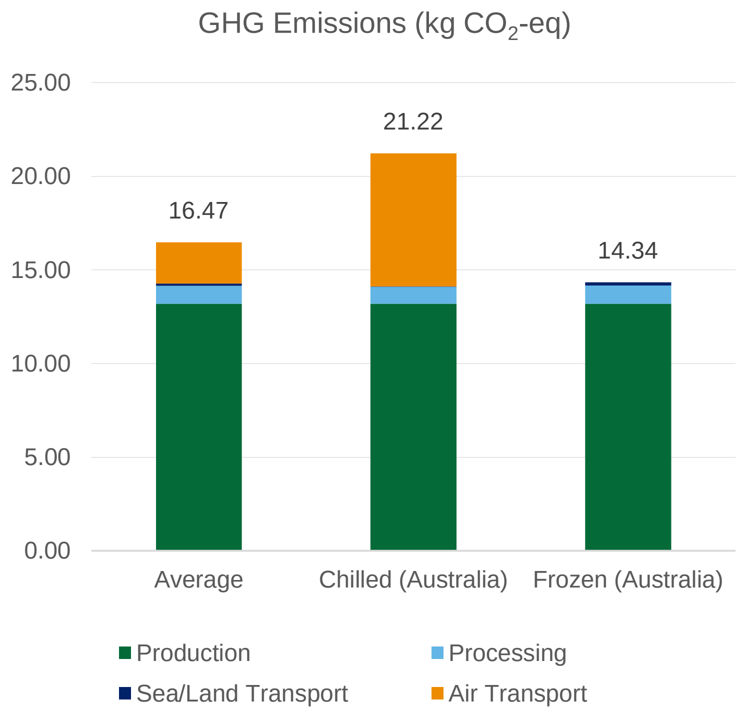


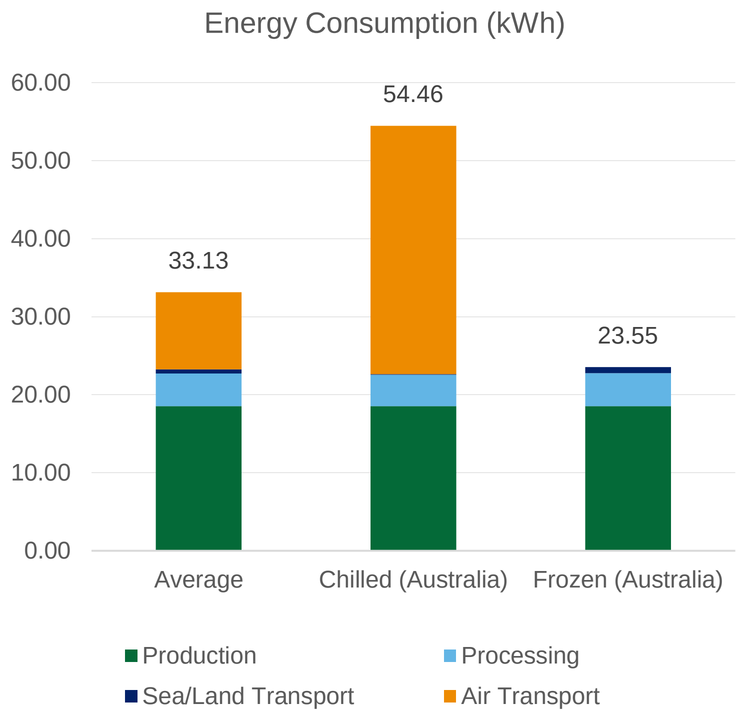


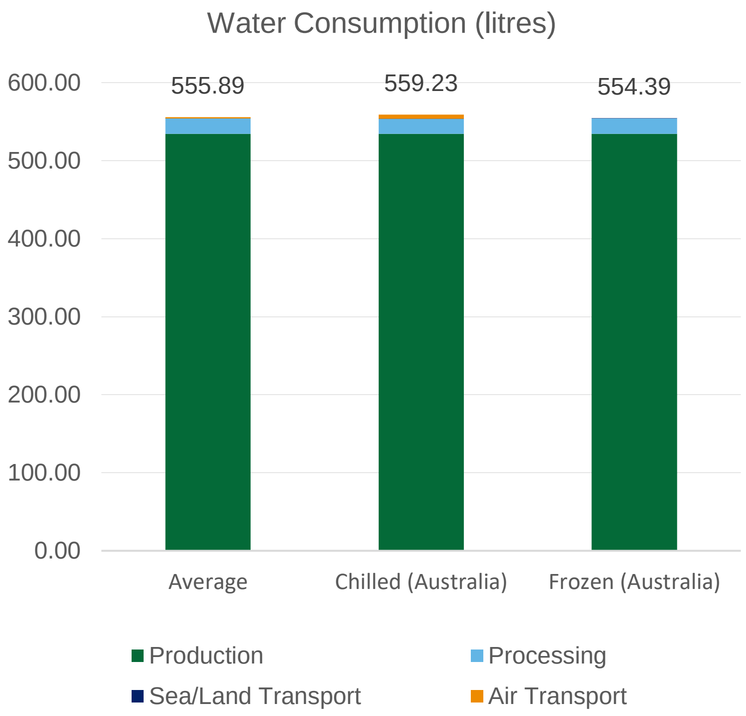


Note: Average is based on the percentage contribution of specific food items and the country of import.

Environmental impact of 1 kg of mutton

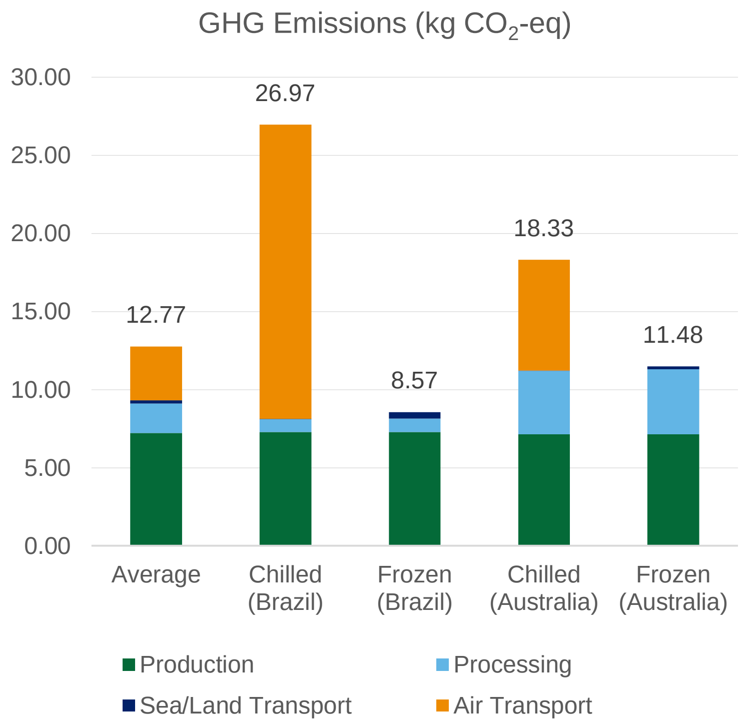


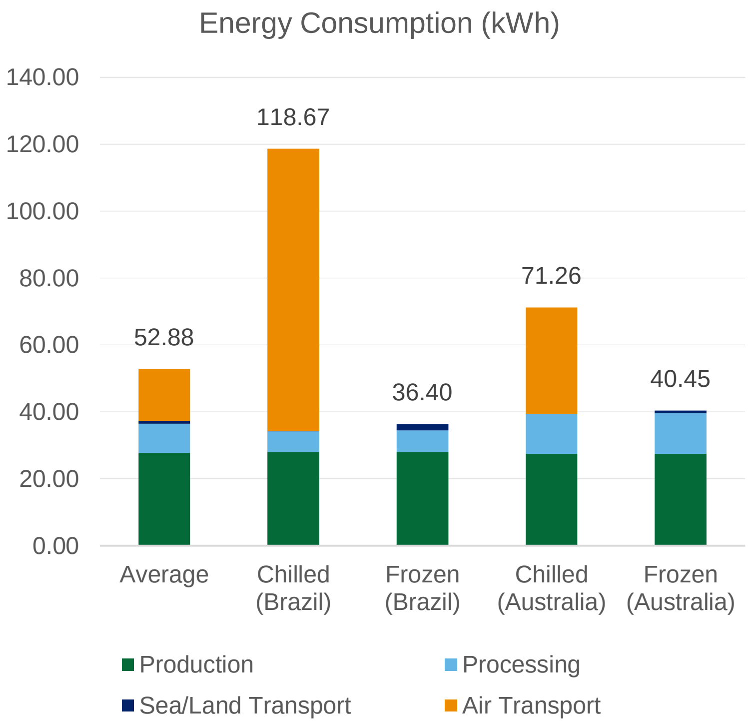


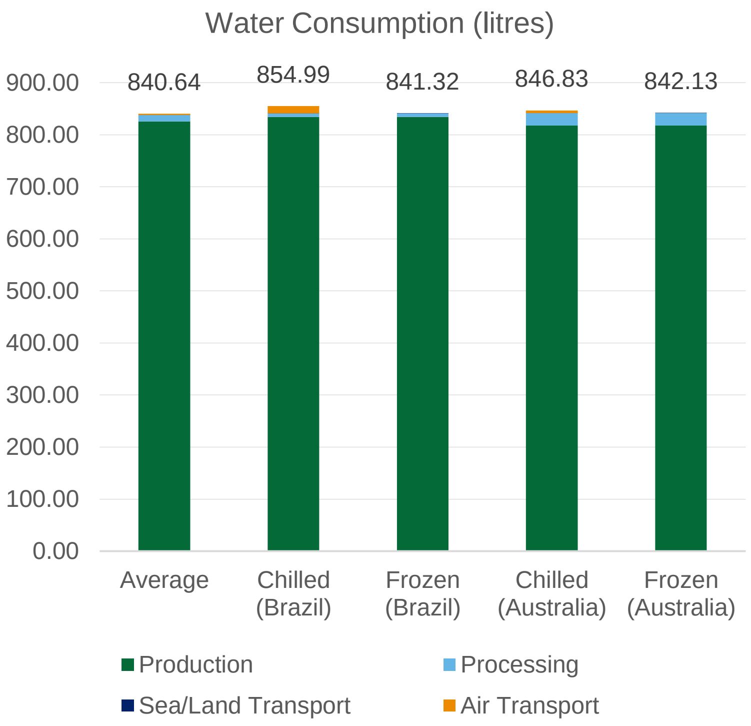


Note: Average is based on the percentage contribution of specific food items and the country of import.

Environmental impact of 1 kg of pork

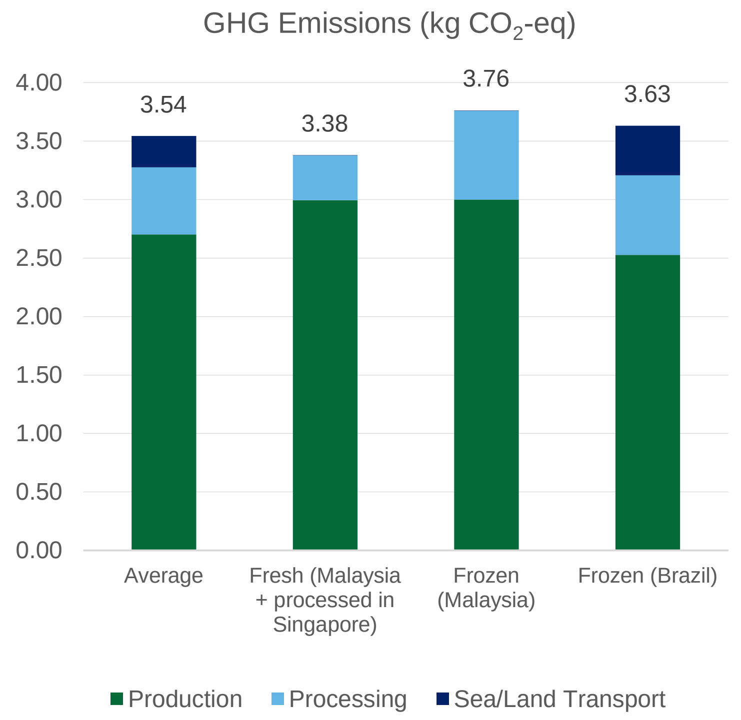


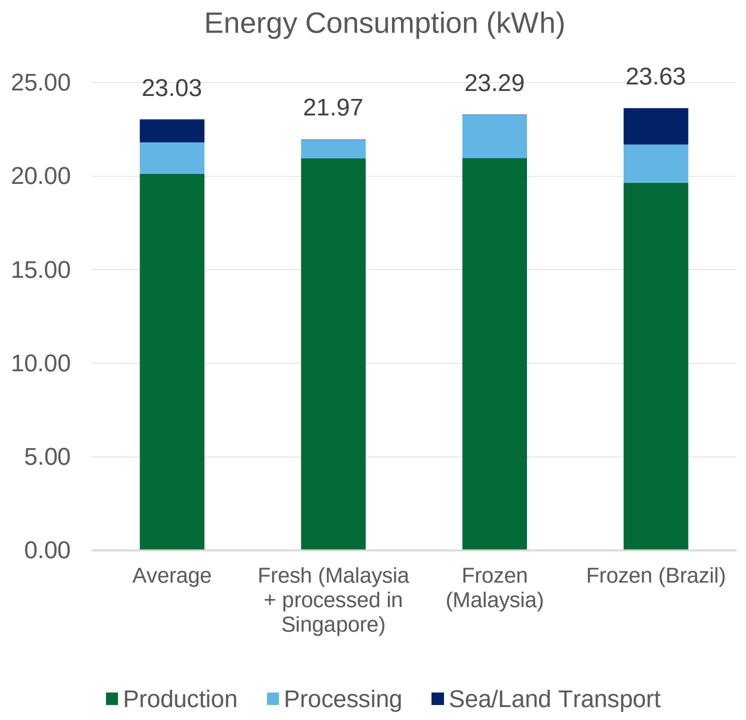


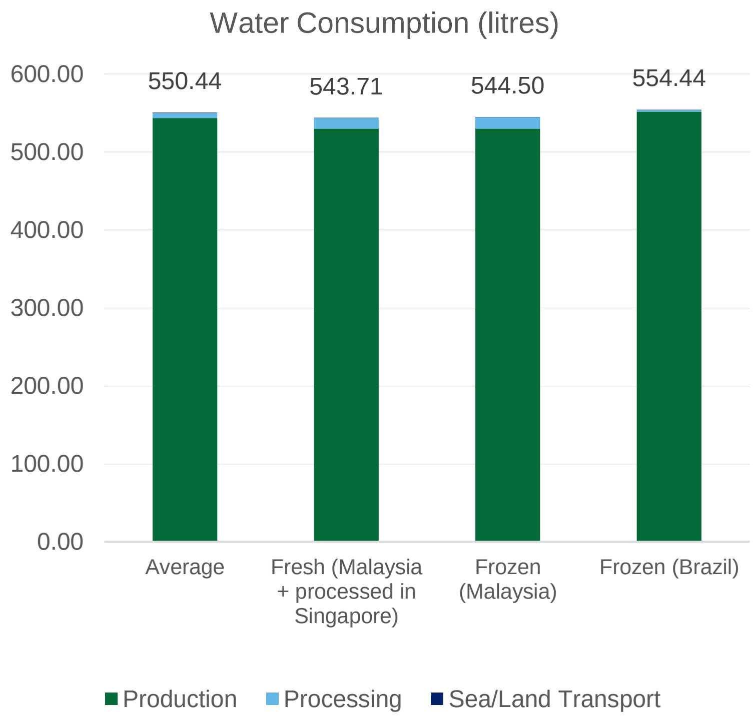


Note: Average is based on the percentage contribution of specific food items and the country of import.

Environmental impact of 1 kg of chicken

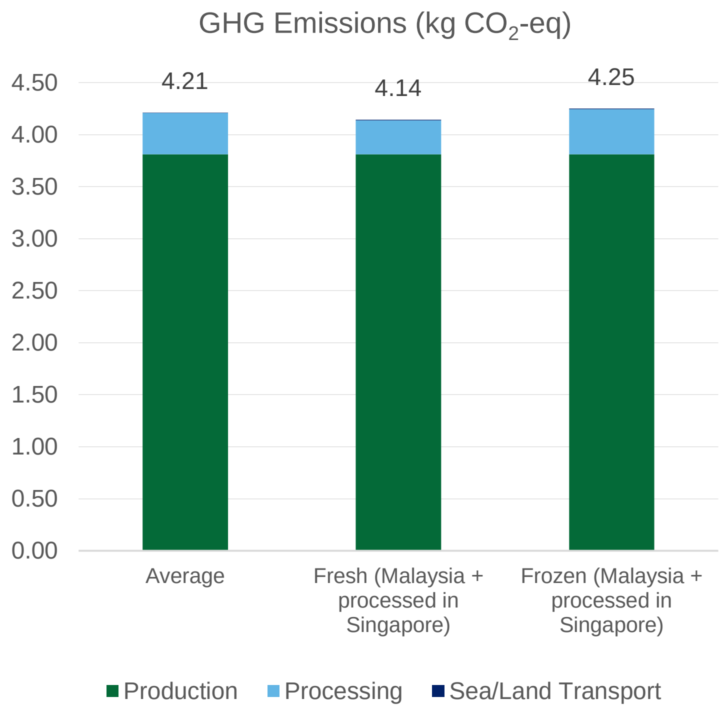


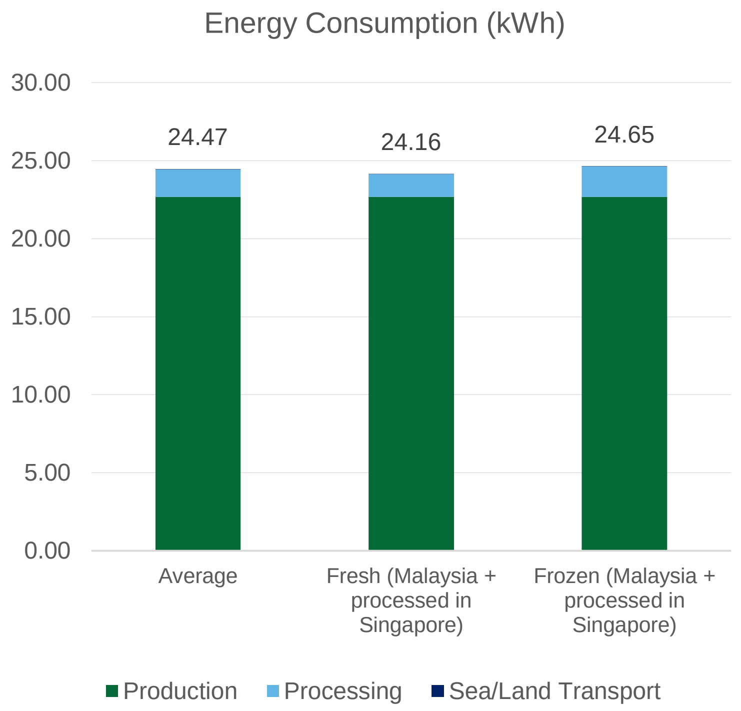


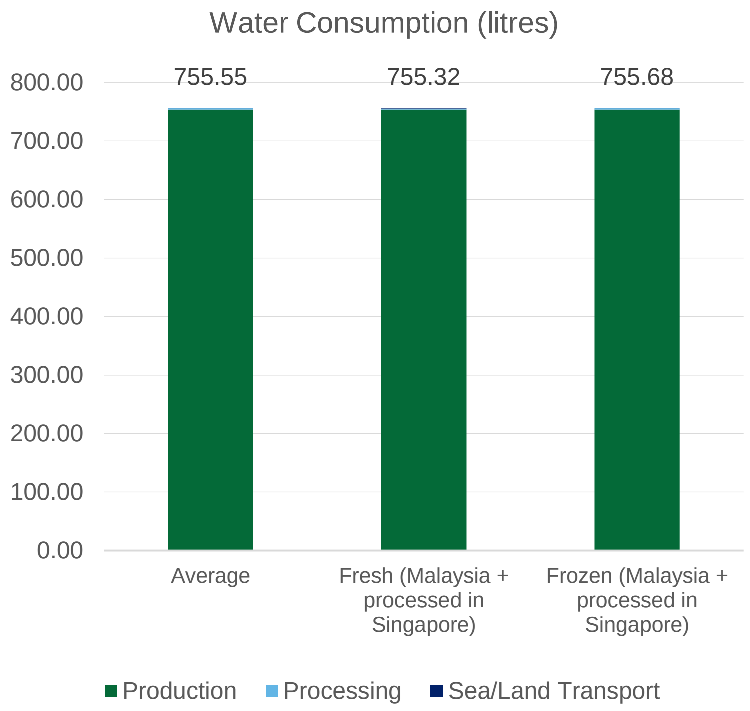


Note: Average is based on the percentage contribution of specific food items and the country of import.

Environmental impact of 1 kg of duck

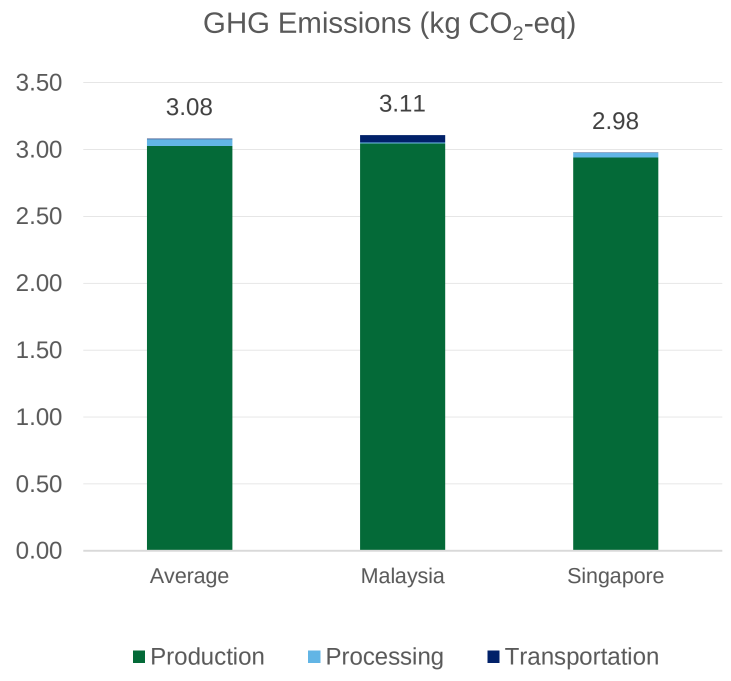


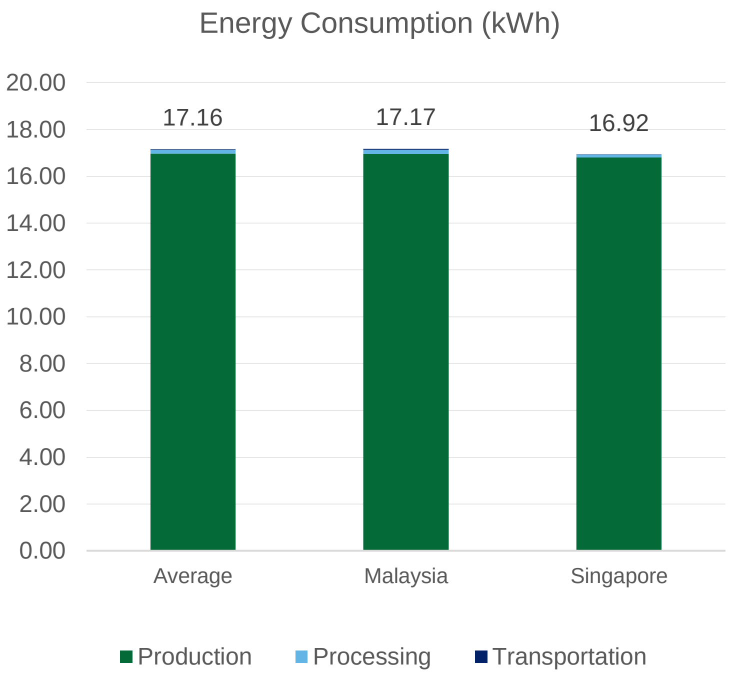


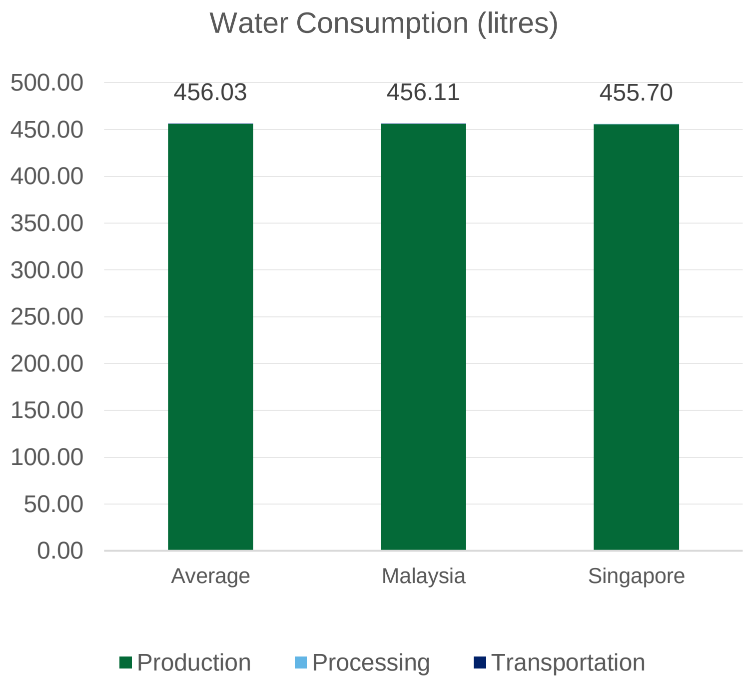


Note: Average is based on the percentage contribution of specific food items and the country of import.

Environmental impact of 1 kg of eggs

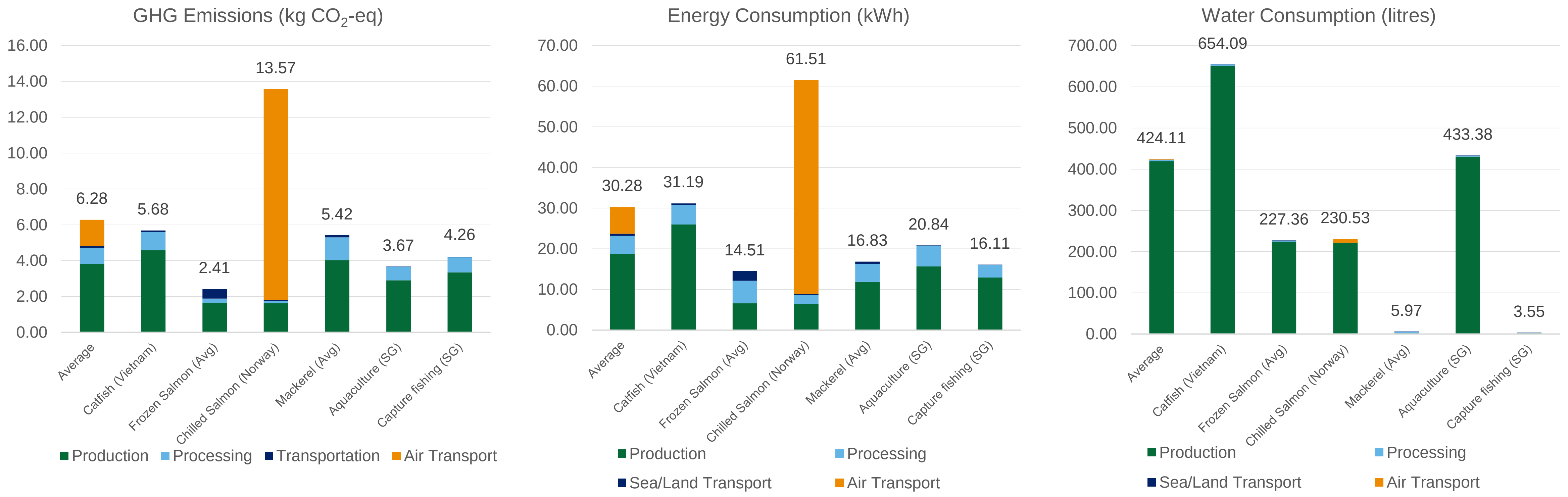






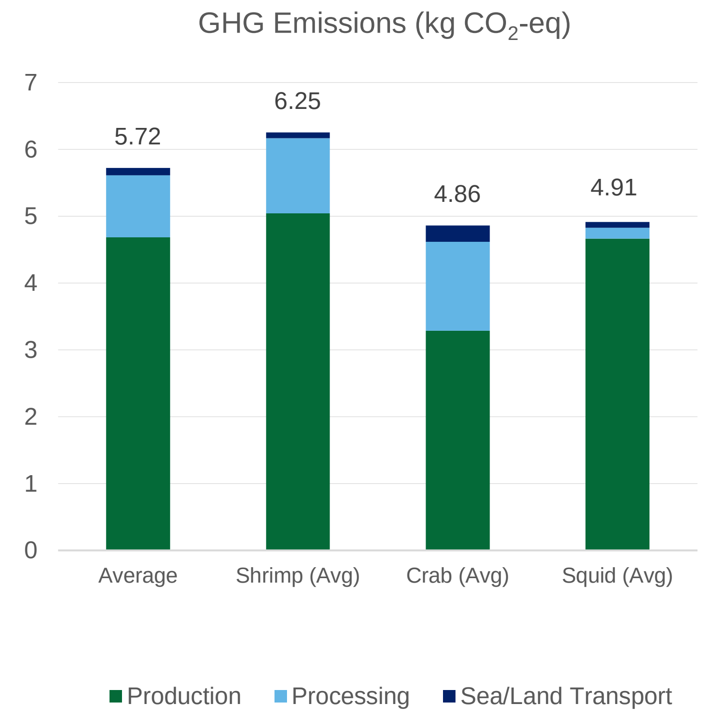
Note: Average is based on the percentage contribution of specific food items and the country of import.

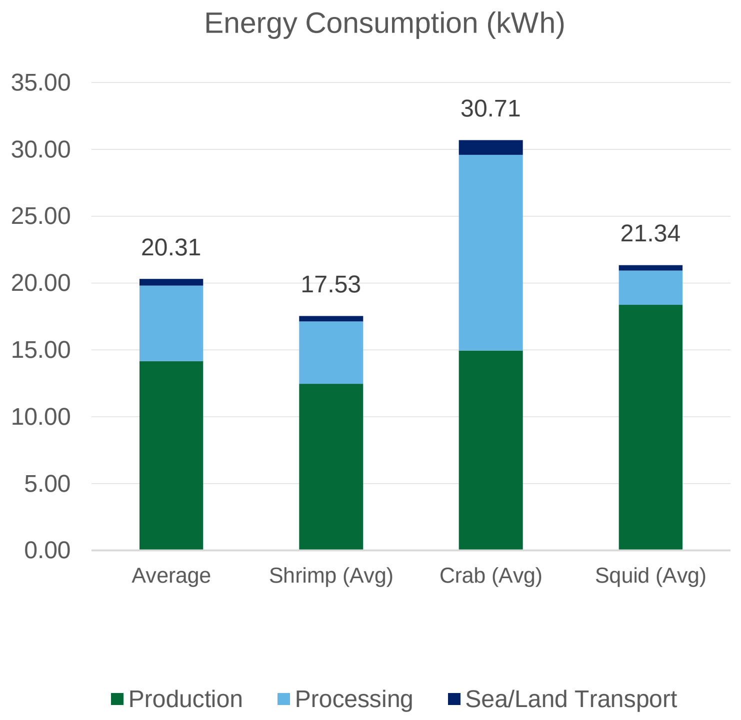
Environmental impact of 1 kg of fish

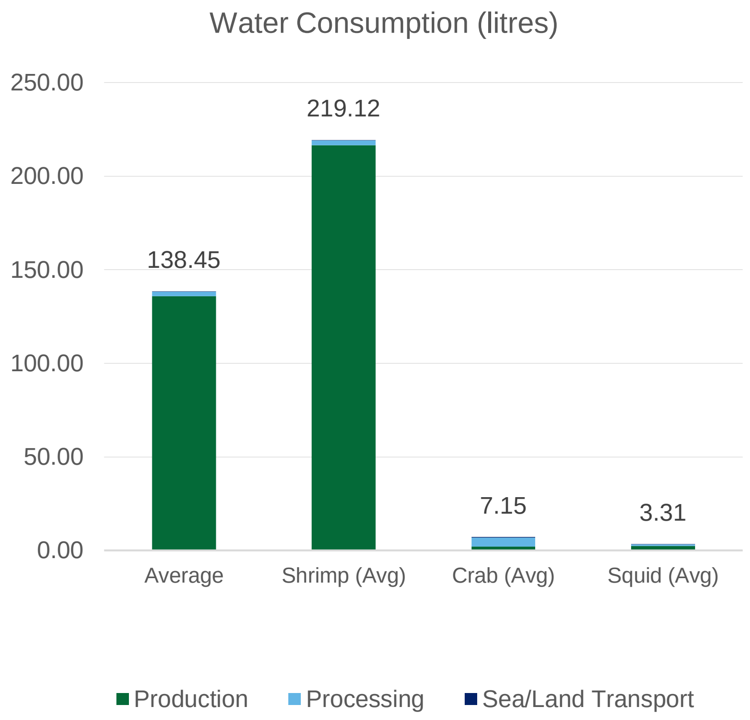


Note: Average is based on the percentage contribution of specific food items and the country of import.

Environmental impact of 1 kg of other seafood

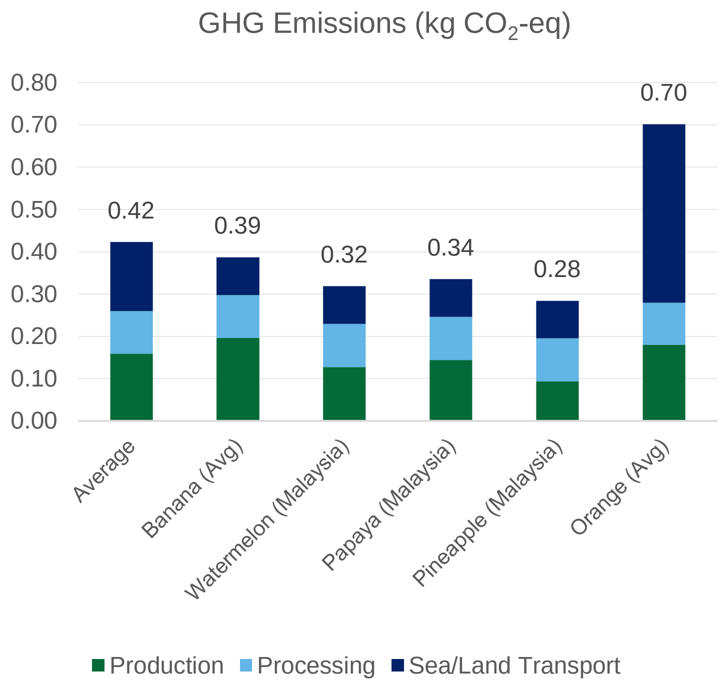


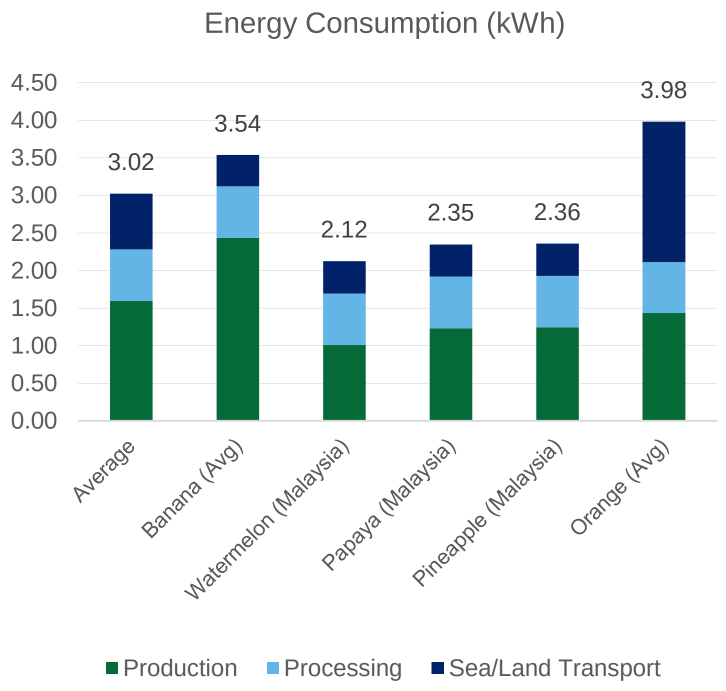


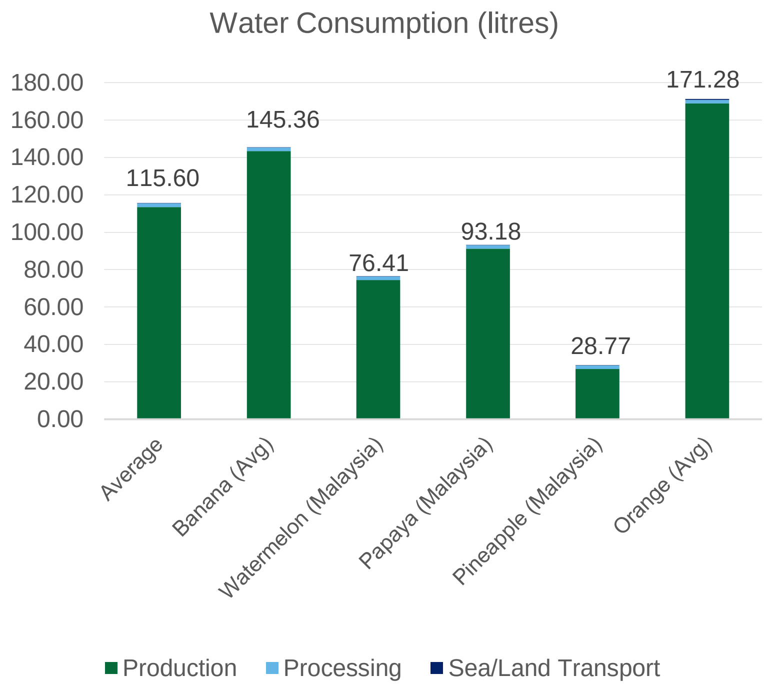


Note: Average is based on the percentage contribution of specific food items and the country of import.

Environmental impact of 1 kg of fruits

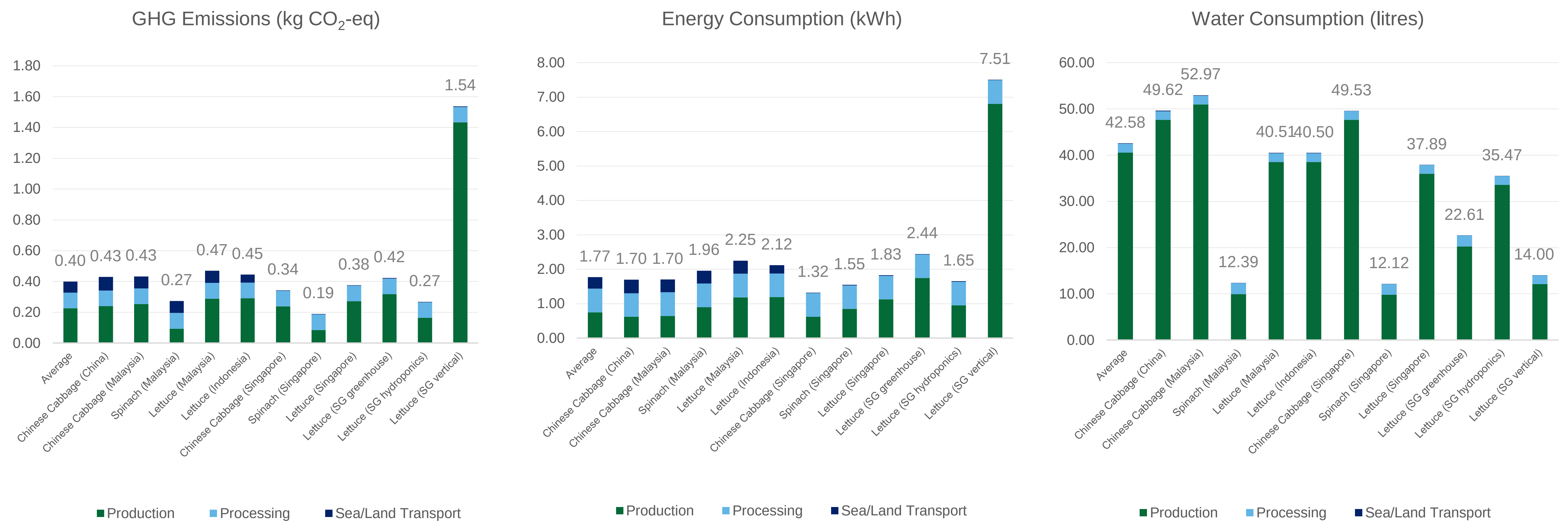






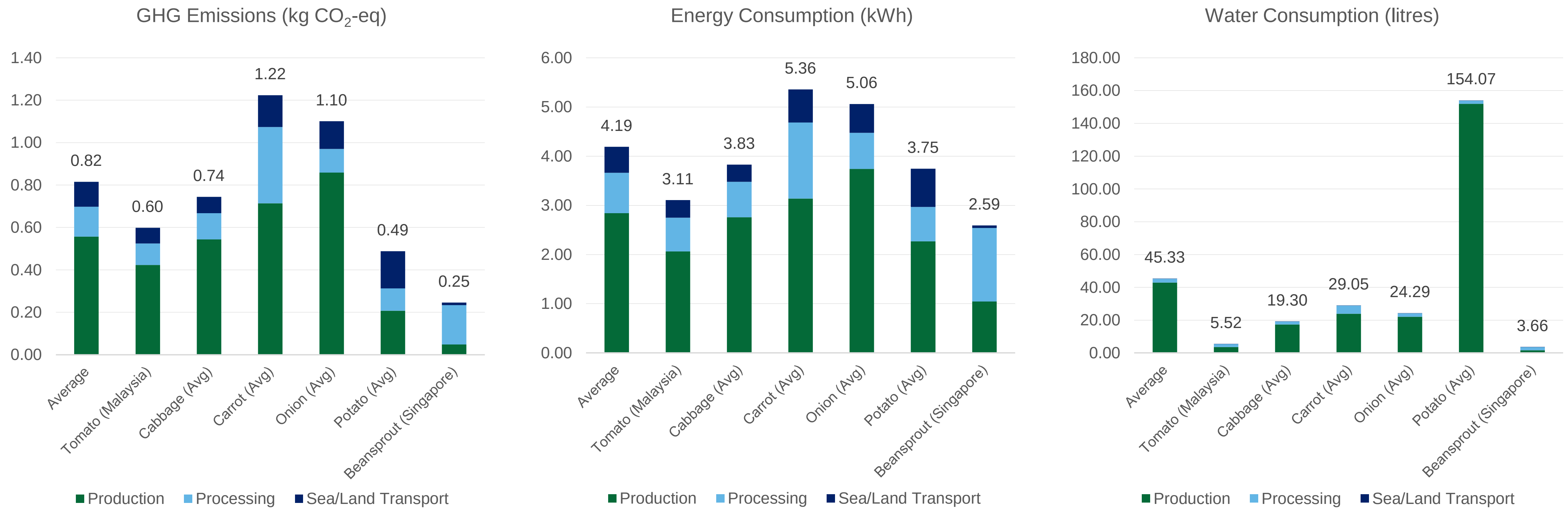
Note: Average is based on the percentage contribution of specific food items and the country of import.

Environmental impact of 1 kg of leafy vegetables



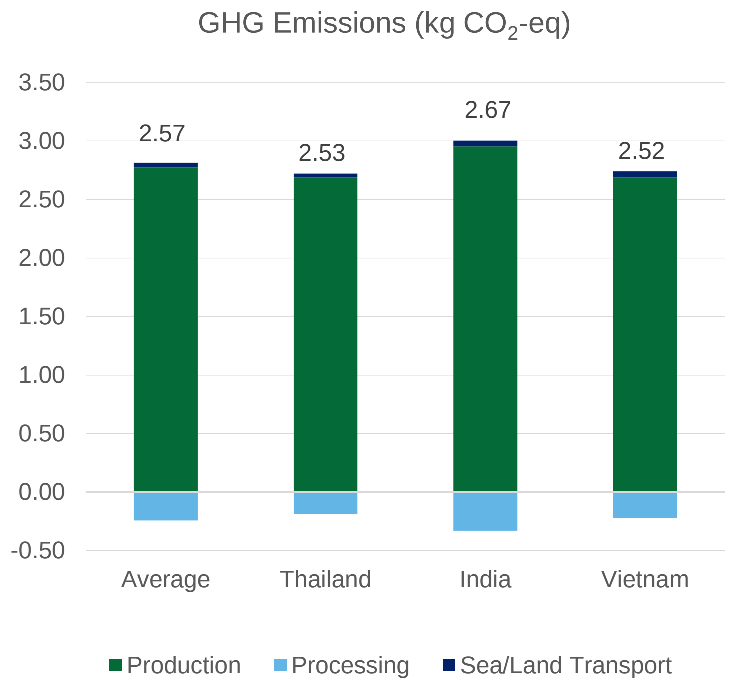
Note: Lettuce (SG greenhouse) refers to greenhouse soil-cultivated production with non-vertical farming. Lettuce (SG hydroponics) refers to non-greenhouse hydroponics production with non-vertical farming. Lettuce (SG vertical) refers to greenhouse hydroponics production with vertical farming. In all cases, no heating or artificial lighting is considered.

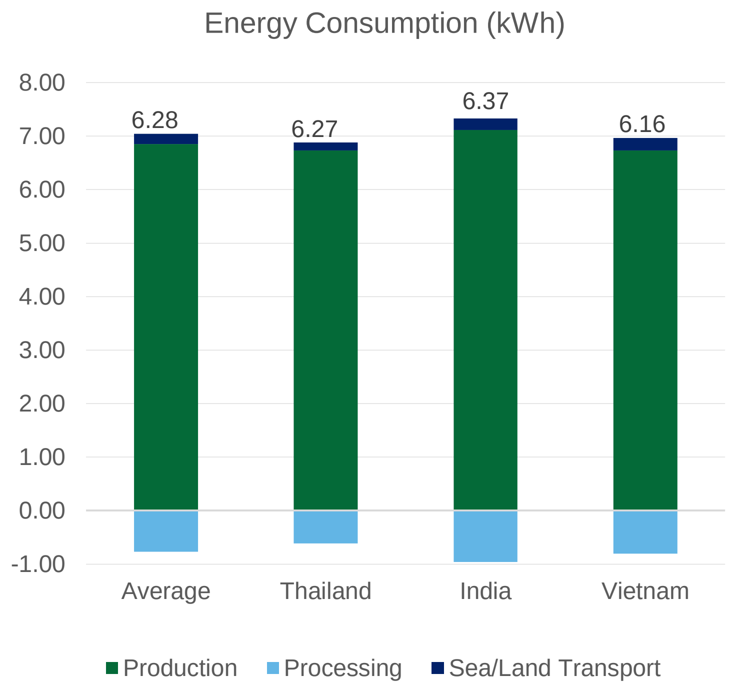
Environmental impact of 1 kg of other vegetables

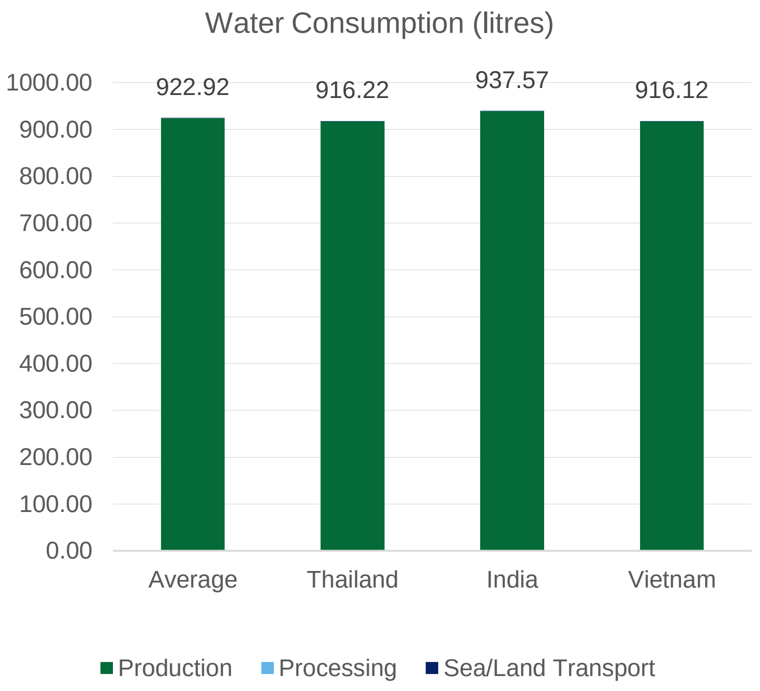


Note: Average is based on the percentage contribution of specific food items and the country of import.

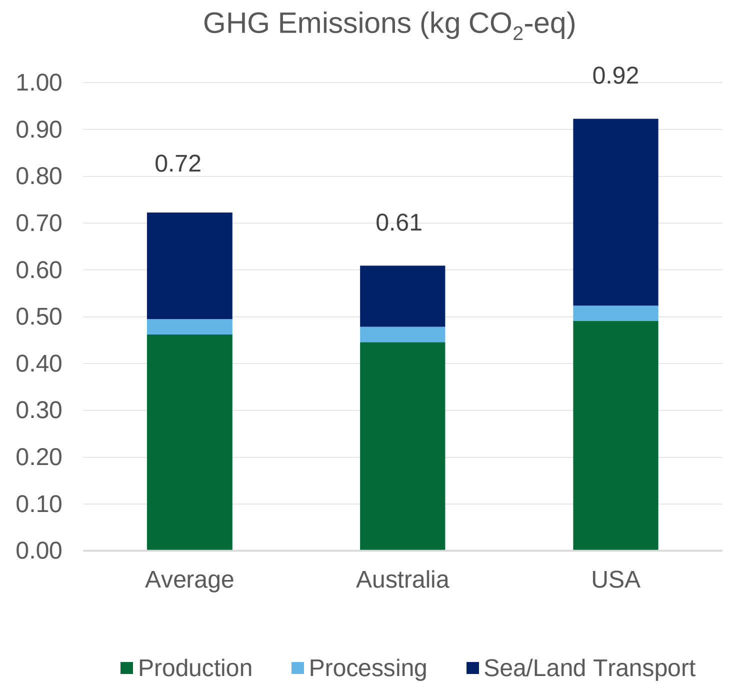
Environmental impact of 1 kg of rice

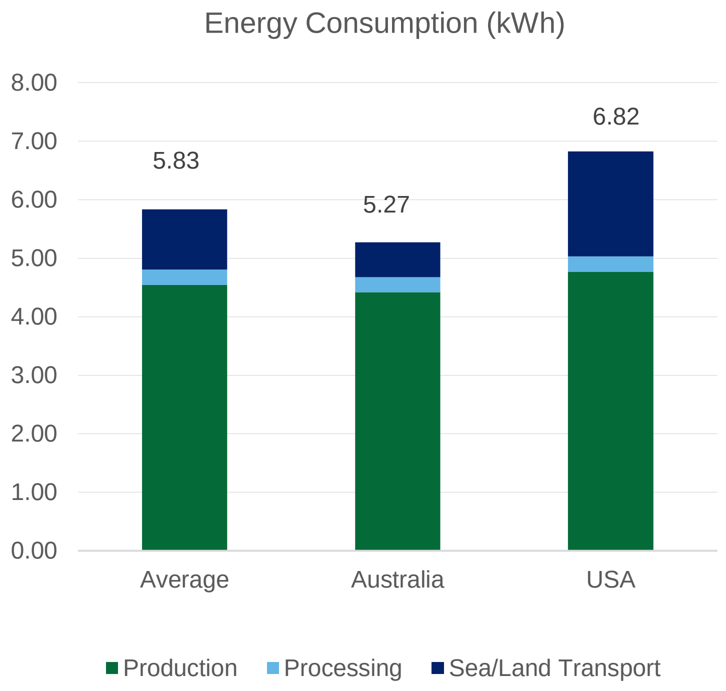


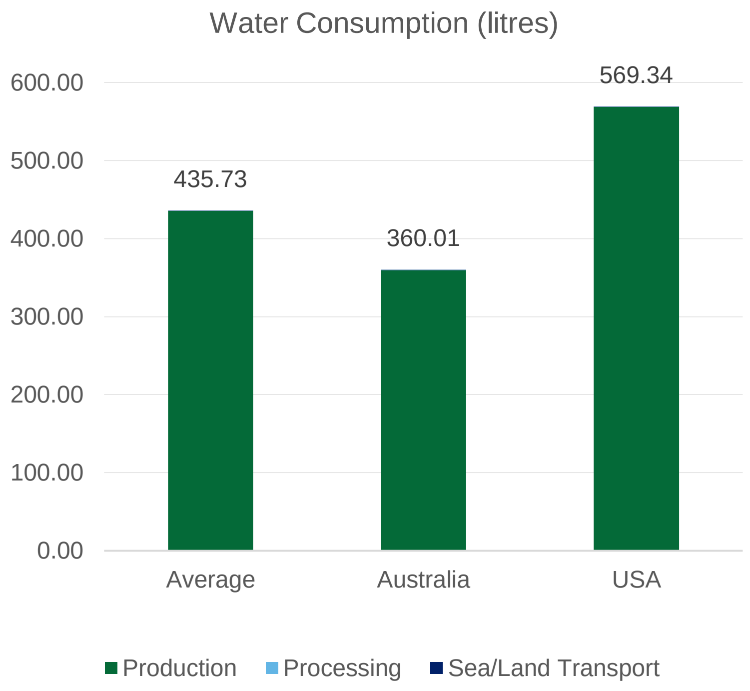




Environmental impact of 1 kg of wheat







Note: Average is based on the percentage contribution of specific food items and the country of import.

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Key Food Item
Chicken (kg meat)	Fresh	Malaysia + processed in Singapore	GHG Emissions	kg CO_2-eq	3.380368	2.995031	0.38144	0.003897	36%
			Energy Consumption	kWh	21.969	20.95033	1.000041	0.018625	
			Water Consumption	litres	543.7095	530.1613	13.54397	0.00432	
	Frozen	Malaysia	GHG Emissions	kg CO_2-eq	3.763021	2.998928	0.761379	0.002714	1%
			Energy Consumption	kWh	23.29289	20.96896	2.310853	0.013085	
			Water Consumption	litres	544.5041	530.1656	14.3	0.00296	
		Brazil	GHG Emissions	kg CO_2-eq	3.63258	2.527702	0.680492	0.424386	46%
			Energy Consumption	kWh	23.63409	19.64725	2.033393	1.953449	
			Water Consumption	litres	554.4439	551.7638	2.157743	0.522355	
Duck (kg meat)	Fresh	Malaysia + processed in Singapore	GHG Emissions	kg CO_2-eq	4.142192	3.812459	0.325677	0.004056	34%
			Energy Consumption	kWh	24.15862	22.69209	1.44714	0.019382	
			Water Consumption	litres	755.3193	753.7943	1.520562	0.004496	
	Frozen	Malaysia + processed in Singapore	GHG Emissions	kg CO_2-eq	4.250369	3.812459	0.433854	0.004056	60%
			Energy Consumption	kWh	24.65039	22.69209	1.938915	0.019382	
			Water Consumption	litres	755.6846	753.7943	1.885818	0.004496	
Mutton (kg meat)	Chilled	Australia	GHG Emissions	kg CO_2-eq	21.2201	13.19894	0.900921	7.120243	30%
			Energy Consumption	kWh	54.4563	18.54286	4.03252	31.88092	
			Water Consumption	litres	559.2277	534.2696	19.57792	5.380136	
	Frozen	Australia	GHG Emissions	kg CO_2-eq	14.34296	13.19894	0.967689	0.176332	70%
			Energy Consumption	kWh	23.55382	18.54286	4.226962	0.783995	
			Water Consumption	litres	554.3851	534.2696	19.90721	0.208239	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Key Food Item
Pork (kg meat)	Fresh	Indonesia + processed in Singapore	GHG Emissions	kg CO_2-eq	9.00934731	7.22039819	1.7484542	0.04049491	17%
			Energy Consumption	kWh	36.3562596	27.8194819	8.35273176	0.18404597	
			Water Consumption	litres	836.689216	825.609536	11.0328988	0.04678044	
	Chilled	Brazil	GHG Emissions	kg CO_2-eq	26.9740328	7.2956226	0.81951735	18.8588928	10%
			Energy Consumption	kWh	118.671078	28.1040681	6.13965788	84.4273521	
			Water Consumption	litres	854.989734	834.045794	6.70111408	14.2428261	
		Australia	GHG Emissions	kg CO_2-eq	18.3298817	7.13954458	4.07009369	7.12024343	4%
			Energy Consumption	kWh	71.2620622	27.5491043	11.8343304	31.8786274	
			Water Consumption	litres	846.825389	817.660082	23.7851704	5.38013636	
	Frozen	Brazil	GHG Emissions	kg CO_2-eq	8.56600375	7.2956226	0.84836555	0.4220156	24%
			Energy Consumption	kWh	36.3957043	28.1040681	6.42275666	1.86887957	
			Water Consumption	litres	841.317456	834.045794	6.7713812	0.50028023	
		Australia	GHG Emissions	kg CO_2-eq	11.4827046	7.13954458	4.16682801	0.17633204	8%
			Energy Consumption	kWh	40.4501858	27.5491043	12.1171432	0.78393822	
			Water Consumption	litres	842.12738	817.660082	24.2590585	0.20823942	
		Netherlands	GHG Emissions	kg CO_2-eq	9.81102315	7.08577643	2.36322208	0.36202464	12%
			Energy Consumption	kWh	39.5040827	27.3518598	10.548284	1.60393892	
			Water Consumption	litres	824.355139	811.824375	12.1017885	0.42897494	
		Spain	GHG Emissions	kg CO_2-eq	9.36335679	7.2956226	1.77765705	0.29007714	6%
			Energy Consumption	kWh	39.9909123	28.1040681	10.6006035	1.28624071	
			Water Consumption	litres	847.050753	834.045794	12.6615132	0.34344598	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Key Food Item
Beef (kg meat)	Chilled	Brazil	GHG Emissions	kg CO_2-eq	38.38723	18.83387	0.694466	18.85889	16%
			Energy Consumption	kWh	106.1078	16.91075	4.763607	84.43343	
			Water Consumption	litres	887.1052	867.0229	5.839463	14.24283	
		Australia	GHG Emissions	kg CO_2-eq	27.49682	18.85724	1.519332	7.120243	8%
			Energy Consumption	kWh	54.65465	16.76855	6.005179	31.88092	
			Water Consumption	litres	867.7766	852.116	10.28049	5.380136	
		New Zealand	GHG Emissions	kg CO_2-eq	29.29078	18.76068	0.632927	9.897177	3%
			Energy Consumption	kWh	65.28326	16.55886	4.411483	44.31291	
			Water Consumption	litres	864.9728	851.6393	5.856836	7.476722	
	Frozen	Brazil	GHG Emissions	kg CO_2-eq	19.9699	18.83387	0.714009	0.422016	36%
			Energy Consumption	kWh	23.73801	16.91075	4.958246	1.869014	
			Water Consumption	litres	873.4112	867.0229	5.887969	0.50028	
		Australia	GHG Emissions	kg CO_2-eq	20.61967	18.85724	1.5861	0.176332	20%
			Energy Consumption	kWh	23.75217	16.76855	6.199621	0.783995	
			Water Consumption	litres	862.934	852.116	10.60978	0.208239	
		New Zealand	GHG Emissions	kg CO_2-eq	19.64468	18.76068	0.648534	0.235474	8%
			Energy Consumption	kWh	22.20997	16.55886	4.605926	1.045184	
			Water Consumption	litres	857.8354	851.6393	5.917614	0.278541	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Key Food Item
Eggs (kg)	Fresh	Malaysia	GHG Emissions	kg CO_2-eq	3.10849	3.045769	0.055363	0.007358	81%
			Energy Consumption	kWh	17.21907	17.00257	0.181337	0.035165	
			Water Consumption	litres	456.1129	455.8614	0.243262	0.008157	
		Singapore	GHG Emissions	kg CO_2-eq	2.955663	2.924229	0.031273	0.000161	
			Energy Consumption	kWh	16.92422	16.80427	0.11918	0.000771	19%
			Water Consumption	litres	455.6971	455.5065	0.190444	0.000179	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Fruits (kg)	Banana	Malaysia	GHG Emissions	kg CO_2-eq	0.382615	0.191647	0.101987	0.088981	41%
			Energy Consumption	kWh	3.538681	2.423172	0.687575	0.427935	
			Water Consumption	litres	147.5876	145.5886	1.902155	0.0969	
		Philippines	GHG Emissions	kg CO_2-eq	0.390919	0.199766	0.101987	0.089166	42%
			Energy Consumption	kWh	3.534318	2.44772	0.687575	0.399024	
			Water Consumption	litres	143.1916	141.1891	1.902155	0.100377	
	Watermelon	Malaysia	GHG Emissions	kg CO_2-eq	0.318382	0.127414	0.101987	0.088981	99%
			Energy Consumption	kWh	2.123419	1.007909	0.687575	0.427935	
			Water Consumption	litres	76.40728	74.40823	1.902155	0.0969	
	Papaya	Malaysia	GHG Emissions	kg CO_2-eq	0.335058	0.14409	0.101987	0.088981	97%
			Energy Consumption	kWh	2.347446	1.231937	0.687575	0.427935	
			Water Consumption	litres	93.18457	91.18551	1.902155	0.0969	
	Pineapple	Malaysia	GHG Emissions	kg CO_2-eq	0.28408	0.093112	0.101987	0.088981	84%
			Energy Consumption	kWh	2.357335	1.241826	0.687575	0.427935	
			Water Consumption	litres	28.76637	26.76732	1.902155	0.0969	
	Orange	Australia	GHG Emissions	kg CO_2-eq	0.50028	0.19825	0.096674	0.205356	24%
			Energy Consumption	kWh	3.012304	1.436364	0.664308	0.911632	
			Water Consumption	litres	172.5841	170.5412	1.811324	0.231592	
		USA	GHG Emissions	kg CO_2-eq	0.996865	0.156613	0.096674	0.743579	31%
			Energy Consumption	kWh	5.372426	1.420645	0.664308	3.287473	
			Water Consumption	litres	173.0522	170.4015	1.811324	0.839338	
		South Africa	GHG Emissions	kg CO_2-eq	0.593861	0.196074	0.101987	0.295801	20%
			Energy Consumption	kWh	3.427926	1.429191	0.687575	1.31116	
			Water Consumption	litres	162.0502	159.8144	1.902155	0.333703	
		Egypt	GHG Emissions	kg CO_2-eq	0.566273	0.180691	0.10312	0.282461	16%
			Energy Consumption	kWh	3.422117	1.477244	0.692538	1.252335	
			Water Consumption	litres	177.4357	175.1955	1.921532	0.318637	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Other Vegetables (kg)	Tomato	Malaysia	GHG Emissions	kg CO_2-eq	0.598867	0.422768	0.101987	0.074113	96%
			Energy Consumption	kWh	3.107066	2.062612	0.687575	0.356879	
			Water Consumption	litres	5.517014	3.53444	1.902155	0.080419	
	Cabbage	China	GHG Emissions	kg CO_2-eq	0.741585	0.534582	0.122128	0.084875	65%
			Energy Consumption	kWh	3.801334	2.699213	0.721776	0.380345	
			Water Consumption	litres	18.90912	16.90804	1.905877	0.095213	
		Indonesia	GHG Emissions	kg CO_2-eq	0.753856	0.579226	0.126156	0.048473	18%
			Energy Consumption	kWh	3.918827	2.967108	0.731996	0.219722	
			Water Consumption	litres	20.74055	18.7585	1.927948	0.054103	
	Carrot	Australia	GHG Emissions	kg CO_2-eq	1.318346	0.743562	0.356276	0.218508	47%
			Energy Consumption	kWh	5.744501	3.240385	1.533757	0.970359	
			Water Consumption	litres	30.05421	24.87218	4.935932	0.246094	
		China	GHG Emissions	kg CO_2-eq	1.173404	0.744659	0.344782	0.083962	31%
			Energy Consumption	kWh	4.967622	3.099317	1.49205	0.376255	
			Water Consumption	litres	28.12657	23.25057	4.781811	0.09419	
		Malaysia	GHG Emissions	kg CO_2-eq	1.063548	0.584422	0.395864	0.083263	18%
			Energy Consumption	kWh	5.007851	2.9295	1.677412	0.400939	
			Water Consumption	litres	28.01693	22.45979	5.466791	0.090347	
	Beansprout	Singapore	GHG Emissions	kg CO_2-eq	0.245715	0.048299	0.185325	0.012091	86%
			Energy Consumption	kWh	2.592055	1.045716	1.492056	0.054283	
			Water Consumption	litres	3.65581	1.649057	1.993202	0.013553	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Other Vegetables (kg)	Onion	China	GHG Emissions	kg CO_2-eq	0.990663	0.806908	0.099793	0.083962	8%
			Energy Consumption	kWh	4.438323	3.3841	0.677968	0.376255	
			Water Consumption	litres	23.84281	21.88397	1.86465	0.09419	
		Malaysia	GHG Emissions	kg CO_2-eq	0.843198	0.645356	0.11458	0.083263	15%
			Energy Consumption	kWh	4.351549	3.207886	0.742725	0.400939	
			Water Consumption	litres	23.33236	21.12456	2.117458	0.090347	
		India	GHG Emissions	kg CO_2-eq	1.186481	0.973262	0.11458	0.098639	53%
			Energy Consumption	kWh	5.209529	4.02493	0.742725	0.441874	
			Water Consumption	litres	24.65833	22.4302	2.117458	0.11067	
		Netherlands	GHG Emissions	kg CO_2-eq	1.119623	0.57053	0.101987	0.447106	9%
			Energy Consumption	kWh	5.945777	3.278819	0.687575	1.979383	
			Water Consumption	litres	24.0854	21.67901	1.902155	0.504229	
	Potato	Bangladesh	GHG Emissions	kg CO_2-eq	0.414978	0.202175	0.11458	0.098222	11%
			Energy Consumption	kWh	3.4443	2.261539	0.742725	0.440037	
			Water Consumption	litres	151.2954	149.0677	2.117458	0.1102	
		China	GHG Emissions	kg CO_2-eq	0.396377	0.212621	0.099793	0.083962	45%
			Energy Consumption	kWh	3.310227	2.256003	0.677968	0.376255	
			Water Consumption	litres	154.4677	152.5089	1.86465	0.09419	
		Indonesia	GHG Emissions	kg CO_2-eq	0.371213	0.202175	0.11458	0.054458	8%
			Energy Consumption	kWh	3.251112	2.261539	0.742725	0.246848	
			Water Consumption	litres	151.246	149.0677	2.117458	0.060782	
		Pakistan	GHG Emissions	kg CO_2-eq	0.483097	0.202175	0.11458	0.166341	10%
			Energy Consumption	kWh	3.744994	2.261539	0.742725	0.74073	
			Water Consumption	litres	151.3723	149.0677	2.117458	0.187118	
		USA	GHG Emissions	kg CO_2-eq	1.096731	0.201	0.10312	0.792612	10%
			Energy Consumption	kWh	6.529572	2.332445	0.692538	3.504589	
			Water Consumption	litres	160.4084	157.5925	1.921532	0.894357	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Wheat (kg)	Wheat	Australia	GHG Emissions	kg CO_2-eq	0.609043	0.445611	0.033018	0.130414	60%
			Energy Consumption	kWh	5.27265	4.419873	0.25851	0.594268	
			Water Consumption	litres	360.0115	359.826	0.030527	0.154908	
		USA	GHG Emissions	kg CO_2-eq	0.923174	0.490742	0.032978	0.399453	34%
			Energy Consumption	kWh	6.824875	4.770377	0.258532	1.795966	
			Water Consumption	litres	569.3428	568.8287	0.030301	0.483853	
Rice (kg)	Rice	Thailand	GHG Emissions	kg CO_2-eq	2.533341	2.688972	-0.188235	0.032605	40%
			Energy Consumption	kWh	6.270161	6.731953	-0.611380	0.149587	
			Water Consumption	litres	916.221650	917.122100	-0.938770	0.038302	
		India	GHG Emissions	kg CO_2-eq	2.671638	2.954330	-0.330820	0.048128	29%
			Energy Consumption	kWh	6.372628	7.113782	-0.960090	0.218936	
			Water Consumption	litres	937.566055	938.965400	-1.456620	0.057275	
		Vietnam	GHG Emissions	kg CO_2-eq	2.518485	2.688972	-0.221641	0.051153	23%
			Energy Consumption	kWh	6.161840	6.731953	-0.802540	0.232430	
			Water Consumption	litres	916.120389	917.122100	-1.062710	0.061000	
Leafy vegetables (kg)	Chinese Cabbage	China	GHG Emissions	kg CO_2-eq	0.429858	0.240616	0.100878	8.84E-02	53%
			Energy Consumption	kWh	1.697833	0.617993	0.682719	0.397121	
			Water Consumption	litres	49.62431	47.6421	1.883198	0.099014	
		Malaysia	GHG Emissions	kg CO_2-eq	0.43304	0.253411	0.101987	7.76E-02	18%
			Energy Consumption	kWh	1.703154	0.641726	0.687575	0.373853	
			Water Consumption	litres	52.97003	50.98361	1.902155	0.084265	
		Singapore	GHG Emissions	kg CO_2-eq	0.342679	0.238802	0.100878	3.00E-03	5%
			Energy Consumption	kWh	1.319076	0.621921	0.682719	0.014436	
			Water Consumption	litres	49.53329	47.64684	1.883198	0.003258	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Leafy Vegetables (kg)	Spinach	Malaysia	GHG Emissions	kg CO_2-eq	0.273495	0.093198	0.102448	0.077848	69%
			Energy Consumption	kWh	1.960628	0.89654	0.689252	0.374835	
			Water Consumption	litres	12.39289	9.948948	2.35945	0.084493	
		Singapore	GHG Emissions	kg CO_2-eq	0.18902	0.084638	0.101334	0.003047	3%
			Energy Consumption	kWh	1.547779	0.848736	0.684378	0.014665	
			Water Consumption	litres	12.11771	9.778871	2.335524	0.003311	
	Lettuce	Malaysia	GHG Emissions	kg CO_2-eq	0.469264	0.289027	0.101987	0.07825	56%
			Energy Consumption	kWh	2.250134	1.185804	0.687575	0.376755	
			Water Consumption	litres	40.51441	38.52732	1.902155	0.084938	
		Indonesia	GHG Emissions	kg CO_2-eq	0.445305	0.290708	0.101987	0.05261	10%
			Energy Consumption	kWh	2.119376	1.192204	0.687575	0.239598	
			Water Consumption	litres	40.49578	38.53501	1.902155	0.058622	
		Singapore (Soil-cultivated)	GHG Emissions	kg CO_2-eq	0.375591	0.271572	0.100878	0.003141	0.2%
			Energy Consumption	kWh	1.826109	1.128276	0.682719	0.015114	
			Water Consumption	litres	37.89475	36.00814	1.8832	0.003415	
		Singapore (Greenhouse soil-cultivated)	GHG Emissions	kg CO_2-eq	0.422315	0.317957	0.101334	0.003023	0.2%
			Energy Consumption	kWh	2.443691	1.744761	0.684378	0.014551	
			Water Consumption	litres	22.6083	20.26949	2.335524	0.003285	
		Singapore (Non-greenhouse hydroponics)	GHG Emissions	kg CO_2-eq	0.26783	0.163904	0.100878	0.003048	0.2%
			Energy Consumption	kWh	1.652446	0.955056	0.682719	0.014671	
			Water Consumption	litres	35.47109	33.58458	1.883198	0.003313	
		Singapore (Greenhouse hydroponics-vertical)	GHG Emissions	kg CO_2-eq	1.537362	1.433359	0.100878	0.003125	(Used in future scenario analysis)
			Energy Consumption	kWh	7.507604	6.809953	0.682719	0.014933	
			Water Consumption	litres	14.00427	12.11761	1.883198	0.003464	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Fish (kg meat)	Catfish	Vietnam	GHG Emissions	kg CO_2-eq	5.684848	4.577025	1.020249	0.087574	97%
			Energy Consumption	kWh	31.18636	25.98651	4.803454	0.396395	
			Water Consumption	litres	654.0944	650.4875	3.505	0.102	
	Salmon (chilled)	Norway	GHG Emissions	kg CO_2-eq	13.57337	1.638121	0.120767	11.81448	59%
			Energy Consumption	kWh	61.50662	6.420893	2.18004	52.90569	
			Water Consumption	litres	230.5335	221.0685	0.532	8.93	
	Salmon (frozen)	Norway	GHG Emissions	kg CO_2-eq	2.294267	1.715716	0.152069	0.426482	3%
			Energy Consumption	kWh	11.95619	6.72504	3.330744	1.90041	
			Water Consumption	litres	232.9262	231.5402	0.883	0.503	
		Myanmar	GHG Emissions	kg CO_2-eq	2.25376	1.698352	0.460176	0.095233	20%
			Energy Consumption	kWh	14.03711	6.813679	6.78574	0.43769	
			Water Consumption	litres	235.421	231.1164	4.196	0.109	
	Mackerel	Norway	GHG Emissions	kg CO_2-eq	4.685541	3.836092	0.445285	0.404163	23%
			Energy Consumption	kWh	15.16221	11.2934	2.068956	1.799852	
			Water Consumption	litres	2.32103	1.52562	0.319	0.477	
		China	GHG Emissions	kg CO_2-eq	5.557604	3.894808	1.566914	0.095882	31%
			Energy Consumption	kWh	16.02574	11.46626	4.120871	0.438615	
			Water Consumption	litres	5.30352	1.54897	3.644	0.11	
		Japan	GHG Emissions	kg CO_2-eq	5.171631	3.894808	1.096601	0.180222	12%
			Energy Consumption	kWh	15.58262	11.46626	3.305276	0.811086	
			Water Consumption	litres	3.77191	1.54897	2.012	0.211	
	Aquaculture	Singapore	GHG Emissions	kg CO_2-eq	3.73018	2.931717	0.791423	0.00704	81.3%
			Energy Consumption	kWh	20.83571	15.6612	5.140608	0.033898	
			Water Consumption	litres	433.3783	430.527	2.844	0.00764	
	Capture fishing	Singapore	GHG Emissions	kg CO_2-eq	4.262754	3.348328	0.891254	0.023171	18.7%
			Energy Consumption	kWh	16.1133	12.93904	3.062684	0.111578	
			Water Consumption	litres	3.54565	1.74793	1.773	0.0251	

Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Other Seafood (kg meat)	Shrimp (frozen)	Vietnam	GHG Emissions	kg CO_2-eq	5.82830545	4.69009838	1.0417998	0.09640727	10%
			Energy Consumption	kWh	62.6322497	44.1890458	16.863006	1.58019786	
			Water Consumption	litres	0.21483072	0.21224691	0.00247245	0.00011136	
		Malaysia	GHG Emissions	kg CO_2-eq	5.90167102	4.75334663	1.0619243	0.0864001	48%
			Energy Consumption	kWh	60.7669715	42.8353327	16.4322778	1.49936105	
			Water Consumption	litres	0.21402444	0.21164831	0.00228199	9.41E-05	
		Indonesia	GHG Emissions	kg CO_2-eq	6.48815366	5.21829645	1.2098633	0.0599939	8%
			Energy Consumption	kWh	64.1579809	45.7856457	17.3710165	1.00131867	
			Water Consumption	litres	0.22055221	0.21662018	0.00386395	6.81E-05	
		China	GHG Emissions	kg CO_2-eq	7.22324152	5.85517759	1.2781812	0.08988274	20%
			Energy Consumption	kWh	68.5560486	49.5998842	17.4796875	1.47647692	
			Water Consumption	litres	0.23303935	0.23017877	0.00275698	0.00010361	
		Singapore	GHG Emissions	kg CO_2-eq	5.13862442	4.50791726	0.61092601	0.01978115	2%
			Energy Consumption	kWh	52.6379817	41.9781655	10.31654	0.34327609	
			Water Consumption	litres	0.2281306	0.22645048	0.00165857	2.16E-05	
	Crab (frozen)	Indonesia	GHG Emissions	kg CO_2-eq	4.86431293	3.28595477	1.35239889	0.22595927	3%
			Energy Consumption	kWh	110.503004	53.8056526	52.9454732	3.75187822	
			Water Consumption	litres	0.00729949	0.00201923	0.00502252	0.00025773	
		Philippines	GHG Emissions	kg CO_2-eq	4.96840779	3.28595477	1.31968914	0.36276389	1%
			Energy Consumption	kWh	112.509817	53.8056526	52.7774442	5.92672074	
			Water Consumption	litres	0.00706734	0.00201923	0.00462775	0.00042035	
		India	GHG Emissions	kg CO_2-eq	5.04473111	3.28595477	1.39885268	0.35992366	10%
			Energy Consumption	kWh	113.109537	53.8056526	53.4223163	5.88156841	
			Water Consumption	litres	0.00738888	0.00201923	0.00495267	0.00041697	

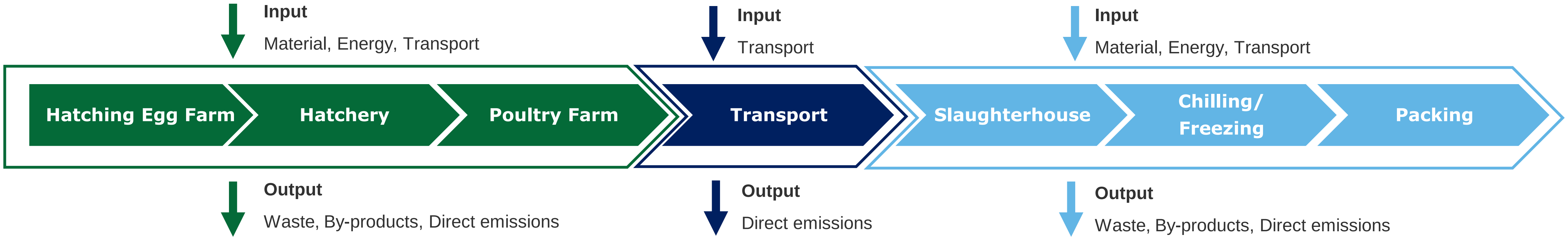
Analysis of environmental impacts of key food items

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Other Seafood (kg meat)	Crab (fresh)	Indonesia	GHG Emissions	kg CO_2-eq	4.79812762	3.28595477	1.32956783	0.18260503	31%
Other Seafood (kg meat)	Crab (fresh)	Indonesia	Energy Consumption	kWh	109.467273	53.8056526	52.5961077	3.06551298	31%
Other Seafood (kg meat)	Crab (fresh)	Indonesia	Water Consumption	litres	0.00722643	0.00201923	0.00499708	0.00021012	31%
Other Seafood (kg meat)	Crab (fresh)	Philippines	GHG Emissions	kg CO_2-eq	4.84477302	3.28595477	1.29685807	0.26196018	26%
Other Seafood (kg meat)	Crab (fresh)	Philippines	Energy Consumption	kWh	110.57516	53.8056526	52.4280787	4.34142868	26%
Other Seafood (kg meat)	Crab (fresh)	Philippines	Water Consumption	litres	0.00692868	0.00201923	0.00460231	0.00030714	26%
Other Seafood (kg meat)	Crab (fresh)	India	GHG Emissions	kg CO_2-eq	4.92228905	3.28595477	1.37602162	0.26031267	11%
Other Seafood (kg meat)	Crab (fresh)	India	Energy Consumption	kWh	111.193543	53.8056526	53.0729508	4.31493914	11%
Other Seafood (kg meat)	Crab (fresh)	India	Water Consumption	litres	0.00725158	0.00201923	0.00492722	0.00030513	11%
Other Seafood (kg meat)	Squid (fresh)	Malaysia	GHG Emissions	kg CO_2-eq	4.76347232	4.60622846	0.06478344	0.09246042	27%
Other Seafood (kg meat)	Squid (fresh)	Malaysia	Energy Consumption	kWh	70.0891032	65.3686048	3.11779944	1.60269893	27%
Other Seafood (kg meat)	Squid (fresh)	Malaysia	Water Consumption	litres	0.00276216	0.00245316	0.00020867	1.00E-04	27%
Other Seafood (kg meat)	Squid (fresh)	Indonesia	GHG Emissions	kg CO_2-eq	4.73865097	4.60622846	0.06478344	0.06763907	1%
Other Seafood (kg meat)	Squid (fresh)	Indonesia	Energy Consumption	kWh	69.6111336	65.3686048	3.11779944	1.12472929	1%
Other Seafood (kg meat)	Squid (fresh)	Indonesia	Water Consumption	litres	0.00273668	0.00245316	0.00020867	7.49E-05	1%
Other Seafood (kg meat)	Squid (fresh)	China	GHG Emissions	kg CO_2-eq	4.90059262	4.77173857	0.03769647	0.09115758	2%
Other Seafood (kg meat)	Squid (fresh)	China	Energy Consumption	kWh	72.1286191	67.7165892	2.9151303	1.49689962	2%
Other Seafood (kg meat)	Squid (fresh)	China	Water Consumption	litres	0.00284145	0.00254128	0.00019506	0.00010511	2%
Other Seafood (kg meat)	Squid (frozen)	Malaysia	GHG Emissions	kg CO_2-eq	4.94249148	4.60622846	0.24492955	0.09133346	6%
Other Seafood (kg meat)	Squid (frozen)	Malaysia	Energy Consumption	kWh	80.2567391	65.3686048	13.303161	1.58497322	6%
Other Seafood (kg meat)	Squid (frozen)	Malaysia	Water Consumption	litres	0.00363288	0.00245316	0.0010802	9.95E-05	6%
Other Seafood (kg meat)	Squid (frozen)	Indonesia	GHG Emissions	kg CO_2-eq	4.91439978	4.60622846	0.24492955	0.06324177	17%
Other Seafood (kg meat)	Squid (frozen)	Indonesia	Energy Consumption	kWh	79.7269067	65.3686048	13.303161	1.0551409	17%
Other Seafood (kg meat)	Squid (frozen)	Indonesia	Water Consumption	litres	0.00360515	0.00245316	0.0010802	7.18E-05	17%
Other Seafood (kg meat)	Squid (frozen)	China	GHG Emissions	kg CO_2-eq	5.07338584	4.77173857	0.21048969	0.09115758	26%
Other Seafood (kg meat)	Squid (frozen)	China	Energy Consumption	kWh	81.8982516	67.7165892	12.6847628	1.49689962	26%
Other Seafood (kg meat)	Squid (frozen)	China	Water Consumption	litres	0.00367741	0.00254128	0.00103102	1.05E-04	26%

7. Annex B: Life Cycle Stages of the 13 Key Food Items

Life cycle stages of chicken and duck

Fresh chicken, fresh and frozen duck *(processing in Singapore)*



Life Cycle Stage Assumptions

- Assume CH_4 and N_2O emission from chickens, ducks, and pullets, as well as manure are the same across countries
- Assume waste is landfilled

- Assume from a single location within source country
- Where Malaysia is the source country, assume from Johor

- Assume waste generated in Singapore is incinerated and landfilled, while waste in other countries is landfilled

Legend

Production
Processing
Transportation

Materials: e.g. feed, water
Energy: e.g. electricity, fuel
Waste: e.g. solid waste, wastewater

By-products: e.g. manure
Transport: e.g. land freight, sea freight
Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of chicken

Frozen chicken

Production (Hatching Egg Farm → Hatchery → Poultry Farm)

- **Input:** Material, Energy, Transport
- **Output:** Waste, By-products, Direct emissions

Processing (Slaughterhouse → Freezing → Packing)

- **Input:** Material, Energy, Transport
- **Output:** Waste, By-products, Direct emissions

Transportation (Transport)

- **Input:** Transport
- **Output:** Direct emissions

Life Cycle Stage Assumptions

Production	Processing	Transportation
• Assume CH_4 and N_2O emission from chickens, ducks, and pullets, as well as manure are the same across countries • Assume waste is landfilled	• Assume waste generated in Singapore is incinerated and landfilled, while waste in other countries is landfilled	• Assume from a single location within source country • Where Malaysia is the source country, assume from Johor

Legend

- Production
- Processing
- Transportation

Materials: e.g. feed, water

Energy: e.g. electricity, fuel

Waste: e.g. solid waste, wastewater

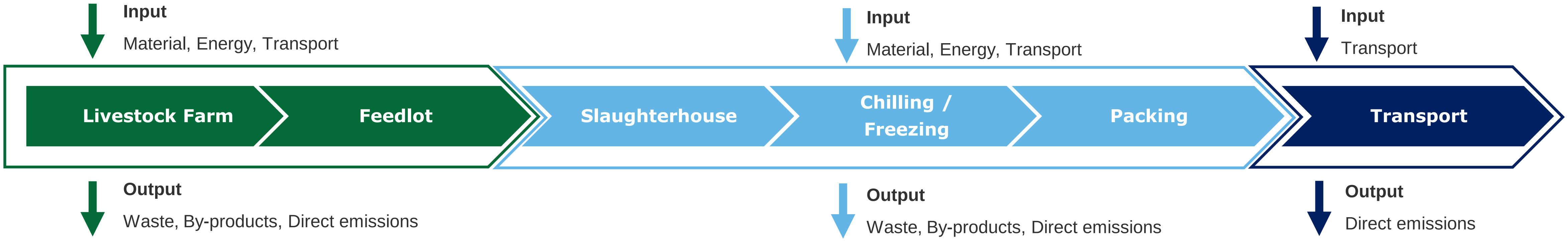
By-products: e.g. manure

Transport: e.g. land freight, sea freight

Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of pork, mutton and beef

Chilled and frozen pork, mutton and beef



Life Cycle Stage Assumptions

Production	Processing	Transportation
• Assume feed mix will be the same for all countries specific to each food item • Assume waste is landfilled • Assume both cattle and mutton food items are involved in the process of pasture grazing	• Assume waste is landfilled	• Assume from a single location within source country

Legend

- Production
- Processing
- Transportation

Materials: e.g. feed, water

Energy: e.g. electricity, fuel

Waste: e.g. solid waste, wastewater

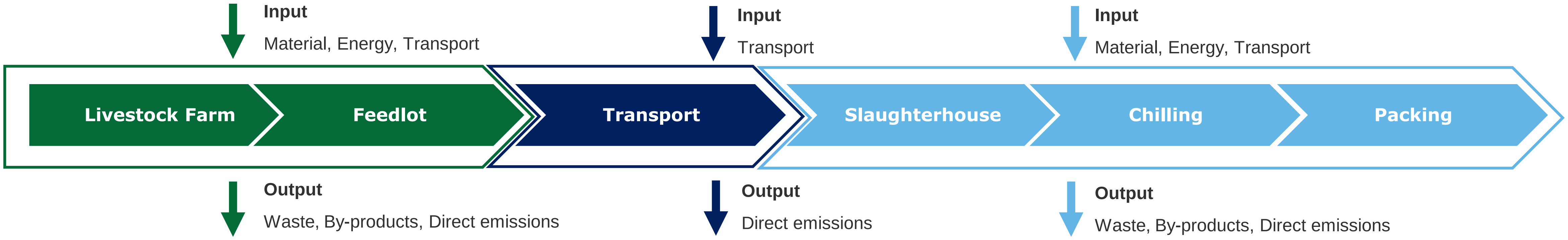
By-products: e.g. hides, manure

Transport: e.g. land freight, sea freight, air transport

Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of pork

***Fresh pork** (processing in Singapore)*



Life Cycle Stage Assumptions

- Assume feed mix will be the same for all countries specific to each food item
- Assume waste is landfilled

- Assume from a single location within source country

- Assume waste generated in Singapore is incinerated and landfilled, while waste in other countries is landfilled

Legend

- Production
- Processing
- Transportation

Materials: e.g. feed, water

Energy: e.g. electricity, fuel

Waste: e.g. solid waste, wastewater

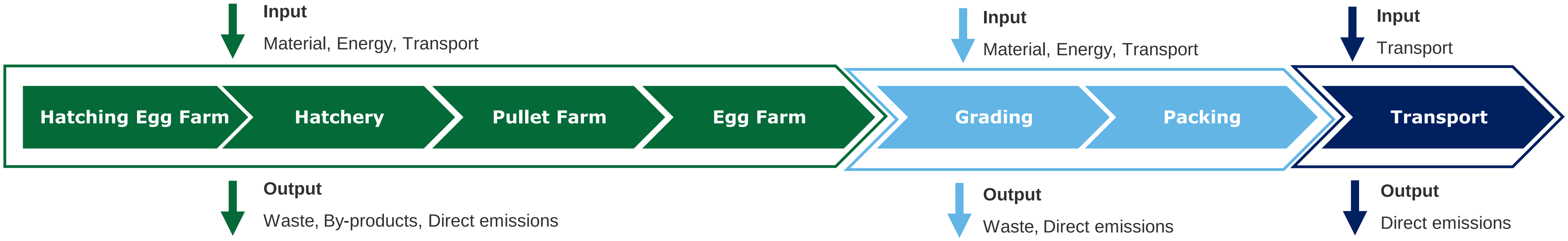
By-products: e.g. manure

Transport: e.g. land freight, sea freight

Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of eggs

Eggs



Life Cycle Stage Assumptions

Production	Processing	Transportation
• Assume similar to chicken meat production hatching egg farm • Assume CH_4 and N_2O emission from chickens/pullets and manure are the same across countries • Assume waste is landfilled	• Assume waste generated in Singapore is incinerated and landfilled, while waste in other countries is landfilled	• Assume from a single location within source country • Where Malaysia is the source country, assume from Johor

Legend

- **Production**
- **Processing**
- **Transportation**

Materials: e.g. feed, water

Energy: e.g. electricity, fuel

Waste: e.g. solid waste, wastewater

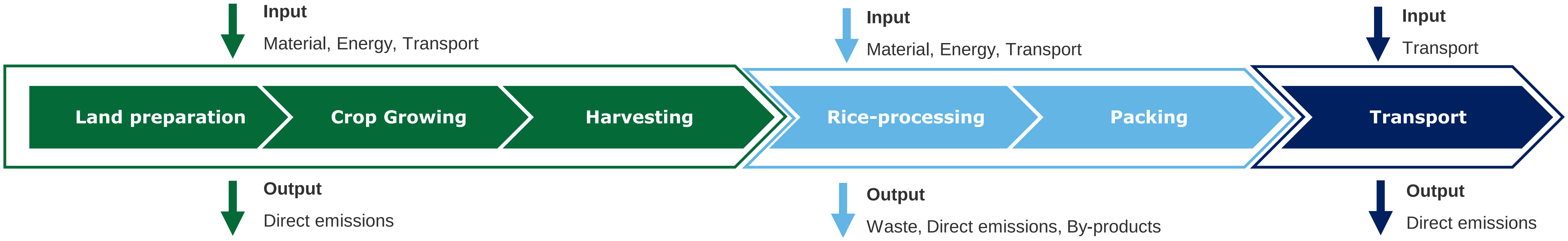
By-products: e.g. manure

Transport: e.g. land freight, sea freight

Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of rice

Rice



Life Cycle Stage Assumptions

Production	Processing	Transportation
• Assume CH_4 and N_2O emission from farming are the same across countries	• Assume waste is landfilled • Consists of Paddy cleaning, De-husking, Husk separation, De-stoning	• Assume from a single location within source country

Legend

- Production
- Processing
- Transportation

Materials: e.g. fertiliser, pesticide, water

Energy: e.g. electricity, fuel

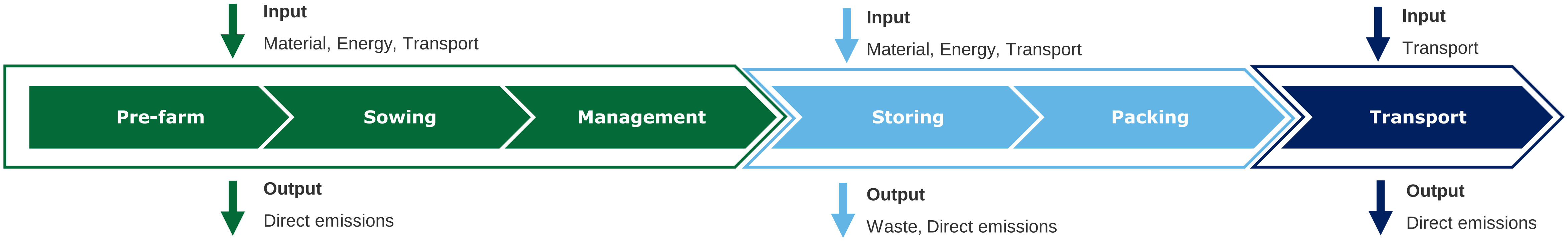
Waste: e.g. solid waste, wastewater

Transport: e.g. land freight, sea freight

Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of wheat

Wheat



Life Cycle Stage Assumptions

Production	Processing	Transportation
• Assume CO_2, CH_4 and N_2O emission from farming are the same across countries	• Assume waste is landfilled	• Assume from a single location within source country

Legend

- Production
- Processing
- Transportation

Materials: e.g. fertiliser, pesticide, water

Energy: e.g. electricity, fuel

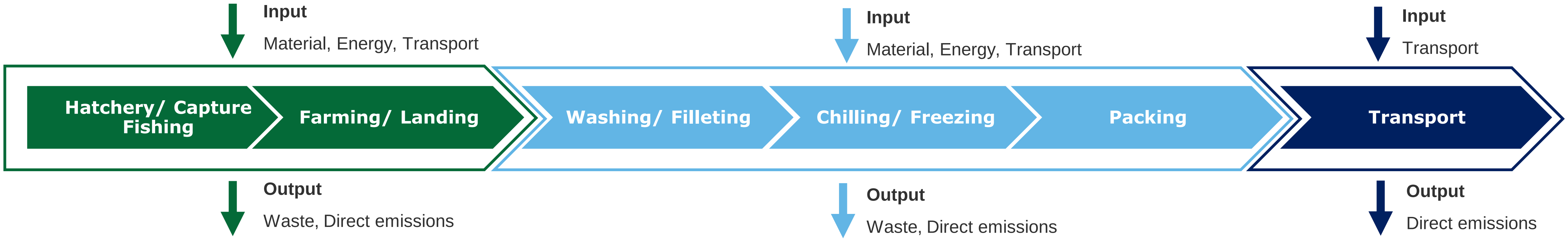
Waste: e.g. solid waste, wastewater

Transport: e.g. land freight, sea freight

Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of fish and other seafood

Fish and other seafood



Life Cycle Stage Assumptions

Production:
- Assume CH_4 and N_2O emission from fish and other seafood are the same across countries
- Assume waste is landfilled

Processing:
- Assume waste is landfilled

Transportation:
- Assume from a single location within source country

Legend

- **Production**
- **Processing**
- **Transportation**

Materials: e.g. feed

Energy: e.g. electricity, fuel

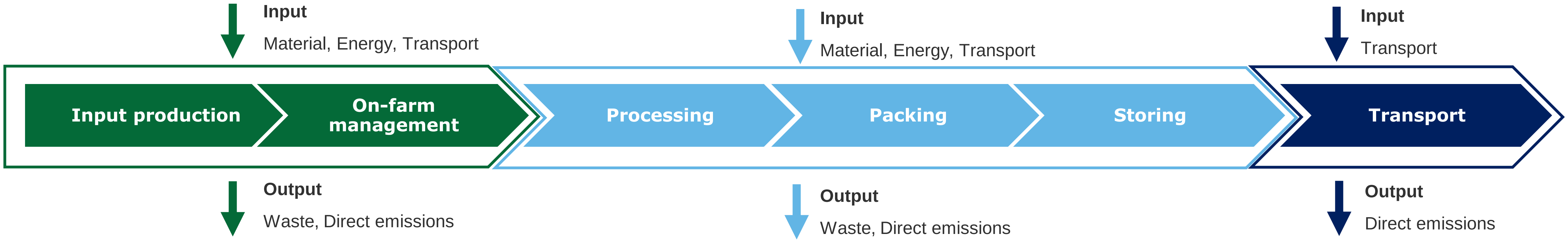
Waste: e.g. solid waste

Transport: e.g. land freight, sea freight, air tranport

Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of leafy vegetables, other vegetables and fruits

Leafy vegetables, other vegetables, and fruits



Life Cycle Stage Assumptions

Production	Processing	Transportation
• Assume CO_2, CH_4 and N_2O emissions from diesel are the same across countries • Assume waste is landfilled	• Assume CO_2, CH_4 and N_2O emissions from diesel are the same across countries • Assume waste is landfilled	• Assume from a single location within source country

Legend

- Production
- Processing
- Transportation

Materials: e.g. fertiliser, pesticide, water

Energy: e.g. electricity, fuel

Waste: e.g. solid waste

Transport: e.g. land freight, sea freight

Direct emissions: e.g. CO_2, CH_4, N_2O

Life cycle stages of chicken

Inclusions

1. **Specific food items: Frozen and fresh chicken**
    - Based on available SFA data and description
2. **Chicken sources: Brazil and Malaysia**
    - Main sources of chicken that make up more than 80% of chicken imports (based on SFA import data)
3. **Live chicken processing in Singapore**
    - Live imported chicken are slaughtered and processed in Singapore

Exclusions

1. **Chicken sources from other countries**
    - Environmental impact of chickens from countries that do not make up the major 80% of supply are not specifically computed
2. **Other forms of processed chicken**
    - Other forms of processed chicken are not considered due to high variability
3. **Feed production mapping and modelling**
    - Embodied impact of feed production is considered in input

Assumptions

1. **Assume different parts of a chicken have the same environmental impact.**
    - Chicken is produced as a whole, and the environmental impact will be considered based on the weight of meat
    - Functional unit is 1 kg of chicken, irrespective of the chicken part
2. **All fresh chicken is supplied from Malaysia. Chicken quantity from Malaysia beyond the fresh chicken quantity import is assumed to be frozen.**
    - Based on FAO data of live chicken import, as compared to SFA data on fresh chicken import
3. **Assume manure is used as fertiliser in other agriculture farms.**
    - Based on report on chicken farm in Malaysia
4. **Assume countries of import follow standard chicken farming procedure, thus activity data of chicken meat production is similar in all countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*
5. **All chicken are barn reared broiler chicken.**
    - Barn reared chicken is the most common method of rearing chicken
    - Broiler chicken is the most common type of chicken reared for food

Life cycle stages of duck

Inclusions

1. **Specific food items: Frozen and fresh duck**
    - Based on FAO data and SFA data and description
2. **Duck sources: Malaysia (reared) and Singapore (processed)**
    - Based on SFA import data
3. **Live duck processing in Singapore**
    - Live imported duck are slaughtered and processed in Singapore

Exclusions

1. **Duck sources from other countries**
    - Environmental impact of duck from countries that do not make up the major 80% of supply are not specifically computed
2. **Other forms of processed duck**
    - Other forms of processed duck are not considered due to high variability
3. **Feed production mapping and modelling**
    - Embodied impact of feed production is considered in input

Assumptions

1. **Assume frozen to fresh ratio is based on that of chicken, at 62% frozen, 38% fresh until more concrete data can be found.**
    - No official data, thus assumed to be similar to chicken
2. **Assume countries of import follow standard duck farming procedure, thus activity data for environmental impact of duck meat production is similar in all countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*
3. **Assume manure is used as fertiliser in other agriculture farms, similar to that of chicken meat production manure.**
    - No official data, thus assumed to be similar to chicken

Life cycle stages of pork

Inclusions

1. **Specific food items: Frozen, chilled and fresh pork**
    - Based on available SFA data and description
2. **Pork sources: Brazil, Indonesia, Australia, Netherlands, Spain**
    - Main sources of pork that make up more than 80% of pork imports (based on SFA import data)

Exclusions

1. **Pork sources from other countries**
    - Environmental impact of pork from countries that do not make up the major 80% of supply are not specifically computed
2. **Other forms of processed pork**
    - Other forms of processed pork are not considered due to high variability
3. **Feed production mapping and modelling**
    - Embodied impact of feed production is considered in input

Assumptions

1. **Assume different parts of a pig have the same environmental impact.**
    - Pork is produced as a whole, and the environmental impact will be considered based on the weight of meat
    - Functional unit is 1 kg of pork, irrespective of the part
2. **Assume frozen to chilled ratio is based on 70% frozen, 30% chilled.**
3. **Assume frozen, chilled and fresh pork as such:**
    - Assumed Brazil-chilled and frozen, Indonesia-fresh, Australia-chilled and frozen, Netherlands-frozen, Spain-frozen
4. **Assume countries of import follow standard farming procedure, thus activity data of pork production is similar in source countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*

Life cycle stages of beef

Inclusions

1. **Specific food items: Frozen and chilled beef**
    - Based on available SFA data and description
2. **Beef sources: Brazil, Australia, New Zealand**
    - Main sources of beef that make up more than 80% of beef imports (based on SFA import data)

Exclusions

1. **Beef sources from other countries**
    - Environmental impact of beef from countries that do not make up the major 80% of supply are not specifically computed
2. **Other forms of processed beef**
    - Other forms of processed beef are not considered due to high variability
3. **Feed production mapping and modelling**
    - Embodied impact of feed production is considered in input

Assumptions

1. **Assume different parts of a cow/bull have the same environmental impact.**
    - Beef is produced as a whole, and the environmental impact will be considered based on the weight of meat
    - Functional unit is 1 kg of beef, irrespective of the part
2. **Assumes beef production is based on medium fed grain farming practice.**
    - Based on initial findings, medium fed grain is a good average to evaluate grass-fed, grain-fed (medium fed, long-fed) in terms of GHG emissions
3. **Assume frozen to chilled ratio is based on that of pork at 70% frozen and 30% chilled until more concrete data can be found.**
    - Assumed to be similar to be based on pork ratio till concrete meat ratio for Singapore is found
4. **Assume countries of import follow standard farming procedure, thus activity data of beef production is similar in source countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*
5. **Water consumption for beef feed intake is ~20% lower than that of rice and double than that of wheat.** Feed intake during livestock production is a mix of forage, grazing and industrial grain feed mix. Among the industrial grain feed mix, high water consuming grains like wheat and barley make up only a fraction of the feed, with other lower water consuming grains like maize making up the rest of the feed mix.

Life cycle stages of mutton

Inclusions

1. **Specific food items: Frozen and chilled mutton**
   - Based on available SFA data and description
2. **Mutton sources: Australia**
   - Main sources of mutton that make up more than 80% of mutton imports (based on SFA import data)

Exclusions

1. **Mutton sources from other countries**
   - Environmental impact of mutton from countries that do not make up the major 80% of supply are not specifically computed
2. **Other forms of processed mutton**
   - Other forms of processed mutton are not considered due to high variability
3. **Feed production mapping and modelling**
   - Embodied impact of feed production is considered in input

Assumptions

1. **Assume lamb and mutton are used interchangeably in data gathering.**
2. **Assume different parts of a lamb/sheep have the same environmental impact.**
   - Mutton is produced as a whole, and the environmental impact will be considered based on the weight of meat
   - Functional unit is 1 kg of mutton, irrespective of the part
3. **Assume frozen to chilled ratio is based on that of pork, at 70% frozen, 30% chilled until more concrete data can be found.**
   - Assumed to be similar to be based on pork ratio till concrete meat ratio for Singapore is found
4. **Assume countries of import follow standard farming procedure, thus activity data of mutton production is similar in source countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*

Life cycle stages of eggs

Inclusions

1. **Specific food items: Hen eggs**
    - Based on available SFA data and description
2. **Eggs sources: Singapore and Malaysia**
    - Main sources of eggs that make up more than 80% of chicken imports (based on SFA import data)

Exclusions

1. **Egg sources from other countries**
    - Environmental impact of chickens from countries that do not make up the major 80% of supply are not specifically computed
2. **Other forms of processed eggs**
    - Other forms of processed eggs are not considered due to small percentage contribution
3. **Feed production mapping and modelling**
    - Embodied impact of feed production is considered in input

Assumptions

1. **Assume hatching eggs production and hatchery stage for eggs production is similar to that of chicken meat production.**
    - No official data, thus assumed to be similar to chicken
    - Functional unit is 1 kg of eggs
2. **Assume manure is used as fertiliser in other agriculture farms, similar to that of chicken meat production manure.**
    - No official data, thus assumed to be similar to chicken
3. **Assume eggs production is via caged hen.**
    - Caged hen eggs production is the most common method of producing eggs in Malaysia and Singapore
4. **Assume countries of import follow standard chicken eggs production procedure, thus activity data of egg production is similar in all countries.** *(If there is significant difference in production procedure, it will be contextualised accordingly.)*

Life cycle stages of rice

Inclusions

1. **Specific food items: Rice**
    - Based on available FAO data and description
2. **Rice sources: Thailand, India, Vietnam**
    - Main sources of rice that make up more than 80% of rice imports (based on FAO import data)

Exclusions

1. **Rice sources from other countries**
    - Environmental impact of rice from countries that do not make up the major 80% of supply are not specifically computed

Assumptions

1. **Type of rice is milled white rice.**
    - Milled white rice is the most common type of rice.
    - 60% of white rice imported from India is assumed to be parboiled.
2. **Assume countries of import follow standard farming procedure, thus activity data of rice production is similar in source countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*

Life cycle stages of wheat

Inclusions

1. **Specific food items: Wheat**
    - Based on available FAO data and description
2. **Wheat sources: Australia, United States**
    - Main sources of wheat that make up more than 80% of wheat imports (based on FAO import data)

Exclusions

1. **Wheat sources from other countries**
    - Environmental impact of wheat from countries that do not make up the major 80% of supply are not specifically computed

Assumptions

1. **Assume countries of import follow standard farming procedure, thus activity data of wheat production is similar in source countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*

Life cycle stages of fruits

Inclusions

1. **Specific food items: Banana, watermelon, papaya, pineapple, orange**
    - Based on top imports in SFA data and description
2. **Fruit sources: Philippines, Malaysia, South Africa, USA, Australia, Egypt**
    - Main sources of fruits that make up specific fruit item imports (based on FAO import data)

Exclusions

1. **Fruits sources from other countries**
    - Environmental impact of specific fruit item from countries that do not make up the major 80% of supply are not specifically computed
2. **Other types of fruits**
    - Other types of processed fruits are not considered due to low proportion of imports

Assumptions

1. **Assume farming procedures are highly similar.**
    - Based on various reports on different types of fruits, farming procedure is highly similar
2. **Assume countries of import follow standard fruit farming procedure, thus activity data of fruit production is similar in all countries.** *(If there is significant difference in fruit farming procedure, it will be contextualised accordingly.)*

Life cycle stages of fish

Inclusions

1. **Specific food items: Catfish, mackerel, salmon**
   - Based on available SFA data and description
2. **Fish sources: Vietnam, Norway, Chile, Malaysia, Indonesia, Thailand**
   1. Main sources of fish that make up 80% of fish imports (based on SFA & Comtrade import data)

Exclusions

1. **Fish sources from other countries**
   - Environmental impact of fish from countries that do not make up the major 80% of supply are not specifically computed
2. **Other forms of processed fish**
   - Other forms of processed fish are not considered due to high variability
3. **Other types of fish**
   - Other types of fish are not considered due to lower proportion of imports
4. **Feed production mapping and modelling**
   - Embodied impact of feed production is considered in input

Assumptions

1. **Assume different parts of a fish have the same environmental impact.**
   - Fish is produced as a whole, and the environmental impact will be considered based on the weight of meat
   - Functional unit is 1 kg of fish, irrespective of the part
2. **Assume countries of import follow standard farming procedure, thus activity data of fish production is similar in source countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*

Life cycle stages of other seafood

Inclusions

1. **Specific food items: Shrimp, crab, squid**
   - Based on available SFA data and description
2. **Other seafood sources: Malaysia, China, Vietnam, India, Indonesia, Philippines**
   - Main sources of other seafood that make up 80% of fish imports (based on Comtrade import data)

Exclusions

1. **Feed production mapping and modelling**
   - Embodied impact of feed production is considered in input
2. **Other types of seafood**
   - Other types of seafood are not considered due to lower proportion of imports

Assumptions

1. **Assume different parts other seafood have the same environmental impact.**
   - Seafood is produced as a whole, and the environmental impact will be considered based on the weight of seafood
   - Functional unit is 1 kg of seafood, irrespective of the part
2. **Assume countries of import follow standard farming procedure, thus activity data of seafood production is similar in source countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*

Life cycle stages of leafy vegetables

Inclusions

1. **Specific food items: Chinese Cabbage, Spinach, and Lettuce**
   - Based on top imports in SFA data and description
2. **Leafy vegetables sources: Malaysia and China**
   - Main sources of leafy vegetables that make up leafy vegetable imports (based on SFA import data)
3. **Leafy vegetables grown in Singapore**
   - A portion of leafy vegetables are grown locally in Singapore

Exclusions

1. **Leafy vegetables sources from other countries**
   - Environmental impact of leafy vegetables from countries that do not make up the major 80% of supply are not specifically computed
2. **Other types of leafy vegetables**
   - Other types of processed leafy vegetables are not considered due to low proportion of imports

Assumptions

1. **Assume farming procedures are highly similar.**
   - Based on various reports on different types of leafy vegetables, farming procedure is highly similar
2. **Assume countries of import follow standard leafy vegetables farming procedure, thus activity data of leafy vegetables production is similar in all countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*
3. **Assume greenhouse in Singapore does not account for heating.**
4. **Assume greenhouse hydroponics to be vertical farming.**
5. **For Non-greenhouse hydroponics production (non-vertical forming)**
   - LCI adapted from Spain’s non-greenhouse hydroponics lettuce production. Less electricity used for irrigation compared to vertical farming case likely due to not requiring energy to pump water up vertical structure.

Life cycle stages of other vegetables

Inclusions

1. **Specific food items: Onion, potato, tomato, cabbage, carrot, beansprout**
   - Based on top imports in SFA data and description
2. **Other vegetables sources: Malaysia, China, Indonesia, Australia, Bangladesh, Netherlands, Pakistan, India, and USA**
   - Main sources of other vegetables that make up other vegetable imports (based on FAO import data)
3. **Other vegetables grown in Singapore**
   - A portion of other vegetables are grown locally in Singapore.

Exclusions

1. **Other vegetables sources from other countries**
   - Environmental impact of leafy vegetables from countries that do not make up the major 80% of supply are not specifically computed
2. **Other types of other vegetables**
   - Other types of processed other vegetables are not considered due to low proportion of imports

Assumptions

1. **Assume farming procedures are highly similar.**
   - Based on various reports on different types of vegetables, farming procedure is highly similar
2. **Assume countries of import follow standard vegetables farming procedure, thus activity data of other vegetables production is similar in all countries.** *(If there is significant difference in farming procedure, it will be contextualised accordingly.)*

7. Annex C: Major Country Sources of the 13 Key Food Items

Major country sources of the 13 key food items (1/3)

		Percentage of Imported Specific Food Items (%)																					
Key Food Items	**Specific Food Items**	**Brazil**	**Malaysia**	**Indonesia**	**Australia**	**Netherlands**	**Spain**	**New Zealand**	**Vietnam**	**Norway**	**Thailand**	**Philippines**	**India**	**China**	**Bangladesh**	**Pakistan**	**USA**	**South Africa**	**Egypt**	**Myanmar**	**Japan**	**Total**	**Singapore***
Chicken	Fresh chicken, frozen chicken	46	37																			**83**	
Pork	Chilled pork, frozen pork, fresh pork	34		17	12	12	6															**81**	
Beef	Chilled beef, frozen beef	54			27			8														**89**	
Duck	Fresh duck, frozen duck		94																			**94**	
Mutton	Chilled mutton, frozen mutton				91																	**91**	
Eggs	Hen eggs		99																			**99**	✓
Rice	Rice								23		40		29									**92**	
Wheat	Wheat				60												34					**94**	
Fruits	Banana		41									42										**83**	
	Watermelon		99																			**99**	
	Papaya		97																			**97**	
	Pineapple		84																			**84**	
	Orange				24												31	20	16			**91**	

** A tick indicates that Singapore is one of the source countries for the key food item*

Major country sources of the 13 key food items (2/3)

Key Food Items	Specific Food Items	Percentage of Imported Specific Food Items (%)																					
		Brazil	Malaysia	Indonesia	Australia	Netherlands	Spain	New Zealand	Vietnam	Norway	Thailand	Philippines	India	China	Bangladesh	Pakistan	USA	South Africa	Egypt	Myanmar	Chile	Total	Singapore*
Fish	Catfish								98													**97**	
	Mackerel		11	61						11	7											**90**	
	Salmon									65											26	**91**	✓
	Aquaculture fish																						
	Captured fish																						
Other seafood	Prawn/Shrimp		48	8					10					20								**86**	
	Crab			34								27	21									**82**	✓
	Cuttlefish/squid		34	18										28								**80**	

** A tick indicates that Singapore is one of the source countries for the key food item*

Major country sources of the 13 key food items (3/3)

Percentage of Imported Specific Food Items (%)

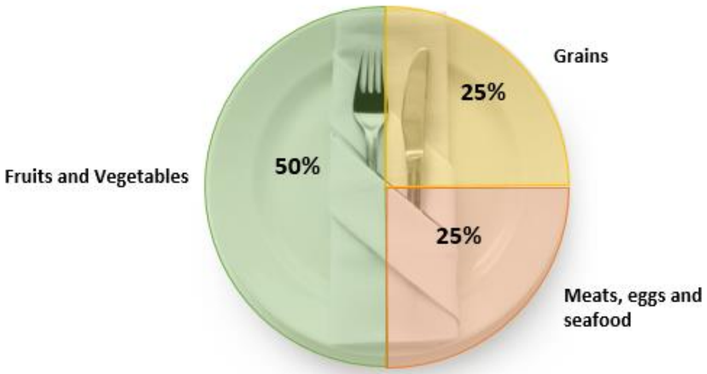
Key Food Items	Specific Food Items	Brazil	Malaysia	Indonesia	Australia	Netherlands	Spain	New Zealand	Vietnam	Norway	Thailand	Philippines	India	China	Bangladesh	Pakistan	USA	South Africa	Egypt	Myanmar	Japan	Total	Singapore*
Leafy vegetables	Lettuce		76	11																		75	
	Spinach/Bayam		79																			79	
	Chinese cabbage (Xiao Bai Cai, Cai Xin)		21											61								79	✓
Other vegetables	Carrot		18		47									31								96	
	Onion		15			9							53	8								85	
	Potato			8										45	11	10	10					84	
	Cabbage			18										65								83	
	Tomato		96																			96	
	Beansprout																						✓

** A tick indicates that Singapore is one of the source countries for the key food item*

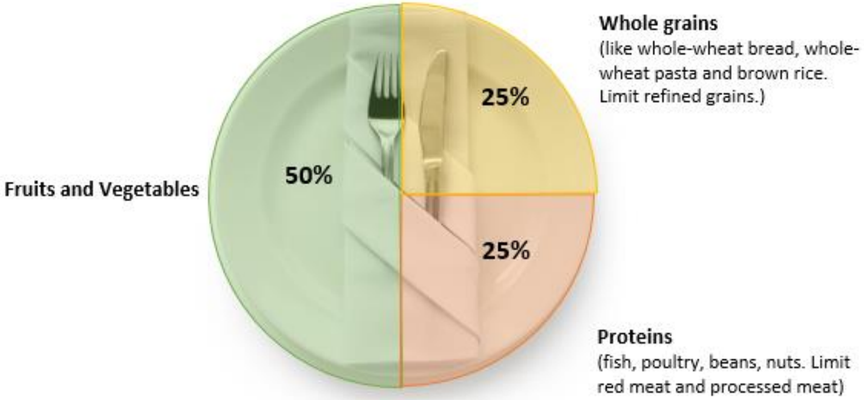
7. Annex D: Optimal Diets Around the World

Optimal diets around the world

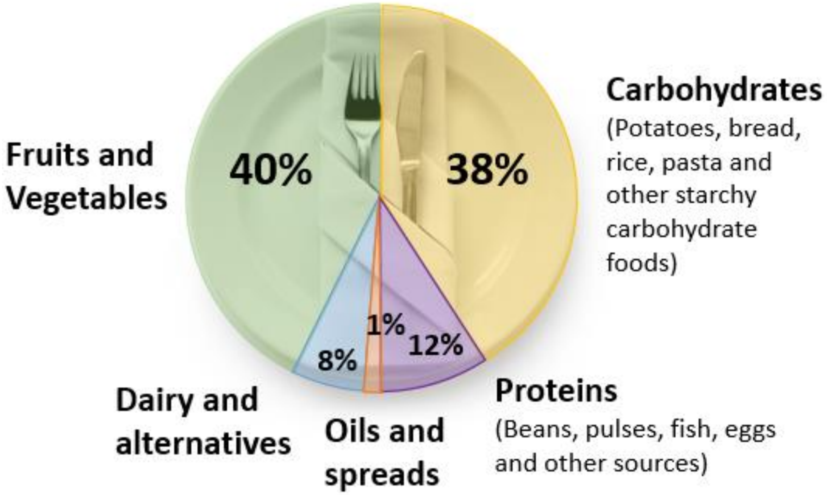
Singapore Optimal Health Diet



US USDA Diet[27]

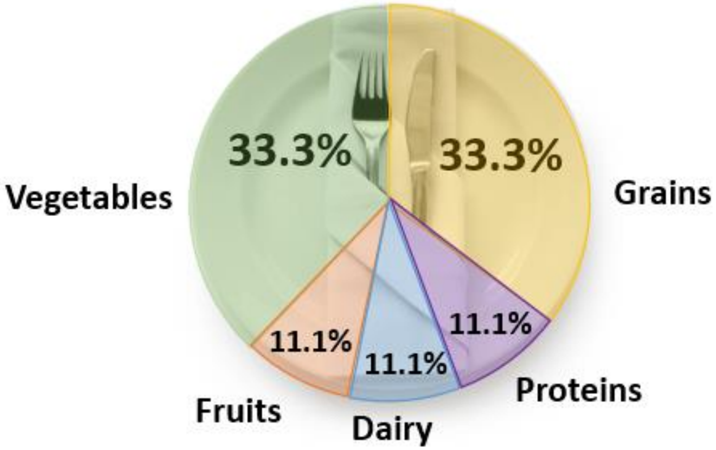


UK Eatwell Diet*[28]



*This adds up to 99% due to rounding up.

Australia Eat for Health Diet*[29]



*This adds up to 99.9% due to rounding up.

[25] United States Department of Agriculture. Center for Nutrition Policy and Promotion. (2018)
[26] Public Health England. (2018)
[27] Australian Government. National Health and Medical Research Council. Department of Health and Ageing. (2019)