**Food Consumption Patterns & CO2 Emissions**

**Group 3 Members:**

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# Introduction

* 1. Greenhouse gas (GHG) emissions such as carbon dioxide (CO2), methane, and nitrous oxide are the main cause of global warming (Caro et al.,2017). Currently, food production contributes 19 to 29% of GHG emissions (Temasek et al., 2019). With a projected increase in global population to 9.6 billion in 2050, the demand for animal products will double, thereby increasing GHG emissions from crop and livestock production by approximately 32% (Caro et al.,2017; Tilman & Clark, 2014).

* 1. A local study (Temasek et al., 2019) highlighted that (i) red meats represented only about 11% of consumption per capita by weight but contributed approximately 40% of GHG emissions[[1]](#footnote-1), and (ii) pork accounted for 28% GHG though it was only 6% of consumption per capita. Also, more than 90% of Singapore's food is imported. To reduce our reliance on food imports, Singapore’s ’30 by 30’ target aims to produce 30%[[2]](#footnote-2) of our nutritional needs locally and sustainably by 2030 (Our Food Future, n.d).
  2. Undoubtedly, a person’s food consumption pattern contributes to a significant proportion of a person’s overall GHG impact. Scenario modelling conducted by Clune et al., (2017) highlighted that by substituting meats with alternative meats, there could be up to 30% reduction in the Global Warming Potential (GWP)[[3]](#footnote-3) of food. Locally, the Health Promotion Board (HPB) recommends an optimal diet of 50% fruit and vegetables, and 25% wholegrains and protein (My Healthy Plate, n.d.).
  3. We are keen to conduct exploratory modelling to investigate if changing our food consumption patterns will have an environmental impact. Below is our problem statement:

Changing our food consumption patterns will have an impact

on greenhouse gas emissions.

* 1. The influence diagram is as below:

Diagram

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# Data Sources

* 1. The data utilised in this study was from 2018, derived from the following sources:
* Singapore Food Statistics 2021 (Singapore Food Agency)
* Environmental Impact of Key Food Items in Singapore (Temasek et al., 2019)

* 1. The raw data comprised information as below from 2018, with all GHG emissions were provided in units of kg CO2-equivalent:

|  |  |  |  |
| --- | --- | --- | --- |
| Key food items | Type of food – chilled, fresh, frozen | Country source | Percentage of total per key food item |
| Production GHG/kg | Processing GHG/kg | Transportation GHG/kg |  |

The Production, Processing and Transportation values were summed to derive the values for a new field “Total GHG per kg per source”. This field was then multiplied with the “Percentage of total per key food item” to derive another new field, “Contributing GHG per kg per source”.

* 1. The total food consumption data was provided at 365kg per capita. We assumed that the total annual food consumption per capita will not change i.e., remains at 365kg for 2030.
  2. From the above, the data model below (Table 1) was created.

1. Include how ratio of respective food item (%) was calculated.
2. Then, this was multiplied with 365kg to derive the values for “Amount of Key Food Item Consumed (kg)”.
3. The next field, “Average GHG Emissions per food item” was derived from summing up the Contributing GHG values calculated in Paragraph 2.2. This value includes the GHG emissions according to the various import distances and type of meat from the raw data.
4. The last field, “Total GHG Emission per food item” was calculated by multiplying the values in (2) and (3).

*Table 1: Data Model*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Key Food Items** | **Ratio of Respective Key Food Item (%)** | **Amount of Key Food Item Consumed (kg)** | **Average GHG Emission per kg of Key Food Item (kg CO 2 eq per kg of food)** | **Total GHG Emission per Key Food Item (kg CO 2 eq)** |
| Beef | 0.82% | 3.0 | 24.29 | 72.87 |
| Mutton | 0.55% | 2.0 | 16.41 | 32.81 |
| Pork | 6.03% | 22.0 | 11.95 | 262.80 |
| Chicken | 9.32% | 34.0 | 3.52 | 119.84 |
| Duck | 0.55% | 2.0 | 4.21 | 8.42 |
| Eggs | 6.03% | 22.0 | 3.08 | 67.75 |
| Fish | 4.11% | 15.0 | 6.17 | 92.59 |
| Other Seafood | 1.64% | 6.0 | 5.36 | 32.18 |
| Fruits | 19.73% | 72.0 | 0.40 | 29.15 |
| Leafy vegetables | 4.38% | 16.0 | 0.39 | 6.16 |
| Other Vegetables | 21.92% | 80.0 | 0.74 | 59.26 |
| Rice | 12.33% | 45.0 | 2.57 | 115.79 |
| Wheat | 12.60% | 46.0 | 0.72 | 33.24 |

# Computation and Analyses Performed

* 1. The objective of the analyses is to explore the change in annual GHG emissions per capita, by changing the ratios of food consumption and including relevant constraints. The decision variables are (a) food consumption ratios (%meat, %veg & fruits, %grains), and (b) ratio of foods imported or produced locally.
  2. The following assumptions and considerations will be considered for the analyses:
* The following factors will not be considered for imports:
  + As the supply and demand, financial regulation and transportation are different for different countries, food pricing will have no impact on the analysis.
  + Countries are assumed to have sufficient resources and are willing to sell.
  + It will be assumed that each import country’s offerings of food types or produce for export to Singapore will not change.
* The total annual food consumption per capita will not change, and the value will remain constant up to 2030.
* Annual GHG emissions per-capita will remain constant up to 2030.
* Singapore will achieve the 30 by 30 goal, and Singapore residents will support and consume local produce regardless of pricing or preference.
* To circumvent possible calculation issues where there is incomplete data, only data on food types from countries that make up around 80% of total foods will be used. It is worth to note that the percentages used each import item in the model are ratios derived from their original values since only 80% of most of the import percentages were available from research. Below is an example for the ratios derived for chicken.

Table

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* 1. The output variables for the model were as below:

**Annual GHG Emission per capita (kg CO2 eq)**

<insert how it is calculated>

**Average GHG Emission (for diet alternatives; kg CO2 eq)**

<insert how it is calculated>

* 1. The input values for the model were as below:

**Total food consumption per capita**

This would be the total food consumption of 365kg per capita as stated in Paragraph 2.3.

**Decision Variables**

There were two decision variables that were used to enact changes in the modelling, and 1 for trade-off analyses.

1. Food Consumption Ratios

The current food consumption ratios as of 2018 in Singapore of 29.04% meat, 24.93% grains, and 46.03% fruits and vegetables were calculated from their individual weight in kgs over the total of 365kg per capita food consumption. The HPB ideal food consumption ratios of 25%, 25% and 50% respectively were also included as constraints for the model.

1. Food Supply Mix

The ratio of locally produced food to import as of 2018 was calculated at 3% and 97%. The ideal targets in line with Singapore’s 30 by 30 target was also included at 30% and 70% as constraints for the model, based on the above assumptions.

1. Diet Alternatives (For trade-off analyses)

This was included for the trade-off analyses and comprised three alternatives – plant-based meats, cultivated meat, and insects. The parameters included were the average % reduction in GHG emissions as compared to meats based on literature review, as well as a column to toggle the respective percentage of each alternative.

**Data Table to Set Minimum Values**

Initial modelling efforts highlighted that Solver would change the food consumption ratios to only comprise fruits and vegetables and completely remove meat from diets. To circumvent this, a minimum value of 20% was included to ensure that the ratio of food items from 2018 would **REDUCE** no more than 20% in 2030 with allowance for increase of consumption of another food item. This value was chosen as an arbitrary value as it seems that this would be a comfortable figure by which an individual may be willing to change their diet. This figure can be toggled further based on any existing data.

Using this 20%, the ratio of food items for 2030 was computed by multiplying the original ratio of food items in 2018 and 80%. To further ensure that all the food sources will remain as is to ensure food diversity, a minimum value of 1% was set per food item.

**Data Model**

This would be the values as stated in Paragraph 2.4.

* 1. The information utilised for the Solver in Excel was as follows:

|  |  |
| --- | --- |
| **Fields** | **Values** |
| Objective Cell | Annual GHG Emission per capita |
| By Changing Variable Cells | Ratios of Respective Key Food Item |
| Constraints | * Food supply   + Import = 70% in line with 30 by 30 target   + Local = 30% in line with 30 by 30 target * HPB optimal diet   + Meat, eggs, seafood = 25%   + Grains = 25%   + Fruits & vegetables = 50% * All % of food items must add up to 100% * <include other constraints per final model> |

# Results

* 1. Based on the input values in Section 3.4, the calculated GHG emissions is 929.42 kg CO2-eq.
  2. Using this calculated GHG emissions, we developed a baseline model, in which Singaporeans adjusted their diet in accordance with HPB’s optimal diet stated in Para 1.3. As seen below, simply changing the diet resulted in a 14% decrease in GHG emissions, from 929.42 to 796.21. This can be attributed to decrease in meat consumption across all meat types, especially of pork and chicken (See Annex 1 for the changes in Ratios of Respective Key Food Item).

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# Trade-off & Scenario Analyses

* 1. Our baseline model allows us to examine how decisions on the Singaporean diet can influence the GHG emissions from our food consumption. In addition, we explored how food production policies, and replacing our diet with various types of meat alternatives may have an impact on GHG emissions. We outlined them into 2 possible scenarios which build on each other.

**Scenario 1: Baseline Model + Meeting Singapore’s 30 by 30 goals**

* 1. The calculated GHG emissions in the baseline model is 796.21 kg CO2-eq. This scenario considers Singapore meeting its target of locally producing 30% of nutritional needs. In our input and baseline models, only 2% of Singapore’s food is locally produced. Increasing it to 30% across selected food types[[4]](#footnote-4) showed that GHG emissions could be reduced further by 15% from a changed diet.

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<insert VERY COOL PINEAPPLE RESULTS from Anne>

**Scenario 2: Scenario 1 + Meat Alternatives**

* 1. The other scenario we explored after adjusting diet and local food production percentage was to explore change in GHG emissions by replacing meats with other meat alternatives. There are 3 main types of meat alternatives - (1) plant-based meats, (2) cultivated meats, and (3) insect substitutes.

* 1. Plant-based meats look and taste like real meat but are made entirely from plants and thus there are no GHG emissions from animal feeding and gas release (Lusk et al., 2022). Cultivated meats on the other hand are cell-based meats grown in vats (Tuomisto, & Teixeira de Mattos, 2011). While it also features no GHG emissions due to animal feeding and gas release, its CO2 contributions are mainly from the electricity used to grow the meats. Hence, its emissions can be higher than simply growing animals[[5]](#footnote-5) for meat if the energy source is not green.
  2. Lastly, insects as a meat alternative are extremely efficient in converting resources into nutrients, and also require much less upkeep than animals. Therefore, it has the lowest GHG emissions[[6]](#footnote-6) amongst all the alternatives. However, it is currently not a full substitute for meat and is mainly added as a protein.
  3. Both plant-based and cultivated meats have already received approval for consumption in Singapore, while SFA is currently seeking inputs for insect consumption. However, in consideration of the points raised earlier, only plant-based meats is a realistic alternative in the near future. We can see in the figure below that by simply replacing 25% of our meat consumption with plant-based meats, we can further reduce the GHG emissions by another 15%.

Change the screenshot + “plan” to “plant”

Table

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* 1. From the various models, we can see that there are various ways to reduce Singapore’s GHG emissions. Comparing the baseline model, Scenarios 1 and 2, changing parameters such as diet, food production policy, and meat substitutes can lead to an overall reduction of 38% in GHG emissions (decrease from 929.42 to 576.30 kg CO2-equivalent).

# Sensitivity Analyses

* What we changed
  + Changed import country
* How the results changed

# Conclusion

* Limitations of model and how we can change it in the future
* Implications of model

# References

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*Understanding Global Warming Potentials*. (2022, May 5). US EPA. Retrieved September 27, 2022, from https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

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1. These figures considered the entire Life Cycle Analysis of the food, starting from the production of farm activities, slaughtering, packaging, storage, to logistics involved in transport and import of food into Singapore, and food waste. [↑](#footnote-ref-1)
2. At the point of the launch of the target, the target was 10% for both eggs and fish, and 20% leafy vegetables. [↑](#footnote-ref-2)
3. GWP was developed to allow comparisons of the global warming impacts of different gases. The larger the GWP, the more a given gas warms the Earth compared to CO2 over 100 years (Understanding Global Warming Potentials, 2022). [↑](#footnote-ref-3)
4. Selected food types currently announced are eggs, fish, and leafy vegetables. [↑](#footnote-ref-4)
5. Current research shows that GHG emissions would be higher for all other meat types except for beef if conventional energy like burning of fossil fuel is used. [↑](#footnote-ref-5)
6. Up to 99% lower GHG emissions than pork in the production phase of the Life Cycle Analysis. [↑](#footnote-ref-6)