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STUDY REPORT

FOOD LOSS AND WASTE IN INDONESIA

SUPPORTING THE IMPLEMENTATION OF CIRCULAR ECONOMY AND LOW CARBON DEVELOPMENT

MINISTRY OF NATIONAL DEVELOPMENT PLANNING/BAPPENAS

2021

FOOD LOSS AND WASTE IN INDONESIA

SUPPORTING THE IMPLEMENTATION OF CIRCULAR ECONOMY AND LOW CARBON DEVELOPMENT

ABOUT THIS RESEARCH

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FOREWORD

Minister of National Development Planning/ Head of National Development Planning Agency

As a country that was agreeing on the global development agenda, Indonesia has committed to supporting the Sustainable Development Goals (SDGs) and greenhouse gas (GHG) emission reduction targets following the Paris Agreement in 2030. This commitment is demonstrated by mainstreaming the SDGs' goals, targets, and indicators in the National Medium Term Development Plan (RPJMN) 2020 - 2024 and prioritize Low Carbon Development programs in National Priority (PN) 6: Build the Environment, Improving Disaster Resilience, and Climate Change. In addition, under the Low Carbon Development program, the Government of Indonesia is also developing the Circular Economy policy as an approach to encourage green and sustainable economic growth.

These steps are the systemic and integrated efforts by the Government of Indonesia in dealing with various development problems, one of which is food loss and waste. With a more than 200 million population, Indonesia can generate a large amount of food loss and waste (FLW) that continues to grow every year. Food loss that occurs in the food preparation supply chain and food waste generated in the process of distribution, service, and food consumption is causing economic and social impact and contributes to the increased greenhouse gas emissions. Therefore, a responsible, integrated, and holistic reduction and handling of FLW can be part of efforts to accelerate the implementation of low carbon development and green economic development to address the challenges of food security and nutrition deficit in Indonesia.

As an initial step in the transformation of FLW management in Indonesia, the Government of Indonesia, supported by the Foreign, Commonwealth, and Development Office, United Kingdom, conducted a Study of Food Loss and Waste in Indonesia. This study has identified baseline data on FLW for the last 20 years and its environment, economy, and social impact and provided recommendations of sustainable FLW management strategies in Indonesia.

By presenting several evidence-based results, we hope that this study can serve as a reference and guide for stakeholders and policymakers and provide an overview of the Government of Indonesia's efforts in managing FLW in the context of implementing a Circular Economy and Low Carbon Development.

Jakarta, June 2021

Dr. (H.C.) Ir. H. Suharso Monoarfa
Minister of National Development Planning/Head of National Development Planning Agency

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

3R	Reduce, Reuse, Recycle
BKP	*Badan Ketahanan Pangan*/Food Security Agency
BSF	Black Soldier Flies
DLH	*Dinas Lingkungan Hidup*/ Environmental Agency
EoL	End-of-Life
FAO	Food and Agricultural Organization
FBS	Food Balance Sheet
FLW	Food loss and waste
GHG	Green House Gases
HORECA	Hotel, Restaurant, Catering
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCDI	Low Carbon Development Initiative
NGO	Non-Governmental Organization
RDA	Recommended Dietary Allowances
SIPSN	*Sistem Pengelolaan Sampah Nasional*/ National Waste Management System
TPA	*Tempat Pemrosesan Akhir*/Landfill
TPS	*Tempat Penampungan Sementara*/Temporary Disposal Site

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MAIN FINDINGS OF FOOD LOSS & WASTE IN INDONESIA

115-184 KG/CAPITA/YEAR

FLW generation in Indonesia in 2000 - 2019 has reached 115-184 kg/capita/year. Based on the food supply chain, the biggest generation occurs in **consumption stage.** Based on the food sector and types, the biggest generation is found in **crops, particularly cereals.** Meanwhile, the most inefficient food sector and category is horticulture plants, especially **vegetables.**

1,702.9 Mt CO_2 EQ

The total FLW-associated emission in 2000 - 2019 (20 years) is estimated at 1,702.9 Mt CO_2 eq, with the average contribution per year equals 7.29% of GHG emission in Indonesia.

213-551 TRILLION RUPIAH/YEAR

The economic loss due to the FLW generation in Indonesia in 2000 - 2019 is approximately IDR 213-551 trillion/year or equals 4-5% of Indonesia's GDP.

61-125 MILLION PEOPLE

The number of people that can be fed from the loss of nutrition (energy) from FLW in 2000 - 2019 is 61-125 million people, or 29-47% of Indonesia's population.

5 MAIN CAUSES & DRIVERS OF FLW IN INDONESIA

1. The lack of implementation of Good Handling Practice (GHP)
2. Insufficient quality of storage
3. Market quality standards & consumer preference
4. Lack of Information/education for food workers & consumers
5. Excess portion & consumers behavior

At the national level, 45 strategies are designed and categorized in

5 POLICIES DIRECTION OF FLW MANAGEMENT IN INDONESIA

1. Behavioral Change
2. Improving Food Support System
3. Strengthening Regulations & Optimizing Funding
4. Utilizing FLW
5. Development of FLW Study & Data Collection

In the Business-as-Usual scenario, it is estimated that FLW generation in Indonesia may reach 344 kg/capita/year in 2045. Meanwhile, with the strategy scenario, it is estimated that the FLW generation can be reduced and reach only 166 kg/capita/year in 2045.

EXECUTIVE SUMMARY

FOOD LOSS AND WASTE IN INDONESIA

SUPPORTING THE IMPLEMENTATION OF CIRCULAR ECONOMY AND LOW CARBON DEVELOPMENT

BACKGROUND

One-third of the food produced for human consumption is lost or wasted in between the harvesting process and consumption process[1], which is known as food loss and waste (FLW). Each year, FLW on a global scale contributes to approximately 4.4 gigatons of greenhouse gas emissions[2]. In 2015, FLW issue became part of the Sustainable Development Goals (SDGs) contained in target 12.3, stating, "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses"[3]. As a country that agree upon the global development agenda, Indonesia has committed to mainstreaming SDGs' goals, targets and indicators in the Medium Term National Development Plan (RPJMN) 2020-2024.

According to the data of the Ministry of Environment and Forestry (MoEF) of the Republic of Indonesia, in 2018, as much as 44% of waste generation in Indonesia was food waste[4]. Indonesia is also claimed to be the second largest FLW producing country in the world, reaching 300 kg per capita per year[5]. However, to this day, Indonesia has not arranged comprehensive information and strategies regarding FLW, especially at the national level. The FLW study in Indonesia aims to discover the FLW database and identify policies and strategies to be implemented in an effort to support low carbon development and circular economy.

The output of this study comprises:

1. Estimation of FLW generation in 2000 - 2019 as well as Green House Gas (GHG) emission, economic and social impacts
2. Causes and drivers of FLW in five food supply chain stages
3. Projection of FLW generation in 2020 - 2045
4. Recommendations for FLW management strategies and policies in 2020 - 2045

The data collection method in this study employed mixed methods (a combination of quantitative and qualitative methods). Quantitative data collection was carried out through secondary data, waste generation survey, and questionnaire survey. Meanwhile, for qualitative, the data collection methods used are literature studies, in-depth interviews, and focus group discussions in Stakeholder Meetings. The analysis was divided into Calculation of FLW Generation, Life Cycle Assessment (LCA), Economic Loss Calculation, Nutrition Loss Calculation, Social Life Cycle Assessment (S-LCA), Analysis of Causes and Drivers of FLW Generation, and System Dynamics Analysis.

This study utilized the Food Balance Sheet (FBS) from the Food Security Agency (BKP) of the Ministry of Agriculture and Statistical Agency of Indonesia (BPS) as a reference for food commodities in Indonesia. The limitation of FLW discussed in the results of this study do not incorporate pre-harvesting food loss, FLW from processed food products but those listed in the FBS, as well as FLW that occurred during the food import-export process.

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[1] FAO. (2011). Global food losses and food waste – Extent, causes, and prevention. Rome.
[2] FAO. (2015). Food wastage footprint and climate change.
[3] United Nations. (2020). Goals 12 Ensure sustainable consumption patterns. Retrieved from https://sdgs.un.org/goals/goal12
[4] Ministry of Environment and Forestry. (2018). *Pengelolaan Sampah Sektor Lingkungan Hidup dan Kehutanan.*
[5] The Economist Intelligence Unit. (2017). Fixing Food – Towards a More Sustainable Food System.

FLW GENERATION IN INDONESIA

In the course of 2000 - 2019, FLW generation in Indonesia reached 23-48 million tons/year (**Figure A**), or equivalent to 115-184 kg/capita/year.

The total FLW generation is derived from five stages of the food supply chain

1. the production stage
2. the post-harvest & storage stage
3. the processing & packaging stage
4. the distribution & market stage
5. the consumption stage

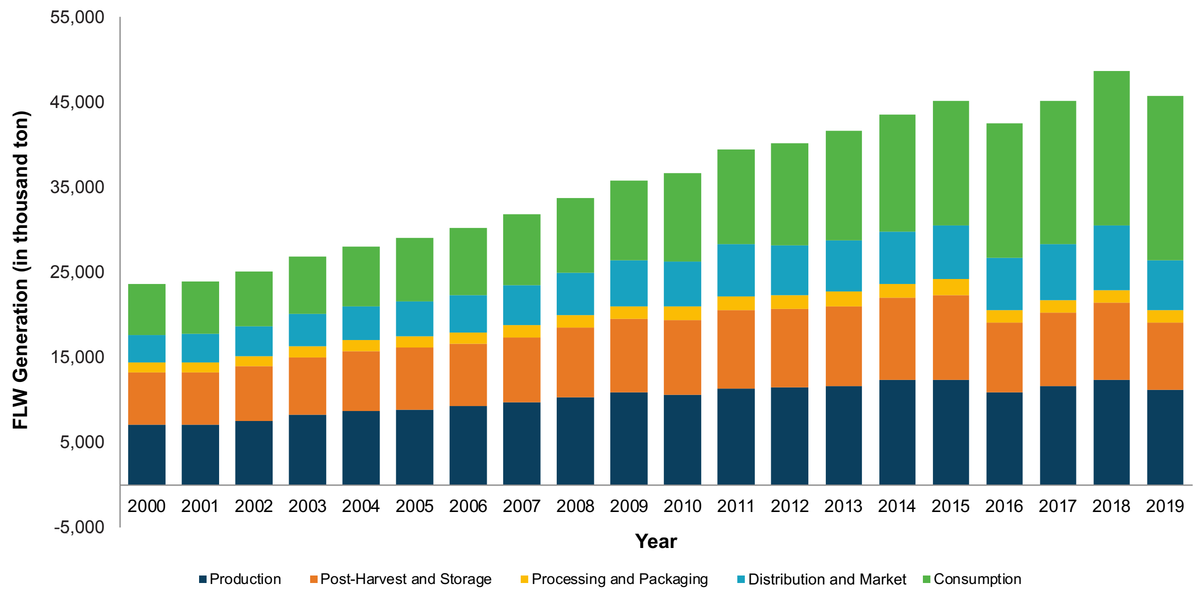


Figure A. Food Loss and Waste Generation in Indonesia from 2000 - 2019 per Food Supply Chain Stage (in thousand tons).

Food loss occurs in the first three stages, while food waste arises in the last two stages. The percentage of food loss in 20 years shows declining, from 61% in 2000 to 45% in 2019, with an average of 56%. Conversely, the percentage of food waste generation in 20 years increases, from 39% in 2000 to 55% in 2019, with an average of 44% (**Figure B**).

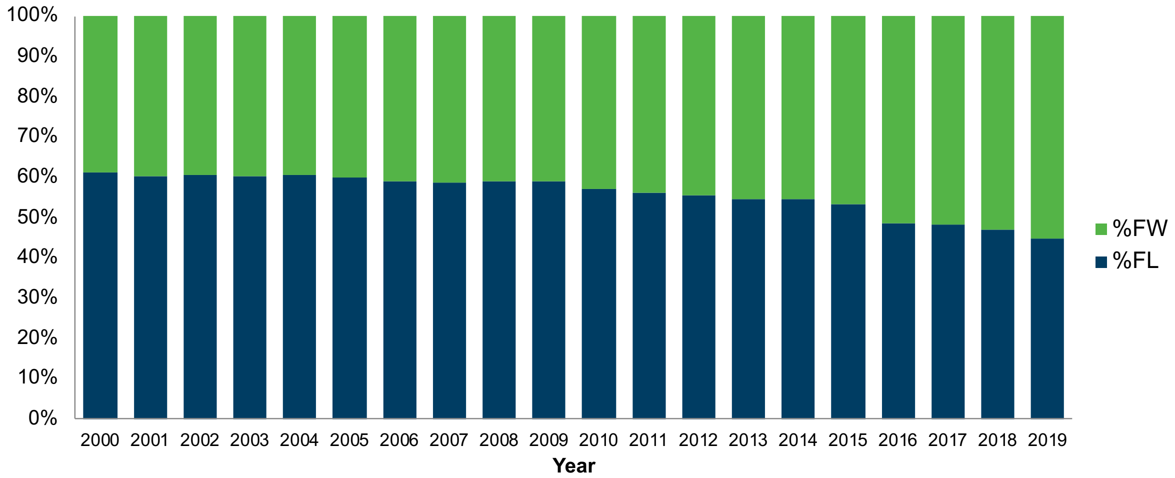
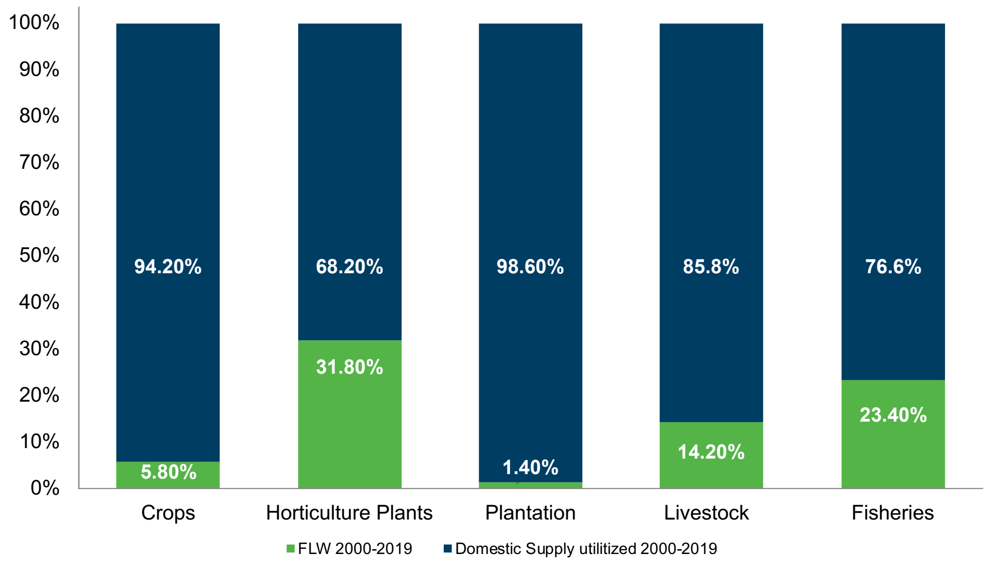


Figure B. Percentage of Food Loss (FL) and Food Waste (FW) Generation to Total FLW in 2000 - 2019.

The critical loss point in which the largest FLW generation occurs is at the consumption stage, with food waste generation of 5-19 million tons/year. In terms of food type, the largest FLW generation is contributed by the crop sector, precisely cereals, totaling 12-21 million tons/year. Meanwhile, the most inefficient type of food is the horticulture sector, especially vegetables – in which the loss reaches 62.8% of the total domestic supply of vegetables in Indonesia (**Figure C**).



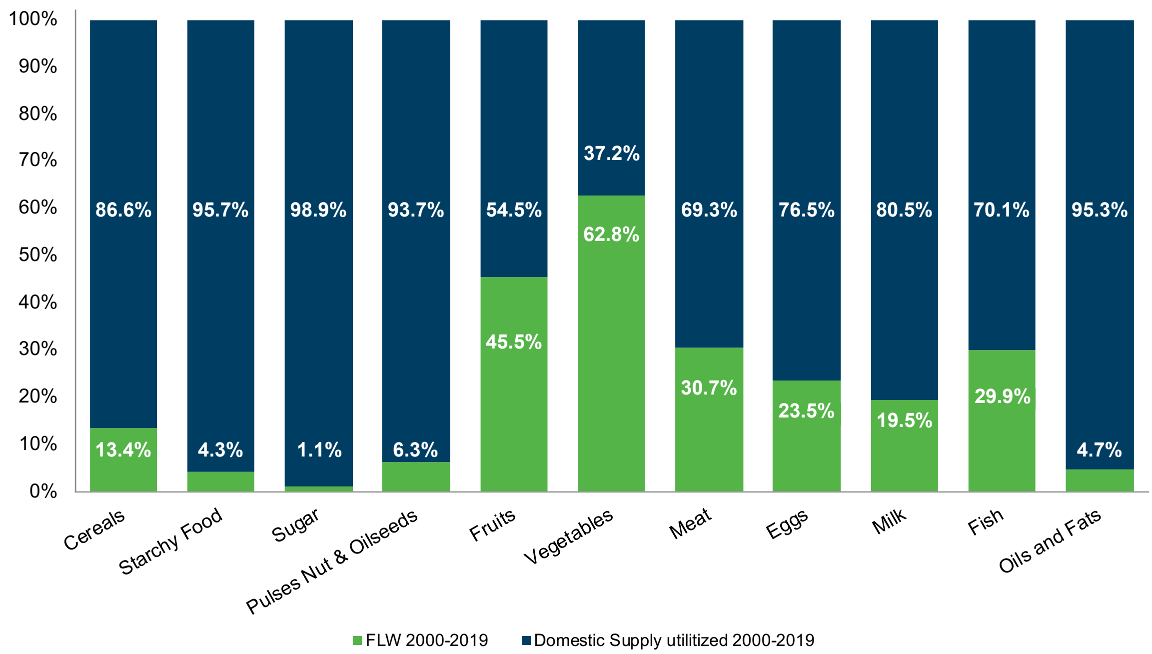


Figure C. Proportion of FLW Generation to Total Domestic Supply 2000 - 2019 in 5 Sectors (top) and in 11 Food Categories (bottom).

ENVIRONMENTAL IMPACT OF FLW: GREENHOUSE GAS EMISSIONS

In this study, LCA global warming potential from GHG is conducted to determine the environmental impact of FLW. The scope of LCA is from material extraction to the final stages of the life cycle neglecting land-use change, infrastructure and out-of-process activities in the supply chain, such as worker transportation, water for sanitation, and others. The FLW generation in the extended food supply chain stage will result in a larger emission load than the emission load of FLW generation in the previous stage. It emerges since the emission load in the food supply chain, which is closer to the end-of-life includes the emission load from the previous stages.

With an average emission of 2,324.24 kg CO_2-eq/1 ton FLW, the total global warming potential of FLW in Indonesia over the past 20 years is reckoned at 1,702.9 Mton CO_2-eq or equivalent to 7.29% average GHG emission in Indonesia over 20 years. The biggest contributor to the global warming potential for 20 years is 2018, while the biggest global warming potential among the five stages of the food supply chain is the consumption stage (**Figure D**). In addition, it is also found that the average emission resulting from 1 ton of food waste generation is about 4.3 times greater than the emission of 1 ton of food loss generation. The average percentage over 20 years of GHG emissions from food loss is 23%, and food waste is 77% (**Figure E**).

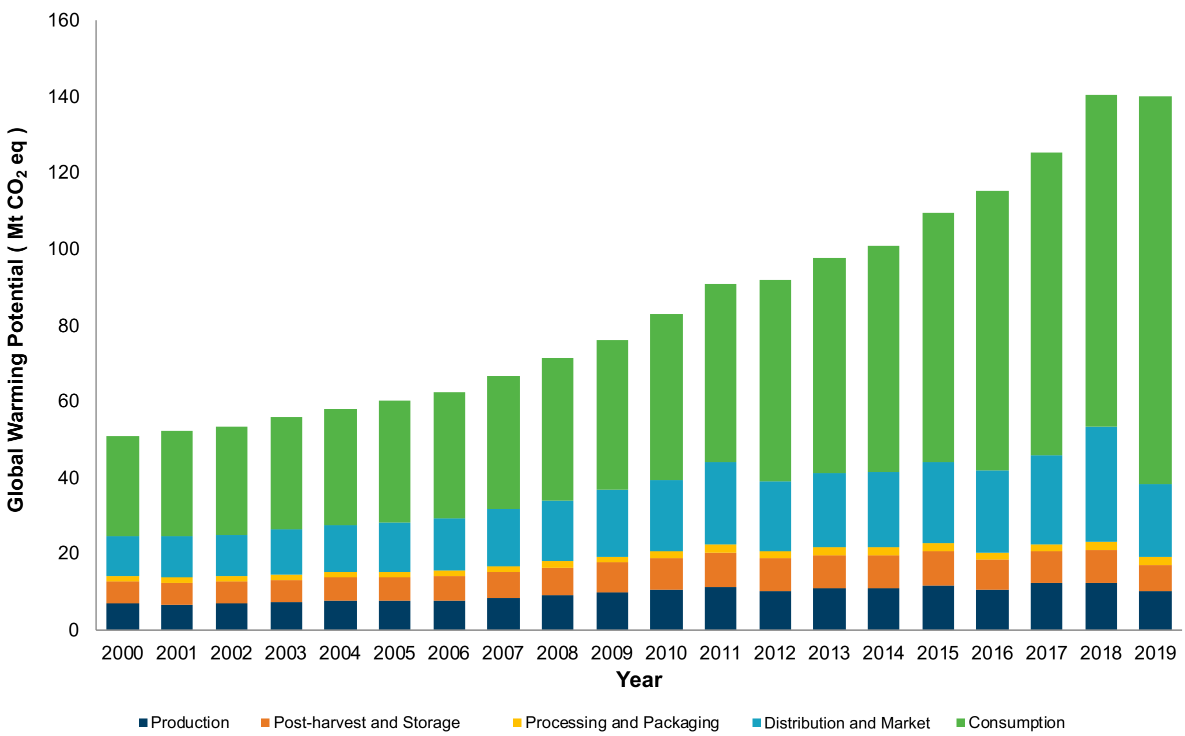


Figure D. Contribution of 5 Stages of Food Supply Chain to Total FLW-Associated GHG Emissions per Year.

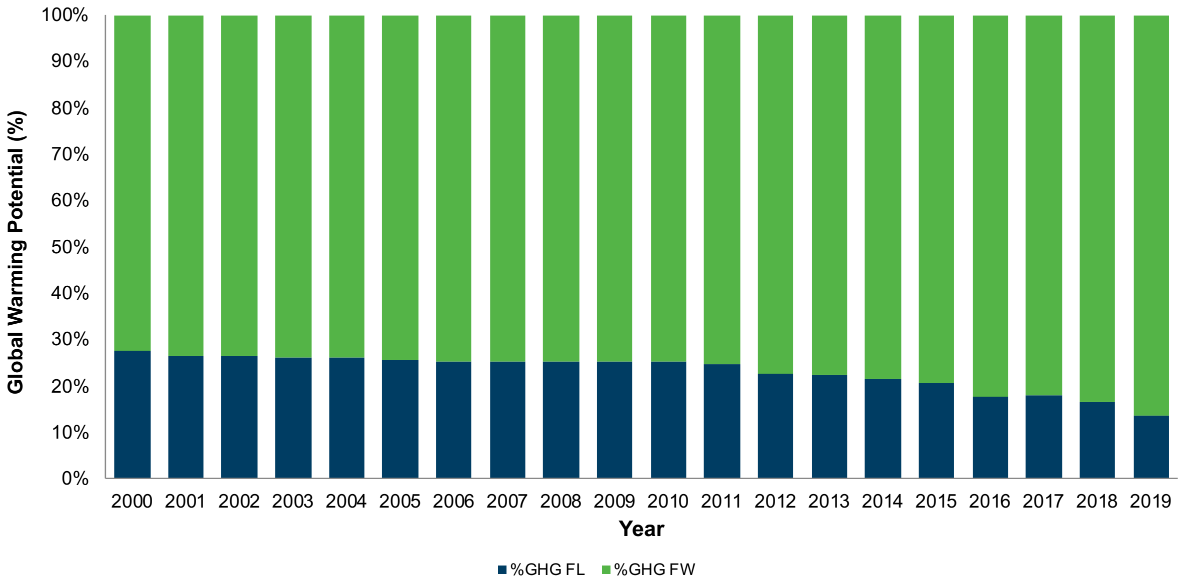


Figure E. Percentage of GHG from Food Loss (FL) and Food Waste (FW) in 2000 - 2019.

When juxtaposed with the five food commodity categories, it shows that the crops, fishery, and horticultural commodity categories are the three main emission contributors with each producing an average of around 39.67%, 22.32% and 20.21% respectively. Given analysis of the contribution per process, the biggest emission hotspot originates from the use of fertilizers and chemicals, especially from the cereals production processing, diesel combustion throughout food supply chain, diesel combustion from fishing vessels, and diesel combustion from production stage to consumption stage. Meanwhile, when various end-of-life scenarios are compared, reducing food waste generation in households is the most significant effort to reduce GHG emissions. For example, when household food waste is reduced by 5%, GHG decreases by 2.98%. Meanwhile, when reductions were carried out with the same value in food waste at hotels, restaurants, catering (HORECA) and food loss at production and post-harvest, the reduction in GHG emissions was only 0.53% and 0.6%, respectively.

ECONOMIC IMPACT OF FLW: POTENTIAL ECONOMIC LOSS

The amount of FLW generation in Indonesia during 2000 - 2019 attained 23-48 million tons/year, which prompts the economic loss of IDR 213-551 trillion/year or equivalent to 4%-5% of Indonesia's GDP/year. There is a possibility that the potential economic loss is of greater value as the data used in calculating economic loss implements available food price data, namely 64-88 commodities out of 146 commodities contained in FBS. The food supply chain stage causing the largest economic loss is the food waste stage, with a value of IDR 107-346 trillion/year. In the scope of types of food (**Figure F** and **Figure G**), crops, particularly cereals, has the largest economic loss. However, this type has good process efficiency. Thus, the proportion of cereal wasted is smaller than the proportion of cereals consumed. Meanwhile, the economic loss value of the horticulture sector, especially vegetables, is not as large as crops, but the efficiency of the process is still not good, causing the proportion of vegetables to be wasted is very high compared to the vegetables consumed.

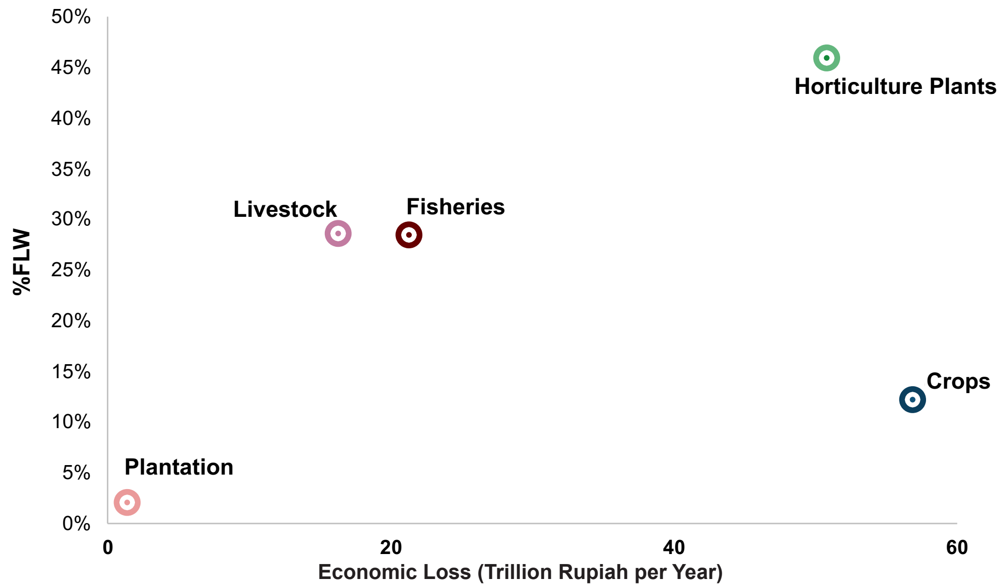


Figure F. Comparison of % FLW to Economic Loss in 5 Food Sectors.

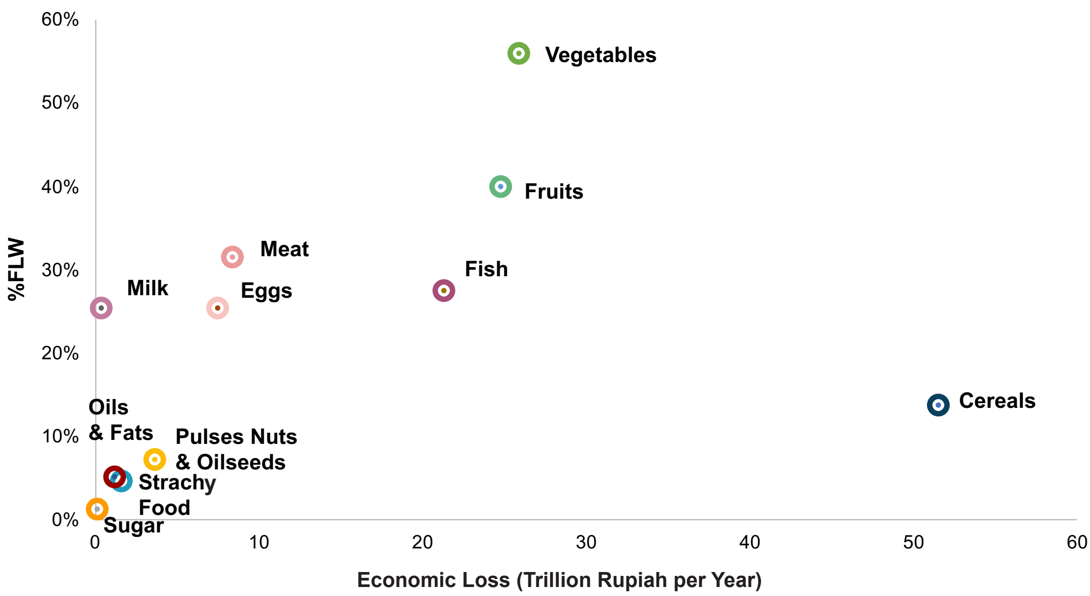


Figure G. Comparison of % FLW to Economic Loss in 11 Food Categories.

SOCIAL IMPACT OF FLW: NUTRITION LOSS

FLW generation of 23-48 million tons/year in Indonesia from 2000 - 2019 has led to nutrition loss. This study reviews the nutrition loss in FLW especially energy, protein, vitamin A, and iron (**Table A**).

The energy loss is 618-989 kcal/capita/day or equivalent to the energy required by nearly 61-125 million Indonesian population (29-47% of Indonesian population). There are 45.7% of Indonesian population with energy deficiency[6]. This implies that 62-100% of the energy deficiency population can be fed with energy from the edible FLW.

The protein loss of FLW is 18-32 grams/capita/day or equivalent to the protein recommended to 68-149 million population on average per year (30-50% of Indonesian population). With 36.1% of Indonesian population has protein deficiency[7], it denotes that 91-100% of the protein deficiency population can be fed with the protein from edible FLW.

Vitamin A loss of FLW is 360-953 Ug RE/capita/day which is equal to the need for vitamin A of 134-441 million people per year (63-166% of Indonesian population).

The iron loss of FLW is 4-7 mg/capita/day or equivalent to the iron needs of 96-189 million people per year (46-72% of Indonesian population). With the number of iron deficiency in pregnant women reaching 40.9% of Indonesian population[8], it signifies that 100% of the pregnant women population with iron deficiency can be fulfilled with edible FLW.

Table A. Nutrition Loss per Individual per Day Due to FLW Generation.

Nutrition Content	Range of FLW Nutrition Loss per individual per day	Nutrition Intake per individual per day	% Indonesian population that can be fed edible FLW	Total of Nutrition deficiency in Indonesia
Energy	618-989 kkal	2,100 kkal	29-47%	45.7%*
Protein	18-32 gr	57 gr	30-50%	36.1%*
Vitamin A	360-953 Ug RE	575 Ug RE	63-166%	N/A
Iron (Fe)	4-7 mg	10.1 mg	46-72%	40.9%**

Notes:
* Health Research and Development Agency. (2014). Diet Total: Survei Konsumsi Makanan Individu Indonesia.)
** Ministry of Health. (2018). Basic Health Research.

[6] Health Research and Development Agency. (2014). Diet Total: Survei Konsumsi Makanan Individu Indonesia.
[7] Ibid
[8] Ministry of Health. (2018). Basic Health Research.

CAUSES & DRIVERS OF FLW IN INDONESIA

In this study, 10 direct causes and 8 indirect drivers of FLW were identified in Indonesia. Based on FAO[9], the factors that may cause FLW could be divided into direct causes and indirect drivers. The direct cause is the action that directly causes FLW by actors in the food supply chain. On the other hand, the indirect driver is the systemic economic, cultural, and political conditions of the food system that affect actors in the food supply chain in their operation - including affecting the FLW generation. These results were obtained according to the analysis of the results of focus group discussions, expert interviews, and practitioner interviews through weighting and the Pareto Method. Of the 18 causes and drivers, 10 are classified as "Very Important" (**Table B**).

Table B. Causes and Drivers of FLW in Indonesia.

Causes and Drivers of FLW in Indonesia			
Type	Very Important	Type	Medaretely Important
D	Lack of implementation of Good Handling Practice (GHP)	I	Market price
D	Insufficient quality of the storage space	I	Inefficient supply chain
I	Market quality standards and consumer preferences	D	Misinterpretation of expiry date and best before
I	Lack of information/education for food workers and consumers	D	Inadequate food preparation
D	Excess food portion and consumers behavior	I	Lack of food waste regulation
D	Technology limitations	I	Limited access to capital
I	Market competition and limited consumer purchasing power	D	Poor harvesting time
D	Poor harvesting techniques	D	Overproduction
I	Limited access to infrastructure		
D	Poor quality of packaging/container		

Information:
D = Direct causes
I = Indirect drivers

[9] FAO. (2019). The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. Rome.

MANAGEMENT STRATEGY & PROJECTION OF FLW GENERATION IN INDONESIA

The strategy for FLW management at the national level is divided into

5 Major Directions (Figure H)

1. Behavioral Change
2. Improving Food Support System
3. Strengthening Regulations & Optimizing Funding
4. Utilizing FLW
5. Development of FLW Study & Data Collection

In the establishment of strategy of FLW management in Indonesia, it prioritizes areas categorized into three: high priority, medium priority, and lower priority. This priority is determined based on hotspot for FLW generation, hotspot for causes and drivers of FLW generation, and hotspot for FLW GHG emissions. The strategy considers the implementation period which is governed according to input from the expert panel (expert judgment) on the ground of accomplishment schedule. The strategy implementation period are separated into three categories; the short term (1 year), medium term (5 years) and long term (25 years).

1 Behavioral Change	Focus on the development of training Institutions in the regions, capacity building for food workers, and education to consumers to increase knowledge about FLW and change behavior.
2 Improving Food System Support	Developing farmer corporations and providing infrastructure and facilities that support the efficiency of the food production process that also contributes to the reduction of FLW.
3 Strengthening Regulations & Optimizing Funding	Optimizing appropriate funding for the improvement of food infrastructure, developing FLW regulations at national and regional levels, as well as strengthening inter-ministries/agency coordination regarding FLW issues.
4 Utilization of Food Loss and Waste	Encouraging the development of a food distribution platform, FLW handling that supports a circular economy, and developing FLW utilization pilot on a city/regency scale.
5 Development of FLW Study & Data Collection	Highlighting the need for the integrated data collection on FLW generation through the census and development of studies to complement FLW data in Indonesia.

Figure H. Five Major Directions of Strategy of FLW Management in Indonesia.

To comprehend the Indonesian condition with and without a strategy for FLW management, it is necessary to conduct FLW generation projections for 2020 - 2045 using a system dynamics model with one "food" aggregate. Based on the projection of the next 25 years, without any control (Business as Usual/BAU), it is calculated that Indonesia's FLW generation in 2045 may reach 112 million tons/year or 344 kg/capita/year. Meanwhile, according to the strategy scenario, it is reckoned that FLW generation in 2045 can be confined at 49 million tons/year or 166 kg/capita/year (**Figure I**). The assumptions of strategy scenario formulated consist of (1) % food loss production decreases from 4.37% in 2022 to 3% in 2045, (2) food spoilage time in storage increases from 8 months in 2022 to 10 months in 2045, (3) shipping to processing delays decreased from 5 days in 2022 to 4 days in 2045, (4) % food loss in processing and packaging decreased from 1.2% in 2022 to 0.8% in 2045, (5) food spoilage time in distribution increases from 18 months in 2022 to 24 months in 2045, (6) food supply chain delays decrease from 7 days in 2022 to 4 days in 2045, and (7) food waste generation consumption is targeted to decrease as much as 35% from 2022 to 2030.

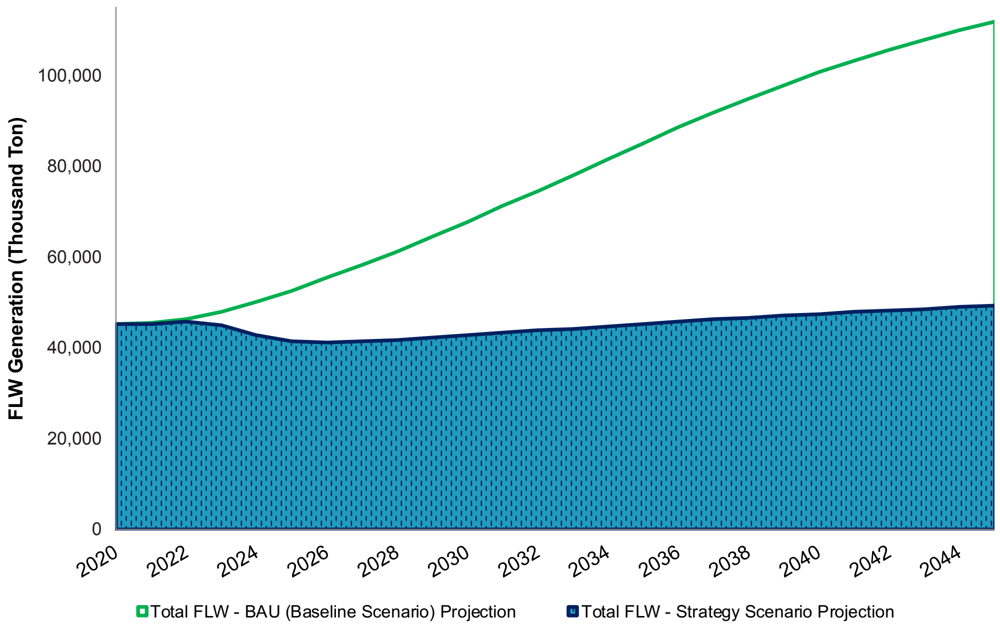


Figure I. Total FLW Generation of BAU Projection to Strategy Projection.

The percentage of FLW generation reduction in 2020 - 2045 of the strategy projection analysis is the result of the discrepancy between BAU generation scenario and strategy generation scenario to BAU generation scenario in that year (**Table C**). The percentage projection result of food loss generation reduction reaches 16.60% (2030) and 33.61% (2045), the percentage projection of food waste generation attains 51.25% (2030) and 68.94% (2045). From this projection, it indicates that in order to achieve the SDG 12.3 target, that is, "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest and processing stages", Indonesia is required to reduce the minimum food waste generation by 2.83% per year. Meanwhile, for the total FLW with the strategy scenario composed in 2045, it is estimated that the FLW reduction can reach 55.88%.

Table C. Projection Results of % FLW generation in 2020 - 2045.

Year	FL Reduction	FW reduction	FLW reduction
2030	16.60%	51.25%	36.90%
2045	33.61%	68.94%	55.88%

1 PREFACE

URGENCY OF FOOD LOSS & WASTE ISSUES IN INDONESIA

A third of all food produced for human consumption is lost or wasted between harvest and consumption processes, known as food loss and waste (FLW)[10]. This FLW accounts for about 4.4 giga-tons of greenhouse gas (GHG) emissions each year[11]. In 2015, the FLW issue became part of the Sustainable Development Goals (SDGs) on target 12.3, namely "By 2030, halve the food waste per capita at the distribution and consumer stages and reduce food loss at the production stage and throughout the supply chain, including the post-harvest losses"[12]. As a country that participates in agreeing on the global development agenda, Indonesia has committed to mainstreaming the goals, targets, and indicators of SDGs in the National Medium-Term Development (RPJMN) 2020-2024, together with Low Carbon Development Initiatives (LCDI), where the developments should be carried in sustainable and low emission manners.

In Indonesia, based on data from the Ministry of Environment and Forestry, 44% of waste generation in 2018 is food waste[13]. Indonesia is also claimed to be one of the largest food waste producing countries, estimated at 300 kg per capita per year[14]. However, Indonesia does not yet have comprehensive information and strategies regarding the FLW generation, especially at the national level. While in fact, reducing and managing FLW responsibly can contribute to the reduction of GHG emissions – where on the global scale the reduction and handling of FLW is estimated to reduce GHGs from food system by up to 11%[15].

The Study of Food Loss and Waste in Indonesia is an initial step to understand the condition of FLW in Indonesia and develop a reduction strategy and handling of FLW with a big goal to support Low Carbon Development in Indonesia.

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[10] FAO. (2011). Global food losses and food waste – Extent, causes, and prevention.
[11] FAO. (2015). Food wastage footprint and climate change.
[12] United Nations. (2020). Goals 12 Ensure sustainable consumption patterns. Retrieved from *https://sdgs.un.org/goals/goal12*
[13] Kementerian Lingkungan Hidup dan Kehutanan. (2018). Pengelolaan Sampah Sektor Lingkungan Hidup dan Kehutanan.
[14] The Economist Intelligence Unit. (2017). Fixing Food – Towards a More Sustainable Food System.
[15] WWF. (2020). Carbon Footprint Exploring the UK's Contribution to Climate Change.

SCOPE OF STUDY OF FOOD LOSS & WASTE IN INDONESIA

The FLW study in Indonesia aims to

1. Estimating FLW generation in Indonesia in 2000-2019, and analysing its GHG emission, potential economic loss, and potential social impacts;
2. Analyzing the causes and management gaps that lead to the emergence of FLW in the five stages of the food supply chain;
3. Projecting the FLW generation from 2020 - 2045; and
4. Developing recommendations for FLW management strategies and policies in 2020 - 2045.

The methodology in this study is a mixed-method, which is a combination of quantitative and qualitative methods (**Figure 1**). Quantitative data collection is carried out through secondary data, waste generation measurement surveys, and questionnaires. As for qualitative data collection, the method used is literature study, in-depth interview, and focus group discussions in Stakeholder Meeting. The analysis carried out in this study is divided into: FLW Generation Calculation, Analysis of Causes and Drivers of FLW Generation, Analysis of Utilization of Ugly/Leftover Food and FLW Treatment, Life Cycle Assessment (LCA), Economic Loss Calculation, Nutrition Loss Calculation, Social Life Cycle Assessment (S-LCA), and System Dynamics. Details of the methodology performed in this study can be seen in **the Appendix**.

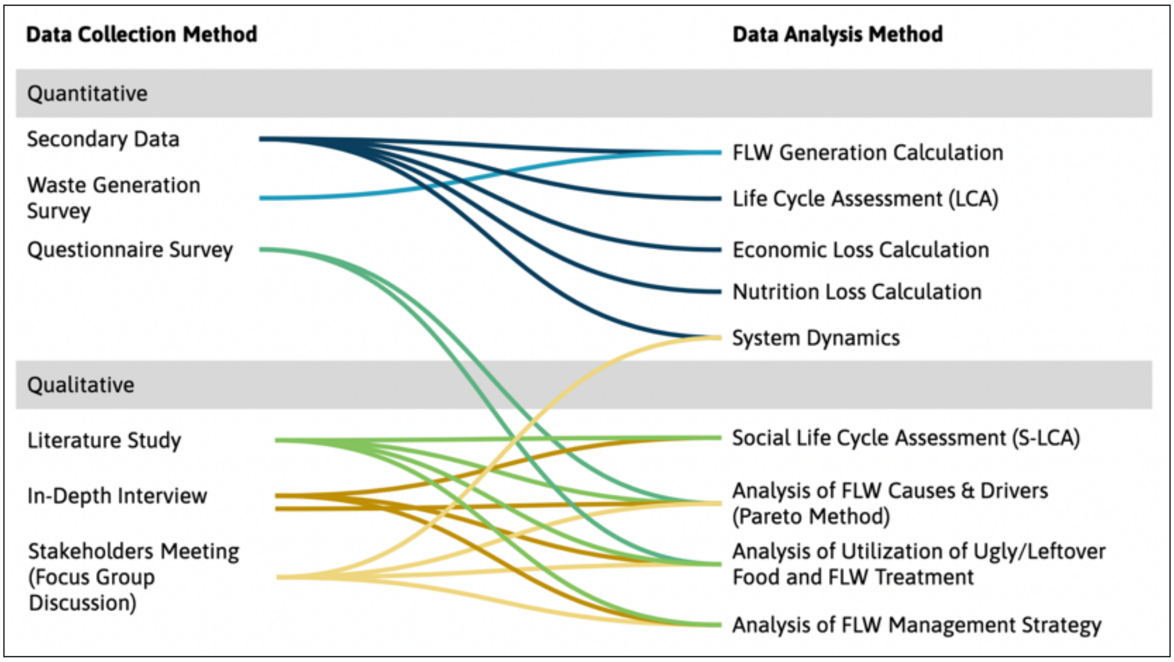


Figure 1. The Overview of Data Collection and Data Analysis Methodology.

This study uses the Foods Balance Sheet (FBS) from the Food Security Agency (BKP) of the Ministry of Agriculture and the Central Statistics Agency (BPS) as a reference for the category and quantity of food commodities in Indonesia. Commodity details are presented in **the Appendix**. The FLW boundary discussed in the results of this study do not include pre-harvest food loss, FLW from processed food products other than those listed in the FBS, as well as FLW that occurs during the food import-export process.

DEFINITION OF FOOD LOSS & WASTE

In this study, food loss (FL) and food waste (FW) definition and scope of food supply chain refer to the definition from FAO[16], without incorporating the loss of food quality. There are 5 (five) food supply chain stages studied:

1. Production;
2. Post-harvest and storage;
3. Processing and packaging;
4. Distribution and market; and
5. Consumption.

The definition of food loss and food waste used is as follows:

Food Loss
The decrease in the quantity of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers.

Food Waste
Refers to the decrease in the quantity of food resulting from decisions and actions by retailers, food service providers and consumers.

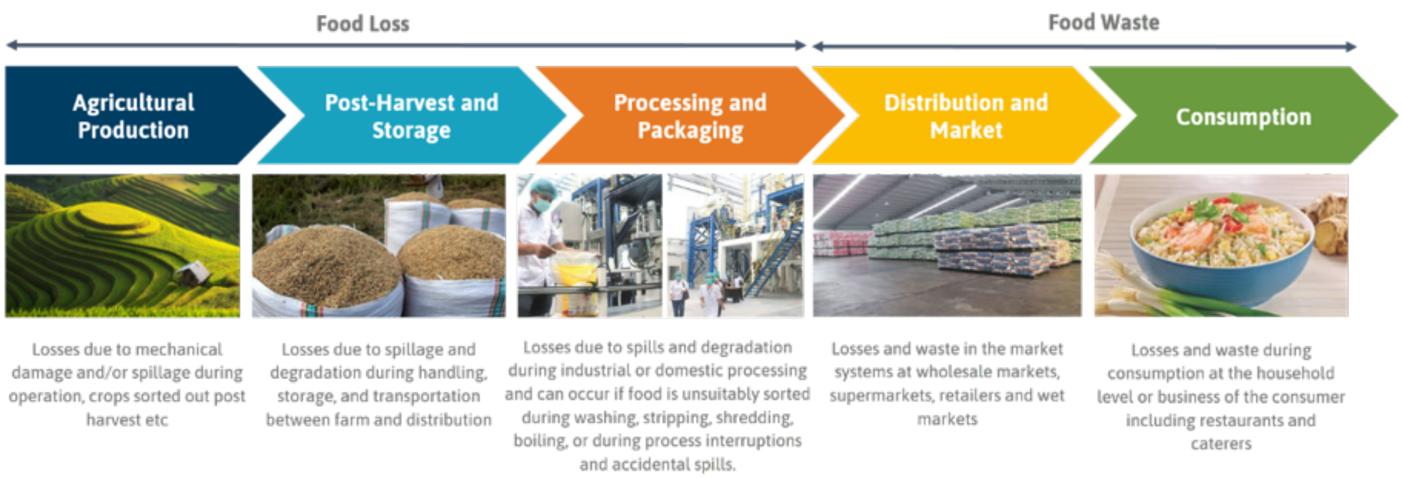


Figure 2. Food Loss and Food Waste Scope in Food Supply Chain. (Picture Source: Various Sources)

[16] FAO. (2011). Global food losses and food waste – Extent, causes, and prevention.

2 EXISTING CONDITION OF FOOD LOSS & WASTE IN INDONESIA

FOOD LOSS & WASTE GENERATION IN INDONESIA

The FLW generation from 146 food commodities in Indonesia that occurred from the production stage to the consumption stage in 2000 – 2019 is in the range of 23–48 million tons/year (**Figure 3**) or 115-184 kg/capita/year. Production stage generation was 7-12.3 million tons/year, in the post-harvest and storage stages, namely 6.1-9.9 million tons/year, in the processing and packaging stages was 1.1-1.8 million tons/year, in the distribution and market stages, namely 3.2-7.6 million tons/year, and the most are in the consumption stage of 5–19 million tons/year. From this consumption stage, it is calculated that 80% comes from households and the remaining 20% are from the non-household sector. Also, it is approximated that 44% of the existing food waste is edible food waste.

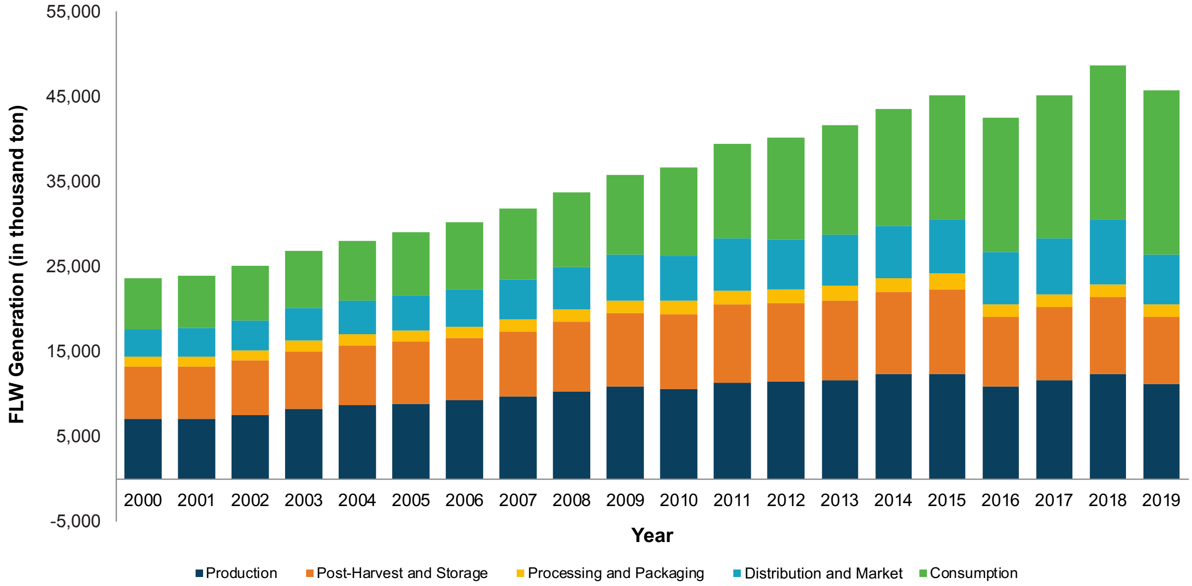


Figure 3. Food Loss and Waste Generation in Indonesia in Food Supply Chain Stage in 2000 - 2019.

The trend of FL contribution compared to FW (**Figure 4**) shows that the percentage of food loss over 20 years tends to decline, from 61% in 2000 to 45% in 2019, with an average of 56%. While the percentage food waste generation for 20 years tends to increase, from 39% in 2000 to 55% in 2019, with an average of 44%.

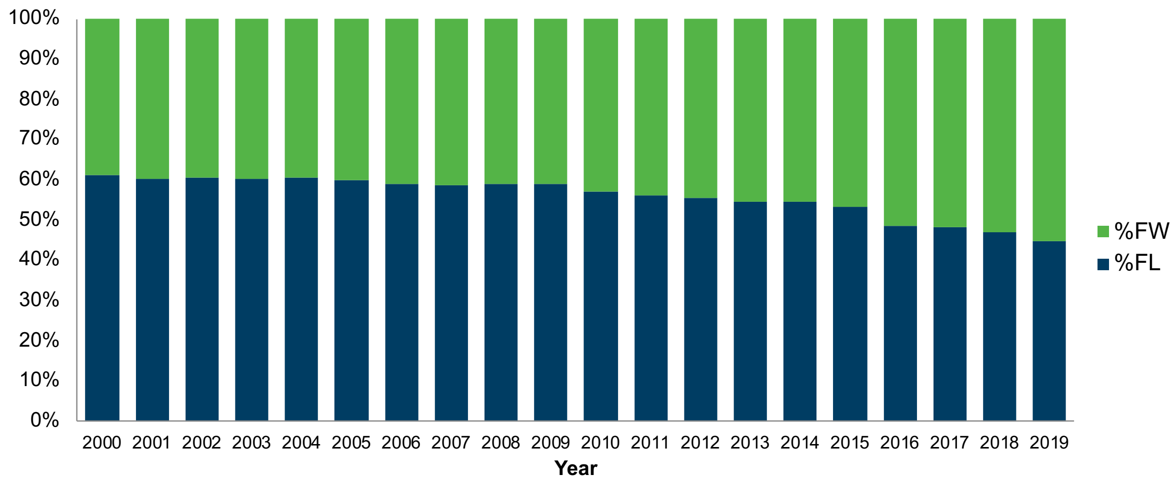


Figure 4. Percentage of Food Loss (FL) and Food Waste (FW) Generation to Total FLW 2000 - 2019.

To understand the FLW hotspots of each food type, the FLW generation data are analyzed based upon 5 (five) food sectors and 11 commodity categories from FBS. The result of analysis in **Figure 4** and **Figure 5** shows that according to the 5 (five) food sectors, crops are the sector with the highest FLW generation, accounting for 46.2% of all sectors or equal to 14-24 million tons/year. Meanwhile, given the 11 food categories in FBS, cereals are the largest FLW generation contributor for 44.3% of all sectors or equal to 12-21 million tons/year.

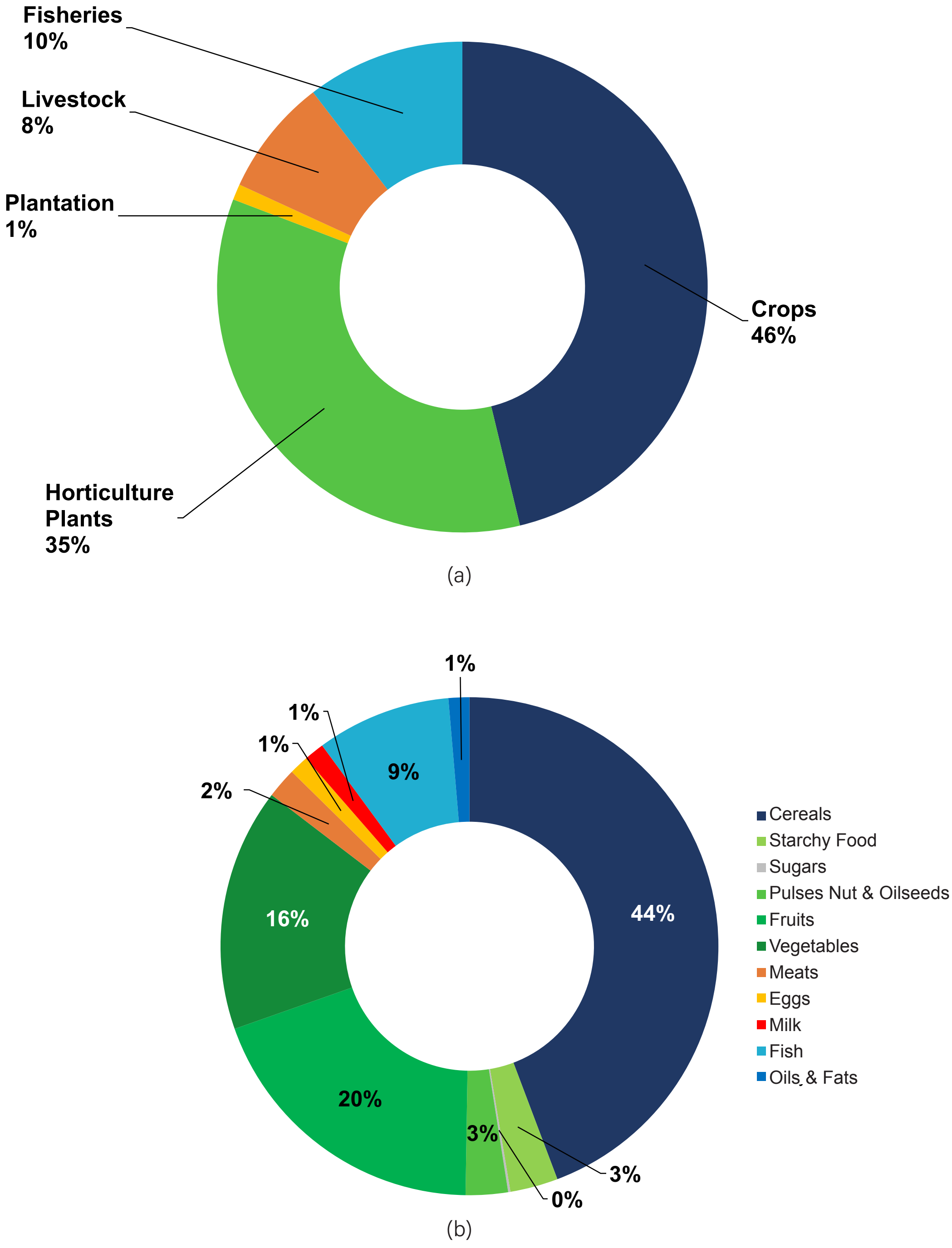
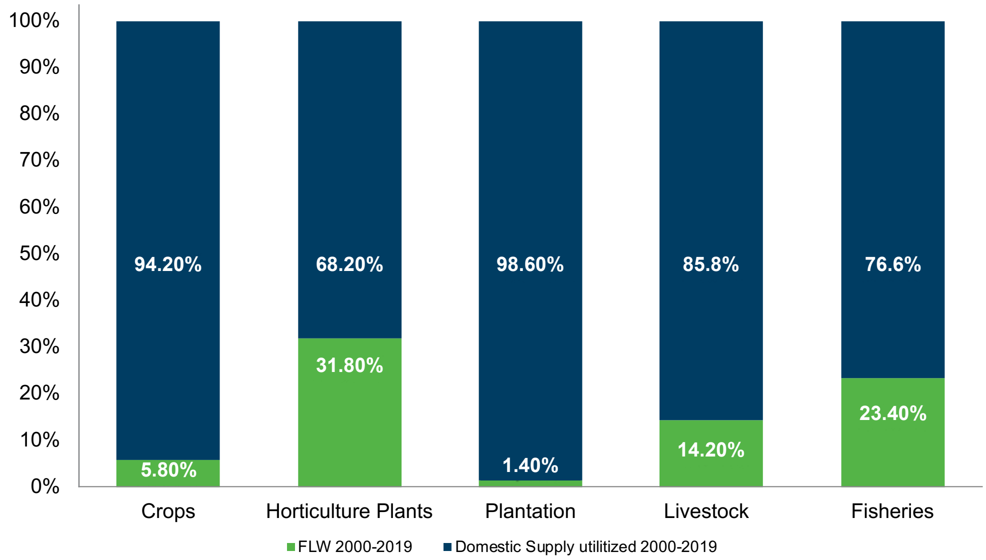
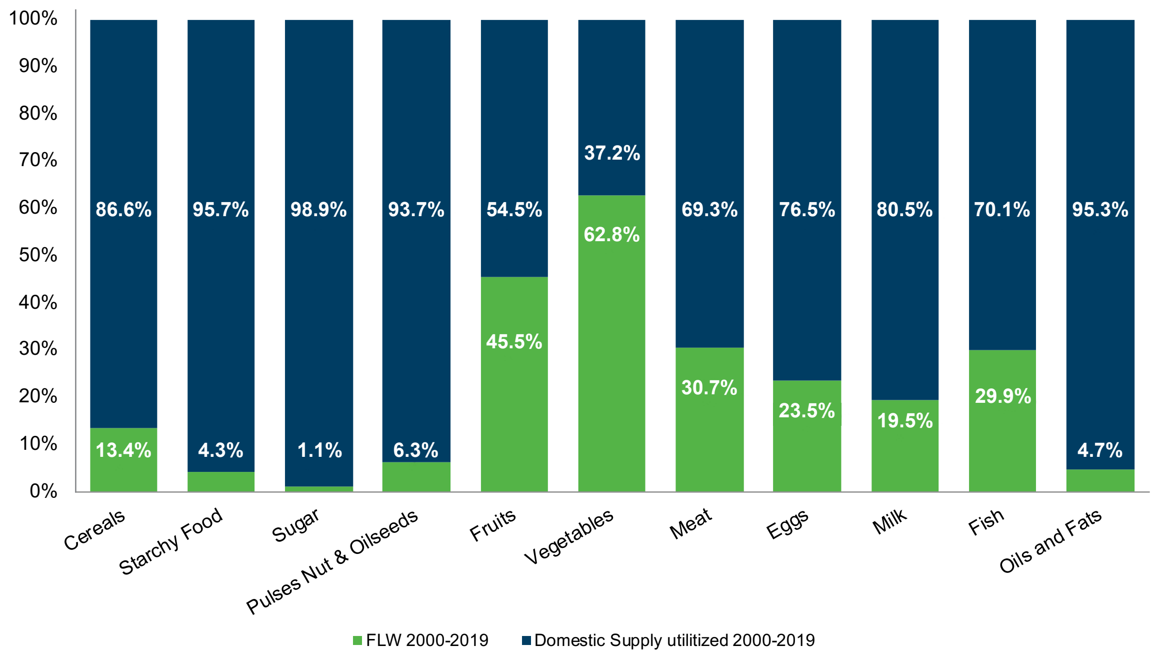


Figure 5. Average Proportion of Indonesia's FLW Generation in 2000 - 2019 (a) in 5 food sectors (b) in 11 food categories.

To comprehend further about hotspots, a comparison between FLW generation and total domestic supply in 5 (five) food sectors and in 11 food categories are carried out, in which the results are presented in **Figures 6 (a)** and **(b)**. Evolved from this comparison, it is known that the largest losses proportion of 5 (five) food sectors is the horticultural sector, (31.8% of the available domestic supply was lost). Meanwhile, in the 11 food categories, the largest losses proportion is vegetables (62.8% of the available domestic supply was lost).



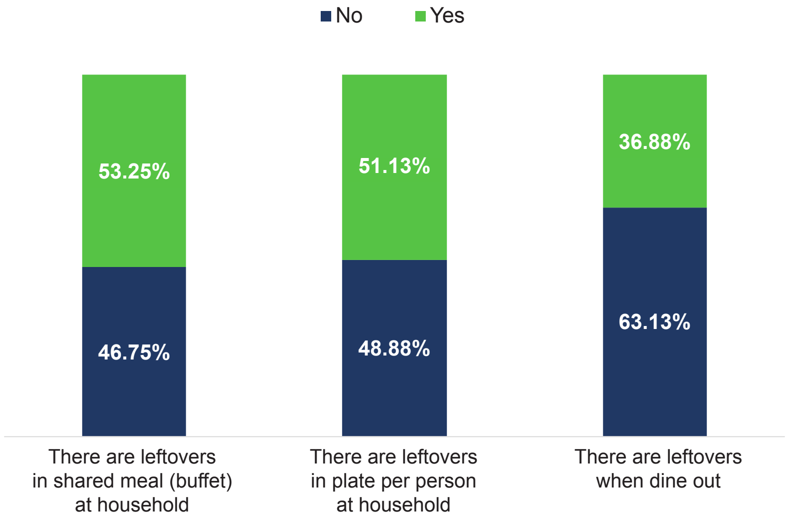
(a)



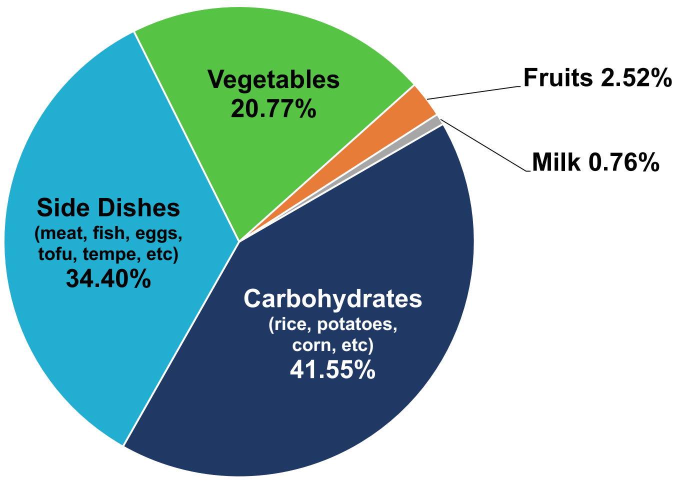
(b)

Figure 6. FLW generation proportion in 2000 - 2019 compared to total domestic supply 2000 - 2019; (a) in 5 food sectors (b) in 11 food categories.

The FLW calculation results are in accordance with the questionnaire results in **Figure 7.** It shows that for household consumption, 53% of respondents stated that there are usually leftover foods from cooked or purchased meal and 51% of respondents admitted that there are commonly food leftovers on the plate per person after consumption. Contradictory with consumer behavior when dining out, 63% of respondents expressed that normally there is no leftover food after consumption. However, for both household and non-household consumption, respondents stated that carbohydrates (rice, potatoes, corn, etc.) are the most common leftover or the most wasted food category.



(a)



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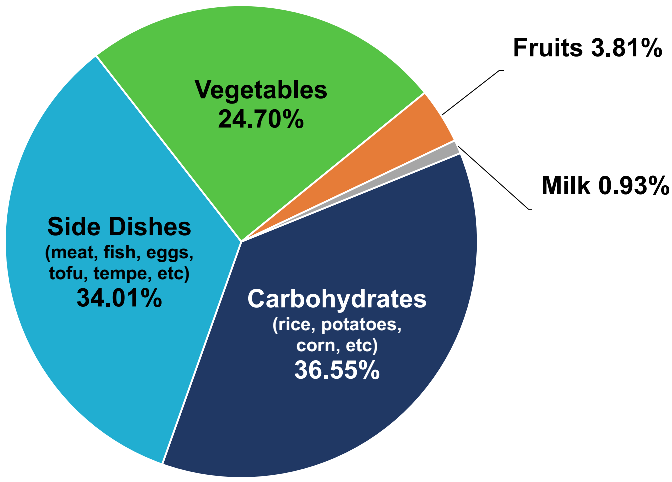


(c)

Figure 7. Community Behavior on Food Waste Generation (a) Leftover Food Presence (b) Type of Leftover Food in Households (c) Type of Leftover Food in Non-Households.

UTILIZATION OF FOOD FIT FOR HUMAN CONSUMPTIONS

Utilization of leftover or ugly food has been carried out in Indonesia, especially related to the use of leftover or ugly food fit for human consumption, among others:

1 Consumed personally by farmers/communities near the farm

Food loss often occurs because the products do not fulfil some of the food quality standards, such as standards for colour, shape, weight, and so on. Products that do not fulfil aesthetic standards but are still nutritious are referred to as "ugly food", despite the fact that this food is still edible. In practice, at the production stage this ugly food will be personally consumed by farmers or distributed to communities near the farm. Several products considered as ugly food are cracked chicken eggs, overripe chillies, or very small tomatoes.

2 Processed into other processed food

Processing ugly food or leftover foods into other foods as a form of FLW prevention is quite common throughout the food supply chain. At the pre-consumption level, as aforementioned, agricultural products that do not meet quality standards are personally consumed by farmers or communities near the farm. The food can be consumed fresh or processed into other forms – for instance, bananas are made into fried bananas, cassava is cooked into chips, and tomatoes are repackaged into jam or sauce. The same applies at the consumption stage, once there are edible leftovers that are aesthetically less suitable to be consumed in its original shape, it needs to be processed into other food products that are still fit for consumption while still containing the right nutrition needed without the need to pay attention to the original form of food that is not suitable standard. For example, leftover rice is processed into crackers by Tunas Nusa, an organization in Bandung.

3 Donation of ugly food and food leftovers to those in need

Apart from ugly food which are often wasted, albeit edible, leftovers from businesses or events activities (restaurants/hotels/catering) are also often thrown away. To keep edible leftovers from being wasted, there have been several organizations in Indonesia that distribute ugly food and edible leftovers to those in need, such as Foodbank of Indonesia (FOI), Garda Pangan, and Food Bank Bandung (FBB). Parties distributing their food to FOI, FBB, or Garda Pangan may come from any stage in the food supply chain. Foodbank also has quality control function, in which they will sort out the quality of the food prior to distribution. Then, the foodbank will select the appropriate recipients so that food distribution becomes right on target. The recipients of food donations are usually less prosperous communities such as the poor, orphans, refugees, and street children.

FOOD LOSS & WASTE HANDLING

Production, Post-harvest and Storage, and Processing and Packaging Stages

1 Used as animal feed

Rotten and not harvested agricultural products are reprocessed into animal feed mixed with cereal and other compositions that are necessary for animals' nutrition for it has good content for animals. These agricultural products are used as one of the raw materials for animal feed because they remain having such quality that can be consumed by livestock and contain good nutrition for the development of livestock. For example, cow and goat feed that is added with food loss of cabbage, banana, soy, and so forth. In addition, dead animals are often fed to other animals, such as dead chicken meat is fed to dogs.

2 Used as a fertilizer

Organic fertilizers are the result of plants and other compositions combination such as crop residues, livestock manure, food waste, and others. Organic fertilizers often made from crops and not suitable for sale is compost. Treating the food loss into compost provide benefits to farmers, such as reducing the accumulation of waste on agricultural land and saving fertilizer cost. One example is cabbage farmers who process unsold cabbage into organic fertilizer.

3 Discarded and landfilled

In some cases, it is found that there is irresponsible food loss handling such as hoarding food waste on the edge of the land or elsewhere. In particular, the chillies that are dumped on the edge of a river near the land, bananas and shallots which are piled on the edge of the land until they rot.

Distribution & Market Stage

1 Traditional Market

As one of the consumer's channels in the food supply chain, market activities have a massive potential in generating food waste.

Unsold food can be returned to the supplier or sold at very cheap prices depending on the product condition. While for food that is rotten, damaged, and improper for sale may become food waste. Following are some activities in existing schemes of food waste handling, which are generally conducted by market managers, the private sectors, and the City/Regency Environmental Service:

- Food waste containment by sellers using simple containers e.g., barrels, plastic bags, wooden boxes or just collected under the kiosk.
- Food waste collection to the market's temporary disposal site (TPS) through cleaning services using carts, however, some sellers collect directly to the roadside around the market.
- Processing facilities on the traditional market are generally for composting, but most of them have not yet operated sustainably due to equipment, maintenance, and operational constraints. One of the successful composting practices in the traditional market is in Surabaya, which composted food waste is distributed to city parks by the Surabaya City Cleanliness and Green Open Space Service (DKRTH).
- The collected food waste is then transported to the landfill (TPA) by trucks. However, transportation often hampers because the transportation fleet and operational schedule are uncertain, so that food waste in the market often piles up and fills the roadside.

2 Retail

Handling food products that are potentially food waste (defect products, do not meet the standard or are improper for sale) is done by returning it to the supplier. While food waste handling practices by retail are generally applied with the following activities:

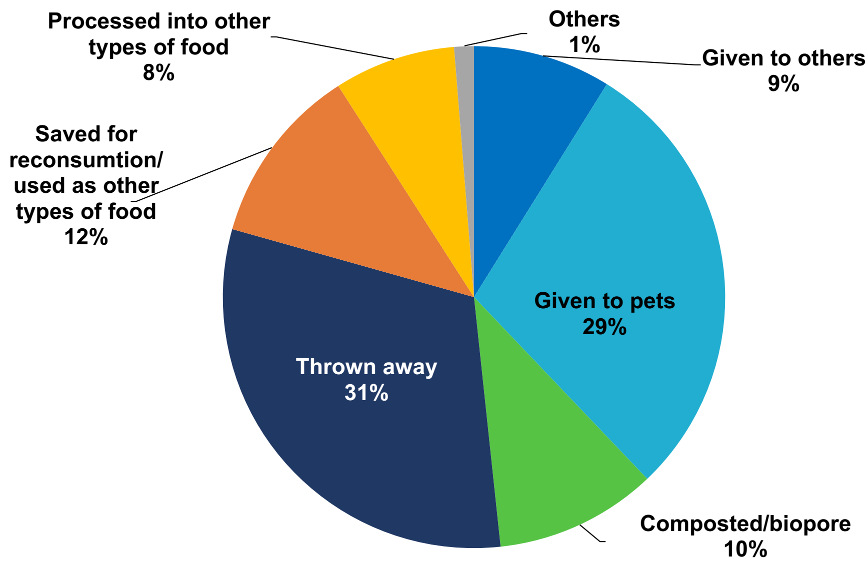
- Containment, using containers, sulo, or separate plastic bags for organic waste.
- Collection, large retail branches usually have TPS, while small retail branches (no TPS) will cooperate with the surrounding community to carry out 3R activities and the residue will be disposed of to the TPS.
- Transportation is mobilized by the Environmental Agency and private sector services twice a week or every day to the landfill (TPA).

One of the retail case studies, Borma in Bandung, has identified an innovative practice in food waste handling, namely a collaborative program of food waste utilization with the community. As an example, if there are unsold prime quality vegetables, it can be distributed to BSF breeder (maggot). Also, if there are cracked eggs but still in good quality, it will be transported to the bakery as bread baking ingredient.

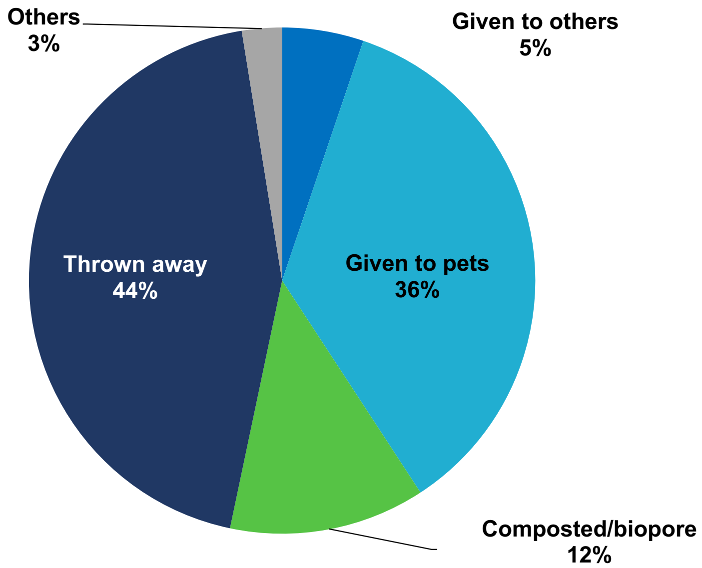
Consumption Stage

1 Household

The practice of food waste handling in the household sector can be represented by the community behavior patterns in managing unconsumed leftovers. From the questionnaire survey, it is known how people in the household treat leftovers from shared portions (food served in a buffet) and individual portions (plates per person). For both types of food waste, the dominant food waste handling is thrown away and fed to pets. The results of the online survey regarding the treatment of Indonesian people to food waste can be seen in **Figure 8.**



(a)



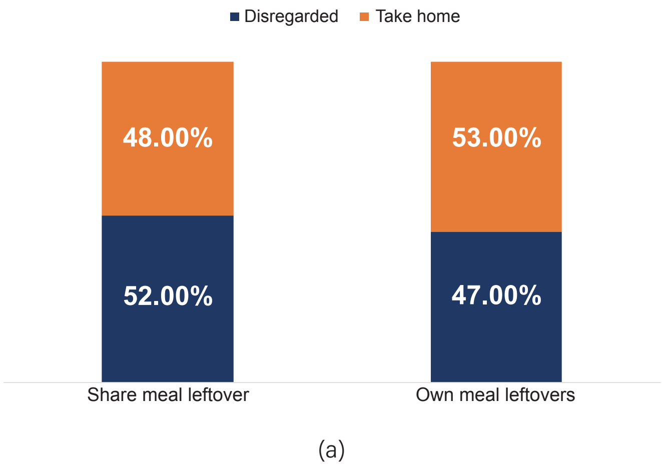
(b)

Figure 8. Community Behavior on Handling Leftover Food in Household
(a) Leftover from a shared meal (buffet) (b) Leftover Food in individual plates.

When the leftovers are disposed of, based on the conducted field survey in three cities, mixed waste (including food waste) from local households will be collected by waste collectors to Temporary Disposal Site (TPS) or by waste trucks to the landfill (TPA). Besides, some people do not subscribe to the collection services, therefore they give the food waste to their pet, hoarded, and then burned in the backyard. On the other hand, there are also some effective waste segregation practices in households and food waste treatment activities at TPS, such as TPS Batununggal Indah (Bandung), TPS Sukamiskin RW 1 Sukamiskin Sub-District (Bandung), and TPS 3R (Reduce, Reuse, Recycle) Bantas (Tabanan). In the cases of Batununggal Indah Bandung and Bantas Tabanan Village, food waste which is part of organic waste is processed using the composting method in the Compost House. When the compost can be harvested, the compost will be delivered to residents for the maintenance of community gardens and/or purchased by residents outside Batununggal Indah and Bantas Village. Meanwhile, in the case of RW 1, Sukamiskin Bandung District, food waste is processed using the Black Soldier Flies (BSF) method and the result is maggot (larva) for animal feed.

2 Non-Household

People's dining out behavior in treating their leftovers from shared portions prefers to be disregarded (52%) rather than wrapped and taken away (48%). However, the leftover food derived from its individual portion/plate is mostly wrapped and taken away (53%) rather than being disregarded (47%). If the leftover food is wrapped and taken away, as much as 60% tend to eat the leftover food at another time, some feed leftover food to pets (19.88%). However, it showed that 4.38% of respondents have the habit of storing leftover food in the refrigerator until it is thrown away. Consumer behavior towards dining out leftovers is shown in **Figure 9.**



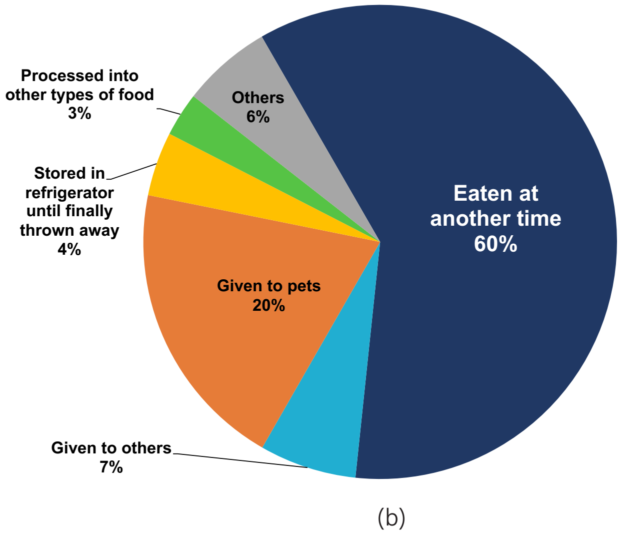


Figure 9. Community Behavior in Handling Dine Out Leftover Food
(a) Handling Leftover Food when Dine Out (b) Treatment for Leftover Food that is Taken Away.

Meanwhile, the food waste handling from the food business sector generally hires private waste collector services or transported by the local Environmental Agency (DLH). The private sector/DLH will transport the food waste mixed along with other waste to the landfill (TPA).

Before the waste is transferred by transportation services, both private and government agencies, the cleaning services at non-household sector locations collect the food waste daily. The case study takes place in the hotel sector, at The Papandayan Hotel Bandung and Hotel Aryaduta Pekanbaru. Every day, food waste is collected 2 times, in the morning and evening. Frequently, the food waste comes from kitchens, rooms, and restaurants. The waste will be sorted out into wet and dry waste. For instance, at Hotel Aryaduta Pekanbaru, food waste originating from the kitchen and buffet is collected for animal feed by the transportation service/vendor. Whereas, food waste from the lunch box will not be segregated and directly categorized as dry waste, then waste collector vendor will transport it to the landfill.

For the non-household sector such as offices, restaurants, and public facilities, waste handling generally consists of containment, collection, and transportation. In non-household sector, locations that already segregate their waste usually cooperate with responsible waste management services to ensure that the segregated waste will not get mixed again. As an example, the Potato Head restaurant in Jakarta that cooperates with Waste4Change to transport their segregated waste that the food waste will be processed by composting or BSF (Black Soldier Flies) method. There is also a business sector that employs food waste, such as in Tabanan Regency, the segregated food waste from hotels is used as animal feed. Also, there is a case study at the Nasi Kapau Restaurant, Uni Ros Pekanbaru, where food waste of leftover rice and meat are fed to animal, while the remaining vegetables, fruit skins, kitchen waste and other leftover food are collected and transported to the TPA.

ENVIRONMENTAL IMPACT OF FOOD LOSS & WASTE

Overview

The environmental impact of FLW that measured in this study is the global warming potential from GHG that arises along the food supply chain. The LCA approach is used to measure this. The process within the scope of this supply chain includes the extraction of materials, the utilization in the processing up to the end-of-life (EoL) stage. Sensitivity analysis is also carried out through different EoL behavioral change scenario against the potential global warming caused. Excluded processes from the global warming potential assessment are processes related to land transfer, infrastructure (buildings, machinery, capital goods), and the use of materials or energy for activities outside the production process (transportation of workers, toilet flush, office electricity, etc.).

GHG is the gases in the atmosphere that can trap the sun's heat, such as carbon dioxide (CO_2), nitrogen dioxide (NO_2), methane (CH_4), and Freon (SF_6, HFC, and PFC). The interconnected processes in the supply chain system cause the emission load of each food product in a longer supply chain stage to increase based on the stages it has passed or, in other words, the emission load in the supply chain that is closer to the EoL includes the emission load from the previous stages. For example, discarded rice will have a greater emission load than the wasted cereal yield due to additional processes such as drying, milling, processing, transportation, market sales, and cooking. When the FLW arises in an increasingly long supply chain, the processes that have been passed starting from processing raw materials, supporting materials, using various electricity and energy, and so on, will also be wasted.

FLW Greenhouse Gases Potential Impact Assessment

This study carried out GHG potential impact assessment from FLW with global warming as the impact, kg CO_2-eq as a unit, and the IPCC 2013 method (100a) as the methodology basis. Impact assessments for these categories were conducted using SimaPro Developer software version 9.1.0.8. The impact assessment results are presented based on a predetermined functional unit, namely 1 ton FLW.

The impact assessment on the supply chain is carried out to determine the potential impact of 1 ton of FL and 1 ton of FW generated from all supply chain stages of all food commodities. In calculating the potential impact of 1 ton of FL, the stages include the production, post-harvest and storage, as well as processing and packaging. Meanwhile, 1 ton of FW's potential impact comprises the distribution and market as well as consumption stages. For the potential impact calculation of 1 ton of FLW, all stages are aggregated vertically, which is the total generation from all stages of the supply chain both FL and FW and horizontally, which is from all food commodities, hence the FLW hotspot can be compared entirely. The impact assessment results for 1 ton of FLW generation in the supply chain during 2000 to 2019 can be seen in **Figure 10.** This value is generated from LCA calculations based on 33,280 data collected from 2025 sources (47.6% statistical sources, 23.2% publications, 11.2% other publications, 8.9% industry data sources, 5.5% academic journals, and 3.6% of the database) with details of data sources which can be seen more clearly in **the Appendix.**

Based on **Figure 10**, it shows that GHG emissions are caused by 1 ton of FLW generation, FL and FW in the supply chain in Indonesia from 2000 to 2019. It is found that the average potential impact per 1 ton of FLW in 20 years is 2,324.24 kg CO_2-eq./1 ton FLW. In the graph, it is also found that the average emission produced by 1 ton of FW is 4,051.5 kg CO_2-eq./1 ton FW or about 4.3 times higher than 1 ton FL, which is 943.29 kg CO_2-eq./ 1 tons of FL. The longer traversed process in supply chain, the greater emission load will be, because emission load in previous stages will be accumulated and added with the subsequent processing. It also means that if FLW occurs at the distribution or consumption stage (FW), the resulting environmental load is 4.3 times higher than the FLW that occurs in the production stage (FL). Thus, if the amount of FW generated at the end of the supply chain (consumption stage) increases, then the potential impact of the FLW generation will be even greater.

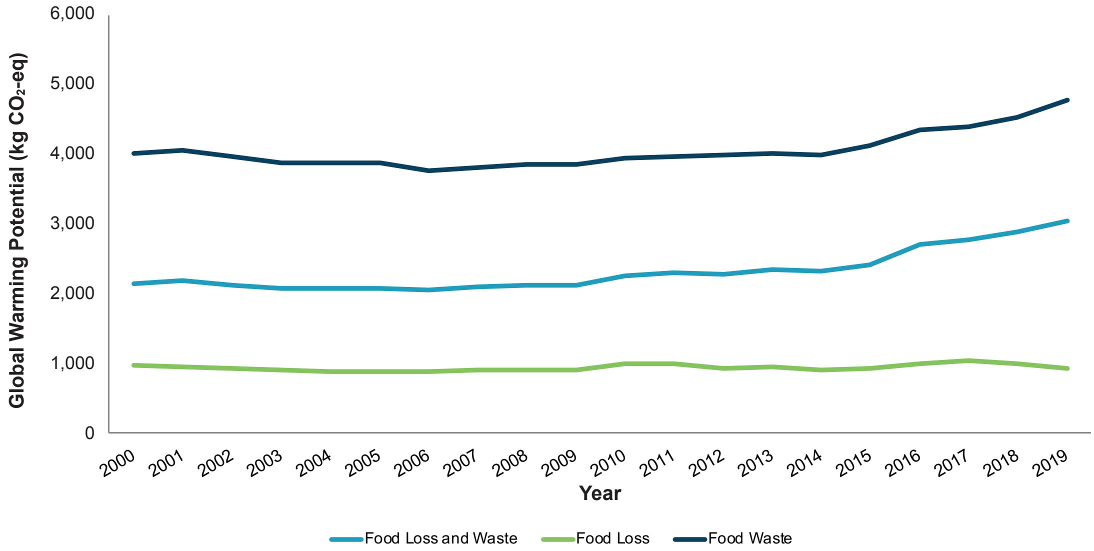


Figure 10. Greenhouse Gas Emission per 1 ton FL, 1 ton FW, and 1 ton of FLW.

Figure 11 shows the GHG emissions generated by FLW compared to total GHG emissions in Indonesia[17]. Based on these data, it shows that the average GHG emission in Indonesia from 2000 - 2018 is 1,129.12 Mton CO_2-eq. Meanwhile, the average GHG emission from FLW from 2000 - 2018 is 82.26 Mton CO_2-eq. or around 7.29% of the total GHG emissions in Indonesia. This figure is consistent with the percentage contribution of GHG emissions generated by FLW compared to total GHG emissions globally by the IPCC, of which FLW contributes around 8-10% to global GHG emissions[18]. Meanwhile, data from World Resource Institute (WRI), GHG emissions from global FLW contributes around 8.2% to global GHG emissions[19].

In 2018, GHG emission from FLW is 140.405 Mton CO_2-eq, which is higher compared to previous years. It is in line with the increasing number of FLW generation annually, especially in 2018 as the highest FLW generation year. This increase is in accordance with the increasing need for food consumption due to population growth of nearly 60 million from 211.5 million in 2000 to 270.6 million in 2019.

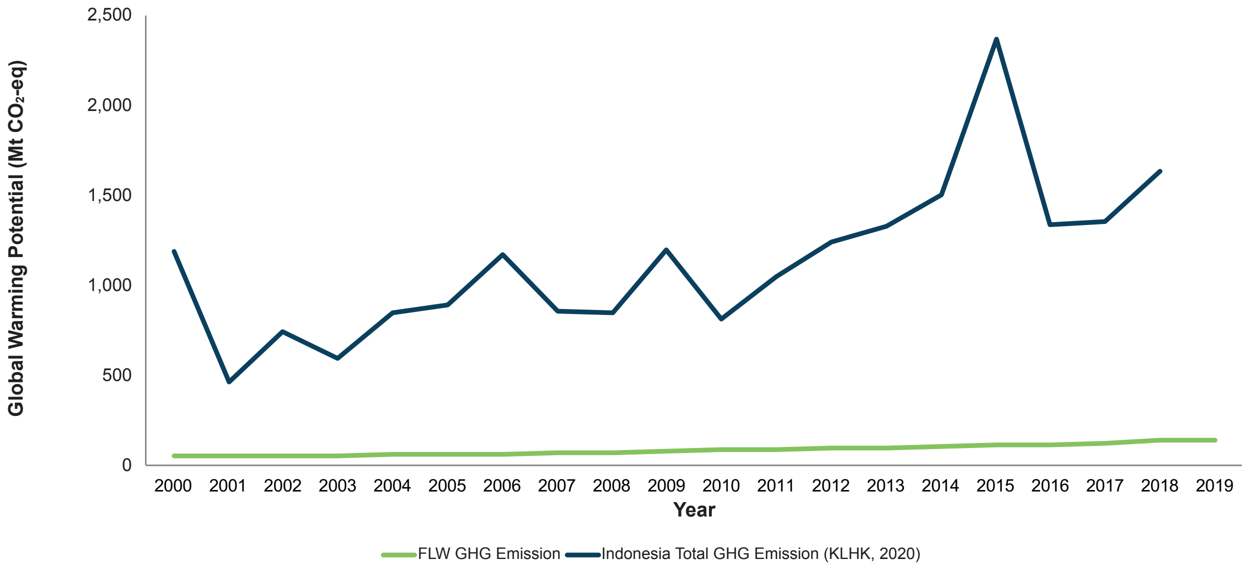


Figure 11. Comparison of FLW's Total GHG Emission and Indonesia's Total GHG Emission.
(Note: Data of Indonesia GHG emission in 2019 is not available)

[17] Kementerian Lingkungan Hidup dan Kehutanan. (2020). Laporan Inventarisasi Gas Rumah Kaca (GRK) dan Monitoring, Pelaporan, Verifikasi (MPV).
[18] IPCC. (2019). Climate Change and Land.
[19] WRI. (2019). Reducing Food Loss and Waste.

Furthermore, the potential GHG impacts are presented based on the five stages of the food supply chain as shown in **Figure 12.** According to **Figure 12,** the total FLW generated over 20 years is estimated at 1,702.9 Mton CO_2-eq with an annual average of about 85.14 Mton CO_2-eq. The total value for 20 years is equivalent to the area of Java and NTB when planted with trees. The biggest contribution in 2018 with an emission of 140.14 Mton CO_2-eq. It is consistent with the increased generation from 2000 - 2018 (**Figure 13**), with a slight difference in 2019.

The consumption stage is the major emission contributor compared to other stages with an average annual emission of around 49.34 Mton of CO_2-eq or equal to 57.95% of the total stages. The potential impact of generation at the consumption stage does not only embrace emissions produced at the time of consumption but also the potential impacts of the entire previous supply chain. Distribution and market generation contributes to around 20.18% or an average of 17.18 Mton CO_2-eq per year. In addition, the main contributor to the FL supply chain is the generation at the production stage with an average emission of around 9.45 Mton CO_2-eq/year or around 11.1% of all stages. Generation in the post-harvest and storage stage contributes to around 8.71% or an average 7.42 Mton CO_2-eq/year and generation at the processing and packaging stage contributes to 2.06% or an average of 1.75 Mton CO_2-eq/year. Meanwhile, if shown in the comparison between FL and FW emissions, the average percentage contribution to GHG emissions for FL is 23% and for FW 77% (**Figure 13**).

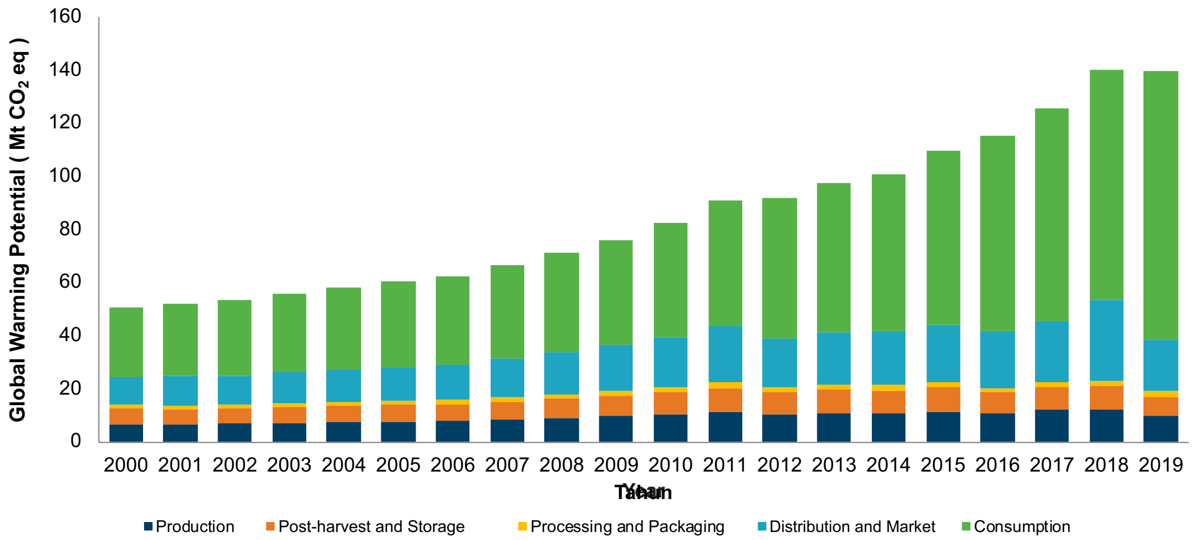


Figure 12. The Contribution of 5 Supply Chains Stages in GHG Emission per Year.

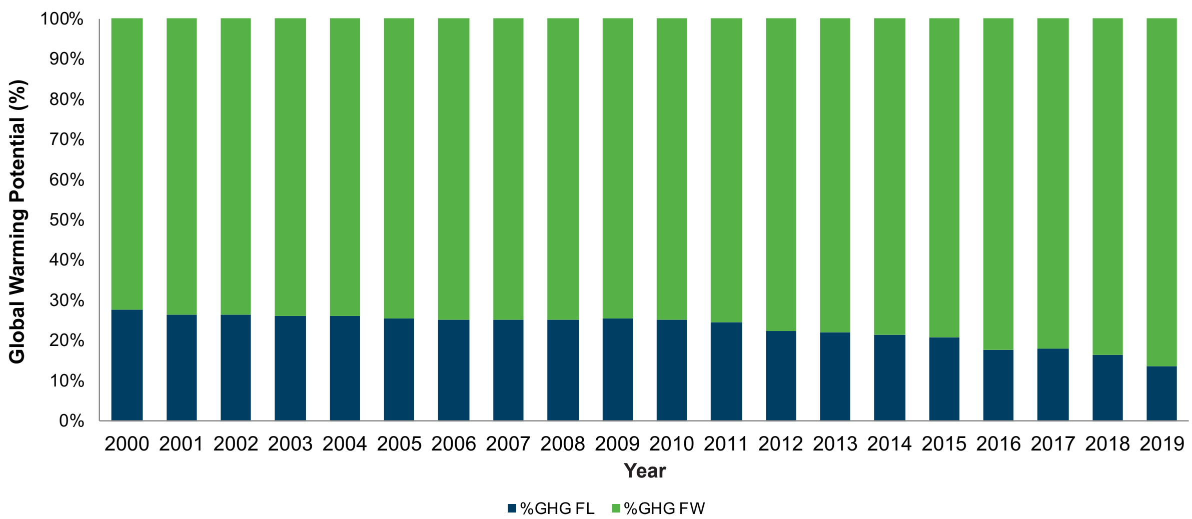
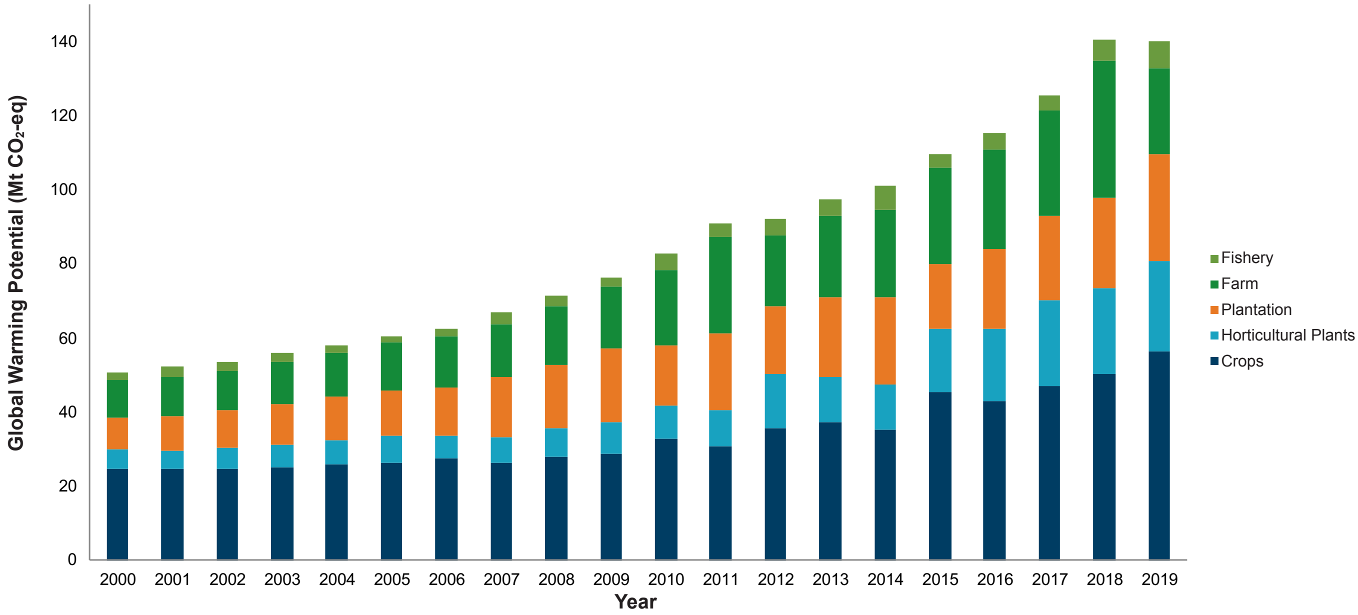


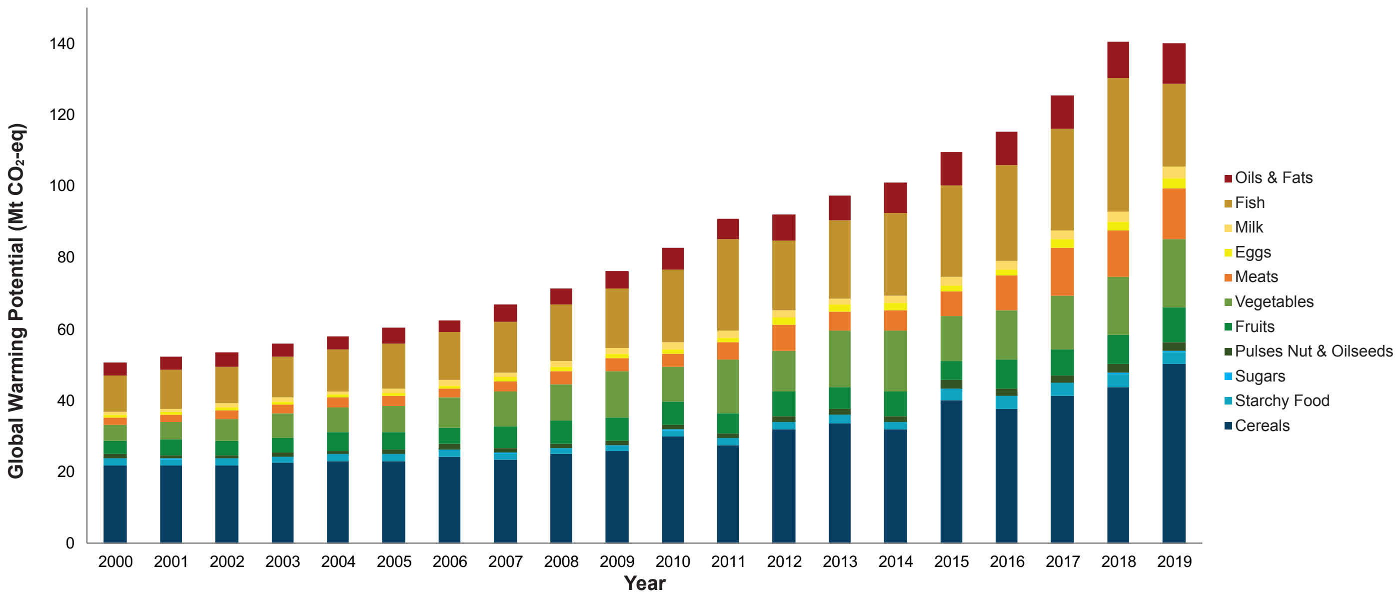
Figure 13. Percentage of GHG from FL and FW in 2000 - 2019.

GHG emissions are analysed based on two classifications, based on 5 (five) food sectors and 11 FBS food categories, as shown in **Figures 14 (a)** and **(b)**. Of the five food sectors, it is found that crops is the main contributors to GHG emissions generated along the FLW supply chain. The FLW generation in the crop sector provides an average GHG contribution of 39.67% or an average of 33.77 Mton CO_2-eq/year. Meanwhile, other sectors including the fisheries sector contribute to an average of 22.32% or an average of 19.01 Mton CO_2-eq/year, the horticultural sector contributes to around 20.21% or an average of 17.21 Mton CO_2-eq./year, the livestock sector contributes to around 13.51% or an average of 11.50 Mton CO_2-eq/year, and the plantation sector contributes to an average of 4.29% or an average 3.65 Mton CO_2-eq/year.

Meanwhile, according to the 11 FBS food categories, it is found that cereals are the largest contributor with an average contribution of around 35.27% or an average of 30.03 Mton CO_2-eq/year. In addition, it is also found that fish and vegetables contribute significantly, to around 22.32% or an average of 19.01 Mton CO_2-eq/year and 13.23% or an average 11.27 Mton CO_2-eq/year.



(a)



(b)

Figure 14. GHG Contribution (a) Based on 5 Food Sectors (b) Based on 11 FBS Categories.

In the previous section, the contribution from each stage of the supply chain is described based upon the total generation per year, in which the consumption stage is the largest contributor because the emissions from the generation in the consumption stage include the emission load from the previous processes. It is not analyzed from the total generation of all stages (aggregate) as in the previous section but is examined from each generation at each stage, the results are as shown in **Figure 15.** For every 1 ton of FLW generated in the consumption stage, emission from the consumption stage alone is 44%, in which 39% are emissions carried over from the production to post-harvest stage, 12% are emissions from the distribution and market stage, and 5% are emissions from processing and packaging. At the consumption stage, 70% of emissions are generated by the EoL FLW stage disposed of in the landfill and emissions from electricity use for storage and processing of food products. In 2019, the EoL process generated by FW at the landfill produced GHG emissions of 917.90 kg CO_2-eq consisting of 718.87 kg CO_2-eq originating from FW generation in households and 199.04 kg CO_2-eq from HORECA.

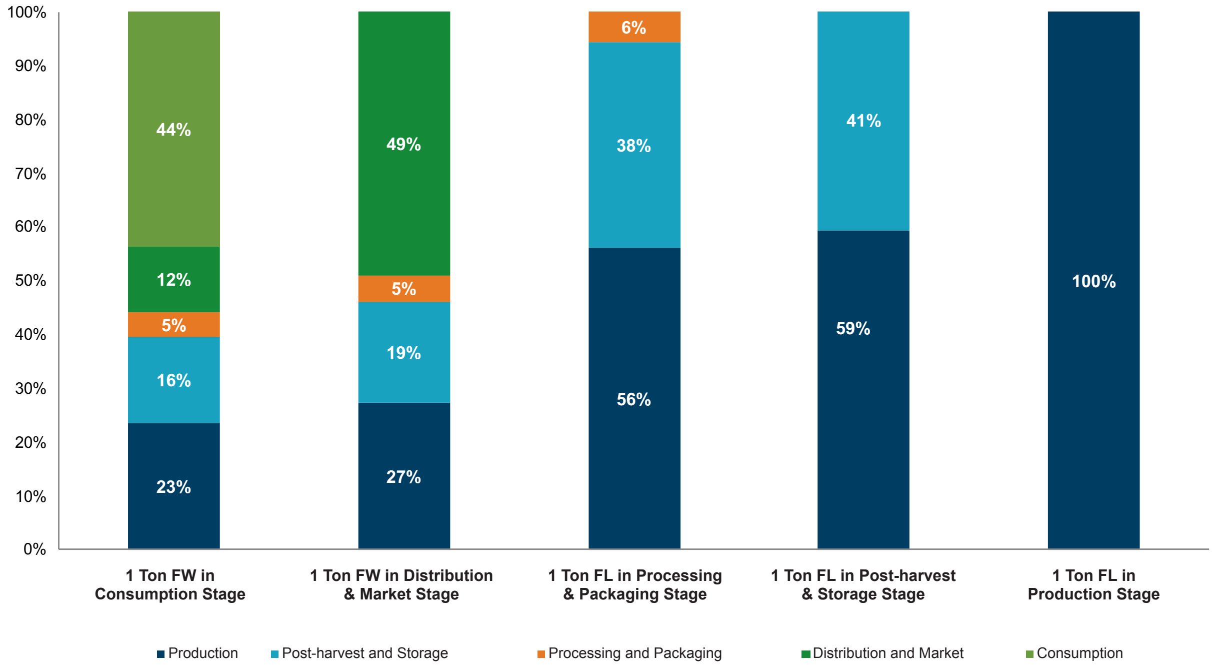


Figure 15. Contribution of GHG Emission based on Emission Source for 1 ton of FLW Generation in Each Stages of Food Supply Chain.

For every 1 ton of FW generated in the distribution and market stage, the emission from that stage alone is 49%, of which 46% are emissions car ried over from production to post-harvest, and meanwhile, 5% are emissions carried over from processing and packaging. At the distribution and market stage, 70% of emissions are originated from transportation activities as well as EoL FLW which are disposed of in the landfill. For every 1 ton of FLW generated in the processing and packaging stage, the emission from the stage alone is 6%, of which 94% are emissions carried over from the production to post-harvest stage. At the processing and packaging stage, 70% of emissions are caused by post-harvest food transportation activities to processing as well as the end-of-life emissions of FLW which are disposed of to the landfill. In the limitation of this study, emissions from the production to post-harvest and storage stages are inseparable but are calculated based on the allocation of the potential impact of the generation in the two stages. At the production, post-harvest and storage stages, 70% of emissions are caused by the fertilizers and chemicals uses, especially in the cereal production process as well as EoL FLW emissions which are disposed of openly (open dumping).

Thus, if it is analyzed based on the source of emissions not the source of generation, then in 2019 with a total GHG emission of 139.97 Mton CO_2-eq, 48.57% of emissions are derived from production activities, post-harvest and storage, 31.61% come from consumption, 15.67% came from distribution and market activities and 4.15% come from processing and packaging activities (**Figure 16**).

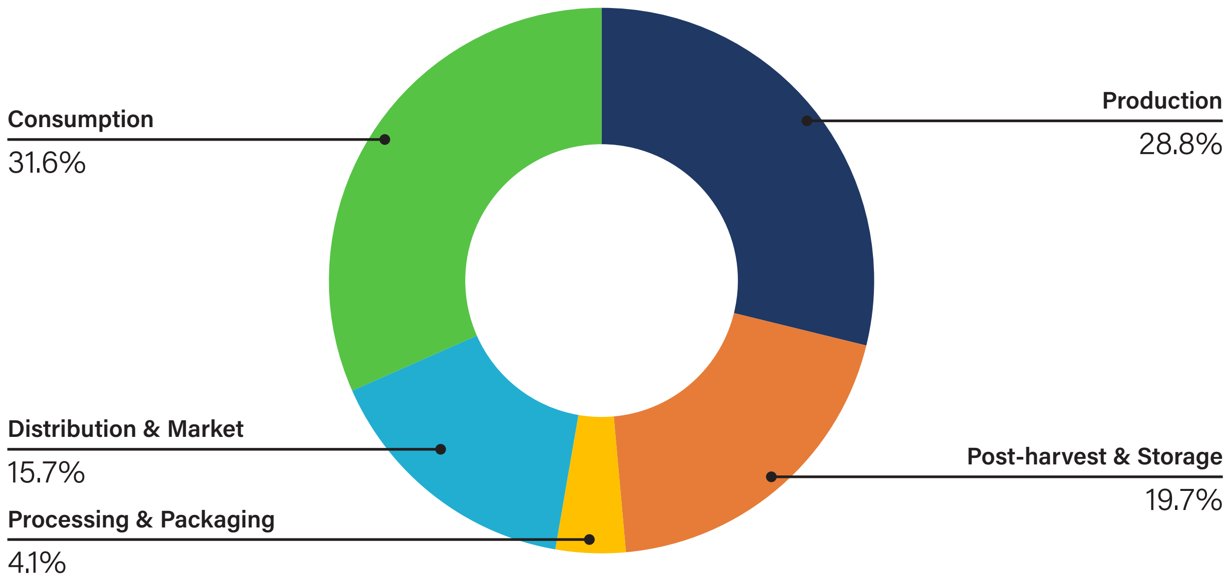


Figure 16. Contribution of GHG Emission based on Emission Source in 2019.

Figure 17 shows the processes that most contribute to FLW GHG emissions, regardless of the stage of the supply chain. Emissions from the fertilizers and chemicals use in the cereal production process are the largest contributors to the potential impact of global warming with an average of 20.94%. It is because the FLW generation from cereal commodities contributes an average of 36% of the total FLW generation. End-of-life emissions of FLW disposal to landfill contributed the second largest with an average of 15.37%. The use and emissions of diesel combustion throughout the supply chain contribute to the third largest with an average of 15.27% from 2000 - 2019. The use and diesel combustion are especially in the boats for fishing. Apart from that, diesel is also used in engines from production to consumption stages but it is insignificant compared to diesel for fishing vessels.

Emissions from transportation activities in the entire supply chain contribute an average of 13.44%. Transportation is not only for food products but also for supporting materials needed in the supply chain. Meanwhile, end-of-life emissions from open dumping contribute to an average of 11.34%. Electricity consumption throughout the supply chain contributes to an average of 6.93%. The biggest electricity consumption comes from household electricity consumption for rice cooking and storage in the refrigerator.

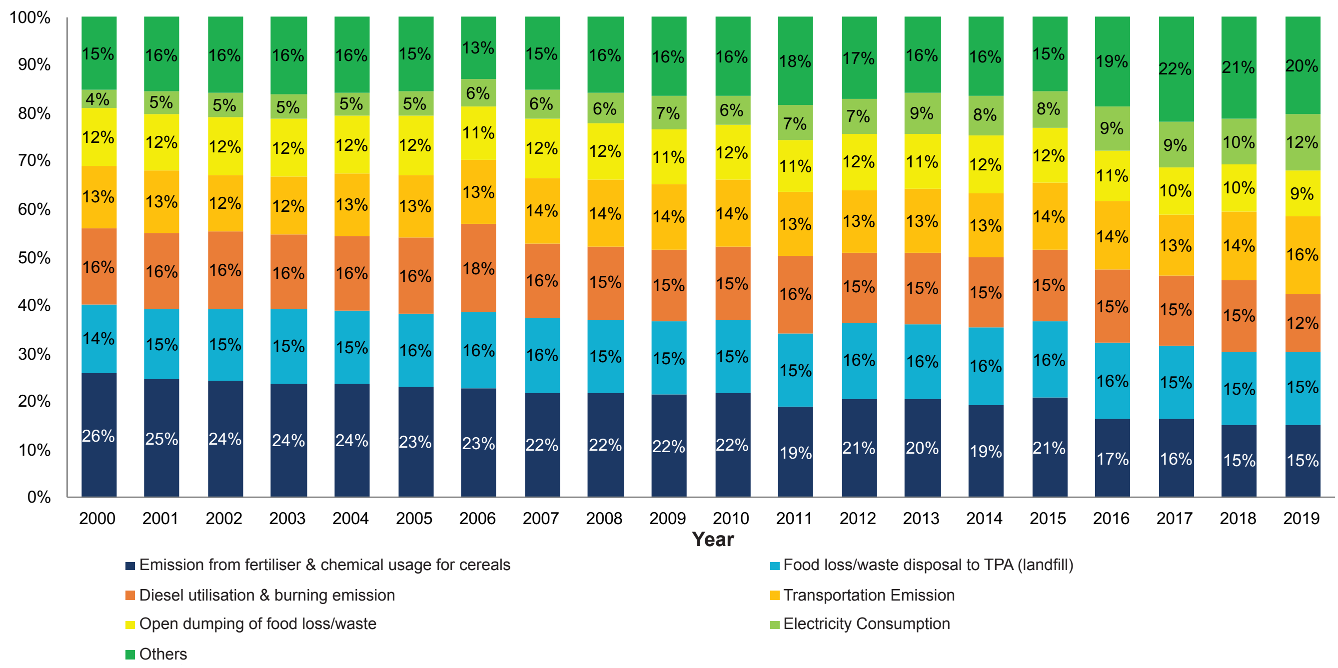


Figure 17. The Processes Contribution in GHG Emission of Total FLW Generation.

End-of-Life Scenario

The GHG emission in the previous discussion shows the potential for global warming due to FLW generation from 5 stages of the supply chain by considering the end-of-life/EoL treatment. In this study, the FLW handlings have been identified at each stage, but there is no quantitative data representing conditions throughout Indonesia. Due to the uncertainty value of FLW's EoL treatment, the GHG emissions calculation by scenario is carried out as a sensitivity analysis to determine the impact of EoL treatment changes on the GHG value emitted. There are 4 groups of scenarios determined, namely:

1 Intervention of FW in Household (HH)

a. Reduce 5% FW generation in household.
The value of 5% is set in this scenario to determine the sensitivity of the reduction to the generated GHG emissions. The reduction of 5% waste generation in household FW can be done in several ways, such as good shopping planning, portion control in cooking, good storage methods for food products, etc.

b. Increase FW treatment in the HH: 10% FW into compost.
In addition to reducing the FW generation, many communities currently utilize FW at the household scale, such as eco enzymes, composting, and others which are gaining attention. Following this trend, it is predicted that there will be a growth in the FW utilization/treatment into compost and reduced disposal of FW in landfills and other unmanaged treatment (combusted, buried, etc.). Thus, the value of increasing the use of FW into compost is determined from 10%-50% in scenario 1b to 1f. The maximum amount of about 50% of household FW becoming compost is according to a field survey conducted, in which around 56% of FW at the consumption stage is inedible.

c. Increase use of FW in the HH: 20% FW into compost

d. Increase use of FW in the HH: 30% FW into compost

e. Increase use of FW in the HH: 40% FW into compost

f. Increase use of FW in the HH: 50% FW into compost by reducing the amount of waste thrown into landfills, combusted or buried as much as 50% of the baseline.

g. Combined a-f scenarios, which is a decrease in the amount of generation and an increase in the utilization

h. An extreme scenario where the composition of edible food waste (around 44% based on a field survey) does not turn into FW but can be consumed, resulting in a decrease in the FLW generation. It is determined that there is a reduction in FW by 40%, in which 4% of the remaining edible food becomes food waste which is disposed of into landfills while 56% of inedible food waste is used entirely as compost.

2 Intervention on FW in HORECA

a. Reduce 5% FW in HORECA.
The value of 5% is set in this scenario to see the sensitivity of the reduction to the generated GHG emissions. The 5% reduction in waste generation in HORECA food waste can be done in several ways, such as better planning, portion control, and better raw material inventory management.

b. Increase use of FW in HORECA to around 50%, into animal feed, composting, or distributed to other parties.
In this scenario, because most of the FW produced is processed food, alternative uses that can be done are distributing to other people or using as animal feed. Cooked food is difficult to compost so composting is limited to unprocessed food ingredients (leftover food preparation, etc.).

Based on the field survey, around 8.85% of FW produced in HORECA is edible food, so in this scenario, it is assumed that 8.85% of FW is distributed to others through food bank mechanisms.

In addition to the utilization in the form of distributing to other parties, this scenario assumes that there will be a reduction in FW thrown into landfills by 50% from baseline, so waste in landfills is around 42.85%. The remaining FW is assumed to be used as animal feed (38.64%) and compost (9.66%). This scenario assumes a requirement for HORECA to have a composting facility.

c. Combined a-b scenarios, which is a reduction in the amount of generation and increase the use of FW in HORECA.

3 Intervention on FL in Production and Post-harvest and Storage

Intervention on FL in production, post-harvest and storage by reducing FL by 5% in the production, post-harvest and storage stages. The value of 5% is set in this scenario to see the sensitivity of the reduction to the generated GHG emissions. Reducing the 5% waste generation in FL can be done in several ways, such as in the scattered food case, it needs a better operational control to increase efficiency. In the event of oversupply harvest, it can be used to give the value-added product.

4 Combined 1g, 2c, and 3a Scenarios.

The household extreme scenario (1h) is not included in this scenario.

The handling of FLW in the sensitivity analysis was adjusted to the results of the study, but the percentage for each type of treatment was assumed based on the literature taken from samples from several regions. The percentage of each treatment for both baseline conditions and the four EoL scenarios can be seen in more detail in **Appendix.**

In the scenario determined, EoL changes are only made at the consumption stage and 2 stages of food loss, namely production and post-harvest and storage. It occurs because 80% of the FLW generation comes from these stages where the processing and packaging stages, as well as distribution and market, do not significantly contribute.

Table 1 shows the results of potential GHG emissions from each FLW handling scenario. From these results, it is found that a 5% reduction of FW generation in households may reduce GHG emissions by 2.98%. Meanwhile, increasing the use of household FW into compost every 10% may reduce GHG emissions by about 0.35%. With a maximum value, which is about 50% of FW used as compost, GHG emissions are reduced by 5.41%. Since the generation at the consumption stage, especially households, is a hotspot or stage that mostly contributes to total GHG emissions, an extreme scenario is conducted, namely a reduction in FW by 40% according to the edible food content in FW at baseline conditions. In addition, it is assumed that 56% of inedible food content in FW in the baseline is used as compost and the remaining 4% is wasted in the landfill. With this extreme scenario, GHG emission reduction will occur by 29.88%.

The 5% reduction of FW generation in HORECA only reduces GHG emissions by 0.53%. It is because the amount of FW generated in HORECA does not contribute significantly to the total generation. However, increasing the use of FW in HORECA to around 50% of the total waste generation, namely into animal feed, compost, or distributing to other parties, can reduce GHG emissions by 3.02%. A 5% reduction in FL from production to post-harvest and storage can reduce GHG emissions by 0.6%. This emission reduction is insignificant compared to the reduction in GHG emissions if there is a reduction in FW generation. It is because the contribution of GHG emissions from generation in the production stage to post-harvest only contributes an average of 19.81% compared to the contribution of generation at the consumption stage with an average of 57.95% to total GHG emissions.

Table 1. Summary of FLW GHG Emission Result for Each FLW Treatment Scenario.

No	Scenario with 2019 Data	Total FLW Generation (ton)	GHG (Mton CO_2-eq)/year	Change on Baseline
0	**Baseline**	**45,786,143.74**	**139.97**	**0.00%**
1	Intervention of FW in Household			
1.a	Decrease food waste generation 5% in HH	45,012,862.67	135.79	-2.98%
1.b	Increase use of FW in HH (10% composted)	45,786,143.74	139.48	-0.35%
1.c	Increase use of FW in HH (20% composted)	45,786,143.74	137.85	-1.51%
1.d	Increase use of FW in HH (30% composted)	45,786,143.74	136.22	-2.68%
1.e	Increase use of FW in HH (40% composted)	45,786,143.74	134.59	-3.84%
1.f	Increase use of FW in HH (50% composted)	45,786,143.74	132.39	-5.41%
1.g	Combine 1a and 1f scenarios	45,012,862.67	128.59	-8.13%
1.h	Extreme scenario: decrease generation by 40%, remaining 4% edible food into landfills and 56% inedible food into compost	39,599,895.20	98.15	-29.88%
2	Intervention of FW in HORECA			
2.a	Decrease FW generation by 5% in HORECA	45,588,778.89	139.23	-0.53%
2.b	Increase use of FW in HORECA	45,786,143.74	135.74	-3.02%
2.c	Combine 2a and 2b scenarios	45,588,778.89	135.21	-3.40%
3	Intervention of FL in Production and Post-Harvest and Storage			
3.a	Decrease FL generation by 5% in production, post-harvest and storage	44,828,679.21	139.12	-0.60%
4	Intervention of FL in Production and Post-Harvest and FW in Consumption			
4.a	Combine 1g, 2c, and 3a scenarios	43,858,033.29	122.98	-12.14%

If all scenarios are combined without incorporating the extreme scenario in the household, namely reducing the amount of generation in the production, post-harvest and storage, and consumption stages by 5% and increasing the utilization of FW to around 50%, then GHG emissions can be reduced by 12.14%.

From the results of the sensitivity analysis on the FLW handling, it can be determined that the generation reduction, especially at the consumption stage, is the main intervention that can be done to significantly reduce the potential GHG impact due to FLW.

This GHG emission reduction will have a greater impact if it is combined with the use of FW in households, for example through composting. Although not as significant as the emission reduction from the household, the reduction in the generation and utilization of FW in HORECA also affects reducing emissions. In general, to be able to optimize the reduction of GHG emissions, each individual is responsible for consuming their food completely and this is the simplest intervention that can be carried out by every level of society in preventing FW, especially at the consumption stage.

ECONOMIC IMPACT OF FOOD LOSS AND WASTE

The amount of FLW generated annually cause economic loss in every food supply chain. Given the FLW generation in Indonesia in 2000 - 2019 reaching 23-48 million tons/year, the economic loss that occurs as a result of FLW is 213-551 trillion rupiah/year or equivalent to 4% - 5% of Indonesia's GDP per year. Due to limited publication data regarding product prices, the calculation of economic loss carried out is based on available producer price data for 88 food commodities in the calculation of FL and 64 food commodities from available consumer price data for calculating FW. Considering that the total food commodities listed on the FBS as a reference for calculating the FLW generation are 146 commodities, it can be determined that there is a potential for greater economic loss than what has been calculated in this study.

Based on the economic loss as shown in **Figure 18,** the largest economic loss is at the FW stage, reaching 107-346 trillion rupiah/year. It is in accordance with the amount of FLW generation that occurs during the FW stage, when compared to the FL stage. It can be seen in **Figure 18,** and the most significant economic loss occurred in 2017 – 2019.

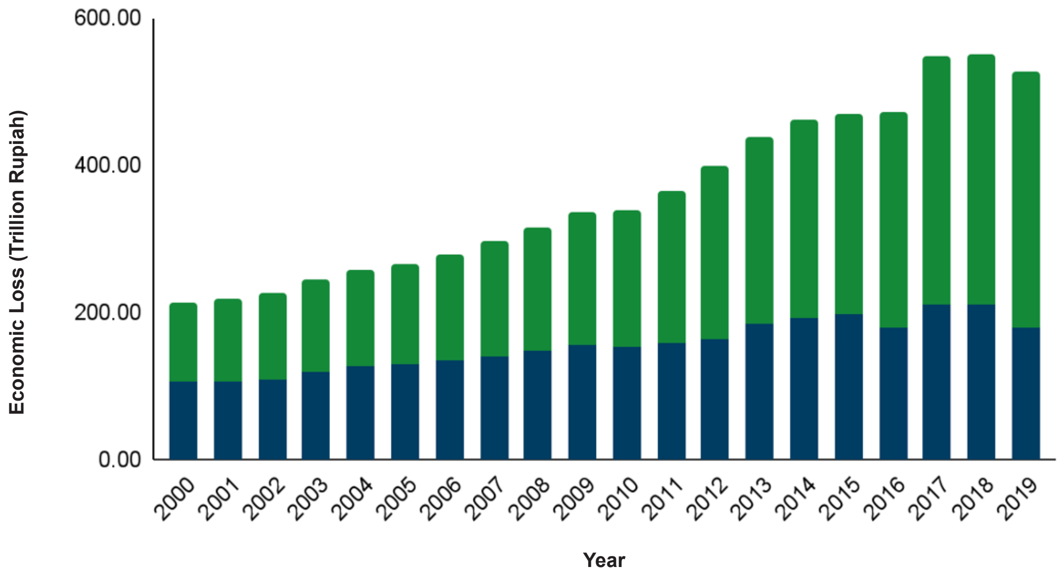
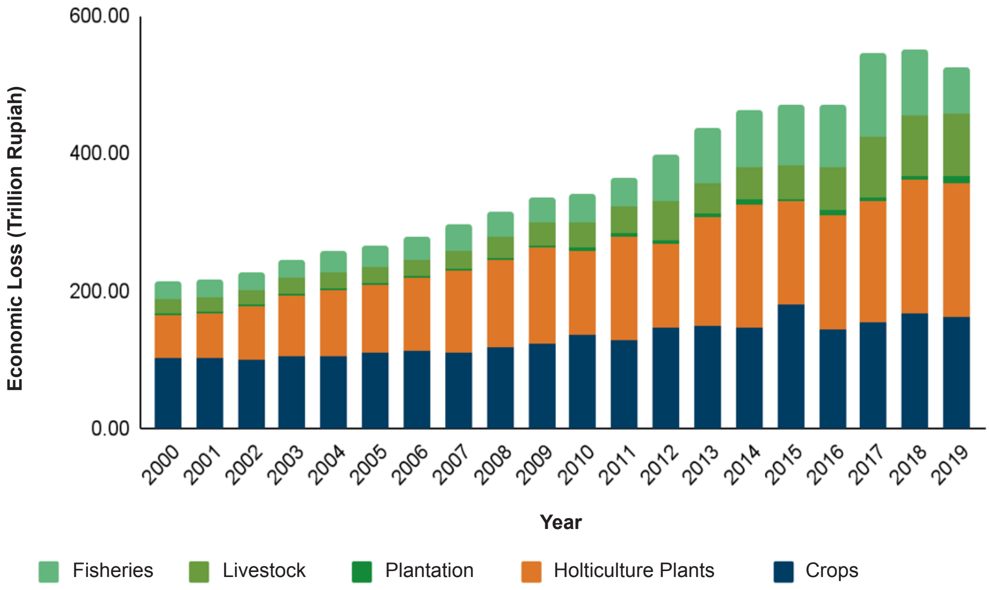
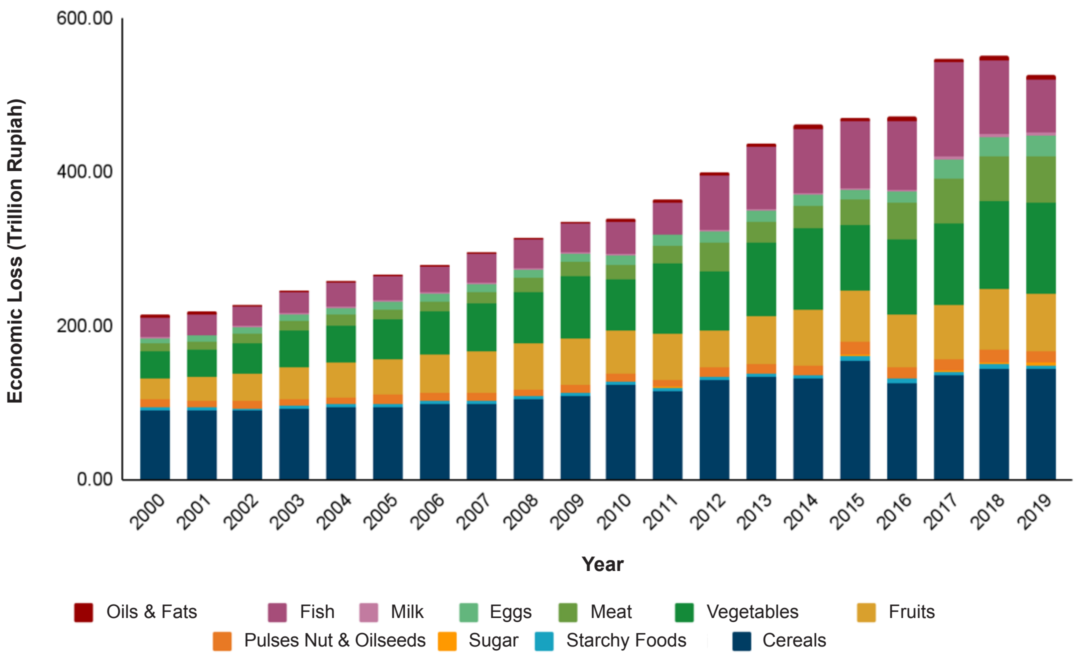


Figure 18. Economic loss due to FLW in 2000 – 2019 (in Trillion Rupiah)

Given **Figure 19 (a)** in category 5 of the food sectors, crops is the sector with the largest economic loss, amounting to 101-179 trillion rupiah/year, which is aligned with the largest FLW generation - in crops. Meanwhile, according to the 11 food categories of FBS as seen in **Figure 19 (b)**, the largest economic loss due to FLW is in the cereal commodity, amounting to 88-155 trillion rupiah/year.



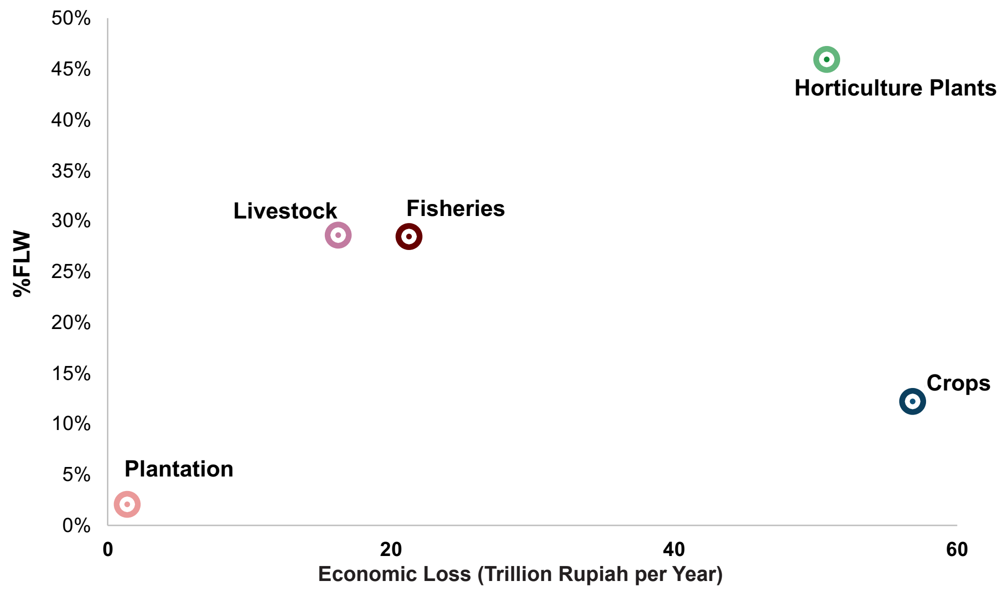
(a)



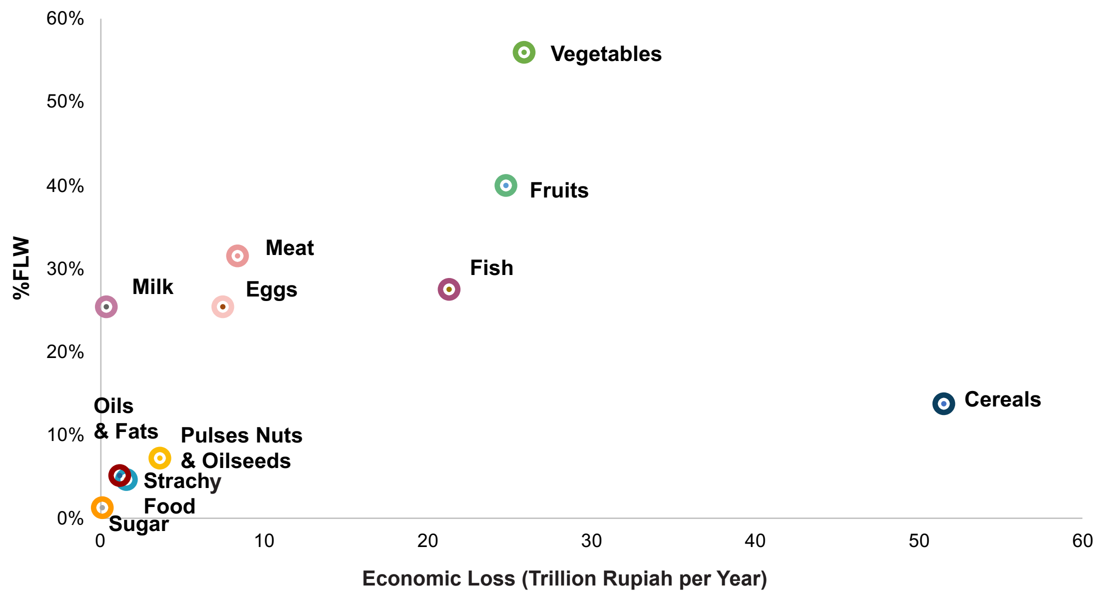
(b)

Figure 19. Economic Loss due to FLW in 2000-2019 (in Trillion Rupiahs) (a) in 5 Food Sectors; (b) in 11 Food Commodity Categories.

To find out which food commodity category has the lowest level of efficiency and the highest economic loss, a comparison is made as shown in **Figure 20.** The efficiency level is described by %FLW, which compares the amount of food that is wasted with that which is consumed in a particular type of food. The crops sector, especially cereals, has the highest economic loss, but this sector has good processing efficiency so that the proportion of wasted cereals is lower than the proportion of cereals consumed. Meanwhile, in the horticulture sector, especially vegetables, the economic loss value is not as high as crops/cereals, but the efficiency of the process is still not good, causing the proportion of vegetables to be wasted very high compared to the vegetables consumed.



(a)



(b)

Figure 20. Comparison of %FLW to Economic Loss in (a) 5 Food Sector and (b) 11 Food Categories.

SOCIAL IMPACT OF FOOD LOSS & WASTE

Nutrition Loss

The portion of food fit for consumption mostly found in the FLW generation indicates that there is a potential for nutrition loss as a result of waste and is not utilized by humans. To understand how much the nutrition loss is, four parameters are performed; energy, protein, vitamin A, and iron, as the results are summarized in **Table 2** and explained as follows.

Table 2. Nutrition Loss from FLW Generation

Nutrition Content	Range of FLW Nutrition Loss per individual per day*	Nutrition Intake per individual per day	% Indonesian population that can be fed edible FLW	Total of Nutrition deficiency in Indonesia
Energy	618-989 kkal	2,100 kkal	29-47%	45.7%**
Protein	18-32 gr	57 gr	30-50%	36.1%**
Vitamin A	360-953 Ug RE	575 Ug RE	63-166%	N/A
Iron (Fe)	4-7 mg	10.1 mg	46-72%	40.9%***

Notes:
* Study of Food Loss and Waste in Indonesia (Bappenas, 2021)
** National Institute of Health Research and Development (2014) in Total Diet Study Book: Survey of Individual Food Consumption in Indonesia
*** Basic Health Research (Riskesdas), Ministry of Health (2018)

1 Energy

According to the FLW generation in Indonesia in 2000 - 2019 reaching 23–48 million tons/year, or equivalent to 115–184 kg/capita/year, it is known that the energy loss due to the FLW generation is 618-989 kcal/capita/day, as shown in **Table 2.** The category of cereal commodities which is the largest contributor to FLW also adds to the category with the largest energy loss of 459.24–693.20 kcal/capita/day.

If an Indonesia population is assumed to require 2100 kcal of energy from food, in one year around 61–125 million people or 29-47% of the Indonesian population can be fed from the energy loss from FLW. In 2014, almost half of Indonesia's population (45.7%) consumed less than 70% of the Recommended Dietary Allowances (RDA) for energy[20]. Assuming that this data is the condition for 2000 - 2019, it means that if all edible FLW per year in this range can be recovered, then the energy RDA for 62-100% of Indonesia energy deficit population can be fulfilled.

[20] National Institute of Health Research and Development. (2014). National Institute of Health Research and Development in Total Diet Study Book: Survey of Individual Food Consumption in Indonesia.

2 Protein

Food commodity categories containing protein are 10 out of 11 FBS categories which are used as a reference for calculating FLW generation, while the sugar category as the exception. The FLW generation from these 10 commodity categories in Indonesia in 2000 - 2019 is 23–48 million tons/year. Departing from this figure, it is known that the protein loss from FLW is 18.55 – 32.22 grams/capita/day, as shown in **Table 2.** Meanwhile, when viewed from protein loss based on existing food commodity categories, the cereal category has the largest protein loss, namely 11.19-17.52 grams/capita/day.

Approximately 68-149 million people or 33–57% of Indonesia's population can fulfil protein needs per individual of 57 grams from protein loss of edible FLW in 2000 - 2019. In 2014, as much as 36.1% of the Indonesian population consumed less than 80% of the RDA for protein[21]. Assuming that this data is the condition for 2000 - 2019, it means that if all edible FLW every year in that range can be restored, then the protein RDA for 91-100% of Indonesia protein deficit population can be fulfilled.

3 Vitamin A

Based on the calculations conducted, 10 of the 11 available food commodity categories contain Vitamin A, except for the sugar category that does not contain Vitamin A. The FLW emerging from these 10 commodity categories in Indonesia in 2000 - 2019 is 23–48 million tons/year. From this figure, it is found that the vitamin A loss is 360–953 Ug RE/capita/day, as shown in **Table 2.** Of the existing Vitamin A loss, 130.12–503.81 Ug RE/capita/year come from oil and fat commodity categories which are labelled as the largest loss. If one Indonesia individual is assumed to require Vitamin A of 575 Ug RE from food, around 134–441 million people or 63-166% of Indonesia population can fulfill their Vitamin A needs from Vitamin A loss of edible FLW in 2000 - 2019.

4 Iron

According to the FLW generation in Indonesia in 2000 - 2019, which is 23–48 million tons/ year, it is found in **Table 2** that the iron content lost from FLW is 4–7 mg/capita/day. Of the existing iron loss, cereal commodities, the largest contributor to FLW, is also the commodity with the largest iron loss, comprising 2.25–3.27 mg/capita/day. If one Indonesian population is assumed to require iron of 10.1 mg from food, around 96-189 million people or 46-72% of the Indonesia population can have their iron needs fulfilled from the iron loss of edible FLW in 2000 - 2019. 40.9% of pregnant women in Indonesia are deficient in iron[22]. Assuming that these data are conditions for 2000 - 2019, it means that if all edible FLW every year in this range can be recovered, then 100% of the population of pregnant women deficit in iron in Indonesia can meet their iron needs.

[21] National Institute of Health Research and Development. (2014). National Institute of Health Research and Development in Total Diet Study Book: Survey of Individual Food Consumption in Indonesia.
[22] Ministry of Health. (2018). Basic Health Research (Riskesdas).

Social Impact Potential in Life Cycle

Social impact potentials gained from interviews and questionnaires outcome mapping are classified into:

1. Mapping for **crop commodities** - based on interviews with experts of food crops and farmers/intermediaries for rice, cassava, soybean.
2. Mapping for **horticultural plants commodities** - based on interviews with experts of horticultural plants and farmers/intermediaries for mango, banana, shallot, cabbage, chili commodities.
3. Mapping for **plantation commodities** - based on interviews with plantation experts as there were no interviews with farmers/intermediaries for sugarcane and oil palm commodities.
4. Mapping for **livestock commodities** - based on interviews with experts of farms and breeders for purebred chicken, eggs and cow's milk.
5. Mapping for **fishery commodities** - based on interviews with experts of fisheries and producers for tilapia.
6. Mapping for the **market stage** (market, retail, hotel, restaurant), **consumption** (household), and **waste processing** (waste handling officers and DLH).

Mapping for groups 1-5 includes mapping on the production process, post-harvest and storage, processing and packaging, and distribution. The inseparable collected data will be included in the mapping of group 6.

The mapping results are then used to determine material topics from all stages of the supply chain that are relevant to the FLW generation. From the selected material topics, a series of social performance indicators in Indonesia are developed based on the Handbook of Product Social Impact Assessment or PSIA[23]. These indicators are useful in identifying the social hotspot position in the supply chain for the commodities under assessment and used to monitor improvements in social performance. The topic for which the indicator is not identified does not become an issue that needs to be measured because it is not a material topic related to FLW. Mapping results can be seen in **Table 3.**

Table 3. Identification of Social Topic Material

Identification of Social Topic Materials			
WORKERS	1. Remuneration 2. Poverty/Fulfilment of Basic Needs 3. Child Labour 4. Excess Working Time/Work and Personal Life Balance 5. Equal Opportunity/Discrimination 6. Worker Safety and Security 7. Freedom of Association and Group Negotiation 8. Migrant Workers 9. Social Benefits (leave, etc.) 10. Labour Conventions/Laws	1. Access to Services and Input 2. Fair Trade 3. Land Rights 4. Women Empowerment 5. Corruption	SMALL ENTERPRENEURS
LOCAL COMMUNITY	1. High Conflict Zone 2. Human Health Issues - Infectious Diseases 3. Employment and Skills Development for Local Communities - Local Workers 4. Relationship with the Community 5. Contribution to Economy Development	1. Consumer Health and Safety 2. Consumer Affordability 3. Accessibility	CONSUMERS

[23] Goedkoop, et al. (2020). Methodology Report Product Social Impact Assessment 2020.

Based on data collected from interviews and surveys at the preliminary stage, it is found that the following social topics are less relevant:

1. **Excess working time/work and personal life balance:** despite of imbalanced working hours among workers in several food sectors, the relationship between FLW generation and non-ideal working hours cannot be measured, thus indicators cannot be developed.
2. **Equal opportunity/discrimination:** currently there is no discrimination case that affects the increase in FLW generation and data shows that the available employment opportunities are adjusted to the abilities of workers.
3. **Migrant workers:** this social topic is less relevant to the conditions of workers in Indonesia, where the workers they hire are local people.
4. **Social benefits:** social topics cannot be developed yet because the relationship between FLW generation and social benefits has not been identified so that indicators cannot be developed.
5. **Land rights:** currently there is no land rights case that affects the increase in FLW generation.
6. **High conflict zone:** currently there is no case of high conflict zones that affects the increase in FLW generation.
7. **Relationships with community:** there is no case of relationship with community that affects the increase in FLW generation.

Other social topics become material topics in which each topic has an indicator as shown in **Table 4.**

Table 4. Inventory Indicator of Material Topic.

No.	Material Topic	Inventory Indicator
1	Remuneration	1. Workers receive a minimum wage according to the Regional Minimum Wage (UMR) 2. There are other forms of allowances (fixed allowances) other than wages 3. Workers obtain Social Security (BPJS Ketenagakerjaan)
2	Poverty/Fulfilment of Basic Needs	1. Productivity and stable food supply 2. Efforts or policy plans to increase worker inclusion
3	Child Labour	1. What is the percentage of workers under 18 years who are not graduated from junior high school? 2. Is there a policy from the production unit not to employ child? 3. Types of work performed by workers under 18 years 4. Time and duration of workers under 18 years 5. Protection for workers under 18 years
4	Worker Safety and Security	1. OHS Policy 2. OHS training for farmers 3. The provision of OHS facilities for workers
5	Freedom of Association and Group Negotiation	1. The number of workers of labour union members 2. The policies or action plans to improve the bureaucracy of trade unions

6	Access to Service and Input	1. Training 2. Implementation by business actors related to training 3. Evaluation and monitoring related to training 4. The assistance of raw materials or supporting materials 5. Assistance with agricultural/fishery/livestock machinery 6. Renewal of agricultural/fishery/livestock machinery 7. Basic infrastructure improvements such as access to clean water and roads 8. An actual action plan to improve access to basic facilities
7	Fair Trade	1. Mutually beneficial cooperation between contributors throughout the supply chain 2. A transparent pricing system for all business actors in the supply chain 3. Whether or not there is fraudulent pricing by big unscrupulous individuals
8	Women Empowerment	1. A campaign or counselling for mothers to organize FW in the household 2. A policy or plan to support and protect women in employment
9	Labour Conventions/Laws	1. Regulations/laws that protect labour farmers, small fishermen and small breeders
10	Human Health Issues - Infectious Diseases	1. Number of cases of HIV, tuberculosis, malaria, dengue fever 2. Communicable disease prevention program
11	Employment and Skills Development for Local Communities - Local Workers	1. Number of skills training held in the area for local communities 2. The number of people or worker community who participate in the training 3. Work plan or policy to employ the surrounding community
12	Contribution to Economy Development	1. Efforts by business actors to invest in the local area that create new sources of livelihood 2. Cooperation that builds mutually between business actors and local governments
13	Consumer Health and Safety	1. Information on health and safety requirements for food providers 2. Safety and halal standard label 3. Food packaging standards 4. Policies or regulations that maintain health and food safety
14	Consumer Affordability	1. Affordable food prices for all levels of community 2. The food pricing according to its quality (e.g., ugly food) 3. Efforts or policies to maintain food prices
15	Accessibility	1. Equality of food products throughout Indonesia 2. Efforts or policies to provide access to adequate food products for the community
16	Corruption	1. Whether or not there is indication of corruption at various levels of the food supply chain 2. Whether or not there is indication of fraud at various levels of the food supply chain 3. Audit and taxes reports of business actors on the right food products supply chain

The indicators that have been developed are not only influenced by the basis of PSIA but also influenced by the policies and strategies suggested. Following these indicators, it is possible that in the future there will be new indicators that are more relevant as well as a reduction in existing indicators as the development of the food supply chain condition in Indonesia. The developed indicators are then used as the basis for measuring the potential social impacts either for follow-up studies or for monitoring and evaluation purposes.

3 MANAGEMENT GAP: CAUSES & DRIVERS OF FOOD LOSS & WASTE IN INDONESIA

CAUSES & DRIVERS OF FOOD LOSS & WASTE

Overview

The FLW generation could be caused by a variety of factors and can occur at various stages along the food supply chain. Based on FAO[24], the factors that may cause FLW could be divided into direct causes and indirect drivers. The direct cause is the action that directly causes FLW by actors in the food supply chain. On the other hand, the indirect driver is the systemic economic, cultural, and political conditions of the food system that affect actors in the food supply chain in their operation - including affecting the FLW generation.

Table 5 summarizes the direct causes and indirect drivers of FLW in Indonesia which is identified according to which stage of the supply chain these causes and drivers occur, and analyzes what aspects of management are associated with these causes. The supply chain analyzed consists of five stages: production, post-harvest and storage, processing and packaging, distribution and market, and consumption. Meanwhile, the management aspects analyzed consist of five aspects: technical, social, institutional, financial, and policy.

Table 5. Causes and Drivers of FLW in Indonesia.

Causes & Drivers	Food Supply Chain Stage					Management Aspects
	Production	Post-harvest & Storage	Processing & Packaging	Distribution & Market	Consumption	
DIRECT CAUSES						
Poor harvesting time	√					Technical
Poor harvesting technique	√					Technical
Overproduction	√					Technical
Technology limitations	√	√	√			Technical
Insufficient quality of the storage space		√	√	√	√	Technical
Poor quality of packaging/container		√	√	√	√	Technical
Lack of implementation of Good Handling Practice (GHP)		√	√	√	√	Technical
Misinterpretation of Expiry Date and Best Before				√	√	Social
Excess food portion and consumer behavior					√	Technical
Inadequate food preparation					√	Technical

[24] FAO. (2019). The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction.

Causes & Drivers	Food Supply Chain Stage					Management Aspects
	Production	Post-harvest & Storage	Processing & Packaging	Distribution & Market	Consumption	
INDIRECT DRIVERS						
Limited access to capital	√	√	√			Financial
Lack of information/education for food workers and consumers	√	√	√	√	√	Social
Limited access to infrastructure	√	√	√			Technical
Inefficient supply chain	√	√	√	√	√	Institutional
Market quality standards and consumer preferences	√	√	√	√		Technical
Market price				√		Policy
Market competition and limited consumer purchasing power				√		Technical
Lack of food waste regulation				√	√	Policy

Based on the analysis carried out from the results of the FGD, expert interviews, and practitioner interviews, hotspots of the causes and drivers of FLW are summarized in **Table 6.**

Table 6. Hotspots of Causes and Drivers of FLW in Indonesia.

Causes and Drivers of FLW in Indonesia			
Type	**Very Important**	**Type**	**Medaretely Important**
D	Lack of implementation of Good Handling Practice (GHP)	I	Market price
D	Insufficient quality of the storage space	I	Inefficient supply chain
I	Market quality standards and consumer preferences	D	Misinterpretation of expiry date and best before
I	Lack of information/education for food workers and consumers	D	Inadequate food preparation
D	Excess food portion and consumers behavior	I	Lack of food waste regulation
D	Technology limitations	I	Limited access to capital
I	Market competition and limited consumer purchasing power	D	Poor harvesting time
D	Poor harvesting techniques	D	Overproduction
I	Limited access to infrastructure		
D	Poor quality of packaging/container		

Information: D = Direct causes, I = Indirect drivers

DIRECT CAUSES

1 Poor Harvesting Time

Harvesting time affects the quality of the food produced. In Indonesia, there is still an assumption that plant growth could be uniformed. This assumption causes harvesting to be taken concurrently even though the types of plants are different. In addition, there is a food harvesting practice that carries out before the food is physically ready to be harvested. For cassava, for example, harvest time could be accelerated by about one month earlier than the harvest schedule. The harvesting process that faster than the supposedly harvesting time should result in the poor quality of the food and eventually be damaged/unsold and becomes food loss.

Several things that encourage faster harvesting times, including:

1. There is a change in land use. For example, the land is used for soybeans in the dry season, while during the rainy season, it is used for rice fields.
2. The presence of pests. For example, javelin/ground buckle (*Scotinophara coarctata*) in rice, which causes a large number of empty unhusked rice.
3. Season/weather. When entering the rainy season, farmers will tend to harvest the product early than it should. Because in the rainy season it is tougher to dry the crops so that the harvest often more prone to rot.

2 Poor Harvesting Technique

In the harvesting technique factor causes food loss, one of the factors have play a role is the plant's shape that affects the harvesting process. For example, at the stage of harvesting cassava, some tubers could be left behind because it is difficult to bury them too deep in the ground and difficult to pull up. About 2-3 tubers are usually left behind, and some are even trampled by workers. At the production level, it was found that in the case of rice, there was a tendency to intentionally produce FL to share it with those around the area. Based on the results of an interview with Said Abdullah from the People's Coalition for Food Security (KRKP) that in rice food commodities, FL generally occurs because there is a loss of about 20-25% in the process of cutting and threshing unhusked rice. However, this loss is usually taken advantage of by local people around, so there is a deliberate factor to thresh rice on the ground so that the neighbors can get rice.

In addition, another case example is the lack of control on fruit trees. The results from an interview with Ronnie S. Natadwijaja, Ph.D., Director of the Center for Sustainable Food Studies, Padjadjaran University, stated that the majority of the fruits in Indonesia are not produced from the orchard, where the fruit plants' shape tends to be very tall so that not all of the fruit could be well harvested, and lots of fallen and damaged fruit, which causes very high FL.

3 Overproduction

On harvest time, where a food commodity has a very high amount of production once, the potential for FL is quite huge because the capacity for food management smaller than the quantity available at that time. For example, during the big mango harvest, a large pile of mangoes usually attracts fruit flies that stick together and cause some mango to rot. FL could also be exacerbated if the main harvest occurs in the rainy season, wherein this season the food is more susceptible to damage.

4 Technology Limitations

Many food workers do not have machines, have machines damaged, or use machines that are still traditional. Generally, these conventional machines have less effectiveness, so the potential for FL is pretty high. For example, in the case of rice:

- At the production stage, rice harvesting tools such as power thresher and combine harvester are expensive, so most farmers only rent tools.
- In the post-harvest stage, harvested unhusked rice could only last about two days, after which it is damaged. If the rice mill does not have a drying machine, a lot of rice will potentially be damaged if the weather does not support rice drying.
- In the processing stage, the technical process for threshing and cleaning cereal is still manual so that a lot of it is still wasted and scattered everywhere. The packaging is too simple and does not pay attention to the respiration of food products, thus affect the products to rot quickly. In milk, there is often a collection of different milk yields and qualities, but they are collected in one place so that the final quality of the milk becomes less specific and the quality standard drops.

5 Insufficient Quality of the Storage Space

The quality of storage space has a significant effect on the potential for FLW. Some elements of storage space that could cause FLW include:

1. **Size of storage space**, for example: in the post-harvest and storage stages, for the livestock storage such as chickens for sale, when the storage space provided was too narrow, then the chickens can stress and die. At the consumption stage, food products need to be stored in the refrigerator. If the refrigerator gets overloaded, and too much mixing and accumulation of various types of food in one room could potentially damage the food stored.
2. **The temperature and humidity of the storage room**, for example, if the refrigerator/meat storage space is not cold enough, could cause meat, vegetables, and other fresh products to rot more quickly.
3. **Storage room hygiene**, for example, if the storage room is not cleaned regularly, molds could develop in the storage room and contaminate food products.
4. **Pests**, for example, rats gnawing on rice storage sacks and causing rice to be scattered in the storage room.

In fisheries, in particular, the issue of storage space quality is crucial, given the need for cold storage along the supply chain. Rahmi Kasri from the Global Alliance for Improved Nutrition (GAIN) said that high fish production is not matched by high market absorption, so a lot of fish production was discarded due to cold chains and warehouses had limited capacity and could not be shipped. In addition, Rahmi Kasri also stated that according to the Indonesian Cold Chain Association, the cold chain capacity for fisheries is only available at 500,000 tons. Meanwhile, according to the Ministry of Marine Affairs and Fisheries (KKP), the available cold chain capacity is 200,000 tons. This capacity still cannot meet the high demand for the cooling chain for fish production in Indonesia.

The existence and implementation of SOPs or regulations in storage space management so a factor that influences storage space conditions. When existing SOPs unavailable or SOPs less implemented accordingly, the quality of storage space can decrease and could lead to FLW.

6 Poor Quality of Packaging/Container

Inadequate packaging for food ingredients could cause food damage. For several types of food products, the packaging is required not only for primary packaging but also for secondary or even tertiary packaging to maintain the quality of food products, especially in the distribution process. For example:

- In the distribution process, when chilies are packed only with plastic and then stacked with other materials to bear a heavy load, the chilies will rot or break.
- In the consumption process, when the fresh food is unpackaged or with inadequate packaging, it easier for the food to oxidize and spoil quickly if it is not eaten immediately by consumers.

7 Lack of Implementation of Good Handling Practice (GHP)

Based on the US National Sustainable Agriculture Coalition, Good Handling Practices (GHP) are good practices that apply in food packaging, storage, and distribution to reduce contamination. Referring to this definition, the lack of GHP in question is related to storing, distributing, and packaging food procedures in Indonesia.

In the distribution process, although distributors usually already have transportation SOPs, they are often ignored, causing damage to packaging and food ingredients. Delays in the distribution process also have the potential to cause FLW. In chickens, for example, too long on the road can cause the chicken to be stressed so that it becomes weak and dies on the road. Meanwhile, for fish, if the distribution vehicle does not use refrigeration technology and relies on ice to cool the fish, there is a possibility that the ice will melt during the trip, which makes the fish prone to rot. Handling during distribution can also cause FLW to arise, for example, transporters sitting or lying on top of their food crops or transporters throwing fish into the vehicle during the loading process.

In the food storage process, the First In First Out (FIFO) concept becomes crucial at any stage in the supply chain to ensure there is no build-up of old stock in storage. At the consumption level, for example, if consumers have good storage facilities but do not understand how to store certain food products, there is the possibility that consumers will make mistakes in storing food which can cause the food to spoil more quickly. For example, it is known that as many as 54.39% of Indonesian consumers who became respondents in this study did not apply the FIFO principle, in which they usually did not have special treatment in storing each type of food purchased. Placing the food ingredients at the back/bottom of the newly purchased food and prioritizing taking food ingredients that were purchased earlier for cooking/consumption will reduce the possibility of food products being stored for too long and resulting in expiration/spoilage before they can be consumed. It is also known that for vegetables and fruit, 76.23% of Indonesians tend to wash and wipe before storing them. Fresh food items such as vegetables and fruit would be better if they were washed when consumed. Washing vegetables and fruit too early from consumption can also cause vegetables and fruit to rot more quickly in storage.

8 Excess Food Portion and Consumer Behavior

In some Indonesians, understanding of 'better is more than less' - this also applies to the preparation and purchase of food. As 50.18% of respondents confirmed that excess portions of food, especially in foods consumed at home, were the main factor causing food leftovers from the portions served. In addition, the behavior and habits of consumers who do not finish food are still quite common. This is usually influenced by lifestyle as well as upbringing and education about appreciating food.

In the case of food purchases, excess food portions could be driven by consumer interest in food discount programs which usually last a limited time. The significant discounts could trigger consumers to spend more than their consumption capacity, which then ends up remaining unconsumed food and becoming food waste. Consumers often 'spendthrift', that taking/ordering more food than their consumption capacity. For example, when consumers arrive hungrily in a buffet restaurant, they may take too much food and eventually become FW. In addition, the unit of sale is also influential. The results of an interview with Catur Utama Dewi from Rikolto found that one of the causes of FW is buying excessive food ingredients due to limited packaging due to the absence of smaller packaging options.

Meanwhile, 61% of respondents stated that leftover food when eating outside the home usually occurs when eating together with other people. The moments of gathering and eating together could drive FW from excess portions because with a culture of 'better is more than less', orders ordered are usually more than the capacity to eat. It could not only in restaurant gatherings but also at events such as weddings or other celebrations. Celebration events like this usually indicate social status so that the more food portions served, the higher the social status will be. Thus, the portion of food often prepared much more than the capacity of the guests present, it not uncommon for food leftovers to be abundant after the event over. According to an interview with Eva Bachtiar from Garda Pangan, FW from weddings and other events also has a lot to do with the economic level. For example, at weddings in the middle to lower classes, food is rarely wasted. Parties in the middle to lower classes will usually distribute leftovers to family, neighbors, etc. On the other hand, at weddings in the middle and upper class, the leftover food usually becomes the business of the catering service provider.

9 Misinterpretation of Expiry Date and Best Before

The difference between 'expiry date' and 'best before' in Indonesia is generally not well understood, both at the retail level and the consumer level. Based on BPOM regulation No. HK. 03.1.23.06.10.5166 about Inclusion of Information on the Origin of Certain Ingredients, Alcohol Content, and Expiration Limits on the Marking/Drugs, Traditional Medicines, Food Supplements, and Food Labels, the term 'expired' is only used on medicines, while for food only use the term 'best before'. This misunderstanding results in the generalization that 'best before' has the same meaning as 'expiry date', even though they have different meanings. Products whose 'best before' time has approached/passed will usually be discarded by retailers/consumers, even though as long as they are stored properly, and there has been no contamination or physical change, food that is approaching or past the 'best before' time is still fit for consumption - in contrast to food that has expired date has passed, where the food product is no longer suitable for consumption.

10 Inadequate Food Preparation

The preparation of food ingredients in the cooking process is a crucial point to prevent FW from occurring in kitchen activities, both in households and in the food industry such as hotels, restaurants, and catering. The results of an interview with Fahrur Rosidi from the Association of Indonesian Food Service Providers (PPJI), stated that food waste can occur from the process of preparing food supplies, wrong menu planning, purchasing a cheap but inefficient menu, selecting a poor supplier, cutting food ingredients, all of which should be done by trained employees.

In addition to the preparation process, the inadequate inventory of available food ingredients is also a trigger for food waste. For example, if there is no regular data collection of needs and stocks based on menu types, it is possible to purchase excess food products which eventually spoil before being utilized.

INDIRECT DRIVERS

1 Limited Access to Capital

Limited access to capital affects the facilities owned by food workers to process food properly. One of the reasons food workers do not use good quality machines is because of limited capital. This issue also applies to food workers whose machines are broken but have not been repaired. In some cases, food workers cannot afford to borrow/rent machines from similar food workers or related agencies with good quality machines, but this does not always apply in all areas in Indonesia. In the processing and packaging stage, many food processing factories still use technology from the 1970-1980s due to limited capital. Meanwhile, the machine assistance available from the government/other institutions is often less effective, so it ends up being used by food workers due to technical constraints. Apart from machines, the limited quality of storage space is also influenced by the capital and operational funds owned by actors in the food supply chain.

2 Lack of Information/Education for Food Workers and Consumers

The limited knowledge of food workers and consumers is the driving force for FLW generation that quite crucial. Based on an interview with Entang Sasraatmadja from Himpunan Kerukunan Tani Indonesia (HKTI) of West Java, that one of the causes of FL is the problem of a mindset in which FL is not considered critical. They think that FL is only a problem of the government, not a part of the problem for farmers, communities, and society in general.

The limited knowledge among food workers is related to harvesting techniques, the capacity to operate machines, and the ability to develop innovative products from food products. Food workers' training/skills development by the government is felt to be lacking by food workers in the field, where training is rarely conducted, sometimes even in one year in an area there is no training at all. In reality, the one-trainer-one-village program did not run optimally, and generally, the trainer did not provide intensive assistance to food workers. In 2020, the National Coordinating Agency for Agricultural, Fisheries, and Forestry Extension Officers was abolished so that the sustainability and progress of extension were increasingly hampered, especially in connection with the absence of a national extension module or the strategy for integrating the system of Agriculture, Fisheries and Forestry which answered the need for increased knowledge and skills of food workers. In addition, the role of independent and private extension workers is still limited in encouraging extension activities at the food worker level. Not a few farmers and farmer groups have to conduct their training for their workers to avoid high crop failures with a learning-by-work system.

On the other hand, there were also cases where there was a reluctance from food workers when taught by extension agents or the government. If the distributor/market asks for direct handling improvements, generally, the workers will immediately follow. This act is because the distributor/market is directly related to the demand for food products. If food workers do not make improvements in handling, there is a concern that these food products will be threatened with unsold sales. However, when extension workers or the government carry out introductory activities, training, or skills and technology development, food workers assume that these activities do not have a direct effect on the prices and profits of the food products that are produced or sold.

As for consumers, the lack of knowledge also affects the habit of leaving food and the tendency to order or serve excess food portions.

3 Limited Access to Infrastructure

Limited infrastructure is a crucial point driving FLW, especially in the upstream food supply chain. The quality of access to road infrastructure from the harvest location outside the area, which is often inadequate (damaged roads, unpaved roads, etc.), has the potential to cause FL through leaks due to shocks. The poor quality of roads also could cause a longer duration of food delivery, which can lead to food spoilage on the way, for example, bruises on fruit and chilies, stress on chickens to lethargy and death, and evaporation of moisture in cabbage. Meanwhile, the absence of water and electricity in the regions will greatly affect the quality of food storage space. If the area is remote enough, it may be difficult to get electricity or clean water, resulting in insufficient storage space.

4 Inefficient Supply Chain

In Indonesia, it found that in some cases, the food supply chain tends to be spread over several areas that are far apart, even though with better regulation, the institutions involved in the food supply chain could focus on certain areas, according to their commodities. In several food commodities, it was also found that there were quite a lot of actors involved, making food products through a long supply chain. This inefficiency in the supply chain can lead to food loss, mainly due to the long-distance traveled or the distribution time due to the long supply chain. For example, chili is one of the agricultural products that are sold to faraway locations because it is durable and preferred, but this causes a lot of intermediaries of supply chains - from small intermediaries, local intermediaries and then distributed to large intermediaries who take them outside the city to the outside province.

5 Market Quality Standards and Consumer Preferences

The presence of certain quality standards in terms of aesthetics (shape, color, weight, etc.) can cause food products that are still fit for consumption to be discarded/unsold. Losses due to aesthetics usually occur in the sorting/grading process, which takes place in the post-harvest and storage stages, processing and packaging, as well as distribution and market. Food products that are edible but do not meet the aesthetic quality standards are usually called 'ugly food'. Some examples of ugly food that do not meet quality standards include:

- Chili whose color does not meet grade A (red) or grade B standards will usually be thrown away or burned.
- Cabbage has to be cut according to the standard shape and weight that is suitable for sale in the market, resulting in waste pieces that are irregular in size will be wasted.

At the distribution and market stage, whether food products are sold or not is strongly influenced by consumer preferences and purchasing power. There is a tendency for consumers not to choose ugly food when shopping and prefer to choose aesthetically good food products. In addition, cultural-based misperceptions are found in the community that can trigger food waste. For example, in fisheries, there is a public perception that the fish stored on ice are of poor quality. This issue encourages sellers not to provide ice when selling captured fish, which in fact, storage without ice can accelerate the process of fish spoilage and result in food waste.

The consumer's taste for certain foods also affects the potential for the emergence of food waste. Based on the results of the questionnaire, consumer tastes were one of the three most popular choices for answers, namely 24.1%. This factor is the most influential, especially when food is served in a buffet, either in restaurants, hotels or at certain events. The foods with the least interest usually leave a fair amount of leftovers. This issue also applies when food is served in packages, where consumers may like most of the contents but have less appetite for some so that it becomes food waste that is not consumed.

6 Market Price

When there is a significant decline in prices in the market, there is a possibility that farmers will leave their food products on the land (not sold). The food products that are left behind, if there is no further use will be FL. For example, during the pandemic, many factories lowered their purchase prices by 35% and even refused to harvest cassava plants due to the accumulation of production products, so that many of the crops were not sold. Based on an interview with Prof. Joni Munarso from the Post-Harvest Agricultural Research and Development Center, Ministry of Agriculture, the potential to suppress losses is there although all technology is implemented. This is because there is no incentive policy for food practitioners. If there is no incentive, then the value of the product generated between food commodities that apply GHP in post-harvest and those that do not apply is the same.

7 Market Competition and Limited Consumer Purchasing Power

In the market, various brands of products or shops are selling the same type of food product. Consumer preferences for particular brands/stores affect whether a food product is sold/not. Usually, new brands/stores will tend to be more difficult to sell because consumers are unfamiliar. In addition, when the purchasing power of consumers is low, the level of demand for food products tends to decrease. In these two schemes, products that are not selected and not purchased by consumers could become food waste.

8 Lack of Food Waste Regulation

The absence of regulations in Indonesia on how retail, market, HORECA, as well as the public, manage their FW causing prevention and management of FW in its implementation is still far from ideal. In the HORECA sector, for example, there is confusion in managing leftovers. Several HORECA agencies want to distribute the leftovers to those in need, but there are three obstacles/concerns:

1. Not knowing where to distribute the food;
2. Worrying about unknown entity reselling the food;
3. Worrying about a decrease in the quality of the food that could lead to poisoning and HORECA who distribute must be responsible.

The results of an interview with Eva Bachtiar from Garda Pangan state that there are several policies abroad that the hospitality industry is not allowed to donate food. This causes the food produced to be displayed for 4 hours. After that, it must be immediately destroyed and may not be given to employees or used as animal feed. In addition, the hospitality industry also has concerns about donating food because:

1. If the handling is not suitable, there is a possibility that the food can be resold, and
2. If the food is poisonous, the industry could be sued.

Without regulations governing how retail, markets, HORECA, and the public can distribute food scraps or food scraps that are still feasible to those in need, as well as how to prevent and handle food waste, most food waste, especially from the business sector, will lead to landfill.

4 STRATEGY & PROJECTION OF FOOD LOSS & WASTE IN INDONESIA

STRATEGY FOR FOOD LOSS & WASTE MANAGEMENT IN INDONESIA

In designing a strategy for FLW handling in Indonesia, priority areas are categorized into three: high priority, medium priority, and low priority. These priorities are determined based on FLW generation hotspots, FLW causes and drivers, and FLW greenhouse gas emission hotspots, as summarized in **Table 7.** The strategy design also considers the strategy implementation period which is determined by expert judgment based on the time feasibility to achieve the strategy. Three categories of the strategy implementation period are the short term period (1 year), medium term period (5 years) and the long term period (25 years).

Table 7. Determination of Priority Area for FLW Strategy in Indonesia.

Parameter	High Priority	Medium Priority	Low Priority
FLW Generation	Production, Consumption	Post-harvest and storage	Processing and packaging, Distribution and market
Causes and Drivers	'Very Important' Causes and Drivers	'Moderately Important' Causes and Drivers	
GHG Emissions	Reducing FW generation in household	Reducing FW generation in HORECA, reducing FL generation, handling FLW generation with non-landfill method	

Strategy for FLW Management in Indonesia consists of 45 strategies which are divided into five major directions, as shown in the following **Figure 21.**

No.	Direction	Description
1	Behavioral Change	Focus on the development of training Institutions in the regions, capacity building for food workers, and education to consumers to increase knowledge about FLW and change behavior.
2	Improving Food System Support	Developing farmer corporations and providing infrastructure and facilities that support the efficiency of the food production process that also contributes to the reduction of FLW.
3	Strengthening Regulations & Optimizing Funding	Optimizing appropriate funding for the improvement of food infrastructure, developing FLW regulations at national and regional levels, as well as strengthening inter-ministries/agency coordination regarding FLW issues.
4	Utilization of Food Loss and Waste	Encouraging the development of a food distribution platform, FLW handling that supports a circular economy, and developing FLW utilization pilot on a city/regency scale.
5	Development of FLW Study & Data Collection	Highlighting the need for the integrated data collection on FLW generation through the census and development of studies to complement FLW data in Indonesia.

Figure 21. Five Main Strategies for FLW Management in Indonesia.

The strategy description is based on five major directions, which are described in **Table 8 - Table 12** as follows.

Table 8. Strategy for Improving Behavioral Change.

STRATEGY FOR IMPROVING BEHAVIORAL CHANGE					
Supply Chain Stage	Aspect	Strategy	Stakeholders	Relevant Policy	Period
High Priority					
1-2	Institution	**A1**-Developing training agencies in each region to provide training and assistance to food workers, one of which is related to the FL prevention and handling.	- Regional Government	No relevant policy	Medium term
2-4	Social	**A2**-Providing Standard Operational Procedure (SOP) training related to the utilization of food storage to intermediaries/collectors/distributors who support the FL prevention.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Regional Government - Training Agencies	Presidential Regulation No.18/2020 RPJMN 2020 - 2024	Medium term
1	Social	**A3**-Providing training especially for farmers/fishermen/young breeders to become entrepreneurs to be able to manage their food products more independently and better so as to prevent FL.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Regional Government - Private Sectors - BUMN (State-Owned Enterprises) - NGOs - Association/Farmer Cooperatives/ Fishers/ Breeders - Education Institution - Training Agencies	1. Presidential Regulation No. 18/2020 RPJMN 2020 - 2024 2. Law No 16/2006 article 16 on Agricultural, fisheries and forestry extension systems	Medium term
1-3	Social	**A4**-Creating a food worker assistance program to be able to operate and maintain work equipment/machinery for food production operations that support the prevention of FLW.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Private Sectors - Association/Farmer Cooperatives/ Fishers/ Breeders - Training Agencies	Law Number 19/2013 on Protection and Empowerment of Farmers (Farmer law)	Long term
1-5	Social	**A5**-Providing training and periodic monitoring to food workers in the supply chain regarding Good Agricultural/ Manufacturing/Handling Practice (GAP/ GMP/GHP), including FLW prevention and handling.	- Ministry of Agriculture - Ministry of Tourism and Creative Economy - Ministry of Industry - Ministry of Marine Affairs and Fisheries - Regional Government - Private Sectors - Association/Farmer Cooperatives/ Fishers/ Breeders - Education Institution - Training Agencies	Law Number 19/2013 on Protection and Empowerment of Farmers (Farmer law)	Long term
5	Social	**A6**-Providing assistance or disseminate educational media so that the community, especially person in charge of family kitchens, understand the issue of FW and can manage independently according to their household conditions.	- Ministry of Environment and Forestry - Regional Government - NGO - Education Institution	1. Law No.18/2008 on Waste Management 2. Government Regulation No.81/2012 on Management of Household and Household-like Waste	Long term

Medium Priority					
4-5	Social	**A7**-Conducting training and dissemination related to the meaning of the label 'Best before' and 'Expiry Date' at the retail level, HORECA, as well as the community, especially housewives, to suppress FW from label misunderstanding.	- Ministry of Tourism and Creative Economy - BPOM (National Agency of Drug and Food Control) - PKK (Family Welfare Movement) - Regional Government - Retailer/Retail Workers Association - NGO - Private Sectors - Training Agencies	No relevant policy	Medium term
1	Technical/ Social	**A8**-Strenghtening the assistance to implement the agricultural calendar of each region that focuses on food diversification/commodity cropping patterns. The agricultural calendar plays a role in preventing the overproduction of certain commodities at the same time that may cause FL.	- Regional Government - Association/Farmer Cooperatives - Education Institution - Research Agency - Training Agency - Offtaker	1. Presidential Regulation No. 18/2020 RPJMN 2020 - 2024 2. Diversification Roadmap of Local Food Sources of Non-Rice Carbohydrates 2020 - 2024	Long term
2-5	Social	**A9**-Conducting training and dissemination of standards and access to appropriate packaging and can prevent the FLW generation, both to food workers and to the community.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - PKK (Family Welfare Movement) - Association/Farmer Cooperatives/ Fishers/ Breeders - Training Agencies	Regulation 86/2019 on Food Safety	Long term
3,5	Social	**A10**-Conducting training to HORECA, MSMEs, and the community, regarding alternative use and processing of value-added food as a solution for ugly food and oversupply.	- Ministry of Tourism and Creative Economy - Ministry of Cooperatives and SMEs - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Regional Government - Private Sectors - NGO - Training Agencies	1. Presidential Regulation No. 18/2020 RPJMN 2020 - 2024 2. Strategic Policy for Food Security and Nutrition 2020 - 2024 3. Government Regulation No 17/2015 on Food Security and Nutrition Article 26 (1)	Long term
5	Social	**A11**-Providing education and assistance to the HORECA industry related to food preparation, food portion regulation, and leftovers as well as FW handling.	- Ministry of Environment and Forestry - Ministry of Tourism and Creative Economy - Regional Government - NGO - Education institution	No relevant policy	Long term
4	Social	**A12**-Conducting education to enrich public knowledge about the quality of food products in order to prevent certain perceptions that create people less likely to buy a product and cause FW.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - PKK (Family Welfare Movement) - Private Sectors - Retail & Traditional Market - NGOs - Education Institution	Presidential Regulation No. 18/2020 RPJMN 2020-2024	Long term

Table 9. Strategy for Improving Food System Support.

STRATEGY FOR IMPROVING FOOD SYSTEM SUPPORT					
Supply Chain Stage	Aspect	Strategy	Stakeholders	Relevant Policy	Period
High Priority					
1-3	Institution	**B1**-Developing a smallholder corporation that involves intermediaries, offtaker and actors in partnership to shorten supply chains, provide price transparency, and handle FLW.	- Association/Farmer Cooperatives/Fishers/ Breeders - Ministry of Marine Affairs and Fisheries - Ministry of Agriculture	1. Regulation of the Minister of Agriculture No. 18/ Permentan/RC.040/4/2018 on Development Guidelines for Agricultural Area based on Farmer Corporation 2. Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Medium term
1-3	Technical	**B2**-Increasing the introduction, use and maintenance of agricultural/livestock/ fishery machinery to facilitate process efficiency and reduce FL.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Regional Government - Private Sectors - BUMN - NGOs - Training Agencies	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Long term
1-3	Technical	**B3**-Providing assistance and improvement of basic facility infrastructure to support the FLW prevention and handling, such as clean water, electricity, and roads.	- Ministry of Public Works and Housing - Ministry of Energy and Mineral Resources - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Private Sectors - BUMN - NGOs	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Long term
2-5	Technical	**B4**-Providing technical assistance for the provision and management of cold chains in local cooperatives, distribution vehicles, retail, and HORECA especially for the food fisheries sector, livestock and horticulture, both new facilities and revitalization of government-owned warehouses to become cold chain storage as an alternative to store various food products with modern management.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Private Sectors - BUMN - Association/Farmer Cooperatives/Fishers/ Breeders	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Long term
Medium Priority					
1-4	Technical	**B5**-Creating a food system platform, especially planting mapping and real-time price update as a medium for price transparency and communication media for farmers, traders, retailers and food-related NGOs.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Trade - Bank of Indonesia - Association/Farmer Cooperatives/ Fishers/Breeders - Private Sectors - NGO -Education institution -Research Agency	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Medium term

3	Technical	**B6**-Improving the quality and grade of tools/technology of the Small-Medium Cereal and Rice Milling Unit (UPGB) and the establishment of regulations related to the concept and technology of cereal milling so as to prevent FL.	- Ministry of Agriculture - BUMN - Private Sectors - Regional Government - Farmer Association	Regulation of the Minister of Trader No 127/2018 on Management of Rice Reserves for Supply Availability and Price Stability	Long term
1-2	Technical	**B7**-Providing access/assistance to ICT (information, communication and technology) for farmers/fishers/breeders to support operations, especially to open access to online training and price transparency, thereby minimizing the occurrence of FL due to the lack of knowledge of food workers and about commodities that are in demand/does not sell in the market.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Information and Communication - Regional Government - Private Sectors - BUMN - NGOs - Association/Farmer Cooperatives/Fishers/ Breeders	1. Presidential Regulation No. 18/2020 RPJMN 2020 - 2024 2. Strategy Policy of Food Security and Nutrition 2020 - 2024	Long term
Low Priority					
4	Technical	**B8**-Supporting MSMEs to market local food products to prevent FW from unsold food products.	- Ministry of Trade - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Regional Government	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Medium term
4	Institution	**B9**-Creating a trading contract system (future contract) to suppress excess supply as a result of unabsorbed product by the market thus causing FW.	- Private Sectors - Association/Farmer Cooperatives/Fishers/ Breeders - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Medium term
4	Technical	**B10**-Prioritizing the fulfillment of regional food needs from local production, except for commodities that are not available in the area as an effort to prevent FW.	- Regional Government	1. Presidential Regulation No. 18/2020 RPJMN 2020 - 2024 2. Presidential Decree No.22/2009 on Acceleration of Food Consumption Diversification Local Resource-Based	Long term
4	Institution	**B11**-Conducting inter-agency socialization regarding import decisions by involving stakeholders who are directly affected by the import process as a form of FLW prevention.	- Ministry of Trade - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Association/Farmer Cooperatives/Fishers/ Breeders	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Long term

Table 10. Strategy for Strengthening Regulations and Optimizing Funding.

STRATEGY FOR STRENGTHENING REGULATIONS AND OPTIMIZING FUNDING					
Supply Chain Stage	Aspect	Strategy	Stakeholders	Relevant Policy	Period
High Priority					
1-5	Institution	**C1**-Strengthening coordination of planning and strategy between Ministries/Agencies (K/L) related to FLW issues.	- Ministry of National Development and Planning/Bappenas - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Environment and Forestry - Ministry of Tourism and Creative Economy - Ministry of Industry - Ministry of Finance	No relevant policy	Short term
1-5	Policy	**C2**-Developing regulations and guidelines for FLW at the national level that address/ mandate derivative regulations for the following: ▪ Increase the efficiency of the food production process through FLW prevention and handling; ▪ Donation of leftovers, including the responsibility for the leftovers and the operational requirements of the food bank as a distributor of leftovers; ▪ Obligations and incentives for HORECA to process FW independently to reduce FW to landfills; ▪ Incentive and disincentive system for producers who have innovations in the massive prevention and management of FLW, and for HORECA sector who do not handle their FLW properly.	- Ministry of National Development and Planning/Bappenas - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Environment and Forestry - Ministry of Tourism and Creative Economy - Ministry of Industry - Ministry of Finance	1. Presidential Regulation No. 18/2020 RPJMN 2020 - 2024 2. Government Regulation No 17/2015 on Food Security and Nutrition article 26 (1) 3. Government Regulation No.86/2019 on Food Safety 4. Presidential Regulation No.97/2017 National Policy and Strategy	Medium term
1-2	Finance	**C3**-Optimizing State Budget and Regional Budget allocation for appropriate and targeted harvest and post-harvest machinery and transportation to support efficient process and prevent FL.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Regional Government	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Medium term

5	Finance	**C4**-Optimizing State Budget and Regional Budget to support education and infrastructure for sorting waste and alternative for non-landfill FW processing.	- Ministry of Public Works and Housing - Ministry of Environment and Forestry - Regional Government	1. Presidential Regulation No. 18/2020 RPJMN 2020-2024 2. Regulation of the Minister of Public Works No.3/2013 on Implementation of Solid Waste Infrastructure and Facilities in Management of Household and Household-like Waste 3. Regulation of the Minister of Finance No.26/2021 on State Budget to Support Waste Management in Regions	Medium term
1-3	Finance	**C5**-Optimizing State Budget and Regional Budget for appropriate infrastructure improvement in the agriculture, livestock and fisheries sectors to support the prevention of FL.	- Ministry of Industry - Ministry of Trade - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Regional Government	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Long term
1-5	Policy	**C6**-Developing policies, guidelines and programs at the regional level related to strategies for the prevention and use of FLW by considering the types of food that are most consumed or hotspots of loss in the area, donations of leftovers, and prioritize efforts to reduce FLW to landfill or leak into the environment.	- Regional Government	1. Presidential Regulation No.97/2017 National Policy and Strategy 2. Regulation of the Minister of Environment and Forestry No.10/2018 National Policy and Strategy	Long term
Medium Priority					
2-3	Technical	**C7**-Conducting periodic audits of the conditions of infrastructure and slaughterhouse systems (RPHU), especially those related to hygiene and product quality assurance to prevent FL.	- Ministry of Agriculture - Regional Government - Ministry of Trade - Ministry of Health	Regulation of the Minister of Agriculture No. 13/Permentan/ OT.140/1/2010 on Requirements for Ruminant Slaughterhouses and Meat Cutting Plant	Medium term
3	Technical	**C8**-Developing green industry standards for all sub-sectors of the food and beverage industry to support the prevention and management of FL.	- Ministry of Industry - Ministry of Environment and Forestry	Minister of Industry Regulation No. 51/M-IND/PER/6/2015 concerning Guidelines for Preparing Green Industry Standards	Medium term

3-5	Policy	**C9**-Developing food quality standards that distinguish the use of 'Best before' and 'Expiration' according to the resistance conditions of each type of food.	- National Agency of Drug and Food Control - Ministry of Industry - Industry/Industry and retailer association - Education institution - Research agency	1. Regulation of Head of Drug and Food Control Agency No. HK. 03.1.23.06.10.5166 on Information Inclusion on the Origin of Certain Ingredients, Alcohol Content, and Expiration Date on Markings/ Labels of Medicines, Traditional Medicines, Food Supplements, and Food 2. Regulation of Head of Drug and Food Control Agency No. HK. 03.1.5.12.11.09956/2011 on Processed Food Registration Procedures	Medium term
4	Policy	**C10**-Regulating the timing and quotas of fresh food product imports to prevent FL as a result of domestic food that is not absorbed by the market.	- Ministry of Trade - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Import/export association	1. Regulation of the Minister of Trade No. 1 of 2018 2. Regulation of the Minister of Trade No. 13/M-DAG/ PER/3/2012 on General Provisions in the Export Sector	Medium term
1-5	Policy	**C11**-Aligning the national level FLW policy with the food system transformation agenda and policies as well as the food product safety and hygiene policies.	- Ministry of National Development and Planning/Bappenas - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Health - Ministry of Industry - National Standardization Agency - National Agency of Drug and Food Control	Government Regulation No. 28/2004 on Food Security, Quality, And Nutrition	Medium term
Low Priority					
4	Policy	**C12**-Regulating the logistic requirements and quality of edible food to cities, and collaborate on the FL handling with food-producing regions to prevent FW in cities.	- Ministry of Trade - Regional Government	No relevant policy	Medium term

Table 11. Strategy for Utilizing FLW.

STRATEGY FOR UTILIZING FLW					
Supply Chain Stage	Aspect	Strategy	Stakeholders	Relevant Policy	Period
High Priority					
5	Technical	**D1**-Conducting a pilot to implement the reduction and utilization of FW accompanied by data collection at the city/district scale, especially by the HORECA sector.	- Ministry of National Development and Planning/Bappenas - Ministry of Environment and Forestry - Regional Government	Presidential Regulation No. 97/2017 concerning the National Strategy for Waste Management	Short term
1-5	Technical	**D2**-Creating a platform to assist the distribution of excess food/ugly food/ leftovers to prevent FLW.	- Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Trade - Association/Farmer Cooperatives/Fishers/ Breeders - Private Sectors - NGO	Presidential Regulation No. 18/2020 RPJMN 2020 - 2024	Medium term
5	Technical	**D3**-Applying waste sorting at the source to support the use of FW through composting, biopores, BSF, eco-enzymes, bioconversion and so on.	- Regional Government - Private Sectors	1. Law No. 18/2008 on Waste Management 2. Government Regulation No. 81/2012 on Management of Household and Household-like Waste	Medium term
1-5	Technical	**D4**-Conducting FLW processing with biopores, composting, BSF, and other alternative technologies to prevent FW from entering the landfill, leaking into the environment, or not being properly managed.	- Regional Government - Private Sectors - NGOs	1. Government Regulation No.81/2012 on Management of Household and Household-like Waste 2. Regulation of the Ministry of Public Works No.3/2013 on Implementation of Infrastructure and Facilities for Management of Household and Household-like Waste	Medium term

Table 12. Strategy for Strengthening Data and Research.

STRATEGY FOR STRENGTHENING FLW DATA AND RESEARCH					
Supply Chain Stage	**Aspect**	**Strategy**	**Stakeholders**	**Relevant Policy**	**Period**
High Priority					
1, 2, 5	Technical	**E1**-Conducting integrated FLW data collection periodically by BPS surveys (Agricultural Census, Fisheries Census, Indonesian National Socioeconomic Survey/SUSENAS). For FL, especially in the staple food commodity.	- BPS (Statistics Indonesia) - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Environment and Forestry	No relevant policy	Short term
1	Technical	**E2**-Compiling a pre-harvest (on-farm) and undesirable yields (fishery) FL study to support the total FLW generation data and understand the causes of FL in the pre-harvesting phase.	- Ministry of National National Development and Planning/Bappenas - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Regional Government - Education institution - Research Agency	No relevant policy	Medium term
1-5	Technical	**E3**-Preparing a study on the relationship between the causes and drivers of FLW at all stages of the supply chain with the FLW generation that occurs at each stage.	- Ministry of National National Development and Planning/Bappenas - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Environment and Forestry - Ministry of Industry - Ministry of Trade - Regional Government - BUMN (State-Owned Enterprises) - Private Sectors - Education institution - Research agency	No relevant policy	Medium term
1-5	Technical	**E4**-Preparing a regional FLW study by adjusting the specific conditions in the area.	- Regional Government - Education Institution - Research Agency	No relevant policy	Medium term

Medium Priority					
1-3	Technical	**E5**-Mapping the potential of FLW with a food system approach and food value chain and disseminating the results to related agencies and farmer/trader associations.	- Ministry of National National Development and Planning/Bappenas - Regional Government - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Ministry of Trade - Ministry of Health - Ministry of Industry - Education Institution - Research Agency	No relevant policy	Long term
Low Priority					
4	Technical	**E6**-Preparing an FLW study in the import-export process to complete the FLW generation data.	- Ministry of National National Development and Planning/Bappenas - Ministry of Trade - Ministry of Agriculture - Ministry of Marine Affairs and Fisheries - Education institution - Research Agency - Export/import industries	No relevant policy	Medium term

PROJECTION OF FOOD LOSS & WASTE GENERATION

Business as Usual (BAU)/Baseline Projection

The Business as Usual (BAU) Projection of FLW 2020 - 2045 is a projection of the total food aggregate into a baseline projection for 2020 - 2045 considered pessimistic which is analyzed with the assumption of the macroeconomy scenario 2020 - 2045, assumption of FBS scenario 2020 - 2045, and the assumptions of baseline projection 2020 - 2045 attached in **Appendix**. From the analysis of the 2020 - 2045 BAU FLW food projection, it is known that the FLW generation per stage of the food supply chain is projected to increase per year on average from 2020 to 2045 (**Figure 22**), namely the production stage (4.36%) with generation of 11.2–22.2 million tons, post-harvest and storage stage (3.13%) with generation of 7.9–16 million tons, processing and packaging stage (1.17%) with generation of 1.3–3.1 million tons, distribution and marketing stage (5.10%) with generation of 5.8–13.4 million tons, and consumption stage (17%) with generation of 18.1–57.1 million tons. The BAU/Baseline FLW generation in 2020-2045 is 45–112 million tons/year, and the BAU/Baseline FLW generation per capita is 165-344 kg/capita/year.

The increase in FLW generation in the BAU/Baseline scenario projection is driven by 3 factors:

1. **Population growth,** from 272 million people in 2019 to 325 million people in 2045.
2. **Economic growth,** it projects an increase in gross domestic product (GDP) and GDP per capita starting in 2022.
3. **Food demand per capita,** it projects an increase from 0.9 kg/capita/day (2020) to 1.6 kg/capita/day (2045).

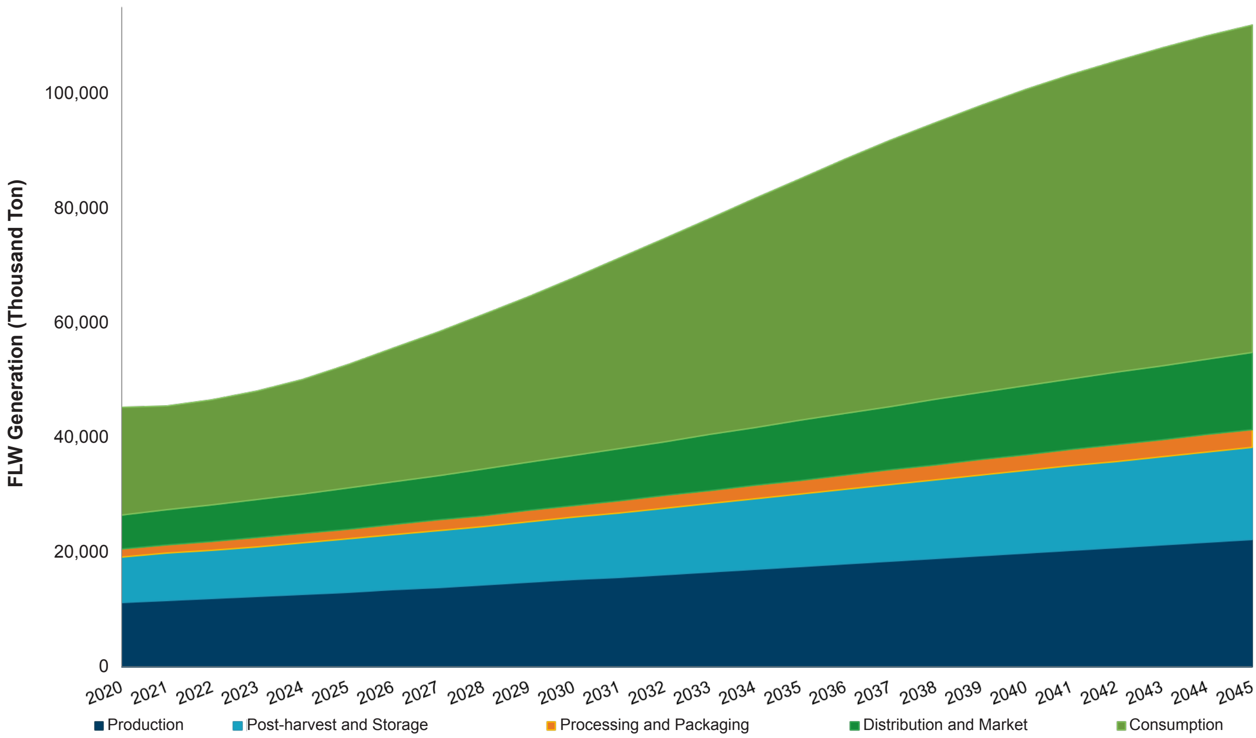


Figure 22. Projection of FLW Generation in 2020 - 2045 in Food Supply Chain (Business as Usual Scenario).

Strategy Projection

The Strategy Projection of the FLW Generation in 2020 - 2045 is an optimistic projection with the addition of policy/strategy interventions from the modelled BAU projection, which is the analysis of the assumption of macroeconomy scenario 2020 - 2045 (see **Appendix**). There are 7 entry point models in the entire food supply chain that have been determined by the results of expert justification (see **Appendix**). Additional policy/strategy interventions have been measured and projected in order to be able to withstand/reduce the FLW generation from 2020 - 2045 determining the following assumptions:

1. **Production Stage,** % FL Production may gradually decrease from 4.37% (2022) to 3% (2045).
2. **Post-Harvest and Storage Stage,** % FL Post-Harvest and Storage is projected to decrease from 3% (2022) to 2.5% (2045).
3. **Processing and Packaging Stage,** % FL Processing and Packaging may gradually decrease from 1.17% (2022) to 0.8% (2045).
4. **Distribution and Market Stage,** % of Distribution and Market FW is projected to decrease from 5% (2022) to 3.8% (2045).
5. **Consumption Stage,** the target of reducing FW generation per capita in consumption is 35% starting from 2022 until it will be achieved in 2030.

The analysis results of the FLW generation projection with policy interventions in 2020 - 2045 produce a Strategy Projection which can be reviewed in **Figure 23.** From the results of strategy projections, it can be determined that the strategy projection FLW generation has decreased the BAU/Baseline FLW in 2020 - 2045 on average in the production stage (19.61%) with generation of 11.1-14.1 million tons, post-harvesting and storage (16.35%) with generation of 8-11.5 million tons, processing and packaging stage (25.55%) with generation of 1.3–1.7 million tons, distribution and marketing stage (24.15%) with generation of 5.8–8.1 million tons, and the average consumption stage (53.78%) with a production of 12.6–18.8 million tons. The projection of FLW generation in 2020 - 2045 is 41–49 million tons/year, and the projection of FLW generation per capita is 142-166 kg/capita/year.

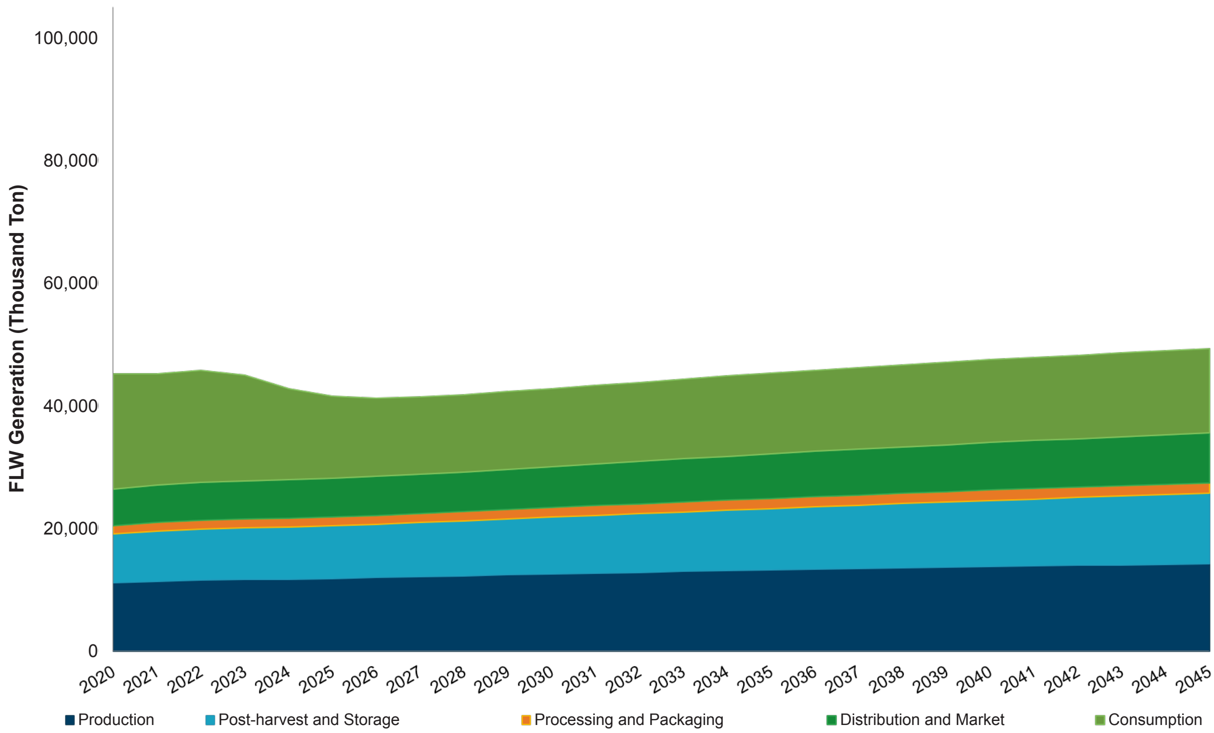


Figure 23. Projection of FLW Generation in 2020 - 2045 per Food Supply Chain (Strategy Scenario).

In **Figure 24,** it shows behavioral change trend of FLW generation per food supply chain stage and the total FLW from the BAU/Baseline projection analysis and analysis of strategy projection. In **Figure 24 (a)**, it can be seen that the FW generation of consumption is increasing year by year. This is in line with the study from FAO that the more advanced/higher the GDP of a country is, the higher the consumption FW generation is compared to the FL generation. So that in **Figure 24 (b)** with policy and strategy interventions, it can be seen that the FW consumption trend has decreased.

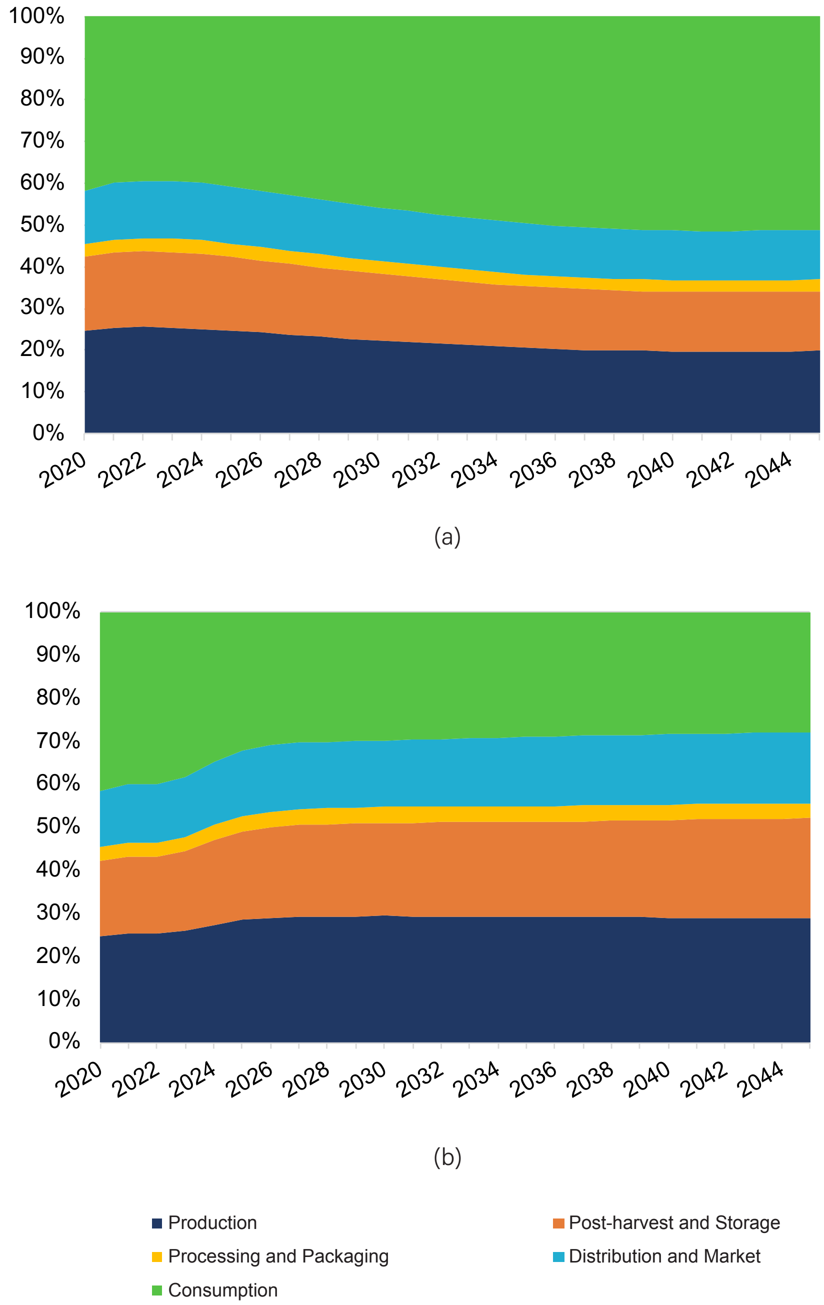


Figure 24. FLW Generation Trend in 2020 - 2045 in Food Supply Chain (a) BAU/Baseline Scenario (b) Strategy Scenario.

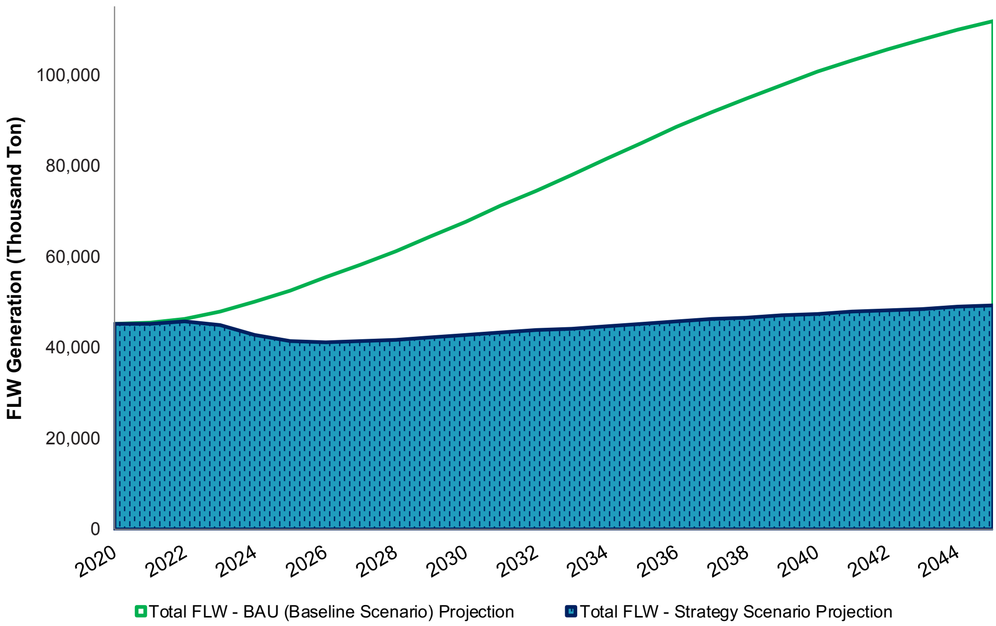


Figure 25. Total FLW Generation BAU Projection against Strategy Projection.

Table 13. The Result of % Reduction of FLW Generation in 2020 - 2045.

Year	% FL Reduction	% FW Reduction	% FLW Reduction
2030	16.60%	51.25%	36.90%
2045	33.61%	68.94%	55.88%

Given **Table 13,** it is known that the projection of the percentage reduction of FLW Generation 2020 - 2045 based on the analysis of strategy projection is the result of a comparison of the difference between BAU and strategy generation and then compared with the BAU generation in that year. The projection of the percentage reduction in the FL generation reaches 16.60% (2030) and 33.61% (2045), the projection of the percentage reduction in FW is 51.25% (2030) and 68.94% (2045). From this projection, it is also known that to achieve the target of SDG 12.3, namely "By 2030, to be able to halve per capita food waste in the distribution and consumption stages and reduce food loss at the production stage and along the supply chain, including post-harvest losses", Indonesia needs to reduce FW generation by at least 2.83% per year. Meanwhile, the total FLW with the strategy scenario prepared in 2045, it is estimated that the FLW reduction can reach 56%.

APPENDIX

Appendix 1 Food Commodity based on Food Balance Sheet

Table (a). Food Commodity Category based on Food Balance Sheet.

Category		Food Commodity
1	Cereals	Unhusked Rice, **Rice**, Maize, Fresh Maize, Wheat, Wheat Flour
2	Starchy food	Sweet Potatoes, **Cassava**, Cassava/Manioc, Cassava/Tapioca, Sago Flour
3	Sugar	**White Sugar**, Other Sugar
4	Pulses Nut and Oil Seeds	Groundnuts in Shell, Groundnuts Shelled, **Soybeans**, Mungbean, Coconut Fresh, Copra
5	Fruits	Avocados, Oranges, Lanzon, Durians, Waterapples, Rose Apple, **Mangoes**, Pineapples, Papayas, **Bananas**, Rambutans, Salacia, Sapodila, Melon, Watermelon, Star Fruit, Mangosteen, Jackfruit, Marquisa, Soursop, Bread Fruit, Apple, Grape, Strawberry, Cantalaupe, Lemon, Pomelo, Date Fruit, Fig, Pear, Apricot/Cherry/Nectarine, Rasberry and Blackberry, Kiwi, Persimon, Longan, Lychee, Dragon Fruit
6	Vegetables	**Shallot (Onion)**, Cucumber, Kidney Beans, String Beans, Potatoes, **Cabbage**, Tomatoes, Carrots, **Chilli**, Bird's Eye Chilli, Eggplant, Mustard Greens, Spring Onion, Swamp Cabbage, Radish, Chayotte, Greenbeans, Spinach, Garlic, Cauliflower, Mushroom, Melinjo, Twisted Cluster Bean, Jengkol, Bell Papper, Snow Pea, Lettuce, Asparagus, Celery, Other (Luffa, Winged Bean, Pare, Pakis)
7	Meat	Beef, Buffalo Meat, Mutton, Lamb, Horse Meat/Other, Pork, Local Chicken Meat, **Improved Chicken Meat**, Duck Meat, Quail Meat, Offal All Kinds
8	Eggs	Local Hen Eggs, **Improved Hen Eggs**, Ducks Eggs, Quail Eggs
9	Milk	**Cow's milk**, Imported milk
10	Fish	**Skipjack/Little Tuna**, Giant Seaperch, Sharks, Pomfret, Anchovies, Indian Oil Sardinella, Indian Mackerels, Narrow Bard/King Mackerels, Milk Fish, Mullets, Mozambique, Tilapia, Common Carp, Catfish, Pangasius spp, **Nile tilapia**, Groupers, Giant Gouramy, Shrimps, Swimming and Mud Crab, Clams, Cuttle Fish, Squids and Octopus, Sea Weeds, Giant Trevally, Siganus, Caesionidae, Scad, Cobia, Java Barb, Others
11	Oil and Fats	Peanut Oil, Coconut Oils, Palm Oils, **Cooking Oils**, Corn Oils, Olive Oils, Sesame Oils, Soybean Oils, Cattle Fats, Buffalo Fats, Goat Fats, Sheep Fats, Pig Fats

Appendix 2 FLW Generation Calculation

FLW generation was calculated using the Food Balance Sheet (FBS) data from the Food Security Agency. FBS represents a comprehensive overview of the food supply chain in a country for some specific period[25]. Therefore, in this study, FBS is used to find out the FLW flow and amount in the food supply chain for each commodity. The calculation used an input-output system, where the losses in the supply chain from production to Distribution and market were calculated based on the loss factor per commodity from FAO and FBS, while the losses in the consumption stage are calculated by combined FBS data with data simulation of food waste amount from waste sampling results (refers to the composition). **Figure (b)** shows the calculation of the FLW generation carried out in this study.

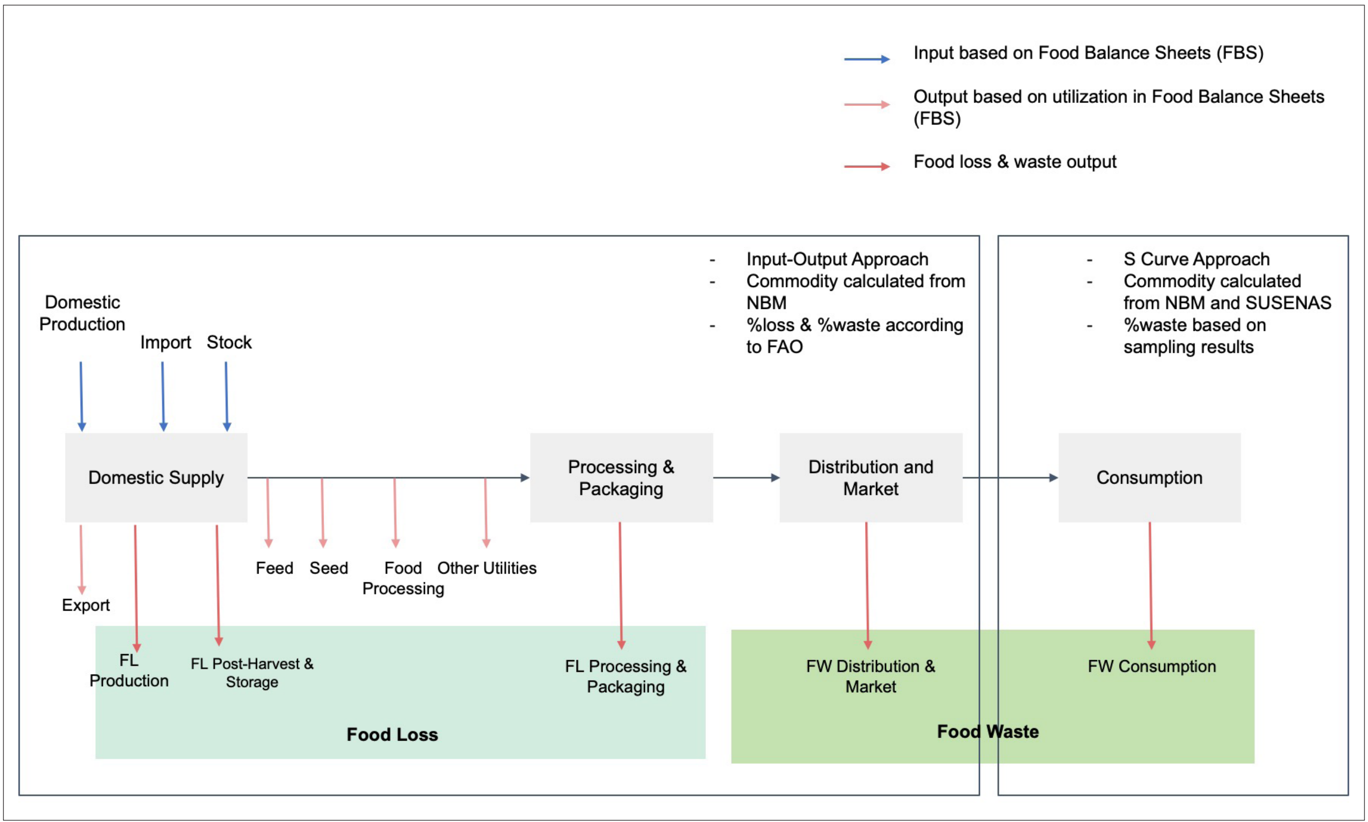


Figure (a). FLW Calculation Flow.

The calculation process to discover the food loss generation in production, post-harvest and storage, and processing and packaging stage are explained in **Figure (b)** and **Table (b)** as follows.

[25] FAO. (2001). Food Balance Sheet: A Handbook.

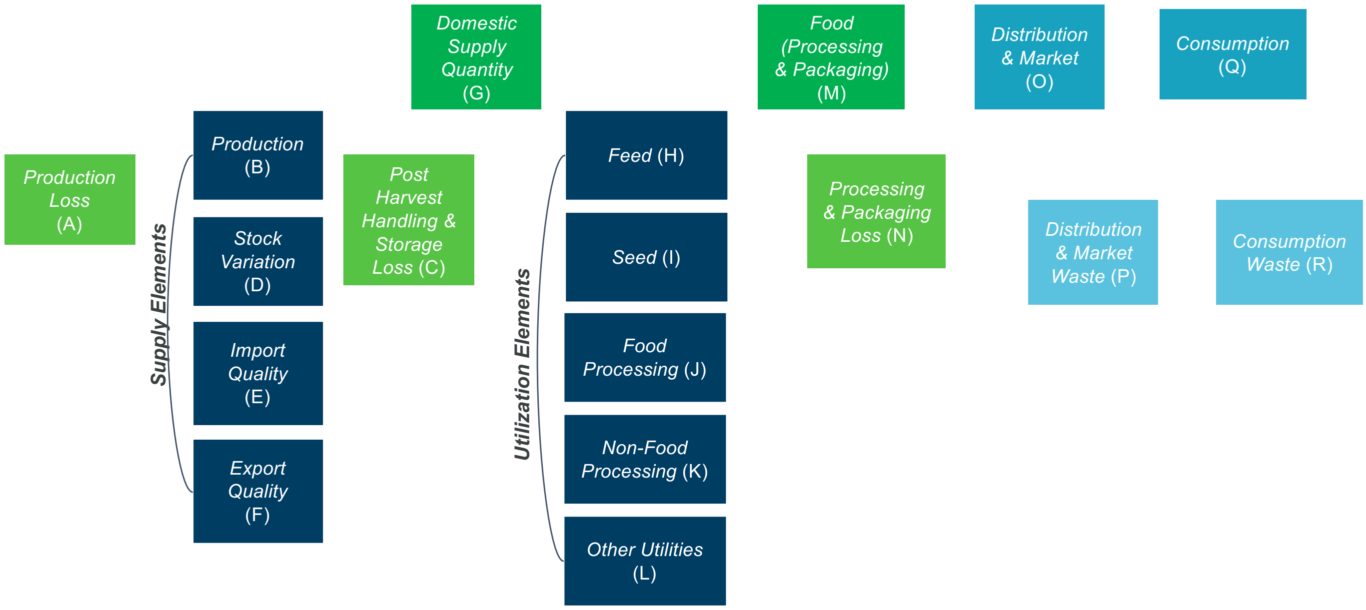


Figure (b). Food Loss Calculation Flow in Food Balance Sheet.

Table (b). Detail Components of Food Loss Calculation Flow in Food Balance Sheet.

Stage	Information
Production Loss **(A)**	Food loss generated at the harvesting stage, calculated using this formula: F=(% PL : (1-% PL)) x A
Production **(B)**	Total food production before transferred to the commodity processing stage
Post-harvest handling & storage loss **(C)**	Food loss that is generated at post-harvest and storage stage, calculated using this formula: G = % PHSL x A
Stock variation **(D)**	Changes in government food supplies
Import quantity **(E)**	Total commodities that come into the country/region
Export quantity **(F)**	Total commodities that are transported abroad/regions
Domestic supply **(G)**	The total domestic food supply, calculated using this formula G = B – C – D + E – F
Feed **(H)**	The number of commodities used as animal feed
Seed **(I)**	The number of commodities used as seeds/seedlings for re-production
Food processing **(J)**	The number of commodities available for human consumption which undergoes further processing
Non-food processing **(K)**	The number of available commodities subjected to further processing to be utilized as industrial needs

Tahapan	Keterangan
Other utilities **(L)**	Commodities used for the food supply of tourists, refugees, schools/dormitories/Islamic boarding schools, public and private stocks as well as the use of non-food industries whose numbers are not available due to unavailable data.
Food **(M)**	Food available for consumption or processed into food derivatives, distributed to markets and consumers. The food value is obtained from the calculation: M = G - (H + I + J + K + L)
Processing & Packaging Loss **(N)**	Food loss that generated at the processing and packaging stage, calculated using this formula: N = % PPL x M
Distribution & Markets **(O)**	Total of food supply at the distribution and markets stage obtained using this formula: O = M - N
Distribution & Markets Waste **(P)**	Food waste generated at the distribution and markets stage, calculated using this formula: P = % DMW x O
Consumption **(Q)**	Total of food supply at the consumption stage is obtained using this formula: Q = O – P
Consumption Waste **(R)**	Food loss generated at consumption is calculated using this formula: R = %CW x Q

Based on FBS, some commodities are processed from fresh/primary product into derivative products. The form change proportion of those products are obtained by using a conversion factor according to each food products. The conversion factors used in this study refers to the conversion factors are listed in **Table (c)** as follows.

Table (c). Conversion Factor of Food Products.

Category		Conversion Factor
Input	Output	
Paddy	Rice	64.02%[26]
Wheat	Wheat flour	0.78[27]
Peanuts with shells	Peanuts without shells	60%[28]
CPO	Palm cooking oil	68.28%[29]

For food commodity that not listed in **Table (c),** the conversion factors are not included in the food loss calculation because those commodities are fresh and do not undergo processing into derivative products.

[26] Food Security Agency of Indonesia . (2019). Guidelines For the Preparation of Food Material Balances.
[27] Food and Agricultural Organization. (2011). Global food losses and food waste – Extent, causes, and prevention.
[28] Food Security Agency of Indonesia . (2019). Guidelines For the Preparation of Food Material Balances.
[29] Ibid.

FLW percentage in the food supply chain in production until distribution and market stage refers to FAO[30] percentage for South and Southeast Asia Region and BKP[31] listed on Indonesia Food Balance Sheet Guidance. The selection of these two sources is based on their proximity to the percentage loss in the field. FLW percentage used in this study is listed in **Table (d).**

Table (d). FLW Weight Percentage in Each Food Supply Chain Stage.

Category	Production	Post-harvest & Storage	Processing & Packaging	Distribution & Market	Source
Cereals	6%	7%	3.50%	2%	FAO, 2011
Oilseeds	7%	12%	8%	2%	
Vegetable and Fruit	15%	9%	25%	10%	
Meat	5.1%	0.3%	5%	7%	
Fish and Seafood	8.2%	6%	9%	15%	
Milk	3.5%	6%	2%	10%	
Egg	8%	-	0.10%	3%	
Sweet Potato	0.74%	2.34%	1.23%	1.35%	BKP, 2019
Cassava (*Ubi Kayu*)	0.52%	1.64%	0.86%	0.95%	
Cassava (*Gaplek*)	0.09%	0.28%	0.15%	0.16%	
Cassava/Tapioca	0.09%	0.28%	0.14%	0.16%	
Sago Flour	0.09%	0.28%	0.15%	0.16%	

FAO: Food and Agriculture Organization UN | BKP: Food Security Agency of Indonesia

For food waste in the consumption stage, the calculation was conducted by combining data from FBS with simulation data of food waste generation in 2019 which refers to the composition of the waste sampling results. Then projected to previous years using the S-Curve Method with the following steps.

1. Cities and Districts in Indonesia are divided into 4 categories based on their population, namely Metropolitan Cities (population of > 1,000,000 inhabitants), Large Cities (population of 500,000 - 1,000,000 inhabitants), Medium Cities (population of 100,000 - 500,000 inhabitants), and Small Cities (population of <100,000 inhabitants).

2. The population data per city/regency is then multiplied by the number of food waste generation per capita per day to get the total food waste generation in that area. Food waste generation per capita per day that is used in the calculation is based on the result of waste generation survey at three cities. The numbers obtained from survey at Bandung city are used to represent metropolitan cities, while the survey result at Pekanbaru city is used to represent big cities and the survey result at Tabanan regency is used to represent small and medium city. The numbers are as follows:
   - Small city/regency : 0.088 kg/capita/day
   - Medium city/regency : 0.088 kg/capita/day
   - Large city/regency : 0.210 kg/capita/day
   - Metropolitan city : 0.380 kg/capita/day

[30] FAO. 2011. Global food losses and food waste – Extent, causes, and prevention.
[31] Food Security Agency of Indonesia. (2019). Guidelines For the Preparation of Food Material Balances.

3. The total of food waste generation for the entire city/district is called "food waste generation simulation". It is assumed that the food waste generation simulation includes the Distribution and Market stage as well as the Consumption stage in the food supply chain. This generalization considers that the total waste generation per city/regency data has included various elements of municipal waste sources such as households, offices, commercials, areas, public facilities, and traditional markets. To determine the waste generation at the Consumption stage, the food waste generation simulation is reduced by the food waste generation at the Distribution and Market stage which is obtained from the FBS calculation.

4. Waste generation per capita data in 2019 at the consumption stage is used as the basis for 2000 - 2018 projections using the S-curve curvature approach which considers:
   - The 2019 waste generation data is used as basic data to project backward since it represents the actual condition based on survey and it is aligned with literature such as the data from Ministry of Environment and Forestry (2020), UNEP Food Index Report (2021), and Waste Sampling (2020).
   - The backward projection with the curvature of the S-curve, the result will be dynamic thus corresponding with the historical pattern of waste generation per capita to GDP per capita.

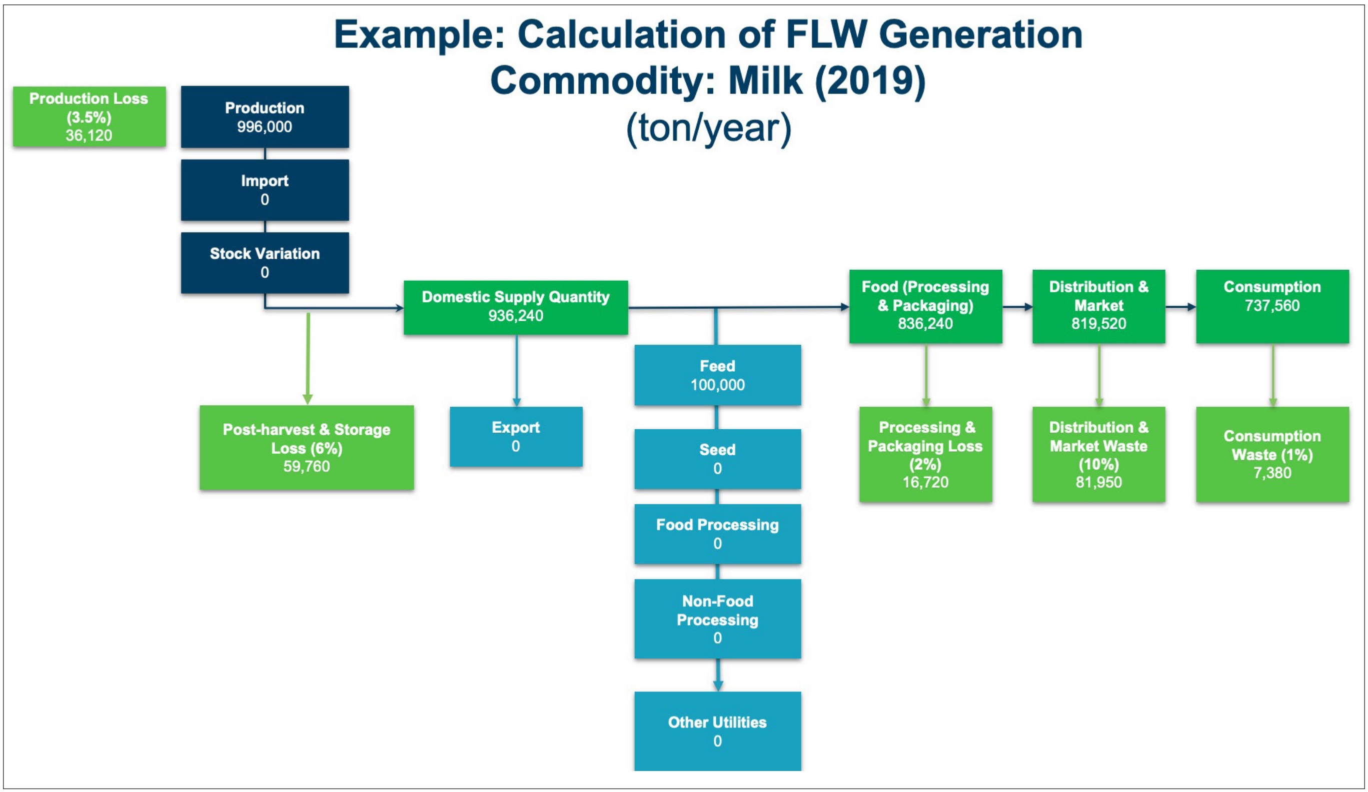
5. To calculate the food waste generation per capita which is assumed to be a function of GDP per capita with an "s" curve pattern, therefore the meaning of variables and parameters uses the following equation are as follows:

$$f(x) = \frac{L}{1 + e^{-k(x - x_0)}}$$

f(x) = food waste generation per capita [kg/capita/day];
x = GDP per capita [million IDR(Constant Price 2010)/capita/year];
L = maximum amount of food waste generation per capita [kg/capita/day];
= 0.5 kg/capita/day;
x_0 = a GDP value per capita that generate f(x) value for 0.5 L
= m*35.42 (GDP per capita of Tabanan City In 2019 [million IDR(2010)/person/year];
with m = as a multiplier; and m = 2.04
k = S-curve growth rate, k = 0.049

6. To determine the food waste generation per commodity at the consumption stage, the food waste generation data at the consumption stage is then being adjusted to the FBS data and food consumption data from the National Social and Economic Survey (SUSENAS), especially from the Indonesians consumption expenditures. Please note, due to data limitation, the expenditures data for 2000 - 2001 that used are based on the extrapolated result from the trend of years after.

   For more detail, an example of FLW calculation in this study can be seen as follows.



Food Balance Sheet (FBS) Calculation for Milk Commodity (Ton/Year)

Production Loss

= (% Weight Production Loss/1-% Weight Production Loss) x Production
= (3.5%/1-3.5%) x 996,000
= 36,120

Post-Harvest Handling & Storage Loss

= (% Weight Post-Harvest, Handling & Storage Loss) x Production
= (6%) x 996,000
= 59,760

Domestic Supply

= Production - Post Harvest Handling & Storage Loss - Stock Variation + Import Quantity - Export Quantity
= 996,000 – 59,760 - 0 + 0 - 0
= 936,240

Food (Processing & Packaging)

= Domestic Supply - (Feed + Seed + Food Processing + Non-Food Processing + Other Utilities)
= 936,240 - (100,000+0+0+0+0)
= 836,240

Processing and Packaging Loss

= % Berat Processing and Packaging Loss FAO x Food (Processing and Packaging)
= 2% x 836,240
= 16,720

Distribution and Market

= Food (Processing and Packaging) - Processing and Packaging Loss
= 836,240 – 16,720
= 819,520

Distribution and Market Waste

= % Weight Distribution and Market Waste FAO x Distribution and Market
= 10% x 819,520
= 81,950

Consumption

= Distribution and Market - Distribution and Market Waste
= 819,520 – 81,950
= 737,560

Consumption Waste

= % Weight Consumption Waste FAO x Consumption
= 1% x 737,560
= 7,380

The Food Waste Consumption Survey Simulation Approach to the Curvature of the S Curve

$$f(x) = \frac{L}{1 + e^{-k(x-x_0)}}$$

f(x) = food waste generation per capita [Kg/people/day];

x = GRDP per capita [million Rp (ADHK 2010)/people/year];

L = maximum rate food waste generation per capita [Kg/people/day];

= a value of GRDP (GDP) per capita which results in an f (x) value of 0.5 L

= m*35.42 (GRDP per capita city of Tabanan in 2019 [million IDR (2010) / person / year]),

where m = as a multiplier; and

k = the growth rate of its "s" curve

Simulate an "s" [f (x)] curve that approximates the scatter of the pair of data resulting from a survey of food waste generation in 3 cities / districts with PDRB per capita of each city, for several values of L (the maximum number of food waste generation per capita)

Calculation of the Food Waste Generation Rate per Capita from the Sampling Simulation Results in 2000-2019 using the S Curve Pattern Curvature considering:

- The 2019 lead rate is used as basic data to project backwards, because the number of waste generation in 2019 is most relevant to the condition of solid waste in Indonesia in terms of data from the Ministry of Environment and Forestry (2019), UNEP Food Index Report (2021) and Waste Sampling (2020).
- Projection to the back with the curvature of the S curve, the results will be dynamic so that it is in accordance with the historical pattern of the per capita waste generation rate of per capita GRDP.

Approach Calculation Method

$$\text{AT year} = \frac{\text{ATs}'}{\text{ATs}''} \times \text{Base Number Result}$$

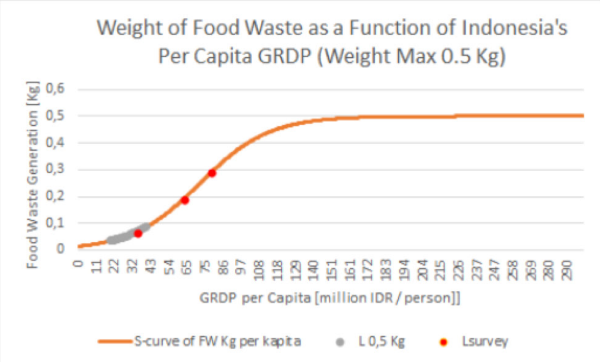
AT year = Generation Rate of Year Calculated (kg/p/day)
ADh = Generation Rate Result of Year Later (kg/p/day)
ATs' = Generation Rate at S Curve of Year Calculate (kg/p/day)
ATs'' = Generation Rate at S Curve of Year Later (kg/p/day

Example of Calculation

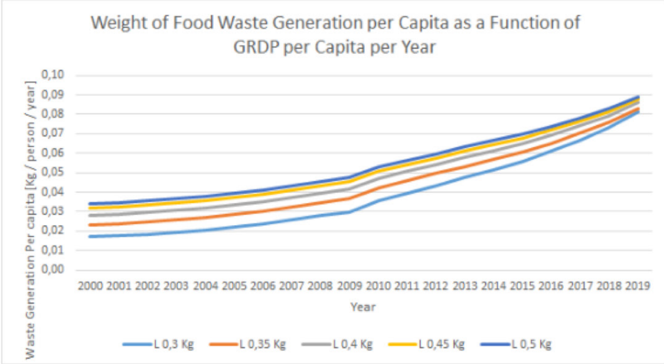
The pattern is calculated using the S L = 0.5 curve

AT 2019 = ADh = 0.1996

$$\textbf{AT 2018} = \frac{0.078}{0.084} \times 0.1996 = 0.1881$$



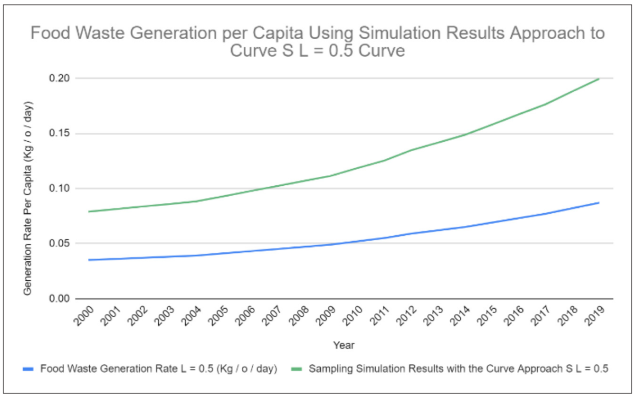
Graph of GDP per Capita and Food Waste Generation per Capita in Indonesia for Maximum Waste Generation 0.50 Kg/person/day



Graph of Indonesia's per Capita Food Waste Generation 2000-2019 for Some Maximum Generation

Food Waste Generation Rate Approach S Curve

Year	S Curve	Generation Rate (Kg/p/day)
	Food Waste Generation Rate L=0.5 (Kg/p/day)	Sampling Simulation Results with the Curve Approach S L = 0.5
2000	0.035	0.0789
2001	0.036	0.0812
2002	0.037	0.0836
2003	0.038	0.0858
2004	0.039	0.0882
2005	0.041	0.0927
2006	0.043	0.0975
2007	0.045	0.1020
2008	0.047	0.1068
2009	0.049	0.1113
2010	0.052	0.1184
2011	0.055	0.1253
2012	0.059	0.1347
2013	0.062	0.1416
2014	0.065	0.1486
2015	0.069	0.1578
2016	0.073	0.1672
2017	0.077	0.1764
2018	0.082	0.1881
2019	0.087	**0.1996**



Food Waste Generation per Capita with a Sampling Simulation Result Approach to the Curvature of the S Curve

- Cities / Regencies in Indonesia are divided into 4 categories based on their population *)
- **Food Waste Generation City / Regency** (Ton/year) = **Population of City/Regency each year** (people) x **Food Waste Generation Rate*)** (kg/people/day)

Simulation of Food Waste Generation National (Ton/year) = Σ **FW Generation Metropolitan City** + Σ **FW Generation Big City** + Σ **FW Generation Medium City** + Σ **FW Generation Small City**

2019 (Food Waste Generation Rate as Base Figure S Curve)
FW Consumption (Ton/year) = **Simulation of National Food Waste Generation** – **Total of Distribution & Retail FW Generation from FBS Commodity**
Food Waste Generation Rate (kg/people/day) = **FW Consumption** (Ton/year) / **Population** (people)

***) Food Waste Generation Rate**

Type of City/Regency	Population (people)	Food Waste Generation Rate (kg/people/day) (Sampling, 2020)
Small	< 100,000	0.088
Medium	100,000-500,000	0.088
Big	500,000-1,000,000	0.210
Metropolitan	> 1,000,000	0.380

2000-2018(Food Waste Generation Rate from the Results of the S Curve Approach)
FW Consumption (Ton/year) = **Food Waste Generation Rate per Capita Curve S** (Kg/people/day) x **Population** (people)

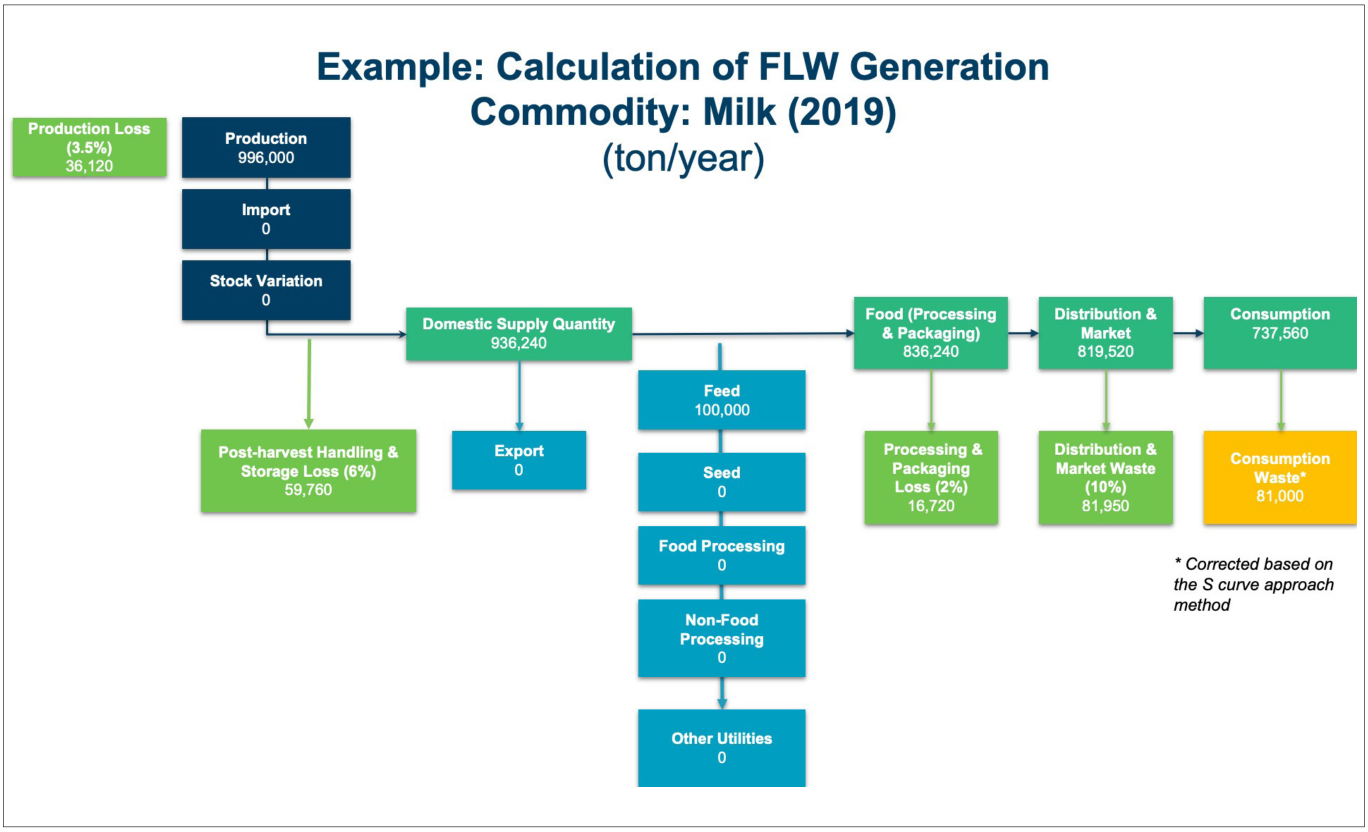
Example:
FW Generation Nasional 2019 (ton/year) = 25,284,000
FW Distribution & Retail NBM 2019 (ton/year) = 5,871,000
FW Consumption 2019 (ton/year) = 19,413,000

FW Consumption per Category (Ton/year) = % **Consumption National Susenas Proportional** x **FW Consumption** (Ton/year)

Example:
FW Consumption 2019 (ton/year) = 19,413,000
% Consumption Milk Susenas Proportional 2019 = 1.6%
FW Consumption per Category (ton/year) = 308,390

FW Consumption per Commodity (Ton/year) = % **FW Konsumsi Commodity FBS Proportional** x **FW Consumption per Category** (Ton/year)

Example:
FW Consumption per Category (ton/year) = 308,390
% FW Cow's Milk FBS Proportional = 36%
FW Consumption per Commodity (ton/year) =111,260


Example: Calculation of FLW Generation
Commodity: Milk (2019)
(ton/year)
Production Loss (3.5%) 36,120
Production 996,000
Import 0
Stock Variation 0
Domestic Supply Quantity 936,240
Food (Processing & Packaging) 836,240
Distribution & Market 819,520
Consumption 737,560
Post-harvest Handling & Storage Loss (6%) 59,760
Export 0
Feed 100,000
Seed 0
Food Processing 0
Non-Food Processing 0
Other Utilities 0
Processing & Packaging Loss (2%) 16,720
Distribution & Market Waste (10%) 81,950
Consumption Waste* 81,000
* Corrected based on the S curve approach method

Appendix 3 Life Cycle Assessment (LCA) Method

Life Cycle Assessment (LCA) is a compilation and evaluation of the input, output, and potential environmental impacts of a product system on the entire life cycle (a collection of processing units with main flows and product flows that perform one or more defined functions and become a product life cycle model). LCA determines the potential environmental impacts during the product life cycle, from raw material acquisition, production, use, end-of-life processing, recycling, and landfill (well known as cradle-to-grave). The principles, conditions, and guidelines for conducting the assessment are listed in ISO 14040: 2016 and 14044: 2017 and have been adopted in the Indonesian National Standards (SNI) respectively in 2016[32] and 2017[33]. In the LCA framework, there are four phases including the definition of objectives and scope, inventory analysis, life cycle impact assessment, and interpretation as shown in **Figure (c).** This LCA study report format will be following the four phases in the LCA framework based on SNI ISO 14040[34].

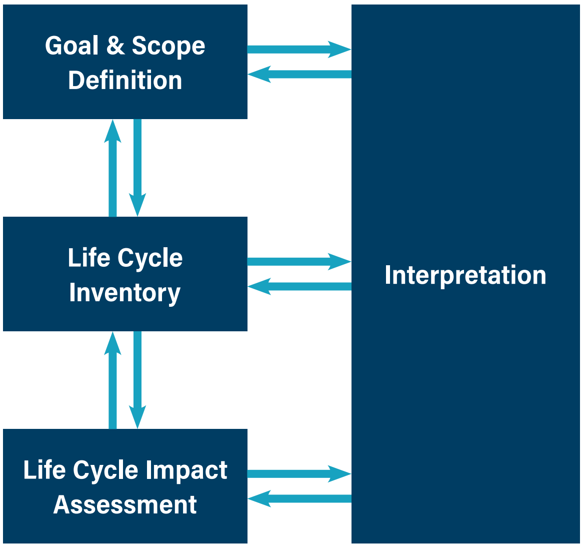


Figure (c). LCA Framework.

LCA Study Objective and Scope

LCA Study Objectives

The objective of the LCA for this study is to assess the global warming potential and the potential social impact from FLW in Indonesia during the 2000 - 2019 period.

This LCA study addresses for:

1. Interval parties such as BAPPENAS (Ministry of National Development Planning), the team of experts, drafting team, and related person in charge.
2. External parties such as consumer and public.

The results of this study are not intended to be a comparative statement because the results will become the baseline data for FLW in Indonesia. The comparative statement of this study is intended for public reading or in other words for external communication. However, it is not used as a product declaration, so the Product Category Rules (PCR) for food supply from any process are not applied.

LCA System Boundary

The LCA analysis in this study uses FBS as a reference for commodities in Indonesia, as shown in **Appendix 1 Table (a).** Commodities in bold text are commodities that have a major contribution to domestic supply in this category group. In this study, a Life Cycle Assessment (LCA) model is developed based on selected commodities that are considered to represent each food commodity category.

System boundary is determined based on study objectives. Processes explained in **Table (d)** **<u>are not included</u>** in the LCA research boundary.

[32] SNI ISO 14040. (2016). Environmental Management
[33] SNI ISO 14044. (2017). Environmental Management
[34] SNI ISO 14040. (2016). Environmental Management

Table (d). LCA System Boundary.

Scope of Boundaries	Boundaries
LCA to calculate Green House Gasses (GHG)	1. FLW that occurs in food material/food import-export activities 2. FLW utilization (will be considered in the alternative scenario) 3. Processed food such as canned meat, frozen food, and others with an exception of sugar and cooking oil 4. Flavourings and herbs 5. The environmental impact burden of the imported food production process and its transportation 6. The environmental burden that is specifically covered for the main food supply chain so that the environmental burden for exported food products into feed, seeds, processing, non-food processing and utilities is not taken into account. 7. Process of making production tools, machines, buildings/infrastructure, vehicle, equipment and other types of infrastructure 8. Employee business trips 9. Travel from or to the employee's residence 10. Research and development activities 11. Routine maintenance activities (e.g., maintenance of tools and machines) 12. Loss of yield or productivity associated with the studied food commodity 13. Potential impact from land transformation

Please note, for point number 6 in the LCA limitation, food loss is only considered for commodities that going through the harvesting process. Losses that occur during the production process will not be considered as food loss but as productivity loss. For instance, infected rice by viruses that cannot be harvested, dead fish that do not meet the target, chickens that die from diseases.

Boundaries and product systems are useful for establishing input and output models of a system to reflect the actual system. This system includes natural raw materials, supporting materials, energy, water, emissions, waste, and products that can be mapped according to their use in the FLW supply chain system. Within the boundaries, it is also necessary to pay attention to land use and land transformation. In addition, the waste end-of-life utilization/treatment cannot be separated and due to the high data uncertainty, the processing and utilization of FLW are shown in the form of a relevant scenario. Product system and system boundaries are shown in **Figure (d).**

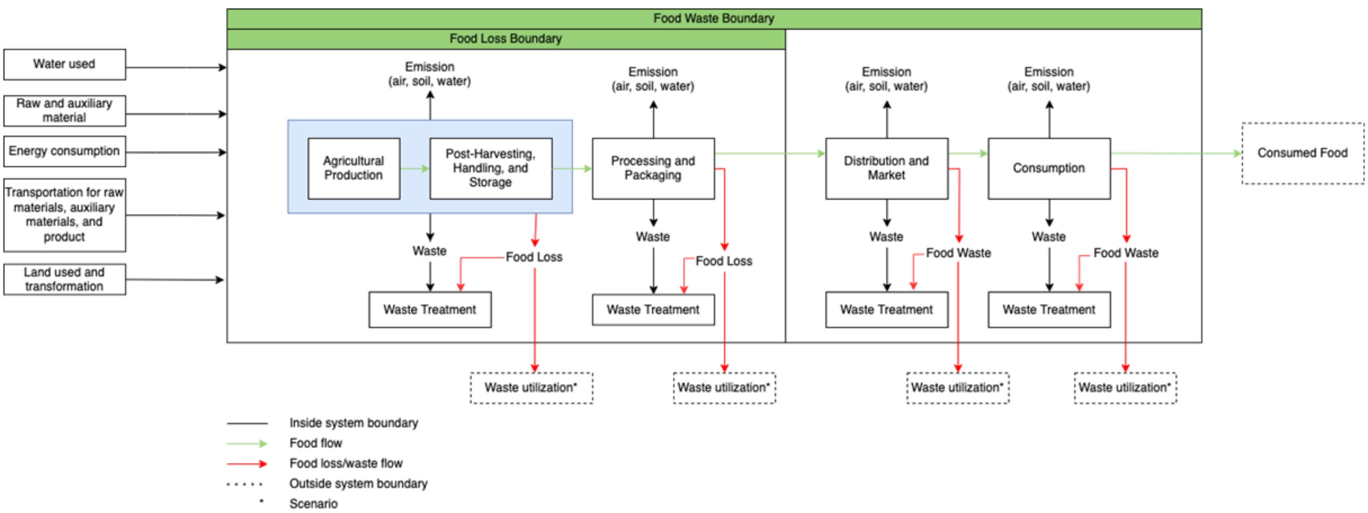


Figure (d). LCA System Boundary.

Each processing unit within the system boundaries in **Figure (d)** will be calculated in LCA, except for data that not included in cut-off data retrieval criteria:

1. Data from production systems that contribute less than 30% of the total, based on parameters of mass, energy or environmental impact values will not be included in the calculation. This criterion is used as the boundary between components with a significant contribution and those that are less significant given that the production system has a wide coverage.
2. Data cut-offs or restrictions will be implemented whenever data is not available in any source and/or cannot meet the cut-off criteria.

All data that is included in the above criteria will be included in the LCA calculation. Primary data that cannot be fulfilled will be represented by secondary data from databases and literature.

Scope of LCA Product System

This study is motivated by the objective to reduce the greenhouse gases (GHG) discharged by FLW generation in Indonesia. In this study, Indonesia's national food production and consumption during the 2000 - 2019 period was used to be analysed.

The scope of this study consists of upstream to downstream (cradle-to-grave) processes, from seedlings to FLW generation. The product system consists of the stages described in **Figure (d),** however, the processes involved in each process in the product system vary according to the commodity. To provide a clearer picture of the process in the product system, food ingredients are differentiated by vegetable and animal ingredients as shown in **Table (e).** In general, the processes at each stage will be adjusted to the specific processes of each commodity to reflect the real condition well.

Table (e). Scope of Plant-Based and Animal-Based Commodity Process.

Stages	Plant-Based	Animal Based
Production, Post-harvest, and Storage	a. Land preparation b. Plant growing/plant planting care/ nursery c. Harvesting d. Post-harvest handling e. Drying/milling/shelling	a. Land preparation b. Feed mill c. Livestock and hatchery (poultry, aquaculture and livestock) d. Harvesting e. Sorting
Processing and Packaging	a. Sorting b. Packaging	a. Slaughtering b. Packaging
Distribution and market	a. Transportation b. Storage c. Retail	a. Transportation b. Storage c. Retail
Consumption	a. Preparation b. Processing c. Consumption	a. Preparation b. Processing a. Consumption

In this study, the collected data is not specific for each chain process and just mentioned to declare there are sub-process in the actual activity. Due to time and resources limitation, sub-process detail will not be divided more specific, therefore the general industrial-scale data will be used. In this study, domestic supply data is a combination of production and post-harvest and storage data, because those two processes are inseparable from the existing actual data. In this study, that land-use change, use of infrastructure and use of materials for operational activities are not included in the scope of the LCA study.

System Function and Unit Function

The product system function in LCA study is customized with food loss and food waste definition in **Figure 2.** While the unit function in this study as follows:

- 1 ton of food loss generation produced from production, post-harvesting and storage, and processing and packaging activities.
- 1 ton of food waste generation produced from distribution and market, and consumption activities.

Allocation Procedures

Allocation term in LCA is defined as partitioning the input or output flows of a process or product system between the product system under study and one or more other product systems. Here are the allocation procedures based on ISO:

1. To the extent possible, the allocation should be avoided, by dividing the processing unit into two or more sub-processes and collecting input and output data relating to the sub-processes.
2. If an allocation is unavoidable, then the inputs and outputs of the system should be shared between products or their different functions in a way that reflects the underlying physical relationship between inputs and outputs.
3. If physical relationships alone cannot be established or cannot be used as a basis for making allocations, then inputs must be allocated by-product or function in a way that reflects other relationships. For instance, the economic value of a product.

In this study, the allocation is according to procedure number 2, where input and output are divided based on mass, to calculate the potential impact of food loss and food waste in the food supply chain.

Category and Life Cycle Assessment

The selection of impact categories is determined to represent national priority issues related to sustainability, such as global warming potential. The potential impact of global warming is a priority following the National Action Plan to Reduce Greenhouse Gases by 26% by 2020 (Presidential Regulation Number 61 of 2011).

Global Warming Potential

Global Warming Potential (GWP) is one of the greenhouse gasses (GHG) emission indicators such as CO_2 and methane (CH_4). GHG emission can increase sun radiation and be reflected by the earth, thus magnify the GHG effects. Ultimately, this could affect the three (3) main areas of protection on earth, namely human health, ecosystem, and resources. These impact categories are expressed in kg CO_2 equivalent (eq) unit.

This study also applying one of the IPCC (Intergovernmental Panel on Climate Change) method. IPCC is an agency of the United Nations (UN) that aims to deal with science related to climate change. This method is the GWP calculation method that is most widely used in LCA studies worldwide, considering that countries have agreed to use it in estimating GHG inventories to report to the UNFCCC and the Kyoto Protocol.

The potential impact assessment was carried out using SimaPro Developer software version 9.1.0.8. The collected inventory data is then entered into SimaPro to be classified and characterized according to the selected impact assessment method. The results of the impact assessment are presented based on the assigned functional units.

Life Cycle Inventory

The life cycle assessment consists of setting the objectives and scope of the study, life cycle inventory, life cycle impact assessment and interpretation. In general, after the determination of objective and scope of the study, life cycle inventory will be conducted and the development of model framework for the process of each selected commodity will be conducted. In composing this model, each component or item of input and output, machines, raw materials, supporting materials and related are also considered so that reflects the processes carried out in Indonesia. The system used also includes end-of-life waste treatment and utilisation which is shown in various scenarios. With these various scenarios, the results of the study can provide an overview of impacts from various treatment methods that are generally applied and the potential development or improvement for appropriate waste treatment methods in the supply chain.

With the model framework as a reference, the data from various sources are sorted, collected, and integrated into the model. Sources of data sought generally consist of, review of journal papers or literature, national statistical data, extrapolated calculation results, publications, and others. From the data that is integrated into the model, it can be found that the proportion of input and output reflects the condition of Indonesia's supply chain. The model and data are then processed internally and inputted into the SimaPro Developer software version 9.1.0.8 as inventory data to estimate GHG inventories and generate global warming potential values. Inventory data of the collected input-output to fulfil the GHG assessment from FLW generation can be accessed at *http://bit.do/FLWproject-LCI.*

Interpretation and Critical Review

The interpretation of the results will be carried out descriptively to meets the objectives and scope of the study. Especially for the assessment of potential impacts will be carried out based on Pareto rules, to describe the processes that contribute the most to the resulting potential impacts.

Critical reviews are only conducted internally to validate the results of potential impact assessment and the consistency of the assumptions, limitations, system scopes, and methods used throughout the study.

Appendix 4 Economic Impact Calculation

The occurrence of FLW in the food supply chain in Indonesia can cause economic value losses received by food supply chain actors. The potential economic value loss calculation due to FLW was carried out from 2000-2019 in Indonesia.
In this study, economic loss potential in food loss is calculated using this formula:

$$EL_p = FL \,.\, P_p$$

EL_p = Economic loss (Rupiah)
FL = Food loss volume (ton)
P_p = Product price (Rp/ton)

In calculating the potential for economic loss due to food loss, the volume of food loss (FL) data comes from the food loss generation data in the Food Balance Sheet (FBS) calculation in 2000 - 2019. Meanwhile, the product price (Pp) is obtained from product constant price adjustment at the producer level in a certain year using the Producer Price Index (IHP). Due to the limitation of product price data, this study only calculates the potential economic loss caused by food waste for 88 out of 146 commodities.
In this study, economic loss potential in food waste is calculated using this formula:

$$EL_k = FW \,.\, P_k$$

EL_k = Economic loss (Rupiah)
FW = Food waste volume (ton)
P_k = Product price (Rp/ton)

For calculation of economic loss potential in food waste, food waste (FW) generation volume comes from the food waste generation data in Food Balance Sheet (FBS) calculation and waste sampling results in 2000 - 2019. Meanwhile, the product price (Pk) is a product constant price adjustment at the consumer level in a certain year using the Consumption Price Index (IHK). Due to the limitation of product price data, this study only calculates the potential economic loss caused by food waste for 64 out of 146 commodities.

Examples of calculating the loss of economic value are as follows.

Economic Loss Calculation in Rice Commodity at Food Loss Stage in 2018

Current Price Rice producer in 2018 $= \frac{\text{IHP food products in 2018}}{\text{IHP food products in 2019}} \text{ x Price of rice from producer in 2019}$

$$= \frac{95.74}{100} \text{ x Rp 9,405.76/Kg}$$

$$= \text{Rp 9,004.81/Kg}$$

Constant Price Rice producer in 2018 $= \frac{\text{IHP Food products in 2019}}{\text{IHP Food products in 2018}} \text{ x Current Price Producer in 2018}$

$$= \frac{100}{95.74}\, x \text{ Rp 9,004.81/Kg}$$

$$= \text{Rp 9,405.76/Kg}$$

Economic loss in Food Loss (EL_p) = FL x P_p

Economic loss in rice commodity in 2018 at Food Loss stage with Constant Price 2019=

Constant Price Producer x Food Loss generation

$$= \left(\left(\text{Rp}\,\frac{9{,}405.76}{\text{Kg}}\right) \text{x } 1000 \text{ Kg}\right) \text{ x } (1{,}194{,}880 \text{ Ton})$$

$$= \text{Rp } 11{,}238{,}754{,}508{,}800$$

Economic Loss Calculation in Rice Commodity at Food Waste Stage in 2018

Current Price Rice Consumer in 2018 $= \frac{\text{IHK whole cereals in 2018}}{\text{IHK whole cereals in 2019}} \text{ x Price of rice at consumer 2019}$

$$= \frac{99.67}{100} \text{ x Rp } 11{,}355.00/\text{Kg}$$

$$= \text{Rp } 11{,}317.78/\text{Kg}$$

Constant Price Rice Consumer in 2018 $= \frac{\text{IHK whole cereals in 2019}}{\text{IHK whole cereals in 2018}} \text{ x Current Price Consumer in 2018}$

$$= \frac{100}{99.67}\, x \text{ Rp } 11{,}317.78/\text{Kg}$$

$$= \text{Rp } 11{,}355.00/\text{Kg}$$

Economic Loss in Food Waste (EL_K) = FW x P_k

Economic loss in rice commodity in 2018 at Food Waste stage with Constant Price 2019 =

Constant Price Consumer in 2018 x Food Waste Generation in 2018

$$= \left(\left(\text{Rp}\,\frac{11{,}355}{\text{Kg}}\right) \text{x } 1000 \text{ Kg}\right) \text{ x } (7{,}440.75 \text{ Ton})$$

$$= \text{Rp } 84{,}489{,}716{,}250{,}000$$

Total of Economic Loss in Rice Commodity in 2018

Total of Economic Loss (EL) = $EL_p + EL_k$

$$= \text{Rp } 11{,}238{,}754{,}508{,}800 + \text{Rp } 84{,}489{,}716{,}250{,}000$$

= Rp 95,728,470,758,800

Appendix 5 Nutrition Loss Calculation

The nutrition loss calculation objective is to measure how many nutritions from food are lost due to FLW and to estimate the number of populations that can be fed a meal-worthy portion from that FLW lost. In calculating the nutrition loss, aspects that need to be considered in this study are related to the determination of the Recommended Dietary Allowances (RDA) and the average nutritional needs of an Indonesian individual.

The RDA for calories, protein, carbohydrates, fats, vitamins, and minerals is determined through the National Widyakarya of Food and Nutrition (WNPG) which is reviewed every five years by a specially assigned team of experts. The results of WNPG are then determined through Regulation of Minister of Health Number 28 of 2019 on the Recommended Dietary Allowances for Indonesian Population attached with RDA per age group and gender as well as physiological status (pregnant, breastfeeding) (Regulation of Minister of Health Appendix 1) and Instructions for Use (Regulation of Minister of Heath Appendix 2).

In addition to the RDA per Individual, Appendix 2 of Regulation of Minister of Health Number 28 of 2019 also states the recommended energy and protein allowances for the average Indonesian population, which are 2,100 kcal and 57 grams of protein. Methodologically, calculations with respect to this matter are presented in Appendix 2, sub-chapter III.A. on the calculation of the average RDA for the average population of a region or country using the following methods:

1. Calculating the percentage (%) of the population according to gender and age corresponds to the age group in the RDA table.
2. Multiplying the RDA for each age group and gender, by the percentage of the population (%) in a region according to the age group and gender.
3. The results of the multiplication are then added downward for each nutrition, then divided by 100.
4. Then, the average RDA for the population in a region/country is obtained.

In this study, there are four nutrition facts calculated in relation to the FLW generation, including energy, protein, vitamin A, and iron. The main rationale why this study only presents four RDAs - Energy Adequacy Ratio (EAR), Protein Adequacy Ratio (PAR), Iron Adequacy Ratio (ADFe), and Vitamin A Adequacy Ratio (VAAR) is because Indonesia currently still has problems with fulfilling the four nutritional needs, besides there are other nutritional problems but not as big as the four nutritional problems.

It should be noted that with a five-year nutritional requirement review through the WNPG, the recommended dietary allowance figures may change within every five years. Since the time period in this study is a long course (2000 - 2019), the RDA ideally used is the WNPG RDA which applies in each period. However, due to the generally small differences and consistency and to help the illustration, the average EAR, PAR, ADFe, and VAAR implemented the latest RDA, which is 2,100 kcal/cap/day; 57 grams of protein/cap/day; 575 Ug RE/cap/day, and 10.1 mg Fe/cap/day. The RDA for vitamin A and iron is the result of calculations that refer to the calculation guidelines above because the weighted average for these two nutritions is not available in the example in Appendix 2 Regulation of Minister of Health.

The nutrition loss, which encompasses energy, protein, vitamin A and iron, is calculated using the following formula.

Energy Loss (2,100 kcal)

Energy Loss (kcal/year)

$$= \frac{\text{Total Weight of FLW (gram/year)x}\left(\frac{\%(\text{EP})}{100}\right)\text{xEnergy Content/100 gram (Kcal)}}{\text{100 gram}}$$

Energy Loss per Indonesia Population (kcal/capita/year)

$$= \frac{\text{Energy Loss (kcal/year)}}{\text{Total Indonesia Population (capita/year)}}$$

Energi Loss per Population per Day (kcal/capita/day)

$$= \frac{\text{Energy Loss per Indonesia Population (kcal/capita/year)}}{\text{365 days}}$$

Information: EP = Edible Portion

Protein Loss (57 gram)

Protein Loss (gram/year)

$$= \frac{\text{Total Weight of FLW (gram/year)x}\left(\frac{\%(\text{EP})}{100}\right)\text{xProtein Content/100 gram (gram)}}{\text{100 gram}}$$

Protein Loss per Indonesia Population (gram/capita/year)

$$= \frac{\text{Protein Loss (gram/year)}}{\text{Total of Indonesia Population (capita/year)}}$$

Protein Loss per Population per Day (gram/capita/day)

$$= \frac{\text{Protein Loss per Indonesia Population (gram/capita/year)}}{\text{365 days}}$$

Information: EP = Edible Portion

Vitamin A Loss (575 Ug RE)

Vitamin A Loss (Ug RE/year)

$$= \frac{\text{Total weight of FLW }\left(\frac{\text{gram}}{\text{year}}\right)\text{ x}\left(\frac{\%(\text{EP})}{100}\right)\text{xVitamin A Content /100gram(Ug RE)}}{\text{100 gram}}$$

Vitamin A Loss per Indonesia Population (Ug RE/Capita/year)

$$= \frac{\text{Vitamin A Loss (Ug RE/year)}}{\text{Total of Indonesia Population (capita/year)}}$$

Vitamin A Loss per Population per Day (Ug RE/capita/day)

$$= \frac{\text{Vitamin Loss per Indonesia Population (Ug RE/capita/year)}}{\text{365 days}}$$

Information: EP = Edible Portion

Iron Loss (10.1 mg)

Iron Loss (mg/year)

$$= \frac{\text{Total Weight of FLW } \left(\frac{\text{gram}}{\text{year}}\right) \text{ x } \left(\frac{\%(\text{EP})}{100}\right) \text{ x Iron Content/100gram(mg)}}{100 \text{ gram}}$$

Iron Loss per Indonesia population (mg/capita/year)

$$= \frac{\text{Iron Loss (mg/year)}}{\text{Total of Indonesia Population (capita/year)}}$$

Iron Loss per Population per Day (mg/capita/day)

$$= \frac{\text{Iron Loss per Indonesia Population (mg/capita/year)}}{365 \text{ days}}$$

Information: EP = Edible Portion

Example of nutrition loss calculation is as follows.

Energy Loss (2100 kcal) on 2019

Energy Loss per Food Commodity (kcal/year)

$$= \frac{\text{Total FLW Generation } \left(\frac{\text{gram}}{\text{year}}\right) \text{x} \left(\frac{\%(\text{BDD})}{100}\right) \text{ x Energy content/100 gram (Kcal)}}{100 \text{ gram}}$$

Energy Loss all Food Commodity (kcal/year) = 96,178,924,399,600 kcal/year

Energy Loss per Population (kcal/capita/year)

$$= \frac{\text{Energy Loss (kcal/year)}}{\text{Population (capita/year)}}$$

$$= \frac{96{,}178{,}924{,}399{,}600 \text{ kcal/year}}{266{,}479{,}301 \text{ capita}}$$

= 360,924.56 kcal/capita/year

Energy Loss per Population per day (kcal/capita/day)

$$= \frac{\text{Energy Loss per Population (kcal/capita/year)}}{365 \text{ day}}$$

$$= \frac{360{,}924.56 \text{ kcal/capita/year}}{365 \text{ day}}$$

= 988.83 kkal

Appendix 6 Assessment Method of Potential Social Impact

General Method

The collected data is primary data from stakeholder interviews based on the FLW study scope. Used method to assess the socioeconomic aspects in this study consists of two main elements:

1. Stakeholders
2. Social topics

In this study, social impacts are assessed by various stakeholders who can be affected throughout the product life cycle or service. Stakeholders such as Workers and Small-scale entrepreneurs are closely connected with the products, because of their close related work scope to the chain, both in production activities and in roles related to maintaining available products. The Local Community consists of people who are indirectly affected by the product because they live close to one of the life cycle stage locations. Users are categorized into (1) professional product users (business-to-business), (2) indirect users, and (3) people who are included in business-to-consumer retail interactions.

Table (f). Grouping Stakeholder Categories (Source: Pre-Sustainability, 2018).

	Life Cycle Stages				
Stakeholders addressed	Supply chain raw material extraction, manufacturing, retail		Use	End of life	
	Small-scale entrepreneurs	Workers	Users	Small-scale entrepreneurs	Workers
	Local communities				

Every stakeholder group is related to various social topics gained from Product Social Impact Assessment (PSIA)[35] combined with Social Hotspot Database (SHDB)[36]. This combination gives a more comprehensive reflection of conditions in Indonesia, such as health and safety, child labour, local employment, and responsible communication. **Table (g)** shows social topics that included in four stakeholder categories based on PSIA, while **Table (h)** shows social topics that included in five stakeholder categories based on SHDB.

[35] Goedkoop, et al. (2020). Methodology Report Product Social Impact Assessment 2020.
[36] Benoit Norris, et al. (2013). The Social Hotspots Database V2.

Table (g). Social Topics for Each Stakeholder Category Based on PSIA.[37]

Social topics for workers	Social topics for local communities
1.1 Occupational health and safety 1.2 Remuneration 1.3 Child labour 1.4 Forced labour 1.5 Discrimination 1.6 Freedom of association and collective bargaining 1.7 Work-life balance	3.1 Health and safety 3.2 Access to material and immaterial resources 3.3 Community engagement 3.4 Skill development 3.5 Contribution to economic development
Social topics for users	**Social topics for small-scale entrepreneurs**
2.1 Health and safety 2.2 Responsible communication 2.3 Privacy 2.4 Affordability 2.5 Accessibility 2.6 Effectiveness and comfort	4.1 Meeting basic needs 4.2 Access to services and inputs 4.3 Women's empowerment 4.4 Child labour 4.5 Health and safety 4.6 Land rights 4.7 Fair trading relationships

Table (h). Social Topics for Each Stakeholder Category Based on SHDB.[38]

Source	Stakeholder Categories	Sub-categories
SHDB	Worker	Wage assessments
		Poverty
		Child labour
		Excessive working time
		Freedom of association, collective bargaining, right to strike
		Migrant labour
		Social benefits
		Labour laws/conventions
		Discrimination and equal opportunity
	Consumer	Occupational toxic and hazards
	Local community	Indigenous rights
		Gender equity
		High conflict zones
		Human health issues – Non-communicable Diseases and other risks
		Human health issues – Communicable Diseases
	Society	Legal system
		Corruption
	Local community	Access to improved drinking water
		Access to improved sanitation
		Children out of school
		Access to hospital beds
		Smallholder v. Commercial Farms (only Agriculture sectors)

[37] Goedkoop, et al. (2020). Methodology Report Product Social Impact Assessment 2020.
[38] Benoit Norris, et al. (2013). The Social Hotspots Database V2.

From the social topics based on PSIA and SHDB, relevant social topics will be selected (selection 1) based on social risk analysis from literature, media information, and SHDB results for Indonesia. Inventory data in form of social issues elaboration from each selected topic is then collected through interviews and a questionnaire survey with the stakeholders involved, to validate relevant social topics. From those interview/questionnaire survey results, the most important social topics/material topics were selected (Selection 2). According to Selection 2, performance indicators will be made for each social topic as a reference for measuring social performance, also for determining the existing conditions of stakeholders throughout the supply chain. However, currently, there are no social performance indicators in Indonesia, so this study will develop contextual indicators based on data collection results. The outcomes of this study are existing conditions mapping and performance indicators for each social topic.

Performance measurement for each social topic will be carried out in the next study after the performance indicators are agreed upon. The final stage, which is a performance measurement or assessment of potential social impacts, will show the social hotspots of the entire supply chain studied. To interpret the results of the potential impact assessment, a five-point reference scale is used to assess social performance. Steps to determine the reference scale are important for interpreting the results and supporting correct decision-making. The assessment approach is carried out on each topic to measure social conditions in quantity. Starting from (-2) to (+2), each score is assigned to reflect certain social conditions according to the topic being assessed. A negative score indicates a condition that is not following local policies and national standards. While a positive value indicates a condition that is very good beyond local policies and international standards. Meanwhile, the value zero (0) indicates a condition that conforms to standards or is acceptable. This potential social impact assessment method refers to the Product Social Impact Assessment (PSIA).

Figure (e) shows the steps of the impact assessment method for the social aspect, from the limits of this study until the determination of performance indicators before the impact assessment is carried out.

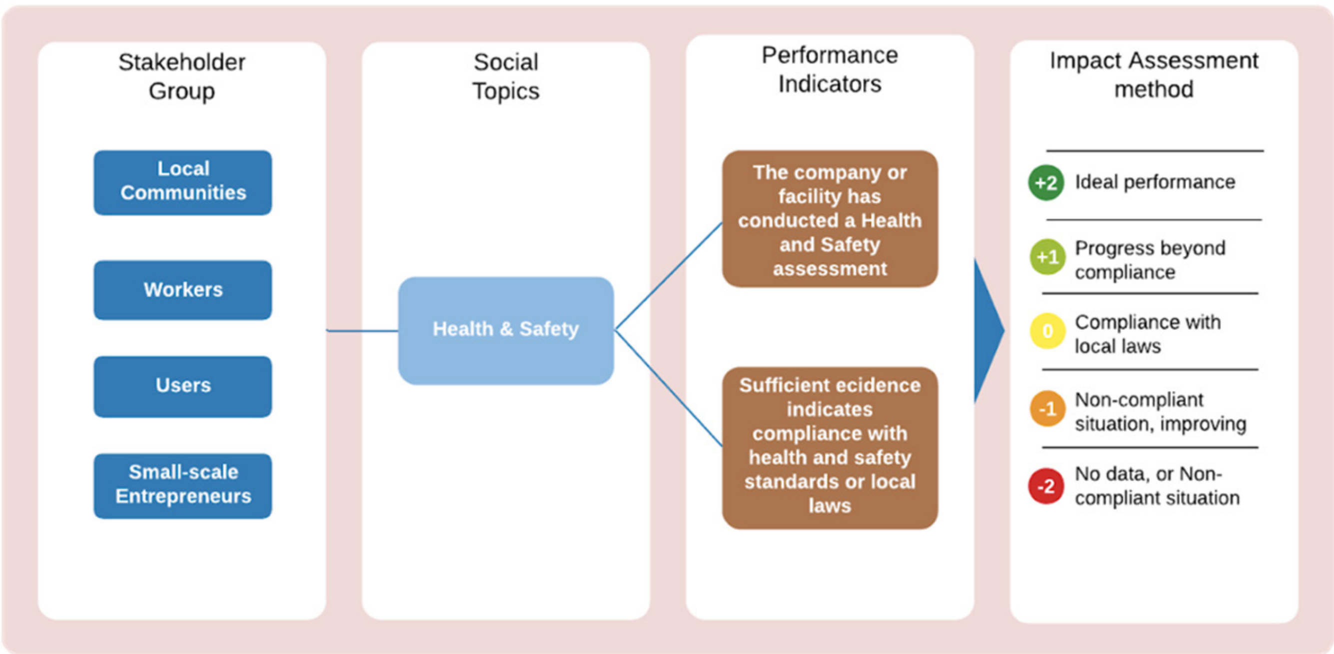


Figure (e). Impact Assessment Method Steps for Social Aspects.[39]

The main stakeholders in this study are the people who are particularly involved in FLW consisting of key actors and the list of experts.

[39] Goedkoop, et al. (2020). Methodology Report Product Social Impact Assessment 2020.

Specific Study Method

In the FLW Study in Indonesia, it is important to capture social issues that are formed in the supply chains of the commodities being studied, the following are the steps that have been conducted:

1. Identifying social risks that occur along the commodity supply chain of FLW study in Indonesia through literature studies related to social issues in agriculture from various Indonesia's media, as well as using social risk provided by the Social Hotspot Database or SHDB[40].
2. Mapping identified social risks with relevant social topics based on the Handbook of Product Social Impact Assessment or PSIA[41].
3. Formulate the inventory data needed to measure social performance or social impact in the form of interview questions and questionnaire surveys for FLW stakeholders.
4. Collecting data through interviews and questionnaire surveys of predetermined stakeholders, entrepreneurs and experts.
5. Mapping the inventory data obtained through interviews with predetermined social topics as the result of study's screening.
6. Identifying quantitative data based on screening result that needed for further studies.

From the results of steps 1 and 2, there are 23 social topics obtained as become social risks for four stakeholders, namely workers, small entrepreneurs, local communities, and consumers which can be seen in **Table (i).**

Table (i). Stakeholder and Social Topics Studied.

Stakeholder	Social Topic
Workers	1. Remuneration 2. Poverty/Fulfillment of Basic Needs 3. Child Labour 4. Excess Working Time/Work-Life Balance 5. Equal Opportunity/Discrimination 6. Worker Safety and Security 7. Freedom of Association and Group Negotiation 8. Migrant Workers 9. Social Allowance 10. Labour Conventions/Laws
Small scale entrepreneurs	1. Access to Services and Inputs 2. Fair Trade 3. Land Rights 4. Women Empowerment 5. Corruption
Local Community	1. High Conflict Zone 2. Human Health Issues - Infectious Diseases 3. Employment and Skills Development for Local Communities - Local Workers 4. Relationship between Communities (Groups) 5. Contribution to Economic Development
Consumer	1. Consumer Health and Safety 2. Consumer Affordability 3. Accessibility

[40] Benoit Norris, et al. (2013). The Social Hotspots Database V2.
[41] Goedkoop, et al. (2020). Methodology Report Product Social Impact Assessment 2020.

Furthermore, the 23 social topics were formulated into interview questions to obtain the inventory data needed (Step 3). It should be noted that not all questions are asked in detail one by one due to time constraints, but in general, they reflect the main priority social topics. Stakeholders interviewed (Step 4) are the parties involved in the food commodity supply chain, there are:

1. Experts
2. Farmers including the Head of Farmers Association
3. Intermediaries/Distributor
4. Traditional market management, sellers, and waste collection officer
5. Retail
6. Hotel, Restaurant
7. Waste management officer and Environmental Agency
8. Household

Data for stakeholders 1-7 are obtained based on temporary interviews, while the household is through a questionnaire survey. In addition to the 23 social topics, other topics that are not directly related to social impacts but also obtained from interviews such as policies, innovations and initiatives will also be mapped in this study.

The collected data from each stakeholder are summarized and mapped based on 23 social topics (Step 5). It should be emphasized that currently there are no social performance indicators in Indonesia, and the results of the mapping will be used to determine the actual social impact indicators for FLW. From the mapping of social conditions in the supply chain, it is found the potential impact of each social topic which in turn can affect the generation of FLW. In general, the relationship between social topics and the food loss supply chain is different compared to food waste, although the processes that occur in the supply chain are difficult to separate. Thus in this study, the relation between social topics and food loss includes processes from production, post-harvest and storage, processing and packaging. On the other hand, the relation to food waste focuses more on the distribution, retail (market, retail and hotel/restaurant), consumption (household), and waste processing (Environment Agency) processes.

The information collected for each of the social topics is used to reflect current social conditions which in turn can affect both positively and negatively the emergence of FLW. For example, good conditions for counselling and assistance can help increase productivity and quality of the products produced, thus potentially reducing the occurrence of FLW and vice versa. Another example is the processing or utilization of food waste that provides added value which can be a credit or a positive impact on the food system and reduce the amount of FLW generation. From the selected topic material indicators will be developed based on PSIA (Goedkop et al, 2020) and specifically for FLW condition. In detail, the potential impacts on each social topic that arise in the supply chain can be seen in **Table (j).**

Table (j). Potential Impact from Each Social Topic.

No	Social Topic	Potential Impact	
		Food Loss	Food Waste
1	Remuneration	In particular discuss the economic conditions of workers, related to wages and allowance received. Low wages of farmers/plantation workers /ranchers/ Fishers have the potential to cause ignorance of the work quality and produced products quality. This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** In particular discuss the economic conditions of workers, related to wages and allowance received. Low wages of workers have the potential to cause ignorance of the work quality and produced products quality. In the distribution and market activities as well as food handling at the HORECA level, the quality of work can affect the occurrence of food waste. Meanwhile, for waste processing workers, the impact on the work quality can lead to mismanagement which leads to can result in the disposal of food waste that can still be used.
			Consumers (Household): The higher-income household has the potential to increase the frequency and quantity of food product expenditure more than they needed. This potential impact can lead to food waste.

2	Poverty/Basic Needs Fulfilment	Influenced by basic human needs such as food, clean water, sanitation and others, an unfulfillment of basic needs has the potential to cause ignorance to work quality and produced products quality. This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Influenced by basic human needs such as food, clean water, sanitation and others, an unfulfillment of basic needs has the potential to cause ignorance to work quality and produced products quality. In the distribution and market activities as well as food handling at the HORECA level, the work quality can affect the occurrence of food waste. Meanwhile, for waste processing workers, the impact on the work quality can lead to mismanagement which leads to can result in the disposal of food waste that can still be used. **Consumers (Household):** Consumers with unfulfilled basic needs has the potential to distribute excess food so that it can reduce the occurrence of food waste.
3	Child Labour	Child labour impacts the deteriorating quality of their childhood hinders access to education and dangerous for their physical and mental development. This could affect their future well-being, especially if there is a potential for malnutrition and stunting. This potential impact has big consequences, but child labour with limited skills can also have a direct effect on food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Child labour impacts the deteriorating quality of their childhood hinders access to education and dangerous for their physical and mental development. This could affect their future well-being, especially if there is a potential for malnutrition and stunting. This potential impact has big consequences, but child labour with limited skills can also have a direct effect on food loss.
4	Excessive Working Time/Work-Life Balance	Affected by health and ability to work, workers have the potential not to produce optimal or standard quality products due to fatigue or not focus on doing the work. This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Affected by health and ability to work, workers have the potential not to produce optimal or standard quality products due to fatigue or not focus on doing the work. In the distribution and market activities as well as food handling at the HORECA level, the work quality can affect the occurrence of food waste. Meanwhile, for waste processing workers, the impact on the work quality can lead to mismanagement which leads to can result in the disposal of food waste that can still be used.
5	Equal Opportunity/Discrimination	Workers cannot work optimally to produce qualified products because they work in an uncomfortable and unfair environment. This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Affected by health, workers are unable to work optimally to produce qualified products because they work in an uncomfortable and unfair environment. In the distribution and market activities as well as food handling at the HORECA or household level, the affected work quality can lead to the occurrence of food waste. Meanwhile, for waste processing workers, the affected work quality can lead to mismanagement which causes the disposal of food waste that can still be used.

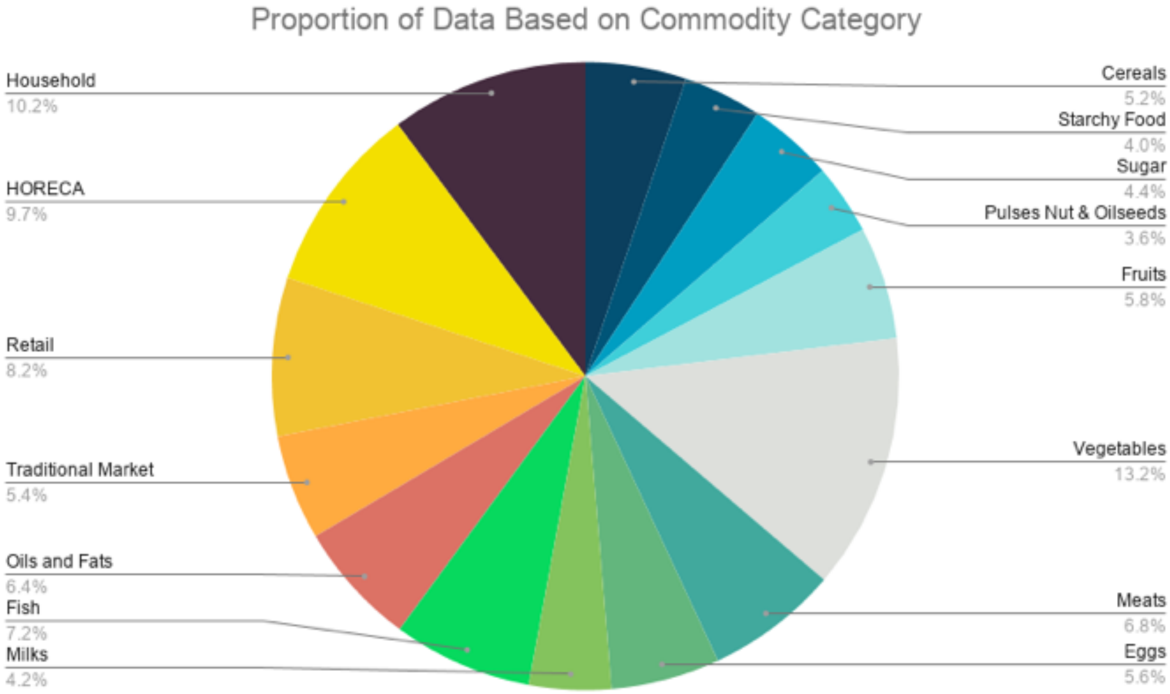
6	Occupational health and safety	The health and safety of workers in the work environment are very important because work accidents can interfere with worker productivity and the quality of products produced. This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** The health and safety of workers in the work environment are very important because work accidents can interfere with worker productivity and the quality of products produced. In the distribution and market activities as well as food handling at the HORECA or household level, the affected work quality can lead to the occurrence of food waste. Meanwhile, for waste processing workers, the affected work quality can lead to mismanagement which causes the disposal of food waste that can still be used.
7	Freedom of Association and Collective Bargaining	Workers who have freedom of association can share knowledge through these associations on how to improve product quality and can collectively support improvements (policies/innovations) in the agricultural sector or other operational activities. This potential impact can reduce food loss occurrence.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** As the result of freedom to associates, workers can share knowledge through these associations on how to improve product quality and can collectively support improvements (policies/ innovations) in the agricultural sector or other operational activities. This potential impact can prevent food loss occurrence.
8	Access to Services and Inputs	Workers' access to raw materials, supporting materials, knowledge, and facilities such as finance or equipment needed to develop. Fulfilling access to services and inputs can help sustain the productivity of farmers/plantation workers/ breeders/Fishers as well as the quality of produced products. This potential impact can reduce the occurrence of food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Influenced by workers' access to raw materials, supporting materials, knowledge, and facilities such as finance or equipment needed to develop. Fulfilling access to services and inputs can help the continuity of productivity and products quality or achieve optimal waste processing/utilization activities. This potential impact can reduce the occurrence of food waste. **Consumers (Household):** Ease of consumer access to food supply and ease of excess food distribution to people in need has the potential to reduce food waste.
9	Fair Trading Relationships	Fairtrade at a compatible selling price with the added value provided can encourage farmers to improve product quality. This potential impact can reduce the occurrence of food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Fairtrade at a compatible selling price with the added value provided can encourage business units to improve product quality. In the distribution and market activities as well as food handling at the HORECA or household level, the affected work quality can lead to the occurrence of food waste. Meanwhile, for waste processing workers, the affected work quality can lead to mismanagement which causes the disposal of food waste that can still be used.
10	Land Rights	Land ownership and territory ensures the continuity of production. Land conflicts can interfere with the production activities which leads to decreased productivity or inhibition of production activities. This also affects the quality of the products produced (for example, if a production activity cannot operate, the produced product cannot be sold or raw materials that have been purchased cannot be used). This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Land ownership and territory ensures the continuity of production. Land conflicts can interfere with the production activities which leads to decreased productivity or inhibition of production activities. This also affects the quality of the products produced (for example, if a production activity cannot operate, the produced product cannot be sold or raw materials that have been purchased cannot be used). This potential impact can lead to food waste.

11	Women's Empowerment	Affected by sex restriction probabilities, the women empowerment inappropriate types of work can affect product quality. This potential impact can reduce the occurrence of food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Affected by sex restriction probabilities, the women empowerment inappropriate types of work can affect product quality, the effectiveness and efficiency of distribution and market activities, as well as food preparation. This potential impact can reduce the occurrence of food waste.
12	Migrant Workers	The possibilities of conflict between migrant workers and local workers can affect the quality of work and the quality of the products produced. This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** The possibilities of conflict between migrant workers and local workers can affect the quality of work and the quality of the products produced. This potential impact can lead to food waste.
13	Social Allowance	Providing health allowance, leave rights, or other social benefits for workers can encourage workers to pay more attention to the work quality and the produced products quality. This potential impact can reduce food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Providing health allowance, leave rights, or other social benefits for workers can encourage workers to pay more attention to the work quality and the produced products quality. This potential impact can reduce food waste.
14	Labour Conventions/Laws	Clear regulations on employment can encourage workers to pay more attention to the work quality and the produced products quality. This potential impact can reduce food loss production.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Clear regulations on employment can encourage workers to pay more attention to the work quality and the produced products quality. This potential impact can reduce food waste production.
15	High Conflict Zone	Conflicts with local communities can disrupt production activities which affect work quality and produced products quality. This potential impact can lead to food loss production.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Conflicts with local communities can disrupt production activities which affect work quality and produced products quality. This potential impact can lead to food waste production.
16	Human Health Issues - Infectious Diseases	Infectious diseases can affect workers' conditions resulting in unfulfillment of applications to the GAP or expected quality standards. This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Affected by health: Infectious diseases can affect workers' conditions resulting in decreased work quality. This potential impact can lead to food waste.
17	Employment and Skills Development for Local Communities - Local Workers	The development of local communities can boost the local economy where local workers who work in agriculture/livestock/fisheries/plantations can pay more attention to the quality of products produced. This potential impact can reduce food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** The development of local communities can boost the local economy where local workers developed skills and can pay more attention to the quality of work and the products produced. This potential impact can reduce food loss.
18	Relationship between Communities (Groups)	Built by trust, communication and so on, good relationships and support with local communities can indirectly accelerate production activities. This potential impact can reduce food loss.	**Consumer (Households), Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Built by trust, communication and so on, good relationships and support with local communities can indirectly accelerate production activities. This potential impact can reduce food loss.

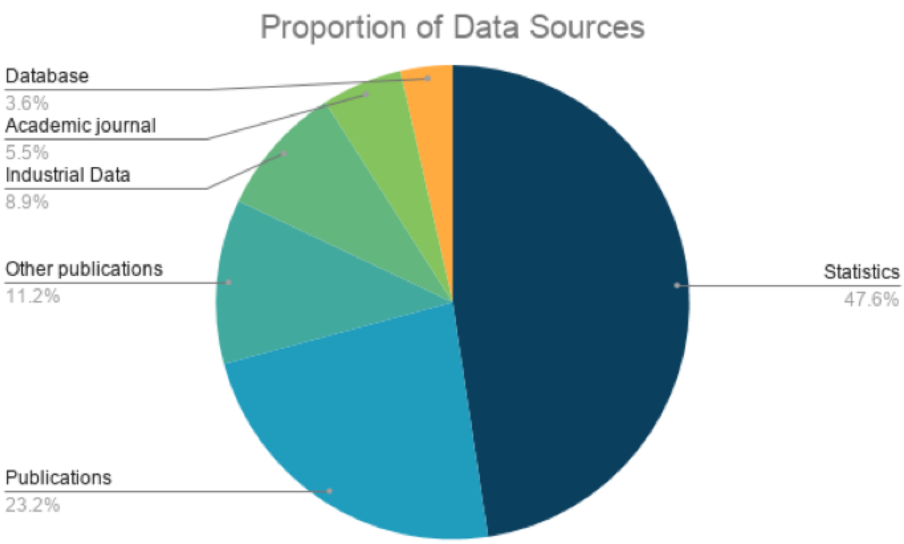
19	Contribution To Economic Development	Aims to increase the economic value of a region, the economic contribution given to an area can increase productivity and the quality of the products produced. This potential impact can contribute to food loss reduction.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Aims to increase the economic value of a region, the economic contribution given to an area can increase productivity and the quality of the products produced. In distribution and market, and food industry, given contribution can elevate the effectiveness and efficiency of waste treatment/utilization. This potential impact can contribute to food loss reduction.
20	Consumer Health and Safety	Rules/standards for health and product safety that are applied to operational activities and products that meet the quality standards desired by consumers. This potential impact can reduce food loss.	**Market Workers/Retail/Hotel/Restaurant:** Rules/standards for health and product safety that are applied to operational activities and products that meet the quality standards desired by consumers. This potential impact can reduce food waste.
			Consumers (Household): The certainty of product safety and health for consumers, whether in the form of certain information or certification, makes consumers give more value to the quality of the product. This potential impact can reduce food waste.
21	Consumer Affordability	Regard to financial factors, whether a product has an affordable value so that the good absorption of food products can reduce the number of unsold food products. This potential impact can reduce food loss.	**Consumers (Household), Market Workers/Retail/Hotel/Restaurant:** Regard to financial factors, whether a product has an affordable value so that the good absorption of food products can reduce the number of unsold food products. This potential impact can reduce food waste.
22	Accessibility	Ease of access or an optimal food supply chain system can reduce the potential of product quality standards degradation in distribution activities. The potential for this impact can reduce food loss.	**Consumers (Household), Market Workers/Retail/Hotel/Restaurant:** To ensure that products can be reached by all sections of society, the ease of access to the food supply chain system for consumers can reduce the potential of product quality standards degradation in distribution activities. This potential impact can reduce food waste.
23	Corruption	Facilities that should be used for the sake of production activities cannot be optimally distributed. This potential impact can lead to food loss.	**Market/Retail/Hotel/Restaurant/Waste Processing Workers:** Facilities that should be used for the sake of production activities cannot be optimally distributed. This potential impact can lead to food waste.
24	Others (Non-Social Topic) The FLW utilization and processing that provides added value to be a credit or positive impact on the food system	Policies or collaboration between the right parties, as well as innovations and initiatives, can encourage the improvement of work quality and the quality of products produced. This potential impact could reduce food loss.	**Consumers (Household), Market Workers/Retail/Hotel/Restaurant:** Policies or collaboration between the right parties, as well as innovations and initiatives, can encourage the improvement of work quality and the quality of products produced. This potential impact could reduce food waste.

Data Quality

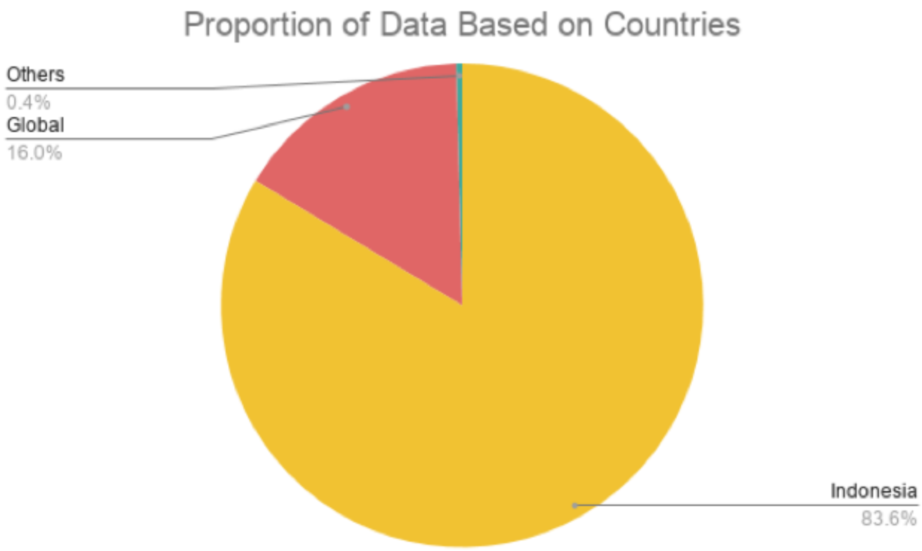
The data used for the GHG emissions calculation includes the production process, post-harvest handling and storage, processing and packaging, distribution, retail (traditional market, modern retail), and consumption (household, HORECA) with a total of **33,280 data.** The figure below shows that the largest data amount is vegetable commodity group data at 13.2% because it includes 3 types of commodities: shallots, cabbage, and chilies.



Data was collected from various sources as shown in the graph below. There are six data sources used, namely (1) statistical data (BPS, Pusdatin, and/or other statistical data provider organizations), (2) academic journals (information obtained from sites that provide scientific studies and have been verified), (3) industrial data (from trade sites or certain companies), (4) official publications (data or information originating from certain associations or organizations such as the government, FAO, UNEP, IPCC), (5) other publications (data or information derived from news, university research that does not include journals such as theses, and other sites), and (6) commercial databases such as Ecoinvent, Agribalyse, and other databases from the LCA SimaPro software.



It can be seen from data origin country in figure below, there are three categories, namely data sources from Indonesia (83.6%), Global data sources (16%) and other data sources (0.4%). Global data sources are information that comes from The Intergovernmental Panel on Climate Change (IPCC) or databases from SimaPro software, while other categories are data sources or information that come from other countries with characteristic conditions similar to the data required.



With 83.6% of the data collected comes from Indonesia through various verified official sources such as statistics, publications, and academic journals, it can be concluded that the collected data have sufficient quality to represent the condition of the food supply chain in Indonesia in calculating Greenhouse Gas emissions.

Appendix 7 System Dynamics Method

System dynamics are methods to learn and manage complex feedback structures, such as those found in business and other social systems. The feedback structure refers to the situation X which affects Y and Y, in turn, affects X possibly through a chain of cause and effect. System dynamics are built into the model using computer simulations to ensure that the hypothesized structure can lead to observed behavior and to examine the effect of alternative policies on the key variables over time. The feedback structure is formed based on the causality between a pair of variables.

In a System dynamics model, a Causal Loop Diagram (CLD) is a tool for obtaining a feedback structure. CLD consists of variables linked by arrows that indicate causal and variable effects. Each causality is assigned a polarity, either positive (+) or negative (-) to show how the dependent variable (effect) changes when the independent variable (cause) changes.

Model Development

In this study, the system dynamics approach is considered to evaluate the baseline of FLW generation in Indonesia in 2000 - 2019 and to project FLW generation for 2020 - 2045 either with policy intervention or not – called Business as Usual (BAU) Scenario and Strategy Scenario. To determine the perspective used in a dynamic system, the conducted stages are:

1. Identify and define the problem
2. Conceptualizing the system that will be used
3. Formulate the model
4. Analyse behavior models
5. Evaluating the model
6. Analyse regulations, and
7. Model implementation

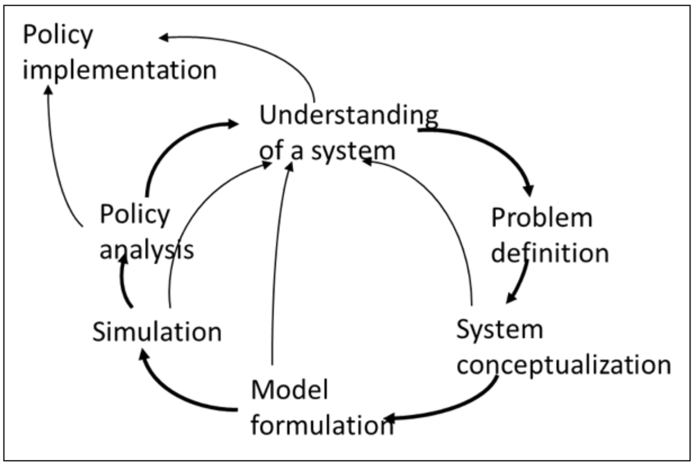


Figure (f). Problem approach with Dynamic Systems steps.[42]

The process begins and ends with an understanding of a system and its problems, thus forming a circle, not a linear progression. **Figure (f)** shows that these stages represent the repetitive nature of the process. The structure of FLW generation projection for 2020 - 2045 was developed with the variables with two possibilities, namely the policy intervention.

[42] Richardson, G. P. and A. L. Pugh, III. (1981). Introduction to System Dynamics Modeling with DYNAMO.

Policy Modeling and Projections of FLW

Policy modelling and projection of FLW using a dynamic systems model approach has been compiled on a causal relationship model as the cause of FLW behavior under the following modeling limitations:

1. Physical structure and decision-makers are formed as elements creating the FLW phenomenon resulting from observations (waste sampling survey), in-depth interviews, stakeholder meetings, FGD, literature studies and expert justification.
2. FLW behavior model employs historical FBS data from 2000 - 2019 with all food commodities aggregated as total food.
3. The 'scattered' historical data (Waste) in the Food Balance Sheet (FBS) is not used as the figure for FLW generation but is recalculated using the FLW fraction at each stage of the food supply chain sourced from FAO (2011) and BKP (2019) data.
4. FLW data from the model are used as historical data for the aggregation of total food from all food commodities and have a level of sensitivity to the dominant food commodities, which are cereals (crops).

The FLW generation projection is modeled and analyzed using the physical structure and decision structure of the FLW model with CLD which in general is presented in **Figure (g).**

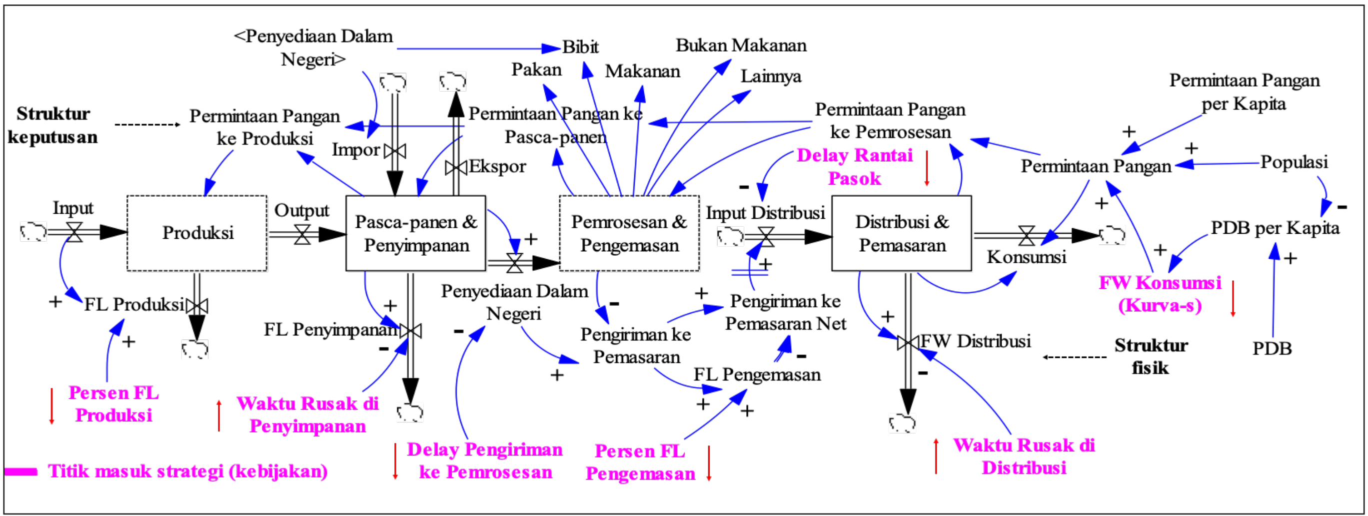


Figure (g). Physical and Decision Structure of FLW Model.

The basic principle in the analysis process (design) of FLW policy using a system dynamics methodology is that the behavior of the FLW phenomenon from which the existing conditions are emerged (caused) by the structure which is shown in **Figure (h).**

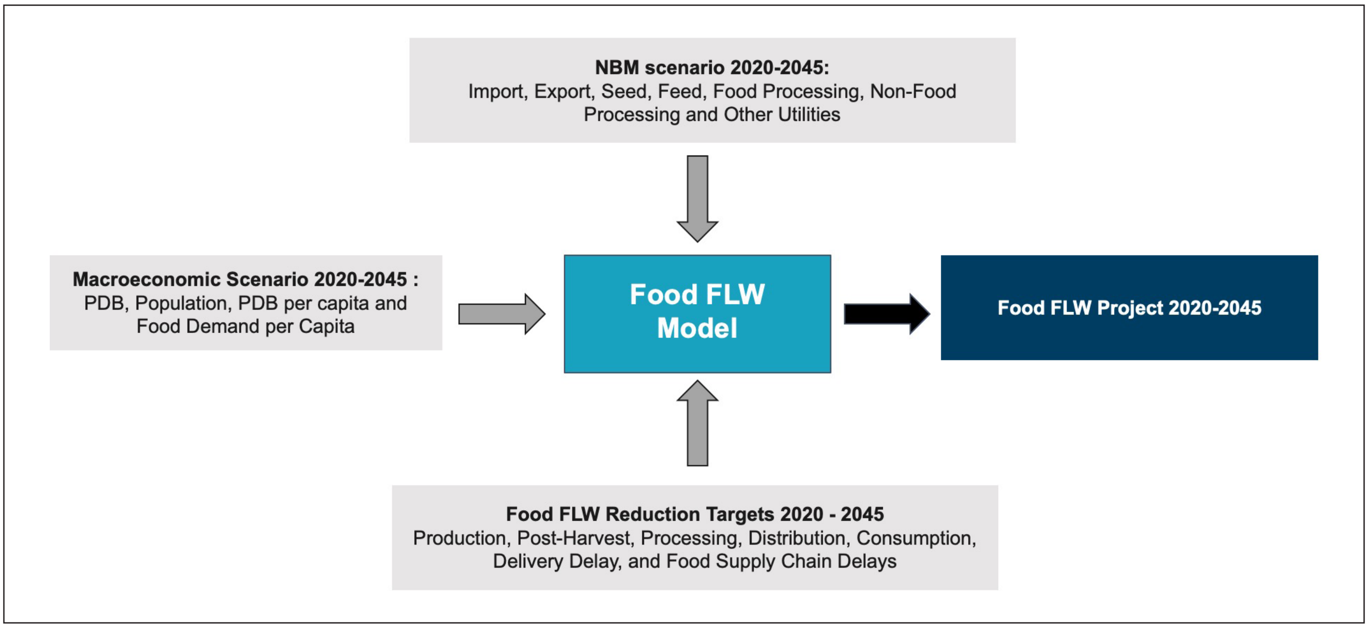


Figure (h). Diagram of FLW Model Simulation Experiment.

As presented in **Figure (h),** the physical structure and policy structure of the FLW in **Figure (g)** requires justification as an experimental method of the Food Model 2020 - 2045 simulation. Some of the elements that require justification include:

1. **Macroeconomy Scenario 2020 - 2045** comprising 1) GDP, 2) Population, 3) GDP per Capita and 4) Food Demand per Capita with the assumptions as shown in **Table (j).**

Table (j). Assumption of Macroeconomy Scenario in 2020 - 2045.

Parameter	Assumption	Source
GDP	GDP rate of-2.1% (2020), 0% (2021), 1% (2022), 2.5% (2023), 4% (2024) and 5.1% (2025-2045)	Bappenas (2019), Bappenas (2021), and Expert justification
Population	Population rate from 1.19% (2020) to 0.4% (2045)	Bappenas, BPS, and UNFPA (2013)
GDP per Capita	GDP per capita 2020 - 2045 increases by 108,548 (2045)	Expert justification
Food Demand per Capita	Food demand per capita 2020 - 2045 increases by 1.6 kg/capita/day (2045)	Expert justification

2. **FBS Scenario 2020 - 2045** consists of 1) Import, 2) Export, 3) Seed, 4) Feed, 5) Food, 6) Non-Food, and 7) Others Utilities, as shown in **Table (k).**

Table (k). Assumption of FBS Scenario 2020 - 2045.

Parameter	Assumption	Source
Import	Import rate remains 10.5%	Figure follows FBS history
Export	Export rate is decreased from 2.5% (2020) to 2.3% (2045)	Expert justification
Seed	Seed rate remains 0.35%	Figure follows FBS history
Feed	Feed rate of 2%	Figure follows FBS history
Food	Food rate of 2%	Figure follows FBS history
Non-Food	Non-food rate of 3%	Figure follows FBS history
Others Utilities	Other rate of 3%	Figure follows FBS history

3. **Targets of FLW Reduction 2020 - 2045** include 1) Production, 2) Post-Harvesting and Storage, 3) Processing and Packaging, 4) Distribution, 5) Consumption, 6) Delivery Delays and 7) Supply Food Chain Delay.

The simulation of the FLW model was carried out through the experiment of several scenarios by producing projection simulations of 2 scenarios, namely:

a. **Business as Usual (BAU)/Baseline projection,** is a pessimistic projection analysis of the business as usual (BAU) projection with the analysis of the assumption of macroeconomy scenario 2020 - 2045 (**Table (j)**), the assumption of FBS scenario 2020 - 2045 (**Table (k)**), and assumptions of baseline projection target 2020 - 2045 or the **target without policy/strategy intervention** (**Table (l)**). The projection results from BAU are used as a baseline for future projections.

Table (l). Assumption of FBS Baseline Projection 2020 - 2045.

Parameter	Assumption	Source
Production Stage	% FL production of 4.18% (2020 - 2045)	Figure follows FBS history
Post-Harvest & Storage Stage	The time food becomes damaged in storage is 8 months (2020 - 2045)	Figure follows FBS history
Processing & Packaging Stage	% FL Processing & Packaging of 1.17% (2020 - 2045)	Figure follows FBS history
Distribution & Market Stage	The time food becomes damaged in distribution and market is 18 months (2020 - 2045)	Figure follows FBS history
Consumption Stage	Reduction target of food waste generation per capita is 0% started in 2020 and completed in 2045	Figure follows FBS history
Delivery Delay	Delivery delay to processing is 5 days (2020 - 2045)	Figure follows FBS history
Supply Food Chain Delay	Supply food chain delay is 7 days (2020 - 2045)	Figure follows FBS history

b. **Strategy Projection,** an optimistic projection analysis with the assumption of macroeconomy scenario 2020 - 2045 analysis (**Table (j)**), assumption of FBS scenario 2020 - 2045 **(Table (k)**), and assumption of strategy projection target or **targets with policy/strategic intervention** (**Table (m)**) which has been analyzed based on results of expert justification, is as follows:

Table (m). Assumption of Strategy Scenario Projection 2020 - 2045.

Parameter	Assumption	Information
Production Stage	Decreasing % FL Production from 4.37% (2022) to 3% (2045)	Expert justification
Post-Harvest & Storage Stage	Increasing damage time in storage from 8 months (2022) to 10 months (2045)	Expert justification
Processing & Packaging Stage	Decreasing % FL Processing & Packaging from 1.17% (2022) to 0.8% (2045)	Expert justification
Distribution & Market Stage	Increasing damage time in distribution and market from 18 months (2022) to 24 months (2045)	Expert justification
Consumption Stage	Decreasing FW generation in consumption from 0% (2022) to 35% (2030)	Expert justification
Delivery Delay	Decreasing delivery delay to processing from 5 days (2022) to 4 days (2045)	Expert justification
Supply Food Chain Delay	Decreasing supply food chain delay from 7 days (2022) to 4 days (2045)	Expert justification

Appendix 8 Analysis of Causes and Drivers of FLW Generation

Information regarding the causes and drivers of FLW generation was obtained through in-depth interviews with food practitioners at all stages of the food supply chain. The analysis to determine the factors causing and driving the FLW generation was conducted using a weight system based on predetermined keywords through related literature studies. Keyword weight was completed by counting the number of keywords contained in the transcripts/field reports from in-depth interviews with food practitioners and experts.

After weighting these keywords, a Pareto analysis was carried out to determine the level of the biggest causes and drivers that produce FLW generation in Indonesia. Pareto analysis in this study was utilized to identify the contribution of the causes with a weight of 80%, so that it may show the critical factors that cause and drive the FLW generation. The Pareto calculation formula is as follows:

$$\text{Causes and Drivers of FLW Generation} = \frac{\text{Factor Weight}}{\text{Total Weight of all Factors}} \times 100\%$$

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