Environmental Assessment for Optimizing Agricultural Production and Food Nutrition Requirement from Traditional Food Intake System in Cambodia

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List of Abbreviations

BF	Breakfast
CO_2 eq	Carbon dioxide equivalent
GHG	Greenhouse gas
LCA	Life cycle assessment
LD	Lunch and dinner
LPG	Liquefied petroleum gas
Mha	Million hectares
Mt	Million ton
VESP	Vegetables and spices
yr	Year

ABSTRACT

A diet choice, a habit of consumption, and cooking style are correlated with environmental impact as climate change as carbon dioxide emission. Effect of the environment is occurred by production activities and energy of cooking through type and quantity of consumptive food. These activities of food production, food preparation, and food cooking are influent to air, water, and land pollution. The food is justified of people's well-being and affected to grow up condition. The people are insufficient to eat food, have eaten too much of high-fat food, high-sugar food, or high-salt food leading to malnutrition as obese, overweight, etc. Therefore, some people have not eaten enough nutrient-rich the same as a vegetable, fruit, bean, meat, and milk according to type and quantity needs. The food is required energy for cooking to improve taste, quality, and safe. Moreover, cooking energy is also affected to human welfare and environmental impact, the people are not utilized clean fuel to cook the food. Nutrient-rich balances have traditional Cambodian food that is sustainable environmental greenness compared to conventional diets. Lack of evidence and knowledge on nutrient intake, the energy of cooking, and the environmentally friendly of traditional food. The connection between food nutrition, the energy of cooking, and its impact on the environment can be evaluated using carbon dioxide (CO_2) emissions from agricultural production and cooking energy according to life cycle assessment (LCA). This study objective was to estimate the CO_2 equivalent (eq) emission based on the traditional Cambodian diet and cooking energy using LCA, beginning at each agricultural production stage and cooking stage through type and amount of food consumption.

In chapter 3, a one-year food consumption scenario with the traditional diet was established. The traditional Cambodian food was selected 12 food sets (FS1-12) which FS1-5 were breakfast sets and FS6-12 were lunch and dinner sets. The food set contented of food items as wheat, rice, rice and noodles, fish, pork, chicken, and beef, egg, vegetables (oil and vegetable spices), and fruits. The food sets were consumed at the same rate and compared using LCA. Therefore, the food serving size is defined on two consumers' age kinds (K1: below and 9 years old and K2: over and10 years old. The food set was 200-205 g for K1 and 330-335 g for K2. Both groups of the food sets were considered on the recommendation of nutrition included food for macronutrients and micronutrients. Therefore, food for macronutrients showed FS1 and FS2 was the low-calorie amounts of K1 and K2 and a high-

calories was FS3 of K1 and K2 as breakfast menu. Moreover, FS9 and FS7 were the high and low-calorie amounts of K1 and K2 as lunch and dinner menu. FS4, FS5, FS6, FS8, FS10, FS11, FS12 of K1 and K2 were calorie amounts as normal. Additionally, food for macronutrients was met nutrient recommendations (Table 3.2; Figure 3.3). Food for micronutrients showed FS5 and FS4 were low and high in Fe and Ca amounts; FS5 and FS1 were low and high in Zn amounts for mineral intake as breakfast menu. Therefore, soluble vitamins in water showed B1, B9, and B12 were low in FS5 amounts; B3, B6, and C were low in FS1, FS4, and FS3 amounts, respectively. Soluble vitamins in fat showed A and D were low in FS5 amounts. The food for micronutrients was met the requirement needs. FS6-12 as lunch and dinner menu of micronutrients showed Fe and Zn were high in FS11 amounts; Ca was high in FS10 for mineral amounts. Soluble vitamins in water showed B1, B6, B9, C was high in FS6 amounts; B2 and B12 were high in FS9 amounts; B3 was high in FS10 amounts. Soluble vitamins in fat showed A and D were high in FS11 and FS10 amounts, respectively. Both of consumers' age of Cambodia's traditional diets were met minimum nutrient for children and maximum nutrient for adults. Food for micronutrients in the proposed scenario was higher than in the existing scenario.

Both consumers went beyond the minimum and maximum food nutrition requirements. The total food consumption and carbon dioxide emission were compared between existing and proposed scenarios. According to the food set consumption was showed that total quantity of food consumption was required the highest 1.48 million tons (Mt) of vegetable, followed by rice 1.18 Mt, and lowest cooking oil 0.04 Mt. The total of food consumption was required 5.1 Mt equal to 50.3% of proposed scenario, decreasing 40.70% compared with the existing scenario. Therefore, the greenhouse gas emission of carbon dioxide equivalent was emitted depending on the typical food items which consisted of the food set. FS5 and FS11 had the lowest and highest emissions (0.3 Mt CO_2 eq/yr and 1.2 Mt CO_2 eq/yr, respectively). Total Cambodian carbon dioxide emission of proposed scenario was emitted 6.9 Mt CO_2 eq, reducing 28.9% compared to existing scenario.

In Chapter 4, a one-year cooking energy scenario based on LPG 24%, firewood 66.7%, and charcoal 7.4% for cooking traditional food was studied on one person through 12 menus of the BF1-5 and LD1-7. The result showed that total cooking emission was emitted depending on LPG, firewood, and charcoal. The LPG had emitted 0.3 kg CO, 1.3 kg PM 2.5, and 0.1 Mt CO_2. Firewood was emitted 149 kg CO, 16 kg PM 2.5, and 0.27 Mt CO_2. Therefore, charcoal was emitted 32 kg CO, 8 kg PM 2.5, and 0.04 Mt CO_2. So, existing and proposed was emitted 0.55 Mt CO_2 eq and 0.41 Mt CO_2 eq, respectively, that reduced 25.54%. In conclusion, the country's existing food production system generates CO_2 emissions of 9.7 Mt CO_2 eq/yr, with the proposed system and cooking energy reducing these by 28.68% to 7.3 Mt CO_2 eq/yr. The food calories, minerals, and vitamins met the recommended dietary allowance and the emission reduction according to traditional Cambodian food through the type and quantity of diet. The people consumed the right amount and type of nutrient food; however, they were still sufficiency on health conditions because of unclean fuel using in the cooking environment.

Chapter 1 Overview Introduction

1.1 Research Background

The environment is affected by the type and amount of food consumption in the production chain which is influenced by diet choice and habit. This subsequently influences the climate through food-related consumption and resource utilization per production as land use, and water use, etc. Two billion people go undernourished and hungry because they have consumed less or nutrient incorrect amount. Therefore, two billion people are overweight and obese, they have overconsumed food with detrimental to human health and the environment [1]. The environment involved in climate change is carbon dioxide emission that is considered by food intake based on human activities and habits.

Some people are sufficient nutrient food intake according to unequal food needs [2]. Nutrient food has consisted of food for macronutrients and micronutrients through the type and amount of consumption needs. Balanced between food nutrition which is cared about health condition and environmental impact which avoided malnutrition happening and carbon dioxide emission.

Deficiency of food for calories becomes a wasting and stunting or underweight status, and excesses of food for calories are becoming overweight or obese that both compared with people height. Minerals and vitamins are very important to people as zinc, calcium, iron, water-soluble vitamin B and C, and fat-soluble vitamin A, and D. However, deficiency of calcium is a risk of bone breaks and associate with vitamin D deficiency, deficiency of zinc caused hair loss, weight loss, and delayed wounds healing, and deficiency of vitamin A caused children night blindness and lead to anemia [3].

In Cambodia, people below 5 years old are suffered stunting 32%, wasting 10%, and underweight 24%, and women are underweight 18%, and overweight 18% [4]. Therefore, adults are suffered obesity and diabetes. Women and men were 2.7%, and 4.8% of obesity, and 7.4%, and 6.9% of diabetes, respectively. Moreover, garment workers had anemia 26.9% and underweight 34.4%, also accessed unbalanced food, safe food, lower vegetables, and fruits consumption [5], [6]. These reasons are affected by calories, minerals, and vitamin deficiency [4]–[7].

High intake of nutrient-rich food has dairy products, vegetables, grains, fruits, and low-fat meat and less intake of sweets, desserts, and high-fat meat and dairy product have been linked to satisfying on results of health to decrease obesity situation [7]–[9]. Consequently, the population of the young generation was known about environmentally friendly through CO_2 emissions to determine on the agriculture and environment.

The food production was emitted 26% of carbon dioxide equivalent that total emissions were 52.4 billion tons. Supply chain emitted 15%; land use emitted 24%; crop production emitted 27%; livestock and fish farms emitted 31%. Emission in Cambodia contributed 0.13% of CO_2 equal to 65.6 Mt CO_2 equivalent from agriculture, industry, energy, and waste [7], [10]–[13]. Therefore, the food area represents around 30% of the world's absolute power utilization to record 22% of all out-greenhouse gas discharges. The significant supporters of the carbon impression of food wastage are grains 34%, trailed by meat 21%, and vegetables 21%. Results of creature cause represent about 33% of the complete carbon impression. To understand the environmental effect is used life cycle assessment (LCA) and evaluated on agricultural production and CO_2 emissions. The SimaPro® v8.0.4 tool was used to calculate CO_2 emissions by selection method of the time horizon of a 100-year for global warming potential.

1.2 Problem Statements

This dissertation has main issues as follow:

1) The imbalance of type and size of food is affected by malnutrition.
2) Malnutrition occurred because food had low-nutrient as sweet, dessert, and high-level-fat have been correlated to be the great rate of overweight and obesity.
3) Low intake food for calories that impacted underweight and growth condition.
4) Low intake of vegetables and fruits impacted minerals and vitamins.
5) Low intake of milk and fish impacted the bone that is the resource of calcium.
6) Low or high carbon dioxide emission through consumer's behavior and activities for agricultural production.
7) Loss nutrient composition in food because of heat and time for cooking.
8) Relationship between health condition and energy of cooking if the people is utilization incorrect energy for cooking.

1.3 Research Objectives

This study aimed at:

1) To study food production depended on food consumption.
2) To estimate carbon dioxide emission according to agricultural production.
3) To study cooking energy to minimize carbon dioxide emissions.
4) To evaluate the environment based on carbon dioxide emission through agricultural production and energy of cooking.

Chapter 2 Literature Review

2.1 Geography of Cambodia

Cambodia is a tropical county that has a border with three countries. There are twenty-five cities and provinces. The country area is 18.1 million hectares (Mha) that have 17.7 Mha of land area and 0.5 Mha of inland. Agriculture production was required to use the land for agriculture (5.6 Mha) that cropland is used 4.1 Mha included arable land 3.9 Mha. The national economy has been included by 20.8% of the agriculture sector as 11.1% of poultry and livestock, 6.9% of the forest, 57.7% of grains, 24.3% of aquatic. Occupied by paddy land 3.3 Mha, vegetable 0.06 Mha, fruit 0.16 Mha [14]. The country is divided into central plain, Tonle Sap, coastal and sea, and plateau and mountain zone. Cambodia has a rainy season and dry season, and also the Tonle Sap Lake (Great Lake) and the Mekong River are used for specialized in agriculture and fishing. Cambodian population has 16.5 million included 1.24 million, they migrated to work abroad [14], [15].

Figure 2.1. Map of Cambodia [15].

2.2 Cambodian Foods

Food is the main resource of calories, minerals, and vitamins to maintain life and growth. Cambodia people are consumed 80% of rice, 10% of meat or egg, and 10% of fat and less consumed vegetables and fruit. They consumed food for calories two or three times per day. Food cuisine menu has like a sour stew, hot pot, stir-fried, salad, toast, etc. Food consumption is based on family economic [16]–[18]. The food is in three categories (breakfast, lunch, and dinner). The breakfast menu has pork salad noodles, beef fried noodles, Khmer sandwich, beef noodles soup, and fried pork with rice, and so on. Pork stir-fry beansprouts, fish (striped snakehead) and water lily sour soup, tomatoes and braised (Siamese mud carp), fried fish (striped catfish) and ginger, fish (striped snakehead) of samlor brahaer Khmer stew, beef lemongrass sour soup, and samlor kako Khmer stew with fish (catfish), pork, and coconut milk and so on were lunch and dinner menu [16].

(a) Breakfast menu.

(b) Lunch and dinner menu plus rice.

Figure 2.2. Cambodia’s Traditional diet menu.

2.3 Recommended Nutrition

Macronutrients and micronutrients determined nutrient food. Food for macronutrients has carbohydrates, protein, and oil [7], [19]–[22]. Total carbohydrate is required 45-65% of total calories intake that was equal to 130 g/day. Nevertheless, sugar intake was less than 25% of total calories and women and men had intake 25 g and 38 g of fiber, respectively [23], [24]. Rice, rice noodles, wheat are primary carbohydrate sources. Bean, fish, pork, chicken, beef, and egg are the proteins that consume 10-20% of total calories or 0.8 g of body weight (kg). Lipid has unsaturated and saturated fat that consumes 25-30% of calories. Saturated fat consumes less than 7% of calories, contains animal fat [7], [20]–[22], [25]–[27]. Micronutrients had vitamins and minerals that required a little amount of needed and were noticed in milk, fruits, and vegetables. The vitamins are defined as the vitamin of soluble water and fat. The soluble vitamins in the water had vitamin C, all vitamins B, and soluble vitamins in fat had vitamin A, D, E, and K [28]. The macronutrients were consumed normally and micronutrients were not balanced consumption that reflected on micronutrient deficiency [20], [28], [29]. Minimum and maximum of food for macronutrients have 525 kcal, and 2725 kcal, respectively, food for micronutrients have 2 mg to 40 mg of zinc, 200 mg to 2000 mg of calcium, 0.73 mg to 45 mg of iron, 400 µg to 3000 µg of vitamin A, 0.4 µg to 2.8 µg of vitamin B12, 40 mg to 120 mg of vitamin C, and 10 µg to 100 µg of vitamin D, and so on. (Table 2.1).

Table 2.1. Food eaten requirement per day of consumption according to food for macronutrients, and micronutrients [3], [20]–[22], [25]–[27], [30], [31].

Age (Year)	Food for Macronutrients			Food for Micronutrients		
	Male (kcal)	**Female (kcal)**	**Total (kcal)**	**Composition**	**Minimum**	**Maximum**
Less than 5	830	780	805	Zn (mg)	2.0	40
5 to 9	1567	1467	1517	Ca (mg)	200	2000
10 to 14	2425	2250	2338	Fe (mg)	0.73	45
15 to 19	2750	2125	2438	A (µg)	400	3000
20 to 29	2650	1950	2300	B1 (µg)	0.2	1.4
30 to 49	2650	2000	2325	B2 (mg)	0.3	1.6
50 to 79	2450	1900	2175	B3 (mg)	4.0	35
Over 80	2200	1750	1975	B6 (mg)	0.1	100
Minimum	550	500	525	B9 (µg)	65	1000
Maximum	3150	2300	2725	B12 (µg)	0.4	2.8
				C (mg)	40	120
				D (µg)	10	100

The macronutrients and micronutrients amounts are defined by the quantity of each item food consumed according to the food menu. Each food item has a different quantity of food composition. Instead of food items have rice, rice noodle, bread, fish, pork, beef, chicken, egg, oil, fruits, vegetables, and so on (Table 2.2).

Table 2.2. Item foods composition of 100 g amounts through food for macronutrients, and micronutrients [3], [30], [31].

Item Food	Food for Macronutrients				Food for Micronutrients											
	Carbohydrate	Protein	Fat	Calorie	Minerals			Vitamins								
					Zn	Ca	Fe	A	B1	B2	B3	B6	B9	B12	C	D
	(g)	(g)	(g)	(kcal)	(mg)	(mg)	(mg)	(µg)	(µg)	(mg)	(mg)	(mg)	(µg)	(µg)	(mg)	(µg)
Wheat	71.2	10.3	1.1	341	2.5	29	2.0	-	0.2	0.1	1.0	0.1	44	-	-	-
Rice	78.4	7.2	0.8	352	0.8	21	1.2	-	0.1	0.0	2.2	0.2	9	-	-	-
Rice noodle	24.0	1.7	0.6	111	0.7	12	0.2	-	0.0	0.0	1.3	0.0	3	-	-	-
Catfish	3.1	16.0	14.7	209	0.2	20	0.7	374	0.0	0.5	2.3	0.0	10	2.2	0.7	13
Siamese mud carp fish	3.6	16.7	4.4	121	1.5	32	0.8	247	0.0	0.1	3.1	0.2	15	1.5	1.6	25
Striped catfish	1.9	14.6	16.5	215	1.6	24	1.3	15	0.0	0.2	0.8	0.1	10	2.2	2.0	13
Striped snakehead fish	-	18.2	2.7	97	0.9	90	0.5	203	0.0	0.1	2.3	0.1	5	1.1	1.7	118
Fish *	2.2	16.4	9.6	161	1.1	42	0.8	210	0.02	0.2	2.1	0.1	10	1.8	1.5	42
Pork	0.2	21.0	3.6	117	2.3	4	1.0	4	0.9	0.2	4.4	0.5	5	1.4	1.0	69
Chicken	0.2	20.4	7.1	148	0.4	14	0.9	20	0.1	0.1	8.0	0.5	9	0.3	0.3	-
Beef	-	21.3	3.5	117	2.2	24	2.5	66	0.1	0.2	5.6	0.5	8	1.3	0.5	3
Egg	1.7	12.9	10.5	155	0.9	47	2.4	237	0.1	0.2	0.4	0.3	80	0.9	-	5
Coconut milk	31.7	7.7	56.0	666	0.7	20	1.6	-	0.0	0.0	0.1	0.0	16	-	0.5	-
Vegetable oil	-	-	100.0	900	0.7	-	0.1	-	-	-	-	0.0	-	-	-	-
Fruit	14.3	1.0	0.9	75	0.2	13	0.7	9	0.1	0.1	0.7	0.0	6	-	30.7	-
Milk	5.8	4.0	3.3	69	0.5	151	0.0	55	0.1	0.2	0.1	0.2	3	0.5	0.4	1
Beansprout	5.1	4.5	0.1	54	0.5	28	1.3	2	0.1	0.1	0.9	0.1	61	-	25.7	-
Yard long bean	4.7	3.6	0.4	42	0.5	49	1.0	17	0.2	0.1	1.1	0.0	62	-	20.0	-
Amaranth spineless	-	3.7	0.5	43	0.9	192	3.4	255	0.0	0.3	0.9	0.2	85	-	43.0	-
Banana flower	2.3	1.6	0.5	42	0.3	44	0.9	16	0.3	0.0	0.6	0.4	25	-	11.0	-
Carrot	5.3	1.5	0.3	51	0.5	56	1.1	313	0.1	0.1	0.6	0.1	19	-	11.8	-
Water spinach	1.2	2.9	0.4	35	0.4	73	2.8	246	0.1	0.2	0.9	0.1	57	-	23.0	-
White mushroom	4.3	2.7	0.2	19	0.5	11	1.2	1	0.1	0.4	3.6	0.1	25	0.0	4.9	2
Water lily	1.1	0.8	0.4	18	0.3	37	0.6	15	0.0	0.0	0.3	0.3	8	-	6.5	-
Unripe papaya	4.3	0.8	0.1	25	0.1	47	0.6	1	0.0	0.0	0.3	0.0	37	-	32.3	-
Unripe banana	14.7	1.2	0.5	73	0.3	26	0.4	15	0.1	0.0	0.6	0.4	25	-	31.0	-
Taro	21.4	2.0	0.1	129	0.8	59	1.0	2	0.1	0.1	0.8	0.3	22	-	5.3	-
Tomato	3.5	0.9	0.3	23	0.4	17	0.9	36	0.1	0.0	0.6	0.1	30	-	32.5	-
Pumpkin leaf	1.8	3.0	0.5	35	0.5	90	3.0	112	0.1	0.1	0.9	0.2	36	-	16.7	-
Pumpkin	6.2	1.0	0.3	45	0.1	39	0.6	139	0.1	0.0	0.6	0.1	16	-	14.3	-
Ivy gourd leaf	1.2	3.6	0.2	37	0.5	57	1.4	336	0.1	0.2	19	0.2	36	-	13.0	-
Gourd wax	2.5	0.5	0.2	22	0.1	23	0.3	-	0.0	0.1	0.3	0.0	5	-	26.0	-
Gourd sponge fresh	3.3	0.8	0.2	20	0.1	19	0.7	4	0.0	0.0	0.4	0.0	7	-	6.3	-
Ginger	5.0	1.0	0.8	36	0.3	36	2.0	-	0.0	0.2	0.8	0.2	11	-	9.0	-
Eggplant	4.0	1.2	0.2	26	0.2	22	0.6	7	0.1	0.1	0.6	0.1	22	-	8.7	-
Cucumber	3.2	0.8	0.1	19	0.2	22	0.7	8	0.0	0.0	0.2	0.0	7	-	8.5	-
Chinese radish	3.3	0.9	0.2	21	0.2	37	0.7	-	0.0	0.0	0.4	0.1	25	-	25.8	-

* Fish was considered as element of calcium intak.

2.4 Environment

The environment is associated with air, water, and land according to climate change arising has from greenhouse gas emissions, and acidification from acid gas emissions, eutrophication, etc. The environmental effect occurred by primary food production activities through food consumption. Method of cooking is also affected to air pollution and human health. The environmental quality of consumer impact is dependent on consumer's needs as food producers, food preparation, and cooking, etc. In the UK, annual vegetable consumption was 10.8 t that had emitted 20.3 Mt CO_2 eq [32].

Chapter 3 Traditional Nutrient-Rich Cambodian Diet Food Production System Using Life Cycle Assessment to Assessment of Carbon Dioxide Emissions

3.1 Introduction

3.1.1 General background

To compare about a greenness of environmental food, the conventional food is unfriendly Foods are the main resource to support human wellbeing that is come from conventional, fast, and traditional food. In Cambodia, traditional foods require a high supplement of macronutrients and micronutrients. The macronutrients are eaten food for calories that it consisted of carbohydrate, protein, and fat. Therefore, micronutrients are eaten food for minerals and vitamins that consisted of vegetables, fruits, milk, and fish. ecology contrasted to the traditional one, thinking about emissions of carbon dioxide (CO_2) through the production of agriculture focus on land and water use [17], [33]. Nonetheless, information and confirmation of nutrient consumption and greenness ecology are not enough yet for different age consumers. The nourishing admissions are fulfilled with natural greenness which is necessary to utilize traditional food for CO_2 evaluation. The environment and human health are impacted by the system of food production. Human activities are caused by environmental effects through climate change that emitted CO_2 emissions [34], [35]. In Cambodia, CO_2 equivalent (eq) is contributed to global data 0.13% which was from transportation, electricity, industry, residential, agriculture, and so on and also equal 65.6 Mt CO_2 eq [10], [36].

3.1.2 Geography of Cambodia, Issues of Food Nutrient, and Carbon Dioxide Emissions

In 2019, the population has 16.5 million in Cambodia that which is a Southeast Asia country [15]. The area of Cambodia has two areas as inland area and land area. The total area is equal to 18.1 million ha (Mha). The area inland has 0.5 Mha and the area of land has 17.7 Mha which is utilized for forestry, organic agriculture, and agriculture. 5.6 Mha is land of agriculture which are occupied by cropland 4.1 Mha, covering 3.9 Mha of arable land. The economic nation contributes by 20.8% of sector of agriculture which has 57.7% of crops, 11.1% of livestock and poultry, 24.3% of the fishery, and 6.9% of forestry. Therefore, the arable land is occupied by 3.3 Mha of paddy cultivation, 0.2 Mha of vegetable cultivation, and 0.2 Mha of fruit cultivation. The Mekong River and the Tonle Sap Lake are the freshwaters that supply freshwater fish for consumption [11], [14], [37], [38]. Throughout, food consumption is inadequate yet for Cambodia and challenged the security of food nourishment.

Food consumption is categorized as food for macronutrients and food for micronutrients. Food for macronutrients has carbohydrates, proteins, fats that are eaten for calories. Food for micronutrients has vegetables, fruits, milk, and fish that are eaten for minerals and vitamins. One person has consumed in a day for the world, developing countries, East Asia, and Southeast Asia consume food for macronutrients that is equal to 2940 kcal, 2850 kcal, 3060 kcal, and 2700 kcal, respectively [39]. In Cambodia, food, protein, and fat supply for one person in a day are 65.4 g, and 32.8 g, and 2472 kcal, respectively. A person has consumed 2411 kcal of food for macronutrients. Macronutrient intake is consumed 1520 kcal of rice, 124 kcal of egg, meat, and milk, 74 kcal of aquatic and aquatic product, 57 kcal of vegetables and fruits, and 135 kcal of oil [2]. As per the Cambodian Demographic Health Survey, adults, and under 5 years old of kids have been impacted by malnourishment. Within Cambodia, under 5 years old of kids are caused by 24% of underweight, 32% of stunting, and 10% of wasting throughout calculations of body mass index. Therefore, women are affected by 14% of underweight, and 18% of overweight [4]. Obesity and diabetes are suffered in adults whose men and women rates were 2.7% and 4.8% of obesity, and 7.4%, and 6.9%, respectively [5], [6]. Food consumption and lack of education are caused by high anemia levels in women in rural areas [5]. Additionally, anemia and underweight are caused by 26.9% and 34.4% of garment workers, respectively. They have no admittance to food safety and eat unbalance of nutrient food, the food was unhygienic and insecure [6]. For, vegetables, fruits, and milk, they consume less amount, which is considered as food for micronutrients.

The health of human and conditions of environment is caused by types and sizes of food consumption. Concerning eating as rice, rice noodles, fish, pork, chicken, beef, egg, fat, fruits, vegetables, and milk that do not contain on a right quantity and type food to indicate malnourishment and impacts of environment because the consumption, production, and environment, are correlated with food diet. Eating foods are fundamental to consumers' health, to be deficiency (underweight, hunger) or excess (overweight, obesity, and diabetes of nourishment), or underprivilege size of serving and type of food. The nutrient-rich food levels have dairy products, low-fat, cereals, vegetables, and fruits have advantaged for wellbeing results of consumers as well as obesity [8]. The diet in low nutrient density has dessert, sweet, and dairy products in high fat which response to the obesity rate and status of poor nutrition in adults and old people [9]. Subsequently, more environmentally friendly food is very necessary to fascinate the younger population. The CO_2 of global greenhouse gases remains a deciding and disturbing aspect in the implementation methods of environmental production through the environmental advantage.

The CO_2 eq emissions are emitted 52.4 billion tons of global greenhouse gas which are accompanied to food production 26%. The food emissions are emitted through the supply chain, livestock and fish farms, crop production, and land use that are equal to 18%, 31%, 27%, and 24%, respectively [36]. Greenhouse gas emissions in Cambodia are emitted within the waste, industry, energy, agriculture, land-use change, and forestry that are equal to 0.7%, 1.2%, 14.1%, 36.4%, and 47.6%, respectively [10], [12]. The agriculture emissions were emitted CO_2 eq 9.3 million t (Mt) that was originated of residues of the crop, management of manure, nitrogen fertilizers of synthetic, soil of agriculture, enteric fermentation [11]. Accordingly, emissions of methane were emitted 0.4 Mt of rice field, and paddy rice soil was emitted 11.7 Mt of global warming potential [13]. Overall global emissions of greenhouse gas within agriculture production are compulsory to investigate, and the best method to comprehend about impacts of the environment is the life cycle assessment (LCA) method.

To indicate the impact of environment on production and agriculture system which is studied on LCA analysis tool. According to a pattern of nutrition, the pattern of consumption food, and quantity of food set menu, several foods have been calculated on their impact on the environment [40]–[42]. The evaluation of the impact environment and food of traditional in Cambodia can be improved to be suitable for young and environmentally alert to populations.

3.1.3 Objective

The malnutrition status of human wellbeing influenced the quantity and type of food set and reflected impacts of the environment, so on. Both environmental issues and the value of nutrition on diets of Cambodia traditional is evaluated by LCA. Cambodia's traditional diet of food set had selected 12 sets that 5 food sets (FS1-5) defined as breakfast set and 7 food sets (FS6-12) defined as lunch and dinner set to determine the consumption of food and item foods which changed to the production food. Every diet is contented with nutrition as the macronutrients, micronutrients that were evaluated to estimate emissions of carbon dioxide emission.

3.2 Materials and Methods

3.2.1 Requirement of Nutrition

Nutrition is contented in foods that are important for body function. Nutrition is allocated in two classifications as macronutrients and micronutrients to support the function of the body. Macronutrients are required in sizeable quantities that have carbohydrates, proteins, and lipids. Cereals, cereal products, fruits, and starchy vegetables as potatoes define carbohydrates that are classified into two forms as complex and simple carbohydrates. In general, it consumes 45%-65% of total food calories. In case, it consumes 25% simple carbohydrate (sugar) based on the number of total calories. Therefore, the proteins of food sources have a bean variety, seafood, dairy products, eggs, and meats that consume 10% to 20% (0.8 g) of calories needed to be multiplied by body weight (kg). One gram of carbohydrates or proteins is equal to four kilocalories of calories. Lipids are defined as unsaturated fat (oil) and saturated fat (fat) which are located in many foods processing, including butter, dairy products, meats, oils, nuts, and seeds. The unsaturated fat as oils, nuts, or seeds consume 25-30% of calories needed, nevertheless, saturated fat as butter, dairy products, meats consume less than 7% of calories needed [20]–[22], [25]–[27].

The micronutrients are required a few amounts which had vitamins and minerals and found in milk, fruits, and vegetables. The vitamins are defined as the vitamin of soluble water and fat. The soluble vitamins in the water had vitamin C, all vitamins B, and soluble vitamins in fat had vitamin A, D, E, and K [28]. In Cambodia, the macronutrients were consumed normally; nonetheless, the micronutrients were not balanced consumption. The deficiency of micronutrients was affected to consumers [20], [28], [29]. The quantity of food was analyzed through one of Cambodia's sets of traditional food to fulfill the requirement of macronutrients and micronutrients according to each food composition. Rice is a domestic product that people have consumed in day to balance the calories needed. The food items and food quantity are investigated on the food set that was suitable to withdraw malnutrition and issues of environment and also correlated to the production of agriculture and consumption food. In Cambodia, according to consumer age was separated into two kinds as K1 and K2. The K1 was kind of consumers age from below and 9 years old. The K2 was kind of consumers age from over and 10 years old.

3.2.2 Nourishment Food

The Cambodian food set in a traditional diet comprised of item foods and serving size of foods. Item of foods had wheat and/or rice (staple food), fish, pork, chicken, and/or beef (meat), eggs, oil, spices, vegetables, fruits, and milk. A toasting menu, roasting menu, soup menu, and stir-fry menu is Cambodia's cuisine [16]. Consumers' ages were calculated size dish amounts for macronutrients and micronutrients needed. In a day, consumers were eaten two or three times meal set to satisfy food needs for macronutrients and micronutrients. The rice, rice noodles, or bread were eaten with Cambodian dishes according to the individual favorite and menu type. The taste of cuisine is stable between spicy, bitter, sour, salty, sweet, and so on [16], [17], [43]. Unhealthiness is caused by diet habits which ate unstable rice, rice noodle, bread, meats, eggs, cooking oil, vegetables, fruits, and milk. Nutrient sufficiency is necessary for the function body to affect wellbeing and human health through food eaten for macronutrients and micronutrients [6], [8], [9]. To evaluate the requirement of food needed was studied by food set which included macronutrients and micronutrients based on serving size of food, age of consumers, assessed on land and water use, and emissions of carbon dioxide equivalent.

3.2.3 Macronutrients, Micronutrients, and Consumption of Food Calculation

The conceptual study determined by serving size of food and item foods to encounter micronutrients and micronutrients requirements that are the root cause to prevent malnutrition status and impact of the environment. By age as the population of Cambodia, applicants were identified into two kinds (K1 and K2) of consumers' age. The food set had selected 12 sets that 5 food sets (FS1-5) defined as breakfast set and 7 food sets (FS6-12) defined as lunch and dinner set to determine the consumption of food and item foods which changed to the production food. Moreover, the production food system was evaluated on land needs and utilization of water based on the production yield, requirement of the product, and/or quantity of animals. According to the requirements of land and quantity of animals was evaluated to estimate carbon dioxide equivalent (CO_2 eq) emissions (Figure 3.1).

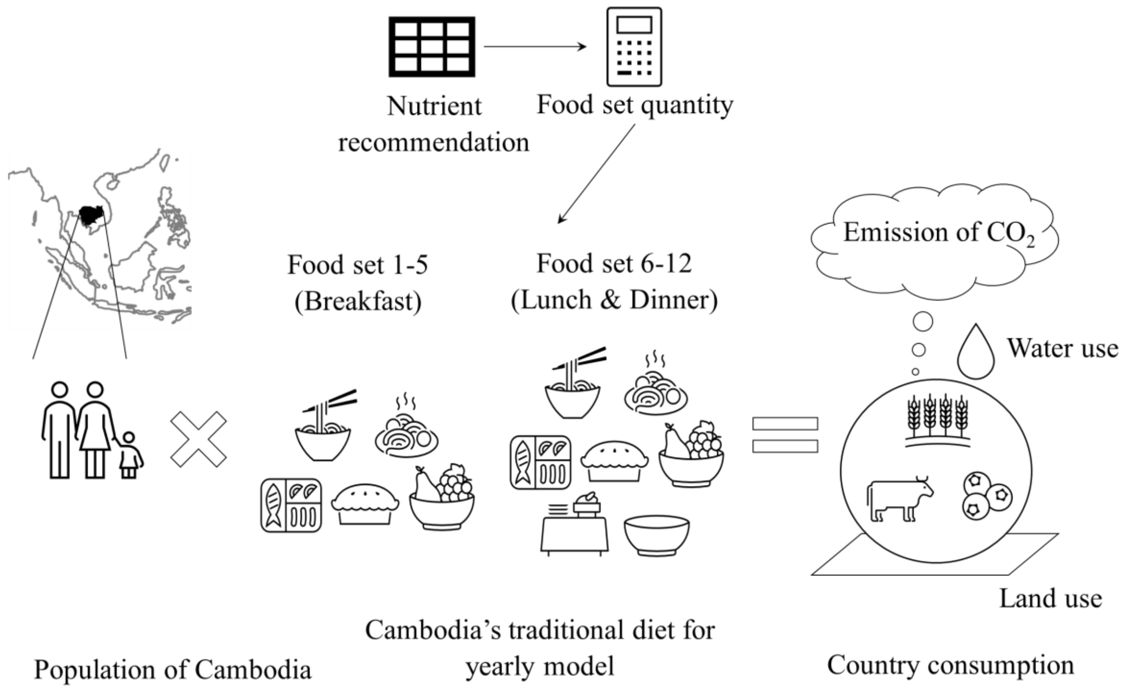

Figure 3.1. Cambodia's traditional diet of food consumption pattern for one yearly modeling to evaluate CO_2 emissions.

The water and land use are investigated on the production phase of the boundary system through food quantity and item foods to calculate CO_2 emissions. The production was determined to cultivate plants and raise animals that had rice, fruit, and vegetable cultivation, and also fish, pig, poultry, and cattle raising. One set of Cambodia's traditional diet was set to compute consumption quantity (Figure 1; Figure 2). The cultivation area was calculated according to each food item's consumption amount. Therefore, the arising area was calculated through carcass weight of animals, and milk and egg yield. The carcass weight per fish head was 1 kg; carcass weight per pig head was 50 kg [11]; chicken carcass weight per head was 1.14 kg; cattle carcass weight per head was 120 kg; milk yield per cattle was 1650 kg [44].

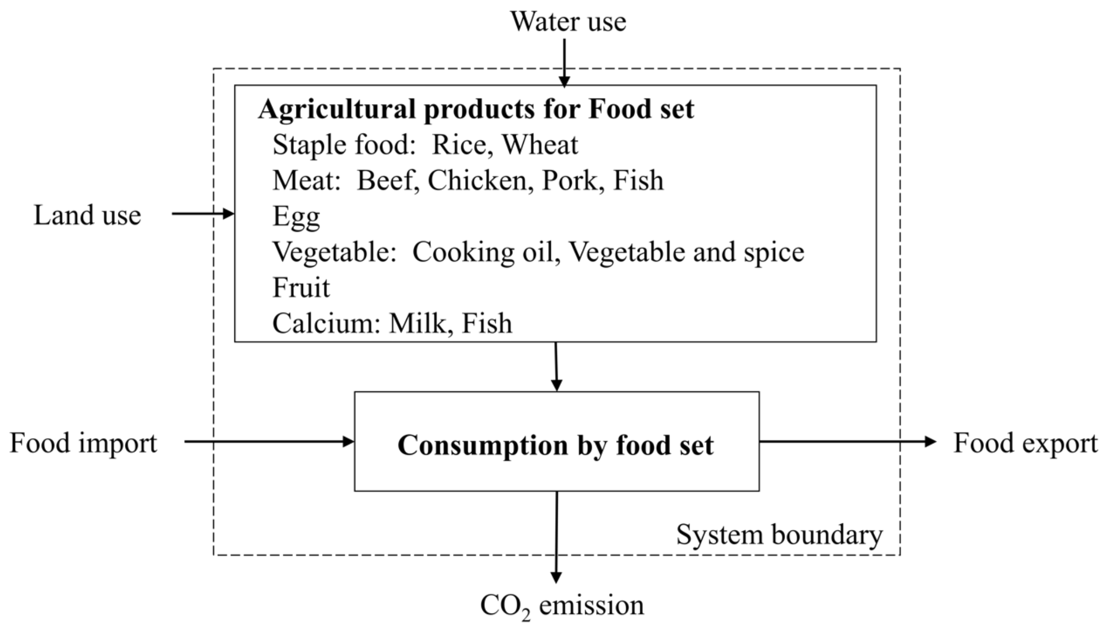

Figure 3.2. System boundary to evaluate CO_2 emissions on Cambodia's traditional diet based on the production of food set.

In Cambodia, people had migrated abroad for working. The requirement of macronutrients and micronutrients was selected in two kinds of consumers. The first kind of consumer (K1) was below and 9 years old that the population is 2.92 million. The second kind of consumer was over and 10 years old that the population is 12.63 million. The total population is 15.55 million that excluded 1.24 million of migration [15]. Existing and proposed scenarios were investigated on each of the item foods to assess carbon dioxide emissions equivalent. Both scenarios are considered in this study, the Cambodia data is referred to calculate the existing scenario [11], and the food set is calculated on the proposed scenario (Table 3.2).

The macronutrients were equal to 100% of consumption amounts. The macronutrients were consumed 30% of lipid, 10% of protein, 60% of carbohydrate[20]–[22], [25]–[27]. Micronutrients were consumed depending on consumers' age. To fulfill micronutrient intake, consumers had consumed the minimum requirements. The K1 and K2 were required 100 g/day, and 400 g/day of vegetables and fruits, respectively. Calcium requirement was intake 50 to 300 ml/day of milk and fish consumption.

Table 3.1. Food for macronutrients and micronutrients of Cambodia of traditional food sets [17].

Food set based on consumer's age*		Food for Macronutrients (g)								Food for Micronutrients (g)					Annually Intake*[1]
		Staple Food		Meat				Egg		Vegetable		Fruit	Calcium		
		Rice	Wheat	Fish	Pork	Chicken	Beef		Oil	VESP	(No) *[2]		Milk	Fish*[3]	
FS1	K1	-	-	-	10	-	-	10	-	50	(1)	50	20	10	
	K2	-	-	-	25	-	-	25	-	100	(1)	50	20	10	
FS2	K1	50 (RN*[4])	-	-	-	20	-	-	-	50	(2)	50	20	10	
	K2	100 (RN)	-	-	-	50	-	-	-	100	(2)	50	20	10	FS1-5
FS3	K1	50	-	10	-	-	-	10	-	50	(3)	50	20	10	each
	K2	100	-	25	-	-	-	25	-	100	(3)	50	20	10	73.0
FS4	K1	50 (RN)	20	-	-	-	20	-	5	50	(4)	50	20	10	(times/yr)
	K2	100 (RN)	50	-	-	-	50	-	5	100	(4)	50	20	10	
FS5	K1	50	-	-	20	-	-	-	-	50	(5)	50	20	10	
	K2	100	-	-	50	-	-	-	-	100	(5)	50	20	10	
FS6	K1	50	-	20	-	-	-	-	5	50	(5)	50	20	10	
	K2	100	-	50	-	-	-	-	5	100	(5)	50	20	10	
FS7	K1	50	20	-	-	-	20	-	-	50	(6)	50	20	10	
	K2	100	50	-	-	-	50	-	-	100	(6)	50	20	10	
FS8	K1	50	20	-	-	-	20	-	-	50	(7)	50	20	10	
	K2	100	50	-	-	-	50	-	-	100	(7)	50	20	10	FS6-12
FS9	K1	50	20	-	-	-	20	-	5	50	(8)	50	20	10	each
	K2	100	50	-	-	-	50	-	5	100	(8)	50	20	10	104.3
FS10	K1	50	20	-	-	-	20	-	-	50	(9)	50	20	10	(times/yr)
	K2	100	50	-	-	-	50	-	-	100	(9)	50	20	10	
FS11	K1	50	-	-	-	20	-	-	-	50	(10)	50	20	10	
	K2	100	-	-	-	50	-	-	-	100	(10)	50	20	10	
FS12	K1	50	10	10	-	-	10	-	5	50	(11)	50	20	10	
	K2	100	25	25	-	-	25	-	5	100	(11)	50	20	10	

* FS1-5: breakfast set, FS6-12: lunch and dinner set; K1: below and 9 years old; K2: over and 10 years old. The food set menu: FS1: Khmer sandwich; FS2: beef noodle soup; FS3: fried pork and egg with rice; FS4: Khmer fish (striped snakehead) noodle soup; FS5: chicken congee; FS6: pork stir-fry beansprouts; FS7: fish (striped snakehead) and water lily sour soup; FS8: tomatoes and braised fish (Siamese mud carp); FS9: fried fish (striped catfish) and ginger; FS10: samlor brahaer Khmer stew with fish (striped snakehead); FS11: beef lemongrass sour soup; FS12: samlor kako Khmer stew with fish (catfish), pork, and coconut milk.

*[1] Annually intake: FS1-5 = (1 time/day × 365 days)/5 food sets; FS6-12 = (2 time/day ×365 days)/7 food sets.

*[2] VESP: vegetables and spices set. The type of VESP number was depended on the food set and consumers' age. The quantity of VESP consumption was 100 g for over and 10 years old. Consumers' age over and 10 years old was divided half of that amount. (1) carrot (33.3 g), Chinese radish (33.3 g), cucumber (33.3 g); (2)

beansprout (33.3 g), carrot (33.3 g), Chinese radish (33.3 g); (3) banana flower (20 g), beansprout (20 g), cucumber (20 g), peppermint (20 g), yard long bean (20 g); (4) Beansprout (25 g), carrot (25 g), Chinese radish (25 g), white mushroom (25 g); (5) beansprout (50 g), garlic chives (50 g); (6) waterlily (100 g); (7) tomato (100 g); (8) ginger (100 g); (9) amaranth spineless (14.3 g), gourd sponge fresh (14.3 g), gourd wax (14.3 g), ivy gourd leaf (14.3 g), pumpkin leaf (14.3 g), taro (14.3 g), white mushroom (14.3 g); (10) water spinach (100 g); (11) eggplant (16.7 g), Moringa leaf (16.7 g), pumpkin (16.7 g), unripe banana (16.7 g), unripe papaya (16.7 g), yard long bean (16.7 g).

*[3] Fish was consumed as calcium composition that resourced in boiling fish, roasted fish, or fish powder.

*[4] RN: rice noodle.

The total of consumption food and composition of nutrition was studied on macronutrients and micronutrient intake. The value of macronutrients and micronutrients were carbohydrates, proteins, lipid; zinc, calcium, and iron minerals and soluble vitamin in water as B and C and soluble vitamin in fat as A and D (Table 2.2).

The food pyramid in Cambodia is determined by each item of food in traditional food. The rice, rice noodles, wheat, fish, pork, chicken, beef, egg, oil are identified as macronutrients needs. Therefore, vegetables, fruits, milk, and fish are identified as micronutrients needs. The food eaten per person was selected into three sets of breakfast, lunch, and dinner based on total calories of food consumption [17], [20], [28].

The Cambodian food set of traditional food has food for macronutrients and micronutrients. The food for macronutrients of food set menu consisted of rice, rice noodles, wheat, fish, pork, chicken, beef, egg, and/or oil. The food for micronutrients consisted of vegetables and spices, fruits, milk, and/or fish to consider for minerals and vitamins intake (Table 3.1).

The food set of FS1-12 was calculated for intake annually. Each of FS1-5 was 73 times/yr that consumed once per day for 365 days, and every of FS6-12 was 104 times/yr that consumed twice per day for 365 days. The intake annually was depended on food set selection to calculate the quantity of production.

One set of traditional food was analyzed. Mass balanced of production was studied that excluded import products. Wheat could not grow in a tropical country like Cambodia. Milk production is unsatisfied with the requirement because of the low production rate.

The SimaPro® v8.0.4 method was used to calculate carbon dioxide equivalent emission as the impact of the environment in the selected method of a 100-year time horizon by global warming potential.

3.3 Results and Discussion

Cambodia's traditional diet is eaten three-time in a day to stable macronutrient and micronutrient needs. The diets have selected twelve food sets (FS1-12) that FS1-5 is the breakfast menu, and FS6-12 is the lunch and dinner menu. The size of dish sets was determined by consumers' age that was 200-205 g for K1 and 330-335 g for K2.

The results of food for macronutrients showed FS1 and FS2 were the low calories amounts of K1 and K2 and a high calorie was FS3 of K1 and K2 as breakfast menu. Moreover, FS9 and FS7 were the high and low-calorie amounts of K1 and K2 as lunch and dinner menu. FS4, FS5, FS6, FS8, FS10, FS11, FS12 of K1 and K2 were calorie amounts as normal. Additionally, food for macronutrients was met nutrient recommendations (Table 3.2; Figure 3.3). Food for micronutrients showed FS5 and FS4 were low and high in Fe and Ca amounts; FS5 and FS1 were low and high in Zn amounts for mineral intake as breakfast menu. Therefore, soluble vitamins in water showed B1, B9, and B12 were low in FS5 amounts; B3, B6, and C were low in FS1, FS4, and FS3 amounts, respectively. Soluble vitamins in fat showed A and D were low in FS5 amounts. The food for micronutrients was met the requirement needs (Table 3.2; Figure 3.3).

Therefore, FS6-12 as lunch and dinner menu of micronutrients showed Fe and Zn were high in FS11 amounts; Ca was high in FS10 for mineral amounts. Soluble vitamins in water showed B1, B6, B9, and C were high in FS6 amounts; B2 and B12 were high in FS9 amounts; B3 was high in FS10 amounts. Soluble vitamins in fat showed A and D were high in FS11 and FS10 amounts, respectively (Table 3.2; Figure 3.3).

Both consumers' age of Cambodia's traditional diets were met minimum nutrients for children and maximum nutrients for adults. Food for micronutrients in the proposed scenario was higher than in the existing scenario [11], [20].

Macronutrients consumed carbohydrate, protein, and fat that was equal to 112 g, 16-30 g, and 12-24 g of total calories per set 591-793 kcal. Micronutrients were Fe 4-12 mg, vitamin A 61-799 µg, B9 29-477 µg, vitamin C 24 g [3], [17], [30], [31].

Table 3.2. Food composition through food for macronutrients and micronutrient of food set.

Food set based on consumer's age*		Qty (g)	Food for Macronutrients				Food for Micronutrients											
							Mineral			Vitamin								
			Carbohydrate (g)	Protein (g)	Fat (g)	Calorie (kcal)	Zn (mg)	Ca (mg)	Fe (mg)	A (µg)	B1 (µg)	B2 (mg)	B3 (mg)	B6 (mg)	B9 (µg)	B12 (µg)	C (mg)	D (µg)
FS1	K1	205	46	12	9	328	1.9	80	2.2	115	0.2	0.2	2.1	0.2	44	0.4	23	5
	K2	335	84	23	13	559	3.5	123	4.1	208	0.3	0.3	4.0	0.4	88	0.6	31	6
FS2	K1	200	50	12	3	287	1.3	76	2.0	102	0.1	0.2	3.1	0.3	28	0.5	26	5
	K2	330	91	23	5	520	2.6	114	3.9	174	0.2	0.3	6.2	0.6	53	0.9	37	6
FS3	K1	205	50	10	9	330	1.2	75	1.8	114	0.2	0.2	2.3	0.3	26	0.5	23	12
	K2	335	91	20	11	562	2.3	113	3.3	204	0.4	0.3	4.3	0.5	52	0.8	31	23
FS4	K1	205	52	12	6	318	1.2	85	25.9	102	0.2	0.2	2.6	0.2	38	0.5	26	28
	K2	335	95	22	7	546	2.1	137	51.3	189	0.3	0.3	4.8	0.4	71	0.8	36	63
FS5	K1	200	50	12	4	291	1.0	70	1.7	80	0.1	0.2	3.9	0.3	27	0.3	24	5
	K2	330	92	23	7	529	1.7	102	3.1	125	0.2	0.3	8.1	0.6	51	0.5	33	5
FS6	K1	205	50	13	8	332	1.4	82	2.0	92	0.3	0.2	2.9	0.3	52	0.6	37	5
	K2	335	92	24	10	565	2.8	124	3.6	148	0.7	0.3	5.7	0.6	99	1.0	58	5
FS7	K1	200	48	11	3	271	1.0	88	1.4	84	0.1	0.1	2.3	0.3	14	0.5	19	28
	K2	330	88	20	4	486	1.9	144	2.4	153	0.2	0.2	4.2	0.5	24	0.8	23	63
FS8	K1	200	50	10	3	279	1.2	66	1.7	104	0.1	0.1	2.6	0.2	27	0.6	32	9
	K2	330	92	19	5	503	2.3	95	2.9	196	0.2	0.2	4.9	0.4	51	1.0	49	17
FS9	K1	205	51	10	11	349	1.2	74	2.3	39	0.1	0.3	2.2	0.2	17	0.7	20	7
	K2	335	93	18	17	608	2.3	110	4.3	44	0.2	0.4	4.0	0.4	30	1.4	26	11
FS10	K1	200	50	11	3	284	1.1	101	1.9	128	0.1	0.2	4.0	0.2	26	0.5	24	28
	K2	330	92	22	4	511	2.1	171	3.4	239	0.2	0.3	7.6	0.4	47	0.8	33	64
FS11	K1	200	48	12	3	284	1.4	92	2.9	172	0.1	0.2	3.2	0.3	39	0.5	27	5
	K2	330	88	24	5	513	2.6	147	5.7	315	0.2	0.4	6.4	0.5	75	0.9	39	6
FS12	K1	205	53	12	7	332	1.1	85	1.9	120	0.2	0.2	2.8	0.3	28	0.6	29	13
	K2	335	96	23	11	580	2.0	130	3.3	224	0.5	0.4	5.3	0.6	52	1.2	42	25
Average of one set	K1	202	50	11	6	307	1.3	82	3.6	105	0.2	0.2	2.8	0.3	30	0.5	26	13
	K2	332	91	22	8	540	2.3	127	6.8	186	0.3	0.3	5.5	0.5	57	0.9	37	25

*Food for macronutrient and micronutrients = Food composition of nutrition (Table 2.2) × 0.01× quantity of food set (Table 3.2).

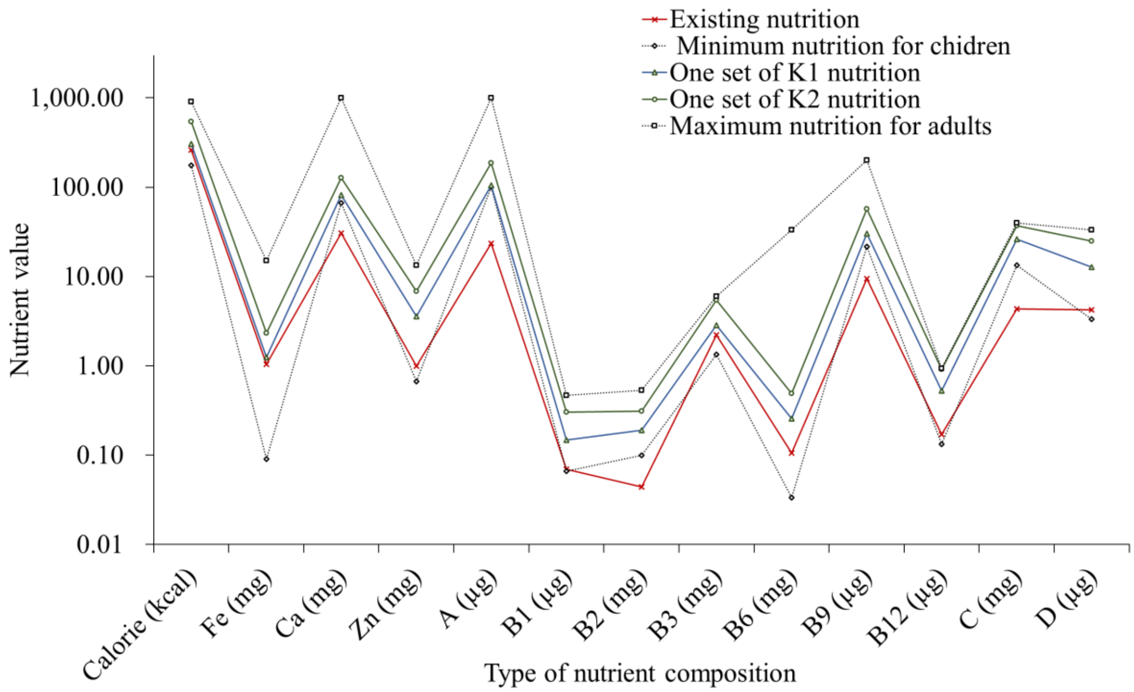

Figure 3.3. The existing and proposed (K1 and K2) scenarios of nutrient value and type of nutrient component through food set of macronutrients and micronutrients to associated on the requirements of minimum and maximum [3], [19], [20].

Macronutrients were identified by the physical movement and consumers' ages [20]–[22], [26], [27]. In a day, it was 1180-1825 kcal by 1-9 years and 950-1300 kcal by 1-5 years. The macronutrients were eaten by consumers' ages (6 to over 80) [21]. The maximum and minimum of micronutrients followed the guideline recommendation [45]. In Cambodia is a developing country, the fast-food is not well-known yet and the price was very expensive because some ingredients imported from other countries. They had preferred traditional food more than fast food. Therefore, 28% of emission was emitted from transportation [11], [20]. So, the consumers should utilize the local product to avoid import production and contribute to reducing the environmental impact based on the emission of transport. Therefore, SDG 2 is food hunger. This study was to minimize the amount of food consumption to fulfill nutrient intake. So, they could set the right amount of food need based on food for macronutrients and food for micronutrients requirement [46].

Table 3.3. Annually of item foods based on consumer's age to determine food needs per person and Cambodia to estimate the total of proposed food.

Item Foods based on consumer's age		Food needs per person (kg/yr)	Food needs in Cambodia (Mt/yr)	Total of Proposed Food (Mt/yr)
Rice	K1	43.80	0.17	1.18
	K2	87.60	1.01	
Rice noodle	K1	7.30	0.03	0.20
	K2	14.60	0.17	
Wheat	K1	3.65	0.01	0.10
	K2	7.30	0.08	
Fish	K1	21.8	0.08	0.52
	K2	38.06	0.44	
Pork	K1	3.86	0.01	0.13
	K2	9.65	0.11	
Chicken	K1	2.19	0.01	0.07
	K2	5.48	0.06	
Beef	K1	3.55	0.01	0.12
	K2	8.86	0.10	
Egg	K1	1.46	0.01	0.05
	K2	3.65	0.04	
Cooking oil	K1	2.66	0.01	0.04
	K2	2.66	0.03	
Vegetable	K1	54.75	0.21	1.48
	K2	109.50	1.27	
Fruit	K1	54.75	0.21	0.84
	K2	54.75	0.63	
Milk	K1	21.90	0.08	0.34
	K2	21.90	0.25	
Total	K1	221.66	0.85	5.06
	K2	364.01	4.21	

Annually of item foods through Cambodia's traditional diet on consumers' age were determined food needs per person and food needs for Cambodia to evaluate a total of proposed food. Existing food in Cambodia was produced 8.6 Mt/yr and proposed food for consumption was required 5.1 Mt/yr. Between existing food and proposed food showed rice and fish were met the requirement that proposed food of rice and fish required 1.18 Mt/yr and 0.52 Mt/yr. The total proposed food was required 0.37 Mt/yr of pork, chicken, beef, and egg that had 0.13 Mt/yr of pork, 0.07 Mt/yr of chicken, 0.12 Mt/yr of beef, and 0.05 Mt/yr of egg amounts. The existing food of pork, chicken, beef and egg were produced 62.16% which was equal to 0.23 Mt/yr, less production than food needs 37.84%. Therefore, vegetables and fruits were required 2.32 Mt/yr that had 1.48 Mt/yr of vegetable amounts, and 0.84 Mt/yr of fruit amounts (Figure 3.4; Table 3.3).

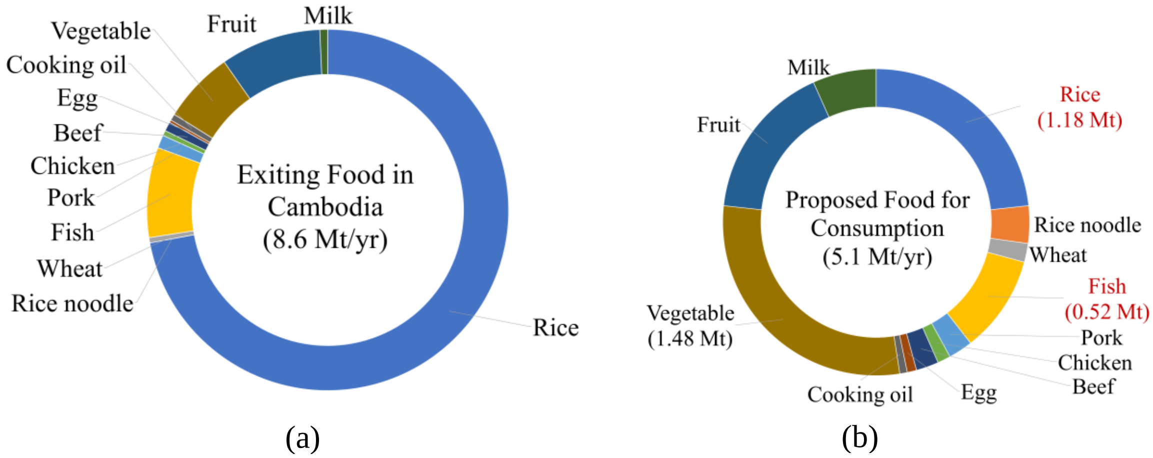

Figure 3.4. (a) Existing food in Cambodia [11], [14], and (b) proposed food for consumption to meet requirements of consumption amount.

In the rural region, the consumers aged 6-17 years old ate a lipid 14.4%, carbohydrate 74.6%, and protein 11% as macronutrient needs and urban region ate a lipid 17.4%, carbohydrate 70.5%, and protein 70.5% as macronutrient needs [20]. One yearly consumption of vegetables, fish, meat, and rice consumed 91 kg/person, 27 kg/person, 27 kg/person, and 300 kg/person [43].

The emission value of each food set based on consumers' ages showed an average of K1 and K2 was emitted 0.258 kg CO_2 eq/set and 0.451 kg CO_2 eq/set, respectively (Table 3.4). The result of total emissions emitted 6.9 Mt/yr of proposed food. Normal emissions were emitted on 0.9 Mt of FS2, 0.8 Mt of FS6, and 0.7 Mt of FS12. Therefore, FS11 emitted the highest emission 1.2 Mt CO_2 eq, and FS4 and FS5 emitted the lowest emission (Figure 3.5).

Table 3.4. SimaPro® calculated on carbon dioxide emission emitted through food set of consumers' ages.

Food Set based on Consumer's Age		Food for Macronutrients (kg)									Food for Micronutrients (kg)			Total (kg)
		Staple Food		Meat				Egg	Vegetable		Fruit	Calcium		
		Rice	Wheat	Fish	Pork	Chicken	Beef		Oil	VESP		Milk	Fish*	
FS1	K1	-	0.052	-	-	0.020	-	0.019	0.023	0.027	0.017	0.074	0.006	0.238
	K2	-	0.104	-	-	0.049	-	0.048	0.023	0.054	0.017	0.074	0.006	0.375
FS2	K1	0.043	-	-	-	-	0.265	-	-	0.027	0.017	0.074	0.006	0.432
	K2	0.086	-	-	-	-	0.661	-	-	0.054	0.017	0.074	0.006	0.898
FS3	K1	0.036	-	-	0.068	-	-	0.019	0.023	0.027	0.017	0.074	0.006	0.270
	K2	0.072	-	-	0.171	-	-	0.048	0.023	0.054	0.017	0.074	0.006	0.465
FS4	K1	0.043	-	0.024	-	-	-	-	0.023	0.027	0.017	0.074	0.006	0.214
	K2	0.086	-	0.060	-	-	-	-	0.023	0.054	0.017	0.074	0.006	0.320
FS5	K1	0.036	-	-	-	0.039	-	-	-	0.027	0.017	0.074	0.006	0.199
	K2	0.072	-	-	-	0.098	-	-	-	0.054	0.017	0.074	0.006	0.321
FS6	K1	0.036	-	0.012	0.068	-	-	-	0.023	0.027	0.017	0.074	0.006	0.263
	K2	0.072	-	0.030	0.171	-	-	-	0.023	0.054	0.017	0.074	0.006	0.447
FS7	K1	0.036	-	-	-	-	0.265	-	-	0.027	0.017	0.074	0.006	0.425
	K2	0.072	-	-	-	-	0.661	-	-	0.054	0.017	0.074	0.006	0.884
FS8	K1	0.036	-	0.024	-	-	-	-	-	0.027	0.017	0.074	0.006	0.184
	K2	0.072	-	0.060	-	-	-	-	-	0.054	0.017	0.074	0.006	0.283
FS9	K1	0.036	-	0.024	-	-	-	-	0.023	0.027	0.017	0.074	0.006	0.207
	K2	0.072	-	0.060	-	-	-	-	0.023	0.054	0.017	0.074	0.006	0.306
FS10	K1	0.036	-	0.024	-	-	-	-	-	0.027	0.017	0.074	0.006	0.184
	K2	0.072	-	0.060	-	-	-	-	-	0.054	0.017	0.074	0.006	0.283
FS11	K1	0.036	-	0.024	-	-	-	-	-	0.027	0.017	0.074	0.006	0.184
	K2	0.072	-	0.060	-	-	-	-	-	0.054	0.017	0.074	0.006	0.283
FS12	K1	0.036	-	-	0.137	-	-	-	0.023	0.027	0.017	0.074	0.006	0.320
	K2	0.072	-	-	0.342	-	-	-	0.023	0.054	0.017	0.074	0.006	0.588
Average of one set **	K1													0.258
	K2													0.451

* Fish was consumed for calcium that resourced from fish powder, boiling fish or roasted fish.

$^{**}CO_2$ eq (kg/kg) = Average of set (kg/set)/Quantity (kg);

CO_2 eq (kg/week) = average of set (kg/set) × 3 (set/day) × 7 (day).

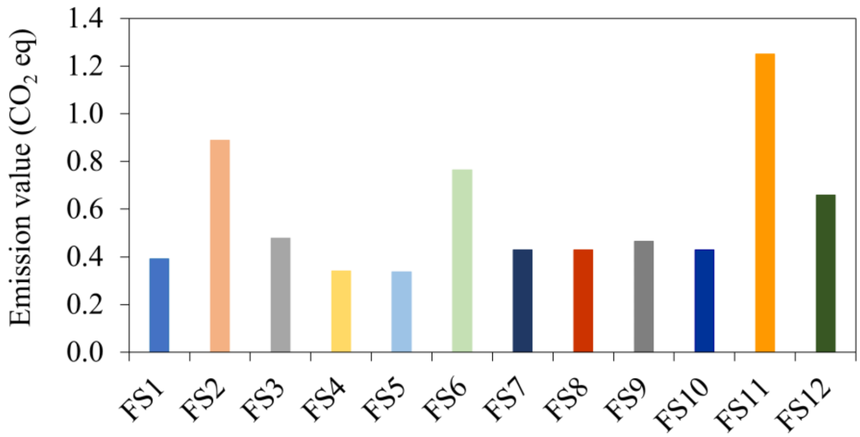

Figure 3.5. Emission value of each food set emitted per one year considered on CO_2 eq through food set emission multiplied by eating time and population.

Table 3.5. Food scenario from existing data and food scenario of proposed food set to calculate water and land use, and CO_2 eq emission.

Item Foods based on Consumer's Age	Food Scenario from Existing data			Food Scenario of Proposed Food Set		
	Water Use (Gt)	Land Use (Mha)	Emission (Mt CO_2 eq)	Water Use (Gt)	Land Use (Mha)	Emission (Mt CO_2 eq)
Wheat	0.02	0.11	0.06	0.06	0.26	0.10
Rice	13.88	2.79	5.24	2.66	0.53	0.85
Rice noodle	-	-	-	0.28	0.09	0.17
Fish	2.55	0.82	0.97	1.93	0.62	0.63
Pork	0.18	0.06	0.79	0.23	0.07	0.86
Chicken	0.03	0.03	0.12	0.05	0.06	0.14
Beef	0.10	0.02	1.05	0.17	0.03	1.53
Egg	0.01	0.04	0.05	0.03	0.08	0.09
Cooking oil	0.02	0.05	0.32	0.02	0.04	0.19
Vegetables and spices	0.06	0.04	0.46	0.15	0.12	0.80
Fruit	0.12	0.06	0.41	0.13	0.06	0.28
Milk	0.15	0.06	0.24	0.91	0.38	1.25
Total	17.12	4.06	9.70	6.78	2.33	6.89

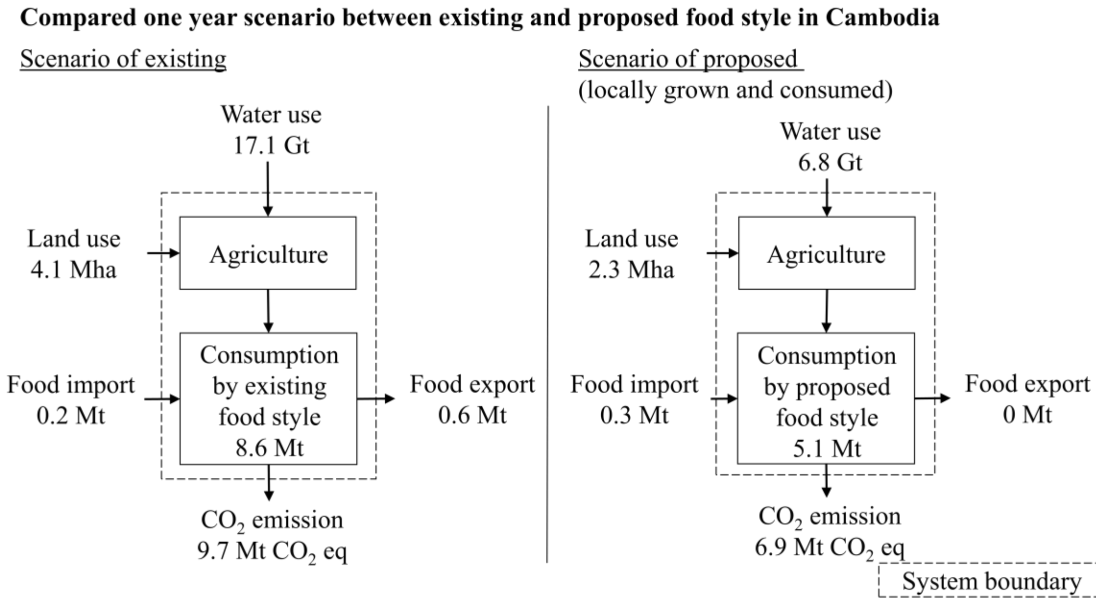

Figure 3.6. Compared one-year scenario for agricultural production between existing and proposed food styles in Cambodia to evaluate water use, land use, and emissions of CO_2.

A yearly comparison between existing and proposed styles in Cambodia showed scenario of existing on water use amounts were utilized 17.1 Gt of water, and land use amounts were occupied 4.1 Mha of land which required for agricultural production in existing. The proposed food on water use amounts was utilized 6.8 Gt of water and land use amounts were occupied 2.3 Mha of land which required for proposed food consumption [11], [14]. Between existing and proposed food, water and land use amounts lowered by 43.90% and 60.23%, respectively (Table 3.5; Figure 3.6). The existing food import amounts were lower than the proposed food import which imported milk and wheat to satisfy the demand of macronutrient and micronutrient amounts. Therefore, the existing food export was 0.6 Mt/yr (Figure 3.6). The proposed food export was zero Mt because this study was dedicated to food set consumption and encouraged the consumers to local production of utilization. To avoid CO_2 emissions rising, the farmers should sell their products in local areas and earn more income. The export products were used transport which emitted 28% of emission [10], [12].

The existing and proposed emitted total carbon dioxide emissions of 9.7 Mt CO_2 eq and 6.7 Mt CO_2 eq, respectively. Following the scenario of proposed were decreased by 28.87% of emission. Therefore, K1 and K2 of proposed in a week were emitted 5.42 kg CO_2

eq and 9.47 kg CO_2 eq, respectively (Table 3.4) to compare with the new Nordic and Mediterranean diets which were higher emissions than the proposed one. The CO_2 eq emitted 25.8 kg new Nordic diet of and 23.56 kg of the Mediterranean diet which determined by tap water, fruits, pasta, potatoes, oil, milk, egg, and beef [42]. The lowest emission was vegetables that emitted 0.37 kg CO_2 eq, the highest emission was beef that emitted 26.61 kg CO_2 eq. Cereal emitted 0.50 kg CO_2 eq; rice emitted 2.55 kg CO_2 eq; chicken emitted 3.65 kg CO_2 eq; pork emitted 5.77 kg CO_2 eq; fish emitted 3.49 kg CO_2 eq; egg emitted 3.46 kg CO_2 eq; butte emitted 9.25 kg CO_2 eq; fruit emitted 0.42 kg CO_2 eq; milk emitted 1.29 kg CO_2 eq, and so on [47]. Solid fat, cheese, and meat emitted 21%, 43%, and 21% of pizza emission which was 3.5 kg CO_2 eq [48]. 0.37 kg, 0.99 kg, and 1.09 emitted CO_2 eq through dairy, chicken homemade, meal ready, respectively [49]. Chicken homemade, meal ready, and tomato pasta were emitted low CO eq to compare proposed.

Emission emitted 3.2% of waste, industry 5.2%, land use and agriculture 18.4% and energy 73.2% and so on that total CO_2 eq 49.4 billion t. Land use for agriculture emitted 23% of the crop and 77% of dairy and meat [47]. 21.0 Mt agriculture, 30 Mt land use change and forestry, and forestry, 5.0 Mt transport, and 9.6 Mt other [10], [12] were emitted CO_2 eq in Cambodia. Methane and nitrous oxide were emitted 17.09 Mt and 89 Mt agriculture, 5.37 Mt and 1.88 Mt land use change and forestry, 2.8 Mt and 0.67 Mt other fuel combustion, 0.28 Mt and 0.26 Mt waste, and 0 Mt fugitive emission and industry, respectively [10], [12]. A 100-year horizon emitted 1.62 Mt CO_2 eq and 0.38 Mt CH_4 [13], [36], [44], [50], [51]. 0.45 Mt CH_4 of paddy field, 9.37 Mt CO_2 of paddy field, 0.18 Mt CH_4 of enteric emissions, and 3.74 Mt CO_2 eq of enteric emissions [11] were emitted in Cambodia.

In an examination through proposed and the existing scenarios were emitted 6.9 Mt CO_2 eq and 9.7 Mt CO_2 eq which reduced 28.87% of CO_2 emission. Reduction of water and land use was 60.23% and 43.90%. Macronutrient and micronutrient diets had met the standard of nutrient requirement.

3.4 Conclusions

Cambodia's traditional diets were studied on total food consumption. It was determined as food for macronutrients and micronutrients to qualify nutrient needs. Water and land use were decreased by 60.23% and 43.90% of the proposed scenario.

The assessment was performed using existing practices and the proposed scenario had food sets. 28.87% CO_2 eq amounts were cut off by following the proposed food.

A chance to decrease water, land use, and emission of proposed food set encountered for wellbeing as recommended nutrition. The usefulness of implementing a diet rich in Cambodian's traditional foods based on LCA to evaluate CO_2 emission reduction which was calculated on food for macronutrients and micronutrients.

Chapter 4 Food Nutrient Diet Consumption Using Cooking Energy to Study Carbon Dioxide Emission

4.1 Introduction

The energy of cooking is solid biomass to cook and heat eatable food. Food is the main resource of food calories, minerals, and vitamins that supports human health and well-being [52]. People use solid biomass (firewood or charcoal) or biogas energy for daily cooking food. Therefore, different types of cooking stoves and the energy source which it has led to a negative impact on human health and the environment [53]. The impact has dependent on the burning biomass of the ineffectiveness cookstove.

About 3 billion people use solid biomass for cooking with an inefficient and polluting stove [54]. 30% of the world's total energy consumption uses the food sector. Therefore, in low GDP countries, cooking energy consumes almost 45% and following by processing, and distribution [55]. Also, the significant amount of energy required to set in the links of the food chain, the food system is accountable for one-third of anthropogenic emissions of greenhouse gases (GHG) as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are related to climate change [35]. Therefore, the emission is emitted depending on the quantity and type of energy cooking per household consumption.

In Cambodia, a total of the household (HH) had 3.44 million households that had 5 members per HH. The household was divided into three different areas. The first area was the Phnom Penh area, it had 0.38 million HH. The second area was other urban which had 0.37 million HH. The thirst area was other rural that had 2.69 million HH. Most of the households in Cambodia was consumed firewood more than charcoal and LPG. Therefore, the household in rural areas was the highest firewood consumption (Figure 1) [38].

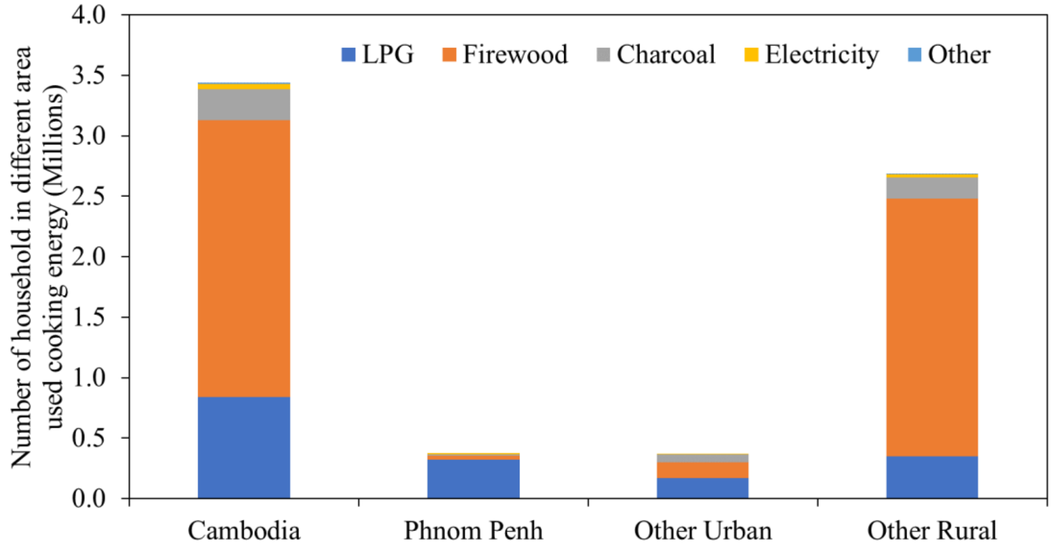

Figure 4.1. Household in a different area used cooking energy from varied resources as LPG, firewood, charcoal, electricity, and other in Cambodia [38].

The firewood was unclean solid biomass and caused significantly through human health and greenhouse gas (GHG) that affected by incomplete combustion and exposure to smoke from the type of biomass and stove [56], [57], [33]. Incomplete combustion and exposure smoke were emitted carbon monoxide (CO), particulate matter 2.5 (PM 2.5), carbon dioxide equivalent (eq) emissions. The people in the world and Cambodia access 59.4%, and 17.7% of clean cooking fuel, respectively, and 40.5%, and 82.3 of without access to clean fuel, respectively [58].

The objective of the study is aimed to estimate carbon monoxide and particulate matter 2.5, and carbon dioxide equivalent emissions. The emission of CO and PM 2.5 were calculated through firewood, charcoal, and liquefied petroleum gas (LPG) consumption per household in a day. The emission of carbon dioxide equivalent was calculated in the whole country of Cambodia by using Intergovernmental Panel on Climate Change (IPCC) method that converted from emission factors of carbon dioxide, methane, and nitrous oxide. This study was selected three types of energy cooking as LPG, firewood, and charcoal.

4.2 Materials and Methods

4.2.1 Food Menu in Cambodia

In Cambodia, many kinds of food menus are available for consumption as hot pot (soup), stew, stir-fry, roast, or toasting [7], [16]. The food menus have consisted of each food item that it had basic food, meat, egg, and vegetables to fulfill the nutrient requirement as calorie food, vitamins, and minerals. This study was selected 12 (FS1-12) menus that FS1-5 and FS6-12 defined as breakfast, lunch, and dinner. FS1: Khmer sandwich; FS2: beef noodle soup; FS3: fried pork and egg with rice; FS4: Khmer fish (striped snakehead) noodle soup; FS5: chicken congee; FS6: pork stir-fry beansprouts; FS7: fish (striped snakehead) and water lily sour soup; FS8: tomatoes and braised fish (Siamese mud carp); FS9: fried fish (striped catfish) and ginger; FS10: samlor brahaer Khmer stew with fish (striped snakehead); FS11: beef lemongrass sour soup; FS12: samlor kako Khmer stew with fish (catfish), pork, and coconut milk. The food menu is cooked with LPG, firewood, and charcoal. Most of the households have relied on firewood more than charcoal and LPG. The firewood is cheaper, but it is unclean biomass for cooking.

4.2.2 Energy Use for Cooking in Cambodia

In Cambodia, the energy is used to cook food that is solid biomass (firewood and charcoal) and gas (LPG). The amount of firewood, charcoal, and LPG is consumed depended on stove type, the quantity of food, and household members. Both charcoal and LPG were clean energy. The firewood is unclean energy, it is carefully used with stove type (traditional stove, improved cookstove, African clean energy, or new Lao stove) on the unclean stove and clean stove. The unclean stove is a traditional Cambodia stove that consumed 2.9 kg/day of wood or 1.4 kg/day of charcoal (Table 1). The clean stove is an improved cooking stove (ICS), African clean energy (ACE), new Lao stove, or gas stove that ICS is consumed 2.0 kg/day of wood or 1.1 kg/day of charcoal. A gas stove is consumed 1.3 kg/day of biogas [59]–[61].

Table 4.1. LPG, firewood, and charcoal consumption per household through control and scenario consumption in Cambodia [61], [62].

Consumption per household		LPG (kg/day)	Firewood (kg/day)	Charcoal (kg/day)	Ref.
Control*	C1	1.30	2.90	1.40	[61]
	C2 (Existing)	0.85[1]*	2.00	1.10	[59], [61], [62]
Scenario[2]*	S1 (75% of C1)	0.98	2.18	1.05	
	S2 (50% of C1)	0.65	1.45	0.70	
	S3 (25% of C1)	0.33	0.73	0.35	
Average = S1+S2+S3 (Proposed)		0.65	1.45	0.70	

* Control had two options as control 1 (C1) and control 2 (C2). C1 and C2 were used traditional cooking stove and improved cooking stove, respectively that consumed by firewood and charcoal.
[1]* LPG consumption has calculated the average between C1 [61] and FAO consumption [62].
[2]* Scenario was a method to reduce consumption of LPG, firewood, and charcoal. The scenario consumption was equal to the amount of C1 multiply reduction percent and divided 100. Divided into three scenarios (S1-3).

This study has selected three kinds of energy cooking as LPG, firewood, and charcoal for cooking food items. Amount of LPG, firewood, and charcoal consumption were consumed by members of the household (HH) and available resources. The household consumption was separated into two sections as two controls (C1, and C2) and three scenarios (S1-3). The C1 and C2 were applied traditional cooking stove and improved cooking stove, respectively. The three scenarios were calculated to depend on the C1 multiply with the percentage of scenario requirement and divided 100 (Table 1). The C1 and three scenarios were calculated for carbon monoxide and particulate matter 2.5 emissions. Therefore, the carbon dioxide equivalent emission was calculated by C2 which was an existing scenario. A proposed scenario was defined by the average of S1, S2, and S3.

4.2.3 Calculation of Emission of Carbon Monoxide, Particulate Matter 2.5, and Carbon Dioxide

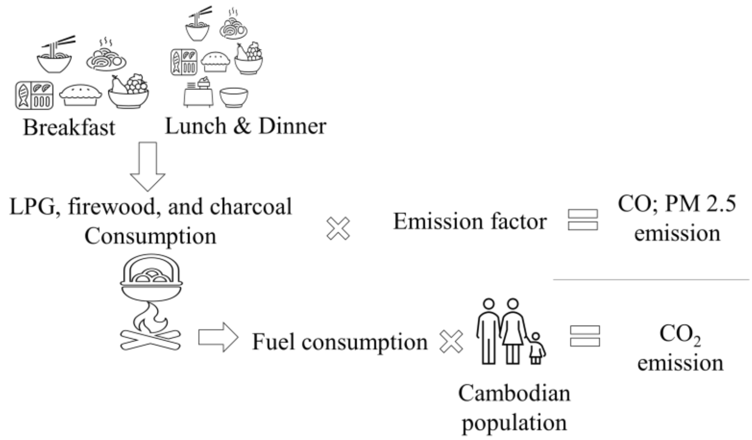

Figure 4.2. LPG, firewood, and charcoal consumption to estimate CO, PM 2.5, and CO_2 eq emissions.

Figure 2 illustrates the study on carbon monoxide (CO), particulate matter 2.5 (PM 2.5), and carbon dioxide equivalent (CO_2 eq) emission through LPG, firewood, and charcoal consumption during household cooking the food. The CO emission factor of LPG, firewood, and charcoal was 0.4 g/kg, 113.0 g/kg, and 46.0 g/kg, respectively. The PM 2.5 emission factor of LPG, firewood, and charcoal were 2.0 g/kg, 12.0 g/kg, and 4.3 g/kg, respectively (Table 2).

Table 4.2. Emissions factor of carbon monoxide (CO) and particulate matter (PM) 2.5.

Emission factor		LPG (g/kg)	Firewood (g/kg)	Charcoal (g/kg)	Ref.
Carbon monoxide	EF_{CO}	0.42	113.00	46.00	[63]
Particulate matter 2.5	$EF_{PM2.5}$	2.00	12.00	4.30	[63]

The emission of CO and PM 2.5 were calculated to depend on LPG, firewood, and charcoal consumption (Table 1) multiply with emission factor (Table 2) by using equation formula (1). This formula was used to calculate the CO and PM 2.5 emission.

$$E = EC_{Cons} \times EF \text{ (Table 1)} \quad (1)$$

Where E = emission of CO or PM 2.5 (g/day)

EC_{Cons} = energy cooking of LPG, firewood, or charcoal consumption (kg/day)

EF = emission factor of CO or PM 2.5 (g/kg)

Therefore, CO_2 eq emission was equal to fuel consumption multiply by total population (Figure 2). The CO_2, methane (CH_4), and nitrous oxide (N_2O) emissions were contented in fuel consumption. The fuel consumption was equal to LPG, firewood, and charcoal consumption multiply by heating value.

The CO_2 eq was compared between the existing and proposed scenarios. The existing scenario of LPG, firewood, and charcoal consumption were 0.9 kg/day, 2.0 kg/day, and 1.1 kg/day, respectively [59], [61], [62]. Therefore, the proposed scenario was consumed 0.7kg/day of LPG, 1.45 kg/day of firewood, and 0.7 kg/day of charcoal (Table 1).

Table 4.3. LPG, firewood, and charcoal consumption, heat value, fuel consumption, and the emission factor of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

	Unit		LPG	Firewood	Charcoal	Ref.
Existing scenario	kg/day	EC_{Cons}	0.85	2.00	1.10	(Table 1)
Proposed scenario	kg/day		0.65	1.45	0.70	(Table 1)
Number of household size	person	N_{size}	4.6	4.6	4.6	[38]
Mass consumption person	kg/yr	M_{Cons}				
Heating value	MJ/kg	H_{Val}	47.3	15.6	29.6	[65]
Fuel consumption	TJ/yr	F_{Cons}				
Emissions factor of carbon dioxide	kg/TJ	EF_{CO_2}	63,070	11,833	11,833	[65]
Emissions factor of methane	kg/TJ	EF_{CH_4}	5	300	200	[65]
Emissions factor of nitrous oxide	kg/TJ	EF_{N_2O}	0.1	4	1	[65]

The emission of the CO_2 eq was emitted according to the type and quantity of LPG, firewood, and charcoal consumption. Formular had calculated mass and fuel consumption of energy cooking and analyzed carbon dioxide emission equivalent from emission factor of CO_2, CH_4, and N_2O (Table 3).

Mass consumption calculation:

$$M_{Cons} = \frac{EC_{Cons}}{N_{size}} \times 365 \quad (2)$$

Where M_{Cons} = mass consumption (kg/yr)

EC_{Cons} = energy cooking of LPG, firewood, or charcoal consumption (kg/day)

Fuel consumption calculation:

$$F_{Cons} = M_{Cons} \times H_{Val} \times 10^{-6} \quad (3)$$

Where F_{Cons} = fuel consumption (TJ/yr)

M_{Cons} = mass consumption (kg/yr)

H_{Val} = heating value of LPG, firewood, or charcoal consumption (MJ/kg)

Emission CO_2 eq calculation:

$$E_{CO_2}eq = F_{Cons} \times \left[\left(EF_{CO_2} \times 1\right) + \left(EF_{CH_4} \times 25\right) + \left(EF_{N_2O} \times 298\right)\right] \quad (4)$$

Where $E_{CO_2}eq$ = emission CO_2 eq (kg/yr)

F_{Cons} = fuel consumption (TJ/yr)

EF_{CO_2} = emission CO_2 (kg/TJ)

EF_{CH_4} = emission CO_2 (kg/TJ)

EF_{N_2O} = emission CO_2 (kg/TJ)

Total CO_2 eq emission depending on the quantity of use and type of biomass.

4.3 Results and Discussion

The results of carbon monoxide and particulate matter 2.5 emission in firewood were emitted higher than charcoal and LPG. The control 1 of firewood was emitted 327.7 g CO/day and 34.8 g PM 2.5/day. Therefore, LPG was emitted 0.6 g CO/day, and 2.6 g PM 2.5/day. Moreover, the average scenario in LPG, firewood, and charcoal had emitted CO and PM 2.5. The charcoal was emitted 31.8 g CO/day and 8.3 g PM 2.5/day (Table 4; Figure 3).

Table 4.4. CO, and PM 2.5 emissions emitted in LPG, firewood, and charcoal consumption.

	LPG (g/day)		Firewood (g/day)		Charcoal (g/day)	
	CO	**PM 2.5**	**CO**	**PM 2.5**	**CO**	**PM 2.5**
Control 1	0.55	2.60	327.70	34.80	64.40	16.80
Control 2	0.36	1.70	226.00	24.00	50.60	13.20
Scenario 1	0.41	1.95	245.78	26.10	48.30	12.60
Scenario 2	0.27	1.30	163.85	17.40	32.20	8.40
Scenario 3	0.14	0.65	36.73	3.90	14.95	3.90
Average	0.27	1.30	148.78	15.80	31.82	8.30

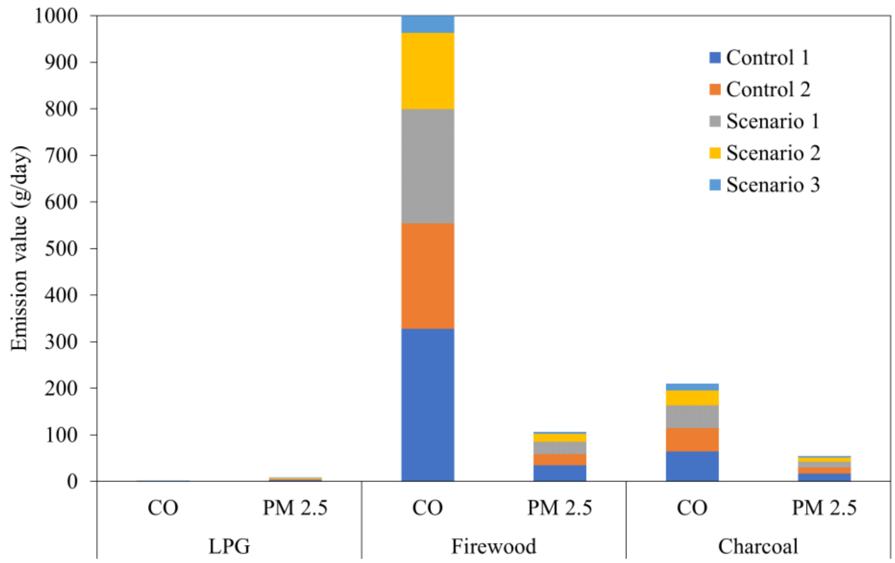

Figure 4.3. Value of CO and PM 2.5 emission emitted per household in a day by using LPG, firewood, and charcoal for cooking.

The CO_2 eq emission was calculated in both existing and proposed scenarios. The result of emission was emitted according to a person and country emission (Table 5).

Table 4.5. Total CO_2 eq emission compared with existing and proposed scenarios based on LPG, firewood, and charcoal.

		Person				Cambodia			
	Consumption (%)	Emission (kg CO_2 eq)		Total emission* (kg CO_2 eq)		Emission (Mt CO_2 eq)		Total emission* (Mt CO_2 eq)	
		Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
LPG	24.4	201.7	154.2	49.2	37.6	0.778	0.595	1.90	0.145
Firewood	66.7	50.8	36.8	33.9	24.6	0.535	0.388	0.357	0.259
Charcoal	9.0	44.3	28.2	4.0	2.5	0.063	0.040	0.006	0.004

*Total emission was equal to emission multiply with consumption (%)

The CO_2 eq in person by proposed and existing scenario were emitted 65 kg CO_2 eq and 87 kg CO_2 eq that existing was equal to 49 kg CO_2 eq of LPG, firewood, and charcoal were emitted, 34 kg CO_2 eq, and 4 kg CO_2 eq, and proposed was 38 kg CO_2 eq of LPG, 25 kg CO_2 eq of firewood, and 3 kg CO_2 eq of charcoal, respectively (Figure 4). Reducing 25.3% of the CO_2 eq emission by the person.

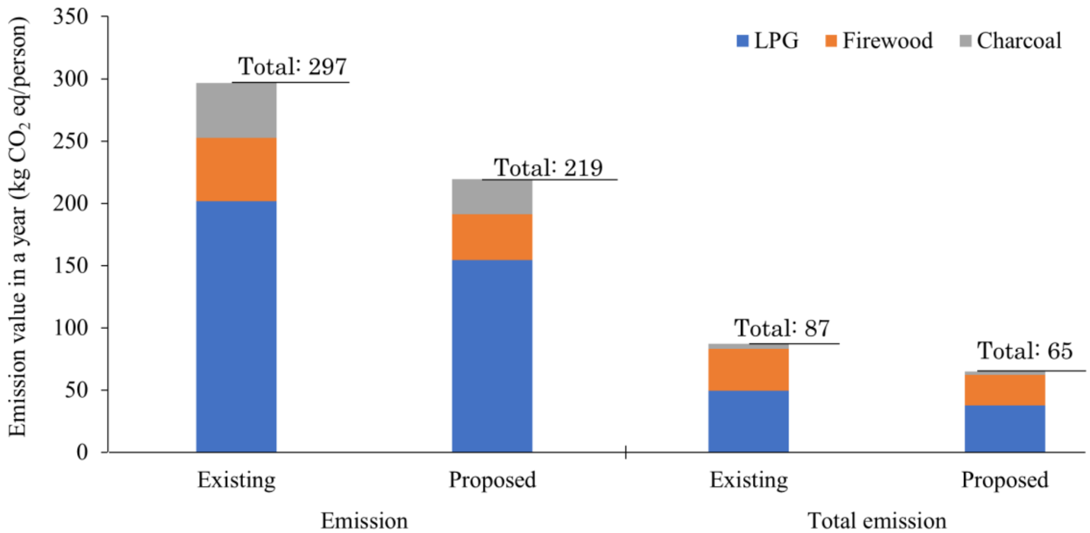

Figure 4.4. Total emission emitted per one person based on existing and proposing scenarios according to the quantity of energy use.

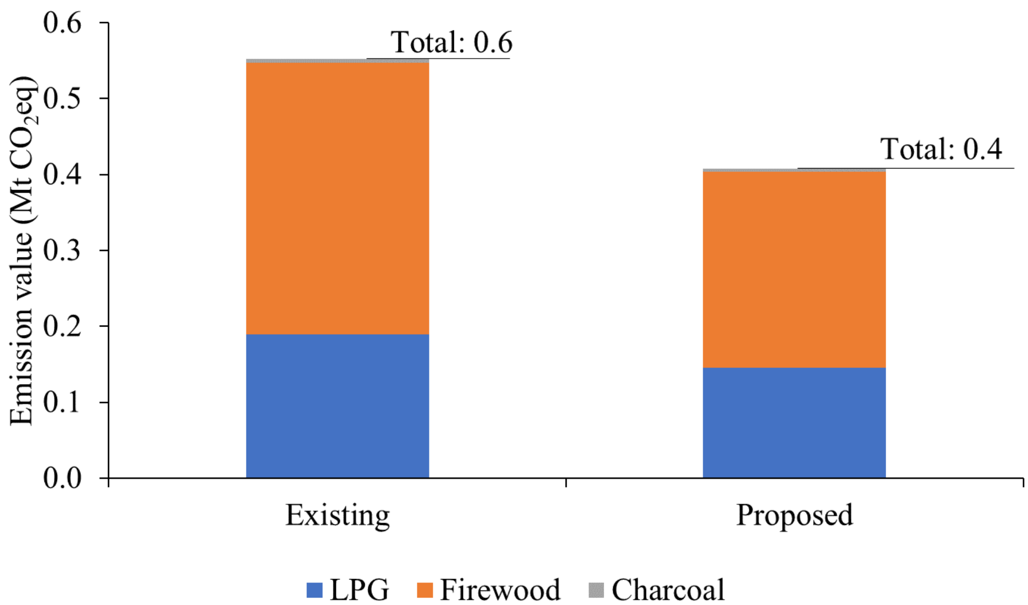

Figure 4.5. Annual total carbon dioxide emission emitted in Cambodia by LPG, firewood, and charcoal use.

The carbon dioxide emission of annual Cambodia based on the existing and proposed was emitted 0.6 Mt CO_2 eq, and 0.4 Mt CO_2 eq, respectively. Both existing and proposed LPG, charcoal, and firewood emission was 0.190 Mt CO_2 eq, 0.357 Mt CO_2 eq, and 0.006 Mt CO_2 eq, respectively, and 0.145 Mt CO_2 eq, 0.259 Mt CO_2 eq, and 0.004 Mt CO_2 eq, respectively (Table 5; Figure 5).

Figure 4.6. the emission of Cambodia country, the result showed that the total was 0.41 Mt CO_2 eq which was from LPG 0.1 Mt CO_2 eq, firewood 0.3 Mt CO_2 eq, and charcoal 0.04 Mt CO_2 eq. Therefore, the emission emitted from Phnom Penh, other urban, and rural areas according to LPG, charcoal, and firewood. In Phnom Penh areas, LPG, charcoal, firewood emitted 0.04 Mt CO_2 eq, 0.004 Mt, 0.003 Mt, respectively. In other urban and rural areas, LPG, charcoal, and firewood were 0.02 Mt CO_2 eq, 0.02 Mt CO_2 eq, 0.01 Mt CO_2 eq, respectively, and 0.04 Mt CO_2 eq, 0.25 Mt CO_2 eq, ad 0.02 Mt CO_2 eq, respectively (Figure 6).

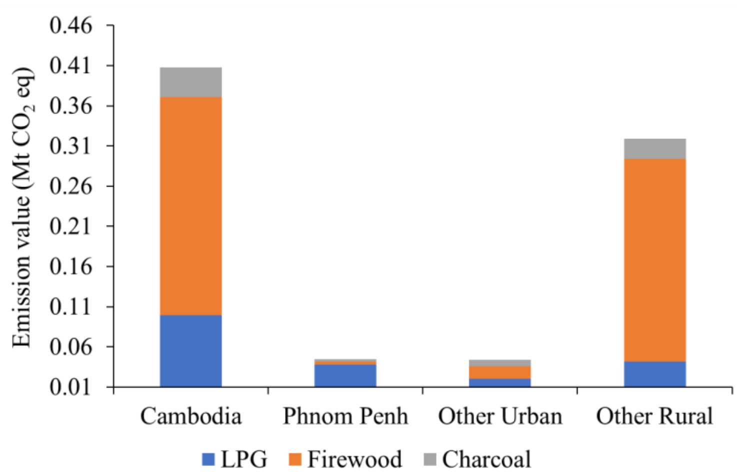

Figure 4.6. Total emission in different areas by LPG, firewood, and charcoal use in Cambodia.

Firewood was consumed 5.21 kg/day/family for cooking and 2.82 kg/day/family for boiling the water [66]. According to the World Health Organization reported women and children under 5 years old that was death caused by air pollution due to inefficient biomass combustion [54], [67]. Therefore, in Cambodia was used unclean biomass and inefficient cooking stove that caused air pollution [38]. The firewood and charcoal were emitted CO 19-136 g/kg, and 1560-1620 g/kg, respectively [68]. The air quality of WHO guidelines of PM 2.5 for 24-hour was 25 $\mu g/m^3$ and annual was 10 $\mu g/m^3$ which Cambodia was 22.1 $\mu g/m^3$ of ambient PM 2.5 concentration. Therefore, in the kitchen was emitted 183 $\mu g/m^3$ of PM2.5 of the traditional cooking stove, 111 $\mu g/m^3$ of ACE, and 35 $\mu g/m^3$ of biogas. Personal exposure was emitted 66 $\mu g/m^3$ of the traditional cooking stove, 47 $\mu g/m^3$ of ACE stove, 28 $\mu g/m^3$ of biogas [61]. The respiration illness was related to solid biomass users and ambient PM 2.5 was linked to malnutrition as stunting [54].

4.4 Conclusions

The emission is occurred by the quantity of use and type of biomass. Biomass as LPG, firewood, and charcoal is accounted for CO, PM 2.5, and CO_2 eq emission through the quantity of energy cooking. The firewood was emitted the highest emission of CO, and PM 2.5 through the traditional cooking stove. The following proposed scenario was reduced CO_2 eq 33.3% of emission. The charcoal CO_2 eq emission was 0.004 Mt CO_2 eq. The LPG CO_2 eq emission was 0.145 Mt CO_2 eq, and the firewood CO_2 eq emission was 0.259 Mt CO_2 eq. However, the source of cooking was affected by the health condition, the household had used in different types of source cooking. Most households in rural areas had used unclean cooking as firewood that emitted CO, PM 2.5, and CO_2 eq emission. These emissions were the main cause to household's health such as respiration, eye, nose, etc.

Chapter 5 General Conclusions

Quantity and type of foods were considered on environmental impact. Activities of food production, food consumption, and cooking food that revered to climate change through carbon dioxide emission. Cambodia's traditional diet was studied on the size of dishes of food for macronutrients and micronutrients. The greenhouse gas emission occurred depending on the quantity and type of food consumption, and the energy of cooking.

In chapter 3, the food consumption in the proposed scenario, the water, and land use requirements were used by 60.23% and 43.90%, respectively that reduced water used and land use compared to the existing scenario of food for macronutrients and micronutrients. The assessment was performed using existing practices and the proposed scenario was set as FS1-12. In the proposed scenario, the food macronutrients and micronutrients fulfilled the recommended nutrition. The carbon dioxide emissions for the traditional Cambodian food set were decreased by 28.87%.

Chapter 4, firewood with the traditional cooking stove was emitted the highest CO and PM 2.5 than charcoal and LPG. Therefore, in 100 horizons of global warming potential (GWP) in person, LPG, firewood, and charcoal emissions of the existing and proposed scenario were emitted 49.2 kg CO_2 eq, 33.9 kg CO_2 eq, and 4 kg CO_2 eq, respectively that compared the proposed scenario were LPG 37.6 kg CO_2 eq, firewood 24.6 kg CO_2 eq, and charcoal 2.5 kg CO_2 eq. Reducing of cooking emission was 25.66% from 87.08 kg CO_2 eq to 64.73 kg CO_2 eq according to the person cooking. Therefore, country emission was emitted depending on existing and proposed scenarios that emitted 0.55 Mt CO_2 eq and 0.41 Mt CO_2 eq, respectively. Reducing of emissions 26.22%.

In conclusion, the food for macronutrients and micronutrients encountered by the size of dishes needs to consider for recommended nutrition. A chance to decrease water, land use, and emission of proposed food set encountered for wellbeing as recommended nutrition. The usefulness of implementing a diet rich in Cambodian's traditional foods based on LCA to evaluate CO_2 emission reduction which was calculated on food for macronutrients, micronutrients, and cooking energy.

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Appendix

Table A1. Illustration of food supply balanced with food demand plus others and equal to food production and import excluding export (existing data) [11], [14].

Food item	Production (Mt)	Demand (Mt)	Supply (Mt)	Import (Mt)	Export (Mt)	Other (Mt)
Wheat	-	0.04	0.04	0.03	-	0.01
Rice	6.62	2.44	6.11	0.06	0.51	3.73
Rice noodle	-	-	-	-	-	-
Fish	0.72	0.54	0.69	0.00	0.03	0.15
Pork	0.10	0.09	0.10	0.00	-	0.01
Chicken	0.03	0.04	0.04	0.01	-	0.00
Beef	0.07	0.07	0.07	0.00	-	0.00
Egg	0.02	0.02	0.02	-	-	0.00
Milk	0.03	0.05	0.06	0.03	-	0.00
Fruit	0.73	0.68	0.77	0.06	0.01	0.09
Cooking oil	0.07	0.04	0.05	0.01	0.04	0.01
Vegetable	0.54	0.49	0.54	0.00	0.00	0.06
Total	8.93	4.50	8.49	0.21	0.59	4.06

Note: (Production + Import)—Export = (Demand + Other); Demand + Other = Supply; "Other" meant for other use purposes as processing, feed, seed, stock, and non-food.

Table A2. Summary about inventory data of agriculture production from plant and animal resources.

Inventory Data	Food Items
Table A3.	Total rice production from paddy resources
Table A4.	Total rice noodle production from paddy resources
Table A5.	Total wheat production (import basis)
Table A6.	Total beef production on raising animals
Table A7.	Total production of milk on raising animals
Table A8.	Total production chicken on raising animals
Table A9.	Total production egg on raising animals
Table A10.	Total production pork on raising animals
Table A11.	Total production fish on raising fish
Table A12.	Total production cooking oil on cultivated plants
Table A13.	Total production vegetable based on cultivated plants
Table A14.	Total production fruit based on cultivated plants

Table A3. Cultivated paddy for production rice inventory data.

Input (Rice)		Qty	Ref.
Paddy production (Mt)	$P_{Prod} = \frac{100}{64} \times RI_{Prod}$	1.84	[14]
Rice production (Mt)	$RI_{Prod} = RI_{Cons}$	1.18	
Rice consumption (Mt)	RI_{Cons}	1.18	Table 3.4
Paddy yield (Mt/Mha)	P_Y	3.45	[11], [14]
Land use (Mha)	$L_{Use} = \frac{P_{Prod}}{P_Y}$	0.53	
Compost fertilizer (N-P-K) requirement (Mt)	$CF_R = 10 \times L_{Use}$	5.34	[14]
DAP fertilizer requirement (Mt)	$DF_R = 0.24 \times L_{Use}$	0.13	[14]
Urea fertilizer requirement (Mt)	$UF_R = 0.25 \times L_{Use}$	0.13	[14]
Water use of product* (Gt)	$W_R = 2.25 \times RI_{Prod}$	2.65	[47]
Emission factor (Mt CH_4/Mha)	EF	0.1561	[51]
Output (Rice)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = L_{Use} \times EF$	0.08	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{RICO_2\,eq}$	0.717	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = RI_{Prod} \times E_{RICO_2\,eq}$	0.85	Table 3.6

* Rice production.

Table A4. Total production of rice noodle on cultivated paddy. inventory data

Input (Rice Noodle)		**Qty**	**Ref.**
Paddy production (Mt)	$P_{Prod} = \frac{100}{64} \times RI_{Prod}$	0.12	[14]
Rice production (Mt)	$RI_{Prod} = \frac{1}{2.5} \times RN_{Prod}$	0.08	
Rice noodle production (Mt)	$RN_{Prod} = RN_{Cons}$	0.20	
Rice noodle consumption (Mt)	RN_{Cons}	0.20	Table 3.4
Paddy yield (Mt/Mha)	P_Y	3.45	[11], [14]
Land use (Mha)	$L_{Use} = \frac{P_{Prod}}{P_Y}$	0.04	
Compost fertilizer (N-P-K) requirement (Mt)	$CF_R = 10 \times L_{Use}$	0.36	[14]
DAP fertilizer requirement (Mt)	$DF_R = 0.24 \times L_{Use}$	0.01	[14]
Urea fertilizer requirement (Mt)	$UF_R = 0.25 \times L_{Use}$	0.01	[14]
Water use of product* (Gt)	$W_R = 2.25 \times RI_{Prod}$	0.18	[47]
Emission factor (Mt CH_4/Mha)	EF	0.1561	[51]
Output (Rice noodle)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = L_{Use} \times EF$	0.01	
Emission as CO_2 eq using SimaPro® (Mt/Mt product**)	$E_{RNCO_2\,eq}$	0.861	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = RN_{Prod} \times E_{RNCO_2\,eq}$	0.17	Table 3.6

* Rice production; ** Rice noodle production.

Table A5. Import production wheat inventory data.

Input (Wheat)		Qty	Ref.
Wheat production (Mt)	$WH_{Prod} = BR_{Cons}$	0.10	
Bread production (Mt)	$BR_{Prod} = BR_{Cons}$	0.10	
Bread consumption (Mt)	BR_{Cons}	0.10	Table 3.4
Land use of product* (Mha)	$L_{Use} = 0.385 \times WH_{Prod}$	0.05	[47]
Water use of product* (Gt)	$W_{WH} = 0.648 \times WH_{Prod}$	3.46	[47]
Emission factor (Mt CH_4/Mha)	EF	0.1561	[51]
Output (Wheat)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = L_{Use} \times EF$	0.01	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{WHCO_2\,eq}$	0.040	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = WH_{Prod} \times E_{WHCO_2\,eq}$	0.10	Table 3.6

* Wheat production.

Table A6. Beef production on raising animal inventory data.

Input (Beef)		Qty	Ref.
Beef consumption (Mt)	$BE_{Prod} = BE_{Cons}$	0.12	
Beef consumption (Mt)	BE_{Cons}	0.12	Table 3.4
Cattle carcass weight (Mt/head)	CA_{CW}	1.20 x10^{-7}	[11], [14], [44]
Land use of product * (Mt)	$L_{Use} = 4.324 \times BE_{Prod}$	0.05	[47]
Quantity of animal (million head)	$QA_{CAB} = \frac{BE_{Prod}}{CA_{CW}}$	0.97	
Feed requirement of product* (Mt)	$CABF_R = 2.5 \times BE_{Prod}$	0.29	[47]
Water use of product* (Gt)	$W_{BE} = 1.451 \times BE_{Prod}$	0.17	[47]
Enteric fermentation (Mt CH_4/head/yr)	EF_{ECAB}	4.70×10^{-8}	[44], [51]
Manure management (Mt CH_4/head/yr)	EF_{MCAB}	1.00×10^{-9}	[44], [51]
Output (Beef)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = QA_{CAB} \times (EF_{ECAB} + EF_{MCAB})$	0.05	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{BECO_2\,eq}$	13.200	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = BE_{Prod} \times E_{BECO_2\,eq}$	1.53	Table 3.6

* Beef production.

Table A7. Milk production on raising animal inventory data.

Input (Milk)		Qty	Ref.
Milk production (Mt)	$MI_{Prod} = MI_{Cons}$	0.38	
Milk consumption (Mt)	MI_{Cons}	0.308	Table 3.4
Milk yield (Mt/head)	MI_Y	1.65×10^{-6}	[11], [14], [44]
Land use of product* (Mt)	$L_{Use} = 0.895 \times MI_{Prod}$	0.34	[47]
Quantity of animal (million head)	$QA_{CAB} = \frac{MI_{Prod}}{MI_Y}$	0.23	
Feed requirement of product*(Mt)	$CAMF_R = 2.5 \times MI_{Prod}$	0.95	[47]
Water use of product* (Gt)	$W_{CAM} = 2.714 \times MI_{Prod}$	1.03	[47]
Enteric fermentation (Mt CH_4/head/yr)	EF_{ECAM}	6.8×10^{-8}	[44], [51]
Manure management (Mt CH_4/head/yr)	EF_{MCAM}	3.1×10^{-8}	[44], [51]
Output (Milk)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = QA_{CAM} \times (EF_{ECAM} + EF_{MCAM})$	0.02	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{MICO_2\,eq}$	3.710	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = MI_{Prod} \times E_{MICO_2\,eq}$	1.41	Table 3.6

* Milk production.

Table A8. Chicken production on raising animal inventory data.

Input (Chicken)		Qty	Ref.
Chicken consumption (Mt)	$CK_{Prod} = CK_{Cons}$	0.07	
Chicken consumption (Mt)	CK_{Cons}	0.07	Table 3.4
Chicken carcass weight (Mt/head)	CK_{CW}	1.14×10^{-9}	[11], [14]
Land use of product* (Mt)	$L_{Use} = 1.222 \times CK_{Prod}$	0.09	[47]
Quantity of animal (million head)	$QA_{CK} = \frac{CK_{Prod}}{CK_{CW}}$	63.07	
Feed requirement of product* (Mt)	$CKF_R = 1.80 \times CK_{Prod}$	0.13	[47]
Water use of product* (Gt)	$W_{CK} = 0.660 \times CK_{Prod}$	0.05	[47]
Enteric fermentation (Mt CH_4/head/yr)	EF_{ECK}	0	[44], [51]
Manure management (Mt CH_4/head/yr)	EF_{MCK}	2×10^{-11}	[44], [51]
Output (Chicken)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = QA_{CK} \times (EF_{ECK} + EF_{MCK})$	0.001	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{CKCO_2\,eq}$	1.950	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = CK_{Prod} \times E_{CKCO_2\,eq}$	0.150	Table 3.6

* Chicken production.

Table A9. Egg production on raising animal inventory data.

Input (Egg)		Qty	Ref.
Egg production (Mt)	$EG_{Prod} = EG_{Cons}$	0.05	
Egg consumption (Mt)	EG_{Cons}	0.05	Table 3.4
Egg weight (98 eggs = 4.878 kg) (Mt/head)	EG_W	4.88×10^{-9}	[11], [14]
Land use of product* (Mt)	$L_{Use} = 0.627 \times EG_{Prod}$	0.03	[47]
Quantity of animal (million head)	$QA_{CKEG} = \frac{EG_{Prod}}{EG_W}$	9.80	
Feed requirement of product* (Mt)	$CKEGF_R = 2.20 \times EG_{Prod}$	0.11	[47]
Water use of product* (Gt)	$W_{EG} = 0.578 \times EG_{Prod}$	0.03	[47]
Enteric fermentation (Mt CH_4/head/yr)	EF_{ECK}	0	[44], [51]
Manure management (Mt CH_4/head/yr)	EF_{MCK}	2×10^{-11}	[44], [51]
Output (Egg)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = QA_{CKEG} \times (EF_{ECK} + EF_{MCK})$	1.96×10^{-4}	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{EGCO_2\,eq}$	1.900	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = EG_{Prod} \times E_{EGCO_2\,eq}$	0.09	Table 3.6

* Egg production.

Table A10. Pork production on raising animal inventory data

Input (Pork)		**Qty**	**Ref.**
Pork consumption (Mt)	$PO_{Prod} = PO_{Cons}$	0.13	
Pork consumption (Mt)	PO_{Cons}	0.13	Table 3.4
Pig carcass weight (Mt/head)	PI_{CW}	5.0×10^{-8}	[11], [14]
Land use of product* (Mt)	$L_{Use} = 1.736 \times PO_{Prod}$	0.22	[47]
Quantity of animal (Million head)	$QA_{PI} = \frac{PO_{Prod}}{PI_{CW}}$	2.53	
Feed requirement of product* (Mt)	$PIF_R = 2.90 \times PO_{Prod}$	0.37	[47]
Water use of product* (Gt)	$W_{PO} = 1.796 \times PO_{Prod}$	0.23	[47]
Enteric fermentation (Mt CH_4/head/yr)	EF_{EPI}	1.0×10^{-9}	[44], [51]
Manure management (Mt CH_4/head/yr)	EF_{MPI}	7.0×10^{-9}	[44], [51]
Output (Pork)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = QA_{PI} \times (EF_{EPI} + EF_{MPI})$	0.02	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{POCO_2\,eq}$	6.830	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = PO_{Prod} \times E_{POCO_2\,eq}$	0.86	Table 3.6

* Pork production.

Table A11. Fish production on raising fish inventory data.

Input (Fish)		Qty	Ref.
Fish consumption (Mt)	$FI_{Prod} = FI_{Cons}$	0.52	
Fish consumption (Mt)	FI_{Cons}	0.52	Table 3.4
Fish carcass weight (Mt/head)	FI_{CW}	1.0×10^{-9}	
Land use of product* (Mt)	$L_{Use} = 0.841 \times FI_{Prod}$	0.44	[47]
Quantity of animal (million head)	$QA_{FI} = \frac{FI_{Prod}}{FI_{CW}}$	523.50	
Feed requirement of product* (Mt)	$FIF_R = 0.80 \times FI_{Prod}$	0.42	[47]
Water use of product* (Gt)	$W_{FI} = 3.691 \times FI_{Prod}$	1.93	[47]
Energy emission factor (Mt CO_2 eq/Mt product*)	EF_{EFI}	0.551	[69]
Output (Fish)			
Total emission CO_2 (Mt CH_4)	$TE_{CO_2\,eq} = FI_{Prod} \times EF_{EFI}$	0.02	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{FICO_2\,eq}$	6.830	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = FI_{Prod} \times E_{FICO_2\,eq}$	0.86	Table 3.6

* Fish production.

Table A12. Cooking oil production on cultivated plant inventory data.

Input (Cooking Oil)		**Qty**	**Ref.**
Cooking production (Mt)	$CO_{Prod} = CO_{Cons}$	0.04	
Cooking oil production (Mt)	CO_{Cons}	0.04	Table 3.4
Land use (Mha)	$L_{Use} = 1.052 \times CO_{Prod}$	0.04	[47]
Water use of product* (Gt)	$W_{CO} = 0.415 \times CO_{Prod}$	0.02	[47]
Emission factor (Mt CH_4/Mha)	EF	0.1561	[51]
Output (Cooking oil)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = L_{Use} \times EF$	6.72×10^{-3}	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{COCO_2\,eq}$	4.600	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = CO_{Prod} \times E_{COCO_2\,eq}$	0.19	Table 3.6

* Cooking oil production.

Table A13. Vegetable production on cultivated plant inventory data.

Input (Vegetable)		Qty	Ref.
Vegetable production (Mt)	$VE_{Prod} = VE_{Cons}$	1.48	
Vegetable consumption (Mt)	VE_{Cons}	1.48	Table 3.4
Vegetable yield (Mt/Mha)	VE_Y	12.80	[14]
Land use (Mha)	$L_{Use} = \frac{VE_{Prod}}{VE_Y}$	0.12	
$CaCO_3$ requirement (Mt/Mha)	$CaCO_{3\,R} = 2 \times L_{Use}$	0.23	[14]
N requirement (Mt/Mha)	$N_R = 0.2 \times L_{Use}$	0.03	[14]
P_2O_5 requirement (Mt/Mha)	$P_2O_{5\,R} = 0.24 \times L_{Use}$	0.03	[14]
K_2O requirement (Mt/Mha)	$K_2O_R = 0.093 \times L_{Use}$	0.02	[14]
Water use of product* (Gt)	$W_{VE} = 0.103 \times VE_{Prod}$	0.15	[47]
Emission factor (Mt CH_4/Mha)	EF	0.1561	[51]
Output (Vegetable)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = L_{Use} \times EF$	0.02	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{VECO_2\,eq}$	0.540	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = VE_{Prod} \times E_{VECO_2\,eq}$	0.80	Table 3.6

* Vegetable production.

Table A14. Fruit production on cultivated plant inventory data.

Input (Fruit)		Qty	Ref.
Fruit production (Mt)	$FR_{Prod} = FR_{Cons}$	0.84	
Fruit consumption (Mt)	FR_{Cons}	0.84	Table 3.4
Fruit yield (Mt/Mha)	FR_Y	13.20	[14]
Land use of product* (Mha)	$L_{Use} = \frac{FR_{Prod}}{FR_Y}$	0.06	
Water use of product* (Gt)	$W_{FR} = 0.154 \times FR_{Prod}$	0.13	[47]
Emission factor (Mt CH_4/Mha)	EF	0.1561	[51]
Output (Fruit)			
Total emission CH_4 (Mt CH_4)	$TE_{CH_4} = L_{Use} \times EF$	0.01	
Emission as CO_2 eq using SimaPro® (Mt/Mt product*)	$E_{FRCO_2\,eq}$	0.331	
Total emission as CO_2 eq (Mt CO_2 eq)	$TE_{CO_2\,eq} = FR_{Prod} \times E_{FRCO_2\,eq}$	0.28	Table 3.6

* Fruit production.