DEVELOPMENT OF A WEB APPLICATION FOR ESTIMATING CO2-EQUIVALENT EMISSIONS OF POULTRY AND SWINE SLAUGHTERING PROCESSES

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ABSTRACT: This study aimed to create a web application to evaluate GHG emissions of poultry and swine slaughtering processes. The development was based on the carbon footprint of the product and life cycle assessment approach. The designed scope involved a cradle-to-gate assessment. The CO_2-eq estimation results are based on the following functional units: per kilogram of animal live weight, or per number of live animals, or a product-based perspective as per kilogram of animal meat or carcass. The developed application can be conceptualized in three main components. First is a web-based user interface, separated in input and output parts. Slaughterhouse information and activity data were required to be entered as site-specific input data while CO_2-equivalent emission was shown as carbon footprint output. Next, the processing system was designed to function regarding various conditions of input data, ranging from minimum to detailed data sets providing a simple, coarse, and detailed estimation. Finally, the system database used to access and store emission factors, historical data, and carbon footprint results was created using a relational database model to organize data in a set of 6 tables. Moreover, many functionalities were considered and incorporated in the application to facilitate the user's estimation such as navigation tool, functional unit selection, data validation and null check, emission factor management, report/export documentation, and data confidentiality and security. The potential of this developed application is expected to aid the Thai slaughterhouse industry calculating their GHG emissions released in the environment, and subsequently leading to CO_2 mitigation.

Keywords: Carbon footprint, Slaughtering process, Poultry and swine, Web application

1. INTRODUCTION

The prediction of the world's population increase is expected to result in significantly increasing meat production possibly affecting the greatest environmental impacts as a result of global consumption [1,2]. With the FAO report, it has become evident that the quantity of global meat consumption per capita is likely to continue increasing, which corresponds to the trend of meat production and slaughtered animals [3]. Slaughtering is a core sector of meat production for domestic consumption and export, especially in Thailand. During the last 20 years, overall meat production in Thailand has increased by almost 30%, especially poultry and swine, about 56% and 23%, respectively [3,4]. It was reported that the Thai animal slaughtering industry is one of the most important and rapidly growing markets for poultry meat exports, placing Thailand in the Top 5 ranking of the world and the first among Southeast Asian countries [5]. Currently, international market opportunities are joining the environmental agenda, and more consumers emphasize green products. Especially consumers in developed countries are becoming concerned about climate change effects,

so greenhouse gas (GHG) emissions during the slaughtering process in Thailand contributing to environmental degradation should be taken into account for industrial management and sustainability.

One method used to measure climate change impact in terms of the amount of GHGs generated from human/industrial activities is called, "Carbon Footprint (CF)" and is based on the life cycle assessment (LCA) approach. CF analysis of a product/process can provide an idea of resource consumption efficiency, affecting the amount of GHGs or CO_2 equivalent (eq) released in the atmosphere. The method can also identify hot spots where the most significant impacts occur for improving performance. In general, numerous studies have been conducted using CF and LCA to evaluate climate change and other environmental impacts for a variety of specific food products such as meat products, organic foods, wine, and milk [6-9]. In our previous studies, "CFPack" was first developed for carbon footprint analysis of food and beverage packaging [10,11], using the Microsoft Excel Visual Basic for Application (Excel/VBA). In the current digital era with the popularity of the World Wide Web (www), most activities are conducted over the

internet. According to researchers, the recent growth of web applications has been helpful in developing environmental management and sustainability [12-14]. However, until now, few specific software packages have been developed and published to help entrepreneurs identifying their GHG emissions online. Therefore, this study aimed to create a web application to estimate CO_2-eq emissions of poultry and swine slaughtering processes in Thailand. The application is expected to aid the Thai slaughterhouse industry measure their greenhouse gas emissions, subsequently leading to reduced emissions.

2. METHODOLOGY

2.1 Scope and System Boundary

The web application was developed to estimate CO_2-eq emissions (or Carbon Footprint of Product – CFP) of the slaughterhouse industry according to the Life Cycle Assessment (LCA) concept. As can be seen in Fig. 1, the scope and system boundary of the estimation defines what is covered in the web application design and development starts by raw material acquisition, raw material transportation to the factory, the slaughtering process and product transportation to customers. In other words, the designed scope is a cradle-to-gate assessment. The CO_2-eq estimation results are based on the following functional units: per kilogram of animal live weight, or per a number of live animals, or a product-based perspective as per kilogram of animal meat or carcass. As all these functional units are the most commonly used in meat production [15], the estimation results will help the industry to monitor the emissions released and to compare the GHG inventory in terms of live animal-based units and carcass-based units.

Fig. 1 Scope of this study

2.2 Data Requirements and Calculation Method

In this study, data involves all relevant activities of raw material acquisition, the slaughtering process, and transportation, for example, total amount of raw materials, energy, water, packaging, and chemical use, waste disposal, vehicle type, fuel type, and transportation distance. These activities are required to be entered in the software by users. In addition, the emission factors which are basically collected from Thailand Greenhouse Gas Management Organization (TGO), the international database, e.g. Ecoinvent and published articles, are also required to develop the web application.

The GHG emissions associated with the activities mentioned above can be generally estimated by multiplying the activity data with emission factors as expressed in Eq. (1) [16]

$$CF = \Sigma \ (\text{Activity Data} \times \text{Emission Factor}) \qquad (1)$$

where CF is the carbon footprint (or GHG emissions) estimated in kilograms of carbon dioxide equivalent (kg CO2-eq), activity data represents a factor that quantifies an activity used to calculate the emissions generated, and emission factor represents a factor that emits the amount of greenhouse gases per unit of the activity data.

3. RESULTS AND DISCUSSION

3.1 Software Description

The web application was developed using a cradle-to-gate assessment scope to quantify the CO_2-eq emissions of poultry and swine slaughtering processes were conceptualized as comprising three main components: a web-based user interface, processing system and a database as shown in Fig. 2. The web-based user interface (UI) is separated in input and output parts. At the input UI, the user needs to provide site-specific data, namely, slaughterhouse general information, activity data, and the user's defined emission factor (EF) if any user wants to calculate with his/her own EF values. Next, the data/program processing system was designed to function using three different data entry conditions, ranging from minimum to detailed data sets providing a simple, coarse, and detailed estimation of the CO_2-eq emissions. Finally, the database was created to access and store EF, historical data, and calculated results. This database enables users to access, query, visualize, analyze, and download data. As a result, this increases the performance of the web application and user interactivity as a whole.
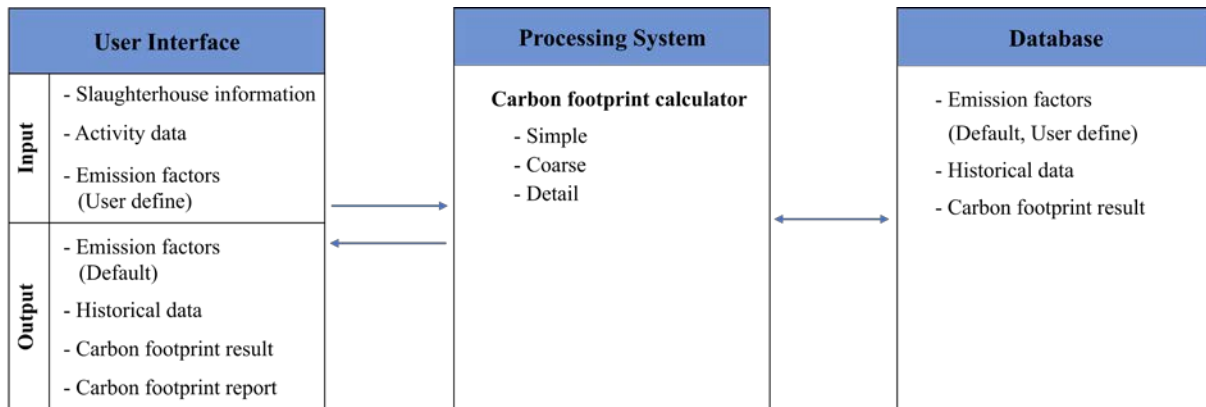
Fig. 2 Major components of the application

3.2 Data Processing Sequence

Figure 3 shows data flow of the developed web application. The tool is broken down in 11 sequential steps, six gather user input (process 1.0-6.0), two are background processing (process 7.0-8.0), two provide feedback to the user (process 9.0-10.0), and the last one manages software by an administrator (process 11.0). At the home page, a general/company user (non-admin and non-group user) can select either a new registration or log-in as current user to access the web application. The system will then connect to the database of the 'user table' and 'group table' to classify the user account in 3 levels as an administrator, the general user or group user, to receive the data accessibility level. After log-in, the general/company user could add a new company or select a company to estimate GHG emissions of the slaughterhouse. At process 2.0, the application will access the database of the 'company table' to show the historical information for the selected company. However, when 'add new company' is selected at this process, the pop-up dialog box will appear for the data entry of its location and general information of the slaughterhouse. After finishing the process 2.0, the user could add new calculations (process 4.0) or go to process 5.0 to 'select historical calculation'. In the case of 'add new calculation' mode, the user has three options to select: simple, coarse or detailed for the data entry in the next process (process 6.0). The selected option will be stored at the database of 'save option table'. At process 7.0, while the calculation process is working, the EF value from the EF table (process 3.0) will be used to multiply with the inventory of activity data input to estimate the GHG emissions. However, when 'select historical calculation' mode is chosen, the user selects to open a previous estimation (process 5.0); he/she can see or edit the existing input data through the web application directly (process 6.0), and recalculate on process 7.0 or see the CF results (process 8.0-9.0).

When each mode is running ('add new calculation' mode or 'select historical calculation' mode), the system will connect to the database of the 'save option table' and 'save input table' to record and retrieve all data to show on a web page. The CF result will be used to create graphs (process 8.0) to present in the next process. At process 9.0, the user is able to change the displayed functional units based on live animals, carcasses or product weight. Once the user changes, the web app will then recalculate and send back the new CO_2-eq results per the functional unit selected by the user. The results will be stored after finishing work at the back end and can be retrieved conveniently for reviewing and updating at the next visit. In addition, all inputs and results can be exported as a PDF file (process 10.0).

3.3 Relational Database Model

The database of this application was developed using a relational database model to organize and store data as a set of six database tables that has the primary key-foreign key rapport to create interaction among all tables (see Fig. 4). The database is the table storing account information, related companies or associations, slaughterhouse information, EFs, historical data of calculation options, and input data related to carbon footprint result. Databases (or tables) are linked in an one-to-many relationship, meaning the data which is a primary key of the first table is associated with the foreign key of the second table as multiple matching rows. For example, the user can create many companies under each user account and each company can estimate its carbon footprint many times. These relations can help to represent accurate data when the user accesses and queries the historical data of each slaughterhouse because the primary key of the 'User ID', 'Company ID', and 'Save Input ID' is uniquely identified in each row of this web application.
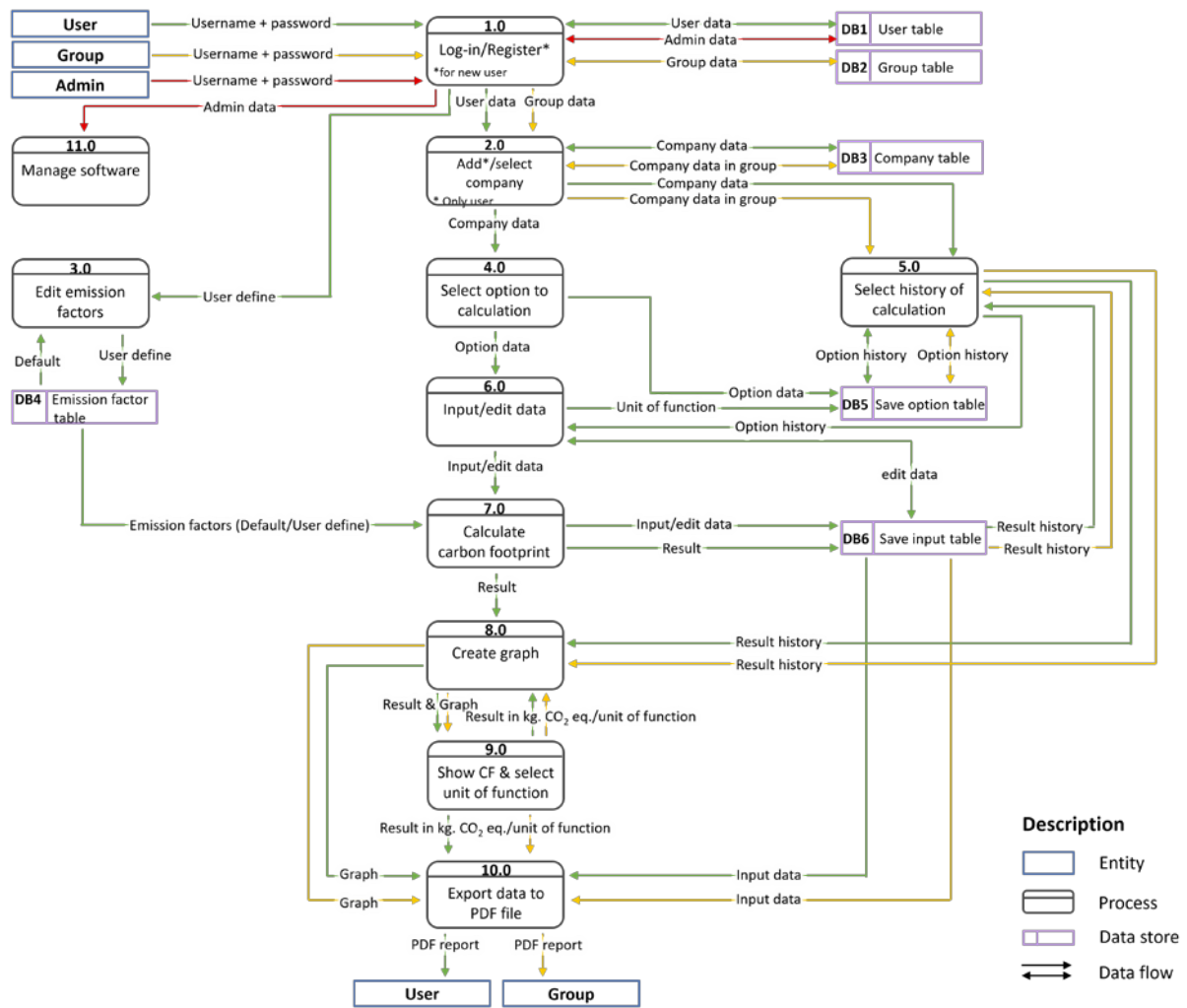
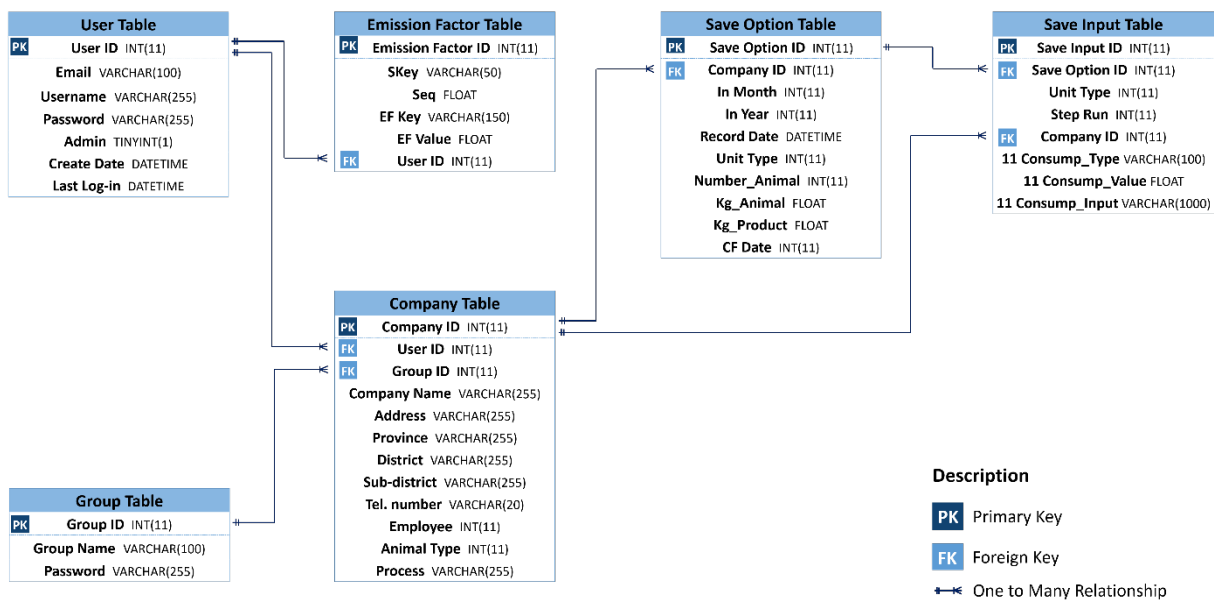Fig. 3 Data flow diagram with entity, process, and data store

Fig. 4 Relational database model of the web application

3.4 Web User Interface

Figure 5 shows examples of the graphical user interface (GUI) of the developed web application: main page, input data page, and result page. The main page depicts the general information of the slaughterhouse involving address, contact number, and types of animal to be slaughtered. Regarding input data, several web pages of different activity data have been created for user's data entry, depending on the analysis option chosen as mentioned above (simple, coarse, or detailed). These pages contain several data items that were reviewed accordingly to the current slaughtering process of the country. In addition, the relevant graphic icons, visual indicators, and drop-down lists were added to the created web pages instead of texts. These features will give an easy-to-understand overview of the data input and make the application more attractive to the user. The result page can present the total CO_2-eq emitted based on live animal-based units or carcass-based units and illustrated as a pie chart or bar graph for different consumption categories or detailed slaughtering activities, respectively.

3.5 Web Application Functionalities

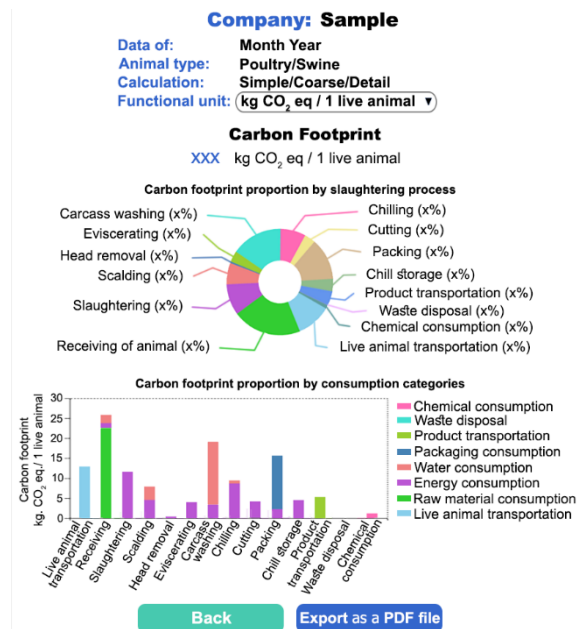### 3.5.1 Three functions of various estimation levels

Unlike many other simple web apps, this tool offers three methods for entering consumables used at the slaughterhouse, covering the easiest to detailed ways to provide input data, called "simple", "coarse", and "detailed", so a small to large scale slaughterhouse will be able to use this tool. When using the easiest method by entering minimal input data, the user will receive a roughly calculated result of total CO_2-eq emissions. On the other hand, the coarse and detailed methods are more complicated but the informative results will be analyzed and visualized for further discussion on different resource type consumption and how the company uses resources for each slaughtering activity. In addition, because of a large number of such inputs is required for coarse and detailed estimation, a navigation tool is provided on the left menu to help the user easily navigate slaughtering steps to indicate where the data entering is up to. At the transition between steps, designed necessary data validation and null check are automatically implemented by setting data requirements for user input to avoid errors. These involve functional units (number of live animals, carcasses, and product meat weight), and mass balance between live animals and meat product (product weight $\not>$ live animals).

(a) Main page

(b) Input data page

(c) Result page

Fig. 5 Examples of web user interface of the developed application

3.5.2 EF management

As mentioned in the methodology section, the default EFs basically collected from various databases can be categorized in eight groups, namely raw material, energy, water, packaging, chemicals, waste disposal, transportation, and product. They were stored and manipulated as in the database table named 'Emission Factor Table'. Most users do not know the EF related to the activity data, so these default values will allow users to immediately estimate the CO_2-eq emitted from their processes by using our web app. These EF values were well chosen from many reliable sources both national and international databases (when not available in Thailand). In addition, when any user knows his/her own EFs and desires to use them for the estimation, the tool is also designed to change, save, and reset these values easily.

3.5.3 Report/export documentation

In addition to displaying the CO_2-eq results over the web page, the application is also able to generate a report and export it in PDF file format. The report contains all general information of the slaughterhouse, the inventory of input data, and calculated CO_2-eq emission results (carbon footprint), including graphs. This will allow the user to easily print and view all information together. It will be useful to assist further discussion on reducing CO_2 emissions.

3.6 Confidentiality to Access the Database

The system offers confidentiality and security for the general/company user to access his/her data. All information including input data inventory and GHG emissions can be saved privately. This means it is available only to the specific company owner to open and edit the historical data and estimation results.

3.7 Software Availability

The developed web application to estimate CO_2-eq emissions (carbon footprint) of the Thai poultry and swine slaughtering industry can be accessed through any device such as desktop computers, laptops, tablets, and mobile phone over an internet connection using Hypertext Transfer Protocol (HTTP) via modern web browser. The web application can be found online at http://www.carbonfootprintthailand.com/Slaughter

4. CONCLUSION

The web application developed in this study is an analytical tool to estimate CO_2-eq emissions for poultry and swine slaughtering processes. The usefulness of this application is to aid Thailand slaughterhouse industries to calculate and understand how much and how they contribute GHG emissions to the environment. It implies the current resource use (inputs) and change, subsequently leading to reduced GHG emissions. The output generated by the web application is reliable because of our careful emission facter selection and system validation testing. Moreover, many functionalities are considered and incorporated in the application to facilitate the user's estimation such as data input conditions (simple, coarse, and detailed data entry), navigation tool, functional unit selection, data validation and null check, EF management, report/export documentation, and data confidentiality and security. All these features are necessary, but the tool should not require too much effort from the user.

5. ACKNOWLEDGMENTS

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