

## WEB APPLICATION SUPPORT FOR CARBON FOOTPRINT MANAGEMENT OF PETROL STATIONS IN THAILAND

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**ABSTRACT:** In Thailand, a “petrol station” is considered an “organization” that not only sells fuels and engine lubricants for motor vehicles but also includes many other facilities provided to satisfy the modern lifestyle of customers. In other words, a petrol station in Thailand comprises a large complex service center offering a wide range of services that contribute greenhouse gas emissions to the atmosphere. This paper aimed to present a specific web application tool developed to estimate the carbon footprint for petrol stations in Thailand. The application system comprises three core components: 1) a web-based user interface; 2) a processing system, incorporating the carbon footprint of the organization (CFO) framework and the calculated model and 3) a database. The site-specific input data or activity data provided by the user was primarily required for the data entry in the system. The processing system will then quantify the amount of greenhouse gas emissions by multiplying the activity data by the emission factor (EF). A database was also created containing default EFs readily used for the calculation, but users can change these values at any time when a more appropriate one is indicated. Finally, the CF calculation results can be evaluated in various functional units: monthly or yearly, per fuel sold, or per area of the petrol station, and visualized in graphs. In addition, the results can be reported by categorizing the emission sources according to the scope of the CFO and the GHGs reporting guidelines (scopes 1, 2 and 3).

*Keywords: Carbon footprint, Organization, Petrol station, Web application*

### 1. INTRODUCTION

Petrol stations in Thailand have increased continuously. From 2007 to 2016 the number of petrol stations in Thailand has increased by 29%, corresponding to the increasing trend of fuel sales at 22% [1]. Currently, more than 26,000 petrol stations are located across the country [1]. In Thailand, petrol stations not only sell fuel and engine lubricants for motor vehicles, but also include many other facilities provided to satisfy the modern lifestyle of customers such as convenience stores, restaurants, souvenir shops, coffee shops, food stalls, toilet facilities, including automatic teller machines (ATMs) and auto mechanic services. In other words, the petrol station is a large complex service center with a wide range of activities that could contribute greenhouse gas emissions to the atmosphere, resulting in the effect labeled global warming.

Carbon Footprint for Organization (CFO) is a quantitative method to measure greenhouse gas emissions from all activities in the organization, including energy used in the building, industrial processes and company vehicles [2]. According to our previous research, studies have developed special carbon footprint calculation programs for food and beverage packaging using Visual Basic for Applications (VBA) in Microsoft Excel [3], [4]. One advantage of this type of program is that it works on

Microsoft Excel in a desktop or laptop. However, the VBA's disadvantage is its unattractive appearance and limited functions compared with other types of available programs, like a web-based application (web app).

In fact, a web app is a subset of information technology (IT) that has become an integral part of modern lifestyle. People use it to facilitate the functioning of nearly all life domains. With the help of information technology, users now can acquire information, connect with people and achieve much more with speed and precision [5]. The web application has the advantage of being easily accessible to show users. Just by having a computer or smartphone device, a web browser and connecting to the internet, users can access the program from anywhere at any time. At the moment, although numerous web applications for carbon footprint calculation are available online, they are all simple carbon footprint calculators for individuals, events or businesses [6], [7], [8]. Researchers have paid little attention to the GHGs of an organization that are needed to estimate accurately the complex service activities that are common to petrol stations in Thailand.

As a result, the aim of this paper was to create a web application to analyze carbon footprint for petrol station in Thailand in the form of web application software. Thus, the owner or petroleum company in Thailand can use our developed web-based

application to calculate greenhouse gas emissions released from their activities. The web app will be served as a supporting tool for carbon management of their organizations.

## **2. METHODOLOGY**

### **2.1 Data Requirements and Calculation Method**

To develop the web application in this study, petrol stations in Thailand were first surveyed to receive an overview of their various service activities. Activity data were collected relating to GHG emissions from different sources situated in the petrol stations including offices, convenience stores, fast food shops, restaurants, coffee shops, retailers and toilet facilities. The examples of data related to those activities were mainly electricity, water and chemical use and waste generated. In addition, the secondary data required in this study were emission factors (EFs). Main sources of the EFs include Thailand Greenhouse Gas Management Organization (TGO) and the international database, e.g., Ecoinvent. Other sources involve published and unpublished articles.

For carbon footprint calculation in this study, the method was based on guidelines for carbon footprints of organizations by the Thailand Greenhouse Gas Management Organization (TGO) [9] and World Business Council for Sustainable Development (WBCSD) [10]. The GHG emission is simply calculated by multiplying activity data with the related emission factor as expressed in Eq. (1) as shown below.

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

Where CF is the carbon footprint estimated in unit of kilograms carbon dioxide equivalent (kg CO<sub>2</sub>eq); the activity data represents a factor that quantifies an activity used to calculate the emissions generated, and emission factor represents a factor that allows GHG emissions to be estimated from a unit of available activity data.

### **2.2 Programing Languages for Web App Development**

To develop the web-based application, five programming languages were used to write the code to support two system components of the software-client and server side. The data processing is handled by the server while results are returned to the client. These five languages include Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript, Active Server Pages (ASP.NET) and Structured Query Language (SQL). At the client side, HTML is used to create a web application structure, in conjunction with CSS and JavaScript

that are used to control the appearance and to make user interactions. At the server side, ASP.NET is used for server processing and to connect to databases, while the database management is achieved with Structured Query Language (SQL). A program called, "Microsoft Visual Studio Community 2017" was used as a platform tool to support writing the code of these five languages.

## **3. RESULTS AND DISCUSSION**

### **3.1 Description of the Web Application**

The developed web application is available online at <http://www.carbonfootprintthailand.com/petrolstation>. It can run on all electronic devices such as desktop computers, laptops, tablets and smartphones through a web browser. It can calculate the carbon footprint of a petrol station by referring to the resources used and activity information of the petrol station. Using the software, developers have designed three different functions of user access level: 1) general user for petrol station level; 2) group user for corporate level, e.g., Shell, ESSO, Bangchak, PTT, Chevron and 3) administrative user for general system management level. Using these levels, allows users to access various parts of the application. At the petrol station level, a general/owner user involves a group of users that can use the main part of the CF calculation system. The general user will be able to create, browse, edit and delete historical results, including being able to edit the EF values. At a corporate level, a group user is in the business level that provides a network of fuel distribution services across the country. This group of users can only browse the calculation results of petrol stations under their business group. The group users will not be able to edit any input data or results of any petrol stations. At the system management level, an administrative user can generally manipulate the overall software system such as deleting user and updating EF default values etc.

To calculate the carbon footprint, the developer has gathered all related EFs needed for the calculation by setting them as the software's default values, so they can be retrieved for the estimations instantly. The software also provides a special function that allows users to change these values at any time when a more appropriate one is indicated.

The CF calculation results can be evaluated in various functional units: monthly, yearly, per fuel sold or per area of the petrol station. These functional units can help entrepreneurs to calculate their GHGs (or CF), and to compare the CF results among petrol stations under the same corporate group.

The application system comprises three core components as shown in Fig. 1: 1) a web application user interface; 2) a processing system, incorporating the carbon footprint of the organization (CFO)

framework and the calculation model and 3) a database. The user interface involves the display section of the web application, where the user can connect and send a request to the web server via a web browser. The processing system will then process the requests, connect to the database to manipulate data and send results to show to the user interface. The database of this developed web application is a data storage system called the Relational Database Management System (RDBMS). More details are described in a later section of this paper.

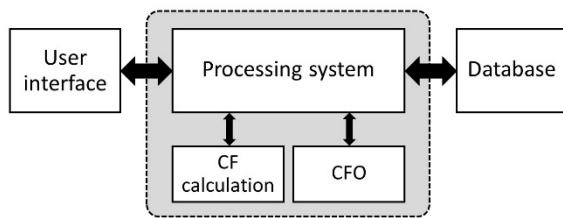


Fig. 1 Main components of the web application

### 3.2 Database Model with RDBMS

The database in this study involved a set of data stored in the application system, designed by using the SQL language of the Relational Database Management System (RDBMS). This database is a type of relational database model to organize and store data as a set of eight database tables (see Fig. 2). These database tables store account information, related companies or associations, petrol station information, EFs, shops and facility types and details, historical data of calculation options and input data related to carbon footprint results. To organize all databases, interaction needs to be created among tables, so a “primary key” which is a column in a database table that uniquely identifies rows in that table, and a “foreign key” which is a column of a table that is the primary key on another table, are assigned to define relationships between the two tables. The relationship was defined in this software as an one-to-many relationship. For example, one User ID of the ‘User Table’ may create many emission factor values in the ‘Emission Factor Table’. Moreover, each user in the ‘User Table’ can create many petrol stations in the ‘Company Table’, and each petrol station can estimate CF many times in the ‘Save Table’.

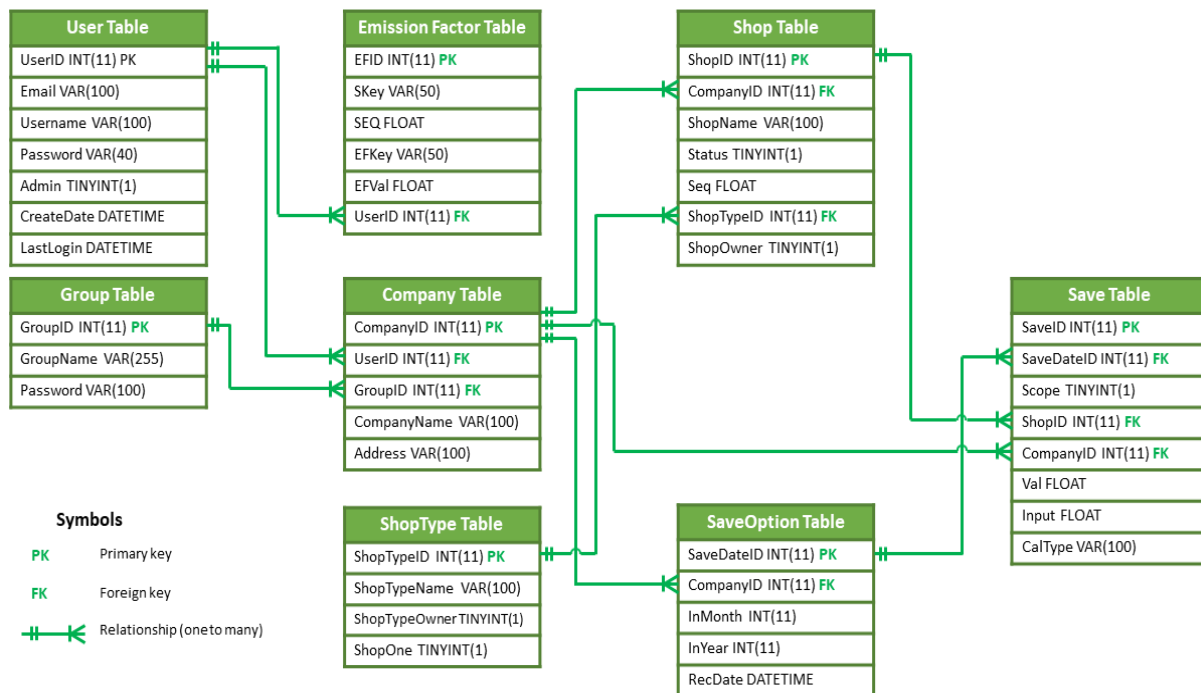


Fig. 2 Relational database model of the web application

### 3.3 Three Scopes of Emission Sources

According to the national guidelines for CFO and the GHG accounting and reporting standard [9], [10], the application was designed to categorize and report the activity or emission sources of a petrol station separately in three scopes (scopes 1, 2, and

3), as presented in Table 1. Direct GHG emissions of scope 1 are released from sources that are owned or controlled by the petrol station while indirect GHG emissions of scope 2 are emissions from the generation of purchased electricity. Finally, indirect GHG emissions of scope 3 are emitted from sources not owned or controlled by the petrol station.

Considering the definition of these scopes and petrol station activities, scope 1 emissions involve onsite electricity generation, vehicle fuel consumption, onsite wastewater treatment system and use of chemicals, refrigerants and fire extinguishers while scope 2 emissions come from the consumption of purchased electricity. Lastly, scope 3 emissions

come from several sources such as fuel consumption of outsourced vehicles, electricity consumption of the rental businesses, use of fuel sold and waste management by the local authority. Moreover, scope 3 also involves raw material acquisition such as use of paper, packaging and water.

Table 1 GHG emissions from a petrol station's activities relating to the scopes of GHG reporting guidelines

Scope	Activity
Scope: 1 Direct emissions	<ul style="list-style-type: none"> <li>• electricity generation</li> <li>• fuel consumption of vehicles owned by petrol station</li> <li>• wastewater treatment</li> <li>• use of chemicals</li> <li>• use of refrigerants</li> <li>• use of fire extinguishers</li> </ul>
Scope: 2 Indirect emissions	<ul style="list-style-type: none"> <li>• electricity consumption</li> </ul>
Scope: 3 Other indirect emissions	<ul style="list-style-type: none"> <li>• water consumption</li> <li>• waste management</li> <li>• fuel consumption of the outsource vehicles</li> <li>• use of paper</li> <li>• use of chemicals, refrigerants, and fire extinguishers in the rental facilities and shops</li> <li>• electricity consumption of the rental facilities and shops</li> <li>• use of sold fuel (products)</li> </ul>

### 3.4 Calculation Sequence

Figure 3 shows the sequence of carbon footprint calculation, 12 processes connected to 3 user groups and 8 database tables (described above in database model section). First is process 1.0, where the general user has to create an account or log in to access the software. User information such as username, password and the level of user will be stored in the database named 'User table' and 'Group table'. After login, the general users can browse or modify EF values in process 2.0. In process 3.0, the general user has to create information about the petrol station. In case the petrol station information is already created, the user can select the existing petrol station which he/she wants to calculate the CF. Process 4.0 allows a user to identify the time period of entering data, e.g., monthly or yearly meaning that all data have to be entered in relation to the selected time period. In process 5.0, the general user has to create and edit the details of shops and service facilities. Another important information needed is whether each shop/service facility is owned by the petrol station or

rented. Such information will allow the software to categorize activities and emission sources according to the scope of the CFO and GHG reporting guidelines at a later step. Next, process 6.0 allows a general user to input activity data such as the volume of water, electricity, and fuel consumption for each shop/service facility previously selected. After completing process 6.0, the web app will use those data to calculate CF in process 7.0. Process 8.0 will use the CF results to create pie and bar graphs, comparing the CF among various shops, activities, the three scopes of the CFO guidelines and showing them all in process 9.0. Here the user can change the displayed functional unit to monthly, yearly, per volume of selling fuel or per petrol station areas. When the functional unit is selected, the software will automatically recalculate CF, recreate graphs and illustrate the results on the web page. The software can export all input data and results in PDF format at process 10.0. For process 11.0, the general user can browse the calculation history and edit the input data. Finally, process 12.0 is the system management tool, which only administrative users can access.

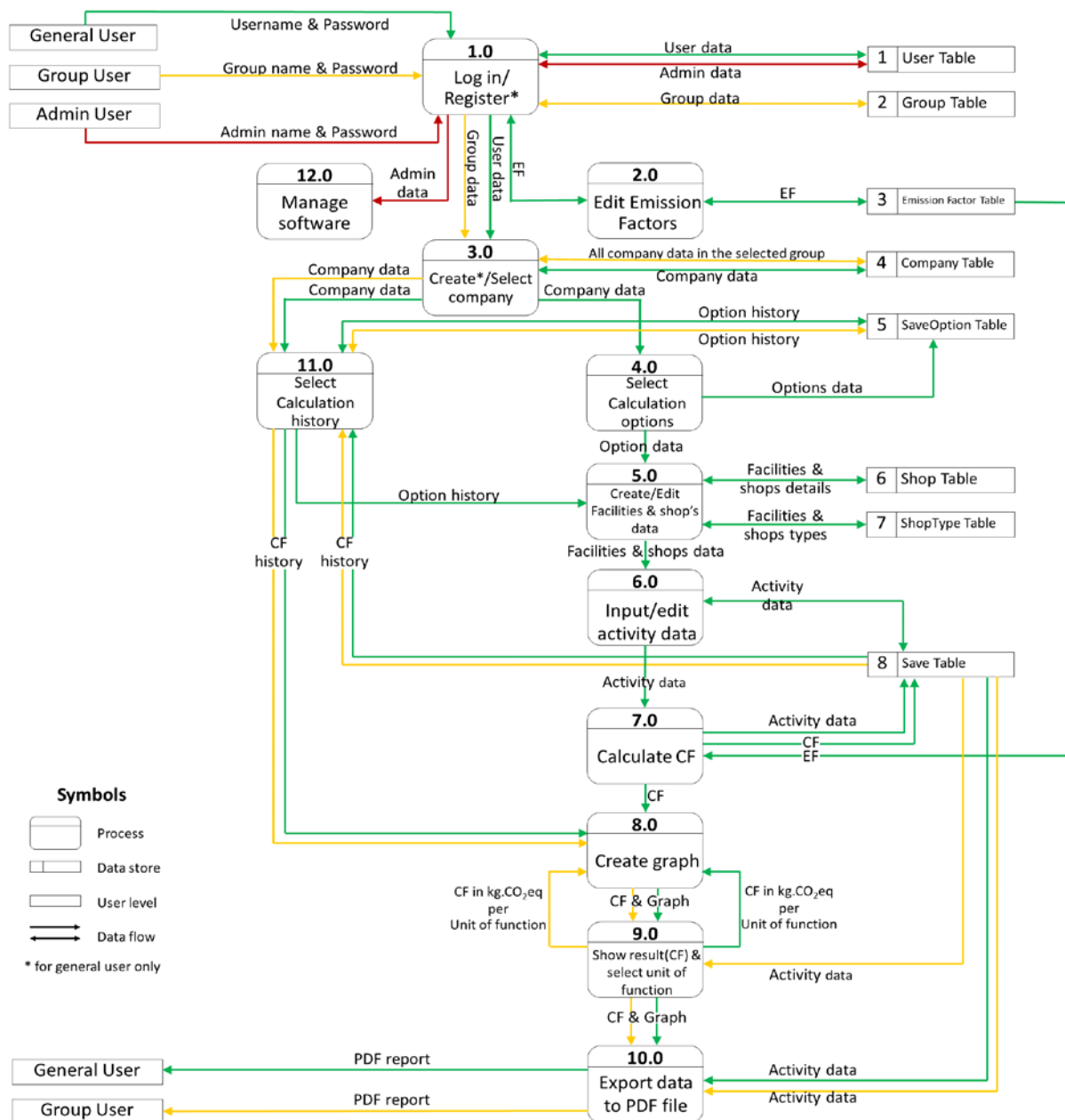
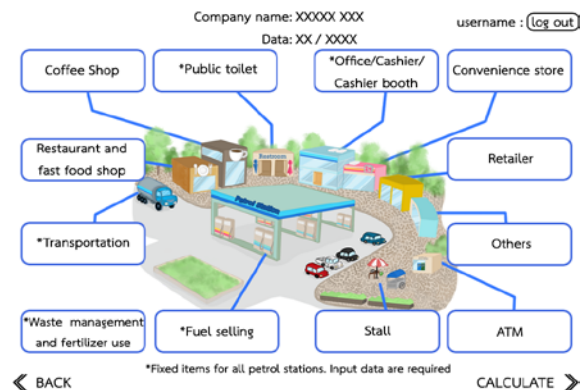


Fig. 3 The sequence of the carbon footprint calculation

### 3.5 Web Application User Interface

Figure 4 shows the main graphical user interface (GUI) of the developed web application, namely, main page, input data page and result page. Main page is well designed as a snapshot of a petrol station, consisting of all twelve categories of shops and service facilities currently provided in petrol stations of Thailand. This page allows users to work easily on relevant service facilities (see Fig. 4a). Fig. 4b depicts an example of an input data page where users have to fill in activity data and resource use. Several web pages of input data were enhanced by adding checklist options, drop down list options, and illustrations to



(a) Main page

**Electricity consumption**  
 Electricity source : Gridmix (Thailand Gridmix Ele) v  
 Quantity : xx

**Water consumption**  
 Water consumption : Provincial Water v  
 Quantity : xx

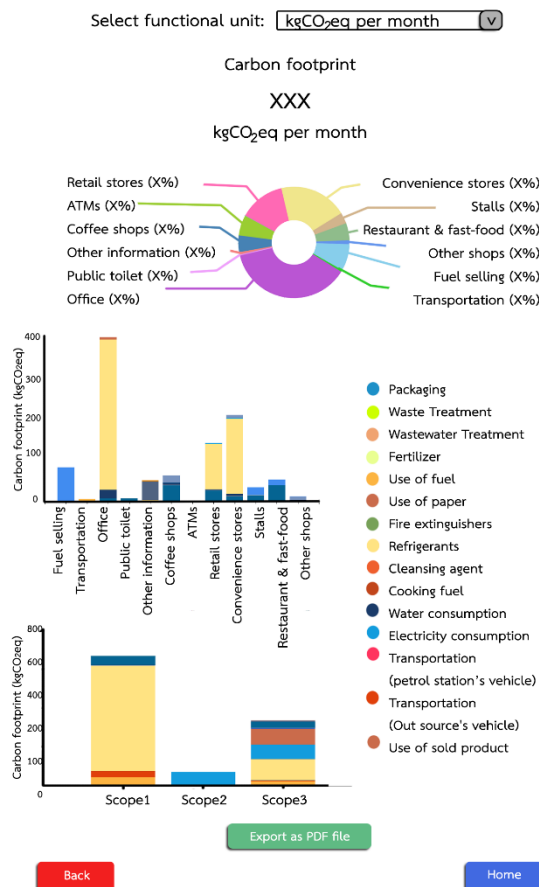
**Fire extinguishers**  
 Type : ☒ Carbondioxide ☐ HFC-134a  
 Volume (kg/month) : xx

**Packaging**  
 1) Packaging type : PET cup v  
 Quantity : xx

2) Packaging type : PP bag v  
 Quantity : xx

Cancel Save

(b) Input data page



(c) Result page

Fig. 4 Main graphical user interface

make it more attractive and easier for users to enter their input data. The result page displays the calculated results in units of kilogram CO<sub>2</sub>-eq relating to the functional units chosen: monthly, yearly, per fuel sold or per area of the petrol station

and illustrated in graphs (Fig. 4c). In addition, the results can be reported following scopes 1, 2 and 3 of the CFO and the GHGs reporting guidelines as mentioned above.

#### 4. CONCLUSION

Clearly, the advantage of web application software is being easily accessible to any user. With a computer or smartphone device, a web browser and connection to the internet, users can access the web app from anywhere at any time. The CF calculation results of the web app can be estimated in various functional units: monthly, yearly, per fuel sold or per area of the petrol station. Therefore, the developed web application in this study can help petrol station owners, petroleum companies and associations in Thailand to account GHG emissions released from their boundaries and operations and to compare the CF results among petrol stations under the same corporate group. Ultimately, it will lead to guidelines for future planning to reduce their emissions.

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