Assessment of GHG Emissions from Tableware Ceramic Production in Thailand

Kannaphat Chuenwong, King Mongkut's University of Technology Thonburi, Thailand
Boonrod Sajjakulnukit, The Joint Graduate School of Energy and Environment, Thailand
Siriluk Chiarakorn, King Mongkut's University of Technology Thonburi, Thailand

The Asian Conference on Sustainability, Energy and the Environment 2015
Official Conference Proceedings

Abstract
Ceramic industry is one of energy intensive industry. This paper reported the energy consumption and GHG emission of tableware ceramic production in Thailand in the boundaries of "gate-to-gate". The activity data of the tableware ceramic manufacturing were collected from a small enterprise manufacturing plant and 1 kg of ceramic bowl (8 inches diameter) was chosen as the functional unit of data analysis. The amount of GHG emission in the unit kg CO_2 e /kg of product was calculated by the method from IPCC 2006 and the emission factors used in this study were from Thailand Greenhouse Gas Management Organization (TGO). The hotspots of energy consumption and GHG emissions were then identified. The results indicated that the energy consumption per functional unit was 21.80 MJ/kg of product and almost 95% of total energy consumption was from liquefied petroleum gas (LPG) consumption during firing. The direct GHG emissions were from LPG used as fuel (47.54%) and from the decomposition of carbonates during firing process (0.26%). While the indirect GHG emission was from the electricity consumption for electrical equipments (52.20%). The total GHG emission based on functional unit was 0.34 kg CO_2 e /kg of product.

Keywords: greenhouse gas emissions, energy consumption, ceramic tableware, ceramic production, Thailand

iafor
The International Academic Forum
www.iafor.org

1. Introduction

The tableware ceramic manufacturing is a traditional industry sector in Thailand. There are approximately 100 tableware ceramic industries in Thailand [1]. Most of them are small and medium-sized. At present, ceramic industry has suffered from high energy cost due to continuous increasing LPG price, which is the key factor affecting a ceramic industry's competitive in the world market.

Various studied are emphasis on energy consumption and greenhouse gas emission from ceramic industry. Quinteiro, *et al.*[2] studied carbon footprint and energy consumption of a commercially produced earthenware ceramic piece. The results indicated that energy hotspots are natural gas production, biscuit firing and condensing boiler. The carbon footprint of the selected ceramic piece is 1.22 kg CO_2e per piece. The total energy consumption during the life cycle of the ceramic piece is 8.19 kWh, and the manufacture stage represents almost 90% of the total energy consumption across the life cycle of the ceramic piece. Peng, *et al.*[3] studied carbon dioxide emission in the ceramic tile manufacturing process and found that about 80% of the total CO_2 is emitted during the processes of firing and drying. Several solution are proposed to reduce CO_2 emission from these two processes and substituting coal with natural gas seems to be the most efficient way. Barros, *et al.*[4] presented the analysis of the consumption and emission levels of the main pollutants is made from ceramic manufacturing process in Spain. The results revealed that main GHG emissions are from raw materials preparation process and thermal treatment process. In addition Monfort, *et al.*[5] analyzed energy consumption and carbon dioxide emissions in the ceramic tile industries from 50 participating companies in Spain. It can be seen that the firing stage emits the highest carbon dioxide in ceramic tile manufacture (185 kg CO_2/t fired product), followed by spray drying of the suspensions (90 kg CO_2/t fired product) and tile drying (20 kg CO_2/t fired product). Ibanez-Fores, *et al.*[6] presented a methodology for identifying sustainable and most appropriate BAT for a given industrial installation and sector. The methodology involves identification of environmental hot spots from an installation by using life cycle assessment (LCA) to guide the selection of candidate BAT option for targeting the hot spots. The selected BAT options are then assessed on sustainability using relevant environmental, economic, technical and social indicators. The results indicate that firing and drying are the hot spots for most sustainability impacts considered.

In Thailand, the report from the Department of Alternative Energy Development and Efficiency (DEDE) presented the energy use data from ceramic industry in Thailand. Natural gas and electricity are the main source of energy for the ceramic manufacturing plants. Liquid petroleum gas (LPG) is used in small and medium scale industries while natural gas (NG) is used primarily as a fuel in large scale Industries [7]. Although, ceramic manufacturing process use a lot of energy and is one of the main contributors to CO_2 emissions, at present there is no data of energy consumption and GHG emission from small ceramic tableware manufacturing plant in Thailand. Therefore, the purpose of this study is to analyze GHG emissions and energy consumption in a small ceramic tableware manufacturing plant. Moreover, the hotspots of energy consumption and GHG emission were identified. The outcome of this study will be important data for ceramic industry to reduce their energy consumptions and GHG emissions.

2. Methods

2.1. Data collection

The general objective of this research is to assess GHG emissions and energy consumption and identify the GHG emissions and energy consumption hotspot from ceramic tableware production. This research was conducted in a small tableware ceramic manufacturing in Thailand. The necessary data from each unit process were collected and 1 kg of ceramic bowl (8 inches diameter) was chosen as the functional unit of data analysis as shown in Fig.1. The average weight of the bowl was 0.785 kg/piece. The assessment of partial product life cycle was carried out in a boundary of gate to gate (raw material preparation, forming, drying, biscuit firing, glazing, glost firing and QC). A scope of study was shown in Fig.2.

Figure 1. A selected ceramic bowl (8 inches diameter) of this study

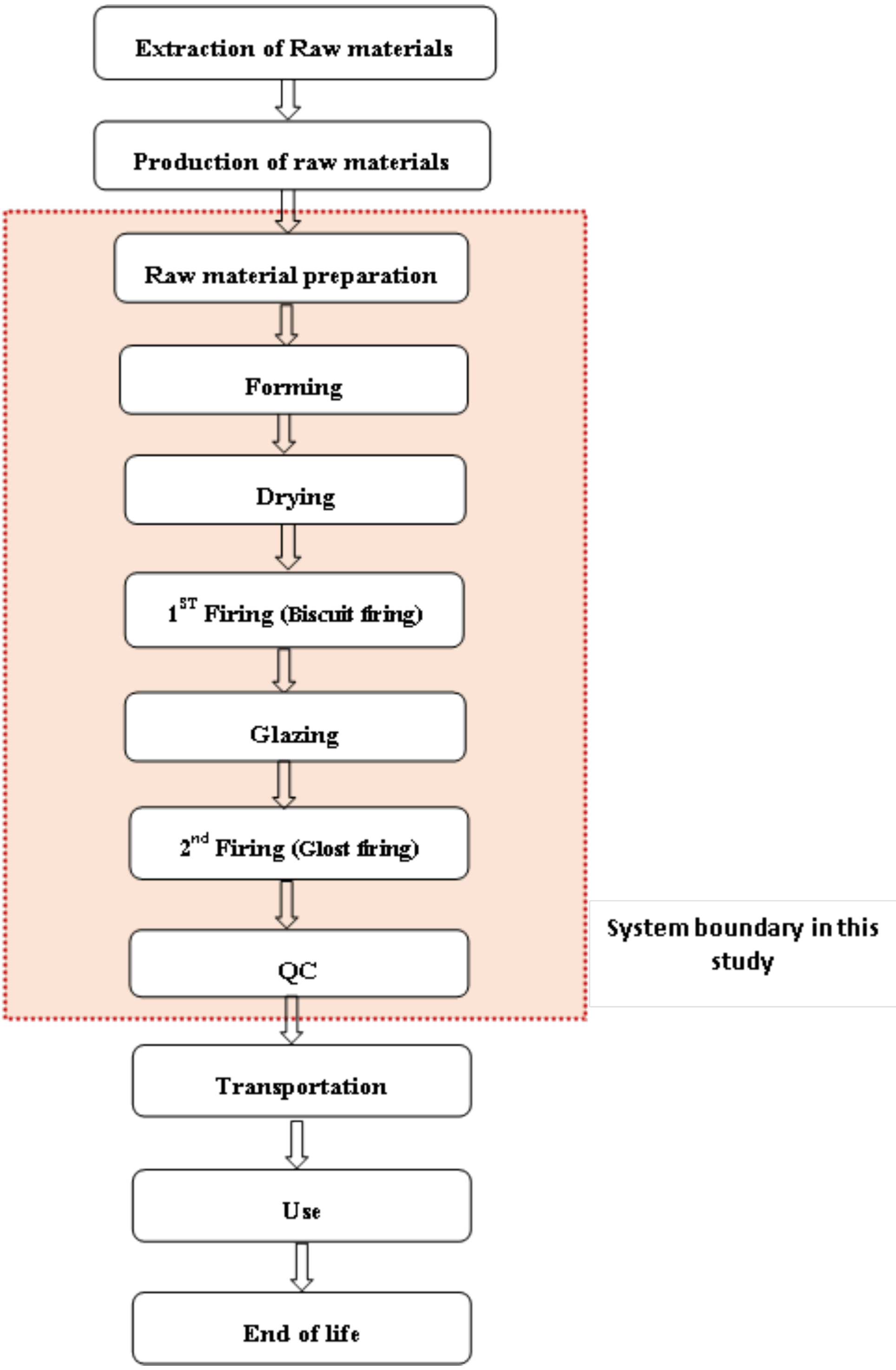


Figure 2. System boundary of this study

2.2. Calculation of GHG emissions

The sources of CO_2 emissions in ceramic production come from electricity consumption, fuel combustion and industrial process. The amount of GHG emission in the unit kg CO_2 e/kg of product was calculated by the method from IPCC 2006 [8] and the heating values of fuel come from the Department of Alternative Energy Development and Efficiency (DEDE), Thailand [7]. The calculation of GHG emissions from fuel combustion and electricity consumption are shown in Eq(1) and

Eq(2). The calculation of GHG emission from decomposition of calcium carbonate is shown in Eq(3). The emission factors used in this study were from Thailand Greenhouse Gas Management Organization (TGO) [9] and IPCC 2006 [8] as presented in Table1.

$$CO_{2\ \text{emission, LPG}} = \text{LPG Consumption (kg)} \times EF_{LPG} \quad (1)$$
$$CO_{2\ \text{emission, electricity}} = \text{Electricity consumption (kWh)} \times EF_{electricity} \quad (2)$$

where
EF_{LPG} = emission factor, $kgCO_2e/kg$

$EF_{electricity}$ = emission factor, $kgCO_2e/kWh$

$$CO_2 \text{ Emissions from decomposition of } CaCO_3 = M \times EF_{CaCO_3} \times F \quad (3)$$

where
EF_{CaCO3} = emissions factor for the particular carbonate, tonnes CO_2/tonne carbonate

M = weight or mass of the carbonate, tonnes

F = fraction calcination achieved for the carbonate, fraction (this study used 1 for F fraction)

Table 1. The emission factors used in this study.

Activity data	Unit	Emission factor	References
Liquefied petroleum gas (LPG)	kg	0.3874 $kgCO_2e$/unit	[9]
Electricity	kWh	0.6093 $kgCO_2e$/unit	[9]
Calcium carbonate ($CaCO_3$)	kg	0.43971 kg CO_2/ unit	[8]

3. Results and Discussion

3.1 Energy consumption and hotspot Identifications

Figure 3 shows the percentage of energy used in the production of ceramic tableware. It was contributed by electricity (5%) and LPG (95%).The electricity is used in forming machine and Liquid Petroleum Gas (LPG) is used in shuttle kiln for firing product. The energy consumption of ceramic tableware production from each process is shown in Table 2.

The total energy consumption of ceramic tableware production was 21.80 MJ/kg of product. The electricity consumption was from raw material preparation and forming process (1.06 MJ/kg of product) and LPG consumption was used for combustion in biscuit firing process (4.02 MJ/kg of product) and glost firing process (16.72 MJ/kg of product). The largest energy consumption was from glost firing (76.70%), followed by biscuit firing (18.44%), raw material preparation (4.50%) and forming (0.37%). Thus, glost firing process was determined as a hotspot of energy consumption, accounted for 76.70% of total energy consumption.

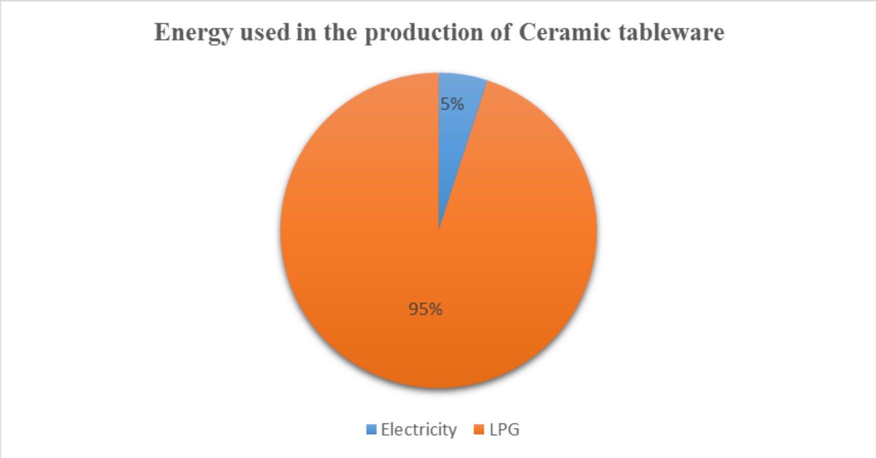


Figure 3. The percentage of energy used in the production of ceramic tableware

Table 2. The energy consumption of ceramic tableware production from each process (per 1 kg of product)

Unit Process	Energy Consumption			
	Electricity (MJ)	LPG (MJ)	Total (MJ)	%
1. Raw material preparation	0.98	-	0.98	4.50
2. Forming	0.08	-	0.08	0.37
3. Drying	-	-	-	-
4. Biscuit firing	-	4.02	4.02	18.44
5. Glazing	-	-	-	-
6. Glost firing	-	16.72	16.72	76.70
7. QC/packing	-	-	-	-
Total	1.06	20.74	21.80	100

3.2 GHG emissions and hotspot identifications

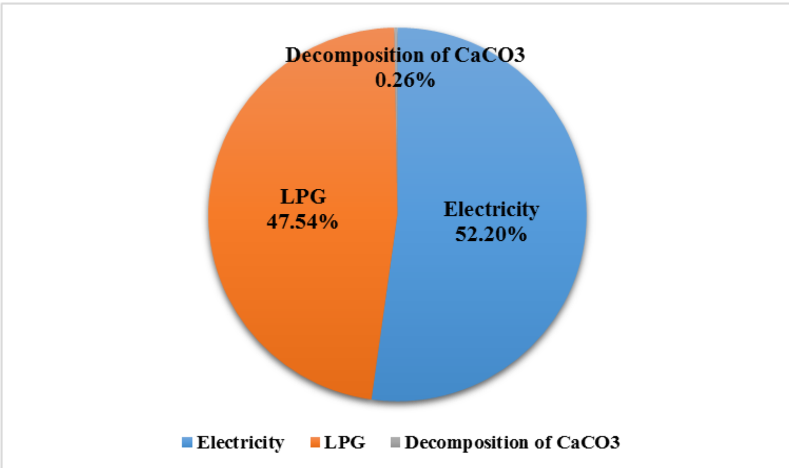
The GHG emissions from ceramic tableware production were from the consumption of energy (electricity and LPG) and the decomposition of calcium carbonate ($CaCO_3$) during glost firing. From Figure 5, the largest GHG emission was from electricity consumption (52.20%), followed by LPG during biscuit and glost firing (47.54%) and decomposition of calcium carbonate (0.26%). The results are shown in Table 3. Total GHG emission was 0.343 $kgCO_2e/kg$ of product. The largest GHG emission was from raw material preparation process (0.166 $kgCO_2e/kg$ of product), followed by glost firing process (0.131 $kgCO_2e/kg$ of product), biscuit firing process (0.032 $kgCO_2e/kg$ of product) and forming process (0.006 $kgCO_2e/kg$ of product).

Thus, raw material preparation and glost firing process was also found to be the hotspot of GHG emission. Accordingly, the energy conservation and GHG mitigation options for ceramic tableware production should be focused in raw material preparation and glost firing process.

Table 3. The GHG emissions in the unit of $kgCO_2e$ per kg of product

Unit Process	GHG Emission ($kgCO_2e$)				
	Electricity	LPG	Decomposition of $CaCO_3$	total	%
1. Raw material preparation	**0.166**	**-**	**-**	**0.166**	**48.41**
2. Forming	0.013	-	-	0.013	3.79
3. Drying	-	-	-	-	-
4. Biscuit firing	-	0.032	-	0.032	9.33
5. Glazing	-	-	-	-	-
6. Glost firing	**-**	**0.131**	**0.0009**	**0.131**	**38.53**
7. QC	-	-	-	-	-
Total	**0.179**	**0.163**	**0.0009**	**0.343**	**100**

Figure 5. Percentages of GHG emissions divided by sources in ceramic tableware production



4. Conclusion

The total energy consumption from the production of 8-inch ceramic bowl was 21.81 MJ/kg of product and almost 95% of total energy consumption was from LPG consumption during firing process. The amount of GHG emission was 0.34 $kgCO_2e$/kg of product. The largest GHG emission was from electricity consumption (52.20%), followed by LPG consumption (47.54%) and decomposition of calcium carbonate (0.26%). Raw material preparation process and firing process in kiln were found to be hotspots of energy consumption and GHG emission. Thus, the energy conservation and GHG mitigation options for ceramic tableware production should be focused in raw material preparation process and glost firing process.

Acknowledgement

The authors would like to thank the Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi (KMUTT), Center of excellence on Energy Technology and Environment, Ministry of Energy (CEE PERDO), Energy Conservation Promotion Fund, Energy Policy and Planning Office (EPPO), The Higher Education Research Promotion and National Research University Project of Thailand (NRU), Office of the Higher Education Commission for financial supports. The authors also would like to thank Lampang Ceramic Association (LCA) and Meesilp Co., Ltd. for their kind collaboration.

References

Department of Industrial Works. Standard industrial classification (Thailand) Tsic 2014. Available online: http://www.diw.go.th.

Quinteiro. P., Araujo. A., Oliveira. B., Claudia. A., Arroja. L. (2012), The carbon footprint and energy consumption of a commercially produced earthenware ceramic piece, *Journal of the European Ceramic Society*, pp.2087-2094.

Peng. J., Zhao. Y., Jiao L., Zheng. W., Zeng. L. (2012), CO_2 Emission Calculation and Reduction Options in Ceramic Tile Manufacturing- The Foshan Case, 2012 International Conference on Future Energy, Environment, and Materials, Energy Procedia, pp.467-476.

Barros. M.C., Bello. P., Roca. E., Casares. J. (2006), Integrated pollution prevention and control for heavy ceramic industry in Galicia (NW Spain), *Journal of Hazardous Materials* Volume 141, pp. 680-692.

Monfort. E., Mezquita. A., Granel. R., Vaquer. E., Escrig, A. (2009), Analysis of energy consumption and carbon dioxide emission in ceramic tile manufacture, Instituto de Tecnologia Ceramica (ITC), Spain.

Ibanez. V., Bovea. M.D., Azapagic. A. (2013), Assessing the sustainability of Best Available Techniques (BAT): methodology and application in the ceramic tiles industry, *Journal of Cleaner Production*, pp. 162-176.

Department of Alternative Energy Development and Efficiency (2007), Study of the energy consumption in the non-metal industry, Available online: http://e-lib.dede.go.th/mm-data/Bib11138.pdf

Intergovernmental Panel on Climate Change (IPCC). *IPCC Guidelines for National Greenhouse Gas Inventories 2006*. Available online: http://www.ipcc-nggip.iges.or.jp/public/2006gl.

Thailand Greenhouse Gas Management Organization (TGO). Emission factor CFP 2014. Available online: http://thaicarbonlabel.tgo.or.th/carbonfootprint/index.php.

Contact email: kannapkat.ch@hotmail.com
Contact email: siriluk.chi@kmutt.ac.th