

Corporate Carbon Footprint of Limestone Aggregate Production in Thailand: an Industrial Rock-Construction as a Case

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ABSTRACT

This research aimed to estimate the carbon footprint of limestone aggregate production in Thailand. An industrial rock-construction was specifically selected. Mining A, located in the central region of Thailand was considered as a case study. Of all potential sources of greenhouse gases (GHGs) emissions, the total amount of GHGs emitted by limestone crushed rock mining of the Mining A in 2015 was 2,922.75 tCO₂-eq. Estimated GHGs intensity was approximately 0.0480 tCO₂-eq/tonne of rock. By scope, emissions from transport activities (53%) (Scope I) was typically higher than Scope II (indirect emission from purchased electricity; 28%). Some strategies to reduce GHGs emissions from limestone aggregate production were recommended.

Key words: carbon footprint, industrial rock-construction, limestone aggregate, Thailand

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INTRODUCTION

Global climate change is a serious problem that our world society is facing today. There are several observations that the earth's climate is continually changing in many parts of the world. Since 1880, for example, the average global temperature has increased by about 0.76 °C. Furthermore, global sea levels have risen roughly 0.17 cm. since nineteenth century (Intergovernmental Panel on Climate Change [IPCC], 2013). It is now clear that a change in climate is due to man-made emissions of GHGs, especially the burning of fossil fuel, deforestation, and other activities. Evidently, IPCC (2013) indicated that atmosphere concentrations of carbon dioxide (CO₂) have significantly increased over 30% since the industrial revolution began. Globally, compared to transport and industrial activities, energy sector certainly has the largest share of GHGs emissions (31%) (United State Environmental Protection Agency [US EPA], 2014).

In Thailand, similarly, the primary sources of GHGs emissions are energy, agriculture and industrial related activities (Office of Natural Resources and Environmental Policy and Planning [ONEP], 2011). While industry plays an important role in the national economy, its production (i.e. mining activity) has long been recognized as causing major environmental problems such as pollution, energy and resources depletion and also GHGs emissions to the atmosphere. All of these perspectives refer to resource intensity. It is therefore very important to consider long-term production planning of mineral production and also give insights into key environmental problems as above mentioned. For instance, to achieve sustainable development goals (SDGs) 13 on climate change (United Nations Development Programme: UNDP, 2016), mining industry can reduce their own energy consumption as well as limit atmospheric GHGs emissions from their production processes. Carbon footprint of an organization, in general, is a tool to quantify climate impacts associated with organization activities. Both direct and indirect sources of GHGs emissions are considered. However, in Thailand, there are very few studies that simultaneously assess the emissions of GHGs from mining and mineral processing industries. The aim of this study is to quantify the total carbon footprint of limestone aggregate production. An industrial rock-construction in Thailand was selected as research case study.

MATERIALS AND METHODS

1. Research case study

Among all types of mineral resources in Thailand, limestone has the largest share of the total production compared to lignite and basalt, respectively. Over half (54%) of mined products are commonly used as an industrial rock for construction (Department of Primary Industries and Mines [DPIM], 2016). The limestone quarrying (Mining A) located in the central region of the country was selected and considered as a case, as depicted in Figure 1.

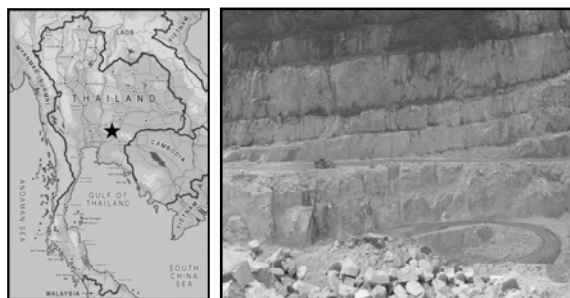


Figure 1 Mining A: research case study

2. Scope of the study

The operational boundaries of this study included all potential sources of GHGs emissions from limestone quarrying. As depicted in Table 1, both scope I (direct GHGs emissions) and scope II (indirect GHGs emission) were accounted. A process flow diagram of limestone aggregate production of a case was illustrated in Figure 2.

Table 1 Potential sources of GHGs emissions from limestone rock mining, by scope

Scope of emission	Scope description	Activities
<i>Scope I</i>	Direct GHGs emissions refer to all emissions from owned or controlled sources (operational control) by the organization.	<p>-Diesel fuel consumption for mobile vehicle combustion (i.e. trucks and excavators).</p> <p>-Ammonium nitrate/ fuel oil (ANFO) blasting agent utilization in drilling and blasting processes.</p>
<i>Scope II</i>	Indirect GHGs emission refer to emission derived from the purchase of electricity that indirectly generated by the organization. This scope is also considered mandatory by the Protocol.	-Purchased grid-electricity consumption for comminution processes (i.e. crushers and screeners).

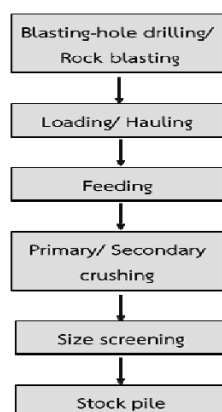


Figure 2 Limestone production processes diagram

3. Carbon footprint estimation

A carbon footprint is the measure of the environmental impact of a particular individual or organization's lifestyle or operation, measured in the unit of CO₂ (National Science and Technology Development Agency [NSTDA], 2016). In this study, the estimation of net GHGs emissions from limestone aggregate production was conducted based mainly on the GHGs Protocol issued by the World Resource Intuition (WRI) and the World Business Council for Sustainable Development (WBCSD). Principally, as illustrated in Eq (1), total GHGs emissions were obtained by multiplying emission factor (EF) with their corresponding activities:

$$\text{GHGs emission} = \text{Activity Data} \times \text{Emission factor (EF)} \quad (1)$$

Where:

- GHGs emission is the total amount of GHGs emissions from limestone rock production include those from direct and indirect sources (unit: tCO₂-eq).
- Activity data is all information used to calculate GHGs emissions from the mining processes and operations such as quantity of diesel-fuel consumed (unit: L), grid-electricity consumed (unit: kWh), and also amount of blasting agent utilized (unit: kg). As noted, data collection for all activity data was carried out each month during the period of study. Annual GHGs emissions finally were reported.
- Emission factor (EF) is defined as the average emission rate of a given GHGs for given sources, relative to unites of activity.

As noted, EF values issued by Thailand Greenhouse Gas Management Organization (TGO, 2015) and United State Environmental Protection Agency (US EPA, 1995) were used in Eq (1). For instance, EF of diesel fuel is 2.7446 kgCO₂-eq/L, EF of blasting agent (ANFO) is 2.390432 kgCO₂-eq/KgANFO and EF of grid-electricity is 0.5813 kgCO₂-eq/kWh. Within this, the total amount of GHGs emissions was expressed in the unit of “tCO₂-eq/year” (tonne carbon dioxide equivalent per year) base on one year data collection (2015). Furthermore, Eq (2) was used to estimate GHGs emission intensity, as follows:

$$\text{Emission intensity} = \text{GHGs emission} / \text{Production} \quad (2)$$

Where:

- Emission intensity is the level of GHGs emissions per unit of production (tCO₂-eq per tonne product).
- GHGs emission is the estimated total GHGs emissions derived from Eq (1).
- Production is the total amount of limestone rock production of Mining A (expressed in the unit of tonne product).

RESULTS AND DISCUSSION

1. Total GHGs emissions

Based on the mining company's data, the consumption of diesel fuel and purchased grid-electricity in 2015 were 292,732 L per year and 871,733 kWh per year, respectively. By weighting method, the productivity of limestone mining operation (Mining A) in 2015 was about 689,147 tonne per year. By considering all potential sources of emissions, the total amount of GHGs emitted by the Mining A as approximately 2,912.75 tCO₂-eq in 2015. As depicted in Figure 2, combustion of diesel fuel related to transport activities released over half of the net emissions (60%), compared to electricity consumption (28%) and blasting agent utilization (14%). By scope of emission, scope I (direct emissions from mobile combustion and blasting agent utilization) was the dominant source of GHGs rather than scope II (indirect emission from purchased electricity consumption) (WRI, 2011 and WBCSD, 2004). These results are similar to other findings in the literatures. For instance, the Environmental Management Office, Department of Primary Industries and Mines and Faculty of Engineering, Chiangmai University of Thailand (2010), reported that the diesel-fuel mobile mining equipment (i.e. haul trucks) was the largest source of emissions (35%) compared to other sources. In the same line, Ercelebi and Bascetin (2009) and Dindarloo *et al.* (2015) also reported that transport activities in surface and open-pit mining were responsible for over half (50-60%) of the total GHGs emissions. However, some studies have argued that electricity consumption for crushing and grinding processes in the coal and metal mining industry (i.e. gold mining) were found to be the largest source of CO₂ emissions (Sterling, 2009; Warmuzinski, 2008; Carras *et al.*, 2009; Kittipongvises, 2015).

2. GHGs intensity

In terms of GHGs intensity, the estimated GHGs intensity in 2015 was approximately 0.0480 tCO₂-eq/tonne product. As above mentioned, emission intensity from diesel-fuel related transport activities was by far the largest share (Figure 3).

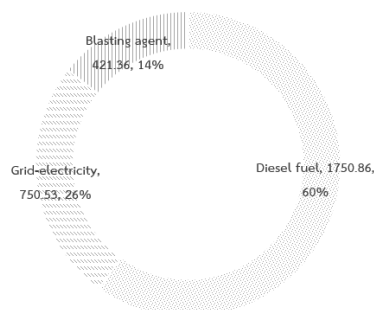


Figure 3 Proportion of GHGs emissions in 2015, by activities

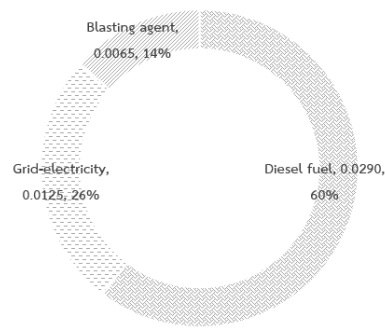


Figure 4 Proportion of GHGs intensity in 2015, by sources

3. Carbon footprint reduction options

It can be seen from Fig. 3 and 4 that combustion of diesel-fuel related to transport activities made the largest contribution of GHGs. Potentially, the following GHGs reduction options for mitigating these GHGs emissions are considered:

- Changing to a less carbon intensive fuel (i.e. CNG) (Delgado and Muncrief, 2015)
- Changing to appropriate vehicle power (i.e. shifting from a higher vehicle power to lower vehicle) (Kecojevic and Komljenovic, 2010)
- Reducing haul truck payload (Kecojevic and Komljenovic, 2010)
- Reducing maximum speeds (Kecojevic and Komljenovic, 2010)
- Managing vehicle acceleration (Parreira and Meech, 2013)
- Improving the mining specific logistics management (Ta *et al.*, 2013)

CONCLUSION

The purposes of this present study were to estimate total carbon footprint and investigate all potential sources of GHGs from the limestone mining operations in Thailand. The potential sources of GHGs were defined as the following:

- (i) Diesel fuel consumption (Scope 1)
- (ii) Blasting agent utilization (Scope 1)
- (iii) Grid-electricity consumption (Scope 2)

The results showed that the GHGs emissions and its intensity were about 2,912.75 tCO₂-eq and 0.0480 tCO₂-eq/tonne rock product in 2015, respectively. Compared to other sources, diesel-fuel vehicles and mobile equipment in mining operations were found to be the largest proportion (74%). GHGs reduction from transportation-related source therefore offers a high potential for mitigating climate change.

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REFERENCES

- Carras, J.N., S.J. Day, A. Saghafi and D.J. Williams. 2009. Greenhouse gas emissions from low-temperature oxidation and spontaneous combustion at open-cut coal mines in Australia. **International Journal of Coal Geology** 78: 161–168.
- Delgado, O. and R. Muncrief. 2015. **Assessment of heavy-Duty natural gas vehicle emissions: implications and policy recommendations**. International Council on Clean Transportation, Washington, DC, USA.
- Department of Primary Industries and Mines (DPIM). 2016. **Industrial rock-construction data source**. Available Source: http://mis.dpim.go.th/sourcestoneservice_public/sourcestone_data/index.html, November 1, 2016.
- Dindarloo, S.R., M. Osanloo and S. Frimpong. 2015. A stochastic simulation framework for truck and shovel selection and sizing in open pit mines. **Journal of Southern African Institute Mining Metallurgy** 115: 209-219.
- Environmental Management Office, Department of Primary Industries and Mines and Faculty of Engineering, Chiangmai University. 2010. **Reporting guidelines for development of mining industry to Clean Development Mechanism (CDM)**. Ministry of Industry, Bangkok, Thailand.
- Ercelebi, S. and G. Bascetin. 2009. A. Optimizing of shovel-truck system for surface mining. **Journal of Southern African Institute Mining Metallurgy** 109: 433-439.
- Intergovernmental Panel on Climate Change (IPCC). 2013. **Climate Change 2013: IPCC Fifth Assessment Report**. Geneva, Switzerland.
- Kecojevic, V. and D. Komljenovic. 2010. Haul truck fuel consumption and CO₂ emission under various engine load conditions. **Mining Engineering Magazine** 13: 44-48.
- Kittipongvises, S. 2015. Feasibility of applying clean development mechanism (CDM) and GHGs emissions reductions in the Gold mining industry: A case of Thailand. **Environmental and Climate Technologies** 15 (1): 34-47.

- National Science and Technology Development Agency (NSTDA). 2016. **Carbon footprint for organization**. Ratchathewi, Bangkok, Thailand.
- Office of Natural Resources and Environmental Policy and Planning (ONEP). 2011. **United Nations Framework Convention on Climate Change**. Phayathai, Bangkok, Thailand.
- Parreira, J. and J. Meech. 2013. **Simulation of an Open Pit Mine to Study Autonomous Haulage Trucks**. The University of British Columbia, Vancouver, Canada.
- Sterling, D. 2009. Identifying opportunities to reduce the consumption of energy across mining and processing plants. **Schneider-Electric**.
- Ta, C., H., A. Ingolfsson and J. Doucette. 2013. A linear model for surface mining haul truck allocation incorporating shovel idle probabilities. **European Journal of Operational Research** 231: 770-778.
- Thailand Greenhouse Gas Management Organization (TGO). 2015. **Emission Factor by Industrial Sectors**. Laksi, Bangkok, Thailand.
- United Nations Development Programme (UNDP). 2016. **Mapping mining to the Sustainable Development Goals: An Atlas**. New York, USA.
- United State Environmental Protection Agency (US EPA). 1995. **Explosives Detonation**. Washington, DC, USA.
- _____. 2014. **Global Greenhouse Gas Emissions Data**. Washington, DC, USA.
- Warmuzinski, K., 2008. Harnessing methane emissions from coal mining. **Process Safety Environmental Protection** 86: 315-320.
- World Resources Institute (WRI). 2011. **The greenhouse gas protocol: A corporate accounting and reporting standard (Revised Edition)**. World Business Council for Sustainable Development, Washington, DC, USA.
- World Resources Institute and World Business Council on Sustainable Development (WBCSD). 2004. **The Greenhouse Gas Protocol (A Corporate Accounting and Reporting Standard: Revised Edition)**. Geneva, Switzerland.