Quantification of GHGs Emissions from Electricity and Diesel Fuel Consumption in Basalt Mining Industry in Thailand

S. Kittipongvises, A. Dubsok

***Abstract*—**The mineral and mining industry is necessary for countries to have an adequate and reliable supply of materials to meet their socio-economic development. Despite its importance, the environmental impacts from mineral exploration are hugely significant. This study aimed to investigate and quantify the amount of GHGs emissions emitted from both electricity and diesel vehicle fuel consumption in basalt mining in Thailand. Plant A, located in the northeastern region of Thailand, was selected as a case study. Results indicated that total GHGs emissions from basalt mining and operation (Plant A) were approximately 2,501,086 $kgCO_2e$ and 1,997,412 $kgCO_2e$ in 2014 and 2015, respectively. The estimated carbon intensity ranged between 1.824 $kgCO_2e$ to 2.284 $kgCO_2e$ per ton of rock product. Scope 1 (direct emissions) was the dominant driver of its total GHGs compared to scope 2 (indirect emissions). As such, transport related combustion of diesel fuels generated the highest GHGs emission (65%) compared to emissions from purchased electricity (35%). Some of the potential implications for mining entities were also presented.

***Keywords*—**Basalt mining, diesel fuel, electricity, GHGs emissions, Thailand.

I. INTRODUCTION

MANY developed countries in the world have greatly benefited from the mining and mineral investment. Recently, a number of developing nations can also point to mineral-led economic development. In Thailand, for instance, the mining and quarrying industry potentially contributed to 3.4-4% of the country's gross domestic product (GDP) [1]. As illustrated in Table I, limestone, lignite, basalt and granite are considered to be the most important natural resources in the period 2011-2014 [2]. However, while mining and mineral processing operations provide developing nations with considerable opportunities for their development, the extraction of mineral resources can somehow put enormous pressure on the surrounding area and lead to negative environmental impacts such as increased air, water, soil pollution, energy and natural resources depletion.

As an increasing user of energy, the mining operation will be definitely responsible for the increased generation of GHGs to the global atmosphere. Evidently, regarding to total GHGs emissions in Thailand in 2012, the country's overall GHG emissions were approximately 227.73 million tones carbon dioxide equivalent ($MtCO_2e$). Within the industrial process and product use (IPPU) sector, 2A mineral industry accounted for over 73.46% of total emissions [3]. In Australia, according to experimental estimates of GHGs emissions induced by categories of final use, [4] reported that the mining and manufacturing sectors were the top two most significant contributors to the total GHGs emissions (both direct and indirect emissions) induced by exports in 2008-2009.

Dr. Suthirat Kittipongvises is with the Environmental Research Institute, Chulalongkorn University (ERIC), Research Program of Toxic Substance Management in the Mining Industry, Center of Excellence on Hazardous Substance Management (HSM), Research Unit of Site Remediation on Metals Management from Industry and Mining (Site Rem), Chulalongkorn University, Bangkok 10330, Thailand (phone +66-2-218-8214; fax +66-2-218-8210; e-mail: suthirat.k@chula.ac.th).
Atima Dubsok is with the Environmental Science Graduate School Chulalongkorn University, Thailand (e-mail: ployatima@gmail.com).

TABLE I
MINERAL RESOURCES CONSUMPTION IN THAILAND DURING 2011-2014 (MILLION TONS) [2]

Mineral resources	2011	2012	2013	2014
Limestone	137.97	147.15	157.96	161.44
Lignite	20.25	18.19	18.92	18.45
Basalt	10.98	10.54	10.22	13.98
Granite	5.02	5.30	7.61	6.91

Although mining extraction is one of the main concerns and important source of GHGs, there have, so far, been a limited number of studies attempting to measure the level of GHGs emissions in various industries in Thailand, including mining and exploration. The aim of this study was to quantify the amount of GHGs emissions emitted from both electricity and diesel vehicle fuel utilization in basalt mining. An industrial rock-construction plant was selected as the research case study.

II. METHODOLOGY

A. Case Study

A basalt mining and processing (Plant A) located in the northeastern region of Thailand, 430 kilometers east-northeast of Bangkok, was selected as the research case study (Fig. 1).

B. Method for GHGs Emissions Estimation

To estimate GHGs emissions, [5] classified an organization's GHGs emissions into three scopes, as follows:

Scope 1. *Direct GHGs emissions*: All emissions are direct emissions from owned or controlled sources of the plant or the entity, including emissions from fossil fuels burned onsite (stationary emission) and also emissions from mobile sources (mobile emission).

Scope 2. *Indirect GHGs emissions*: Indirect GHGs emissions refers to all indirect emissions from the purchase of electricity, heat or steam consumed that indirectly generated by the plant or the entity.

Scope 3. *Other indirect GHGs emissions:* Scope 3 emissions cover all other indirect GHGs emission that occur from sources not operated by the plant or the entity such as solid waste disposal, wastewater handling, and waste incineration, etc.

Only scope 1 and 2 were accounted and considered in this study. All sources of GHGs emissions were depicted in Table II.

Fig. 1 Research case study: Basalt mining

TABLE II
SCOPE AND SOURCES OF GHG$_S$ EMISSION [2]

Scope	Sources of emissions
Direct emissions, as in (1)	Emissions from transport-related combustion of fuels (mobile combustion activities)
Indirect emissions, as in (2)	Emissions associated with purchased electricity from the grid.

The estimation of GHGs from both direct and indirect emission (Table II) can be done by the following calculation:

$$\text{Emission} = \text{Quantity of fuel combusted}_{ab} \times \text{EF} \quad (1)$$

where: a= fuel type, b = vehicle type, EF = 2.7446 $kgCO_2eq/L$ of fuel consumption [6], [7].

$$\text{Emissions} = \text{Electricity consumed} \times \text{EF} \quad (2)$$

where: a = Quantity of electricity purchased from the grid (kWh), EF = 0.581 $kgCO_2eq$/ kWh of electricity consumed [6], [7].

Based on a two year average (2014-2015), the calculations were expressed in the unit of "kilogram carbon dioxide equivalent ($kgCO_2e$)", as the representative of the total GHGs emissions.

C. Basalt Mining Process

Geomorphologically, basalt is an extrusive igneous rock or volcanic rock, with commonly 45-55% SiO_2 and less than 10% feldspathoid, formed by the rapid cooling of basaltic lava from interior of the crush and exposed at or very close to the surface of a planet. There are three main steps of basalt rock quarrying process: (i) mining, (ii) transport and (iii) comminution, as depicted in Fig. 2.

Mining: Drilling is a primary mean of basalt rock extraction. Blasting is then conducted by discharging an explosive agent (i.e. ammonium nitrate fuel oil) in a borehole.

Transport: Mined rock is directly transported to the processing plant by truck. The proportion of fuel consumed during mining transport is correspondingly high, compared to other sources.

Comminution: The purpose of comminution process is to reduce the size of basalt block, as small as desired range of grain size, by using both primary and secondary crushing machines. Among all the sources, this process requires large amount of electricity.

Fig. 2 Basalt rock mining process

III. RESULTS AND DISCUSSION

A. Electricity and Diesel Fuel Consumption

In terms of productivity, the average value of basalt rock production of the plant A (from 2014 to 2015) was approximately 1,095,000 tons/year. In the case of mining operations, the fuel consumption of diesel vehicle and electricity utilization, on average, were ranged between 0.376-0.602 liters/ton product/year and 0.951-1.234 kWh/ton product/ year, respectively (Table III).

TABLE III
ANNUAL DIESEL FUEL AND ELECTRICITY CONSUMPTION PER TON PRODUCT OVER 2014-2015

Year	2014	2015
Average diesel fuel consumption (liters/ton product)	0.602	0.376
Average electricity consumption (kWh/ton product)	1.234	0.951

B. GHGs Emissions Quantification

Total GHGs emissions: Both scope 1 and 2 (direct and indirect sources of emissions) were considered in this study. In terms of carbon intensity, the results found that the total GHGs emissions of basalt mining (Plant A) were about 2,501,086 $kgCO_2e$ and 1,997,412 $kgCO_2e$ or 2.284 and 1.824 $kgCO_2e$ /ton of product in 2014 and 2015, respectively. When compared to the findings done by [8], the results of this research were within the range of other studies (1.48 – 2.52 $kgCO_2e$ per ton hard rock aggregate). By scope, Fig. 3 clearly indicated that scope 1 (i.e. diesel fuel consumption) was by far the dominant driver of its total GHGs emissions compared to scope 2 emissions. Some of these results contradict with [9], in which it was indicated that electricity consumption in the comminution process made the greatest contribution to the GHGs footprint.

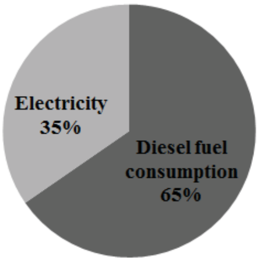

Fig. 3 Percentage of GHGs emissions, by source

Emissions from diesel fuel consumption: GHGs emissions from transport related combustion of diesel fuels of the Plant A in 2014 and 2015 were 1,811,436 $kgCO_2e$ and 1,130,775 $kgCO_2e$, respectively.

Emissions from purchased electricity: For electricity consumption, the total GHGs emissions from both electricity used in the mineral processing operation and also electricity used in the staff dormitory were approximately 689,650 $kgCO_2e$ and 866,637 $kgCO_2e$ in 2014 and 2015, respectively. As such, compared to other sources, the majority of CO_2 emissions came from electricity used by the mining equipment (88-90%) (Fig. 4).

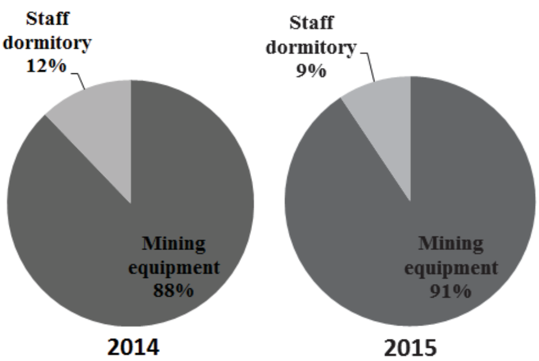

Fig. 4 Emissions from purchased electricity of the basalt mining operation over 2014-2015

In this study, as diesel fuel consumption generated the highest GHGs emission, the mining industry has to identify many energy savings in diesel using activities. There are, in fact, many variables that can affect haul truck fuel consumption such as liters of diesel per tons transported, the distance travelled, the payload per cycle, rolling resistance, and also an individual hauling task. Potential technological and operational options to reduce GHGs emissions are haul truck payload management, total rolling resistance reduction, vehicle idling time reduction and also the adoption of less carbon-intensive fuels (i.e. LPG, CNG, LNG instead of diesel).

IV. Conclusion

Minimizing carbon emissions from industry requires a sustained and focused effort. Minerals and mining industry are one among many sectors closely examining its GHGs footprint. In this study, the largest contributors to GHGs emission in basalt mining were diesel-using activities (i.e. for truck and mining equipment), which accounted for about 65% of total CO_2 emissions. Meanwhile, emissions from purchased electricity were the second largest source (35%). Therefore, considerations of energy conservation and energy efficiency should urgently start with the mineral exploration plan. Mine operators, meanwhile, have to consider both cost and benefits of each emission reduction technology in a sustainable manner.

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Kittipongvises, S. is currently a lecturer at Environmental Research Institute, Chulalongkorn University (ERIC), Bangkok, Thailand. She finished her Ph.D. in Sustainability Science from the Graduate Program in Sustainability Science, Graduate School of Frontier Sciences, the University of Tokyo, Japan in 2013. In 2008, she also earned her Master degree from the Environmental Engineering and Management from the School of Environment, Resources and Development (SERD), Asian Institute of Technology (AIT), Thailand. Her research focuses on climate change mitigation, GHGs emissions quantification, green mining industry, and also sustainable development concept. Furthermore, she has presented her research at various conferences including International Climate Change in Copenhagen, Denmark in 2009, International Coanference of Climate Change and Global Warming (ICCCGW), the World Academy of Science, Engineering and Technology, Venice, Italy in 2011, International Conference on Sustainability Science (ICSS), Arizona, USA in 2012, International Conference on Ecology, Ecosystems and Climate Change, Athens, Greece in 2013, and International Conference on Environmental Science and Development, Amsterdam, Netherland in 2015.