ARTICLE CASE

Carbon Management in an Emissions-Intensive Industry in a Developing Economy: Cement Manufacturing in Indonesia

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ABSTRACT Around 600 Mt carbon dioxide equivalents (CO_2e) of anthropogenic greenhouse gases (GHG) emission originates from energy production and consumption in Indonesia annually. Of this output, 40 Mt CO_2e comes from cement production. This makes the cement industry a key sector to target in Indonesia's quest to reduce its emissions by 26% by 2020. Substantial opportunities exist for the industry to reduce emissions, mainly through clinker substitution, alternative fuels, and the modernization of kiln technologies. However, most of these abatement options are capital intensive and considered as noncore business. Due to this, the private sector is unlikely to voluntarily invest in emission reduction unless it saves money, improves revenue, enhances the strategic position of the firm, or unless governments provide incentives or force adoption through regulatory and policy controls. In this study, we review the profile of the Indonesian cement industry and assess the carbon management and climate policy actions available to reduce emissions. The case highlights opportunities for improved carbon management in emission-intensive industries in developing countries.

KEY MESSAGE

Students along with industrial observers will evaluate how current operations in Indonesian cement industry affect greenhouse gases (GHG) emission reduction opportunities. With these results, they will gain insight into the factors that hinder and encourage GHG emission reductions along with possible intervention opportunities.

INTRODUCTION

The Indonesian government has committed to lowering greenhouse gases (GHG) emissions by 26% by 2020 through domestically funded initiatives. In addition to this, it is also targeting an additional 15% reduction through international support. Achievement of these goals will depend heavily on the forestry and energy sectors (production and consumption) [1–3]. Previous GHG emission reduction efforts in the country were primarily focused on deforestation, forest fires, and peatland degradation. More recently, the Indonesian government has increased its focus on the country's energy production and consumption sector.

The Indonesian government estimates that Indonesia's GHG emissions[1] from the production and consumption of energy will rapidly increase from 598 Mt carbon dioxide equivalent (CO_2e) in 2014 to between 2,900 and 3,829 Mt CO_2e by 2050 [4]. Current GHG emission reduction priorities concentrate on high-consumption sectors, of which manufacturing is the leader, accounting for more than one-third of total energy consumption in Indonesia [4, 5].

Based on the International Standard Industry Classification 1990 (ISIC 1990), Indonesian industries fall into 23 sectors and 343 subsectors. Half of the GHGs are

1. The standard unit used to describe greenhouse gas emissions is t CO_2e (tonne of carbon dioxide equivalent) and Mt as million metric tonnes.

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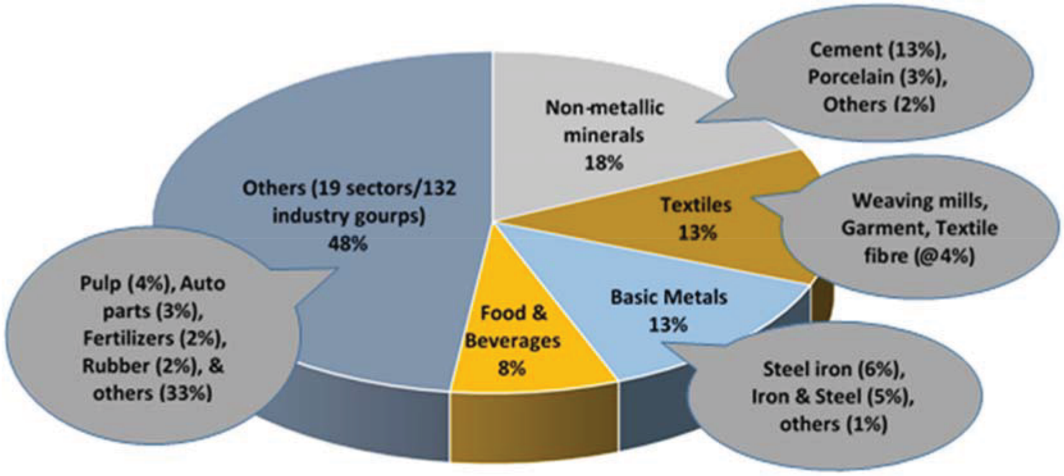

FIGURE 1. Indonesian greenhouse gas emissions contribution from manufacturing in 2005 (Source: Ref. [6]).

generated from just four of the 23 sectors with only 11 of the total 343 subsectors responsible for the emissions [6].

The cement industry, which is in the nonmetallic mineral sector, is the most significant contributor to GHG emissions [6]. In 2005, it accounted for approximately 13% of the total GHG emissions from the manufacturing sector, or around 4% of Indonesia's total GHG emissions from energy consumption and production sector (Figure 1).

Previous research has shown that the global cement industry has significant impact on GHG emissions in the world with an output of approximately 7% of the total global GHG emissions, or one-quarter of GHG emissions from global industrial activities [7]. In Indonesia, the cement industry also produces significant GHG emissions, and it has been listed as one of the top priority for GHG emission reductions by the government [6]. Further analysis is now needed to determine the energy intensity of cement production, its emissions, potential reductions, challenges, and the role of government in the Indonesian cement industry. The results of such an analysis can be used to generate comprehensive information to support ameliorative measures in the Indonesian case.

CASE EXAMINATION

Overview of the Cement Industry in Indonesia

Intensive infrastructure by government, high population growth, and open markets drive cement production in Indonesia. Annual consumption is around 243 kg per capita, compared with Thailand (443), Vietnam (661), Malaysia (751), and Singapore (1,100) [8].

Cement companies in Indonesia consist of locally owned (private and state) and foreign investments. The largest is PT Semen Indonesia Tbk, with an output capacity of 31,800 t/year. This firm is state owned and the holding company of PT Semen Gresik, PT Semen Padang, and PT Semen Tonasa. The installed capacity of cement production in Indonesia is currently more than 75,000 t/year and should increase significantly due to rapid investment in factories (Figure 2) [9].

From 2012 to 2017, a total of US$6.68 billion was invested in the cement industry across the archipelago. This investment leads to the building of 19 new factories, which is an increase of 111% compared to 2012. However, since 2014, the national demand for cement has weakened in line with constrained economic growth and purchasing power. Despite the sales decline, the industry has not seen any relief in marketing and distribution costs [10]. A change in buying patterns due to large-scale infrastructure projects has also seen more purchasing in bulk rather than in bags. This shift negatively affects revenue. Excess supply, together with rising energy prices and the costs of labor and raw materials, has severely impacted the cement industry [10, 11]. To stimulate demand, the government has asked state-owned cement companies to reduce the regular selling price per sack by IDR 3,000 (US$0.25) or equivalent between 5 and 6%, although this move naturally challenges profitability [10]. Under these circumstances, companies need to

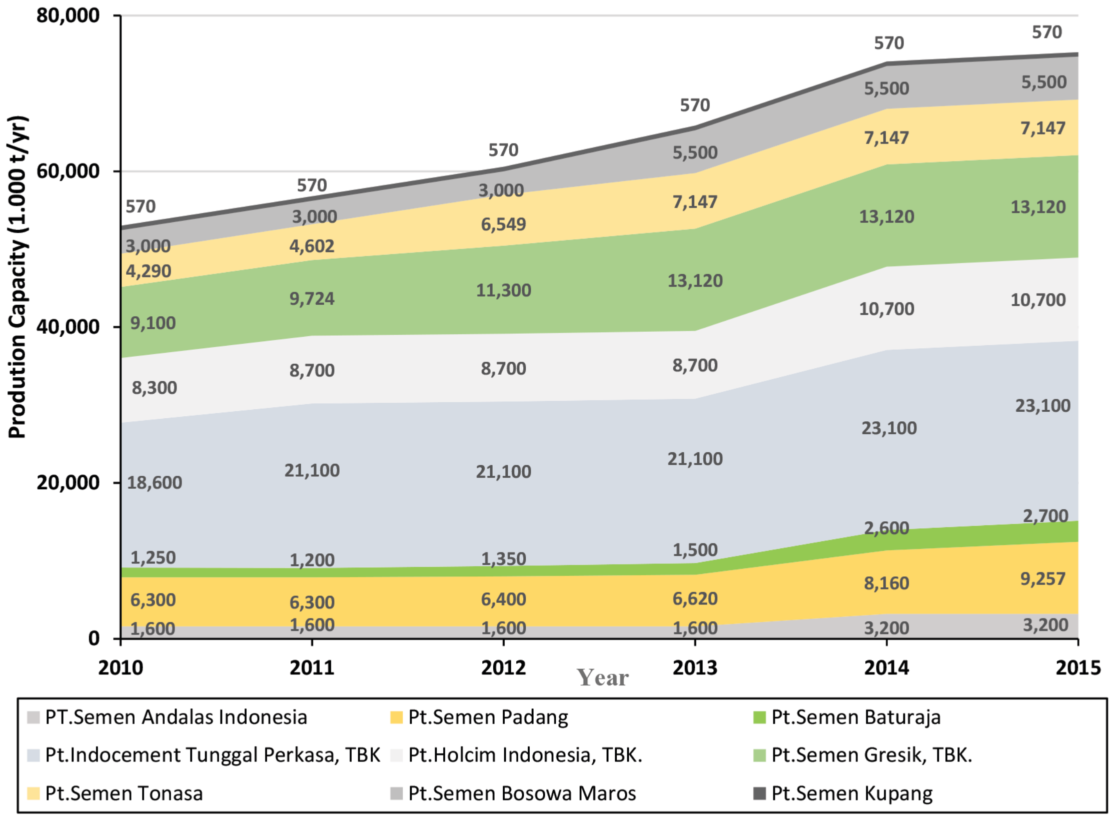

FIGURE 2. Production capacity of cement companies in Indonesia (Source: Ref. [9]).

consider actions that focus on lowering additional expenditure and increasing productivity. Innovation in areas such as energy conservation can ensure that firms undertake more efficient industrial energy use to maintain profitability. Therefore, efforts to improve environmental performance could still be possible despite weakening market conditions.

Cement Production

Cement is made by mixing and grinding clinker with other materials such as gypsum and silica sand depending on product specification. Clinker is a dark gray, nodular material made by heating limestone and clay soils at a temperature of about 1,400–1,500°C to achieve calcination and lime mineralization. Of the energy needed for cement production, around 90% is expended in making clinker [12]. The clinker can be partially replaced by clinker substitution, such as fly ash, which consists of wastes containing silica, aluminum, and iron oxides derived from other industrial and energy processes (e.g., power plants or other coal-burning facilities). The use of these substitutes can significantly reduce GHG emissions.

The GHG emissions generated to produce 1 t of cement vary across the globe. In 2005, there were 0.84 t CO_2e in Indonesia, 0.63 t CO_2e in Germany, 0.81 t CO_2e in North America, and 0.9 t CO_2e in Russia [13]. In 2012, the average GHG emission worldwide was 0.79 t CO_2e in creating 1 t of cement [14].

Emissions in cement production consist of heat, dust, and gases, the latter two are measured volumetrically. Depending on the factory, the dust will either be released into the atmosphere or collected to be reused in subsequent production. Presently, gases, such as CO_2, SOx, and NOx, are simply vented into the atmosphere. GHG emissions can be measured by calculating the amount of total GHG emissions generated as a result of the activities involved in cement production.

Greenhouse gases emission-generating activities are usually divided into three categories. First are direct emissions from the calcination process to produce clinker, the main ingredient in cement making. Emission produced is equal to 0.5 t CO_2e per tonne of clinker, representing 50–70% of the total of the cement production outflow. Second, direct emissions from fuel combustion of inputs

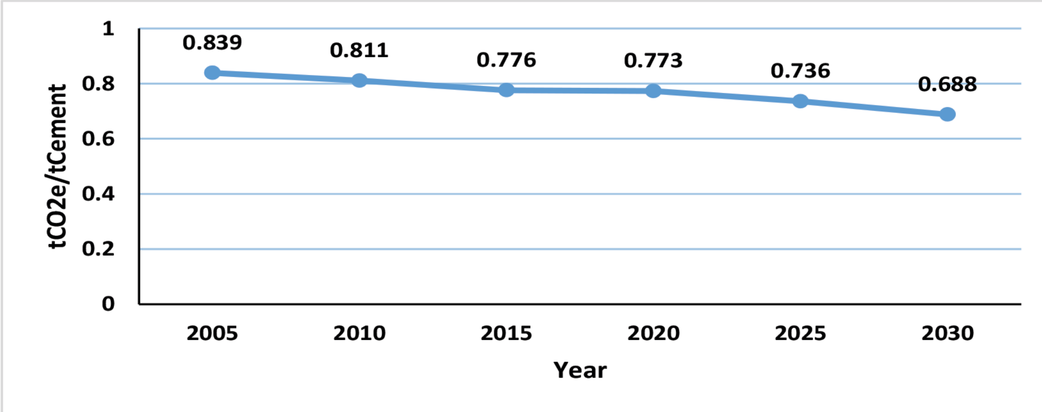

FIGURE 3. Projection of emission intensity in Indonesia's cement sector (Source: Ref. [15]).

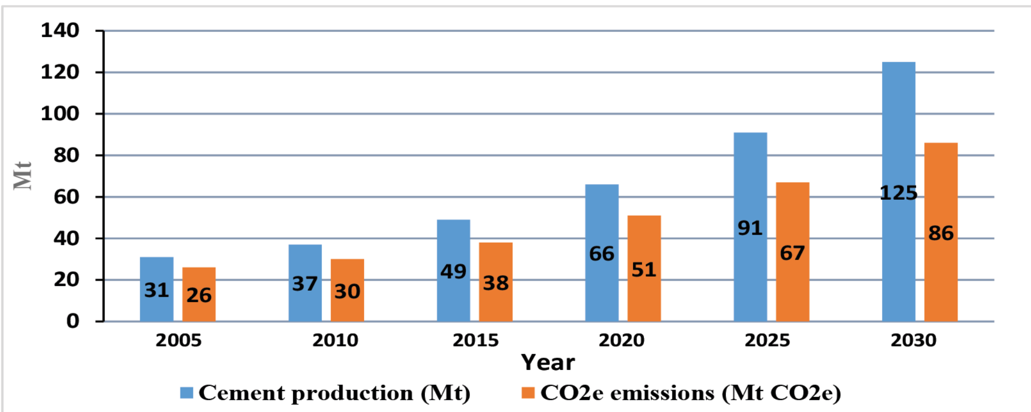

FIGURE 4. Projection of cement production and greenhouse gases emissions in Indonesia's cement sector (Source: Ref. [15]).

such as coal can account for up to 34% of the total. Finally, indirect emissions associated with electricity consumption contribute about 12% [13, 14].

Cement production in Indonesia is forecast to see a fourfold increase from 31 Mt in 2005 to 125 Mt in 2030. Yet, GHG emissions will rise only threefold from 26 Mt CO_2e in 2005 to 86 Mt CO_2e in 2030, due to the projected decrease of about 18% in emission intensity[2] levels over the same time span (0.839 in 2005 to 0.688 in 2030) (Figure 3). Presently, the level of GHG emissions has reached 40 Mt or an increase of 54% compared with 2005 (Figure 4) [15].

The average GHG emissions across Indonesian cement plants in 2005 were 1.444 Mt CO_2e/year, a level well above those of the average factory in other manufacturing subsectors (Table 1). The Indonesian government regards the cement industry as an energy-intensive sector, in that 30–40% of its production costs are energy related. Therefore, targeting it in climate mitigation policies has become a key priority in improving energy efficiency and reducing GHG emissions in the manufacturing industry.

Improving Energy Efficiency in Cement Production

The global cement industry faces the challenge of conserving material and energy resources [16–18]. Madlool et al. [19] determine that there were opportunities to improve energy efficiency for cement factories around the world because the low level of energy utilization ranged from 18 to 49%. Apart from the potential of improving efficiency due to the current level of energy utilization, the use of substitutes for fuel and clinker presents an alternative option to reduce GHG emissions [20].

2. Emissions intensity describes the average emission rate from a given source relative to a given intensity of activity in a production process.

TABLE 1. Highest greenhouse gases (GHG) emitting the Indonesian manufacturing sector among medium and large firms in 2005

Manufacturing sectors	Number of plants	International Standard Industry Classification (ISIC) Code	Estimated GHG (Million t CO_2e)	Average GHG per plant (Million t CO_2e)
Cement	18	26411	26	1.444
Steel rolling industry	66	27102, 27101	10.1	0.153
Textile	808	17114, 18101, 17111, 17122, 17112	13.1	0.016
Pulp and paper	52	21011, 21012	4.9	0.094
Ceramic	15	26202	2.9	0.193
Fertilizer	9	24122	1.9	0.211
Crude palm oil	295	1514, 15144	1.9	0.006

Sources: Refs. [6, 15].

Indonesian industries have been receiving energy subsidies for many years and this, inevitably, would hamper any from policy initiated by the government that could lead to the elimination of public assistance or implementation of carbon taxes to drive efficiency improvements. Serious efforts are needed to convince the cement industry that efficiency has many benefits, such as reducing costs and GHG emissions, lowering environmental impact, and raising competitive value.

Many companies still have not implemented energy efficiency as an essential facet of their business or core competencies. The divergence between effective levels to minimize energy costs and actual levels achieved is referred to as an energy efficiency gap [21–24].

According to the Indonesian Cement Association, the energy required to produce 1 t of cement in 2012 was approximately 883,181 kcal. The energy sources involve coal and electricity. The amount of coal needed is 0.15 t, equivalent to 760,000–780,000 kcal. The amount of electricity is 120 kWh, equivalent in energy units to 103,181 kcal (1 kWh = 859.845 kcal) [25]. The use of low-calorie coal (containing 5,100 kcal for each kilogram) still dominates cement manufacturing; a somewhat wasteful situation because, to produce the same heat energy, it would require less amount of coal with a higher calorific value. The domestic high-calorie coal is designated for the export market.

Emission Reductions

The cement industry requires high capital investment and long-term outlooks for returns on investments. Innovations in emission reduction pose substantial costs and lengthy time spans. Yet, the opportunity for financial gain or cost savings is significant in attracting business to make improvements. The benefits can be a product with lower cost and better quality than those of competitors [26], and also complying with regulations regarding environmental policy or market conduct and evidencing social/moral responsibility [27].

The Government of Indonesia has defined a roadmap for companies through the Regulation of the Minister of Industry (Permen Perindustrian 12/2012) and sets out quantitative targets for emission reductions but does not feature a reward/penalty scheme [3]. Still, it demonstrates the seriousness of the government's stance toward this sector, notwithstanding that other high-energy intensive industries remain to be regulated.

Furthermore, Government regulation PP 70/2009 of Energy Conservation draws on supporting laws to increase effectiveness in reducing emissions. Proceeding from PP 70/2009 is the Regulation of the Minister of Energy and Mineral Resources (Permen ESDM 14/2012), which provides finance to corporations which meet energy targets. The regulations create an opportunity for professional audits without burdening the business, since returns will be funded by other parties such as the Indonesian Climate Change Trust Fund. Through this support, it is expected that recommendations will emerge for high-efficiency improvement.

The National Climate Change Council in Indonesia has foreseen significant emission reductions by 2030 based on the three direct and indirect emission-generating categories mentioned above. First, clinker substitution can offer 7.5 Mt CO_2e at an average cost saving of US$25 for the reduction of 1 t of CO_2e.

Second, the utilization of alternative fuels such as industrial waste is estimated to reduce emissions by 4.5 Mt CO_2e at an average cost of US$8 per tonne of CO_2e reduction. Third, adoption of the latest technology will lead to further potential emission reduction of 12% (or 9 Mt CO_2e). This last avenue is capital intensive and tends to be avoided [15]. Therefore, the projected reduction of GHG emissions should be focused on increasing the use of clinker and fuel substitution.

Initiatives to reduce emissions have been taken by several companies. Some have used the Clean Development Mechanism (CDM) to access financial benefits from GHG emission reduction. CDM is a mechanism that enables GHG emissions reduction projects in developing countries to obtain certified emission reduction credits (CERs). These CERs can be traded and used by industrialized countries to fulfill their emission-reductions commitment under the Kyoto Protocol. Through this mechanism, industrialized countries unable to control exhaust GHG emissions are given flexibility in meeting their reduction targets by required to buy in countries or companies which can reduce GHG emissions in their production. For example, PT Semen Indonesia has binding cooperation with the Swedish Government in this CDM Project based on an Emission Reduction Purchase Agreement. Revenues earned by PT Semen Indonesia from Sweden are in the form of sales of Certified Emission Reduction (CER) issued by the United Nations Framework Convention on Climate Change. PT Semen Indonesia Tbk has been able to reduce emissions by 222,977 t CO_2e per year through the utilization of biomass from coconut peat as an alternative fuel, one which is widely available. Through the CDM mechanism, PT Semen Indonesia earns revenue from selling the resulting GHG emissions reductions. In the first phase, the CER traded has been 193,536 t CO_2e at a price of EUR 3.75 per CER. The deal will provide an annual income of EUR 725,760 or IDR 10.1 billion for 6 years (2012–2018) [28]. Under the same initiative, PT Indocement expects to reduce its emissions by 469,750 t CO_2e in 2017. The GHG emissions reduction activity is focused on the calcination process where a clinker substitute will be added to produce a new cement mix (Portland Composite Cement) [29].

Strategy to Enhance Production Efficiency

Production efficiencies relate to a factory output/input quantum. In cement production, the conversion of material input to output is close to 100% because almost all the waste can be reused. This situation means that production efficiency can only be achieved, first, by reducing energy input per unit output or, second, by reducing noxious output, principally GHG gases.

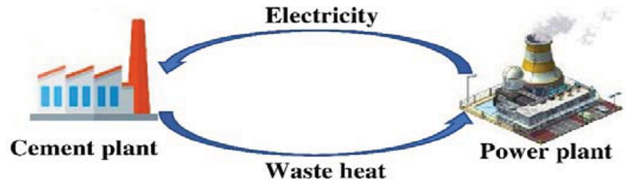

FIGURE 5. Waste heat recovery power generation.

Improvement of energy efficiency and reduction of GHG emissions could be principally achieved by: adjusting the chemical composition of cement, in particular, to reduce clinker usage; and by changes to the manufacturing process. Emissions from limestone calcination to produce clinker can be decreased through clinker substitution or production of blended cement and raw material selection. The manufacturing process can be enhanced by energy management and investing in the latest equipment.

The process of converting raw material into clinker under high temperature in a kiln could be a key area to focus on enhancing production efficiency to reduce GHG emissions in cement factory [30]. Furthermore, grinding and milling also offer an opportunity for energy saving [31], and alternative fuels such as biomass and waste can be an option to reduce GHG emissions. The waste heat from the process can be used to operate a power plant or Waste Heat Recovery Power Generation which is being implemented by some cement factories. This innovation can encourage the creation of an eco-industrial complex that has the concept of exchange or reuse to minimize the use of energy, raw materials, and minimize waste. The exchange is in the form of a power plant that utilizes heat from the exhaust gas from the cement plant and distributes the electricity generated back to the cement plant (Figure 5). In the future, the Carbon Capture and Storage will probably be a viable alternative to carbon-free operation [15].

Issues in Strategy Formulation

There is still a lack of policy and regulatory support in creating a strategy formulation for GHG emission reduction.

Supports are needed, among others, in setting new cement standards and they act to hamper product and process improvements.

In connection with utilization of the latest technology, the Indonesian Ministry of Industry needs to identify existing options and provide additional incentives such as the removal or moderation of government import duties. These incentives need to be given to anticipate the reluctance of the industry to implement because of high costs. If the interventions are still not adequate and investment inefficiency persists, a subsidy policy is required [21]. Appropriate energy and economic policies will help solve the problem as carbon costs increase to keep enhancing the competitiveness of domestic industries [22].

The cement industry needs to analyze and calculate their GHG emissions to provide carbon footprint information, which can be used as an indicator of best practice or overall sustainability, followed by identification of mitigation measures and their implementations. These steps are taken so that business analysts can determine the impact on a company's activities due to carbon costs.

The industry is also experiencing other difficulties in reducing GHG emissions, especially in adjusting to official policies. Some of the government policies have the potential to hinder the introduction of clinker substitutes as stipulated in provisions such as Government Regulation No. 85 of 1999 and PP No.101/2014. The regulation does not permit the purchase or import of hazardous and toxic materials such as fly ash, so the opportunity for clinker substitution with high-quality domestic fly ash is limited [32]. The cement industry may experience other limitations in obtaining fly ash because it is needed in production of asphalt and is used widely in the construction industry [15].

Cooperation between the Ministry of Industry and other agencies, including the Customs Board, the Ministry of Forestry and Environment, and the Ministry of Finance, is critical. This collaboration should support the import of clinker replacement materials and the utilization of coal combustion waste, such as fly ash. Cooperation can also support the acceleration and acceptance of fly ash for environmental-friendly building materials by means of certificates issued under the Indonesian National Standard.

CONCLUSION

The industrial sector accounts for the most significant GHG emissions in Indonesia, nearly one-third of the national total GHG emissions from energy production and consumption sector. The leading contributor is cement manufacturing, growing strongly and responsible for about 7% of total GHG emissions in 2017, or around 20% of GHG emissions from industrial activity. Emissions from cement plants are expected to increase by more than 300% in 2030 when comparing levels achieved in 2005. The industry is thus a natural target for reduction measures required by the government.

The sources of emissions from the cement industry include the process of calcination, burning coal for clinker production, and burning fossil fuels in industrial power plants. Most (i.e., 70%) of the GHG emissions emerge from the calcination process. Hence, it is the focus of intervention, with attention directed to subactivities, clinker substitution stands out, followed by the use of alternative fuels, and application of the latest technology.

Research shows the potential for GHG emissions reductions in global cement production to be significant, that is, up to 50% [29]. Furthermore, reduction opportunities in Indonesia cement industry are expected to reach 21 Mt CO_2e in 2030 by some estimates [15]. Compared to other industries that have a larger number of factories and a more complex and diverse production process, the Indonesian cement industry has fewer factories with the similar production process, this makes the proposed implementation of GHG emissions reduction actions more feasible and can be easily replicated.

However, GHG emission reduction is not a core activity in the cement industry as it requires a large capital outlay and often considered an unimportant component in the industry's decision-making process. This condition is generally influenced by a lack of expertise in developing mitigation opportunities that are appropriate to the conditions of the company [21, 33]. Excellent carbon management is needed for benchmarking and in demonstrating intervention options. Action should begin with measurement of emissions from all production activities, leading to identification and implementation of ways to foster mitigation.

The choice of intervention should be determined from an analysis of carbon costs and consideration of the means of cost reduction and enhancement of profitability. Through all the stages of management, policymakers can assess abatement options and costs by describing the cost-effectiveness available to be able to overcome their concerns about investment shortcomings or efficiency gaps.

This case study has concerned a heavy and noxious industry that works with vast quantities of materials and energy. However, the use of emission intensity as a standard for measuring industrial performance is straightforward and can be widely applied. Therefore, it will not be difficult for the industry to establish its aspirations and targets because it refers to lowering the level of emission intensity, thus allowing readers to monitor the steps needed in coming years.

CASE STUDY QUESTIONS

1. How are emissions measured, and what are the current and future levels emanating from the cement industry in Indonesia?
2. What are the sources of emissions and their potential for reduction?
3. What are the factors that have the potential to inhibit and encourage the decision process and implementation for emission reduction?

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COMPETING INTERESTS

The authors have declared that no competing interests exist. Paul Dargusch is a Section Editor at Case Studies in the Environment, and he was not involved in the peer-review of this article.

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