STRATEGIES FOR IMPROVING THERMAL AND ELECTRIC ENERGY EFFICIENCY IN THE VIETNAMESE CEMENT INDUSTRY

by
Linh Nguyen

A capstone submitted to Johns Hopkins University in conformity with the requirements for the degree of Master of Science in Energy Policy and Climate

Baltimore, Maryland
May 2020

ABSTRACT

Cement production is one of the main engines for economic growth in Vietnam. Over the past few years, Vietnam has emerged from being an importer of cement to one of the top ten cement producers in the world. In 2018, the country exported 30 million tons of cement to earn over USD 1 billion. Vietnam is striving to become the leading producer with ambitious plans for capacity expansion. Despite positive contributions to the economy, Vietnam's cement industry is highly energy-intensive and the major contributor to the rise in GHG emissions. There is currently a lack of consensus by the Ministry of Construction (MOC) on best practices to promote and incentivize investments in energy efficiency projects. This research paper aims to conduct a holistic assessment of Vietnam's cement value chain and provide recommendations based on international best practices to overcome investment barriers in thermal and electric efficiency projects. The results indicate that the MOC must enforce stringent regulations to control production overcapacity, reduce input costs, address poor chain governance, and improve inefficient thermal production technologies and processes. Current actions by the MOC and international donors such as the World Bank (WB), Green Climate Fund (GCF), International Finance Corporation (IFC), and Nordic Development Bank are concentrated on improving market awareness. The MOC must focus more on programs and policies that increase the opportunity costs of not investing in EE solutions to trigger EE investments.

ACKNOWLEDGEMENTS

I would first like to express my gratitude to Ashley Lawson, my thesis mentor, and professor at Johns Hopkins. Ashley's lectures on energy and climate finance were what sparked my interest in writing my research paper on financing strategies for sustainable development. Her support and expertise on the subjects discussed in this paper have been invaluable.

I would also like to thank my academic advisor, Daniel Zachary, for not only providing his guidance throughout my writing process but also throughout the Energy Policy and Climate program at Johns Hopkins. His door was always open for me whenever I had any questions about my research writing or academic pursuits.

Finally, I would like to thank my parents for their unwavering support and unconditional selflessness that has opened many doors for me to learn, grow, and succeed in whatever I choose to do. My accomplishments would not have been possible without them.

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LIST OF ABBREVIATIONS

BAU	Business as Usual
EE	Energy Efficiency
EVN	Electricity of Vietnam
GCF	Green Climate Fund
GHG	Greenhouse Gas
MOC	Ministry of Construction
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MRV	Monitoring, Reporting and Verification
NATIF	National Technology Innovation Fund
NDF	Nordic Development Fund
PHPC	Preheater/Precalciner
RSF	Risk Sharing Facility
UNIDO	United Nations Industrial Development Organization
USD	United States Dollars (currency)
VICEM	Vietnam Cement Industry Corporation
VINACOMIN	Vietnam National Coal and Mineral Industries Group
VNCA	Vietnam National Cement Association
VND	Vietnamese Dong (currency)
WB	World Bank
WHR	Waste Heat Recovery

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1. INTRODUCTION

1.1 Cement Industry Context

Cement is paramount for economic growth and poverty reduction in Vietnam. It is an essential ingredient in the production of concrete, which is needed for the construction of large infrastructure projects in the transportation, energy, water, and building sectors. The growing need for infrastructure and property construction to foster economic development has created a robust domestic market for cement in Vietnam. As of 2018, Vietnam had 82 cement production lines which equate to a total production capacity of over 95 million tons (Huu, 2019). Around 65 million tons of cement were consumed in the domestic market. The other 30 million tons of production surplus was exported to earn over USD 1 billion (Huu, 2019). Vietnam is now one of the top ten cement producers in the world and is striving to become the leading producer as the government plans to expand production capacity two folds over the next ten years.

Despite its positive contributions to the economy, the Vietnamese cement industry is highly energy-intensive and has become one of the major contributors to the rise of greenhouse gas (GHG) emissions in the nation. Energy intensity can be defined as the ratio of energy use to gross domestic product (GDP). It is an indicator of how efficiently energy is converted to monetary output (Bhatia, 2014). The majority of energy consumption in the cement production process is in the form of coal consumption for combustion during thermal processing and electricity consumption for machine and equipment operation.

In 2013, the weighted average thermal energy consumption per ton of clinker (intermediary product of cement) produced by 47 cement plants in Vietnam was 3,698MJ/ton. The thermal energy consumption for clinker production with the best available technology is less than 2,930MJ/ton. The release of CO_2 from coal combustion and thermal inefficiencies have made the cement industry one of the most air polluting industries in Vietnam. According to the Asian Development Bank (ADB), the industry contributed to 75% of total industrial GHG emissions. In addition to direct emissions of GHG, the industry is also responsible for indirect emissions from consuming electricity that predominantly comes from coal-fired power plants.

Studies by the Nordic Development Fund (NDF) have shown, however, that the electric power efficiency of cement production in Vietnam is world-class (NDF, 2016). Nevertheless, electricity prices in Vietnam are highly volatile and vulnerable to hikes as the power sector is heavily reliant on imported coal for electricity generation. Therefore, the Vietnamese cement industry needs to continue to focus on electric efficiency measures to avoid increases in operating costs. With increases in international stakeholder expectations regarding environmental safeguards in production value chains, the cement industry must consider pathways for sustainable and low-carbon development to remain competitive in global markets. One of the most economical ways to do so is to take the energy savings approach, which would not only minimize input costs but also mitigate direct and indirect GHG emissions.

1.2 Energy Efficiency Investment Barriers

While the Vietnamese cement industry has tremendous energy savings potential, there are several technical, financial and institutional barriers preventing EE investments. Vietnam's institutional framework has not created an enabling environment for EE growth. The main legislation that governs Vietnam's cement industry is the Master Plan for the Development of Vietnam Cement Industry (Master Plan 1488) administered by the Ministry of Construction (MOC). The technical criteria that cement plants must conform to include having 1) thermal energy consumption be less than 730 Kcal/kg clinker, 2) electric energy consumption of less than 90 kWh/ton of cement, and 3) discharged dust volumes below 30 mg/Nm^3 (Hoàng, 2011). However, these technical criteria do not have legislative force and are not legally binding on the industry or government. There are no EE policy or program objectives incorporated in the plan, which prevents financial resource allocation to reach EE targets. Therefore, cement companies have no reason to oblige and invest in energy-saving technologies. The only piece of legislation for this is the Energy Efficiency and Conservation Law and the Law on Environmental protection, which puts more emphasis on directly regulating GHG emissions rather than energy consumption.

In addition to the lack of regulations on EE, there have been no policy incentives to address the poor lending culture by Vietnamese commercial banks for EE projects. Many of these banks are reluctant to extend loans to EE projects because of their lack of knowledge of potential EE gains. The benefits of EE projects are in terms of "energy savings," which are gains associated with minimizing money leaking out rather than maximizing money flowing in. This is a rather abstract concept that requires a more complex understanding from a banker's perspective. The lack of a reliable MRV system to establish a baseline for energy savings further exacerbates the abilities to model EE projects and estimate benefits. Therefore, government incentives are necessary to mobilize investments by reducing the high capital costs and minimize the perceived risks of EE projects. The government of Vietnam has recognized the importance of promoting EE and has been working with international donors and agencies such as the World Bank (WB), Green Climate Fund (GCF), International Finance Corporation (IFC) and the Nordic Development Fund (NDF) to come up with financing instruments for enabling EE scale-up.

1.3 Research Significance

Existing literature on energy-efficient cement industry development in Vietnam has largely been focused on technical assistance and capacity building for GHG mitigation actions. The NDF has worked closely with the MOC to develop a plan to set up a reliable MRV system and identify and design support instruments to overcome barriers for the implementation of GHG mitigation actions. There are limited studies specifically on overcoming EE investment barriers and enabling EE market expansion in the Vietnamese cement industry. While technical assistance and capacity building are both important elements, they only serve as initial steps to facilitate an EE scale-up in the industry.

EE markets in Vietnam are still under-developed and will require additional support from the government to expand. Without large clusters of viable EE projects, service providers and financiers will be reluctant to enter the market. Although the Vietnamese government has recognized the importance of EE, they still lack consensus on best practices to promote and incentivize investments in EE projects. EE policies and programs range from incentive-based vs direct subsidies, market-based vs interventionist mechanisms, etc. Choosing an appropriate mechanism and determining the roles of key stakeholders will require an in-depth understanding of both the conditions of the industry and the country. A study on Vietnam's current cement production value chain and research on international best practices is necessary to determine EE projects and programs that are suitable for the nation's local market and institutional environment.

1.4 Research Objectives

The objective of this research paper is to conduct a holistic assessment of Vietnam's cement value chain and provide recommendations based on international best practices to overcome investment barriers in thermal and electric efficiency projects. This paper argues that the lack of consensus on best practices to promote EE investments is the major barrier preventing EE development in the cement industry. To determine policies and programs appropriate in the context of Vietnam will require an in-depth analysis of the cement production process and stakeholders involved. A value chain analysis framework based on that laid out by the United Nations Industrial Development Organization (UNIDO) was chosen to diagnose the current conditions of Vietnam's cement industry. The analysis will 1) determine EE process and technology development potentials, 2) assess public and private capacity, and 3) identify EE finance and policy gaps. The results of the analysis will be used to recommend solutions to fill in identified gaps and overcome investment barriers for EE projects.

2. LITERATURE REVIEW

The NDF established the Nordic Partnership Initiative (NPI) pilot program in 2014 to improve Vietnam's readiness to scale-up mitigation actions in the cement sector. The program aims to address gaps in the availability and quality of GHG emissions data, and potential technical and institutional barriers to implementing GHG mitigation actions in the cement sector. A series of studies were conducted on the Vietnamese cement industry. Given that the objective of this research paper is to assess Vietnam's cement value chain and provide recommendations to overcome investment barriers in EE projects, two studies by the NDF were chosen for review. The first is a technical report entitled "Energy and CO2 Emission Scenario Analysis of the Cement Industry," which seeks to quantify energy consumption and CO2 emissions in Vietnam's cement sector. The second is the "Final Readiness Plan for the Cement Sector in Vietnam," which uses findings in the aforementioned technical report to make recommendations on financing arrangements and stakeholder engagement plans to prepare for mitigation actions.

The technical report, "Energy and CO2 Emission Scenario Analysis of the Cement Industry" analyzes the historical cement production, energy consumption and CO2 emissions to quantify energy and CO2 mitigation potential in the Vietnamese cement industry. The data used in this study was taken from the Vietnam cement sector, and CO2 emission database, which was established for the NPI Pilot program. The database contains data for 35 out of 55 cement companies, which covers 69% of total installed capacity and 71% of Vietnam's cement production in 2013. This provides an adequate representation on the conditions of Vietnam's cement sector. The results of the analysis show that in 1995, CO_2 emissions were 4.6 $MtCO_2$ and increased to 46.2 $MTCO_2$ in 2013. The cement sectoral average CO_2 emissions per ton of cement was 15% higher than that of the global average. Additionally, approximately 94% of the emissions were direct emissions from thermal processes and 6% were indirect emissions from electricity consumption. While Vietnam's cement industry does lag in terms of thermal energy efficiency, its electric power efficiency is high. The report ultimately recommends that the cement industry prioritize improvements in operational management and practice instead of equipment upgrades. If cement companies do invest in equipment, they should focus on alternative fuel solutions, as well as waste heat recovery (WHR) systems.

Following this report was the "Final Readiness Plan for the Cement Sector in Vietnam," which analyzes potential mitigation actions from international experiences and global best practice using the Marginal Abatement Cost (MAC) analysis. The analysis accounts for the different production capacity expansion scenarios and suggests which mitigation actions to prioritize in each scenario. The results of the analysis reveal that the most effective way to reduce CO_2 emissions in the cement sector is to 1) limit cement production capacity to a maximum of 1,000kg cement per capita per year, 2) to reduce the clinker content in cement from 83% to 69%, 3) to substitute coal by alternative, waste and biomass fuels, and 4) to improve thermal energy efficiency by improving process know-how rather than equipment upgrades. These results were used to provide recommendations on ideal legal and institutional frameworks as well as financing arrangements. These recommendations were geared towards preparing the cement industry for participation in international climate finance through carbon market mechanisms and results-based approaches.

Both reports discussed in this literature review emphasized capacity building and technical assistance to prepare the Vietnamese cement industry for implementing mitigation actions. However, according to the VICEM, the biggest barrier that cement companies face for implementing mitigation actions is the lack of access to finance. Thus, a more detailed study on ways to overcome the lack of investment in energy-efficient and low-carbon production technologies and processes is necessary. The Final Readiness report by the NDF does examine financing arrangements to facilitate the industry's participation in international climate finance. Nevertheless, this is only one of the many financing mechanisms that could be explored. This paper will fill this research gap by conducting an in-depth assessment of Vietnam's cement industry using a value chain analysis approach to understand the current conditions of the industry and make judgments on mechanisms that are best suited for Vietnam's context. This is needed to address the lack of consensus on best practices to promote EE in Vietnam. The paper will incorporate data from the database established by the NPI pilot program and seek useful prototypes from the two reports discussed.

3. RESEARCH METHODOLOGY

3.1 Rationale for Value Chain Analysis Framework

A value chain analysis approach was chosen to study Vietnam's cement industry. Value chain analysis has been widely adopted to understand the operation and coordination of actors involved in the process of adding value and transforming a primary product to an end-product. The results of this analysis are often used by key stakeholders to make informed decisions on value chain intervention measures.

Although many value chain analysis frameworks exist, the Industrial Value Chain Diagnostics tool developed by UNIDO was specifically chosen for several reasons. Firstly, this tool is specifically tailored for industrial value chains in the manufacturing sector. It details dimensions, parameters, and indicators that enable users to study how to sustainably expand manufacturing capacities. The specificity of this tool makes it ideal for examining one of the largest manufacturing industries in Vietnam. Secondly, as Vietnam attempts to meet both production capacity and GHG mitigation goals, it is important to choose a framework that is capable of taking into consideration both factors. UNIDO's tool is an integrated tool that facilitates a holistic assessment of the value chain by taking into account all pillars of sustainable development. Thirdly, Vietnam currently does not have a comprehensive roadmap for a low-carbon cement industry. Therefore, an in-depth diagnosis of the entire cement value chain is necessary to examine how specific actors in the chain can be adequately supported to effectively implement chain development strategies.

3.2 Scope and Objectives

The objective of the value chain analysis is to create a holistic assessment of the existing conditions of Vietnam's cement production process to identify barriers for EE scale-up and provide appropriate recommendations. The value chain analysis will focus on examining the technologies and processes involved during the raw material preparation, fuel preparation, clinker production, clinker cooling, and cement grinding stages of cement production. These stages were chosen for this study because they consume the most energy and release the most GHG emissions. The analysis will discuss both direct GHG emissions from thermal processes and indirect GHG emissions from electricity consumption released at each segment of the chain. It will then analyze the roles and relationships of chain actors, which include raw material suppliers, coal suppliers, electric utilities, processors, and operators. It will also seek to understand how the chain is governed by the MOC. It will examine the coordination between the MOC and cement companies. The three cement companies that will be studied in this research paper are the state-owned Vietnamese Cement Industry Cooperation (VICEM), joint-ventures, privately-owned companies.

3.3 Methodology and Limitations

The first step in the value chain analysis process is creating a map of the value chain. A value chain map is a graphical representation and overview of how a product gets transformed from raw material to an end-product. It highlights actors in the chain and their functions in the process of adding value to a product as it moves along the chain. The cement value chain map will create a static snapshot of the cement production process and the chain actors, inputs, outputs, and end-markets involved. It will overlay data on GHG emissions and energy consumption collected by the NDF. It is important to note that this map is not sufficient for locating chain bottlenecks and areas for intervention. The purpose of the map is to create a broad overview of the current conditions of the cement value chain. Further analysis of the chain will be based on dimensions and parameters recommended by UNIDO is necessary for this in-depth analysis.

Seven core dimensions will be used in this analysis as suggested by UNIDO's industrial value chain framework:

1) *Sourcing of inputs and supplies:* The objective of this dimension is to provide insights on the availability of inputs and supplies that are required for producing and processing the commodities being studied. The dimension is also used to understand the transport and logistics arrangements of these input. Because the scope of this research paper is limited to the cement production process, transportation and logistics arrangements will not be included in analysis.
2) *Production capacity and technology:* The purpose of this dimension is to understand the current production capacity and technology use throughout the value chain. The production capacity can be determined by examining the type of machinery and equipment installed and the process know-how of people involved in the production process. The use of technology throughout the value chain does not just constitute actual efficiencies of a machine or equipment as a result of high-tech research and development, but also technical knowledge and innovative process know-how of

operators. This dimension can be used to make judgments on potential production capacity technology upgrades.

3) *End-markets and trade:* This dimension aims to depict supply and demand imbalances as well as trade barriers and market access limitations for end-products. It can be used to understand consumer preferences and market standards and regulations to provide recommendations on possible ways to access and remain competitive in end-markets
4) *Governance of the value chain:* This dimension deals with the power dynamics exerted by value chain actors. This is important because it affects the transaction and flow of knowledge throughout the chain. The dimension also deals with the quality of relationships between actors and service providers or regulatory institutions. An understanding of the relationships of these stakeholders will enable the identification of strategies to improve chain governance and efficiency.
5) *Sustainable production and energy use:* This dimension can be used to evaluate the current impacts of the value chain on natural resource consumption, energy use, emissions, and waste management. This dimension is useful to uncover ways to decouple the economic prosperity of the value chain from environmental degradation.
6) *Finance of the value chain:* The objective of this dimension is to identify existing financing sources in various segments of the value chain. This dimension should ultimately highlight financing gaps and necessary areas for intervention to support chain development.

7) *Legal and Institutional Framework:* The purpose of this dimension is to study the legal documents that affect the development of a value chain in a country. This will include examining whether there exists an enabling environment to realize full chain development potential. This dimension should ultimately inform areas for policy intervention and regulation enforcement.

The results from this analysis will be used to address these four core questions to 1) determine realizable EE potentials, 2) assess public and private capabilities, and 3) identify EE finance and policy gaps. Based on these results, the research paper will look into international experiences in EE development in industries. It will then tailor these models to suit the prevailing market and policy environment and institutional capacity to recommend a potential long-term strategy for EE development in Vietnam.

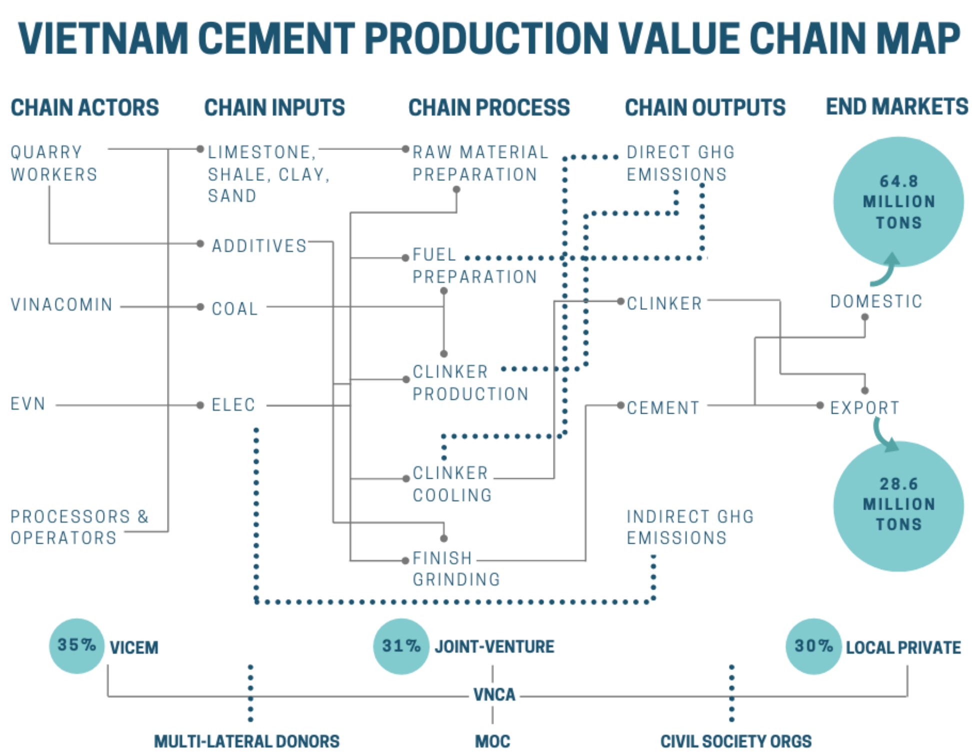
One of the biggest limitations of this methodology is the lack of reliable data. Data for chain assessment will be taken from the studies carried out by the NDF as discussed in the literature review. Because Vietnam's cement monitoring, reporting, and verification (MRV) system is still in its early stages of development, the database only contains data for 35 out of 55 cement companies in Vietnam. This data is from 2013 and encompasses 3 joint-venture companies, 9 VICEM state-owned companies, and 23 private local companies. This covers around 64% of the total number of production lines, which constitutes 69% of total cement production capacity in Vietnam. Nevertheless, according to the NDF, the data is per standards set by the Cement Sustainability Initiative (CSI) and sufficient to represent the conditions of the Vietnamese cement industry.

4. ANALYSIS

4.1 Value Chain Map Overview

A value chain map (refer to Figure 1) was created to visualize the cement production process in Vietnam. The map illustrates the cement production process and the actors involved in transforming inputs into cement and clinker for domestic consumption and export. Before diagnosing the value chain, it is important to briefly discuss and describe each segment of the cement production value chain.

Figure 1: Value Chain Map of Cement Production in Vietnam



Source: Data taken from the 2019 Vietnam Cement Market Report by FiinGroup

4.1.1 Raw Material Preparation

The first stage in the chain process is raw material preparation. During this stage, limestone, the main ingredient for cement, is extracted from the quarry along with other raw materials like shale, clay, and sand. Raw material suppliers would transport the raw material from the quarry to grinding and blending facilities. The technology involved in preparing raw material varies depending on whether cement would be produced with a wet or dry process. In a dry process, the raw material is ground into a fine powder called raw meal using either a horizontal ball mill or vertical roller mill. In a wet process, the raw material is ground with water to create a slurry with a moisture content of around 30-40% (IFC, 2017). Both processes require electricity acquired by Electricity of Vietnam (EVN), a state-owned electric utility.

4.1.2 Fuel Preparation

The second stage in the production process is solid fuel preparation. The main fuel source for cement production in Vietnam is coal. Solid coal is supplied by state-owned Vietnam National Coal and Minerals Industry Holding group (Vinacomin). It is ground using vertical roller mills, which require some electricity to power, but not as much as that required to process raw materials. ground coal is then fed into the pyro-processing system of the kiln for clinker production.

4.1.3 Clinker Production

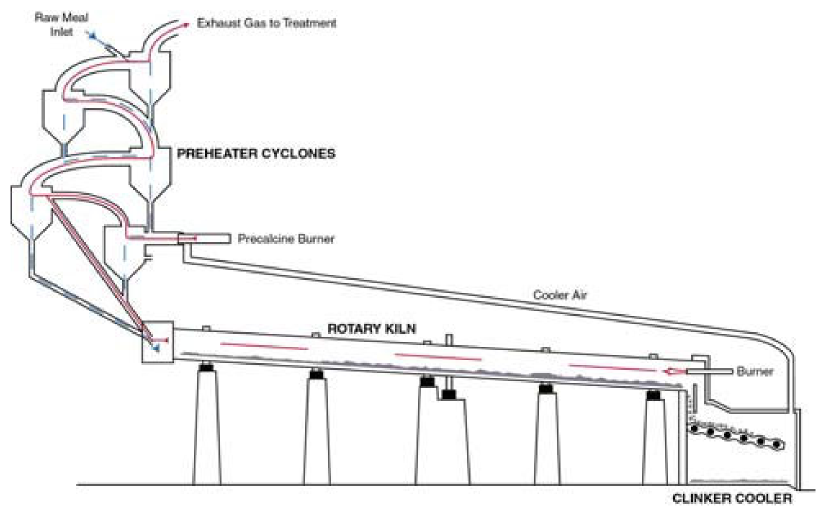
The clinker production stage is regarded as the most energy-intensive process of cement production and accounts for around 90% of total energy use (IFC, 2017). Clinker is an intermediary product of cement and can be exported separately to global markets. Clinker production involves the pyro-processing (thermal processing) of raw materials (predominantly limestone) in large kilns. During pyro-processing, the raw material is first dried so that all moisture is driven off. Then, the calcium carbonate from limestone is broken down into carbon dioxide and calcium oxide, or free lime, in a process called calcination. The final step is clinkering, which is when lime reacts with other minerals to form calcium silicates and calcium aluminates.

The two main types of kilns used for clinker production are rotary kilns and vertical shaft kilns. Many of Vietnam's earlier cement plants had vertical shaft kilns, which produces low-quality cement and is smaller in scale. With the Government's aggressive production expansion targets to meet growing demand, as of 2019, all 82 cement production lines in Vietnam have rotary kilns with higher production capacity (Lê, 2019). While rotary kilns can produce higher quality cement in larger quantities, their energy efficiencies vary depending on the type of production process.

Rotary kilns are divided into dry and wet processes, depending on how raw materials were prepared in the raw material preparation stage. Wet process kilns often require a lot more thermal energy from coal combustion to evaporate all water from the slurry before calcination. Dry process kilns are more efficient because the raw meal is fed into the kiln already has low moisture content and does not require as much thermal energy for drying.

There are three major technologies used to improve kiln thermal efficiencies in the dry process: dry kiln without preheaters, suspension preheater kilns (PH) and preheater/precalciner (PHPC) kilns (IFC, 2017). Kilns with preheaters use exhaust gas to heat raw materials before they enter the kiln, which increases the thermal efficiency of the system because less energy would be needed to heat the raw materials during pyro-processing. The addition of precalciners to calcine, or breakdown calcium carbonate from limestone, after they have passed the preheater and before they reach the kiln further increases the thermal efficiency of the system (IFC, 2017).

Figure 2: Rotary Cement Kiln (Dry Process with Cyclonic Preheaters)



Source: U.S. Department of Energy, Energy and Emissions Reduction Opportunities for the Cement Industry (Washington, DC: 2003)

The rotary kilns in Vietnam uses a mix of wet and dry processes with and without PH and PHPC technologies. Figure 2 shows that the heat input not only significantly varies between wet and dry processes, but also with specific technologies involved in dry processing. The analysis section will dive deeper into these technologies and processes.

Figure 3: Table Showing Specific Thermal Energy Consumption by Rotary Kiln Type

Kiln Type	**Heat Input (MJ/ton of clinker)**
Wet	5,860-6280
Dry	4,600
- Cyclone Suspension Preheater	3,550 - 4,180
- Cyclone Suspension Preheater with Precalciner	3,140

Source: Based on N.A. Madlool et al., “A Critical Review on Energy Use and Savings in the Cement Industries,” Renewable and Sustainable Energy Reviews 15, no. 4 (2011): 2,042-60

4.1.4 Clinker Cooling

Once clinker is discharged from the kiln, it is cooled in either a planetary or grate cooler powered by electricity. Grate coolers involve air flowing perpendicular to the clinker flow, while planetary coolers involve airflow through tubes that surround the discharging end of the kiln. Planetary clinkers are regarded as a more energy-efficient technology and can re-route heated air for use in thermal processing.

4.1.5 Finish Grinding

After the clinker has been cooled, it enters the final finish grinding stage in cement production. The clinker is ground into a fine powder in a cement ball mill that is powered by electricity. During the milling, clinker is blended with additives such as fly ash from power plants, pozzolans or slag. Typical Portland cement is comprised of 95% clinker and 5% additives (IFC, 2017).

Blended cement has one or more additives and lowers clinker content. The more additives blended in during the cement production process, the less clinker is required. Changing the clinker to additives ratio in cement could reduce the energy consumption of the cement production process.

4.1.6 Chain Governance

As of 2019, there were 82 cement production lines owned by Vietnamese Cement Industry Corporation (VICEM), a state-owned cement company, international joint-ventures, and local private companies (Huu, 2019). VICEM took the largest market share of 35% in 2014 (Stoxplus, 2015) and continues to lead in production capacity. The MOC governs the entire cement value chain in Vietnam. They are responsible for developing and revising the Cement Master Plan, monitoring activities within the chain through the Vietnamese National Cement Association (VNCA), and coordinate with other ministries to ensure that cement production reaches domestic and export targets (NDF, 2016). Other supporting actors of the chain that work with the MOC and cement companies include multilateral donors such as the WB, GCF, IFC, and NDF, and other civil society organizations. They extend financing, consulting, and conduct research and development for the chain to support chain development.

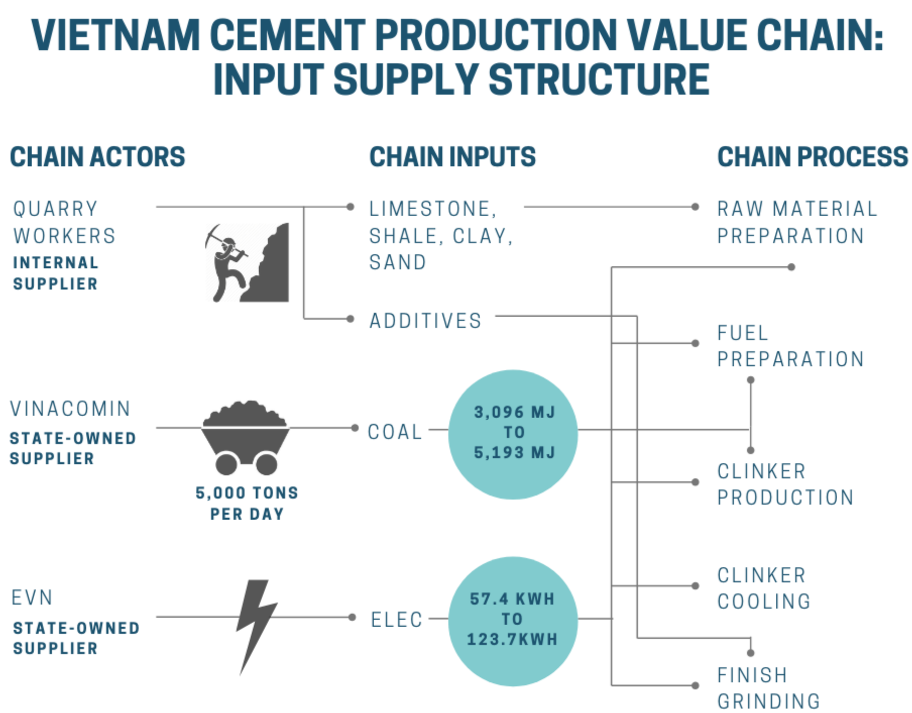
4.2 Value Chain Assessment

While a value chain map is a good tool to provide a brief overview of the chain process, it is not adequate to fully gauge the conditions of Vietnam's cement industry. This section seeks to examine the value chain using the seven core dimensions outlined by UNIDO. The result of this assessment will ultimately be used to determine areas for energy efficiency upgrades and policy and financing gaps.

4.2.1 Sourcing of Inputs and Supply – Coal and Electricity

This dimension seeks to understand the nature and availability of inputs and characteristics of input suppliers. The three main inputs that will be assessed are raw materials (limestone, shale, clay, and sand), additives (gypsum, silica, iron ore), coal, and electricity. These inputs were chosen because they are the primary products required for the production of clinker and cement.

Figure 4: Map of Input Supply Structure in the Cement Production Value Chain in Vietnam



Source: Nordic Partnership Initiative Pilot Program Report

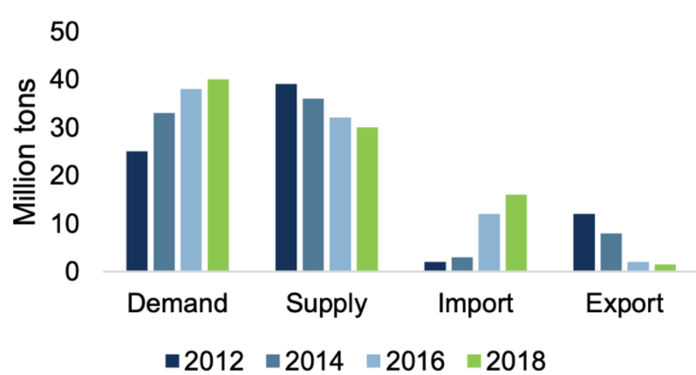
Raw Materials

Raw materials such as limestone, shale, clay and sand are self-mined in quarries. These raw materials are typically heavy and expensive to transport, so cement plants are often situated within 10 km from quarries to minimize transportation costs. The majority of cement companies self-mine their raw materials by obtaining a license for the exploitation and use of limestone and other raw materials at a quarry. This license is pursuant to article 10 of Vietnams' Mineral Law (Le, Schiappacasse, & Muller, 2019). Additives such as gypsum, silica, iron ore are sourced from local suppliers. However, cement companies under VICEM must purchase additives that are sourced and managed internally by VICEM (Nguyen, VICEM Hoang Mai Cement - Initial Valuation Report, 2019).

Thermal Coal

Coal input to fuel thermal combustion for cement production is supplied by the state-owned Vietnamese National Coal and Mineral Industries Group (Vinacomin). Vinacomin is responsible for producing and supplying 95% of coal in Vietnam (Enerdata, 2019).

Figure 5: Demand and Supply of Vietnam's Coal Industry from 2012-2018



Source: VIRAC, General Statistic Office, FPTS research

The graph above shows that the demand for coal has been increasing, while supply has been depleting. This has led to a sharp increase in domestic coal prices. Over the past 5 years, manufacturers have been actively seeking imported coal to reduce their input costs. While Vietnam was previously a net exporter of coal, they began to be import-dependent from 2014 onwards. VICEM subsidiaries purchase their coal supply internally from VICEM-managed suppliers. Previously, these subsidiaries have enjoyed coal supply discounts from VICEM suppliers that range from 15-20% compared to domestic prices (Nguyen, VICEM But Son Cement - Initial Valuation Report, 2019). However, domestic coal prices have increased at levels that exceed the benefits of the discount. Furthermore, VICEM suppliers have been slow to find a stable source of imported coal, leaving VICEM subsidiaries extremely susceptible to the volatile nature of coal prices in recent years. Domestic coal prices have hiked by 7.3% per year, which is equivalent to a 1.5% increase in production cost (Nguyen, VICEM But Son Cement - Initial Valuation Report, 2019). VICEM subsidiaries have been the worst affected by hikes in domestic coal prices because they are unable to diversify their supply sources like joint-ventures and private local cement companies. These hikes are likely to worsen as coal supplies continue to get depleted to meet growing demand over the years ahead.

Electricity

The electricity sector is the largest consumer of coal supplies in Vietnam and accounted for 67% of total coal consumption in 2016. Electricity of Vietnam (EVN) is the main state-owned producer and supplier of electricity, which is predominantly from coal-fired power plants. The growing demand for electricity means a faster depletion rate for tight coal resources and higher electricity prices. To ensure that electricity prices are not too high and protect the manufacturing sector from high input costs, the government of Vietnam put a subsidy on imported coal for the electricity sector. However, this subsidy is being phased out and the price of imported coal now closely reflects market prices. In 2019, EVN hiked its electricity price by 8.4%. In response to this hike, VICEM cement companies had to increase their cement price by USD 11.29/ton. The chairman of VNCA speculates that cement producers are expected to face significant increases in input prices as a result of coal and electricity supply constraints (Global Cement, 2020).

Several conclusions can be drawn from examining the input supply of the Vietnamese cement production value chain:

1) Domestic coal supplies are being depleted and causing an increase in input prices for both thermal coal and coal-generated electricity.
2) Cement companies under VICEM are being directly impacted by supply limitations because of poor internal management by VICEM.

4.2.2 Production Capacity and Technology of Cement Plants

The purpose of this dimension is to understand the current capacity utilization, thermal energy efficiency, and electric efficiency of Vietnam's cement plants to make judgments on opportunities for expanding capacities or upgrading production technologies.

Capacity utilization

The capacity utilization rate can be defined as the ratio between the actual output produced and the potential output at maximum capacity (CFI, n.d.). This metric is used to assess cement operating efficiencies and provide insights on whether production capacity expansion is necessary. Based on data in Vietnam's MRV database, in 2013, the installed capacity for clinker was 41 million tons and for cement was 42 million tons, which encompass around 71% of Vietnam's cement production (NDF, 2016).

Historical data from 2009-2012 suggest that the average clinker capacity utilization was around 80% and reached 85% in 2013 for a plant. In 2011-2012, only around half of clinker plants reached 80% utilization and in 2013, around 60% reached this 80% utilization (NDF, 2016). Cement plants had higher utilization rates of around 85% in 2009 and up to 100% in 2013 (NDF, 2016). From this, it can be deduced that while there are opportunities to expand cement production capacity, clinker production capacity expansion should be limited (NDF, 2016).

Thermal energy efficiency

Pre-heater and pre-calciner (PHPC) technologies are installed in 92% of clinker production facilities in Vietnam. The other 8% have pre-heater kilns with no pre-calciner (PH). PHPC technologies improve the thermal efficiency of clinker production. With PHPC, it would ideally take 3,300MJ to produce a ton of clinker. The recorded yearly average energy consumption for clinker production with PHPC in Vietnam, however, was recorded to be 3,660 MJ per ton of clinker in 2013. The global average for PHPC technology is 3,390 MJ per ton of clinker, which makes the PHPC efficiency in Vietnam 7% higher. It was found that only 4 out of the 33 PHPC kilns reached the global average.

While recent clinker installations have been assumed to have better thermal energy efficiency, it was reported that in 2010, ten new installations with PHPC technology consumed above 4,000 MJ per ton of clinker. This level surpasses energy consumed by older installations. One reason for this is that the recently built installations were to replace the existing pre-heater without pre-calciner technologies at older cement plants with inefficient vertical shaft kilns. According to NDF, not one of the 20 recently built clinker installations met the thermal efficiency standards set by the Cement Master Plan. Furthermore, some evidence suggests that small private local cement companies lack the technical expertise to install and operate PHPC technology. Therefore, it is important to not only focus on technology upgrades but also process know-how to ensure that full EE potentials are realized. Foreign joint-ventures have been reported to have the best available technology for production, operating performance, and production techniques compared to local private and state-owned cement companies (Nguyen, VICEM But Son Cement - Initial Valuation Report, 2019).

Electric Efficiency

The study by the NDF found that although Vietnam's cement production process does not meet thermal efficiency standards, its electric efficiency is top tier. The average electricity required to produce a ton of clinker is 59 kWh, which is 27% more efficient than the global average. Furthermore, the average electricity to produce a ton of cement is 87 kWh, which is 12% better than the Southeast Asia averages. This is an indication that less emphasis should be put on improving the electric efficiency of production equipment for cement production in Vietnam.

The results of this dimension highlight the following:

1) The capacity utilization rate for cement plants are not economical and do not warrant future capacity expansion.
2) Opportunities to improve the thermal efficiencies of production processes are not just limited to technology upgrades but also process know-how. Even with efficient technologies, smaller private local companies lack the technical expertise the ensure that EE potential is fully realized.
3) Less emphasis should be put on improving the electric efficiencies of Vietnam's production process as the average consumption is more efficient than that of the global average.

4.2.3 End-markets and Trade

This dimension aims to study the characteristics of the end-products of the cement production value chain and analyze domestic and international end-markets. It is important to understand the nature of end-product supply and consumer demands at end-markets to assess market access limitations and trade barriers.

End-product Physical Characteristics

Portland cement is one of the major end-products of Vietnam's cement value chain. The two main types of cement that Vietnam produces are Ordinary Portland Cement (OPC) and Portland Cement Blended (PCB). PCB is the most popular cement end-product that has lower clinker content and more additives (Nguyen, VICEM But Son Cement - Initial Valuation Report, 2019). Additives for PCB include fly ash, coal slag, pozzolan. OPC is another popular cement end-product in Vietnam and is made using only clinker and gypsum additives (Nguyen, VICEM But Son Cement - Initial Valuation Report, 2019). The higher clinker content of OPC compared to PCB makes OPC a more energy-intensive cement product. In addition to OPC and PCB, Vietnam also produces cement products like Pozzolanic Portland cement, blast-furnace Portland cement, white Portland cement, sulfate resisting Portland cement, and low-heat Portland cement upon request (Matsui, n.d.).

Portland cement clinker is another major end-product of Vietnam's cement value chain. Clinker is an intermediate product of the value chain that when ground to a fine powder produces cement. Vietnam produces clinker to export to other countries that lack the raw material to make cement (Vietnam News, 2019). Clinker exports are often low in value and worth less than cement products.

End-product Standards

Vietnamese cement is ranked based on their pressure bearing standard called Marx. The three Marx cement grades are 30, 40, and 50 and are based on the compressive strength of cement samples after being solidified for 28 days. Cement products fall under two packaging forms: bagged cement, which requires full packaging, and bulk cement, which is directly poured into cement vehicles for delivery to construction sites.

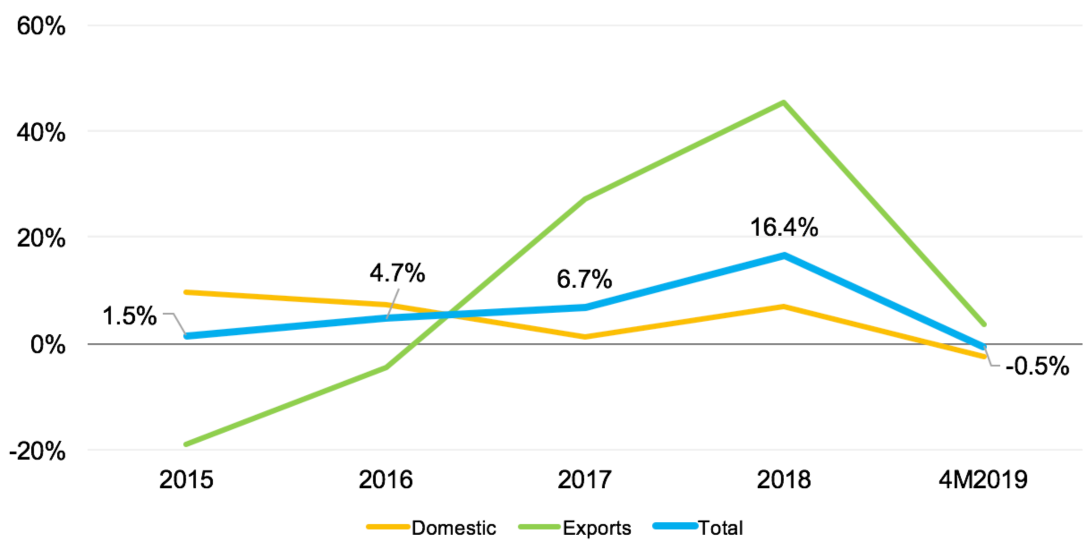
When sold in the domestic market, the two main cement product standards are TCVN 2682 and TCVN 6260. Portland cement that meets TCVN 2682 standards has additives level that is less than 1% of the product weight and higher clinker content, while Portland cement that meets TCVN 6260 can have additives levels up to 40 % of the product weight. Both standards require than cement products have quality preservation times of 60 days from the manufacturing date. Cement products that are sold for export must meet the American Society for Testing and Materials (ASTM) standards, which have more stringent technical requirements (i.e. stricter preservation time) than those set out by TCVN.

The main cement products on the market right now are bagged cement (OPC and PCB 30, 40) and bulk cement. These cement products must be in accordance with the properties and quality standards set by the MOC. Cement products between manufacturers, therefore, lack differentiation and compete based on price (Nguyen, VICEM But Son Cement - Initial Valuation Report, 2019).

Domestic Market Demands

Vietnam's domestic market consumption grew to a record high of 64.8 million tons in 2018 (FiinGroup JSC, 2019). This growth is largely attributed to improvements in residential, industrial, and hospitality real estate, as well as growth in the construction market. However, the domestic market lost momentum in the first four months into 2019. As shown in figure 3, domestic cement sales growth rates saw a 7% increase in 2018 from the previous year, but a 2.5% decline in 2019. Although urbanization has played a huge part in the increase in domestic cement sales, Vietnam's urbanization rate is still on the low end at 36% in 2018 (Plecher, 2020). Therefore, domestic cement consumption still has not reached its peak.

Figure 6: Clinker and Cement Sales Growth, Year-Over-Year



Source: 2019 Vietnam Cement Market Report by FiinGroup

International Market Demands

Export activities have been a good solution to Vietnam's sluggish domestic consumption. Over the past four years, both clinker and cement export sales have increased. Vietnam's main export competitors have been China and Thailand, which accounted for 41.3% of total Asian exports.

However, both these countries have plans to limit their supply, which will open up export markets for Vietnam.

The Ministry of Industrial & Information Technology (MIIT) and the China Cement Association plans for China reduce its production output by 392.7 million tons of cement by 2020. This supply reduction is 6.4% of the total world cement capacity and 4 times the total of the design capacity in Vietnam. China's plans to limit supply is as a result of more stringent pollution control policies. Similar to China, Thailand will not increase its export output in an effort to curb GHG emissions for polluting cement factories. The country plans to put restrictions on the licensing of new cement projects and stabilize annual capacity at 48-50 million tons. The World Cement Association predicts that the supply limitations of these two export giants will cause a cement supply shortage and higher cement prices in Asia. Cement prices in Asia has been around 58% higher than that of Vietnam since 2017. This is in part due to the issuance of Decree 146 by the Vietnamese government in 2018, which imposed a 0% export tax and VAT refund on exporters. The government has plans to fill supply gaps in international markets by expanding export volumes through both capacity expansion incentives and favorable government policies.

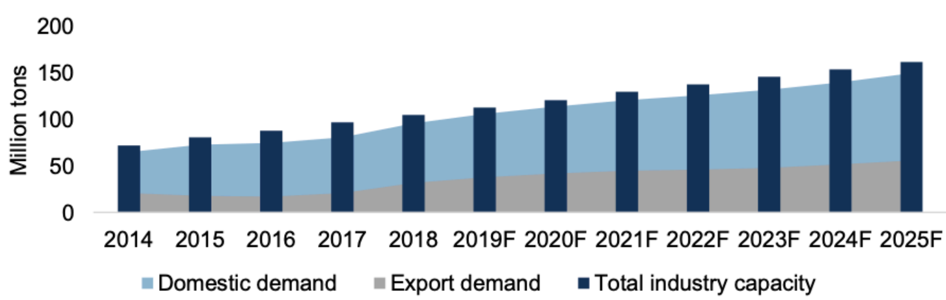
The majority of Vietnam's exports since 2010 have been to Bangladesh, China, and the Philippines. Despite potential gaps in international cement supplies, the VNCA speculates that Vietnamese exporters may face difficulties in the coming years from unfavorable trade policies. For example, the Philippines has announced in 2019 that it would put a customs duty of $4.81

per metric ton on cement imports, which are mostly from Vietnam (Le H. , 2019). In 2016, Vietnam accounted for 88 percent of imports in the Philippines (Le H. , 2019).

Several conclusions can be drawn from the analysis of this dimension:

1) There is and will continue to be excess cement production capacity. FiinGroup forecasts that the industry will not reach equilibrium until 2028 despite the positive trends in both domestic and export demands.

Figure 7: Forecast of Cement Consumption and Production in Vietnam 2019-2030



Source: BiinFrom and FPTS research

2) Clinker production is the most energy-intensive product and the value of clinker products is low. Thus, increasing the supply of clinker as an end-product for export is neither financially justified nor environmentally. Furthermore, increasing the production of PCB cement that has lower clinker content compared to OCB cement could reduce the energy-intensity of the value chain.

3) Cement companies could face market access limitations from a lack of product differentiation as a result of cement product standards set by the MOC. Competition

based solely on price could potentially be a major barrier to entry into global markets, especially with the rise of unfavorable trade policies.

4.2.4 Governance of the value chain

The objective of this dimension is to identify dominant actors in the value chain and to understand how they govern the chain. The results from the analysis of this dimension will highlight areas for chain operation improvements.

VICEM is a state-owned enterprise that currently holds the largest market share at around 35%. VICEM has ten production members and 16 production lines with a total capacity of 27 million tons of cement/year. VICEM also manages eight input supply companies that provide fuel, coal dust, and packaging. VICEM subsidiaries procure raw materials like coal and gypsum for production from VICEM-managed suppliers. Also, subsidiaries are required to follow VICEM consumption zoning policies, which specify markets they are permitted to sell to. The figure below shows VICEM's production value chain management mechanism for one of its subsidiaries, Hoang Mai Cement (HOM).

Figure 8: VICEM Management Mechanism for HOM

Source: FPTS

There are several limitations to VICEM's management mechanism of the production value chain. Firstly, the tight input supply management by VICEM has made production materials more expensive for VICEM subsidiaries. VICEM subsidiaries have been adversely affected by having to procure more expensive imported coal because VICEM mismanaged internal coal suppliers (refer to section 4.2.1). The effects of this increase in input cost have had more impacts on smaller cement companies like HOM. The table below compares the coal prices if HOM were to self-import directly from TKV (Vietnamese abbreviation for Vinacomin) and if they were supplied internally through VICEM Cement Transportation (VTV).

Figure 9: Estimated Cost of Coal Directly Imported from TKV and Indirectly Imported by VTV

	Self-import from TKV	Import through VTV
Listed selling price	2,375.000 VND/ton	
Transportation costs	30,000 VND/ton	
Purchase price (excluding VAT)	2,415,000 VND/ton	2,620,000 VND/ton
Difference in coal price compared to self-import		8.49% higher
Difference in material costs compared to self-import		2.34% higher

Source: HOM, TKV, VTV, FPTS

Secondly, VICEM zoning policies have limited domestic market expansion among VICEM members. Zoning policies were designed by VICEM to ensure that VICEM subsidiaries within proximity to each other are not under competitive pressure. However, this is hurting smaller VICEM cement companies as they face competition from large private local companies and foreign joint-ventures within their assigned consumption zone. For example, HOM had been assigned to serve demands in Nghe An and other central provinces in Vietnam. (Nguyen, VICEM Hoang Mai Cement - Initial Valuation Report, 2019) However, two more cement production lines from foreign joint-ventures are expected to come online in 2020 with a total capacity of 4 million tons per year (2.5 times higher than HOM). HOM will likely face competitive pressures in the upcoming years because of the output management by VICEM.

High input prices and restricted end-markets have put smaller VICEM subsidiaries, like HOM, in a bad financial position. As a result, these subsidiaries are unable to upgrade their inefficient production lines that consume more energy and raw materials. The figure below compares the production technology and energy consumption of HOM and Vissai Song Lam, a foreign joint-venture (Nguyen, VICEM Hoang Mai Cement - Initial Valuation Report, 2019).

Figure 10: Cement Production Technology and Energy Consumption of HOM and Vissai Song Lam

	Hoang Mai (1996)	Vissai Song Lam (2016)
Production technology	Dry rotary kiln	Dry rotary kiln
Fuel consumption	800 kcal/kg clinker	750 kcal/kg clinker
Fuel prices used	2.4 mil VND/ton	2 mil VND/ton
Power use	102 kwh/ton	90 kwh/ton
Estimated cost cut	5 - 8% total production cost	

Source: HOM, Vissai, FPTS

The figure highlights how even though both cement plants have dry rotary kilns, HOM's plant consumes more fuel and power than Vissai's plant. Vissai factories have adopted some technical changes in their production process to improve operations and reduce input consumption (Nguyen, VICEM Hoang Mai Cement - Initial Valuation Report, 2019).

Foreign joint-ventures, such as Vissai, take the second largest share of the market at 31%, followed by private local cement companies at 30%. In recent years, some of these cement companies, including Vissai, Xuan Thanh, Chinfon, and Nghi Son cement, have been rapidly expanding their production capacity and market price. However, because their brand recognition is not as strong as that of VICEM, they have had to reduce their cement prices and implement large discounts to win the market from VICEM (Nguyen, VICEM But Son Cement - Initial Valuation Report, 2019). There has been intense price competition between VICEM and foreign joint-ventures and large private cement enterprises, especially as a result of inadequate domestic consumption (Nguyen, VICEM But Son Cement - Initial Valuation Report, 2019). Nevertheless, if VICEM does not undergo restructuring and continues with its current management mechanism of the value chain, it could lose its market position.

Overall, several conclusions can be drawn from the analysis of this dimension.

1) VICEM's input supply management has led to increases in production costs among subsidiaries particularly during periods of domestic coal supply shortage. Subsidiaries are unable to procure cheaper imported coal supplies directly from Vinacomin.
2) VICEM's zoning policies have limited domestic end-markets for subsidiaries and increased competitive pressures for small companies that have to compete with foreign joint-ventures and private companies with large financial resources.

3) VICEM must undergo restructuring or it could lose its market position as foreign joint-ventures and private companies are expanding production capacities rapidly and deploying novel technologies and practices to foster efficient growth.

4.2.5 Sustainable production and energy use

This dimension aims to assess whether the value chain is considering environmental sustainability in production processes to foster long-term low carbon and energy-efficient development. To assess the sustainability of production processes, this dimension will discuss the use of fuels and alternative fuels, clinker content in cement, CO_2 content per ton of cement, and CO_2 content per ton of clinker.

Fuel and alternative fuels

Coal, the most CO_2 intensive fuel, is used for thermal processing in almost all production lines in Vietnam. Less than 1% of production lines use biomass and waste as an alternative fuel source. Production lines in other South Asian countries such as Thailand and the Philippines are using alternative fuel sources for around 12% of production (NDF, 2016). The use of alternative fuels will put less pressure on the tight coal supplies in Vietnam and protect cement companies from volatile coal input prices. Alternative fuels are not a popular option for Vietnamese cement producers because there are not many reliable suppliers. Chinfon Cement Corporation, a foreign joint-venture, had plans to produce cement using alternative materials like soles of shoes, scrap fabrics, old car tires. However, there is currently no system to collect these wastes to ensure reliable fuel input over a long period. The company is reluctant to invest in production technologies that can use alternative fuels if alternative fuel resources are unreliable (Dutch Business Association Vietnam, n.d.).

Clinker content in cement

The clinker content of Vietnamese cement has been approximately 82% from 2009 to 2013. Clinker content in cement is an important consideration because, as aforementioned, clinker production is an energy-intensive process so adding less of it and more additives to cement may decrease energy consumed per ton of cement. Vietnam's clinker content is 8% higher than that of the global average of 75% (NDF, 2016). The NDF speculates that Vietnam could reduce its clinker content to 69% by adding more slag, fly ash, pozzolana, and limestone to cement.

CO2 content per ton of Clinker

The clinker production process is a thermal energy-intensive process. The combustion of coal during thermal processing leads to the release of CO_2 emissions, among other air pollutants. The average CO_2 emissions per ton of clinker in Vietnam is 880 and 890 kg CO_2. This is 5% higher than the South East Asia average of 840 kg CO_2 per ton of clinker (NDF, 2016). The trend in Vietnam's CO_2 emissions per ton of clinker from 2009 to 2013 has shown no signs of improvement. Most of Vietnam's cement plants today do not have waste heat recovery systems that re-route waste heat to be used as an alternative fuel source to increase energy efficiency and decrease coal consumption for thermal processing. More waste heat projects are being planned as the government recognizes the importance of conserving coal resources.

CO_2 content per ton of Cement

The NDF estimates that when taking account thermal energy consumption, fuel mix, clinker content and CO_2 emissions per ton of clinker, the entire cement value chain results in 725-750kg CO_2 per ton of cement. This amount has been on an increasing trend, with an average increase of 0.5% per year (NDF, 2016). The sectoral average for CO_2 emissions per ton of cement is around 15% higher than that of the global average. This is also higher than national averages of other South East Asian countries like India, the Philippines and Thailand, which emit 600kg, 690kg and 700kg CO_2 per ton of cement respectively (NDF, 2016).

Three conclusions can be drawn from the analysis of this dimension:

1) There are opportunities to reduce reliance on coal for thermal processing through alternative fuels such as biomass and waste, but there are investment barriers due to a lack of reliable alternative fuel suppliers.
2) Clinker content in Vietnamese cement is 8% higher than the global average. Vietnam has the potential to reduce clinker content from 82% to 69% by increasing additives in the cement mix.
3) If Vietnam plans to expand production capacities, they must focus on controlling CO_2 emissions from both clinker and cement production as levels exceed regional and global averages. There are opportunities for investments in WHR systems that can increase the thermal efficiencies of plants.

4.2.6 Finance of EE in Value Chain

This dimension will look into access to finance for EE projects through financial institutions such as the State Bank of Vietnam and commercial banks, as well as international donors such as the WB, GCF, and IFC. This is necessary to determine any gaps in finance hampering EE development in the chain.

State Bank of Vietnam (SBV) and Commercial Banks

The SBV has implemented monetary policy measures over the past few years to control inflation, lower interest rates, and restore bank liquidity to create an enabling environment for credit institutions to decrease lending rates. SBV has also required banks to lower interest rates for existing loans to ease borrowers' burden. Bank liquidity has gradually improved, which has stabilized financial markets to meet the economy's capital needs (GCF, 2017). Measures taken by SBV have both increased their capital controls over banking and improved credit risk management. Credit activities have been on an upward trend since 2015 reflecting strong economic activity from accommodative monetary policy (GCF, 2017).

Despite favorable interest rates and credit growth, there continues to be a poor lending culture for EE projects. Access to finance for energy-intensive industrial enterprises have been limited despite the financial viability of EE technology investments. Financial institutions consider EE lending to be high risk and lack the technical expertise to appraise EE investments. The high perceived credit risks associated with EE lending have led to high collateral requirements. Project-based financing, which focuses on cash flows in the form of energy savings, have also not yet been widely accepted by financial institutions. As a result, there have been insufficient financing supplies by financial institutions for the high up-front capital expenditure of EE investments.

Vietnam Development Bank (VDB)

The VDB supplies financing for climate mitigation projects under a re-lending program of the European Investment Bank (EIB) for climate change mitigation in Vietnam. Financial support is available for projects with committed capital of USD 1.77 million in preferential credit (UNIDO, 2019). Loans are currently only provided for state investment credits and re-loan foreign investments that are authorized by the MOF. Therefore, projects eligible for loan support have been invested and implemented in Vietnam to mitigate climate change impacts and have demonstrated the ability for loan repayment. VDB is currently supporting some WHR, alternative fuels, and additives projects in cement production (UNIDO, 2019).

International Finance Corporation (IFC)

The IFC began a funding program for the Vietnam Energy Efficiency and Cleaner Production (EECP). In November 2018, the IFC disbursed USD 63 million for the program. The program objective is to assist commercial banks in developing market strategies and financial products for enterprises that wish to achieve higher energy efficiency, reduce environmental impacts, minimize production costs, and improve productivity in production lines. IFC works directly with commercial banks such as Viettinbank and VP bank on building capacity to appraise and manage loans for sustainable energy projects in enterprises (UNIDO, 2019).

National Technology Innovation Fund (NATIF)

The NATIF is a state financial and non-profit institution established in 2015 to promote technological innovation and research and development activities. NATIF provides grants, preferential loans, subsidized loan interest rates and loan guarantees, and financial support for science and technology activities carried out by organizations, businesses, and individuals (UNIDO, 2019). While half of this fund can be used for preferential loans, subsidized loan interest rates and loan guarantees, the primary financial product of the fund is grant aids. The total charter capital of NATIF is VND 1 billion from the state budget and gets replenished each year in accordance with the Law of Technology Transfer and Law of State budgets (UNIDO, 2019).

One of the first units to receive support from the NATIF was the Construction and Industry Equipment Joint Stock Company, the main supplier of construction equipment like conveyor belts, concrete mixers etc. NATIF has approved 28 projects and is evaluating 57 additional projects worth around VND 3.674 trillion or USD 157 million, none of which are EE projects for cement production technologies (Vietnam Economic News, 2018).

The World Bank (WB)

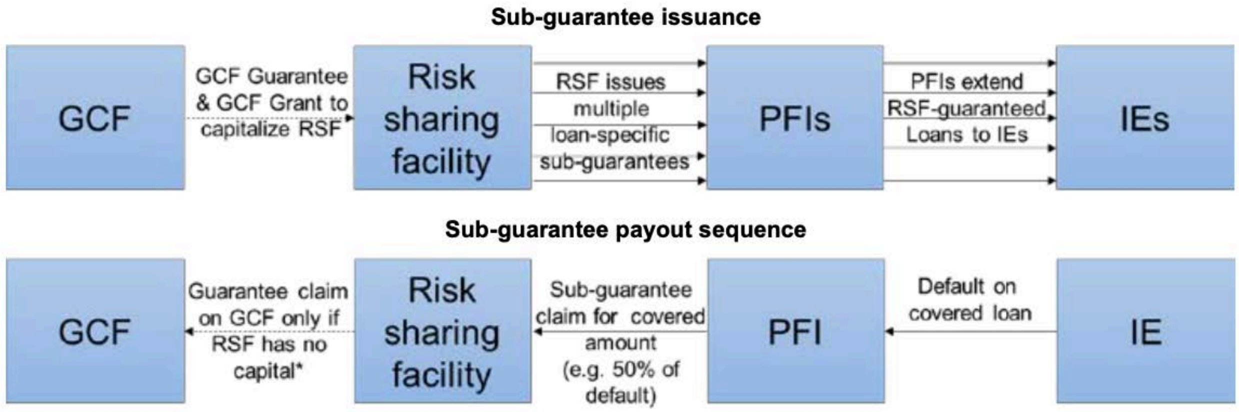
The Vietnam Energy Efficiency for Industrial Enterprises (VEEIE) program is funded by the WB to unlock energy savings potential and reduce GHG emissions in energy-intensive industries. There are two major interrelated components to the project that total up to USD 158 million (UNIDO, 2019). The first is loans for EE investment projects at USD 156.3 million, of which USD 100 million is from the WB, USD 25 million is from PFIs and USD 31.3 million is from IEs (UNIDO, 2019).

Loans from the program will be issued to Participating Financial Institutions (PFIs), which are selected by the Ministry of Industry and Trade (MOIT) based on well-defined criteria. PFIs are to extend loans to sub-borrowers and sub-projects that are eligible based on selection criteria under the Operational Manual (OM) of the VEEIE program. PFIs are responsible for project implementation, technical evaluation environmental and social assessment, procurement, and financial management of subprojects and will bear all the associated risks. PFIs will be under the supervision of the MOIT.

The second component to the VEEIE program is a grant from the WB's International Development Association (IDA) for technical assistance for USD 1.7 million. This component aims to support the MOIT in monitoring and supervising the implementation and activities of subprojects.

The Scaling Up Energy Efficiency for Industrial Enterprises (SUEEIE) in Vietnam is another program funded by the WB in collaboration with the GCF. This program aims to promote a lending culture by commercial banks for EE sub-projects through the establishment of Risk Sharing Facilities (RSF). Through GCF-RSF, PFIs can extend loans to finance sub-projects that are backed by partial credit risk guarantees. GCF-RSF will cover 50% of any default on loan repayments by IEs to PFIs during the life of a sub-project (GCF, 2017). PFIs are fully responsible for the EE lending process and must supervise all sub-loans to ensure they comply with the guidelines set by the WB and GCF. They are responsible for selecting eligible sub-projects based on the criteria defined in the WB's Operational Manual. EE sub-projects must demonstrate they meet minimum energy savings and high IRR/payback. The figure below illustrates the GCF-RSF Sub-guarantee issuance and payout sequence.

Figure 11: GCF-RSF Sub-guarantee Design



Source: GCF

Both VEEIE and SUEEIE serve as excellent sources of funding to overcome investment barriers for EE projects in the cement industry. But to benefit from these sources, cement enterprises must identify large clusters of viable EE projects for the industry. This will require support from the government as many enterprises still lack the expertise and interest in participating in EE project development.

Nordic Development Fund (NDF)

The Nordic Partnership Initiative Pilot Program aimed to improve the Vietnamese cement industry's readiness to participate in international climate financing to scale up mitigation actions. The program focused on setting up a data and MRV system that meets international standards, as well as identify and design support instruments for mitigation actions. The program ran from 2012 to 2014 and cost EUR 1.5 million (NDF, 2011). This was the first program specifically aimed at improving EE development in the Vietnamese cement industry. The program emphasizes capacity building and technical assistance for the industry to eventually participate in carbon-markets and results-based financing.

Figure 12: Table Summarizing of Finance Sources for EE Financing in the Vietnamese Cement Industry

Financing Entity	**Product**	**Challenges**
SBV and Commercial Banks	Competitive Interest Loans	Poor lending culture for EE projects by commercial banks due to lack of technical expertise and high perceived credit risks
VDB	Loans for state investment credits and re-loan foreign investments	Not aimed to encourage commercial lending for EE projects. EE projects
NATIF	Grants, preferential loans, subsidized loan interest rates and loan guarantees for technology innovation and R&D	Lack of participation by cement companies
IFC	Capacity building for commercial banks to finance EE in industries	Lack of viable EE projects to benefit from commercial lending
WB and GCF	Capacity building and technical assistance for local financial institutions, industrial enterprises and public entities	Requires active involvement by government and cement enterprises

NDF	Capacity building and technical assistance for cement industry participation in international climate finance	Requires active involvement by government and cement enterprises

The table above summarizes the current sources of finance available for EE projects in the Vietnamese cement industry. From this, the following conclusions can be arrived at:

1) Programs available to support EE projects in the cement industry are focused on capacity building and technical assistance to increase access to finance from local financial institutions and international carbon market mechanisms. For these programs to be successful would require active participation from the government and cement companies to identify viable EE projects.
2) There is limited financial support by the state for cement EE projects and weak demand for EE financing by cement companies.

4.2.6 Legal and Institutional Framework

The purpose of this dimension is to draw a picture of the current legal and institutional framework that of the cement industry. This is necessary to identify policy gaps and legal framework enhancement strategies.

The Ministry of Construction (MOC)

The MOC is the main entity responsible for the management of the entire cement industry. It is in charge of developing, implementing, and making adjustments to Master Plan 1488, the only legal framework that governs the cement industry. This framework subject to the Prime

Minister's approval but fully executed by the MOC. The MOC closely cooperates with MONRE and the MOIT to ensure that cement production is per resource consumption guidelines. The MOC also proposes policies and promulgates regulations for sustainable development of the cement industry (NDF, 2016).

Master Plan 1488 contains GHG emissions reductions and EE objectives and targets but does not have any legislative force and is not legally binding. The two main legal documents under which the Master Plan is based on is the Law on Energy Efficiency Conservation (EE&C), which requires energy-intensive industries to report energy consumption data to the MOIT periodically, and the Law on Environmental Protection (LEP), which was recently developed to regulate GHG emissions in industries. These laws also lack enforcement protocols and do not incentivize compliance by cement companies. There are also no incentive mechanisms administered by the MOC to facilitate EE development in the cement industry. Furthermore, cement standards and production line regulations are geared towards capacity expansion targets and reducing costs rather than improving efficiencies.

This dimension indicates that:

1) There is an insufficient effort by the MOC in regulating energy consumption and GHG emissions in the cement industry.
2) There are no incentive mechanisms administered by the MOC to facilitate EE development.
3) Cement standards and production line regulations do not account for efficiency targets.

5. RESULTS AND RECOMMENDATIONS

5.1 Results

The aim of this research paper is to analyze the current conditions of Vietnam's cement value chain and identify finance and policy gaps preventing investments in thermal and electric energy efficiency improvements. The results of this analysis will be used to provide recommendations on the most appropriate EE investment drivers, solutions, and products suitable for Vietnam's cement industry to overcome investment barriers. The table below provides a summary of the results.

Figure 13: Table Summarizing Value Chain Analysis Results

Dimension	Results
Source of Inputs and Supply – Coal and Electricity	- Domestic coal supplies are being depleted and causing an increase in input prices for both thermal coal and coal-generated electricity. - Cement companies under VICEM are being directly impacted by supply limitations because of poor internal management by VICEM.
Production Capacity and Technology of Cement Plants	- The capacity utilization rate for cement plants are not economical and do not warrant future capacity expansion. - Opportunities to improve thermal efficiencies are not just limited to technology upgrades but also process know-how. - Less emphasis should be put on improving electric efficiencies.
End-markets and Trade	- There is and will continue to be excess cement production capacity. The industry will not reach equilibrium until 2028.

	- Clinker products are low in value and require the most energy for production. Increasing the production of PCB cement that has lower clinker content could reduce energy-intensity of the value chain. - Cement companies could face market access limitations from a lack of product differentiation as a result of cement product standards set by the MOC.
Governance of the Value Chain	-VICEM's input supply management has led to increases in production costs among subsidiaries particularly during periods of a domestic coal supply shortage. - VICEM's zoning policies have limited domestic end-markets for subsidiaries, putting a higher financial burden for small companies as they have to compete with foreign joint-ventures and private companies with larger financial resources. - VICEM must undergo restructuring or it could lose its market position.
Sustainable Production and Energy Use	- There are opportunities to reduce reliance on coal for thermal processing through alternative fuels like biomass and waste, but there are investment barriers due to a lack of reliable alternative fuel suppliers. - Vietnam has the potential to reduce clinker content from 82% to 69% by increasing additives in the cement mix. - Vietnam must focus on controlling CO_2 emissions from both clinker and cement production as levels exceed regional and global averages. There are opportunities for investments in WHR systems that can increase the thermal efficiencies of plants.
Finance of EE in Value Chain	-Programs available to support EE projects in the cement industry are concentrated on capacity building and technical assistance to increase access to finance from local financial institutions and international carbon markets. - There is limited financial support by the state for cement EE projects and weak demand for EE financing by cement companies.

Legal and Institutional Framework	- There is an insufficient effort by the MOC in regulating energy consumption and GHG emissions in the cement industry. - There are no incentive mechanisms administered by the MOC to facilitate EE development. - Cement standards and production line regulations do not account for efficiency targets.

Two major conclusions can be drawn from the results of the value chain analysis. Firstly, more actions by the MOC in the form of stringent regulations and incentivizing policies are required to control production overcapacity, reduce high input costs from reliance on expensive imported coal, address poor chain governance, and improve inefficient thermal production technologies and processes. Secondly, most of the current actions by the state and international agencies are focused on raising market awareness through capacity building and technical assistance.

5.1 Recommendations

The Institute for Industrial Productivity (IIP) compiled a collection of EE financing best practices for governments and companies in their Delivery Vehicles for Financing of Industrial Energy Efficiency report. IIP concludes that there are two key characteristics that EE project developers for the industrial sector should focus on to foster long-term energy-efficient and low-carbon development in industries:

1) Increasing market awareness: Both the industry and the financing sector must have a technical understanding of EE solutions and benefits. Projects that increase market awareness may include technical assistance, training/capacity building, energy audits, conferences, etc.

2) Increasing opportunity cost of not investing in EE solutions: There must be more recognition of the value of energy savings to trigger EE investment decisions. Projects that bring down the EE solution costs to levels below BAU solution costs to facilitate EE investments may include tax incentives, EE targets/penalties, subsidy reductions, etc.

Figure 14: Table Showing EE Investment Drivers, Solutions and Products

Key EE investment Drivers	Solutions/Scope	Products	Program Examples
Market Awareness	Awareness within industry sector	• Technical assistance • Energy audits • Conferences • Training / capacity building	• CHUEE • Eff. VT • NYSERDA • EBRD EA • EERSF
	Awareness within financial sector	Private-market financing supported by public money and/ or guarantees (e.g., ESCO)	• Risk-sharing • Leveraging commercial financing • Guarantee • Knowledge dissemination
Increasing opportunity cost of not investing in EE solutions	Increasing business-as-usual solution costs	• SBC and equivalent • Carbon tax • EE targets / penalties • Subsidy reductions	• NYSERDA • Eff. VT
	Decreasing EE solution costs	Cheap financing (grants, low-interest rate loans, etc.)	• CHEEF • EERSF • Efficiency Vermont • NYSERDA • EBRD EA
	Decreasing uncertainty / risk	Risk sharing facilities, guarantees	• EERSF • CHUEE • EERSF • ME
		Long-term stable and consistent policies	• Eff. VT • NYSERDA

Source: IIP

The results discussed in section 5.1 suggest that Vietnam is currently receiving adequate support from the NDF, IFC WB, and GCF for increasing market awareness within the industry and financial sector through technical assistance and capacity building programs. Furthermore, the WB and GCF are providing support for decreasing EE solution costs and reducing uncertainties in financing EE projects through cheap financing, RSFs, and guarantees. The only EE investment solution that the cement industry is lacking is increasing BAU solution costs.

Even though funding sources are available, the demand for funding is low because cement companies lack incentives to scrap old inefficient production technologies and adopt more efficient operations strategies. The best way to address this is to increase the cost of using outdated and inefficient technologies through EE targets and penalties strictly enforced by the MOC. The MOC should incorporate EE targets into Master Plan 1488 and make compliance mandatory. The MOC must also set guidelines for energy audits and reporting with the technical assistance and capacity building trainings from international agencies. For any progress to occur in accelerating EE investments in the cement value chain will require strong actions by the MOC.

REFERENCES

(2020, February 18). Retrieved from Global Cement: https://www.globalcement.com/news/item/10477-vietnamese-exports-face-pressure-in-2020

Bhatia, S. (2014). *Energy resources and their utilisation.*

Cemnet News. (2019, April 03). Retrieved from https://www.cemnet.com/News/story/166277/vicem-reacts-to-electricity-price-increase-by-upping-cement-prices.html

CFI. (n.d.). *Capacity Utilization* . Corporate Finance Institute.

Dutch Business Association Vietnam. (n.d.). *Cement makers turn to alternative fuels* . Retrieved from https://dbav.org.vn/cement-makers-turn-to-alternative-fuels/

Enerdata. (2019, December 19). *Vietnam will restructure state-run coal company Vinacomin* . Retrieved from https://www.enerdata.net/publications/daily-energy-news/vietnam-will-restructure-state-run-coal-company-vinacomin.html

European Environment Agency. (n.d.). *Energy Efficiency and Energy Consumption in Industry*. Retrieved from http://www. eea.europa.eu/data-and-maps/indicators/energy-efficiency-and-energy-consumption-6/assessment

FiinGroup JSC. (2019, April 11). *Vietnam Cement Market 2019 Report.*

GCF. (2017). *Scaling up Energy Efficiency for Industrial Enterprises in Vietnam Funding Proposal.*

Global Cement. (2018, July 18). *Vicem exports majority of sales in first half of 2018* . Retrieved from https://www.globalcement.com/news/item/7806-vicem-exports-majority-of-sales-in-first-half-of-2018

Global Cement. (2019, April 03). *Electricity tariff hike set to hit cement prices in Vietnam* . Retrieved from Global Cement: https://www.globalcement.com/news/item/9051-electricity-tariff-hike-set-to-hit-cement-prices-in-vietnam

Hoàng, H. T. (2011). *Ratifying the cement industry development plan in Vietnam for the period 2011 - 2020 with vision to 2030.*

Huu, T. (2019, 11 1). Retrieved from https://en.nhandan.org.vn/business/item/7046302-measures-for-sustainable-development-of-cement-industry.html

IFC. (2017). *IMPROVING THERMAL AND ELECTRIC ENERGY EFFICIENCY AT CEMENT PLANTS: INTERNATIONAL BEST PRACTICE.* Washington, DC: International Finance Corporation.

Le, H. (2019, September 6). *Philippines slaps new tariffs on cement imports from Vietnam* . Retrieved from VN Express: https://e.vnexpress.net/news/business/industries/philippines-slaps-new-tariffs-on-cement-imports-from-vietnam-3978423.html

Le, L. T., Schiappacasse, P., & Muller, B. (2019). *Towards Responsible Aggregate Mining in Vietnam.*

Lê, V. H. (2019, 04 25). *Xi măng còn đó nỗi lo dư cung* . Retrieved from NDH: https://ndh.vn/hang-hoa/xi-mang-con-o-noi-lo-du-cung-1244701.html

Matsui, A. (n.d.). *THE INTRODUCTION OF CEMENT AND CONCRETE TECHNOLOGY.* Nghi Son Cement Corporation.

NDF. (2011, December 13). *Nordic Partnership Initiative Pilot Programme [NDF C34]* . Retrieved from https://www.ndf.fi/project/nordic-partnership-initiative-pilot-programme-ndf-c34

NDF. (2016). *Energy and CO2 emission scenario analysis of the Vietnam cement industry.*

NDF. (2016). *Final Readiness Plan for the Cement Sector in Vietnam.* Nordic Development Fund.

Nguyen, L. (2019). *VICEM But Son Cement - Initial Valuation Report.* FPT Securities.

Nguyen, L. (2019). *VICEM Hoang Mai Cement - Initial Valuation Report.* FPT Securities.

Plecher, H. (2020, 02 11). *Urbanization in Vietnam*. Retrieved from Statista: https://www.statista.com/statistics/444882/urbanization-in-vietnam/

Stoxplus. (2015, September 25). *Cement Fact Sheet*. Retrieved from https://www.slideshare.net/hnguyenh/vietnam-cement-industry-factsheet

The World Bank. (2005). *THAILAND - ENERGY EFFICIENCY REVOLVING FU.*

UNIDO. (2019). *HANDBOOK ON HOW TO ACCESS GREEN FINANCING IN VIET NAM.*

Vietnam Economic News. (2018, 08 28). *Vietnam supports business in technology innovation*. Retrieved from http://ven.vn/vietnam-supports-business-in-technology-innovation-34219.html

Vietnam News. (2019, 02 26). Retrieved from Vietnam News: https://vietnamnews.vn/economy/505998/cement-clinker-demand-to-edge-up-this-year.html

Vietnam News. (2019, February 26). *Cement, clinker demand to edge up this year*. Retrieved from https://vietnamnews.vn/economy/505998/cement-clinker-demand-to-edge-up-this-year.html

World Bank. (2010). *Potential for Climate Change Mitigation Opportunities in the Industry Sector in Viet Nam. Background Paper.*