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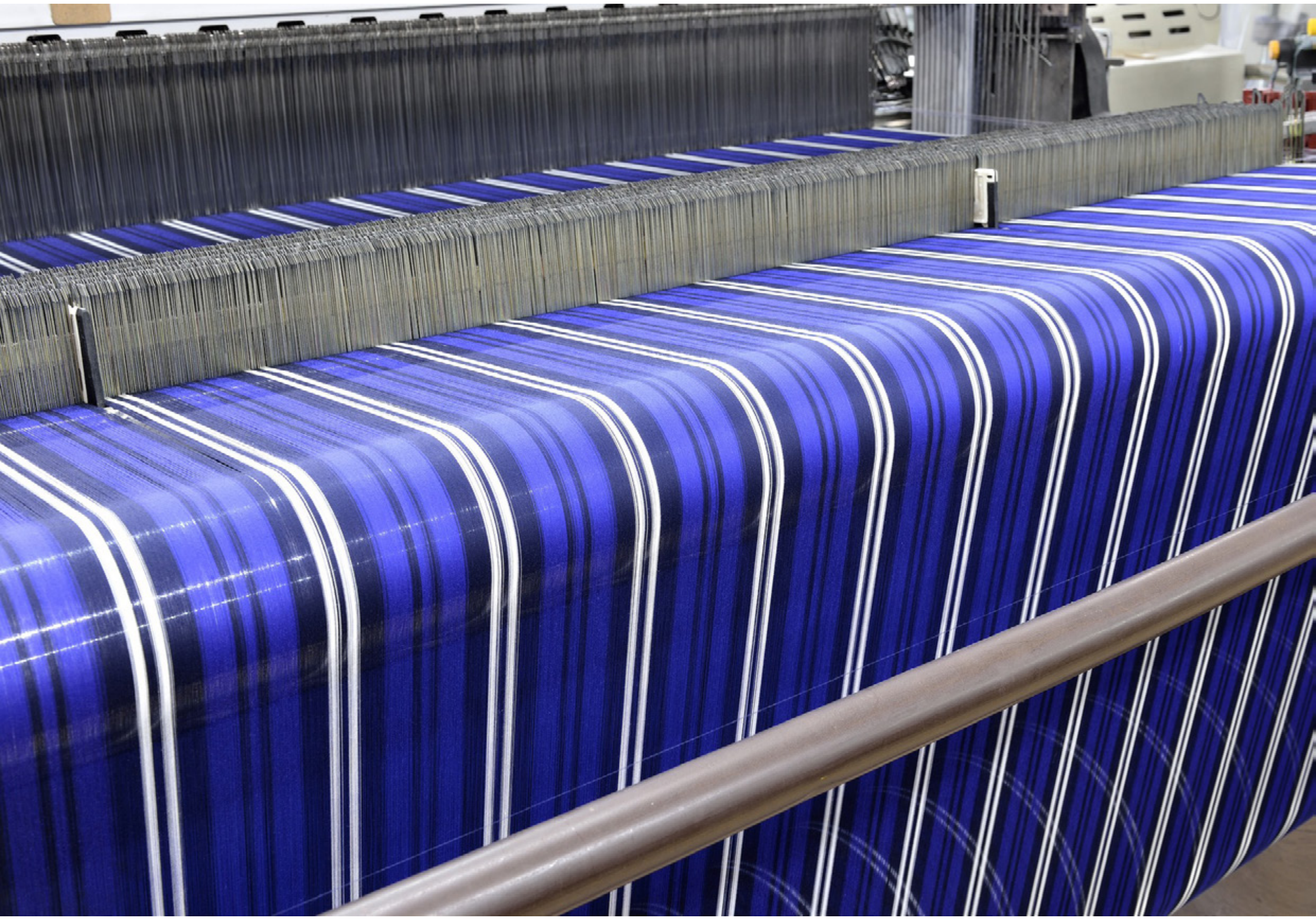
Industrial Supply Chains Decarbonization in Southeast Asia



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Executive Summary

Industry sector is the largest contributor of greenhouse gas (GHG) emissions globally. In Southeast Asia industry is also one of the top emitters of GHG emissions. With significant economic and industrial output growth projected for countries in Southeast Asia in the next few decades, the energy use and GHG emissions related to the industry sector is projected to grow substantially in the absence of aggressive GHG abatement policies and strategies by countries in the region.

The private sector has a substantial potential to drive industrial decarbonization actions. For many companies and brands whose supply chain emissions are significantly greater than operational emissions, it is clear that to take meaningful action, companies must leverage their purchasing power, and collaborate with their supply chains. However, according to CDP, with only 29% of suppliers reporting an absolute decrease in 2019 emissions, it is clear purchasers and their suppliers in Southeast Asia and other regions must do much more.

In this report, we first analyze the industrial energy use in five major energy consuming countries in Southeast Asia: Indonesia, Malaysia, Philippines, Thailand, and Vietnam. The following chapters discuss different aspect of improving energy efficiency and reducing GHG emissions in industry in Southeast Asia through supply chain sustainability. We discuss the key barriers to supply chain decarbonization, leading practices for promoting low-carbon industrial supply chains, and the importance of performance measurement systems and their corresponding key performance indicators (KPIs) for promoting supply chain sustainability. The case-studies for supply chain sustainability are focused on the textile and apparel sector as well as electronics product manufacturing sectors. These two sectors have a large supply chain in Southeast Asia.

A detailed analysis of obstacles to supply chain decarbonization highlights economic, information-related, and market barriers. Economic aspects such as high investment costs, hidden costs, and low profitability can often hinder suppliers (especially Small to Medium Enterprises (SMEs)) from implementing low-carbon projects. Insufficient information on costs, benefits and technologies, as well as a lack of technical expertise to develop energy management or decarbonization plans poses another major challenge. Additionally, market barriers in the form of existing technical and regulatory hurdles across multiple geographies also need to be overcome.

We also discuss the importance of performance measurement systems and their corresponding key performance indicators (KPIs) for promoting supply chain sustainability. With the assistance of KPIs, companies are able to successfully track the performance of their suppliers on environmental and social issues. Reporting requirements set out by the Global Reporting Initiative (GRI) standards and the CDP supply chain program assess performance across a wide range of categories such as energy, emissions, GHG targets, water consumption, etc., providing a comprehensive understanding of the company's progress on key issues.

Based on international best practices identified in this study, companies can take the following actions to lower the carbon footprint of their supply chains:

- Develop stronger relationships with their suppliers through supplier engagement programs and help their suppliers establish their own sustainability management systems and policies, which would help suppliers systematically measure and track their GHG emissions.

- As part of developing a method for managing supplier data, companies can either create or outsource a data collection system or leverage an existing GHG reporting and disclosure program.
- Set GHG reduction and carbon neutrality targets that cover their supply chains.
- Translate GHG reduction and carbon neutrality targets further into actionable targets for their individual suppliers.
- Encourage and support suppliers to transition to renewable energy which is key to achieving scope 3 GHG reduction targets.
- Encourage and support suppliers to identify and implement energy efficiency opportunities and adopt ISO 50001 energy management standard
- Set internal carbon pricing. This scheme provides companies an opportunity to assess risks associated with future regulations concerning mandatory carbon prices, and consequently work towards identifying cost saving and revenue prospects of investment in innovative low carbon technologies and decarbonization of operations.
- Provide information and educational materials to their suppliers to support their effort and build capacity for energy efficiency improvement and low carbon transitions.

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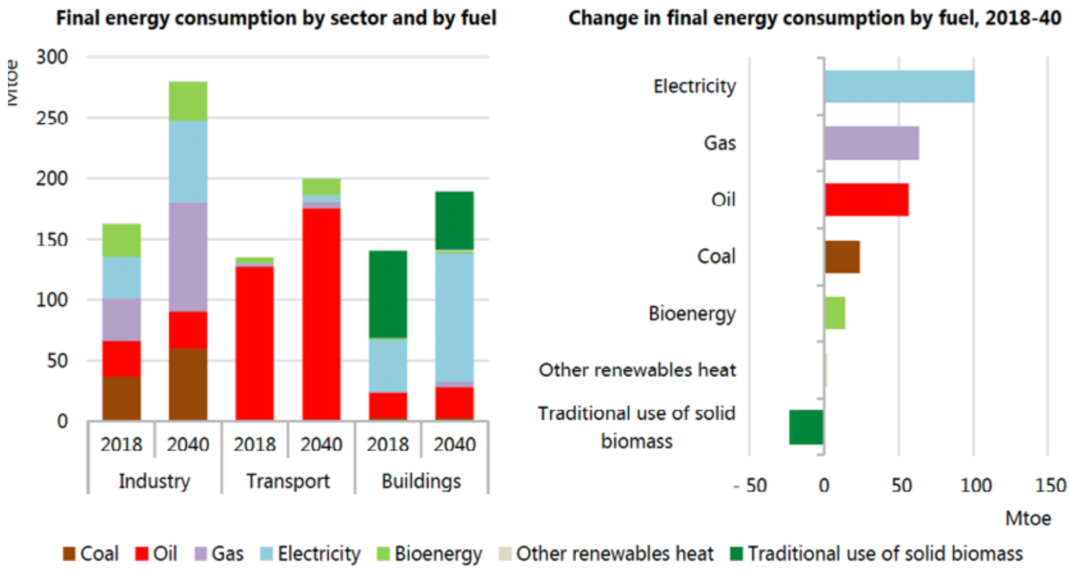
PALLADIUM
FASHION MALL
กรุงทองพลาซา
MORE THAN 400 Shops

1 Introduction

Home to nearly 650 million people, the rapidly growing economies of Southeast Asia region are shaping many aspects of the global economic and energy outlook. The regions' GDP is projected to triple by 2040 (ASEAN Center for Energy, 2020). The region is becoming more dependent on imported fossil fuels, which put the energy security of the region at risk. Since 2000, overall energy demand of Southeast Asia has grown by more than 80% and a large share of this growth has come from fossil fuel. Oil and coal have the largest share of energy mix in the region and the share of coal is increasing. This has increased the air pollution and GHG emissions in the region (IEA, 2019a). With significant economic, population, and industrial output growth projected for countries in Southeast Asia in the next few decades, the energy use and GHG emissions related to the industry sector is projected to grow substantially in the absence of aggressive GHG abatement policies and strategies by countries in the region. Figure 1 shows International Energy Agency (IEA)'s projection for final energy use and as well as change in final energy use by fuel type in Southeast Asian countries during 2018-2040 under Stated Policies Scenario[1].



Note: The change in fuel (non-electricity) values in the graph on the right do not include the amount of fuel burned for electricity generation

Figure 1. Final energy consumption in Southeast Asia - million tonnes of oil equivalent (Mtoe) (IEA, 2019a[2])

As can be seen from Figure 1, industry sector is the largest consumer of energy among major economic sector and it is projected that industry will remain the top energy consuming sector in the region in 2040. Around two-third of energy used in industry in Southeast Asia are fossil fuels.

1 The Stated Policies Scenario (STEPS) assesses where today's policy frameworks and ambitions, plus continued evolution of known technologies, might take Southeast Asia's energy sector in the period to 2040. This scenario only considers policies that have been announced ("stated") and does not take a position on how these policies might evolve in future (IEA, 2019a).

2 It should be noted that the 6th ASEAN Energy Outlook projects even a higher energy use for the industry sector in ASEAN countries in 2040, of around 380 Mtoe (ASEAN Center for Energy, 2020). The difference between the projections by IEA and ASEAN Center for Energy could be because of differences in industry boundaries, methodology and projections assumptions.

Figure 2 shows the projected rise in electricity demand in Southeast Asia, with the industrial sector accounting for a significant share of the increase in demand. Electricity demand is projected to more than double between 2020 and 2040. In addition, Figure 3 depicts the projected rise in primary energy consumption by the industrial sector in Southeast Asia, and a major proportion of this energy consumption is attributable to non-energy intensive industries such as food and beverage, textile, electronics manufacturing, machinery, etc. (EIA, 2016).

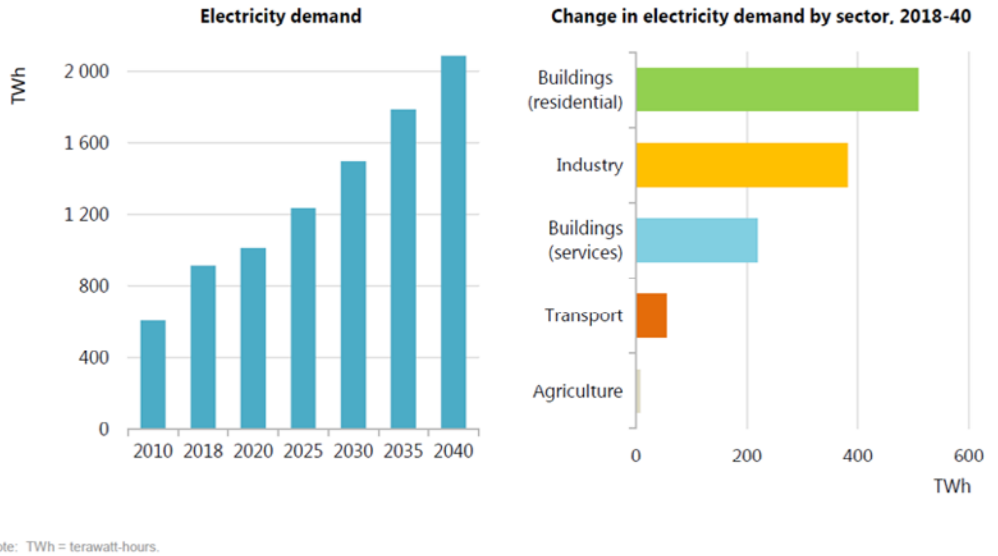


Figure 2. Projected growth in electricity demand in Southeast Asia and breakdown of major contributors to demand growth (IEA, 2019a)

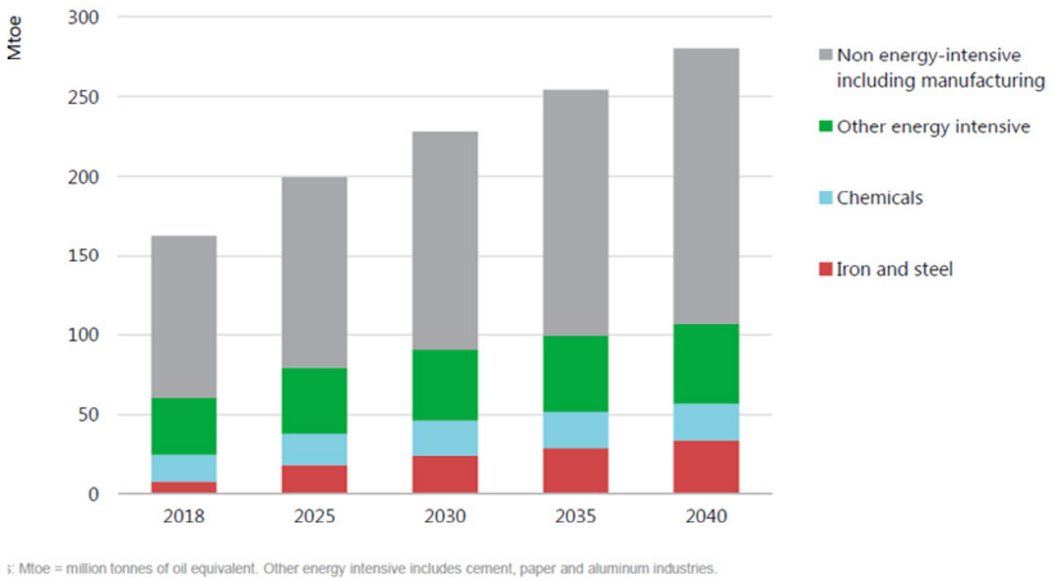


Figure 3. Projected primary energy consumption by industry sector in Southeast Asia (IEA, 2019a)

Prior to China's rise as a global manufacturing hub in the 1990s, he members of the Association of Southeast Asian Nations (ASEAN[3]) played a crucial role in international supply chains. More recently, rising labor costs, increasing trade tariffs, and the COVID-19 crisis have highlighted the dangers of over-reliance of global chains on a single country-China. These issues have forced multi-national corporations to consider diversifying their operations and ASEAN countries are regarded as the best alternative, with numerous manufacturing companies having already relocated to these countries over the past few years (Livingston, 2020).

With such an increasing trend in industrial energy use and GHG emissions in Southeast Asia, the private sector has a substantial potential to drive industrial decarbonization actions. For many companies and brands whose supply chain emissions are significantly greater than operational emissions, it is clear that to take meaningful action, companies must leverage their purchasing power, and collaborate with their supply chains. However, according to CDP, with only 29% of suppliers reporting an absolute decrease in 2019 emissions, it is clear purchasers and their suppliers in Southeast Asia and other regions must do much more. It is critical that brands work with their suppliers to ensure their climate ambitions are not being undone further up the value chain. Companies that are serious about taking meaningful action to mitigate their environmental risks must leverage their purchasing power, and work with their suppliers in Southeast Asia, to ensure their climate ambition cascades upstream.

Supply chains are largely viewed as an extension of a company's own operations and as a result, companies are held accountable by their investors and customers for supply chain practices that are not in line with acceptable sustainability standards. Investors are highly likely to evaluate their investment portfolio based on the level of risk preparedness of a company and consumers are increasingly conscious about environmental and social issues, which further pushes companies to pursue sustainable supply chain management.

The integration of environmental, social and governance (ESG) criteria for shaping key decisions taken by companies has been gaining immense popularity. These criteria help companies make responsible procurement decisions through engagement with suppliers that adhere to set standards. As a result, companies are able to reduce their risk exposure and are less vulnerable to the effects of future climate legislation and environmental compliance issues while reducing the energy and carbon footprint of their products.

In this report, we first analyze the industrial energy use in five major energy consuming countries in Southeast Asia: Indonesia, Malaysia, Philippines, Thailand, and Vietnam. Following are a few chapters in which we discuss different aspects of improving energy efficiency and reducing GHG emissions in industry in Southeast Asia through supply chain sustainability. We discuss the key barriers to supply chain decarbonization, leading practices for promoting low-carbon industrial supply chains, and the importance of performance measurement systems and their corresponding key performance indicators (KPIs) for promoting supply chain sustainability. The case-studies for supply chain sustainability are focused on the textile and apparel sector as well as electronics product manufacturing sectors. These two sectors have a large supply chain in Southeast Asia.

3 The Association of Southeast Nations (ASEAN) includes 10 Member States – Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam.

2

Industrial Energy Use and Emissions In Selected Asian Countries

2.0 Methodology

The detailed explanation of methodology is explained in Appendix 1. The industrial energy use analysis of this study focuses on five major energy consuming countries in Southeast Asia: Indonesia, Malaysia, Philippines, Thailand, and Vietnam.

To analyze the industrial energy use and emissions, we obtained the energy use data by subsectors and fuel type in 2017 from IEA's world energy statistics (IEA, 2019b). While IEA data for Thailand, Vietnam, and Philippines has good level of industrial subsector information, it lacks sufficient subsector-level data for Malaysia and Indonesia. For Malaysia, we obtained detailed industrial subsector-level energy use from Malaysian government open data portal (Hazwanie, 2018). The latest year for which these data was available for Malaysia was 2016.

For industrial energy use by subsector data for Indonesia, we obtained a dataset reported by the BPS-Statistics Indonesia (BPS, 2018) and used the data to disaggregate the total industrial energy use by fuel type given by IEA's world energy statistics for Indonesia and thereby estimate the subsector-level energy use.

Once we had industrial energy use by subsector and fuel type, first we used the CO_2 emissions factor of each fuel as well as electricity grid in each country to estimate total CO_2 emissions of industry sector in each country. In addition to analyzing and estimating industrial energy use and CO_2 emissions by subsector in each country, we estimated the energy use in two major industrial energy systems in each country: industrial motor systems and industrial boilers and steam systems.

2.1 Overview

Based on the method explained in the methodology section, we analyzed total electricity and fuel use as well as total final energy use in five selected countries (Figure 4). Indonesia has the largest final energy use in industry followed by Vietnam and Thailand. Over two-third of final energy use is fuel use and less than one-third is electricity use in industry.

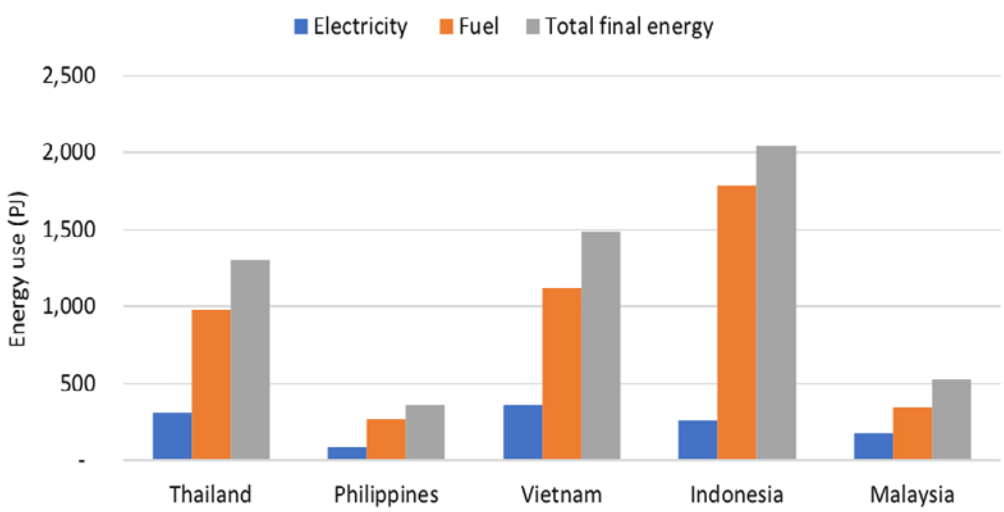


Figure 4. Final energy use in industry sector in selected countries in 2017 (Note: Malaysia's data are for 2016) (IEA, 2019b)

In addition, we estimated the energy-related CO_2 emissions in the selected countries. Figure 5 shows the comparison of energy-related CO_2 emissions in industry sector in these countries. Overall, industry sector accounts for around 27%-35% of total annual CO_2 emissions in these countries. In the following subsections, we will present country-specific results of energy and CO_2 emissions analysis for industry sector in each country.

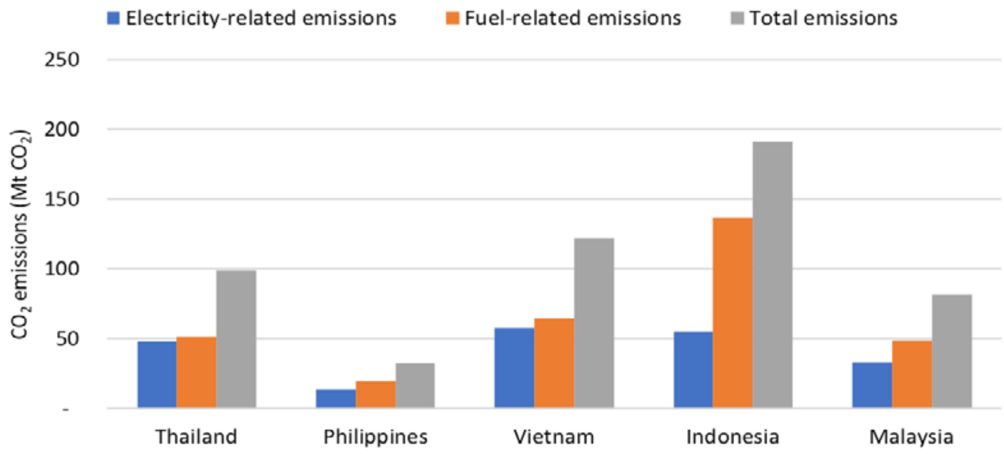


Figure 5. Energy-related CO_2 emissions in industry sector in selected countries in 2017 (Note: Malaysia's data are for 2016)

2.2 Industrial Energy Use and Emissions in Indonesia

Figure 6 shows the estimated final energy use in industrial subsectors in Indonesia in 2017. The industry classification for Indonesia is slightly different than the other countries studied because of different classification used by BPS Indonesia. The non-metallic minerals (primarily the cement industry), textile and apparel sector, and food and beverage industry are the top three energy consumers in Indonesian industry. Figure 7 shows the corresponding estimated energy-related CO_2 emissions in industrial subsectors in Indonesia in 2017.

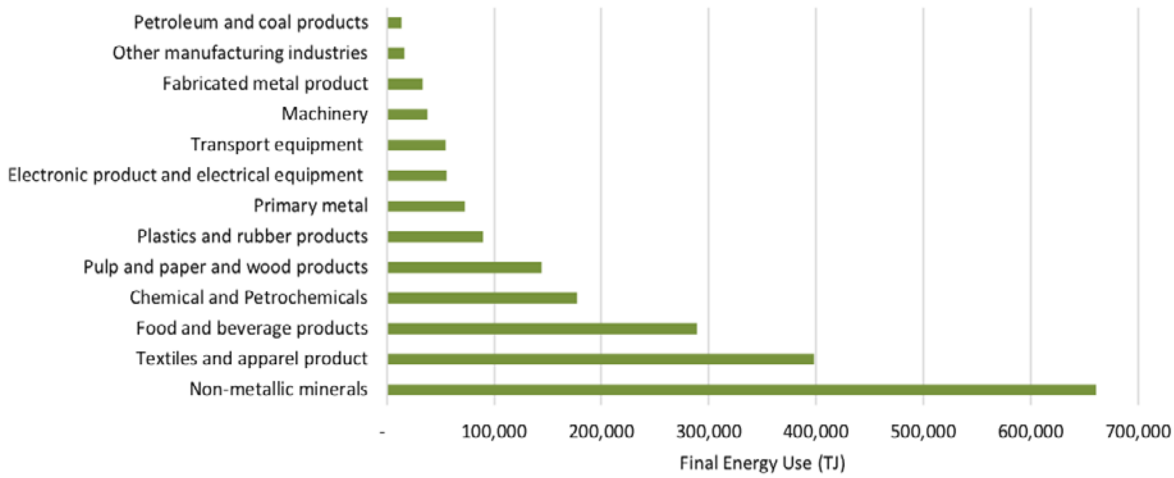


Figure 6. Estimated final energy use in industrial subsectors in Indonesia in 2017 (estimated based on (IEA, 2019b) and (BPS, 2018)).

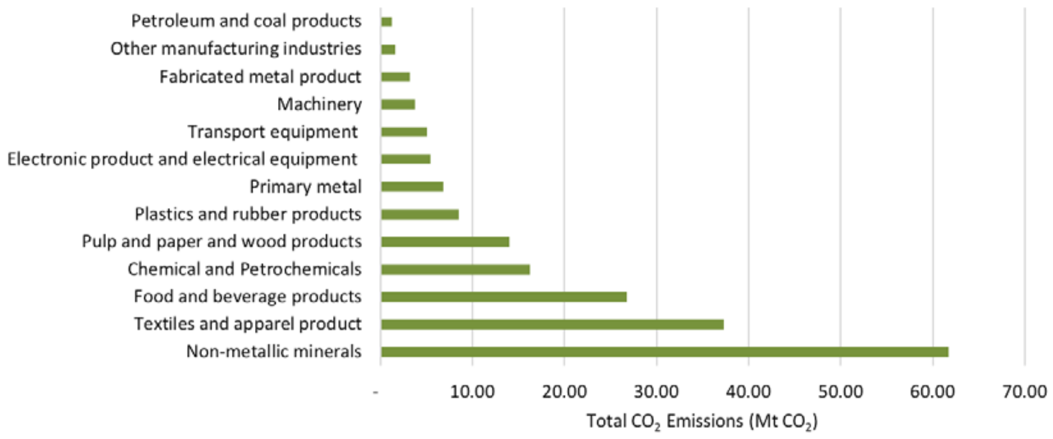


Figure 7. Estimated energy-related CO_2 emissions in industrial subsectors in Indonesia in 2017

We also estimated the electricity use in industrial motor systems in Indonesia in 2017. Industrial motor systems in Indonesia consumed around 51,800 GWh of electricity in 2017. Figure 8 shows the electricity use in industrial pump, fan, and compressed air systems in Indonesia. The textile and apparel, chemical and petrochemical, and pulp and paper industry have the largest combined electricity use for these three motor systems.

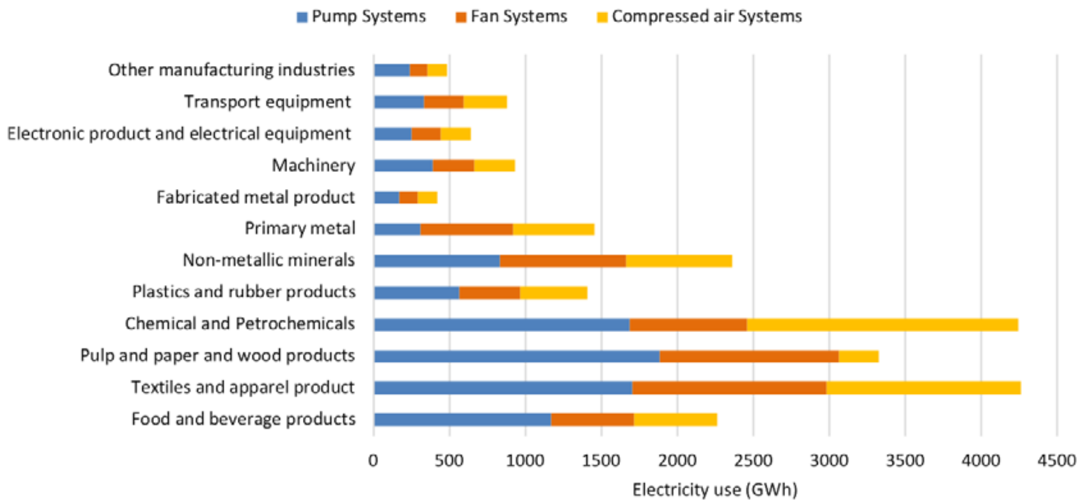


Figure 8. Estimated electricity use in three industrial motor systems in Indonesia in 2017

We also estimated the industrial boiler and steam systems fuel use in Indonesia in 2017. Table 1 shows the steam systems fuel use by each subsector in Indonesia. Industrial steam systems use approximately 639,000 TJ of fuel in 2017. The food and beverage, textile and apparel, and pulp and paper industry are the top three sectors for steam systems fuel use in Indonesia.

Table 1. Estimated fuel use in industrial boilers and steam systems in Indonesia in 2017

Industrial secto	Estimated Steam Systems Fuel Use (TJ/year)
Food and beverage products	176,440
Textiles and apparel product	190,310
Pulp and paper and wood products	111,520
Petroleum and coal products	4,740
Chemical and Petrochemicals	84,500
Plastics and rubber products	25,330
Non-metallic minerals	14,960
Primary metal	7,680
Fabricated metal product	2,850
Machinery	2,260
Electronic product and electrical equipment	7,540
Transport equipment	5,950
Non-specified	4,950
Total	638,990

2.3 Industrial Energy Use and Emissions in Malaysia

Figure 9 shows the estimated final energy use in industrial subsectors in Malaysia in 2016. The iron and steel industry, non-metallic minerals (primarily the cement industry), and food, beverage, and tobacco industry are the top three energy consumers in Malaysian industry. Figure 10 shows the corresponding estimated energy-related CO_2 emissions in industrial subsectors in Malaysia in 2016. In terms of energy-related CO_2 emissions, non-metallic minerals, iron and steel, and chemical sector are ranked the top three most emitting sectors in Malaysia.

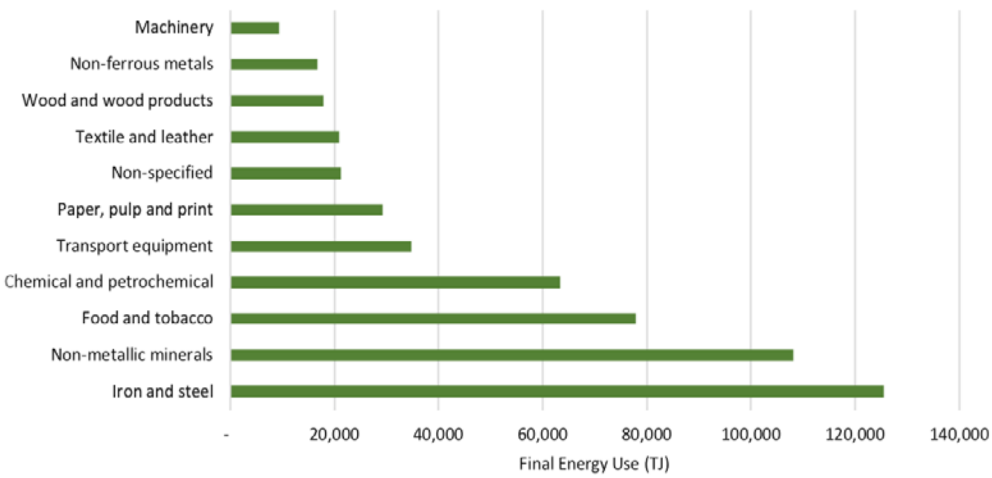


Figure 9. Final energy use in industrial subsectors in Malaysia in 2016 (Hazwanie, 2018)

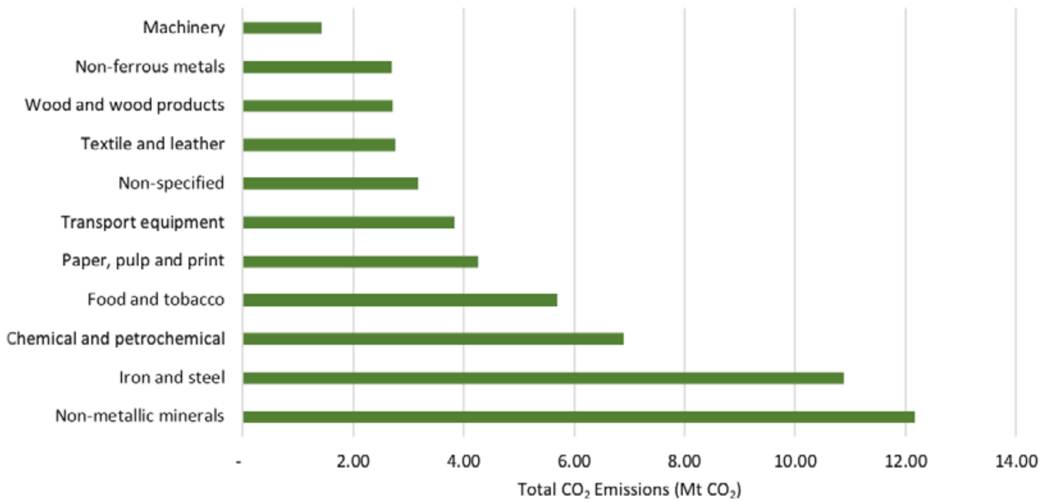


Figure 10. Energy-related CO_2 emissions in industrial subsectors in Malaysia in 2016

Industrial motor systems in Malaysia consumed around 14,700 GWh of electricity in 2016. Figure 11 shows the electricity use in industrial pump, fan, and compressed air systems in Malaysia. The chemical and petrochemical, and pulp and paper, and nonmetallic minerals industry have the largest combined electricity use for these three motor systems.

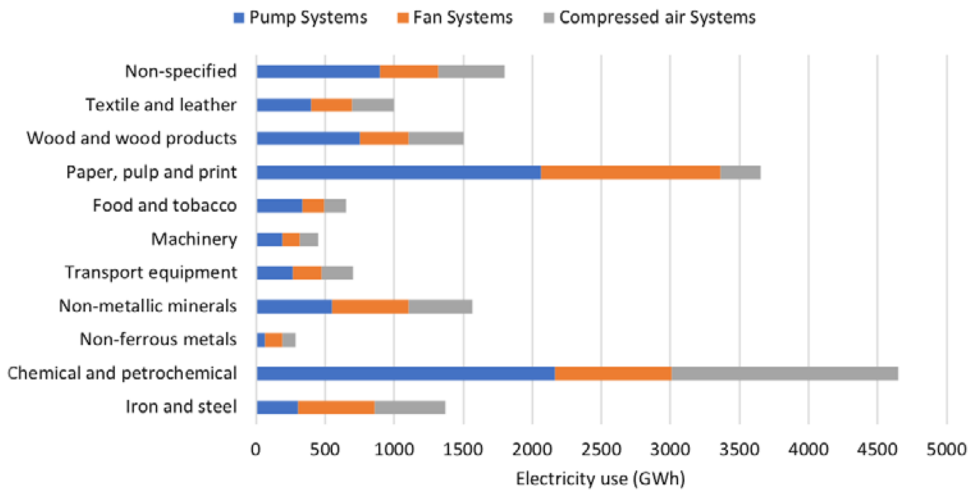


Figure 11. Estimated electricity use in three industrial motor systems in Malaysia in 2016

Table 2 shows the steam systems fuel use by each subsector in Malaysia. Industrial steam systems use approximately 65,000 TJ of fuel in 2016. The food and beverage, iron and steel, and chemical industry are the top three sectors for steam systems fuel use in Malaysia.

Table 2. Estimated fuel use in industrial boilers and steam systems in Malaysia in 2016

Industrial sector	Estimated Steam Systems Fuel Use (TJ/year)
Iron and steel	23,610
Chemical and petrochemical	22,540
Non-ferrous metals	600
Non-metallic minerals	1,670
Transport equipment	4,790
Machinery	540
Food and tobacco	46,380
Paper, pulp and print	8,450
Wood and wood products	2,220
Textile and leather	4,890
Non-specified	3,160
Total	65,080

2.4 Industrial Energy Use and Emissions in Philippines

Figure 12 shows the estimated final energy use in industrial subsectors in Philippines in 2017. It can be seen that the non-metallic minerals (primarily the cement industry), food and beverage, and iron and steel industry are the top three energy consumers in Philippines industry. Figure 13 shows the corresponding estimated energy-related CO_2 emissions in industrial subsectors in Philippines in 2017.

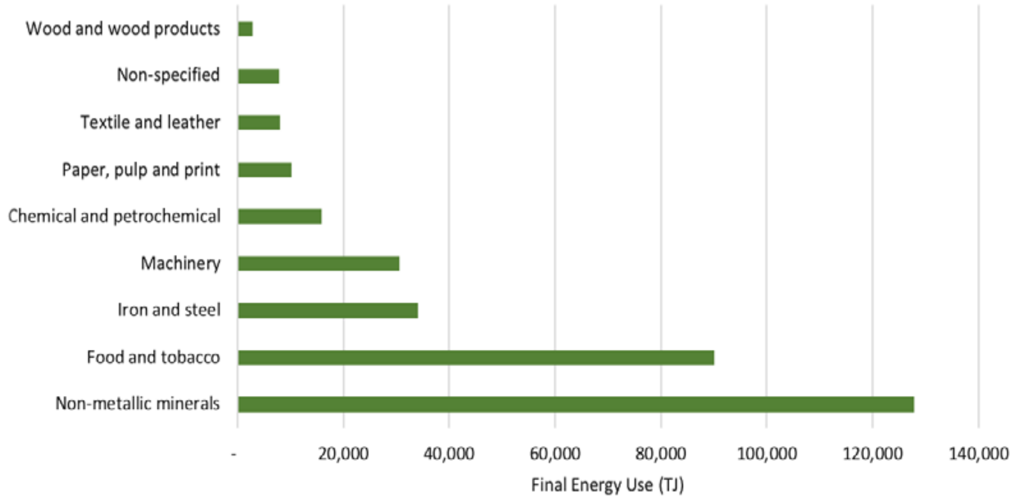


Figure 12. Final energy use in industrial subsectors in Philippines in 2017 (IEA, 2019b)

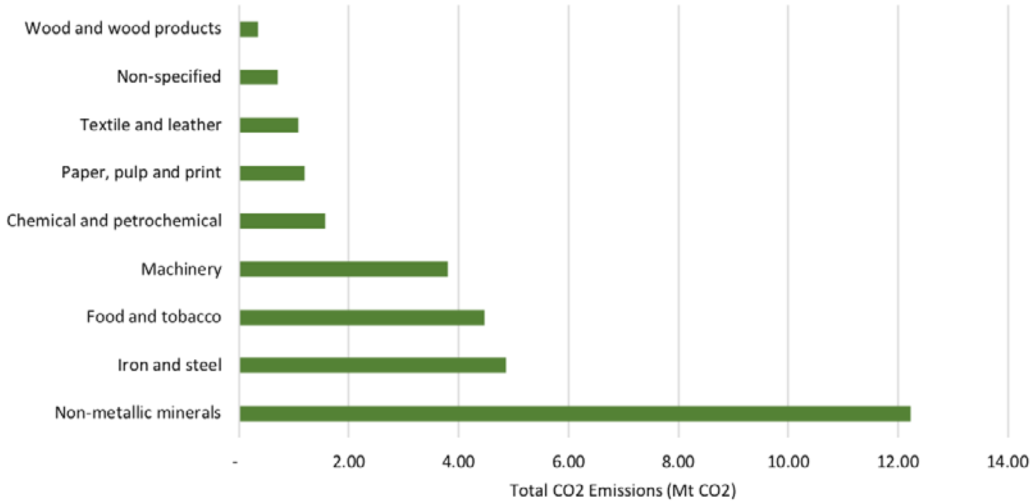


Figure 13. Energy-related CO_2 emissions in industrial subsectors in Philippines in 2017

Industrial motor systems in Philippines consumed around 7,500 GWh of electricity in 2017. Figure 14 shows the electricity use in industrial pump, fan, and compressed air systems in Philippines. The machinery, chemical and petrochemical, and food and beverage industry have the largest combined electricity use for these systems.

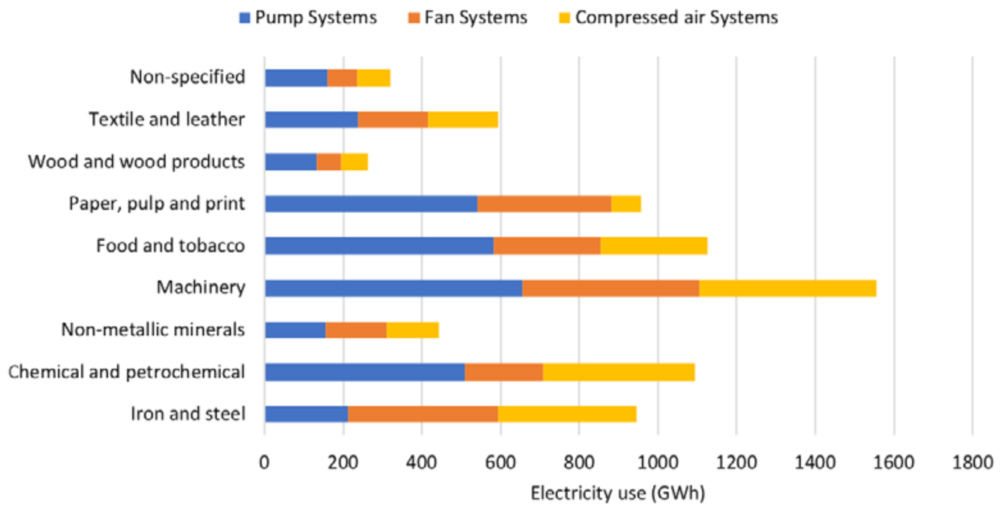


Figure 14. Estimated electricity use in three industrial motor systems in Philippines in 2017

We also estimated the industrial boiler and steam systems fuel use in Philippines in 2017. Table 3 shows the steam systems fuel use by each subsector in Philippines. Industrial steam systems use approximately 57,600 TJ of fuel in 2017. The food and beverage, chemical and petrochemical, and iron and steel industry are the top three sectors for steam systems fuel use in Philippines.

Table 3. Estimated fuel use in industrial boilers and steam systems in Philippines in 2017

Industrial sector	Estimated Steam Systems Fuel Use (TJ/year)
Iron and steel	5,610
Chemical and petrochemical	5,860
Non-metallic minerals	2,420
Machinery	1,520
Food and tobacco	49,850
Paper, pulp and print	4,400
Wood and wood products	250
Textile and leather	510
Non-specified	2,590
Total	57,570

2.5 Industrial Energy Use and Emissions in Thailand

Figure 15 shows the estimated final energy use in industrial subsectors in Thailand in 2017. The non-metallic minerals (primarily the cement industry), food and beverage, and non-specified industry are the top three energy consumers in Thailand's industry. Figure 16 shows the corresponding estimated energy-related CO_2 emissions in industrial subsectors in Thailand in 2017. The same three sectors are also top CO_2 emitters in Thailand's industry.

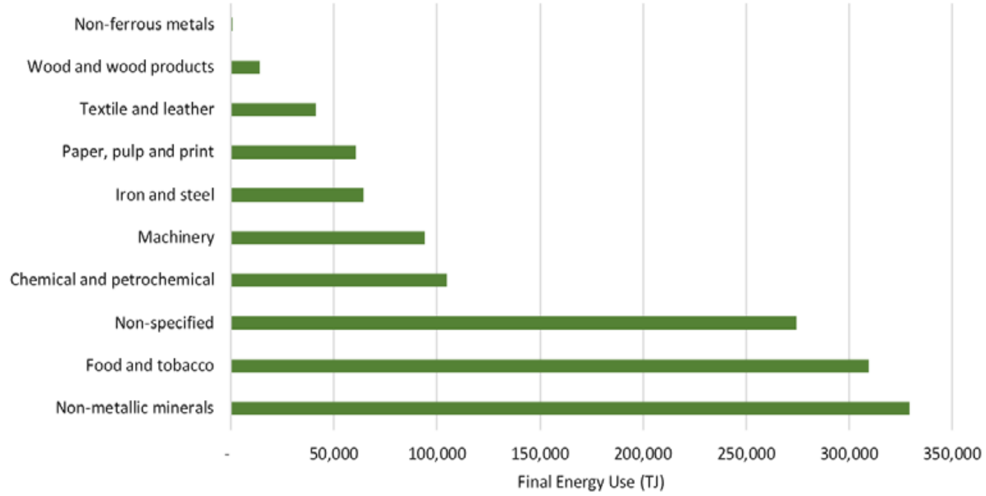


Figure 15. Final Energy Use in Industrial Subsectors in Thailand in 2017 (IEA, 2019b)

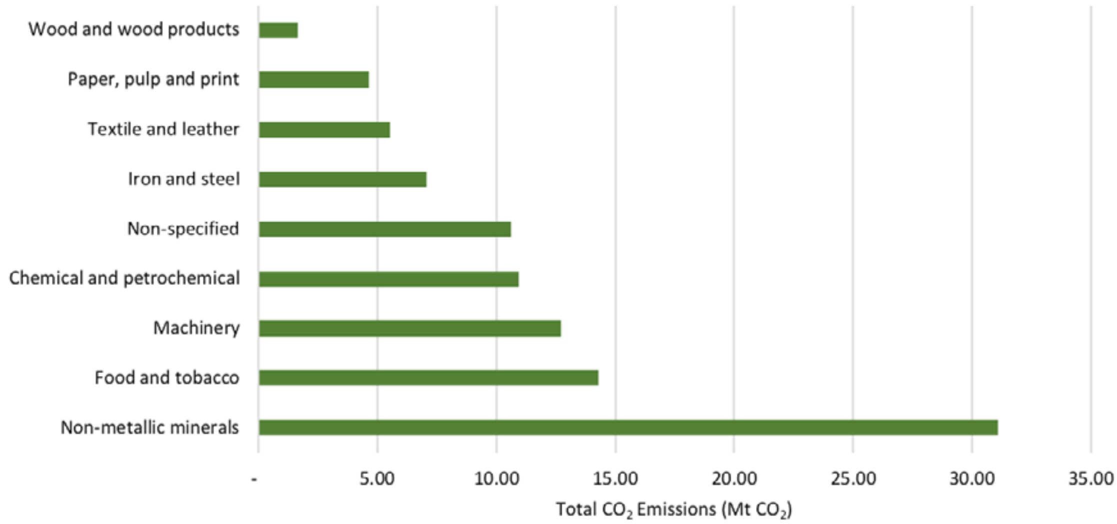


Figure 16. Energy-related CO_2 Emissions in Industrial Subsectors in Thailand in 2017

Industrial motor systems in Thailand consumed around 27,600 GWh of electricity in 2017. Figure 17 shows the electricity use in industrial pump, fan, and compressed air systems in Thailand. The chemical and petrochemical, machinery, and food and beverage industry have the largest combined electricity use for these systems.

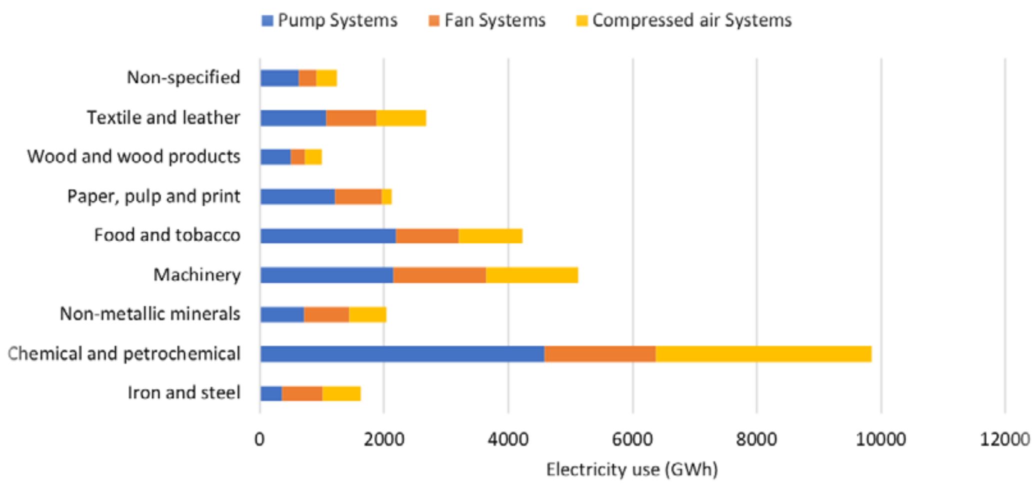


Figure 17. Estimated electricity use in three industrial motor systems in Thailand in 2017

Table 4 shows the steam systems fuel use by each subsector in Thailand. Industrial steam systems use approximately 350,000 TJ of fuel in 2017. The food and beverage, pulp and paper, and non-specified industry are the top three sectors for steam systems fuel use in Thailand.

Table 4. Estimated fuel use in industrial boilers and steam systems in Thailand in 2017

Industrial sector	Estimated Steam Systems Fuel Use (TJ/year)
Iron and steel	8,020
Chemical and petrochemical	31,120
Non-ferrous metals	120
Non-metallic minerals	5,940
Machinery	3,630
Food and tobacco	167,280
Paper, pulp and print	43,310
Wood and wood products	2,350
Textile and leather	5,080
Non-specified	132,000
Total	350,000

2.6 Industrial Energy Use and Emissions in Vietnam

Figure 18 shows the estimated final energy use in industrial subsectors in Vietnam in 2017. The non-metallic minerals (primarily the cement industry), textile and apparel sector, and food and beverage industry are the top three energy consumers in Vietnamese industry. Figure 19 shows the estimated energy-related CO_2 emissions in industrial subsectors in Vietnam in 2017. The same three sectors are the top CO_2 emitters in Vietnam.

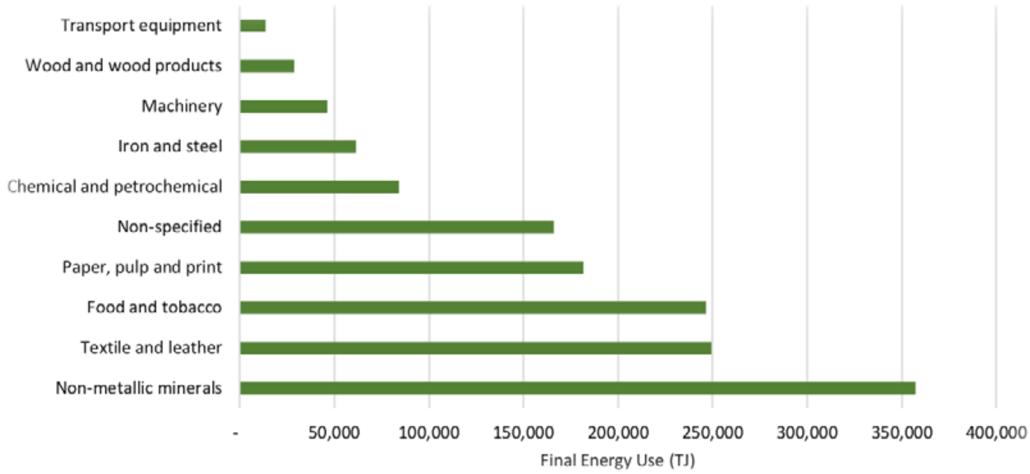


Figure 18. Final Energy Use in Industrial Subsectors in Vietnam in 2017 (IEA, 2019b)

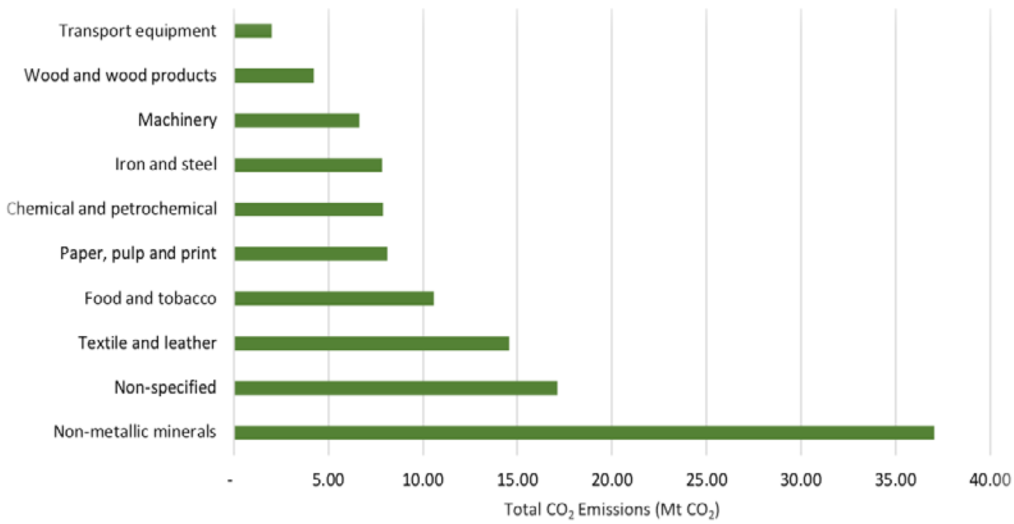


Figure 19. Energy-related CO_2 emissions in industrial subsectors in Vietnam in 2017

Industrial motor systems in Vietnam consumed around 35,500 GWh of electricity in 2017. Figure 20 shows the electricity use in industrial pump, fan, and compressed air systems in Vietnam. The chemical and petrochemical, pulp and paper, and non-specified industry have the largest combined electricity use for these systems.

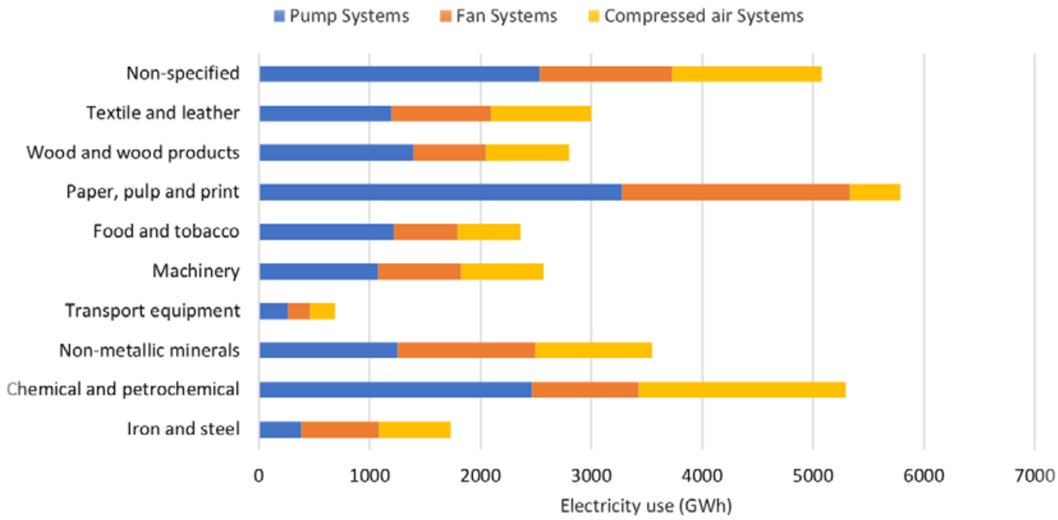


Figure 20. Estimated Electricity Use in three Industrial Motor Systems in Vietnam in 2017

We also estimated the industrial boiler and steam systems fuel use in Vietnam in 2017. Table 5 shows the steam systems fuel use by each subsector in Vietnam. Industrial steam systems use approximately 458,000 TJ of fuel in 2017. The food and beverage, pulp and paper, and textile and apparel industry are the top three sectors for steam systems fuel use in Vietnam.

Table 5. Estimated fuel use in industrial boilers and steam systems in Vietnam in 2017

Industrial sector	Estimated Steam Systems Fuel Use (TJ/year)
Iron and steel	6,540
Chemical and petrochemical	32,530
Non-metallic minerals	6,030
Transport equipment	420
Machinery	1,680
Food and tobacco	143,670
Paper, pulp and print	132,600
Wood and wood products	2,350
Textile and leather	117,450
Non-specified	62,000
Total	458,040


Kowloon (W)
九龍(西)
Airport Express Station
機場快綫站
Finance Street
金融街

3 Supply Chain Sustainability to Drive Industrial Energy Efficiency and Decarbonization

Climate change is putting ever increasing pressure on the ability of businesses to run smooth operations, ensure business continuity, and deliver products and services to meet the needs of their customers (WEF, 2020). Climate-related impacts will become more prominent not only for companies' own operations, but also supply chains. As corporate supply chains are becoming increasingly complex, with numerous interdependent linkages spanning across multiple geographies, companies face increasing challenges of building and maintaining resilient supply chains in the context of changing climate.

Supply chain related activities by multinational corporations contribute to 80% of global trade (UNCTAD, 2013), and can constitute 5.5 times more GHG emissions than a company's direct operations (CDP, 2019a). Supply chain management with a focus on supply chain decarbonization, therefore, plays an important role in facilitating the transition to a low-carbon economy. Furthermore, carbon emissions associated with global supply chains will become increasingly regulated with numerous national and international policy developments underway, and combined with further fiscal disincentives to emit carbon (C2ES, 2016), this could force companies to seriously address climate-related risks from their supply chain activities. In return, effective supply chain management can help companies apply their sustainability initiatives as part of maintaining their brand integrity, business continuity, and managing operational costs (UNGC and BSR, 2015).

According to the U.S. EPA Center for Corporate Climate Leadership, *"scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly impacts in its value chain. Scope 3 emissions include all sources not within an organization's scope 1 and 2 boundary"* (U.S. EPA, 2020). The Greenhouse Gas Protocol (GHG Protocol) defines scope 1 emissions as those direct GHG emissions occurring *"from sources that are owned or controlled by the company"*, and scope 2 emissions as *"GHG emissions from the generation of purchased electricity consumed by the company"*, and indicates that scope 3 emissions for one organization therefore represent scope 1 and 2 emissions of another organization (WRI and WBCSD, 2004). The GHG Protocol Corporate Value Chain (Scope 3) Standard provides an international methodology for companies to account for scope 3 emissions from 15 categories of their value chain activities, including both upstream and downstream operations (see Figure 21) (WRI and WBCSD, 2011a).

The following chapters highlight barriers to supply chain decarbonization, leading business practices to help companies move towards decarbonizing their supply chain operations, and key performance indicators (KPIs) used by companies for assessing their supply chain's sustainability performance.

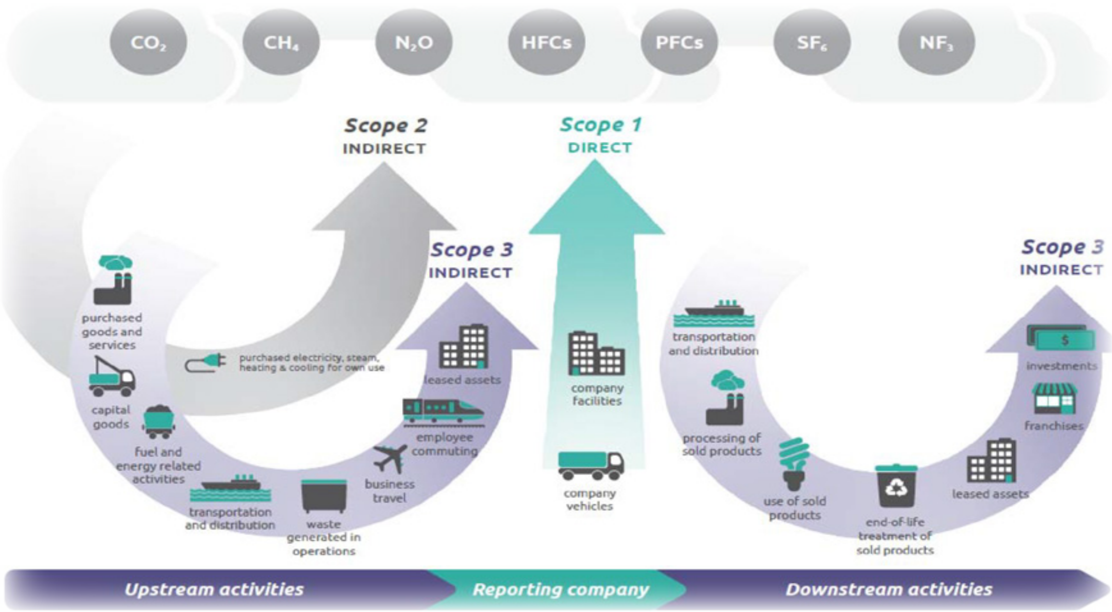


Figure 21. Overview of Various Scopes and GHG Emission Categories for Scope 3 (WRI and WBCSD, 2011a)

4 Barriers to Supply Chain Sustainability

Despite its significant benefits, the implementation of supply chain sustainability and decarbonization in Asia is challenging, and companies continue to encounter barriers that prevent them from implementing effective measures. The barriers to supply chain sustainability in Asia and other parts of the world are represented by a combination of market, technical, and organizational factors (BSR, 2014).

It is essential to move beyond corporate and geographic boundaries in order to achieve the goal of supply chain decarbonization. Since companies are increasingly sourcing on a global scale, they are operating in differing national and international institutional contexts. The sustainability practices of a supply chain can be compliant with the law in one Asian country, yet they may not meet the minimum standard of another country's law. In addition, there is an abundance of local and global sustainability standards and benchmarks for supply chains that are not always compatible (WEF, 2009). Better coordination among supply chain partners in terms of strategic and operational decisions is often a precursor for establishing and preserving a competitive edge. It helps companies lower their environmental and social impacts while improving their economic status. Hence, it is crucial to acknowledge the potential effect of supply chain interactions at lowering the overall carbon footprint. However, a large proportion of companies continue to pay secondary attention to their partners' application of sustainability and energy management practices in their business activities. The risk sharing, cost saving and lead and response time reduction potential generated on account of collaboration among supply chain partners results in the addition of value to each partner and to the supply chain as a system (Marchi & Zanoni, 2017).

Some of the major barriers affecting the widespread adoption of supply chain sustainability and decarbonization measures in Asia are explained below.

4.1 Economic Barriers

Economic aspects play an important role in supply chain decarbonization in Asia, and factors such as high investment costs, hidden costs and low profitability can often hinder suppliers (especially Small to Medium Enterprises (SMEs)) from implementing low-carbon projects particularly in the developing countries in Asia. A European Central Bank survey reveals that for many companies, especially SMEs, receiving access to capital is the most challenging issue (ECB, 2015). Most energy efficiency initiatives, renewable energy developments, and other low-carbon projects require capital investment, and particularly for SMEs, the time and money necessary to implement a strong supply chain sustainability program can be a significant barrier. Industry collaboration can help companies pool their resources and share the expenses of establishing expectations and engaging with suppliers.

4.2 Information Barriers

These include insufficient information on costs, benefits and technologies, as well as the lack of awareness, knowledge, and expertise to interpret and analyze technical information to develop energy management or decarbonization plans. Irrespective of the amount of importance given to energy and decarbonization by different companies, raising awareness regarding efficient utilization of energy and depicting its importance in terms of a cost and benefit framework demands more attention (Marchi & Zanoni, 2017).

While energy audits provide a snapshot of the current situation of energy use in a specific company, they may not be clear what initiatives deliver the best results in terms of corporate advantage and shared value in the supply chain (Marchi & Zanoni, 2017). Sustainability practices should be evaluated just like any other business practice and organizations should try to map the business impact of different sustainability initiatives, making a selection based on the people, planet, profit (PPP) framework.

Cost-benefit assessments are essential as companies are constantly striving to earn profits, and the energy bill could account for a significant proportion of an organization's total production cost. Combining this techno-economic information regarding energy efficiency improvements in a company and its supply chain, in order to provide a complete picture to the company's management and investors is crucial. The notion that energy efficiency measures typically come with a higher cost could indeed be true. This is because of the higher investment costs associated with new and more efficient equipment as compared to their paid-off obsolete equivalents. However, upfront costs represent only one of the many components of a product's life cycle cost. The cost savings observed from a reduction in energy consumption, improvement in production processes, lower maintenance costs, etc. as a result of investment in high efficiency equipment can typically make up for the high investment costs and lead to a favorable return on investment. Assessing costs and benefits through a life cycle perspective offers a thorough evaluation of the effect of supplier interventions on the overall economic and environmental performance of a company's value chain (Marchi & Zanoni, 2017).

4.3 Market Barriers

There are various market barriers to supply chain decarbonization. For example, the complexities associated with traditional power purchase agreements (PPAs) – the standard method to contract for renewable electricity – and the absence of adequate market incentives serve as a challenge for the procurement of renewable energy for driving supply chain decarbonization. The technical and regulatory barriers in China have made it increasingly difficult for corporations to procure renewable energy. With abundant wind resources and the recent wind power development in Northwest China, an inflexible grid and lack of transmission lines to the industrial Southeast has meant that in some instances over 40 percent of that generation is curtailed (Boren, 2017). Traditional PPAs can also pose barriers for some corporations in terms of creditworthiness, project size, tenor and other risks. Companies are overcoming these barriers by signing PPA deals with other buyers (i.e., aggregated PPAs) and negotiating for more flexible terms.

Another market barrier is the challenge associated with implementing a carbon pricing scheme. Some companies have alluded to a lack of clarity and understanding regarding the working of carbon pricing programs. Additionally, companies are apprehensive of a carbon pricing since business units with the highest GHG emissions could interpret these such programs as a disciplinary measure. The challenge of putting forth a strong defense for an internal carbon fee program is also viewed as an obstacle (Alhuwalia, 2017).
In addition to the three categories of barriers, there exist other barriers to the implementation of supply chain decarbonization initiatives, some of the more specific internal and external barriers have been identified as follows: *"Lack of top management commitment and support, unclear organizational objective, resistance to change, lack of motivation and employee empowerment, poor corporate structure, mistrust among employee and supply chain partners, unwillingness to implement supply chain practices, lack of integration among supply chain partners, lack of collaboration among supply chain partners, lack of responsiveness and lack of customer satisfaction index" (Islam & Anis, 2018)*

5 Best Practices for Building low-carbon Supply Chains in Textile & Apparel and Electronic Products Sectors

This chapter highlights leading business practices, to help companies move towards decarbonizing their supply chain operations.

5.1 Supply Chain Engagement and Assessment

Since businesses cannot manage what they cannot measure, conducting supply chain assessments and requesting information about scope 1 and scope 2 emissions from their suppliers can help companies prioritize high-risk areas in their supply chain, such as suppliers with high GHG emissions, and help them take strategic decisions about their supply chain decarbonization (CDP, 2019a). Viewing a supply chain as an extension of a company's own operations, products and services, workforce and community, can enable companies to take a holistic view on managing their supply chains and better adapting to globalized and fast-changing markets (UNGC and BSR, 2015).

As companies are moving towards more mature supply chain management programs, they can work towards developing stronger relationships with their suppliers through supplier engagement programs and help their suppliers establish their own sustainability management systems and policies, which would help suppliers systematically measure and track their GHG emissions. Having understood the need for collaboration along their extensive supply chain, companies can manage their sustainability risks more effectively and integrate sustainable practices in manufacturing, processing, and other operations and processes of their product or service development.

Clear benefits of supplier engagement include (UNGC and BSR, 2015): (1) Reducing GHG emissions that can drive other resource efficiencies, including materials, water, and waste reduction; (2) More efficiently designed processes and systems which reduce required energy and materials inputs; (3) Improving health and safety conditions for supplier workers by driving emissions reduction; and (4) Optimization and management of procurement and sourcing costs as a result of the benefits listed above.

Depending on the extensiveness of a company's supply chain, the number of vertical and horizontal suppliers may vary significantly. Therefore, companies often prioritize Tier 1 suppliers that are most critical to their product or service. The GHG Protocol outlines a four-step supplier engagement guidance aimed at helping companies collect GHG data when developing their scope 3 GHG inventories. According to this guidance, companies should develop a strategy for collecting GHG emissions data from its suppliers that is based on the following steps: *"(1) Identify the internal departments responsible for data collection; (2) Select suppliers and identify supplier information; (3) Engage the procurement staff, and (4) Develop a method for managing supplier data"* (WRI and WBCSD, 2011b).

As part of developing a method for managing supplier data, companies can either create / outsource a data collection system or leverage an existing GHG reporting / disclosure program. For example, companies can analyze suppliers' metrics from their suppliers' annual CDP Supply Chain disclosures. Around 115 organizations with US$3.3 trillion in combined annual procurement, as members of the CDP Supply Chain program, requested their suppliers to report their current and future risks and opportunities related to environmental issues such as climate change, deforestation and water in 2019. CDP found that 63% of CDP Supply Chain program members either use, or are considering using, CDP data to influence supplier contracting decisions (CDP, 2019a).

Companies can also review their suppliers' environmental and corporate social responsibility (CSR) performance by looking at the sustainability indices by the Dow Jones Sustainability Indices and the Global Reporting Initiative. Many multinational corporations also develop their own code of conduct to set expectations for their suppliers when they enter into a contractual agreement. To develop such codes of conduct, companies can consult and reference internationally accepted sector-specific standards and protocols, such as the Kimberley Process for jewelry industry, Forest Stewardship Council Certification for wood and paper products, the Responsible Business Alliance code of conduct for the electronics industry, the SA8000 for responsible labor practices and ISO 26000 guideline that provides indicators for companies to make their supply chain more sustainable. They can help companies identify relevant inputs for their own supplier engagement program and codes of conduct. According to the UNGC, a supplier code of conduct is a *"natural extension of corporate values statements and seen as an affirmation of existing expectations rather than a new set of requirements"*. It should be noted that some of these may not cover energy and carbon footprint of the companies and their decarbonization efforts (UNGC and BSR, 2015).

Standards imposed by procuring companies for their suppliers may foster further engagement with Tier 2 and Tier 3 suppliers down the supply chain, creating cascading impacts. In fact, over one third of suppliers which responded to CDP 2019 Supply Chain Questionnaire are requesting information from their suppliers, driving upstream change in their own supply chain (CDP, 2019a).

Lately, Environmental, Social and Governance (ESG) criteria have gained widespread recognition for promoting *"environmentally friendly, socially acceptable, and ethically righteous"* practices across a company's internal as well as external management process (Kodiak Rating Community, 2017). These criteria are helping shape sourcing decisions made by companies, ensuring that they engage with supply chain partners that are consistent with their own standards, thus minimizing their ESG related risks (Kodiak Rating Community, 2017). In addition, ESG criteria are also being utilized by investors for assessing their investment portfolio, in order to avoid companies deemed to be a greater financial risk on account of their exposure to environmental or other risks (Chen, 2020).

Case Study 1: Levi Strauss & Co., an American multinational apparel company is committed to achieving a 40% reduction in its global supply chain emissions by 2025. To meet this ambitious goal, the company regularly assesses sustainability performance of its suppliers using the Sustainable Apparel Coalition's Higg Index, which serves a similar purpose to procuring companies as the CDP Supply Chain program. To engage its suppliers and help them reduce their GHG emissions, the company has signed a $2.3 million cooperation pact with the International Finance Corporation (IFC), which aims to follow the Partnership for Cleaner Textiles (PaCT) principles. As part of this agreement, IFC will work with 42 selected LS&Co. suppliers and mills across various geographies - Pakistan, Bangladesh, Sri Lanka, India, Mexico, Lesotho, Colombia, Turkey, Egypt, and Vietnam, to help reduce their carbon and water footprint (Levi Strauss & Co., 2019).

Case Study 2: Google launched its own Responsible Supply Chain program in 2012, which aims to reduce risks and improve results across its supply chain, by means of a supplier code of conduct, a supplier engagement program, community investment and partnerships. It started utilizing the CDP Supply Chain platform in 2018 to obtain information from its key suppliers through the climate change and water questionnaires, in order to understand suppliers' progress and shortcomings and consequently work towards further integrating sustainable practices in the supply chain. In 2019, Google was successful in ensuring that 94% of its targeted suppliers were under its supplier code of conduct agreement, which lays out a wide range of social, environmental and ethical guidelines. The environmental aspect of the code of conduct instructs suppliers to pursue resource efficiency and clean energy to reduce their GHG emissions, maintain updated environmental permits, restrict use of hazardous substances and work towards reducing and properly managing waste streams (Google, 2019a).

Case Study 3: Microsoft has also developed a code of conduct for its suppliers, in alignment with the Responsible Business Alliance (RBA) framework, which is aimed at upholding human rights, labor, health and safety, environmental, and business ethics practices. In 2020, its top suppliers succeeded in reducing their combined carbon footprint by 21 million metric tons of CO_2e. Additionally, Microsoft has been utilizing the Social and Environmental Accountability Academy platform for tracking the performance of its supply chain partners and promoting improvements through the provision of training (Microsoft, 2020).

5.2 Setting GHG Reduction and Carbon Neutrality Targets

There are a number of reasons that drive companies toward adopting a GHG reduction target, some of which are summarized as follows: *"Minimizing and managing risks, achieving cost savings and stimulating innovation, preparing for future regulations, demonstrating leadership and corporate responsibility, and participating in voluntary programs"* (WRI and WBCSD, 2004). These reasons represent a combination of factors that would help ensure organizations' viability heading into an ever more uncertain future reeling from the impacts of global warming.

Companies are increasingly setting ambitious GHG reduction goals, however, to achieve the determined goals and targets, companies need to seek support from their supply chain (UNGC and BSR, 2015). As meeting these targets is a responsibility shared by the procuring company and its suppliers, companies need to regularly communicate and engage with their suppliers, systematically collect supplier specific GHG data and continuously improve supplier engagement programs. As companies develop more mature supply chain management strategies, they can focus on integrating these processes with the procurement function, requiring suppliers to cascade the requirements further down the supply chain, and identifying opportunities to improve supplier performance.

Companies often set GHG reduction goals at a high-level for the entire establishment, translating each objective further into actionable targets for their individual suppliers. For example, certain companies establish goals requiring them to allocate a specific proportion of their spend (or volume) with the highest performing suppliers, while others underscore goals highlighting sustainability as a crucial aspect alongside other commercial and technical criteria, regarding supply decisions (UNGC and BSR, 2015).

A goal setting approach that is currently gaining momentum is the Science-based targets (SBTs) methodology which provides an emissions reduction pathway that companies can use to achieve a reduction in their scope 1 and 2 GHG emissions, in order to stay within the 1.5 or 2 degree Celsius warming scenario, as recommended by the 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report (SBTi, 2018). However, the SBT methodology can also be applied to developing a roadmap for the reduction of scope 3 emissions (Labutong & Hoen, 2018). Prior to setting scope 3 science-based targets using the SBT criteria, a company should conduct a scope 3 screening to identify hotspots (in terms of highest GHG emissions) in its value chain, to better understand where to focus its GHG emission reduction efforts (SBTi, 2018).

Case Study 1: Apple has accomplished its goal of achieving 100% renewable electricity for its own facilities and carbon neutrality for its corporate emissions. In 2020, Apple announced its commitment to become 100% carbon neutral for its supply chain and products by 2030. An important component of this commitment is expanding its Supplier Energy Efficiency Program, which supports 92 suppliers as of 2019. The US-China Green Fund, a $100 million fund set up by Apple would work towards promoting accelerated energy efficiency projects for Apple's suppliers. More than 70 of Apple's suppliers have made the commitment to utilize 100% renewable energy for Apple production, which will lead to avoided emissions of over 14.3 million metric tons of CO_2e annually. Apple is planning to engage its suppliers to facilitate their transition to clean energy by : (1) Demonstrating leadership in suppliers' energy markets which represent varying levels of statutory and regulatory requirements; (2) Sharing lessons learned from own investments in renewable energy and relevant tools to make clean energy adoption easier; (3) Connecting suppliers to high-quality projects through the development of joint funds that provide suppliers with greater purchasing power and the in turn ability to pursue a wide range of clean energy projects; (4) Advocating for strong clean and renewable energy policies (Apple, 2019).

Case Study 2: In 2019, Levi Strauss & Co. signed the Business Ambition for 1.5°C pledge, a campaign initiated by the UN Global Compact that intends to encourage leading businesses to make a commitment towards setting science-based targets. As part of the SBT initiative, it aims to achieve a 90% reduction in its scope 1 and scope 2 emissions, and a 40% reduction in scope 3 emissions by 2025 from a 2016 base-year. It is also a member of the RE100 campaign (see Section 5.3) with a pledge to transition to 100% renewable powered electricity for its owned-and-operated facilities by 2025. Additionally, Levi Strauss & Co. has advocated for stronger energy and climate policy action on the state and federal level as a cofounding member of the Business for Innovative Climate and Energy Policy (BICEP) network, and has also signed onto the Fashion Industry Charter for Climate Action which aims to promote industry-wide collaboration amongst leading fashion companies to achieve net zero GHG emissions for the apparel and footwear industry (Levi Strauss & Co., 2018).

Case Study 3: PUMA has set a science-based emissions reduction target in 2019. It aims to achieve a 35% reduction in scope 1 and 2 emissions and a 60% reduction in scope 3 emissions (GHG emissions per million € in sales) by 2030, compared to a 2017 baseline. In addition, PUMA is also a signatory of the Fashion Industry Charter for Climate Action which aims to achieve industry-wide GHG emission reductions (SGB Media, 2019).

Case Study 4: Under the SBT initiative, Panasonic Corporation has committed to a 30% reduction in its scope 1 and 2 emissions, and a 30% reduction in its scope 3 emissions by 2030, compared to a 2013 baseline. In addition, it strives to achieve a 100% reduction in scope 1 and 2 emissions by 2050, keeping its science-based target in line with the 2°C global warming scenario (SBTi, 2020). The corporation's commitment to powering its global business operations through 100% renewable electricity by 2050 as part of the RE100 campaign (see Section 5.3) (RE100 Initiative, 2020a), is in synchronization with its science-based targets.

5.3 Develop and Implement Renewable Energy Projects

Encouraging suppliers to transition to renewable energy is key to achieving scope 3 GHG reduction targets. Currently, a quarter of Fortune 500 companies have announced that they are, or will be, carbon neutral, powered entirely by renewable energy or achieving a science-based emission reduction goal by 2030. At the forefront of this transition are multinational corporations that are doubling down on sustainability and renewable energy procurement strategies. In recognizing the intrinsic value of sustainable and climate resilient assets, these companies are reducing carbon emissions of their global operations and creating platforms and incentives as models for others to follow.

Some of the world's most influential businesses have committed to sourcing 100% renewable electricity for their own operations as part of the RE100 initiative. In order to become a part of the RE100 campaign, companies must strictly adhere to the joining criteria laid out by the Climate Group in collaboration with CDP. The initiative sets minimum requirements regarding setting renewable electricity targets such as: 100% by 2050, with incremental steps of 60% by 2030 and 90% by 2040. Currently, over 260 companies with significant energy footprints have signed onto the RE100 initiative (RE100 Initiative, 2020b).

Case Study 1: In an effort to integrate renewables across its supply chain, NIKE initiated a rooftop solar photovoltaic (PV) program for suppliers' factories in China, Indonesia and Vietnam. In addition, NIKE is also working towards helping suppliers enter virtual power purchase agreements (VPPAs), to meet their sustainability goals. Through its collaboration with USAID and its Vietnam Low Emission Energy Program (V-LEEP), NIKE is working towards promoting regulations and programs necessary for the adoption of renewable energy direct PPAs. NIKE is also helping with policies in China and Indonesia regarding renewable PPAs (NIKE, 2019). Also, NIKE is a member of the RE100 initiative, with a commitment to achieve 100% renewable electricity in owned and operated facilities by 2025 (RE100 Initiative, 2020a).

Case Study 2: Apple is working towards creating new clean energy projects and helping its supply chain transition to clean power. With recently completed renewable energy projects in various states across the US, the renewable capacity for Apple's corporate operations now exceed 1 GW. Greater than 80% of Apple's renewable energy requirement for its facilities is fulfilled through clean energy projects developed by the company itself. The Supplier Clean Energy Program plays a crucial role in Apple's overall GHG emission reduction plan. Manufacturing related emissions account for close to 75% of Apple's overall carbon footprint and most of these emissions are generated as a result of electricity utilized for creating product parts. As a result, Apple intends on enhancing energy efficiency at supplier facilities, and subsequently help suppliers use clean, renewable electricity (Apple, 2020). Apple is a member of the RE100 initiative and announced that all its facilities across 43 countries are powered by 100% renewable electricity in 2018 (Apple, 2018).

Case Study 3: The Ingka Group (franchise partner of IKEA Group) has set an ambitious target of achieving climate positive status by 2030. The group will make a €600 million investment over the next year, which would work towards helping suppliers adopt renewable energy and would also contribute towards developing carbon removal projects (such as reforestation, better forest management, etc.) to drive the transition towards becoming a climate positive company within the next decade. It is one of the founding partners of the RE100 campaign, committing to consuming 100% renewable electricity by 2025 and producing as much renewable energy as the total energy consumption of its operations by 2020 (Ingka Group, 2020).

5.4 Develop and Implement Energy Efficiency Projects

Beyond strategic supplier engagement and carbon goal setting, procuring companies drive decarbonization in their supply chain through the adoption of energy efficiency measures in their supply chain. The ISO 50001 energy management standard is an internationally accepted standard that provides companies a systematic guideline for improving their energy performance. The ISO 50001 standard works well in conjunction with the ISO 14001 standard, a leading environmental management system which lays the groundwork for company personnel as well as suppliers to focus on the environmental aspect of supply chain management, while ISO 50001 enables companies to set energy efficiency targets, prioritize energy efficiency practices through investments and keep track of the energy management performance and relevant outcomes (Jabbour, et al., 2016). The plan-do-check-act (PDCA) approach which forms the basis of the standard, helps ensure an iterative process necessary for the continuous energy performance improvement (see Figure 22).

Although many suppliers are interested in adopting energy efficiency initiatives, they often lack the resources, business motivation, and capacity to implement energy management programs at scale. Large multinational companies, in contrast, have the required resources and expertise to help their suppliers adopt better energy efficiency strategies through pilot programs that continuously expand to engage more suppliers in their value chain.

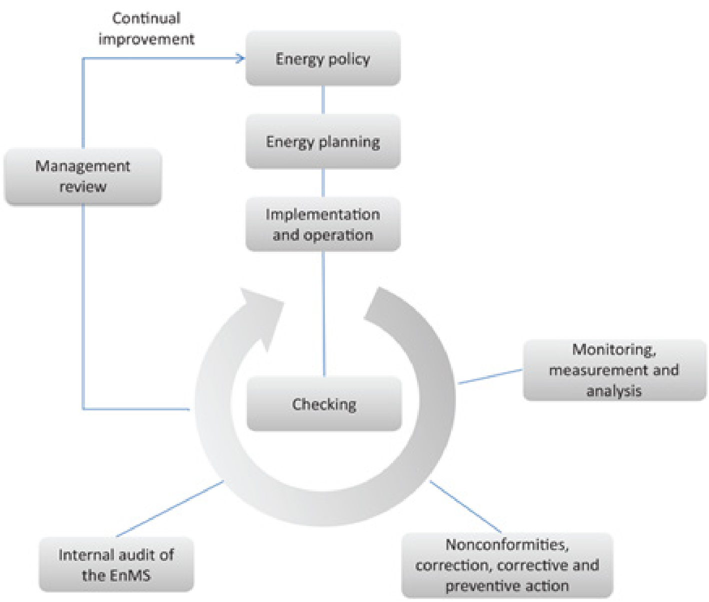


Figure 22. Energy management system (EnMS) model according to ISO 50001 (ISO, 2011)

The Clean by Design program initiated by National Resources Defense Council (NRDC) intended to help multinational corporations reduce their overall environmental impact through efficiency improvements in the manufacturing processes of their suppliers, mostly located in developing countries with few pollution control measures. In 2018, the Clean by Design program was integrated with the Apparel Impact Institute (Aii). On account of the proven success of the Clean by Design program across over 100 textile mills in China, a core set of its principles, criteria and metrics were identified to serve as the foundation of Aii's mill sustainability efforts (Aii, 2018).

The Textile Sustainability Hub also aims to fill the knowledge gap on cleaner production in the textile and apparel industry. It is an information hub that researches, identifies and shares best

practices for sustainability and cleaner production in the textile and apparel industry (Textile Sustainability Hub, 2020).
The Climate Group in collaboration with Alliance to Save Energy, launched the EP100 initiative which aims to improve the energy productivity of companies, enabling them to reduce their emissions and improve their competitiveness. In order to be recognized as an EP100 member, companies choose among three commitments (EP100 Initiative, 2020):

1. Double energy productivity: Under this commitment, companies pledge to double their economic output per unit of energy consumed by their own operations globally within a time span of 25 years, with the earliest baseline year being 2005.

2. Implement an Energy Management System: Under this commitment, companies pledge to implement an energy management system across all of their facilities within a time frame of 10 years and set an energy productivity target.

3. Net Zero Carbon Buildings: Under this commitment, companies pledge to own, occupy and develop net zero carbon emission buildings by 2030. Such buildings greatly promote energy efficiency and are powered by renewable sources.

Currently, there are around 111 companies that have made commitments to become members of the EP100 campaign.

Case Study 1: In order to achieve scope 3 GHG emission reductions, Google worked with the China National Institute of Standardization (CNIS) to launch an 18-month pilot program for assisting supply chain partners with energy management best practices, adoption of ISO-certified environmental management systems, keeping track of energy performance at establishments with Google production, improving energy conservation efforts, and improving overall performance. The program focuses on the following aspects (Google, 2019b):

1. Training and coaching: Supply chain partners are provided a customized training plan for implementing environmental management systems and identifying opportunities for energy conservation that in turn lead to cost savings.
2. Energy savings, cost savings, and productivity improvements: Suppliers can achieve significant productivity and energy cost reduction benefits through an in depth understanding of energy consumption patterns of their facilities.
3. Continuous improvements in energy performance: Participating companies showcase their energy performance improvements through assessments and adherence with local laws.
4. Internal recognition: Participation in the program helps companies demonstrate their improved energy performance standing to their stakeholders.

One of Google's suppliers that participated in this pilot program is Gold Circuit Electronics (GCE), a Taiwan-based manufacturer and distributor of printed circuit boards. GCE developed an action plan to adopt ISO 50001 and received certification in 2019. Through workshops, GCE and its partners discovered three projects with an annual energy savings potential of 227,000 kWh. In addition, GCE is also involved with Google's energy-efficiency deep retrofit program aimed at identifying energy conservation opportunities at other GCE facilities (Google, 2019b).

Case Study 2:, Kering, a French multinational luxury goods company, has collaborated with the NRDC since 2014, when they launched the specially tailored Kering Clean by Design program across the company's major supplier mills. Participating mills were subjected to a resource efficiency assessment which helped develop facility-specific action plans to improve the mill's resource efficiency. As a result of this program, Kering helped its suppliers implement over 150 energy and water efficiency projects, leading to 100% transition away from fossil fuels and an average GHG emission reduction of 12% per textile mill (Kering, 2019).

Case Study 3: Gap Inc., an American multinational apparel company, transitioned its Mill Sustainability Program after a span of five years from a pilot into an initiative in 2018, to drive improvements in the environmental and social performance of its suppliers. It has worked on the Clean by Design program in partnership with National Resources Defense Council (NRDC) since 2014, which led to an engagement with 20 mills and recently in 2018, the program found a new home at the Apparel Impact Institute. In 2017, the company also established its own Mill Efficiency Program in China which aims to work with a local environmental firm for the evaluation of energy and water-conservation prospects at six mill facilities. Cumulatively, these facilities led to savings in excess of 1.4 billion liters of water and avoided greater than 37,000 tons of CO_2e on an annual basis. Similarly, in 2018, Gap Inc. introduced the Taiwan Mill Efficiency Program, an extension of the Clean by Design collaboration in China, which led to on-site assessments at four participating mills resulting in the identification of GHG reduction opportunities of over 7,000 tons CO_2e (Gap Inc., n.d.).

Case Study 4: In 2018, Columbia Sportswear decided to promote sustainability practices among its supply chain partners by engaging with the Apparel Impact Institute (Aii) on the Clean by Design program. This effort aims to complement Columbia's existing sustainability efforts, which involve the measurement of suppliers' environmental performance through the utilization of Sustainable Apparel Coalition's Higg Facility Environmental Module (FEM) tool. The Clean by Design program is being implemented at three facilities across China and Taiwan, belonging to one of Columbia's key manufacturing partners (Aii, 2020).

Case Study 5: In collaboration with the Apparel Impact Institute (Aii), Target intends on expanding its Clean by Design initiative in order to drive energy and emissions performance improvements at suppliers' facilities. International Finance Corporation's Vietnam Improvement Program (VIP) would play a crucial role in helping Target's suppliers in Vietnam improve their resource efficiency while cutting back on operating costs. The apparel and textile industry is among Vietnam's largest exporters and makes a substantial contribution towards the economy (Target, 2019).

5.5 Set Internal Carbon Price

As per CDP disclosures, more than 1,300 companies including over a hundred Fortune 500 companies are currently utilizing or have committed to utilizing an internal carbon price scheme in 2017 (CDP, 2017). This scheme provides companies an opportunity to assess risks associated with future regulations concerning mandatory carbon prices, and consequently work towards identifying cost saving and revenue prospects of investment in innovative low carbon technologies and decarbonization of operations (The World Bank, n.d.).

Around 500 companies have disclosed their existing or future vulnerability to regulations related to carbon pricing. It is critical that companies carefully evaluate their business practices and anticipate future policy scenarios, since they would be held accountable by investors for a lack of carbon risk preparedness (CDP, 2017).

Case Study 1: Revenue from the internal carbon pricing scheme at Microsoft is utilized for funding renewable energy, energy efficiency, and other emission reduction projects, alongside researching low carbon technologies; and increasing awareness amongst employees regarding climate risks and opportunities (C2ES, n.d.). This has led to a reduction in CO_2 emissions by 9.5 million tonnes and the procurement of 14 billion kWh of renewable power (Gold Standard, n.d.).

Case Study 2: LG Electronics, a global electronics company, utilizes the internal carbon pricing mechanism for driving investments in low carbon technologies and navigating GHG regulations. The carbon pricing scheme covers all its scope 1 and 2 emissions and its value is set according to the market price of carbon determined by the Korean Emissions Trading Market (CDP, 2019b).

Case Study 3: LVMH, a French multinational luxury goods organization, launched an internal carbon fund for reducing its GHG emissions by 25% between 2013 and 2020, aimed at tackling production, logistics, and stores' scope 1 and 2 emissions. Each of its 70 fashion houses helped contribute towards financing low-carbon projects through the adoption of a $13.50 per metric ton carbon fee. These projects included the procurement of energy efficient equipment, ensuring higher utilization of renewable energy, and R&D investments for improving energy performance tracking (Alhuwalia, 2017).

Case Study 4: Kering, a global luxury group, has instituted an internal price of carbon with the objective of engaging suppliers, and pursuing energy efficient and low-carbon investments, while upholding stakeholder expectations. Currently, it uses a global uniform pricing scheme which values emissions at €73.5 per metric ton of CO_2e, applicable across all its activities (scope 1, 2 and 3) (CDP, 2019c).

6 Supply Chain Sustainability Performance Measurement and key Performance Indicators

The proper development and utilization of performance measures is integral for the evaluation and supervision of supply chain management programs. These performance measures can be utilized for the process of selecting suppliers, tracking supplier performance, and for general supplier expansion purposes. The use of performance measurement systems has been highly recommended for the purposes of sustainable supplier assessment (Hervani, Helms, & Sarkis, 2005). The identification of relevant Key Performance Indicators (KPI) is crucial to the success of performance measurement systems.

There are both internal and external pressures that drive the adoption of a performance measurement system for green supply chain management. The internal factors are largely associated with an organization's ultimate goal of reducing costs and enhancing profits through efficient consumption of resources and less generation of waste, which in turn reduces the environmental impact. External factors include pressure from consumers, competitors and government authorities that demand better practices on the environmental front to ensure business continuity. The threat posed by the prospect of regulation and environmental compliance issues forces organizations to innovate and adopt industrial best practices. In addition, consumer attitude towards a company's environmental impact and constant innovation from competing firms compel firms to become more sustainable.

Ensuring that performance measurement systems utilize appropriate environmental perfor mance indicators is crucial since these indicators play a decisive role in the evaluation of a supply chain's sustainability performance. The Toxics Releases Inventory and the Global Reporting Initiative (GRI) have outlined a list of environmental performance indicators which cover a wide range of issues, from GHG emissions to energy recovery and recycling. Some of these are as follows: *"fugitive non-point air emissions, stack or point air emissions, discharges to receiving streams and water bodies,underground injection on-site, releases to land on-site, discharges to publicly owned treatment works, other off-site transfers, on-site and off-site energy recovery"* (Hervani, Helms, & Sarkis, 2005). The environmental performance indicators utilized by an organization are dependent on the organization's stance concerning environmental management. Reactive organizations usually limit themselves to selecting performance indicators which are essential to meet the regulations. On the other hand, organizations that are proactive tend to choose performance indicators that assist with their ultimate goal of procurement from green suppliers, helping minimize their overall ESG related risks.

A study analyzed academic literature to understand the range of sustainability metrics utilized for performance measurement with regards to Sustainable Supply Chain Management and Green Supply Chain Management, leading to the identification of over 2,500 metrics. It conducted a content analysis of 445 published articles and found that the most frequently used metrics were: quality, air emissions, energy use and GHG emissions (Ahi & Searcy, 2015).

The analysis of three sustainability dimensions (economic, social and environmental) across a range of range of standards and guidelines has led to the identification of 18 attribute categories and each attribute category is associated with a specific number of sustainability performance indicators (Saeed & Kersten, 2017). The hierarchical levels described above are represented in Figure 23.

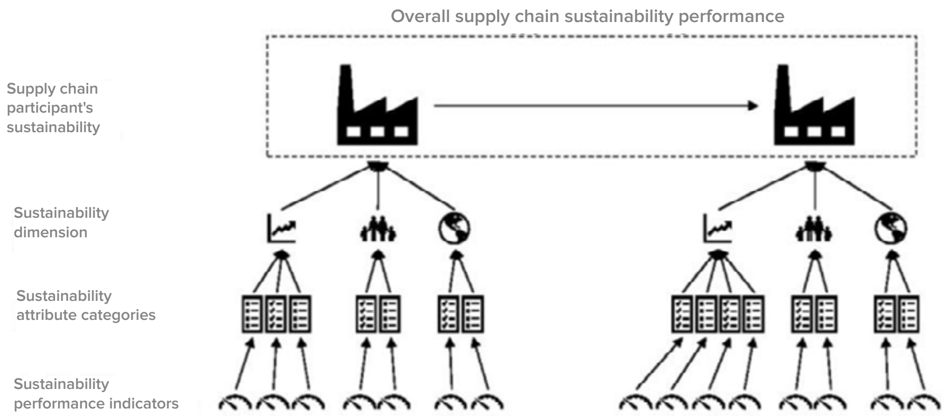


Figure 23. Supply Chain Sustainability Performance Measurement (Saeed & Kersten, 2017)

The environmental sustainability dimension is categorized into 8 different attributes: *"Energy efficiency, material efficiency, water management, waste management, emissions, land use, environmental compliance and supplier assessment"* (Saeed & Kersten, 2017). The sustainability performance indicators developed for each attribute category are selected on the basis of fulfilment of certain criteria which ensure that the indicators achieve their ultimate goal of assessing the sustainability performance of the supply chain. Table 6 depicts sustainability performance indicators developed for each of the 8 attribute categories of the environmental sustainability dimension.

Table 6. Developed performance indicators for different attributes of environmental sustainability dimension (Saeed & Kersten, 2017)

Attribute	Sustainability Performance Indicators
Energy efficiency	Total annual energy consumption of an organization
	Specific annual energy consumption of an organization
	Total annual renewable energy consumption of an organization
Material efficiency	Total annual material consumption of an organization
	Specific annual material consumption of an organization
	Total annual recycled/reused material consumption of an organization
	Total annual hazardous materials consumption of an organization
	Specific annual hazardous materials consumption of an organization
Water management	Total annual volume of water consumption within an organization
	Specific annual volume of water consumption within an organization
	Total annual volume of water recycled/reused by an organization
	Percentage of annual volume of water recycled/reused by an organization
	Total volume of wastewater discharged by an organization
	Specific volume of wastewater discharged by an organization
Waste management	Total annual amount of waste generated by an organization
	Specific annual amount of waste generated by an organization
	Total annual amount of hazardous waste generated by an organization
	Specific annual amount of hazardous waste generated by an organization
	Specific annual amount of waste recycled/reused by an organization
	Percentage of waste recycled/reused by an organization
Emissions	Total annual amount of direct GHGs (CO_2, CH4, N2O, HFCs, PFCs, SF6, NF3) emissions (Scope 1) by an organization
	Total annual amount of indirect emissions (Scope 2) by an organization
	Total annual amount of other GHG emissions (Scope 3) by an organization

Attribute	Sustainability Performance Indicators
	Specific annual GHG emissions (Scope 1 & 2) by an organization
	Total annual amount of ozone-depleting substances by an organization
	Total annual amount of particulate emissions by an organization
	Total annual air emissions by an organization
Land use	Total size of operational site/facility
	Specific size of operational site/facility
Environmental compliance	Total annual number of non-compliance with environmental regulations
Supplier assessment	Percentage of suppliers' subject to sustainability assessment
	Percentage of local/national/provincial suppliers of an organization

With the objective of promoting better accountability and sustainable practices, the Global Reporting Initiative (GRI) has developed a set of standards with guidelines highlighting best practices regarding sustainability self-assessments, focusing on social, environmental and economic impacts. The GRI environmental standards cover topics ranging from materials, energy, water and effluents, biodiversity, emissions, waste, environmental compliance and supplier environmental assessments. Each standard has certain mandatory reporting requirements, recommendations and guidance which help promote transparency among reporting companies (GRI, 2020).

Similarly, since its launch in 2008, the CDP supply chain program has aimed to facilitate manufacturers in disclosing their sustainability performance with the help of questionnaires that cover topics such as climate change, water security and forests. The program has brought together over 110 major procurement organizations, representing a cumulative amount of $3.3 trillion in purchase expenditure. These organizations are now pushing their suppliers to disclose their sustainability performance and aim for constant improvements, which has resulted in close to 35% of all supplier respondents establishing a structured carbon reduction goal (CDP, 2019a). The program has basically helped companies evaluate and drive progress towards meeting their scope 3 emissions reduction and resource efficiency targets, by offering a comprehensive supplier engagement and performance tracking platform.

The GRI standards and the CDP supply chain program help companies collect detailed information related to their suppliers' energy consumption, emissions, GHG targets, etc. through the utilization of performance indicators. This information drives corporate decisions regarding procurement, and the level of required engagement with supply chain partners. In 2013, CDP and GRI signed a memorandum of understanding (MoU) that aimed to achieve better alignment of disclosure guidelines between the CDP and GRI assessments. Then CDP technical director, Mr. Pedro Faira mentioned this would ensure "*more consistent corporate reporting….whilst reducing the reporting burden for companies"* (Hardcastle, 2016).

The following section discusses certain existing mechanisms utilized by the Textile & Apparel and Electronics sectors for promoting supply chain sustainability practices. Specifically, the Green Electronics Council's EPEAT program and the Sustainable Apparel Coalition's Higg Index tool are examined in greater detail below.

EPEAT Program

EPEAT is described as "the leading global ecolabel for the IT sector". Managed by the Green Electronics Council, it aims to promote sustainable procurement practices amongst both private and public entities. It allows manufacturers to register their products on the EPEAT online registry based on the product's ability to meet certain mandatory and optional guidelines set out by the program (GEC, n.d. - a).

The program lays out a wide range of criteria for different IT sector products, which are required to be satisfied by manufacturers in order to receive the bronze, silver or gold certification from EPEAT. Some of the products covered under the program are computers and displays, imaging equipment, televisions, servers and mobile phones. Table 7 provides a high level list of criteria addressed by the EPEAT program.

Table 7. List of criteria addressed by EPEAT program (GEC, n.d. - b)

Product	Criteria list
Computers and Displays	Substance management; materials selection; design for end of life; product longevity/lifecycle extension; energy conservation; end-of-life management, packaging; life cycle assessment and carbon footprint; corporate environmental performance; corporate social responsibility
Imaging Equipment	Reduction/elimination of environmentally sensitive material; material selection; design for end of life; product longevity/life cycle extension; energy conservation; end-of-life management; corporate performance; packaging; consumables; indoor air quality
Televisions	Reduction of use of hazardous substances; materials selection; design for end of life; product longevity/life cycle extension; energy conservation; end-of-life management; corporate performance; packaging
Servers	Energy efficiency; management of substances; preferable materials use; product packaging; design for repair, reuse and recycling; product longevity; responsible end of life management
Mobile phones	Supply chain management of materials; sustainable materials use; substances of concern; energy use requirements; end of life management; packaging; corporate sustainability; life cycle assessment; supply chain impacts

The EPEAT program specifies certain mandatory and optional requirements within each high level criterion listed in Table 7. For example, within the corporate sustainability criterion listed under the Mobile phones product category, certain mandatory and optional requirements are set forth by EPEAT, as provided below (GEC, n.d. - b).

Corporate Sustainability Criterion for Mobile Phones:

Mandatory requirements:

1. Corporate sustainability reporting:
   Manufacturers are required to publish a corporate sustainability report which adheres to the core reporting guidelines of the GRI Standards or any other related framework such as CDP, Sustainability Accounting Standards Board, etc.

Optional requirements:

1. Corporate sustainability reporting in the supply chain:
   Manufacturers are required to demonstrate that at least three supply chain partners disclosed information regarding their operations, as per the selected GRI topics (energy, emissions, etc.).

2. Third party assurance of corporate sustainability reporting:
   Manufacturers are required to obtain an independent third party certification (according to relevant standards) of the data reported by them as part of the mandatory reporting requirement.

The reporting guidelines laid out under these requirements of the EPEAT program utilize KPI for tracking the social and environmental performance of electronics companies and their suppliers, resulting in the promotion of supply chain sustainability.

As per the EPEAT program structure, bronze rating is provided to products that fulfil all mandatory requirements, silver rating is provided to products which satisfy all mandatory as well as 50% of all optional requirements, whereas, the gold rating is received by products that fulfil all mandatory as well as 75% of all optional requirements for every criterion (GEC, n.d. - a).

The Higg Index

Developed by the Sustainable Apparel Coalition, the Higg Index is a set of sustainability self-assessment tools that aim to standardize the process of evaluating and enhancing sustainability of a company or product (Henkel, 2020). It provides organizations clear guidelines for improvement and outlines industry-wide best practices. The Higg Index tools have been divided into three categories: Product tools, Facility tools and Brand and Retail tools.

Higg Product Tools: The two Higg Product tools are: Higg Materials Sustainability Index (Higg MSI) and Higg Product Module (Higg PM). These tools leverage life cycle assessment data to provide insights regarding the sustainability impact of different materials and products of the apparel, footwear and textile industries. The sustainability impacts assessed by the Product tools include: *"Global warming potential, nutrient pollution in water (eutrophication), water scarcity, fossil fuel depletion and chemistry"* (SAC, n.d. - a).

Higg Facility Tools: The two Higg Facility tools are: Higg Facility Environmental Module (Higg FEM) and Higg Facility Social and Labor Module (Higg FSLM). The Higg FEM helps manufacturers assess the environmental impact of their individual facilities and the Higg FSLM helps companies ensure appropriate working conditions for workers across all facilities (SAC, n.d. - b). These tools work towards building a robust supply chain through a reduction in negative environmental impacts and provision of safe and fair environment for all workers.

The Higg FEM takes the following measures into account as part of its assessment framework: *"Environmental management systems, energy use and GHG emissions, water use, wastewater, emissions to air, waste management and chemical use and management"*. Similarly, the Higg FSLM takes the following factors into account: *"Recruitment and hiring, working hours, wages and benefits, employee treatment, employee involvement, health and safety, termination, management systems, facility workforce standards and those of value chain partners, External engagement on social and labor issues with other facilities or organizations, community engagement"* (SAC, n.d. - b).

Higg Brand Tool: The Higg Brand and Retail module helps brands and retailers develop a comprehensive picture of their value chain sustainability impact. The tools assesses a range of environmental and social impacts, which assist firms' efforts towards meeting their corporate sustainability goals (SAC, n.d. - c).

Over 200 organizations are currently utilizing the Higg Index set of tools to better manage their environmental impacts and address key social challenges that are a crucial aspect of every apparel, footwear and textile companies' value chain (Henkel, 2020).

Below we present a couple case studies that demonstrate how companies have approached the process of integrating sustainability practices within their value chain by means of tracking key performance indicators.

Case Study 1: H&M Group

The group developed the Sustainability Impact Partnership Programme (SIPP) with the objective of promoting best environmental and social practices among suppliers. The SIPP framework utilizes the Sustainable Apparel Coalition's (SAC) Higg Facility Tools, where suppliers disclose their environmental and social performance data through self-assessments. These assessments are validated by the H&M Group itself and suppliers that set ambitious targets and constantly strive for performance improvements are rewarded by the group, thus incentivizing sustainability practices (H&M Group, 2019).

The H&M group utilizes certain KPI to measure the organization's own as well as its supply chain's progress towards certain sustainability goals. Some of the environmental and social sustainability measuring KPI are mentioned in Table 8.

Table 8. Abridged list of environmental and social sustainability KPI (H&M Group, 2019)

KPI	Progress: Year 2019	Goal
% change in net CO_2 emissions from own operations (scope 1 + 2) compared with previous year, including renewables	+8 %	Climate positive by 2040 at the latest
% renewable electricity in own operations	96%	100% by 2030
% of water recycled out of total production water consumption	13%	15% by 2022
% of facilities in own operations with water-efficient equipment	67%	100% by 2020
% of recycled or other sustainably sourced cotton (certified organic, recycled or Better Cotton)	97%	100% by 2020
% of recycled or other sustainably sourced materials of total material sourced (commercial goods)	57%	100% by 2030
Number of supplier factories implementing improved Wage Management Systems (% of production volume covered)	804 (88%)	---
Number of supplier factories that have implemented democratically-elected worker representation (% of production volume covered)	898 (85%)	---

Case Study 2: The Hewlett-Packard Company (HP)

In 2019, HP tracked around $6 billion in new sales and reported the proportion of shipped models that adhered to eco-labeling schemes like the EPEAT program and ENERGY STAR ratings. Table 9 provides additional details regarding these proportions.

Table 9. Eco-labelling across HP portfolio (% models, for products shipped in 2019) (HP, 2019)

Product	EPEAT Program	ENERGY STAR
Personal systems	72%	91%
Printers	81%	94%

HP also collaborates with its suppliers through the CDP Supply Chain Program and utilizes GRI guidelines to develop its sustainable impact report. In addition, Table 10 reports certain supply chain environmental performance indicators tracked by HP.

Table 10. Environmental Impact of Suppliers – Performance Indicators (HP, 2019)

KPI	Progress: Year 2018
First-tier production supplier and product transportation-related GHG emissions intensity (tonnes CO_2e/$ million HP net revenue)	76.4
Production suppliers with GHG emissions reduction-related goals (% of spend)	94%
Production supplier renewable energy use (% of total energy use)	23%
Production suppliers that reported using renewable energy (% of spend)	78%
Production suppliers with water-related goals (% of spend)	93%
Production suppliers with waste-related goals (% of spend)	72%

7 Conclusion and Policy Recommendations

Supply chain activities of multi-national organizations account for around 80% of global trade annually and can constitute 5.5 times more GHG emissions than the company's direct operations. In order to meet Paris Climate Agreement goals and also ensure business continuity and reduce companies' risk exposure, it is imperative to promote sustainable supply chain management practices by overcoming barriers and implementing industry-wide best practices to build low-carbon supply chains.

We analyzed industrial energy use in five major energy consuming countries in Southeast Asia: Indonesia, Malaysia, Philippines, Thailand, and Vietnam. In addition to analyzing the energy use at the subsector-level, we also analyzed the energy use for key major industrial energy systems: motor systems and steam systems. Since such system-level energy sue data are not available for targeted countries, our effort to estimate these data will provide useful insight and information for various stakeholders.

The main barriers to supply chain sustainability practices are mainly categorized into economic, information, and market barriers. We identified the best practices for building low-carbon supply chains using following key strategies: supplier engagement and assessment by means of supplier codes of conduct and sustainability disclosure programs; setting GHG reduction and carbon neutrality targets through campaigns such as the science-based targets initiative; developing and implementing renewable energy projects by directly engaging with suppliers and through initiatives like RE100; developing and implementing energy efficiency programs by promoting the adoption of energy management systems and through initiatives like EP100; and setting an internal carbon price for internalizing carbon risks and assessing opportunities for funding innovative low-carbon technologies. We also underscore the importance of performance measurement systems and their corresponding key performance indicators (KPI).

A list of government policies that could help promote industrial energy efficiency and decarbonization and sustainable supply chains are presented below:

- Capacity building: policies such as information dissemination and training programs for energy efficiency improvement and decarbonization, top management awareness-raising programs, financial incentives especially for SMEs, provision of energy assessment tools and guidelines are some of the programs that can help improving energy efficiency and decarbonizing supply chain.

- Energy audit programs: High-quality energy audits can provide detailed cost-effective analyses of all identified measures and technologies, based on a plant's specific operating conditions and can provide packages of customized recommendations for plants to consider.
- Technical assistance through Enterprise Performance Rating Systems: enterprise performanc rating programs can help enterprises save energy and costs, through providing technical assistance or by requiring adoption of a standardized energy management system. Enterprises that participate in the program can get assistance, guidance or training on identifying and understanding energy efficiency opportunities.

- Design system-specific policies and standards: the traditional approach in many developing countries is to focus on equipment efficiency only and not on the entire energy systems (e.g.

motor systems or steam systems). While the use of more efficient equipment results in energy savings, optimization of the entire system will result in much larger energy savings. Policymakers in ASEAN should design programs and policies that are targeted at the systems and not an equipment alone to achieve greater energy savings and CO_2 emissions reductions.

- ISO 50001 energy management systems: Many of the energy efficiency measures involve improved operational and maintenance practices, which can be undertaken within a continuous improvement approach within industries. Hence, the adoption of energy management systems such as International Organization for Standardization (ISO) 50001- Energy Management Systems can aid in implementation of such measures in a more systematic manner. In addition, energy management systems can provide a framework that helps to ensure that the energy savings fromsystems optimization measures are sustainable and do not diminish over time.

- Providing favorable tax treatment or incentives through technology promotion lists: Many countries provide tax reduction and other financial incentives to enterprises that install targeted energy efficiency and decarbonization technologies that are included in a technology promotion list.

- Reducing energy efficiency investment risk through the use of green banks, or providing direct loans and grants for energy efficiency and decarbonization projects, or public private partnerships to mobilize energy efficiency and decarbonization investment.

- Government procurement policies: Public procurement accounts for an average of 12 percent of gross domestic product (GDP) in Organization for Economic Cooperation and Development (OECD) countries, and up to 30 percent of GDP in many developing countries. When public entities leverage their large-scale purchasing power by buying goods and services with a lower carbon footprint, they help drive markets in the direction of sustainability, reduce the negative impacts of their use of goods, and produce positive environmental and social benefits.

- Reduce or remove energy subsidies for industrial consumers: fossil fuel prices for industry sector are heavily subsidized in many ASEAN countries and are quite low compared to international prices. If subsidies are reduced and prices of fossil fuels moves towards international market prices, energy efficiency and decarbonization technologies will become much more financially viable.

- Carbon pricing: Establishing a carbon pricing policy that charges polluters a fee per ton of CO_2 emissions emitted by them can reward cleaner producers and incentivise polluting industries to lower emissions.

- Adoption of policies supporting RD&D: The government can promote the development and adoption of low-carbon technologies by funding research efforts at government laboratories and academic institutions, establishing research partnerships with private companies, providing fiscal incentives for corporate R&D, etc.

- Adopt international policy best practices that fits best to local conditions: there are many types of industrial energy efficiency and decarbonization worldwide, so policymakers in ASEAN have numerous options to use as models.

- Consumption-based emissions accounting: it can inform policymaking that aims to address embodied carbon in trade. Such policy interventions can be divided along the broad phases of the supply chain: production, the intermediate supply chain, and consumption. Policies listed under production include those that regulate within national borders, while intermediate products may be traded across borders. Consumption policies address consumption by households, government, businesses, and other actors. A selection of policies is summarized in Table 11.

Table 11. Consumption-based Policy applications by product lifecycle phase

Lifecycle Phase		
Production	**Intermediate Supply Chain**	**Consumption**
• Point-source and industry-level regulations • Product location at sale • National emissions targets • New metrics for emissions accounting	• Border tax adjustments • Technology transfer policies (offsets) • Best Available Technology standards • Voluntary agreements by trade associations	• Policies targeting household behaviors • Government and business procurement • Retailer certifications and product choice • Information, ranking, and award campaigns

Energy efficiency stimulates economic growth and creates jobs in a variety of ways (direct, indirect, and induced jobs creation). Investment in energy efficiency creates more jobs per dollar invested than traditional energy supply investments. Energy efficiency also creates more jobs in the local economy, whereas energy supply jobs and investment dollars often flow outside the province or country. Job growth projections associated with building new power generation do not match the job growth that would result from investing an equivalent amount in energy efficiency. Policies can be an effective mechanism to encourage energy efficiency investments in industrial sector while driving job creation and increasing the benefits flowing into the local economy as well as improving energy security.

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Appendices

Appendix 1. Methodology for Energy Use Analysis

The industrial energy use analysis of this study focuses on five major energy consuming countries in Southeast Asia: Indonesia, Malaysia, Philippines, Thailand, and Vietnam.
To analyze the industrial energy use and emissions, we obtained the energy use data by subsectors and fuel type in 2017 from IEA's world energy statistics (IEA, 2019b). While IEA data for Thailand, Vietnam, and Philippines has good level of industrial subsector information, it lacks sufficient subsector-level data for Malaysia and Indonesia. For Malaysia, we obtained detailed industrial subsector-level energy use from Malaysian government open data portal (Hazwanie, 2018). The latest year for which these data was available for Malaysia was 2016.

For industrial energy use by subsector data for Indonesia, we obtained a dataset reported by the BPS-Statistics Indonesia (BPS, 2018). This dataset contains energy use by industrial subsectors and fuel type in Indonesia based on a large survey of industrial energy consumer in Indonesia by BPS. However, since the BPS survey does not cover all industrial plants in Indonesia and it only covers a large sample of them, we could not use these data directly. In stead we used the BPS data to disaggregate the total industrial energy use by fuel type given by IEA's world energy statistics for Indonesia and thereby estimate the subsector -level energy use. We also cross-checked the IEAtotal industrial energy use by the total energy use for industry published by the ministry of Energy in Indonesia and they were in line.

Once we had industrial energy use by subsector and fuel type, first we used the CO_2 emissions factor of each fuel as well as electricity grid in each country to estimate total CO_2 emissions of industry sector in each country. Fuel emissions factors are obtained from IPCC (IPCC, 2006) and electricity grid CO_2 emissions factors in the studied countries in 2016 are from IGES (Takahashi & Louhisuo, 2020). We assumed biofuels used in the industry are carbon neutral.

In addition to analyzing and estimating industrial energy use and CO_2 emissions by subsector in each country, we estimated the energy use in two major industrial energy systems in each country: industrial motor systems and industrial boilers and steam systems.
According to the IEA, around half of global electricity consumption is attributable to electric motor systems. Industrial electric motor systems account for about 70% of total global industrial electricity usage. In this study, we also did a more detailed analysis on pump systems, fan system and compressed air systems which represent three main types of industrial motor systems.

The share of electricity used by pump, fan, and compressed air systems varies among manufacturing subsectors. Table 12 shows the share of total motor systems electricity use in each U.S. manufacturing subsector. These shares are obtained from U.S. DOE's Manufacturing Energy and Carbon Footprints (U.S. DOE, 2018). It also shows the share of pump, fan, and compressor systems from total motor sys tems electricity use. Since such detailed systems-level analysis for each manufacturing subsector is not available for the selected countries studied in report, we used the values from U.S. DOE to estimate systems level energy use in industry in each country. While the differences between the industry in the U.S. and selected countries make this estimate to have some level of uncertainty, since we used subsector-level data to make these estimates our results have high level of accuracy. Based on these values, the estimated total industrial motor systems electricity use is about 75-80% of total electricity use in industry in the five studied countries.

Table 12. Share of motor systems electricity use in each manufacturing subsector (U.S. DOE, 2018)

Industrial Subsector	Motor systems electricity use as % of total electricity use in each sector*	Pump systems electricity use as % of total motor systems electricity use **	Fan systems electricity use as % of total motor systems electricity use**	Compressed air systems electricity use as % of total motor systems electricity use **
Iron and steel	45%	9%	16%	15%
Chemical and petrochem-ical	80%	41%	16%	31%
Non-ferrous metals	17%	10%	20%	15%
Non-metallic minerals	64%	13%	13%	11%
Transport equipment	62%	13%	10%	11%
Machinery	64%	16%	11%	11%
Food and tobacco	83%	15%	7%	7%
Paper, pulp and print	88%	43%	27%	6%
Wood and wood products	68%	32%	15%	17%
Textile and leather	75%	16%	12%	12%
Non-specified	68%	32%	15%	17%

* These shares include process cooling and refrigeration and non-process-facility HVAC.

** These shares exclude systems that are in process cooling and refrigeration and non-process-facility HVAC.

Steam systems are another major energy system in industry sector. Steam is used extensively as a means of delivering energy to industrial processes. Steam holds a significant amount of energy on a unit mass basis that can be extracted as mechanical work through a turbine or as heat for process use. In addition, steam can be used to control temperatures and pressures during chemical processes, strip contaminants from process fluids, dry paper products, and in other miscellaneous applications.

Table 13 shows the share of steam systems fuel use in each U.S. manufacturing subsector. These shares are obtained from U.S. DOE's Manufacturing Energy and Carbon Footprints (U.S. DOE, 2018). For the same reason mentioned above for the motor system, we used the values in Table 13 from U.S. DOE to estimate steam systems energy use in industry in each industry subsector in each country.

Table 13. Share of steam systems fuel use in each manufacturing subsector (U.S. DOE, 2018)

Industrial Subsector	Steam systems fuel use as % of total fuel use in each sector
Iron and steel	24%
Chemical and petrochemical	57%
Non-ferrous metals	18%
Non-metallic minerals	2%
Transport equipment	21%
Machinery	20%
Food and tobacco	68%
Paper, pulp and print	88%
Wood and wood products	40%
Textile and leather	55%
Non-specified	50%

Appendix 2. Energy Policies Addressing Industrial Energy Use and Emissions

Country	Policy	Description	Notes
Thailand	Energy Conservation Promotion Fund (EN-CON Fund) Year: 1992 (IEA, 2021)	ENCON Fund is meant to con-tribute towards promot-ing en-ergy conservation through awareness raising, as well as the adoption of energy efficient technologies and promoting the develop-ment of renewable energy sources.	The Fund has been used to support vari-ous mechanisms like: grants, subsidies, tax incen-tives, the Energy Efficiency Revolving Fund (EERF), the ES-CO Fund, etc.
	Climate Change Mas-ter Plan 2015 – 2050 Year: 2015 (Asia Pacific Energy Portal, n.d.)	The Climate Change Master Plan (CCMP) 2015-2050 aims to achieve climate-resilient and low-carbon growth in line with sustainable devel-opment path by 2050. Three key strategies: Climate change adaptation Mitigation and low carbon de-velopment Enabling environment on cli-mate change management	Medium term mitiga-tion target: Reduce GHG emissions by 7 to 20% from BAU by 2021, In-crease contri-bution of renewable energy to 25% of na-tional primary energy consumption by 2021 Long term mitigation target: Reduce energy intensi-ty by 25% from BAU by 2030
	Thailand Power De-vel-opment Plan (PDP2015) 2015 – 2036 Year: 2015 (Asia Pacific Energy Portal, n.d.)	Main themes: Energy security: fuel diversi-fi-cation, to reduce depen-dence on one particular fuel source Economy: maintaining ap-pro-priate power generation costs, implementing energy efficiency Ecology: limiting environ-mental and social impacts Aims to integrate energy sav-ings from the Energy Efficien-cy Development Plan (EEDP).	EEDP goal: Reduce energy intensity by 30% by 2036 relative to baseline year (2010)
Malaysia	National Green Tech-nol-ogy Policy Year: 2009 (Asia Pacific Energy Portal, n.d.)	Four pillars: Energy – Aims to achieve en-ergy independence and pro-mote efficient energy use Environment – Conserve and reduce environmental impact Economy – Enhance devel-op-ment through the use of tech-nology Social – Improve quality of life for all	Aims to reduce growth in energy consumption with growth in econo-my through wide-spread adoption of green technology.
	National Policy on Cli-mate Change Year: 2010 (Asia Pacific Energy Portal, n.d.)	Main goals: Mainstreaming climate change Integration of balanced adapta-tion and mitigation responses Enhancement of institutional and implementation capacity	One of the ten men-tioned strategic thrusts of the policy focuses exclusively on renewable energy and energy efficiency.

Country	Policy	Description	Notes
	National Energy Effi-ciency Action Plan (NEEAP) 2016 – 2025 Year: 2016 (Asia Pacific Energy Portal, n.d.)	The National Energy Effi-ciency Action Plan aims to achieve the following: 1. 50,594 GWh of electricity savings over BAU scenario 2. Reduction in electricity de-mand growth by 6%	Only confined to elec-tricity usage. Aims to establish an energy efficiency plan, build a framework, ensure implementa-tion, create sustaina-ble funding mecha-nisms and promote private sector invest-ment.
	Green Technology Mas-ter Plan 2017 – 2030 Year: 2017 (Asia Pacific Energy Portal, n.d.)	The plan is an outcome of the Eleventh Malaysia Plan (2016 – 2020), aiming to promote green growth. Some priorities of the plan include: improved demand side management in elec-tricity thermal and transport, incorpo-rating smart grid technology, improving upon NEEAP	Provides a framework for integrating green technologies into the growth of the nation.
	The Twelfth Malaysia Plan (12MP) 2021 – 2025 Year: 2021 (Malaysian Government, 2020)	Encompasses: Economic Empowerment Environmental Sustainability Social Re-engineering	Environmental sus-tainability aspects fo-cuses on renewable energy, energy effi-ciency, cli-mate change mitigation and adapta-tion, etc.
Indonesia	National Master Plan for Energy Conserva-tion Year: 2005 (IEA, 2021)	Indonesia National Master Plan for Energy Conserva-tion (RIKEN) sets a goal of de-creasing energy intensity by 1% annually until 2025. In order to reach this goal, en-ergy savings potentials have been identified as follows: industry 15-30%, commercial buildings 25%, households 10-30%.	Sets sectoral energy conservation targets.
	Energy Law No. 30/2007 Year: 2007 (Asia Pacific Energy Portal, n.d.)	This law aims at significantly reducing the economy's de-pendence on imported refined oil while boosting the use of other energy sourc-es, including natural gas, biofuels and geo-thermal resources. In particular, the Energy Law sets out to es-ta-blish the National Energy Council, which is tasked with designing and formulating the national energy policy, and to determine the nation-al energy general plan.	

Country	Policy	Description	Notes
	Energy Conservation (Government Regu-la-tion No. 70/2009) Year: 2009 (IEA, 2021)	Government Regulation No. 70/2009 on Energy Con-serva-tion makes provisions for the proper utilization of energy re-sources, energy sources and energy through the application of energy efficient technology; efficient and rational utilization of energy; and responsibilities of the government, regional governments, entrepreneurs and communities. It is the im-plementing legislation on ener-gy conservation with regard to the Energy Law.	Aims to prepare an energy efficiency guideline for stake-holders, provide fiscal and tax incen-tives for adoption of energy efficient equip-ment, establish fiscal incen-tives to promote ener-gy efficiency among industrial energy us-ers, setting up MEPS for equipment, etc
	National Action Plan for Reducing Green-house Gas Emissions Year: 2011 (IEA, 2021)	The National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK) is a fol-low up to Indonesia commit-ment to reduce GHG emission by 26% in 2020 from the BAU level with its own efforts and reaching 41% reduction with international support.	Priority sectors: Agri-culture, Forestry and Peatland, Energy and Transport, Industry and Waste manage-ment.
	National Energy Ef-fi-ciency Award (PEEN) Year: 2012 (IEA, 2021)	National Energy Efficiency Award (PEEN) is an initia-tive of the Government of Indonesia to promote energy efficiency in building and industry sectors.	To recognize organiza-tions which have suc-cessfully implemented energy conserva-tion measures
	Energy Management Regulation (Minister of Energy and Mineral Re-sources, No. 14/2012) Year: 2012 (IEA, 2021)	It establishes provisions for energy preservation and man-agement by improving efficien-cy in energy use and control over its consumption, in order to achieve effective and ration-al use of energy resources.	For energy users con-suming greater than 6,000 toe annually. Establishes a frame-work for high energy users to follow. Forc-es them to develop and imple-ment an en-ergy conservation plan, conduct regular energy audits and submit performance reports to the gov-ernment on an annual basis.
	Clean Technology Fund (CTF) Year: 2012 (IEA, 2021)	The Clean Technology Fund (CTF) aims to accelerate Indo-nesian initiatives to promote energy efficiency and renewa-ble energy, and to help reach the objective of increasing electricity access from 65 per-cent of the pop-ulation to 90% percent by 2020. It also aims to support the government to meet its long-term goal of re-ducing greenhouse gas emis-sions by 26% in 2020.	Climate investment fund plan. Aims to use fi-nancing mechanisms to enable the expan-sion of geothermal projects, promote en-ergy effi-ciency and renewable energy.

Country	Policy	Description	Notes
	National Energy Poli-cy (Government Regu-la-tion No. 79/2014) Year: 2014 (Asia Pacific Energy Portal, n.d.)	The policy aims to provide the direction of national en-ergy management to achieve energy independence and national en-ergy security to support na-tional sustainable development. In particular, it focuses on re-establishing Indonesia's energy indepen-dence by re-directing energy resources from export to the domestic market, and aims to rebalance the energy mix towards indigenous energy supplies.	An all-encompassing national energy policy that focuses on re-newable energy, ener-gy efficiency, reduc-ing energy imports, etc.
	Green Industry Stand-ar-ds (Ministerial Regu-la-tion No.51/2015) Year: 2015 (IEA, 2021)	The Ministry of Industry has set mandatory minimum standards for various heavy industry sec-tors, which specify limits on the amount of energy used to pro-duce one ton of product. Sets standards for various in-dustries like cement, textiles, pulp and paper, ceramics, etc.	Sets maximum specif-ic thermal and electric energy limits for dif-ferent heavy industry sec-tors.
	Establishment of En-ergy Conservation Services Companies (Ministerial Regulation No.14/2016) Year: 2016 (IEA, 2021)	Helps develop Energy Cons-er-vation Service Companies (ESCOs) that help implement energy saving projects, reduce energy costs, etc.	
	National Energy Gen-eral Plan (RUEN) Year: 2017 (Asia Pacific Energy Portal, n.d.)	RUEN sets out the energy management plan which consti-tutes application and imple-mentation of energy policy across sectors to achieve the targets of Na-tional Energy Pol-icy.	Among other goals, it aims to reduce prima-ry energy intensity by 1% every year until 2025, and also strives for reductions in the final ener-gy consump-tion by 17% and 39% by 2025 and 2050 re-spectively.
Philippines	National Climate Change Action Plan (NCCAP) 2011 – 2028 Year: 2011 (Asia Pacific Energy Portal, n.d.)	Prioritizes food security, water sufficiency, ecolog-ical and en-vironmental stability, human security, climate-smart indus-tries and services, sustainable energy, and knowledge and capacity development.	Aims to promote and expand energy effi-cien-cy and conserva-tion, among other goals.

Country	Policy	Description	Notes
	Industrial Energy Man-agement System ISO 50001 Year: 2014 (IEA, 2021)	The project aims to pro-mote sustainable energy manage-ment system and achieve ener-gy efficiency best practices within the Phil-ippine industrial setting with the purpose of achieving energy savings and con-tributing to climate change mitigation efforts. This objec-tive will be achieved through the introduction of energy management system (EnMS) standards (compliant with ISO 50001), systems optimization (SO) for steam, compressed air, and pumps, and financial opportunities for energy effi-ciency invest-ments.	Focuses on develop-ing a standard (frame-work) that helps organizations follow a system-atic approach to reduce their energy intensity. Global Environment Facility (GEF) funded the project to intro-duce National Energy Manage-ment Standard in the Philippines, in-corporate industrial energy systems opti-mization, which is compatible with ener-gy management stan-dard developed by ISO and UNIDO.
	Philippine Energy Plan (PEP) 2016 – 2030 Year: 2016 (Asia Pacific Energy Portal, n.d.)	The Philippine Energy Plan (PEP) 2016-2030 formulates comprehensive sectoral roadmaps to ensure a timely implementation of the ener-gy agenda.	A truly comprehensive energy plan that lays out detailed action plans (short, medium and long term) for oil and gas, coal, renew-able en-ergy, alterna-tive fuels, energy effi-ciency and conserva-tion, etc.
	Power Development Plan (PDP) 2016 – 2040 Year: 2016 (Asia Pacific Energy Portal, n.d.)	The Power Development Plan (PDP) 2016-2040 encompasses all subsectors - generation, transmission, distribution and supply; as well as the devel-opment of the market, other institutional support mecha-nisms and electrification roadmaps.	Aims to promote greater investments in more efficient tech-nologies such as the smart grids, etc.
	The Philippines Ener-gy Efficiency and Conser-vation Roadmap 2017 – 2040 Year: 2017 (Asia Pacific Energy Portal, n.d.)	The roadmap is a detailed out-line of the strategic plans and actions required to create a more energy-ef-ficient Philip-pines across all sectors of economic activity.	Among other goals, it aims to achieve 15% to-tal energy savings by 2040 in the indus-trial sector. Also, an economy-wide improvement in ener-gy intensity of 3% by 2040.
	The Energy Efficiency and Conservation Act Year: 2019 (Asia Pacific Energy Por-tal, n.d.); (IEA, 2021)	An act institutionalizing energy efficiency and conservation, enhancing the efficient use of energy, and granting Incentives to energy efficiency and con-servation projects.	Aims to establish a framework for develop-ing energy efficiency and conservation poli-cies, promote the sen-sible use of energy, increase the usage of renewable and energy efficiency technologies and set forth the re-sponsibilities of each government agency and private entity. Among other goals, aims to improve aver-age Specific Energy Consumption (SEC) by at least one per-cent (1%) year per year.

Country	Policy	Description	Notes
Vietnam	Energy Audit and En-er-gy Efficiency Incen-tives (part of 21/2011/ND-CP) Year: 2011 (IEA, 2021)	The policy combines energy auditing, investment incen-tives, and tax exemptions for effi-cient equipment to promote energy efficiency and ensure compliance.	Focuses on promoting manufacture of energy efficient equipment (through incentives, tax ex-emptions), es-tablishing a national target pro-gram, raising awareness, etc.
	Mandatory Energy Audit and Manage-ment for Major Energy Users (part of 21/2011/ND-CP) Year: 2011 (IEA, 2021)	The policy governs the desig-nation of major energy users and the reporting re-sponsibili-ties, audit require-ments, as well as energy efficiency plans.	Only applies to major energy users. Does not set any mandatory energy ef-ficien-cy targets. Main-ly focuses on identify-ing and listing major energy users, ensuring that they conduct timely energy audits and report their pro-gress.
	Regulations on Indus-tri-al Energy Efficiency (Cir-cular 02/2014 / TT-BCT) Year: 2014 (IEA, 2021)	This regulation defines the economic and efficient ener-gy use in general industrial pro-cesses and management and solutions for the chemi-cal in-dustry. It also specifies Specif-ic Energy Consump-tion for se-lect industries.	Focuses on efficiency of combustion pro-cess-es, heating and cooling systems, air condition-ers, hot water supply, electrical en-gines, light-ing tech-nology and com-pressed air systems. Also provides specific energy consumption and energy efficiency guidelines for select in-dustries like raw rubber production, NPK fertil-izer produc-tion, water paint pro-duction and solvent paint production.
	National Energy Effi-ciency Programme (VNEEP) for the peri-od of 2019 – 2030 Year: 2020 (ASEAN Center for Ener-gy, 2019)	Among other objectives, the National Energy Efficiency Programme aims to achieve the following: 5-7% of energy saving in the period of 2019-2025 8-10% of energy saving in the period of 2019-2030 Reduce power loss to: less than 6.5% by 2025 less than 6% by 2030	This policy sets a na-tional energy efficien-cy roadmap. It in-cludes energy con-sumption re-duction targets for specific industries, in addi-tion to the overall national level targets. Acts as a comprehen-sive policy for pro-mot-ing energy con-servation.

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