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Preliminary Roadmap for Industrial Decarbonization – Vietnam

Report

United Nations Industrial Development Organization (UNIDO)

INDUSTRIAL DECARBONIZATION ACCELERATOR

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Contents

Acronyms

ADB	Asian Development Bank
AL	Action Line
ASEAN	Association of Southeast Asian Nations
BAT	Best available technology
BF	Blast furnace
BOF	Basic oxygen furnace
CBAM	Carbon Border Adjustment Mechanism
CCUS	Carbon capture, utilisation, and storage
DOE	Department of Energy
DR	Demand response
DSM	Demand-side management
EAF	Electric arc furnace
EE	Energy efficiency
EI	Energy Institute
ENERTEAM	Energy Conservation Research and Development Centre
ETP	Energy Transition Partnership
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
H2	Hydrogen
H2-DRI	Hydrogen-based direct-reduced iron
IE	Industrial electrification
IEA	International Energy Agency
IEVN	Institute of Energy of Vietnam
IF	Induction furnace
IPMVP	International Performance Measurement and Verification Protocol
JETP	Just Energy Transition Partnership
LCFFES	Low-carbon fuels, feedstocks, and energy sources
ME	Material efficiency
MOIT	Ministry of Industry and Trade
N2	Nitrogen
NDC	Nationally Determined Contribution
NET	Negative emissions technology
NGO	Non-government organisation
PDP8	Power Development Plan 8
PV	Photovoltaic
RE	Renewable energy
US	United States
WHR	Waste heat recovery

1. Executive Summary

UNIDO's Proposition

UNIDO is coordinating the Clean Energy Ministerial Industrial Deep Decarbonisation Initiative (IDDI), a global coalition of public and private organisations that work to stimulate demand for low carbon industrial materials. In collaboration with national governments, IDDI works to standardise carbon assessments, establish ambitious public and private sector procurement targets, as well as incentivise investments in low-carbon product development and industry guideline design.

Against this backdrop, the "Industrial Decarbonisation Baseline Assessments" project is supporting the development of an industry decarbonisation roadmap in consultation with key stakeholders to identify the appropriate decarbonisation pathways for heavy industries including steel, cement, and concrete specific to the Vietnam situation, in line with the goals of the Paris Agreement and Sustainable Development Goal 7 (SDG 7). The focus will be on the highest CO_2 emitting industries wherein low carbon technologies can have the greatest impacts. This will be achieved by carrying out the following activities:

1. In-depth analysis of industrial decarbonisation;
2. Roadmap to achieve industrial decarbonisation;
3. Service model.

In this context, the following summary was prepared, which also presents industry specific questions as an initial action to secure the participation and contributions of the various parties involved in the industrial sector, energy sector, and other sectors responsible for achieving CO_2 emission reduction objectives.

Overview

- Vietnam's greenhouse gas emissions are very high, with an increase of 878% between 1990 and 2014. In 2020, Vietnam emitted 254 Mtpa CO_2. The production of electricity and heat was responsible for 66% of CO_2 emissions in 2020.
- According to the Vietnam Energy Efficiency Program (VNEEP) Energy Statistics 2020, the industrial sector contributed approximately 36.6% to GDP in 2020.
- Processing industries consume 78% of total industrial sector electricity in Vietnam. Food processing (12%), non-metallic minerals (10%), iron and steel processing (7%), as well as iron and steel products (7%) are the subsectors with highest electricity consumption equal to 42.5 TWh or 36% of total industrial sector electricity consumption.
- Vietnam's commitment to achieving carbon neutrality is outlined in the Power Development Plan 8, which was approved in May 2023. It proposes boosting wind and solar capacity to 42% of total power generation by 2045. In 2045, renewable energies, including large-scale hydroelectricity, will account for 53% of total capacity.
- International assistance for the implementation of Power Development Plan 8 and the establishment of the Just Energy Transition Partnership (JETP) is being coordinated by the International Partners Group (IPG). The IPG supported the development of the JETP Resource Mobilisation Plan (RMP), which was completed at the end of 2023. The Resource Mobilisation Plan is the first and very important step in implementing the JETP, and to ensure a successful transition.
- As noted in its Nationally Determined Contribution (NDC) 2022, Vietnam has put significant efforts to reduce GHG emissions in different areas like energy, transportation, farming, waste, and industry. The efforts generated good results from 2014 to 2020 by reducing emissions by about 85 million tonnes of CO_{2eq} by 2020.

Despite ongoing programmes, Vietnam still faces significant structural and institutional challenges to meet its NDC commitments. Reaching net-zero CO_2 emissions will require considerable additional investments, operational changes, and societal support.

Barriers and Drivers

The transition to a low carbon economy is essential to tackle climate change and promote a sustainable future. However, the issue of industrial decarbonisation is broader and encompasses broader barriers and drivers and among which we list the following:

Barriers

- Regulatory and enforcement: Commitments and strategies, prepared by different ministries, set targets and priorities in inconsistent ways can limit initiatives. Furthermore, the substantial number of climate change policies makes it challenging to effectively understand how climate change responses are integrated into the allocation of public budgets, due to capacity limitations.
- Technical and knowledge: Personnel lack the necessary skills and technical capacity to develop EE projectsand lack access to, comprehensive knowledge about, and experience in energy efficiency measures or emerging low-carbon technologies, all of which hinder progress.
- Electricity tariff: Relatively low electricity tariffs in Vietnam as well as the uncertainty around the timing and clear plans for increases do not motivate end users to adopt EE practices or technologies due to the limited potential for cost savings.
- Financial and economic: Inadequate support mechanisms or insufficient financial resources dedicated to EE or decarbonisation projects. International financing schemes and government funding other than those focused on capacity building (such as those supporting project-based financing) face a number of mainstreaming challenges, including terms and conditions not suitable for uptake by local enterprises.
- Awareness and capacity: Local industries and institutions may not all possess the knowledge, experience, or resources to adopt or finance decarbonization projects, resulting in inadequate uptake or difficulties in developing effective initiatives.

Drivers

- Implement the world's first carbon border adjustment mechanism (**CBAM**) effective as of October 2023. the CBAM is expected to have a significant impact on emission intensive economies like Vietnam that export to the EU.
- **Government commitments** to reducing GHG emissions, thereby resulting in new policies and regulations that affect the production and business of enterprises.
- **Access to capital** can drive down the capital and operating expenses of low-carbon infrastructure, helping industry to expand investments on new technologies, increase labour productivity and reduce production operating costs.
- **High renewable energy potentials**: Vietnam has immense potential for wind, solar and other renewable-based projects. At present, hydropower holds the largest share amongst all renewable energy sources, followed by wind and biomass. However, solar energy, biogas, and waste-to-energy technologies remain untapped, and it has been projected that Vietnam's renewable potentials are sufficient to address the growing power demands.

Status of the Whole Industrial Sector

Energy

According to the VNEEP Vietnam Energy Statistics 2020 (2019-2020) and General Statistics Office (2021), the share of energy consumption in industry has rapidly increased in recent years, representing over 50% of final energy consumption by 2020. The most energy-intensive industrial segments include the food processing, non-metallic minerals, iron and steel processing, as well as iron and steel products. The analysis revealed the need to focus on specific strategies for these subsectors to optimise energy use and promote decarbonisation in areas wherein consumption is most significant.

CO_2 Emissions

There was a significant 70% increase in industrial GHG emissions between 2016 and 2020. Coal is the main energy source in industry, with a share of 35% of total domestic consumption, followed by natural gas, and there are multiple energy sources depending on the subsector and regional availability. The most significant subsector emitters in 2020 were manufacturing products from other non-metallic minerals with 31% of total GHG emissions, metallic production with 12%, textiles with 11%, and food, beverage, and tobacco processing with 10%.

Preliminary Roadmap for Industrial Decarbonisation

Industrial decarbonisation in Vietnam is driven by a combination of factors that include international commitments, global pressures, technological advances, national regulations, civil society pressure, access to natural resources, and economic benefits. These drivers are shaping the transition to a more sustainable industry aligned with climate change objectives while promoting the country's competitiveness and economic development.

The objective of the Preliminary Roadmap is to define a preliminary path to develop and promote the implementation of decarbonisation in the Vietnamese industrial sector. This preliminary path will serve as a basis for detailing policy and technology issues followed by details on each of the key sectors herein. The pillars that support the proposed path in the short, medium, and long terms are outlined below.

Policy options: Modifications to the current regulatory/policy framework to review and update or create additional regulations and standards that allow for a smooth transition to the adoption, development, and implementation of the Preliminary Roadmap within the scope of public policies and instruments. This can also help to align internal targets and priorities, helping to reduce regulatory and enforcement barriers.

Technological pathways: Various technologies are identified in the five main pathways to be implemented with the aim of achieving net zero carbon in the industrial sector by 2050. The five pathways are: energy efficiency (EE), industrial electrification (IE), low-carbon fuels, feedstocks, and energy sources (LCFFES), carbon capture, utilisation, and storage (CCUS), and alternate approaches including material efficiency (ME) and negative emissions technologies (NETs).

Financial requirements: Provide an estimate of the financial investments required to implement the Preliminary Roadmap based on the data and information collected and analysed.

Policy options and financial requirements to ensure the implementation of technological pathways and achieve decarbonisation by 2050 are:

1. Increase data collection on the use of highly efficient materials and technologies and their life cycle impacts to establish benchmarks and promote best practices (including best practices in production methods)
2. Improve considerations on life cycle impacts in climate regulations to promote material and technology efficient practices at the design stage.
3. Set incentives for reuse and recycling to reduce the need to produce higher-emitting primary materials and improve their integration in supply chains to facilitate these strategies.
4. Promote research and development of technologies that recover energy through subsidy programmes that encourage both companies and research institutions to invest in projects related to the development of more efficient technologies, including the adaptation of existing technologies to the Vietnamese reality as well as the development of innovations in the field of energy efficiency.
5. Define performance standards for industrial equipment and processes, which must be reviewed periodically to incorporate technological advances and best practices in energy efficiency.
6. Establish regulations that ensure furnaces and boilers must be supplied with auxiliary equipment that recovers heat, such as economisers, air preheaters, heat pumps, among others.
7. Introduce incentives and/or requirements and targets for the implementation and certification of ISO 50001 energy management systems by large energy consumers.
8. Train energy managers for industry; certification would recognise professionals with solid skills in energy management with a special focus on thermal systems and decarbonisation.
9. Expand financing lines for technological innovations focused on decarbonisation under conditions that enable the implementation of projects, including the possibility of obtaining subsidies.
10. Regulate the carbon market to allow industries with demonstrably reduced emissions to be financial compensated for investments made in decarbonisation.

Technological pathways are determined for the two main industrial subsectors: cement and steel.

Status of Key Industries

Vietnam's industrial sector remains a major direct emitter of GHG and therefore also has an important contribution to make by both decarbonising its primary fuel sources and adopting energy efficient and low-carbon industrial processes and measures. According to a recent study by Asian Development Bank (ADB), the estimated utility efficiency potential for Vietnam is equivalent to approximately 13% of Vietnam Electricity's (EVN) sales in 2019, with industries accounting for about 18% of the EE potential.

Steel

Vietnam is the thirteenth largest steel producer in the world and an ASEAN leader in both steel production and consumption. Vietnam's steel industry includes more than 100 companies, including a number of producers with low production capacity (<1 million tonnes per year). In 2022, production was estimated at 20 million tonnes of finished steel. In 2022, the majority of domestic steel was produced using the basic oxygen furnace (BOF) process (about 65%), while the remainder used the electric arc furnace (EAF) and induction furnace (IF) processes (about 35%). Globally, BOF plants account for two-thirds of capacity. Currently, up to 90% of planned capacity in Asia is being developed under BOF projects.

Steel production currently accounts for 8% to 9% of global CO_2 emissions. Emissions from vary by production method: on average, it is estimated that the production of one metric tonne of steel results in about 1.8 to 2.2 metric tonnes of CO_2 when using blast furnaces, 0.4 to 0.8 metric tonnes of CO_2 when using electric furnaces, and 0.1 metric tonnes of CO_2 when using hydrogen energy. In 2018, the production of one tonne of steel in 2018 resulted in about 1.85 tonnes of CO_2 according to the World Steel Association (WSA); WSA also estimates that carbon emissions per tonne of steel average 1.89 metric tonnes in 2020.[1]

Strategies to reduce carbon emissions from steel production include:

- **EE**: Integrated steelmaking route based on blast furnace (BF) and basic oxygen furnace (BOF), induction furnace (IF) route uses recycled steels primarily recycled steels and direct reduced iron (DRI) on hot metal and electricity.
- **IE:** EAF plants using primarily recycled steels and direct reduced iron (DRI) or hot metal and electricity and maximising efficiencies. Electrification of equipment such as steam boilers.
- **LCFFES**: DRI with implementation of technological options: (i) Electrolytic hydrogen instead of natural gas or coal; (ii) natural gas with high levels of hydrogen electrolytic mixture; (iii) CO_2 capture based on chemical absorption; (iv) CO_2 capture based on physical adsorption.
- **CCUS**: Implementation of pilot projects that use CCUS technology in industry.
- **ME/NET**: Installation of renewable technologies (wind and solar), reuse of steel and other construction materials and buildings lifetime extension, improving building design and construction, and lightweight vehicles.

The development and execution of a Roadmap for Industry Decarbonisation represents a structural shift that requires significant investments, government involvement, and industry leadership. Details on roles, responsibilities, and support need to be further refined with industry participation.

Cement

Vietnam is the third largest cement producer globally, and emissions from this production account for about 15% of total emissions from the economy. There are 90 cement production lines in Vietnam with a total capacity of about 122 million tonnes per year. In 2021, cement and clinker production volume reached 101.22 million tonnes.

Due to the need for very high heat and significant process emissions of carbon dioxide, cement manufacturing is also a key area of interest for decarbonisation efforts. However, economic factors, including low profit margins, capital intensity, and long asset life, make decarbonising cement production a challenging endeavour. In addition, decarbonising cement production also requires changes throughout the production supply chain. Like its impacts on steel production and export, the CBAM is expected to increase cement costs globally, thus

[1] The estimated average for 2020 is higher, which may be due to reliance on BOF production method.

affecting carbon intensive producers like Vietnam. A study by McKinsey & Company estimated that additional costs can reach €180 billion or more by 2050 globally.

Strategies to reduce carbon emissions from cement production include:

- **EE**: Thermal EE in clinker production/waste heat recovery, ISO 50001 system to control energy consumption, technology management and production process management, control system (process optimisation).
- **IE**: Electrification of key equipment such as kilns, pre-calciners and furnaces.
- **LCFFES**: Alternative fuels including biofuel, biomass, and hydrogen and alternative raw/binding materials (belite clinker, calcium silicates, alkali-activated binders/geopolymers, carbide slag, etc.)
- **CCUS**: Implementation of pilot projects that use CCUS technology in industry. Post-combustion CCUS, oxygen enrichment and oxy-fuel technology, carbonation and carbon curing for concrete.
- **ME/NET**: Installation of renewable technologies (wind and solar), reducing the clinker-to-cement ratio, use of clinker alternatives such as fly ash from coal-fired power plants and slag from steel-blast furnaces.

Financial Requirements

Based on the reliable information collected and analysed[2], the needed investments to implement specific technologies identified in the technological pathways and contribute at the decarbonisation of the whole industrial sector in 2050 are estimated to be **on average 9.3 billion USD**.

Technological Pathway	Average Investment – Industry (millions USD)			Total (billion USD)
	2030	2040	2050	
CCUS[3]		3,304	1,321	**4.6**
Energy Efficiency	243	97	97	**0.4**
Biofuel	1,130	452	452	**2.0**
Materials Efficiency	636	254	254	**1.1**
Photovoltaic solar power and wind power	623	249	249	**1.1**
Total	**2,631**	**4,356**	**2,374**	**9.4**

Financial Requirements for Cement and Steel Subsectors

Needed investments are also calculated for the two targeted subsectors. As showed in the table below, the highest investment (average and maximum) is necessary to achieve the decarbonization of the cement industry.

Cement

For **cement** sector investments are estimated to be **on average 1.4 billion USD**.

[2] The calculation is made by estimating CO_2 emissions of the industrial sector and subsectors multiplied by the average and the maximum abatement cost (related to the % of emission reduction of target year: 50% reduction by 2030, 80% reduction by 2040, and 100% reduction by 2050) of the technology pathway and by the % of implementation of such technology as follows: EE (25%), IE (20%), LCFFES (20%), ME/NET (15%), and CCUS (20%).

[3] CCUS technology implemented by 2040.

Technological Pathway	Maximum Investment – Industry (millions USD)			Total (billion USD)
	2030	2040	2050	
CCUS		189	189	0.4
Energy Efficiency	69	14	14	1
Biofuel	322	64	64	0.4
Materials Efficiency	181	36	36	0.3
Photovoltaic solar power and wind power	178	36	36	0.3
Total	751	339	339	1.4

Steel

For **steel** sector investments are estimated to be **on average 0.6 billion USD**.

Technological Pathway	Average Investment – Industry (millions USD)			Total (billion USD)
	2030	2040	2050	
CCUS		75	75	0.1
Energy Efficiency	27	5	5	0.04
Biofuel	128	26	26	0.2
Materials Efficiency	72	14	14	0.1
Photovoltaic solar power and wind power	70	14	14	0.1
Total	297	134	134	0.6

Next Steps

In addition to offering suggestions for technical and policy actions, the Preliminary Roadmap points out the next steps to be followed. This strategic direction is essential to ensure that the proposals presented are not limited to the initiatives and industrial segments initially addressed but are integrated into a broader development and implementation process, which includes other industrial segments, such as the food and beverage and textile subsectors. The partnership with the United Nations Industrial Development Organization (UNIDO), an institution recognized internationally as an entity dedicated to sustainable industrial advancement and the promotion of partnerships between public and private sectors to achieve common objectives, offers a significant advantage by providing technical expertise, resources and a global perspective.

Subsequent project design should be a participatory process, involving ongoing consultations with relevant stakeholders, including representatives from the private sector, academics, non-governmental organizations and other key actors. This inclusive approach ensures that the project is shaped by a variety of perspectives, making it more robust, adaptable and acceptable to all involved.

It should also be noted that key initiatives such as the JETP, the development of the RMP and the level of support it has received, and the success of its measures and the level of funding they can obtain will go a long way towards making other decarbonization step possible, especially in the near term (from 2023 to 2030), as many measures to be implemented by the JETP are related or intertwined with the measures and actions identified under the various decarbonisation pillars.

By clearly indicating these next steps, the Preliminary Roadmap not only provides a strategic vision, but also establishes a tangible path towards practical implementation of the proposals presented. This action-oriented approach is crucial to transform recommendations into tangible results, such as detailed advice for each industrial subsector.

2. Background

2.1. Energy Context and GHG Emission Context

Vietnam's greenhouse gas emissions are very high, with an increase of 878% between 1990 and 2014. In 2020, Vietnam emitted 254 Mtpa CO^2. The production of electricity and heat was responsible for 66% of CO^2 emissions in 2020. In 2021, energy consumption in transport (decreased to 16.7% of total from 19.7%) and commerce and other services (increased to 6.5% of total from 3.8%) experienced the most significant change compared to pre-pandemic levels (see **Figure 1**).

At the same time, the share of energy consumption in industry has rapidly increased in recent years, as depicted in **Figure 1**, representing over 50% of final energy consumption by 2020 (much higher than the US industry of 33% in the same year). According to the Vietnam Energy Efficiency Program (VNEEP) Energy Statistics 2020, the industrial sector contributed approximately 36.6% to GDP in 2020.

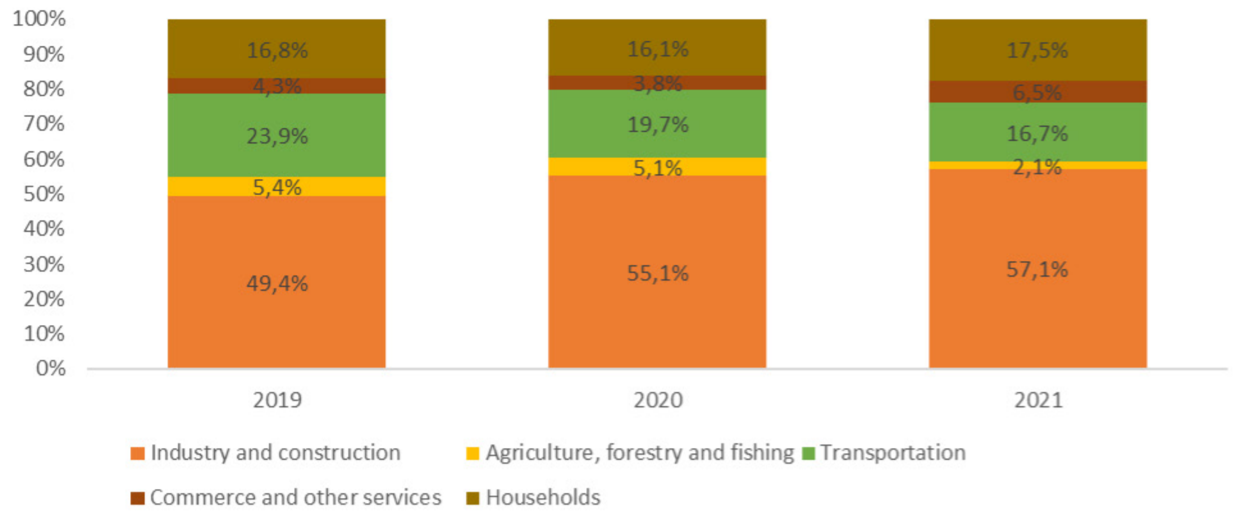

Figure 1. Total Final Energy Consumption per Sector[4]

In parallel with gross domestic product (GDP) growth, electricity demand in Vietnam has grown extremely rapidly in recent years. From 2018 to 2022, electricity demand grew by over 25%, which is twice the growth rate of the Philippines and over three times that of Thailand, Indonesia, and Malaysia over the same period.

Industrial emissions comprise both direct emissions (onsite emissions from processing or energy consumption) and indirect emissions from energy use (emissions from electricity generation).

Based on emissions from energy use, the segmentation of electricity consumption per subsector reveals that processing industries consume 78% of total industrial sector electricity in Vietnam. Food processing (12%), non-metallic minerals (10%), iron and steel processing (7%), as well as iron and steel products (7%) are the subsectors with highest electricity consumption equal to 42.5 TWh or 36% of total industrial sector electricity consumption (see **Figure 2** below).

4 Source: VNEEP Vietnam Energy Statistics 2020 (2019-2020), General Statistics Office (2021).

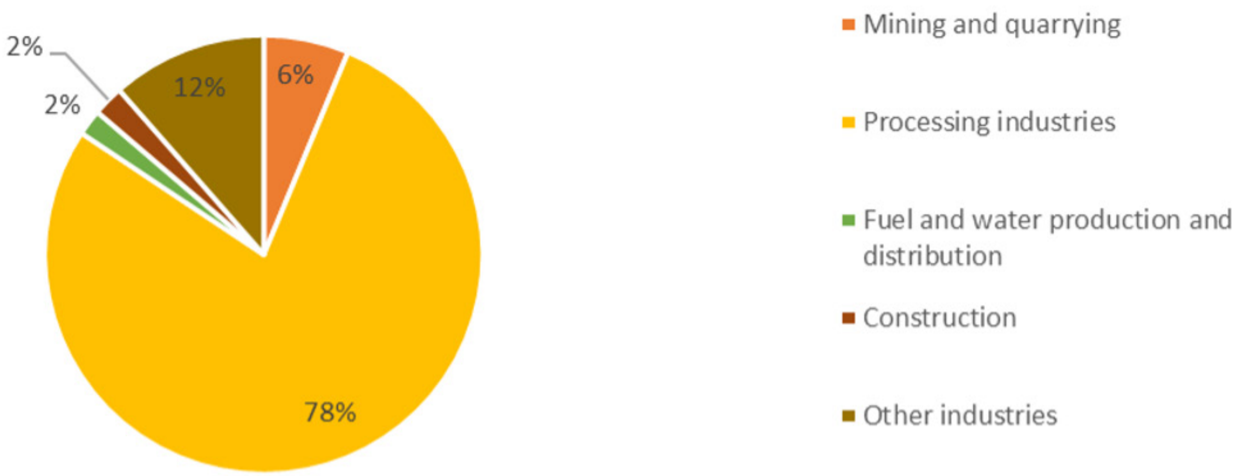

Figure 2. 2020 Electricity Consumption per Subsector, Source: VNEEP Vietnam Energy Statistics 2020

Before 2020 in the industrial sector, Vietnam took steps to decrease greenhouse gas (GHG) emissions by using different methods such as replacing clinker in cement composition and using high-efficient technologies for chemicals and steel production. However, there was a significant 70% increase in industrial GHG emissions between 2016 and 2020. Coal is the main energy source in industry, with a share of 35% of total domestic consumption, followed by natural gas, and there are multiple energy sources depending on the subsector and regional availability. The most significant subsector emitters in 2020 were manufacturing products from other non-metallic minerals with 31% of total GHG emissions, metallic production with 12%, textiles with 11%, and food, beverage, and tobacco processing with 10% (see Figure 3).

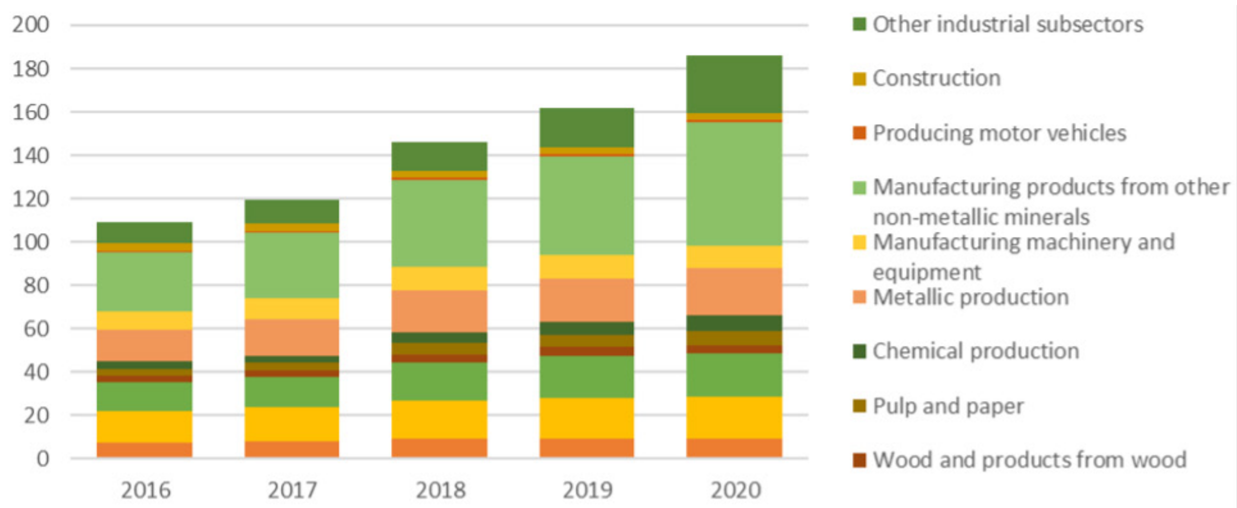

Figure 3. Total CO^2 (in MT) Emissions in Industrial Subsectors from 2016 to 2020. Note: Only key subsectors are shown.[5]

As noted in the Nationally Determined Contribution (NDC) 2022, Vietnam has invested significant efforts to reduce GHG emissions in different areas such as energy, transportation, farming, waste, and industry. This generated good results from 2014 to 2020, thereby reducing emissions by about 85 million tonnes of CO^2eq by 2020.[6] If Vietnam does not fully implement and enhance its existing climate change and green growth policies, there could be a substantial rise in GHG emissions by 2030.

5 Source: 2022 UNIDO Draft Report on Industrial Sector.

6 From 2022 NDC.

2.2. Decarbonization Actions

Climate change represents not only an environmental challenge, but also an economic one for industry. Adverse weather events can disrupt operations and the supply chain while increasing production costs. Additionally, stricter regulations and consumer pressure for sustainable products are redefining the industrial landscape.

According to international best practices,[7] investing in energy efficiency, optimising processes, reducing input costs by making better use of raw materials, recycling materials, minimising waste, reusing water, properly managing waste, and mitigating GHG emissions are already part of the daily operations of organisations under sustainable development activities. In this context, researching energy efficiency, reducing GHG emissions, and transitioning to cleaner energy sources are crucial to mitigating the impacts of climate change. The sustainable development practices mentioned above not only contribute to reducing emissions, but also strengthen companies' resilience in the face of climate challenges.

Therefore, given the climate change scenario, the decarbonisation of the industrial sector is not only a strategic choice, but also an urgent need to guarantee the long-term sustainability of Vietnamese industry.

In summary, the adoption of energy efficiency (EE) actions and existing material efficiency (ME) strategies, industrial electrification (IE), low-carbon fuels, feedstocks and energy sources (LCFFES), carbon capture, utilisation, and storage (CCUS), and alternate approaches, including negative emissions technologies (NETs), are key components in the Vietnamese industrial decarbonisation strategy (see Figure 4).

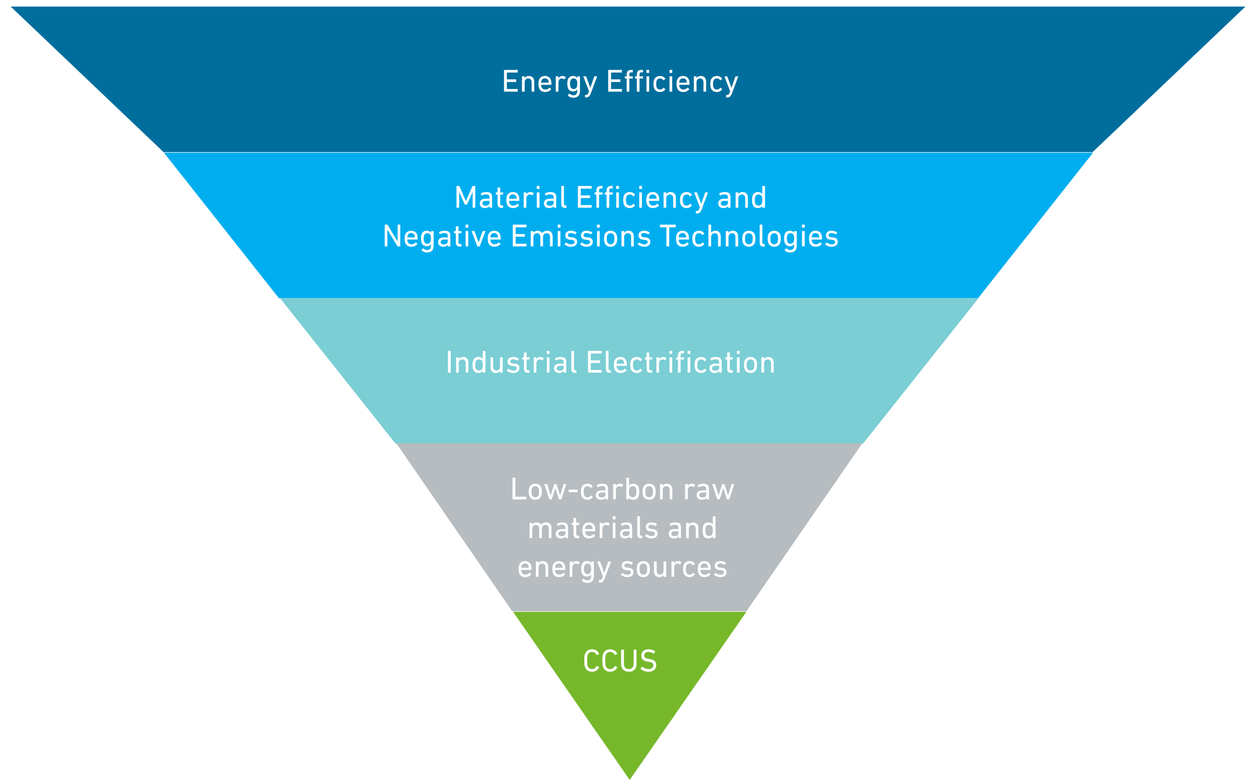

Figure 4. Technological Pathways for Decarbonisation of the Industrial Segment in Vietnam

7 https://www.gov.uk/government/publications/industrial-decarbonisation-strategy.

Note on the Inclusion of Material Efficiency

According to the International Energy Agency (IEA), ME strategies contribute to CO^2 emission reductions throughout value chains, and ME opportunities exist at each life cycle stage, from design and fabrication, to use and finally to end of life. Improved ME along with energy efficiency strategies serve to reduce some of the deployment needs for other CO^2 emission mitigation options while achieving the same emission reductions, thus contributing to clean energy transitions.

The IEA has examined the potential for material efficiency and the resulting energy and emission impacts for key energy intensive materials such as steel, cement, and aluminium. It also analysed the building construction and vehicle value chains. The current IEA key policy and actions to improve material efficiency include: Increasing material use data collection and benchmarking; improving consideration of the life cycle impact of climate regulations at the design stage; and promoting repurposing, reusing, and recycling at end of product and building lifetimes. Adopting these ME strategies as well as practical and achievable actions such as those listed above could enable further reductions in the demand for several key materials and further contribute to energy efficiency impacts. This is extremely important for a country like Vietnam that is still developing, thus leading to additional needs for buildings, factories, and other structures.

Other material efficiency strategies are not yet mature and require additional research and development. These future ME strategies are included in the same pillar as NETs. This is because no single ME or NET strategy that is currently known can be relied upon to provide emission reductions at sufficient scale on its own. Furthermore, not all the potential negative consequences of any NET or ME strategy have been determined. Therefore, it would be highly prudent to look at a number of strategies as they become available (or developed) to be built upon in order to learn not only about the benefits, but also the negative consequences as part of any risk management strategy in addressing climate change.

2.3. The Importance of Industrial Decarbonization

The industrial sector is a vital contributor to Vietnam's GDP as well as a significant source of employment in this developing nation. However, the sector is also a notable contributor to overall GHG emissions primarily due to reliance on fossil fuels and energy-intensive manufacturing processes.

Vietnam's commitment to the Paris Agreement underscores the need to decarbonise its industries. Decarbonisation in Vietnam implies reducing dependence on imported fossil fuels, fostering energy security, and promoting the adoption of renewable energy sources. This shift will enhance resilience against the volatility of global oil prices as well as the physical impacts of climate change, which can disrupt energy supplies and industrial productivity.

Moreover, embracing cleaner technologies and green energy will open up new markets, attract investment, and create more jobs. Vietnam is a significant exporter of goods, including those from carbon intensive industries. The implementation of carbon adjustment schemes will affect how Vietnam manufactures products for export. Those industries most likely affected by the upcoming Carbon Border Adjustment Mechanism (CBAM) will need to adopt it quickly, which may mean that they need to transition to other fuels, alternative production technologies, and even feedstocks.

A collaborative approach involving government, industry, non-government organisations (NGOs), and civil society is essential to drive decarbonisation. Stakeholder engagement is critical in aligning policies, investments, and innovations toward sustainable industrial practices. By mapping out key players and their roles, Vietnam can develop a cohesive strategy that not only addresses the climate crisis, but also positions its industrial sector for long-term sustainability and growth in alignment with its global commitments.

3. Process for the Development of the Roadmap

3.1. Literature Review

Desk research was used to gather information from secondary sources such as industry reports, government publications, chamber of commerce data, international finance institution publications, third-party databases, and news articles. This secondary research helped to identify and extract information and provided insight into the current industrial situation and characteristics thereof such as the overall production capacity, main representatives within industry subsectors, main types of technology and technical capabilities, investments required, regulatory and commercial drivers and barriers, the overall location of activities, etc.

For Vietnamese industries, available information on production and other statistics is available in aggregate, but industry specific details – in both Vietnamese and English – are limited. Such data can also be confidential or not widely shared, even with government agencies or international NGOs. Many of the available government scenarios and other forecast documents tend to use proxy data for the region or industry. Nevertheless, the analysis included the key documents outlined below (and others as cited) as the basis for the results of the work outlined herein.

Law on Economical and Efficient Use of Energy (No. 50/2010/QH12) and its subordinate regulations. The Law was established in 2010 and is applied by the Ministry of Industry and Trade (MOIT). With the Decree detailing the Law on Economical and Efficient Use of Energy and measures for its implementation (No. 21/2011/ND-CP) these documents form the foundation for EE regulations in Vietnam. The Decree is focused on areas such as statistical energy indicators, major energy users, energy labeling, the promotion of energy efficient practices, and inspection procedures. The introduction of major energy users classified based on their energy consumption levels is notable. The Decree also introduces the role of energy managers who are responsible for planning and implementing energy efficient practices.

Directive on Promoting Electricity Conservation during 2023-2025 and the Subsequent Years: This Directive enhances electricity conservation efforts from 2023 to 2025 and beyond to save a minimum of 2% in total electricity consumption annually until 2025. The goals include reducing electricity losses across the power system to below 6% by 2025 and decreasing peak load capacity by at least 1,500 MW through demand-side management (DSM), demand response (DR), and renewable energy (RE) programmes.

Power Development Plan 8 (PDP8) for the period of 2021-2030 with a vision to 2050: The PDP8 outlines Vietnam's electricity generation plans aligned with the commitments made through its Just Energy Transition Partnership (JETP) agreed to in 2022. The plan emphasises widescale infrastructure modernisation and the prioritisation of renewable electricity generation. The plan's ambitious goals include more than doubling Vietnam's power generation capacity from 69 GW in 2020 to 150 GW by 2030 and achieving carbon neutrality by 2050. Additionally, the plan outlines measures to completely discontinue coal powered generation by 2050.

National Adaptation Plan for the period 2021-2030 with a vision to 2050: The overall objective of this Plan is to mitigate vulnerability and risks from the negative impacts of climate change by strengthening the resilience and adaptive capacity of natural, economic, and social systems. Two of the goals specifically target the industrial sector through Sustainable Development Goal 7 (Ensure access to sustainable, reliable, affordable, and modern energy for all), and Sustainable Development Goal 17 (Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development).

National Energy Efficiency Programme: Vietnam Energy Statistics 2020: The Institute of Energy of Vietnam (IEVN) prepared annual energy statistics under MOIT management. Although there were interruptions in the 2016-2018 period, IEVN maintained energy data collection from focal macro data sources such as central government agencies as well as big industrial groups and corporations post-COVID-19.

Statistical Review of World Energy: This document is published annually by the Energy Institute (EI), the chartered professional membership body for people who work in energy. This document has been in continuous publication for more than 70 years and is viewed as one of most comprehensive, objective, and timely collection and analysis of global energy production, consumption, and emission data.

US DOE Industrial Decarbonisation Roadmap: The U.S. Department of Energy's (DOE) Industrial Decarbonisation Roadmap was prepared for the US and identifies four key pathways to reduce industrial emissions. The US DOE roadmap presents an agenda for government, industry, and other stakeholders to work together to accelerate emission reductions and position the US industrial sector as a global leader in decarbonisation.

Diagnostic Review and Analysis of Energy Efficiency Development in Vietnam - Final Report (31 January 2022). This report was prepared by the Just Energy Transition Partnership (JETP) and contains the current energy and EE landscape of Vietnam and in which relevant policies, regulations, market barriers, and gaps are discussed.

Energy Conservation Research and Development Centre (ENERTEAM), 2023 Report on GHG emissions from steel production in Vietnam.

Cement Sustainability Initiative (CSI) Getting the Numbers Right database provides a range of emissions per tonne of cement or national averages in South and Southeast Asian countries like India, the Philippines, and Thailand. All sources agree that the Vietnam cement sectoral average CO^2 emissions per tonne of cement is about 15% higher than the global average and higher than in other regional economies.

Green Growth: Capturing Asia's $5 trillion green business opportunity. Report by McKinsey & Co, 2023. The report covers the market size of green businesses in Asia, including associated risks and potential rewards for businesses that move early into this business sector.

Charting a path for Vietnam to achieve its net-zero goals. Report by McKinsey & Co, 2023. The report discusses opportunities across sectors in Vietnam, which can be used to potentially accelerate decarbonisation to achieve net-zero emissions by 2050.

As this Report was being prepared, a number of notable initiatives were also underway or just completing. A key initiative was the development of the Resource Mobilization Plan (RMP) for the implementation of the Just Energy Transition Partnership (JETP). The RMP represents the first step in implementing the JETP, and is necessary to ensure a successful transition to clean energy. The RMP is based on the Nationally Determined Contribution, Power Development Plan and National Energy Master Plan for the period 2021 - 2030, vision to 2050, it sets out a list of specific projects to mobilize finance from donors and partners. The RMP was released at the end of 2023, and the details contained therein have been incorporated into relevant sections of this Report as appropriate.

3.2. Interviews with Stakeholders

Concurrent with the desk research activities, the research team also conducted stakeholder consultations; a list of interviewed stakeholders is presented in Table 1.

Table 1. List of Interviewed Stakeholders

Stakeholders	Department
Ministry of Industry and Trade	Energy Efficiency and Sustainable Development Department
Ministry of Planning and Investment	Department of Science, Education, Natural Resources and Environment
Vietnam National Cement Association	Cement Product Specialist
Vietnam Foundry and Metallurgy Science and Technology Association	Senior Expert
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	Development Expert
Asian Development Bank (ADB)	Energy Expert
Vietnam Low Emissions Energy Programme	Senior Expert
Bank for Investment and Development of Vietnam	Senior Expert (Pending)

The stakeholder profiles included government agencies responsible for industrial policies and the planning and implementation of industrial decarbonisation or other activities in support of the NDC as well as representatives from industry and industry associations, the banking/finance sector, and international development institutions supporting these activities.

3.3. Sector Data Analysis

Once the information was collected from both secondary and primary sources, the research team analysed it to identify data and data sources on emissions and emissions factors, technology developments, trends, patterns, potential, and key findings related to appropriate subsectors and stakeholders. Based on the information gathered, the research team also assessed the current financial options and investments required to pursue types of technologies and measures and the available levels of financial support for industrial decarbonisation currently planned or offered by financial institutions and other actors in the financial sector.

There were some limitations in the data-collection process for both desk research and stakeholder consultations. For the consultation process, there were challenges related to accessing government agencies, especially when it comes to meeting with policy makers. For the desk research activities, challenges during the collection process included a lack of available data. There were also challenges with obtaining information regarding ongoing projects or projects under development (for example, the RMP).

4. Presentation of the Roadmap

To design the Preliminary Roadmap outlined herein, the team started from the premise that, to define and propose lines of action, it is necessary to address the threats and weaknesses faced by the industrial sector. This assumes that the conjunction between these two variables results in the emergence of primary barriers that must be addressed in the Preliminary Roadmap through proposed paths to guarantee the implementation of actions that lead to the intended final result of achieving full industrial sector decarbonisation by 2050. Given the imperative need to overcome identified barriers, it is necessary to develop a strategic set of actions. These actions are articulated around two main axes, development and implementation. Hence, the Preliminary Roadmap not only diagnoses, but also outlines guiding efforts through specific paths and carefully planned activities. This approach is aimed at not only short-term actions, but also medium and long terms actions to maximise positive impacts.

4.1. Objectives

The objectives of the Preliminary Roadmap for initial industrial decarbonisation are defined as a general objective and specific objectives.

4.1.1. General Objective

The general objective is to define a preliminary path to develop and promote the implementation of decarbonisation in the Vietnamese industrial sector. This preliminary path will serve as a basis for detailing policy and technological issues for each key sector at a later stage.

4.1.2. Specific Objectives

Specifically, the Preliminary Roadmap takes into account the following aspects:

1. Identify and prioritise the levels of effort necessary to develop and implement the Preliminary Roadmap for the decarbonisation of the industrial sector;
2. Propose elements and actions for the development of the Preliminary Roadmap;
3. Propose an approach for the progressive implementation of the Preliminary Roadmap;
4. Identify interest groups through which the development and implementation of the Preliminary Roadmap is promoted;
5. Propose a set of actions, key paths, and specific activities designed to promote the development and implementation of the Preliminary Roadmap;
6. Define the time horizons to implement the proposed actions and activities in the short, medium, and long terms.

4.2. Conceptual Structure of the Roadmap

The conceptual framework and rationale provide the essential structure for the preparation of this Preliminary Roadmap. Represented clearly and comprehensively in Figure 5 below, these conceptual and logical elements form the solid foundation upon which strategies and actions will be developed, guiding the path toward the effective decarbonisation of the industrial sector.

Figure 5 should be read from bottom to top. The basis of the framework relates to the analysis conducted on policies, the regulatory framework, and the market. The analysis served to identify gaps, barriers, and mitigation actions. Based on the results of the analysis, the pillars to structure the Preliminary Roadmap are defined and the components that determine the lines of action are identified.

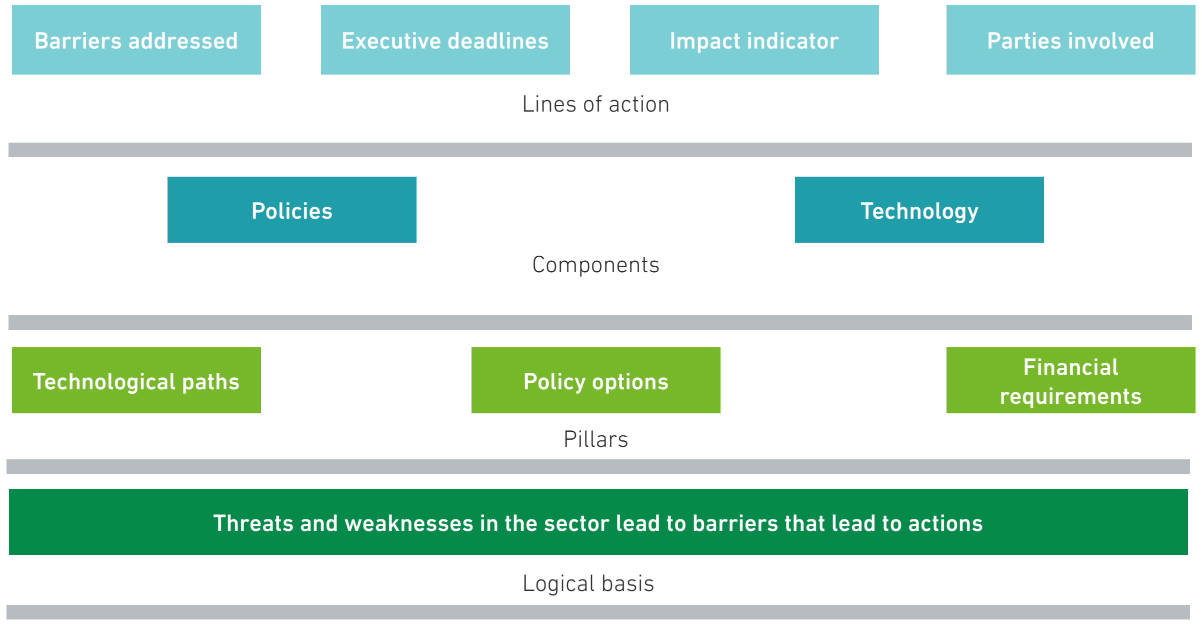

Figure 5. Conceptual framework for designing the preliminary roadmap

4.3 Pillars of the Roadmap

Based on the above, the Preliminary Roadmap was structured to address three critical areas of attention, which, in turn, translate into the pillars that support the proposed path in the short, medium, and long terms. The three critical areas are outlined here below.

Based on the above, the Preliminary Roadmap was structured to address three critical areas of attention, which, in turn, translate into the pillars that support the proposed path in the short, medium, and long terms. The three critical areas are outlined here below.

Technological pathways: Various technologies are identified in the five main pathways to be implemented with the aim of achieving net zero carbon in the industrial sector by 2050. The five pathways are: EE; IE; LCFFES; CCUS; and alternate approaches including ME and NETs.

Policy options: Considers modifications to the current regulatory/policy framework to review and update or create additional regulations and standards that allow for a smooth transition to the adoption, development, and implementation of the Preliminary Roadmap within the scope of public policies and instruments.

Financial requirements: Provides an estimate of the financial investments required to implement the Preliminary Roadmap and presents the link to existing financial programmes/initiatives and other potential sources.

4.4. Technological Pathways

As mentioned previously, technological pathways involve the intensification of EE, IE, LCFFES, CCUS, and alternate approaches including ME as well as NETs. It is estimated that the distribution of efforts for each technological path is 25% EE, 20% IE, 20% LCFFES, 20% CCUS, and 15% ME/NETs. For each pillar, the Preliminary Roadmap identifies the main barriers and opportunities as well as the main development needs. The result is an integrated action plan for industries to achieve net-zero emissions by 2050. Specifically, the Preliminary Roadmap highlights technological pathways to reduce emissions by 100%, which was estimated by a recent ADB report to be about 186 million tonnes of CO^{2}/year by 2050.[8] According to the RMP, for the power sector, the implementation of PDP8 alone will cost USD 134.7 billion in the period to 2030, of which USD 119.8 billion USD for power generation sources and USD 15.0 billion for the power transmission grid expansion and improvement.

8 Pathways to Low Carbon Development for Vietnam. Asian Development Bank, Manila, Philippines, 2018.

The five technological pathways identified (see Figure 6) to achieve net zero emissions by 2050 in industry were evaluated through international benchmarking and connections with existing roadmaps in Vietnam. In addition, the priorities and resources available for the activities under each pathway will also be influenced by the priorities and resources available for JETP under the RMP, as some activities are linked, or dependent on the availability of clean energy and other technologies required by industry sectors for their transition. In particular, the following JETP priorities can have significant impacts on the pace and degree of industrial decarbonization efforts in Viet Nam:

#1. Power Transmission Grid Project;

#2. Projects on Battery Storage and Pumped Storage Hydro Power Plants;

#4. Projects on Energy Efficiency

#6. Project on Coal Power Flexibility and Coal Power Plant Transition.

EE	IE	LCFFES	CCUS	ME/NET
• High efficient technologies and smart systems • Energy management • Waste heat recovery/ combined heat and power • Systems optimisation	• Electric boilers • Heat pumps • Electric heaters and dryers • Renewable sources to cover electricity demand	• Alternative feedstocks • Replacing fossil fuels by alternatives with fewer environmental impacts • Development of more sustainable low-emission energy sources • Low carbon hydrogen	• Post-combustion capture • Carbon utilisation	• Post-combustion capture • Carbon utilization

Figure 6: Five Technological Pathways of Industrial Decarbonisation

Detailed descriptions of the measures to be developed under the five technological pathways are presented in the following subsections.

4.4.1. Energy efficiency (EE) - 25% contribution

Methodology: It involves improving the use of energy in industrial processes to reduce energy consumption. This may include implementing more efficient technologies, optimising processes, and integrating smart systems to monitor and control energy use.

International Benchmarking: Many countries have similar strategies to improve energy efficiency in industry. Germany, for example, is known for its initiatives aimed at energy efficiency in industrial processes. The United Kingdom has also been strongly active in industrial decarbonisation.

Additional Measures and Costs Information: the 2023 version of the RMP, which was released at the end of the year, also included a number of representative industrial decarbonisation measures and costs. These are shown below:

It should be noted that the below measures are parts of the spectrum of energy efficiency and process improvement that can contribute to the overall emissions reduction from the BAU case, and are assumed to be included in the various initiatives required to meet the NDC reduction targets by 2030, or can only be achieved with additional investments.

Table 2: Selected EE Measures in the Energy Sector for the Period 2021-2030[9]

Measures	Potential to reduce emissions (millions USD tonne CO^2eg)			Emission reduction cost (a) (USD / tCO^2eq)	Additional financing need (b) (million USD)
	2021 - 2030	2025	2030		
E7. Optimization of clinker combustion cycle	2.05	0.18	0.38	-12.02	22.9
E8. Reduce clinker kiln heat loss	3.66	0.33	0.70	-14.49	4.2
E9. Waste heat recovery from cement production	12.03	1.05	2.23	0.36	194.4
E10. Use of vertical mill in cement production	6.89	0.54	1.38	2.68	734.1
E11. Applying improved technology in the production of baked bricks	7.46	0.65	1.50	-18.03	17.6
E12. Preheating of scrap steel before putting it into an electric arc furnice (EAF)	0.23	0.01	0.06	-60.39	8.7
E13. Heating in steel mill	1.38	0.08	0.34	-72.21	36.2
E14. Gas Heat Recovery from Oxygen Blower (BOF)	5.31	0.39	1.25	-34.16	120.7
E15. Spraying powdered anthracite coal into blast furnices	4.57	0.22	1.41	-85.45	37.7
E16. Improve energy efficiency in sub-industries (except the sub-sectors brick, cement, and iron and steel production)	56.82	3.85	14.25	-71.69	1,153.8

IE Pathway

- EE or transformative technologies: High efficiency equipment and appliances that meet international standards.
- Smart manufacturing: Computer integrated manufacturing, high levels of adaptability and rapid design changes, digital information technology, and more flexible technical workforce training. Other goals sometimes include rapid changes in production levels based on demand, supply chain optimisation, efficient production, and recyclability. Smart factories comprise interoperable systems, multi-scale dynamic modeling and simulations, intelligent automation, strong cybersecurity, and networked sensors.
- Storage and recovery of energy and heat: Installation of waste heat recovery systems in thermal processes.
- Strategic energy management: Implementation of ISO 50001, management commitment to long-term energy performance goals, energy planning and implementation, and systems for measuring and reporting energy performance.

9 Source: 2023 RMP

4.4.2. Industrial electrification (IE) - 20% contribution

Methodology: Industrial electrification means replacing current technologies or processes that use fossil fuels (especially onsite), including internal combustion engines, kilns, and gas boilers, with electrically powered equivalents such as electric vehicles, ovens, or heat pumps. These replacements are typically more efficient, reducing energy demand, and have a growing impact on emissions as electricity generation is decarbonised and is made more efficient.

International Benchmarking: Select industry subsectors in the US, EU, or Association of Southeast Asian Nations (ASEAN) such as steel, cement, and aluminium have been working to adopt IE processes. Benchmarking will be focused on the appropriate international subsectors as well as within the region.

IE Pathway

- Technology shift: Adopting electrically powered production methods, for example by shifting from basic oxygen furnaces to electric arc furnaces or replacing low and medium-temperature coal boilers with cleaner electrical alternatives.
- Shift in process heat production: The electrification of how onsite process heat is generated, including the use of induction, radiative heating, or advanced heat pumps. Electrification should preferably be sourced from renewable energy.
- Adoption of energy storage options for onsite generation: Industries can also invest in new equipment and retrofits that enable flexible electricity consumption via intermediates like thermal storage and chemical feedstocks that enable the transition to clean electricity.
- Grid optimisation: Ensuring industrial loads predominantly consume power below median price, which can provide more available peak power for other grid users. This balancing of production and consumption preserves transmission capacity for high-grade power required for industries with lower carbon intensity. intensity.

4.4.3. Low-carbon fuels, feedstocks, and energy sources (LCFFES) - 20% contribution

Methodology: Focused on replacing fossil fuels with alternatives with fewer environmental impacts as well as developing more sustainable raw materials and energy sources with low emissions.

International Benchmarking: Countries like the Netherlands have roadmaps for transitioning to low-carbon fuels in the industrial sector.

LCFFES Pathway

- Biofuels: The use of biogas from landfills as well as sewage treatment plants for the generation of electrical and thermal energy, especially in the cement industry, must be stimulated and encouraged along with an expansion of the use of residual sludge generated in the filtration processes of sewage treatment plants.
- Low-carbon hydrogen (H2) ammonia: Integrate technologies and processes to extract H2 from ammonia. Ammonia can be decomposed (cracked) over a catalyst to produce the desired H2 along with nitrogen (N2), a non-toxic gas that does not cause a greenhouse effect. Furthermore, ammonia can be an excellent transition fuel.
- Mixture of H2 with low carbon content: Mixture of H2 with fuels used in thermal processes.
- Low carbon H2 for process and heat: Replacement of used fossil fuels with H2. This will require the inclusion of certain boiler technologies that are not yet sold in Vietnam.
- Reducing the amount of raw materials used in the manufacture of industrial materials to generate less waste per product and improve waste management. Numerous material efficiency strategies can be applied at the design, manufacturing, use ,and end-of-life stages:
  - Design stage: Optimised design; design for use, long life, and reuse;
  - Manufacturing stage: Reducing material losses and overuse in material/product manufacturing and construction;
  - Use stage: Service life extension and repair, more intensive use;
  - End of life: Remanufacturing, reuse, and recycling.
- Expanded use of recycled content: Packaging, bags, car components, furniture, building materials, paint pots, and curbs.

4.4.4. Carbon capture, utilisation, and storage (CCUS) - 20% contribution

Methodology: These involve technologies to capture carbon emissions generated during industrial processes followed by the safe use or storage of the captured carbon.

International Benchmarking: Norway and Canada have advanced CCUS technologies, seeking to significantly reduce industrial emissions.

CCUS Pathway

- CO_2 pipelines: Build the pipeline for CCUS;
- CO_2 tests: Perform pipeline tests to measure process capacity and performance;
- Direct air capture: Direct solid and liquid air capture. Solid air capture is based on solid adsorbents operating at room temperature at low pressure (i.e. under vacuum) and medium temperature (80-120 °C). Liquid air capture relies on a basic aqueous solution (such as potassium hydroxide) that releases captured CO^2 through a series of units operating at high temperature (between 300 °C and 900 °C);
- CO_2 bioconversion: Use CO^2 as fuel or integrate it into the fuel process.

4.4.5. Alternate approaches including material efficiency (ME) and negative emissions technologies (NETs) - 15% contribution

Methodology: The circular economy is viewed as an alternative economic model capable of reducing environmental, economic, and social issues stemming from the depletion of earth's natural resources. In a circular economy, resources are circulated rather than dispersed, looking to maintain the value of materials in the economy and minimising waste through strategies such as redesigning, reusing, repurposing, or recycling. Besides directly contributing to the circular economy and decarbonisation, material efficiency and recycling strategies can be applied to renewable technologies to further enhance their contribution to decarbonisation.

International Benchmarking: Many EU countries have implemented successful circular economy programmes, especially Nordic countries. However, it should be noted that implementing circular economy and negative emission technologies at the industrial level can be much more challenging than at the commercial or residential levels.

ME and NET Pathways

- Recycling of wind turbines at their end of life instead of either disposal, repurposing old electric vehicle batteries to store energy from photovoltaic (PV) panels in homes, or enhancing recovery from PV modules at end of life.
- Designing industrial equipment and products for long life, reducing weight and material losses during manufacturing and construction, lifetime extension, more intensive use, reuse and recycling;
- For the steel subsector, examples include improving product manufacturing yields and extending building lifetimes, improving building design and construction, and reusing steel;
- For the buildings sector, ME includes reduction of material demand, designing buildings for extended lifetimes through energy efficiency retrofits;
- For the cement subsector, ME includes improved material properties (i.e. reducing the cement content in concrete) to reduce overall cement demand;
- For the transport sector, vehicle weight reduction is a key emission reduction strategy as it results in reductions in both steel and fuel demand.[10]

10 This needs to be considered in light of the fact that the reduced use of some materials may cause the demand for other materials to increase; therefore, such strategies need to ensure that they still deliver overall favourable emission benefits in the value chain.

4.5. Political Options

The political options to ensure the implementation of technological pathways and achieve decarbonisation by 2050 are presented below:

1. Increase data collection on the use of highly efficient materials and technologies and their life cycle impacts to establish benchmarks and promote best practices (including best practices in production methods);
2. Improve considerations on life cycle impacts in climate regulations to promote material and technology efficient practices at the design stage;
3. Set incentives for reuse and recycling to reduce the need to produce higher-emitting primary materials and improve their integration in supply chains to facilitate these strategies;
4. Promote research and development of technologies that recover energy through subsidy programmes that encourage both companies and research institutions to invest in projects related to the development of more efficient technologies, including the adaptation of existing technologies to the Vietnamese reality as well as the development of innovations in the field of energy efficiency;
5. Define performance standards for industrial equipment and processes, which must be reviewed periodically to incorporate technological advances and best practices in energy efficiency;
6. Establish regulations that ensure furnaces and boilers must be supplied with auxiliary equipment that recovers heat, such as economisers, air preheaters, heat pumps, among others;
7. Introduce incentives and/or requirements and targets for the implementation and certification of ISO 50001 energy management systems by large energy consumers;[11]
8. Train energy managers for industry; certification would recognise professionals with solid skills in energy management with a special focus on thermal systems and decarbonisation;
9. Expand financing lines for technological innovations focused on decarbonisation under conditions that enable the implementation of projects, including the possibility of obtaining subsidies;
10. Regulate the carbon market to allow industries with demonstrably reduced emissions to be financial compensated for investments made in decarbonisation.[12]

4.6. Financial Requirements

In terms of necessary investments, an average amount of 9.3 billion USD is estimated considering the measures related to EE (0.5 billion USD), solar and wind technologies (1.1 billion USD), replacement of fuel with biofuel (2 billion USD), ME (1.1 billion USD), and CCUS (4.6 billion USD).

It should be noted that even if the funding is available, there may be other challenges to industrial enterprises in implementing energy efficiency and decarbonisation projects, depending on the terms and conditions that are offered. Therefore, it will behove the government and international partners to apply the many lessons learned to date on financing industrial decarbonisation and energy efficiency projects in order to facilitate and scale up these types of projects. For example, past experiences indicated that loan terms and conditions may result in cases where the total funding uptake can be less than the amount that was set aside.[13]

4.6.1. Methodology

Based on the information provided by the Energy Conservation Research and Development Centre (ENERTEAM)

11 Ministry of Industry and Trade (MOIT) runs a training programme, but it is not ISO 50001 accredited.

12 Planned in 2017 but now will pilot from 2025 to 2027 and be fully operational by 2028.

13 The World Bank's Vietnam EE Financing was started with an original total project budget of USD 102 million. This is so far the largest project financing industrial EE projects in VN. But only USD 53 million could be used.

on the CO_2 emissions[14] from certain industrial subsectors, including cement and steel, it was possible to estimate investment costs for the implementation of certain technologies. The emission reduction scenarios (50% reduction by 2030, 80% reduction by 2040, and 100% reduction by 2050) have been established and the technological pathway contributions have been applied (as defined in Subsection 3.4 above) to calculate the needed investment based on the abatement costs defined by the IEA[15] as reference. ME (1.1 billion USD), and CCUS (4.6 billion USD).

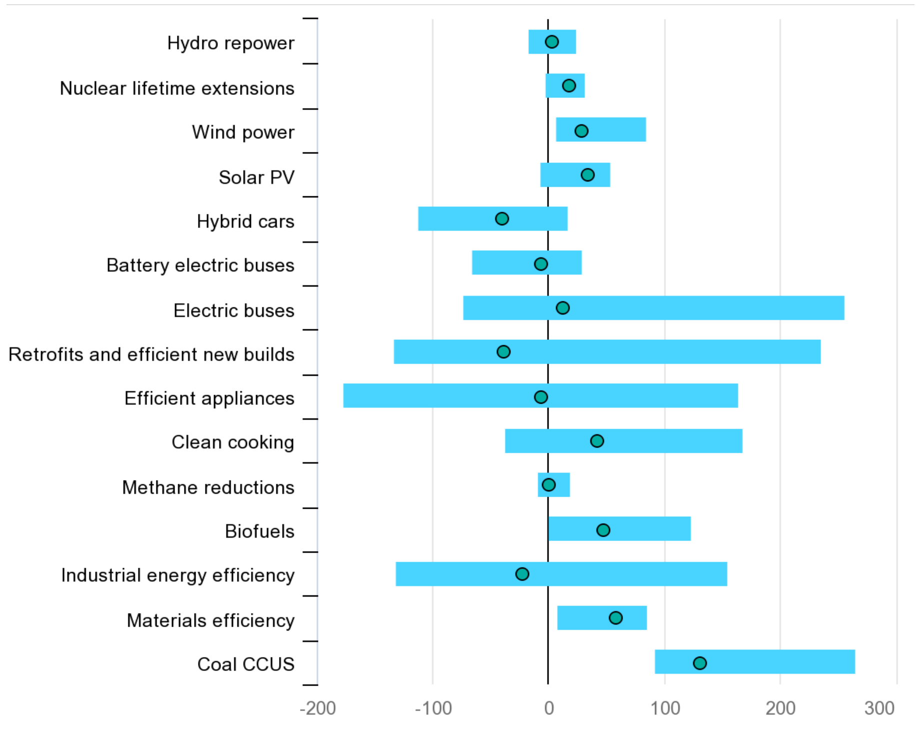

Figure 7: GHG Reduction Costs for Selected Measures - Sustainable Recovery Plan (IEA 2020)

The investment needed (see Table 2 below) for the implementation of a few technologies and measures is calculated by multiplying the CO_2 emissions of the target year by the average[16] abatement cost of specific technologies and by the implementation percentage of technological pathways: EE (25%), RE (20%), ME (15%), biofuel (20%), and CCUS (20%). We assumed that CCUS technologies will not be implemented before 2040.

Table 3. Average investment - Industry Decarbonization

Investment USD - Industry	Average Investment – Industry (millions USD)			Total (billion USD)
	2030	2040	2050	
CCUS		3,304	1,321	4,625
EE	243	97	97	437
Biofuel	1,130	452	452	2,034
ME	636	254	254	1,144
Photovoltaic solar power and wind power	623	249	249	1,121
Total	**2,631**	**4,356**	**2,374**	**9,360**

14 Report by Energy Conservation Research and Development Centre (ENERTEAM), 2023.

15 https://www.iea.org/data-and-statistics/charts/ghg-abatement-costs-for-selected-measures-of-the-sustainable-recovery-plan.

16 Instead of considering the minimum, we considered the average as the most recent abatement cost (IEA) for 2020.

5. Specific Technologies for Industrial Segments (Cement and Steel)

The technological pathways for the cement and steel subsectors are presented below.

5.1. Cement Industry

Based on the “Technical Report: Benchmarking results for cement sector”[17] and the characteristics of Vietnam’s cement industry, the following measures are recommended for each technological pathway (see Figure 8).

EE	• Thermal energy efficiency in clinker production/waste heat recovery • ISO 50001 system to control energy consumption • Technology management and production process management • Control system (process optimisation)
IE	• Electrification of key equipment such as kilns, pre-calciners and furnaces
LCFFES	• Alternative fuels including biofuel, biomass, and hydrogen • Alternative raw/binding materials (belite clinker, calcium silicates, alkali-activated binders/ geopolymers, carbide slag, etc.)
CCUS	• Post-combustion CCUS • Oxygen enrichment and oxy-fuel technology • Carbonation and carbon curing for concrete
ME/NETs	• Installation of renewable technologies (wind and solar) • Reducing the clinker-to-cement ratio • Use of clinker alternatives such as fly ash from coal-fired power plants and slag from steel-blast furnaces

Figure 8: Decarbonisation Measures in Technological Pathways for the Cement Industry in Vietnam

Energy Efficiency

The gradual replacement of obsolete units and equipment with new lines using the BATs is proposed. Process optimisation and control, heat recovery in coolers, vertical mills and waste heat recovery (WHR) equipment for generating electrical energy will play a leading role in GHG emission reductions. Furthermore, upgrading calciners and preheaters would significantly contribute to reducing heat losses.

Industrial Electrification

Kiln feed and cooler consume almost 30% of electricity consumption in cement facilities in Vietnam. The electrification of heating equipment for indirect calcination, potentially in combination with CCUS technologies, could be a strategic measure. Other electrification options can be explored such as electric pre-calciners and furnaces. These technologies, particularly if powered by renewable sources, could be highly relevant.

LCFFES

Fuel switching has large potential for decarbonisation in cement production. A shift away from fuels like petroleum coke to less carbon-intensive fuels such as natural gas and sustainable biomass can reduce emissions from industry.

CCUS

This involves the development and implementation of CCUS technologies, as of 2040, to achieve an accumulated reduction in GHG emission by 2050. Post-combustion CO_2 capture technologies can be integrated into existing cement production processes without significant alterations. Oxy-fuel technology using oxygen instead of air in cement kilns simplifies the capture process. Furthermore, captured CO_2 can be used in the concrete curing process, production of aggregates and construction materials, or other innovative processes. Moreover, combining captured CO_2 with hydrogen to produce chemicals and fuels offers a pathway to new industries and technologies.

17 Development of a pilot crediting programme applicable to the steel sector in Vietnam, 2020.

ME and NET

ME and NET strategies in the immediate term include the installation of renewable technologies such as wind and solar systems and the use of clinker substitutes such as supplementary cementitious materials, i.e. fly ash, blast furnace slag, natural pozzolans, ground limestone, and calcined clay. It is expected that measures such as the incorporation of circular economy practices may not generate noticeable impacts until 2030 or beyond.

5.2. Steel Industry

Based on recent studies and an analysis of the characteristics of Vietnam's steel industry, the following measures are recommended for each technological pathway.

EE	• Integrated steelmaking route based on blast furnace (BF) and basic oxygen furnace (BOF) • Induction furnace (IF) route uses recycled steels primarily recycled steels and direct reduced iron (DRI) on hot metal and electricity • Improved process control
IE	• Electric arc furnace (EAF) route uses primarily recycled steels and DRI or hot metal and electricity • Electrification of steam boilers
LCFFES	• Direct reduced iron (DRI) with implementation of technological options: (i) Electrolytic hydrogen instead of natural gas or coal; (ii) natural gas with high levels of hydrogen electrolytic mixture; (iii) CO_2 capture based on chemical absorption; (iv) CO_2 capture based on physical adsorption
CCUS	• Using carbon-rich steelmaking waste gas to produce basic chemicals • Smelting reduction using oxygen-rich current
ME/NETs	• Installation of renewable technologies (wind and solar) • Reuse of steel and other construction materials • Buildings lifetime extension, improving building design and construction, and lightweight vehicles

Figure 9: Decarbonisation Measures in Technological Pathways for the Steel Industry in Vietnam

Energy Efficiency

Energy efficiency technologies that are already available or will be available in the coming years include several measures to optimise blast furnace technology, such as reducing the coke rate through the injection of pulverised coal or dry quenching coke to promote heat recovery. Alternative injection materials to pulverised coal, such as hydrogen, could also be used. The use of such alternatives would reduce emissions associated with the coke process and improve the performance of conventional blast furnaces. For such technologies, the main barriers are economic. Therefore, new measures to reduce GHG emissions from energy generation/consumption will depend on public policies and additional investments.

Industrial Electrification

EAF technology inherently offers a lower carbon footprint compared to the traditional BF-BOF steelmaking route, primarily because it relies mostly on electricity that can be sourced from renewable energy. In Vietnam, there are already about 34 EAF technology units producing crude steel. After the production of crude steel using EAF, the steel undergoes various rolling and finishing processes that involve reheating furnaces as well as ladle and tundish heating. Traditionally, these processes have relied on fossil fuels and their electrification represents a viable pathway for reducing the carbon footprint of the steel industry, especially if power is supplied by renewable technologies (mostly wind and solar).

LCFFES

Use of natural gas: Government actions such as opening the natural gas market would allow for an additional contribution to GHG reductions in the order of 2.5% by reducing global energy consumption, with natural gas playing a role as a transition fuel to substitute coal and as a bridge to technologies still under development, such as hydrogen production technology. Another solution is using hydrogen to replace natural gas in the direct iron reduction stage. If the hydrogen is low carbon, the emission intensity of steel would be very low.

CCUS

Reduction of smelting by using oxygen-rich current allows energy consumption reductions in the process via blast furnaces. It also produces a more concentrated stream of CO_2, thus facilitating carbon capture. CCUS can also be used to decarbonise different steel production routes such as top-gas recycling in blast furnaces with CCUS, DRI with post-combustion CCUS, and oxygen-rich smelt reduction with CCUS. CCUS technologies vary greatly in their commercialisation status, with most of them currently at the pilot stage. The main challenges for CCUS technologies are achieving further reductions in costs and improving operational efficiencies as well as having suitable CO_2 transport systems and storage sites.

ME and NETs

For steel production, ME includes ranging from efficient steel product design, product manufacturing and use, and steel product end of life. Another important ME technology is scrap-based EAF steel production. EAF steelmaking can use a wide range of scrap types. External factors such as the implementation of the CBAM[18] will help the steel subsector to increase capacity on data capture, process improvements, and raw material inventories.

18 https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en.

6. Financial Requirements for Investment in Industrial Subsectors

In terms of the necessary investments in the cement and steel subsectors, an average of 1.4 billion USD is estimated for the cement sector and 0.6 billion USD for the steel sector for the implementation of specific technologies as per the IEA abatement cost. The distribution of average investment costs by target year and technology in the subsectors is presented in Table 3 and Table 4.

Table 4. Average Investment – Industrial Decarbonisation – Cement Subsector

Investment USD - Cement	2030	2040	2050	Total (million USD)
CCUS		189	189	377
EE	69	14	14	97
Biofuel	322	64	64	451
ME	181	36	36	254
Photovoltaic solar power and wind power	178	36	36	249
Total	**751**	**339**	**339**	**1,428**

Table 5. Average Investment – Industrial Decarbonisation – Steel Subsector

Technological Pathway	Maximum Investment – Industry (millions USD)			Total (million USD)
	2030	2040	2050	
CCUS		75	75	149
EE	27	5	5	38
Biofuel	128	26	26	179
ME	72	14	14	101
Photovoltaic solar power and wind power	70	14	14	99
Total	**297**	**134**	**134**	**566**

7. Implementation of the Preliminary Roadmap

7.1. Resources for implementing the Preliminary Roadmap

The adoption of specific policies for the development of low-carbon technologies, training of human resources to develop and implement viable decarbonisation actions in a sustainable manner, the availability of adequate financial resources in volume, and feasibility conditions are key elements to achieve mitigation targets (2030 and 2040) and the neutralisation of CO_2 emissions in Vietnamese industry (2050).

Some factors that indicate the need for training in industries include:

- Implementation of ISO 50001 Energy Management System programmes to maximise and sustain the benefits of investments and continually improve energy and carbon performance.
- Training industry and other professionals on international best practices in energy performance measurement, monitoring, verification, and reporting, including the International Performance Measurement and Verification Protocol (IPMVP).
- Specialisation in the adoption of EE actions in thermal systems (heat and cold) since the EE potential in this segment is much higher than that of the electrical segment mainly due to recent technological advances.
- Technical assistance for the development of sectoral performance indicators and specific benchmarks possibly broken down by company size. Although this initial analysis is not comprehensive, it constitutes an important step to move forward with the implementation of the Preliminary Roadmap.

In addition, the 2023 RMP for JETP also pointed out the need for comprehensive and coordinated research, development and mainstreaming of critical technologies. As a result, the RMP called for investment programs in the areas of Energy Savings and Efficiency Programs, EE and Electrification in Industrial Production, EE and Electrification in Construction Sector, as well as the establishment of a Centre of Excellence for Renewable Energy, Energy Storage, and Energy Efficiency. These investment programs/projects will go a long way towards supporting specific industrial subsectors in their emissions reduction actions with both knowledge and potential sources for funding.

7.2. Strategic Framework for the Implementation of the Preliminary Roadmap

Based on the results of the analysis carried out, the Preliminary Roadmap was developed based on a set of actions identified for short, medium, and long-term approaches for the development and implementation of measures to achieve carbon neutrality in the industrial sector by 2050.

This subsection provides information about the necessary efforts and recommendations for the implementation of the proposed action lines. A prioritisation of action lines is also proposed based on two general criteria, the level of effort involved in implementing the action lines and the timelines to achieve planned results.

7.2.1 Details on the Lines of Action and Recommendations for the Implementation of the Preliminary Roadmap

practical purposes, each one is identified by the acronym AL (Action Line) followed by its consecutive number (1, 2, 3, etc.) and preceded by the first letter of the component to which it corresponds (T = Technology; P = Policy). Certain aspects that are recommended to be considered for implementation follow below (see Table 5). The timelines are also indicated for ALs that must be implemented in the short (until 2030), medium (until 2040), and long (until 2050) terms.

It should also be noted that key initiatives such as the JETP, the development of the RMP and the level of support it has received, and the success of its measures and the level of funding they can obtain will go a long way towards making other decarbonization step possible, especially in the near term (from 2023 to 2030), as many measures to be implemented by the JETP are related or intertwined with the measures and actions identified under the various decarbonisation pillars.

Table 6. Action Lines and Recommendations for the Implementation of the Preliminary Roadmap

Component	Timeline	Action Line	Recommendations
Technology	Short-term	TAL 1: High-efficient equipment.	Conduct an assessment in each industrial subsector to determine the number of old and inefficient equipment. Develop an action plan to replace such equipment with high-efficiency products whose characteristics are aligned with international standards.
	Short-term	TAL 2: Alternative fuels.	Based on alternative fuels already produced in the country and estimate their potential to be used in industry for specific processes.
	Short-term	TAL 3: Process to reduce the use of primary materials.	Carry out a life cycle assessment of the most energy consuming industrial segments and determine the actions to be taken to minimise the use of primary materials.
	Short-term	TAL 4: Energy management and system optimisation.	Introduce incentives and/or requirements for the implementation and certification of energy management systems.
	Short-term	TAL 5: Industrial Decarbonisation Professional Workforce.	Strengthen the capacity of industrial professionals to adopt decarbonisation measures and efficient management systems (ISO 5001, IPMVP, etc.).
	Medium-term	TAL 6: Renewable technologies.	Determine the electricity generation needs from renewable technologies. Develop an action plan for installing new technologies.
	Medium-term	TAL 7: Low carbon hydrogen plants and pilot projects.	Identify opportunities in industrial subsectors to install low-carbon hydrogen plants and select facilities to develop pilot projects.
	Long-term	TAL 8: CCUS plants and pilot projects.	Identify opportunities in industrial segments to install CCUS systems and select facilities to develop pilot projects.
Policy	Short-term	PAL 1: Development and update of standards for industrial equipment.	Based on the best international/regional standards and practices, define standards and certification of energy efficient and sustainable industrial equipment.
	Short-term	PAL 2: Develop a specific roadmap for each industrial subsector.	Each industrial subsector must have its own roadmap. An assessment of each subsector may be necessary to determine specific actions and identify facilities that need to be prioritised to meet national and international commitments.
	Medium-term	PAL 3: Create a national incentive programme for the purchase of equipment to increase EE in industries and the installation of new renewable technologies.	Determine the actions to be implemented in national programmes through a consultation process with key stakeholders and identify financing and human resource needs to implement the programme. The programme should include a replacement strategy to determine the timeline and investments for replacing old and inefficient equipment.
	Medium-term	PAL 4: Disseminate and support the adoption of ISO 50001 (Energy Management System) by industries as a way of transforming the EE culture in companies.	Organise an awareness campaign aimed at industry with the involvement of financial institutions involved in financing mechanisms for the decarbonisation of industry. Through a national industry survey, determine the capacity needs of industrial companies and define a training programme.
	Medium-term	PAL 5: Create an individual target for EE and energy efficiency credits (compensation between those who achieve targets and those who do not achieve targets).	Build on international experience and, through a consultation process with industry representatives, define EE targets. Develop a monitoring and verification system to assess industry's progress in meeting EE targets and establish a pyramid of penalties for non-compliance.
	Long-term	PAL 6: Explore the opportunity to establish a Super ESCO or a similar financial mechanism to ensure the decarbonisation of industry.	The Super ESCO model could serve to accelerate the operationalisation of national ESCOs and ensure the implementation of highly efficient projects in industry.

7.2.2. Schedule for Preliminary Roadmap Implementation

Finally and with the aim of completing the strategic approach proposed for the implementation of the Preliminary Roadmap, below is a proposed execution sequence for the identified and proposed action lines along with suggested deadlines to successfully achieve the development and the implementation of the Preliminary Roadmap (see Figure 10). Note that it will be necessary to coordinate the activities in this schedule with other key initiatives that are planned or underway, including those that have been identified by the 2023 RMP for JETP, which will result in significant impacts to 2030.

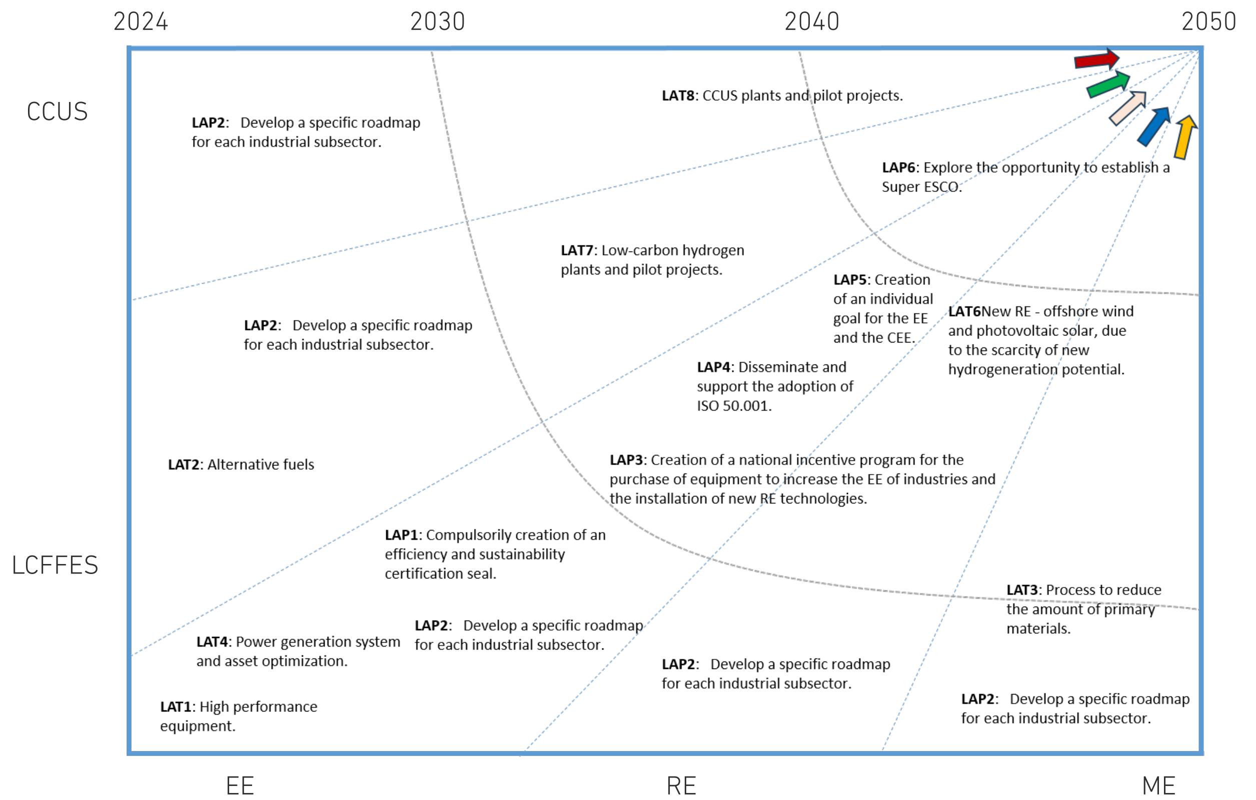

Figure 10. Timeline for Implementing the Preliminary Roadmap

8. Conclusions

In addition to offering suggestions for technical and policy actions, the Preliminary Roadmap points out the next steps to be followed. This strategic direction is essential to ensure that the proposals presented are not limited to the initiatives and industrial segments initially addressed but are integrated into a broader development and implementation process, which includes other industrial segments, such as the food and beverage and textile subsectors. The partnership with the United Nations Industrial Development Organization (UNIDO), an institution recognized internationally as an entity dedicated to sustainable industrial advancement and the promotion of partnerships between public and private sectors to achieve common objectives, offers a significant advantage by providing technical expertise, resources and a global perspective.

Subsequent project design should be a participatory process, involving ongoing consultations with relevant stakeholders, including representatives from the private sector, academics, non-governmental organizations and other key actors. This inclusive approach ensures that the project is shaped by a variety of perspectives, making it more robust, adaptable and acceptable to all involved.

By clearly indicating these next steps, the Preliminary Roadmap not only provides a strategic vision, but also establishes a tangible path towards practical implementation of the proposals presented. This action-oriented approach is crucial to transform recommendations into tangible results, such as detailed advice for each industrial subsector.

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