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WORLD ECONOMIC FORUM

Transitioning Industrial Clusters towards Net Zero: National Policy Enablement for Industrial Decarbonization – Part II

WHITE PAPER

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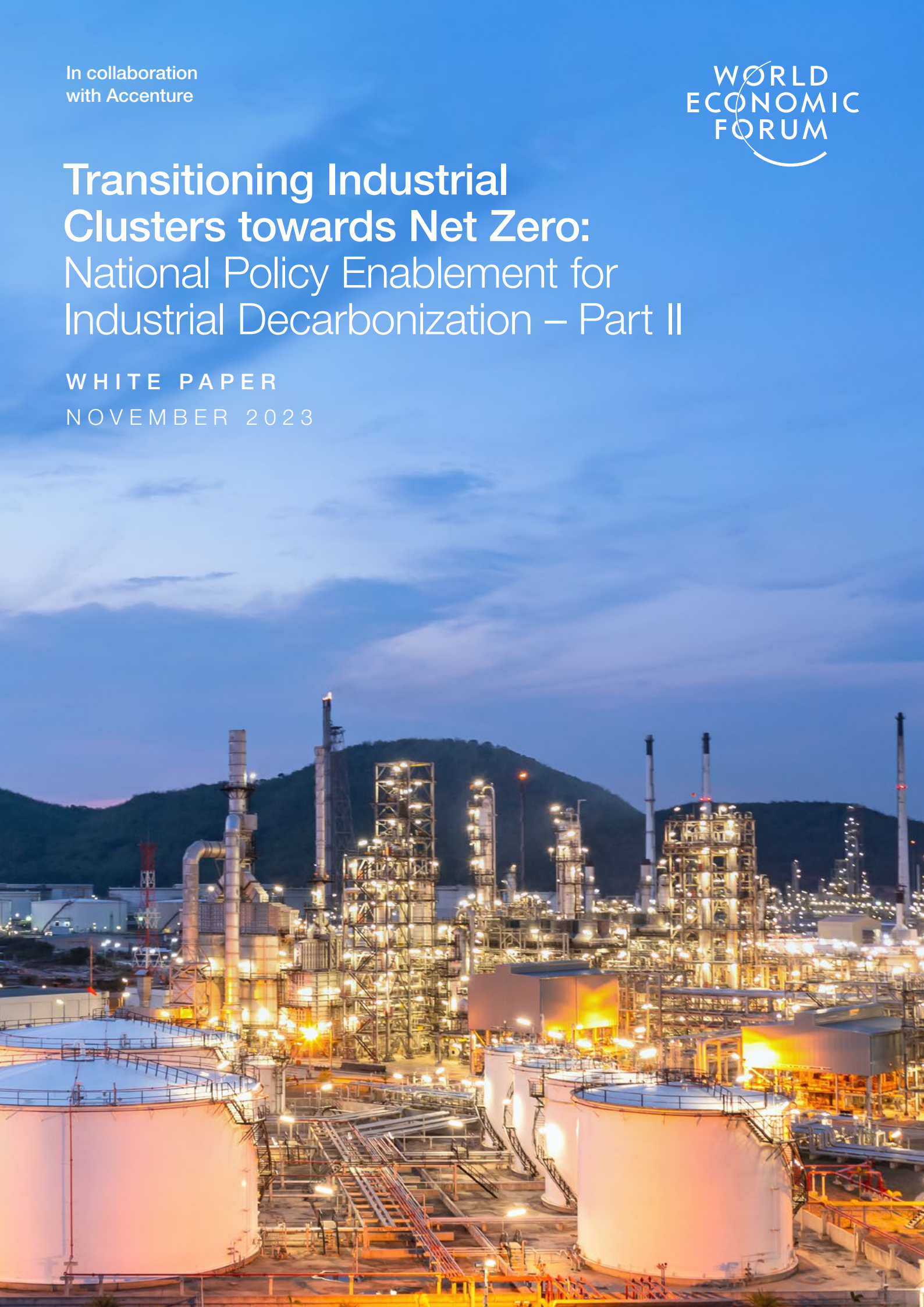

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Contents

Foreword

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We understand the importance of decarbonization of industrial clusters in achieving net zero and the crucial role that regulators and policy-makers play. Public-private collaboration has reached all-time highs as technology and policy innovation have enabled more robust and accelerated growth in green solutions for industry.

As the Transitioning Industrial Clusters towards Net Zero initiative expands into new geographies, we have developed additional comprehensive analyses of the strategies and actions employed by multiple federal governments to propel industrial decarbonization. This analysis complements our first publication, *Transitioning Industrial Clusters towards Net Zero: National Policy Enablement for Industrial Decarbonization*, by providing a nuanced and concise overview of an additional 10 countries, including our first countries from the Middle East and Africa.

This paper will provide a deep dive into the contextual reasoning behind the industrial cluster approach for decarbonization, which has seen increasing adoption by policy-makers globally. The analysis supports our initiative community of 20 industrial clusters, covering 11 countries across four continents, with a cumulative carbon emissions reduction or abatement potential of 626 million tonnes.

Thank you to all of those participating in research and policy analyses for their time and contributions to this paper.

Executive summary

Strong collaboration in partnerships is necessary to navigate the complex themes for industrial clusters decarbonization.

Industrial clusters have become a focal point for governments worldwide, leading to a rise in initiatives to tackle industrial carbon emissions. Government commitment and institutional alignment serve as key enablers for accelerating action.

It is observed that EU policies, such as the Carbon Border Adjustment Mechanism (CBAM), have a strong influence on industrial decarbonization in other nations including the United Arab Emirates, Brazil and South Africa. Among countries in Asia, Japan and India are leading in terms of policy frameworks for hydrogen. Meanwhile, in emerging economies, policy frameworks for carbon capture, utilization and storage (CCUS) are still in the early stages of development. With the diversity in policy emphasis, it is critical to note the importance of the local context in each country's transition journey and to read this paper with due respect and consideration of this dimension.

This paper reviews the legislated policies driving industrial decarbonization in a selection of ten nations across the Americas, Europe, Asia-Pacific, Middle East and Africa, as well as the enabling mechanisms to promote a collaborative, market-oriented industrial clusters approach. Across these policies, analysis has shown the following:

1. There is a noticeable trend towards promoting the adoption of renewable energy sources. Governments are implementing diverse strategies, setting multiple goals for various renewable energy sources such as green hydrogen, solar, wind and biofuels. For a number of countries, including Japan, India, Malaysia and South Africa, this approach aims to ensure a comprehensive and balanced transition towards cleaner and more sustainable energy solutions, with observed emphasis on enhancing energy security and access.

2. The prioritization of renewables is also reflected in the portion of funding or financial incentives allocated, which in many countries is significantly higher than the allocation for other solutions such as energy efficiency, hydrogen and CCUS.

3. Broad sets of fiscal incentives are in use, including grants, subsidies, guarantees, tax incentives, as well as multilateral aid funding.

4. **In the near term**, the decarbonization of industries is driven primarily by the switching of energy sources to renewables in parallel with the electrification of industrial heating, **supported by a range of government subsidies, schemes, projects, grants and tax incentives**. Significant budgets are allocated towards **increasing the proportion of clean energy in primary energy production** through direct government initiatives or by providing incentives to encourage private sector participation.

5. A significant number of nations have embarked on **the development of CCUS projects, as well as the conversion and use of blue and green hydrogen**. These initiatives are fuelled by the collective efforts of both the private and public sectors, which collaborate through partnerships or take individual leadership roles in driving these projects forward.

6. Nations are adopting a comprehensive approach by implementing initiatives to **reduce emissions effectively, accelerate the adoption of electrification and clean energy, and enhance energy efficiency**. They are tailoring their policies and initiatives to make use of their unique geographical and economic advantages, enabling them to pursue individualized approaches in harnessing these benefits.

7. The potential of carbon pricing is gaining prominence in emerging markets, with three South-East Asian countries announcing plans for carbon tax mechanisms. Challenges to implementation are concerns around the economic impact of carbon pricing, e.g. reduced competitiveness and high energy costs.

TABLE 1 | National investment in key decarbonization technologies

Nation	Hydrogen	Carbon capture, utilization and storage (CCUS)	Systemic efficiency and circularity	Direct electrification and renewable heat
	Federal funding and support measures (inclusive of multilateral funding)			
Brazil	Exploring	Exploring	Exploring	Investing
Sweden	Seeding	Investing	Exploring	None[1]
Portugal	Seeding	None	Seeding	Exploring
Brunei Darussalam	None[2]	None[3]	None[4]	Ambition stated
Thailand	Ambition stated	Seeding	Exploring	Exploring
Malaysia	Ambition stated	Investing	Investing	Investing
India	Investing	Ambition stated	Investing	Investing
Japan	Investing	Investing	Seeding	Investing
United Arab Emirates	Investing	Investing	Investing	Investing
South Africa	Seeding[5]	None	Exploring[5]	Investing[5]

Notes: 1) State support is not required in Sweden as this has been long-established with a mature and competitive market; **2)** In September 2023, the Department of Energy published a study on green hydrogen production in Brunei; **3)** Brunei Shell Petroleum, a joint venture between Shell (50%) and the Brunei Government (50%) is exploring potential CCUS solutions in Brunei Darussalam; **4)** In 2022, an MoU was signed between Bank Islam Brunei Darussalam (BIBD) and Brunei Darussalam National Council on Climate Change (BNCCC) to collaborate in climate solutions including investment in energy conservation; **5)** Inclusive of multilateral funding from JETP.

TABLE 2 | Recognition of the importance of carbon pricing

Nation	Emissions trading scheme	Carbon tax
Brazil	None at present	None at present
Sweden	EU Emissions Trading System (EU ETS)	Yes, carbon tax applicable for non-ETS sectors inclusive of industry and households and has been progressively increasing since its introduction in 1991. Current tax rate is €122 per tonne as of 2023.
Portugal	EU ETS	Carbon tax for the aviation sector, applicable to commercial flights and business flights, in force July 2023; tax rate of €2 per passenger.
Brunei Darussalam	None at present; the country's National Climate Change Policy sees carbon pricing as a key lever contributing to a carbon reduction of 46%. Plans to introduce carbon pricing by 2025.	None
Thailand	Voluntary Carbon Market	Studying the introduction of carbon tax to energy, transport and industrial sectors (covering over 90% of Thailand's emissions).
Malaysia	Voluntary Carbon Market	Announced plans for carbon tax.
India	None	Good and Services Compensation Cess (on coal production), superseding the Clean Energy Cess. Tax rate of $5 per tonne (400 Indian rupee per tonne) of coal production.
Japan	ETS planned; voluntary cap and trade in Tokyo Metropolitan City and Saitama Prefecture.	Tax for climate change mitigation (TCCM) in place since 2012, reforms/ revisions announced on hold due to rising energy prices in 2023. TCCM tax rate of about $2 per tonne (289 Japanese yen per tonne).
United Arab Emirates	Carbon credits trading desk planned (credits from ADNOC carbon mitigation projects, to be available as offsets to lower carbon footprint of exports to EU).	None
South Africa	None	Carbon tax introduced June 2019; emission allowances (basic tax-free allowance covering 60-75% of emissions, plus additional offsets and allowances) until 2025 to ease the transition has led to low effective tax rate.

The Transitioning Industrial Clusters towards Net Zero initiative

Catalysing the decarbonization of industrial clusters globally.

The Transitioning Industrial Clusters towards Net Zero initiative is led by the World Economic Forum in collaboration with Accenture and the Electric Power Research Institute (EPRI). The initiative aims to convene and accelerate co-located industries on their net-zero transition, making use of opportunities for collaborative investment de-risking, clean energy market creation and cluster-based decarbonization.

The initiative convenes industrial players at all stages of ambition development in an impartial forum to collaboratively shape strategies and share lessons learned. In parallel, the initiative continues to develop thought leadership and incubate best practices for the signatory clusters community. This policy analysis will be complemented by a financing deep dive for industrial clusters in Europe and selected emerging economies.

The initiative's 20 signatory clusters are distributed across 11 countries and continue to expand to new geographies, including India (with the support of Bain & Company) and China.

Scope of work and research approach

This second edition includes a fourth geography with the inclusion of Africa. Nations selected for review within these geographies were driven both by the interest of the Transitioning Industrial Clusters towards Net Zero community and expansion plans for the initiative.

This paper was developed through a thorough review of national and collaboration-of-nations legislation and other federal public documentation. Further, in a subset of geographies, local experts were interviewed, or additional desktop research was completed to understand the partnership, policy, finance and technology strategies of "flagship" industrial clusters.

A summary of both this policy review and flagship industrial cluster profiling is presented herein.

1 Americas

1.1 Brazil

Industry contributes 34.6% of total primary energy consumption; major industrials face the challenge of meeting 2050 neutrality targets.

Renewable energies account for 48% of the primary energy demand in Brazil, yet the country remains among the top five global carbon emitters, accounting for more than 3% of global emissions in 2020.[1] Most of its emissions (46% in 2020) are related to land use change, especially deforestation of tropical forests.[2]

Brazil has committed to carbon neutrality by 2050. However, several states and cities, such as São Paulo and Rio de Janeiro, have published even more ambitious emission reduction targets, mainly associated with the energy transition. Large industrial companies continue to make progress towards decarbonization, both through published commitments to reduction targets and through the development of innovative sustainability projects, which are estimated to create 2 million jobs by 2030.

FIGURE 1 **Industrial cluster challenges and opportunities in Brazil**

61 Mt CO_2*

60% of industrial emissions are concentrated in iron, steel and cement processes

*Million tonnes of carbon dioxide

43%

Reduction required in greenhouse gas (GHG) emissions (from 2005 levels) by 2030 to stay on track for net zero by 2050

2 million

Estimated net increase of Brazilian jobs by 2030 from transitioning to a greener economy

Sources: Observatório Do Clima, Empresa de Pesquisa Energética (EPE); World Resources Institute.

Brazil's approach to industrial decarbonization

Brazil's clean energy policy development

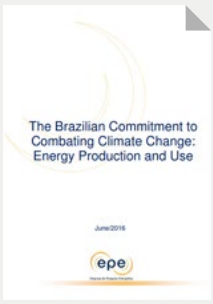
Although Brazil does not have enabling policies specific to industrial clusters, there are a host of public sector initiatives that catalyse and support clean energy and industrial decarbonization investments. Beginning with 2010's *National Plan on Climate Change*, which created the first commitments to reduce emissions and deforestation, Brazil has developed a quantified, time-bound decarbonization pathway and continues to show progress and additional investment in scaling the technologies, relationships and financing availability that will enable it.

FIGURE 2 **Brazil policy empowering industrial decarbonization**

gov.br

National Plan on Climate Change
November 2010

Plan for Low Carbon Economy in Industry
June 2013



The Brazilian Commitment to Combating Climate Change: Energy Production and Use
June 2016

Renovabio: National Policy for Biofuels
December 2017

National Guidelines for Climate Neutrality
February 2022

National Program Zero Methane
March 2022

National Guidelines for Climate Neutrality[3]

This landmark publication from Brazil's Ministry of the Environment lays the foundation for an operational strategy by which Brazil can achieve net zero by 2050. The publication, segmented by responsibility and sector opportunities, lays out a comprehensive series of goals and enablers, including those highlighted below. The guidelines envision implementation would be advanced by the whole of the country, including state, municipalities and civil society.

Energy generation

- Achieve 50% renewable energies in the composition of the energy matrix and 10% efficiency gains in the electric sector by 2030.
- Promote the use of energy from waste, including solid urban waste.

Heavy industry

- Provision for direct financial support for research, development and innovation of low-carbon technologies.
- Promote the mitigation of the oil and gas industry's carbon emissions through the adoption of more energy-efficient technologies in production units, including direct electrification.

National Programme Zero Methane

The 2022 *National Programme Zero Methane*[4] from the Ministry of the Environment aims to reduce methane emissions by 30% by 2030 (from 2020 levels), which Brazil committed to with over 100 other nations at COP26. The programme proposes to reduce methane emissions by encouraging the consumption of biomethane and financing the construction of biodigesters and distribution infrastructure.

FIGURE 3 | **Brazil's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	Carbon capture, utilization and storage (CCUS)	Hydrogen
– Brazil aims to increase electrical efficiency by 10% by 2030, equivalent to 105 terrawatt hours (TWh). – The *National Programme Zero Methane* aims to reduce methane emissions by encouraging the consumption of biomethane from waste and financing the construction of biodigesters and distribution infrastructure. – By 2024, the aim is to eliminate dumpsites in the country and shift towards enhanced waste management practices that prioritize energy efficiency and environmentally-friendly disposal methods.	– *The Brazilian Commitment to Combating Climate Change* plans an increase of the share of electricity in final energy consumption from 17.2% in 2014 to 19.7% in 2030 by using the increase in investment into the electricity sector, which is expected to reach $9 billion by 2029. – The same document plans an increase of the share of vehicles with electric propulsion to 1.7% in 2025 and 4.5% by 2030.	– Brazil has announced plans to reforest 12 million hectares of degraded areas by 2030, the initiative will include planting 73 million trees in hopes in restoring carbon-capture forests and prevent reaching an ecological tipping point. – The Conselho Nacional de Política Energética (CNPE) has developed Programa Combustível do Futuro to help facilitate the use of carbon capture and storage (CCS) technology associated with the production of biofuels.	– The Brazilian government launched the National Hydrogen Program, with the objective to develop the hydrogen sector in Brazil and increase its competitiveness in the global renewable energy market. – Brazilian Program Fuel of the Future intends to support R&D projects related to green hydrogen by enabling inter-ministerial collaboration through the Fuel of the Future Technical Committee (CT-CF). – In 2022, Fuel of the Future launched a BRL 50 million (Brazilian real) public bid to fund and support sustainable fuel projects from companies and universities.

Sources: Swedish Energy Agency, 2021; Secretaria de Qualidade Ambiental; Ministério do Meio Ambiente, 2022; Vander Velde, Bruno, "'Audacious' reforestation effort grows in Brazil", *Conservation*, 2023, https://www.conservation.org/blog/audacious-reforestation-effort-grows-in-brazil; EPE, 2021; Programa Nacional do Hidrogênio, 2021; Machado, Nayara, *EPBR*, 2022.

Green Hydrogen Hub in Pecém-Ceará

FIGURE 4 | **Concept of Green Hydrogen Hub in Pecém-Ceará**

Source: "Pecém Industrial and Port Complex Presents its Green Hydrogen HUB at the Hydrogen Americas Summit 2022", *Hydrogen Central*, 10 October 2022, https://hydrogen-central.com/pecem-industrial-port-complex-presents-green-hydrogen-hub-hydrogen-americas-summit-2022/.

Key industries:
Renewables, hydrogen, port and logistics

The hub comprises the Port of Pecém and an industrial area totalling over 19,000 hectares (ha), which has the capacity to produce up to 1.3 million tonnes of green hydrogen per year by 2030. The hub has a focus on export to European markets via the Port of Rotterdam as a green hydrogen receiving hub, in addition to potential opportunities to supply domestic end-use and support industrial decarbonization in the region, e.g. steel and cement plants in adjacent industrial areas.

Highlighted emissions reduction initiative

The hub, a joint venture between the Ceará State Government and the Port of Rotterdam, has secured 22 memorandums of understanding (MOUs) for the production and export of green hydrogen, of which two involving AES and Fortescue Future Industries have evolved into pre-contracts. Among the companies who have signed the MOU with Pecém Hub include Engie, TotalEnergies and Neoenergia, Iberdrola's Brazilian subsidiary.

The hub highlights the value of partnerships between corporates and is an example of cross-border collaboration to deliver new infrastructure necessary for industrial decarbonization.

2 Europe

2.1 Sweden

Sweden's decarbonization efforts will focus on the industrial and transport sectors to meet 2045 goals.

Sweden's electricity and heating sector is predominantly fossil-free, given the country's early adoption of carbon-neutral resources. As a result, the focus for decarbonization now rests on the industry and transport sectors.

In 2020, Sweden launched an ambitious target of becoming a "fossil-free welfare state by 2045", targeting net-zero emissions for the entire economy. For its industrial sector, representing about 40%[5] of total final energy consumption and about 30%[6] of total CO_2 emissions, the target is to have negative emissions by 2045. This would entail a reduction of more than 16 Mt CO_2. Twenty-two industries have already provided roadmaps for going fossil-free or climate-neutral by 2045 via electrification, biofuels, circularity and energy efficiency measures.[7]

The development of the fossil-free roadmaps was overseen by Fossil Free Sweden, a government initiative led by a national coordinator, facilitating a bottom-up sector-led effort, mostly through industry associations. This spotlights the importance of industrial associations and their role in facilitating a highly collaborative approach towards the development of sector decarbonization roadmaps.

Existing industrial clusters provide an established ecosystem for expanding the scope of industrial symbiosis and support economic value creation. For instance, increased integration of the energy system between industrial facilities within the Stenungsund industrial cluster alone could represent cost savings of approximately SEK 200 million (Swedish krona) (around €17.7 million).[8]

FIGURE 5 **Industrial cluster challenges and opportunities in Sweden**

NET ZERO BY
2045
Primarily through an 85% reduction in emissions from 1990 levels: the industry is targeting negative CO_2 emissions after 2045

60%
Potential reduction in emissions from steel, chemical and cement industries in Sweden through efficiency and circularity of materials and energy

~10 Mt CO_2
Emissions from industry that can be reduced through electrification, use of hydrogen and CCS

Sources: Statistics Sweden, Industrial transition programme, Circular Economy Strategy, Industrielle Kologi; Government Offices of Sweden, 2021.

Sweden's approach to industrial decarbonization

Sweden's clean energy policy development

The oil crisis of the 1970s led Sweden to adopt less carbon-intensive sources in its power sector. Biomass is the main mode of decarbonization in the heating and industry sectors due to the prevalence of district heating networks and abundant access to biomass from forestry. At the Stockholm+50 meeting in June 2022, Sweden reinforced its commitment and focus on decarbonization.

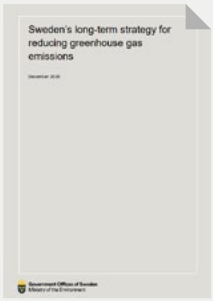
Industrial clusters present sizeable economic and decarbonization opportunities in Sweden to achieve national targets, primarily through expanding the scope of industrial symbiosis within established ecosystems. Energy-intensive industries such as steel, cement and concrete have identified electrification as one of the key means of achieving carbon neutrality in their respective industry roadmaps.

FIGURE 6 **Sweden policy empowering industrial decarbonization**

Regeringskansliet

Sweden climate policy framework
June 2017

Industriklivet "Industrial Leap"
January 2018



Sweden's long-term strategy for reducing greenhouse gas emissions
December 2020

Strategy for fossil free competitiveness
June 2020

Circular Economy Strategy
July 2020

Industry climate and energy transition
March 2021

Industriklivet "Industrial Leap", 2018

The "Industrial Leap"[9] made available a total of €80.6 million in 2022, and projects that run until 2029 can be funded. These funds support feasibility studies, research, pilot and demonstration projects and investments to reduce GHG emissions, contribute to permanent negative emissions and influence other sectors of society to achieve the 2045 climate neutrality goals. Supported areas of exploration include improving the efficiency of industrial processes, negative emissions and "strategically important" industrial initiatives focused on new low-emissions technologies with applications outside of heavy industry. This policy is part of the European Recovery and Resilience Facility as well as the NextGenerationEU transformation programme. It is set to support Sweden's alignment with national and European net-zero targets.

Strategy for fossil free competitiveness, 2020

This policy outlines roadmaps for 22 industries to transition to fossil-free or climate-neutral operations by 2045.[10] It sets ambitious targets for industrial clusters, including for the heating sector to become fossil-free by 2030 and the goal of generating 3 gigawatts (GW) of electrolysis-powered hydrogen by 2030, with a subsequent target of 8GW by 2045. Many proposed initiatives by Fossil Free Sweden need to be implemented before the European Hydrogen Backbone infrastructure reaches Sweden by 2030.

FIGURE 7 | **Sweden's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– A *Circular Economy Strategy* has been released for Sweden, aiming to transform production, consumption and business models towards circular practices.	– Only 2% of Sweden's electricity mix comes from fossil fuels, with most of the electricity generated by hydropower and nuclear power and a recent growth in merchant wind power. There is also a growing number of electricity transmission networks to neighbouring countries with a renewable-dominated power sector. – Since 2002, residual heat and waste have been used as fuels together with biomass for heat sources, in district heating networks as well as industry.	– Swedish Energy Agency designated a National Centre for CCS in December 2020, responsible for planning and promoting CCS in Sweden. – Agency actively negotiating bilateral storage agreements to export carbon dioxide without violating the London Protocol.	– Sweden's National Hydrogen Strategy, released in August 2021, highlights the potential reduction of 7.1 million tonnes of CO_2e per year in direct emissions by 2045 through current hydrogen projects in the country. – HYBRIT is a collaborative project between LKAB, SSAB, and Vattenfall, aiming to produce fossil-free steel using hydrogen. The project received a grant of €143 million from the European Union's Innovation Fund in 2021. – H2 Green Steel is a pilot plant that utilizes hydrogen as a reducing agent for steel production. As a private venture, it successfully raised €260 million in Series B equity funding in October 2022.

Sources: Swedish Strategy for Circular Economy, 2020; National Centre for CCS; Fossilfritt Sverige; HYBRIT; H2 Green Steel, 2022.

INDUSTRIAL CLUSTER SPOTLIGHT

Industry Park of Sweden

Key industries:
Electricity, natural gas, ammonia, water

Industry Park of Sweden (IPOS)[11] is a long-standing example of industrial symbiosis in Sweden, demonstrating the value to the site and nearby city through the circularity of materials and energy.

Chemical businesses have been operating on the site since 1872. Waste heat from the sulphuric acid plant was used for the district heat network of Helsingborg city as early as 1974 and eel farming in 1982.

IPOS estimates annual avoided emissions of 120,000 tonnes of CO_2 for the cluster itself, in addition to avoided emissions of 1,600,000 tonnes of CO_2 for the nearby city of Helsingborg. In 2016, IPOS was awarded the EU Sustainable Energy Award.

Highlighted emissions reduction initiative

Six-hundred-gigawatt hours (GWh) equivalent of excess heat is sent from the sulphuric acid plant to the energy centre. The plant alone accounts for 90% of the excess heat sent to the energy centre that provides all heating needed in IPOS, as well as around 35% of the heating needs of the city of Helsingborg. The Energy Central also produces 50GWh of electricity per year, which is used by IPOS and accounts for approximately 30% of electricity demand.

2.2 Portugal

The Portuguese industrial sector is rapidly moving forward to reduce its emissions by 30% to achieve GHG emissions targets by 2030.

The latest data from the Portuguese Environment Agency show that Portugal is meeting its progressive reduction targets for GHG emissions. GHG emissions without land use, land-use change and forestry (LULUCF) totalled around 56.5 Mt CO_2 equivalent (Mt CO_2e) in 2021, 2.8% less than the previous year and 34.8% less than in 2005.[12]

Portugal has made significant progress in its net-zero ambitions, driven by government funding in green hydrogen initiatives and decarbonization of the industrial sector. The government sees industrial clusters as an opportunity to scale up renewable gas and has allocated capital to support the development of these projects. With access to European funding to further increase from 2025, Portugal should see its *Portuguese Recovery and Resilience Plan* pay off in its support for renewable gas production and decarbonization. The government plans to allocate €185 million towards green hydrogen production and €715 million towards decarbonization of industry from 2021-2029.[13] Efforts to decarbonize industry and move towards a more sustainable future will drive significant economic and environmental impact as renewable energies are projected by 2050 to meet emissions neutrality goals.

FIGURE 8 **Industrial cluster challenges and opportunities in Portugal**

35-40%
The industrial sector must reduce emissions by 35-40% to achieve the overall GHG target for 2030

65%
Energy dependency from other nations should be limited to 65% by 2030, notably down from the 74% registered in 2019

€185 million
Funds allocated to the production of green hydrogen for the years 2021-2029

Sources: República Portuguesa, 2019; Portugal Energia; International Energy Agency (IEA), 2021.

Portugal's approach to industrial decarbonization

Portugal's clean energy policy development

The Portuguese government has aligned with the Paris Agreement and embraced ambitious European emissions reduction goals, taking proactive steps to make catalysing funding accessible in the marketplace. There are no national funding mechanisms for carbon capture investments yet, but increasing support for hydrogen, renewable gas and industrial decarbonization has been provided by the *National Energy and Climate Plan* (PNEC), with financial support through the *Portuguese Recovery and Resilience Plan*.

FIGURE 9 | **Portugal policy empowering industrial decarbonization**

Roadmap for Carbon Neutrality 2050 (RNC2050)
June 2019

National Energy and Climate Plan 2021-2030 (PNEC 2030)
December 2019

National Strategy for Hydrogen
August 2020

Portuguese Recovery and Resilience Plan
April 2021

Portugal 2030
November 2021

***Portuguese Recovery and Resilience Plan* (PRRP)**

The *Portuguese Recovery and Resilience Plan* (PRRP)[14] is a nationwide programme until 2026 that will implement a set of reforms and investments (€16.6 billion), allowing the country to resume sustained economic growth. The PRRP highlights the investment of €3.06 billion in energy transition, with €370 million in hydrogen and renewables, of which €185 million are allocated to hydrogen and renewable gases, and €715 million in industry decarbonization. The PRRP execution is under way, with 10% of the funds committed to energy transition already having been distributed.

Selected technology demonstration projects to be funded within the hydrogen and renewable gases allocation include electrolysis, thermochemical/ hydrothermal, biogas enrichment and methanation. Further to hydrogen market maturity, a target of 264 megawatts (MW) in renewable gas production capacity was defined.

FIGURE 10 | **Portugal's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– A fund of €715 million is being launched through the PRRP (component 11) to promote systemic efficiency, electrification and adaptation of industrial equipment to hydrogen. – The funds, allocated from 2021 to 2025, will be distributed based on projects' GHG reduction capacity. They will be equally allocated among small, medium and large projects (more than €25 million), with grants capped at €10 million. – Industry decarbonization will be supported by funds from Portugal 2030, which will become available once PRRP funds are exhausted.	– The PNEC 2030 sets a goal for 47% of the total share of the energy system to be renewable generation by 2030. – The PNEC 2030 emphasizes the need for electrifying buildings, transport and industry.	– National financing mechanisms in Portugal do not currently support investments in carbon capture and government roadmaps at present do not include industrial carbon capture solutions.	– €185 million will be invested through 2025 in projects focused on the development and testing of new technologies such as electrolysis, thermochemical and hydrothermal processes, biological processes, biogas enrichment from anaerobic digestion of biomass materials (excluding biogas production), and methanation. – Grants for these projects are capped at €15 million.

Sources: República Portuguesa, 2021; Recuperar Portugal; IEA, 2022.

3 Asia and Oceania

3.1 Brunei Darussalam

Industrial processes are the second largest contributor to Brunei's emissions in 2020, which is heavily represented by the oil and gas sector.

As part of its *National Climate Change Policy*, Brunei has committed to a 50% emissions reduction by 2035 and has announced a net-zero target by 2050.[15] About 35% of Brunei's total 2020 emissions can be directly attributed to industrial processes (largely cement manufacturing and natural gas processing) and 39% of total 2020 emissions arising from power generation are largely due to industrial sector operations.[16]

The oil and gas industry is a major contributor to the country's exports of goods and services, accounting for about 60.5% of total gross domestic product (GDP) in the last 10 years.[17]

FIGURE 11 **Industrial cluster challenges and opportunities in Brunei**

99%
Share of electricity generation from natural gas in 2019 (~1% from oil, less than ~0.5% from solar)

30%
Target power generation proportion from renewables by 2035, to be primarily fulfilled by solar photovoltaics (PV)

25%
Annual savings in natural gas consumption via power generation at full solar capacity (900MW)

Sources: International Energy Agency (IEA); Reuters; Accenture.

Brunei's approach to industrial decarbonization

Brunei's clean energy policy development

To meet the nation's 50% emissions reduction by 2035 goal, Brunei has put forward supporting legislation to rapidly increase the uptake of solar installations and energy efficiency improvements across the nation's industrial sectors. From the launch of the *Energy White Paper* to the Sustainable Energy Division's Guidebook on *Solar PV Rooftop and Net Metering Programme*, or Protokol Hijau creating guidelines for reforestation, proper waste disposal and efficient energy usage; the nation is continuing to track forward with the support of the Association of Southeast Asian Nations (ASEAN) neighbours.

FIGURE 12 **Brunei policy empowering industrial decarbonization**

Energy White Paper
2014

Brunei Darussalam's Second National Communication
2017

Nationally Determined Contribution
2020

National Climate Change Policy
2020

Protokol Hijau
2021

Standard and Labelling Order
2021

Solar PV Rooftop and Net-metering Programme
2022

National Climate Change Policy, 2020

The Brunei Darussalam National Council on Climate Change (BNCCC), and Brunei Climate Change Secretariat (BNCCS) launched the nation's first climate change policy, the *Brunei Darussalam National Climate Change Policy* (BNCCP),[18] on 25 July 2020. The policy is guided by the principles of achieving Wawasan Brunei 2035 and promoting Brunei Darussalam's economic security, sustainability and prosperity through a low-carbon approach.

The BNCCP has defined 10 key decarbonization strategies for the energy transition and low-carbon economy to deliver a 50% emissions reduction from the business-as-usual (BAU) scenario by 2035.

Key decarbonization strategies include increasing the total share in power generation from renewables by 30% and 100MW solar PV installation by 2025, carbon pricing, increasing carbon sinks, sales of electric vehicles, power management, waste management, etc.

POLICY SPOTLIGHT

Carbon pricing in BNCCP

Carbon pricing is one of the BNCCP's main strategies to achieve the outlined targets,[19] with a carbon pricing mechanism planned for implementation by 2025. This will encourage emissions reduction from industrial clusters, thus boosting domestic demand for low-carbon technologies. Brunei is working closely to develop this legislation with the ASEAN Centre for Energy and neighbouring states like Singapore.

FIGURE 13 | **Brunei's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– Energy white paper highlights importance of green industry which promotes sustainable methods of production and consumption, i.e. energy efficient, low-carbon and minimize waste with less pollution. – 10% reduction in emissions from electricity by managing power efficiency.	– The BNCCP has defined 10 key strategies for the energy transition and low-carbon economy to deliver a 50% emissions reduction from BAU scenario by 2035. – 30% of the total share in power generation expected from renewables and 100MW solar PV installation by 2025.	– The BNCCP anticipates a 46% reduction in emissions through imposing a price on carbon emissions from carbon-intensive industries (all sectors) and power utilities.	– None at present, Department of Energy (previously known as Ministry of Energy) in Brunei Darussalam supported pilot hydrogen export project at SPARK (see industrial cluster spotlight on page 18).

Sources: "Towards a Low Carbon and Climate-resilient Brunei Darussalam", *Brunei Darussalam National Council on Climate Change*, 3 July 2023, https://climatechange.gov.bn/SitePages/Pages/Home.aspx#page=1; Ministry of Energy, 2022; Ministry of Natural Resources and Environment.

INDUSTRIAL CLUSTER SPOTLIGHT

Sungai Liang Industrial Park (SPARK)

Key industries:
Energy, chemicals

Sungai Liang Industrial Park (SPARK) was developed to explore economic diversification opportunities with a holistic value focus as the nation seeks to diversify from its strong reliance on upstream oil and gas. Major multi-national corporations and industries with operations in SPARK include:

– TotalEnergies' onshore gas processing plant with an average processing capacity of 50,000 barrels of oil equivalent per day (boe/d).

– Brunei Methanol Company, a joint venture between Mitsubishi Gas Chemical Company, Itochu Corporation and Brunei Government-owned company Mirkhas Sdn Bhd, has a daily methanol production capacity of 2500 million tonnes.[20]

– Brunei Fertilizer Industries is one of South-East Asia's largest fertilizer plants, with a production capacity of over 1.3 million tonnes of urea per annum.[21]

Highlighted emissions reduction initiative

In 2020, the world's first international hydrogen export using chemical carriers was set up between Brunei and Japan as part of a demonstration project that converted hydrogen from Brunei's natural gas supply to methylcyclohexane (MCH) for shipping to Japan, where it is used as fuel at the Mizue power station owned by Toa Oil Company.

The demonstration operation was started by the Advanced Hydrogen Energy Chain Association for Technology Development (AHEAD) with subsidies from the New Energy and Industrial Technology Development Organization (NEDO). Corporates participating in the demonstration include Mitsubishi Corp, Mitsui, Chiyoda and NYK Line. At full operation, the system will support 210 tonnes of transported hydrogen per year.[22] Cross-industry collaboration was a key enabler of this demonstration of hydrogen export.

3.2 Thailand

Rapid industrialization has led to 10% annual growth in emissions, Thailand must facilitate industrial decarbonization to maintain competitiveness.

Thailand boasts a robust industrial cluster ecosystem and continues to implement increasingly powerful federal initiatives with the aim of facilitating more sustainable industrial development to achieve net zero by 2065. With industrial CO_2 emissions representing 30% of Thailand's total, the 66 industrial estates in Thailand – with more in the development and planning phases – will be key to driving reduction in industrial GHG contributions.

The Industrial Estate Authority of Thailand (IEAT), a government body under the Ministry of Industry, is tasked with the development and management of industrial estates either in a government-anchored programme or through a joint venture with private partners. In 2010, the IEAT instituted an integrated sustainability programme – Eco-Industrial Town (EIT) – to drive sustainability in industrial estates. This programme currently focuses on circular economy and waste management, energy efficiency and driving reuse to transform industrial estates into sustainable industrial communities.

FIGURE 14 **Industrial cluster challenges and opportunities in Thailand**

46%
Share of industrial sector in total electricity consumption in 2021

20%
Target share of renewable energy in power generation by 2037

20%
Target reduction in GHG emissions by 2030

Sources: Energy Policy and Planning Office; Asia Pacific Energy

Thailand's approach to industrial decarbonization

Thailand's clean energy policy development

A narrative on sustainability has been present in Thailand's policy planning since the 1970s when the "sufficiency economy" philosophy was incorporated as part of its national strategy. Thailand has a strong industrial cluster ecosystem but has not federally legislated support for industrial decarbonization since 2018, emphasizing a lack of published specific and measurable environmental targets.

FIGURE 15 **Thailand policy empowering industrial decarbonization**

Eco Industrial Town Programme
2010

The Twelfth National Economic and Social Development Plan 2017-2021

20-years National Strategy 2018-2037

Power Development plan (PDP 2018-2037)

Thailand 4.0 National Strategy
2018

Thailand's Long-Term Low Greenhouse Gas Emission Development Strategy
2022

Thailand's Long-Term-Low Emission Development Strategy, 2022

Thailand's Long Term-Low Emission Development Strategy (LT-LEDS)[23] submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in November 2022, outlines a high-level pathway to decarbonization of power generation that would be covered in the National Energy Plan that is being drafted. This publication is slated for launch in 2023 (not yet launched at the time of reporting). The LT-LEDS also outlines the strategy for decarbonizing the country's manufacturing and industrial sector, which focuses on energy efficiency and electrification of processes in the next decade. The pathway sees CCUS operationalization by around 2040, followed by the use of hydrogen closer to 2045 towards carbon dioxide neutrality by 2050 and eventually net-zero greenhouse gas emissions by 2065.

Eco-Industrial Town programme, 2010

The Eco-Industrial Town (EIT) programme,[24] launched by the Industrial Estate Authority of Thailand (IEAT) in 2010, is an integrated programme that aims to transform industrial estates into sustainable industrial communities. Industrial estates are defined in Thailand as industrial areas developed and managed by the IEAT, which centrally facilitates all integrated services such as approvals/licensing and utility services for operations.

The Green Industry Programme is an accreditation programme under the EIT for industrial companies committed to creating sustainable operations. Accredited companies are promoted through government channels and benefit from the Ministry of Industry's financial support programmes based on the level (1-5) of accreditation achieved.

Compelling benefits to be achieved through accreditation include waivers of operational permitting fees, reduced number of audits and a host of tax exemptions.

FIGURE 16 | **Thailand's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– Thailand has formulated the Energy Efficiency Plan (EEP) and an action plan, which specifies a target of 30% energy intensity reduction from BAU by 2037. – Relevant core measures to industrial clusters include energy efficiency improvements, mandatory application of the Energy Efficiency Resource Standard, soft loan provisions for energy efficiency improvements.	– The *Alternative Energy Development Plan* targets to increase the proportion of renewable and alternative energy in the form of electricity, heat and biofuels of final energy consumption by 30% in 2037. – The Energy Conservation (ENCON) Fund, established under the 1992 Energy Conservation and Promotion Act is the government's key financial mechanism to support energy efficiency and renewable energy development. The fund is sourced from a tax on all petroleum sold in the country. In 2020, a budget of THB 2 billion (Thai baht) from ENCON was allocated to support eligible energy efficiency and renewable energy projects.	– Thailand's updated National Energy Plan 2022, which is currently being drafted is expected to outline CCUS as one of the strategies to reach net-zero by 2065. – State-owned national oil company PTT is gearing up to develop Thailand's first CCS project at Arthit offshore gas field. The project is currently in the process of preliminary front-end engineering and design (pre-FEED) study and is expected to commence CCS operations by 2026.	– In the *Alternative Energy Development Plan*, hydrogen is included as part of the "alternative fuels" category with a set target goal of 10 kilotonnes of oil equivalent (KTOE) in total by 2036. – In 2022, PTT signed an MOU with Saudi Arabia's Aramco to strengthen energy cooperation including blue and green hydrogen and various clean energy initiatives.

Sources: Ministry of Energy, *Thailand Alternate Energy Development Plan 2018*, 2018, https://policy.asiapacificenergy.org/node/4351; Ministry of Energy, *Thailand Energy Efficiency Plan 2018*, 2018, https://policy.asiapacificenergy.org/node/4352; "Encon allots B2bn budget", *Bangkok Post*, 27 August 2020, https://www.bangkokpost.com/business/1975255/encon-allots-b2bn-budget; PTTEP, *PTTEP initiates Thailand's first CCS project, pushing towards Net Zero Greenhouse Gas Emissions* [Press release], 6 June 2022, https://www.pttep.com/en/Newsandnmedia/Mediacorner/Pressreleases/Pttep-Initiates-Thailand-First-Ccs-Project-Pushing-Towards-Net-Zero-Green-House-Gas-Emissions.aspx.

INDUSTRIAL CLUSTER SPOTLIGHT

Eastern Economic Corridor and Smart Park Industrial Estate[25]

Key industries:

Robotics, medical equipment, aviation, aerospace, electric vehicles (EVs), smart electronics, robotics, biotechnology

The Eastern Economic Corridor (EEC) is an initiative of the Thailand government to revitalize the country's traditional industrial region on the east coast, covering three provinces of Rayong, Chonburi and Chachoengsao with the aim of realizing transformative development and social uplift.

Within the EEC, the Smart Park Industrial Estate is being developed as a sustainable industrial estate under the Thailand 4.0 policy to serve high-tech or "S-Curve" industries alongside increased solar and battery storage capacity. The industrial estate is expected to contribute THB 53 billion ($1.5 billion) to Thailand's GDP and seed creation of 7,500 jobs.

Highlighted emissions reduction initiative

A peer-to-peer energy trading system is being implemented in collaboration with platform provider PowerLedger[26] to enable renewable energy trading from solar panels installed on industrial facilities within the park. Built on an autonomous financial settlement system and secure banking interface, the system removes barriers to participation in the industrial cluster's clean energy market.

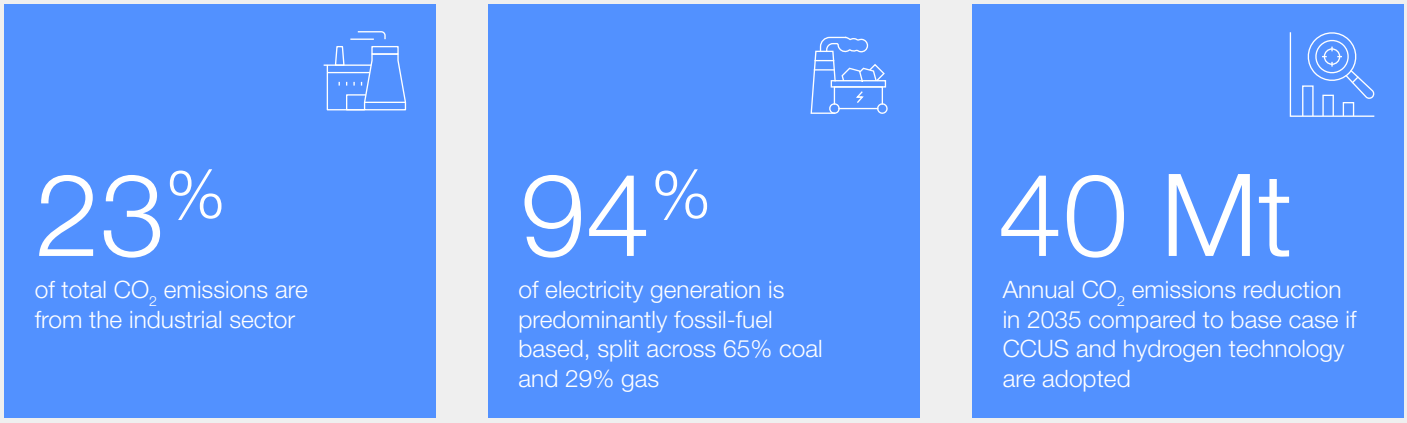
3.3 Malaysia

23% Malaysia's carbon emissions come from the industrial sector, which relies on an energy mix of 94% fossil-fuel-based generation.

The *National Energy Transition Roadmap* (NETR) launched in July 2023 sets an ambitious target of 70% renewable energy by 2050. The *New Industrial Master Plan 2030,* launched in September 2023, has identified the push for net zero as a mission for the country's manufacturing sector over the next few years out to 2030. Recognizing the abundant renewables potential in Malaysia, policies focused on renewables have been periodically approved, including the Large Scale Solar competitive bidding programme.

Other stakeholders, such as state governments and the private sector, are also accelerating energy transition efforts. The Sarawak state government aspires to embark on the hydrogen economy with up to three hydrogen plants in their pipeline, while state-owned energy company PETRONAS has pioneered CCS development in Malaysia through the development of the Kasawari CCS project that will potentially reduce CO_2 emissions by 3.7 million tonnes annually by 2025-2026.

FIGURE 17 **Industrial cluster challenges and opportunities in Malaysia**[27]



Sources: Accenture; Suruhanjaya Tenaga Energy Commission.

Malaysia's approach to industrial decarbonization

Malaysia's clean energy policy development

The Malaysian government has accelerated the push for its sustainability agenda, releasing low emissions and clean energy policies across multiple national policy documents in recent years. The federal government aims to balance the energy sector as a catalyst for socioeconomic growth while meeting low-carbon aspirations by 2040, which impacts environmental sustainability and energy optimization at industrial clusters.

FIGURE 18 | **Malaysia policy empowering industrial decarbonization**

Renewable Energy Act
2011

Green Technology Master Plan Malaysia 2017-2030
2017

Malaysia Renewable Energy Roadmap
2021

Twelfth Malaysia Plan
2022

National Energy Policy 2022-2040
2022

National Energy Transition Roadmap
2023

New Industrial Master Plan 2030
2022

New Industrial Master Plan 2030

The *New Industrial Master Plan 2030* (NIMP)[28] provides strategic direction to the country's manufacturing sector. The NIMP adopts a missions-based approach to transform the manufacturing sector in a push towards increased economic complexity and resilience, underpinned by digital technology and sustainability. The four missions are:

- Advance economic complexity
- Tech up for a digital nation
- Push for net zero
- Safeguard economic security.

The NIMP 2030 identifies four new growth areas that are relevant to industrial clusters' decarbonization:

- Advanced materials
- Electric vehicles
- Renewable energy
- CCUS.

It is estimated that RM 95 billion (Malaysian ringgit) of investments, predominantly from the private sector, would need to be mobilized over the next seven years for NIMP 2030. In terms of public funding, the government has earmarked RM 8.2 billion for the implementation of NIMP action plans. The implementation of NIMP calls for close coordination between government and industry players, facilitated via the NIMP 2030 Steering Committee.

National Energy Transition Roadmap

The *National Energy Transition Roadmap* (NETR)[29] aims to drive a fundamental transformation of Malaysia's economy and to position Malaysia as a regional leader in South-East Asia's energy transition. The NETR identifies ten flagship projects under NETR's six energy transition levers.

- Energy efficiency
- Renewable energy
- Hydrogen
- Bioenergy
- Green mobility
- CCUS

With NETR, the government aims to open up investment opportunities between RM 435 billion to RM 1.85 trillion by 2050 and catalyse hydrogen and CCS development paths in Sarawak. The NETR flagship projects relevant to industrial decarbonization include:

- Integrated Renewable Energy Zone: Large-scale sustainable development comprising 1GW solar PV, industrial park, zero-carbon city and data centre.
- Sarawak Hydrogen Hub: Implementation of three green hydrogen plants within the next two years, collaborating with strategic partners led by the Sarawak State Government through the Sarawak Economic Development Corporation (SEDC).
- CCS for industry: The Ministry of Economy led the effort to develop policies and regulatory framework for carbon capture, including transboundary carbon movement; PETRONAS CCS projects for Kasawari and Lang Lebah gas fields, expected to be operational earliest by 2026 and 2028, respectively.

National Energy Policy 2022-2040

The *National Energy Policy 2022-2040* (NEP)[30] outlines Malaysia's key priorities for the energy sector in the years ahead. It indicates the federal government's focus on the energy sector as a catalyst for GDP growth and job creation while outlining energy transition and green economy opportunities in line with its *Low Carbon Nation Aspiration 2040,* serving as a priority stepping stone towards net-zero GHG emissions by 2050.

Key NEP end-state vision highlights include affordable and reliable access to energy, a lead position in environmental sustainability and green economy in ASEAN and continuous efficient use of energy.

FIGURE 19 **Malaysia's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– Energy Audit Conditional Grant (2021-2025): An energy efficiency programme under the 12th Malaysia Plan that provides grants up to MR 100,000 for the industrial sector to conduct an energy audit and reduce their energy OPEX.	– Green Technology Financing Scheme (GTFS) 3.0: A MR 2 billion scheme to directly assist in overcoming financial barriers to renewable energy adoption; open to sectors in energy, water, building and townships, transport, waste and manufacturing. – Green Investment Tax Allowance (GITA) and Green Income Tax Exemption (GITE): Income tax allowance or exemptions equivalent to 70% of statutory income for renewable energy projects for companies seeking to acquire qualifying green technology assets (under the MyHIJAU Directory).	– The *National Energy Transition Roadmap* has announced plans to develop policies and framework for carbon capture projects, which would also cover transboundary carbon movement.	– The Sarawak State Government has expressed aspiration to embark into the hydrogen economy as it has abundant resources in hydropower that can support the economy. This lays the foundation for federal policy-makers to develop policies to encourage hydrogen production across the country. – An action plan in the NEP also signals focus in unlocking opportunities and long-term competitive advantage in the energy hydrogen economy.

Sources: Sustainable Energy Development Authority (SEDA); GTSF Malaysian Green Technology and Climate Change Corporation (MGTC); MGTC; Ministry of Economy.

INDUSTRIAL CLUSTER SPOTLIGHT

Pengerang Regional Hub

Key industries:
Oil and gas

Pengerang is a regional hub for the oil and gas industry, with three complexes, PETRONAS Pengerang Integrated Complex (PIC), Pengerang Industrial Park (PIP) and DIALOG Pengerang Deep Water Terminal (PDT), spanning over 8,000 acres.[31]

The PIC, a 6,200-acre complex, is driven by the Refinery and Petrochemical Integrated Development (RAPID) project supported by associated decarbonization facilities and systems. This includes a co-generation plant of 1.3GW capacity (natural gas) equipped with heat recovery steam generators, solar plants with 400MW capacity planned for the next five years, and implementation of the Energy and Loss Management System.

Meanwhile, the PIP, spanning 790 acres, supports industries in the oil and gas sector. PIP has an allocated right-of-way for pipe racks, which enables the potential exchange of energy and materials between PIP and PDT facilities, which could enhance circularity and other resource synergies.

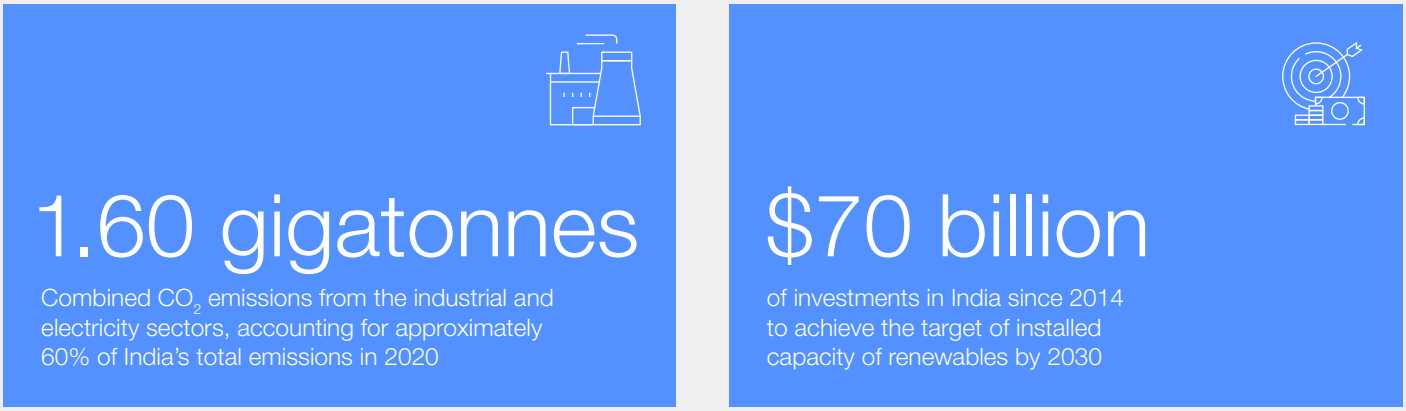
3.4 India

India has committed to net zero by 2070, emphasizing an equitable transition, balancing growth ambitions and limiting emissions.

Although the country has comparatively low carbon emissions per capita globally, it remains the third largest emitter of CO_2 in the world after China and the US, with around 31% of emissions attributed to the growing industrial economy. The country has been aggressively integrating renewables across sectors to achieve 500GW of non-fossil fuel-based electricity installed capacity by 2030. At the same time, India acknowledges the need for new technologies and carbon abatement mechanisms to reach its target of reducing CO_2 emissions by 50% by 2050.

India has committed to reducing its emissions intensity by 45% by 2030, below its 2005 baseline levels. The country aims to reinforce its electricity network to support green energy technologies, improve fuel efficiency and transport systems, incorporate demand side management, promote material efficiency, invest and carry out energy-transition-related research, and strengthen international cooperation to increase access to financing and know-how to achieve decarbonization in a sustainable manner.

FIGURE 20 **Industrial cluster challenges and opportunities in India**



Sources: NITI Aayog, 2022; India Brand Equity Foundation 2023.

India's approach to industrial decarbonization

India's clean energy policy development

India's approach to a long-term low-carbon development strategy hinges on considerations such as support from developed economies in areas of finance, technology transfer and capacity building to facilitate efficient energy ecosystems. To balance the country's growth ambitions with the responsibilities of decarbonization, the country has prioritized energy efficiency, cleaner transport, and greening of heavy industries primarily through renewable energy, green hydrogen and carbon credit mechanisms.

FIGURE 21 | **India policy empowering industrial decarbonization**

सत्यमेव जयते

National Action Plan on Climate Change
October 2008

National Mission for Enhanced Energy Efficiency
August 2021

Green Open Access Rules and Regulations
June 2022

The Energy Conservation (Amendment) Bill
December 2022

National Policy on Biofuels (Amendments)
June 2022

National Green Hydrogen Mission
September 2022

National Mission for Enhanced Energy Efficiency (NMEEE)

The NMEEE[32] is one of the eight national missions under the *National Action Plan on Climate Change* (NAPCC) and targets decarbonization in industries through energy efficiency measures. It aims to strengthen markets through the implementation of innovative business models that promote carbon footprint reduction for energy-intensive industries. The NMEEE consists of four initiatives to enhance energy efficiency:

1. **Perform, achieve and trade (PAT) scheme:** An energy efficiency credit trading scheme for industries. *The Energy Conservation (Amendment) Bill of 2022* strengthens the principles of PAT by empowering the central government to specify a carbon credit trading scheme.

2. **Market transformation for energy efficiency (MTEE):** Promote the use of energy-efficient equipment through innovation and cost reduction.

3. **Energy Efficiency Financing Platform (EEFP):** Platform to connect project developers implementing energy efficiency programs and financial institutions (FIs).

4. **Framework for Energy Efficiency Economic Development (FEEED):** Development of fiscal instruments to promote energy efficiency. The framework covers risk-sharing mechanisms for participating financial institutions.

National Policy on Biofuels (2022 amendments)

The *National Policy on Biofuels (2022 amendments)* published by the Ministry of Petroleum and Natural Gas aims to achieve 20% ethanol blending in petrol by 2025-26, ahead of previously set targets by 2030. The policy also sets a target of 5% blending of biodiesel in diesel and direct sale of biodiesel by 2030. In support of the biofuel targets, the policy has expanded the scope of raw material feedstock production to include biomass, starch-containing materials, algae and seaweed. In terms of financial incentives, allocations would be provided by the Department of Food and Public Distribution for setting up ethanol distilleries of various feedstocks.

The policy is meant to promote the use of domestic energy sources in the form of biofuels, which could aid in sustainability goals and enhance the country's energy security by reducing reliance on fossil fuel imports.

FIGURE 22 | **India's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– The Ministry of New and Renewable Energy is promoting setting up "waste to energy" projects for generating biogas/ bio-compressed natural gas/ biogas-based power from industrial waste and other sources. The ministry has earmarked INR 8.6 billion (Indian rupee) for provision of financial assistance to project developers, allocated based on the planned installed capacity of the plants.	– India has targeted increasing its renewables capacity to 500GW by 2030 with aims to meet 50% of its energy requirements from renewables. Industries are expected to be a major offtaker as they consume about 50% of the power produced in India. – The Ministry of Power has mandated renewable purchase obligation (RPO) for power distribution companies (DISCOMs) at approximately 44% (of the total energy consumed) by 2030. Energy storage obligations are set at 4% (of the total energy consumed) by 2030, and are subject to meeting minimum threshold of 85% stored energy from renewable sources, on an annual basis.	– While the Government of India has yet to develop legislations for carbon capture, it acknowledges the role of CCUS in the country's journey to net zero by 2070. – The Ministry of Petroleum and Natural Gas is developing the 2030 roadmap for CCUS for the oil and gas sector in India.	– In 2023, the government published the *National Green Hydrogen Mission*, which aims to set out the action plan for building India's green hydrogen ecosystem. – Under the plan, India's green hydrogen production capacity is expected to reach at least 5 million metric tonnes (MMT) per annum by 2030, with potential to reach 10 MMT per annum with growth of export markets. – The production capacity targeted by 2030 is likely to use over $96 billion (INR 8 trillion) in total investments and create over 600,000 jobs.

Sources: Ministry of New and Renewable Energy; Ministry of Power.

3.5 Japan

Decarbonizing industrial clusters is critical for Japan's carbon neutrality as heavy-emitting industries account for 67% of carbon emissions.

To achieve carbon neutrality by 2050 and the 2030 goal of 46% GHG emissions reduction from 2013 levels,[33] Japan is dramatically changing its energy and industrial landscape, aiming for a virtuous cycle of environmental and economic growth.

Renewables and nuclear power are important not only for decarbonization, but also for energy security in Japan, an island nation with an energy self-sufficiency rate of only 11% today.[34] To increase the contribution of renewables in the power mix to 36-38% by 2030, the government is taking measures such as promoting large-scale offshore wind projects and accelerating power grid upgrades. Steady restarts of idle nuclear power plants and the extension of the operational lifetime, as well as the materialization of a replacement plan, are also on the national agenda, with safety as a top priority.[35]

Hydrogen and ammonia will play a key role in decarbonizing hard-to-abate sectors like steel and chemicals, as well as the electricity sector. Japan expects to introduce 3 million tonnes of hydrogen equivalent (MtH_2e) by 2030 and 20 MtH_2e by 2050.[36]

To support renewables, nuclear power and hydrogen/ammonia, as well as other priority areas such as energy efficiency and CCUS, the government is committed to mobilizing all available policy tools, including subsidies, finance and regulations.

FIGURE 23 **Industrial cluster challenges and opportunities in Japan**

Sources: Greenhouse Gas Inventory Office of Japan (GIO), part of National Institute for Environmental Studies (NIES), Center for Global Environmental Research (CGER), Earth System Division (ESD), and National Institute for Environmental Studies (NIES), 2023; Ministry of Economy, Trade and Industry 2023; Japan Iron and Steel Federation, 2022; Japan Chemical Industry Association, 2022.

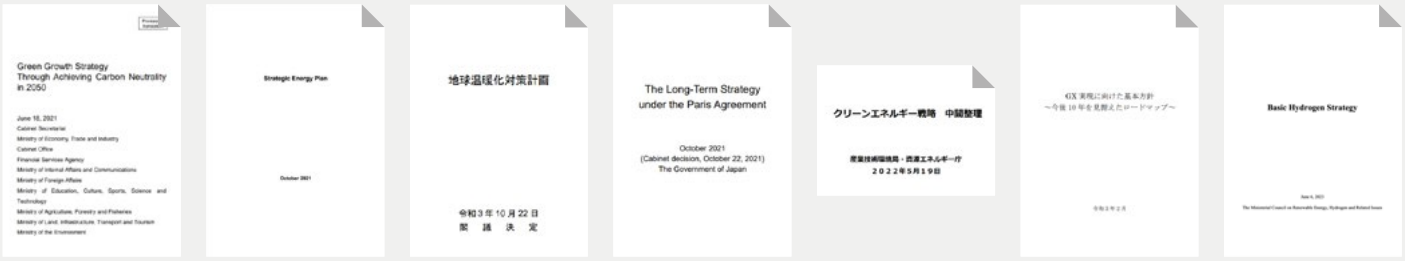
Japan's approach to industrial decarbonization

Japan's clean energy policy development

The Japanese government has launched initiatives focusing on the decarbonization of industrial complexes and ports, recognizing their potential as the hubs for low-emission energy and circular materials (e.g. hydrogen/ammonia, CO_2, recycled heat, waste plastics) and as the testbed for nascent technologies.[37, 38] There are more than 70 local councils at ports and industrial complexes all over Japan where public and private stakeholders discuss pathways towards net zero.[39] In this landscape, effective collaboration in partnerships is critical to progressing such discussions.

With a variety of policy measures, including subsidies, financial assistance and regulations, Japan's industry is steadily moving towards decarbonization.

FIGURE 24 | **Japan policy empowering industrial decarbonization**



Green Growth Strategy Through Achieving Carbon Neutrality in 2050
2021

The 6th Strategic Energy Plan
2021

Global Warming Countermeasure Plan
Updated 2021

The Long-Term Strategy under the Paris Agreement
2021

Clean Energy Strategy: Interim Report
2022

Basic Policy for the Realization of GX
2023

Basic Hydrogen Strategy: 2023 Revision
June 2023

The 6th Strategic Energy Plan

The 6th Strategic Energy Plan,[40] approved by the cabinet in October 2021, sets out a path for energy policy to achieve carbon neutrality by 2050 and the 46% GHG reduction goal by 2030 (from 2013 levels). It outlines the policy approach to overcome the country's structural challenges in the energy supply and demand, guided by the government's basic stance towards energy called "S + 3E (safety, energy security, economic efficiency and environment)". The key policy actions by 2030, looking ahead to 2050, include:

- Expanding renewable energy through measures such as setting promotion zones for solar and wind, introducing a feed-in premium (FIP) scheme for the market integration, and increasing the grid capacity.
- Proceeding with the restart of nuclear power plants that are compliant with the new regulatory standards.
- Phasing out inefficient thermal power plants and promoting hydrogen/ammonia co-firing and CCUS while maintaining an appropriately resilient thermal power portfolio.
- Positioning hydrogen/ammonia as new resources and accelerating the commercialization of an international supply chain as well as domestic production using surplus renewable power.

As an ambitious outlook for energy supply and demand in 2030, the share of non-fossil resources in the power generation mix is expected to increase from around 24% in 2019 (18% renewables + 6% nuclear) to approximately 59% in 2030 (36-38% renewables + 20-22% nuclear + 1% hydrogen/ammonia).

Basic Policy for the Realization of GX

The *Basic Policy for the Realization of GX*,[41] approved by the cabinet in February 2023, sets out Japan's approach towards the green transformation (GX), defined as an initiative to shift the industrial and social structures that have been fossil energy-centred since the Industrial Revolution to become clean energy-centred.

The policy also outlines a financial policy package to accelerate the investment required for the GX, estimated at over JPY 150 trillion in the next decade, in combined private and public funding. The package consists of:

- Supporting up-front investment through issuance of the GX Economy Transition Bonds (provisional name) worth JPY 20 trillion in the next 10 years.
- Introducing a carbon pricing scheme consisting of an emissions trading system (ETS) and a "carbon surcharge", which fossil fuel importers will be charged.
- Implementing "blended finance", through which a public institution mitigates the risks that private financiers cannot tolerate, in addition to further promoting green and transition finance.

FIGURE 25 | **Japan's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– Under the 2022 Revised Energy Conservation Act, large energy consumers have an obligation to submit medium- to long-term plans and periodic reports on the transition to non-fossil energy, and the government suggests targets for the five top energy-consuming industries (steel, chemical, cement, paper and vehicles).	– Various subsidies and tax break schemes are in place for renewables, including JPY 169 billion from the Green Innovation Fund to lower the cost of offshore wind and develop next-generation solar cells. – The recent shift from the feed-in tariff (FIT) to the FIP scheme is expected to lower the total electricity cost through the market integration of renewables. To further use renewable potential, the government will accelerate the upgrade of power grid. – To accelerate the project formation of offshore wind, the government selects project developers through public calls for designated promotion zones. Starting from 2023, a public institution, Japan Organization for Metals and Energy Security (JOGMEC), will conduct the assessment of seabed and wind conditions of candidate sites, to avoid redundant investments by private developers.	– The *Roadmap for Carbon Recycling Technologies* specifies goals, challenges, and timeframes for CO_2 utilization technologies. In addition, the *Final Report on CCS Long-term Roadmap* sets out the government's targets to commence full-scale CCS operations by 2030 and realize the storage of 120-240 $MtCO_2$ per year by 2050, suggesting the need for public support and the development of laws about issues such as safety rules and operators' responsibilities. – The Green Innovation Fund allocates JPY 513 billion for R&D and demonstration of various CCU technologies.	– The *Basic Hydrogen Strategy (revised 2023)*, sets four targets including introducing 12 Mt of hydrogen per year by 2040 in Japan, reducing hydrogen supply cost to JPY 30 per normal cubic metre (Nm3) by 2030, Japanese companies (including part manufacturers) deploying 15GW of electrolysers by 2030 globally, attracting public and private investments into hydrogen and ammonia supply chain.

Sources: Ministry of Economy, Trade and Industry, 2023; Agency for Natural Resources and Energy, 2021; Cabinet Secretariat, 2023.

3.6 United Arab Emirates

The path to carbon neutrality for the United Arab Emirates requires concerted efforts to decarbonize its industrial and electricity sector.

The United Arab Emirates government is promoting large-scale solar projects and improving energy efficiency across key areas like public transport, real estate and private consumption. The United Arab Emirates' commitment to decrease its reliance on fossil fuels is also reflected in the importance of the development of a peaceful nuclear energy sector to complement its net-zero strategy.

National targets alongside emirate-specific targets and commitments will guide the achievement of the United Arab Emirates' carbon neutrality by 2050. Abu Dhabi quadrupled its renewable energy portfolio in the past decade with commitments of $20 billion.

The United Arab Emirates government has also placed emphasis on carbon capture reduction initiatives alongside hydrogen as a key element in their path to net zero.[42]

FIGURE 26 **Industrial cluster challenges and opportunities in the United Arab Emirates**

82%

of the United Arab Emirates' carbon emissions come from electricity generation and industry

95%

of energy demand is met by fossil fuels, comprising gas, oil and coal

$20 billion

allocated to fund 15GW of new renewable energy projects, from $100 billion clean energy partnership between the United Arab Emirates and the United States (PACE).

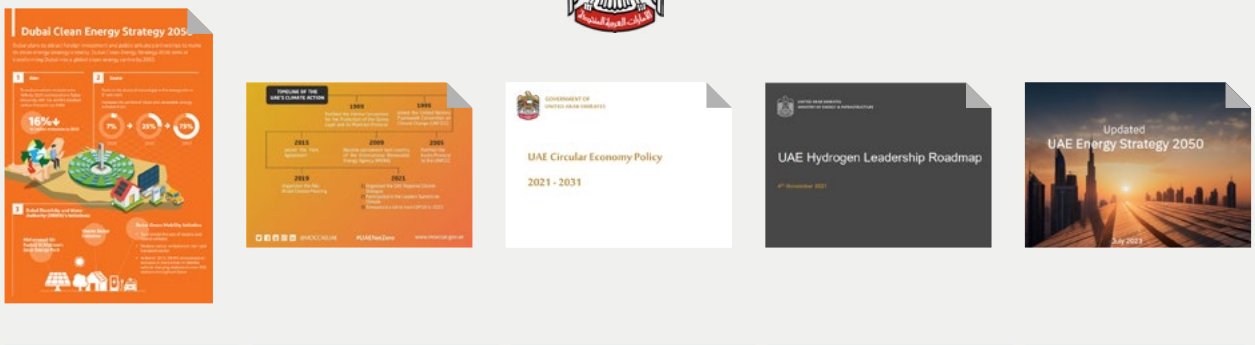
Source: "U.S., UAE say $20 billion investment to fund 15 gw in new clean energy", *Reuters*, 15 January 2023, https://www.reuters.com/business/sustainable-business/us-uae-say-20-billion-investment-fund-15-gw-new-clean-energy-2023-01-15/.

The United Arab Emirates' approach to industrial decarbonization

The United Arab Emirates' clean energy policy development

The United Arab Emirates does not have an action plan specific to industrial clusters, however, there are a multitude of policies and initiatives that support the shift to clean energy sources and decarbonization of the industrial sector. The foundation for a sustainable future was laid in 2012 with the Green Economy Initiative, which set the United Arab Emirates' first policies and programmes in the areas of energy, environment and investment. Since then, the United Arab Emirates has proactively enacted legislation supporting their larger commitments.

FIGURE 27 | **United Arab Emirates policy empowering industrial decarbonization**



Dubai Clean Energy Strategy 2050
2015

UAE Net Zero 2050
2021

UAE Circular Economy Policy
2021

UAE Hydrogen Leadership Roadmap
2021

UAE Energy Strategy 2050
2023

UAE Energy Strategy 2050

The strategy sets targets to increase the share of clean energy in the country's energy mix, enhance energy efficiency and reduce carbon emissions.[43] On the supply side, the strategy aims for an energy mix that incorporates renewable, nuclear, green and transitional energy sources to satisfy the United Arab Emirates' economic and environmental objectives. To achieve its renewable energy targets, the strategy includes a goal of 30% clean energy capacity by 2030, increasing to 35% by 2035. On the demand side, the strategy aims to decrease energy demand by 40% from energy-intensive sectors by 2050 with efforts on energy efficiency like retrofitting buildings and improving industrial processes.

Additionally, the strategy outlines 2031 targets for low-carbon hydrogen to reduce emissions in hard-to-abate sectors by 25%, with hydrogen production of 1.4 million tonnes per annum (MTPA). The United Arab Emirates aims to establish a hydrogen R&D centre and two hydrogen oases in the country.

FIGURE 28 | **The United Arab Emirates' legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– The *Integrated Waste Management Strategy 2021-2041* is intended to promote innovation in waste management with a budget of $20.28 billion. – The Ras Al Khaimah *Energy Efficiency and Renewables Strategy 2040* outlines the emirate's approach to energy efficiency, which aims minimum savings across key resources like water and electricity. – *Dubai Green Building Specifications and Standards*, which aim to enhance the performance of buildings by decreasing their use of energy, water and materials.	– Under the *Dubai Clean Energy Strategy 2050*, the government is setting up the Mohammad bin Rashid Al Maktoum Solar Park, with a planned capacity of 5,000MW by 2030. – The Abu Dhabi Department of Energy introduced the Clean Energy Certificates Scheme which allows obtaining a tradeable certification of the energy source used by any business or operation in Abu Dhabi.	– ADNOC, an energy group owned by the Abu Dhabi government plans to increase its CO_2 capture capacity to approximately 5 million tonnes per year by 2030, an increase of over 500%. – The United Arab Emirates government is involved in international efforts to promote CCUS via its membership in Carbon Sequestration Leadership Forum.	– Abu Dhabi Hydrogen Alliance, comprised of ADNOC, Mubadala and ADQ, will promote low-carbon green and blue hydrogen in emerging markets and develop a hydrogen economy in the United Arab Emirates. – The United Arab Emirates launched the *Hydrogen Leadership Roadmap* as a comprehensive national plan to support domestic low-carbon industries, contribute to the nation's net-zero ambition.

Sources: Ministry of Economy, Trade and Industry, 2023; Agency for Natural Resources and Energy, 2021; Presidential Climate Commission, 2023; Ministry of Land, Infrastructure, Transport and Tourism, 2020.

4 Africa

4.1 South Africa

South Africa has begun to develop strong momentum on their "just energy transition" journey to net-zero GHG emissions.

South Africa has committed to a just energy transition: "ensuring that the lives and communities that are tied to high-emitting energy industries are not left behind in the shift towards a low emissions economy".[44]

The country is working towards a net-zero GHG emissions goal by 2050, which has not yet been signed into law. The country's industrial sector has a relatively high emissions intensity (more than double the G20 average),[45] largely driven by coal electricity, which dominates the country's power mix at over 80% of electricity generated in 2022.[46]

The country is currently facing an energy crisis largely due to the issues facing the state-owned electricity utility, Eskom, which has resulted in ongoing blackouts lasting as long as 12 hours a day. The situation has served as a catalyst for shifting investment and procurement of renewable energy for the country, which is expected to grow up to 46% of South Africa's installed electricity capacity by 2030.[47] Building a green hydrogen economy has also become a focus of both the government and private sector.

FIGURE 29 **Industrial cluster challenges and opportunities in South Africa**

40%

Percentage of direct and indirect emissions of energy-related CO_2 emission are from the industrial sector

350-420 Mt CO_2e

GHG emissions target by 2030, representing a 13-27% reduction relative to 2020 GHG emissions

$8.5 billion

Funds allocated to South Africa under the Just Energy Transition Partnership signed at COP26, primarily flagged for infrastructure for electricity, new energy vehicles and green hydrogen sectors

Sources: Climate Transparency, 2021; Republic of South Africa, 2021; The Presidency Republic of South Africa, 2022.

South Africa's approach to industrial decarbonization

South Africa's clean energy policy development

Although South Africa lacks a specific action plan for industrial clusters, it has implemented various policies and initiatives aimed at promoting the adoption of clean energy sources and reducing carbon emissions in the industrial sector. The government of South Africa has prioritized the transformation of the electricity sector by transitioning from coal to renewable energy sources. Additionally, funds have been allocated for the advancement of green hydrogen technologies.

FIGURE 30 **South Africa policy empowering industrial decarbonization**

Carbon Tax Act, 2019
2019

Integrated Resource Plan
2019

South Africa's Low Emission Development Strategy 2050
2020

Hydrogen Society Roadmap for South Africa 2021
2021

South Africa's Nationally Determined Contribution Under the Paris Agreement
2021

South Africa's Just Energy Transition Investment Plan
2022

Just Energy Transition Investment Plan

The *Just Energy Transition Investment Plan*[48] signed at COP26 by the governments of South Africa, France, Germany, the UK, the US and the EU "sets out the scale of need and the investments required to support the decarbonization commitments made by the Government of South Africa". The plan stipulates the allocation of the $8.5 billion that has been pledged and is primarily earmarked for electricity infrastructure – namely, coal decommissioning and new solar, wind and hydro projects – ($6.9 billion/81%), green hydrogen ($500 million/6%), and new energy vehicles ($200 million/2%). The remaining 11% ($900 million) is split across planning and implementation capacity, skills development, economic diversification and innovation, and social investment and inclusion.

It also details the broader $98.7 billion that is required for prioritized investments across electricity, new energy vehicles (NEVs), and green hydrogen sectors to achieve the just transition. The plan underscores the role of multilateral energy transition funding in decarbonizing emerging economies.

Hydrogen Society Roadmap for South Africa

Both the public and private sector in South Africa have ambitions for the country to become a leader in green hydrogen production.

In 2021, the cabinet approved the *Hydrogen Society Roadmap for South Africa*, which was developed by the Department of Science and Innovation. It serves as a national framework to facilitate the integration of hydrogen-related technologies in various sectors of the economy, ultimately seeking to stimulate local demand and build a viable export market for renewable (green) hydrogen.

The document details 70 prioritized actions, each to be championed by a key national government department, across six high-level outcomes:

1. Decarbonization of heavy-duty transport
2. Decarbonization of energy-intensive industry (cement, steel, mining, refineries)
3. Enhanced and green power sector (main and micro-grids)

4. Centre of Excellence in Manufacturing for hydrogen products and fuel cell components
5. Creating an export market for South African green hydrogen
6. Increase the role of hydrogen in the South African energy system in line with the move towards a net-zero economy.

The implementation of the roadmap is expected to contribute to the goal of a just and inclusive net-zero carbon economic growth for societal well-being by 2050. Operationalization of the plan will be guided by the *Green Hydrogen Commercialisation Strategy*, which is currently under final review by the cabinet.

FIGURE 31 **South Africa's legislative support for key technologies**

Systemic efficiency and circularity	Direct electrification and renewable heat	CCUS	Hydrogen
– The National Energy Efficiency Strategy (post-2015) seeks to promote energy efficiency across sectors through policy and fiscal incentives. The expected impact for industry sector is 15% reduction in energy consumption by 2030. – In February 2022, the Finance Minister announced an extension of the Energy Efficiency Tax Credit (section 12L) through 31 December 2025, through which energy efficiency initiatives can generate tax deductions of 95 cents per kilowatt hour (kWh) (or equivalent) of energy-efficiency savings.	– The Renewable Independent Power Producer Programme was established in 2011 with the goal of adding additional electricity capacity to South Africa's grid through private sector investment in renewable energy. It is a competitive tender process which auctions new renewable electricity capacity in bid windows, in which winning projects are awarded long-term power purchase agreements (more than 20 years). – In 2022, the government announced the removal of licensing requirements for private power generation systems of any capacity, further facilitating the development of utility-scale, embedded renewable generation projects. – In February 2023, the Finance Minister announced an expanded tax incentive (section 12B of South Africa's *Income Tax Act*) for businesses for renewable energy projects. Businesses are now able to claim a 125% deduction in the first year for a renewable energy project (wind, concentrated solar, hydropower, biomass and photovoltaic projects) with no thresholds on generation capacity, on investments brought into use for the first time between 1 March 2023 and 28 February 2025.	– None at present. The private sector is exploring potential of carbon capture solutions for decarbonization of energy intensive industries (see industrial cluster spotlight on page 36).	– The *Hydrogen Society Roadmap for South Africa*, published in 2021, details 70 actions to be taken by various national government departments in support of developing and deploying hydrogen and hydrogen-related technologies in the country. – The *Green Hydrogen Commercialisation Strategy*, currently under final review by the cabinet and expected to be approved in late 2023, details how the *Hydrogen Society Roadmap* can be operationalized, lists key opportunities for localization and manufacturing, and provides guidance on policies, incentives and financing.

Sources: Department of Energy, 2013; South African Government; The Presidency Republic of South Africa, 2022; Department of Forestry, Fisheries and the Environment, 2022; South African Government News Agency, 2023; The Department of Trade, Industry and Competition, 2022; Department of Science and Innovation, 2021.

INDUSTRIAL CLUSTER SPOTLIGHT

Vaal Industrial Cluster

The Vaal region is the birthplace of industrialisation in South Africa and a centre of heavy industry, manufacturing and engineering. Several industrial companies in chemicals, steel, manufacturing and oil refinery industries, along with several public sector players and funders, are working to develop a Vaal Energy Transition Industrial Cluster. The cluster's goal will be to co-develop decarbonization projects such as wastewater recycling, renewable energy generation and electrification of heating processes, the production of green hydrogen, and the capture and use of carbon.

This will be complemented by efforts to develop new skills in the region, attract additional manufacturing capacity to drive job development, encourage economic growth, and ultimately improve the lives of those in nearby communities. Several bilateral MOUs have already been signed by partners, including an MOU for carbon capture from the steel manufacturer and use by a chemicals company as a carbon feedstock, an example that paves the way for the cross-cluster collaboration that will take place in the near future.

Conclusion

Beyond national pledges, governments must play an active role in accelerating the shift towards net zero. Governments can strategically guide private sector investments towards industrial decarbonization solutions. While promoting these investments, they must also ensure that the broader benefits for the community are not overlooked during the transition. Six key themes have emerged when considering industrial decarbonization:

- Governments should continue to focus their efforts on developing and implementing comprehensive policy frameworks and packages that support the transition. The development of standards and specifications that enable cross-border collaboration should also be accelerated. For example, mandates such as Brazil's biofuels target and India's RPO for power distribution companies at 44% for renewable energy.

- These incentives aim to encourage private sector participation and include a variety of policy tools beyond just public funding, such as mandates and tariffs. This enables the creation of holistic value chains that incubate innovation and accelerate scaled deployment of decarbonization technologies. For example, in South Africa, businesses deploying renewables can claim tax incentives allowing 125% deduction in the first year. In addition, the Renewable Independent Power Producer Programme also provides opportunities for businesses to enter into competitive bids to secure power purchase agreements, driving private investments for renewable generation projects.

- Carbon pricing has an important role in mobilizing investments into industrial clusters' decarbonization and could have flow-on impacts on industrial decarbonization in other geographies. For example, Brazil is spurring investments in potential hydrogen export hubs (to Europe) and catalysing the development of net-zero industrial clusters.

- Industrial clusters are enablers of strengthened private-public collaboration and cross-industry partnerships are core elements that support efforts to deploy shared infrastructure and low-carbon ecosystems at scale, driving significant regional impact. In Japan, the government is focusing efforts on ports and industrial complexes through public-private collaboration to drive the clean energy transition due to their potential as hubs for low-emission energy and circular materials.

- Finally, green energy transitionary plans that integrate existing assets with decarbonization solutions could provide a path to accelerate the transition to net zero. Linkages and integration of these assets into conversion plans, such as retrofitting or repurposing old infrastructure with new green infrastructure, could avoid the cumulating of stranded assets and associated negative impacts on economies and communities. For example, Energias de Portugal's (EDP) repurposing of a coal power plant for green hydrogen production by 2025 in Sines Cluster, Portugal.[49]

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Endnotes

1. Empresa de Pesquisa Energética, *Relatório Síntese*, 2021, https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-601/topico-588/BEN_S%C3%ADntese_2021_PT.pdf.
2. System for Estimating Greenhouse Gas Emissions, *Análise das emissões brasileiras de gases de efeito estufa e suas implicações para as metas climáticas do Brasil 1970-2020*, 2021, https://www.oc.eco.br/wp-content/uploads/2021/10/OC_03_relatorio_2021_FINAL.pdf.
3. Ministério do Meio Ambiente, *Diretriz para uma estratégia nacional para neutralidade climática*, 2022, https://www.gov.br/mma/pt-br/assuntos/climaozoniodesertificacao/clima/diretrizes-para-uma-estrategia-nacional-para-neutralidade-climatica_.pdf.
4. Ministério do Meio Ambiente, *Programa Nacional Metano Zero*, 2022, https://www.gov.br/mma/pt-br/assuntos/climaozoniodesertificacao/ProgramaMetanoZero.pdf.
5. Swedish Energy Agency, *Energy in Sweden 2022: An overview*, 2022.
6. This number has been computed using – "Greenhouse gas emissions from Sweden's economy increased in 2021", *Statistics Sweden*, 12 May 2022, https://www.scb.se/en/finding-statistics/statistics-by-subject-area/environment/environmental-accounts-and-sustainable-development/system-of-environmental-and-economic-accounts/pong/statistical-news/environmental-accounts---emissions-to-air-q4-2021/#:~:text=Total%20greenhouse%20gas%20emissions%20from,GDP%20increased%20by%204.8%20percent.
7. Fossil Free Sweden, *Roadmap for fossil free competitiveness: Summaries 2018-2020*, 2020, https://fossilfrittsverige.se/wp-content/uploads/2020/12/Sammanfattning_Webb_ENG_2020.pdf.
8. "Industrial Symbiosis in Sweden", *Linköping University*, n.d., http://www.industriellekologi.se/symbiosis/stenungsund.html.
9. "The Industrial Leap", *Swedish Energy Agency*, 27 January 2023, https://www.energimyndigheten.se/en/innovations-r--d/energyintensive-industry/the-industrial-leap/.
10. Fossil Free Sweden, *Strategy for fossil free competitiveness*, 2021, https://fossilfrittsverige.se/wp-content/uploads/2021/01/Hydrogen_strategy_for-_fossil_free_competitiveness_ENG.pdf.
11. "Industry Park of Sweden", *Green Cluster*, https://www.greenclustercy.org/industry-park-sweden.html.
12. Agencia Portuguesa do Ambiente, *Inventário Nacional de Emissões 2023*, 2023, https://apambiente.pt/sites/default/files/_Clima/Inventarios/20230421/20230315MemoEmissoes2023.pdf.
13. República Portuguesa, *Recuperar Portugal, Construindo o future: Plano de Recuperação e Resiliência*, 2021, https://recuperarportugal.gov.pt/wp-content/uploads/2021/10/PRR.pdf.
14. Ibid.
15. Brunei Darussalam National Council on Climate Change, *Brunei Darussalam National Climate Change Policy*, 2021, http://www.mod.gov.bn/Shared%20Documents/BCCS/Brunei%20National%20Climate%20Change%20Policy.pdf.
16. "Emissions Database for Global Atmospheric Research – Country Fact Sheet: Brunei", *European Commission,* https://edgar.jrc.ec.europa.eu/country_profile/BRN.
17. Ministry of Finance and Economy, Brunei Darussalam, *Towards a Dynamic and Sustainable Economy: Economic Blueprint for Brunei Darussalam*, 2020, https://www.mofe.gov.bn/Shared%20Documents/OTHERS/banner/Brunei%20Darussalam's%20Economic%20Blueprint.pdf.
18. Brunei Darussalam National Council on Climate Change, *Brunei Darussalam National Climate Change Policy*, 2021, http://www.mod.gov.bn/Shared%20Documents/BCCS/Brunei%20National%20Climate%20Change%20Policy.pdf.
19. "Workshop on Carbon Pricing Policies for Brunei Darussalam", *ASEAN Centre for Energy*, 22 September 2021, https://aseanenergy.org/workshop-on-carbon-pricing-policies-for-brunei-darussalam/.
20. "Company Profile", *Brunei Methanol*, n.d., https://www.brunei-methanol.com/company-profile.
21. "Brunei Fertilizer Industries", *Brunei Fertilizer Industries*, n.d., https://www.bfi.com.bn/.
22. NYK Line, *World's First Global Hydrogen Supply Chain Demonstration Project Starts in Earnest* [Press release], 26 June 2020, https://www.nyk.com/english/news/2020/20200625_01.html.
23. Ministry of Natural Resources and Environment, *Thailand's Long Term-Low Emission Development Strategy*, 2022, https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf.
24. "Thailand Eco Development Policy", *Industrial Estate Authority of Thailand*, 2023, https://eco.ieat.go.th/th/development-policy.
25. Apisitniran, Lamonphet, "IEAT looks to Smart Park to serve EEC S-curve sectors", *Bangkok Post*, 5 October 2021, https://www.bangkokpost.com/business/2192635/ieat-looks-to-smart-park-to-serve-eec-s-curve-sectors.
26. "BCPG Signs MOU To Provide Smart Energy Infrastructure In Thailand Smart Park, Using the Powerledger Platform", *Powerledger*, 8 February 2018, https://www.powerledger.io/media/bcpg-signs-mou-to-provide-smart-energy-infrastructure-in-thailand-smart-park-using-the-power-ledger-platform.
27. Accenture, *System Value Analysis Malaysia*, 2022, https://www3.weforum.org/docs/WEF_System_Value_Analysis_Malaysia_2022.pdf.

28. Economic Planning Unit, Prime Minister's Department, *National Energy Policy 2022-2040*, 2022, https://www.ekonomi.gov.my/sites/default/files/2022-09/National_Energy_Policy_2022-2040.pdf.
29. Ibid.
30. Ibid.
31. Li Tiing, Chai and Lim, Angeline, "The Pengerang Integrated Complex", *PETRONAS*, 2 October 2021, https://www.petronas.com/flow/technology/pengerang-integrated-complex; Johor Corporation, *Endless Growth Opportunities: JCorp Industrial Parks*, n.d., https://d2av87rmal5htu.cloudfront.net/tpm/files/e0/e0074077-0e8e-4629-af6a-9daab229586b.pdf; "Penerang Deepwater Terminals", *DIALOG*, n.d., https://www.dialogasia.com/pengerang-deepwater-terminals.
32. Ministry of Power, *National Mission for Enhanced Energy Efficiency* [Press release], 2021, https://www.pib.gov.in/PressReleasePage.aspx?PRID=1744431.
33. Greenhouse Gas Inventory Office of Japan (GIO), Center for Global Environmental Research (CGER), Earth System Division (ESD), and National Institute for Environmental Studies (NIES), *National Greenhouse Gas Inventory Report of Japan (NIR)*, 2023, https://www.nies.go.jp/gio/en/archive/nir/jqjm1000001v3csj-att/NIR-JPN-2023-v3.0_gioweb.pdf.
34. International Renewable Energy Agency (IRENA), *Energy Profile: Japan*, n.d., https://www.irena.org/-/media/Files/IRENA/Agency/Statistics/Statistical_Profiles/Asia/Japan_Asia_RE_SP.pdf.
35. Cabinet Secretariat, *GX*実現に向けた基本方針（案）～今後*10*年を見据えたロードマップ～, 2022, https://www.cas.go.jp/jp/seisaku/gx_jikkou_kaigi/dai5/siryou1.pdf.
36. Ministry of Economy, Trade and Industry, *Advisory Committee for Natural Resources and Energy Conservation and New Energy Subcommittee Hydrogen Policy Subcommittee/Resources and Fuels Subcommittee Ammonia and Other Decarbonized Fuel Policy Subcommittee Joint Meeting Interim Report*, 2023, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/20230104_1.pdf.
37. Ministry of Economy, Trade and Industry, *Arrangement of issues for the realization of a carbon-neutral industrial complex*, 2022, https://www.meti.go.jp/shingikai/energy_environment/carbon_neutral_complex/20220324_report.html.
38. "Carbon Neutral Port (CNP) Initiative", *Ministry of Land, Infrastructure, Transport and Tourism*, 2008, https://www.mlit.go.jp/en/kowan/kowan_fr4_000011.html.
39. Ministry of Land, Infrastructure, Transport and Tourism, *Recent Movements Concerning the Formation of CNP, etc.*, 2023, https://www.mlit.go.jp/kowan/content/001586144.pdf.
40. Ministry of Economy, Trade and Industry, *Strategic Energy Plan*, 2021, https://www.enecho.meti.go.jp/category/others/basic_plan/pdf/strategic_energy_plan.pdf.
41. Cabinet Secretariat, *GX*実現に向けた基本方針（案）～今後*10*年を見据えたロードマップ～, 2022, https://www.cas.go.jp/jp/seisaku/gx_jikkou_kaigi/dai5/siryou1.pdf.
42. "Environment and energy", *United Arab Emirates*, 2023, https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy; "UAE Energy Diversification", *Embassy of the Unites Arab Emirates,* https://www.uae-embassy.org/discover-uae/climate-and-energy/uae-energy-diversification.
43. "UAE National Energy Strategy 2050: Presentation for CEM Long Term Energy Scenarios", *United Arab Emirates Ministry of Energy & Industry*, n.d., https://www.irena.org/-/media/Files/IRENA/Agency/Webinars/UAE-Presentation_LTES.pdf?la=en%26hash=7AB6DF56E17BE7CE5841CF5015DA9BE55F10C919.
44. "Just Energy Transition", *Presidential Climate Commission*, n.d., https://www.climatecommission.org.za/just-energy-transition.
45. Climate Transparency, *South Africa – Climate Transparency Report: Comparing G20 Climate Action Towards Net Zero*, 2021, https://www.climate-transparency.org/wp-content/uploads/2021/10/CT2021SouthAfrica.pdf.
46. Pierce, Warrick and Monique Le Roux, *Statistics of utility-scale power generation in South Africa*, CSIR Energy Centre, 2023, https://www.csir.co.za/sites/default/files/Documents/Statistics%20of%20power%20in%20SA%202022-CSIR-%5BFINAL%5D.pdf.
47. Department of Mineral Resources and Energy, *Integrated Resource Plan 2019*, 2019, https://www.energy.gov.za/irp/2019/IRP-2019.pdf.
48. "South Africa's Just Energy Transition Investment Plan", *Presidential Climate Commission*, 2023, https://www.climatecommission.org.za/south-africas-jet-ip.
49. Goncalves, Sergio, "EDP to transform Sines coal plant into hydrogen hub by 2025", *Reuters*, 14 October 2021, https://www.reuters.com/business/sustainable-business/edp-transform-sines-coal-plant-into-hydrogen-hub-by-2025-2021-10-14/#:~:text=LISBON%2C%20Oct%2014%20(Reuters),first%20production%20expected%20by%202025.

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