THAILAND TAXONOMY

Manufacturing Sector

May 2025

THAILAND TAXONOMY BOARD

Table of Contents

List of Figures

List of Tables

Thailand Taxonomy Boad

Manufacturing sector

1. Department of Climate Change and Environment, Ministry of Natural Resources and Environment
2. Bank of Thailand
3. Securities and Exchange Commission
4. Stock Exchange of Thailand
5. Department of Alternative Energy Development and Efficiency, Ministry of Energy
6. Thailand Greenhouse Gas Management Organization
7. Office of Natural Resources and Environmental Policy and Planning, Ministry of Natural Resources and Environment
8. Department of Industrial Works, Ministry of Industry
9. Thai Industrial Standards Institute, Ministry of Industry
10. Industrial Estate Authority of Thailand
11. Board of Trade of Thailand
12. Federation of Thai Industries
13. Renewable Energy Industry Club, Federation of Thai Industries
14. Thai ESCO Association
15. Thai Bankers' Association
16. Association of International Bank
17. Government Financial Institutions Association

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1. Manufacturing sector background

The manufacturing sector contributes 27% to Thailand's GDP in 2022, rising from 13% in 1960.[1] The sector will account for 73% of Thailand's total exports in 2022 and employ almost 5.84 million workers in 2021, or roughly 15% of the total labour force.[2] Office of Industrial Economics identifies and tracks the performance of Thailand's economically important manufacturing industries, given their shares in the country's production, domestic consumption, and exports and imports. As for the most climate-material manufacturing subsectors, their economic status is as follows:

- **Petrochemicals:** Thailand's petrochemical industry is the largest in ASEAN with a total production capacity in 2021 of 35 million tons, comprising 13.4 million tons of upstream products, 8.5 million tons of intermediate goods and 13.3 million tons of downstream outputs. [3] Over 80% of Thai upstream and intermediate production is for domestic use as inputs for further downstream processes.[4] Naphtha is the main feedstock (68% of total feedstock consumption). Ethylene is the world's most widely produced olefin and accounts for 41% of Thailand's total upstream production, with the country's capacity to produce ethylene being ranked 9th in the world.[5]
- **Cement:** Thailand is among the largest producers of cement in Asia. Cement production (excluding clinker) in Q1/2023 reached 10.92 million tons, representing a quarter-on-quarter (QoQ) increase of 8.05 % from Q4/2022 but a year-on-year (YoY) decrease of 3.49% from the same quarter in 2022.[6] Approximately 91% of cement produced is for the domestic market, with 9% of production exported. Around 60%

[1] World Bank, "World Bank Open Data," World Bank Open Data, n.d., https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=TH.

[2] National Statistical Office, "The Labor Force Survey Whole Kingdom Quarter 4: October-December 2021," Ministry of Digital Economy and Society of Thailand, https://webapps.ilo.org/surveyLib/index.php/catalog/8045/related-materials

[3] Thian Thiumsak, "Industry Outlook 2023-2025: Petrochemicals," krungsri research, n.d., https://www.krungsri.com/en/research/industry/industry-outlook/petrochemicals/petrochemicals/io/io-petrochemicals-2023-2025.

[4] Ibid.

[5] Ibid.

[6] Office of Industrial Economics, "Report on the Industrial Economics Status in Q1-2023 and Outlook for Q2- 2023,"n.d., https://www.oie.go.th/assets/portals/1/files/quarterly_industrial/Q1_2023andOutlookQ2_2023_en.pdf.

of the output is used in private sector construction (mostly in residential and commercial properties), and the remaining 40% in public sector projects.[7]

- **Iron and steel**: Thailand produces more long steel products than flat ones. As of November 2023, Thailand's production of finished steel products stood at 472,545 tons, contracting 20.5% (YoY) from 2022.[8] Thai steel products are consumed more domestically than exported, roughly at a 91:9 ratio. Long products (deformed bar and structural steel) are mainly used in the construction business, while flat products tend to be used in sectors such as automobiles and electrical appliances.[9]

- **Aluminium:** As of 2022, Thailand had a total production capacity of over 710,000 tons but actually produced only 571,000 tons, or 80% of the production capacity, with a total market value of approximately 80 billion baht.[10] Thai aluminium producers can be divided into two categories: flat roll, with a combined production capacity of up to 410,000 tons, and extrusion, with a production capacity of up to 300,000 tons. Thailand ranks second in the world in terms of the complete closed-loop recycling of aluminium cans at 91%.[11]

- **Plastic products:** Thailand is the world's 11th biggest exporter of plastics and the 2nd biggest in the ASEAN.[12] The Thai plastics industry benefits from the large and competitive domestic petrochemicals sector. Around 59% of the produced output is exported, and the remaining 41% is used to manufacture products for domestic industries, most notably in auto assembly, electronics and electrical appliances and

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[7]Puttachard Lunkam, "Industry Outlook 2023-2025: Construction Materials," krungsri Research, n.d., https://www.krungsri.com/en/research/industry/industry-outlook/construction-construction-materials/construction-materials/io/construction-materials-2023-2025.

[8] IRON & STEEL INTELLIGENCE UNIT and IRON AND STEEL INSTITUTE OF THAILAND, "THAILAND STEEL INDUSTRY REPORT – September 2023 - OIE," report, September 2023, https://km.fti.or.th/wp-content/uploads/2023/10/4.ภาวะอุตสาหกรรมเหล็กและเหล็กกล้า-โดยสถาบันเหล็กและเหล็กกล้าแห่งประเทศไทย-28-ก.ย.66.pdf.

[9] Taned-Mahattanalai, "Industry Outlook 2019-2021: Steel Industry," Krungsri Research, n.d., https://www.krungsri.com/en/research/industry/industry-outlook/construction-construction-materials/steel/io/io-steel-20.

[10] ฐานเศรษฐกิจ and ฐานเศรษฐกิจ, "จีนทุ่มตลาดหนัก อะลูมิเนียมไทยป่วน! จี้เร่งใช้เอดีปกป้อง," Thansettakij, March 9, 2023, https://www.thansettakij.com/columnist/exclusive-area/558442.

[11]Reedtradex, "Thai Aluminium to Reach Global Market and Save the Planet / เตรียมพร้อมอลูมิเนียมไทย ก้าวไกลและรักษ์โลก," n.d., https://www.reedtradex.co.th/enews/mtx23enews12/index_en.html.

[12] Aphinya Khanunthong, "Industry Outlook 2021-2023: Plastics," krungsri.com, n.d., https://www.krungsri.com/en/research/industry/industry-outlook/petrochemicals/plastics/io/io-plastics-21.

construction.[13] Polypropylene (PP), Polyethylene Terephthalate (PET), Low-Density Polyethylene (LDPE)/ Linear Low-Density Polyethylene (LLDPE) and High-Density Polyethylene (HDPE) represent 78% of all resins consumed in Thailand, with around 18% of key resins being recycled as of 2018.[14]

The primary plastics production industry in Thailand is witnessing significant growth, driven by robust demand across various sectors such as packaging, automotive, and construction. As of 2024, the market size is expected to grow by approximately USD 10.75 billion from 2023 to 2028, reflecting a compound annual growth rate of 5.18%[15]. Key factors contributing to this growth include advancements in plastic manufacturing technologies, increased investments, and a rising demand for lightweight, durable materials. The packaging sector remains the largest segment, fueled by the booming e-commerce market and the need for sustainable packaging solutions. Key factors contributing to this growth include advancements in plastic manufacturing technologies, increased investments, and a rising demand for lightweight, durable materials. The packaging sector remains the largest segment, fueled by the booming e-commerce market and the need for sustainable packaging solutions[16].

- **Automotives:** Thailand is the largest automotive producer in Southeast Asia and is ranked 10th globally as a production base.[17] The Thai automotive industry is structured in a pyramid, with car makers on top and auto parts makers in lower layers. As of 2022, there were 27 motor vehicle makers and 18 motorcycle makers. [18] In 2022, Thailand's car production totalled 1.88 million cars, of which 44.7% (around 0.84 million cars) were assembled for the domestic market and the remaining portion (around 1 million cars) for export. Pickups represented 62% of total car production in

[13] Ibid.

[14] Open Knowledge Repository, "Market-Study-for-Thailand-Plastics-Circularity-Opportunities-and-Barriers," n.d., https://openknowledge.worldbank.org/bitstreams/76c48f2a-d0c2-5a70-b801-43e37d851fc1/download.

[15] Mordor Intelligence, "Thailand Plastic Market Size & Share Analysis - Growth Trends & Forecasts (2024 - 2029)", n.d., https://www.mordorintelligence.com/industry-reports/thailand-plastics-market

[16] Industry Team, Bank of Ayudhya Public Company Limited,"Thailand Industry Outlook 2024-2026", January 10, 2024, https://www.krungsri.com/en/research/industry/summary-outlook/industry-outlook-2024-2026

[17] Thailand Board of Investment, "Thailand Automotive Industry, situation from ICE to Next-generation vehicle," July 6, 2023, https://www.boi.go.th/upload/content/20230706%20EN%20TAI_.pdf.

[18] Thai Automotive Industry, "Thai Automotive Industry - Facts and Figures," 2022, https://data.thaiauto.or.th/images/PDF/Navigator/Thai_Automotive_Industry-Facts_and_Figures_2022.pdf.

Thailand, while passenger cars accounted for a 35% share and other commercial vehicles (trucks, vans, and buses) for the remaining share. Battery electric vehicles remain the newcomer in Thailand's motor vehicle market, which is currently dominated by internal combustion engine vehicles. [19]

- **Electrical appliance Industry**: Thailand is a major producer and exporter of electrical appliances such as refrigerators, microwave ovens, thermos pots, household fans, washing machines, air-conditioners, compressors, rice cookers etc. In Q1/2023, exports of electrical appliances were valued at USD 8.2 billion, an increase of 18.5% (QoQ) compared to the previous quarter and an increase of 8.1% (YoY) from the same quarter last year. Products that experienced an increase in exports were air conditioners (43.1%), refrigerators (27.3%), and washing machines (26.4%).[20] The production index of the electrical appliance industry is expected to expand by approximately 4.0%.[21]

While being a main driver of the Thai economy, the manufacturing sector has recently experienced weakening conditions due to declining exports. In 2023, the manufacturing industries, particularly those associated with exports, contracted by 3 % (YoY) on average for the first three quarters of the year.[22] Exceptions were the automotive and petroleum refining sectors, which expanded in 2023.[23] From the investment perspective, manufacturing is driving foreign direct investment (FDI) flows into Thailand.

FDI in 2022 proved largest in metal products and machinery, followed by electrical and electronic products as well as services, with recent investment applications approved by the Board of Investment of Thailand in 2023 shifting towards electrical appliances and electronics

[19] Ibid.

[20] Office of Industrial Economics, "Report on the Industrial Economics Status in Q1-2023 and Outlook for Q2- 2023,"n.d., https://www.oie.go.th/assets/portals/1/files/quarterly_industrial/Q1_2023andOutlookQ2_2023_en.pdf.

[21] Ibid.

[22] World Bank, "Thailand Economic Monitor - Thailand's Path to Carbon Neutrality: The Role of Carbon Pricing," World Bank, Bangkok December 2023, https://documents1.worldbank.org/curated/en/099121223123018912/pdf/P5010091ef52cc09d1b46c1af1a43820def.pdf

[23] The office of Industrial Economics, "Montly Report Industrial Index April 2023 - April 2024," n.d., https://www.oie.go.th/view/1/industrial_indices/EN-US.

as well as electric vehicles.[24] Investments in the manufacturing of EV batteries are also rising in Thailand, due partly to the "30@30" policy --which sets the goal for 30% of vehicles made in Thailand to be zero-emission vehicles (ZEV) by 2030[25], and to related government support measures aimed at enabling Thailand to become a hub of electric vehicles manufacturing in ASEAN. Ahead of the 2030 target, ZEV production is expected to reach 225,000 units/year in 2025.[26]

1.1 Major climate and environment-related issues

Climate change presents key transition and physical risks for Thailand's manufacturing industries, calling for the adoption of climate change mitigation and adaptation strategies across sub-sectors.

As a major contributor to Thailand's GHG emissions, Thailand's manufacturing sector is developing strategies to accelerate decarbonisation. The sector currently produces a large amount of GHG emissions from chemical and physical processes, accounting for 37% of the country's final energy consumption. Cement production is Thailand's second highest emitting individual activity after rice cultivation. While traditionally focused on growth and production efficiency, Thai manufacturers are increasingly recognising the urgent need for sustainable practices. Many are adopting cleaner technologies, implementing energy-efficient processes, and optimising resource usage to minimise their carbon footprint.

Recognising the need to accelerate mitigation actions, the Ministry of Industry (MIND) implements the Bio, Circular and Green economic model to drive economy-wide decarbonisation and sustainable growth of Thai manufacturing industries.[27] External factors also act as an additional driver for the low-carbon transition of the manufacturing sectors. For

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[24] World Bank, "Thailand Economic Monitor - Thailand's Path to Carbon Neutrality: The Role of Carbon Pricing," World Bank, Bangkok December 2023, https://documents1.worldbank.org/curated/en/099121223123018912/pdf/P5010091ef52cc09d1b46c1af1a43820def.pdf

[25] TDRI, "Clean Energy Needs Far Clearer Policy," TDRI: Thailand Development Research Institute, September 2, 2022, https://tdri.or.th/en/2022/08/clean-energy-needs-far-clearer-policy/.

[26] S&P Global, "Thailand braces to make a big splash in EV sector," Nov 8 ,2023, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/110823-thailand-braces-to-make-a-big-splash-in-ev-sector

[27] United Nations Framework Convention on Climate Change, "Thailand LT-LEDS (Revised Version)," November 8, 2022, https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf

example, the introduction of the Carbon Border Adjustment Mechanism (CBAM) by the European Union in October 2023 is expected to accelerate mitigation actions in aluminium and steel, which are the two current Thai CBAM goods, and potentially in more sectors in the future.[28] Moreover, partnerships with governmental bodies and international organisations are fostering the development of eco-friendly regulations and incentives. However, challenges persist, including ensuring the inclusivity of small and medium-sized enterprises in decarbonisation and sustainability efforts.

Apart from contributing to climate change, manufacturing industries suffered tremendous damage from the severe floods in 2011, which hit seven industrial parks in the northern suburbs of Bangkok, affecting 730 companies and disrupting global supply chains of electronic components, disk drives and auto parts.[29] Physical risks from climate change can also affect the manufacturing sector through other channels, such as changes in the quantity and quality of water supply and higher frequency of extreme heat events affecting workers' welfare. More investment in adaptation and resilience measures is needed to reduce the vulnerability of the manufacturing sector to physical risks from climate change.

Waste is another important problem associated with the manufacturing sector (for more on that please read Waste Sector information). During the coronavirus epidemic, industrial waste volumes fell sharply due to quarantines at factories, falling demand and supply chain disruptions, but have since recovered and even increased. For example, it was 18.05 million tonnes in 2020 but rose to 35.55 million tonnes by 2022. However, the government's efforts to reduce the total volume of industrial waste are yielding results compared to 2015, when

[28] In the short term, the effects of the CBAM on the Thai industry are expected to be slight. Among the CBAM goods, the most important ones for Thailand are iron and steel (around 1.5% of exports to the EU) and aluminium (around 0.4% of exports), while the sales of other CBAM goods to the EU are either very low or non-existent. However, the list of CBAM goods will gradually expand to match those covered under the EU ETS, while other countries (such as the US and Canada, etc.) are also considering measures similar to CBAM. This will likely significantly amplify the impacts of carbon border adjustments on Thai manufacturers and exporters across more sectors in the long run. For more information see: Prapan Leenoi, “Countdown to the CBAM: How prepared is Thailand for the introduction of the EU carbon tax?,” krungsri Research, August 03, 2023, https://www.krungsri.com/en/research/research-intelligence/cbam-2023.

[29] Nikkei Editorial, “Global Companies Must Learn From Thai Floods That Upended Supply Chains,” Nikkei Asia, October 13, 2021, https://asia.nikkei.com/Opinion/The-Nikkei-View/Global-companies-must-learn-from-Thai-floods-that-upended-supply-chains.

the volume of waste was 37.4 million tonnes[30]. Industrial waste management, key challenges remain in enhancing the monitoring of the renewal of factories that lack industrial waste management, mandating them to carry out industrial waste management systematically and legally, and enforcing the law on industrial factories that have not been legally entered into the industrial waste management system[31].

Another problem is the country's production and consumption of plastics, a large portion of which, due to mismanagement, often end up in the oceans. Approximately 51,000 tons of uncollected and improperly disposed plastic waste in Thailand gets washed into the sea each year, and the country is ranked sixth in the world on this indicator[32]. According to a World Bank study, despite a high municipal solid waste collection and recycling rate of 88.8% in Thailand, remaining uncollected plastic waste and many unsanitary disposal facilities result in an estimated 428 ton/year of mismanaged plastic waste[33]. Only about 25% of the country's plastic waste is recycled. For used plastic packaging, the current obstacles in recycling are the lack of recycling facilities for soft plastic bags, while the beverage boxes still have no proper systems for collection and value-adding.[34] To address this problem more systematically, Thailand is in the process of drafting the Extended Producer Responsibility (EPR) Law, which promotes the sustainable management of plastic waste with the participation of the plastic manufacturing industry[35].

[30] Office of Natural Resources and Environmental Policy and Planning"ปริมาณกากของเสียอุตสาหกรรม (อันตรายและไม่อันตราย) (2558-2565),"n.d., http://env_data.onep.go.th/reports/subject/view/153

[31] Pollution Control Department, "Thailand State of Pollution Report," 2022, https://www.pcd.go.th/wp-content/uploads/2022/08/pcdnew-2022-08-08_08-30-05_795080.pdf.

[32] United Nations Environment Programme, "Circular solutions for plastic pollution,"n.d., https://wedocs.unep.org/bitstream/handle/20.500.11822/41861/behavior_change.pdf?sequence=3&isAllowed=y.

[33]World Bank, "Plastic Waste Material Flow Analysis for Thailand- Summary Report," 2022, https://documents1.worldbank.org/curated/en/099515103152238081/pdf/P17099409744b50fc09e7208a58cb52ae8a.pdf.

[34] Nationthailand, "Packaging Producers Push for Enactment of EPR Law," Nationthailand, August 11, 2023, https://www.nationthailand.com/thailand/general/40030126.

[35] Ibid.

1.2 Key sectoral climate policies

The Department of Industrial Works (DIW), Ministry of Industry (MINDI) has prepared **the NDC Sectoral Action Plan for the IPPU Sector (2021 – 2030)** to reduce GHG emissions in the manufacturing sector by setting targets for implementation in two phases:

- The preparation phase (2019 – 2020) supports the implementation of measures according to the NDC roadmap starting in 2021;
- The action phase (2021 - 2030) has targets for driving key measures and supporting measures to reduce GHG emissions in the manufacturing sector to achieve the goal within the year 2030, according to the NDC Roadmap and Action Plan.

As major GHG emissions from the manufacturing sector are from the cement, chemical, refrigeration, and air conditioning industries, respectively, key mitigation measures in the sector focus mainly on clinker substitution and substitution of high global warming potential (GWP) refrigerants.[36] Specifically, the NDC Sectoral Action Plan for IPPU includes two main mitigation measures:

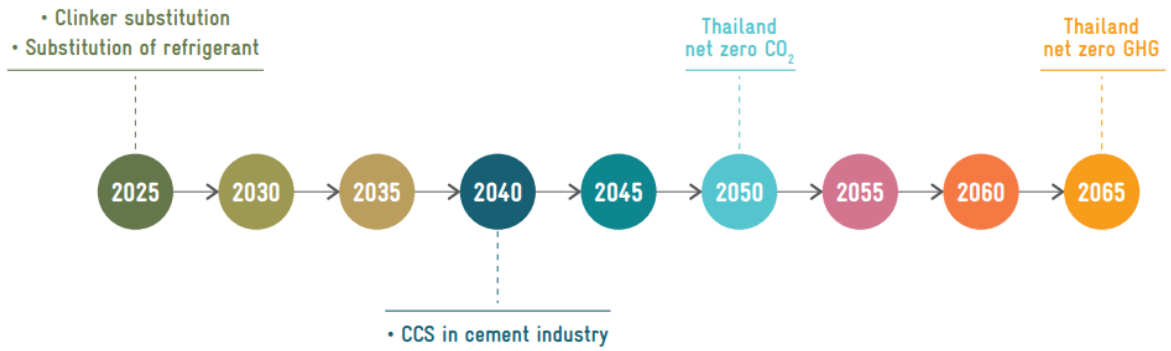
- **Clinker substitution measures** with two sub-activities: the use of clinker substitutes in the hydraulic cement production process and the increased use of cement substitutes in ready-mixed concrete.
- **Refrigerant replacement measures** with two sub-activities: refrigerant modification under the Thailand Refrigeration and Air Condition Nationally Appropriate Mitigation Actions (RAC NAMA) project[37] and the proper disposal of waste and deteriorated refrigerant.

By 2040, it is also expected that carbon capture utilization and storage (CCS/ CCUS) technologies will contribute substantially to further carbon removal from the cement industry.

[36] United Nations Framework Convention on Climate Change, "Thailand LT-LEDS (Revised Version)," November 8, 2022, https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf.

[37] Thailand RAC NAMA, "Thailand Refrigeration and Air Conditioning Nationally Appropriate Mitigation Action (RAC NAMA)," n.d., https://www.egat.co.th/home/wp-content/uploads/2023/11/4.-Factsheet-RACNAMA_EN.pdf.

Figure 1 Manufacturing sector decarbonisation timeline



Source: ONEP (2022). Thailand's Long-Term Low Greenhouse Gas Emission Development Strategy (Revised Version November 2022)

Energy efficiency, fuel-switching, and electrification of end-use technologies are also key to the decarbonisation of manufacturing industries. According to LT-LEDS, the electrification of end-use technologies in the industrial sector includes replacing non-electricity-based technologies with electricity-based ones. The potential to replace fossil fuels partially or completely with renewables, such as biomass and solar, in heating applications also exists in the manufacturing industries. Green hydrogen produced using renewable-based electricity will also play an important role in the decarbonisation of hard-to-abate sectors that cannot be electrified easily, such as iron and steel, aluminium, and cement. Hydrogen burners could be used in conjunction with electric heating to generate the high temperatures required in many heavy industrial processes and replace fossil fuel burning.[38]

Apart from national climate policy goals in the IPPU sector, several industry-level climate actions have also been implemented to accelerate decarbonisation in various manufacturing sectors in Thailand. For example:

- Thai cement manufacturers have begun to invest in green technology, including in the production of hydraulic cement, to help cut CO2 emissions. The Thai Cement Manufacturers Association (TCMA) has set the "Mission 2023" for cutting GHG emissions by at least 1 million tons of CO2 by 2023 by encouraging all sectors to use hydraulic

[38] United Nations Framework Convention on Climate Change, "Thailand LT-LEDS (Revised Version)," November 8, 2022, https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf.

cement in all types of construction projects.[39] The Thai cement industry has also pledged to reach net zero emissions by 2050. The TCMA has published the Thailand Net Zero Cement & Concrete Roadmap 2050, which seeks to halve GHG emissions by 2030 and ultimately achieve net zero by 2050.[40]

- An MOU was signed between the Aluminium Industry Club of the Federation of Thai Industries (FTI), the National Metal and Materials Technology Center, and 11 aluminium producers to mutually determine the median GHG emission value to serve as a baseline for decarbonisation. In addition, the industry is increasingly using solar-powered electricity generation and recycled aluminium scraps as raw materials.[41]

- The National Electric Vehicle Policy Committee sets the vision for Thailand to be one of the most important EV production bases and component parts in 2035. Current EV promotion measures include supply-side measures (e.g., EV and charger standards, testing facility[42], supply chain transition program, End-of-Life Vehicle program, investment promotion scheme) and demand-side measures to incentivise EV purchases (e.g., customs tax, excise tax, subsidy, and annual road tax) and infrastructure development.[43]

- The bioplastics industry in Thailand is expanding rapidly, driven by both domestic and international demand for sustainable materials. As the country strives to reduce its environmental footprint, the production and use of bioplastics have been prioritized. In 2023, Thailand was one of the largest producers of bioplastics in the ASEAN region, with a production capacity of approximately 95,000 tons per year. The industry is expected to grow at a rate of around 20% through 2025, reflecting increasing

[39]Asia Cement, "TCMA Together With 25 Alliances Announced 'Mission 2023' on Greenhouse Gas Mitigation," Asia Cement, March 31, 2022, https://www.asiacement.co.th/en/tcma-together-with-25-alliances-announced-mission-2023-on-greenhouse-gas-mitigation#:~:text=We%20therefore%20announced%20%22MISSION%202023,gas%20emission.%22%20stated%20Mr.

[40] TCMA, "Thailand 2050 Net Zero Cement & Concrete Roadmap," n.d., https://www.thaicma.or.th/th/ebook_detail/3/197.

[41] Prachachat.net, "ส่องอุตฯอะลูมิเนียมปี'65 ต้นทุนสิ่งแวดล้อมดันราคาขายพุ่ง," Prachachat.Net, February 18, 2022, https://www.prachachat.net/economy/news-865746.

[42] The Automotive and Tyre Testing, Research and Innovation Center (ATTRIC)

[43] Clement Choo and Leah Chen, "Thailand braces to make a big splash in EV sector," S&P Global, November 8, 2023, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/110823-thailand-braces-to-make-a-big-splash-in-ev-sector.

investments and favorable government policies[44]. Economic incentives from the Thai government, such as tax benefits and subsidies, are bolstering the bioplastics sector. These measures aim to promote the use of renewable resources, which in Thailand include locally available agricultural products like cassava, sugarcane, and corn.

The government has introduced initiatives like the "Thailand 4.0" model, which supports the development of bioplastics as part of the country's shift towards an innovation-driven economy. Challenges remain, however, including higher production costs compared to conventional plastics and the need for greater consumer awareness and infrastructure to handle bioplastic waste effectively.

2. Manufacturing activities climate materiality

Manufacturing activities in GHG inventories are covered by the Industrial Process and Product Use (IPPU) category under Thailand's GHG inventory. It is important to note that this category only accounts for the emissions accompanying the chemical processes of manufacturing and does not cover the emissions accompanying the generation of electricity for the production processes (except for the captive power plants situated within the factory)[45]. The national GHG inventory data will be used to assess the mitigation potential of the inclusion of activities in the Taxonomy. The table below includes only activities that contribute more than 1% to the overall IPPU sector emission volume and compares them to the proposed activities to be covered under the manufacturing sector under this Taxonomy.

Table 1 Industrial Process and Product Use sector emission profile

Subsector	IPCC 2006 Code	Manufacturing sector GHG Emission, total in GgCO2eq (share of total sectoral emission, %)	Corresponding proposed activities under the Thailand Taxonomy
Cement Production	2A1	15,803.16 (38.99%)	Manufacturing of cement
Chemical Industry	2B	11,668.31 (28.79%)	Manufacturing of hydrogen

[44] Mordor Intelligence, "Thailand Plastic Market Size & Share Analysis - Growth Trends & Forecasts (2024 - 2029)", n.d., https://www.mordorintelligence.com/industry-reports/thailand-plastics-market

[45] Please note that IPCC methodology that serves as a basis for creating GHG inventories is not . The Taxonomy itself mostly requires measurement of Scope 1+2 emissions (see particular activity cards and Business Guide for clarifications).

Subsector	IPCC 2006 Code	Manufacturing sector GHG Emission, total in GgCO2eq (share of total sectoral emission, %)	Corresponding proposed activities under the Thailand Taxonomy
			Manufacturing of carbon black Manufacturing of soda ash Manufacturing of chlorine Manufacturing of ethylene, propylene, butadiene Manufacturing of aromatics (acetylene, benzene, xylene, and toluene) Manufacturing of anhydrous ammonia Manufacturing of nitric acid Manufacturing of plastics in primary form
Iron and Steel Production	2C1	425.32 (1.05%)	Manufacturing of iron and steel
Refrigeration and Air conditioning	2F1	10,383.15 (25.62%)	Covered in the Energy sector of Phase I (4.1.9; 4.1.10; 4.1.11)
Electrical Equipment	2G1	756.09 (1,86%)	Covered by five activity cards in the Enabling activities as well as by the auxiliary transitional activity

Source: Thailand's First BIennial Transparency Report [46]

The largest proportion of emissions from the manufacturing sector for Thailand is the production of cement and chemicals, both of which have been proposed to be included in the Taxonomy. In addition, almost all international taxonomies include activities such as the production of aluminium, iron, and steel because these activities consume a lot of electricity and have significant associated emissions.

[46] "Thailand's First Biennial Transparency Report under the United Nations Framework Convention on Climate Change." UNFCCC. Published December 26, 2024. https://unfccc.int/documents/645098

Furthermore, manufacturing of hydrogen involves the production of low-carbon hydrogen, which can subsequently be used for energy production, in transport or in industry.

In addition to activities directly aimed at reducing production-related emissions in the climate-material manufacturing activities above, it is also proposed to include a number of enabling manufacturing activities in the Taxonomy:

1. **Manufacturing of batteries**. This activity includes the production of batteries capable of storing electricity and thereby increasing the potential use of renewable energy sources as opposed to non-renewable ones.
2. **Manufacturing of renewable energy technologies and products**. This activity includes the production of technologies and components necessary for the operations of renewable facilities and the production of low-carbon energy as defined by the Taxonomy, such as solar panels, blades of wind generators, turbines for hydroelectric power plants, etc.
3. **Manufacture of low-carbon technologies for transport**. This activity includes the assembly and production of components for vehicles that meet the criteria of this taxonomy (zero tailpipe emissions).
4. **Manufacturing of energy efficiency equipment for buildings**. This activity includes the production of various components and machines that help reduce the emission of buildings and their consumption of basic resources (water or energy).
5. **Manufacturing of other low-carbon technologies**. This activity includes the manufacturing of electronics and household appliances that meet the highest performance level of the energy rating system introduced by the National Energy Authority, as well as machinery needed to decarbonise other sectors of the economy.
6. **Carbon capture-related activities.** These are important for the manufacturing sector as they enable even the most emitting of hard-to-abate activities to reduce their emission intensity. The following activities are covered here:
    - **Point-source capture of CO2.** This activity clarifies the rules for using carbon capture technology within the framework of this taxonomy.
    - **Transportation of captured CO2.** This activity determines the rules for transporting carbon captured in the carbon capture process.

- **Permanent sequestration of captured CO2**. This activity determines the rules for the disposal of carbon captured in industrial and other processes.
- **Utilisation of captured CO2**. This activity determines how the captured CO2 can and cannot be used.

3. Manufacturing criteria scope

The criteria for manufacturing cover a heterogeneous group of activities in nature and technological structure, which will be specifically defined in the respective subchapter.

Eligible expenditure also covers the costs of the facilities and supporting infrastructure associated with the production process. In practice, this means that not only revenues associated with the production of low-carbon cement, or upgrades of facilities are considered aligned with the Taxonomy, but also a project to construct a new cement plant that will produce low-carbon cement is eligible.

4. Manufacturing criteria methodological approach

Unlike the energy sector, which can be decarbonised fairly quickly given the availability of capital, for many high-emitting activities in the manufacturing sector, there is simply no available technology way to do so. All activities in this sector can be divided into five groups:

- **Hard-to-abate activities**. These are the activities that the economy needs in the long term, but cannot be decarbonised overnight and need gradual decarbonisation;
- **Interim** (only production of plastics). This activity has a definite role in the economy until 2050[47], but in their present form must be gradually phased out completely by this date. The main production processes in it should be transformed to such an extent that it is no longer a threat to the fulfilment of the objectives of the Taxonomy.

[47] This statement is given for methodological reasons and does not affect the activity cards that serve as the only source of technical screening criteria. Interim activities activity cards are still usable after 2050.

- **Enabling**[48]. Activities in the second category (for example, the production of low-emission cars or batteries) may involve significant emissions, but the products they produce are considered critical for the decarbonisation of the economy as a whole, and thus their emissions are negligible compared to the overall benefit to climate.
- **Related to carbon capture and storage**. These activities help decarbonise the economy by capturing, transporting, and burying carbon that would otherwise be released into the atmosphere.
- **Auxiliary transitional activity**. This section includes the introduction of energy efficiency and decarbonisation measures in manufacturing activities not specified in the Thailand Taxonomy designed to enable as many businesses as possible to participate in the implementation of the Taxonomy.

Manufacturing sector activities often have complex production chains, and in order to use the Taxonomy it is very important to determine how much of these chains are covered by the criteria. For such activities, the Taxonomy offers the following definitions:

- **Activity coverage**. These diagrams or descriptions show the parts of an activity's production chain to which the Taxonomy's criteria and thresholds apply. This means that these elements of the production chain can be replaced during the application of the Taxonomy (e.g. through the application of amber-category measures) and funds coloured compliant (as adaptation or green finance) can be requested for them. Chain elements outside of this diagram or description CANNOT be subject to change within the Taxonomy criteria and funding defined by the Taxonomy categories cannot be requested for them.

[48] An enabling economic activity should qualify as contributing substantially to one or more of the environmental objectives when it directly enables other activities to make a substantial contribution to one or more of those objectives. Such enabling activities should not lead to a lock-in of assets that undermine long-term environmental goals, considering the economic lifetime of those assets, and should have a substantial positive environmental impact, on the basis of life-cycle considerations: European Union [EU], "REGULATION (EU) 2020/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2020 on the Establishment of a Framework to Facilitate Sustainable Investment, and Amending Regulation (EU) 2019/2088," Official Journal of the European Union (EU, June 22, 2020), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0852.

- **Scope of emissions calculation**. These diagrams or descriptions show how the emission of an activity should be counted to calculate whether or not the activity meets the criteria and thresholds. Typically, the diagrams and descriptions are consistent with the sum of Scope 1 and Scope 2, but sometimes some elements of these scopes are not included because they are not climate-material for the activity. It is important to note that emission calculations are not important in all applications of the Taxonomy, but only when required to determine thresholds. In most cases, it is required to verify that the activity fits the green category, but not the amber or red categories, which are simpler to define and apply.

Important note 1: the Taxonomy aims to reduce emissions in sectors that are notable contributors to climate change via GHG emissions. Many other sectors and activities (e.g., textiles, food, paints, etc.) are important to the Thai economy, but are not themselves large emitters of greenhouse gases. Those parts of their value chains that are climate material (mostly production of steel, iron, aluminium, transportation etc.) are included in the relevant sections of the Taxonomy (manufacturing or transportation sections). For activities that do not have their own decarbonisation criteria, the activity "Introduction of energy efficiency and decarbonisation measures in manufacturing activities not specified in the Thailand Taxonomy" has been developed (read details below).
Important note 2: At the end of each activity card, there is a 'Criteria reference' line referring to a document that is the methodological basis for the criteria in the activity card (most commonly referring to Climate Bonds Initiative sectoral criteria[49]). These documents and their contents are not part of the criteria, and fulfilment of the conditions specified in these documents is not necessary for compliance with the Thailand Taxonomy. The purpose of this reference is to provide a source of criteria for those who wish to become more familiar with the theoretical and methodological framework, and to provide material for further updating of the criteria when the Taxonomy is revised.

[49] Climate Bonds Criteria are used as a major source of reference due to their status as a universal standard applied in the majority of the world's taxonomies

4.1 Hard-to-Abate Activities

This category includes the production of steel and iron, cement, basic chemicals, aluminium, and hydrogen. Individual decarbonisation trajectories have been developed for the green category for these activities taking into account data provided by Thai ministries and agencies that are in line with the Climate Bonds Initiative Standards Criteria[50]. The trajectory leads to net-zero emissions in 2050. Wherever possible, science-based transition pathways (or methodologies of their creation) have been adopted from other organisations:

- **Basic chemicals**: Teske et al. (2022); ICF and Fraunhofer ISI study for the EC (2021)
- **Cement**: Science-Based Targets Initiative
- **Iron and Steel**: IEA Net-Zero Emissions (IEA NZE)
- **Aluminum**: International Aluminum Institute based on IEA
- **Hydrogen**: MIT Energy Initiative's SESAME platform

In most cases, these pathways were modified in line with the country data provided by relevant Thailand government bodies and professional associations. For more information on calculation of individual decarbonisation pathways please see prefaces for specific manufacturing activities.

As for the amber category, given the scale of challenges associated with the decarbonisation of the selected manufacturing sectors and the lack of technologically and economically feasible low-carbon alternatives, these sectors have been defined as inherently "in transition." While in other sectors it is possible to delineate a boundary between red and amber, for most manufacturing activities, the boundary is harder to define because data is often not available to build a trajectory with any credibility or scientific basis, meaning that the line between ineligible and amber would be arbitrary.

This approach takes into account the objectives set by NDC Thailand wherever possible. It should be noted that the decarbonisation measures themselves (amber category) are not tied to any timeframe other than the sunset date defined by the ASEAN Taxonomy (2040) and can

[50] CBI, "The Standard," Climate Bonds Initiative, April 29, 2024, https://www.climatebonds.net/standard/the-standard.

be applied to achieve decarbonisation by any year, either 2050 or 2065, as defined by the current version of Thailand's NDC.

For this reason, specific provisions were introduced for the amber category in this class of activities:

- **Introduction of specific decarbonisation measures**: individual decarbonisation measures are proposed in order to circumvent the lack of availability of data. The adoption of those technologies acts as a proxy for decarbonisation. Application of these measures helps to reduce the emission intensity of industrial processes and move it closer to the established decarbonisation pathway.
- **Transition plans**: in order to qualify as transition, a credible transition plan towards net-zero must be adopted at the entity level. This is necessary to ensure that movement towards net-zero is not a one-off push of a single facility, but a consistent strategic course of the manufacturing entity. We recommend for the transition plans to be prepared in line with Transition Finance Principles outlined by the International Platform on Sustainable Finance[51] or ASEAN Transition Finance Guidance[52].

As for the red activities, they are absent from hard-to-abate subsectors activity cards (except for plastics where the red category includes the production of all types of plastics not mentioned in green or amber category due to their heavy environmental footprint) due to their significant environmental footprint. This is because the nature of this category prevents it from being fully decarbonized in a short time.

4.2 Interim activities

Financing credible transition paper[53] by Climate Bonds Initiative defines interim activities as "activities currently needed but should be phased out by 2050 – e.g. recycling of plastics or

[51] International Platform of Sustainable Finance [IPSF], "IPSF Transition Finance Report," European Commission (IPSF, November 2022), https://finance.ec.europa.eu/system/files/2022-11/221109-international-platform-sustainable-report-transition-finance_en.pdf.

[52] ASEAN Capital Markets Forum [ACMF], "ASEAN Transition Finance Guidance," ACMF (ACMF, October 17, 2023), https://www.theacmf.org/images/downloads/pdf/ASEAN%20Transition%20Finance%20Guidance%20Version%201%20-%20FINAL%2017%20Oct%202023.pdf.

[53] Climate Bonds Initiative. *Financing Credible Transitions*. London: Climate Bonds Initiative, 2021. https://www.climatebonds.net/files/reports/cbi_fincredtransitions_final.pdf.

production of energy from municipal waste". Manufacturing sector of the Thailand Taxonomy includes only manufacturing of plastics as such an interim activity. The criterion for this activity encourages the recycling of existing plastic by mechanical or chemical means and the subsequent production of new goods from recycled plastic.

4.3 Enabling activities

An enabling activity directly enables other activities to make a substantial contribution to one or more of those objectives. Such enabling activities should not lead to a lock-in of assets that undermine long-term environmental goals, considering the economic lifetime of those assets, and should have a substantial positive environmental impact, on the basis of life cycle considerations. The following activities are considered enabling:

- Manufacturing of batteries
- Manufacturing of renewable energy technologies
- Manufacturing of low-carbon technologies for transport
- Manufacturing of energy-efficiency equipment for buildings
- Manufacturing of other low-carbon technologies

Because of the intrinsic nature of enabling activities, there is only the green category available and no amber category.

4.4 Carbon capture, transportation, utilisation, and storage

Technologies such as Carbon Capture and Storage (CCS) and Carbon Capture, Utilisation and Storage (CCUS) have significant potential to contribute to the decarbonisation of industry, but only if carbon remains permanently stored and is either securely locked in geological structures or reused for manufacturing processes/durable[54] products manufacturing and does not get back into the atmosphere.

Thus, the green category in CCS/CCUS-related activities is related to the proper handling, transportation, and monitoring of leaks during the capturing process, transportation and

[54] The product is considered durable if its expected lifespan is longer than 3 years. Bureau of Economic Analysis. "Durable Goods." *U.S. Department of Commerce*. Accessed March 10, 2025. https://www.bea.gov/help/glossary/durable-goods)

storage of CO2, and the amber category is related to the retrofitting of existing pipelines. The thresholds themselves were constructed to match those applied by the European Union Taxonomy.

Captured CO2 may either be transported and stored or used on-site for other industrial processes that require a source of carbon. Huge quantities of CO2 are currently used each year, mainly in in the fertiliser industry and for enhanced oil recovery (which is not aligned with the objectives of Thailand Taxonomy) while new utilisation pathways in the production of CO2-based synthetic fuels, chemicals and building aggregates are gaining momentum.

4.5 Auxiliary transitional activity: Introduction of energy efficiency and decarbonisation measures in manufacturing activities not specified in the Thailand Taxonomy

This activity has been specifically designed to allow as many industrial companies as possible to participate in the application of the Taxonomy. It involves the introduction of energy efficiency measures, the electrification of production processes and the replacement of non-renewable energy sources with renewable ones. The activity can be applied to decarbonise and improve the energy efficiency of all activities that do not have a separate item in the Taxonomy.

This activity was developed specifically for Thailand Taxonomy and has no precedent in other taxonomies. As the wide variation in applications precludes the development of a single best practice for all types of activities, its activities in Green category should comply the international standards such as SBTi. The Amber category has two options:

- **Improve energy efficiency by at least 40% relative to the baseline energy intensity of the facility**. This threshold has been defined according to the Draft 2024 Energy Efficiency Plan, which aims to reduce the energy intensity of the Thai economy by 36% by 2037 (compared to 2010 baseline). Adapting this figure to the mechanisms of the taxonomy and the general sunset date (2040), this figure was raised to 40% and extrapolated to the baseline of a particular enterprise.
- **Electrification and replacement of energy sources with renewable energy**. Electrification is considered by climate science to be one of the most effective ways to decarbonise because it allows access to renewable energy connections. This activity

does not contain any targets or thresholds, as replacing any amount of energy consumption with renewable energy is a contribution to the Taxonomy targets. It is important to note that only the direct connection of an enterprise to renewable energy sources is taken into account, the purchase of PPA certificates is not included, as this does not lead to an actual reduction in the emission intensity of a particular enterprise.

This activity may not be applied to decarbonising industries associated with the extraction, transport or storage of hydrocarbons, or the production of components for these processes, or any other type of industry that promotes the use of hydrocarbons and their derivatives (e.g., prohibited for application to facilities producing internal combustion engine vehicles).

5. Criteria application scheme

Either the financial flows (CapEx and OpEx) associated with a production process or with the entire production facility can qualify as eligible.

The amber category that applies to investment measures (those for hard-to-abate subsectors) cannot be used to assess revenues. It can only be used to define the alignment of CapEx. Such an approach has a major upside in that it rewards individual decarbonisation efforts whilst also facilitating emissions reduction from hard-to-abate sectors in the absence of available data. However, the amber category for these activities has a sunset date of 2040, limiting the timeframe of the eligibility of measures. Following this date, the amber category will no longer be applicable, as the target year for achieving net-zero emissions approaches. All legacy high-emission industries are expected to be progressively phased (all amber activities become out-of-scope after this date). This period aims to offer an opportunity to reward positive climate impacts while low or zero-emission technologies remain underdeveloped and expensive.

Table 2 Usability implication of the measures-based approach

	Green	Measures-based amber	Activity-based ("traditional") amber
Taxonomy is used to define the alignment of CapEx	CapEx is eligible if a given activity currently meets the green criteria, and the measure will help to	Financing of specific measures (each of them might have additional measure-	CapEx is eligible if a given activity currently meets the amber criteria, and the measure will help to

	Green	Measures-based amber	Activity-based ("traditional") amber
	keep below the future green criteria (so assume need to assess the transition plan/CapEx plan)	specific criteria) is eligible as amber	achieve green criteria (so assume the need to assess transition plan/CapEx plan)
Taxonomy is used to define the alignment of revenues associated with activities.	Revenue is eligible if the activity meets green criteria	Not available	Revenue is eligible if the activity meets the Amber criteria

Note: this distinction between measures-based and activity-based amber is important for the methodology of the chapter but does not affect application scheme. Only three statuses are available for the taxonomy: green activities, amber activities, and red activities.

6. Manufacturing subsector criteria and thresholds

6.1 Hard-to-Abate Activities

1. Manufacture of basic chemicals

The scope of the activity defined under Thailand taxonomy includes assets and activities involved in the production of a number of eligible organic and inorganic basic chemicals. The eligible basic chemicals that are under the scope of the Taxonomy are defined in Table below.

Table 3. Eligible basic chemicals under the scope of Thailand Taxonomy

Chemical groups	Eligible assets
Inorganic basic chemicals	• Ammonia • Chlorine • Disodium carbonate/Soda ash • Nitric acid • Carbon black
Organic basic chemicals	• High-value chemicals (ethylene, propylene, butadiene) • Aromatics BTX (acetylene, benzene, toluene and xylene) • Methanol

Decarbonisation trajectories for nitric acid, high value chemicals and aromatics BTX were calculated based on the Climate Bonds Initiative methodology, which integrated data provided by the Federation of Thai Industries (FTI). The thresholds for 2025 were calculated as follows: 15% was subtracted from the average emission intensity data for each product type obtained from FTI (to aim for the "best in class" installations), and then the values for 2030 and 2035 were calculated as a proportional reduction in emission intensity to values compliant with the Climate Bonds Basic Chemicals Criteria. Although technologies to decarbonise the chemical industry to Climate Bonds Criteria-aligned thresholds exist today, applying these thresholds only from 2040 onwards will give the Thai chemical industry sufficient time to prepare and make the necessary capital investments.

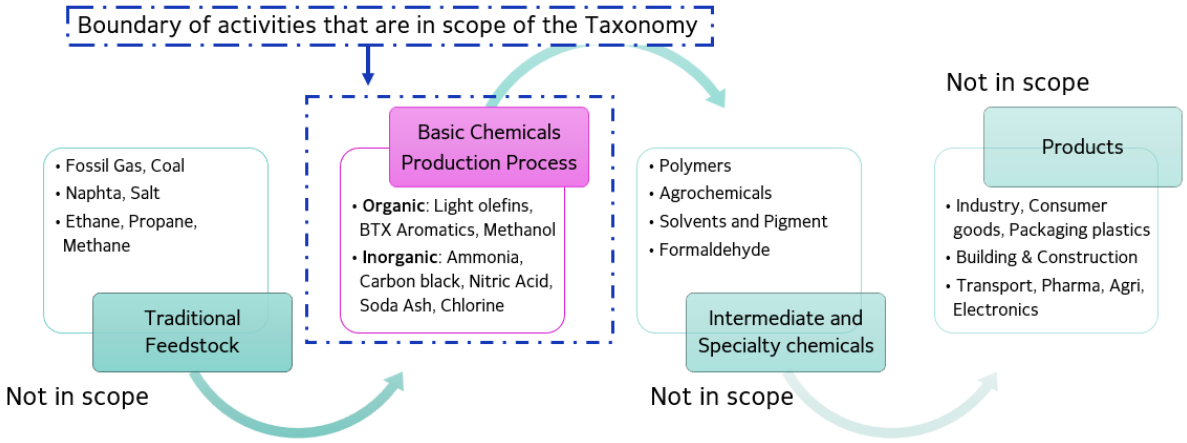
For ammonia, chlorine, soda ash, carbon black and methanol, their decarbonisation pathways, requirements and thresholds are taken directly from the Climate Bonds Basic Chemicals Criteria and are compliant with the best available technology in the world.

Thresholds and pathways for all mentioned chemicals except chlorine in these criteria are based on the alignment to Paris Agreement-aligned decarbonisation pathways for the entire chemical sector published by Teske et al. (2022)[55] With the reduction rates from Teske et al.'s pathway and taking as basis the thresholds for 2022, the thresholds were extrapolated to 2025 first using the 4.7% annual reduction to have the 2025 base value. Afterwards, the aforementioned reduction rates were applied to calculate the 2030, 2035, 2040, 2045 and 2050 threshold. For nitric acid, high value chemicals and aromatics Teske's values are applied only at 2040 and after.

The value chain of basic chemicals production, along with boundary of production activities within the scope of taxonomy is specified in Figure below.

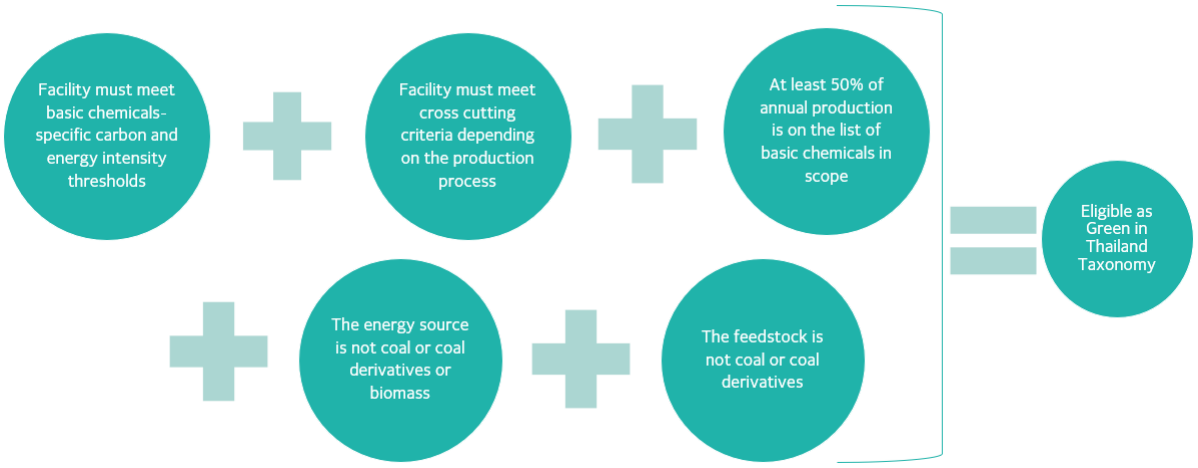
[55] Sven Teske et al., "1.5 °C Pathways for the Global Industry Classification (GICS) Sectors Chemicals, Aluminium, and Steel," SN Applied Sciences/SN Applied Sciences 4, no. 4 (April 1, 2022), https://doi.org/10.1007/s42452-022-05004-0.

Figure 2 Basic Chemicals production value chain and activities within the scope of the Taxonomy criteria



In order to be compliant with green criteria, all important elements of the facility and technological process should correspond to the criteria stipulated in the respective activity card. An overview of that list is given in Figure below.

Figure 3 Green criteria overview for manufacturing of basic chemicals



The scope of emissions calculations for the production of the basic chemicals is as follows:

- **Nitric acid and soda ash**: scope 1 emissions, which include all direct emissions from the production processes, such as emissions generated during the chemical reactions and emissions from fuel combustion on-site.
- **Carbon black, high value chemicals and aromatics**: scope 1 as defined above plus scope 2 emissions which includes indirect emissions from the energy imported from off-site.

- **Methanol and ammonia**: associated GHG emissions counted as the life cycle emissions of hydrogen used as feedstock.
- **Chlorine**: only electricity consumption intensity is within the scope. No separate GHG accounting for the whole production process is required for chlorine, as all emissions in its production chain are associated with electricity consumption.

Amber criteria of the activity include decarbonisation measures that are applicable within the basic chemical production facility where the **entity has a transition plan aligned with the commitments under the Paris Agreement.** The framework for the Amber criteria is specified in the Figure below.

Figure 4 Amber criteria framework for manufacturing of basic chemicals

Manufacture of basic chemicals criteria and thresholds

Sector	Manufacturing
Activity	Manufacturing of basic chemicals
ISIC code	C201
Description	Production of carbon black, soda ash, chlorine, anhydrous ammonia, nitric acid, ethylene, propylene, butadiene, benzene, acetylene, xylene, toluene, methanol
Objective	Climate change mitigation; Resource resilience and circular economy promotion
Green	For the activity of production of a certain listed chemical or a facility as a whole to be aligned with the green category of Thailand Taxonomy, it must comply with the following requirements: • More than 50% of the facility's production (by volume) is made up of chemicals included in the scope of the present article (listed in the "Description" line under manufacture of basic chemicals criteria and thresholds;

	• All activities carried out on the facility that fall within the scope of the present article need to meet specific carbon or energy intensity thresholds defined in Table 4 (see below the present activity card); • Facility operators must check whether Additional requirement 1 or Additional requirement 2 listed below apply to their activities. If yes, these requirements must be further fulfilled. • **Additional requirement 1:** applicable if the facility is using fossil gas, hydrogen, biomass, or heat supplied from alternative sources as a fuel source. These facilities are eligible only if they meet the following criteria: • Fossil gas or naphtha: only eligible for existing unabated GHG facilities prior to 2040; • If facilities use biomass or hydrogen as a fuel source, they should meet Taxonomy's green criteria of these activities; • Facilities using heat supplied from alternative sources, such as geothermal, solar thermal, and waste heat recovery: The heat source must comply with the green category of the Taxonomy's most up-to-date criteria for each source of energy. • **Additional requirement 2:** applicable if the facility is using fossil gas, hydrogen, biomass, or heat supplied from alternative sources as a fuel source. These facilities are eligible only if they meet the following criteria: 1. Fossil gas or naphtha: Only eligible for existing unabated[56] GHG facilities prior to 2040; 2. If facilities use biomass or hydrogen as a fuel source,it should meet Taxonomy's green criteria of these activities; 3. Facilities using heat supplied from alternative sources, such as geothermal, solar thermal, and waste heat recovery: The heat source must comply with the green category of the Taxonomy's most up-to-date criteria for each source of energy.
Amber	In order to be aligned with the amber category, the manager of the facility must implement at least one of the measures mentioned in Table 5. By implementing this measure, the manager of the activity must, as a minimum, achieve the result indicated in the "Mitigation criteria" column of Table 5. If the application of the

[56] Unabated industrial facilities refer to industrial facilities that continue to emit greenhouse gases without any significant mitigation measures, such as carbon capture, utilization, and storage or other emissions-reduction technologies.

	listed measure does not lead to the result indicated in the column, the application of this measure cannot be considered eligible. In addition: ● Eligible decarbonisation measures or retrofitting activities (CapEx) should be implemented prior to the designated sunset date (2040). ● More than 50% of the facility's production is made up of chemicals included in the scope of the present article (listed in the "Description" line under manufacture of basic chemicals criteria and thresholds); ● A company that owns the facility should have a transition plan aligned with the commitments under the Paris Agreement and/or net zero GHG emissions target of Thailand.
Red	Activities that do not comply with the green or amber category are harmful to the objective of climate change mitigation.
Criteria reference	Climate Bonds Basic Chemicals Criteria

Table 4 Basic chemicals decarbonisation pathways[57]

Asset type	2025	2030	2035	2040	2050
Production of ammonia	● Uses hydrogen as feedstock that meets the Taxonomy criteria for hydrogen production (green category) OR Ammonia is recovered from wastewater. AND ● CO_2 from ammonia production should not be used for urea production.				
Production of nitric acid[58] (t CO2e /t nitric acid)	0.527	0.263	0.131	0.007	0
Production of chlorine	2.45 MWh electricity/t chlorine OR carbon intensity of the electricity used meets the Taxonomy criteria for electricity	1.85 MWh electricity/t chlorine OR carbon intensity of the electricity used meets the Taxonomy criteria for electricity	Carbon intensity of electricity used meets the Taxonomy criteria for electricity generation (green category)		

[57] CBI, "Basic Chemicals Criteria", April, 2023 https://www.climatebonds.net/files/files/standards/Chemicals%20-%20Basic/Sector%20Criteria%20-%20Basic%20Chemicals%20%28April%202023%29.pdf

[58] Modelled proxy data is used here instead of real data due to limited availability. The number will be updated in the future.

Asset type	2025	2030	2035	2040	2050
	generation (green category)	generation (green category)			
Production of carbon black (t CO2e/t carbon black)	1.141	0.63	0.34	0.20	0
Production of disodium carbonate/soda ash	0.789 t CO_2e/t disodium carbonate/ soda ash AND carbon intensity of the electricity used meets the Taxonomy criteria for electricity generation (green category)	0.44 t CO_2e/t disodium carbonate/ soda ash AND carbon intensity of the electricity used meets the Taxonomy criteria for electricity generation (green category)	0.23 t CO_2e/t disodium carbonate/ soda ash AND carbon intensity of the electricity used meets the Taxonomy criteria for electricity generation green category)	0.14 t CO_2e/t disodium carbonate/ soda ash AND carbon intensity of the electricity used meets the Taxonomy criteria for electricity generation (green category)	0 t CO_2e/t disodium carbonate/ soda ash AND carbon intensity of the electricity used meets the Taxonomy criteria for electricity generation (green category)
Production of high-value chemicals (ethylene, propylene, butadiene)[59]	0.77	0.68	0.60	0.43 in 2040 and 0.26 in 2045	0.09
Production of aromatics BTX[60]	0.348	0.174	0.087	0.0012	0

[59] The data and decarbonization pathway on the production of high-value chemicals (ethylene, propylene, butadiene) have been obtained from the Petrochemical Industry Club, the Federation of Thai Industries. As the data is sample data from Thai producers, the pathway will be considered once more comprehensive data becomes available and/or significant technological advancements.

[60] The current GHG data on the production of aromatics BTX (only benzene, xylene, and toluene) has been obtained from the Petrochemical Industry Club, the Federation of Thai Industries. Due to the data limitation of Thai manufacturers in

Asset type	2025	2030	2035	2040	2050
(acetylene, benzene, xylene, and toluene) (t CO2e/t aromatics BTX)					
Production of methanol	Uses hydrogen as feedstock that meets the Taxonomy criteria for hydrogen production (green category)				

Table 5 Decarbonisation measures for the chemical industry[61]

Area	Activity	Mitigation criteria
General Measures		
Energy efficiency measures	Revamps, modifications, or acquisition of equipment (boilers, furnaces, reactors, heat exchanger, distillation columns and other separation units, etc.)	At least a 30 % improvement in energy efficiency.
Switching to low-carbon process technologies	Revamps, modification and acquisition of equipment and other infrastructure needed for the implementation and operation of low carbon process technologies.	The technology does not release direct process CO_2 emissions, e.g., methane pyrolysis catalytic partial oxidation of methane to methanol.
Carbon Capture and Storage	Infrastructure related to CO_2 capture of emissions from the basic chemicals production, transportation, and storage	• The minimum capture rate from the entire facility should be 90% (capture only, without transportation or storage). • There is evidence[62] that demonstrates the CO_2 will be suitably transported and stored in line with the

specific product categories, proxy data is used for pathway calculations. A data review will be considered once more comprehensive data becomes available and/or significant technological advancements.

[61] CBI, "Basic Chemicals Criteria", April, 2023 https://www.climatebonds.net/files/files/standards/Chemicals%20-%20Basic/Sector%20Criteria%20-%20Basic%20Chemicals%20%28April%202023%29.pdf

[62] Either directly from the issuer or through contracts or agreements with a third party

Area	Activity	Mitigation criteria
		Taxonomy criteria (green category)
Relating to the feedstock used		
Using hydrogen as a feedstock	Infrastructure for production using hydrogen that is aligned with the Thailand Taxonomy (green category) OR Refurbishment and retrofitting of facilities to use hydrogen that is aligned with the Thailand Taxonomy (green category) OR Acquisition of equipment to produce basic chemicals using hydrogen that is aligned with the Thailand Taxonomy (green category)	Hydrogen used as a feedstock meets the thresholds set out in the Taxonomy for green category (green category)
Using biomass as a feedstock	Infrastructure for production using biomass OR Refurbishment and retrofitting of facilities to use biomass OR Acquisition of equipment to produce basic chemicals using biomass	The biomass used complies with the criteria applicable for biomass sourcing set out in the Taxonomy Bio-energy criteria (green category)
Using CO_2 as a feedstock[63]	Infrastructure for production using CO_2 as a feedstock OR Refurbishment and retrofitting of facilities to use CO_2 as a feedstock OR	1. The source of CO_2 sources is either: ● Direct emissions from chemical production; OR ● Direct emissions from other industrial activities

[63] Please refer to Waste management sector for more details

Area	Activity	Mitigation criteria
	Acquisition of equipment to produce basic chemicals using CO_2 as a feedstock	2. The basic chemical produced is used for the manufacture of durable products (e.g. construction materials stored in buildings or recyclable products, e.g. PET). 3. If the basic chemical produced is used for products that release CO_2 immediately when the products are used (such as in urea, carbonated beverages, or fuels), the capital investment is not eligible. 4. CO_2 is not used for enhanced oil recovery, and the production of other forms of fossil energy sources. 5. This measure may involve the need for electricity when electrochemical processes are used, and also the need for hydrogen as a feedstock. If so, that hydrogen must comply with the Taxonomy criteria (green category)
Use of recycled material as feedstock (e.g. using olefins recovered from plastics chemical recycling processes)	Infrastructure for the production using recycled feedstock OR Refurbishment and retrofitting of facilities using recycled feedstock OR Acquisition of equipment to produce basic chemicals using recycled feedstock	Recycled material should: ● represent at least 20% of the feedstock in regions without local recycling regulations or with lower recycled content requirements. ● represent more than 20% of the feedstock in regions with local recycling regulations. If the region has a higher recycled content percentage, it should prevail.

Area	Activity	Mitigation criteria
		• have lower cradle-to-gate emissions than the virgin material OR Recycled feedstock is certified by International Sustainability and Carbon Certification (ISCC)
Relating to energy used		
Electrification of the processes	Revamps, modifications, and acquisition of equipment (furnaces, reactors, separators, etc.) and other infrastructure necessary for electrification of the processes	Electricity must be low-carbon and comply with the most up-to-date Taxonomy criteria for electricity grids (green category)
Heat supplied from geothermal, solar thermal or waste heat recovery systems	New heat exchange equipment, such as evaporators, furnaces, boilers, etc., OR Revamps or modifications to heating-related equipment in the existing process	Heat supply complies with the most up-to-date Taxonomy criteria for the relevant source of energy (green category)
Using hydrogen as an energy source	Revamps or modifications to equipment (boilers, furnaces, burners, etc.) in existing utility systems required for the use of hydrogen as fuel OR Infrastructure for the production of a basic chemical in scope using hydrogen as an energy source	The hydrogen to be used meets the Taxonomy criteria for hydrogen production (green category)
Using biomass or biogas as an energy source	Revamps or modifications to equipment (boilers, furnaces, burners, etc.) in existing utility systems required for the use of biomass as fuel OR	The bioenergy complies with the Taxonomy Bio-energy criteria (green category). Primary organic

Area	Activity	Mitigation criteria
	Infrastructure for the production of a basic chemical in scope using biomass as an energy source	streams[64] are only eligible if certified as sustainable by Roundtable on Sustainable Biomaterials or International Sustainability and Carbon Certification. Wood is eligible only if produced on a sustainable plantation as defined by the Thailand Taxonomy's Forestry Criteria when using biomass as a reducing agent and/or for energy generation.

2. Manufacture of cement

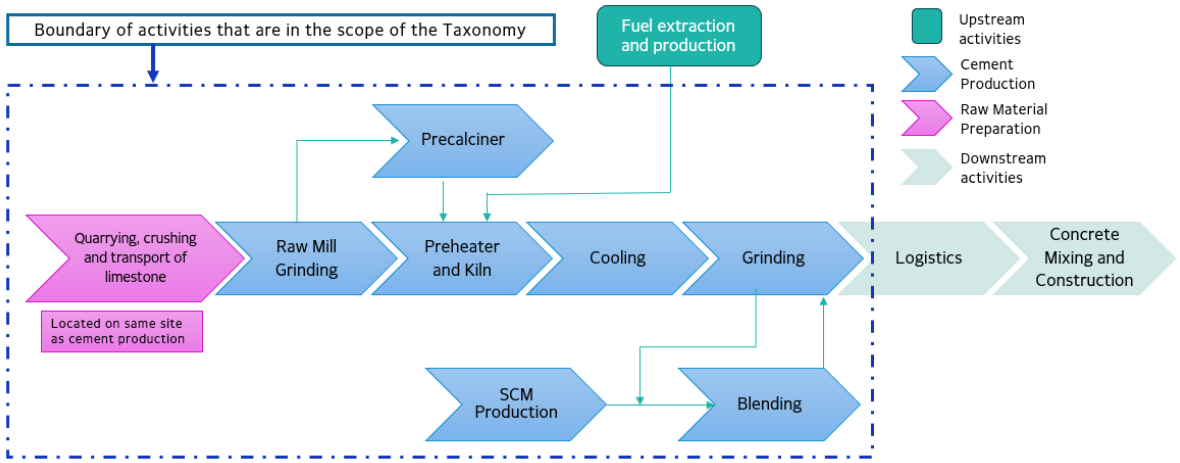
Decarbonisation trajectories for cementitious products were calculated according to data provided by Thai Cement Manufacturers Association (TCMA). TCMA has adopted Thailand 2050 Net Zero Cement and Concrete Roadmap [65], compliant with the Paris Climate Agreement and assuming full decarbonisation of the sector by 2050.

The scope of the activity included under Thailand Taxonomy covers assets and activities involved in the production of cement, with the scope boundary beginning at the quarry of limestone and ending at the final blended cement product. The quarrying activity is included in the scope only if it is integrated into the same geographical location as cement production facilities and operations (separate quarries can't be assessed against the Taxonomy). The cement production facilities themselves may be integrated from quarries to blended cement, or they may be responsible for only one stage of production, for example, clinker production, grinding, or blending. The boundary is illustrated in the figure below

[64] Primary organic streams or sources are those which come directly from the land and without having undergone any processing, apart from cleaning. They maintain all the biological qualities they had when they were still on the plants. Secondary organic streams or sources are those that have undergone processing or have been used.

[65] Thai Cement Manufacturers Association. *Thailand 2050 Net Zero Cement & Concrete Roadmap*. Bangkok: Thai Cement Manufacturers Association, October 2024. https://www.thaicma.or.th/en/ebook_detail/3/197

Figure 5 Cement production activities within the scope of the Taxonomy criteria



Apart from the activities defined in the boundary in the figure above, the activities and assets in the cement production value chain that are **out of the scope** of the Taxonomy activity are as follows:

- **Production of fly ash and blast furnace slag**: Production of these through coal power or steel production is not eligible. However, the processing of such materials extant from a power plant that no longer functions can be eligible.
- **Concrete**: the production of concrete itself and associated activities (mix design, mixing itself, transportation to site, quality control, etc.) are out of scope.
- **Quarrying**: quarrying in and of itself (i.e., that is separate from a cement plant or is a pure-play quarry company) is not within scope.

Additionally, the entities in the cement production value chain that are **out of the scope** of the Taxonomy activity are as follows:

- **Pureplay concrete producers:** Companies whose sole activity is the production of concrete itself and associated activities (mix design, mixing itself, transportation to site, quality control, etc.).
- **Pureplay quarrying companies:** Companies whose sole activity is quarrying (i.e., separate from a cement production company).
- **Pureplay clinker production companies:** Companies that solely produce clinker, which is then sold downstream for further processing into cement. Note: companies

that produce clinker and cement are within the scope of a company that purchases clinker.

In order to be compliant with green criteria, all important elements of the facility and technological process should correspond to the criteria stipulated in the respective activity card. An overview of that list is given in the figure below.

Figure 6 Green criteria framework for manufacturing of cement

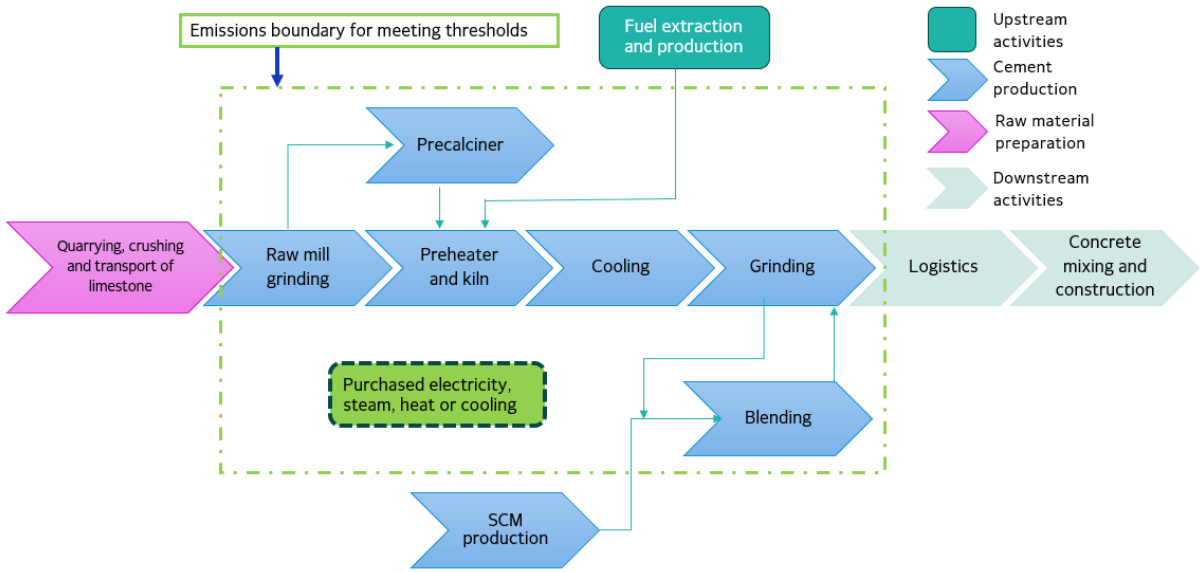
The facility level emission intensity threshold is in terms of t CO2/ t cementitious product or t CO2/ t cement (equivalent), wherein "cementitious product" means clinker, cement and cement substitutes produced by the reporting entity.

The scope of emissions that must be covered when assessing compliance with the Taxonomy is detailed in the figure below and includes the following:

- **Direct (scope 1) emissions from cement production**
  - Burning fossil fuels to heat kilns (thermal emissions);
  - Calcination emissions (process emissions);
  - Emissions from alternative fuels and raw materials;
  - On-site power generation.
- **Indirect (scope 2) purchased energy emissions.**
  - Purchase of electricity, steam, heat, or cooling.
- **Off-site (scope 3) indirect impacts in the value chain not owned or controlled by the reporting entity (upstream)**
  - As the carbon intensity of the final cement product is the metric, facilities responsible for one specific production stage (for example, grinding facilities) must partially incorporate scope 3 emissions;

- However, this is only scope 3 emissions up to the point of the finished cement, not downstream emissions associated with transporting or using the clinker/cement product.

Figure 7 Emission boundary for meeting the thresholds of manufacturing of cement activity card



Amber criteria of the activity include decarbonisation measures that are applicable within the cement production facility where the entity **has a transition plan aligned with the commitments under the Paris Agreement.** These eligible decarbonisation measures or retrofitting activities (capital investments) must be implemented prior to a defined sunset date of 2040.

Manufacturing of cement criteria and thresholds

Sector	Manufacturing
Activity	Manufacturing of cement
ISIC code	2394
Description	Production of cementitious products
Objective	Climate change mitigation
Green	For the cement production activity to be aligned with the Taxonomy, the activities need to meet specific emissions intensity thresholds for cementitious products defined in Table: Cementitious products decarbonisation pathway. Additional requirement to align with other activities in Thailand Taxonomy:

	• If facilities use biomass or hydrogen as a fuel source, they should meet the green criteria for these activities. • If facilities use waste as a fuel source, including municipal solid waste, they should meet the following criteria: ▪ Align with the green criteria in waste management sector ▪ Maximum of waste of recycling potential[66] must be removed prior to burning; ▪ Municipal solid waste will not be eligible as a fuel type after 2050. • If the plant uses CCS/CCUS equipment on site, it should meet the green criteria of CCS/CCUS.
Amber	Eligible decarbonisation measures or retrofitting activities (capital investments) must: • Be implemented prior to 2040 (sunset date); • Constitute one or more of the following actions: - Installation, upgrade, and operation of pre-calciners; - Installation, upgrade, and operation of heat recovery systems; - Installation, upgrade, and operation of digitised control equipment or infrastructure. This may include: ▪ Sensors and measurement tools (including software to allow real-time and close control of processes to improve efficiency); ▪ Communication and control (including advanced software and control rooms and automation of plant processes). - Installation, upgrade, and operation of testing equipment. For example (but not limited to): ▪ Automated X-ray diffractometer systems - Electrification of heat (for example, electrified kiln processes); - Installation, upgrade, retrofit and operation of measures which achieve emissions savings equivalent to the emissions decrease for facilities over the lifespan of the debt instrument;

[66] A list of waste of recycling potential can be found here or similar Thailand definition can be used: "How Do I Recycle Common Recyclables | US EPA," US EPA, December 1, 2023, https://www.epa.gov/recycle/how-do-i-recycle-common-recyclables.

	- Installation, upgrade, and operation of carbon capture and storage equipment that is aligned with Taxonomy criteria for CCS/CCUS: Point-source capture of CO2 (green category); - Infrastructure, revamps, or modifications of equipment needed for the production of cement using hydrogen as a fuel that is aligned with Taxonomy criteria for hydrogen (green category). • The facility must have net-zero plan aligned with the commitments under the Paris Agreement.
Red	Activities that do not comply with the green or amber category are harmful to the objective of climate change mitigation.
Criteria Reference	Climate Bonds Cement Criteria

Table 6 Clinker decarbonisation pathway

Year	2025	2030	2035	2040	2045	2050
Carbon intensity (t CO2/ t cementitious or t cementitious product)	0.654	0.543	0.418	0.293	0.147	0

3. Manufacturing of basic iron and steel

International Energy Agency Net-Zero Emissions (IEA NZE)[67] decarbonisation pathway adjusted in line with the ClimateAligned Finance Framework for Steel[68] approach has been utilised to construct these criteria. The IEA NZE Benchmark utilised by the Sustainable STEEL Principles is a modified version on the "Net Zero by 2050" scenario published by the IEA in 2021, with the following modifications:

- Yearly emissions and scrap utilisation data was interpolated using the decadal emissions and scrap utilisation data published by the IEA in the "Net Zero by 2050" report;
- Scope 1 emissions were taken directly from the IEA's "Net Zero by 2050" report, while Scope 2 emissions were estimated using the technology shares of total production

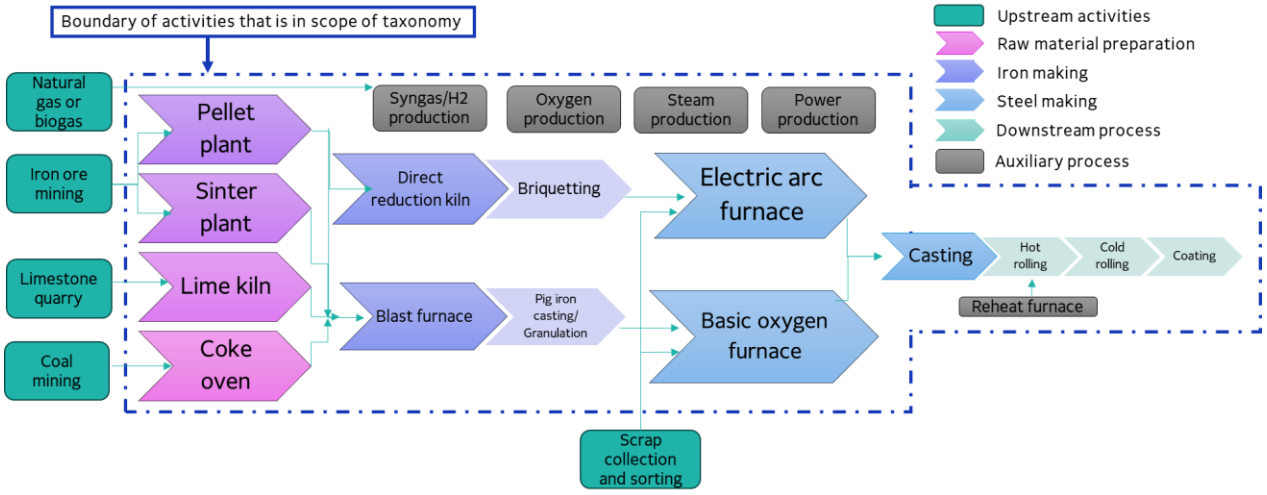
[67] IEA, "Iron & Steel - IEA," n.d., https://www.iea.org/energy-system/industry/steel.

[68] Climate Alignment, "Sustainable Steel Principles Framework," June 2022, https://climatealignment.org/wpcontent/uploads/2022/06/sustainable_steel_principles_framework.pdf.

included in the report paired with the corresponding emissions factors included in the Mission Possible Partnership model[69].

The scope of the activity involves assets and activities associated with the production of iron and steel, with the scope boundary beginning at the raw material preparation stage and ending at the final steel product coming out of the rolling and coating stages. The stages of steel production that are under the scope of the Taxonomy are defined in the figure below.

Figure 8 Steel production value chain and activities within the scope of the Taxonomy criteria.



Apart from the activities and facilities defined in the figure 8, the activities and assets in the cement production value chain that are **out of scope** are as follows:

- **Iron mining:** Mining in and of itself (i.e., separate from a steel plant) is not certifiable under these criteria;
- **Coal mining:** a coal mine cannot be certified. However, producers using coal need to comply with the additional qualitative criteria specific to the use of coal;
- **Steel alloying (alloying is not a climate-material process that can be separated from steelmaking);**
- **Steel scrap collection and sorting (it is defined by the Waste Sector);**
- **Raw material preparation and downstream processes:** assets and activities dealing solely with the production of coke, iron ore pellets and other raw materials that are

[69] "Steel," Mission Possible Partnership, n.d., https://www.missionpossiblepartnership.org/action-sectors/steel/.

not part of an iron or steel production facility are out of the scope, as are assets only dedicated to downstream activities such as rolling, and finishing.

Additionally, the entities in the iron and steel production value chain that are **out of scope** are as follows:

- **Pureplay iron ore mining companies:** companies whose sole activity is the mining of iron ore (i.e., separate from a steel production company);
- **Pureplay coal companies:** companies whose sole activity is coal mining (i.e., separate from a steel production company);
- **Pureplay stainless and high alloy steels production companies:** companies whose sole activity is the production of stainless and high alloy steels and associated activities;
- **Pureplay steel scrap collection and sorting companies:** Companies whose sole activities are the collection and sorting of steel scrap.

Usability notes

In order to be aligned with the green category, steel facilities must comply with two sets of criteria: facility-specific (based on the major technological process utilised by the facility, for example blast furnace or direct reduction of iron facilities) and cross-cutting (related to feedstock used by the facility regardless of the main technological process utilised on it). Since steel production facilities can operate for many years, new facilities should already be built with CO2 emissions mitigation technologies in place or avoid CO2 generation entirely by limiting the use of fossil fuels. The technical challenges are such that this is very important at the design stage – if a plant is not designed to have, for example, CCS/CCUS implemented, it is very difficult to retrofit later.

The amber criteria of the activity include decarbonisation or retrofitting measures that are applicable within the steel production facility. To acknowledge and promote the decarbonisation efforts, new and existing facilities that do not meet criteria designed for the green category at the outset but have been designed to envisage full alignment over time and by 2040 at the latest can be classified as amber. Apart from that, a measures-based approach is also included.

Manufacturing of iron and steel criteria and thresholds

Sector	Manufacturing
Activity	Manufacture of basic iron and steel
ISIC code	2410
Description	Operations of conversion by reduction of iron ore in blast furnaces and oxygen converters or of ferrous waste and scrap in electric arc furnaces or by direct reduction of iron ore without fusion to obtain crude steel, which is smelted and refined in a ladle furnace and then poured and solidified in a continuous caster in order to produce semi-finished flat or long products
Objective	Climate change mitigation
Green[70]	In order to be eligible as green, activities and facilities where they take place must comply with all of the following: • Applicable facility-specific mitigation criteria (**Table 7**) • Applicable cross-cutting criteria (**Table 8**) Facilities using hydrogen as a fuel or reductive agent are eligible only if hydrogen complies with Taxonomy criteria for hydrogen (green category)
Amber	**Option 1** Eligible facilities and assets that are mentioned in **Table 7** but do not meet the criteria identified in this table can be classified as amber only if (must comply with all criteria): • The facility has been designed to and is implementing all necessary actions to meet the criteria for the green category by 2040 at the latest; • The facility, from the onset of its operations, is using CCS/CCUS, which operates to capture at least 20% of emissions; • A facility has a transition plan aligned with the commitments under the Paris Agreement.
	Option 2 Specific technological measures can be implemented to decarbonise steel and iron production if they: 1. are implemented prior to the sunset date (2040); 2. enable the eligible assets to meet the criteria identified in **Table 7** (examples of compliant measures are listed in **Table 8);**

[70] Green activity threshold does not require any specific decarbonisation threshold as emission is limited by the technical solutions suggested for each particular facility type

	3. comply with applicable cross-cutting criteria listed in **Table 8.**
Red	Activities that do not comply with the green or amber category are harmful to the objective of climate change mitigation. CCUS for the production of products that release CO2 immediately when these are used (such as in urea, carbonated beverages, or fuels), for enhanced oil recovery, and the production of other forms of fossil energy sources is harmful to the objective of climate change mitigation.
Criteria Reference	Climate Bonds Steel Criteria

Table 7 Eligible iron and steel production facilities

Facility technology type (eligible assets)	Facility-specific mitigation criteria
BF-BOF (Blast Furnace – Basic Oxygen Furnace)	• Has to have CCS/CCUS meeting taxonomy criteria for CCS/CCUS; • CCS/CCUS should capture at least 70% of all emissions.
Smelting reduction	• Has to have CCS/CCUS meeting Taxonomy criteria for CCS/CCUS; • CCS/CCUS should capture at least 70% of all emissions.
Direct Reduced Iron (DRI)	If fossil gas-based: • Has to have CCS/CCUS meeting Taxonomy criteria for CCS/CCUS; • CCS/CCUS should capture at least 70% of all emissions. If 100% hydrogen-based: • hydrogen meets carbon intensity thresholds and specific Taxonomy criteria for hydrogen (green category).
Electric Arc Furnace (EAF)	• Needs to use 70% of scrap as total annual inputs; OR • The combined scrap and (100%) hydrogen-based DRI meeting taxonomy criteria for DRI (green category) should add to at least 70% of the EAF's total annual inputs.
DRI – EAF	If fossil gas-based: • Has to have CCS/CCUS meeting taxonomy criteria for CCS/CCUS; • CCS/CCUS should capture at least 70% of all emissions. If 100% hydrogen-based: • hydrogen meets carbon intensity thresholds and specific taxonomy criteria for hydrogen (green category).

Table 8 Cross-cutting criteria for iron and steel

Eligible assets	Cross-cutting mitigation criteria
Facilities that use fossil gas as a reducing agent and/or for energy generation	Using fossil gas both as a reducing agent and for energy generation is only eligible for existing facilities prior to 2040. To qualify after 2040, such facilities would have to use fossil gas combined with CCS/CCUS measures that meet the Taxonomy criteria for CCS/CCUS and: • Utilisation of direct CO2 emissions from steel production is used for the manufacture of durable products and does not lead to enhanced oil recovery and the production of other forms of fossil energy sources. • Projects using fossil gas (even if) combined with CCS/CCUS should demonstrate that on-site activities: MRV (Monitoring, Reporting and Verification), and mitigation measures for methane leaks as per the best practice recommended[71]. Any venting or burning within the limits of the steel plant shall be avoided, except in emergency situations, in such case it shall be reported and accounted for in the GHG assessment. • Projects using fossil gas (even if) combined with CCS/CCUS should demonstrate that upstream activities provide evidence of having MRV (Monitoring, Reporting and Verification) and mitigation measures for methane leaks as per the best practice recommended[72].
Facilities that use coal as a reducing agent and/or for energy generation	Using coal, both as a reducing agent and fuel in the steelmaking process, is only eligible for existing facilities prior to 2040. After 2040, facilities would have to use coal combined with CCS/CCUS measures that meet the Taxonomy criteria for CCS/CCUS and utilisation of direct CO2 emissions from steel production is used for the manufacture of durable products and does not lead to enhanced oil recovery and the production of other forms of fossil energy sources.

[71] Best practice can be found in the report: Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector. Monitoring, Reporting and Verification (MRV) and Mitigation. United Nations Economic Commission for Europe. 2019: United Nations Economic Commission for Europe, "Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector," ECE ENERGY SERIES (UNITED NATIONS, 2019), https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf

[72] ibid

Eligible assets	Cross-cutting mitigation criteria
	Projects using coal should demonstrate the following: • Upstream activities: Provide evidence of having MRV (Monitoring, Reporting and Verification) in place, as well as mitigation measures for methane leaks as per the best practice recommended[73].
Facilities that use biomass as a reducing agent	Facilities using biomass as a reducing agent are only eligible if they use the following sources of biomass: • **Food or feed crops:** If food crops are used, they must be certified as a renewable feedstock (defined as feedstock certified by Roundtable on Sustainable Biomaterials or International Sustainability and Carbon Certification) • **Plantation wood:** the wood plantation shall demonstrate to meet the requirements set out for "Forestry plantation" activities of the Taxonomy. • **Industrial crops.** AND Primary organic streams[74] are only eligible as fuel if certified as sustainable by Roundtable on Sustainable Biomaterials or International Sustainability and Carbon Certification. Wood is eligible only if produced on a sustainable plantation as defined by the Thailand Taxonomy's Forestry Criteria
Facilities using CCS/CCUS	Facilities using CCS/CCUS are only eligible if the CCS/CCUS meets Taxonomy criteria for CCS/CCUS and utilisation of direct CO2 emissions from steel production is used for the manufacture of durable products (e.g., construction materials stored in buildings or recyclable products, e.g., PET). CO2 should not be used for products that release the CO2 immediately when these are used (such as in urea, carbonated beverages, or fuels), nor for enhanced oil recovery and the production of other forms of fossil energy sources.

[73] ibid

[74] Primary organic streams or sources are those which come directly from the land and without having undergone any processing, apart from cleaning. They maintain all the biological qualities they had when they were still on the plants. Secondary organic streams or sources are those that have undergone processing or have been used.

Table 9 Criteria for capital investments in decarbonisation measures for steel facilities

Eligible Assets	Facility-specific mitigation criteria
Optimisation of electric arc furnaces, installation and operation of other mitigation measures associated with EAF facilities	Implement decarbonisation measures that: ● enable the facility to increase the scrap total annual input; OR ● enable the facility to increase the share of renewable energy used by the facility.
Measures associated to a production line with a blast furnace (BF)	● No relining; ● The emissions intensity of the facility should be below 1.8 tCO2/t steel by 2040; ● Decarbonisation measures should decrease emissions (tCO2/t steel) between 2024 and 2040 by: - by 15% if emissions < 2.0 tCO2/t steel and if the production line with BF became operational in 2007 or later; OR - by 20% if emissions >2.0 tCO2/t steel and if the production line with BF became operational in 2007 or later; OR - at least 50% of the production line with BF became operational prior to 2007.
Measures associated with a production line with a DRI or smelting reduction	● Implement decarbonisation measures to decrease emissions (tCO2/t steel) between 2024 and 2040 by: ○ If fossil gas based: 20%; OR ○ If coal based: 40%.
Installation of CCS/CCUS	CCS/CCUS must meet relevant CCS/CCUS criteria from Thailand Taxonomy
Measures involving biomass or bioenergy	Biomass and bioenergy must meet relevant criteria from Thailand Taxonomy.
Measures involving the use of hydrogen	Hydrogen must meet relevant hydrogen criteria from Thailand Taxonomy.

Table 10 A non-exhaustive exemplary list of decarbonisation measures that comply with the amber category

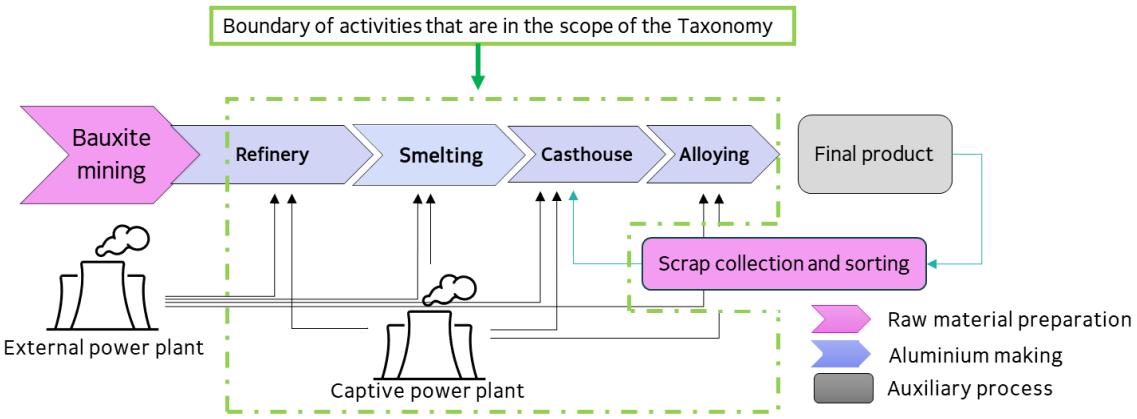
Asset and activity types	Example of compliant CapEx
Heat recovery	Installation, upgrade, and operation of heat recovery systems
Optimisation of blast furnace	Pulverise coke injection, top gas recycling, stove waste gas heat recovery
Optimisation of basic oxygen furnace	Recovery of basic oxygen furnace gas and sensible heat
Optimisation of coke plant	Coke dry quenching
Optimisation of sinter plants	Sinter plant heat recovery
Optimisation of EAF	Oxyfuel burners, EAF scrap preheating, CHP from waste heat
Optimisation of rolling finishing and reheating furnace	High-efficiency burner, flue-gas monitoring, combustion optimisation, exhaust gas heat recovery
Optimisation of casting	Near net-shape casting
Optimisation of monitoring and control systems	Installation, upgrade, and operation of advanced sensors and digitised control equipment and systems
Carbon capture and storage	Installation, upgrade, and operation of infrastructure and equipment related to CO2 capture of emissions from steel production.
Fuel switching	Infrastructure revamps or modifications of equipment needed for the production of steel using hydrogen or biomass as a reducing agent
Electrification of heat	Electrification of reheating furnacing

4. Manufacturing of aluminium

Aluminium is a critical metal with applications in a multitude of renewable energy technologies. Its special characteristic is that it can be recycled and reused without any loss of quality, and these criteria maximise the incentives for the use of recycled aluminium and its recycling.

Under the present criteria, both the aluminium production process and the financial flows associated with it (revenues), as well as the entire aluminium-producing enterprises that meet the parameters, can be verified.

Figure 9 Scope of activities covered by the manufacturing of aluminium criteria (primary aluminium)



Scoping for the production of secondary aluminium is not included as secondary aluminium is automatically aligned with the taxonomy without any additional criteria or requirements.

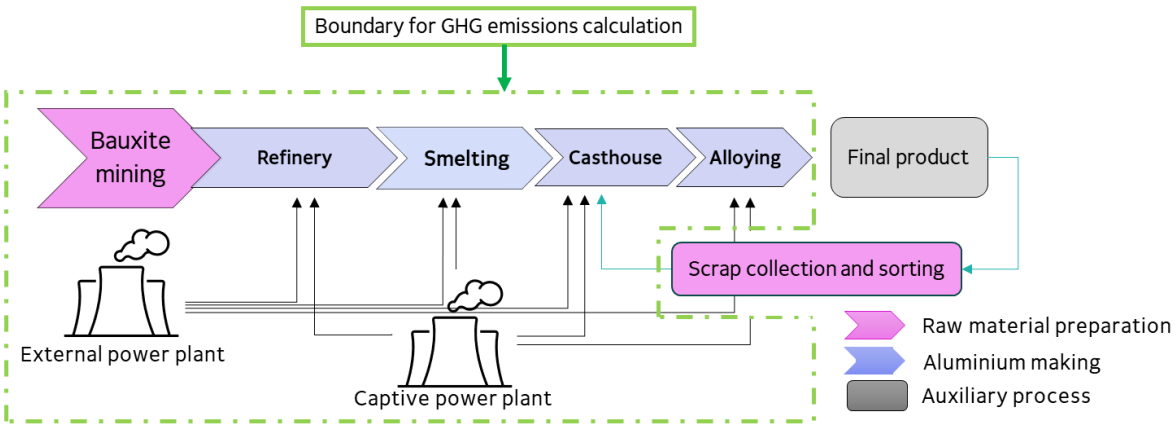
It is important to note that decarbonisation of the aluminium production chain is possible both in the case of primary aluminium production and secondary aluminium production (e.g., a project to replace generating capacity from hydrocarbon generation to renewable generation). This, however, is not a mandatory requirement.

Scoping boundaries for GHG calculation include scope 1 and scope 2 as defined by the International Aluminium Institute[75]:

- Scope 1: Fuel combustion in furnaces/boilers on-site, Coke calcination, Anode production, Anode consumption, PFC emission, Lime production
- Scope 2: Emissions from purchased electricity, heat, or steam

[75] International Aluminium Institute, "The Aluminium Sector Greenhouse Gas Protocol," 2006, https://ghgprotocol.org/sites/default/files/2023-03/aluminium_1.pdf.

Figure 10 GHG emission calculation scope for manufacturing of aluminium activities (primary aluminium)



Scoping for the production of secondary aluminium is not included as secondary aluminium is automatically aligned with the taxonomy without any additional criteria or requirements.

Methodological approach

The main emissions from aluminium production are emitted during electricity generation (60%). A further 15% or so are emitted from the combustion of fuel directly at the smelter, and a further 15% from physical and chemical processes at the smelter[76]. Decarbonisation of the aluminium production chain can, therefore, be carried out in three main ways[77]:

- Improving the energy profile: increasing the share of renewable energy consumption, installing CCS/CCUS, and improving the energy efficiency of technologies.
- Reduce fuel consumption in production through the introduction of CCS/CCUS, inert anodes, refinery, and cast house electrification.
- Increasing the share of recycled aluminium through the development of an aluminium waste collection system at all stages.

Aluminium production criteria

Sector	Manufacturing
Activity	Manufacturing of aluminium
ISIC code	2420

[76] International Aluminium Institute, "Aluminium Sector Greenhouse Gas Pathways to 2050," International Aluminium, September 2021, https://international-aluminium.org/resource/aluminium-sector-greenhouse-gas-pathways-to-2050-2021/.

[77] Ibid.

Description	Manufacture of aluminium through primary alumina (bauxite) process or secondary aluminium recycling.
Objective	Climate change mitigation; Resource resilience and circular economy promotion
Green	**Primary aluminium production** where the economic activity complies with all of the following criteria is aligned with the taxonomy if all of the following requirements are met: • the GHG emission intensity does not exceed thresholds presented in Table Aluminium decarbonisation pathway; • the average carbon intensity for the consumed electricity does not exceed parameters established for green electricity production as defined by Thailand Taxonomy; • the electricity consumption for the manufacturing process does not exceed 14.86MWh/t Al. **Secondary aluminium production** is automatically eligible
Amber	Specific technological measures can be implemented to bring aluminium production emission and energy intensity in line with the requirements of the green category if: • They are implemented before the established sunset date (2040); • They decrease either emission intensity or electricity consumption intensity of the production process; • The facility has a transition plan aligned with the commitments under the Paris Agreement.
Red	Activities that do not comply with the green or amber category are harmful to the objective of climate change mitigation.
Criteria Reference	EU Manufacture of Aluminium Criteria; Singaporean Taxonomy

Table 11 Aluminium decarbonisation pathway

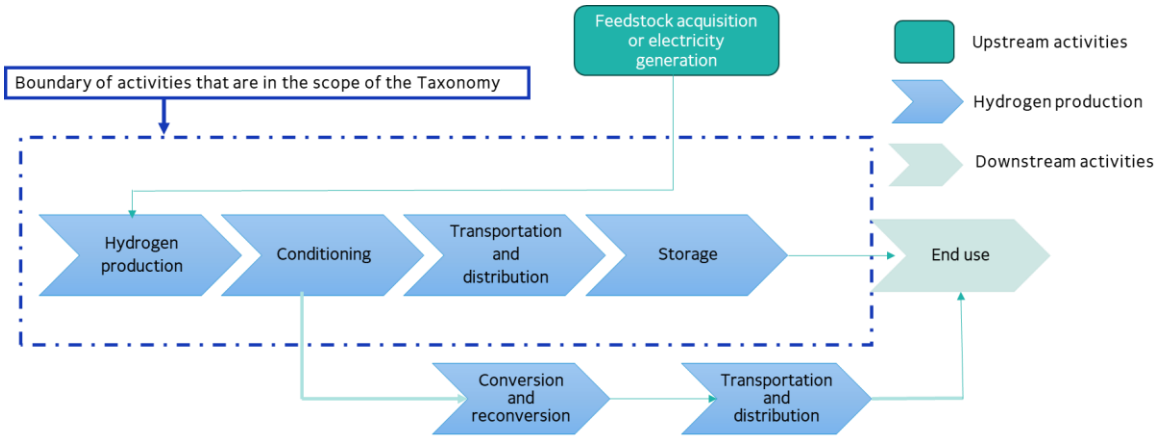
Asset Type	CO2e emissions intensity (tonnes CO2e per tonne of aluminium manufactured)				
	2025	2030	2035	2040	2050
Production of primary aluminium through electrolysis	1.484	1.185	0.826	0.520	0.311

5. Manufacturing of hydrogen[78]

There are numerous end-to-end hydrogen production pathways, however they are tailored to energy sources, conversion technology, and transport method selected. Thus, it is preferable to develop pathway-agnostic carbon emissions benchmarks. Climate Bonds suggests to use the projection of decreasing threshold values performed to ensure that assets and activities are aligned to a transition pathway that contributes to the 1.5°C target. These benchmarks have 2030, 2040 and 2050 targets that get stricter over time to offer guidance to investors and industry on how emissions should reduce in upcoming decades. Hydrogen production carbon intensity benchmarks can be met by different energy sources and technology options, as has been verified using carbon intensity values estimated by MIT Energy Initiative's SESAME platform[79].

The scope of the activity involves assets and activities associated with the production, conditioning, conversion, transportation, and storage of hydrogen. It covers activities across the hydrogen value chain, except for end-users, which are part of each end-use sector criteria. The stages of hydrogen production that are under the scope of the Taxonomy are defined in the figure below.

Figure 11 Hydrogen production value chain and activities within the scope of the Taxonomy criteria.



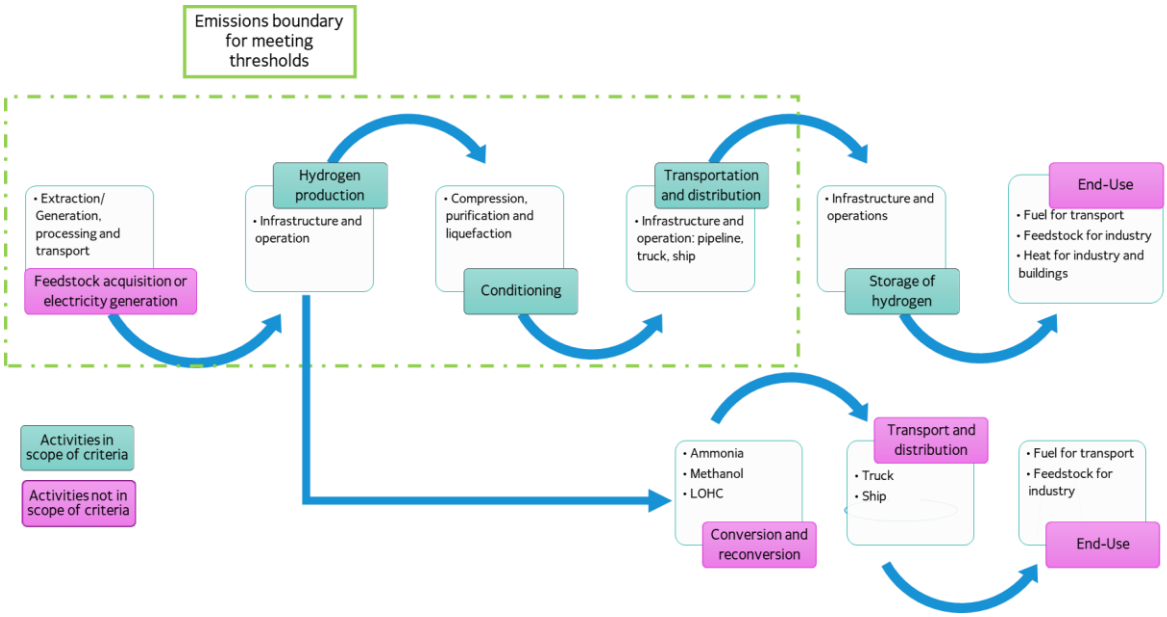
[78] The approach in this section does not categorize hydrogen as "green," "brown," or "blue," but instead specifies only the greenhouse gas emission intensity. For more information, please refer to the FAQ section under Thailand Taxonomy.

[79] MIT Energy Initiative, "SESAME," Main, April 30, 2024, https://energy.mit.edu/research/sesame/.

If hydrogen is converted to ammonia or other carriers before transportation, that conversion is out of scope and therefore, for these criteria, it is only up to the point before it is converted, which is relevant and should meet the proposed threshold. The conversion, transportation, and storage **are not currently in scope** due to a lack of global guidance, although additional research is going into developing criteria for those parts of the process separately.

The emission boundary within the hydrogen production value chain for the calculation of carbon intensity thresholds is defined on figure below.

Figure 12 Emission boundary for meeting the thresholds of manufacturing hydrogen



Hydrogen is not a primary energy source but an energy carrier whose production requires high amounts of energy. It can be produced from different energy sources, such as fossil fuels, biomass, renewables, nuclear, and via diverse conversion technologies. Nevertheless, most of its production today is based on fossil fuel-based alternatives: steam methane reforming (SMR) of natural gas and coal gasification; these production pathways have high carbon footprints; hence, making hydrogen production less emission intensive is essential to contribute to decarbonisation of the economy.

Traditionally, different processes used in hydrogen production were associated with certain colours, e.g., "green hydrogen" or "grey hydrogen". However, there is no scientifically verifiable separation of hydrogen by colour, so these criteria will use the traditional Thailand Taxonomy method of creating criteria based on limiting the emission intensity per unit of production.

Starting limitation of 3 kgCO2e/kgH2 sets a limit that effectively cuts off the overwhelming majority of fossil fuels-based hydrogen production that does not use CCS/CCUS.

To meet the green criteria, hydrogen must be produced according to a decreasing decarbonisation pathway over time, and technologies must meet specific criteria.

The amber criteria of the activity include decarbonisation or retrofitting measures that are applicable within the hydrogen production facility and those that are implemented before the established sunset date of 2040. The facility must also have a decarbonisation plan aligned with the commitments under the Paris Agreement.

Manufacturing of hydrogen criteria and thresholds

Sector	Manufacturing
Activity	Manufacturing of hydrogen
ISIC code	2011
Description	Manufacture of low-carbon hydrogen
Objective	Climate change mitigation
Green	The facility must comply with all of the following requirements: • Hydrogen production must meet specific carbon intensity thresholds (**Table 12**)[80]; • Facilities must meet relevant requirements listed in Table in the Annex depending on the feedstock, electricity source and application of CCS/CCUS; • Facilities that meet the specific intensity thresholds presented in Table in the Annex do not have to meet the following requirements associated with CCS/CCUS listed in Table in the Annex: minimum capture rate from process and energy emission streams should be 90% or emissions reduction at the facility level have to be at least of 50%. **Note**: The use of fossil gas as a feedstock by facilities following 2040 is not recommended but given substantial uncertainty regarding the availability of

[80] To demonstrate compliance with any of the emissions intensity thresholds set in the Table 12, issuers are required to carry out a life cycle assessment within the system boundary defined in the scope of the present criteria in line with recommendations given in Annex.

	hydrogen that is aligned with the Thailand Taxonomy (green category), it is not a criterion at this stage. This should be re-evaluated in future iterations.
Amber	Specific technological measures can be implemented to decarbonise hydrogen production if: • They are implemented before the established sunset date (2040); • They are included in the list and comply with the criteria stipulated in Table in the Annex; • A facility has a transition plan aligned with the commitments under the Paris Agreement.
Red	Facilities or measures for which: • The energy source is oil, coal, or coal derivatives; • The feedstock is coal or coal derivatives; • The energy source is biomass from primary sources; • The use of wood and other dedicated crops is enabled; are harmful to the objective of climate change mitigation.
Criteria Reference	Climate Bonds Hydrogen Criteria; Singapore Taxonomy

Table 12 Hydrogen carbon intensity thresholds

Asset Type	2025	2030	2040	2050
Production of hydrogen (kgCO2e/kgH2)	3	1.5	0.6	0

6.2 Interim activities

1. Manufacture of plastics in primary form

The proposed criteria only cover plastics in primary form and not the final products. For the guidance on plastic waste management please refer to the Waste section of the taxonomy.

Manufacturing of plastics in primary form criteria and thresholds

Sector	Manufacturing
Activity	Manufacturing of plastics in primary form
ISIC code	2013

ISIC description	Manufacture of resins, plastics materials and non-vulcanisable thermoplastic elastomers, the mixing and blending of resins on a custom basis, as well as the manufacture of non-customised synthetic resins.
Objective	Climate change mitigation; Resource resilience and circular economy promotion
Green	The activity must comply with at least one of the following: ● production of primary plastics from post-consumer recycled (PCR) plastic waste using mechanical recycling methods; ● In cases where primary plastic cannot be processed through mechanical recycling or is not economically viable, all primary plastic must be produced through environmentally sound[81] chemical recycling. Additionally, it must have a lower life-cycle greenhouse gas (GHG) emission compared to production using fossil-based raw materials. ● Primary plastic produced partially or entirely from renewable raw materials must be certified (or domestic/ international certification equivalent) by: - Roundtable on Sustainable Biomaterials (RSB) or - International Sustainability and Carbon Certification (ISCC) Additionally, it must have a lower life-cycle GHG emission than production using fossil-based raw materials. Life-cycle greenhouse gas emissions must be calculated using ISO 14067:2018, ISO 14064-1:2018 or comparable. The activity must comply with both of the following: ● The activity does not use food or feed crops from the land that was converted from high-carbon stock land after 01.01.2010. ● Wood biomass must come from plantations that comply with “Forestry Plantation” criteria of the Thailand Taxonomy

[81] “Environmentally sound” manner means taking all practical steps to ensure that wastes are collected, transported, and disposed of (including after-care of disposal sites) in a manner which will protect human health and the environment against the adverse effects which may result from such wastes. Definition is taken from Basel Convention on the control of the transboundary movement of hazardous waste and their disposal https://www.basel.int/portals/4/basel%20convention/docs/text/baselconventiontext-e.pdf

Amber	N/A[82]
Red	• Primary plastic polymer production is harmful to the objective of climate change mitigation. • Activities that do not comply with the green or amber category are harmful to the objective of climate change mitigation.
Criteria Reference	EU Taxonomy Manufacture of Plastics in Primary Form Criteria

6.3 Enabling Activities

This section includes manufacturing activities that may emit some emissions themselves; however, their significant impact on the decarbonization of other sectors is substantial that these initial emissions can be neglected. During the transition from the current state of the economy and society to a sustainable society compatible with the objectives of the Paris Agreement and national decarbonisation targets, this type of activity can be most beneficial. In the future, as the economy develops and the products of these sectors become more widespread, it may be necessary to account for the production and initial issuance of these assets. Until then, the prevention of harm from their use will be achieved through adherence to the DNSH principles.

1. Manufacture of batteries

Sector	Manufacturing
Activity	Manufacturing of batteries
ISIC code	2720
Description	Manufacture or recycling of rechargeable batteries, battery packs and accumulators for transport, stationary and off-grid energy storage, and other industrial applications; manufacture of respective components (battery active materials, battery cells, casings, and electronic components).
Objective	Climate change mitigation; Resource resilience and circular economy promotion
Green[83]	The activity complies with one of the following criteria:

[82] The plastic production criteria do not contain an amber category because this type of production cannot be progressively improved by gradually replacing different elements of the production chain. It can only be completely modified according to the type of raw material consumed.

[83] The issue of raw material sourcing can't be currently addressed due to the absence of scientific criteria. The Taxonomy should be updated in this regard soon as these criteria are developed. For the time being, possible harm from the improper resource extraction is addressed through the DNSH principles

	• The economic activity manufactures rechargeable batteries, battery packs and accumulators (and their respective components), including from secondary raw materials. • The activity repurposes batteries that have been produced • Recycling of end-of-life batteries
Amber	N/A
Red	N/A
Criteria Reference	EU Taxonomy Manufacture of Batteries Criteria

2. Manufacture of renewable energy technologies

Sector	Manufacturing
Activity	Manufacturing of renewable energy technologies
ISIC code	Various codes
Description	Production of technologies, components and parts that are necessary for functioning of low-carbon or renewable energy technologies as defined by the Energy section of Thailand Taxonomy.
Objective	Climate change mitigation; climate change adaptation; sustainable use and protection of marine and water resources; pollution prevention and control
Green	The economic activity manufactures renewable energy technologies that meet the green criteria set out in Thailand Taxonomy (green category)
Amber	N/A
Red	Manufacturing of components, machinery and equipment used solely for the extraction, production, or distribution of fossil fuels is harmful to the objective of climate change mitigation.
Criteria Reference	EU Taxonomy Manufacture of Renewable Energy Technologies Criteria

3. Manufacture of low-carbon technologies for transport

Sector	Manufacturing
Activity	Manufacturing of low-carbon technologies for transport
ISIC code	Various codes
Description	Manufacturing, repair, maintenance, retrofitting, repurposing, and upgrade of low carbon transport vehicles, rolling stock and vessels, as well as components that help vessels to transition from amber to the green category
Objective	Climate change mitigation

Green	Manufacturing of low-carbon transport vehicles and their respective key components[84], fleets and vessels meeting the criteria set out in Thailand Taxonomy (Green and Amber categories) are eligible.
Amber	N/A
Red	Manufacturing of internal combustion engines-based vehicles is harmful to the objective of climate change mitigation.
Criteria Reference	EU Taxonomy Manufacture of Low-Carbon Technologies for Transport Criteria

4. Manufacturing of energy efficiency equipment for buildings

Sector	Manufacturing
Activity	Manufacturing of energy efficiency equipment for buildings
ISIC code	Various codes
Description	Manufacturing of energy efficiency equipment for buildings
Objective	Climate change mitigation; Climate change adaptation (depending on whether manufactured equipment supports mitigation or adaptation efforts)
Green	The economic activity manufactures one or more of the following products and their key components necessary to support activity "**Installation, maintenance and repair of special-purpose building equipment**" from Thailand Taxonomy, including (but not limited to): • light sources rated in the highest class of energy efficiency in accordance with local market standards[85]; • space heating and domestic hot water systems rated in the highest two populated classes of energy efficiency in accordance with local market standards; • cooling and ventilation systems rated in the highest two populated classes of energy efficiency in accordance with local market standards; • presence and daylight controls for lighting systems; • heat pumps compliant with the technical screening criteria set out in the Taxonomy (green category); • facade and roofing elements with a solar shading or solar control function, including those that support the growing of vegetation;

[84] Components intended solely for use in vehicles that fulfil the criteria of the taxonomy

[85] For Thailand hereinafter this benchmark is established as Energy Label No.5 Three Stars rating or Energy Saving Label (whichever is applicable)

	• energy-efficient building automation and control systems for residential and non-residential buildings; • zoned thermostats and devices for the smart monitoring of the main electricity loads or heat loads for buildings and censoring equipment; • products for heat metering and thermostatic controls for individual homes connected to district heating systems, for individual flats connected to central heating systems serving a whole building, and for central heating systems; • district heating exchangers and substations compliant with the district heating/cooling distribution activity set out in the Taxonomy (green category); • products for smart monitoring and regulating of heating systems and censoring equipment.
Amber	N/A
Red	Manufacturing of building equipment that facilitates the utilisation of fossil fuels is harmful to the objective of climate change mitigation.
Criteria Reference	EU Taxonomy Manufacture of Energy Efficiency Equipment for Buildings

5. Manufacture of other low-carbon technologies

Sector	Manufacturing
Activity	Manufacturing of other low-carbon technologies
ISIC code	Various codes
Description	Manufacturing of household goods that fall into the highest class of national energy efficiency scheme[86] and manufacture of technologies aimed at substantial GHG emission reductions in other sectors of the economy
Objective	Climate change mitigation
Green	The activity manufactures one of the following:

[86] For Thailand hereinafter this benchmark is established as Energy Label No.5 Three Stars rating or Energy Saving Label (whichever is applicable)

	• Household goods that meet the highest performance level for a given good according to the Energy Label No.5[87] rating system or Energy Saving Label rating system[88]. • Technologies that are aimed at and demonstrate substantial life cycle GHG emission savings[89] compared to the best performing alternative technology/product/solution available on the market (including technologies and equipment needed to make substantial contribution to the objectives of the Thailand Taxonomy). • Equipment for waste treatment in line with the Taxonomy criteria for Waste management sector
Amber	N/A
Red	N/A
Criteria Reference	EU Taxonomy Manufacture of Other Low-Carbon Technology Criteria

6.4 CCS/CCUS-Related Activities

1. CCS/CCUS: Point-source capture of CO2

Sector	CCS/CCUS
Activity	Point-source capture of CO_2
ISIC code	No code
Description	Capture of CO_2 from a point source in an industrial or power generation facility
Objective	Climate change mitigation
Green	The activity complies with all of the following criteria: • Point-source capture of CO_2 is eligible only as a supplementary activity for the activities in the Taxonomy (for example, in the Manufacturing section) • Point-source capture of CO_2 is eligible as green if it makes the target activity compatible with the green criteria for a specific activity. The applicability of this option to each individual sector can be found in a specific activity article (relevant to sections related to the production of cement, iron and steel, aluminium, hydrogen and basic chemicals).

[87] Energy Efficiency Standards Promotion Division and Energy and Environment Management Department, Electricity Generating Authority of Thailand, "โครงการฉลากประหยัดไฟฟ้าเบอร์ 5 -," EGAT, n.d., https://labelno5.egat.co.th/home/

[88] กรมพัฒนาพลังงานทดแทน และอนุรักษ์พลังงาน กระทรวงพลังงาน, "ฉลากประสิทธิภาพสูง," n.d., http://www.gmwebsite.com/upload/asiapackprint.com/file/D3.pdf.

[89] Life-cycle GHG emission savings are calculated using ISO 14067:2018, ISO 14064-1:2018 or similar standards.

Amber	The activity complies with all of the following criteria: • Point-source capture of CO_2 is eligible only as a supplementary activity for the activities in Thailand Taxonomy (for example, in the Manufacturing section) • Point-source capture of CO_2 is eligible as amber if it makes the target activity compatible with the amber criteria for a specific activity. Applicability of this option to each individual sector can be found in a specific activity article (relevant for sections related to the production of cement, iron and steel, aluminium, hydrogen, and basic chemicals as well as energy generation from fossil gas).
Red	N/A
Criteria Reference	Singaporean Taxonomy

2. Transportation of captured CO2

Sector	CCS/CCUS
Activity	Transportation of captured CO_2
ISIC code	No code
Description	Captured CO_2 transportation via pipelines, ships, railroad cisterns or trucks
Objective	Climate change mitigation
Green	The activity complies with all of the following criteria: • The CO_2 transported from the installation where it is captured to the injection point leads to: ○ **If transported by sea**: CO2 leakages[90] are less than 3% of the mass of CO2 transported regardless of the distance and less than 2% after 2040 OR ○ **If transported via pipeline**: CO2 leakages are less than 0.5% of the mass of CO2 transported. • The CO_2 is delivered to a permanent CO_2 storage site that meets the criteria for underground geological storage of CO_2 set out in the activity «Permanent sequestration of captured CO_2» article; • Appropriate leak detection systems are applied, and a monitoring plan is in place, with the report verified by an independent third party;

[90] Leakages are defined as fugitive losses due to equipment leaks, accidents, sabotage and exploitation issues.

	• The activity may include the installation of assets that increase flexibility and improve the management of an existing network.
Amber	The activity complies with all of the following criteria: • Retrofitting of the existing CO_2 transportation systems in order to bring down the leakage rate from the current rate to the rate specified in the green category is eligible as amber; • The starting leakage rate may not be above 10 % of the mass of CO_2 transported, regardless of the mode of transportation; • The CO_2 is delivered to a permanent CO_2 storage site that meets the criteria for underground geological storage of CO2 set out in Section «Permanent sequestration of captured CO2»; • Appropriate leak detection systems are applied, and a monitoring plan is in place, with the report verified by an independent third party; • The activity may include the installation of assets that increase flexibility and improve the management of an existing network. • The sunset date for this activity is designated as 2040.
Red	Transportation or retrofitting of transportation systems that do not comply with relevant green and amber criteria are harmful to the objective of climate change mitigation.
Criteria Reference	EU Taxonomy Transport of CO2 Criteria; Singaporean Taxonomy

3. Permanent sequestration of captured CO2

Sector	CCS/CCUS
Activity	Permanent sequestration of captured CO_2
ISIC code	No code
Description	Permanent storage of captured CO_2 in appropriate underground geological formations. This activity does not include nature-based sequestration activities.
Objective	Climate change mitigation
Green	Construction or operation of a permanent CO_2 storage facility is eligible if the facility complies with requirements and recommendations of ISO 27914:2017 (or any other comparable national or international standard) for geological storage of CO_2.
Amber	N/A

Red	Construction of new facilities that fail to comply with ISO 27914:2017 (or any other comparable national or international standard) is harmful to the objective of climate change mitigation.
Criteria Reference	EU Taxonomy Underground Permanent Geological Storage of CO2 Criteria; Singaporean Taxonomy

4. Utilisation of captured CO2

Sector	CCS/CCUS
Activity	Utilisation of captured CO_2
ISIC code	No code
Description	Utilisation of carbon captured by point-source capture or direct air capture of CO2
Objective	Climate change mitigation
Green	Captured CO2 can be used for the manufacture of durable products (e.g., construction materials stored in buildings, polymers or recyclable products that will not be incinerated as a final disposal alternative) or for implementing other Taxonomy-aligned activities (e.g. mixing it with cement or adding it to chemicals).
Amber	N/A
Red	• Use of CO2 for products that release the CO2 immediately when the products are used (such as in urea, carbonated beverages, or fuels) is harmful to the objective of climate change mitigation. • Use of CO2 for enhanced oil recovery, and the production of other forms of fossil energy sources is harmful to the objective of climate change mitigation.
Criteria Reference	Activity card is created for Thailand Taxonomy.

6.5 Auxiliary transitional activity

1. Introduction of energy efficiency and decarbonisation measures in manufacturing activities not specified in the Thailand Taxonomy

Sector	Manufacturing
Activity	Introduction of energy efficiency and decarbonisation measures in manufacturing activities not specified in the Thailand Taxonomy
ISIC code	Various codes
Description	Introduction of energy efficiency or electrification measures and change of energy sources in manufacturing activities that lead to substantial reduction of emission

Objective	Climate change mitigation
Green	Activities whose emission intensity figures are on the trajectory developed using the latest version of the SBTi methodology for this type of activity are compliant with the green category of Thailand Taxonomy. This option is only available for activities in the manufacturing sector that do not have their own activity card in this Taxonomy.
Amber	Measures to improve energy efficiency within the manufacturing sector (as defined by the last version of ISIC system) can be recognised as transitional (amber) under Thailand Taxonomy if the activity does not have specific criteria included in the taxonomy, and: **Option 1 (must comply with all three):** • The applied measures increase energy efficiency (energy input per unit of output) by at least 40% relative to the energy efficiency of facility baseline before the measures were applied. Final reduction of the emission intensity must be achieved no later than the Taxonomy sunset date for amber activities (2040). • If the production facility where the activity takes place uses hydrocarbons in any form (fuel or feedstock), the application of measures shall lead to a reduction in the use of hydrocarbons. • The facility has a transition plan that is consistent with the Paris Agreement commitments[91]. **Option 2 (must comply with both):** • Measures taken lead to electrification of the main production processes; • Measures implemented lead to change the type of electricity consumed by the enterprise from non-renewable to renewable (compliant with the green category of the Thai Taxonomy). Acquisition of PPA certificate does not count for this criterion, the manager of the facility must provide proof of direct connection to a renewable energy source or proof of in situ renewable installation. Any % of replacement of non-renewable electricity with renewable one is considered compliant with this criterion.
Red	Application of energy efficiency measures for the activities associated with:

[91] Applicable if a credible Paris-aligned reference pathway is developed by a scientific body or an industry organisation. In case if an activity in question does not have such a path developed, this requirement may be ignored

	• manufacture of equipment for the extraction of oil, gas, and coal; • manufacture of equipment for transportation, storage, and processing of any hydrocarbons; • manufacture of vehicles, ships, planes with internal combustion engines. • manufacture of weapons and weapon systems (ISIC Code 2520) is harmful to the objective of climate change mitigation.
Criteria Reference	Designed for Thailand Taxonomy, target is based on Draft Energy Efficiency Plan 2024

Annex: Additional information on sustainable hydrogen production

Table 13 Eligible measures for hydrogen production decarbonisation

Area	Activity	Mitigation criteria
General		
Equipment and components to produce low-carbon hydrogen	Acquisition and installation of electrolysers and membranes for electrolysers.	Automatically eligible
Carbon Capture and Storage	Installation / acquisition of infrastructure related to CO2 capture of emissions from hydrogen production.	• The minimum capture rate from process and combustion emission streams is 90%[92]. • A quantitative performance report of the CCS/CCUS operations, including the following information: - Intended capture rate capacity, maximum capture rate capacity, intended annual capture of CO2, transport of CO2, and storage of CO2. • Demonstrated MRV (Monitoring, Reporting and Verification) and mitigation measures for methane leaks on site and upstream. • There is evidence[93] that demonstrates the CO2 will be suitably transported and stored in line with the CCS/CCUS criteria of Thailand Taxonomy.
Carbon Capture and Utilisation	Infrastructure related to capture, transportation, and utilisation of CO2 emissions from hydrogen production.	• The minimum capture rate from process and energy emission streams should be 90% or emissions reduction at the facility level have to be at least 50%. [94]

[92] A minimum capture rate must be demonstrated only for specific investments on CCS/CCUS infrastructure. Entire facilities certification does not need to meet this requirement if the facility meet the total carbon intensity benchmark.

[93] Either directly from the facility or through contracts or agreements with a third party.

[94] A minimum capture rate must be demonstrated only for specific investments on CCS/CCUS infrastructure. Entire facilities that have CCS/CCUS embedded do need to meet this requirement if the facility meet the carbon intensity benchmark.

Area	Activity	Mitigation criteria
		• Issuers must present a quantitative performance report of the CCS/CCUS operations, including the following information[95]: - Intended capture rate capacity, maximum capture rate capacity, annual capture of CO2, annual transport of CO2, and annual utilisation of CO2. • Issuers must demonstrate MRV (Monitoring, Reporting and Verification), as well as mitigation measures for methane leaks on site and upstream[96]. • There is evidence[97] that demonstrates the CO2 will be suitably transported in line with the Taxonomy criteria for CCS/CCUS. • CO2 must be used for the manufacture of durable products (e.g., construction materials stored in buildings, or recyclable products that will not be incinerated as a final disposal alternative). • CO2 should not be used for products that release the CO2 immediately when the products are used (such as in urea, carbonated beverages, or fuels)

[95] CCS/CCUS performance report must be verified by an independent third party.

[96] Neil Slater, "DNV GL Launches Certification Framework and Recommended Practice for Carbon Capture and Storage (CCS/CCUS)," DNV, January 17, 2018, https://www.dnv.com/news/dnv-gl-launches-certification-framework-and-recommended-practice-for-carbon-capture-and-storage-CCS/CCUS--108096.

Monitoring alternatives include satellite-based or drone-based measurement. Additional guidance can be found in the report Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector. Monitoring, Reporting and Verification (MRV) and Mitigation.

United Nations Economic Commission for Europe, "Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector," ECE ENERGY SERIES (UNITED NATIONS, 2019), https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf.

[97] Either directly from the facility or through contracts or agreements with a third party

Area	Activity	Mitigation criteria
		• CO2 is not used for enhanced oil recovery, and the production of other forms of fossil energy sources.
Electrification of processes	Revamps, modifications and acquisition of equipment and other infrastructure necessary for the electrification of the processes	Automatically eligible
Relating to the feedstock used		
Using biomass as a feedstock	• Infrastructure to produce hydrogen using biomass; • Refurbishment and retrofitting of facilities to use biomass; • Acquisition of equipment to produce hydrogen using biomass;	• The biomass used complies with the criteria applicable for biomass sourcing set out in the Taxonomy criteria for bioenergy. • Primary organic streams are only eligible if certified as sustainable by Roundtable on Sustainable Biomaterials or International Sustainability and Carbon Certification. • Wood is eligible only if produced on a sustainable plantation as defined by the Thailand Taxonomy's Forestry Criteria
Using landfill gas as a feedstock	• Infrastructure to produce hydrogen using landfill gas; • Refurbishment and retrofitting of facilities using landfill gas as a feedstock; • Acquisition of equipment to produce	Issuers must demonstrate MRV (Monitoring, Reporting and Verification) and mitigation measures for methane leakages on-site and upstream[98]. Landfill gas complies with the Taxonomy criteria for waste management and landfill gas recovery.

[98] Monitoring alternatives include satellite-based or drone-based measurement. Additional guidance can be found in the report United Nations Economic Commission for Europe, "Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector," ECE ENERGY SERIES (UNITED NATIONS, 2019), https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf.

Area	Activity	Mitigation criteria
	hydrogen using landfill as a feedstock;	
Using manure-biomethane	• Infrastructure to produce hydrogen using manure biomethane; • Refurbishment and retrofitting of facilities using manure biomethane; • Acquisition of equipment to produce hydrogen using manure biomethane;	• Issuers must demonstrate MRV (Monitoring, Reporting and Verification), as well as mitigation measures for methane leaks. • Manure biomethane complies with the Taxonomy criteria for waste management criteria for composting.
Relating to the electricity source		
Using wind, solar, hydro, and geothermal energy-based electricity	• Infrastructure to produce hydrogen using renewable energy sources • Refurbishment and retrofitting of facilities using renewable energy sources • Acquisition of equipment to produce electrolytic hydrogen using renewable energy sources	Renewable energy produced on-site must comply with the most up-to-date Taxonomy criteria for the relevant source of energy. Issuers must demonstrate the use of only additional renewable electricity. To do that, issuers can implement the following options: • Renewable-based[99] captive power generation, OR • A power purchase agreement demonstrating a commercial link of the electrolyser with new renewable power capacity; OR • Excess of renewable-based electricity that would have been otherwise curtailed. Further, the temporal and geographical correlation between the additional renewable

[99] Energy produced from renewable sources such as wind, solar, and small hydropower generation

Area	Activity	Mitigation criteria
		electricity generation and the electrolyser electricity consumption must be demonstrated. • **Temporal correlation**: Issuers must demonstrate that the electricity is produced and used simultaneously, on a monthly basis, using telemetry measurement techniques. Renewable electricity that has been locally stored can be used as well. • **Geographic correlation**: Issuers must demonstrate physical capacity to transport the electricity from the renewable generation plant to the electricity consumption site. The electricity must not pass a zone of grid congestion.
Using low-carbon electricity	Infrastructure for the production of hydrogen using electricity from the grid.	The carbon intensity of the electricity grid must ensure that the production process is in compliance with the total carbon intensity benchmark in Table: Hydrogen carbon intensity thresholds.

Life cycle assessment recommendations

Methodological notes for Life Cycle Assessment (LCA) of hydrogen emissions:

- The life cycle assessment should follow the latest releases of ISO std[100] (ISO 14040, ISO 14044 for life-cycle assessment, and ISO 14067 for product carbon footprint). The Recommendation 2013/179/EU will be acceptable for assets located in the EU. Results should be verified by an independent third party.

[100] ISO standards available at: ISO/TC 207/SC 5 [ISO], "ISO 14044:2006 - Environmental Management — Life Cycle Assessment — Requirements and Guidelines," ISO, 2006, https://www.iso.org/standard/38498.html.; ISO/TC 207/SC 5 [ISO], "ISO 14040:2006 Environmental Management — Life Cycle Assessment — Principles and Framework," ISO, 2006, https://www.iso.org/standard/38498.html.

- GHG emissions must be estimated for a purity of 99.9% vol, and a gauge pressure of at least 3 MPa using correction factors. For pressures higher than 3 MPa, additional energy compression emissions must be included as well.
- The methodology factor in a Global Warming Potential for a period of 100 years (GWP100) for methane should be 28[101].
- GHG emissions accounting:

$$Etotal = E1 + E2 + E3 + E4 + E5 - E6 + E7 + E8$$

E total: Total emissions

E1: Upstream feedstock-related emissions (including sourcing[102], processing, transport, and storage)

E2: Upstream energy-related emissions (including sourcing, processing, transport, and storage)

E3: Fugitive emissions (Including hydrogen emissions)

E4: Process emissions

E5: CCS/CCUS emissions related to energy consumption and leakages

E6: Carbon emissions captured

E7: Compression and purification emission (Energy required to compress and purify hydrogen)

E8: Transportation emissions to the site where hydrogen will be used (energy and electricity-related emissions and fugitive emissions during transportation)[103]

[101] Fifth Assessment Report- IPCC

[102] Depending on the feedstock, it can be extraction, cultivation, or collection

[103] Transportation infrastructure emissions are not included

Additional guidance for different production pathways up to the point of production[104]

The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) methodology working paper contains guidelines for a calculation method for GHG accounting for the following production pathways up to the point of production[105]:

- Steam Methane Reforming combined with CCS/CCUS: **Appendix P1 of IPHE working document**
- Biomass as a feedstock combined with CCS/CCUS: **Appendix P5 of IPHE working document**
- Manure-based production: **P5.4** Bio-digestion
- Landfill gas-based production: **P5.4** Bio-digestion
- Biomass from secondary sources: **P.5.5** Biomass gasification.
- The IPHE working document also has guidelines for emission sources and allocation for biomass-based production:
- Emissions sources in Biomass-Based Hydrogen Routes/CCS/CCUS: **Appendix P.5.6**
- Allocation for the Biomass/CCS/CCUS pathway: **Appendix P.5.7**

[104] The IPHE methodology will develop guidelines for transport emissions accounting in the coming months.

[105] IPHE, "Methodology for Determining the Greenhouse Gas Emissions Associated With the Production of Hydrogen" (IPHE Hydrogen Production Analysis Task Force, November 2022), https://www.iphe.net/_files/ugd/45185a_6159cefcd88f4d9283ab0e60f4802cb4.pdf.