Net-Zero Transition: Opportunities for Vietnam

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BloombergNEF

Contents

Section 1. Executive summary

$2.4 trillion

Total investment required for Vietnam to reach net-zero emissions by 2050

5%

Average energy supply investment as a share of GDP between 2024 and 2050 under BNEF's Net Zero Scenario

2026

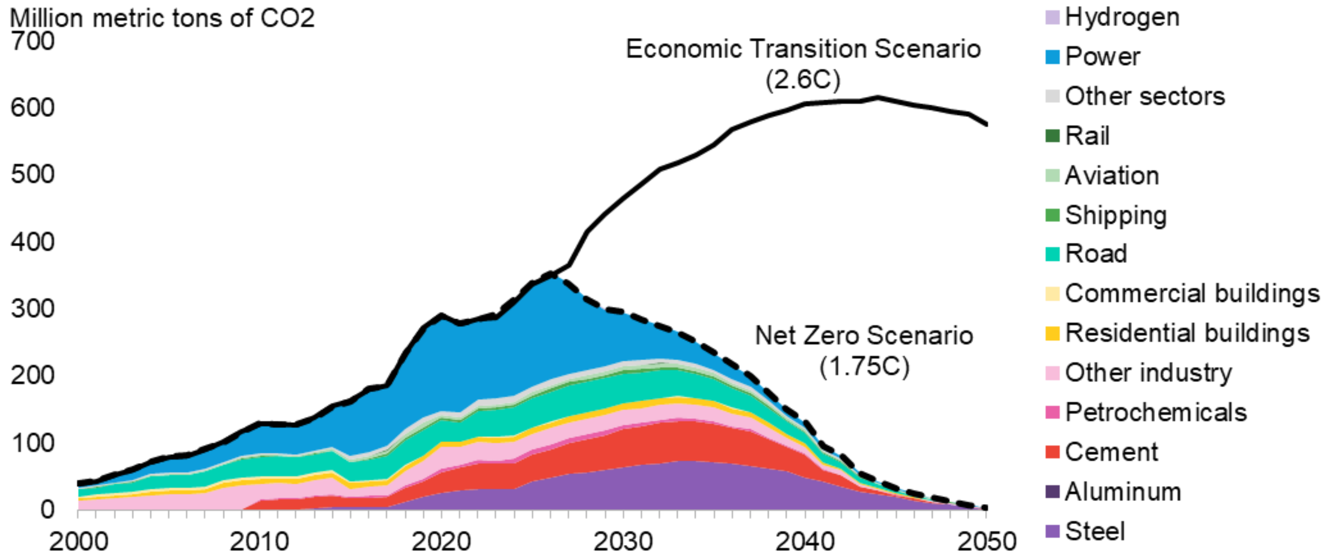
Year when Vietnam's energy-related emissions need to peak under BNEF's Net Zero Scenario

Vietnam has committed to a target of achieving net zero by 2050. To remain on course, it needs to accelerate emission reductions in this decade. This report explores the investment opportunities associated with these efforts and provides recommendations for Vietnam's net-zero transition based on the two scenarios considered by BloombergNEF's New Energy Outlook.

A 2050 net-zero goal requires Vietnam's energy-related emissions to peak before 2030

- **The emissions trajectories differ vastly between the economics-led and climate scenarios:** In BNEF's Net Zero Scenario (NZS), Vietnam's energy-related emissions need to peak in 2026 at 353 million metric tons (MtCO2) to be consistent with the Paris Agreement goal of keeping global warming to well below 2C above pre-industrial levels. This is 18 years earlier than emissions modeled under the Economic Transition Scenario (ETS), in which energy-related emissions peak in 2044, reaching 616MtCO2.
- **Power sector emissions to hit the highest point first:** In the NZS, the power sector rapidly ramps up renewable energy capacity to displace fossil-fuel generators and emissions peak in 2026. Transport sector emissions peak in 2029 and fall quickly, largely driven by the electrification of road transport. Industry emissions are the last to peak in 2033 and then fall sharply in the late 2030s due to the adoption of carbon capture and storage (CCS) technology and hydrogen to decarbonize heavy industries. In the ETS, emissions from all sectors except industry peak before 2050 and decline thereafter, though at a slower pace than in the NZS.

Figure 1.1: Vietnam's energy-related emissions and net-zero carbon budget – Economic Transition Scenario and Net Zero Scenario



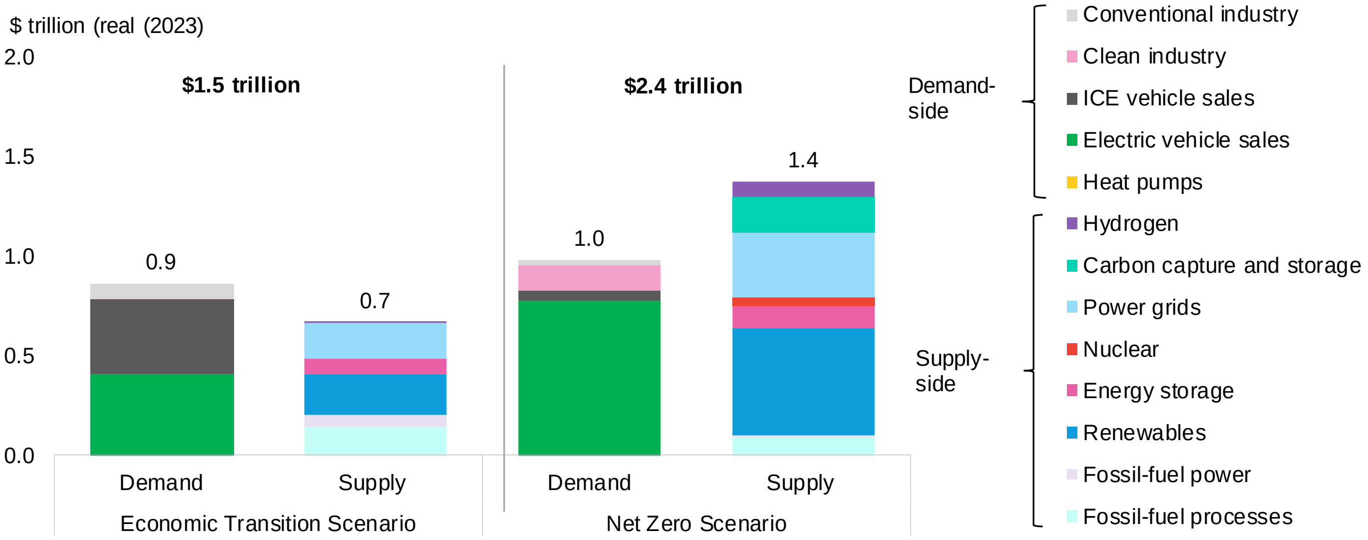
Source: BloombergNEF

- **Clean power, CCS, and energy efficiency are the top three abatement drivers:** Clean power (36%), CCS (27%), and energy efficiency (15%) lead Vietnam's emission reductions. These three sets of tools account for 78% of the total CO2 emissions abatement under the NZS while the remainder comes from electrification, bioenergy and hydrogen.

Unprecedented levels of net-zero investment opportunities in Vietnam from 2024-2050

- **A potential $2.4 trillion investment opportunity to be unlocked:** Efforts to drive net-zero emissions in Vietnam by mid-century presents an investment opportunity of $89 billion a year between 2023 and 2050. From 2024 to 2030, the average annual investment is $46 billion.
- **Energy system investment as a share of the national economy:** Under the NZS, investment in energy supply is equivalent to 5% of Vietnam's annual average gross domestic product (GDP) between 2024 and 2050, double the share under the ETS. Demand-side investment accounts for an annual average of 2.8% and 3.3% of national GDP during this period under the ETS and NZS, respectively.

Figure 1.2: Vietnam's energy investment and spending across 2024-2050 – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF. Note: ICE is internal combustion engine. The numbers above the bars indicate cumulative investment and spending figures from 2024 to 2050.

- **Renewables and electric vehicle sales account for the lion's share of supply and demand spending, respectively:** Out of the $1.4 trillion in supply-side investment required under the NZS from 2024 to 2050, renewable power plants account for 39%, followed by power grids with 23%. EVs make up the largest share of demand-side investment under the NZS, accounting for 80% of the $1 trillion in spending required by mid-century. They are followed by clean industry, accounting for 13%.

Section 2. Introduction

This report, part of the BloombergNEF New Energy Outlook series, examines the potential energy transition pathways for Vietnam, and the opportunities arising for the country as a result of the global energy transition. This section examines the current state of energy transition in Vietnam and the country's future goals. It also explains the scenarios considered by the New Energy Outlook.

2.1. Report context

Vietnam is among the fastest-growing economies in the world. Over the last decade, its rapid economic expansion has been accompanied by a swift rise in greenhouse gas emissions due to an increased reliance on fossil fuels. Since 2019, Vietnam has been the largest renewables market in Southeast Asia, thanks to policies such as feed-in tariffs for solar and wind projects.

At the 26th Conference of Parties (COP26) climate summit at the end of 2021, Vietnam formally set a target to reach net-zero emissions by 2050. At the end of 2022, Vietnam and the International Partners Group (IPG[1]) announced the Just Energy Transition Partnership (JETP), to unlock financing to support the country's just and sustainable energy transition. The $15.5 billion JETP funding package for Vietnam is supported by sovereign members of IPG as well as financial institutions that have signed onto the Glasgow Financial Alliance for Net Zero (GFANZ[2]).

As a GFANZ member, HSBC Group, through HSBC Vietnam, has taken a leading role in supporting Vietnam's energy transition. In November 2022 at COP27, HSBC Vietnam signed a memorandum of understanding with the Ministry of Natural Resources and Environment (MONRE) to assist the latter with "a practical approach in realizing its strategies in the alignment with Vietnam's net zero emissions targets as well as to build a framework that unlocks international financing sources to support these goals". This report commissioned by Bloomberg Philanthropies aims to support the collaboration between HSBC and MONRE.

2.2. National context

Vietnam's decarbonization target

A year after Prime Minister Pham Minh Chinh announced the country's commitment to net zero by 2050 at COP26, Vietnam in November 2022 submitted its updated Nationally Determined Contribution (NDC). The latest NDC lays out its ambition to lower the country's greenhouse gas emissions by 15.8% by 2030 versus anticipated levels in a business-as-usual scenario. With international financial and technological support, Vietnam in the NDC aims to lower emissions

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1 The IPG comprises Group of Seven members – Canada, the European Union, France, Germany, Italy, Japan, the UK and the US – plus Denmark and Norway.

2 Glasgow Financial Alliance for Net Zero (GFANZ) members include Bank of America, Citi, Deutsche Bank, HSBC, Macquarie Group, Mizuho, MUFG, Prudential Plc, Shinhan, SMBC and Standard Chartered.

further, by 43.5% by 2030 relative to a business-as-usual trajectory (Table 2-1). In the previous 2020 NDC, the targets were 9% and 27%, respectively.

Table 2-1: Vietnam's 2030 greenhouse gas emissions by sector with unconditional and conditional contributions relative to business-as-usual (BAU) scenario under its Nationally Determined Contribution (NDC)

	NDC 2022		NDC 2020	
	Reduction by 2030 relative to BAU (unconditional)	Reduction by relative to BAU (conditional)	Reduction by relative to BAU (unconditional)	Reduction by relative to BAU (conditional)
Energy	7.0%	24.4%	5.5%	16.7%
Agriculture	1.3%	5.5%	0.7%	3.5%
Land use, land use change and forestry	3.5%	5.0%	1.0%	2.3%
Waste	1.0%	3.2%	1.0%	3.6%
Industrial process	3.0%	5.4%	0.8%	0.9%
Total	**15.8%**	**43.5%**	**9.0%**	**27.0%**

Source: *Vietnam's 2022 and 2020 Nationally Determined Contributions (NDCs), BloombergNEF.*

At COP26, Vietnam also pledged to reduce methane emissions by 30% from 2020 levels by 2030 and joined the Global Coal to Clean Power Transition Statement, the Glasgow Leaders' Declaration on Forests and Land Use to prevent and reverse deforestation and land degradation by 2030, and the Adaptation Action Coalition to mobilize resources for climate change adaptation.

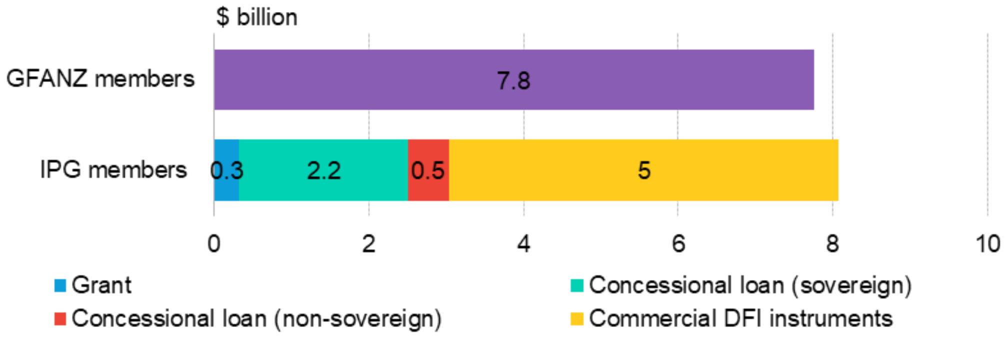
Just Energy Transition Partnership to support Vietnam's transition to net-zero emissions

In December 2022, Vietnam and the IPG established the JETP at a summit convened in Brussels by the Association of Southeast Asian Nations and the European Union to support Vietnam in delivering its goal of net zero by 2050. JETP sovereign members and members of GFANZ have committed to providing Vietnam with $15.5 billion of finance to transition to a low-carbon economy. Vietnam and JETP partners agreed on four targets:

- Bringing forward the projected peaking date for all greenhouse gas emissions in Vietnam from 2035 to 2030
- Reaching peak annual power sector emissions of 170 million metric tons of carbon dioxide equivalent by 2030
- Limiting Vietnam's peak coal-fired generation capacity to 30.2 gigawatts (in 2023, this totaled 26.7GW)
- Accelerating the adoption of renewables so that renewable energy accounts for at least 47% of electricity generation by 2030

On the sidelines of COP28 in 2023, Prime Minister Pham Minh Chinh launched the Resource Mobilization Plan (RMP), detailing the mobilization of $15.8 billion from JETP partners. IPG members are committed to $8.1 billion in finance for Vietnam, while the remaining of $7.8 billion comes from GFANZ members (Figure 2.1). The blueprint provides details on the structure of the $8.1 billion from IPG members. Only 4% of funding is in grant form, while 34% will be in the form of concessional loans, including sovereign (27%) and non-sovereign loans (7%). Commercial instruments issued by development finance institutions account for another 62%. However, it doesn't provide a breakdown of funding from GFANZ members.

Figure 2.1: Just Energy Transition Partnership (JETP) funding amount and indicative structure for Vietnam



Source: JETP Resource Mobilization Plan, BloombergNEF. Note: GFANZ is the Glasgow Financial Alliance for Net Zero. IPG is the International Partners Group comprising the Group of Seven plus Denmark and Norway. DFI is development finance institution.

The RMP has identified specific projects for each of the three priority areas, including grid infrastructure, energy storage and offshore wind power plants. Additional priorities are energy efficiency, solar power projects and transition of coal power plants (Table 2-2).

Table 2-2: Investment priorities and projects in Vietnam's Resource Mobilization Plan for implementing Just Energy Transition Partnership (JETP)

	Investment priorities	Proposed investment projects
Main priorities	Grid infrastructure	Vietnam Electricity Group's (EVN) 500-kilovolt (kV), 220kV, 110kV and 22kV transmission lines
		For offshore wind projects
	Energy storage	Battery storage • EVN's 50-megawatt (MW)/50-megawatt-hour (MWh) battery project • 7MW/7MWh battery project at a 50MW solar power plant • 105MW/105MWh battery project at a 400MW solar power plant
		Pumped storage hydropower plants • 1,200MW Bac Ai pumped hydropower plant
	Offshore wind	6 gigawatts (GW) of grid-connected offshore wind power projects
Additional priorities	Energy efficiency	Smart and Energy Efficiency City project to retrofit, upgrade and expand streetlighting system with 2.6 million lighting points
	Solar power	Additional 25-30GW of solar photovoltaic (PV) by 2030, including 16GW of solar with energy storage system
	Transition of coal power plants	Ninh Binh (100MW; 49 years old) (unspecified transition fuel) Pha Lai 1 (440MW; 40 years old) to 100% green hydrogen Pha Lai 2 (600MW; 22 years old) to 100% green ammonia Cao Ngan (115MW; 17 years old) to 100% biomass Van Phong (1,432MW; commissioned in August 2023) to partial biomass and CCS

Source: Resource Mobilization Plan for implementing Just Energy Transition Partnership, BloombergNEF.

The selection of specific investment projects within certain categories will be carried out through negotiations among managing agencies, projects owners, financiers, and other stakeholders on the basis of compliance with Vietnam's legal provisions and taking into account the selection criteria such as development, technology transfer and just transition.

Large emitting corporates lead the nation's decarbonization

To achieve the emission reduction goals under its updated 2022 NDC, the government issued regulations in January 2022 (Decree 06/2022/ND-CP), mandating large emitting corporates to report their emission inventories and undertake emission mitigation activities.

Mandated companies are those emitting more than 3,000 tons of CO2 or consume energy above 1,000 tons of oil equivalent per year in five sectors, namely power, industry, building, transport and waste (Decision 01/2022/QD-TTg). Corporates are required to report direct greenhouse gas emissions that occur from sources controlled or owned by them (Scope 1) and indirect emissions associated with the purchase of electricity, steam, heat or cooling[3] (Scope 2). Companies will report every two years, starting in 2024 and undertake mitigation activities from 2026.

As of August 2024, 2,166 companies are required to report their emissions, with those in light industries such as food and tobacco, paper, pulp and printing, wood and wood products accounting for 82% of the total, followed by those in the steel and transport sectors (Figure 2.2). In terms of annual energy consumption, mandated companies in light industries led with 50% of total energy consumption, followed by power (26%), waste (10%) and steel (6%) (Figure 2.3).

Figure 2.2: Mandated companies to report emission inventories in Vietnam as of August 2024, by sector

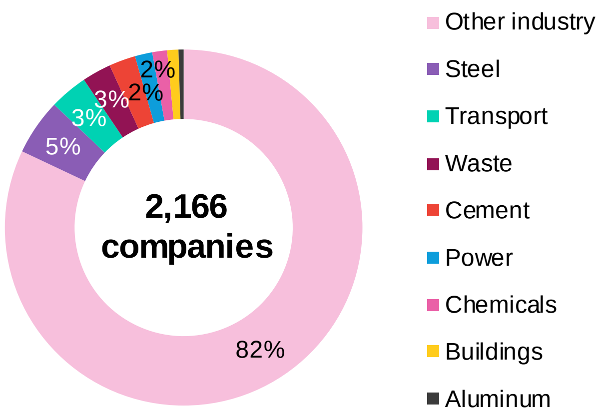
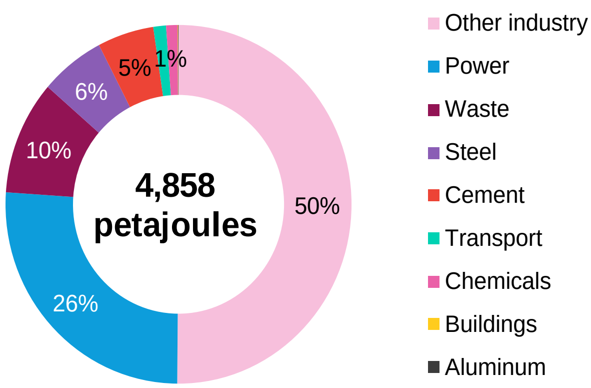


Figure 2.3: Total final energy consumption by mandated companies to report emission inventories in Vietnam, by sector



Source: Decision 13/2024/QD-TTg, BloombergNEF. Note: 'Other industry' includes other non-ferrous metals, other non-metallic minerals, food and tobacco, paper, pulp and printing, wood and wood products, textile and leather, machinery, transport equipment, construction; mining and quarrying and industry not further specified. Regulation does not specify which is the year for final energy consumption by mandated corporates.

The government will impose a carbon cap that mandated sectors can emit every year for the period from 2026 to 2030. Firms with a larger carbon footprint that are not able to meet their allowance for the year would have to enter the secondary market to buy extra units or credits.

3 According to Circular 38/2023/TT-BCT and Circular 17/2022/TT-BTNMT

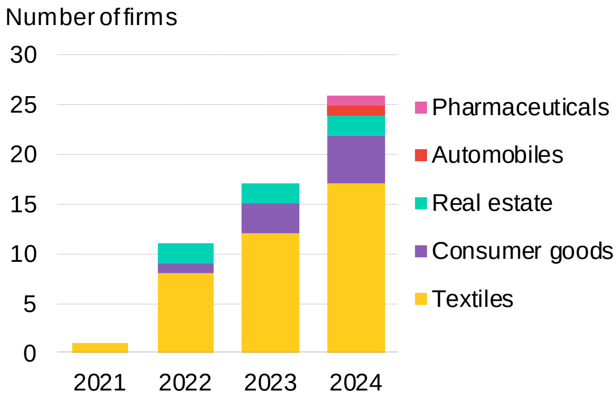
Vietnam plans to launch a pilot carbon market in 2025 and introduce a fully operational carbon market by 2028.

Even before the push from regulators, companies in the country have already started to set their own decarbonization targets, largely in the form of clean power purchases. Vietnam is the manufacturing base for many members of the RE100 (Figure 2.4). This is a voluntary initiative where members are committed to meeting all their electricity needs with renewables. The number of Vietnam-based companies setting emission reduction objectives that meet the standards of the Science Based Targets initiative (SBTi) grew to 26 companies in 2024, 63% more than the 16 that joined in 2023 (Figure 2.5). Textile companies dominate these commitments, amounting to 65% of the total of 26 companies in the market, likely because their key exporting markets are in Europe, where companies usually set stringent internal decarbonization targets.

Figure 2.4: Selected RE100 members with operations in Vietnam by industry of operations

Source: BloombergNEF, logos from company websites.

Figure 2.5: Cumulative number of Vietnamese firms with a science-based emissions reduction target



Source: Science Based Targets Initiative (SBTi), BloombergNEF. Note: Data updated to June 2024.

2.3. Scenarios at BloombergNEF

This research forms part of the library of energy-transition scenarios at BNEF.

The core scenario used in BNEF research is the Economic Transition Scenario showing how the transition could unfold solely based on economic forces and technology tipping points that push the balance in favor of low-carbon technologies, without further policy action. In addition to the ETS, BNEF has developed a range of global, sector-based, and country-level scenarios, including detailed modeling in the transport sector.

Scenarios are future-focused simulations combining several uncertain parameters into an internally consistent narrative. They are predominantly used for medium- to long-term investigative studies and may also include sensitivities to key variables. Scenarios differ from forecasts, which are usually shorter-term predictions of what we think will happen.

The *New Energy Outlook* presents two carefully calibrated scenarios, rather than a range of outcomes based on sensitivities. Our scenarios are therefore best understood as reference scenarios, instead of sensitivities or stress-testing scenarios (Table 2-3).

Table 2-3: Two scenarios in BNEF's New Energy Outlook

Economic Transition Scenario (ETS)	Net Zero Scenario (NZS)
• Exploratory base case, which describes how the power, industry, transport and buildings sectors might evolve as a result of cost-based technology changes	• Normative climate scenario, which describes a tough but achievable stretch to get on track for net zero by 2050 by meeting sectoral carbon budgets
• Consistent with a 2.6C warming outcome	• Consistent with a 1.75C warming outcome
• Assumes no further policy support for energy transition beyond existing measures	• No overshoot or reliance on net-negative emissions post-2050
• Low-carbon transition is largely limited to the power and transport sectors	• Fully decarbonizes power, transport, industry and buildings by 2050
• Uses bottom-up sub-sector models, instead of a top-down general equilibrium model or integrated assessment models • Uses consistent macro-economic inputs across both scenarios • Leverages proprietary data and expertise of 200 analysts • Models at yearly granularity for transport, industry and buildings sectors and hourly granularity in the power sector to 2050 • Offers data transparency on country- and sector-level data inputs and results	

Source: BloombergNEF

Economic Transition Scenario

The ETS is BNEF's base-case assessment of how the energy economy might evolve from today as a result of cost-based technology change to 2050. It combines near-term market activity, the uptake of new consumer-facing energy products, least-cost system modeling and trend-based analysis to describe the deployment and diffusion of commercially available technologies and their tipping points.

This scenario incorporates near-term legislation and policies designed to affect competitive economics, but does not assume either country-level, or corporate, long-run energy and climate objectives are necessarily met. Technology transition only occurs in this scenario where it lowers system costs or offers an attractive pay-back proposition for consumers. In this way the ETS describes how the energy sector might evolve in the absence of further major climate policy intervention, but in a world where clean technologies can compete on a level playing field.

BNEF scenarios take a demand-led modeling approach. Population and economic activity across the world continue to expand, driving up demand for energy-intensive commodities such as steel, cement, aluminum and chemicals. So too does the demand for movement of goods and people by road, rail, air and sea. With population growth and higher GDP comes an increase in commercial and residential building stock and with it a rise in demand for space and water heating, electricity for lighting and appliances and either gas or electricity for cooking.

In our modeling, countries' electricity-intensity of GDP evolves in line with changes to the dominant forms of economic activity, and energy efficiency improves over time throughout the economy via incremental improvements on both the demand and supply side. Carbon prices are included where compliance schemes are already in place, driven by market fundamentals.

Greenhouse gas emissions under our New Energy Outlook ETS are consistent with a 67% chance of limiting global temperature rise to 2.6C by 2100.

Net Zero Scenario

The Net Zero Scenario describes an economics-led evolution of the energy economy to stay within a carbon-emissions constraint and achieve net-zero emissions in 2050, with no overshoot or reliance on net-negative emissions after 2050. We take a sector-led approach to decarbonization, meaning that countries' carbon budgets are largely determined by the sectoral make-up of their economies, and the expected growth in those sectors. Neither historical responsibility nor availability of finance is taken into consideration.

The NZS combines faster and greater deployment of renewables, nuclear and other low-carbon dispatchable power technologies with the uptake of cleaner fuels, most notably hydrogen and bioenergy, in end-use sectors. Carbon capture and storage emerges toward the end of the 2020s, allowing some continued fossil fuel use in electricity generation and industry. Additionally, accelerated electrification and increased recycling of materials further contribute to emissions reductions. The NZS is therefore not an extension of the ETS: it describes a fundamentally different energy economy.

While the technological choices in the NZS are primarily guided by economics, we also account for countries' strategic priorities and strengths, firm and legislated existing policy, and local resources.

Greenhouse gas emissions under our *New Energy Outlook* 2024 NZS are consistent with a 67% chance of limiting global temperature rise to 1.75C by 2050. This trajectory is also consistent with a 33% chance of staying within 1.5C, and a better-than-67% chance of staying below 2C.

The NZS shows a plausible, global pathway – with country-level detail for key economies – to achieving the main goals of the Paris Agreement and staying well below 2C. The more ambitious target of 1.5C looks increasingly out of reach, but concerted action can still put the world on a trajectory that approaches this benchmark and avoids the worst effects of climate change.

Emissions covered

The modeling in this report primarily focuses on carbon dioxide emissions from fuel combustion in the energy sector: power, transport, industry and buildings. These collectively account for about 69% of greenhouse gas emissions, based on shares in 2019[4] (Figure 2.6).

Energy-related emissions from electricity and heat generation, industry and transport have been growing fastest, increasing about 80% since 1990. This growth varies by country but has most recently been seen in emerging economies with rising GDP and population.

Total greenhouse gas emissions worldwide in 2019 were around 49.7 billion metric tons of CO2 equivalent (GtCO2e), up 48% from 33.7GtCO2e in 1990.[5] By sector, the largest share of global emissions comes from electricity and heat generation, accounting for 32% of the total, or 15.8GtCO2e. The second-largest category is industry, including industrial processes, with 19%, or 9.4GtCO2e, followed by transport and international aviation and shipping (bunker fuels) at 17%, or 8.4GtCO2e. Buildings account for 3.1GtCO2e, or 6%.

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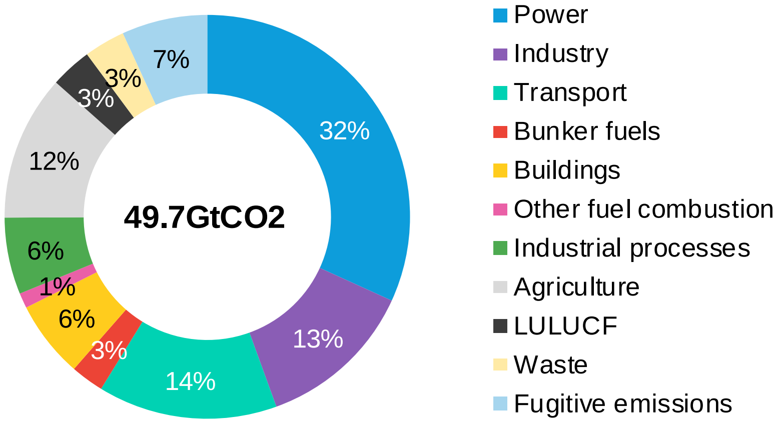
4 Calculations done using data using IPCC, Special Report on Global Warming of 1.5C, https://www.ipcc.ch/sr15/

5 BNEF uses 2019 as the base year to calculate the share of energy-related emissions in total emissions. The latest data available from Climate Watch covers 2020 but is unsuitable as a base year for our purposes due to the highly distorting impact of the Covid-19 pandemic.

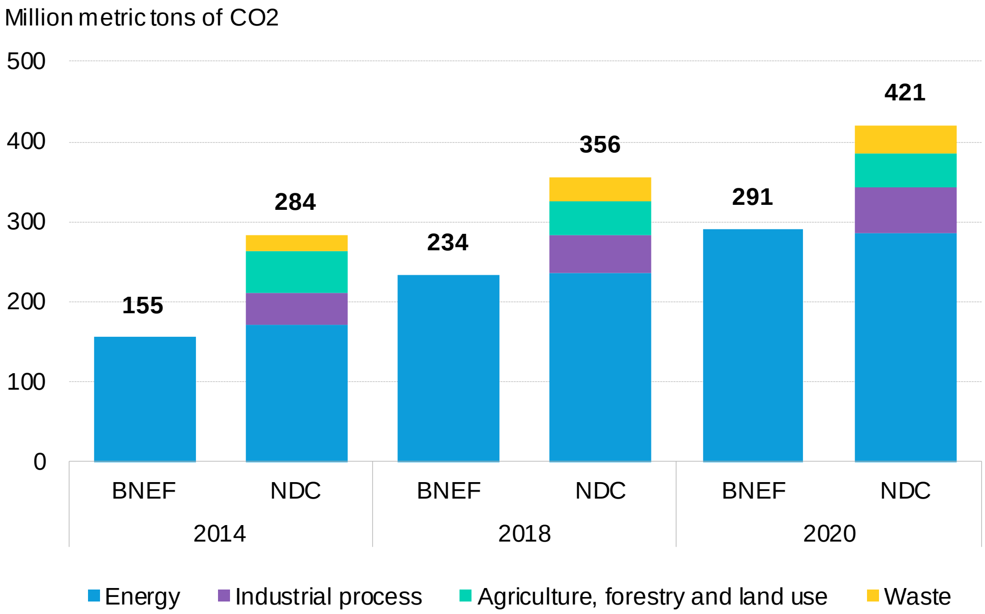
Figure 2.6: Estimated global greenhouse gas emissions in 2019



Source: World Resources Institute, International Energy Agency, BloombergNEF. Note: GtCO2 is billion metric tons of carbon dioxide. Includes all CO2 and CO2-equivalent emissions. LULUCF is land-use, land-use change and forestry. Fugitive emissions refer to the unintentional release of greenhouse gases from industrial processes, equipment, or infrastructure.

Figure 2.7 shows how the historical emissions covered by the BNEF scenarios for Vietnam compare to overall emissions covered by the country's technical report on national emissions inventories in 2018 and 2020.

Figure 2.7: Vietnam's historical carbon dioxide emissions covered by BNEF's modeling and total greenhouse gas emissions included in Vietnam's Nationally Determined Contributions (NDC)



Source: BloombergNEF, Vietnam technical Nationally Determined Contribution (NDC). Note: The base year is 2014. Emissions data for 2018 and 2020 are from draft report auditing emissions for these two years shared by the Ministry of Natural Resources and Environment.

2.4. Modeling approach

This section outlines the general scenario modeling approach and methodology at BloombergNEF, and the guiding principles used for net-zero modeling.

Principles of energy modeling

Sectoral approach

Full sectoral and country-level data are published in the *New Energy Outlook 2024: Data Viewer* (web | terminal)

The *New Energy Outlook* follows a sectoral and country-level modeling approach. The modeling employs a series of interlinked sector-focused bottom-up models at a regional, country and sub-country-level granularity, building on sector and regional expertise of BNEF analysts and proprietary data. We do not use general equilibrium or integrated assessment models.

The four primary sectors modeled are those representing the majority of energy demand – power, industry, transport, and buildings.

Once energy demand has been modeled, energy-supply investment, supply-chain investment, metals demand, grid implications, emissions, land use implications and other outputs are derived. By keeping consistent macro-economic inputs such as population, economic growth, oil, gas and coal prices, the modeling allows detailed insights into the tipping points for low-carbon solutions.

Annual outputs are provided in the *New Energy Outlook: Data Viewer* (web | terminal) across all data sets from today to 2050, and historic data to 2000.

In order to model technological change and changes in energy choices across power, industry, transport and buildings, we rely on three broad approaches:

- **Least-cost modeling** is our gold standard, where our models find a cost-optimal solution for demand in individual sectors, such as the power sector and various industrial sectors.
- We also use **technology uptake modeling**, which looks at costs and technology crossover points to project the uptake of technologies by consumers or businesses, such as for electric vehicles, clean shipping, heat pumps and small-scale solar and batteries.
- We use **trend-based** models for other sectors, examining past patterns and projecting them forward based on analyst insights on technology choices and readiness, company roadmaps and political-economy factors.

Table 2-4: Sectoral modeling approaches in New Energy Outlook 2024

		Sub-sectors	Description	Type of model
Transformation sectors				
Energy industry	Power	26 generation and storage technologies	• NEFM-2 power system models hourly increments for 55 sub-regional models; model solves for a capacity mix that minimizes system costs, while dispatching to meet demand at every hour • Technology uptake modeling for solar PV	Least-cost and technology uptake
	Heat	Heat	Takes heat demand from buildings and industry models and uses trend-based analysis to model future energy use	Trend-based
	Fuel production	Hydrogen	Dynamically models in-country hydrogen production	Least-cost

		Sub-sectors	Description	Type of model
End-use sectors				
Transport	Road transport	Passenger cars, commercial vehicles, two-three-wheelers	Cost-based modeling considers policies, sales trends and EV model launches in the short-term, and consumer uptake dynamics (Bass diffusion model) in the long run	Technology uptake
	Aviation	Passenger and freight	Determines future jet fuel use via forecasts for passenger and freight demand, incorporating efficiency improvements, uptake of sustainable aviation fuels, and new aircraft technology and fuels	Trend-based
	Shipping	Containers, oil tankers, chemical tankers, gas tankers, bulk carriers, general cargo	Determines future shipping fuel use based on demand for freight by vessel and route type, order books and fleet turnover and estimates for new-build vessels. Includes uptake for liquefied natural gas (LNG), ammonia and methanol, and biofuels	Technology uptake
	Rail	Urban, high-speed, conventional and freight	Uses total cost of ownership model	Trend-based
Industry	Steel, aluminum, cement		Least-cost model that minimizes total system cost using various levelized costs of production to meet demand forecasts, by sub-sector and country	Least-cost
	Chemicals	Petrochemicals	Trend-based energy modeling, building on detailed demand forecasts	Trend-based
	Other industry	Pulp and paper, food processing, tobacco, textiles, wood processing, machinery and others	Trend-based models for final energy consumption	Trend-based
Buildings	Residential, commercial	Heat pumps	Models heat pumps as consumer uptake model, and general buildings energy demand as trend-based model	Technology uptake and trend-based

Source: BloombergNEF. Note: All sectors modeled bottom-up in annual increments.

Constraints and considerations

We minimize the use of constraints to avoid pre-determining model outcomes, so that the results can light a path for what a future energy economy could look like.

We do, however, consider potential supply chain and manufacturing constraints, by avoiding sudden leaps in adoption of any particular technology overnight. We also constrain near-term results by applying judgment around existing policy regimes and project pipelines. Where we can 'see' the short-term outcomes already around the corner, we constrain models to avoid over-writing those.

With that said, there are numerous barriers (or required enablers) for the energy transition. Rather than treating these all as modeled constraints, we provide detailed analysis on them based on the outputs of the core modeling, to derive conclusions on what is needed to enable the transition. This includes impacts on grids, metals and critical materials supply, investment and land use.

We do not aim to resolve (global) supply-demand balances, trade or prices.

Emissions constraints, applied only in our NZS, are discussed below.

Emissions constraints in the Net Zero Scenario

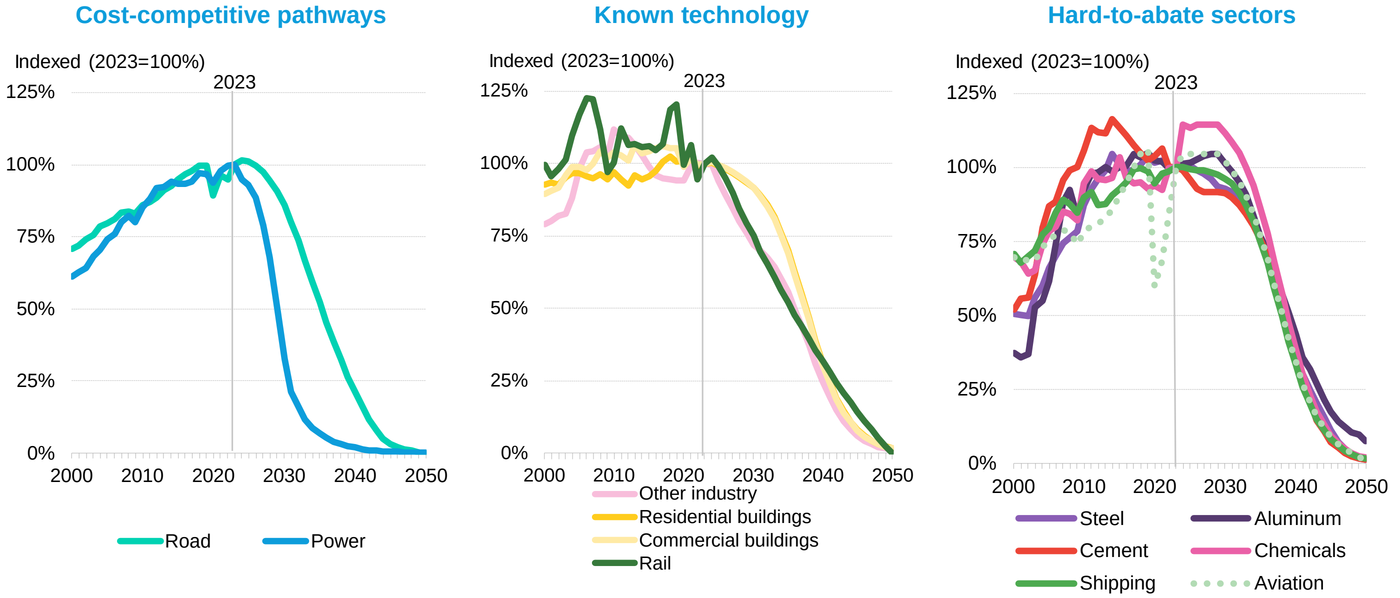
Our base-case ETS does not have an emissions constraint. The NZS constrains global and sectoral emissions to achieve a Paris-aligned outcome, with temperature-change results based on Intergovernmental Panel on Climate Change carbon budget data. We do not use marginal abatement driven by an assumed global carbon price or run our own climate models.

- **A sector-led approach.** Carbon budgets are modeled at a sector level and account for historical emissions trends, projected emissions growth and available abatement options to ensure an 'orderly transition' that avoids step changes, wherever possible, and maintains economic and social security.
- **Skepticism toward unproven future technology solutions.** Our modeling relies on commercially available technologies today, and those that have shown technology readiness and a conceptual pathway to scale. We prefer technologies that could be globally available, have wide-ranging applications and pathways. We limit technologies that are unproven or in early development stages at the time of writing, such as direct air capture.
- **Country carbon budgets.** These are determined by the sectoral make-up of each country's economy, the expected growth in those sectors, and their relative progress under the base-case ETS. In practice, this means that those countries with growing demand for power, say, end up with a higher power-sector budget than those with flat or falling demand. Neither historical 'responsibility' nor availability of finance are taken into consideration. Every sector and country must get to net zero by 2050. There are no exceptions.
- **No overshoot.** Our scenarios end in 2050 and do not rely on net-negative emissions post-2050. Over 99% of the emissions reductions are achieved by actual abatement, fuel switching or CCS. Carbon-removal technologies, such as direct air capture technologies, are only used to address some residual emissions, such as those not captured by CCS technologies.
- **No behavioral change.** BNEF modeling does not rely on behavioral change, assuming the same demand trends for useful energy services, such as mobility (air travel, demand for road transport services), materials (for example, steel and aluminum) and useful services from energy, in both scenarios.
- **Same effort assumption for non-energy emissions.** BNEF assumes emissions outside the energy sector will decline at the same rate as those covered in our analysis. This avoids making over-optimistic assumptions about hard-to-abate sectors outside the scope of our analysis, such as land-use and land-use change and forestry (LULUCF) or agriculture.

Sector emissions budget

In the NZS, sectoral emissions budgets fall into three groups. The first group comprises sectors that already have visibility on cost-competitive pathways using abatement technologies available today – such as power and road transport. This group is assigned the most ambitious temperature-equivalent carbon budgets.

Figure 2.8: Sector and sub-sector emissions budgets – Net Zero Scenario



Source: BloombergNEF. Note: Emission trajectories indexed to 2023 values. Aluminum direct emissions in 2050 are near zero (about 14 million metric tons of CO2) but show up in the chart as absolute emissions today are low.

The second group of sectors are those where technology solutions are known but are not yet economically competitive or deployed at scale – such as buildings, light industry and rail. 'Hard-to-abate' sectors make up the third group – where the future technology or fuel mix is just coming into view.

Table 2-5: Sector carbon budgets groupings

Group	Sector	Sub-sector	Emission trajectory	Carbon budget
Cost-competitive pathway	Power	Power	• The power sector has seen the steepest emissions reductions to date, with strong momentum from low-carbon technologies	1.6C equivalent target
	Transport	Road transport	• Increasingly cost-competitive abatement options are available in the form of electric vehicles • Challenges arise from the necessary speed of consumer uptake, manufacturing capacity, infrastructure and the need to decarbonize heavy-duty commercial transport	1.78C for passenger vehicles, buses, and two- and three-wheelers 1.82C for commercial vehicles 1.8C for the sector
Known technologies	Buildings	Residential, commercial	• Abatement options exist, but retrofitting is difficult and expensive • Emissions decline moderately to 2030 and exponentially thereafter	1.9C for residential 1.9C for commercial
	Industry	Other industry	• Emissions decline linearly from today to 2050 in low-temperature industries, accelerating the declining trajectory since 2010	1.7C-1.8C
	Transport	Rail	• Emissions decline steadily to 2050	1.8C
Hard-to-abate	Transport	Aviation,	• Aviation emissions plateau at 2024 levels up to 2030, before entering a period of accelerated decline that slows down in the final years.	1.9C

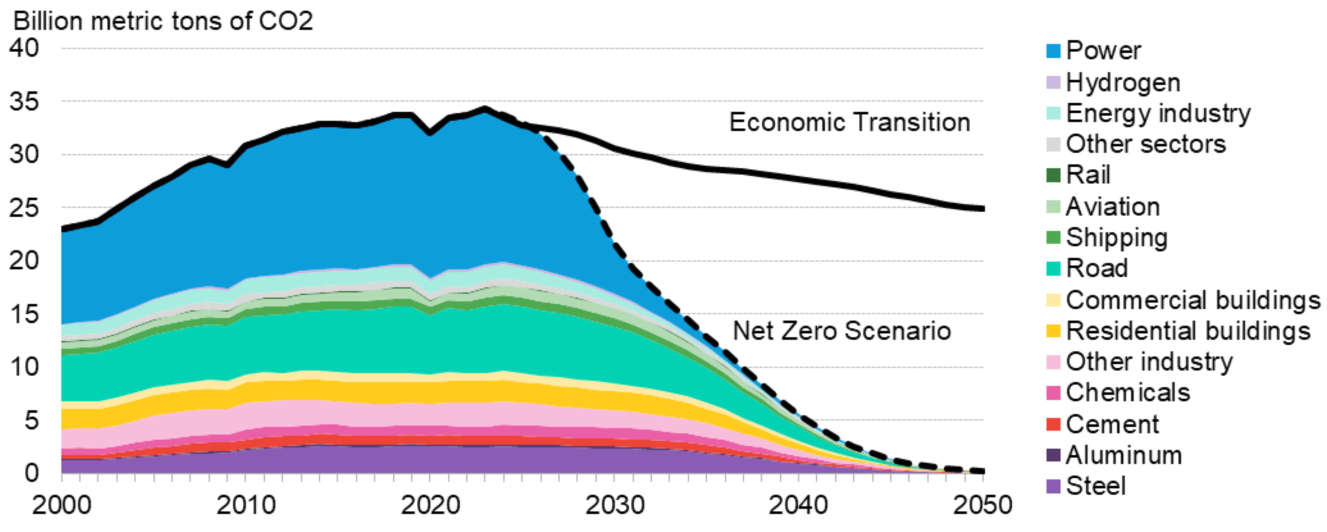
Group	Sector	Sub-sector	Emission trajectory	Carbon budget
		Shipping	• In shipping, emissions moderately decline from 2024 to 2030, and then decline exponentially to 2050	1.9C
	Industry	Chemicals, steel, cement, aluminum	• Chemicals emissions plateau at 2024 levels, before entering a period of accelerated decline • Cement emissions continue to fall moderately to 2030, continuing a trend that started in the 2010s, while steel emissions start declining moderately • Both cement and steel emissions decline exponentially after 2030 • Direct aluminum emissions are already small, they decline exponentially after 2030	1.9C

Source: BloombergNEF

Total emissions budget

Adding all sector emissions curves gives the total carbon budget for fuel combustion in the energy sector. Our modeling suggests emissions need to fall 37% by 2030 from 2023 values and drop 84% to 2040. If achieved, this orderly transition would reach net-zero emissions in 2050 and achieve the Paris Agreement objective, with global warming of 1.75C by 2050, without overshoot or the need for net-negative emissions post-2050.

Figure 2.9: Global energy-related emissions and net-zero carbon budget – Economic Transition Scenario and Net Zero Scenario

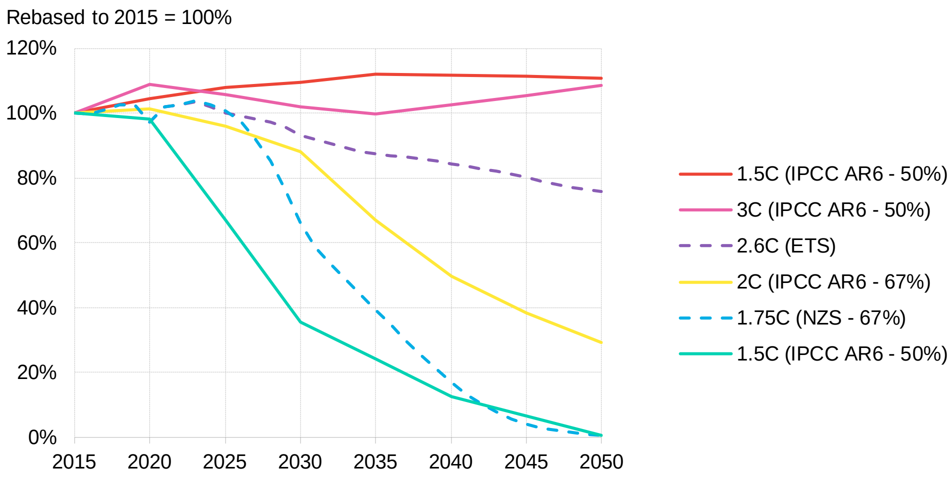


Source: BloombergNEF

In contrast, emissions in our ETS fall only 10% by 2030 and an average 1% a year to 2040, resulting in emissions consistent with 2.6C warming trajectory by the end of the century.

Figure 2.10 shows the emissions trajectories consistent with different temperature outcomes under the IPCC's Sixth Assessment Report. According to our calculations the NZS is consistent with a 1.75C target, with a 67% likelihood of limiting warming to this level.

Figure 2.10: Global annual carbon emissions in IPCC and BNEF scenarios



Source: BloombergNEF, Intergovernmental Panel on Climate Change (IPCC) 2022: Summary for Policymakers. Note: ETS is Economic Transition Scenario; NZS is Net Zero Scenario; AR6 is the IPCC's Sixth Assessment Report. The base year is 2015. The scope of the New Energy Outlook covers 69% of global carbon dioxide emissions under the IPCC's 1.5C scenario – historical and future emission trajectories are adjusted upwards to match those of the IPCC's scenario.

Technology inclusion and readiness in the Net Zero Scenario

To achieve such rapid decarbonization requires the unprecedented ramp-up of technologies that are not yet being deployed at scale. In addition to already at-scale technologies such as renewables and EVs, we also include deep-decarbonization technologies that:

- **Could be globally available:** can be deployed in most markets
- **Can have wide-ranging applications:** flexible and have use-cases across multiple sectors and industries
- **Have a pathway to scale:** possess apparent technology-readiness and a plausible pathway to scale

Given the high levels of uncertainty on future technology development, our scenario is best interpreted as a set of goals that each technology sector must work toward, rather than a prediction of the growth of specific next-generation low-carbon technologies. For example, to fulfill their respective roles in our NZS, hydrogen and CCS must become fully commercially available by the end of this decade, with different speeds depending on the sub-sector.

In the power sector modeling, hydrogen-fired gas plants, coal and gas equipped with CCS, and nuclear plants (both conventional and next-generation technology, such as small modular reactors) emerge in the form of pilot projects in 2027. They deploy at full scale from 2030 onward.

In industry, some sectors already use hydrogen and CCS today; hence we assume earlier uptake of these technologies. In steel, for example, hydrogen-fired direct-reduction furnaces or CCS retrofits can be deployed immediately.

Deployment of deep-decarbonization technologies will also depend on the buildout of corresponding network and storage infrastructure. In electricity, efforts to renew and expand the power grid need to be accelerated. For hydrogen and CO2, completely new transport grids and storage infrastructure will be needed. While this may pose an additional challenge to reach the goals of the scenario, we do not assume it delays or constrains the uptake of the supply technologies themselves.

Macroeconomic assumptions

The near-term economic outlooks published by international organizations, such as the International Monetary Fund (IMF) and the Organisation for Economic Co-operation and Development (OECD), emphasize the significant uncertainty and the downside risks that pervade GDP growth and inflation projections.

GDP projections in this report are a combination of IMF's World Economic Outlook from October 2023 and the OECD's long-term GDP projections from 2021. Where long-term projections are not available, we have used our own in-house model to estimate long-term growth. For population, we use World Bank estimates, specifically its dataset from May 2023.

BNEF uses consistent GDP and population assumptions across both scenarios. We are investigating how to incorporate feedback loops between modeling and macroeconomic outputs in future reports.

Section 3. Emissions and abatement

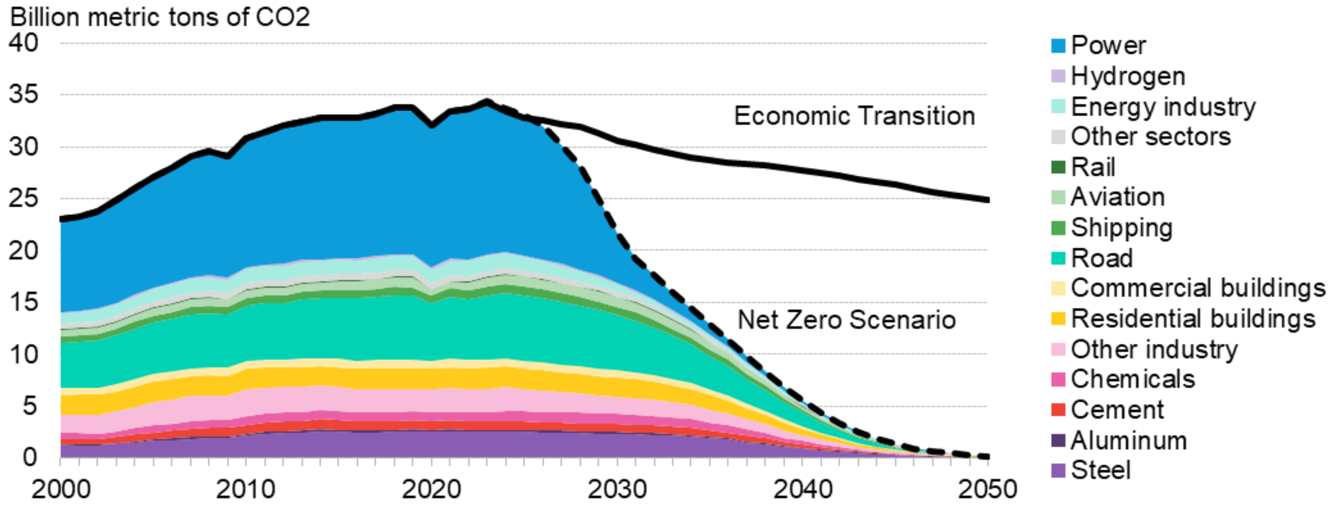
In BNEF's Net Zero Scenario, Vietnam's energy-related emissions need to peak in 2026 at 353 million tons of carbon dioxide to be consistent with the Paris Agreement goal of keeping global warming to well below 2C above pre-industrial levels. Clean power, carbon capture and storage, and energy efficiency are the top three abatement drivers to help Vietnam achieve net zero by 2050. These three sets of tools account for 78% of the total CO2 emissions abatement under the NZS while the remainder comes from electrification, bioenergy and hydrogen.

Total global emissions budget

To meet the Paris Agreement goal to limit the global temperature increase to well below 2C above pre-industrial levels, under BNEF's Net Zero Scenario, global energy-sector emissions have to decline immediately from their current high of about 34.3 billion metric tons of CO2 in 2023. By 2030 they drop 37% to 21.7GtCO2. By 2040 they plummet further to 5.6GtCO2 and approximate zero in 2050. Emissions reductions by necessity have to be steepest this decade.

Emissions in the power sector see the most immediate decline due to availability of cost-competitive technologies such as solar, wind and energy storage. Power-sector emissions peak at 14.7GtCO2 in 2023. By the early 2040s the sector is effectively carbon-neutral (Figure 3.1). Emissions in transport, industry and buildings also clearly depart from the Economic Transition Scenario trajectory, but more modestly initially, reflecting the more limited availability of economic abatement options. From 2031 onward all sectors enter a steeper decline.

Figure 3.1: Global energy-related emissions and net-zero carbon budget – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF

If industry and buildings manage to reduce emissions from now on, they would have reached peak emissions in 2014 and 2018, respectively. Transport emissions in the NZS peak in 2024 while power emissions hit the highest point in 2023 in both scenarios.

Energy-related emissions decline 27% by 2050 in the ETS compared with today, or 1.1% a year, falling to 24.9GtCO2. This is similar to emissions in 2003 but with a GDP that is more than three times as large. Our modeling shows emissions to peak in 2023 at about 34.3GtCO2 and enter a steady decline thereafter. This marks a clear reversal of rising emissions seen in the past decades, yet also a reinforcement of a trend of slowing emissions growth since 2017. This dynamic has been driven by an accelerated uptake of solar and wind, the switch from coal to gas in markets like the US and slowing industrialization, most notably in China.

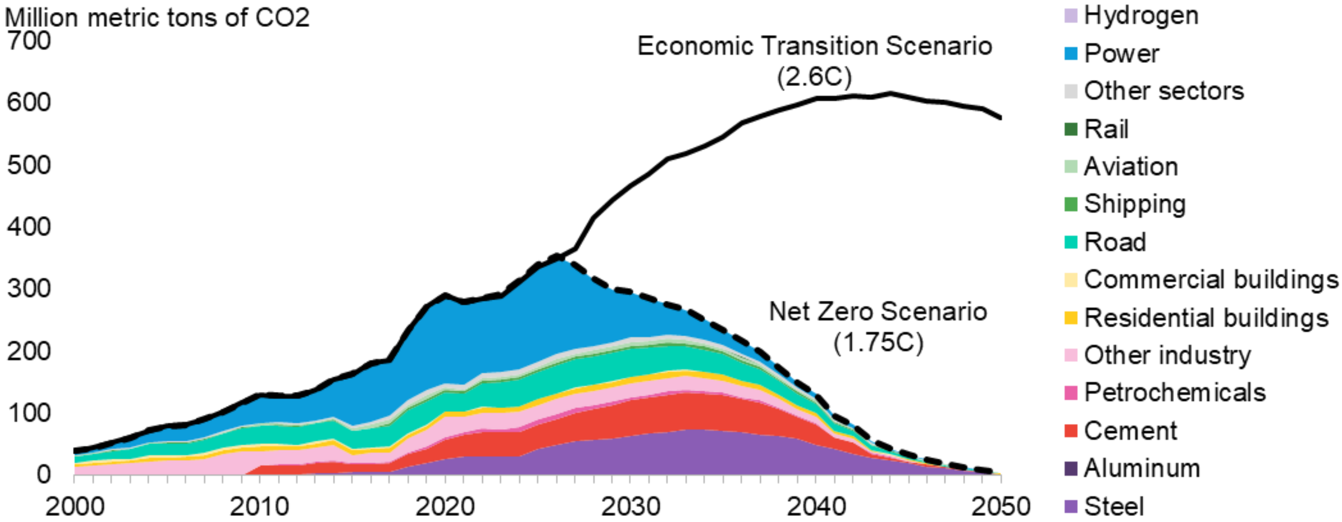
Vietnam’s energy-related emissions and net-zero carbon budget

In BNEF’s NZS, Vietnam’s energy-related emissions need to peak in 2026 at 353 million tons of CO2 to be consistent with the Paris Agreement goal to keep temperature increases well below 2C compared to pre-industrial levels. This is 18 years earlier than under the ETS, which sees energy-related emissions peaking in 2044 at 616MtCO2 (Figure 3.2).

Our modeling shows that while 1.5C looks increasingly out of reach, there are still plausible pathways to stay within 1.75C of warming. This path requires a revolution in the energy sector to increase momentum and accelerate emissions reductions.

In the NZS, the power sector needs to rapidly ramp up renewable capacity to displace fossil-fuel generators and peaks in 2026. While carbon capture and storage and hydrogen will play a role in decarbonizing the power sector, the role of hydrogen will be limited compared to CCS. Transport sector emissions peak in 2029 and fall quickly particularly due to the electrification of road vehicles.

Figure 3.2: Vietnam’s energy-related emissions and net-zero carbon budget – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF

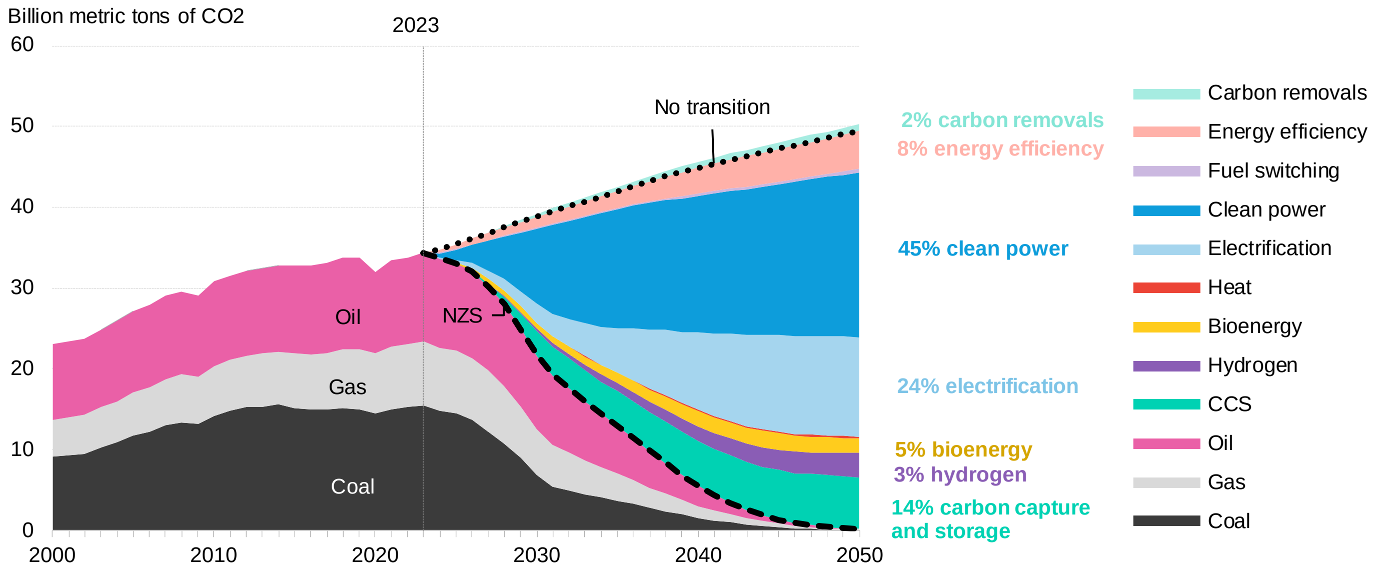
Vietnam's industrial sector emissions are the last to peak in 2033 and then begin a steep decline in the late 2030s due to the adoption of CCS and hydrogen to decarbonize heavy industries such as steel, cement and petrochemical production. Emissions from the buildings sector, which are already lower than industrial and transport emissions, decline relatively slowly from their peak. In the ETS, emissions from all sectors except industry peak before 2050 and are on a declining path, though at a slower pace than in the NZS.

Abatement drivers in the Net Zero Scenario

To understand the scale of change needed to reach net-zero emissions, we compare the contribution of emissions-saving technologies and other measures with a 'no- transition' pathway, which charts a route in which no further decarbonization efforts are made (Figure 3.3).

Decarbonizing the power sector accounts for about half of emissions abated over 2024-2050. Power is already the biggest carbon-emitting energy sector today and under the NZS, power generation is set to grow further due to new demand from a growing population and additional electrification of end-use sectors compared to the ETS. Within 'clean power', wind generation is responsible for 18% of emissions avoided compared to a 'no-transition' scenario, followed by solar (17%), and nuclear (4%). Other renewables – including hydro power, geothermal, bioenergy for power generation and solar thermal – contribute 6%.

Figure 3.3: Global carbon dioxide emissions reductions from fuel combustion by measure – Net Zero Scenario versus 'no transition' scenario



Source: BloombergNEF. Note: The 'no transition' scenario is a hypothetical counterfactual that models no further improvement in decarbonization and energy efficiency. In power and transport, it assumes the future fuel mix does not evolve from 2023 (2027 in the shipping sector). For all other sectors, the counterfactual to the Net Zero Scenario (NZS) is the Economic Transition Scenario. 'Clean power' includes renewables and nuclear, and excludes carbon capture and storage (CCS), hydrogen and bioenergy, which are allocated to their respective categories. 'Energy efficiency' includes demand-side efficiency gains and more recycling in industry.

Electrification of end-use sectors accounts for the next quarter of emissions abatement. It is a major vector of decarbonization due to its economics and ease of implementation. If processes can be electrified, they can be decarbonized more easily with mature technologies in the power sector.

In the buildings sector, for example, it can avoid 9 out of 10 tons of emissions by displacing fossil fuels for heating and hot water with electric alternatives. In transport, electrification abates 60% of emissions, largely as electric vehicles gain ground in road transport, and cuts out 38% of emissions in industry.

CCS in industry and power can help bridge a critical gap to achieve a 1.75C temperature outcome, if it can be deployed at scale and quickly. CCS contributes 14% of global emissions reductions – almost as much as solar overall. Three-quarters of emissions reductions are in power with the remainder in industry. Still, CCS can only be considered completely carbon-neutral if it is accompanied by additional carbon removal technologies. These may for example come in the form of direct air capture and are needed to abate the residual, non- captured 10% emissions not captured during the CCS process. Carbon removals account for 2% of emissions abatement over 2024-2050.

Bioenergy contributes 4% in hard-to-abate sectors, mostly in aviation and shipping as biofuels and in industry as solid fuel. Zero-carbon hydrogen meanwhile only contributes 3% to emissions abatement, predominantly to replace fossil-fuel based hydrogen production, in industrial processes as well as in aviation, shipping and heavy trucking. Our modeling also highlights the significant interdependencies between individual solutions; for example, sustainable aviation fuels also require copious amounts of zero-carbon hydrogen for processing.

Demand-side energy efficiency, newly shown in New Energy Outlook 2024, further contributes 9% of abatement via lower electricity demand, reduced energy use in industry from more recycling, and decreased energy use in shipping, aviation and buildings.

The case of Vietnam

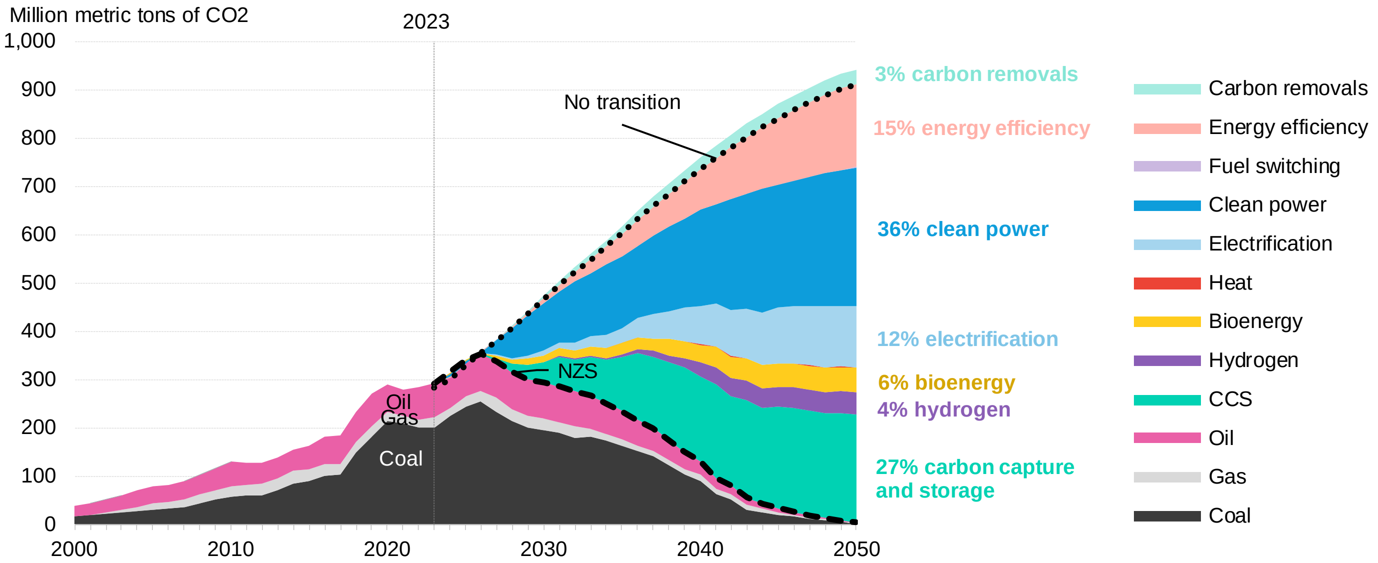
Clean power, CCS, and energy efficiency are the top three contributors to emission reduction in Vietnam. These three sets of tools account for 78% of the CO2 emissions abatement under the NZS while the remainder comes from electrification, bioenergy and hydrogen (Figure 3.4). Switching generation to clean power from fossil fuels accounts for 36% of all emissions abated until mid-century 2050. Within clean energy, solar and wind account for 17% and 16% of abatement, respectively, compared to a counterfactual 'no transition' scenario.

CCS gains in importance from the late 2030s to sequester emissions from fossil fuel plants and tackle hard-to-abate sectors, where cleaner solutions are currently either limited or prohibitively expensive. CCS is the second-largest abatement technology after clean power, accounting for 27% of Vietnam emissions abated between 2024 and 2050 under the NZS. CCS is mainly applied to capture emissions from power sector (58%), followed by heavy industries such as steel and cement (41%).

Energy efficiency contributes to 15% of the total abatement over 2024-2050, including demand-side efficiency gains in households, buildings and more recycling in industry and supply side (power sector) as well.

Electrification accounts for 12% of the total emissions abatement under the NZS, mainly in buildings, industry and hydrogen production. Replacing fossil fuels with electric alternatives will help to lower emissions in these sectors. In Vietnam's industrial sector, electrification is more prevalent in light than heavy industry. Hydrogen production will be electrified from 2030 in this scenario. The electrification rate in transport is only 5% due to the low penetration of EVs.

Figure 3.4: Vietnam's carbon dioxide emissions reductions from fuel combustion by measure – Net Zero Scenario versus 'no transition' scenario



Source: BloombergNEF. Note: The 'no transition' scenario is a hypothetical counterfactual that models no further improvement in decarbonization and energy efficiency. In power and transport, it assumes the future fuel mix does not evolve from 2023 (2027 in the shipping sector). For all other sectors, the counterfactual to the Net Zero Scenario (NZS) is the Economic Transition Scenario. 'Clean power' includes renewables and nuclear, and excludes carbon capture and storage (CCS), hydrogen and bioenergy, which are allocated to their respective categories. 'Energy efficiency' includes demand-side efficiency gains and more recycling in industry.

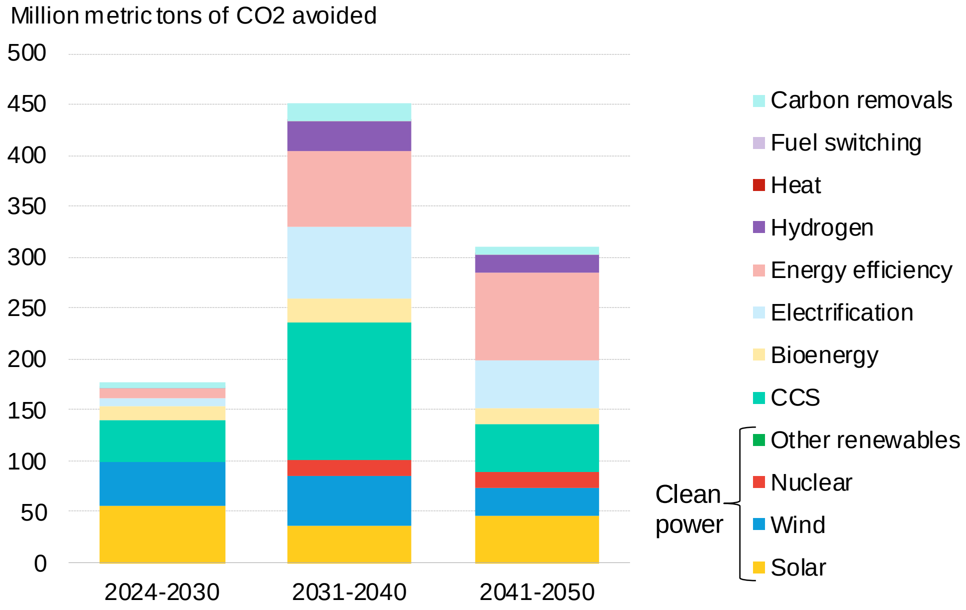
Progress in the next six years is critical

By the end of this decade, the power sector dominates Vietnam's emissions abatement. Solar and wind generation alone accounts for 57% or 99MtCO2 avoided in this decade (Figure 3.5).

CO2 emissions abatement in the next 10 years is decisive to Vietnam's net-zero pathway. Emission reduction between 2031 and 2040 needs to accelerate and more than double the total abatement from 2024 to 2030 to hit 433MtCO2. Between 2031 and 2040, CCS is the single largest contributor with 31% of the total, abating emissions from coal and gas fleet, followed by clean power (20%) and improvements in energy efficiency (17%).

The abatement momentum needs to be carried to 2050, with emission reductions from 2041 to mid-century being 303MtCO2, or 70% of the previous decade. Energy efficiency gains and clean power drive the decade's abatement, each with 29%.

Figure 3.5: Vietnam's net carbon dioxide emissions reductions by period and measure/technology – Net Zero Scenario versus 'no transition' scenario



Source: BloombergNEF. Note: Data shows the net contribution of each technology to carbon emissions abatement by time period compared to a counterfactual 'no transition' scenario in which there is no further action toward decarbonization. Time period lengths differ. CCS is carbon capture and storage. 'Other renewables' includes all other non-combustible renewable energy in electricity generation, including hydro, geothermal and solar thermal.

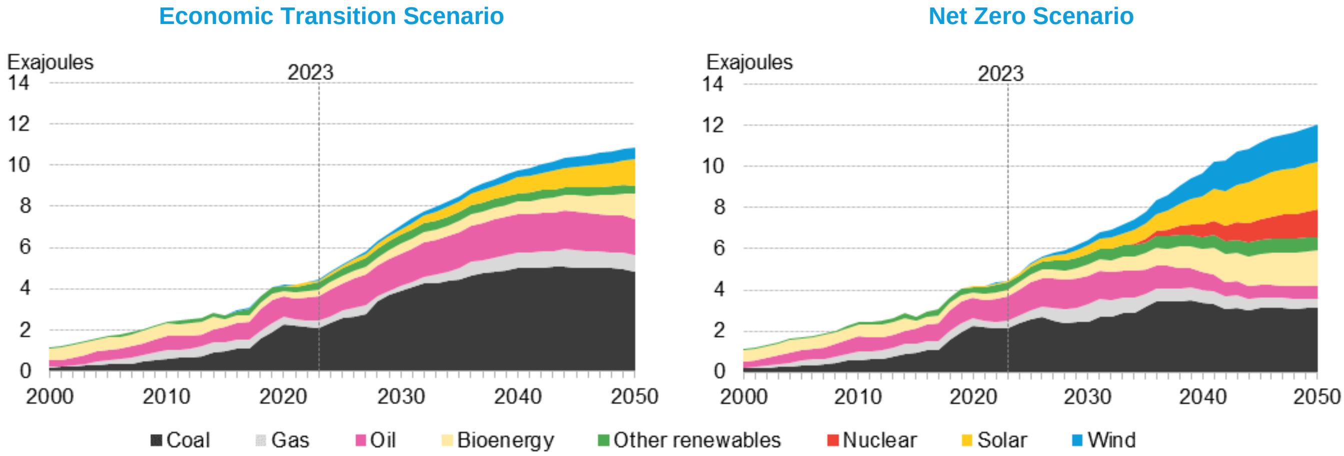
Section 4. Vietnam’s energy supply outlook

In both the Economic Transition Scenario and the Net Zero Scenario, increasingly cheaper renewable energy sources displace fossil fuels to become the dominant source of power generation. Vietnam sees coal, oil and gas peaking before 2050 in the economics-led scenario. Electricity and CCS dominates Vietnam’s final energy demand under the climate scenario due to greater electrification of end-use sectors and emission abatement for power and industry sector.

Fossil fuels persist under both scenarios

Fossil fuels make up for the majority of Vietnam’s primary energy consumption in 2023 at 83%. Under the Net Zero Scenario, while absolute consumption continues to rise, the overall share declines to 35% of primary energy in 2050. Renewables displace fossil fuels to become the dominant source of power generation under both the NZS and Economic Transition Scenario.

Figure 4.1: Vietnam's primary energy consumption, by fuel – Economic Transition Scenario and Net Zero Scenario



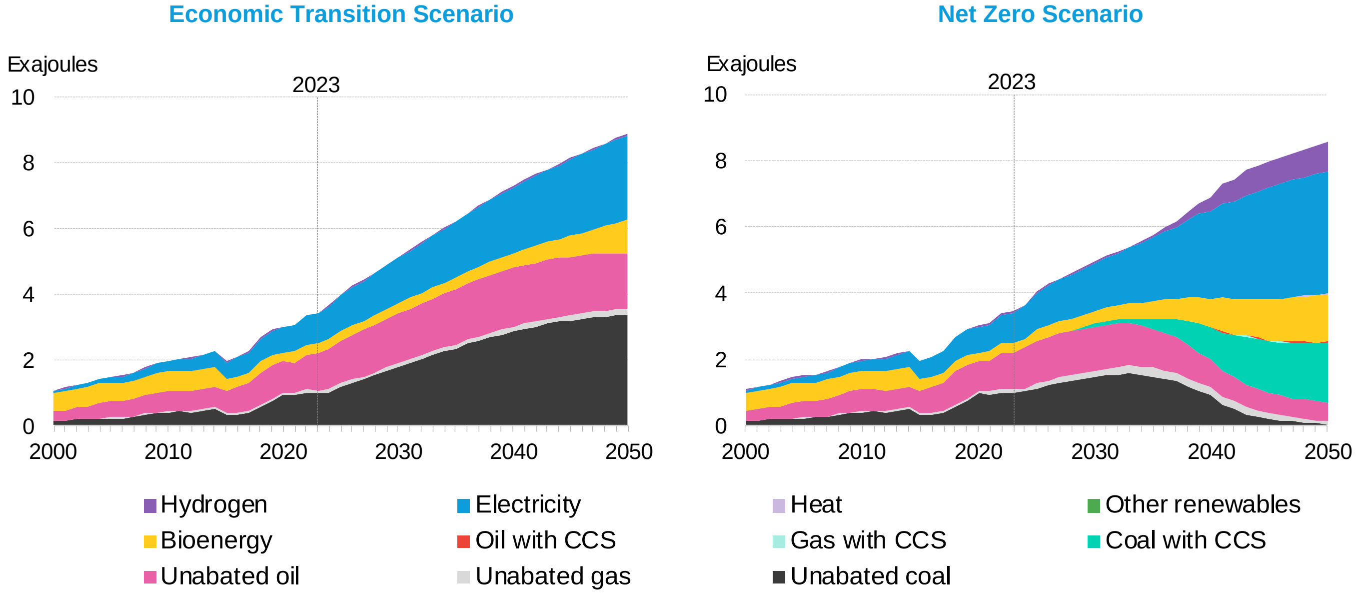
Source: BloombergNEF

Electricity and CCS dominates Vietnam’s final energy demand under NZS

Vietnam’s final energy demand in 2050 is 4% lower under the NZS compared to the ETS because of greater electrification, which lowers overall conversion losses. Under the ETS, Vietnam’s total final energy demand reaches 8.9 exajoules (EJ) in 2050, up 160% from 3.5EJ today. In the NZS, final energy demand rises to 8.6EJ, a 150% increase.

Electricity use under the NZS jumps more than threefold from 0.9EJ in 2023 to 3.7EJ in 2050, accounting for 43% of the total final energy demand (Figure 4.2). This is due to greater electrification of end-use sectors such as electric vehicles in road transport. In the net-zero pathway, Vietnam sees carbon capture and storage and clean hydrogen, which are currently not in use, play a vital role. Unabated coal is nearly eliminated by 2050 under the NZS and is replaced with coal power generation paired with CCS, which meets 21% of final energy demand.

Figure 4.2: Vietnam's final energy consumption, by fuel – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF. Note: CCS is carbon capture and storage.

Vietnam sees coal, oil and gas peaking before 2050 in the base case

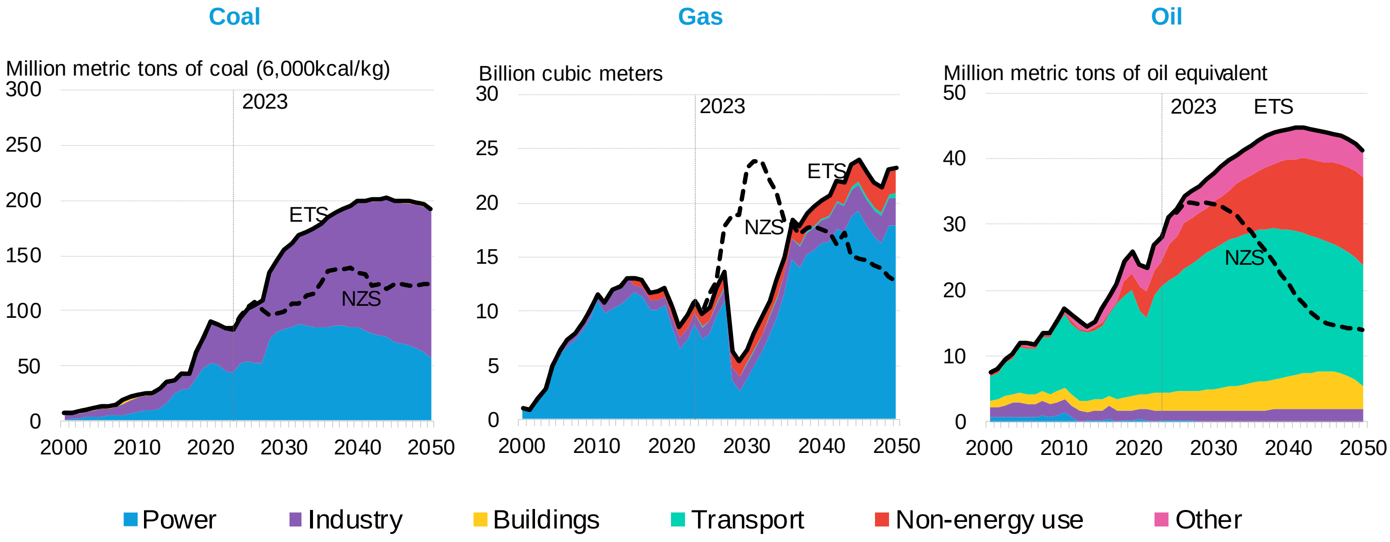
Under the ETS, Vietnam sees coal, gas and oil demand peaking in the early 2040s and falling through 2050 due to the replacement of renewables in the power sector, deployment of clean hydrogen in industry, and adoption of EVs in the transport sector.

Coal demand reaches 192 million metric tons in 2050 under the ETS while in the NZS, it is 35% lower at 124Mt. Coal consumption in the industry sector under the NZS drops more significantly than in the power sector compared to the base-case scenario. Industry consumes 46% less coal in the NZS than the ETS due to the deployment of clean hydrogen while the power sector only sees a 12% fall in coal consumption (Figure 4.3).

Under the NZS, gas demand initially increases, particularly for power generation, to displace higher-emitting coal power generation and starts to decline from 2033. By 2050, gas demand under the NZS is up 16% compared with 2023 levels. In contrast, under the base case, gas demand initially declines, as the power sector becomes more dependent on coal and solar, which are cheaper than gas plants running on imported LNG. Under the ETS, gas demand starts to grow again in 2030s due to higher electricity demand. Vietnam's cumulative gas consumption between 2024 and 2050 under the NZS is 460 billion cubic meters (bcm), 5% higher than in the ETS.

In the transport sector, a switch to EVs and low-carbon fuel causes oil use to peak in 2043 and then fall 9% to 41 million tons of oil equivalent (Mtoe) in 2050 under the ETS. Under the net-zero pathway, this peaks earlier in 2026. Oil consumption falls to just 14Mtoe in 2050, nearly halving from 2023.

Figure 4.3: Vietnam's coal, gas and oil consumption, by sector – Economic Transition Scenario versus Net Zero Scenario

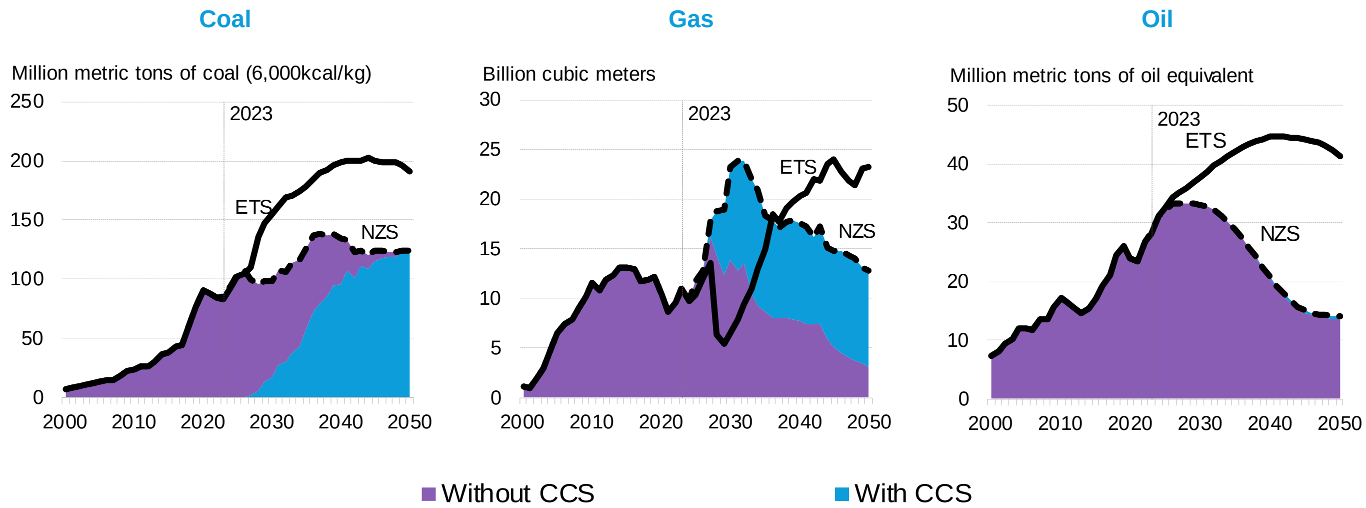


Source: BloombergNEF. Note: ETS is Economic Transition Scenario; NZS is Net Zero Scenario. Non-energy use is for non-combusted fuel consumption, mostly as feedstock in industry (petrochemicals).

CCS is critical to abating power and industry emissions

Under the NZS, coal and gas use paired with CCS starts to play a significant role from 2028 in abating emissions. By 2050, there is virtually no coal consumption without CCS. Applications that use natural gas as feedstock can continue.

Figure 4.4: Vietnam's emissions abated with carbon capture and storage, by fuel – Economic Transition Scenario versus Net Zero Scenario



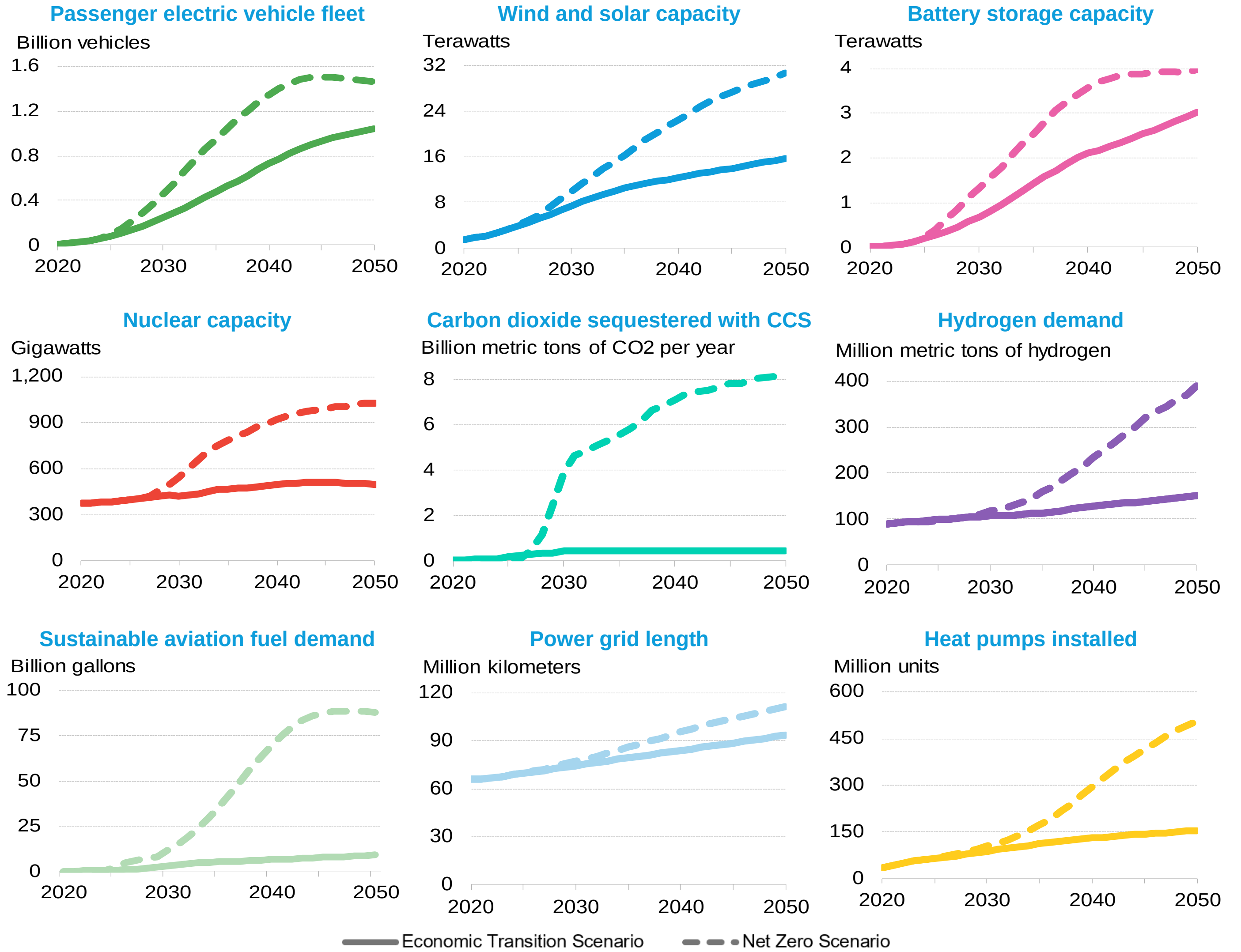
Source: BloombergNEF. Note: ETS is Economic Transition Scenario; NZS is Net Zero Scenario; CCS is carbon capture and storage.

Emissions associated with the limited amount of unabated gas power generation that remains are addressed via carbon removal. CCS does not play a role in abating emissions from oil use as the fossil fuel is mostly used in sectors that are not suitable for CCS applications, such as in residential buildings, road transport and non-energy use (Figure 4.4).

Section 5. Net-zero transition investment opportunities

Efforts to drive net-zero emissions in Vietnam by mid-century unlocks a potential $2.4 trillion investment opportunity for energy supply and demand. Under the NZS, investment in energy supply is equivalent to 5% of Vietnam's annual average GDP between 2024 and 2050 while the share of investment in energy demand is 3%. Renewables and electric vehicle sales account for the lion's share of supply and demand spending, respectively.

Figure 5.1: Selected technology drivers in BNEF's global scenario modeling



Source: BloombergNEF. Note: Wind includes offshore and onshore. Solar includes small-scale and utility-scale solar PV. Battery storage includes stationary storage. CCS is carbon capture and storage, and the Economic Transition Scenario shows the current project pipeline.

Annual electric vehicle sales under the ETS almost triple to 41 million vehicles, up from 14 million in 2023. Solar deployment more than triples, reaching 6,833 gigawatts in 2030 compared to 1,733GW today. Onshore wind annual capacity additions meanwhile double while offshore wind annual capacity additions grow from 12GW to 40GW in 2030. To help integrate these renewables on the grid, battery annual installations grow more than threefold to provide energy shifting services. The ETS also sees a continued increase in nuclear capacity, which rises by 12% globally in our base case.

However, each of these key technologies is still at a fraction of the scale that is needed in our Net Zero Scenario. Others that are needed to decarbonize hard-to-abate sectors and squeeze out the last remaining emissions are still in early stages of deployment.

Table 5.1: BNEF's investment and spending classification framework

Energy supply *The production and supply of fuels and electricity*		**Energy demand** *The consumption of fuels and electricity enabled by end users*	
Power generation capacity	Renewables, nuclear, energy storage, unabated fossil-fuel generation	**Electrified heat**	Sales of heat pumps
Power networks	Transmission and distribution of power grids, and electric vehicle charging infrastructure (both commercial and residential)[6]	**Industry**	Production and recycling facilities for aluminum, cement, petrochemicals and steel. Includes both clean plants and conventional plants
Fossil fuel processes	Upstream, midstream and downstream value chains of the oil, natural gas and coal sectors	**Road transport**	Sales of both battery-electric and plug-in hybrid and internal combustion engine cars, buses, trucks, and two- and three-wheelers
Carbon capture and storage	Abated power generation plants, and infrastructure to capture, store and transport carbon dioxide		
Hydrogen	Hydrogen-combined gas turbines, and green and blue hydrogen production, storage and transport facilities		

Legend: Green text = low-carbon; black text = fossil-fuel-based.

Source: BloombergNEF

Less than 10% of the wind and solar capacity needed by 2050 has been installed, and effectively none of the hydrogen electrolyzers, carbon capture and storage capacity, or sustainable aviation fuel infrastructure.

That said, the ramp rates needed for the four technologies that do exist today at scale – EVs, wind, solar and nuclear power – are very different. Each of these technologies see peak annual deployments considerably higher than today's levels. Annual EV sales will need to increase sixfold, from 14 million in 2023 to 90 million in 2030, in order to satisfy net-zero targets and meet

6 Commercial chargers include public, work and depot chargers. Residential chargers include home chargers.

sector carbon budgets. Solar installations will need to more than double and new wind build will need to quadruple.

Capital investment versus consumer spending

In this section of the report, the dollar figures represent either **capital investment** or **consumer spending**, in line with national accounting conventions.

The former refers to the gross investment in physical assets that yield continuous service beyond the point of purchase. These include power generation capacity, power grids, commercial EV chargers, fossil-fuel processes, carbon capture and storage, hydrogen and industrial production plants. Meanwhile, 'spending' refers to the expenditure of consumers and households (essentially the end users), reflecting the sales of heat pumps, electrified and internal combustion engine vehicles, and residential EV chargers.

Please note that both capital investment and consumer spending are described as 'investment' throughout this report, unless specified.

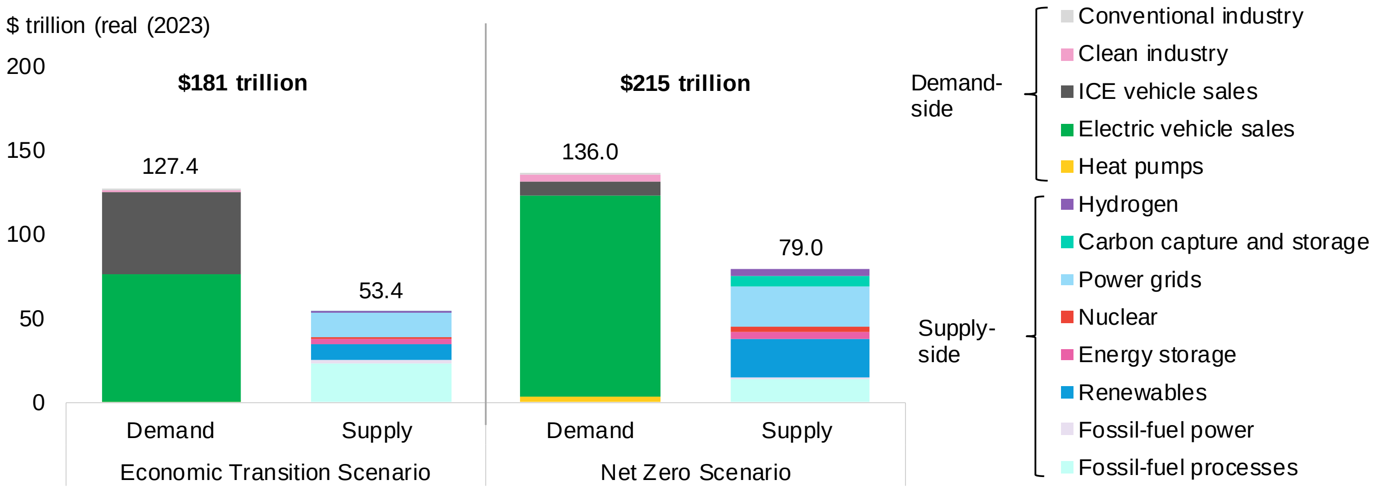
5.1. Global investment requirements

Global investment and spending are only 19% higher in the Net Zero Scenario than the Economic Transition Scenario

In the ETS, companies, financial institutions, governments and consumers invest a total of $181 trillion to 2050 on energy-related infrastructure, technology and products (Figure 5.2). This is split across $53 trillion for energy supply (both fossil fuels and low-carbon) and $127 trillion for demand-side products (almost entirely for passenger vehicles, both electric and internal combustion engine-based).

Total investment in the Net Zero Scenario is only 19% higher, at $215 trillion. This relatively small difference is because EVs are expected to reach cost-competitiveness with ICE vehicles in the coming years, meaning demand-side spending is only slightly higher than the ETS at $136 trillion.

Figure 5.2: Global energy investment and spending across 2024-2050 – Economic Transition Scenario and Net Zero Scenario



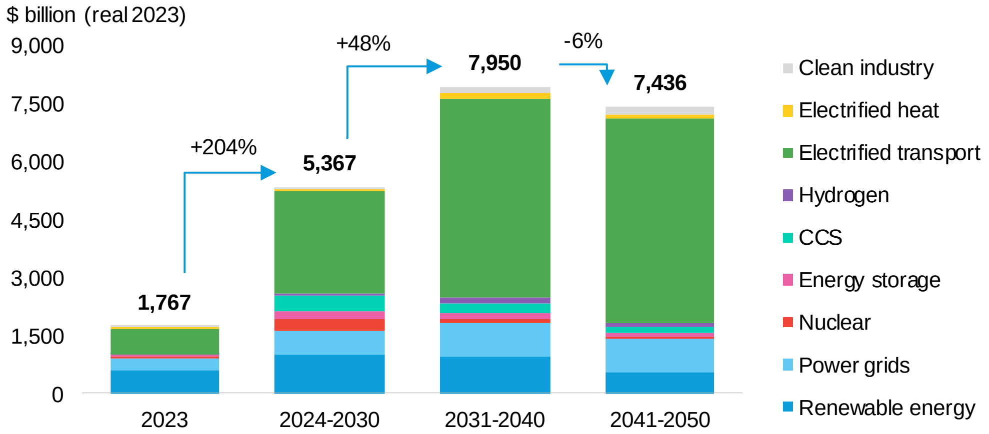
Source: BloombergNEF. Note: ICE is internal combustion engine. The numbers above the bars indicate cumulative investment and spending figures from 2024 to 2050.

But supply-side investment is significantly larger at $79 trillion. This is because clean energy technologies are more capital-intensive than traditional energy sources. That said, operating expenditure is excluded from this analysis and would likely be higher for fossil-fuel technologies.

Today, energy supply investment is spread roughly evenly across fossil fuels and low-carbon sources, at over $1 trillion apiece. Getting on track for the NZS requires a significant rise for clean energy supply and a gradual scaling down for fossil fuels. For every dollar invested in fossil-fuel supply, $4.50 must go to low-carbon energy supply by 2030. The ratio averages just under 3:1 over the rest of this decade, equating to $2.7 trillion of annual investment in clean energy supply and $0.9 trillion in the fossil-fuel side.

Our *Energy Transition Investment Trends 2024* report (web | terminal) concluded that $1.8 trillion was invested in low-carbon energy technologies in 2023. Using the same scope, the NZS requires this figure to rise to an average of $5.4 trillion per year from 2024 to 2030 – a tripling of the current pace of investment (Figure 5.3).

Figure 5.3: Global energy transition investment, actuals versus required annualized levels across 2023-2050 – Net Zero Scenario



Source: BloombergNEF. Note: Figure for 2023 shows actuals. Excludes investment in fossil-fuel processes and power and conventional energy, and spending on internal combustion engine vehicles, which are not captured in 2023 investment actuals reported in BNEF's Energy Transition Investment Trends report (web | terminal). CCS is carbon capture and storage.

The 19% difference between the investment totals in the NZS and ETS is small, and lower operating costs for clean energy could narrow the gap further. But that small gap masks large differences in investment choices, with the NZS representing a breathtaking leap in the speed of clean technology deployments. This underscores the need for stable, long-term policy signals – empowered by strong political will – to divert investment away from fossil-fuel-based pathways and toward low-carbon solutions.

5.2. Vietnam's investment requirements

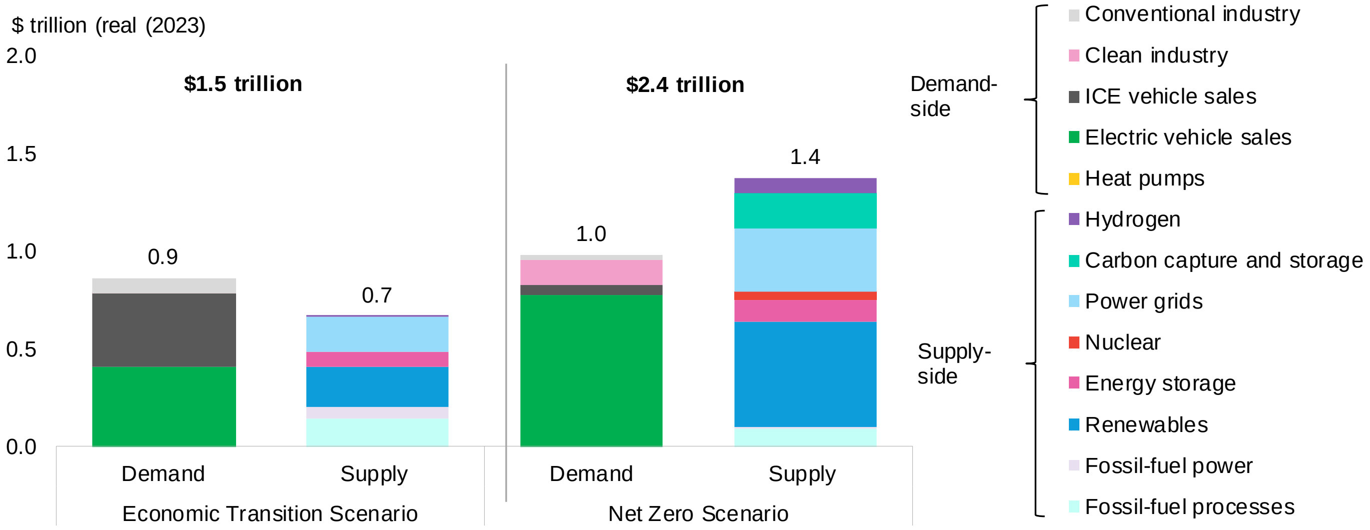
Under the ETS, investment required in energy supply and demand reaches $1.5 trillion over 2024-2050. To remain on course for net zero by 2050, investment needs to rise 54% to $2.4 trillion (Figure 5.4).

Vietnam's required investment in energy supply and demand is 54% higher in the Net Zero Scenario than the Economic Transition Scenario

Demand-side investment under the NZS of $1 trillion is just 14% higher than in the ETS. Of this, 80% goes to EV sales as they are expected to be cost-competitive with ICE vehicles in the coming years. Clean industry is the next largest recipient, with about 10% of the demand-side investment.

However, funding requirements for the supply side more than doubles under the NZS compared to the ETS as emerging clean technologies, which are more capital-intensive, must be deployed to abate emissions. Investment in renewables and power grids also needs to more than double under the NZS. Investment in CCS reaches $183 billion under the NZS, whereas it is zero under the ETS.

Figure 5.4: Vietnam's energy investment and spending across 2024-2050 – Economic Transition Scenario and Net Zero Scenario

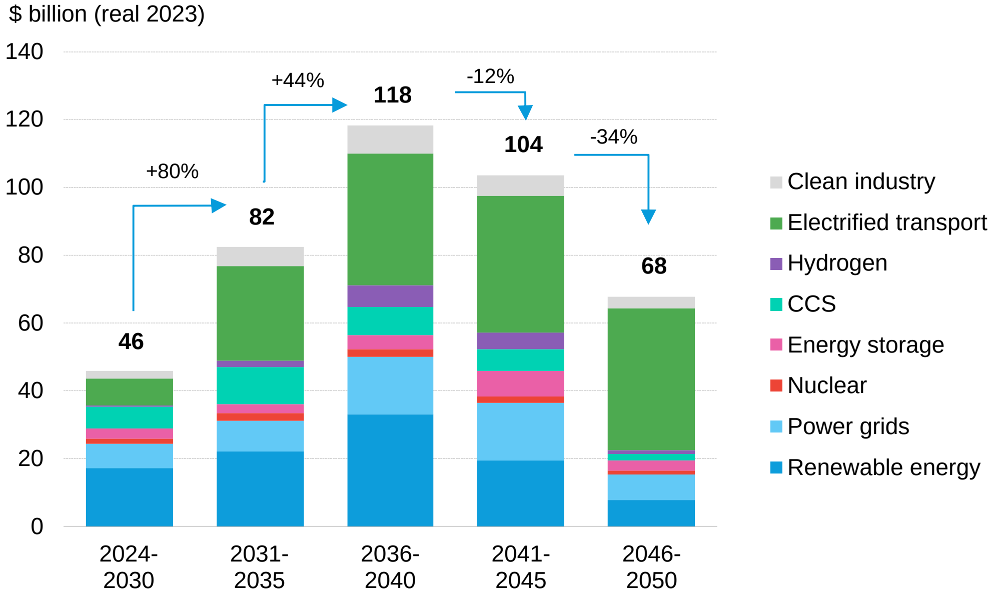


Source: BloombergNEF. Note: ICE is internal combustion engine. The numbers above the bars indicate cumulative investment and spending figures from 2024 to 2050.

Reaching net-zero emissions by mid-century requires investment in both demand and supply to increase massively for each decade out to 2050. For 2024-2030, energy transition investment averages $46 billion a year. This figure nearly doubles in the next decade at an average of $100 billion annually. The last decade before 2050 sees a decrease in investment, particularly in renewable energy as it had rapidly ramped up from 2031 to 2040 (Figure 5.5).

In terms of sectoral spending, only EVs and energy storage continuing to climb every year from 2024 to 2050. Annual investment in EVs and energy storage rises to $41 billion and $5 billion, respectively, from 2041-2050, from $8 billion and $3 billion a year in the remainder of this decade.

Figure 5.5: Vietnam's energy transition investment, required annualized levels across 2024-2050 – Net Zero Scenario



Source: BloombergNEF. Note: Excludes investment in fossil-fuel processes and power and conventional energy, and spending on internal combustion engine vehicles, which are not captured in 2023 investment actuals reported in BNEF's Energy Transition Investment Trends report (web | terminal). CCS is carbon capture and storage.

Vietnam's supply-side investment

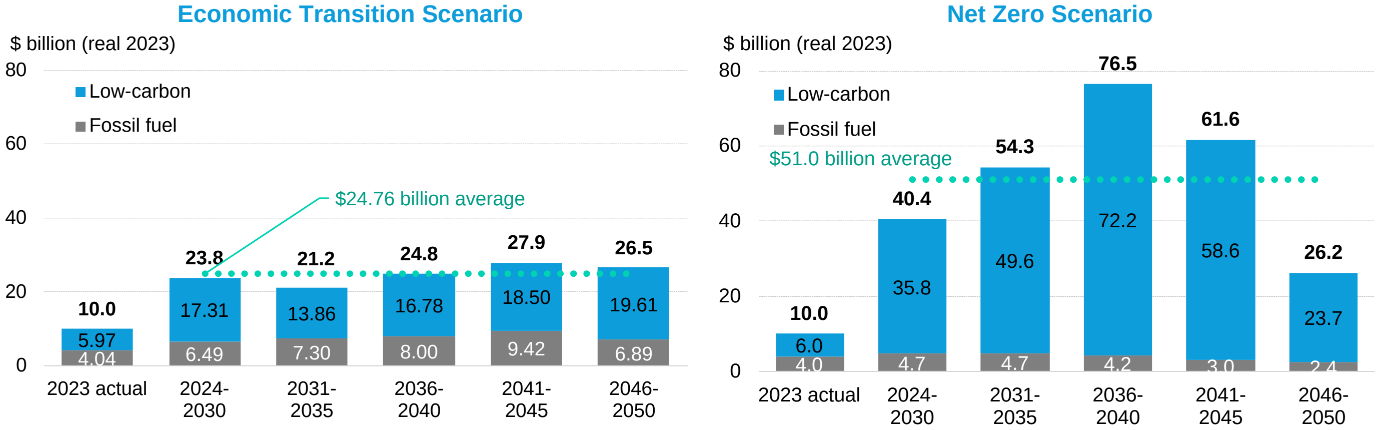
The net-zero emissions pathway for Vietnam requires a total of $1.4 trillion in supply-side investment from 2024 to mid-century. This amount is more than double that under the ETS at $668 billion. Under the NZS, investment in fossil fuels remains more or less the same as in 2023, at an annual average of $4 billion the rest of this decade and the next, before falling to $2.7 billion a year in the last decade to 2050 (Figure 5.6).

Meanwhile, Vietnam's supply-side investment needs to surge to $36 billion per year for the rest of this decade under the NZS. As the next decade is decisive to Vietnam's emissions abatement, low-carbon investment needs to rise even more, averaging $61 billion a year the next decade. Between 2041 and 2050, this figure will decline to $41 billion annually.

In the ETS, although there is no carbon budget to force decarbonization on the supply side, investment in low-carbon options consistently exceeds that in fossil fuels from 2024 to 2050. This is largely because clean power options such as solar and wind are already cost-competitive with fossil fuels. However, annual low-carbon investment in the ETS between 2024 and 2050 is only around 36% of that under the NZS.

Also, in the ETS, investment in fossil fuels will continue to climb gradually until 2050 compared to $4 billion in 2023 to reach $8.2 billion a year in 2041-2050 due to the increasing fossil-fuel power capacity and energy demand from industry.

Figure 5.6: Vietnam's annualized investment in energy supply – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF, International Energy Agency. Note: Numbers show annualized investment over respective time period. IEA data has been used to estimate historical fossil-fuel supply investment.

Energy system investment as a share of Vietnam's economy

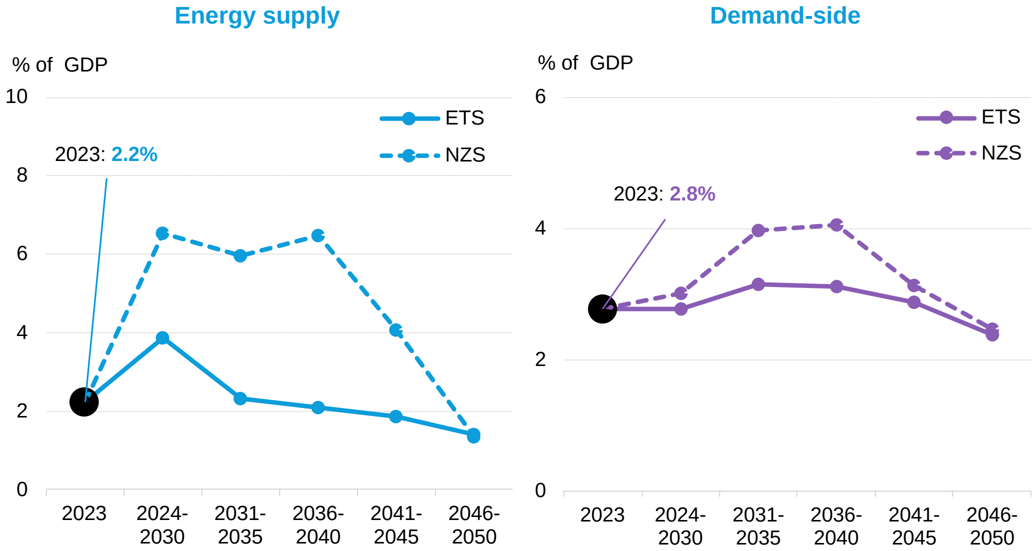
In general, the share of supply- and demand-side energy investment and spending accounts for a greater share of national gross domestic product in the climate scenario than the ETS throughout 2024 to 2050.

Investment in energy supply is equivalent to an average 5% of Vietnam's GDP between 2024 and 2050 under the NZS. Each decade's figure varies significantly. To reach net-zero emissions, this investment needs to account for 6.5% and 6.3% of national GDP for the rest of this decade and the next, respectively, nearly tripling from 2.2% in 2023. The larger share indicates that supply-side investment needs to accelerate in the next two decades to decarbonize the power sector. This percentage will dip to 2.6% from 2041 to 2050 (Figure 5.7).

Under the ETS, overall capital expenditure averages 2.5% of national GDP between 2024 and 2050, half of the share in energy supply investment under the NZS.

The difference between the share of demand-side investment as a percentage of Vietnam's GDP between 2024 and 2050 under both scenarios is significantly smaller than that for energy supply. On average, demand-side investment during this period accounts for 2.8% and 3.3% of national GDP under the ETS and NZS, respectively. This share rises to 4% for the next decade under the latter scenario as EVs start to replace ICE vehicles.

Figure 5.7: Energy investment and spending as a share of Vietnam's gross domestic product across 2020-2050 – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF, International Monetary Fund, Organisation for Economic Co-operation and Development. Note: ETS is Economic Transition Scenario; NZS is Net Zero Scenario. GDP forecast based on BNEF estimates using IMF and OECD inputs. The scope for both energy supply- and demand-side includes both investment and spending. Historical values do not account for capital investment for conventional industry.

5.3. Power

Power generation takes the lion's share of Vietnam's supply-side spend

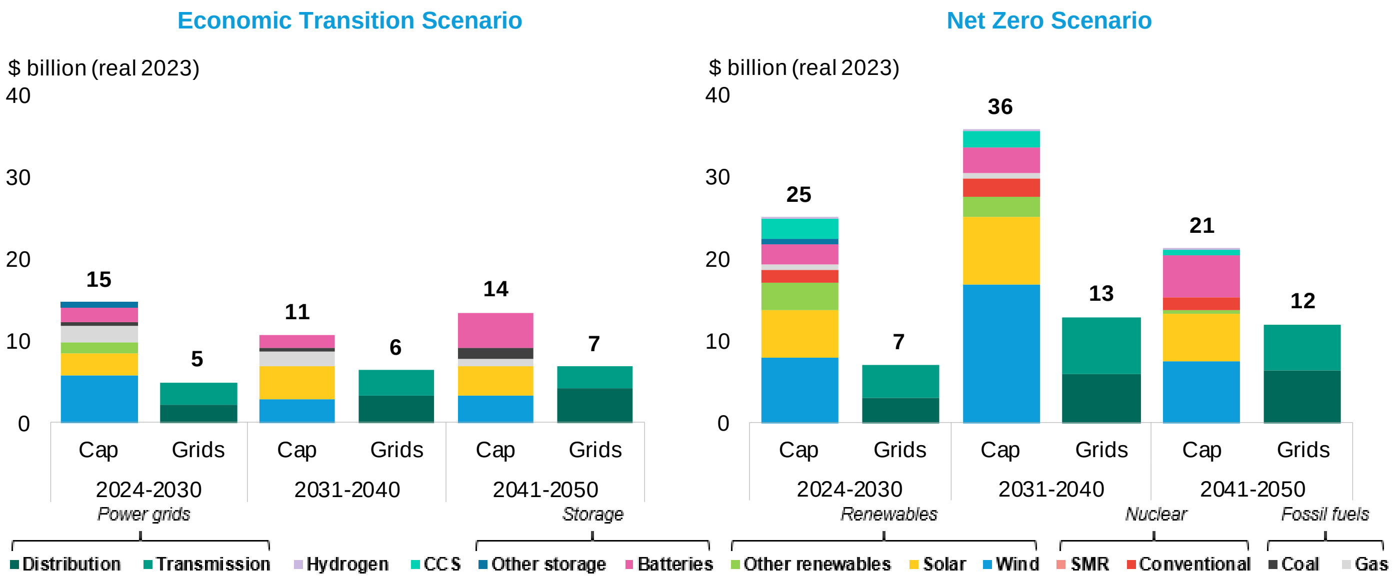
The power generation fleet presents the greatest investment opportunity for Vietnam under the NZS in efforts to decarbonize the economy's largest-emitting sector. Under this scenario, annual investment in expanding power capacity averages $25 billion and $36 billion for 2024-2030 and the next decade, respectively. Investment will then decline to $21 billion a year on average in 2041-2050 (Figure 5.8).

In terms of power generating technologies, most of the investment the rest of this decade and the next is in solar and wind, with 55% and 70%, respectively. Batteries and CCS make up much of the remainder to address the intermittency of renewables and abate emissions from coal and gas power plants.

In the ETS, the better economics of clean power technologies also drives significant investment in solar and wind capacity, irrespective of the net-zero target. Investment in these two technologies averages $4 billion annually between 2024 and 2050. The increasing penetration of solar and wind in the power system inevitably requires investment in battery storage to provide stability for the grid. Battery storage investment accounts for 11% of the total investment in power capacity annually for the rest of this decade and reaches 33% per year between 2041 and 2050.

In the ETS, investment in fossil fuel capacity continues, with an annual average of 11% of the total investment in power capacity between now and mid-century.

Figure 5.8: Annualized investment in Vietnam's power capacity and grids – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF, International Energy Agency. Note: 'Cap' stands for capacity; 'Grids' refer to power grids, specifically transmission and distribution; SMR refers to small modular nuclear reactors. The 'other renewables' category comprises biomass, hydro and geothermal. Fossil-fuel power generation comprises coal and oil generation, alongside both combined and open cycle gas turbines.

Comparing BNEF's scenarios with Vietnam's Power Development Plan VIII

The Vietnamese government approved the Power Development Plan (PDP) VIII in May 2023. The PDP VIII includes a detailed plan for the next 10 years, and a high-level plan for 2050. Table 5-2 and Figure 5.9 compare BNEF's ETS and NZS results with the PDP VIII.

Solar, wind and battery energy storage capacity have the biggest differences between BNEF NZS by 2050 and PDP VIII

BNEF's economics-led scenario sees the installed capacity of solar being 25GW and 96GW higher than the PDP VIII by 2030 and 2050, respectively. To achieve net zero by 2050, solar capacity needs to grow much more. The current gap in solar capacity between BNEF's NZS and Vietnam's PDP VIII by 2050 is 333GW. Additionally, Vietnam has considerable potential to expand battery energy storage, with a gap of 90GW between the PDP VIII and the NZS by 2050 (Table 5-2).

While Vietnam aims for offshore wind to assume a significant role by 2050 in the current power plant at 81GW, the NZS sees a much more limited role for it with just 36GW. The gap for offshore wind capacity between PDP VIII and the ETS is even larger at 69GW. This is because offshore wind will remain more expensive than other renewable energy technologies, such as solar and onshore wind.

Table 5-2: Significant capacity differences in BNEF scenarios compared to the Power Development Plan (PDP) VIII, by technology

Technology	BNEF ETS 2030 (GW)	BNEF NZS 2030 (GW)	BNEF ETS 2050 (GW)	BNEF NZS 2050 (GW)
Coal with CCS	Not considered in PDP VIII			
Coal using biomass and ammonia	Not considered in BNEF scenarios			
CCGT	-24	-33	16	-4
CCGT with CCS	Not considered in PDP VIII			
Gas peaker	3	7	-8	-24
Hydrogen	0	3	-26	-20
Nuclear	Not considered in PDP VIII			
Utility-scale PV	16	62	65	302
Small-scale PV	9	9	31	31
Onshore wind	-8	-2	-24	66
Offshore wind	-0.5	0.4	-69	-45
Battery storage	11	17	54	90

Source: BloombergNEF. Note: ETS is Economic Transition Scenario; NZS is Net Zero Scenario; CCS is carbon capture and storage; CCGT is combined-cycle gas turbine. The darker the color, the greater the difference in capacity in BNEF scenarios compared to the PDP VIII Gray indicate there is no difference between BNEF scenarios and PDP VIII.

CCS and nuclear are needed to help Vietnam reach net zero by 2050

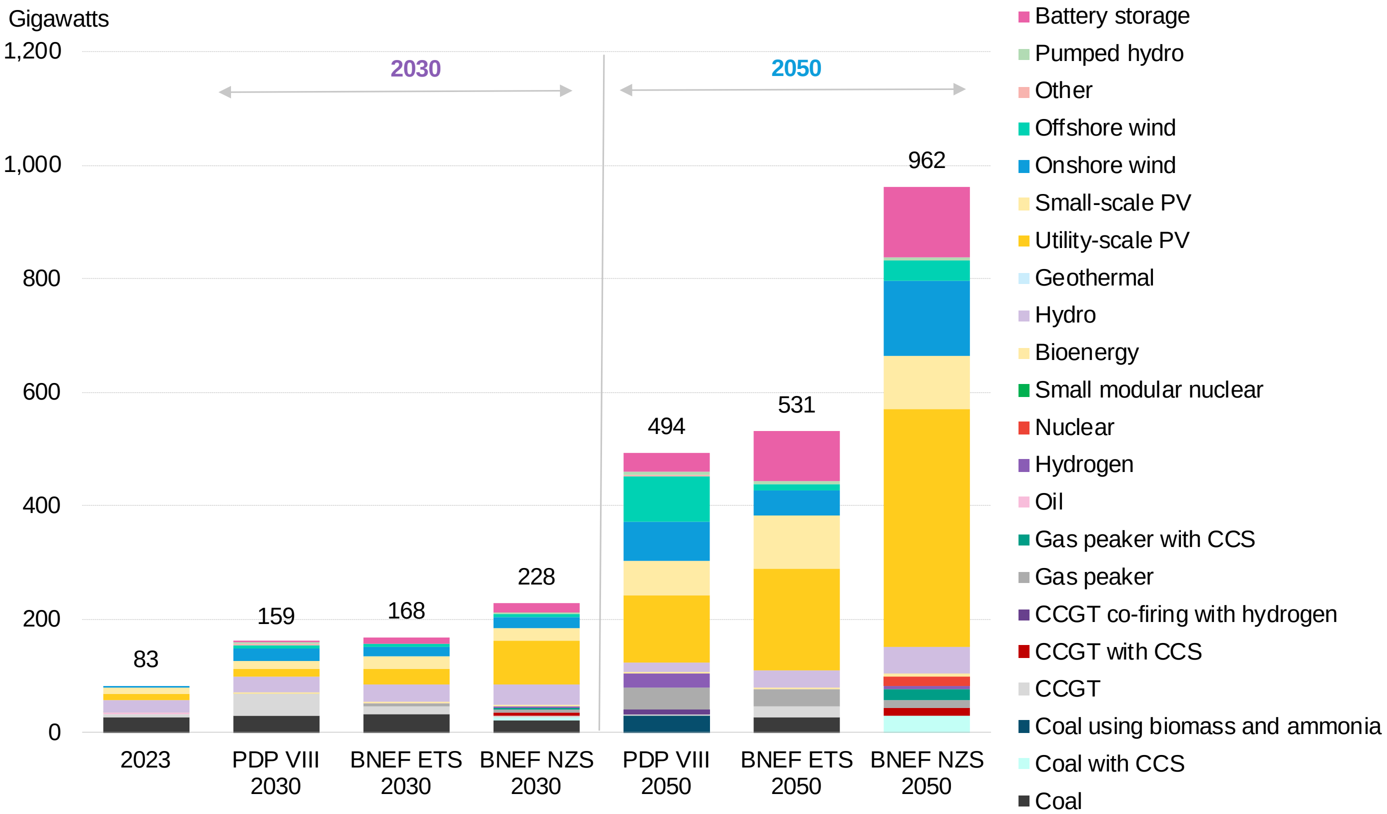
To abate emissions from thermal power plants by 2050, PDP VIII is considering replacing fossil fuels with clean ammonia and hydrogen. It does not take into account the use of CCS or nuclear unlike BNEF's NZS, which sees those technologies as more economic options to achieve the required emissions abatement. Under the NZS, thermal power plants equipped with CCS make up 43GW or 4% of the total capacity in 2050. The NZS also expects 16.5GW of nuclear capacity by mid-century.

PDP VIII expects 26GW of power plants running on hydrogen by 2050, accounting for 5% of total capacity. BNEF's NZS, however, expects only 6GW of hydrogen-fueled power plants by 2050 due to the relatively high cost of using clean hydrogen for power generation.

Both PDP VIII and NZS see solar and wind dominating the 2050 total installed capacity, which doubles under NZS compared to PDP VIII

In the PDP VIII, Vietnam aims for solar and wind capacity to account for 67% of the total installed capacity by 2050. A similar trend is also seen in BNEF's NZS, where these two technologies account for the majority of Vietnam's capacity with 71% by 2050. However, to meet the net zero goal by mid-century, the total installed capacity under the NZS needs to reach 962GW, doubling the 2050 planned capacity in the PDP VIII (Figure 5.9). This increase in power capacity is primarily driven by rising electricity demand in the industry, transport, and hydrogen sectors.

Figure 5.9: Comparison of projected installed capacity in Vietnam's Power Development Plan (PDP) VIII and Economic Transition Scenario (ETS) and Net Zero Scenario (NZS) by 2030 and 2050



Source: Power Development Plan VIII. BloombergNEF. Note: CCS is carbon capture and storage. CCGT is combined-cycle gas turbines. PV is solar photovoltaic. PDP VIII installed capacity by 2050 is the average of the low and high range. As PDP VIII only provides the total planned capacity by 2050 for solar and energy storage, ratios between small- and utility-scale solar and between pumped hydro and battery energy storage are assumed.

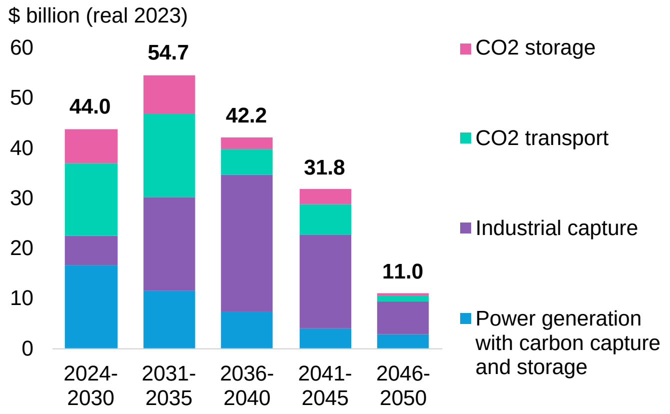
5.4. CCS and hydrogen

Vietnam's net zero requires $258 billion for CCS and hydrogen

In the NZS, CCS and hydrogen are crucial for Vietnam to decarbonize power and hard-to-abate sectors. While CCS is an important abatement technology in industrial sectors, most emissions in absolute terms are captured in the power sector (58%). This is followed by 41% of emissions from heavy industry, 20% from steel manufacturing and 17% from cement production.

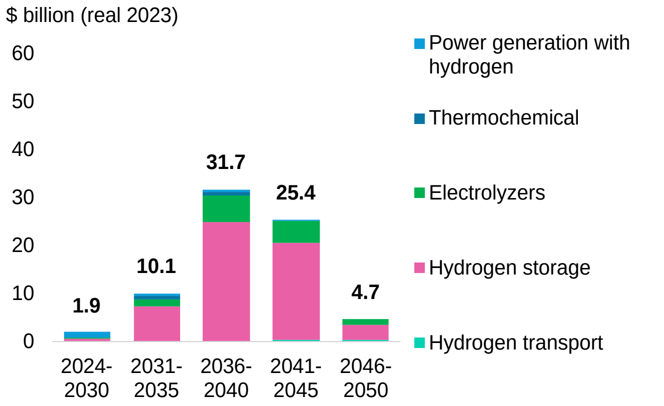
Investment in CCS required for Vietnam under the net-zero path totals $183.8 billion (Figure 5.10). Paring thermal power plants with CCS receives more investment than in industry's use of the technology this decade. However, from next decade onwards, industry's investment in CCS is always higher than the power sector's due to the former's limited options to decarbonize. Around 42% or $78 billion of the total investment in CCS goes to fitting heavy industry plants with CCS. Investment in fossil fuel-fired power plants paired with CCS accounts for $42 billion (23%). The remaining $64 billion goes to CCS infrastructure to transport and store CO2 emissions.

Figure 5.10: Vietnam's cumulative investment in carbon capture and storage across 2024-2050, Net Zero Scenario



Source: BloombergNEF. Note: 'Power generation with carbon capture and storage' refers to both generating assets and the capture components; 'transport' refers to pipelines; 'storage' refers to facilities to sequester the CO2; 'industrial capture' refers to individual capture systems for use within industry.

Figure 5.11: Vietnam's cumulative investment in hydrogen across 2024-2050, Net Zero Scenario



Source: BloombergNEF. Note: 'Power generation with hydrogen' refers to hydrogen-fired power generation; 'thermochemical' refers to hydrogen production facilities equipped with carbon capture and storage; 'transport' refers to pipeline infrastructure.

Hydrogen helps Vietnam decarbonize steel production and transport but remains a niche use case elsewhere. Under the NZS, iron and steel production are the single-largest user of hydrogen by mid-century, accounting for 74% of total demand. This is followed by the transport sector (22%), particularly road and aviation.

Hydrogen investment under the NZS for Vietnam is less than half of investment in CCS at $73.7 billion by 2050. Most goes to hydrogen storage with $56 billion, followed by $13 billion for electrolyzer production (Figure 5.11). Our modeling suggests a very limited role of hydrogen in power generation due to the availability of other cheaper decarbonization options such as wind and solar.

Similar to the global picture, in the ETS, Vietnam only sees $2.5 billion investment in hydrogen and no investment in CCS given the absence of a net-zero target. Hydrogen application under the ETS is mostly limited to iron and steel production.

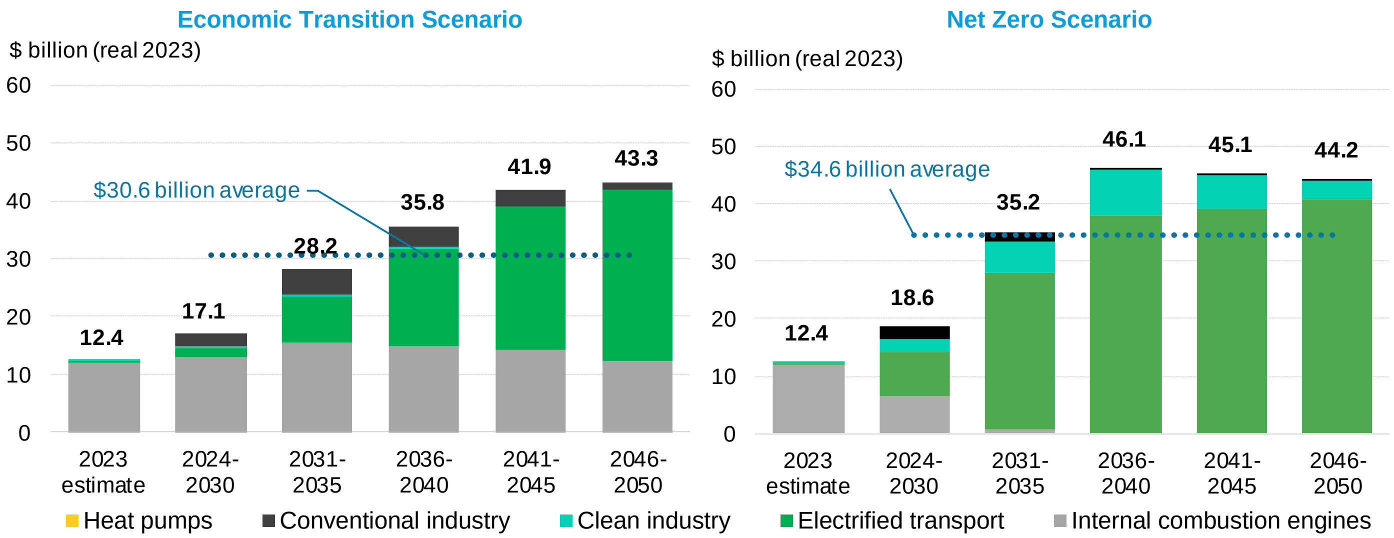
5.5. Demand-side investment

EVs dominate investment and spending in Vietnam from 2031 onwards under the NZS

A carbon budget under the NZS will force decarbonization not only in supply side but also in demand side. There will be a great shift from traditional vehicles to EV among consumers and from conventional industry to clean industry among businesses. Under the NZS, investment in demand side totals $983 billion between now and 2050, with EV sales accounting for 80% of the total investment. Annual investment during this period averages $34.6 billion. To reach net-zero emissions, investment in ICE needs to quickly decline from $6.6 billion per year for the rest of this decade to only $0.4 billion annually on average in the next decade. The second largest sector for demand-side Investment is clean industry, totaling $131 billion between 2024 and 2050.

In the ETS, annual investment in demand side between now and 2050 is just 13% lower than that under the NZS on average. The total investment during this period is $866 billion. However, total investment in ICE and unabated industry remains dominant in the total investment for the remaining of this decade and next decade with 90% and 60%, respectively. Only in the last decade before the mid-century, investment in EV and clean industry starts to account for most of the decade's investment at 63%. EV dominates the investment as it becomes cost-competitive with conventional vehicles.

Figure 5.12: Vietnam's annualized demand-side investment, by scenario



Source: BloombergNEF. Note: Numbers show annualized investment over respective time period. Estimate for 2023 based on data from BNEF's Energy Transition Investment Trends (web I terminal). Does not include historical investment for conventional industry, which is likely a minor portion of overall demand-side investment and spending.

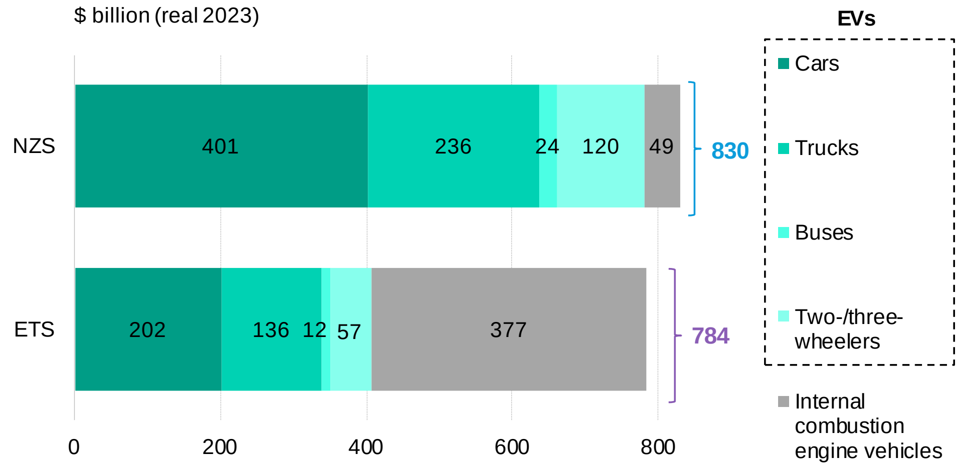
5.6. Transport

Road vehicles are the dominant driver of Vietnam's demand-side spending

The government set a goal of 100% road transport using electricity or green energy by 2050 in the National Action Plan, which was approved in 2022, to reduce emissions in the transport sector. As transport is the third-largest contributor to Vietnam's total emissions in 2023, decarbonizing it is crucial to achieving net zero.

Our modeling for a net-zero pathway shows that by 2050, EVs dominate total investments for road transport with 94%. More than half of the investment in EVs goes toward passenger cars, followed by trucks. Investment in two-wheeler EVs totals $120 billion by 2050 due to the popularity of this segment in the country (Figure 5.13).

Figure 5.13: Vietnam's cumulative road transport spending opportunity, by type and scenario



Source: BloombergNEF. Note: ETS is Economic Transition Scenario; NZS is Net Zero Scenario.

Total investment in road transport under the ETS is just 6% lower than the NZS. However, the distribution differs significantly. Although EVs account for more than half of the total in the ETS, ICE vehicles retain a significant role with 48%. In the NZS, ICE investment only accounts for 6% of road transport spending.

5.7. Industry

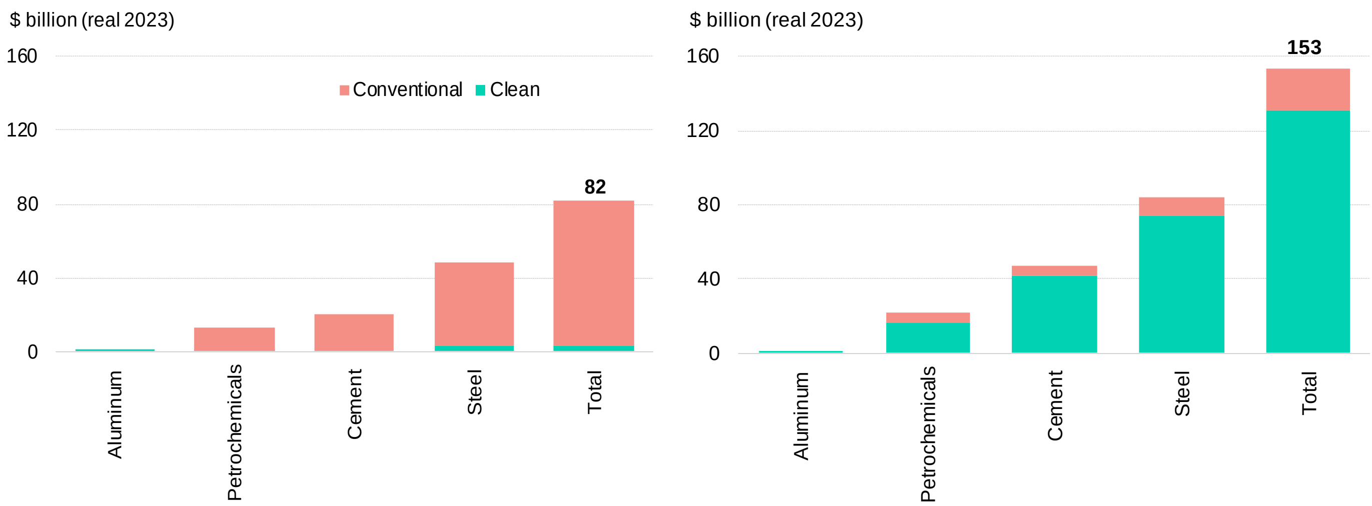
Steel production dominates Vietnam's industry investment

Continued economic growth will underpin investment in industrial clusters and production facilities to satisfy rising demand for materials and metals in Vietnam. By 2050, cumulative investment in the country's new production and recycling plants for aluminum, cement, petrochemicals and steel reaches $82 billion in the ETS, and nearly twice as high at $153 billion in the NZS. This is due to the need to deploy capital-intensive technologies such as CCS and expensive fuels as hydrogen to decarbonize heavy industry.

The steel sector accounts for the largest investment in industry in Vietnam with 59% and 55% under the ETS and NZS, respectively, due to increasing steel manufacturing in the coming years. This is followed by investment in cement and petrochemicals in both scenarios. However, the investment ratio for clean and conventional industries in each scenario diverges significantly.

In the NZS, the investment required to decarbonize industry totals $153 billion from 2024 to 2050. Investment in clean industry dominates the total with $131 billion, while conventional industry, which is powered by fossil fuels, receives only $22 billion. In contrast, the economics-driven pathway sees conventional industry nearly monopolize investments with 96% compared to just 4% for clean industry (Figure 5.14).

Figure 5.14: Vietnam's industry investment across 2024-2050, by scenario

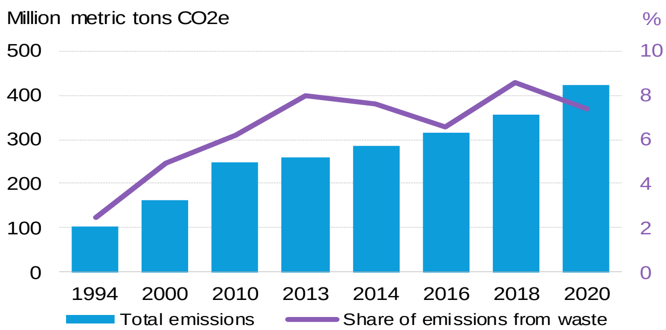


Source: BloombergNEF. Note: Includes investment in new production facilities and recycling plants. Conventional plants include refineries and smelters powered by fossil fuel-based power, blast oxygen furnaces and unabated electric arc furnaces. Clean industry includes facilities that reduce overall operational emissions by 90% or more, excluding unit costs of hydrogen production and carbon capture and storage.

5.8. Waste

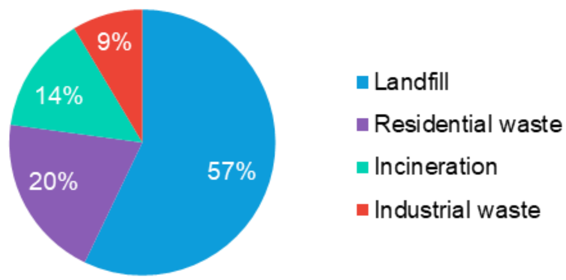
Vietnam's greenhouse gas emissions come from four sectors, namely energy, industrial process, agriculture, forestry and land use and waste. In 2020, waste was the lowest-emitting sector, with emissions amounting to 35MtCO2e or 7% of Vietnam's total greenhouse gas emissions[7] (Figure 5.15). The share of emissions from energy, industrial process and agriculture, forestry and land use were 68%, 13% and 10%, respectively.

Figure 5.15: Share of emissions from waste in Vietnam's total greenhouse gas emissions



Source: Ministry of Natural Resources and Environment (MONRE), BloombergNEF.

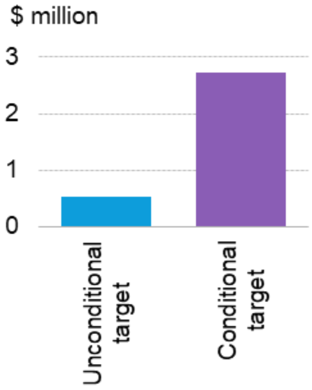
Figure 5.16: Share of emissions from Vietnam's waste sector, by sub-sector in 2020



Source: MONRE, BloombergNEF. Note: Chart shows BNEF estimates based on data from MONRE.

[7] According to a draft report on 2018 and 2020 emissions by MONRE.

Figure 5.17: Additional investment in the waste sector from 2021-2030 to achieve Vietnam's Nationally Determined Contribution targets



Source: Ministry of Natural Resources and Environment, BloombergNEF.

In the NDC updated in 2022, Vietnam projected emissions from the waste sector to reach 46MtCO2e under the business-as-usual (BAU) scenario. To achieve Vietnam's net-zero goal, the government also set out emission reduction targets for the waste sector by 2030 at 17% by national resources and 63% with international resources compared to the BAU scenario. According to the Ministry of Natural Resources and Environment (MONRE), an additional investment of nearly $3 million this decade is required to meet the conditional target for the waste sector of a 63% reduction by 2030 compared to the BAU scenario (Figure 5.17).

Emissions from the waste sector is reported to come from four sub-sectors in 2020, including landfill (57%), residential waste (20%), incineration (14%) and industrial waste (9%) (Figure 5.16). The MONRE has laid out measurements for the National Action Plan to reduce emissions in the waste sector to achieve targets in the updated NDC.

Table 3: Proposed measures to reduce emission in waste sector in Vietnam

Emission reduction measures	2030 target with national resources	2030 targets with international resources
Reduce and classify residential solid waste per capita	10%	10%
Recycle solid waste	35%	100%
Produce compost from degradable solid waste	32%	70%
Generate electricity from waste	9%	60%
Dispose solid waste in sanitary landfills and capture gas from landfills for power generation	30%	70%
Processing food waste via anaerobic digestion and use gas for power generation		30%
Produce refuse-derived fuel (RDF) pellets from combustible waste		40%
Optimal treatment of residential wastewater		40%
Residential wastewater treatment with methane captured		40%
Optimal treatment of industrial wastewater		30%
Industrial wastewater treatment with methane captured		40%

Source: Ministry of Natural Resources and Environment (MONRE), BloombergNEF.

Section 6. Agriculture and land use

The tools and technologies developed to reach net zero require vast amounts of land and bioresources, which are in limited supply. These technologies often compete directly with efforts to preserve nature and the resources needed to feed a growing global population. Energy transition pathways will be determined by these land, biological and cost constraints. In some cases, the pathways will narrow as land limitations bite.

Across most decarbonizing sectors, net-zero solutions have a greater land footprint than the fossil-fuel technologies they displace. BNEF finds there is ample suitable land when considering each segment in isolation, but competition for land is rising quickly.

Clean power

Wind and solar farms are much more land-intensive than fossil-fuel plants. Decarbonization of the power system could require millions of square kilometers of land dotted with wind turbines and covered in solar arrays. Together they could cover anywhere from 0.2% to 23% of the total landmass of major economies by 2050 and must therefore be deployed alongside agricultural activities in a way that preserves food security.

Our modeling shows that a lack of suitable land could become acute, particularly in densely populated markets that are forested and mountainous, such as South Korea, Japan and Indonesia.

Regional land requirements

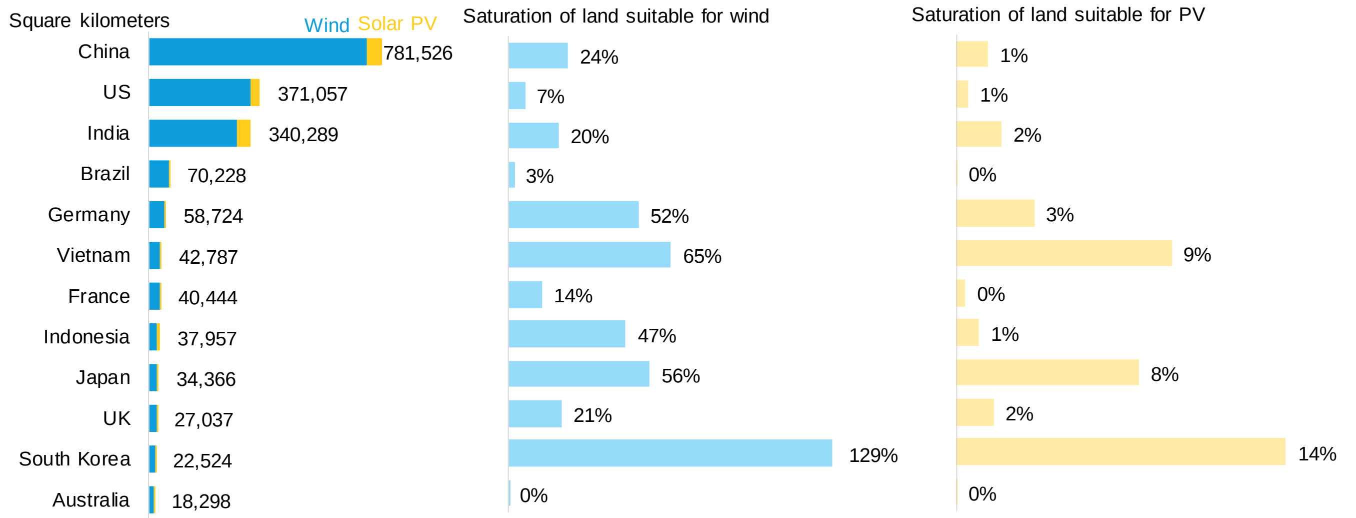
The land demands of solar and onshore wind are unequally distributed across the world, as population and power demand are poorly correlated with a jurisdiction's landmass. As a result, land shortages may constrain clean energy build in small, populous markets while it remains plentiful in more expansive regions. We find the power sector can reach net-zero emissions without clean energy projects affecting food security or other land uses in most places, so long as renewable subsidies do not encourage landholders to produce power instead of food.

Our modeling indicates that, theoretically, most markets have enough suitable land for renewables deployment under the ETS. But there could be pinch points in the NZS. A small number of islanded and densely populated nations are unlikely to fully exploit their wind and solar resources without affecting food production or driving deforestation.

Our geospatial analysis shows that land supply is tightest in South Korea, where NZS wind installations could require 29% more land than is deemed suitable. South Korea, Vietnam and Japan are also the most land-constrained countries for solar deployment out of the markets discussed. For Vietnam, the land required to installed wind and solar capacity to achieve net zero account for 65% and 9% of the total land deemed potentially appropriate for these two technologies, respectively (Figure 6.1).

Where the suitable land for deployment is exhausted, these countries may need to find ways to increase energy yields per hectare through technological innovation, or strategically invest in alternative technologies that are more expensive today but less land-intensive in the future, such as offshore wind, geothermal or nuclear.

Figure 6.1: Regional land demand of peak renewables and saturation levels – Net Zero Scenario



Source: BloombergNEF. Note: Wind is onshore wind. PV is photovoltaic. Saturation is the land required (demand) as a proportion of the land that has been identified as suitable (supply), for the respective technology. Suitable land constraints account for land characteristics and resource availability, but not for proximity to existing grids, infrastructure or local labor availability.

Biofuels and bioplastics

Demand for biofuels for road transport and aviation drives significant demand for arable land in the coming decades. Their role will be questioned if land-use pressures undermine food security or lead to increased deforestation.

To alleviate these concerns, biofuel and bioplastic producers need to utilize waste feedstock wherever available, promote agronomic efficiencies through plant science, double cropping and cover cropping[8], and rapidly electrify road transport in order to free up feedstock for harder-to-abate segments such as aviation.

Projected land requirements

Biofuels and bioplastics demand peaks at 4.8 million square kilometers of cropland in 2044 under the NZS, an area 20% larger than the EU. To achieve this, an area of farmland the size of Washington state in the US needs to be diverted into feedstock production each year between 2023 and 2044.

The land footprint then declines to 2050 as demand for e-fuels increases and eases land pressure from biofuel feedstocks. In contrast, the land needed for road biofuels and bioplastic feedstocks declines under the ETS, from 916,000km^2 in 2023 to 736,000km^2 in 2050. In doing so, a cultivated area larger than Florida is made available for other purposes.

[8] Double cropping refers to harvesting two crops in a calendar year. Cover cropping is planting to cover the soil rather than for the purpose of being harvested.

Global land demand drivers

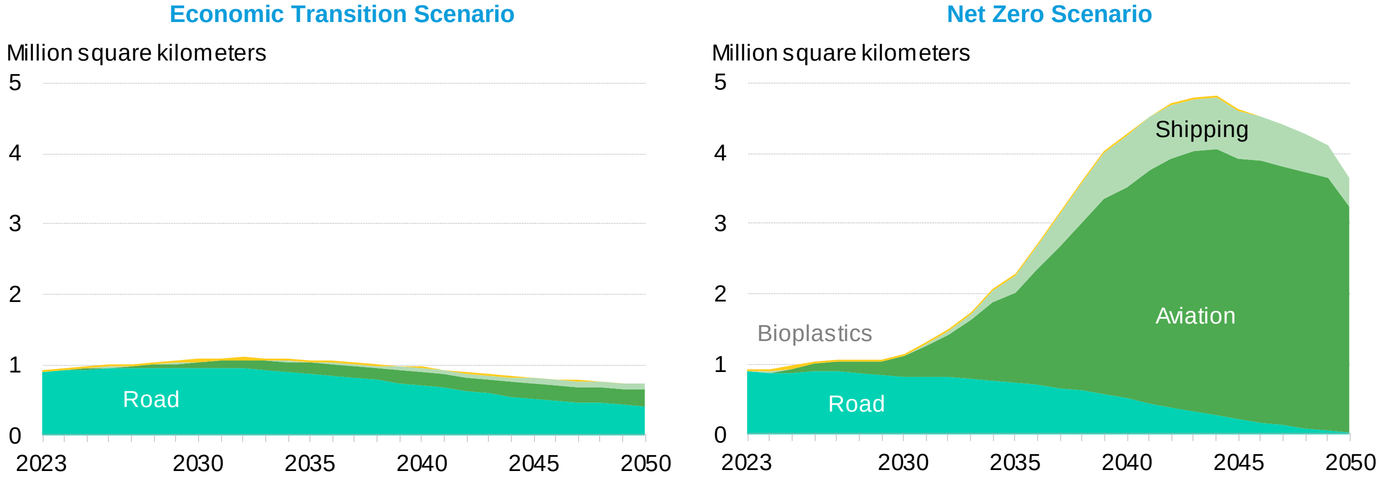
Under the NZS, 3.7 million km^2 of biofuel feedstock is under cultivation in 2050, five times more than in the ETS. Land demand from bioplastics peaks in the late 2020s in both scenarios as producers then shift to waste feedstock.

The sources of biofuels demand, and therefore land use, differ greatly between our two pathways. Biofuels are almost eliminated from road transport under the NZS, as a much greater share of the vehicle fleet is electrified. Aviation rises to become the largest consumer of biofuels, with sustainable aviation fuels (SAF) feedstock cultivated across 3.8 million km^2 of land in 2044. This means that much of the feedstock capacity currently supplying road fuels can be reorientated to aviation, partially easing a likely supply constraint if both segments were to rely on biofuels.

On the other hand, under the ETS, ethanol blending still plays a large role for road fuels, with 409,000km^2 of feedstock cultivation in 2050. Aviation achieves limited emissions reductions in this scenario, with SAF requiring only 240,000km^2 of land in 2050.

Land cultivating biofuels for shipping increases from a negligible base in 2023 to 84,000km^2 under the ETS and 404,000km^2 under the NZS.

Figure 6.2: Global land footprint of biofuels and bioplastics – Economic Transition Scenario and Net Zero Scenario



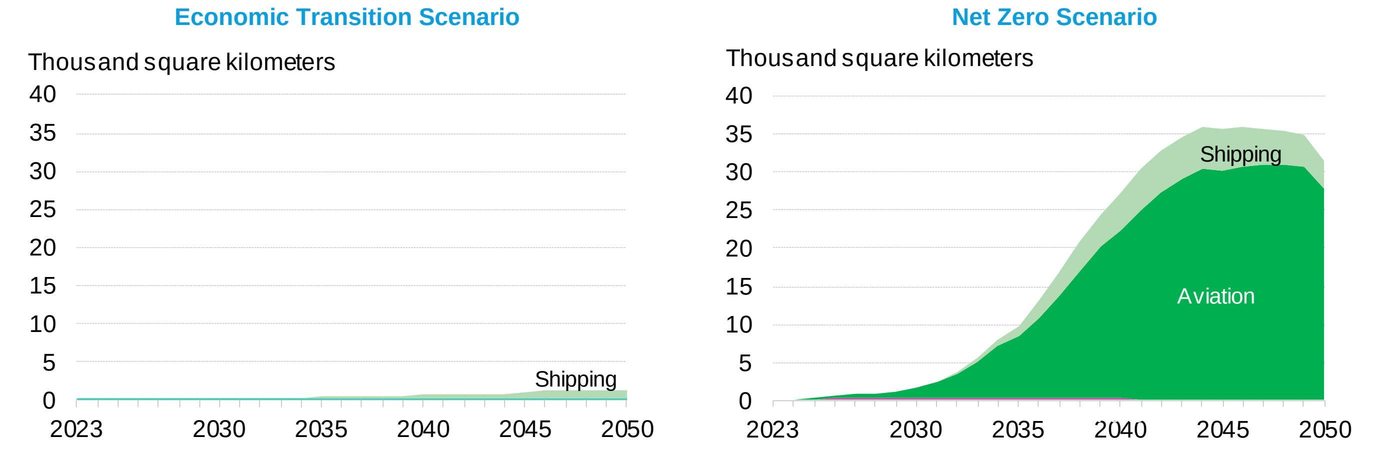
Source: BloombergNEF

Bioplastics demand and land impacts remain small, even in the NZS, as other decarbonization technologies outcompete bio-based routes in cost and scale. As a result, the land required for bioplastic feedstock is minimal, and the shift to waste-based feedstocks further reduces the footprint of their production.

Vietnam’s land demand drivers

Under the net-zero pathway, Vietnam sees massive land required for biofuels to decarbonize the transport sector but limited demand for bioplastics, which also mirrors the global trend.

Figure 6.3: Vietnam’s land footprint of biofuels and bioplastics – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF

The total land needed for biofuels under the NZS reaches 31,445km^2 by 2050, up from just 1,381km^2 under the economics-driven scenario. The largest driver for biofuel feedstock is the demand of sustainable aviation fuel (SAF) to decarbonize the aviation sector in Vietnam. Replacing petroleum-based fuels to SAF under the NZS requires a 27-fold increase in the total land size for the feedstocks. In the ETS, demand remains negligible due to the high cost of SAF.

The second-largest driver for biofuels in Vietnam under the NZS is the shipping sector. Land demand for biofuel feedstock for the industry rises approximately threefold to 3,574km^2 compared to the ETS. Lastly, in the transport sector, road biofuels do not play a big role in Vietnam in both scenarios as electrification mostly substitutes ICE vehicles.

Section 7. Policy recommendations

To stay on track for net zero by 2050, Vietnam can consider a range of policies targeting the power, industry, transport, agriculture, and waste sectors.

For the power sector, policies that support accelerating deployment of renewables and batteries coupled with expansion of the grid will be critical in the short-term. In the longer term, setting out phase out targets for unabated fossil fuel power plants will be necessary.

The industry sector can benefit from having a national roadmap for decarbonization, implementing supply and demand side policies for low-carbon emission materials, and promoting energy efficiency. In transport sector, accelerating EV adoption and deployment of charging infrastructure as well as stimulate the uptake of sustainable fuels in aviation and shipping can reduce emission footprint.

Lastly, alleviating land pressures from biofuel feedstocks and mining activities for critical minerals is critical to ensure transition, food security and biodiversity.

Table 4: Policy recommendations for Vietnam's net-zero pathway

Power	Industry	Transport	Agriculture and waste
Implement the Direct Power Purchase Agreement (DPPA) scheme	Launch national roadmaps for heavy industry decarbonization	Tighten vehicle emissions standards to achieve phaseout target	Agronomic practices
Organize competitive bidding processes for renewable projects	Implement supply and demand side policies for low-carbon emission materials	Accelerate EV adoption through targeted incentives	Waste management and feedstock
Establish a regulatory framework for the offshore wind sector	Establish a well-designed carbon market for large industrial emitters	Speed up deployment of charging stations	Alternative technologies
Scale up grid investment to support renewables integration	Promote the use of clean energy in light industry	Stimulate the uptake of low-carbon fuel in aviation and shipping	Alleviating land pressures from mining activities for critical metals
Support clean firm capacity and long-duration energy storage	Establish and enforce industrial efficiency standards		
Set phaseout targets for unabated fossil fuel power plants			

Source: BloombergNEF

7.1. Power

Implement the Direct Power Purchase Agreement (DPPA) scheme

The government's approval of the DPPA scheme in July 2024 is a positive step toward expanding renewable energy in Vietnam. The government now needs to translate this policy into concrete market development. This included providing policy implementation details, such as program charges, to enable large corporate users to meet their clean energy goals and help project developers diversity revenue streams.

Organize competitive bidding processes for renewable projects

Many governments have shifted from fixed offtake prices to competitive auctions and tenders for large scale renewable projects to hosting. BNEF has tracked 113 economies that have completed or announced such competitive bidding process for clean power so far. See *Clean Energy Auctions Help Offshore Wind Gain Steam* (web | terminal). While rules vary, auctions and tenders can help set prices and reduce the cost of delivered power.

Establish a regulatory framework for offshore wind sector

Offshore wind power will play a role in decarbonizing Vietnam's energy mix, with a projected 36GW of capacity by 2050 under the net zero scenario. Having well-established and clear regulations for the industry is critical to kickstart the sector and attract foreign investors. Given the nascent and capital-intensive nature of the offshore wind sector, foreign players can leverage expertise from mature markets and access capital at lower cost to develop projects.

Scale up grid investment to support more renewables

A successful energy transition requires robust transmission infrastructure. Under the NZS, Vietnam needs $322 billion in grid investment by mid-century. Increasing investment in grids, particularly from the private sector, is needed to accelerate integration of renewable energy supply.

Support clean firm capacity and long-duration energy storage

A zero-carbon pathway necessitates more variable renewable supply. To ensure a resilient and reliable power system, the government can consider regulating the inclusion of flexible energy storage in power projects fueled by intermittent sources like solar and wind. Vietnam could look to practices in other countries, such as co-location mandate in China, which requires renewable energy projected to be co-located with energy storage systems.

Set phaseout targets for unabated fossil fuel power plants

Vietnam has made strides in limiting coal power, with no new coal power plants added to the system after 2030. However, as NZS does not have room for an unabated fossil fuel fleet, the government needs stricter policies. Vietnam can consider setting targets to phase out the existing coal power plants without abatement solutions.

7.2. Industry

Launch national roadmaps for heavy industry decarbonization

Heavy industry faces one of the toughest paths to net-zero emissions. A national strategy is essential to set the direction to decarbonize this sector. Some countries such as Japan and Brazil are developing or finalizing such strategies.

Implement supply and demand side policies for low-carbon emission materials

In the NZS, CCS and hydrogen are key to decarbonizing Vietnam's big industrial emitters in sectors such as steel and cement. On the supply side, Vietnam could initiate pilot and demonstration projects using hydrogen in steelmaking via subsidy or capital expenditure support to create a market for these emerging technologies. Initiative like this has been introduced by India. To foster the demand for these materials, the government can leverage regulations such as green procurement mandates and incentives like subsidies for the green premium gap.

Establish a well-designed carbon market for large industrial emitters

Vietnam has taken steps toward industry decarbonization by imposing requirements for large emitters in the country to report emissions inventories and adopt mitigation plans starting from 2026. There are currently 175 mandated companies from heavy industries, such as steel, cement and chemicals. The government aims to have a fully operational carbon market by 2028 so that companies can buy or sell allowances or credits. Ensuring robust policy details such as data quality, allowance allocation will be critical to enforce emissions reduction among industrial emitters and spur innovation.

Promote the use of clean energy in light industry

Light industries, such as non-ferrous metals, food and tobacco, and textiles and leather, make up 82% of the firms in Vietnam that are mandated to reduce emissions. Switching to clean energy and electrification are easiest for light industry, which only uses low-temperature heat. Vietnam can facilitate this transition by offering low-cost grid access and lowering the threshold for participation in the DPPA mechanism.

Establish and enforce industrial efficiency standards

Energy efficiency is one of the top three contributors for emissions abatement in Vietnam under the NZS, contributing to 15% of the total abatement. Policymakers in the country can consider regulating energy performance standards by setting a minimum efficiency level for various products.

7.3. Transport

Tighten vehicle emissions standards to achieve phaseout target.

Vietnam sets a target of 100% of road transport to be electrified or running on green fuel by mid-century. Imposing lower permissible emission level will push manufacturers to transition to zero tailpipe vehicles as it is more challenging and costly for them to keep ICE vehicles compliant.

Accelerate EV adoption through targeted incentives

With EVs still more expensive compared to ICE vehicles in the near to medium term in Vietnam, policy support is crucial for accelerating adoption. For manufacturers, the government can consider corporate tax exemptions and grants to support upfront costs and scale up production. For consumer, incentives such as purchase subsidies, EV tax credits and affordable financing options can make EV more accessible.

Speed up deployment of charging stations

Accelerating the adoption of EV also equates to speed up the installations of charging infrastructure, both at home and at public. The government can mandate and incentivize the deployment of charging points in new home and workplace buildings while simplifying and streamlining the permitting process.

Stimulate the up-take of low-carbon fuel in aviation and shipping

Vietnam is exploring partial fuel switching in aviation to reduce the sector's emissions footprint from 2027 onwards. The government could consider introducing blending mandates for aviation fuel and provide fiscal supports for the supply side.

7.4. Agriculture and waste

Alleviating land pressures from biofuel feedstocks

There are several pathways to minimize the impact of biofuels on the food system. We can categorize these as agronomic practices, minimizing food waste, using waste products as biofuel feedstock, and alternative technology pathways.

Agronomic practices

Improved and entrepreneurial farming practices will be needed to support a growing population. This could include double cropping to grow multiple harvests each year and regenerating land that is currently less productive or suitable for cropping.[9] In March 2023, Corteva Agriscience partnered with Chevron and oilseed processor Bunge to support southern US growers to plant a winter canola crop for biofuel production following their main soy or cotton harvest.

Corporate agricultural multinationals are moving to genetically modify and breed oilier crops with a higher ratio of oil to meal and residues than conventional varietals. This would result in more biofuel per cropped acre. For example, Corteva has backed ZeaKal, a startup that plans to commercialize its first batch of high oil content soy seeds in 2024. Cover crops such as camelina and pennycress, which are grown out of the main cropping season to protect or 'cover' the fallow soils, could also relieve pressure on land. BP, Bunge, Chevron and Bayer are all exploring leguminous cover crops that can be harvested and pressed for oil.

Waste management and feedstock

Agricultural and food waste can be minimized to reduce the footprint of the food system, making more land available for other purposes such as growing biofuels crops. The remaining waste can be collected and converted into biofuels and sustainable materials through processes such as anaerobic digestion. Waste feedstocks from forestry, agriculture or even municipal solid waste can also be processed from gas-to-liquids. However, these technologies are less mature and

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9 Our land supply analysis considers only land the UN Food and Agriculture Organization deems "very suitable" or "suitable" for each crop.

more costly than first generation biofuels. Waste feedstocks from agriculture and forestry offer large emissions reductions over conventional fuels, but they are challenging to aggregate.

Used cooking oil has a much lower land-use intensity compared to virgin crops and roughly 80% have lower lifecycle emissions than conventional jet fuel. However, its supply is constrained and collecting and aggregating the feedstock can be challenging.

Alternative technologies

While biofuels are seen as the aviation industry's most viable decarbonization pathway in the short term, other options with lower land requirements exist. Most of these depend on green hydrogen (made from splitting water using renewable electricity), the scaling up of which would increase the amount of land needed for wind and solar.

Battery-electric and hydrogen fuel-cell planes may be able to service routes up to a few thousand kilometers. Combustible fuels produced through a power-to-liquid process that uses green hydrogen and captured carbon dioxide as inputs could potentially serve both short and long-distance routes. However, these e-fuels are a nascent technology with high costs.

Heavy-duty road transport can be decarbonized through electrification or hydrogen in place of biofuels.[10] Shipping is likely to turn to green methanol or ammonia to move past transitional fuels, such as very-low-sulfur fuel oil and LNG.[11]

Alleviating land pressures from mining activities for critical metals

There are several ways to minimize the land and nature impacts of critical metals.

Improved mining technologies such as direct lithium extraction could significantly reduce water and land use in lithium operations.

Governments in China and Europe are laying out regulations to promote EV battery recycling, with required material recovery rates, collection networks and lifetime battery traceability. In the US, recycled material production can benefit from production tax credits under the Inflation Reduction Act, which also treats recycled content as a locally produced material, helping cars qualify for the EV credit. Continued government support and investment in the sector will play a crucial role in ensuring secondary sources of metals become a competitive alternative to meeting the raw materials demand of the energy transition.

Novel technologies, such as deep-sea mining and 'agromining' (the process of obtaining metals from certain plants that absorb and store them), are seen by some as ways to increase supply and improve the sustainability of critical metals. According to a lifecycle study conducted by deep-sea miner The Metals Company (formerly known as DeepGreen), harvesting undersea pebbles containing nickel, cobalt, copper and manganese would release 70% less CO2 emissions and consume almost 90% less water than an equivalent land-based mining operation.[12]

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10 For more, see *NetZero Pathfinders Quarterly: The Transport Edition* (web | terminal).

11 These pathways also impact land use. Methanol generally uses a biomass feedstock (accounted for in modeling); hydrogen would require additional renewable build to be considered a zero-carbon fuel.

12 For more, see *Deep-Sea Rocks Offer 'Greener' Supply of Battery Metals* (web | terminal).

However, both methods have flaws. Agromining would require vast amounts of cropping land, which is already in short supply due to food, fuel, and fiber production.[13] Meanwhile, deep-sea mining has been criticized as having the potential to be disastrous for marine ecosystems.

Biodiversity and the energy transition

At the heart of the Global Biodiversity Framework (GBF) struck by nearly 200 countries at the United Nations Biodiversity Conference (COP15) in Montreal, Canada, was an agreement to conserve 30% of land, inland waters, and coastal and marine areas by 2030.[14] The GBF also calls for 30% of degraded ecosystems to be restored. To achieve these targets, degraded agricultural land would need to be taken out of production and restored, all while food demand and biofuel consumption increase. At the time of that agreement, only 17% of land and inland waters were globally protected areas or under other effective area-based conservation measures.

Conservation targets and programs will also impact extractive industries mining transition metals, many of which tend to be located beneath biodiversity hotspots. For example, some of the richest copper, nickel and cobalt reserves in the world sit in South America, the Democratic Republic of Congo and Indonesia. This may lead EV battery manufacturers to develop alternative chemistries if resource supply is constrained by rainforest protections.

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13 For more, see *Technology Radar: Agromining* (web | terminal).

14 For more, see *Biodiversity COP's Bold Targets Now Need Follow-Through* (web | terminal).

Appendices

Appendix A. Data sources for key inputs

This appendix lists select key inputs to our modeling across power, transport, industry and buildings. All assumptions apply to both Economic Transition Scenario and Net Zero Scenario, unless stated otherwise. Due to the lead times, complexity and necessary sequencing of modeling stages, by the time of publication, BNEF may have released updated cost estimates to those used in this outlook.

Commodity prices

Long-term fuel prices in NEO are inputs to our energy models and are estimated based on demand expectations from previous scenarios and in-house supply curves. Most national and regional fuel prices are derived from major hub prices, such as Henry Hub gas, Brent oil and Newcastle coal. Fuel prices do not change dynamically throughout the modeling. Prices account for short-term dynamics and, in the case of gas, hub prices reflect forward curves. Prices do not vary by scenario.

Coal

We produce country-level coal price forecasts based on our *2H 2023 Levelized Cost of Electricity* report from December 2023. For each market, our thermal coal prices consider:

- The balance of domestic and imported supply
- The heating value for different grades of coal
- The cost of mining, internal transportation, shipping from key export regions, and coal processing
- Taxes and levies, including applicable taxes, environmental levies and price controls
- Expected demand from mid-term coal-to-gas-switching dynamics in the Asia Pacific region

Figure A.1: Thermal coal prices – seaborne and global range

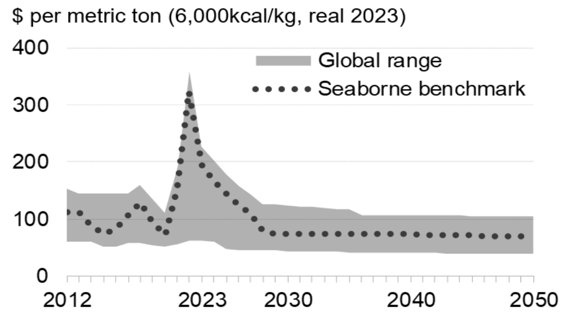
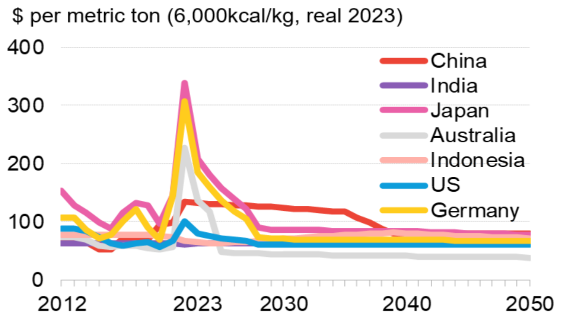


Figure A.2: Thermal coal prices in selected markets



Source: BloombergNEF. Note: kcal/kg refers to kilocalories per kilogram. See New Energy Outlook 2024 Data Viewer (web | terminal) for the associated data. Country-level data can be also found on the 'Market' tab in Energy Project Valuation Model (EPVal) (web | terminal) and in the LCOE Data Viewer (web | terminal).

Gas

We model with the country-level gas price forecasts from our *2H 2023 Levelized Cost of Electricity* report from December 2023. These factor in the balance of domestic and imported supply, long-term contracts indexed to oil (see below), internal transportation, shipping from key export regions, processing costs and taxes.

In addition, our hub prices, which feed into our country-level prices, are constructed using forward curves on the Bloomberg Terminal (as of March 2023), and factor in the impact of other hub prices in the context of a global natural gas market.

Figure A.3: Natural gas hub price assumption

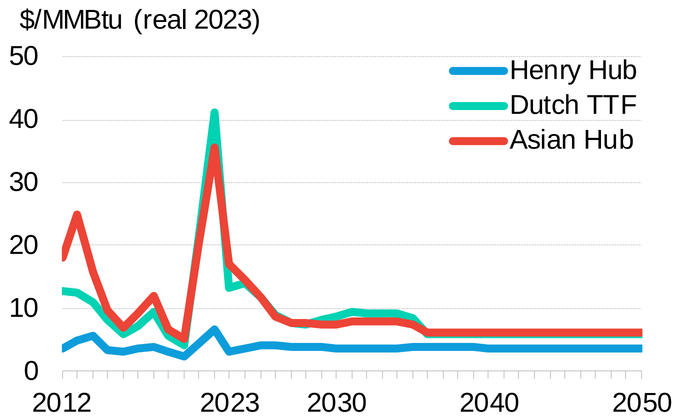
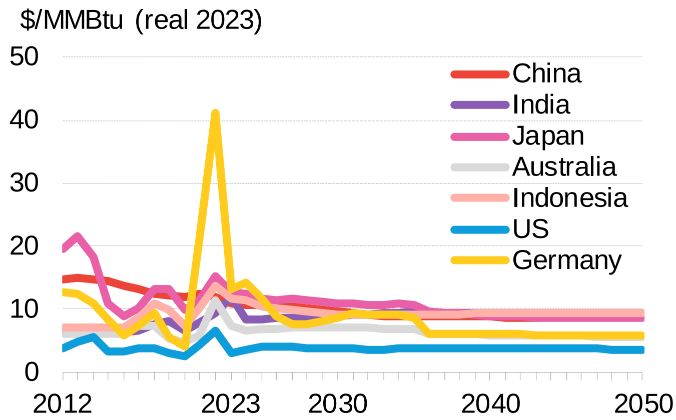


Figure A.4: Natural gas delivered prices in selected markets



Source: BloombergNEF, RBAC. Note: TTF refers to Title Transfer Facility. MMBtu is million British thermal units.

Oil

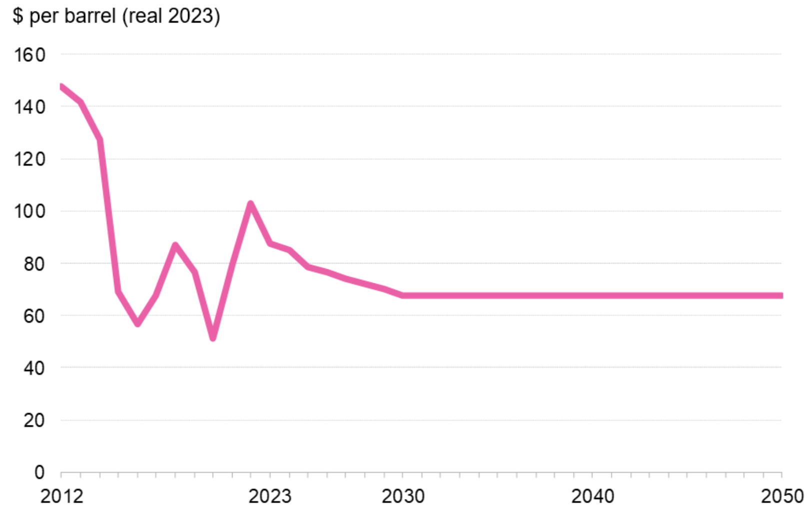
We model with the global oil price forecast from our *2H 2023 Levelized Cost of Electricity* report from December 2023.

The oil price forecast in *NEO 2024* is based on:

- The average Brent forecast between 2023-25 from outlooks found on CPFC<GO> (as of February 2023), when it reaches $78.68 a barrel in real terms
- The World Bank's Brent forecast at around $67.77 a barrel in 2030

We then hold our assumed price flat in real terms out to 2050.

Figure A.5: Brent oil price assumption

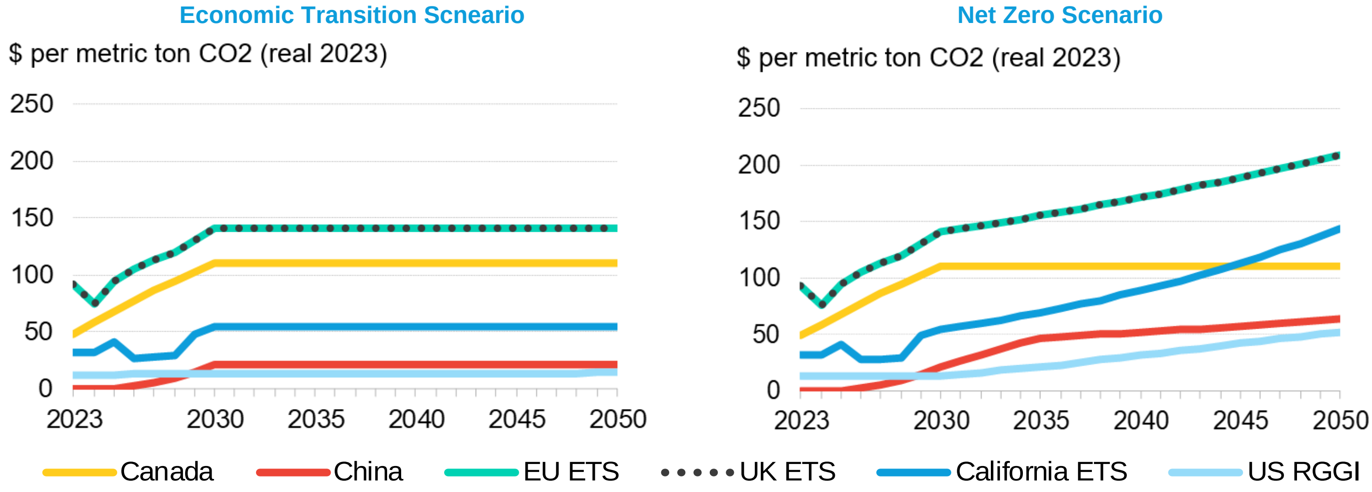


Source: BloombergNEF

Carbon

We consider carbon prices in regions with carbon markets. Price forecasts are developed by BNEF's carbon teams – see here for more BNEF carbon market coverage.

Figure A.6: Carbon price assumptions, by scenario



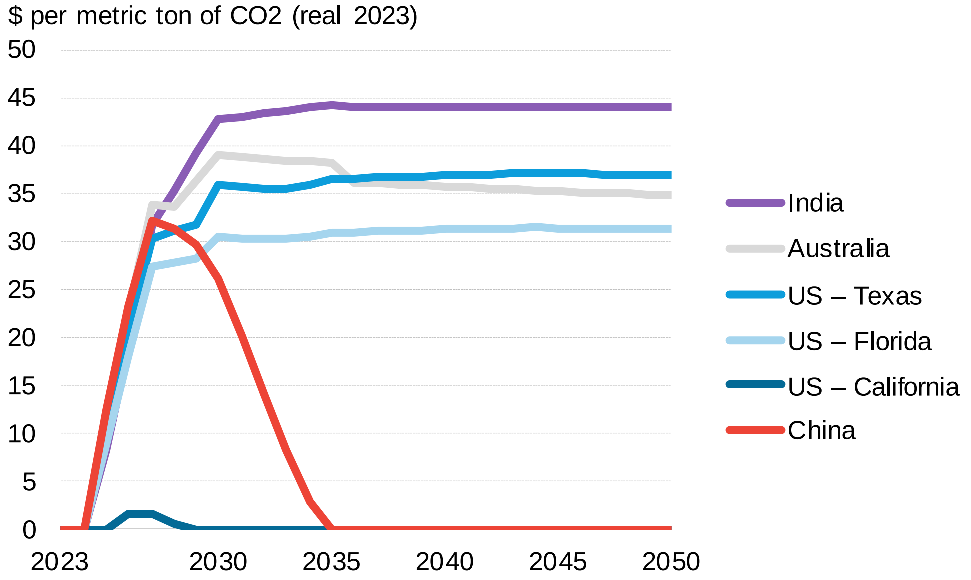
Source: BloombergNEF. Note: ETS refers to emissions trading system; RGGI is the US Regional Greenhouse Gas Initiative.

Higher carbon prices increase the cost of generation from fossil fuels, particularly coal-fired power. Prices are based on the supply and demand for allowances, forecast emissions and national targets. In the ETS, we hold prices flat in real terms post-2030. In the NZS, carbon prices continue to rise in markets where fewer allowances are expected to be allocated to drive decarbonization, or where government net-zero goals exist.

The role of shadow carbon prices

In addition to the stated carbon price forecasts, our power modeling also introduces a 'shadow' carbon price in the NZS in regions without carbon taxes or markets, or where either of these are insufficient to trigger fuel switching to carbon capture and storage or hydrogen. This is to ensure that emission reductions are not only achieved by plant closures, but also via changes in dispatch decisions within the existing fleet.

Figure A.7: Shadow carbon price assumptions for selected markets



Source: BloombergNEF. Note: 'US – Texas' refers to the independent system operator known as the Electric Reliability Council of Texas (Ercot); 'US – California' is the California Independent System Operator (Caiso).

The shadow carbon price is designed to push unabated fossil fuel-fired generation higher in the plant stack, such that low- and zero-carbon technologies will be dispatched first, despite their nominally higher marginal cost of generation. The shadow price generally reflects the gap between the short-run marginal cost of unabated coal or gas and equivalent plants with CCS, not hydrogen, which is more expensive than CCS in most markets. Europe does not require a shadow carbon price as its carbon market, the EU Emissions Trading System, is already sufficient to guarantee priority dispatch for CCS.

Hydrogen

The delivered hydrogen prices used in our modeling include production, transport and storage costs. Production costs are based on our *2023 Hydrogen Levelized Cost Update* report from July 2023. The levelized production costs from this analysis are adjusted as we assume a fully fledged hydrogen market forms as demand grows under the NZS. We assume pipeline transport costs of $0.77 per million British thermal units and storage costs of $1.54-5.39/MMBtu (depending on whether a country uses salt or rock caverns).

Figure A.8: Hydrogen price by component in Germany

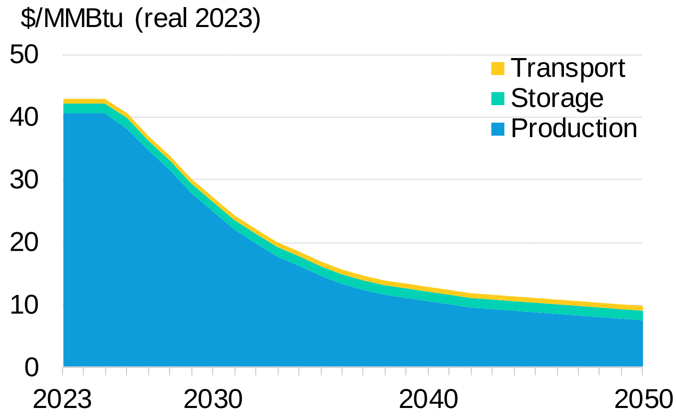
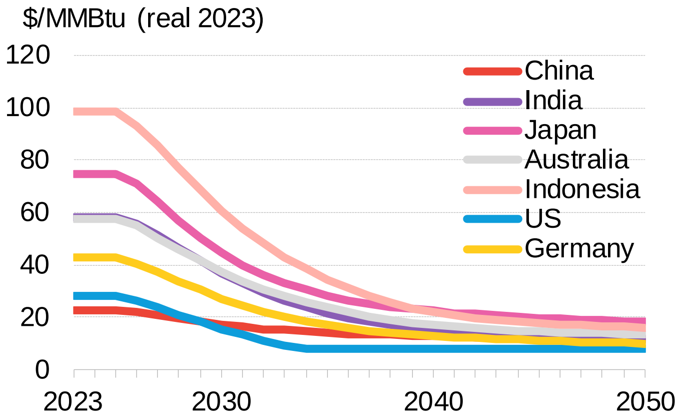


Figure A.9: Delivered hydrogen price in selected markets



Source: BloombergNEF. Note: Prices based on hydrogen production via dedicated onshore wind or solar. MMBtu is million British thermal units. See New Energy Outlook 2024 Data Viewer (web | terminal) for the associated data. Country-level data can be also found on the 'Market' tab in Energy Project Valuation Model (EPVal) (web | terminal) and in the LCOE Data Viewer (web | terminal).

Macroeconomic data

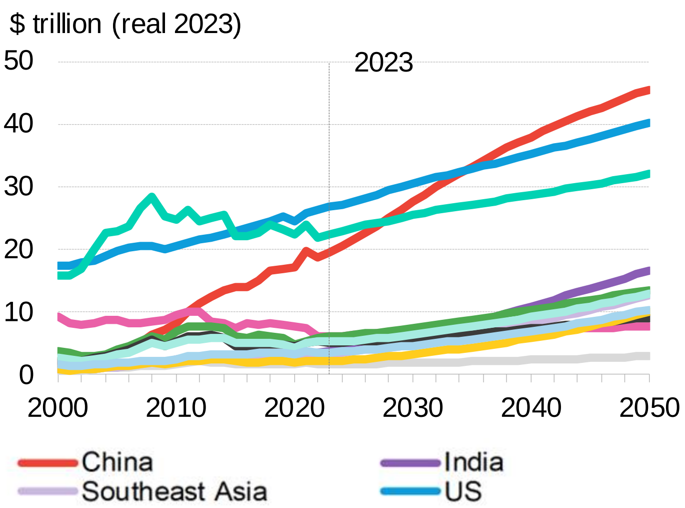
We use the same GDP and population forecasts across our scenarios.

GDP: Historical data and short-term forecasts for GDP are from the October 2023 edition of the International Monetary Fund's (IMF) *World Economic Outlook*. Long-term GDP forecasts are from the Organisation for Economic Co-operation and Development's (OECD) *Economic Outlook No. 109 - October 2021 - Long-term baseline projections*. The GDP of countries not covered by the OECD's analysis have been estimated internally. GDP data is measured in real 2023 US dollars. Nominal series in local currency have been converted to real US dollars using market exchange rates and the USD GDP deflator from the OECD.

Both short- and long-term GDP forecasts from the IMF and OECD have been cross-checked against Bloomberg Economics' long-term forecasts, available on BECO <GO> on the Bloomberg Terminal.

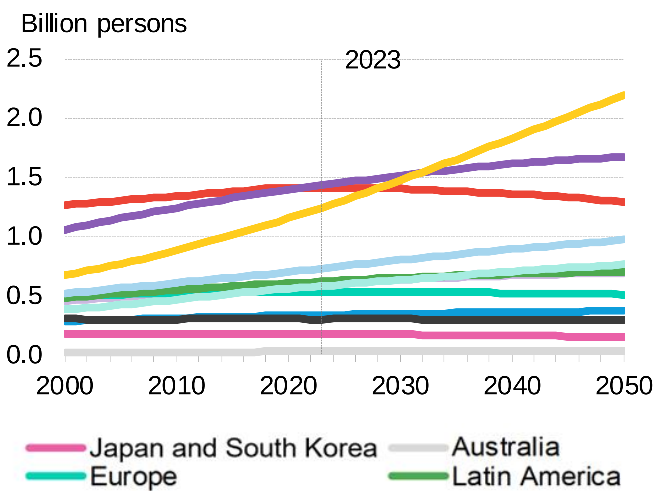
Population: Historical data and long-term forecasts for population are from the World Bank's *Population Estimates and Projections* from May 2023. For territories not covered by the World Bank dataset, the UN's World Population Prospects 2019 Revision dataset has been used.

Figure A.10: Gross domestic product by market/region



Source: BloombergNEF, Bloomberg, International Monetary Fund, Organisation for Economic Co-operation and Development. Note: Nominal series in local currency have been converted to real US-dollars using market exchange rates and the US dollar GDP deflator from the OECD. They are therefore not adjusted for purchasing power parity.

Figure A.11: Population outlook by market/region



Source: BloombergNEF, Bloomberg, World Bank, United Nations.

Levelized costs

Current and forecast cost estimates are based on proprietary BNEF research and models.

Levelized cost of electricity

Cost inputs for power sector based on *2H 2023 Levelized Cost of Electricity*

- *2H 2023 LCOE Update: An Uneven Recovery* (web | terminal)
- *2H 2023 LCOE Update: Data Viewer* (web | terminal)
- *Energy Project Valuation Model* (web | terminal)

Levelized cost of hydrogen

Cost inputs for hydrogen based on 2023 Hydrogen Levelized Cost Update

- *2023 Hydrogen Levelized Cost Update: Green Beats Gray* (web | terminal)
- *Hydrogen Project Valuation Model* (web | terminal)

Levelized cost of material production

Industry cost inputs based on the following BNEF publications:

- *Decarbonizing Aluminum: Technologies and Costs* (web | terminal)
- *Decarbonizing Steel: Technologies and Costs* (web | terminal)
- *Aluminum Project Valuation Model (AluVal 1.1)* (web | terminal)
- *Chemicals Production Valuation Model (ChemVal 1.1)* (web | terminal)

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