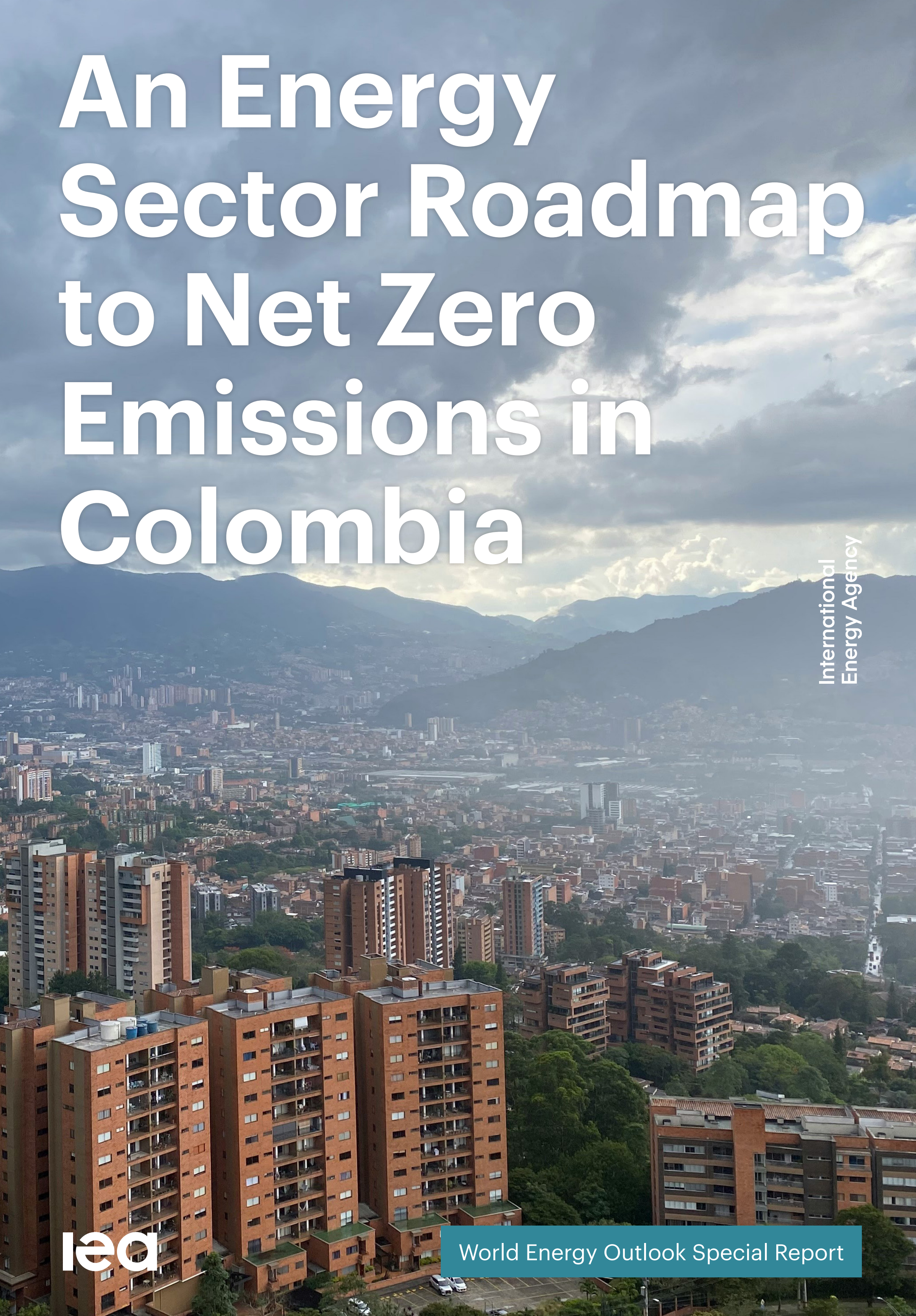
An Energy Sector Roadmap to Net Zero Emissions in Colombia



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Colombia is one of the region's growth success stories

Colombia is the third-largest country in Latin America and the Caribbean (LAC) by population, with 53 million inhabitants. Its economy has grown steadily since 1971, even during the "lost decade" experienced by LAC in the 1980s, and with very few exceptions during global crises. GDP has increased by an annual average of 2.4% since 2015, outpacing the regional average of 1.2%. This growth has been accompanied by tangible improvements in indicators of living standards for Colombia's population: access to clean cooking and electricity have significantly improved, both standing at more than 90% in 2024; the country's poverty rate has fallen from 24% in 2000 to below 8%.

Fossil fuel exports have been important for its economic growth…

In Colombia's economy, exports are mostly driven by natural resources and less by high-value goods. While the service and agriculture sectors account for a high share of Colombia's GDP, fossil fuels still comprised 10% of GDP and 45% of total exports in 2024, despite declining production trends. Colombia is currently the sixth-largest coal exporter globally and the fourth-largest oil exporter in the region, meaning its economy is exposed to fuel price volatility. Exporting primary materials and importing higher-value goods such as refined products or cars places Colombia as a net importer in monetary terms.

…and fossil fuels lead Colombia's energy mix

Over 75% of Colombia's total energy demand was met by fossil fuels in 2024, of which oil comprised more than 40%, followed by natural gas and coal. Oil is the main fuel used to meet transport demand at 90%, while coal plays a core role in meeting industry's needs at 40%; electricity feeds 40% of energy demand from buildings. Overall, electricity accounted for 18% of Colombia's final consumption in 2024. Hydropower represented around two-thirds of the country's electricity generation over the past decade, although the annual share fluctuated by as much as 10 percentage points as weather patterns caused by El Niño and La Niña cycles affect rainfall and temperature, impacting reservoir levels.

Greenhouse gas emissions have grown; Colombia has pledged to achieve net zero emissions

Economic and population growth have resulted in Colombia's total energy demand almost doubling between 2000 and 2024. As three-quarters of this growth has been supplied by fossil fuels, energy-related greenhouse gas (GHG) emissions increased by more than 50% over the same period. Energy-related emissions comprised around 30% of its total GHG emissions in 2021. Other key sources of emissions are from land use, land-use change and forestry, which represented almost 40% of the total in 2021. Agricultural emissions represent 20% of the 2021 total.

Colombia's Long-Term Strategy E2050, published in 2021, sets out an overarching objective to achieve net zero GHG emissions by 2050. Colombia aims to meet this target by reducing its energy-related 2050 GHG emissions by 90% compared with 2015; the remaining 10% of emissions are to be captured or offset through land-based CO_2 sequestration.

A pathway towards net zero emissions

At the request of and in consultation with the Government of Colombia, the International Energy Agency (IEA) has prepared this report, "*An Energy Sector Roadmap to Net Zero Emissions in Colombia*". The work was carried out in close collaboration with the Mining and Energy Planning Unit (Unidad de Planeación Minero Energética [UPME]) and the Ministry for Mines and Energy (Ministerio de Minas y Energía [MME]). The IEA's contribution complements – and has benefited from – the high-quality modelling and analysis already being conducted in Colombia to identify pathways towards a net zero emissions target.

There is no single pathway to net zero emissions for Colombia. This report presents *a* pathway to reach this goal, not *the* pathway. Our analysis is centred on the IEA's Announced Pledges Scenario (APS), in which Colombia reaches its net zero pledge by 2050 alongside all other countries meeting their announced long-term net zero emissions targets.

Colombia can leverage a strong base of clean energy resources

Colombia's end-use consumption per capita is structurally low – a quarter of the OECD average: it has a high ownership rate of two/three-wheelers versus thirstier cars for its congested cities; non-energy-intensive industries account for a high share of industrial demand; and its climate means few households require space heating. Colombia has plentiful undeveloped resources to supply clean energy. Potential remains in the country's well-developed hydropower sector, enabled by the undulating landscape which provides sites for dams near population centres. Colombia's solar and wind resources are also strong: the solar PV capacity factor averages around 17%, with highest potential in the centre and north, while wind capacity factors can reach more than 45% in La Guajira – levels above global averages.

A journey of two important steps: decarbonise the power sector and expand electrification through to 2035…

Up to 2035, the pathway reverses Colombia's trend of rising emissions by deploying clean energy technologies, enabling a decline in fossil fuel demand. It results in a 30% emissions reduction in 2035 in the APS compared with today's levels. The power sector contributes half of this fall as solar PV and, in part, wind take hold, reducing the emissions intensity of the power sector by more than 85% to less than 35 grammes of CO_2 per kilowatt hour. The electrification of end uses – for example, electric vehicle (EV) sales reach 80% of the market in 2035 in the APS – displaces fossil fuels, offsetting emissions increases from economic growth. Furthermore, strong policies and declining fossil fuel production lead to energy-related methane emissions declining by around 75% to 2035.

…then accelerate clean technology in end uses post-2035

After 2035, clean technology deployment in end-use sectors – which had already started to make inroads – further accelerates, becoming the main driver of emissions decline. The transport sector alone accounts for half of the emissions decline from 2035 to 2050, as continued EV sales embed into an increasingly electrified vehicle stock. Around 40% of emissions reductions come from the industry and buildings sectors, as electrification and efficiency improvements take hold. Bioenergy, hydrogen and carbon capture, utilisation and storage (CCUS) contribute to these emissions reductions – they play a crucial role in long-distance transport and energy-intensive industries. In the power sector, solar PV and wind expansion continues, complemented by a 50% increase in the capacity of dispatchable low-emissions sources from 2035 to 2050, to ensure that rapidly rising electricity demand can be met by renewables substituting fossil fuels, with a coal phase-out by 2040.

Electrification of the growing vehicle fleet decarbonises the transport sector

The transport sector currently accounts for almost 40% of Colombia's total final consumption and emissions, mostly in the form of imported refined oil products. Although two/three-wheelers make up 70% of vehicles, cars and vans account for almost half of transport demand, and economic growth more than doubles car ownership by 2050 in the APS. The rollout of EVs is crucial to arrest the emissions increase: the share of EVs in car sales rises sharply from a third in 2030 to virtually all cars by 2040, increasingly permeating the car fleet so that by 2050 more than 80% of cars on the road are EVs. Electric buses follow suit, building on the 1 500 already deployed in Bogotá, supporting public transport decarbonisation in cities with challenging geographies for metro infrastructure. Despite Colombia's mountainous terrain and challenges in meeting long-distance charging requirements, 70% of all heavy freight trucks are electric by 2050, with biofuels and hydrogen filling the gap.

Electrification becomes increasingly competitive in light industry

Colombia's industry sector is poised for substantial growth, particularly in non-energy-intensive industries, nearly doubling output by 2050. In the APS, electricity becomes the leading source of energy in industry by 2050, followed by bioenergy. Electrification is driven by non-energy-intensive industries, such as the food industry, which accounts for a quarter of Colombia's current industrial energy demand. As carbon prices rise, heat pumps and electric boilers become increasingly competitive for low-temperature processes. By displacing coal, electricity's share of energy for food processing rises from around 15% in 2024 to 45% by 2050. Energy-intensive industries see slower electrification, but advances in hydrogen, bioenergy and CCUS technologies offer long-term potential to reduce emissions.

Efficiency gains balance energy demand increases from air conditioning use

Rising incomes, expanding floorspace and increasing access to household equipment drive energy demand in buildings along the pathway. The share of electricity in the sector's fuel mix doubles to 80% by 2050, supported by widespread cooking electrification and the rapid uptake of cooling demand, as the rate of air conditioner ownership is projected to more than quadruple by mid-century. Efficiency gains – especially through ambitious minimum energy performance standards for air conditioning and appliances – play an important role in curbing demand growth, avoiding 215 PJ by 2050 – half of the current buildings demand.

Variable and dispatchable renewables underpin the power sector transition

Solar PV emerges as the leading power generation source, with capacity exceeding 65 GW by 2050, similar to Brazil's current capacity. It helps meet electricity demand that, including hydrogen production, almost quadruples to 300 TWh in 2050 in the APS. While wind capacity grows to 25 GW by 2050, dispatchable low-emissions capacity from hydro, nuclear, bioenergy and geothermal doubles to 30 GW, strengthening system reliability. Grid flexibility is further supported by a rapid scale-up of battery storage, rising to 48 GW in 2050. Some natural gas and oil generation remains for backup use and electricity access in remote areas. The electricity grid, spanning over 750 000 km in 2024, nearly doubles to meet rising demand and integrate variable renewables, calling for annual grid investment to rise to USD 4.2 billion by 2050.

Alternative fuels make up the balance

Tapping into the potential of Colombia's agriculture sector and other residues, the share of bioenergy in total energy demand rises from 10% in 2024 to 25% in 2050. Domestic liquid biofuel production shifts from conventional to emerging sources like waste and residues; solid bioenergy increases in energy-intensive industries and power; and gaseous bioenergy takes a higher share of power generation. Meanwhile, low-emissions hydrogen production surges through water electrolysis projects, reaching around 1.2 million tonnes by 2050 in the APS as Colombia capitalises on its strong renewables potential and competitive production costs. Early growth in low-emissions hydrogen is export-driven, but domestic demand, especially from transport and industry, rises steadily.

A just transition will need to manage employment shifts between sectors

Just energy transitions are central to Colombia's policy framework. In the APS, the country accelerates its progress in increasing access to electricity and clean cooking: 4.2 million people gain access to clean cooking by 2030 to reach universal access. A shift to low-emissions technologies creates new employment opportunities, estimated at an additional 77 000 jobs by 2035. However, declines in fossil fuel employment mean that total energy sector employment is set to remain stable to 2035 in the APS at around 300 000 jobs. Transition employment challenges will likely be most acute in fossil fuel-producing departments such as La Guajira, Cesar (coal) or Meta (oil). Some synergies are possible: around a third of current low-emissions projects are within 50 kilometres of coal mines. Strategic support for industries linked to the energy transition could even increase the total number of energy sector jobs, accompanied by the retraining of workers to help them switch employment to low-emissions technologies.

Energy security and resilience are tested by natural hazards

Colombia's electricity security is influenced by its climate variability. It has alternating wet and dry seasons, with El Niño and La Niña events amplifying swings in precipitation and temperature patterns. With hydropower generation currently leading, and a pathway to net zero emissions increasingly reliant on variable renewables, weather patterns and climate change emphasise the need to plan a resilient energy system. Hydropower output could decline up to 25% by 2100 under high-warming scenarios. Complementary dispatchable low-emissions sources like bioenergy, geothermal and nuclear power will help alleviate pressure, but as renewable energy expands and fossil fuel use declines, better management of the grid and scaling up system flexibility will be paramount. Furthermore, droughts and wildfires – both aggravated by El Niño – are further considerations for grid siting and management; over half of Colombia's current networks lie in fire-prone zones. While the required infrastructure for the electrification of end uses introduces new security challenges, it also enhances energy security by reducing dependence, especially on refined oil products.

It is essential to overcome investment barriers for a successful transition

Clean energy investment is expected to exceed fossil fuel investment for the first time in 2025 and reach almost 85% of total annual energy investment by 2035 in the APS. The power sector transition accounts for half of clean energy investment, mainly to build out grid infrastructure, solar PV, wind generation and battery storage; the balance is for end uses such as EVs and building retrofits. International public finance is crucial to mobilise private investment in the transition, especially given the lower revenues from fossil fuels. Colombia's Country Platform is a key initiative to mobilise resources to support this transition, although high financing costs and access to long-term debt remain key challenges.

Colombia's energy economy will pivot on a net zero pathway

On a net zero pathway, Colombia's energy sector economy will pivot towards clean energy technologies, presenting growth opportunities. As production from its mature oil and gas fields wanes, and barring significant investment in new developments, its fossil fuel market size is set to decline whether a net zero pathway is taken or not. Yet the decarbonisation of Colombia's energy system shifts the focus to other market sectors: the size of the clean energy market is projected to rise fivefold by 2050 in the APS, bringing with it a new set of job opportunities and revenue streams. With strategic planning and support for specific industries, Colombia's clean energy market size could exceed that in the APS, potentially by one-third in 2050. Realising these opportunities will depend on co-ordinated action and strong investment to support the shift away from fossil fuels.

An Energy Sector Roadmap to Net Zero Emissions in Colombia aims to provide Colombian and international stakeholders with a clear outline of how Colombia can achieve net zero emissions, the role the energy sector can play, and the needed actions and investments. The report lays out a possible pathway, but not the only pathway, for Colombia to achieve net zero emissions by 2050.

Using scenario analysis, this report illustrates a pathway that is based on: a detailed understanding of Colombia's national and regional circumstances; the most recent analysis of global market for fuels and technologies; recognition of Colombia's strategic priorities; and robust evaluation and analysis of the key drivers of energy service demand.

Chapter 1 provides an overview of Colombia's current energy landscape, including key trends in supply and demand, the energy mix, and the policy environment shaping energy development.

Chapter 2 presents a detailed, sector-by-sector analysis of the net zero emissions pathway, beginning with an assessment of total primary energy demand and covering the end-use sectors—transport, industry, and buildings—as well as the power sector and the role of fuels such as oil, gas, coal, and bioenergy.

Chapter 3 explores the broader implications of the net zero pathway, focusing on the just energy transition, electricity security, climate resilience, and investment and financing.

Colombia today

State of play

S U M M A R Y

- Colombia is the third-largest country in Latin America and the Caribbean by population, with 53 million inhabitants. Colombia's GDP per capita was around USD 21 500 (PPP) in 2024 – slightly above the regional average, but less than half the OECD average. The country's poverty rate – i.e. the number of people living on less than USD 3 a day – is below 8%, having fallen from 24% in 2000, while the electricity access rate increased from 87% to 93% over the same period.
- Colombia's population lies mostly in the central Andean region and the coastal regions, with an urbanisation rate of 83%. Energy resources are widely distributed. Fossil fuel resources of oil and gas lie in the sparsely populated eastern half and along the more populous Caribbean coast; coal-rich basins are in the northeast. Hydropower resources are found in the central area, close to population centres. Regions with strong potential for renewables, notably wind and solar, include remote areas such as La Guajira in the north, while the country's rocks hold potential for geothermal energy. Colombia is the world's tenth-largest coal producer, with reserves that could supply the country for more than 50 years. The country also has oil and natural gas reserves; it is a net exporter of oil, although it became a net importer of gas in 2024 as domestic production declined and energy demand grew. Fossil fuels are an important part of the economy, accounting for 45% of its exports.
- The total energy demand in Colombia almost doubled from 2000 to 2024, reaching 2 027 PJ. The proportion sourced from fossil fuels was relatively flat during this period at 76%. Modern bioenergy has played an increasing role in the mix, more than tripling since the turn of the millennium. The country has strong potential from solar and wind, yet in 2024 these sources accounted for less than 1% of the energy supply.
- Hydropower is a cornerstone of Colombia's electricity generation, making around two-thirds of the mix over the past decade. Its share is in decline as opportunities for expansion are limited. It is also subject to interannual variability, driven in part by El Niño and La Niña cycles, which impact rainfall and temperature. To meet rising energy demand, power generation using fossil fuels has increased – since 2000 natural gas-fired generation has more than doubled while coal is more than five times higher.
- Colombia's total energy sector, comprising both the supply and end-use of energy, accounted for around 30% of total carbon dioxide equivalent (CO_2-eq) emissions in 2021. In comparison, land use, land-use change and agriculture contribute around 60% of total CO_2-eq emissions. Colombia has set a target to reach net zero greenhouse gas (GHG) emissions by 2050 through reducing its energy-related GHG emissions by 90% compared with 2015.

1.1 Overview

Colombia is a medium-sized country located in the northwestern part of South America. It has 3 200 kilometres of coastline, giving access to both the Caribbean Sea and Pacific Ocean. The fifth-largest country in Latin America and the Caribbean by area, Colombia has the third-largest population at 53 million, having grown by an average of 1.4% per year for the past decade – a growth rate more than 50% higher than the rest of Latin America and the Caribbean. The country's population increased by just over half a million in 2024 alone. It is also younger than in many advanced economies, with a median age of 32.7 years. However, declining birth rates and rising life expectancy are slowly ageing Colombia's population. The country's population is also highly urbanised, with 83% living in cities, and is largely concentrated in the central Andean region where Bogotá, the national capital, is situated, and the coastal regions.

Table 1.1 ▹ Key indicators in Colombia, 2000-2024

				2000-2024	
	2000	2010	2024	Change	CAAGR
Population (Millions)	39.1	44.1	52.8	35%	1.4%
GDP (USD billion PPP [2024])	491	727	1 133	131%	4.1%
GDP per capita (Thousand USD PPP [2024])	13	17	21	71%	2.6%
Urbanisation (%)	73.9%	77.9%	82.7%	9 pp	0.5%
Poverty rate (%)	23.9%	13.1%	7.7%	-16 pp	n.a.
Inequality (Gini)	58.4	54.6	54.8	-6%	n.a.
Global gender gap	-	0.7	0.7	-	n.a.
Electricity access rate (%)	87%	95%	93%	6 pp	n.a.
Clean cooking access rate (%)	78%	85%	92%	14 pp	n.a.
Total energy supply (PJ)	1 105	1 341	2 027	83%	2.9%
Total energy supply per capita (GJ)	28	30	38	36%	1.5%
Share of fossil fuels in total energy supply (%)	76.5%	75.9%	75.9%	0 pp	0.0%
Share of renewables in electricity generation (%)	75.5%	70.7%	63.8%	-11 pp	-0.8%
Energy sector CO_2 (Mt CO_2)	62.7	66.4	105.7	69%	2.5%
Energy intensity (MJ per USD PPP)	2.3	1.8	1.8	-20%	-1.1%
Energy intensity excl. TUOB (MJ per USD PPP)	2.1	1.7	1.7	-17%	-0.9%
Carbon intensity of TES (t CO_2/MJ)	56.7	49.5	52.2	-8%	-0.4%

Notes: CAAGR = compound average annual growth rate; GJ = gigajoule; MJ = megajoule; Mt = million tonnes; n.a. = not applicable; PJ = petajoule; pp = percentage points; PPP = purchasing power parity; t = tonne; TES = total energy supply; TUOB = traditional use of biomass. Poverty rate is the proportion of the total population living on less than USD 3 per day (2021 PPP). Global gender gap ranges from 0 to 1, with 1 reflecting total equity, 0 reflecting total inequity. The 2024 poverty and electricity access rates are based on 2023 data.

Sources: World Bank (2025a), UN DESA (2025), IMF (2025a), WEF (2025), WEF (2010), World Bank (2024), and OLADE (2024).

The modern economy of Colombia includes activities in fossil fuels, metals, agriculture and services. Economic growth was robust throughout the 20th century, and since the turn of the millennium both inflation and unemployment have been relatively stable omitting the impacts of the COVID-19 pandemic. During 2025 Colombia's GDP is expected to rise by 2.4% – slightly ahead of the 2.0% expected for Latin America and the Caribbean as a whole.

The clean cooking access rate has improved from 78% in 2000 to 92% in 2024, well above the global average of 76%, while electricity access rate increased from 87% to 93% over the same period, also above the global average of 91%. Fossil fuels account for over 76% of Colombia's energy demand – higher than nearby countries such as Brazil and Chile, which are below 65% – and 45% of its exports are concentrated in oil and coal, reflecting the country's broad dependence on conventional energy sources. This dependence creates both risks for fiscal stability and opportunities to diversify through renewable energy development.

1.2 Economic and social context

Colombia's economy showed remarkable resilience during Latin America's "lost decade" of the 1980s. While regional growth stagnated, Colombia maintained average GDP growth of 3.3%, down from 5.6% in the 1970s but still close to double the regional average, making Colombia one of the best performers in Latin America and the Caribbean.

Figure 1.1 ▷ Annual rate of change in GDP in Colombia, 1971-2024

Colombia's GDP has grown by an annual average of 3.6% since 2000

Source: IEA analysis based on IMF (2025a).

In 1999, Colombia entered its first recession since the Great Depression, with GDP contracting by 4.2% in a single year and unemployment climbing to around 20%. The crisis was triggered by reduced capital inflows, compounded by high interest rates causing indebtedness of households, firms and the government at the time. Following structural reforms, the economy recovered swiftly, recording average annual GDP growth of 3.8% per year from 2000 to 2019.

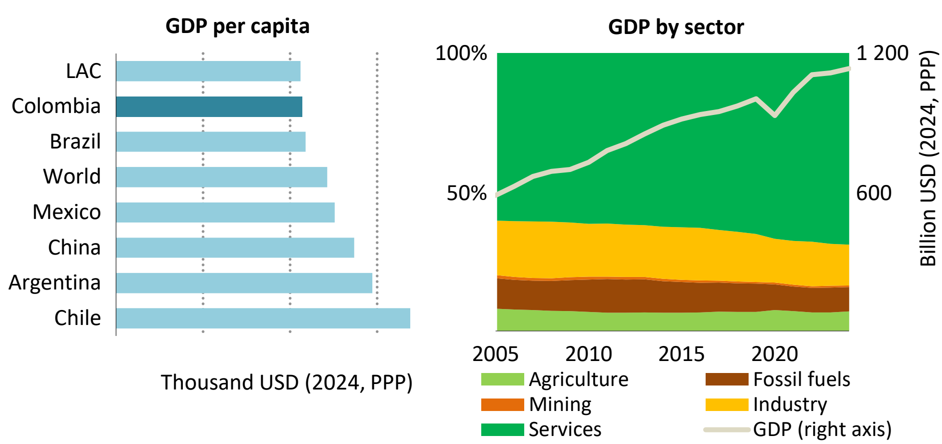
In 2020, the COVID-19 pandemic caused Colombia's GDP to fall by 7.2%. The economy rebounded quickly, with output in 2021 expanding by 10.8%, surpassing pre-pandemic levels. Growth moderated thereafter, with GDP rising by 1.7% in 2024 (0.7% per capita).

1.2.1 GDP structure

Colombia's GDP per capita stood at about USD 21 500 (2024, PPP) in 2024. This level is slightly above the average for Latin America and the Caribbean, but remains below the global average and less than half the OECD benchmark. The economy is predominantly service based, with services accounting for nearly 70% of GDP and increasing in importance over time. Industry's contribution has gradually declined, from around 20% in 2005 to about 15% in 2024.

Fossil fuel extraction – oil, gas and coal – consistently represents close to 10% of GDP, underscoring the economy's dependence on natural resources. Agriculture, forestry and fishing accounted for roughly 9.3% of GDP in 2024 and continue to play a significant role; their share of the economy is nearly 50% larger than in nearby countries such as Peru (World Bank, 2025b).

Figure 1.2 ▹ GDP per capita in 2024, and GDP breakdown by sector in Colombia, 2005-2024



With strong economic growth, Colombia's GDP per capita is higher than the Latin American average, but remains below the world average, with services taking a rising share of GDP

Note: LAC = Latin America and the Caribbean.

Source: IEA analysis based on (IMF, 2025b).

Colombia's exports account for 16% of national GDP, underscoring the significant role of foreign trade in the country's economy. Despite its strategic location and multiple trade agreements, export diversification remains limited, with commodities leading exports.

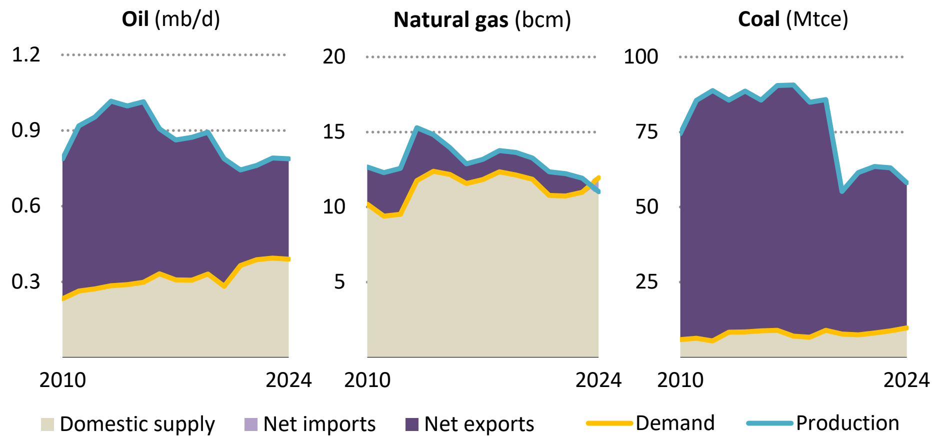
In 2024, total exports reached USD 49.5 billion and fossil fuels accounted for 45% of exports, leaving the country vulnerable to global commodity price fluctuations. Oil remained the top export, followed by coal and coffee. Imports reached USD 64.1 billion, with nearly half coming from the United States and China, led by transport equipment and machinery, resulting in an overall trade deficit for Colombia (DANE, 2024).

1.2.2 Resources

Fossil fuels

Fossil fuels have long led Colombia's exports, accounting for about 57% in 2010. By 2024, their share had declined to around 45%, with oil alone comprising 30%. Colombia was the fourth-largest crude oil producer in Latin America and the Caribbean in 2024, behind Brazil, Venezuela and Argentina (IEA, 2025). Crude oil output averaged nearly 780 000 barrels per day, of which less than half was used domestically, although production has generally trended downwards since its 2013 peak. In 2024, Colombia held around 2 billion barrels of oil reserves, and oil remains the country's most traded energy commodity, accounting for almost 30% of total export revenues. In 2024, Colombia's main crude oil export destinations were the United States, India, China and Spain, with Panama serving primarily as a transit hub for shipments to the Pacific Basin. In the first half of 2025, crude oil exports amounted to 78 million barrels, around 5% lower than in the first half of 2024 (Kpler, 2025).

Figure 1.3 ▻ Fossil fuel imports and exports in Colombia, 2010 and 2024



Colombia is a net exporter of oil and coal; it became a net importer of natural gas in 2024

Note: bcm = billion cubic metres; mb/d = million barrels per day; Mtce = million tonnes of coal equivalent.

Colombia has historically been a notable natural gas producer and exporter, with remaining reserves of about 80 billion cubic metres (bcm). However, with declining production and growing demand, in 2024 the country became a net importer, bringing in around 2.5 bcm of liquefied natural gas (LNG), mainly from the United States and Trinidad and Tobago.

Colombia stands out as Latin America and the Caribbean's leading coal producer, making it the world's tenth-largest producer and sixth-largest exporter in 2023. More than 90% of all production is exported, mainly to Europe and the Mediterranean region. Despite vast reserves of over 4 500 Mt – enough to supply the country for more than 50 years – coal exports have gradually declined over time (MME, 2021).

Renewable resources

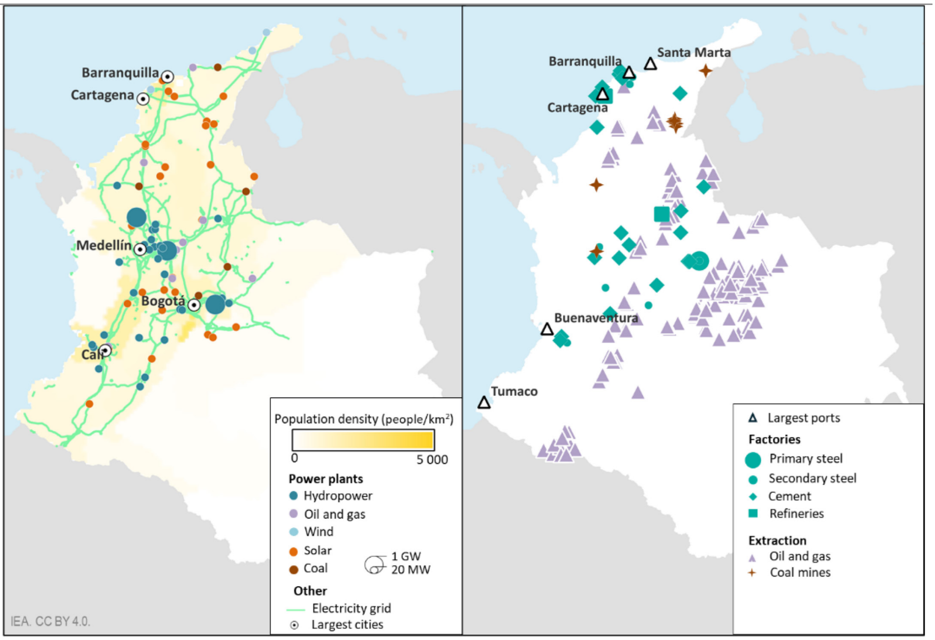
Colombia has significant hydropower resources with room to expand further. However, opportunities for large-scale expansion may face challenges, as the potential development of new dams faces social opposition and additional reservoir capacity is limited by geography. As it stands only 6% of the total installed hydropower capacity has reservoirs that can serve as seasonal storage (IEA, 2023).

Solar photovoltaics (PV) and onshore wind have emerged as growth areas in recent years due to wide resource availability – their combined installed capacity in 2024 was just over 2 gigawatts (GW). In addition, Colombia has some of the best natural conditions for offshore wind in the world, attracting private sector interest in developing projects. The country's Caribbean coastline has been estimated to have total technical resource potential of 109 GW (MME, 2022). However, it features many protected areas and critical habitats. Taking environmental, social and technical constraints into consideration, its developable potential is still estimated at about 50 GW, which is nearly 2.1 times the country's total existing generation capacity. Regulatory and investment barriers remain, such as complex permitting procedures, limited transmission infrastructure and the form of contractual agreements. Other renewables such as geothermal and bioenergy are also present in Colombia, although to a lesser extent. Colombia's geothermal potential is estimated at around 1 170 megawatts (MW), concentrated mainly in the volcanic regions of Caldas, Risaralda and Tolima, and a pilot exploration project has started in the volcanic region of Nariño.

Energy-related infrastructure

The majority of Colombia's energy-related infrastructure is in the more densely populated north-west of the country. Most of its hydropower capacity – the well-established backbone of Colombia's power sector – is located close to the major cities Bogotá and Medellín. Solar PV and wind capacity is growing along the northern coastline. Colombia's major ports are located on both the Caribbean and Pacific coastlines for the export of its crude oil production.

Figure 1.4 ▷ Overview of Colombia's existing energy-related infrastructure



Colombia's hydropower resources are generally located close to its main population centres. Ports on both the Pacific and Caribbean coasts aid market access for oil exports

Note: km² = square kilometre.

Sources: IEA analysis based on power plants from Global Energy Monitor (2025a); electricity grid from Open Street Map (2025); population density from Global Human Settlement (2023); largest ports from Marine Insight (2022); coal mines from Global Energy Monitor (2025b); cement and steel production plants from Spatial Finance Initiative (2021); oil and gas extraction sites from Global Energy Monitor (2025c).

1.2.3 Social setting

In recent decades Colombia has experienced rapid urbanisation. The share of the population living in urban areas nearly doubled between 1950 and 2018, according to the latest national census (OECD, 2022a). By 2024, more than 80% of the population was living in cities, with Bogotá alone having around 8 million inhabitants. Bogotá and a few other major cities, including Medellín, Cali, Barranquilla and Cartagena, account for much of population and economic activity. Colombia's population is relatively young compared with the OECD average, although ageing pressures are beginning to emerge driven by declining fertility rates.

Despite progress in reducing poverty and expanding the middle class, inequality and insecurity remain high. The Gini index stood at 55.3 in 2024, well above the OECD average. Poverty rates have declined, but relative poverty varies widely between departments, ranging from 14% to 66%. This 52 percentage point gap is more than three times higher than the OECD average difference of around 16 points, indicating Colombia's stark regional disparities (OECD, 2024). Between 2005 and 2016, house prices in Colombia increased significantly, far outpacing household income growth and making housing increasingly unaffordable for many families.

In 2024, about 8% of the population still relied on wood for cooking and heating needs (UN DESA, 2025). These households are mostly concentrated in remote areas where people are disproportionately affected by the lack of access to clean cooking solutions, often due to socioeconomic challenges and geographic isolation. The adoption of liquefied petroleum gas (LPG) and natural gas cooking has contributed to improvements, especially LPG, whose use in both urban and rural areas has been successfully promoted by the Colombian government through dedicated public trust funding programmes known as FONENERGIA (Law 2099 of 2021). By 2030, the government aims to halve the remaining population without access to electricity and clean cooking by connecting 100 000 families to electricity supplies and providing 200 000 families with clean cooking every year.

1.2.4 Investment and labour market

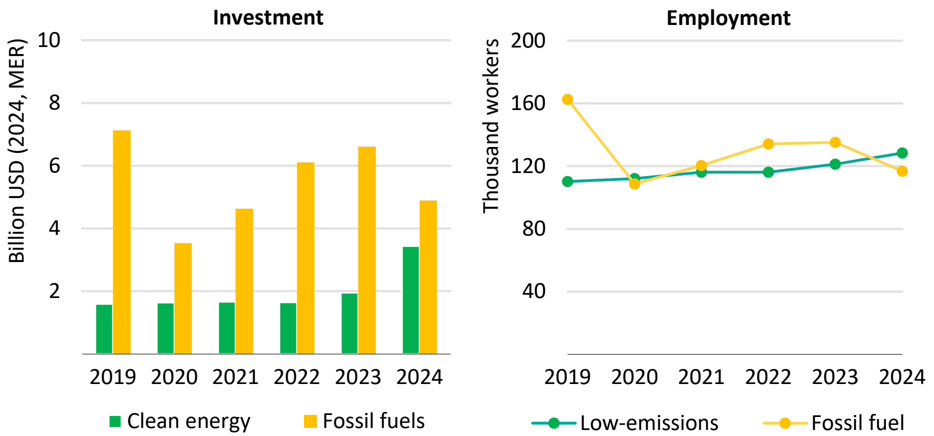
Clean energy investment accelerated sharply in 2024, surpassing USD 3 billion. While in previous years such investment had remained at less than one-third of fossil fuel levels, in 2024 it rose to about 70%. Overall, clean energy investment increased by more than 75% year-on-year, contrasting with a 25% decline in fossil fuel investment. This shift has been driven mainly by renewables, grid and storage infrastructure, energy efficiency measures and end-use electrification. Foreign direct investment has also supported this momentum, doubling between 2010 and 2019, with inflows into renewable energy growing nearly eightfold between 2018 and 2021 (OECD, 2022b).

The broader labour market is characterised by high levels of informality, which limits the inclusiveness of economic growth. Around 60% of Colombia's labour force was considered informal in 2014 based on contributions to health and pension systems. While this share declined to around 48% in 2024, it remains elevated despite periods of strong economic growth (ILO, 2024).

The surge in investment is reshaping Colombia's employment patterns, with substantial potential for job creation in low-emissions energy, most specifically in grid, power generation, efficiency and bioenergy activities. Grid-related roles accounted for over 30% of low-emissions employment in 2024, with the majority in distribution. Power generation jobs are largely driven by hydro, alongside growth across sectors including manufacturing, construction, utilities and wholesale activities. This reflects the broader expansion of low-emissions fuel across multiple parts of the economy.

Overall, low-emissions jobs now represent 52% of total energy employment, surpassing fossil fuels in 2024. In contrast, fossil fuel employment fell by 33% in 2020 and has yet to recover to pre-COVID levels, with coal and oil jobs down by 35% and 26% respectively from 2019 levels. While investment in fossil fuels would lessen this decline, new projects in clean energy are reinforcing the shift – the 2.4 GW Ituango hydropower plant stands out as a flagship example of how clean energy investment is generating employment and strengthening Colombia's economy.

Figure 1.5 ▻ Energy investment and employment in Colombia, 2019-2024



Clean energy investment in Colombia rose by over 70% in 2024, driving stronger clean energy employment

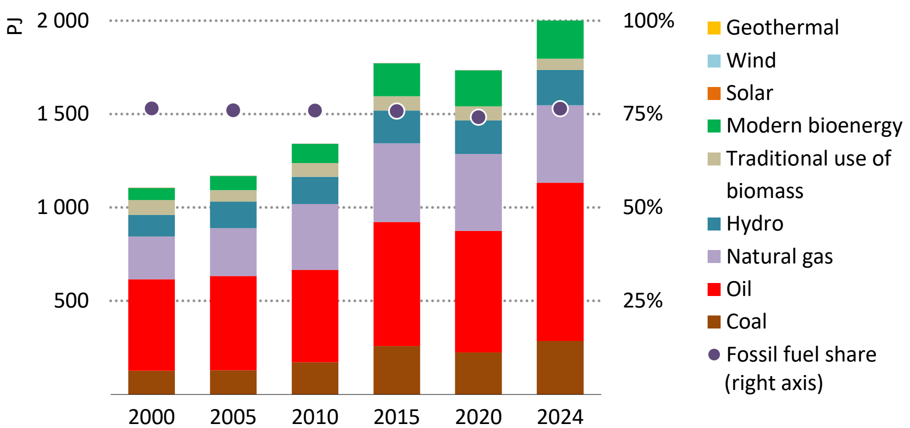
1.3 Energy and emissions trends

1.3.1 Energy demand and supply

Although Colombia possesses abundant renewable energy potential, particularly hydropower, wind and solar, its energy system has historically relied heavily on fossil fuels. The share of fossil fuels in total energy demand has remained flat, unchanged from 76% between 2000 to 2024. Over the same period, absolute fossil fuel consumption grew by about 83%, underscoring the country's continued reliance on coal, oil and gas amid rising energy demand.

By 2024, Colombia's oil production had slightly increased by 100 000 barrels per day compared with 2000, far behind rates of increase in domestic demand. Colombia's oil comes from onshore production, with the Llanos Basin and the Middle Magdalena Valley being the most significant oil plays. Since 2019, coal production has declined following the closure of the Prodeco mines, while investment in new capacity has lagged amid market headwinds and weakening long-term demand for thermal coal. Coal production remains a vital sector in some parts of Colombia – in the departments of El Cesar and La Guajira, which together account for over four-fifths of national production, coal plays a key part in the regional economy's investment and employment (Energy Analytics Institute, 2024).

Figure 1.6 ▻ Total energy demand by fuel in Colombia, 2000-2024



IEA. CC BY 4.0.

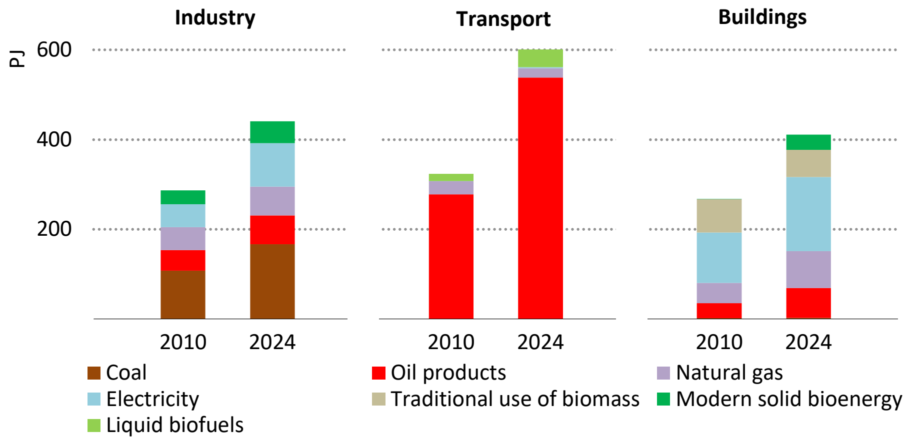
Oil has been the main fuel in Colombia's energy mix for over five decades, while modern bioenergy has been the fastest-growing fuel

Natural gas production peaked in 2013 and has generally declined since, largely due to the depletion of mature fields and a lack of new developments. While most of Colombia's gas consumption is still met by domestic production, the country has increasingly relied on LNG imports over the past decade to supply rising demand. This marks a major shift from Colombia's historical position as a net exporter of natural gas, underscoring the growing mismatch between domestic supply and demand. LNG imports arrive through the Cartagena terminal, which experienced record volumes in both 2023 and 2024, reaching 1.03 bcm and 2.67 bcm respectively (S&P Global, 2025). Traditional bioenergy use in Colombia has declined since 2000, increasingly displaced by other energy sources. This trend reflects progress in clean cooking access. Conversely, modern bioenergy has increasingly played a larger role in Colombia's energy mix, growing from 65 PJ in 2000 to 218 PJ today.

1.3.2 Energy demand

Colombia's demand for energy services has risen steadily over the past quarter of a century, driven by sustained economic growth, rising incomes and increasing urbanisation. Colombia's industrial base has also expanded, with growth concentrated in steel production and light manufacturing. Heavy and light industries serve both rising domestic demand and export markets, with industrial output nearly doubling since 2000. Growth in output has led industrial energy demand to increase steadily since 2010, growing from 288 PJ in 2010 to 445 PJ in 2024, primarily from growing coal and electricity consumption. Modern biomass use has also expanded, especially in light industries such as the food industry, where agricultural residues are used for heat and cogeneration.

Figure 1.7 ▷ **Demand by sector in Colombia, 2010 and 2024**

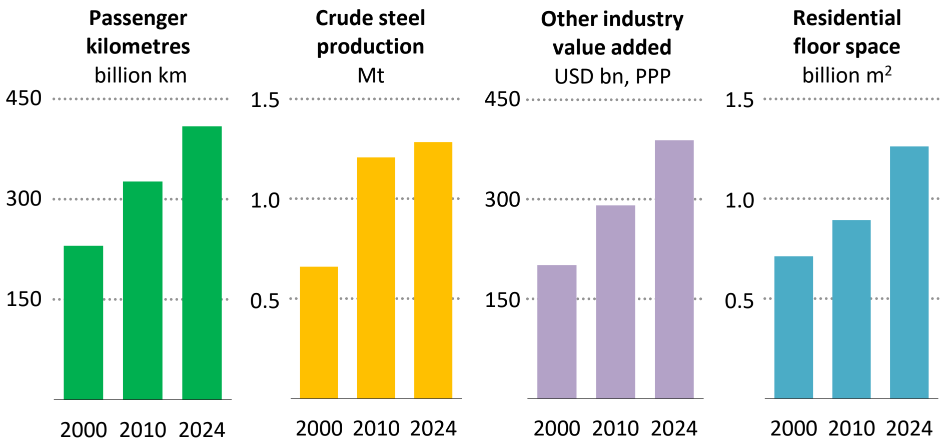


Oil consumption growth has been driven by the transport sector, while the buildings sector has driven increased electrification

The overall demand for transport has grown significantly as Colombians have gained purchasing power and greater mobility. The average Colombian now travels 32% further by road per year than in 2000, requiring continued investment in road infrastructure and public transit. Growth in transport demand has overwhelmingly been met by internal combustion engine vehicles since 2010. Oil remains the primary energy source in the transport sector, growing by 261 PJ between 2010 and 2024. However, biofuel mandates have led to some growth in liquid biofuels, increasing from 16 PJ in 2010 to 40 PJ in 2024, serving as a key policy tool in moderating growing oil demand, as well as supporting the domestic biofuel industry.

Residential floor space in Colombia grew by 77% between 2000 and 2024, while the population increased by only 35% over the same period. Colombians now live in homes that are 12% larger than in 2000, reflecting a shift toward larger, more energy-intensive dwellings and the continued expansion of the urban housing stock. Higher incomes and more space per household have raised demand for heating, cooling, lighting and appliances. Traditional biomass use in buildings has fallen from 79 PJ in 2000 to 60 PJ in 2024, as improved access to modern energy and clean cooking solutions reduces reliance on firewood for cooking and heating. At the same time, electricity demand for buildings is growing fastest due to expansion in the use of appliances and air conditioning, particularly in urban centres. Overall, this transition represents a modernisation of the energy mix in buildings, with substantial co-benefits for indoor air quality and quality of life.

Figure 1.8 ▻ Key drivers of energy services demand growth in Colombia, 2000-2024



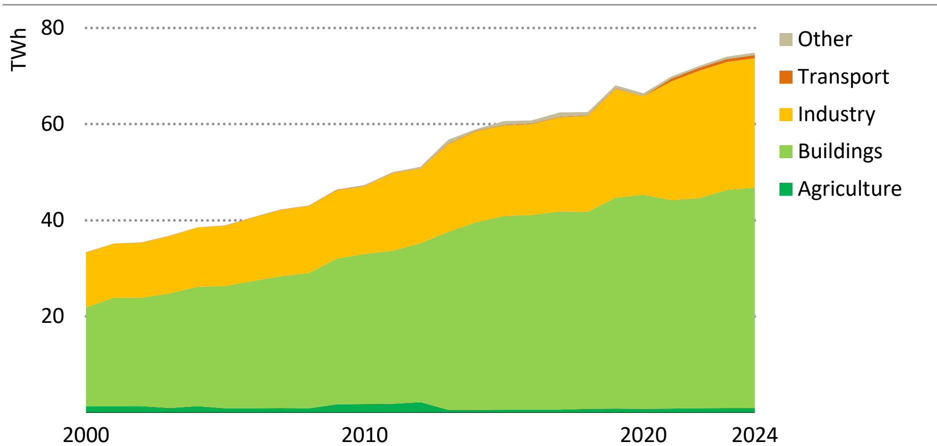
IEA. CC BY 4.0.

Rapid growth across housing, industry and transport have been key drivers of Colombia's energy demand growth

1.3.3 Electricity sector

Colombia's electricity demand has doubled since 2000, increasing by over 40 terawatt hours (TWh), an average annual increase of around 3.5%. This notable increase is well above the Latin America and the Caribbean average, which was only 2.6%, as well as being higher than the global average of 3.1%.

Figure 1.9 ▻ Electricity demand by sector in Colombia, 2000-2024

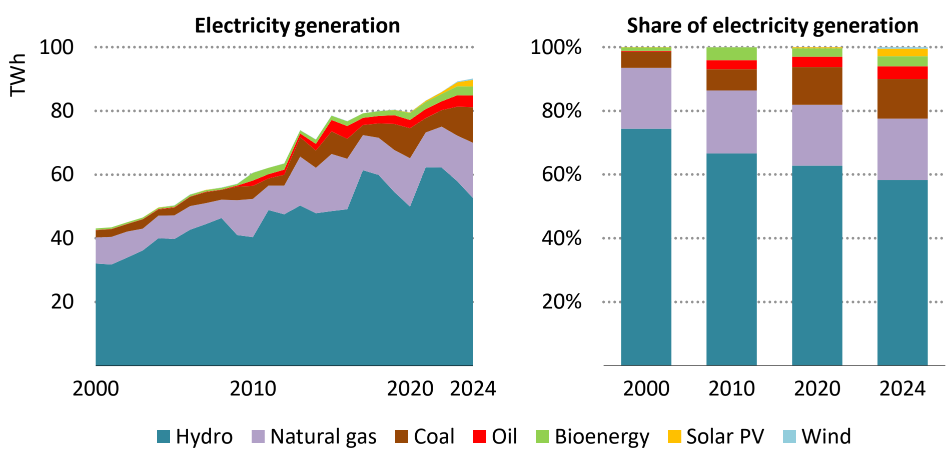


IEA. CC BY 4.0.

Electricity demand has doubled since 2000, led by increases in buildings and industry

The buildings sector has led the change in Colombia, accounting for 60% of the total increase in electricity demand over the period since 2000. This has primarily been driven by growth in end-uses – including cooking, heating, cooling and appliances – along with the trend towards larger dwellings and the overall expansion of housing stock. The industry sector has also grown substantially in Colombia since 2000, accounting for another 35% of the total increase in electricity demand. Driven primarily by on-site use in the growing steel manufacturing industry, as well as the electrification of light industries such as the food industry, electricity use in industry has accelerated even further in recent years.

Figure 1.10 ▷ Electricity generation by source and share in Colombia, 2000-2024

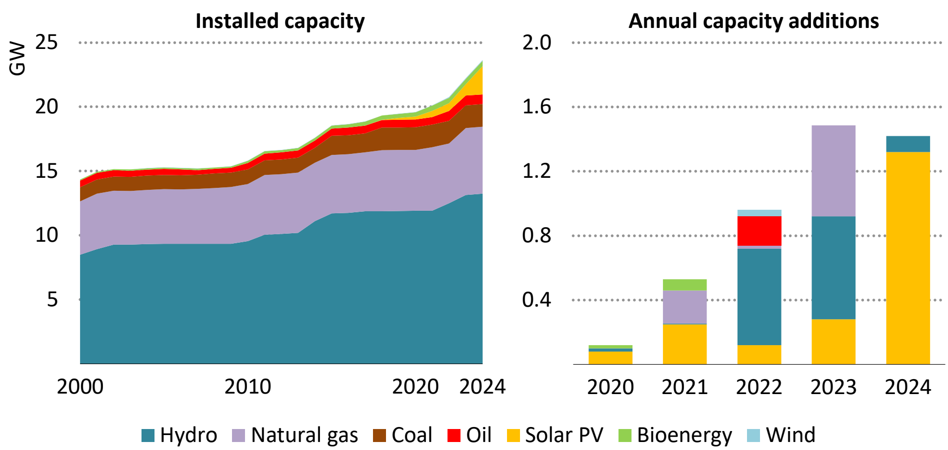


Electricity generation has doubled since 2000, with an increasing share met by fossil fuels

Hydropower has long been the cornerstone of Colombia's electricity mix, accounting for the vast majority of generation and reaching over 80% in the early 2000s. However, despite increasing in absolute terms, its share of electricity generation has declined to around two-thirds over the past five years. Although generation from hydro plants has increased over recent decades, it is also subject to notable interannual variability, driven in part by the El Niño and La Niña cycles, which affect rainfall and temperature. These fluctuations may result in variations in capacity factors, which require system operators to undertake careful planning to ensure reliability. For example, in 2017 hydro generation experienced a 25% upward shift compared with the previous year. Renewables have continued to diversify in recent years, with bioenergy rising since 2010 and accelerated growth in solar PV and wind over the past five years. As a result, non-hydro renewables accounted for around 5% of total electricity generation in 2024. Despite these increases, the overall share of renewables in the electricity mix has declined by around 5 percentage points on average since 2000, although it remains high.

Driven by the recent rise in electricity demand and interannual fluctuations in hydro, fossil fuels have increased to account for around 30% of total generation over the past five years. Since 2000, natural gas-fired generation has more than doubled while coal-fired generation is more than five times higher. Oil-fired generation, which has grown consistently since around 2010 in remote areas, now ranks as the fourth-largest source of electricity generation in Colombia, following hydro, natural gas and coal.

Figure 1.11 ▷ Installed electrical capacity by source in Colombia, 2000-2024



IEA. CC BY 4.0.

Renewables, led by hydro and solar PV, account for two-thirds of all capacity additions since 2000

Since 2000, Colombia has expanded its hydro capacity by over 50%, rising from around 8 GW to 13 GW. This growth includes the commissioning of major projects such as the 820 MW Sogamoso Hydroelectric Project in late 2014 and the 400 MW El Quimbo Dam in 2015, along with the partially completed 2.4 GW Ituango plant where final completion of all turbines is expected in 2027. It also includes around 120 small hydro plants (up to 10 MW). Fossil fuel capacity growth has been steady but more modest, with just over 3.5 GW added, primarily in the form of natural gas power plants. These include both open-cycle and combined-cycle units, as well as retrofits such as the Termocandelaria expansion project, which upgraded from open-cycle to combined-cycle in 2023, improving both efficiency and output. Coal capacity also grew marginally, with new projects such as the Gecelca 3.2 and the Termotasajero II, while oil-fired capacity additions have largely been small, decentralised diesel generators.

Much of Colombia's fossil fuel fleet is ageing, with many plants approaching 30 years of operation and numerous coal-fired plants already above 40 years of operation. The gas-fired fleet is on average five to ten years younger than coal, while the average age of oil-fired units varies widely depending on location. Although the nominal lifespan of these types of plants is around 40 years, refurbishments and system upgrades are quite common, with readily available components in many cases. Bioenergy has also contributed to capacity expansion over the past 15 years, albeit on a smaller scale.

Over the past five years, solar PV has become the main new source of capacity that is helping to meet demand growth. Large-scale projects such as Guayepo I and II – which were completed in 2024 with a combined capacity of nearly 500 MW – have led this expansion, along with the advent of smaller rooftop and residential installations. Despite only beginning to ramp up around 2020, solar PV has accounted for around 20% of total capacity additions in Colombia since 2000. Recent policy support has helped to foster this growth, including competitive auctions that awarded 4.4 GW of solar capacity to developers. While most of this growth has been centred near areas of high electricity demand, recent initiatives have begun expanding solar access to rural communities, increasing both renewable generation and electricity access. Wind power has also added to Colombia's installed capacity over the past three years, with smaller onshore installations such as the 20 MW Guajira I that may signal the beginning of greater changes to come as the country begins to explore its wind potential on the path towards net zero emissions. Wind resources are strong for both onshore and offshore sites; however, recent challenges including environmental permitting delays and a lack of social licence will need to be resolved for wind to grow ambitiously in the future. Initiatives such as the Optimised Environmental Licence for Wind Projects (LAEólica) that help to reduce timelines and administrative burdens without compromising environmental standards or impacting local communities will support the expansion of wind power.

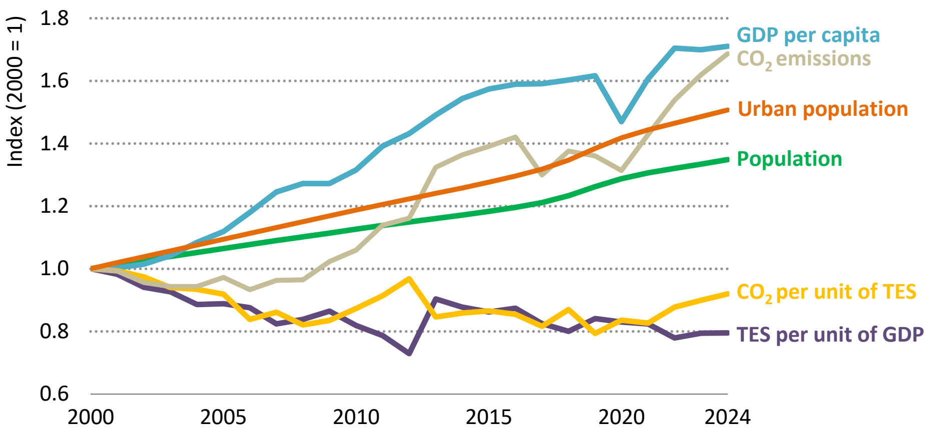
1.3.4 Energy sector emissions trends

Between 2000 and 2024 Colombia's population and GDP per capita grew by 35% and 71% respectively, exerting strong upward pressure on energy use and emissions. Furthermore, the urban population has also grown faster than the general population, with urbanisation increasing from 74% to 83% over the same period. Generally, urbanisation increases energy consumption – as people move to cities, higher incomes, greater access to energy services and more energy-intensive lifestyles drive demand.

Despite growth in population, incomes and energy demand, Colombia now pollutes less and uses less energy for every dollar of GDP than in the past. From 2000 to 2024, emissions and energy intensity per dollar of GDP have declined by 8% and 20% respectively, reflecting improvements in technology and energy management, and changes in fuel preferences, underscoring a gradual shift toward less energy-intensive economic growth. However, Colombia has yet to achieve a significant decoupling of economic and energy demand growth as both trends have shown little improvement over the past decade.

Energy-related emissions accounted for roughly 30% of Colombia's total emissions in 2021 (UNFCCC, 2024). Between 2000 and 2021 energy emissions increased by 48%, rising from 62 Mt CO_2-eq to 92 Mt CO_2-eq, albeit declining slightly from 2019 levels. In addition to emissions from the energy sector, Colombia released large quantities of greenhouse gases (GHGs) from other sources, in particular CO_2-eq from land use, land-use change and forestry, which represented almost 40% of total emissions in 2021. Land use, land-use change and forestry emissions stem mainly from deforestation (forest conversion to pasture, cropland and settlements) and forest degradation, with smaller contributions from fuelwood extraction. Agricultural emissions, representing 20% of the 2021 total, were mainly methane from cattle and livestock digestion, nitrous oxide from agricultural soils, and the burning of crop residues.

Figure 1.12 ▹ Change in key energy-related variables in Colombia, 2000-2024



Colombia's population, per-capita income and emissions have grown, although its energy intensity has declined

Note: TES = total energy supply.

1.4 Energy and climate policy landscape

Colombia's energy and climate objectives are outlined in the country's Long-Term Strategy E2050, which sets out an overarching objective to achieve net zero GHG emissions by 2050 as well as sectoral adaptation and mitigation targets. By 2050, Colombia aims to reduce its GHG emissions by 90% compared with 2015. The final 10% of emissions are to be captured or offset through land-based CO_2 sequestration. Pathways for achieving sectoral goals are laid out in sectoral climate change management plans (referred to as PIGCC), including one for the energy sector. Interim targets are established in the 2021 Climate Action Law and Colombia's Nationally Determined Contributions (NDCs) under the Paris Agreement. In its submission to the United Nations Framework Convention on Climate Change (UNFCCC) in 2020, Colombia stated the aim to reduce its emissions by 51% by 2030 compared with its baseline scenario, corresponding to a cap of 169 Mt CO_2-eq. A subsequent declaration in

September 2025 stated the aim to cap its GHG emissions at between 155 Mt CO_2-eq and 161 Mt CO_2-eq in 2035.

Colombia's energy and climate goals are aligned with the broader sustainable development agenda in its National Development Plan 2022-2026, which sets priorities for investment in the energy transition (Departamento Nacional de Planeación, 2023). In 2024, the government published a Just Energy Transition Roadmap, outlining how the country intends to decarbonise while ensuring that workers, communities and vulnerable groups benefit equitably from the transition (MME, 2024a). In the roadmap the government affirms that an equitable energy transition requires universal access to affordable clean energy services.

1.4.1 Universal access policies

Over the past two decades Colombia has made notable progress towards its goal of achieving universal access to electricity and clean cooking. Government initiatives – like the National Rural Electrification Plan and the Massive Natural Gasification Programme – have driven this change. Subsidies for natural gas connections and LPG cookstoves, distributed via the Social Energy Fund, proved particularly impactful.

Despite this substantial progress, Colombia remains off track to achieve United Nations Sustainable Development Goal 7 – ensuring universal access to clean cooking by the end of the decade. While clean cooking access is almost complete in urban areas, reaching the remainder of the population in more remote areas requires a shift in policy focus from natural gas to LPG and electric cookstoves.

Most recently, Colombian policy makers have taken measures to support energy communities and distributed generation in order to expand access to reliable and affordable electricity in remote areas. As of 2025, Colombia has established a clear legal framework for energy communities and their integration into the national energy system, as well as guidelines for their registration and fiscal support. The Colombia Solar programme, introduced in 2025, promotes self-generation among low-income households and small businesses, subsidising up to 60% of the cost of installing on-site solar energy.

Table 1.2 ▷ Key universal access policies in Colombia

Policy	Status
National electricity access targets	Yes
National clean cooking targets	Partially
Government support for distributed generation	Yes
Subsidies for clean cookstoves	Partially
Government spending on grid expansion to remote areas	Yes

Policy implemented: Yes No Partially

1.4.2 Energy supply policies

Colombian policy on fossil fuel extraction has undergone a marked shift in recent years. Until relatively recently, clean energy sources were presented as opportunities to diversify energy supply, rather than opportunities to displace fossil fuels. Colombia's Long-Term Strategy E2050 first set a vision of declining fossil fuel use, calling for a progressive reduction in the dependence on fossil fuels in the energy matrix and the national economy. This was followed by the 2023 announcement that Colombia would stop granting new exploration licences for oil and gas. In that same year, Colombia joined the Fossil Fuel Non-Proliferation Treaty.

Colombia has developed a mature policy framework for biofuels in road transport, anchored in Laws 693 (2001) and 939 (2004), which established mandatory blending of ethanol with gasoline and biodiesel with diesel. The policies are supported by tax incentives, price stabilisation mechanisms and blending mandates that secure steady demand for domestic producers. Put together, these measures have created one of Latin America and the Caribbean's largest biofuels markets, producing around 500 million litres of sugarcane ethanol and more than 700 million litres of palm oil biodiesel annually. More recent bioenergy policies have focused on the aviation sector. In 2024, the government launched the country's first national sustainable aviation fuels (SAF) roadmap, setting production targets for 2035 and 2050. Colombia also joined the International Civil Aviation Organization's ACT-SAF programme to further develop regulatory and technical capacity in this field.

In 2021, Colombia launched a Hydrogen Roadmap, updated through the Just Energy Transition Roadmap in 2024, to guide pilot projects, attract investment, and create rules and incentives for developing a domestic hydrogen industry. Since then, the government has amended Law 2099 to clarify the legal status of hydrogen and to ensure that hydrogen projects are eligible for the same funding incentives as non-conventional renewables. Over 30 pilot and pre-commercial hydrogen projects have been launched, with several already operational, including a refinery-scale low-emissions hydrogen plant in Cartagena and hydrogen-powered buses in Bogotá.

Table 1.3 ▷ Key energy supply policies in Colombia

Policy	Status
Phase-out of domestic fossil fuel extraction	Yes
Biofuel mandate for road transport	Yes
SAF mandate for aviation	No
Financial support to incentivise SAF production and consumption	Partially
Fiscal incentives for low-carbon hydrogen production	Yes

Policy implemented: Yes No Partially

1.4.3 Power sector policies

Over the past 10 years, policy makers have sought to grow and diversify clean power generation by supporting non-hydro renewables such as solar PV, wind and biomass, as well as expanding small-scale hydro. Law 1715 of 2014 laid the ground for the expansion of these renewables, primarily by introducing tax incentives and other fiscal support. Long-term auctions were used to scale up solar PV and onshore wind, with two auctions in 2019-2021 awarding contracts for almost 3 GW of capacity for a 15-year period, as well as the 4.4 GW auction in 2024. Between 2022 and 2024, the legal framework for offshore wind development was reformed through Resolutions 40284, 40712 and 40368 in order to adjust the rules for the offshore area allocation process and amend the timeline and provisions for the use of maritime areas.

Although fossil fuel generation has also grown significantly over the past two decades, there are signs that this trend may change in the coming years. In 2023, Colombia joined the Powering Past Coal Alliance, pledging to phase out existing unabated coal-fired power, avoid building new coal-fired power without operational carbon capture and storage, and otherwise support coal phase-downs. Colombia reinforced this commitment in 2024 by signing the joint declaration "No New Coal-Fired Power Plants in LAC" with other Latin American and Caribbean countries.

Despite notable advances, variable renewables still accounted for only 3% of Colombian power generation in 2024. Uptake has been slowed by social acceptance and environmental permitting obstacles, which have extended commissioning timelines for solar PV and onshore wind projects. Long lead times to finalise permits increase project risk and create financing challenges. Slow transmission infrastructure development is also affecting the pace of expansion.

Recognising these challenges, in 2025 Colombia introduced LASolar, a fast-track licensing mechanism for medium-sized solar projects, aiming to cut environmental licensing times by around 70%. Lawmakers have also proposed exempting wind projects under 100 MW from full environmental licensing to shorten approval times. In 2024, the Ministry of Mines and Energy unveiled the 6 GW Plus Plan, which aims to resolve regulatory, social and permitting bottlenecks to accelerate stalled solar and wind projects.

Table 1.4 ▷ Key power sector policies in Colombia

Policy	Status
National targets for clean electricity generation capacity	No
Government investment in grid infrastructure	Partially
Carbon pricing for the power sector	Partially
Financial incentives for low-carbon power generation	Yes
Administrative reform to reduce permitting delays	Partially

Policy implemented: Yes No Partially

1.4.4 *Electrification policies*

In Colombia's Long-Term Strategy E2050, decarbonisation pathways targeting carbon neutrality by 2050 rely on electricity to cover up to 70% of final energy consumption. To achieve this, the share of electricity use in demand sectors must more than triple. Such a rapid transformation can only be achieved if operating expenses of electric technologies are competitive compared with fossil fuel choices. Due to their superior efficiency, electric technologies, such as electric vehicles (EVs) and heat pumps, remain competitive even when the price of electricity is higher than the price of fossil fuels. However, the price of electricity in Colombia today is almost double the price of fossil fuels, which disincentives households from investing in clean technologies.

Recognising this challenge, since 2024 Colombian legislators have initiated reforms of the electricity market reliability mechanism, with the aim of making household electricity more affordable relative to gas (MME, 2024b). At the same time, FEPC (Fondo de Estabilización de Precios de los Combustibles) is undergoing revision to reduce the level of fossil fuel subsidies and thereby align Colombian fossil fuel prices more closely with international markets. While this reform is widely understood to be driven by fiscal considerations, it will nevertheless improve the competitiveness of electric technologies.

A national carbon tax has been in operation since 2017. However, the mechanism currently has a limited role in levelling out the cost of electricity as against other fuels. Carbon prices have increased only marginally since 2017, remaining below USD 7 per t CO_2-eq in 2025. Exemptions include residential consumption of natural gas and LPG and most industrial uses of natural gas. Colombian lawmakers have committed to increasing the cost of carbon by complementing the national carbon tax with a new emissions trading system. The 2021 Climate Action Law requires the system to be fully operational by the end of this decade.

Established in 1994, Colombia's tiered electricity price mechanism ensures that low-income households are provided with a lower electricity tariff (Administrative Department of the Public Function, 1994). While the policy has delivered wide-ranging social benefits, it can only drive electrification in combination with other measures, given that households benefiting from lower rates are the least likely to have the disposable income needed to invest in clean energy technologies.

Successive governments have worked to address the price premium of electric technologies. Colombians purchasing an EV benefit from a lower rate of VAT and reduced annual ownership taxes, as well as a full exemption from import tariffs. The measures have been coupled with an investment drive in public charging infrastructure and mandatory requirements for public procurement of electric buses. Law 1964 requires that all buses purchased are zero-emission vehicles by 2035, with incremental targets to be met as of 2025. The government aims to increase the number of EVs in the national fleet to 600 000 by the end of the decade. In the buildings sector, policies that promote energy efficiency and on-site renewables indirectly benefit some electric technologies, but do not address the upfront cost barrier of electric cookstoves or electric water heaters.

Table 1.5 ▹ Key electrification policies in Colombia

Policy	Status
Financial incentives for industrial decarbonisation/innovation	Partially
National electric vehicle stock targets	Yes
Electric vehicle purchase incentives	Yes
Fiscal measures to reduce the cost of electricity	Partially
Government spending on charging infrastructure	Partially
Financial incentives for electric water heaters	No
Financial incentives for electric cookstoves	No
Carbon pricing for energy-intensive industries	Partially
Public procurement of low-emissions vehicles, buildings and materials	Yes
Financial incentives for industrial heat pumps	Partially

Policy implemented: Yes No Partially

1.4.5 Energy efficiency policies

Colombia's Indicative Action Plan (PAI) for the development of the Programme for the Rational and Efficient Use of Energy (PROURE) aims to reduce energy consumption by 10% in 2030 against the business-as-usual scenario, primarily by implementing measures in the buildings and transport sectors (see Chapter 2, Box 2.1).

In the past decade, the Colombian government has gradually expanded requirements for efficiency labelling of energy-related products, with labelling rules now covering most household appliances. The scope of minimum energy performance standards (MEPS) is more limited, applying only to lighting equipment, refrigerators, freezers and air conditioners, as well as industrial motors. In 2023, lawmakers reformed MEPS for air conditioners and public procurement rules for industrial motors to raise efficiency requirements. In the transport sector, only buses, commercial vehicles and diesel passenger cars are covered by fuel economy standards, despite gasoline vehicles representing the vast majority of passenger car sales.

Since 2016, developers of new buildings have been required to comply with building energy codes. The government has established targets to progressively tighten codes and expand their scope to ensure that by 2050 all new buildings are net zero-carbon buildings. Working with the World Bank, the Colombian government has set up a programme that offers mortgages with preferential interest rates to property buyers of highly sustainable dwellings, certified by Excellence in Design for Greater Efficiencies (EDGE). EDGE buildings achieve superior efficiency than that required by mandatory building codes, and now represent a quarter of all residential construction in Colombia.

Complementing such regulations, Colombian lawmakers have established several financial incentives to promote energy efficiency improvements. Law 1715 of 2014 introduced tax credits for investments in energy efficiency, as well as VAT and import duty exemptions for such measures. It also introduced tax incentives for industrial actors to upgrade natural gas boilers to more efficient models. The same law established Colombia's Fund for Non-Conventional Energies and Efficient Energy Management (FENOGE), which manages the disbursement of household subsidies and loans. FENOGE provides grants and credit lines to major energy efficiency projects that subsidise efficient lighting, cookstoves and refrigeration equipment, among other appliances, for households as well as the purchase of efficient motors in industry. The institution also manages programmes for vulnerable communities, such as programmes offering the replacement of household appliances. The phase-out of inefficient, polluting cookstoves has been one of the main priorities of successive Colombian governments since the early 1990s, primarily via subsidies for natural gas connections and LPG cylinders. The ADMIRE Project, launched in 2016 with UNEP support, explores how public policy instruments can most effectively tackle this issue, providing the government with recommendations on how to adjust the policy framework in years to come.

Currently, Colombia has very few passenger trains relative to its population. Residents of Medellín benefit from the only rapid mass transit system in the country. Buses are the most common mode of public transport. Colombia's Long-Term Strategy E2050 calls for shifting passengers to electric mass transit and growing the role of rail in freight transport. The 2022-2026 National Development Plan designates rail reactivation and mass transit development as national priorities. Several major rail projects are either in development or in the planning phase, such as Bogotá's Regiotram de Occidente and the Cerrejon railway overhaul. In 2024, the government announced plans to invest more than USD 10 billion in projects to expand rail and rapid mass transit in the upcoming planning period.

Table 1.6 ▷ Key energy efficiency policies in Colombia

Policy	Status
Economy-wide energy efficiency targets	Yes
MEPS for industrial motors	Yes
Industry-wide efficiency mandates	Partially
Fuel economy standards for buses and commercial vehicles	Yes
Fuel economy standards for gasoline passenger cars	No
Building energy codes for new construction	Yes
Financial incentives for highly sustainable construction	Yes
Government investment in district cooling infrastructure	Yes
MEPS for household appliances and air conditioners	Partially
Energy performance requirements for public buildings	Yes

Policy implemented: Yes No Partially

Note: MEPS = minimum energy performance standards.

A pathway to net zero emissions by 2050

How do different sectors contribute?

SUMMARY

- This outlook presents a possible pathway for Colombia to meet its target of attaining net zero emissions by 2050 and its current Nationally Determined Contribution (NDC). The pathway is embedded in the Announced Pledges Scenario (APS) in which the ambitions and pledges of all countries and industries are achieved.
- Energy demand drivers are projected to continue, albeit slowing toward 2050. Urban expansion pushes the population to 57 million people by 2035, gradually plateauing at around 59 million by 2050. GDP rises by 2.6% per year until 2035, then slows to 1.8% growth per year, led by industry and services.
- Colombia's net zero pathway unfolds in two phases. From now to 2035, efforts focus on renewable expansion decarbonising the power sector, driving half of a 31 Mt CO_2 reduction and lowering coal and gas use. Colombia also reaches universal access to clean cooking by 2030. In the second phase, after 2035, clean energy adoption accelerates in end-use sectors, reducing the share of fossil fuels in total demand to 12% by 2050. Around half of the 58 Mt CO_2 cut comes from EVs making inroads in the stock, while industry electrification, efficiency gains and fossil-free cooking in buildings account for further reductions.
- End-use energy demand peaks around 2035, with the following decline mainly due to efficiency improvements and electrification, despite activity growth. In transport, EVs drive decarbonisation with a stock of 24 million by 2050 displacing 400 kb/d of oil demand. In industry, electrification and bioenergy substitute fossil fuels; the share of low-emissions fuels in non-energy-intensive industries such as the food industry increases from 48% currently to 93% by 2050. Key decarbonisation measures in buildings are reducing the share of fossil fuels for cooking and water heating from 75% in 2024 to 18% by 2050 and adopting more efficient air conditioners.
- Renewables expansion drives power sector decarbonisation. Electricity demand nearly quadruples by 2050 from 2024 levels as end uses electrify and hydrogen production ramps up. The installed capacity of solar PV rises most from just over 2 GW in 2024 to more than 30 GW in 2035. Wind, hydro, biomass, nuclear and battery storage further underpin the electricity mix decarbonisation. By 2050 almost all electricity generation is low-emissions, as coal-fired generation is phased out and only some natural gas-fired capacity remains to support system adequacy and flexibility.
- Fuel supply shifts significantly in response to evolving demand in the APS. The production of oil, natural gas and coal falls by up to two-thirds by 2035, and continues to decline through to 2050. Meanwhile, low-emissions fuel production rises, reaching 5 kboe/d of emerging biofuels and 1.2 Mt of low-emissions hydrogen by 2050.

2.1 Overview

There are various pathways for Colombia to achieve net zero emissions. These pathways depend not only on policy implementation, technology costs and deployment, and infrastructure development, but also macroeconomic developments and energy prices. These factors are not only influenced by developments in Colombia, but also by the global context. For example, fossil fuel prices – determining the value of Colombian fuel exports – are affected by global demand and geopolitical trends, and the deployment of clean energy technology is affected by technology costs, which may be lower with more widespread deployment in other countries.

Considering these uncertainties, this chapter does not present the definitive pathway, but rather one potential pathway to reach net zero emissions. This possible pathway is based on analysis of the national and regional characteristics of Colombia's energy system and latest insights into global policy and technology developments. Starting with the scenario design and macroeconomic assumptions, the chapter sets out the overall trends for emissions and energy demand, details on sectoral pathways, and the impacts on fuel supply.

2.1.1 Scenario design

This *Net Zero Roadmap for Colombia* builds on three scenarios that are modelled in the IEA Global Energy and Climate Model and which reflect the impact of policies, targets, strategies and pledges on the energy system.[1] The modelling also includes the latest energy market and cost data and builds on the latest projections for economic and population trends. While this roadmap focuses on the scenario pathways for Colombia, the modelling is embedded in global scenarios, allowing an assessment of the impacts of global trends on the Colombian energy system, such as energy prices, trade and technology development. None of these scenarios is a prediction or a forecast, but they are designed to explore possible pathways under the boundary conditions embedded in their definition and provide guidance to policy makers.

The central scenario of this roadmap is the **Announced Pledges Scenario** (APS), which meets Colombia's national target to reach economy-wide net zero emissions by 2050 by reducing greenhouse gas (GHG) emissions by 90% compared with 2015, enshrined in domestic law in 2021. In the global context, the APS is a normative scenario assuming that all governments will meet, in full and on time, all announced climate-related commitments, including longer-term net zero emissions targets and pledges in Nationally Determined Contributions (NDCs), as well as commitments in related areas such as energy access. Pledges made by businesses and other stakeholders are also taken into account where they add to the ambition set out by governments.

[1] Further details about the IEA Global Energy and Climate Model and the scenario assumptions can be found in the model documentation (IEA, 2025a).

Two further scenarios are used, primarily to provide reference points that can help to contextualise the magnitude of the action required for the net zero pathway. The less ambitious scenario is the **Stated Policies Scenario** (STEPS), which provides a sense of the prevailing direction of energy system progression, based on a detailed review of energy-related policies that have been adopted or indicated. In addition, the STEPS assumes certain progress in addressing and overcoming deployment challenges and barriers for new technologies. However, the STEPS does not assume that aspirational goals, such as those included in the Paris Agreement, are achieved.

The **Net Zero Emissions by 2050** (NZE) **Scenario** is also a normative scenario and provides a more ambitious reference point. It presents a possible pathway for a global, energy system-wide transition to net zero emissions by 2050. The NZE Scenario assumes a significant degree of international collaboration to demonstrate, commercialise and diffuse key low-emissions technologies on an accelerated timeframe, leading to lower costs for clean energy technologies than in other scenarios. In contrast to many national net zero pledges, the NZE Scenario does not rely on offsets outside the energy sector and therefore reaches significantly lower emissions by 2050, including in the case of Colombia.

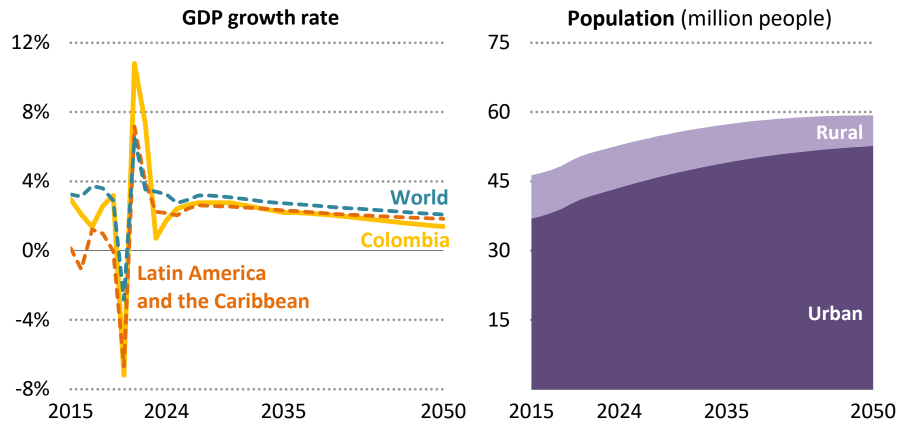
2.1.2 GDP, population and CO_2 price

All three scenarios build on the same projections for population and gross domestic product (GDP). Based on the latest UN projections, the population of Colombia is set to grow further from today's level of around 53 million to 59 million inhabitants by 2050. However, steadily declining fertility rates, which have decreased from 2.6 in 2000 to around 1.6 today, lead to a significant slowdown in the population growth rate, from around 1.3% today to 0.4% by 2050. Similar to many countries in South America, population growth is driven by the urban population, since much of the land is covered by rainforest and mountains leading to most economic activity taking place in cities, with the urbanisation rate increasing by 6 percentage points to 89% in 2050 (Figure 2.1). The rural population is projected to continue on a declining trend that started in late-1990s, decreasing from around 9.2 million people today to 6.6 million people by 2050.

Economic growth is projected to accelerate to 2.6% per year over the next decade – 0.2 percentage points higher than the average growth rate in the past decade – driven by strong growth in the industry and service sectors. Colombia's economy expands faster than the average for Latin America and the Caribbean (LAC), which grows by around 2.4% per year over the next decade. In the long term, saturation effects and a lower population increase slow down growth in services and industry, leading to 1.8% overall GDP growth per year between 2035 and 2050. GDP per capita remains at a similar level to LAC, increasing from around USD 21 000 (2024, purchasing power parity [PPP]) today to USD 33 000 by 2050.

Carbon pricing is another essential input for the scenarios and a policy measure to improve the competitiveness of clean energy technologies through price signals. Carbon pricing complements direct policy measures, enabling the wider deployment of clean energy technologies, which remain a key driver of the decarbonisation pathway. Following global assumptions for advanced economies with carbon price schemes and net zero pledges in place, the APS assumes a significant uplift in the carbon price in Colombia. The carbon price is assumed to rise gradually from a level of around USD 5 per tonne of carbon dioxide (t CO_2) today under the new emissions trading scheme, which is currently in development, to around USD 160/t CO_2 by 2035 and USD 200/t CO_2 by 2050.

Figure 2.1 ▻ GDP and population projections in Colombia and selected regions, 2015-2050



GDP and population growth are projected to remain strong over the coming years until around 2035, then slowing towards 2050

Note: GDP calculated on the basis of year 2024 US dollars in purchasing power parity (PPP) terms.

Sources: IEA analysis based on IMF (2025) and Oxford Economics (2025) for GDP projections. IEA analysis based on United Nations (2024) and UN DESA (2018) for population projections.

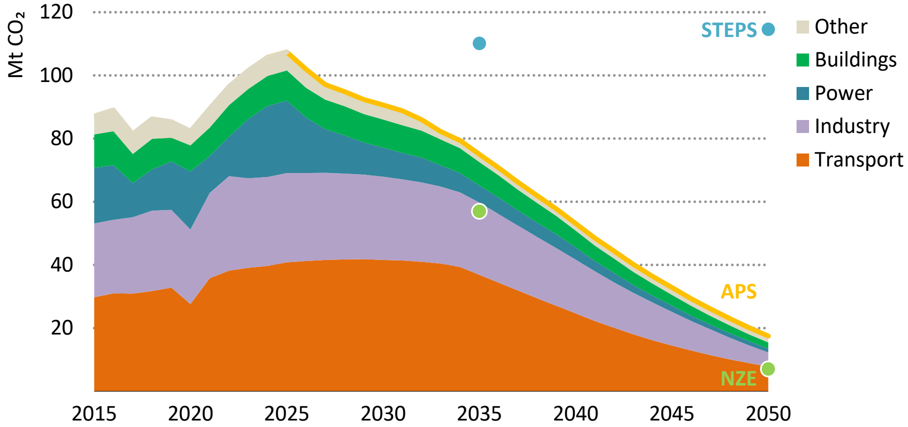
2.2 Pathway for the energy sector

2.2.1 Emissions pathway and milestones

The presented pathway to reach Colombia's net zero target by 2050, the APS, can be split into two phases. In the first phase, from today until 2035, the primary target is to halt the rising emissions seen over recent years and start a declining trend. Annual emissions are reduced by around 30% by 2035 compared with current levels (Figure 2.2). The power sector contributes half of the emissions reductions of 31 million tonnes of carbon dioxide (Mt CO_2) by 2035, using technologies that are often already cost-competitive such as solar photovoltaics (PV) and wind. This rapid expansion puts Colombia at the forefront of decarbonised electricity generation globally. The emissions intensity of the power sector is already around half of the global average due to the important role of hydropower, although

El Niño can lead to significant differences between years. In the APS, it declines from around 190 grammes of CO_2 per kilowatt hour (g CO_2/kWh) over the past five years to around 35 g CO_2/kWh by 2035, 75% below the global average. Outside the power sector, rapid electrification of end-use sectors ensures that activity increases driven by economic growth are more than offset and these emissions also start to decline, albeit at a slower pace. The deployment of electric vehicles (EVs) is the key driver, reaching 80% of sales by 2035.

Figure 2.2 ⊳ CO_2 emissions by sector and scenario in Colombia, 2015-2050

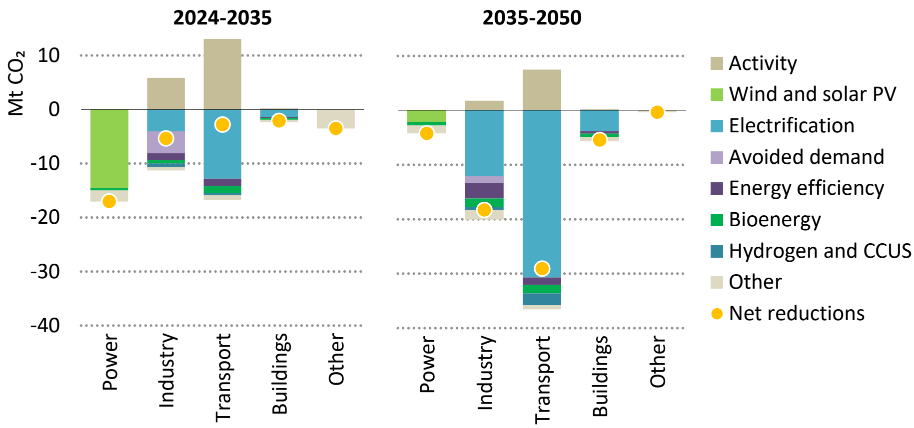


On the pathway to reaching the net zero pledge, emissions start to decrease over the coming decade, the decline accelerating after 2035

Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; Mt CO_2 = million tonnes carbon dioxide. Other includes other energy sector and agriculture.

In the second phase from 2035 to 2050, the primary focus is the reduction of emissions in end-use sectors as deployment makes inroads in the existing stock and other technologies mature. The transport sector alone accounts for around half of the 57 Mt CO_2 reductions between 2035 and 2050, with a further 40% coming from buildings and industry. The key driver is electrification, contributing almost 70% of the emissions reduction over this period across sectors and benefiting from the availability of low-emissions electricity (Figure 2.3). Rapid solar PV and wind expansion continues to cover the rising electricity demand. Energy and material efficiency improvements through higher fuel economy in vehicles, more efficient appliances, and the reduced use of basic materials such as steel and cement through substitution and circularity, contribute a further 10%. The role of bioenergy, hydrogen and carbon capture, utilisation and storage (CCUS) is similar, also accounting for around 10% of the emissions reduction; yet it is crucial to decarbonise end uses such as cement, aviation and heavy-duty vehicles. Notably, bioenergy already plays a relevant role and smaller nascent hydrogen projects are in the pipeline, while political consultations on CCUS have just started, which offers the opportunity to focus on sectors where CCUS provides most benefits.

Figure 2.3 ⊳ **CO_2 combustion emission changes by mitigation measure and sector in Colombia in the APS, 2024-2050**



Wind and solar PV expansion are the highest priority to reduce emissions in the short term, enabling electrification of end uses, especially in the transport sector

Notes: CCUS = carbon capture, utilisation and storage; PV = photovoltaic. Activity refers to increases from economic growth. Other reductions include other fuel switching and process emissions. Other sectors include the other energy sector and agriculture.

Total energy sector combustion emissions fall to around 14 Mt CO_2 by 2050 in the APS, levels broadly aligned with the Long-Term Strategy E2050 (MADS, 2024). Remaining emissions are mainly in sectors where decarbonisation solutions are not mature yet or have a high cost premium, such as heavy-duty transport, aviation, shipping and energy-intensive industries. The difference in the trajectories of total emissions between the APS and STEPS is significant, with total emissions in the STEPS remaining above the current level reaching around 115 Mt CO_2 by 2050. In the NZE Scenario, where the energy sector reaches net zero emissions without any offsets, hard-to-abate sectors are further decarbonised and the level of ambition for efficiency savings is increased, resulting in total emissions of around 7 Mt CO_2 by 2050.

The reduction of methane emissions is an integral part of reaching the national net zero GHG emissions target and of Colombia's participation in the Global Methane Pledge. Colombia's energy sector emitted around 1 Mt of methane emissions in 2024 (equivalent to nearly 30 Mt CO_2-eq on a 100-year timeframe). Roughly half of these emissions came from coal mines, 40% from oil and gas facilities, and the remaining 10% from end use, for example transport and stationary applications such as cooking. Energy-related methane emissions fall by around 75% to 2035, and by 90% by 2050. The decline in coal production plays a leading role in reducing methane emissions from coal, while the implementation of national regulations and best industry practices are key to achieving the reductions in the oil and gas sector.

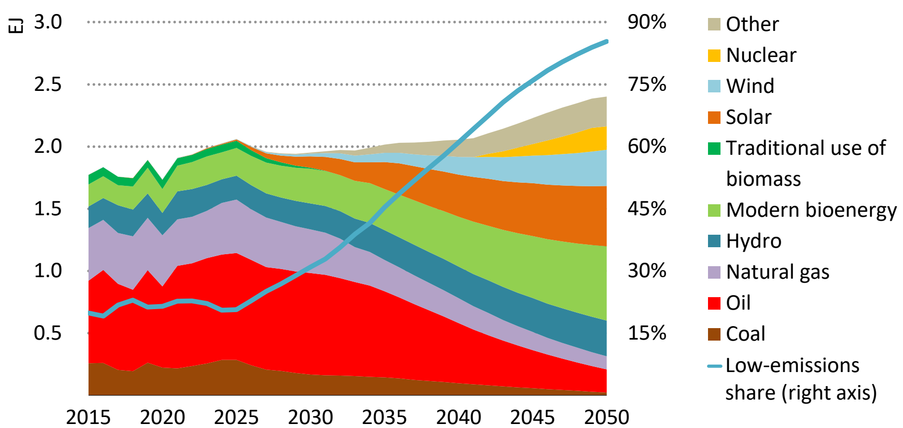
Table 2.1 ▷ Key milestones by sector in Colombia in the APS, 2030-2050

Year	Sector	Milestone	Reference (2024)
2030	Clean cooking	• 4.2 million people gain access to reach universal access • Clean cooking investment to reach USD 38 million annually	1.1 million people since 2018
	Investment	• International public finance averages USD 0.6 billion per year over the next five years to mobilise private capital	USD 0.1 billion
2035	Power	• Renewables surpass 90% of total electricity generation • Solar PV capacity surpasses 30 gigawatts (GW)	64% 2 GW
	Transport	• EV sales surpass 80% of vehicle sales • Sustainable aviation fuels (SAF) account for 4% of aviation demand • Non-fossil fuels reach 20% of transport demand	1% 0% 7%
	Buildings	• Almost 50% of cookstoves sold are electric • Half of household appliance sales are best available technology • Energy efficiency of air conditioner sales improves further by 4% per year from 2024	< 5% 10% 4% since 2015
	Industry	• Clinker-to-cement ratio reaches 0.66 • Electrification rate is at 31% for total industry and 39% for non-energy-intensive industries	0.75 22% and 27%
	Investment	• Clean energy investment reaches USD 17 billion	USD 3.4 billion
	Just transition	• Transition away from fossil fuels to clean sectors creates 77 000 jobs	
2040	Total	• The share of fossil fuels in total demand is reduced to 33%	70%
	Power	• Coal generation is completely phased out	11 TWh
	Industry	• Heat pumps contribute around 10% of heat demand below 200 °C in non-energy-intensive industries	0%
2045	Power	• Natural gas generation decreases by 75% from 2024 levels	17 TWh
2050	Total	• The share of fossil fuels in the total demand is reduced to less than 10%	70%
	Power	• Solar PV installed capacity reaches 69 GW • Wind installed capacity reaches 25 GW	2 GW 0.1 GW
	Transport	• Virtually all cars sold are electric vehicles • At least 200 000 public charging points for electric cars • SAF accounts for 19% of the total aviation demand • Non-fossil fuels account for 75% of transport demand	1% 1 100 0% 7%
	Buildings	• All new buildings are zero-carbon-ready buildings	20%
	Industry	• 5.4 Mt CO_2 captured and stored of which 4.9 Mt are from cement production • Clinker-to-cement ratio reaches 0.57 • Heat pumps contribute almost 15% of heat demand below 200 °C in non-energy-intensive industries • Total industry electrification rate reaches 56%	0 Mt CO_2 0.75 0% 22%
	Investment	• Clean energy investment reaches USD 19 billion	USD 3.4 billion

2.2.2 Total energy demand

Total energy demand is influenced by opposing dynamics in the APS. Increasing population and economic activity lead to rising demand, while the integration of renewables, efficiency improvements and electrification reduce the demand for fuels, leading to demand remaining at similar levels until 2035 (Figure 2.4). After 2035, hydrogen production increases, offsetting higher efficiencies elsewhere in the system, and leading to a 20% demand increase by 2050 compared with 2035.

Figure 2.4 ▹ Total energy demand and share of low-emissions fuels in Colombia in the APS, 2015-2050



Colombia significantly increases the share of low-emissions fuels to reach its net zero target by 2050 through substitution mostly of fossil fuels by renewables

Notes: EJ = exajoules. Other includes geothermal and waste.

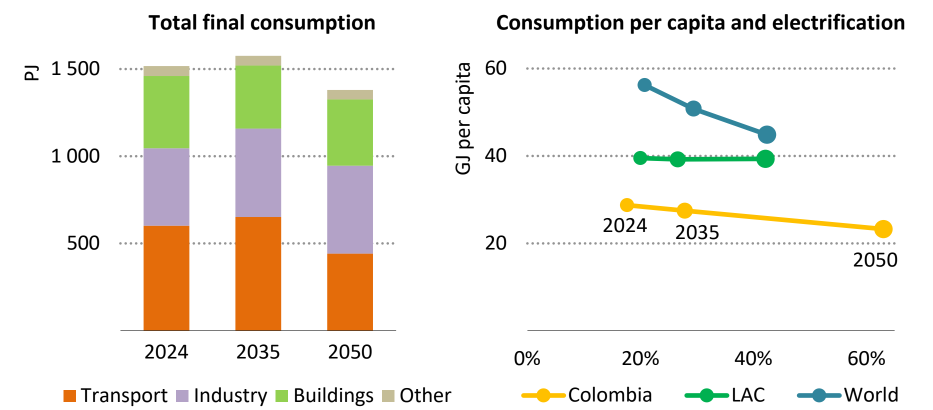
Demand for all fossil fuels, which currently lead total energy demand in Colombia, declines immediately (coal and natural gas) or towards the end of this decade (oil), leading to a decreasing share of fossil fuels in the APS. As renewables in the power sector and industrial electrification replace natural gas and coal demand, the share of low-emissions fuels overtakes the fossil fuel share around 2038, and by 2050 fossil fuels account for less than 13% of total energy demand. Demand for oil, currently the most consumed fuel at 390 thousand barrels per day (kb/d) and mainly used in the transport sector, starts to decline moderately to 340 kb/d in 2035 and then drops significantly to around 90 kb/d by 2050 as the deployment of EVs accelerates. However, oil remains the leading fossil fuel in 2050 since some uses in heavy freight transport, aviation, shipping and as a feedstock in industrial processes are more difficult to substitute.

On the renewables side, solar PV and wind drive the substitution of fossil fuels, directly in the power sector and through the electrification of end uses. Both technologies together reach a share of 14% of total demand by 2035, which increases to 32% by 2050. The demand for hydropower and bioenergy, currently together accounting for just over 20% of total energy supply, only expands gradually and maintains a similar share until 2050. The remaining traditional use of biomass is phased out as Colombia reaches full access to clean cooking by 2030.

2.3 Pathways for end-use sectors

Total final consumption increases by around 4% until 2035 in the APS. Demand rises in the transport sector, driven by an increasing population and higher mobility, and in the industry sector due to growth in manufacturing. In the buildings sector, reaching full access to clean cooking leads to the substitution of traditional use of biomass with more efficient fuels and hence declining demand (Figure 2.5). After 2035, efficiency and material savings in the industry sector offset increasing production, and efficiency gains from electrification in the transport sector reduce demand significantly. Only the buildings sector sees increasing demand, which is driven mainly by greater ownership of air conditioners.

Figure 2.5 ▷ Total final consumption by sector and consumption per capita compared to electrification in Colombia and selected regions in the APS, 2024-2050



Population and economic growth increase final consumption until 2035 when rapid electrification and further efficiency improvements accelerate and offset activity growth

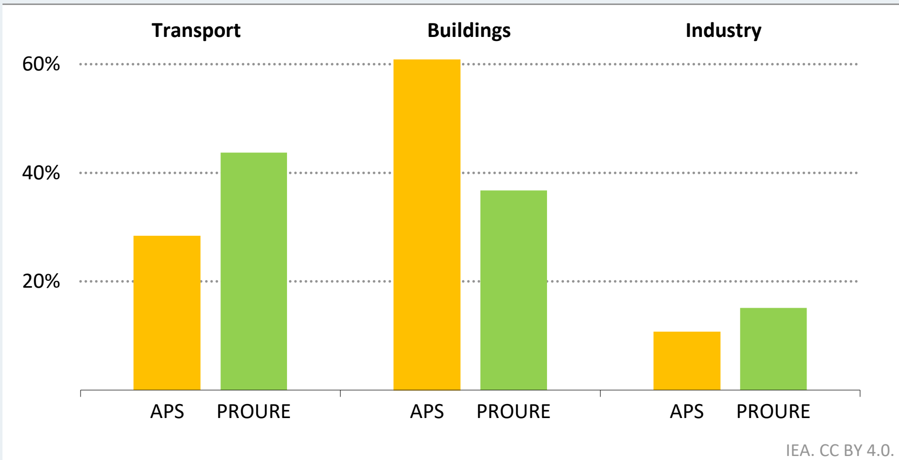
Notes: PJ = petajoules; GJ = gigajoules; LAC = Latin America and the Caribbean. APS results for other regions are based on *WEO-2024*.

Colombia remains a country with structurally low final consumption per capita as ownership of less fuel-intensive two/three-wheelers is higher than cars to move in cities, space heating is not widely required, and the industry sector is led by light industries. These factors facilitate electrification of Colombia's energy consumption. While the current level of electrification in Colombia is slightly below the LAC and global average, it reaches more than 60% by 2050 compared with around 40% globally and in LAC. The electrification of end-use sectors leads to significant energy savings per capita as solutions such as EVs and industrial heat pumps consume less energy than conventional technologies (Box 2.1).

Box 2.1 ▹ Energy efficiency in Colombia: Opportunities through the national plan PAI PROURE

Energy efficiency measures are an important form of mitigation across end-use sectors on the pathway to net zero emissions, particularly in a country with as significant population and economic growth as Colombia. They reduce the need for additional energy supply, lower operational costs for end users (often with short payback periods for slightly higher upfront investment) and increase energy security. Colombia has already published a national energy efficiency strategy under the name PAI PROURE (Plan de Acción Indicativo del Programa de Uso Racional de Energía), adopted via a resolution from the Ministry of Mines and Energy in 2022. The plan includes comprehensive measures across the transport, buildings and industry sectors, with a timeline of 2022 to 2030.

Figure 2.6 ▹ Contribution to energy efficiency savings by sector in the APS compared with today and in PAI PROURE compared with a baseline scenario, 2030



Efficiency gains in buildings are more pronounced in the APS than in PROURE, which relies more on efficiency gains from the deployment of EVs

Source: IEA analysis based on MME (2021).

The proposed measures reduce consumption by on average around 190 petajoules (PJ) per year until 2030 against a business-as-usual scenario. The annual growth rate of energy consumption is reduced from 2.4% to 0.4%, avoiding on average around

9.5 Mt CO_2 per year. Under the implemented measures, around 40% of energy is saved in the transport sector (Figure 2.6), mainly through EVs, a further 40% in buildings, mainly through the substitution of firewood use, more efficient refrigerators and the use of LED lighting, and a further 15% in industry through more efficient equipment, waste heat recovery and energy management systems (MME, 2022).

In the APS, energy efficiency savings lead on average per year to around 90 PJ of avoided energy use across all sectors up to 2030 compared with today's levels, more than the current annual energy demand of two/three-wheelers in Colombia. Most of these savings are in the buildings sector, where the substitution of firewood for cooking and appliance efficiency improvements following the pledge under the Super-Efficient Equipment and Deployment (SEAD) initiative contributes most to the savings (CEM, 2021). In the transport sector, which is the second most important in terms of savings, three-quarters of the total savings by 2030 stem from EVs. The industry sector contributes around 10% of the savings, for example through an increase in motor efficiency, more efficient boilers and energy management systems, for which the existing ISO 50100 norm provides a good framework, currently adopted by few plants. The potential of energy efficiency is even higher given that it reaches on average 115 PJ each year until 2030 in the NZE Scenario compared with today.

PAI PROURE requires significant investment, which is most cost-efficient in the buildings sector. Out of the planned investment of approximately USD 40 million, 55% would be directed to transport, 25% to buildings and 11% to industry. The efficient execution of the PROURE programme is an important lever for Colombia's net zero pathway. In the APS, final energy consumption grows by around 0.6% per year to 2030, which is close to the results envisaged by the programme. Regular updates on the progress of the programme would be helpful for tracking purposes and for the sharing of best practices in the different sectors. Beyond 2030, efficiency efforts in the APS need to accelerate, leading to plateauing demand until 2035 and achieving declining demand (down by around 0.9% per year in the APS) for the period 2035 to 2050.

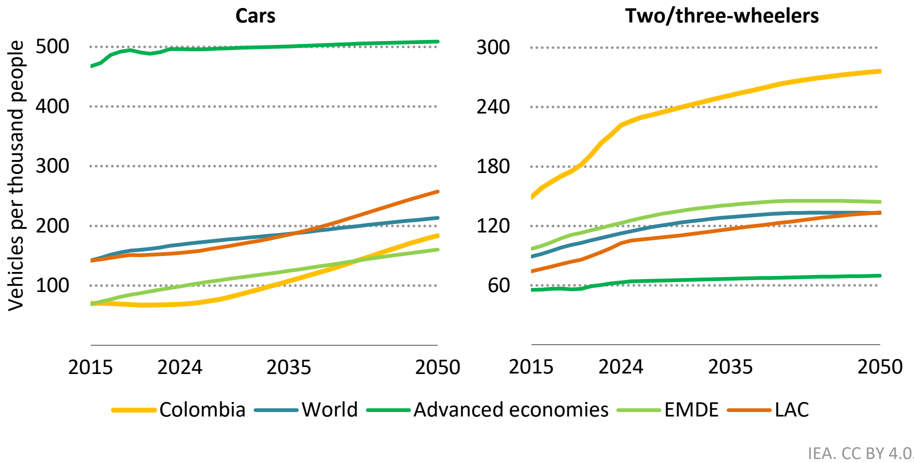
2.3.1 Transport

Colombia's transport sector is important for the decarbonisation pathway. Transport currently accounts for around 40% of total final consumption and CO_2 emissions, with a high reliance on oil contributing 90% of the sector's demand. While around 10% of transport demand is met by biofuels (7%) and natural gas (3%), electricity plays only a marginal role despite steady growth in recent years, reflecting the small share of EVs and the lack of electric rail in Colombia.

Colombia has one of the highest ownership rates of two/three-wheelers in the world, a reflection of its high urbanisation rate and a range of socio-economic factors. Nearly one in five people own a two/three-wheeler, while the car ownership rate is below one in ten, leading to two/three-wheelers accounting for 70% of all vehicles in 2024 (Figure 2.7).

Popularity of two/three-wheelers stems from higher affordability, lower fuel consumption, advantages in navigating congested roads and the lack of public transport options. However, car ownership grows strongly in the APS, more than doubling by 2050 compared with today's level and bringing Colombia closer to the global average.

Figure 2.7 ▷ Car and two/three-wheel vehicle ownership in Colombia and other regions in the APS, 2024-2050



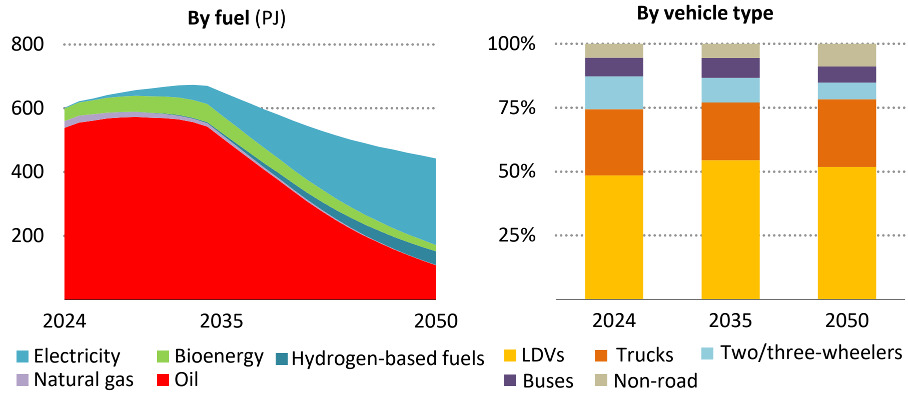
Car ownership in Colombia more than doubles by 2050 compared with today's levels, but two/three-wheelers remain a popular means of transport

Note: EMDE = emerging market and developing economies.

The type of new cars deployed in Colombia is influenced by the global market as car sales rely heavily on imports. In 2024, cars ranked as Colombia's second-largest import product, valued at around USD 2.8 billion, primarily sourced from Brazil, Mexico, the People's Republic of China (hereafter China) and South Korea. Imports of passenger cars from China more than tripled over the past five years, while Chinese imports accounted for more than 73% of Colombia's EV sales in 2024, up from 52% in 2023 (Sinoimex, 2025; IEA, 2025b).

Rising vehicle ownership and growing bus activity drive increasing demand in the transport sector in the medium term, rising by 8% by 2035 compared with today's levels. Oil demand for transport peaks in 2029 after which the share starts to decline to 78% by 2035 as the deployment of EVs makes inroads in the vehicle stock, reaching nearly one in four vehicles (Figure 2.8). The faster deployment after 2035 leads to a sharp decline in the use of oil, falling to around 20% of road transport demand by 2050 – below the average level in LAC. Given that Colombia currently imports diesel, the reduction in oil demand can also help strengthen long-term energy security. The declining share of combustion engines in cars also leads to declining bioenergy demand after 2035.

Figure 2.8 ⊳ Energy demand for transport by fuel and vehicle type in Colombia in the APS, 2024-2050



Electricity and hydrogen drive Colombia's transport energy demand diversification to 2050, while road transport continues to account for 90% of total transport

Note: LDVs = Light-duty vehicles, which include passenger light-duty road vehicles and light commercial road vehicles.

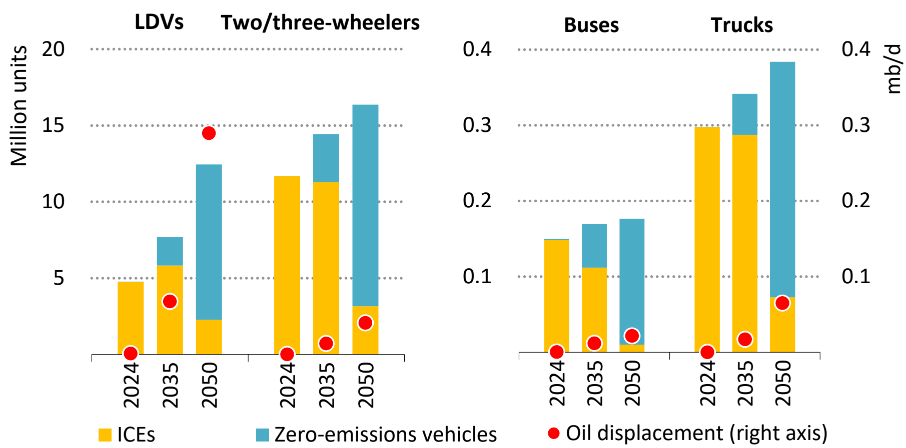
The electrification of road transport is the key driver to reducing reliance on oil in the transport sector. Road transport currently accounts for around 95% of transport sector energy consumption in Colombia, of which around one-third is from cars despite the comparably low ownership rates. By 2035, battery EVs reach around 80% of new car sales, rising further to more than 95% by 2050, compared with just 6% today (Figure 2.9). Electrification is also set to make major inroads among buses and trucks, which by 2035 contribute more than 40% of total road electricity demand.

Bogotá already stands out as a global leader, rolling out one of the region's largest fleets of electric buses (Box 2.2), a shift that is already moving energy demand from oil to electricity (City of Bogotá, 2022). The higher efficiency of electric motors compared with combustion engines leads to a decrease of 35% in total transport energy demand by 2050 compared with the peak in 2033, despite increasing vehicle ownership rates. Decarbonising long-distance trucking remains a challenge in Colombia. While electrification is likely to progress in the light-duty vehicle fleet, heavy-duty vehicles that are used most commonly for intercity transport face greater barriers due to limited charging infrastructure and challenge of deploying grid networks in the country's mountainous terrain. Co-ordinated planning and investment in grid expansion and charging infrastructure, particularly along national freight corridors, will be essential to support future progress.

To further accelerate the transition, Colombia could also consider a robust fleet renewal programme given its ageing stock, as it would increase the penetration of more efficient vehicles such as EVs. For instance, Canada's national vehicle scrappage programme led to around 140 000 vehicle retirements, which is around 10% of the country's annual car sales.

Similarly, China's Equipment Renewal and Trade-in of Consumer Goods policy demonstrates how targeted scrappage incentives can accelerate the replacement of inefficient vehicles, improve overall fuel efficiency and drive electrification, with EVs making up around 50% of new car purchases under the 2024 trade-in initiative.

Figure 2.9 ▻ Electrification share of transport stock and oil displacement in Colombia in the APS, 2024-2050



Cars and two/three-wheelers lead the electrification of road transport and by 2050 electrification of road transport displaces around 0.4 mb/d of oil demand

Note: ICE = internal combustion engine, including gasoline, diesel, and natural gas; mb/d = million barrels per day.

From a policy perspective, the national zero-emission vehicle target of 600 000 EVs across all modes except two/three-wheelers by 2030 is a key driver for the deployment of EVs. Achieving this target implies that annual EV sales need to accelerate significantly compared with recent years, growing from 7% to 30%, more than today's share in the United Kingdom. EV registrations also remain highly concentrated in departments with larger cities, with 80% concentrated in Bogotá DC, Antioquia (Medellín) and Valle del Cauca (Cali) as of early 2025 (Fenalco, 2025). Achieving the target requires accelerated sales and broader regional deployment. Currently, only less than 1% of the vehicle fleet, excluding two/three-wheelers, is electric, but reaching 600 000 would raise this to about 9% by 2030. Deployment really accelerates after 2030 to get on the pathway to the economy-wide net zero emissions target. The increasing cost-effectiveness of EVs also drives adoption after 2035, with payback times reducing to 4 years by 2035 and approaching around 3.5 years by 2050, compared with around 7 years today.

The increasing share of EVs also has implications for infrastructure. A lack of charging infrastructure has long been a barrier to EV expansion. However, between 2022 and 2024 Colombia's public charging network grew by 60%, reaching 1 100 public chargers in 2024.

Meeting charging needs for 8.9 million electric cars by 2050 in the APS requires almost 200 000 public charging points, or roughly 8 000 added each year – similar to Sweden's 2024 rollout.

Box 2.2 ▹ Electric city bus fleet in Bogotá

Bogotá, Colombia's capital and its most populous city with a population of around 8 million in 2024, is currently implementing ambitious plans to electrify its public bus system. Since 2019, Bogotá has deployed 1 486 battery electric buses within its integrated public transport system (SITP), making Bogotá the city with the second-largest electric bus market in LAC, after Santiago (ICCT, 2024). This is larger than the combined fleets of Mexico and Japan in 2024. By the end of 2024, the electric bus fleet in the region reached 6 055 vehicles, with Bogotá and Santiago together accounting for 65% of the regional total.

Air quality concerns linked to chronic congestion have been major drivers of Bogotá's transition to electric buses. The long-delayed metro system – first proposed in the 1940s and now scheduled to begin commercial operations in 2028 – has further reinforced reliance on buses. To guide this transition, the city adopted the Zero and Low Emission Mobility Strategy (2023-2040), which sets a target for a 100% zero- or low-emission TransMilenio fleet by 2036.

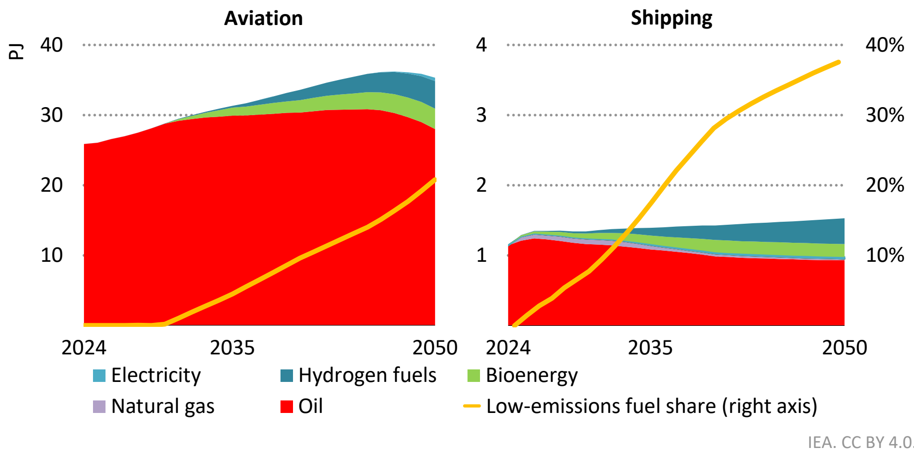
Progress to date has been notable: Colombia's public charging network for all vehicles has expanded by 60% over the past two years. Still, meeting future targets will require substantial investment in charging infrastructure and electricity grid capacity. Support for fast-charging and depot facilities, combined with co-ordination on power planning and public–private partnerships for shared charging infrastructure, could help ensure that charging networks keep pace with fleet electrification.

Aviation and shipping

Both domestic aviation and shipping energy demand are projected to increase towards 2050, although aviation demand peaks in the mid-2040s before declining slightly thereafter due to efficiency gains. Aviation in Colombia currently relies entirely on oil. This dependency is projected to fall to 80% by 2050, driven by the gradual adoption of biofuels and hydrogen-based fuels from the late-2030s onward (Figure 2.10). Shipping in Colombia also relies heavily on oil today, but there is stronger momentum behind the low-emissions fuel share, reaching 38% by 2050. However, hydrogen and ammonia are the most important fuels to substitute oil, accounting for nearly a quarter of domestic navigation energy demand by 2050.

Colombia can build on its decades-long experience of producing biodiesel and ethanol to serve increasing domestic and also global biofuel demand. The country has ambitious plans, with its Sustainable Aviation Fuels (SAF) Roadmap aiming to produce around 380 million litres of SAF (13 PJ) by 2035 and 1.7 billion litres (57 PJ) by 2050. With domestic SAF demand projected at around 1.4 PJ in 2035 and 6.6 PJ in 2050, this scale of production positions Colombia as an exporter of SAF. Supporting this ambition, Ecopetrol, for instance, has announced an investment of up to USD 700 million in a SAF production plant, expected to produce 6 000 barrels per day (9 PJ) of SAF by 2030, signalling a strong push toward cleaner aviation (Reuters, 2025).

Figure 2.10 ▷ Aviation and shipping energy consumption in Colombia in the APS, 2024-2050



Biofuels gain increasing importance in both aviation and shipping as they provide one of the most viable options for decarbonising these hard-to-abate sectors

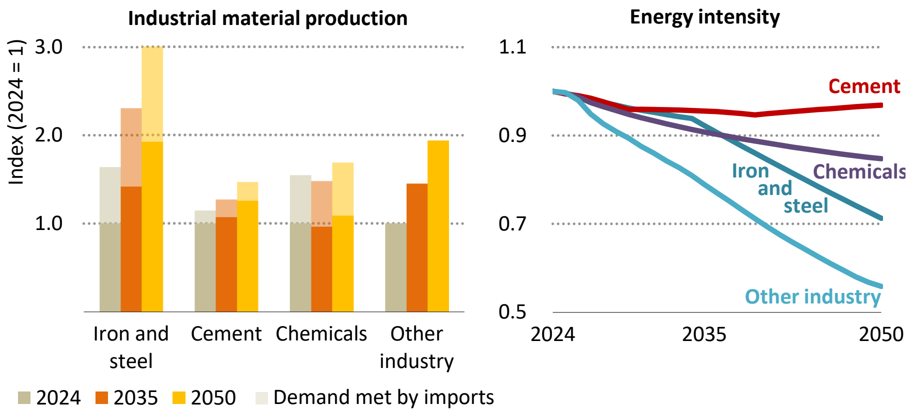
Note: The figure shows only domestic demand for aviation and shipping.

SAF deployment is challenged by a production cost gap compared with fossil kerosene, costing three to seven times more. The price disparity is expected to increase airline operating costs and, in turn, put upward pressure on ticket prices. However, in the APS the increase in airline cost per passenger remains negligible, largely offset by factors such as continued improvements in aircraft efficiency and expected maturation of the SAF market, which is expected to drive down today's high prices. In Colombia, where the SAF share is expected to remain below 5% by 2035, its impact on airline cost per passenger is projected to be minimal. Avianca Cargo, The Queen's Flowers and Repsol together reported their first operation with Book & Claim SAF in 2025 (Aerolatinnews, 2025). Domestic production can leverage the use of physical SAF for future demand. Ultimately, the widespread rollout of SAF remains heavily dependent on strong policy support such as mandates.

2.3.2 Industry

Rising industrial output across different sectors contributes significantly to economic growth in Colombia over the coming years. Production particularly grows in iron and steel and non-energy-intensive industries, nearly doubling by 2050 relative to today's levels. Despite this growth, Colombia remains a key importer of materials, with roughly 60% of domestic steel demand and 20% of cement demand met by imports in 2050 (Figure 2.11).

Figure 2.11 ⊳ Industrial material production and energy intensity relative to 2024 levels in Colombia in the APS, 2024-2050



Steel production and manufacturing grow fastest, but Colombia remains dependent on imports; material and energy efficiency savings limit the impact of increasing production

Note: Other industry includes non-energy-intensive industries. Their activity and energy intensity is calculated using value added while other sectors use physical production.

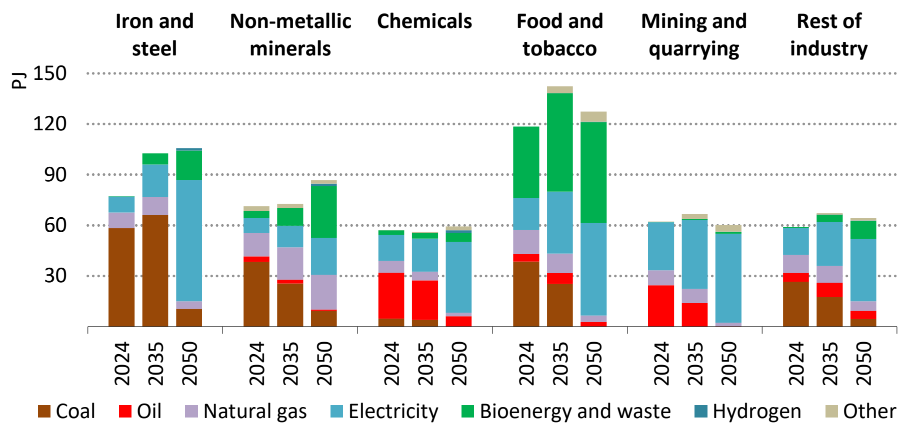
Material efficiency improvements can be an important measure to temper the increase in activity. These reductions are achieved through measures such as lifetime extension, increased recycling and improved design practices in downstream applications. In the APS, material efficiency measures reduce demand by 11% for steel, and 9% for cement and chemicals, relative to the STEPS by 2050. Progress in energy efficiency is another important pillar of Colombia's industrial decarbonisation in the APS. Measures such as the PROURE action plan help drive energy efficiency improvements by mandating performance targets for industry, promoting motor replacement, combustion optimisation and waste heat recovery. By implementing these measures, energy intensity (energy demand as a percentage of industrial value added) improves by 2% per year until 2050 in non-energy-intensive industries. Energy-intensive industries can also benefit from the PROURE programme to get closer to best available technologies, but decarbonisation can also lead to slower efficiency improvements; for example, the deployment of CCUS in the cement sector after 2035 slows the intensity gains.

Transitioning fuel mix towards cleaner sources

Increasing production drives industry energy demand, which is projected to grow continuously from around 445 PJ today to 508 PJ by 2035 and 503 PJ by 2050. By mid-century, electricity is expected to be the leading energy source for Colombia's industry sector, representing 56% of energy demand while displacing significant volumes of coal and oil (Figure 2.12). Electricity is followed by biomass at 25% of total industry energy demand in

2050, and natural gas at 8%. Energy demand declines most in the mining sector, mainly due to lower coal production, while the food, steel and cement industries remain important.

Figure 2.12 ▷ Energy demand in industry by fuel and subsector in Colombia in the APS, 2024-2050



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Electricity and modern biomass displace coal and oil, but natural gas consumption remains resilient especially for higher-temperature applications

Coal use in industry declines across all sectors. Driven by the deployment of low-emissions technologies, coal demand falls from around 165 PJ in 2024 to around 24 PJ in 2050. For example, in the iron and steel sector, currently the most coal-intensive industrial subsector, auxiliary processes are increasingly electrified, and the share of scrap-based electric arc furnaces slightly increases despite an already high level of around 85% of all metallic inputs today. By 2050, electricity replaces more coal as the remaining iron-based steel production shifts to hydrogen-based direct reduced iron given Colombia's attractive low-emissions hydrogen potential.

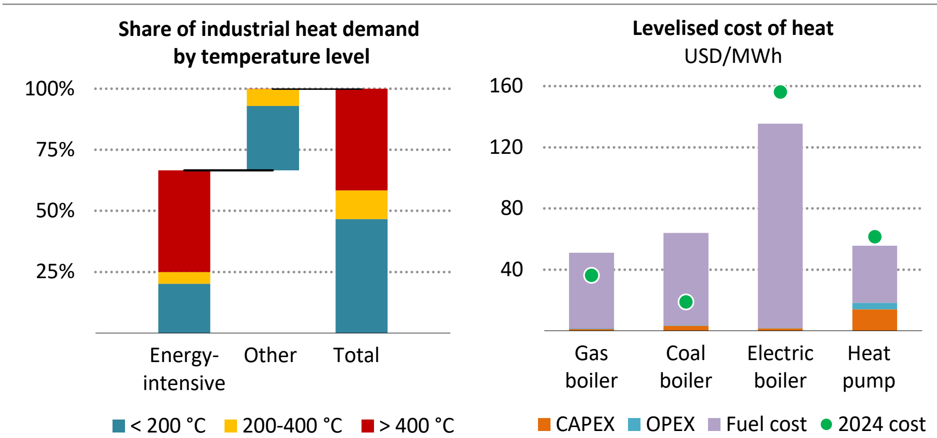
Natural gas demand in the industry sector remains constant from 2024 to 2035 in the APS, before declining from around 65 PJ in 2035 to 40 PJ by 2050. Natural gas demand falls more slowly than oil or coal use because energy-intensive industries, such as the cement industry, switch from coal to natural gas as a near-term emissions reduction measure to serve high-temperature heat demand. The share of natural gas in cement production increases from 19% to 25% by 2035, reducing the use of coal by a third. The natural gas share remains constant until 2050 as other decarbonisation options such as clinker substitution, CCUS and silicates become more viable.

Biomass has long been used in light industries, but has not historically played a significant role in more energy-intensive sectors. In the APS, however, demand rises from 50 PJ in 2024 to almost 125 PJ by 2050, spanning both energy-intensive and non-energy-intensive industries. In non-energy-intensive industries, biomass use comes mainly from burning agricultural residues for process heat and cogeneration. Looking ahead, it is expected to be increasingly deployed in cement production for kiln heating and in iron and steel for preheating and drying processes, serving as a partial substitute for coal.

Shifting low-temperature processes from natural gas to electricity

Electricity's share of industrial energy demand increases from 22% in 2024 to 56% in the APS by 2050. This growth is driven by greater deployment of electric boilers and heat pumps, particularly in low- and medium-temperature applications. The share of electricity consumption in non-energy-intensive industries, where nearly 80% of heat demand is below 200 °C, drives this increase, growing from 27% in 2024 to 60% by 2050, a level similar to that seen today in China, Japan and Korea. The food industry, currently relying for around half of its energy needs on fossil fuels, is particularly well suited to heat pump deployment. Processes often require heating with precise temperatures and cooling at the same time and generate waste heat that can be used to improve the coefficient of performance of heat pumps. As industrial gas prices rise – due to higher reliance on imports and partly reflecting Colombia's increasing carbon price – and heat pump technology matures, heat pumps are expected to reach near-parity with gas boilers on a levelised cost basis by 2030 (Figure 2.13), creating a major opportunity to accelerate the electrification of Colombia's industry sector.

Figure 2.13 ▷ Share of industrial heat demand by temperature level in 2024, and levelised cost of heat in Colombia, 2030



Roughly 45% of heat demand is below 200 °C, showing the potential for electric heat pumps, which can be cost-competitive in 2030 in the APS

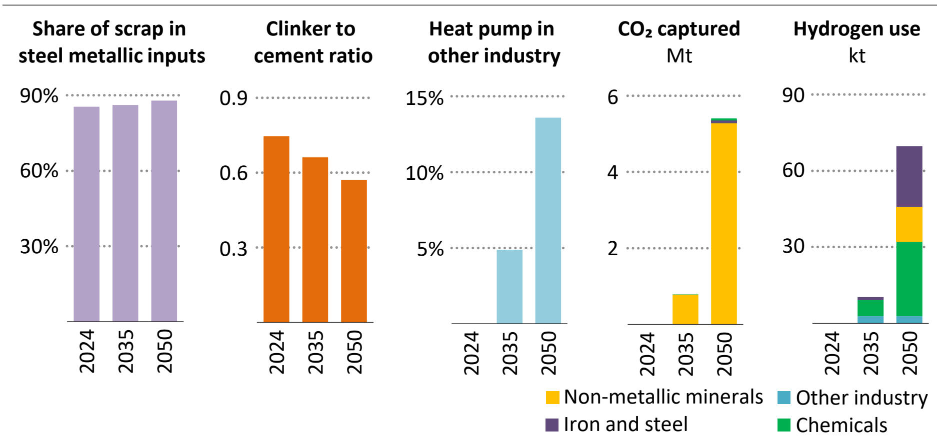
Notes: MWh = megawatt hour. Heat pump costs refer to ambient source heat pumps. CAPEX, OPEX and fuel costs pertain to 2030 estimates from the APS. Heat pump assumed to have a coefficient of performance of 3.5.

Existing energy efficiency incentives, such as those under Law 2099 of 2021 (Función Pública, 2021), could support this transition by allowing firms to deduct up to 50% of their investments from income tax, improving heat pump competitiveness. However, widespread adoption still faces hurdles, as heat pumps require significantly higher upfront capital costs and might impact the plant configuration. Grants and capacity building can help to buffer the high investment costs and increase awareness of the technology.

Energy-intensive industries have a greater reliance on high-temperature heat to drive production processes. Therefore, electrification in this sector rises only marginally from 17% currently to 23% by 2035. One example is the electrification of pulping, drying and finishing processes in the pulp and paper sector, traditionally reliant on fossil fuel-based heat. With novel technologies maturing and becoming more cost-competitive, electricity's share in energy-intensive industries increases significantly to over 50% by 2050, driven partially by the production of iron and ammonia based on electrolytic hydrogen.

The heterogeneity of the industry sector requires different decarbonisation measures. In the iron and steel sector, the share of scrap in metallic inputs continues to rise slightly from 85% to 88% by 2050, reducing the need for energy-intensive iron production (Figure 2.14). In the cement sector, lower clinker ratios are achieved through greater use of supplementary materials such as limestone and calcined clay that reduce the fossil fuel intensity. Heat pumps are mainly deployed in non-energy-intensive industries, which have greater potential due to lower process temperatures, reaching a share of 14% by 2050. The potential also exists to electrify processes in energy-intensive industries such as chemicals and paper.

Figure 2.14 ▻ Industry milestones and clean technology deployment in Colombia in the APS, 2024-2050



Decarbonisation is driven by growing secondary metal production, lower clinker use, electrification, and modest deployment of CCUS and hydrogen

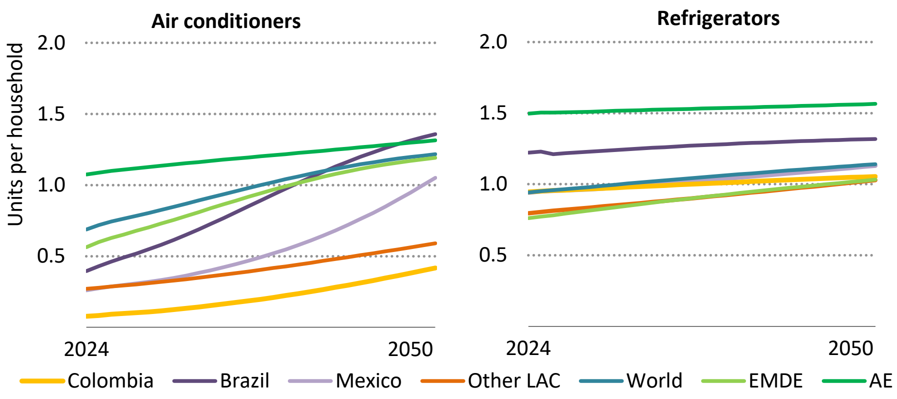
Notes: Mt = million tonnes; kt = thousand tonnes. "Heat pump in other industry" refers to the total heat demand under 200 °C supplied by heat pumps in non-energy-intensive industries.

Although significant decarbonisation occurs, the deployment of low-carbon technologies such as CCUS and hydrogen remains limited in Colombia's energy transition. By 2050, only about 5 Mt CO_2 are captured in industry, around half of Brazil's CCUS capacity across all sectors today. Hydrogen use in industry reaches about 70 kt, primarily in direct reduced iron and electrolytic ammonia. One way to accelerate the deployment of these capital-intensive technologies is through partnerships with international development organisations that can provide technical co-operation, funding and expertise for sustainable development. Such collaboration can help countries advance hydrogen and CCUS pilots, develop industrial hubs and leverage global expertise to scale up these technologies.

2.3.3 Buildings

Driven by growth in population and incomes, Colombian residential floorspace is set to expand from 1.2 billion square metres to almost 2 billion by 2050. As household purchasing power rises, Colombians benefit from greater availability of energy technologies in buildings, most notably water heaters, air conditioners and other appliances. For several household appliances, such as refrigerators and washing machines, ownership rates in Colombia are already relatively high, and further growth is limited. However, ownership of air conditioners remains low and is expected to rise faster in Colombia than in any other major LAC country (Figure 2.15). Today, the average rate of air conditioner ownership per Colombian household stands at less than 10%, compared with 40% across LAC countries. Although a large share of the population is concentrated in cooler areas at higher elevations, 60% reside in warmer departments with substantial cooling needs. At the same time, Colombia's climate is changing, with heatwaves becoming more frequent and annual cooling degree days – an indicator of how hot average daily temperatures are – set to increase 20% by mid-century.

Figure 2.15 ▷ Ownership of air conditioners and refrigerators by selected countries and regions in the APS, 2024-2050



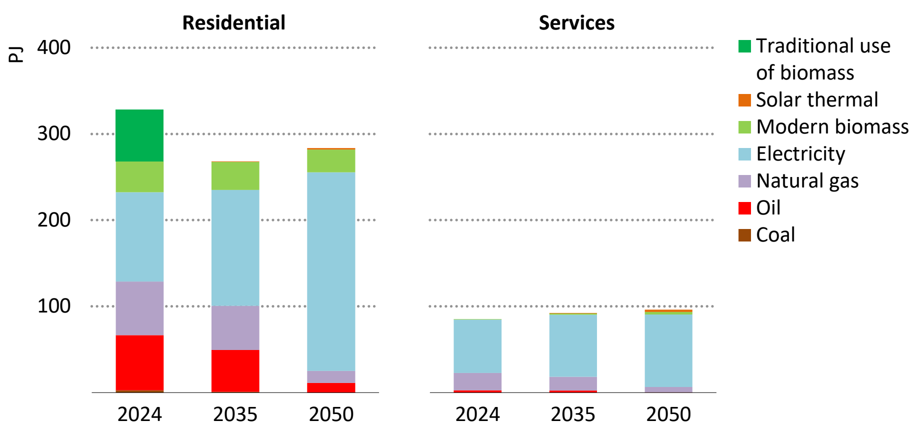
Ownership of air conditioners is expected to rise faster in Colombia than the average for LAC, but temperate climate zones in parts of the country limit ownership levels

Note: AE = advanced economies.

Despite the strong growth in appliance ownership, buildings sector energy demand declines in the coming years in the APS. The key driver is achieving universal access to clean cooking by 2030, in line with UN Sustainable Development Goal 7 (see Chapter 3, Section 3.2). Over four million people are set to substitute firewood for cooking as well as water and space heating with more efficient and less polluting solutions. Over the next decade, the decrease in traditional use of biomass drives an overall reduction in energy consumption from 414 PJ to 360 PJ, despite a 25% increase in electricity consumption during this period.

After 2035, energy consumption grows to 380 PJ by 2050, driven by increased use of air conditioning and household appliances, which outweigh equipment efficiency gains. In the APS, electricity accounts for 80% of the fuel mix in 2050 compared with 40% today (Figure 2.16). Stringent efficiency requirements for household appliances ensure the availability of electricity needed for accelerated electrification of end uses such as cooking and water heating in the residential sector. In the services sector, the electrification rate already stands at 70% currently and reaches 90% by mid-century.

Figure 2.16 ▷ Energy demand in buildings by fuel and sector in Colombia in the APS, 2024-2050

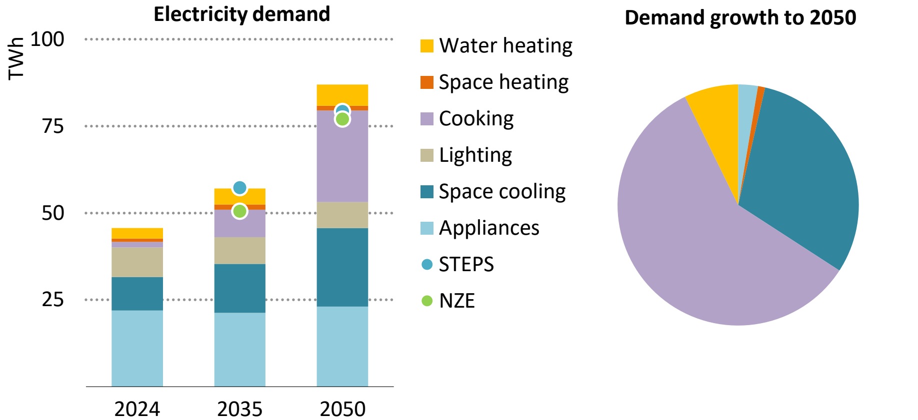


In the APS, the share of electricity in the fuel mix doubles from 40% to 80% by 2050. Universal access to electricity and clean cooking is achieved within this decade.

Electricity demand growth shaped by cooking and cooling

In the APS, the electrification of cooking accounts for most of the electricity demand growth in the buildings sector to 2050 (Figure 2.17). The majority of cookstoves currently sold in Colombia are powered by fossil fuels, most notably natural gas and LPG. While there are government measures to subsidise the purchase of efficient cookstoves, these primarily boost natural gas and LPG cookstove sales, thanks to the much lower operating costs of using fossil fuels compared with electricity. The superior efficiency of electric cookstoves is outweighed by the impact of electricity prices that are three times more expensive than natural gas. In the APS, the market share of fossil fuel cookstoves reduces from 80% today to 20% in 2050, with the share of electric cookstoves rising to almost 70% of the stock. The climate impact of the remaining gas use is further mitigated thanks to a biomethane blending rate that reaches 35%. Achieving a 70% cooking electrification rate would put Colombia on a par with current levels in South Africa, Australia and Canada. In the NZE Scenario, fossil fuel technologies for cooking are phased out more rapidly, which cuts direct buildings sector emissions by a further 1.1 Mt CO_2 in 2050 compared with the APS. Developments in other LAC countries show that reforms in subsidy programmes to incentivise the adoption of electric cookstoves in areas with reliable grid connection can be effective. Countries such as Costa Rica, Ecuador and Paraguay have seen a sharp increase in the sale of electric cookstoves following such reforms, proving that their widespread adoption remains within reach for Colombia, especially given the wide scope of its existing framework of household fuel subsidies.

Figure 2.17 ▹ Electricity demand in buildings by end use in Colombia in the APS, 2024-2050



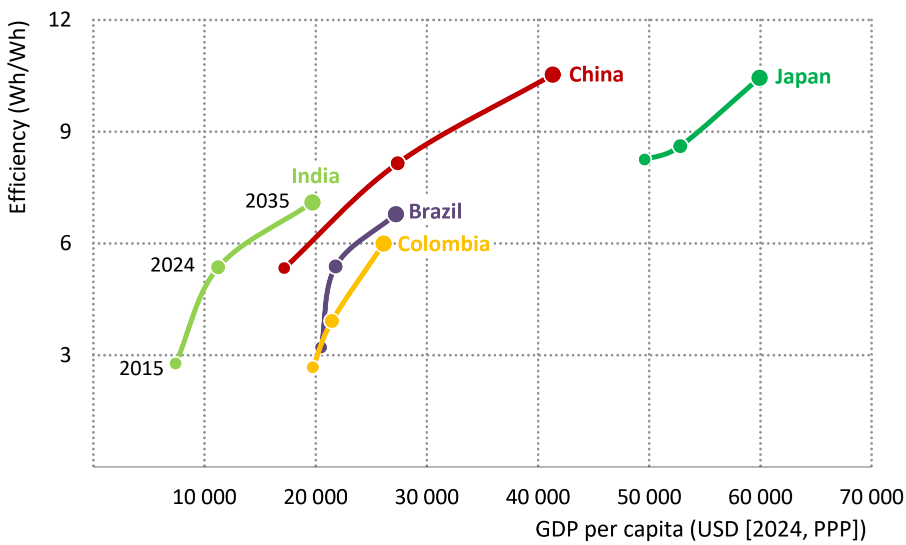
In the APS, the electrification of cooking accounts for most of the electricity demand growth to 2050, while efficiency gains curb demand growth for cooling and appliances

Despite faster electrification in the NZE Scenario, greater efficiency gains ensure that electricity demand growth is more limited compared with the APS. In the NZE Scenario, best available technologies (BAT) represent virtually all sales of appliances and lighting equipment by 2035. Conversely, in the STEPS, appliance efficiencies improve modestly, leading to rapid electricity demand growth despite limited electrification of end uses like cooking and water heating. Only refrigerators, freezers, air conditioners and industrial motors are currently subject to minimum energy performance standards (MEPS). Most household appliances are merely covered by labelling requirements. In the APS, BAT account for half of all household appliance sales in 2035. BAT appliances are the norm in new buildings and major renovations, as envisaged in Colombia's National Roadmap for Net Zero Carbon Buildings (CCCS, 2021). The greatest impact stems from increasing the efficiency of air conditioners sold. This is the biggest factor in limiting the growth of cooling demand in the APS to 13 TWh by 2050, compared with growth of 20 TWh in the STEPS.

Raising efficiency in Colombia's air conditioning market

Since 2019, air conditioners sold in Colombia are required to comply with MEPS and carry an energy label under the RETIQ framework (Reglamento Técnico de Etiquetado de Equipos que Usan Energía). Over time these standards have been tightened and the scope extended to cover split and window units. While MEPS have improved the average efficiency of units sold, most models remain below the performance of best available inverter technologies in leading global markets (Figure 2.18). Air conditioners sold in Colombia are less efficient than those sold in other comparable cooling markets, such as Brazil and India.

Figure 2.18 ▻ Energy efficiency of air conditioner sales and economic growth by selected countries in the APS, 2015-2035



Air conditioners sold in Colombia are less efficient than those sold in other comparable markets

Notes: Wh/Wh = cooling capacity in watt hours over power consumption in watt hours. The harmonisation has been performed to ISO standard group 1 climate conditions, with different models for fixed speed units and inverter units. APS results for other regions are based on *WEO-2024*.

Most air conditioners sold in Colombia are imported from China. Since 2020, the Chinese government has substantially increased efficiency requirements for air conditioners sold domestically. This poses both risks and opportunities for importing countries like Colombia. On one hand, Colombian consumers will benefit from greater product availability in the premium segment of the air conditioning market, as manufacturers in China scale up the production of highly efficient units. On the other hand, if importing countries do not upgrade MEPS in tandem with the world's largest cooling markets, there is a risk of their market being flooded with inefficient technologies that can no longer be sold in the manufacturer's country of origin.

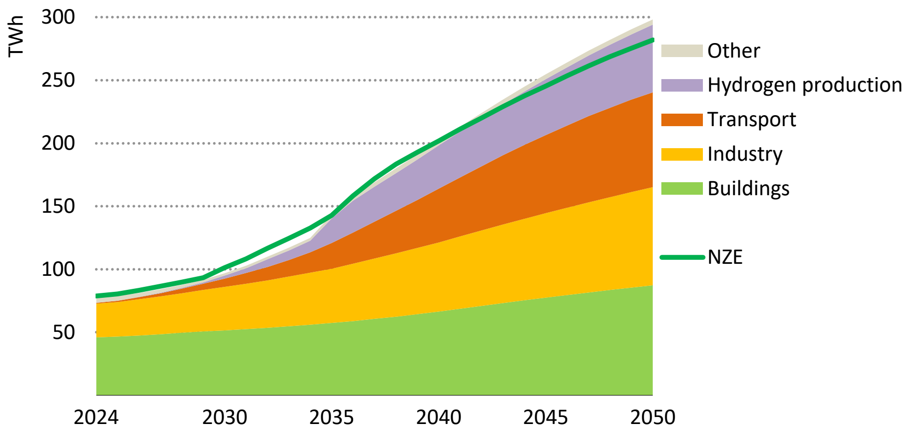
This can lower the upfront cost of new air conditioners, but result in higher lifecycle costs. This is especially the case in countries like Colombia, where electricity prices are relatively high, as shown in the IEA Special Report on Affordable and Fair Clean Energy Transitions (IEA, 2024a). In Colombia, the most efficient air conditioners are cheaper than less efficient models over a ten-year life span. Nevertheless, the upfront cost of such units is substantially higher, typically costing at least 50% more than less efficient models. Successful cooling efficiency campaigns combine MEPS with subsidies that at least partially address the purchase premium of more efficient units. In the APS, the average cooling seasonal performance factor (efficiency) of air conditioners sold in Colombia rises from 3.9 today to 6.0 in 2035. An improvement on this scale can only be achieved by reforming MEPS and the energy labelling framework in line with Colombia's major trading partners, while expanding consumer support programmes like purchase subsidies, scrappage schemes, low-interest loans and on-bill financing.

2.4 Pathway for the electricity sector

2.4.1 Electricity demand

Electricity demand nearly quadruples from 2024 levels to reach 300 TWh by 2050 in the APS, corresponding to an average annual growth rate of over 5%. This ambitious acceleration – up from the 3.4% annual growth observed from 2000 to 2024 – outpaces the average in LAC countries of 4.1% in the APS and is due to a combination of drivers across sectors (Figure 2.19). The largest of these is transport, which accounts for one-third of the total increase to 2050, driven by the electrification of two/three-wheelers, cars, buses and trucks. The rapid rise of hydrogen production in Colombia in the APS, which begins before 2030, is the second-largest driver of electricity demand, responsible for another quarter. In industry, the electrification of food, textile and some energy-intensive industries accounts for nearly a further quarter. Finally, the buildings sector adds another 20% to electricity demand by 2050 as efficiency gains almost offset additional demand from the electrification of cooking and water heating, increased air conditioning and greater appliance ownership. Efficiency gains across all sectors are even stronger in the NZE Scenario, where electricity demand is 5% lower than in the APS (at 280 TWh).

Figure 2.19 ▷ Electricity demand by sector in Colombia in the APS and NZE Scenario, 2024-2050



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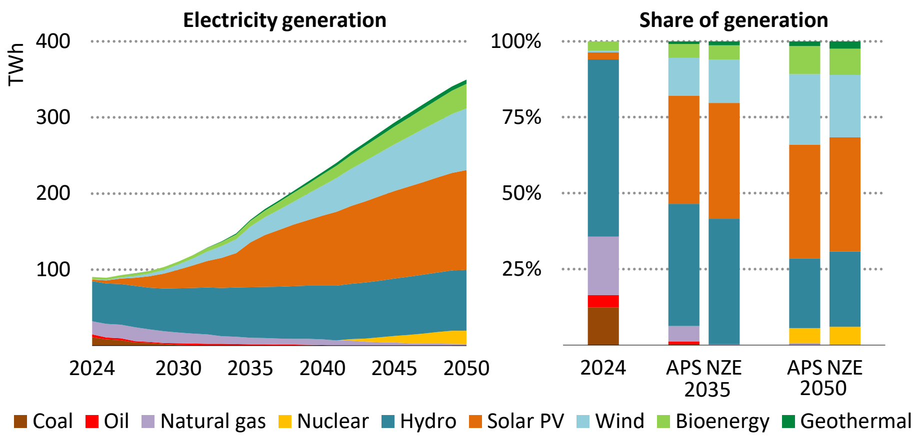
Electricity demand almost quadruples to 2050 in the APS, driven by EVs, hydrogen production and the electrification of industry

2.4.2 Electricity generation

Electricity generation from low-emissions sources increases rapidly in the APS, meeting all the additional electricity demand and displacing most fossil fuel-based generation by 2050. Coal is completely phased out by 2040, while natural gas-fired generation declines by nearly 90% by 2050 (Figure 2.20). Non-hydro renewables – led by new solar PV and wind – expand 45-fold to 2050, growing from around 5% of total electricity generation in 2024 to nearly three-quarters by 2050. Nuclear power enters the mix after 2040 and – together with bioenergy – account for most of the remaining generation by 2050.

Colombia's power mix continues to diversify with new sources of low-emissions generation in the APS. Solar PV grows rapidly to become the second-largest source of electricity generation by 2035 in the APS, before rising further to become the largest by 2050, generating over 125 TWh and accounting for nearly 40% of the electricity supply. Hydro continues to grow in absolute terms, remaining the largest source through to 2035, although its share of electricity generation decreases from around 60% in 2024 to one-quarter in 2050. Due to potential climate effects, including decreased rainfall and changes to El Niño and La Niña cycles, hydropower capacity factors decline slightly from 2024 levels in the APS, reducing generation (see Chapter 3, Section 3.3). Wind power also grows significantly, from less than 1% of total electricity generation in 2024 to around 15% by 2035 and up to almost 25% by 2050. A combination of both onshore and offshore wind contributes, with 10% of wind generation dedicated to low-emissions hydrogen production in 2050. Generation from other renewables including bioenergy and geothermal also increases, with their share in the mix rising to 10% by 2050. The APS sees Colombia's first nuclear power plants commissioned in the early 2040s, with nuclear generation ramping up to almost 20 TWh (around 5% of the electricity mix) by 2050. In addition to decarbonisation, this low-emissions dispatchable source of electricity also helps to ensure continued electricity security for Colombia.

Figure 2.20 ▷ Electricity generation by source in Colombia in the APS and NZE Scenario, 2024-2050



Solar PV takes centre stage, displacing fossil fuels almost completely, with rising shares of wind and other low-emissions sources

Natural gas-fired generation declines in the APS, with its share more than halving from around 20% in 2024 to 5% by 2035, decreasing further to 1% by 2050. The remaining gas-fired capacity plays an important role in electricity security, generating mainly at times of low renewables output, when the system needs it most. Due in part to domestic natural gas production, these generation units also help to provide affordable electricity at a time of rapid demand increase. Coal is reduced to just a marginal reserve contribution by 2035 and is phased out entirely by 2040, in line with recent political momentum, including the Powering Past Coal Alliance, which Colombia joined in September 2023. Due to the difficultly in developing carbon capture projects power generation in recent years – with only a handful of projects installed to date globally, mostly outside the power sector – the APS does not include this technology in Colombia. The implementation of a carbon price helps to reduce fossil fuel use in electricity generation. Oil-fired generation, already accounting for a very small share of Colombia's electricity supply today, is almost entirely phased out by 2050, with the exception of units providing off-grid access to electricity in remote communities.

In the NZE Scenario, electricity generation is around 5% lower than in the APS by 2050, reflecting differences in projected electricity demand. Fossil fuels are essentially phased out by 2035 in the NZE Scenario, whereas in the APS they continue through to 2050. The electricity mix in 2050 is broadly similar across both scenarios, apart from the residual fossil fuel use in the APS. Compared to the APS, the NZE Scenario places greater reliance on hydro, wind and nuclear power, while solar PV plays a slightly smaller role.

2.4.3 Installed capacity

On the path towards a decarbonised power system, Colombia's installed power capacity grows strongly, expanding from just under 25 GW in 2024 to around 80 GW in 2035, and then doubling again to around 170 GW by 2050 (Table 2.2). This increase in total installed capacity is driven primarily by growth in new renewables such as solar PV and wind with variable availability, alongside other low-emissions sources such as nuclear (Figure 2.22). It requires significant investment (see Chapter 3, Section 3.4). By 2050, low-emissions sources account for nearly all the total installed capacity in the APS, as fossil fuels decline rapidly – with coal phased out and less than 2 GW of combined natural gas- and oil-fired capacity remaining online.

Table 2.2 ▷ Installed capacity by source in the APS and NZE Scenario, 2024, 2035 and 2050 (GW)

		2035		2050	
	2024	**APS**	**NZE**	**APS**	**NZE**
Low-emissions					
Solar PV	2	33	36	69	64
of which for hydrogen production	*-*	*4*	*4*	*8*	*17*
Wind	0.1	7	7	25	22
of which for hydrogen production	*-*	*2*	*2*	*3*	*2*
Hydro	13	17	17	22	23
Bioenergy	0.4	1	1	5	5
Geothermal	-	0.3	0.4	1	1
Nuclear	-	-	-	2.2	2.5
Fossil fuels					
Natural gas	5	3	-	1	0.5
Coal	2	0.4	-	-	-
Oil	1	0.4	-	0.2	
Storage					
Battery storage	-	21	23	48	39

Installed capacity of renewables and nuclear increases significantly in the APS, from 16 GW in 2024 – most of which is hydro – to become nearly all the installed capacity by 2050, with a wide range of new sources including solar PV, wind, bioenergy, geothermal and nuclear. Although solar PV leads the way, one-third of all installed capacity by 2050 is from non-solar low-emissions sources, with around 50 GW of wind and hydro alone. The diversification of low-emissions sources in Colombia is a key part of the decarbonisation pathway in the APS.

Wind power in Colombia is in its nascent stage, with less than 100 megawatts (MW) in operation at the end of 2024. However, the country's vast wind resources provide ample opportunities to expand ambitiously, both onshore and offshore. Current projects are building momentum, such as the Guajira II (403 MW), which is under construction and set to begin operations towards the end of 2025. In the APS this momentum accelerates, in line with the ambitions of the Offshore Wind Roadmap for Colombia and recent announcements (The Renewables Consulting Group, 2022). By 2035, total installed wind capacity reaches around 7 GW, increasing to 25 GW by 2050, comprising around 15 GW onshore and 10 GW offshore. This includes capacity dedicated to power generation and over 2 GW for hydrogen production. However, for wind to grow ambitiously in the APS, recent challenges in wind markets will need to be addressed. Recent delays – particularly in environmental permitting and social acceptance – will need to be resolved for planned projects to restart as well as to ensure that future projects are not similarly delayed.

Hydro capacity rises by around 9 GW to reach around 22 GW by 2050 in the APS. Although Colombia has significant untapped hydro potential and hydropower is currently the largest source of electricity generation, further expansion faces growing social acceptance challenges, particularly due to localised impacts on communities near large-scale plants. In part to account for this, expansions in the APS include both large-scale and small hydro plants. As the existing hydro fleet continues to age, retrofits will be an important part of keeping Colombia's legacy plants in operation.

The APS also projects growth in other dispatchable low-emissions renewables, including bioenergy, another option with significant resource potential in Colombia. In the APS, it rises quickly after 2030 and expands to around 5 GW by 2050. Due to its high capacity factor, bioenergy plants can provide significant dispatchable power, even at smaller installed capacities. However, its cost-competitiveness is highly dependent on fuel costs, which increase rapidly with transport distance. The APS includes both solid bioenergy and biogas plants, based on fuel production capacity in Colombia.

Geothermal is yet another domestic low-emissions dispatchable resource in Colombia. A current project in the Nereidas Valley is expected to bring around 30 MW online by the early 2030s, with an estimated resource potential of up to 1 GW nationwide. Looking ahead, next-generation geothermal technologies could unlock an entirely new option for Colombia – provided the technology matures and costs decline over the next decade – since they are not as location-constrained as conventional geothermal, widely expanding the resource potential (IEA, 2024b).

In the APS, Colombia's first nuclear power plants are commissioned in the early 2040s, with installed capacity reaching over 2 GW by 2050. This is in line with recent ambitions at the national level, including interest in both small modular reactors (SMR) as well as traditional large-scale reactors, although competitiveness and commercial readiness of newer technologies remain to be proven at scale.

This suite of mostly new technologies in Colombia provides several options to depend on in a decarbonised power sector, leveraging a broad variety of natural resources to create opportunities across the country. However, there is also the potential for challenges to slow their development, with some at a very early stage of commercialisation in Colombia. If wind permitting delays persist, hydro growth proves more difficult, bioenergy and geothermal projects take longer to begin, and nuclear faces permitting obstacles, solar PV in combination with battery storage will have an even bigger role to play. At the same time, if the deployment of these sources moves even faster than in the APS – and also if the performance of solar PV panels proves to be higher – the capacity of solar PV could be much less. In the APS, solar PV reaches 40% of total installed capacity by 2050.

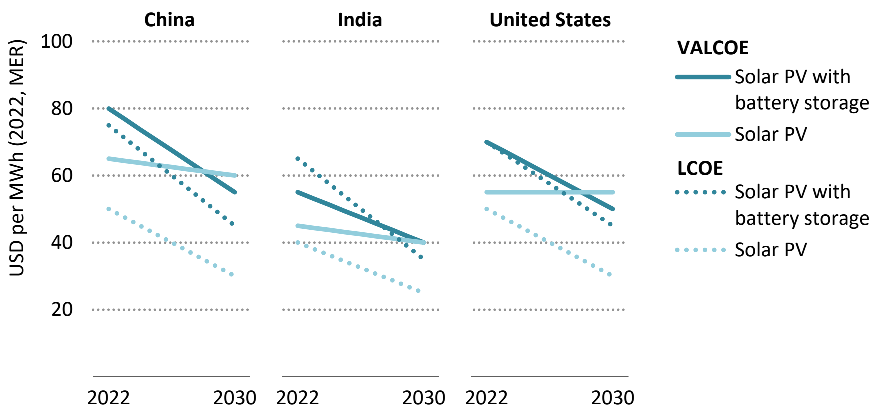
Solar PV capacity rises from just 2.3 GW in 2024 to over 30 GW by 2035 and continues to over 65 GW by 2050. This increase stems from the rapid growth of both utility-scale and rooftop solar PV, with nearly 10 GW of rooftop capacity expected to be installed by 2035. It also includes nearly 8 GW of solar PV dedicated to hydrogen production by 2050. To enable the expansion of solar PV, policies that remove barriers and reduce investment risks will be essential. The anticipated 2026 update to Colombia's National Energy Plan will serve as a critical roadmap in this regard. For utility-scale solar, continued support through initiatives like the 2024 auction (4.4 GW) will be key to sustaining momentum. To accelerate the uptake of rooftop solar PV, affordability measures, such as the recently announced 6 GW Plus Plan, which aims to equip over one million low-income households with solar systems, can provide vital financial assistance for first-time buyers. Pairing solar PV and battery storage can increase the value that solar PV adds to the system, and in turn encourage additional uptake of paired systems (Box 2.3).

Box 2.3 ▹ Solar PV paired with battery storage increases system value and long-term competitiveness

Solar PV is already one of the most cost-competitive sources of electricity today – as installed costs have dropped 90% over the past decade – and it is set to play a key role in Colombia's decarbonisation. However, the value of standalone solar PV tends to decrease as its share of generation increases. This cannibalisation effect results from the imperfect alignment between solar PV generation hours and daily demand profiles, which reduces the market value of all solar PV output as penetration rises. At the same time, as the share of all variable renewables increases – as it does in the APS – the value of system flexibility rises. Pairing solar PV with battery storage allows electricity to be shifted to periods of higher demand and prices, mitigating the cannibalisation effect and enhancing both its capacity and flexibility value.

Standard metrics of competitiveness such as the levelised cost of electricity (LCOE) do not account for these system values, including only the direct costs of each technology: construction, financing, fuel, maintenance, and costs associated with carbon price. To better account for the differences in value that technologies provide to the power system, the IEA developed and uses the value-adjusted LCOE (VALCOE), a more comprehensive measure of competitiveness that combines the technology costs (LCOE) with the value of three system services (energy, flexibility and capacity), drawing on detailed hourly modelling of electricity demand and supply. The metric takes the perspective of system planners and is applicable in all regions, reflecting the differing and changing needs of power systems based on demand patterns, overall generation mix and renewables penetration.

Figure 2.21 ▷ VALCOE and LCOE of solar PV with and without battery storage in the APS, 2022-2030



Solar PV plus battery storage provides higher value than standalone solar PV in the VALCOE

Notes: MER = market exchange rate; LCOE = levelised cost of electricity; VALCOE = value-adjusted LCOE. APS results are based on *WEO-2023*.

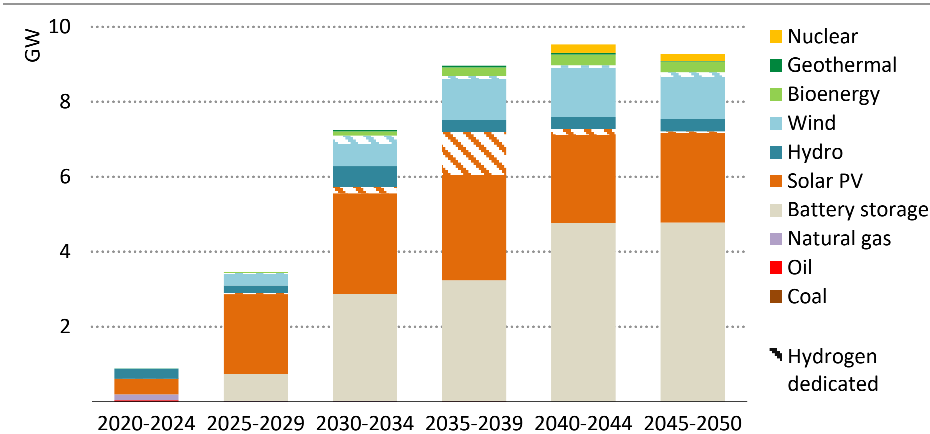
Based on VALCOE analysis of China, India and the United States – with additional regions such as Colombia to follow – pairing solar PV with battery storage makes it much more cost-competitive than standalone solar PV (Figure 2.21). While VALCOE analysis is region-specific, these results nonetheless showcase the increasing importance of generating energy at the right time and providing flexibility and capacity services to the grid. However, assessing a system based on the LCOE alone would indicate that solar PV without storage is the lower-cost choice, ignoring the potential impacts of cannibalisation effects at higher shares of solar PV. Pairing solar PV and battery storage is already one of the most competitive options and will become increasingly valuable to the system as shares of variable renewables increase.

Installed fossil fuel capacity declines steadily in the APS, with half retiring by 2035, coal fully phased out by 2040, and less than 2 GW remaining by 2050. Some natural gas-fired plants remain online in 2050, but total natural gas capacity falls by 80% compared with today, consisting mainly of peaking units. Most oil-fired plants also retire, although small, decentralised diesel generators continue operating to provide electricity access in remote communities. Despite potential near-term additions of natural gas – including 400 MW from the Buenaventura project currently at the permitting stage – overall fossil fuel additions remain near zero in the APS, with no new coal capacity and only limited oil-fired additions.

Battery storage grows rapidly in the APS, increasing from near zero capacity in 2024 to over 20 GW by 2035 and around 50 GW by 2050. This growth is driven by the increasing share of variable renewables, particularly solar PV, which increases the need for short-term power system flexibility that batteries provide through energy shifting. While fossil fuels and hydro are currently the main sources of flexibility in power systems, battery storage can provide many of the same services alongside hydro in a decarbonised system, helping to ensure continued electricity security (see Chapter 3, Section 3.3). When paired with solar PV – whose maximum generation hours are not fully aligned with peak electricity demand – batteries make solar a more dispatchable and valuable resource.

Compared with the NZE Scenario, the APS features higher installed capacities of solar PV, wind and battery storage – needed to meet higher electricity demand – while maintaining similar levels of other low-emissions capacity. In contrast, fossil fuels are essentially phased out in the NZE Scenario by 2050, whereas the APS continues to rely on small amounts of natural gas- and oil-fired capacity.

Figure 2.22 ▷ Average annual capacity additions by source in Colombia in the APS, 2024-2050



Solar PV builds on recent momentum and grows steadily to 2050, with rising wind and hydro, and the first nuclear plants alongside battery storage

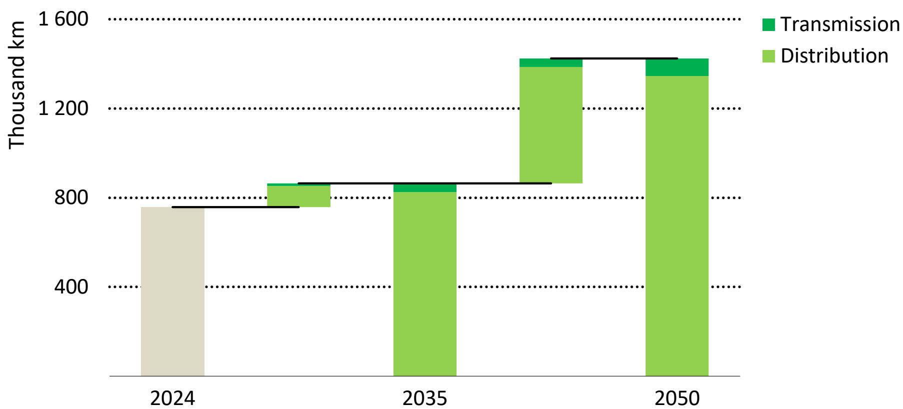
2.4.4 Electricity grids

The electricity grid is a combination of overhead lines and underground cables, transformers, substations and many other components that work together to deliver electricity to consumers. In 2024, Colombia's grid spanned over 750 000 kilometres (km), with around 80% being overhead lines and 20% underground cables. This includes about 30 000 km of transmission lines – high-voltage infrastructure connecting power plants to distribution networks and large users such as industrial facilities. It also includes roughly 730 000 km of distribution lines, which carry electricity the final distance to end users, including households, as well as connecting distributed energy resources such as solar PV, wind and battery storage to the grid, making it a bidirectional power flow in many cases. Beyond lines and cables, the electricity grid includes advanced technologies such as synchronous condensers and other flexible alternating current transmission systems (FACTS) that help with grid stability. Colombia's grid faces challenges, from the mountainous terrain of the Andes and long distances between demand centres, to the exposure to natural disasters (see Chapter 3, Section 3.3.1). For offshore wind, subsea cables connect turbines to the mainland grid, requiring careful and early planning, along with specialised ships for installation.

In the APS, the electricity grid expands due to two main drivers: rising electricity demand and increasing variable renewable generation. As electricity demand increases, new power plants are needed, and grids are essential to connect the additional supply with demand centres. As the share of variable renewables and demand flexibility – e.g. through bidirectional charging – increases, grids need to adapt to handling more bidirectional power flows. At the same time, the increasing risk of extreme weather events requires reinforcements to become more resilient to potential outages. Sensors and power electronics alongside advanced planning are essential to manage the increasing complexity – including digitalisation to better plan, anticipate and control more complex power flows (see Chapter 3, Section 3.3.2). As variable renewables such as solar PV and wind expand rapidly in the APS, grids need to move in step to avoid becoming a bottleneck – as seen already in Colombia, with many major wind projects dependent on the completion of the Colectora I transmission line in 2026.

By 2035 in the APS, the electricity grid expands by over 100 000 km – about 90% of which consists of new distribution lines – while several high-voltage transmission projects also move forward, including the 500 kilovolt transmission line and substation projects in the La Guajira department in the short term. By 2050, as electricity demand continues to grow and the renewable share accelerates, grid expansion speeds up further. The total grid length in 2050 is around 90% higher than in 2024 (Figure 2.23). While most of this growth occurs at the distribution level, it also includes about 50 000 km of new transmission lines, requiring significant expansion in high-voltage equipment such as transformers, substations, interconnections and reactive power compensation devices to provide continued stability and enhanced flexibility to the system. These high-voltage lines, though fewer in number, require significantly more planning and permitting compared with distribution lines, with longer project timelines due to their increased complexity and logistics and the need for additional technical studies and environmental permits. Grid expansion requires significant investment in the APS, with grids accounting for around 40% of total power sector investment by 2050 (see Chapter 3, Section 3.4).

Figure 2.23 ▷ Electricity grid expansion by type in Colombia in the APS, 2024-2050



Total grid length increases by 90% – around 650 000 km – by 2050 in the APS

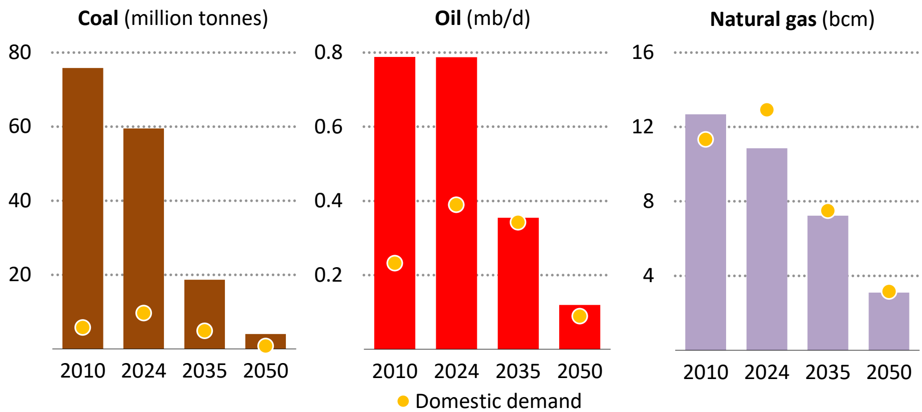
2.5 Energy production in the pathway

2.5.1 Fossil fuels

The changing demand trends lead to a major transformation of Colombia's energy supply, accelerating declines in the production of fossil fuels. Coal production drops sharply, falling by 93% between 2024 and 2050 in the APS (Figure 2.24). Colombia is currently among the top ten coal exporters globally. However, as most of Colombia's key export destinations are countries with net zero commitments, such as the Netherlands, Turkey and South Korea, the APS sees the structural decline of global coal markets driving down the country's coal production.

Colombia's oil production has been in structural decline since peaking at over 1 mb/d in 2013. The sector faces challenges as production declines from the existing mature fields and few new fields are developed. This falling supply prompts efforts to apply enhanced recovery techniques to existing reservoirs and to develop new fields. For instance, Ecopetrol recently declared commerciality of the Lorito discovery (Upstream, 2025), signalling economic viability and a move toward development, with output expected in the tens of thousands of barrels per day in the coming years. Nevertheless, in the APS, Colombia's oil production falls to around 350 kb/d by 2035 and further to about 120 kb/d by 2050. The natural gas sector faces similar structural pressures: while Petrobras's discovery of the Sirius field potentially increases national reserves significantly, if developed it will not reverse the overall downward trend in production. Domestic output no longer fully covers demand, requiring growing LNG imports to bridge the gap. Imports are likely to be priced above historical domestic levels, as declining output from mature fields and a prolonged lull in upstream investment have led to increased reliance on imports. Declining natural gas demand in the APS reduces the need for imports and leads to levels similar to domestic natural gas production of about 7 bcm by 2035 and to 3 bcm by 2050.

Figure 2.24 ▹ Coal, oil and natural gas supply and domestic demand in Colombia in the APS, 2010-2050



Fossil fuel production and exports enter structural decline as global climate ambition reduces demand and increases competitiveness in global markets

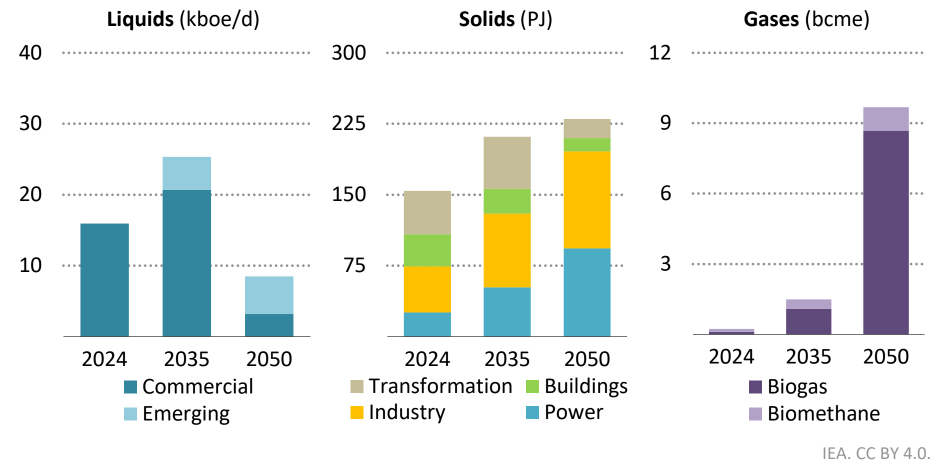
Notes: mb/d = million barrels per day; bcm = billion cubic metres. The global APS fossil fuel demand for supply modelling is based on *WEO-2024*.

2.5.2 Bioenergy

Bioenergy is an important lever in the APS for reducing emissions across all end-use sectors, supplying 25% of energy demand by 2050. Although it offers many benefits, the use of bioenergy is constrained by land availability and sustainability criteria, which means it is best deployed strategically in otherwise hard-to-abate contexts.

Liquid biofuel demand grows from 2024 to 2035; however, the mix between commercial and emerging sources undergoes a significant transformation. After 2035, Colombia's liquid biofuel production shifts from crop-based fuels, mainly blended into gasoline and diesel, toward emerging biofuels, which are produced from non-food-based crop feedstocks, wastes and residues (Figure 2.25). Emerging biofuels production requires more complex production pathways than their commercial alternatives. However, they can avoid competition with food for agricultural land use, thereby reducing the sustainability impacts associated with commercial biofuels. Commercial liquid biofuels expand from 16 thousand barrels of oil equivalent per day (kboe/d) in 2024, peak at 21 kboe/d in 2035, and then decline sharply to 3 kboe/d by 2050 as gasoline demand falls with accelerating EV adoption. In contrast, emerging biofuels scale up from zero to become the main liquid biofuel source by 2050, remaining essential for hard-to-electrify transport, such as aviation, shipping and trucking.

Figure 2.25 ▷ Liquid, solid and gaseous bioenergy supply in Colombia in the APS, 2024-2050



Solid and gaseous bioenergy supply grows, while conventional liquid biofuel supply peaks in the coming decade

Notes: bcme = billion cubic metres equivalent; kboe/d = thousand barrels of oil equivalent per day. Transformation refers to solid biofuels consumed in the energy conversion process.

Solid bioenergy supply also grows significantly in the APS, rising from around 154 PJ in 2024 to 230 PJ by 2050. Bioenergy use in buildings declines steadily as the use of traditional biomass for cooking and heating is phased out. This shift reflects Colombia's development progress, leading to improved indoor air quality and a reduction in premature deaths from air pollution. By contrast, the adoption of biomass in industry and the power sector is the key driver of growth, with demand doubling in industry to around 100 PJ by 2050 and nearly quadrupling in the power sector to almost 100 PJ by 2050 compared with today's levels.

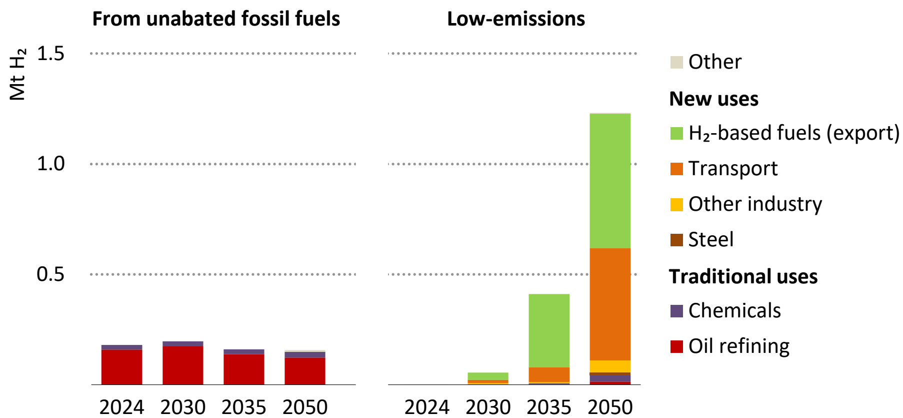
Gaseous bioenergy production, in the form of biogas and biomethane, rises more than fortyfold in the APS. Starting from 0.2 billion cubic metres of natural gas equivalent (bcme) currently, production reaches 9.7 bcme in 2050, supported by the country's significant agricultural and livestock resources and by demand increasingly underpinned by growing biogas use in the power sector, where it is a comparatively cheap source of electricity generation. Expanding the domestic supply of biogas provides the opportunity to phase out natural gas, helping alleviate pressure on Colombia's declining gas resources while utilising existing assets such as dispatchable power plants in the system.

2.5.3 Hydrogen and hydrogen-based fuels

In 2024, Colombia produced less than 200 kt of hydrogen, almost entirely for conventional uses and accounting for around 0.2% of the global total of nearly 100 Mt. But Colombia has good resources for wind and solar PV to play a more important role supplying low-emissions hydrogen, especially in La Guajira department. The most favourable locations in Colombia indicate potential production of around 1-1.5 Mt hydrogen that could be produced at less than USD 3.5 per kilogramme even under conservative assumptions for electrolyser prices in the coming years (IEA, 2025c).

Some projects are already targeting this potential: if all announced low-emissions hydrogen projects in Colombia with stated start dates by 2030 are realised, which are based on water electrolysis, domestic production could reach around 240 kt. This would represent around 0.6% of the world's announced low-emissions hydrogen capacity and place Colombia fifth in LAC (IEA, 2025c). However, the development pipeline has yet to mature: over 70% of the volume is at the feasibility stage, while less than 0.3% has reached operation, construction or final investment decision (FID), compared with about 11% for the global pipeline.

Figure 2.26 ▻ Hydrogen and hydrogen-based fuel production by end use in Colombia in the APS, 2024-2050



Hydrogen production triples by 2035, driven by projects using water electrolysis, and rises sevenfold by 2050, mainly to produce hydrogen-based fuels

Notes: Exports and demand for road transport, aviation and marine fuels include hydrogen that is converted to hydrogen-based fuels. For hydrogen-based fuels, the equivalent hydrogen amount corresponds to the stoichiometric hydrogen inputs needed to produce these fuels.

In the APS, low-emissions hydrogen production in Colombia overtakes unabated fossil-based generation by 2035, supported by targets set out in Colombia's Just Energy Transition roadmap (MME, 2024) and projects that are at least at the feasibility stage. By 2050, low-emissions hydrogen production rises to around 1.2 Mt (Figure 2.26), accounting for almost 90% of the domestic hydrogen production and almost 0.5% of global low-emissions hydrogen production, a share nearly three times higher than today's fossil-based share and highlighting Colombia's potential for competitive low-emissions hydrogen production. The installed capacity of electrolysers rises from 3.6 GW in 2035 to 9.5 GW in 2050, which requires additional infrastructure such as reliable electricity grids unless hydrogen production is located close to the demand centre or export terminal.

Early production uptake is driven by exports of hydrogen-based fuels, while domestic use expands over time to meet broader decarbonisation pledges. The production of hydrogen-based fuels accounts for more than 80% of low-emissions hydrogen production by 2035 – mainly to produce ammonia, for example to co-fire in power plants or reconvert to hydrogen, and to produce synthetic oil used in the transport sector. This reflects modest domestic demand policy goals, making it more likely that production serves overseas markets. However, realising these exports strongly depends on the stringency of measures to create demand in potential importing regions and in international shipping and aviation.

Domestic hydrogen use expands beyond 2035 to meet broader decarbonisation pledges. The share of hydrogen-based fuels for export decreases to one-half by 2050, as domestic demand gains momentum. The transport sector emerges as a key driver, reaching 510 kt of hydrogen demand in 2050, spurred by efforts to decarbonise aviation, shipping and freight. Industry becomes the second-largest source of domestic demand, with onsite hydrogen use in existing applications – such as ammonia for fertilisers, steelmaking and refining – rising to 100 kt hydrogen by mid-century. Colombia's competitive cost level for low-emissions hydrogen opens further opportunities to substitute imports (see Chapter 3, Section 3.2) and to develop new export markets for low-emissions industrial products. The recent discoveries of natural hydrogen reserves in the Cordillera Oriental and Sinú-San Jacinto basins (MME, 2025) are not considered in the APS as their commercialisation is still uncertain given challenges around exploration and understanding the subsurface potential and existence of accumulation in sufficient quantities (IEA, 2025c).

A just, secure and well-financed pathway

Key elements to pave the way

SUMMARY

- Colombia's energy transition offers a unique opportunity to deliver a just, secure and well-financed pathway to net zero emissions by 2050. While the country has already made notable progress, for example on access to electricity and clean cooking, the government has an active role to play in managing upcoming challenges. As fossil fuel revenues are projected to decline, so the energy market pivots to clean energy markets. The market size of clean energy technologies is set to grow fivefold by 2050 in the Announced Policies Scenario (APS), led by solar PV, wind and low-emissions hydrogen, with further upside potential from domestic industrial development.
- Colombia is set to close the clean cooking access gap by 2030 in the APS, thanks to sustained investment in LPG and natural gas infrastructure. However, reaching the remaining 4.2 million people – mostly in non-interconnected zones – requires targeted financing, innovative delivery models and culturally sensitive engagement. Energy affordability remains a core policy priority; increased demand together with reforms to subsidies and carbon pricing may raise household energy bills in the short term, but bills fall below today's level by mid-century through electrification and efficiency gains. The energy transition also offers new industrial and employment opportunities, with low-emissions sectors such as renewables and low-emissions hydrogen adding 77 000 jobs by 2035 keeping total energy employment stable.
- Electricity security is increasingly shaped by climate variability. Colombia's hydropower-dependent grid is vulnerable to El Niño and La Niña events, which impact rainfall and reservoir levels. In high-emissions scenarios, hydropower capacity factors could decline by up to 25% by the end of the century, compared with just 7% in low-emissions pathways. Wildfires pose additional risks, with over half the grid exposed to recurring fire hazards. Enhancing system flexibility through battery storage, demand response and resilient infrastructure is essential. Seasonal and interannual variability in solar, wind and hydro output requires a diversified mix of dispatchable low-emissions technologies, including geothermal, bioenergy and nuclear.
- Clean energy investment is estimated to exceed fossil fuel investment in 2025 and is set to rise sharply, reaching nearly 85% of total energy investment by 2035 in the APS. Key drivers include solar PV, wind, and rising investment in grids and battery storage. End-use electrification also accelerates, with transport alone attracting over USD 5 billion in 2035. State-owned enterprises and corporates remain the largest investors, contributing roughly 70% of investment by 2035, despite households increasing their share. Colombia's Country Platform aims to mobilise resources to support this transition, although high financing costs and access to long-term debt remain key challenges.

3.1 Introduction

The pathway to net zero in Colombia will require multiple layers of support to facilitate the transition to clean energy technologies. In this chapter we examine how the foundations for that pathway could be laid so that Colombia can move towards a more just and resilient energy system with support from investment and accessible financing.

Government plays a central role in a pathway to net zero emissions by establishing rules and regulations, defining objectives, and ultimately supporting the deployment of clean energy technologies by mobilising a combination of the national budget, international support and private sector investment. The market size of today's energy sector, with its related revenues and taxes from extractive industries, is essential to the current national budget in Colombia. The fossil fuel market size is projected to contract as the production of fossil fuels declines. This is the case not only under global climate pledges in the Announced Pledges Scenario (APS), but also in the Stated Policies Scenario (STEPS). Extractive industries currently account for around 10% of GDP (DANE, 2025a) and 10% of government revenues, the bulk of which stems from oil production. But oil's importance to Colombia's economy is waning: crude oil production peaked in 2013 at 1 million barrels per day; by 2024 it was around 780 000 barrels per day. The decline is set to continue as existing fields mature and few new fields are developed. With declines expected also in natural gas production and exports of coal, the market size for fossil fuels in Colombia shrinks by 50% from 2024 to 2050 in the STEPS and by 85% in the APS (Figure 3.1).

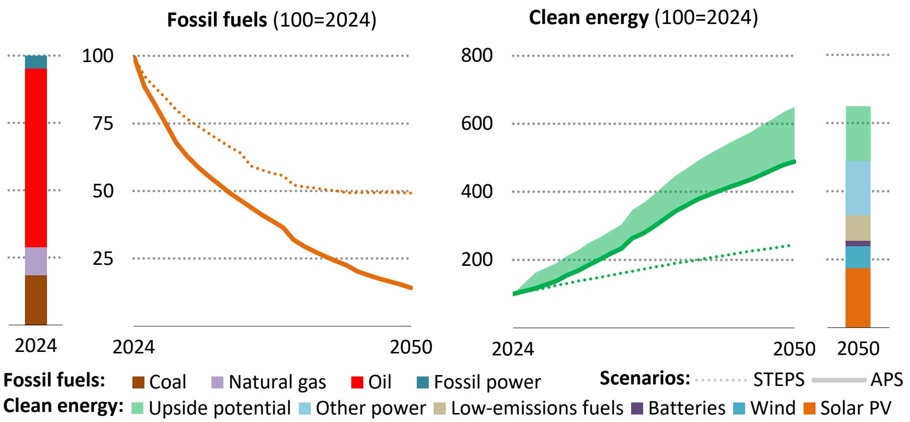
Yet the decarbonisation of Colombia's energy system will shift focus to other market sectors. The electrification of end uses, for example through electric vehicles (EVs), industrial heat pumps and electric cooking, alongside a significant increase in low-emissions electricity generation technologies, reduces the share of fossil fuels in Colombia's total energy demand from 76% in 2024 to 12% by 2050 in the APS. Fossil fuel revenues correspondingly shift to electricity sector utilities, which have different investment, revenue and ownership structures, although some companies such as Ecopetrol are active in both.

The market size of clean energy, including the installation and maintenance of low-emissions electricity generation and the production of low-emissions fuels, is projected to rise fivefold by 2050 in the APS. Currently led by existing hydropower projects, the domestic value creation from clean energy deployment drives this growth. Around two-thirds of the clean energy market growth to 2050 in the APS comes from the installation and maintenance of solar PV and wind, and the production of low-emissions hydrogen. In the STEPS, the market for clean energy is only half the size of that in the APS by 2050.

With strategic planning and support for specific industries, Colombia's clean energy market size could exceed that in the APS, potentially by one-third in 2050. Avenues to achieve this include some limited manufacturing of EVs and solar PV modules, further expanding existing production of low-emissions hydrogen for fertilisers, the extraction of copper and the production of biofuels for exports (upside potential).[1]

[1] Section 3.2.4 includes a more detailed description of the measures in this upside potential.

Figure 3.1 ▷ Evolution of market size of fossil fuels and clean energy in Colombia in the STEPS and APS, 2024-2050



The market for fossil fuels declines sharply, but the market for clean energy presents a growth opportunity for Colombia, even more so if upside potential is tapped

Notes: Market size represents the domestic value-added portion of the total market size, and is calculated based on production multiplied by the global unit price. It includes solar, wind, biofuels, low-emissions hydrogen production and batteries deployed in the APS. The upside potential includes expanded production of biofuels and critical minerals, a low share of domestic manufacturing of EVs and solar PV panels, and ammonia production for fertilisers. Biofuels include biodiesel, ethanol and sustainable aviation fuels. For next-generation geothermal there is no upside potential assumed as it would substitute other clean energy technologies.

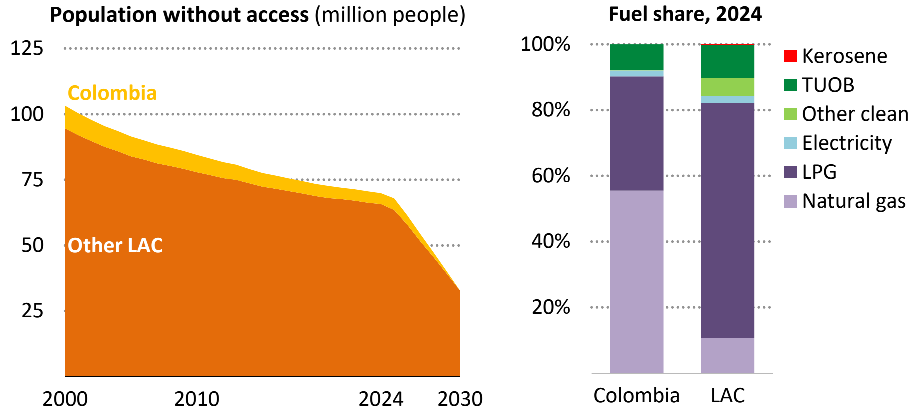
3.2 Just transition

Most of Colombia's energy use is in households, to serve basic needs at home and provide mobility for daily life. Also, a significant share of jobs are either directly or indirectly related to energy: the energy sector is one of the country's key employers, and the industry sector an important share of energy demand. This section considers the impact of the pathway to net zero emissions on the population of Colombia.

3.2.1 Access to clean cooking

Colombia has achieved a clean cooking access rate of 92%, surpassing the regional average. All clean cooking fuels, including biogas, electricity, liquefied petroleum gas (LPG), natural gas and pellets provide net emissions reductions compared to the traditional use of biomass. Progress has been driven primarily by the expansion of natural gas, which has provided clean cooking access to more than 15 million people over the past two decades. Natural gas continues to be the main source of clean cooking for over half of the population, followed by LPG, which serves around 35% (Figure 3.2). Colombia reaches full access to clean cooking in the APS by 2030, providing clean solutions to the remaining 4.2 million people.

Figure 3.2 ⊳ Population without clean cooking access in the APS, 2000-2030, and cooking fuel mix, 2024



Colombia has been a regional leader in clean cooking progress and could become one of the first countries in LAC to close the access gap by 2030

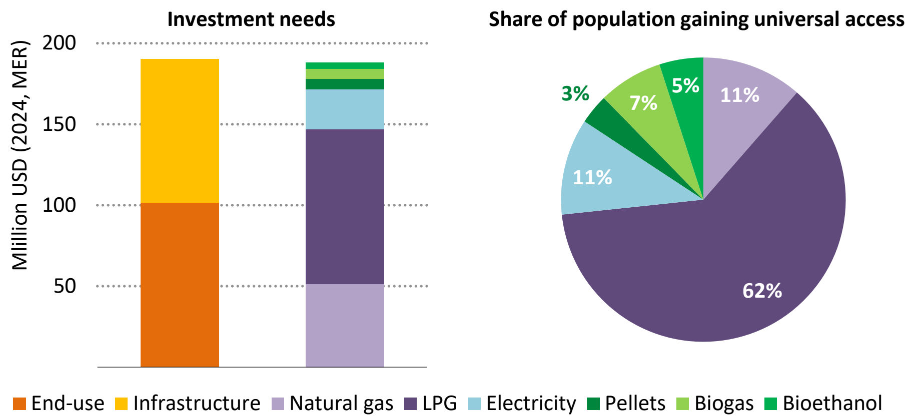
Notes: LAC = Latin America and the Caribbean; LPG = liquefied petroleum gas; TUOB = traditional use of biomass; Other clean comprises biogas and biodigester systems.

To continue fostering progress, Colombia has put forward a Plan Nacional de Sustitución de Leña (PNSL), which integrates energy access, health benefits and social inclusion as part of its just transition and climate justice framework, outlining a roadmap to help bridge the access gap (UPME, 2023a). The document provides transparency with data from recent years showing that the pace of improvement in clean cooking access rates has slowed and states that greater effort is needed to bridge the gap. This slowdown in progress is in part explained by the fact that the remaining population without access is far from major settlements and scattered across the territory, but is also due to economic, political and cultural barriers. These include limited public financing, the absence of robust policy frameworks and the difficulties of extending infrastructure to sparsely populated and remote areas. Additionally, fuel stacking remains widespread in rural communities, where traditional practices continue despite the health and environmental risks they pose.

Extending access to remote areas remains the critical challenge to achieving universal clean cooking in Colombia, given the complexity and cost of service delivery. Most of the remaining population without access live in the Zonas no Interconectadas (Non-Interconnected Zones), with Vaupés, Vichada and Guainía among the departments with the largest access gaps (UPME, 2023a). Addressing these barriers requires more efficient and targeted approaches to household adoption. Affordability is a central concern, pointing to the need for instruments such as tax reductions on fuels and equipment, targeted end-user incentives, regulations supporting partial refills, and innovative business models such as pay-as-you-go. Mobilising climate finance and carbon markets offers additional opportunities to close financing gaps and make modern cooking solutions more accessible. Challenges around cultural barriers to the acceptance of clean cooking solutions over traditional fuels such as firewood can benefit from partnering with local health authorities to help deliver messages around the benefits of clean cooking.

Investment in clean cooking must reach close to USD 190 million to achieve universal access (Figure 3.3). Around half of this goes to infrastructure projects, to help expand the existing natural gas network, with the remainder to supply other cooking fuels to smaller municipalities and rural areas and to promote community-based solutions. While LPG expansion remains essential for universal access, Colombia is simultaneously advancing decentralised renewable energy projects to ensure long-term sustainability and equitable transition. Pellets, biogas and biofuels also provide solutions to communities where fuel can be produced locally or in nearby locations, providing an affordable and clean solution to households where the distribution of LPG would be too costly. As observed in many countries, households in Colombia are projected to evolve their cooking styles, with electric cooking gaining importance after universal access is reached, especially in remote regions where the grid infrastructure or decentral power generation is not available yet (see Chapter 2, Section 2.3.3).

Figure 3.3 ▷ Investment needs to provide universal access to clean cooking and fuel share among population gaining access in Colombia



Close to USD 190 million in investment is needed to bridge the clean cooking access gap, primarily for LPG to help reach the most remote population centres

Note: LPG = liquefied petroleum gas; MER = market exchange rate.

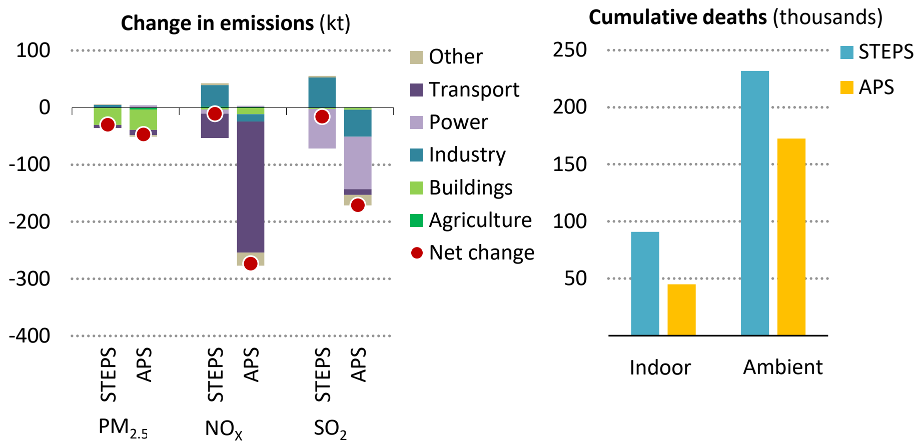
3.2.2 Reducing air pollution

More than 60% of Colombians are exposed to polluted air[2], with major consequences for health and economic productivity. In Bogotá, for instance, the annual average concentration

[2] Polluted air corresponds to having exposure to $PM_{2.5}$ density more than 5 microgrammes per cubic metre, in accordance with the annual AQG level recommended by the World Health Organisation (WHO, 2021).

of fine particulate matter ($PM_{2.5}$) was roughly 17 microgrammes per cubic metre (μg/m^3) in 2024 (IIASA, 2025), over three times the World Health Organisation (WHO) annual guideline of 5 μg/m^3 (WHO, 2021), posing clear risks to public health. In 2024, air pollution caused more than 26 premature deaths per day in Colombia. Beyond the direct impacts on premature deaths, air pollution also slows economic growth by raising healthcare costs, reducing productivity and increasing early retirements.

Figure 3.4 ▷ Change in air pollution by pollutant and source, and total number of premature deaths in the STEPS and APS, 2024-2050



Reductions in major air pollutants under the APS could avoid 46 000 household air pollution deaths and 59 000 ambient air pollution deaths between 2024 and 2050

Note: NO_X = nitrogen oxides; $PM_{2.5}$ = particulate matter with a diameter of 2.5 μm or less; SO_2 = sulphur dioxide; kt = thousand tonnes.

Source: IEA analysis based on modelling from IIASA, (2025)

Currently stated policies only lead to minor improvements in air pollution (Figure 3.4). $PM_{2.5}$ declines over the projection period in the STEPS, mainly due to abatement in buildings from reduced biomass combustion for cooking and heating, and reduced NO_X emissions primarily from improvements in transport. However, SO_2 emissions rise, driven by industry. The decarbonisation of the energy sector can provide significant improvements in air pollution. In the APS, air pollution abatement for $PM_{2.5}$ increases by 50% while abatement for NO_X and SO_2 increase by more than ten-fold relative to the STEPS, with emissions from every source declining over time as the energy system shifts away from fossil fuels to cleaner energy sources and the production of fossil fuels declines significantly. This significant transformation of the energy system results in around 46 000 fewer household air pollution deaths and 59 000 fewer ambient air pollution deaths between 2024 and 2050, highlighting the substantial health benefits of decarbonisation.

Box 3.1 ▷ Community engagement

Public participation and community engagement are vital to ensuring successful people-centred energy transitions. Such engagement builds public support, incorporates local perspectives, democratises access to energy, spurs development and helps to create acceptance of appropriate energy transition plans. Clear rules governing this engagement process and community-based projects can ensure the consideration of people's rights while providing planning security for the private sector.

In Colombia, community engagement is particularly crucial for large-scale projects, which are often located in indigenous territories. The right to prior consultation with indigenous or Afro-descendent communities is enshrined in Colombia's Constitution and in the International Labour Organization (ILO) Convention No. 169, which has been ratified by the country. The department of La Guajira, where the best wind energy resources are located, is also one of the most impoverished regions in the country. Its population, over 40% of whom are indigenous, has limited access to public utilities. Electricity access in La Guajira stands below 60%, compared with a national average of 93%.

The results of prior consultations in La Guajira have been mixed. Notable successful experiences include an agreement with 97 indigenous Wayuu communities for the construction of the Alpha-Beta to Cuestecitas transmission line, which is essential for advancing renewable projects in that area. Meanwhile, a lack of social acceptance for some wind projects has caused delays, leading in some cases to the abandonment of project proposals. Obtaining a social licence for wind and transmission projects in La Guajira is a determining factor for the implementation of renewable projects in Colombia. Strengthening the institutional capacity of government entities to conduct prior consultations and monitor compliance with agreements is essential to improving the effectiveness of these processes. Moreover, including mandatory social investments and requirements for local community labour in project auctions could further enhance social acceptance and ensure more inclusive benefits from the energy transition.

A further way in which Colombia has implemented principles of community engagement is the creation of a strategy for "energy communities", which was enshrined in the 2022-2026 National Development Plan and further developed in regulation from the Ministry of Mines and Energy. By April 2025, 285 such communities had been selected. These communities receive training and support to manage, operate and maintain distributed energy generation and self-consumption systems to gain access to electricity or clean cooking, or to improve the quality of existing services. While expanding these communities can further deepen the role of citizens in the transition, their deployment needs to be carefully overseen by energy planners and policy makers to ensure seamless integration into the central energy system and compliance with existing regulations. The model should be complemented with measures to strengthen youth participation in particular, by expanding education, civic engagement and leadership opportunities, ensuring that younger generations – who will live with the long-term impacts of today's decisions – have a real voice in shaping them.

By consolidating these efforts with strong safeguards for legal rights (including the statutory consultation process "Consulta Previa"), supportive regulation for community-led initiatives, transparent and participatory decision-making, and the active inclusion of women, indigenous peoples, youth and other vulnerable groups, Colombia can continue to position itself at the forefront of a just, inclusive and locally grounded clean energy transition.

3.2.3 Keeping energy bills affordable

Ensuring affordable, reliable energy access to all citizens remains a core priority of Colombia's energy policy. Household energy bills, including residential and transport energy use, have historically been kept low through fossil fuel subsidies and electricity tariff structures that protect vulnerable households. These subsidies helped to cushion the impact of the 2022 global energy crisis on household bills, but the fiscal burden has risen sharply in recent years. Explicit fossil fuel subsidies in Colombia reached 2.5% of GDP in 2022 (Gutierrez et al., 2024), above the Latin America and Caribbean average of 0.9% (Black et al., 2023).

The current subsidy system is already undergoing initial changes, providing the opportunity to target vulnerable households. The long-standing price stabilisation mechanism for transport fuels, called the FEPC, has begun phasing out support for gasoline, with diesel expected to follow. While this reform can free up important national budget, it is important to consider a gradual phase-out and accompany it with targeted offsetting measures to protect the most vulnerable households. For electricity and natural gas, a cross-subsidy system based on housing characteristics shields some consumers from high tariffs. However, the system also faces budget pressure and targets inadequately: it is estimated that currently about 80% of all energy subsidies are reaching non-poor households (Fedesarrollo, 2021). Improving the targeting could enhance policy effectiveness, for example by using household income and vulnerability indicators from the SISBEN IV[3] instead of housing characteristics. At the same time, rising reliance on more expensive LNG imports might put upward pressure on electricity prices. Gas-fired power plants may set the marginal price more frequently, especially if investment in new capacity fails to keep pace with demand growth or during dry years such as El Niño, when hydropower generation is reduced.

Inequalities in energy access and affordability also persist in Colombia. National electricity coverage exceeds 90%, but access drops to below 50% in some rural and remote areas (UPME, 2023b). Despite recent measures, regional disparities in affordability remain pronounced: the Caribbean coast, for example, faces both higher tariffs and lower service reliability – a double inequity – due to costly networks with high technical and non-technical losses and frequent outages. Nearly 2 million Colombians – mainly in remote and island areas – still rely on costly, polluting diesel generation with limited hours of service. Extending reliable and clean electricity to these Non-Interconnected Zones remains a pressing policy

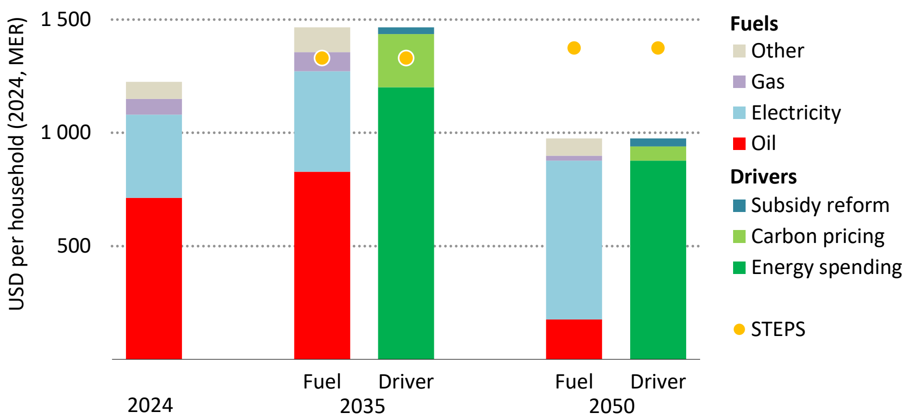
[3] SISBEN (Sistema de Identificación de Potenciales Beneficiarios de programas sociales) is Colombia's social registry for social programmes and is based on census data.

challenge, with significant implications for equity and economic opportunity. Rising demand for cooling could further deepen these divides, especially in hot regions where electricity is already expensive and unreliable.

Decarbonising energy demand can help to address many of these challenges with strong uptake of electrification technologies in the APS, such as EVs and heat pumps, and of efficiency improvements such as building retrofits. While electricity demand rises, fossil fuel consumption falls sharply, lowering the fiscal burden and mitigating the household impact of phasing out untargeted fossil fuel subsidies. Lower fossil fuel consumption also reduces the import dependence on natural gas, diesel and gasoline and limits exposure to international price volatility. Electricity prices are expected to become more stable and less tied to gas markets in the APS, as solar PV and wind expand and substitute natural gas power generation. These changes strengthen system resilience and affordability, but require an electricity system that can securely serve the entire population, even in remote areas.

3

Figure 3.5 ▹ Average annual household energy bill by fuel and driver in Colombia in the APS and STEPS, 2024-2050



Household bills increase by 2035 due to carbon pricing and subsidy removal, but fall to 2050 driven by energy efficiency; CO_2 revenues can cushion additional costs

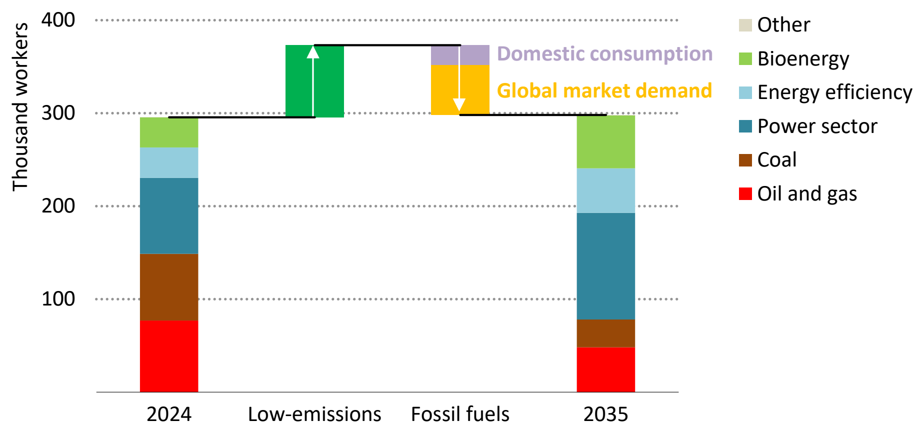
Notes: MER = market exchange rate. Energy spending includes the combined effects of fuel prices, consumption and taxes.

Energy bills could decline in the long term in the APS, despite higher economic activity and at the cost of an increase in the coming decade. Energy bills rise by about 20% in the APS to 2035, mainly as a result of carbon pricing and subsidy removals (Figure 3.5). Taking out these effects, bills are lower than in the STEPS. By mid-century, household bills in the APS fall to around 20% below today's levels and remain well under those in the STEPS, which keep steadily increasing. This shows that investment in low-emissions equipment in the short term leads to sustained long-term savings on energy bills. The reforms to carbon pricing and subsidies also generate new public revenues that can be redirected to target support for low-income households, for instance through direct payments on energy bills, or support for investment in low-emissions technologies via subsidies or concessional loans.

3.2.4 Opportunities for industry and employment through the transition

The energy sector in Colombia currently employs close to 300 000 people, around 1% of the country's labour force. These jobs are almost evenly split between fossil fuel industries and low-emissions industries. Coal mining is the energy sector's single largest employer, followed by oil extraction and the power grid. Together these three sectors alone account for 40% of the energy workforce while contributing more than 10% to national GDP (DANE, 2025a). This dependency creates a vulnerability for the Colombian economy, but the decarbonisation of the country in the global context provides the opportunity to create new jobs.

Figure 3.6 ▷ Energy sector employment in Colombia in the APS, 2024-2035



Colombia's energy employment transforms over the coming decade, with seven out of ten workers employed in low-emissions sectors

In the APS, jobs in the energy sector stay at a similar level by 2035, albeit with a different composition (Figure 3.6). Most of the losses result from the reduction in global demand for oil and coal, with Colombia currently exporting over half of its oil production and over 90% of its coal production. Low-emissions sectors, in contrast, add 77 000 jobs over the coming decade as the economy electrifies, making the power sector the single largest employer, accounting for 40% of all energy jobs.

The coal sector sees the fastest production decline and is a very important source of jobs in Colombia today, accounting for over 70 000 jobs. By 2035, around 40 000 of these will be lost, partially as a result of the reduction in domestic demand, but mainly due to lower global demand, particularly as current trade partners decarbonise. This expected decrease in demand will affect all fossil fuels, albeit at different levels. Well over 90% of Colombia's coal production is exported, while for oil this share is below 60%.

Colombia's economy is exposed to the coal transition, with its tenth-highest position in the Coal Transitions Exposure Index globally stemming from risks in economic dependence and a gap in developing alternatives (IEA, 2022). Its large coal mines primarily dedicated to exports are almost exclusively concentrated in the north of the country (Department of La Guajira) and partially in the northeast (Department of Cesar), presenting a challenge for policy makers in ensuring a smooth and just transition into other sectors. This underscores the need to promote alternative sectors such as sustainable agriculture, industry and tourism to help diversify and make local economies more resilient. In an effort to create cross-collaboration and knowledge sharing around just energy transitions, Colombia is planning to host the 2026 International Conference on the Progressive Phase-out of Fossil Fuels, promoting global co-operation on just and equitable transitions for fossil-dependent regions.

The domestic pathway to net zero and the global decarbonisation provide opportunities to create jobs in new sectors. By 2035, Colombia is set to add around 20 GW of renewables capacity, making the power sector and related infrastructure the key driver of job growth, with, for example, around 8 000 jobs created in the transmission and distribution grid. Increased efficiency in end uses creates around 15 000 jobs and higher bioenergy demand 24 000 jobs. These jobs are widespread across the country, but overlap primarily with high-density population centres where economic opportunities are already most prevalent, and departments with outstanding resources, such as the La Guajira and Cesar. These two coal-dependent departments are being prioritised by Colombia's NDC 3.0 update through territorial just transition plans aimed at economic diversification and social inclusion. Transitioning from coal mining will be easier for those that live in close proximity to announced low-emissions projects, with the latter able to absorb around a third of existing coal jobs within a 50 km radius. Beyond these drivers, which are essential for the decarbonisation of Colombia's energy system in the APS, there are further sectors with upside potential to create additional jobs (Figure 3.7):[4]

- **Critical minerals:** Colombia already hosts the Cerro Matoso mine, the largest nickel mine in South America. While Colombia faces strong competition in nickel extraction from Indonesia, a number of possible projects exist to develop copper and molybdenum deposits in the country, such as the Alacrán copper project. If successful, this project would supply 360 thousand tonnes (kt) of copper per year, placing Colombia in the top 15 copper-producing countries – a mineral that is fundamental to the energy transition for grids and other clean technologies. The refining of copper can create additional industrial value in the country and thereby jobs.

- **Low-emissions hydrogen:** Colombia has significant potential, especially in the La Guajira department, to produce a highly competitive low-emissions hydrogen. The hydrogen can either be used directly domestically, converted into hydrogen-based fuels and

[4] See Section 3.1 for an economic assessment of the upside potential.

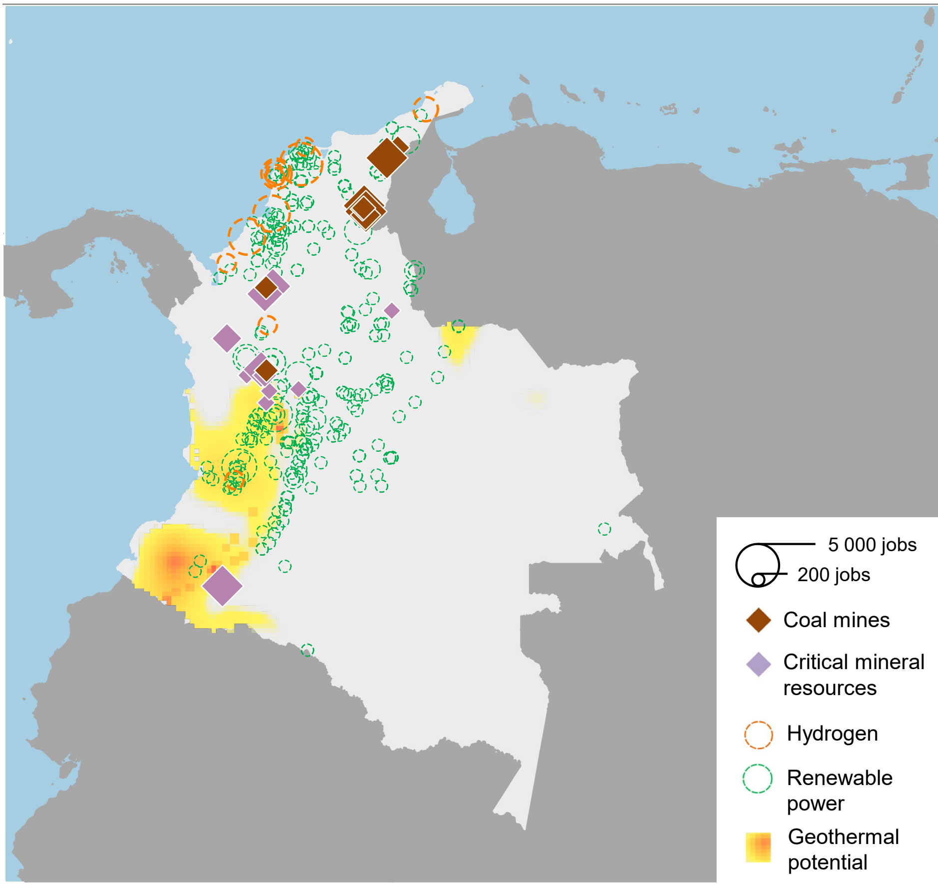
exported, or upgraded to a higher-value material such as ammonia for fertilisers or iron. Beyond the low-emissions hydrogen production projected in the APS, which is around 1.2 Mt by 2050, the case of ammonia for fertilisers is particularly interesting for the creation of new jobs as it could reduce high import dependency for the important agriculture sector (see Box 3.2). The fertiliser industry can also create new mining jobs for the production and beneficiation of rock phosphates. However, new infrastructure might be required as those reserves are in the centre of the country.

- **Biofuels:** biofuel production could further expand beyond production of 10 000 barrels of oil equivalent per day in the APS by 2050, mainly through emerging technologies with the potential to produce sustainable aviation fuels (SAF) for export. Depending on the production route, this could be located in departments with palm oil, such as Meta or Santander, for production through the traditional hydrotreated esters and fatty acids (HEFA) pathway and in departments with sugarcane, such as Cauca, for the alcohol-to-jet pathway. But to reduce the burden on land use, this production can also move to other locations with the availability of advanced feedstock resources, such as crop residue, forestry residue or the organic part of municipal waste.

- **Clean energy technology manufacturing:** Colombia has the potential to participate more actively in clean energy technology supply chains, notably including its growing domestic market. From now to 2050, the country installs in total 72 GW of solar PV and deploys 25 million EVs (three-quarters of all vehicle sales) in the APS. Besides the installation and maintenance associated with this deployment, domestic manufacturing can create domestic employment opportunities and value added. Particularly for EVs and solar PV modules, Colombia can build on existing automotive manufacturing industries, with a production capacity of 300 000 light vehicles and 1 million two/three-wheelers per year (Procolombia, 2025), proximity to critical resources in the region, low-cost renewable electricity and port infrastructure for imports of upstream products, such as polysilicon and wafers.

- **Next-generation geothermal:** No longer location constrained, advancements in geothermal drilling open up a much wider variety of locations in Colombia, particularly in the north and south of the country. As technologies from the oil and gas sector are fundamental for these advancements, transferring jobs could require less retraining. As a dispatchable power source, it has the potential to either substitute other baseload low-emissions technologies such as hydropower, nuclear or bioenergy, providing the same services to the energy system, or it could take pressure off the ambitious ramp-up of solar PV and wind. As detailed in *The Future of Geothermal Energy*, the levelised cost of electricity from geothermal could come down to USD 30-75 per MWh if construction costs come down to the range of USD 2 000-5 000 per kW by 2050, making next-generation geothermal competitive in Colombia (IEA, 2024a). However, to unlock market potential for next-generation geothermal for electricity generation, innovation and process improvements will be needed to reduce costs significantly, and projects will need to leverage low cost of capital rates.

Figure 3.7 ▷ Coal mines, critical mineral resources and announced low-emissions projects in Colombia as of 2024



Announced low-emissions projects include some close to existing coal mines offering potential for job transfers; smaller mines are close to critical mineral resources

Notes: Renewable power includes hydropower, solar PV and wind. Red indicates a high and yellow a low potential for next-generation geothermal in energy density.

Sources: IEA analysis based on Global Energy Monitor (2025a), Global Energy Monitor (2025b), IEA (2025a) and Project InnerSpace™ calculations for Enhanced Geothermal Systems based on GeoMap™ data for the geothermal potential.

Low-emissions jobs differ from mining jobs in terms of skill level in some cases. While renewables projects and critical minerals mining require similar skills to coal mining, retraining and upskilling will be required to ensure that people can stay in the labour market. To ensure a transition that brings benefits to all, policy makers should also incentivise and facilitate the distribution of energy projects in the more rural and remote areas of the country and in coal mining regions. Initiatives that can help create opportunities include tailored government support for communities and workers with a focus on skills and training, ensuring robust social dialogue and stakeholder participation, especially among youth, women and indigenous communities. Colombia has several private sector initiatives and civil society projects supporting a just and inclusive energy transition; similar government-led programmes dedicated to labour transition can help offer a pathway for retraining and upskilling workers in clean energy. Shifts in employment can also increase opportunities for youth in communities that are highly dependent on coal for their economy. The recent extension of Law 1715 of 2014, issued in Resolution 736 of 2025, already provides an incentive to attract new industries through tax credits, for example for parts in EVs (UPME, 2025).

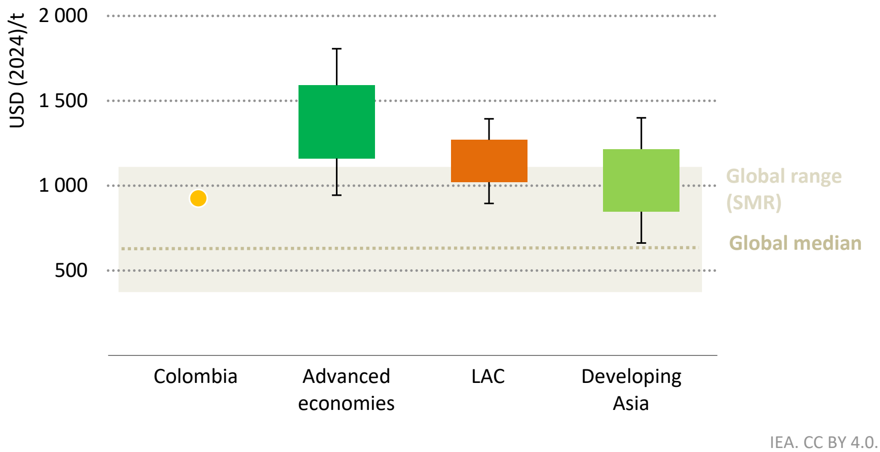
Box 3.2 ▹ Can Colombia reduce its dependency on fertiliser imports?

Colombia's agriculture sector, which accounts for roughly 9% of GDP and employs about 3 million people, is viewed by the government as a strategic national priority and a key pillar of rural development (World Bank, 2025a). While Colombia produces small amounts of rock phosphate-based fertiliser, the country remains heavily dependent on imports, with around 75% of fertiliser demand met by foreign suppliers (FAOStat, 2025). One of Colombia's main fertiliser producers, importers and blenders, Monómeros Colombo Venezolanos, supplies around 30% of the domestic market, leaving the country highly reliant on its continued operation for national food security. This dependence on global fertiliser markets made Colombia particularly vulnerable during the 2021-2022 price spikes, when costs surged following Russia's invasion of Ukraine, China's self-imposed restrictions on phosphate and urea exports, and COVID-related shipping and logistics bottlenecks that disrupted key global suppliers.

A large, strategic agricultural sector coupled with exposure to volatile global fertiliser markets creates opportunities for Colombia to invest in domestic ammonia production, a key input into fertiliser supply chains. Colombia could produce electrolytic ammonia for roughly USD 900 per tonne in 2035, a cost premium of around USD 300 per tonne compared with the projected 2035 global median cost of ammonia from steam methane reforming (SMR), the most common production method today (Figure 3.8). Though the premium is material, the levelised cost of producing electrolytic ammonia in Colombia remains below the upper bound of the historical price range and would support long-term decarbonisation goals, bolster the competitiveness of agricultural exports in global markets adopting carbon border measures, and reduce exposure to volatile international markets while strengthening food security.

Policy mechanisms such as contracts-for-difference or long-term offtake agreements could accelerate market development and narrow the cost premium. Given that Colombia spent roughly USD 480 million on nitrogen-based fertiliser imports in 2022, spending roughly one-half of that amount in domestic electrolytic ammonia production could supply the ammonia needed for a nascent but expanding phosphate fertiliser industry, leveraging Colombia's promising rock phosphate deposits. Assuming a mix of phosphate and nitrogen fertiliser production methods, this could yield the ammonia required for over 600 kt of fertiliser products, equivalent to roughly 60% of current fertiliser imports, leading to stronger domestic supply chains and supporting low-carbon industrial growth in Colombia.

Figure 3.8 ▹ Levelised cost of electrolytic ammonia production in the APS, 2035



Electrolytic ammonia production is economic in Colombia compared to other regions, but still carries a significant cost premium over SMR production

Notes: SMR = steam methane reforming; LAC = Latin America and the Caribbean. Global median (SMR) refers to 2035 projected cost. Global range (SMR) refers to upper and lower range of 2024 international ammonia prices.

3.3 Electricity security and climate resilience

A core element of Colombia's net zero pathway is increasing electrification of the energy system, to be met in part by the growth of renewables and corresponding grid expansion. Together these alter the energy system's profile of risks and vulnerabilities to natural hazards, such as extreme weather events, and slow-onset changes from climate change. This section examines the implications of these.

3.3.1 Climate resilience of the electricity system

Climate variation is a core element in Colombia's electricity security. Located in the Intertropical Convergence Zone (ICZ) and being affected by the Caribbean Low-Level Jet (CLLJ) – a strong easterly wind – Colombia has two periods of high rainfall and two drier periods per year, with the wet periods corresponding to cloudy skies and weaker winds, and the dry seasons experiencing clearer skies and stronger winds. These elements are key considerations when exploring Colombia's wind and solar potential – essential components of the pathway set out by the APS.

In addition, the interannual variations of El Niño and La Niña (ENSO, i.e. El Niño-Southern Oscillation) have a significant impact on the country's hydropower-based electricity system. El Niño events in Colombia are associated with less frequent rainfall and higher temperatures, causing droughts, while La Niña has the opposite effect, increasing flood and landslide risks. More than half of all months between 1992 and July 2025 were marked by El Niño or La Niña conditions (NOAA, 2025).

ENSO events have shaped Colombia's entire electricity system. In 1992, when Colombia's electricity mix comprised 78% hydropower, the country suffered a severe energy crisis due to an El Niño-induced drought that led to the aggregated hydropower reservoir level falling to below 30% of its capacity. This coincided with 20% of thermal power plants being out of service due to maintenance failures. Colombia experienced a generation deficit of 25%, causing power outages (Pulgarin-Morales, Krueger, 2025). The incident triggered major electricity sector reform (Corte Constitucional, 1992).

The impacts of climate change on ENSO – a highly complex, global phenomenon – are subject to a high degree of uncertainty. Recent studies find that global warming tends to lead to a decrease in overall ENSO amplitude by the end of the century (Callahan et al., 2021), while high-emissions scenarios see an increase in the frequency of La Niña events and ENSO-related variability in rainfall (Geng et al., 2023; Cai et al., 2022). It is therefore critical for Colombia to enhance its electricity system's resilience and improve its disaster risk management capabilities with respect to droughts and floods.

Climate variations challenge Colombia's hydropower sector

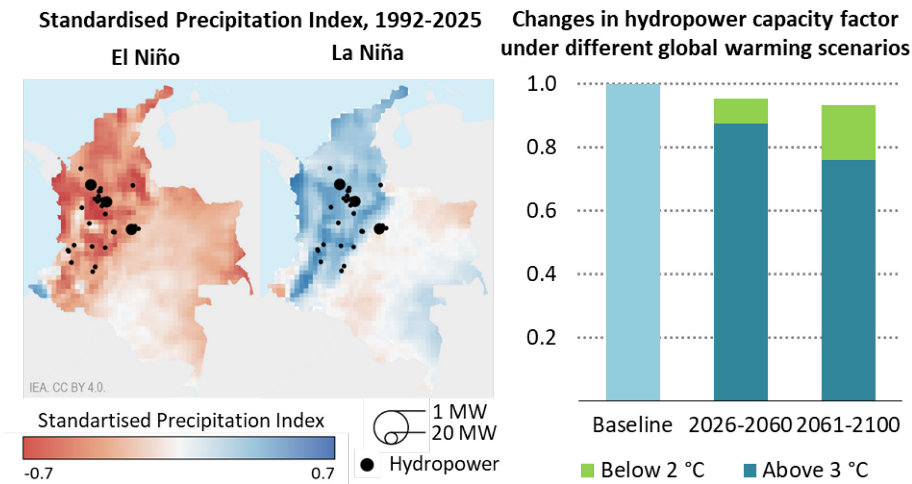
Colombia's hydropower generation faces substantial challenges caused by the interannual variations of ENSO. El Niño events bring, to parts of Colombia, less frequent rainfall, which reduces reservoir inflow, and higher temperatures, which increase evaporation from water reservoirs. The resulting lower water levels directly reduce the amount of water available for hydropower generation, leading to a substantial drop in electricity output. Furthermore, hydropower plants are constructed to operate for multiple decades, making them more prone to the effects of climate change during their lifespan.

IEA analysis of precipitation patterns shows that, across all of Colombia's hydropower plants, in El Niño months between 1992 and 2025 the Standardised Precipitation Index (SPI)[5] decreased to 0.4 below the baseline. This raised the probability of below-average rainfall to 66% and increased the risk of a moderate drought by 27% to 73%. Over the same period, nearly three-quarters of the hydropower plants experienced a severe drought at some point during El Niño months. For instance, Colombia experienced severe drought in 2015 and 2016

[5] The Standardised Precipitation Index (SPI) quantifies precipitation anomalies relative to the climatological average in the pre-industrial period (1850-1900) which is set to zero. Values below zero represent drier conditions, while values above zero indicate wetter conditions. Moderate droughts are defined as months with an SPI value of below -1. Severe droughts are defined as months with an SPI value of below -2.5.

during El Niño months, with rainfall amounts falling to 40% below usual levels and reservoir water levels dropping by 60% to 70% (Sustainable Water & Energy Solutions Network, 2020). Droughts cause a decrease in hydroelectricity output. For example, in April 2024, during an El Niño-induced drought the share of the country's power supply met by hydropower dropped to 46% (Bloomberg Linea, 2024) from an annual average of 68% over the past decade. To mitigate the impacts, the country suspended electricity exports to neighbouring Ecuador (IMF, 2024). However, there is complex interplay between local and large-scale hydro-climatological phenomena: studies have shown that some river flows into hydropower reservoirs between 2000 and 2024 increased during El Niño periods, while others decreased (Ochoa et al., 2025). This highlights the need for tailored water management approaches for each reservoir.

Figure 3.9 ▷ El Niño and La Niña and climate change impacts on Colombia's hydropower fleet



El Niño and La Niña are associated with more extreme rainfall patterns reducing hydropower outputs; limiting global warming can reduce impacts on the capacity factor

Notes: Left-hand graphic: The figure shows the mean one-month Standardised Precipitation Index (SPI-1) from 1992 to August 2025. The classification of ENSO months is based on the Oceanic Niño Index (ONI) where El Niño months correspond to ONI values above 0.5 °C and La Niña months to ONI below -0.5 °C. Right-hand graphic: Baseline refers to the period 1971-2010. The Below 2 °C scenario corresponds to the SSP1-2.6; the Above 3 °C corresponds to the SSP3-7.0.

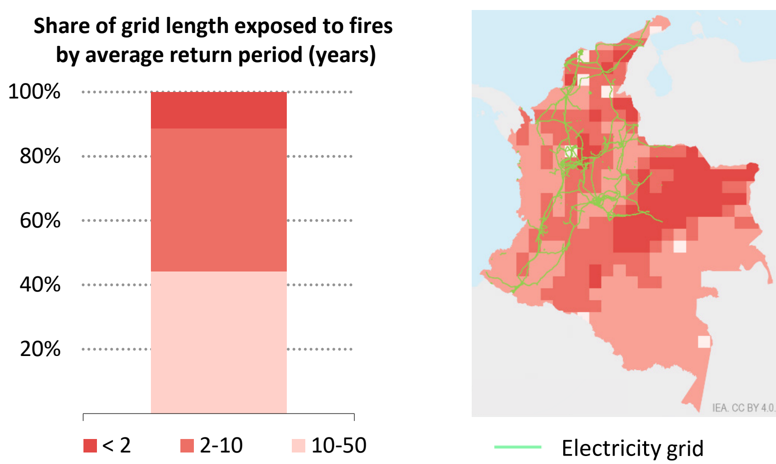
Sources: IEA analysis based on NOAA (2025); Copernicus (2025).

IEA analysis using global warming scenarios shows that Colombia's existing hydropower plants and reservoirs are likely to face more days above 35 °C by the end of the century across all climate scenarios. In scenarios associated with global warming of less than 2 °C (Below 2 °C) and around 3 °C by the end of the century (Around 3 °C), most plants are exposed to slightly drier conditions; while global warming of more than 3 °C (Above 3 °C) could expose the plants to substantially drier conditions by the end of the century. If no additional resilience measures are implemented on time, IEA models project that Colombia's hydropower capacity factor may decline by nearly 25% until the end of the century in the Above 3 °C scenario, while in the Below 2 °C scenario, the capacity factor's decline is limited to 7% (Figure 3.9). A decline in hydropower generation risks broader effects on Colombia's power system. Measures to mitigate this risk could include optimising water resource and basin management, diversifying the electricity mix with the complementary renewables solar and wind, while investing in energy storage such as pumped hydropower or batteries to increase the system's flexibility and allow for a greater share of variable renewables in the system.

Wildfire risk to energy infrastructure

Colombia faces high wildfire risk due to its climate and geography. For example, in 2024 hot and dry conditions linked to El Niño placed about 90% of Colombia's municipalities under imminent risk of wildfires, triggering a national state of emergency and leading to the loss of about 15 000 hectares of tree cover (Global Forest Watch, 2024) .

Figure 3.10 ⊳ Electricity grid exposure to wildfire risk in Colombia in 2025



Over half of Colombia's national electricity grid is built in areas at risk of experiencing a wildfire at least every two to ten years on average

Notes: The map shows the average annual probability of at least one fire occurring within a 0.5° × 0.5° (~3 000 km²) grid cell. Probabilities are estimated using a negative binomial generalised linear model (GLM) based on historical fire records, above-ground biomass carbon density, and the Fire Weather Index (FWI). Probability classes (< 1%, 1-2%, 2-10%, 10-50%, and 50-100%) are expressed as the corresponding average interval between fires in each grid cell: more than 100, 50-100, 10-50, 2-10 and less than 2 years, respectively. These intervals represent long-term statistical expectations rather than precise predictions for individual years.

Sources: IEA analysis based on FWI from CEMS (2019), historical burned area from MODIS (2017), biomass carbon density from Santoro et al., (2021), electricity grid from OpenStreetMap (2025).

In dry seasons, sparks from electricity lines can start wildfires in their vicinity, posing a direct threat to secure electricity supply. Fire can damage towers and deposit soot on insulators (Sediver Research Center, 2019), which can cause further line sparking or even short circuits (Oak Ridge National Laboratory, 2019), and lead to unplanned power outages. IEA analysis shows that 10% of Colombia's national electricity grid is built in areas that are expected to experience a wildfire every two years on average, over 40% of the network can expect wildfires every two to ten years, and another 40% of the grid is in areas that experience wildfires every 10-50 years (Figure 3.10).

This high exposure to wildfire requires additional measures to protect Colombia's electricity networks and ensure security of supply. During the wildfires of 2024, grid operators took proactive measures to protect distribution networks in Bogotá and Cundinamarca by deploying about 1 500 field staff to respond to disruptions and focusing attention on medium-voltage lines at highest risk (ENEL, 2024). Measures to mitigate wildfire risk include deploying spark prevention units on grids, undergrounding power lines, enhanced vegetation management and public safety power shutoffs. Additional emerging technologies to enhance grid resilience are new AI and remote sensing tools, along with fibre optic sensors, to monitor heat exposure and guide recovery efforts.

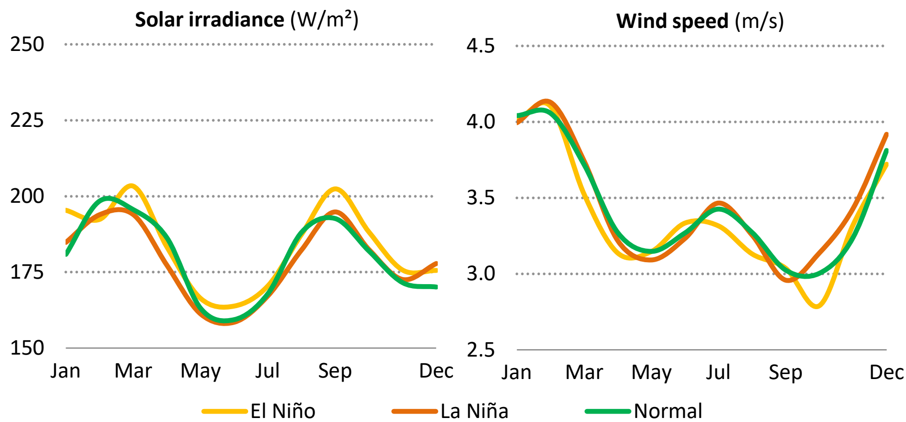
3.3.2 Electricity security

System flexibility

Electricity security – already essential for the functioning of modern economies – will become increasingly important as end uses electrify. To ensure demand is always met, electricity systems must be flexible to manage variability in demand and supply – ranging from maintaining instantaneous grid stability to balancing the system hour by hour and across seasons. Driven by the pace of variable renewable energy deployment and the electrification of end uses, electricity system flexibility needs evolve in scale and complexity in the APS, with short-term flexibility needs increasing up to fivefold by 2050 in the APS for some regions (IEA, 2024b). Most of Colombia's flexibility needs are currently met by coal-, natural gas- and oil-fired power plants, which respond within seconds to frequency and demand fluctuations, can sustain high output for extended periods and provide inertia. Hydro provides much of the hourly balancing, but seasonal or interannual variations in hydro output can increase long-term flexibility needs that are then covered by thermal generators. However, as Colombia's power sector decarbonises in the APS, new electricity security challenges emerge.

Solar PV and wind expand rapidly in the APS, reaching half of total electricity generation by 2035 and nearly two-thirds by the mid-2040s. These rising shares increase electricity supply fluctuations, since solar PV and wind power generation have hourly, seasonal and interannual variability. While solar PV has a pronounced daily cycle, wind tends to vary less from hour to hour but more across days and weeks. Solar experiences maximum daily output between mid-morning and mid-afternoon, while wind output profiles vary by location – though neither are perfectly aligned with electricity demand that peaks earlier in the morning and in the evening. Momentary changes in solar PV and wind output create additional variability, as clouds pass overhead and wind speeds gust up and down, while daily and weekly variations in weather conditions further affect generation. Consequently, short-term flexibility needs are much greater in a decarbonised electricity mix.

Figure 3.11 ▷ Average monthly solar irradiance and wind speed in Colombia, 2015-2024



Solar irradiance and wind speed are highest during dry seasons, with interannual fluctuations up to 8% due to the effects of El Niño and La Niña

Notes: m/s = metres per second; W/m² = watts per square metre. El Niño, La Niña and Normal are based on monthly averages of each type during 2015-2024.

Source: IEA analysis based on Copernicus Climate Change Service: ERA5 hourly data on single levels from 1940 to present Copernicus Climate Change Service (2025).

Seasonal flexibility needs are driven by long-term variations in demand and the output of solar PV, wind and hydro. During the dry seasons, clearer skies and stronger winds lead to higher solar PV and wind output, and the effect of the CLLJ and El Niño years further boosts generation. During the wet seasons, increased cloud coverage and weaker winds limit solar PV and wind output, and La Niña further limits generation (Figure 3.11). The extent of these effects shows regional variation: the Pacific and Caribbean coasts experience the highest seasonal variability of solar PV output, while the Amazon is highly affected by ENSO; wind is especially affected by the CLLJ, particularly on the Caribbean coast; and, compared to coastal regions, the Andes and other inland areas have lower average wind speeds and experience higher seasonal variation. The peaks in solar PV and wind output coincide throughout part of the year, meaning that seasonal variation is even higher as a result. Conversely, their variations complement hydro output, which is highest during the cloudy, less windy peak rainfall periods, helping mitigate overall seasonal variability in electricity supply. The interannual variations in hydro create an additional challenge though, with annual output fluctuating by as much as 25% in recent years.

To address these variations in solar PV and wind output, short-term flexibility that ranges from the millisecond response time to providing additional power on a weekly timescale will be needed (IEA, 2024c). The existing hydro and fossil fuel fleet is well-suited to handle much of this role as long as capacity remains online – they can respond within minutes and sustain high generation levels for weeks. But their generation hours decline to 2050 in the APS, so a refocusing of fossil fuel plant operations towards system adequacy and flexibility services will be essential. At the same time, alternative sources of flexibility are set to become increasingly important over time, notably battery storage and demand response.

Batteries are well-suited to complement solar PV by charging during periods of high solar output and discharging during evening peaks (see Box 2.4). In addition to energy shifting, batteries can provide a broad suite of services that are essential for electricity security. Their split-second responsiveness can provide ancillary services such as synthetic inertia, frequency regulation, voltage support and operating reserves, as well as secure capacity to maintain the adequacy of the power supply. If placed strategically in grids, batteries can also provide congestion management, enabling the deferral of investment in transmission and distribution infrastructure. Battery storage is increasingly affordable – costs have fallen by 90% over the past decade – and, due to its modularity, quick to deploy once permits and a grid connection have been secured. They are highly scalable, from small residential systems to utility-scale units near demand centres. At the household level, batteries paired with rooftop solar PV can store and shift on-site generation, reducing grid demand and easing pressure on grids. Furthermore, provided enabling regulation and the right incentives are in place, behind-the-meter batteries can be aggregated into virtual power plants that are able to provide many of the same system services as utility-scale batteries.

Demand response, such as flexible EV charging and optimised use of smart air conditioners, heat pumps and power-to-heat in industry, offers a cost-effective source of flexibility by shifting consumption away from peak periods. This requires that consumers are incentivised to participate.

For seasonal flexibility, thermal power plants remain a key source through to 2050 in the APS, but their role shifts from bulk generation to providing secure capacity – supplying less than 1% of total electricity generation – as variable renewables take on a leading share. Hydropower continues to play an important role, though its effectiveness depends on robust water resource management amid rising drought risks.

Hydro reservoirs offer valuable long-term flexibility, but expansion potential in Colombia is limited. As a result, other low-emissions dispatchable sources – such as nuclear, bioenergy and geothermal – become essential. These technologies can ramp up and down as needed and provide seasonal flexibility, while supplying around 15% of total electricity generation by 2050 in the APS, underscoring their critical role in electricity security. Curtailment becomes an integral feature of future power systems once the variable renewable share exceeds 30%. While often linked to inflexible generation or grid bottlenecks, curtailment can also be a cost-effective alternative to overbuilding grid and storage infrastructure.

Electricity grids

Colombia's electricity grid has expanded rapidly over the past two decades, led by reforms that introduced competition, unbundled generation, transmission and distribution, and opened the sector to private investment. This has led to a more than 50% increase in the transmission system up to around 30 000 km, linking new generation to demand centres with a focus on regional integration – including 230 kV and 500 kV expansions to carry inland hydropower to coastal regions and major high-voltage lines to transmit solar PV and wind generation in bulk. Interconnections with neighbouring countries further add to existing grid resilience: five with Ecuador, three currently inactive ones with Venezuela, and a planned link with Panama. At the distribution level, 37 regional utilities manage over 750 000 km of networks. Power losses have fallen from more than 20% in the early 2000s to around 12% today, due in large part to modernisation and anti-theft programmes. As Colombia moves towards a decarbonised electricity system with high shares of solar PV and wind in the APS, new challenges will emerge for continued grid stability and security.

Table 3.1 ▹ Challenges and best practices for grid resiliency with high shares of solar PV and wind in Colombia

Plans, new technologies and regulation
Advancement of existing projects and plans
• Resolve current environmental permitting and social issues delaying some planned projects in the National Energy Plan 2022 • Modernise ageing assets and reinforce redundancy in outage-prone distribution networks • Expand transmission lines that are already becoming saturated with new solar PV and wind • Accelerate electricity access plans through integrated planning
Implementation of new technologies improving controllability
• Monitor the condition of high-voltage assets using sensor-based diagnostics to extend equipment lifetime and improve reliability • Monitor frequency and voltage stability in real time, for example via a wide-area monitoring system (WAMS) • Employ satellite imagery to detect vegetation encroachment and structural weaknesses • Establish resilient communication networks with strong cybersecurity measures • Deploy advanced technologies to ensure grid stability or optimise operation: flexible AC transmission systems (FACTS) – including static synchronous compensators (STATCOMs) and power flow control devices, battery storage, smart inverters with grid-forming capabilities and dynamic line rating • Strengthen regional interconnections to enhance grid flexibility and optimise resource sharing
Revision of existing regulations reflecting new challenges to the system
• Classify resilience events according to their nature and impact • Define technical and economic criteria for evaluating resilient infrastructure projects • Establish a regulatory framework that fosters innovation through the testing, validation and deployment of technologies, while ensuring system flexibility, operational efficiency, reliability and interoperability • Design incentive schemes and create dedicated funding instruments (public, multilateral, mixed) to promote resilience investment, particularly in rural and high-vulnerability areas

Continued next page…

Table 3.1 ▷ Challenges and best practices for grid resiliency with high shares of solar PV and wind in Colombia (continued...)

Prevention and response
Prevention against natural hazards in grid planning and construction
• Integrate risk maps for areas prone to earthquakes, landslides, floods and wildfires in transmission line planning • Build transmission towers and substations engineered to withstand seismic shocks and extreme wind conditions • Deploy underground lines in urban areas to reduce exposure to storms and wildfires • Elevate coastal and flood-prone infrastructure to mitigate tsunami and inundation damage
Adaptation to reduce the impact of natural hazards and other failures
• Align automatic load-shedding schemes and generator protection systems • Adapt grid codes to the changing generation mix • Employ islanded microgrids and storage to keep critical services powered during outages, especially in remote areas • Use demand response to mitigate grid stress by shifting demand to off-peak periods • Design contingency plans for inverter-rich systems and deploy real-time wide area monitoring of generation • Limit the spread of failures by focusing on containment during outages • Provide diverse communication pathways and stronger voltage support to weak grids areas • Ensure recovery plans emphasise restoring service quickly and safely with regular updates to clarify the roles of different control centres • Apply operator certification programmes and simulations to further strengthen human preparedness • Ensure black-start plants and critical substations have on-site staffing, supported by fallback communication systems and pre-positioned crews to reduce restoration times

3.4 Investment and financing

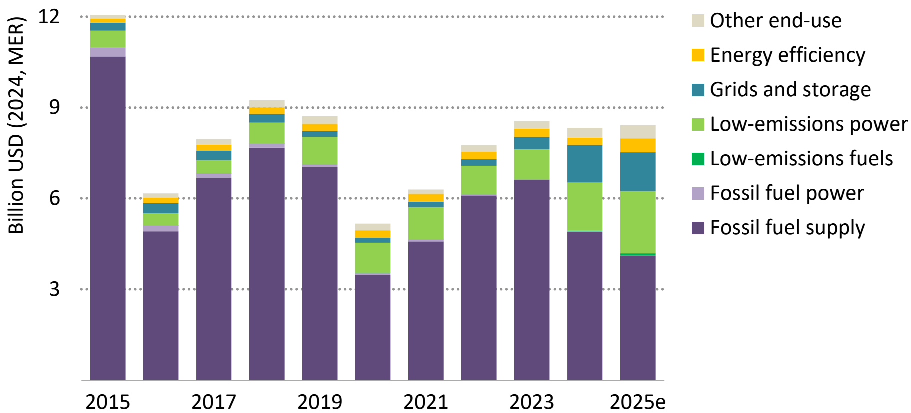
Colombia's pathway to net zero emissions will involve a shift towards clean technologies. This section examines the scale and possible sources of investment that will be required to support this shift.

3.4.1 Recent investment trends confirm energy transition opportunities

Clean energy investment this year is expected to exceed 50% of total spending in Colombia's energy sector, rising from around 40% in 2024, with total investments expected to increase to over USD 8 billion in 2025 (Figure 3.12). Colombia's rapid shift towards clean energy technologies has cemented the country's energy transition and highlights the role that strong policy commitments have in enabling investment to shift from fossil fuels towards renewable power, grids, end-use electrification and energy efficiency.

From 2015 to 2019, energy investment was on average 5% higher than today and led by spending on fossil fuel supply. Investment in low-emissions power, grids and end uses equated to one-fifth of spending on fossil fuel supply. The sharp fall in oil prices in 2016 led total energy investment to almost halve compared with the previous year as investment in fossil fuel supply dropped to USD 5 billion, highlighting the country's exposure to volatile energy markets. In January 2020, Colombia released its 2020-2050 National Energy Plan, emphasising the development of wind and solar power in the country's electricity mix (UPME, 2020). Following Russia's invasion of Ukraine, higher fuel prices raised investments in fossil fuel supply again. However, government efforts to diversify the country's economy have led to a shift in its trade balance as investments in fossil fuels – which account for nearly half of Colombia's exports in 2024 – decrease while power sector investment rises (DANE, 2025b).

Figure 3.12 ▷ Historical energy investment in Colombia, 2015-2025e



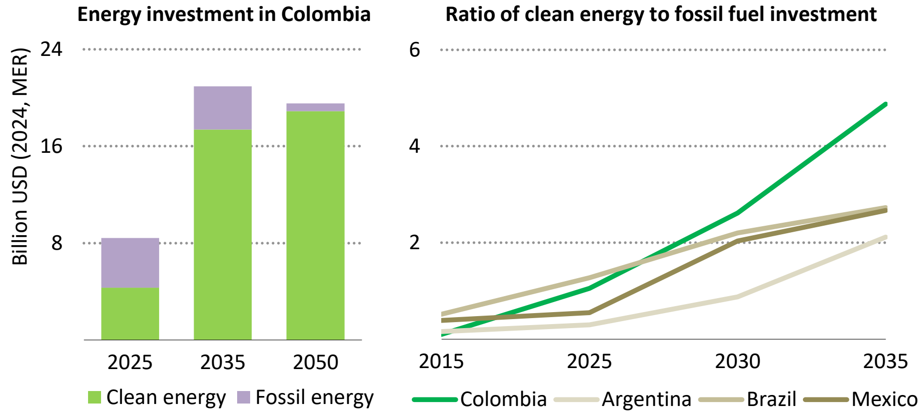
Recent investment trends signal a transition away from fossil fuels, with more than half of investments going to clean energy for the first time in 2025

Note: 2025e = estimated values for 2025.

Colombia's strong commitment to transition its energy sector and reach carbon neutrality by 2050 continues to drive the country's energy investment, with the share of investment in fossil fuels continuing to decline into the future (Figure 3.13). In the APS, the share of clean energy investment rises to nearly 85% in 2035 and exceeds 95% by 2050, compared with around 60% and 75% in the STEPS over the same periods. Earlier this year, Colombia launched its Country Platform, an initiative that will support its just and inclusive energy transition by facilitating collaboration with international partners, mobilising investment and building technical capacity. The first phase of the Country Platform will focus on the energy sector, while its second phase will expand to environmental conservation and restoration.

Compared with other fossil fuel exporting countries in Latin America and the Caribbean, Colombia invests significantly more into clean energy than on fossil fuels: in 2025, for every dollar spent on fossil fuels just over one dollar is also expected to be spent on clean energy, with this ratio rising by five-fold by 2035 in the APS. Other major exporters in the region also spend more on clean energy than on fossil fuels, though to a lesser extent.

Figure 3.13 ▷ Investment in clean and fossil energy in Colombia and regional investment in the APS, 2015-2050



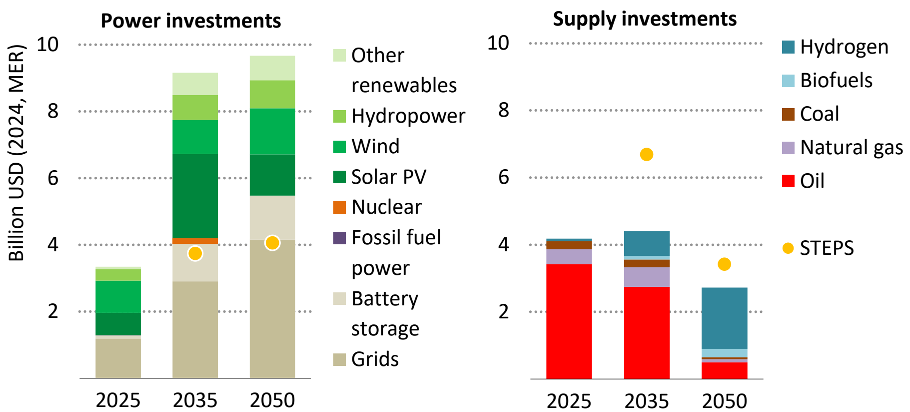
Clean energy investment drives future spending in the APS and exceeds trends in other countries in the region

3.4.2 Investment needs for power, fuel supply and end use

In 2025, Colombia's investment in low-emissions power generation reaches its highest level to date, totalling over USD 2 billion. The rapid decarbonisation of the power sector in the coming years leads total power generation investment to more than double by 2035 relative to 2025 (Figure 3.14). Solar PV and onshore wind development account for over 60% of this growth. Offshore wind, however, also sees significant growth in the coming decade following the country's first offshore wind tender, which is set to award up to 3 GW of capacity and for which eight bidders prequalified in 2024. Hydropower investment doubles to nearly USD 0.8 billion as large-scale projects are completed. In the mid-2030s, Colombia also begins investing in nuclear power for the first time, averaging USD 0.5 billion over the second half of the decade, to support the development of several small modular reactors that come online in the 2040s. Investment in fossil fuel power is limited in the APS, totalling USD 20 million in 2035 and subsequently falling to zero by the late 2040s.

In 2025, investment in grids and battery storage in Colombia totals USD 1.3 billion in the APS and rises steadily to 2050, peaking in 2045 at USD 6 billion. The most recent transmission plan outlines five major projects which aim to improve grid stability and reliability while expanding network connectivity throughout the country (UPME, 2024). Investment in utility-scale battery storage, meanwhile, also grows significantly in the APS, reaching USD 1.1 billion in 2035 and rising by an additional 20% by 2050.

Figure 3.14 ▷ Total investment in the power and supply sectors in Colombia in the APS, 2025-2050



Investment in clean power and fuels rises sharply over the next decade and continues increasing to 2050

In 2025, total fuel supply investment in Colombia is expected to fall by nearly 15% from the previous year to USD 4.2 billion. Investment in oil supply accounts for 82% of this total, followed by natural gas (11%) and coal (6%). Biofuels and hydrogen remain in the early stages of development, accounting for investment of nearly USD 80 million in 2025.

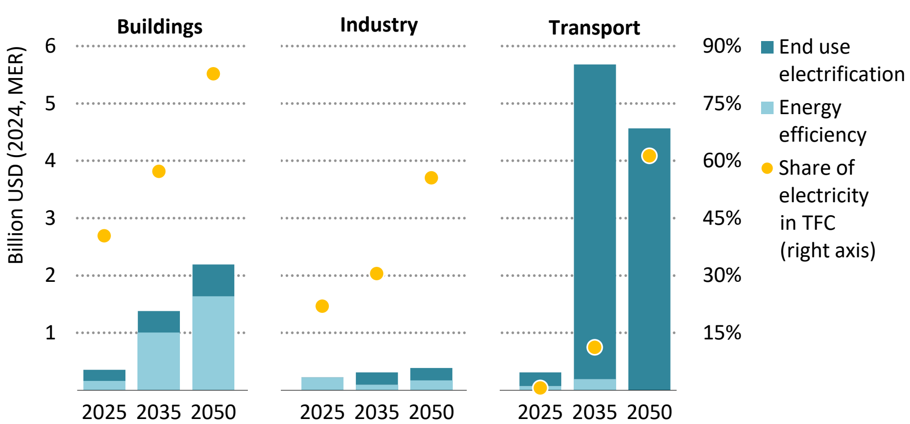
Investment in all fossil fuels decreases in the long term as lower global demand and more competitive markets lead to declining production. Keeping production at current levels already requires significant investment. In the APS, oil investment falls by 30% to USD 2.7 billion by 2035 relative to 2024. Meanwhile, oil and natural gas production costs rise as depleted fields require more expensive recovery techniques to maintain production and bans on future oil and gas exploration activities come into effect. By 2050, oil investment falls to USD 0.5 billion as key sectors – especially transport – are electrified. Investment in natural gas increases by 30% between 2025 and 2035. The development of offshore natural gas resources, notably the Sirius 2 discovery located in the Caribbean Sea, drives natural gas production investment up by 57% over the next decade. By 2050, however, investment in natural gas supply declines rapidly to USD 87 million, accounting for just 3% of total supply investment. In 2025, total investment in coal supply is USD 0.2 billion and holds steady through to 2035 as Colombian coal continues to serve rising energy demand in emerging market and developing economies, but investment ultimately falls by 80% to USD 60 million by 2050.

Low-emissions fuels are in the early stages of development in Colombia, with biofuels investment first appearing in 2026. By 2035, annual investment in hydrogen increases tenfold, bolstered by Colombia's Just Energy Transition Roadmap (MME, 2024) and government initiatives to establish emissions thresholds, certification schemes and environmental safeguards (MME, 2021). Investment in biofuels also scales up significantly with the increasing production of emerging biofuels, averaging USD 150 million annually over the coming decade. Investment in clean fuel supply surpasses that of fossil fuel supply for the first time in the early 2040s, and by 2050 over three dollars are spent on hydrogen and bioenergy fuels for every dollar spent on fossil fuel supply.

Investment in energy efficiency and end-use electrification in Colombia is estimated to reach USD 0.9 billion in 2025, more than tripling compared with a decade earlier. Over the next decade, the implementation of stricter energy efficiency standards and policies to accelerate electrification – particularly with the increasing share of EVs in the transport sector – will see rapid growth in investment across all end-use sectors, with investment in 2035 estimated to reach over USD 7 billion in the APS, double the level reached in the STEPS.

Annual investment on transport electrification accelerates sharply over the next decade, reaching over USD 5 billion in 2035 under the APS (Figure 3.15). Colombia has implemented a range of incentives (e.g. lower taxes, exception from vehicle restrictions and preferential parking) to ensure progress towards its target of registering 600 000 EVs by 2030. While most investment occurs over the next 15 years, the transport sector continues to account for the largest share of total end-use investment, totalling USD 4.6 billion annually, or around two-thirds, in 2050. The decreasing cost premium of EVs in the long term leads to declining investment despite increasing deployment.

Figure 3.15 ⊳ End-use sector investment and electrification rates in Colombia in the APS, 2025-2050



Electrification drives end-use investment, with EVs accounting for 80% of the total in 2035

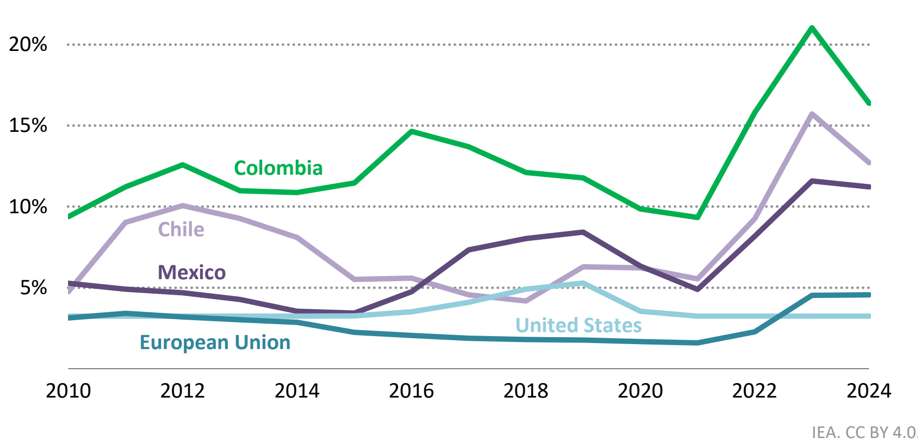
Note: TFC = total final consumption.

Increasingly stringent building codes and higher upfront costs of efficient appliances and air conditioners lead to investment in buildings reaching nearly USD 1.4 billion in 2035 in the APS – more than quadrupling since 2024. In the industry sector, investment in energy efficiency, electrification and near-zero technologies (CCUS and low-emissions hydrogen) remains steady at around USD 0.2 billion over the coming decade in the APS. Industrial electrification is particularly important in this context, accounting for nearly three-fifths of this investment.

3.4.3 Mobilising finance for the energy transition

Despite strong economic recovery following the global economic slowdown caused by the COVID-19 pandemic, Colombia's economy is emerging from a period of high inflation and monetary policy remains tight. Debt sustainability has also been a major concern, as the country's credit rating fell below investment grade in 2021 and fell again in 2025 to its current rating by S&P of BB with a negative outlook (S&P Global, 2025). Despite having recovered to pre-COVID-19 levels, Colombia's fiscal debt remains high, reaching 6.8% of GDP in 2024 (Ministro de Hacienda y Crédito Público, 2025). While lending rates to corporates have begun to decline since peaking in 2023, financing costs of about 16% in 2024 are over three times higher in Colombia than in the European Union and the United States (Figure 3.16). The high cost of debt dampens the investment environment in the country, including in the energy sector, making it difficult for clean energy projects to achieve adequate risk-adjusted returns given the capital-intensive nature of these investments.

Figure 3.16 ▷ Lending rates to corporates in Colombia and selected countries and regions, 2010 to 2024



High financing costs in Colombia are a major barrier to scaling up investment

Note: European Union lending rates are computed using a weighted average according to GDP.

Sources: IEA analysis based on World Bank (2025), European Central Bank (2025), US Federal Reserve (2025) and Banco Central Chile (2025).

Maintaining the pace of the current transition away from fossil fuels will require incentivising further investment in clean energy. Given the country's difficult fiscal position, support from international partners will be essential to achieve Colombia's net zero transition. While utility-scale solar PV projects backed by a solid power purchase agreement can typically find adequate capital, wind projects located in La Guajira, which face high social and environmental licensing challenges, become harder to finance. Public involvement is essential for these projects – as well as the grid infrastructure expansion necessary to connect them to the rest of the country – and should be considered a priority for international support.

Over the next decade, financing from the private sector will also be critical to support the development of renewable power in addition to end-use electrification and efficiency. Despite accounting for the large majority of financing for energy spending to 2035 in the APS (Figure 3.17), private capital remains difficult to mobilise today. Stabilising the regulatory environment, streamlining permitting processes and expanding grid infrastructure would remove barriers to unlocking additional sources of private sector finance.

Table 3.2 ⊳ Profile and assets of Colombia's four development banks

Bank name	Mandate	Main clients	Billion USD (2024)	
			Total assets (2024)	Total lending (2024)
Bancóldex	Supporting public policy, productivity of MSMEs, internationalisation and sustainable development.	MSMEs, corporate enterprises and project finance (in debt); private equity funds (in equity).	2.15	1.31
Financiera de Desarollo Nacional (FDN)	National-scale infrastructure.	Private investors, large infrastructure projects and public-private partnerships.	2.12	1.62
Financiera de Desarollo Territorial (Findeter)	Regional-scale infrastructure.	Municipalities, regional governments and public utilities.	3.97	3.35
Fondo para el Financiamiento del Sector Agropecuario (Finagro)	Rural and agricultural development.	Farmers, agricultural businesses and rural banks.	4.71	1.64

Note: MSME = micro, small and medium-sized enterprises.

Public-private partnerships (PPP), which were instrumental in developing the country's road infrastructure, can also play an important role in managing different risks in financing Colombia's clean energy transition. PPP structures are key to accessing both multilateral and bilateral funding support, as many multilateral development banks and bilateral development finance institutions (DFIs) require a sovereign entity to be involved to secure financing. DFI support is particularly critical for energy access projects in isolated regions, where 7% of the population, exceeding over 1.3 million households, still do not have access to reliable electricity supply. These projects, which tend to be very small, have high transaction costs and project risks weighing down on returns, making it difficult for them to attract sufficient commercial capital. These difficult financing conditions, in addition to a lack of competitive processes to allocate projects, lead to sponsors struggling to find bankable projects to invest in.

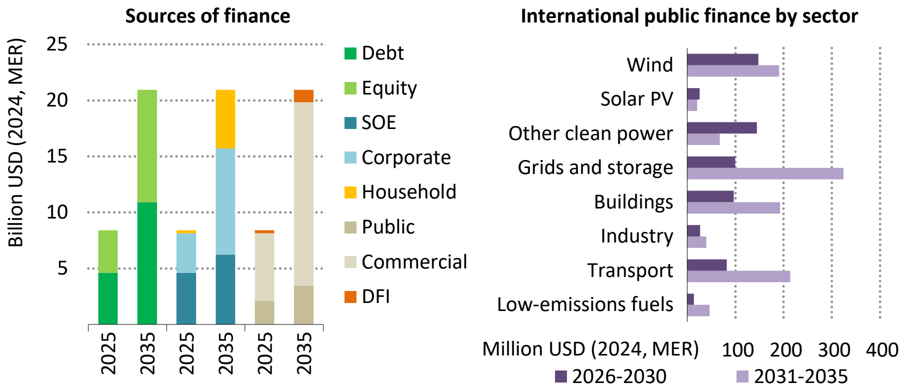
Funding from DFIs was instrumental in financing a solar and battery project to bring 24/7 electricity to 840 families in La Guajira, with a possible future expansion to provide electricity to an additional 3 000 families. Financiera de Desarrollo Nacional (FDN) – Colombia's national development bank co-owned by the government of Colombia, IFC, CAF and Sumitomo Mitsui Corporation – structured the financing, mobilising concessional funds from CIF and IDB and securing senior debt from FDN. The project, led by private developers AES Colombia and Soluna Energy, comprises both solar PV capacity and battery storage. Concessional debt from a new CIF and IDB fund dedicated to social and environmental projects and channelled through FDN was blended with senior debt from FDN of COP 11.6 billion (USD 3 million) and a liquidity line of COP 1.12 billion.

Bankability concerns have been raised for small- and medium-sized projects, where risks associated with offtakers, public acceptance and environmental licensing threaten to increase project costs. Capacity-building initiatives to support the government in mitigating these risks will boost investor confidence. For larger-scale projects, such as grid expansions, infrastructure providers and equipment manufacturers can also benefit from stable policy and procurement frameworks to localise production, expand supply chains and deliver equipment on time. Meanwhile, today's high interest rates also make access to long-term debt challenging, further affecting the bankability of projects. Increasing availability of local currency financing is critical, as electricity tariffs are set in Colombian pesos and high hedging costs typically make projects uneconomic.

Sources of finance

Currently, about half of all energy sector investments in Colombia are made by state-owned enterprises, mainly Ecopetrol (the country's integrated oil and gas company) and transmission system operator Interconexión Eléctrica. In 2025, state-owned enterprises are estimated to account for 90% and 22% of total investments in fossil fuel supply and low-emissions power, respectively. As Colombia accelerates its investment in clean energy – notably by expanding renewable power, accelerating energy efficiency and electrifying end uses – corporates and households play an increasing role in energy sector investment. In 2035, corporates account for the largest share of total energy investment in the APS at 60%, while the share met by households rises from less than 1% today to 8% (Figure 3.17). Growing investment in new generation capacity, grids and storage expansion leads debt financing to rise in the period to 2035 in the APS, while the importance of end-use investment – particularly for EVs, which use a high share of equity financing – results in roughly equal shares of debt and equity financing. The increase in debt financing goes primarily to the power sector for investment in new generation capacity and to expand grids and storage.

Figure 3.17 ▷ Capital structure, investors and financiers for total annual energy investment, and average annual need for international public financing by sector in Colombia in the APS, 2025-2035



IEA. CC BY 4.0.

Corporates and households scale up their investment. Over the next ten years, Colombia receives over USD 8.6 billion of international public finance in the APS

Note: SOE = state-owned enterprise; DFI = development finance institution.

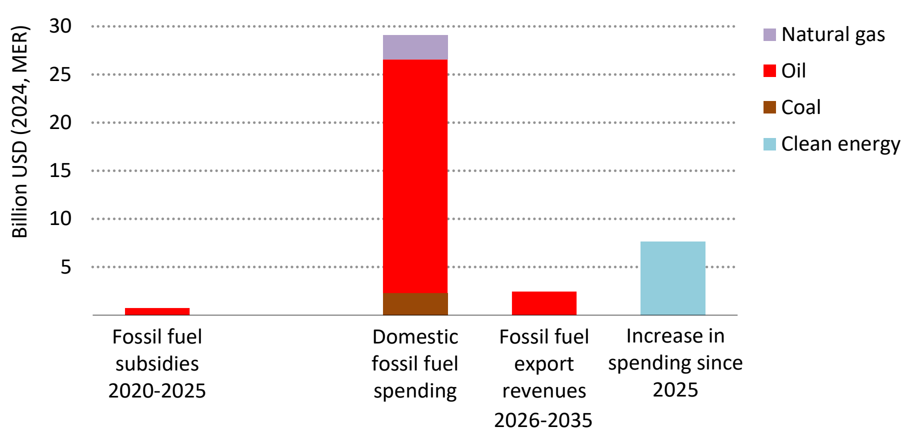
The public sector, which today accounts for 25% of total energy financing, mainly supports the equity portion of investment by state-owned enterprises, in addition to energy access initiatives, public transport projects and incentives for buildings efficiency and EV adoption. An increase in public financing to support rising investment in the APS in 2035 is needed to support universal electricity access initiatives, continued financing incentives for buildings and transport, the development of low-emissions fuels and to expand grids and battery storage.

Commercial sources of finance currently account for the majority (72%) of financing in the energy sector and are particularly important for financing the development of clean fuels and renewable power, in addition to improvements in electrification and energy efficiency in the transport sector. As investment in clean energy rises over the next decade, so does the share of commercial financing, which reaches 78% of total investment by 2035 in the APS. Initiatives to deepen domestic capital markets, in addition to regional financial integration, can contribute to increasing access to commercial financing. The nuam exchange, for example, is expected to fully integrate the Colombia, Santiago and Lima stock exchanges, facilitating flows of finance throughout the region (OECD et al., 2024).

International public finance (IPF) (mainly from DFIs) plays a relatively small role in the country's energy investment, currently standing at just 3% of the total. For certain sectors, such as solar PV installations for electricity access in isolated regions and the expansion of transmission grids and storage, financing from DFIs provides much-needed capital to support publicly driven investment. Over the next ten years, as Colombia accelerates its clean energy investment, the portion of finance coming from IPF is estimated to rise to an average of 5% in the APS. Meeting the country's net zero target will require a cumulative USD 8.6 billion of IPF from 2026 to 2035, averaging about USD 0.9 billion annually over this period. Nearly 20% of this finance is required to support solar PV in remote regions and to develop the abundant wind potential in La Guajira, which may benefit from additional guarantees to maintain project bankability amid complex community consultation and environmental licensing processes. Investment in grids and storage, building energy efficiency and transport electrification also require support from IPF, which can be mobilised in part through Colombia's Country Platform. Finally, access to support from multilateral climate funds is especially important for financing large-scale electricity generation projects: Bancoldex's 2024 accreditation from the Green Climate Fund, for instance, will strengthen its ability to facilitate decarbonisation initiatives in the business sector (IEA, 2025b).

Achieving Colombia's goal of net zero emissions by 2050 will require the economy's continued transition away from fossil fuels and towards expanding investment into a portfolio of clean energy technologies, including renewable power, nuclear, grids, energy storage, energy efficiency, end-use electrification and low-emissions fuels. Investment in these technologies requires, on average, an additional USD 7.5 billion per year over the next ten years (Figure 3.18). By comparison, domestic investment on fossil fuels averages just under USD 30 billion per year over the same period with net fossil fuel export revenues averaging around just USD 2.5 billion annually in the APS.

Figure 3.18 ▹ Average increase in annual clean energy investment, spending on fossil fuels and export revenues for coal in the APS, 2026-2035



Annual domestic investment in fossil fuels is nearly four times higher than the additional clean energy investment needed in 2035 relative to 2025

Public funding will be needed to drive clean energy development in more nascent technologies such as CCUS and low-emissions hydrogen, as well as to support nuclear power development. Charges on domestic fossil fuel use, as well as revenues from net exports of fossil fuels, could be important sources of public funding for the transition. The continued phase-out of fossil fuel subsidies, which averaged USD 0.7 billion annually from 2020 to 2025, could free up additional resources and improve the attractiveness of energy efficiency and electrification investment in end-use sectors. However, international and commercial sources of funding will continue to be essential as Colombia navigates rising fiscal debt, which may limit the availability of public funds for spending on clean technologies.

ANNEXES

Data tables

General note to the tables

This annex includes historical and projected data for the Announced Pledges Scenario following five datasets:

- A.1: Colombia energy supply.
- A.2: Colombia final consumption.
- A.3: Colombia electricity sector: gross electricity generation and electrical capacity.
- A.4: Colombia CO_2 emissions: carbon dioxide (CO_2) emissions from fossil fuel combustion and industrial processes.
- A.5: Colombia economic and activity indicators: selected economic and activity indicators.

The definitions for regions, fuels and sectors are outlined in Annex B.

Abbreviations/acronyms used in the tables include: CAAGR = compound average annual growth rate; CCUS = carbon capture, utilisation and storage; EJ = exajoule; GJ = gigajoule; GW = gigawatt; Mt CO_2 = million tonnes of carbon dioxide; TWh = terawatt-hour. Use of fossil fuels in facilities without CCUS is classified as “unabated”.

Both in the text of this report and in these annex tables, rounding may lead to minor differences between totals and the sum of their individual components. Growth rates are calculated on a compound average annual basis and are marked “n.a.” when the base year is zero or the value exceeds 200%. Nil values are marked “-”.

Data sources

The Global Energy and Climate Model is a very data-intensive model covering the whole global energy system. Detailed references on databases and publications used in the modelling and analysis may be found in Annex E of the *World Energy Outlook 2025*.

The formal base year for this year’s projections is 2023, as this is the most recent year for which a complete picture of energy demand and production is available. However, we have used more recent data wherever available, and we include our 2024 estimates for energy production and demand in this annex. Estimates for the year 2024 are based on the IEA *Global Energy Review 2025* report in which data are derived from a number of sources, including the latest monthly data submissions to the IEA Energy Data Centre, other statistical releases from national administrations, and recent market data from the IEA *Market Report Series* that cover coal, oil, natural gas, renewables and power. Investment estimates include the year 2025 data, based on the IEA *World Energy Investment 2025* report. Historical data for gross power generation capacity (Table A.3) are drawn from the Power Plant Units database and the World Electric Power Plants database both published by S&P Global Market Intelligence; the International Atomic Energy Agency PRIS database; the Global Coal Plant Tracker, and the Global Oil and Gas Plant Tracker databases both published by Global Energy Monitor.

Definitional note: Energy supply and transformation tables

Total energy supply (TES) is equivalent to electricity and heat generation plus the *other energy sector*, excluding electricity, heat and hydrogen, plus total final consumption, excluding electricity, heat and hydrogen. TES does not include ambient heat from heat pumps or electricity trade. *Solar* in TES includes solar PV generation, concentrating solar power (CSP) and final consumption of solar thermal. *Biofuels conversion losses* are the conversion losses to produce biofuels (mainly from modern solid bioenergy) used in the energy sector. *Low-emissions hydrogen production* is merchant low-emissions hydrogen production (excluding onsite production at industrial facilities and refineries), with inputs referring to total fuel inputs and outputs to produce hydrogen. While not itemised separately, *geothermal* and *marine* (tidal and wave) energy are included in the *renewables* category of TES and *electricity and heat sectors*. While not itemised separately, *non-renewable waste* and *other sources* are included in TES.

Definitional note: Energy demand tables

Sectors comprising total final consumption (TFC) include *industry* (energy use and feedstock), *transport* and *buildings* (residential, services and non-specified other). While not itemised separately, *agriculture* and *other non-energy use* are included in TFC. While not itemised separately, non-renewable waste, *solar thermal* and *geothermal* energy are included in *buildings*, *industry* and *TFC*.

Definitional note: Electricity tables

Electricity generation expressed in terawatt-hours (TWh) and installed electrical capacity data expressed in gigawatts (GW) are both provided on a gross basis, i.e. includes own use by the generator. Projected gross electrical capacity is the sum of existing capacity and additions, less retirements. While not itemised separately, *other sources* are included in total electricity generation. Hydrogen and ammonia are fuels that can provide a low-emissions alternative to natural gas- and coal-fired electricity generation – either through co-firing or full conversion of facilities. Blending levels of hydrogen in gas-fired plants and ammonia in coal-fired plants are represented in the scenarios and reported in the tables. The electricity generation outputs in the tables are based on fuel input shares, while the hydrogen and ammonia capacity is derived based on a typical capacity factor.

Definitional note: CO_2 emissions tables

Total CO_2 includes carbon dioxide emissions from the combustion of fossil fuels and non-renewable wastes; from industrial and fuel transformation processes (process emissions); and from flaring and CO_2 removal. CO_2 removal includes: captured and stored emissions from the combustion of bioenergy and renewable wastes; from biofuels production; and from direct air capture.

The first two entries are often reported as bioenergy with carbon capture and storage (BECCS). Note that some of the CO_2 captured from biofuels production and direct air capture is used to produce synthetic fuels, which is not included as CO_2 removal.

Total CO_2 captured includes the carbon dioxide captured from CCUS facilities, such as electricity generation or industry, and atmospheric CO_2 captured through direct air capture, but excludes that captured and used for urea production.

Definitional note: Economic and activity indicators

The emissions intensity expressed in grammes of carbon dioxide per kilowatt-hour (g CO_2 per kWh) is calculated based on electricity-only plants and the electricity component of combined heat and power (CHP) plants.[1] *Primary chemicals* include ethylene, propylene, aromatics, methanol and ammonia. Industrial production data for *aluminium* excludes production based on internally generated scrap. Heavy-duty truck activity includes freight activity of medium freight trucks and heavy freight trucks.

Abbreviations used include: GDP = gross domestic product; GJ = gigajoule; m^2 = square metre; Mt = million tonnes; pkm = passenger-kilometres; PPP = purchasing power parity; tkm = tonne-kilometre.

Annex A licencing

[1] To derive the associated electricity-only emissions from CHP plants, we assume that the heat production of a CHP plant is 90% efficient and the remainder of the fuel input is allocated to electricity generation.

Table A.1: Colombia energy supply

				Announced Pledges (PJ)			Shares (%)			CAAGR (%) 2024 to:	
	2010	2023	2024	2035	2040	2050	2024	2035	2050	2035	2050
Total energy supply	1 341	1 990	2 027	1 976	2 030	2 385	100	100	100	-0.2	0.6
Renewables	248	442	417	925	1 273	1 898	21	47	80	7.5	6.0
Solar	-	4	7	217	339	485	0	11	20	37	18
Wind	-	1	2	74	142	292	0	4	12	39	21
Hydro	145	208	189	240	255	288	9	12	12	2.2	1.6
Modern solid bioenergy	84	181	171	221	224	235	8	11	10	2.4	1.2
Modern liquid bioenergy	18	39	40	57	45	25	2	3	1	3.3	-1.8
Modern gaseous bioenergy	1	8	8	52	131	335	0	3	14	19	15
Traditional use of biomass	74	62	60	-	-	-	3	-	-	n.a.	n.a.
Nuclear	-	-	-	-	-	189	-	-	8	n.a.	n.a.
Natural gas	353	381	415	241	192	102	20	12	4	-4.8	-5.3
Unabated	346	375	408	232	180	84	20	12	4	-5.0	-5.9
With CCUS	-	-	-	2	5	12	-	0	1	n.a.	n.a.
Oil	494	845	847	663	465	170	42	34	7	-2.2	-6.0
Non-energy use	29	38	37	36	36	36	2	2	2	-0.2	-0.1
Coal	172	258	286	145	98	24	14	7	1	-6.0	-9.1
Unabated	172	258	286	142	94	21	14	7	1	-6.2	-9.6
With CCUS	-	-	-	2	4	4	-	0	0	n.a.	n.a.
Electricity and heat sectors	341	497	530	754	1 082	1 849	100	100	100	3.3	4.9
Renewables	171	243	228	666	1 016	1 639	43	88	89	10	7.9
Solar PV	-	4	7	212	330	472	1	28	26	36	18
Wind	-	1	2	74	142	292	0	10	16	39	21
Hydro	145	208	189	240	255	288	36	32	16	2.2	1.6
Bioenergy	25	30	30	90	176	391	6	12	21	11	10
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Ammonia	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Nuclear	-	-	-	-	-	189	-	-	10	n.a.	n.a.
Unabated natural gas	101	118	142	66	58	18	27	9	1	-6.7	-7.6
Natural gas with CCUS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Oil	19	37	38	14	8	2	7	2	0	-8.7	-11
Unabated coal	50	99	123	7	-	-	23	1	-	-23	n.a.
Coal with CCUS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Other energy sector	238	300	300	273	369	506	100	100	100	-0.9	2.0
Biofuels conversion losses	-	47	46	58	51	25	100	100	100	2.1	-2.3
Low-emissions hydrogen (offsite)											
Production inputs	-	-	-	69	121	188	100	100	100	n.a.	n.a.
Production outputs	-	-	-	48	87	139	100	100	100	n.a.	n.a.
For hydrogen-based fuels	-	-	-	43	67	95	-	90	68	n.a.	n.a.

Table A.2: Colombia final consumption

				Announced Pledges (PJ)			Shares (%)			CAAGR (%) 2024 to:	
	2010	2023	2024	2035	2040	2050	2024	2035	2050	2035	2050
Total final consumption	**977**	**1 510**	**1 517**	**1 575**	**1 487**	**1 380**	**100**	**100**	**100**	**0.3**	**-0.4**
Electricity	170	265	268	438	594	869	18	28	63	4.6	4.6
Liquid fuels	433	749	747	706	506	198	49	45	14	-0.5	-5.0
Biofuels	18	39	40	57	45	25	3	4	2	3.3	-1.8
Ammonia	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Synthetic oil	-	-	-	-	1	4	-	-	0	n.a.	n.a.
Oil	415	710	707	649	459	169	47	41	12	-0.8	-5.4
Gaseous fuels	132	169	176	167	159	146	12	11	11	-0.5	-0.7
Biomethane	1	4	4	13	18	33	0	1	2	11	8.5
Hydrogen	-	-	-	6	19	44	-	0	3	n.a.	n.a.
Synthetic methane	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Natural gas	131	166	172	147	119	65	11	9	5	-1.4	-3.7
Solid fuels	242	327	327	254	214	148	22	16	11	-2.3	-3.0
Solid bioenergy	132	160	155	113	114	122	10	7	9	-2.8	-0.9
Coal	110	164	169	139	98	24	11	9	2	-1.8	-7.2
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Industry	**288**	**444**	**445**	**508**	**514**	**503**	**100**	**100**	**100**	**1.2**	**0.5**
Electricity	51	96	97	155	198	280	22	31	56	4.4	4.2
Liquid fuels	46	70	65	55	47	16	15	11	3	-1.5	-5.2
Oil	46	70	65	55	46	15	15	11	3	-1.5	-5.5
Gaseous fuels	52	63	65	72	70	66	15	14	13	0.9	0.1
Biomethane	-	1	1	6	9	22	0	1	4	18	13
Hydrogen	-	-	-	-	1	5	-	-	1	n.a.	n.a.
Unabated natural gas	49	60	62	62	52	26	14	12	5	0.0	-3.3
Natural gas with CCUS	-	-	-	2	5	12	-	0	2	n.a.	n.a.
Solid fuels	140	215	218	218	189	129	49	43	26	0.0	-2.0
Modern solid bioenergy	31	51	49	78	89	102	11	15	20	4.3	2.9
Unabated coal	108	161	167	136	93	21	38	27	4	-1.8	-7.7
Coal with CCUS	-	-	-	2	4	4	-	0	1	n.a.	n.a.
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Chemicals	43	61	57	56	58	59	13	11	12	-0.2	0.1
Iron and steel	93	78	77	103	108	106	17	20	21	2.7	1.2
Cement	31	43	41	42	44	53	9	8	11	0.2	1.0
Aluminium	-	-	-	-	-	-	-	-	-	n.a.	n.a.

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Table A.2: Colombia final consumption (continued)

				Announced Pledges (PJ)			Shares (%)			CAAGR (%) 2024 to:	
	2010	2023	2024	2035	2040	2050	2024	2035	2050	2035	2050
Transport	**324**	**594**	**602**	**651**	**561**	**442**	**100**	**100**	**100**	**0.7**	**-1.2**
Electricity	-	2	2	73	154	271	0	11	61	39	21
Liquid fuels	294	571	578	562	384	131	96	86	30	-0.3	-5.5
Biofuels	16	39	40	54	42	19	7	8	4	2.8	-2.8
Oil	278	532	538	508	340	108	89	78	24	-0.5	-6.0
Gaseous fuels	30	20	21	16	24	40	3	2	9	-2.4	2.5
Biomethane	-	-	-	1	1	-	-	0	-	n.a.	n.a.
Hydrogen	-	-	-	5	18	39	-	1	9	n.a.	n.a.
Natural gas	30	20	21	10	6	1	3	2	0	-6.5	-11
Road	290	565	569	616	524	403	95	95	91	0.7	-1.3
Passenger cars	93	178	183	259	232	188	30	40	43	3.2	0.1
Heavy-duty trucks	62	156	156	147	131	117	26	23	26	-0.5	-1.1
Buildings	**268**	**413**	**414**	**361**	**356**	**380**	**100**	**100**	**100**	**-1.2**	**-0.3**
Electricity	112	163	165	207	239	314	40	57	83	2.1	2.5
Liquid fuels	33	69	67	51	37	11	16	14	3	-2.5	-6.7
Biofuels	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Oil	33	69	67	51	37	11	16	14	3	-2.5	-6.7
Gaseous fuels	46	82	85	75	59	35	21	21	9	-1.1	-3.4
Biomethane	1	2	3	6	8	10	1	2	3	6.5	4.7
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Natural gas	45	79	82	67	49	20	20	19	5	-1.8	-5.3
Solid fuels	77	99	97	27	19	14	23	7	4	-11	-7.2
Modern solid bioenergy	-	35	34	26	18	14	8	7	4	-2.4	-3.4
Traditional use of biomass	74	62	60	-	-	-	14	-	-	n.a.	n.a.
Coal	2	3	3	1	-	-	1	0	-	-9.5	n.a.
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Residential	208	329	328	268	263	284	79	74	75	-1.8	-0.6
Services	60	84	85	92	93	96	21	25	25	0.7	0.5

Table A.3: Colombia electricity sector

				Announced Pledges (TWh)			Shares (%)			CAAGR (%) 2024 to:	
	2010	2023	2024	2035	2040	2050	2024	2035	2050	2035	2050
Total generation	**61**	**89**	**90**	**166**	**228**	**350**	**100**	**100**	**100**	**5.7**	**5.3**
Renewables	43	62	58	155	220	330	64	94	94	9.4	6.9
Solar PV	0	1	2	59	92	131	2	36	37	36	17
Wind	0	0	0	21	39	81	0	12	23	42	22
Hydro	40	58	53	67	71	80	58	40	23	2.2	1.6
Bioenergy	2	3	3	8	15	32	3	5	9	9.2	9.8
of which BECCS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
CSP	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Geothermal	-	-	-	1	3	6	-	1	2	n.a.	n.a.
Marine	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Nuclear	-	-	-	-	-	17	-	-	5	n.a.	n.a.
Hydrogen and ammonia	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Fossil fuels with CCUS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Coal with CCUS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Natural gas with CCUS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Unabated fossil fuels	18	27	32	10	8	2	36	6	1	-9.7	-9.6
Coal	4	9	11	1	0	-	12	0	-	-23	n.a.
Natural gas	12	14	17	8	8	2	19	5	1	-6.4	-7.7
Oil	2	4	4	1	1	0	4	1	0	-8.6	-11

				Announced Pledges (GW)			Shares (%)			CAAGR (%) 2024 to:	
	2010	2023	2024	2035	2040	2050	2024	2035	2050	2035	2050
Total capacity	**16**	**22**	**24**	**84**	**120**	**173**	**100**	**100**	**100**	**12**	**8.0**
Renewables	10	14	16	59	85	122	67	70	71	13	8.2
Solar PV	-	1	2	33	50	69	9	40	40	28	14
Wind	0	0	0	7	13	25	0	8	15	54	26
Hydro	10	13	13	17	19	22	56	20	13	2.3	2.0
Bioenergy	0	0	0	1	2	5	2	2	3	11	10
of which BECCS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
CSP	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Geothermal	-	-	-	0	1	1	-	0	0	n.a.	n.a.
Marine	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Nuclear	-	-	-	-	-	2	-	-	1	n.a.	n.a.
Hydrogen and ammonia	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Fossil fuels with CCUS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Coal with CCUS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Natural gas with CCUS	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Unabated fossil fuels	6	8	8	4	3	1	33	4	1	-6.7	-6.9
Coal	1	2	2	0	-	-	7	0	-	-13	n.a.
Natural gas	4	5	5	3	2	1	22	3	1	-5.6	-6.1
Oil	0	1	1	0	0	0	3	1	0	-5.2	-5.2
Battery storage	-	-	-	21	33	48	-	25	27	n.a.	n.a.

Table A.4: Colombia CO_2 emissions

	2010	2023	2024	Announced Pledges (Mt CO_2) 2035	2040	2050	CAAGR (%) 2024 to: 2035	2050
Total CO_2*	**66**	**102**	**106**	**74**	**52**	**17**	**-3.2**	**-6.9**
Combustion activities (+)	**62**	**95**	**100**	**69**	**48**	**15**	**-3.3**	**-7.1**
Coal	14	24	26	11	7	2	-7.3	-10
Oil	30	52	52	45	31	10	-1.4	-6.3
Natural gas	17	19	21	12	10	5	-4.6	-5.5
Bioenergy and waste	0	0	0	0	- 0	- 1	-5.5	n.a.
Other removals (-)**	**-**	**-**	**-**	**-**	**-**	**-**	**n.a.**	**n.a.**
Biofuels production	-	-	-	-	-	-	n.a.	n.a.
Direct air capture	-	-	-	-	-	-	n.a.	n.a.
Electricity and heat sectors	**12**	**19**	**22**	**5**	**4**	**1**	**-12**	**-11**
Coal	5	9	12	1	0	-	-23	n.a.
Oil	1	3	3	1	1	0	-8.4	-10
Natural gas	6	7	8	4	3	1	-6.8	-7.6
Bioenergy and waste	-	-	-	-	-	-	n.a.	n.a.
Other energy sector**	**6**	**5**	**5**	**1**	**1**	**1**	**-15**	**-5.8**
Final consumption**	**48**	**77**	**78**	**67**	**47**	**14**	**-1.3**	**-6.3**
Coal	9	14	15	11	7	2	-2.8	-8.1
Oil	28	48	48	44	30	10	-0.8	-6.0
Natural gas	7	9	9	8	6	3	-1.6	-4.7
Bioenergy and waste	0	0	0	0	- 0	- 1	-5.5	n.a.
Industry**	19	28	28	23	17	5	-1.9	-6.8
Chemicals**	2	3	3	2	2	0	-1.7	-8.7
Iron and steel**	6	5	5	5	4	1	-0.2	-6.3
Cement**	6	9	8	7	5	1	-1.9	-7.7
Aluminium**	0	0	0	0	0	-	0.0	n.a.
Transport	22	39	40	37	25	8	-0.7	-6.1
Road	19	37	38	35	22	6	-0.7	-7.0
Passenger cars	6	12	12	15	11	4	2.0	-4.6
Heavy-duty trucks	4	10	10	8	5	1	-2.2	-9.3
Buildings	5	10	10	7	5	2	-2.3	-5.9
Residential	4	8	8	6	5	2	-2.3	-6.2
Services	1	1	1	1	1	0	-2.0	-4.8
Total CO_2 removals**	**-**	**-**	**-**	**0**	**0**	**1**	**n.a.**	**n.a.**
Total CO_2 captured**	**-**	**-**	**-**	**1**	**3**	**8**	**n.a.**	**n.a.**

*Includes industrial process and flaring emissions.
**Includes industrial process emissions.

Table A.5: Colombia economic and activity indicators

				Announced Pledges			CAAGR (%) 2024 to:	
	2010	2023	2024	2035	2040	2050	2035	2050
Indicators								
Population (million)	44	52	53	57	58	59	0.8	0.4
GDP (USD 2024 billion, PPP)	727	1 113	1 133	1 496	1 661	1 959	2.6	2.1
GDP per capita (USD 2024, PPP)	16 501	21 315	21 454	26 097	28 413	33 045	1.8	1.7
TES/GDP (GJ per USD 1 000, PPP)	1.8	1.8	1.8	1.3	1.2	1.2	-2.7	-1.5
TFC/GDP (GJ per USD 1 000, PPP)	1.3	1.4	1.3	1.1	0.9	0.7	-2.1	-2.4
CO_2 intensity of electricity generation (g CO_2 per kWh)	197	210	249	33	17	3	-17	-15
Industrial production (Mt)								
Primary chemicals	0.5	0.6	0.6	0.6	0.6	0.6	-0.3	0.3
Steel	1.2	1.4	1.3	1.8	2.1	2.5	3.3	2.6
Cement	10	14	13	14	15	17	0.6	0.9
Aluminium	0.0	0.0	0.0	0.0	0.1	0.1	2.6	2.7
Transport								
Passenger cars (billion pkm)	72	144	148	269	344	461	5.6	4.5
Heavy-duty trucks (billion tkm)	58	154	153	191	211	257	2.0	2.0
Buildings								
Households (million)	12.3	14.8	15.0	16.9	17.5	18.3	1.1	0.8
Residential floor area (million m^2)	894	1 238	1 263	1 573	1 715	1 968	2.0	1.7
Services floor area (million m^2)	208	298	303	376	407	465	2.0	1.7

Definitions

This annex provides general information on terminology used throughout this report including: units and general conversion factors; definitions of fuels, processes and sectors; regional and country groupings; and abbreviations and acronyms.

Units

Area	km^2	square kilometre
	Mha	million hectares
Distance	km	kilometre
Emissions	ppm	parts per million (by volume)
	t CO_2	tonnes of carbon dioxide
	Gt CO_2-eq	gigatonnes of carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
	kg CO_2-eq	kilogrammes of carbon-dioxide equivalent
	g CO_2/km	grammes of carbon dioxide per kilometre
	g CO_2/kWh	grammes of carbon dioxide per kilowatt-hour
	kg CO_2/kWh	kilogrammes of carbon dioxide per kilowatt-hour
	USD/t CO_2	US dollars per tonne of carbon dioxide
Energy	MJ	megajoule (1 joule x 10^6)
	GJ	gigajoule (1 joule x 10^9)
	TJ	terajoule (1 joule x 10^{12})
	PJ	petajoule (1 joule x 10^{15})
	EJ	exajoule (1 joule x 10^{18})
	W	watt (1 joule per second)
	kW	kilowatt (1 watt x 10^3)
	MW	megawatt (1 watt x 10^6)
	GW	gigawatt (1 watt x 10^9)
	TW	terawatt (1 watt x 10^{12})
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
	MBtu	million British thermal units
Energy density	Wh/kg	watt hours per kilogramme
Energy equivalence	kboe/d	thousand barrels of oil equivalent per day
	Mtoe	million tonnes of oil equivalent
	bcme	billion cubic metres of natural gas equivalent
	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)

Mass	kg	kilogramme
	t	tonne (1 tonne = 1 000 kg)
	kt	kilotonne (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonne (1 tonne x 10^9)
Monetary	USD million	1 US dollar x 10^6
	USD billion	1 US dollar x 10^9
	USD trillion	1 US dollar x 10^{12}
Volumetric	bcm	billion cubic metres
	barrel	one barrel of crude oil
	kb/d	thousand barrels per day
	mb/d	million barrels per day

General conversion factors for energy

	Multiplier to convert to:					
Convert from:	EJ	Gcal	Mtoe	MBtu	bcme	GWh
EJ	1	2.388 x 10^8	23.88	9.478 x 10^8	27.78	2.778 x 10^5
Gcal	4.1868 x 10^{-9}	1	10^{-7}	3.968	1.163 x 10^{-7}	1.163 x 10^{-3}
Mtoe	4.1868 x 10^{-2}	10^7	1	3.968 x 10^7	1.163	11 630
MBtu	1.0551 x 10^{-9}	0.252	2.52 x 10^{-8}	1	2.932 x 10^{-8}	2.931 x 10^{-4}
bcme	0.036	8.60 x 10^6	0.86	3.41 x 10^7	1	9 999
GWh	3.6 x 10^{-6}	860	8.6 x 10^{-5}	3 412	1 x 10^{-4}	1

Note: There is no generally accepted definition of barrel of oil equivalent (boe); typically the conversion factors used vary from 7.15 to 7.40 boe per tonne of oil equivalent. Natural gas is attributed a low heating value of 1 MJ per 44.1 kg. Conversions to and from billion cubic metres of natural gas equivalent (bcme) are given as representative multipliers but may differ from the average values obtained by converting natural gas volumes between International Energy Agency (IEA) balances due to the use of country-specific energy densities. Lower heating values (LHV) are used throughout.

Currency conversions

Exchange rates *(2024 annual average)*	1 US dollar (USD) equals:
British Pound	0.78
Chinese Yuan Renminbi	7.20
Euro	0.92
Indian Rupee	83.67
Japanese Yen	151.37

Source: World Bank Data: Official exchange rate (Local Currency Units per USD, period average), https://data.worldbank.org/indicator/PA.NUS.FCRF, accessed September 2025.

Definitions

Agriculture: Includes all energy used on farms, in forestry and for fishing.

Agriculture, forestry and other land use (AFOLU): A sector included in greenhouse gas accounting frameworks which encompasses managed ecosystems. AFOLU emissions include greenhouse gas emissions from agriculture, land use, land-use change and forestry.

Ammonia (NH_3): A compound of nitrogen and hydrogen (NH_3) that is an industrially produced input to fertiliser manufacturing, resulting in substantial carbon dioxide (CO_2) emissions from the use of fossil fuel inputs to generate the input hydrogen. With properties similar to liquefied petroleum gas, ammonia can also be used directly as a fuel in direct combustion processes, as well as in fuel cells, and can be cracked to release its hydrogen content. As it can be made from low-emissions hydrogen, ammonia has the potential to be a low-emissions fuel if the production process, including nitrogen separation, is powered by low-emissions energy. Produced in such a way, ammonia is considered a low-emissions hydrogen-based liquid fuel.

Aviation: This transport mode includes both domestic and international flights and their use of aviation fuels. Domestic aviation covers flights that depart and land in the same country; flights for military purposes are included. International aviation includes flights that land in a country other than the departure location.

Back-up generation capacity: Households and businesses connected to a main power grid may also have a source of back-up power generation capacity that, in the event of disruption, can provide electricity. Back-up generators are typically fuelled with diesel or gasoline. Capacity can be as little as a few hundred watts. Such capacity is distinct from mini-grid and off-grid systems that are not connected to a main power grid.

Battery storage: Energy storage technology that uses reversible chemical reactions to absorb, store and release electricity on demand.

Biodiesel: Diesel-equivalent fuel made from the transesterification of vegetable oils and animal fats, hydrogenated vegetable oil (HVO), thermal processes such as gasification and fermentation.

Bioenergy: Energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. It includes solid bioenergy, liquid biofuels and biogases. Excludes hydrogen produced from bioenergy, including via electricity from a biomass-fired plant, as well as synthetic fuels made with CO_2 feedstock from a biomass source.

Biogas: A mixture of methane, CO_2 and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment. It includes landfill gas and sewage sludge gas, and it can be upgraded by removing non-methane constituents, principally CO_2.

Biogases: Include both biogas and biomethane.

Biogasoline: Includes all liquid biofuels used as a substitute for gasoline.

Biojet kerosene: Kerosene substitute produced from biomass. It includes conversion routes such as hydro-processed esters and fatty acids (HEFA) and biomass gasification with Fischer-Tropsch. It excludes synthetic kerosene produced from biogenic carbon dioxide.

Biomethane: Biomethane is a near-pure source of methane produced either by "upgrading" biogas (a process that removes any carbon dioxide and other contaminants present in the biogas) or through the gasification of solid biomass followed by methanation. It is also known as renewable natural gas.

Buildings: The buildings sector includes energy used in residential and services buildings. Services buildings include commercial and institutional buildings and other non-specified buildings. Building energy use includes space heating and cooling, water heating, lighting, appliances and cooking equipment. It also includes energy used by data centres and desalination plants.

Bunkers: Include both international marine bunker fuels and international aviation bunker fuels.

Capacity credit: The proportion of the nameplate generating capacity of an electrical generator that can be reliably expected to generate electricity during times of peak demand on the grid to which it is connected. The sum of all capacity credits across an electricity system is useful as an approximation of the firm power that the system can reliably provide at a given time.

Carbon capture, utilisation and storage (CCUS): The process of capturing carbon dioxide emissions from fuel combustion, industrial processes or directly from the atmosphere. Captured CO_2 emissions can be stored in underground geological formations, onshore or offshore, or used as an input or feedstock in manufacturing.

Carbon dioxide (CO_2): A gas consisting of one part carbon and two parts oxygen. It is an important greenhouse (heat-trapping) gas.

Chemical feedstock: Physical energy products used as raw materials to produce chemical products, typically in the petrochemicals sector. Examples are crude oil-based ethane or naphtha to produce ethylene in steam crackers.

Clean cooking systems: Cooking solutions that release less harmful pollutants, are more efficient and environmentally sustainable than traditional cooking options that make use of solid biomass, coal or kerosene. It refers to improved cook stoves, biogas/biodigester systems, electric stoves, liquefied petroleum gas, natural gas or ethanol stoves.

Clean energy: In *power*, clean energy includes: renewable energy sources; nuclear power; fossil fuels fitted with CCUS; hydrogen and ammonia; battery storage; and electricity grids. In *efficiency*, clean energy includes energy efficiency in buildings, industry and transport, excluding domestic navigation. In *end-use applications*, clean energy includes: direct use of renewables; electric vehicles; electrification in buildings, industry and international marine transport; CCUS in industry and direct air capture. In *fuel supply*, clean energy includes low-emissions fuels, direct air capture and measures to reduce the emissions intensity of fossil fuel production.

Coal: Consists of both primary coal, i.e. lignite, coking and steam coal, and derived fuels, e.g. patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas works gas, coke-oven gas, blast furnace gas and oxygen steel furnace gas. Peat is also included.

Coalbed methane (CBM)**:** Category of unconventional natural gas that refers to methane found in coal seams.

Coal-to-gas (CTG)**:** A process by which mined coal is first turned into synthesis gas or syngas, i.e. a mixture of hydrogen and carbon monoxide, and then into synthetic methane.

Coal-to-liquids (CTL)**:** The transformation of coal into liquid hydrocarbons. This can be achieved through either coal gasification into synthesis gas or syngas, i.e. a mixture of hydrogen and carbon monoxide, combined with Fischer-Tropsch or methanol-to-gasoline synthesis to produce liquid fuels, or through the less developed direct-coal liquefaction technologies in which coal is directly reacted with hydrogen.

Coking coal: A type of coal that can be used for steel making (as a chemical reductant and a source of heat), where it produces coke capable of supporting a blast furnace charge. Coal of this quality is commonly known as metallurgical coal.

Concentrating solar power (CSP)**:** Thermal power generation technology that collects and concentrates sunlight to produce high temperature heat to generate electricity.

Conventional natural gas: Refers to natural gas extracted using traditional drilling techniques. It includes both onshore and offshore natural gas, including from the Arctic.

Conventional oil: Refers to oil extracted using traditional drilling methods. It includes onshore and offshore crude oil, including from the Arctic, enhanced oil recovery and natural gas liquids produced from conventional gas fields.

Critical minerals: A wide range of minerals and metals that are essential for key energy, digital and other modern technologies, but whose supply chains are vulnerable to disruption. While definitions and criteria vary across countries, they typically include chromium, cobalt, copper, gallium, germanium, graphite, lithium, manganese, molybdenum, nickel, platinum group metals, zinc, and rare earth elements.

Data centres: facilities that house information technology (IT) equipment, such as servers, storage systems and networking equipment, and are equipped with cooling and other auxiliary systems to keep the IT equipment operating under optimal conditions.

Decomposition analysis: A statistical method that decomposes an aggregate indicator to quantify the relative contribution of a set of pre-defined factors leading to a change in the aggregate indicator. This report uses an additive index decomposition of the type Logarithmic Mean Divisia Index (LMDI).

Demand-side integration (DSI)**:** Consists of two types of measures: actions that influence load shape such as energy efficiency and electrification; and actions that manage load such as demand-side response measures.

Demand-side response (DSR)**:** Describes actions which can influence the load profile such as shifting the load curve in time without affecting total electricity demand, or load shedding such as interrupting demand for a short duration or adjusting the intensity of demand for a certain amount of time.

Direct air capture (DAC)**:** A type of CCUS technology that captures CO_2 directly from the atmosphere using liquid solvents or solid sorbents. It is generally coupled with permanent storage of the CO_2 in deep geological formations or its use in the production of fuels, chemicals, building materials or other products. When coupled with permanent geological CO_2 storage, DAC is a carbon removal technology, and it is known as direct air capture and storage (DACS).

Dispatchable generation: Electricity from technologies whose power output can be readily controlled up to the nameplate capacity, i.e. increased to maximum rated capacity or decreased to zero, in order to help match supply with demand.

Electric arc furnace: Furnace that heats material by means of an electric arc. It is used for scrap-based steel production but also for ferroalloys, aluminium, phosphorus or calcium carbide.

Electric vehicles (EVs)**:** Electric vehicles include battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs).

Electricity demand: Defined as total gross electricity generation less own use generation, plus net trade (imports less exports), less transmission and distribution losses.

Electricity generation: Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own use. This is also referred to as gross generation.

Electrolysis: Process of converting electric energy to chemical energy. Most relevant for the energy sector is water electrolysis, which splits water molecules into hydrogen and oxygen molecules. The resulting hydrogen is called electrolytic hydrogen.

End-use sectors: Include industry, transport, buildings and other, i.e. agriculture and other non-energy use.

Energy demand: See total energy supply.

Energy-intensive industries: Includes production and manufacturing in the branches of iron and steel, chemicals, non-metallic minerals (including cement), non-ferrous metals (including aluminium), and paper, pulp and printing.

Energy-related and industrial process CO_2 emissions: Carbon dioxide emissions from fuel combustion, industrial processes, and fugitive and flaring CO_2 from fossil fuel extraction. Unless otherwise stated, CO_2 emissions in this report refer to energy-related and industrial process CO_2 emissions.

Energy sector greenhouse gas (GHG) **emissions:** Energy-related and industrial process CO_2 emissions plus fugitive and vented methane (CH_4) and nitrous oxide (N_2O) emissions from the energy and industry sectors.

Energy services: A personal or societal gain from the use of energy. Includes, *inter alia,* heating, cooling, lighting, entertainment, mobility, nourishment, hygiene and education. Also see useful energy.

Ethanol: An alcohol with broad application in the chemical sector and as a fuel additive. When produced from bioresources it is known as bioethanol, which has applications as biogasoline, a liquid fuel, and as a biochemical. In this report, the term exclusively refers to bioethanol.

Fischer-Tropsch synthesis: Catalytic process to produce synthetic fuels, e.g. diesel, kerosene or naphtha, typically from mixtures of carbon monoxide and hydrogen (synthesis gas or syngas). The inputs to Fischer-Tropsch synthesis can be from biomass, coal, natural gas, or hydrogen and CO_2.

Fossil fuels: Coal, oil and natural gas. Total fossil fuel use is equal to unabated fossil fuels plus fossil fuels with CCUS and non-energy use of fossil fuels.

Gaseous fuels: Fuels in gaseous form including natural gas, biogas, biomethane, hydrogen and synthetic methane.

Gases: See gaseous fuels.

Gas-to-liquids (GTL)**:** A process by which methane reacts with oxygen or steam to produce synthesis gas or syngas, i.e. a mixture of hydrogen and carbon monoxide, followed by Fischer-Tropsch synthesis. This is similar to the process used in coal-to-liquids.

Geothermal: Heat derived from the sub-surface of the earth, usually using a working fluid such as water and/or steam to bring the energy to the surface. Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity if the temperature is adequate.

Heat (end-use)**:** Can be obtained from the combustion of fossil or renewable fuels, direct geothermal or solar heat systems, exothermic chemical processes and electricity (through resistance heating or heat pumps which can extract heat from ambient air and liquids). This category refers to the wide range of end-uses, including space and water heating, and cooking in buildings, desalination and process applications in industry. It does not include cooling applications.

Heat (supply)**:** Obtained from the combustion of fuels, nuclear reactors, large-scale heat pumps, geothermal or solar resources. It may be used for heating or cooling, or converted into mechanical energy for transport or electricity generation. Commercial heat sold is reported under total final consumption with the fuel inputs allocated under power generation.

Heavy-duty trucks (HDTs)**:** Include both medium freight trucks (gross weight 3.5 to 15 tonnes) and heavy freight trucks (gross weight >15 tonnes).

Heavy-duty vehicles (HDVs)**:** Include both medium freight trucks (gross weight 3.5 to 15 tonnes), heavy freight trucks (gross weight >15 tonnes) and buses.

Heavy industries: Iron and steel, chemicals and cement.

Hydrogen: Hydrogen is used in the energy system as an energy carrier, as an industrial raw material, or is combined with other inputs to produce hydrogen-based fuels. Unless otherwise stated, hydrogen in this report refers to low-emissions hydrogen.

Hydrogen-based fuels: Includes ammonia and synthetic hydrocarbons (gases and liquids) that derive their energy content from a pure, or nearly pure, hydrogen feedstock. If produced from low-emissions hydrogen, these fuels are low-emissions hydrogen-based fuels.

Hydropower: Refers to the electricity produced in hydropower projects. It excludes output from pumped storage and marine (e.g. tidal and wave technologies).

Improved cook stoves: Intermediate and advanced improved biomass cook stoves (ISO tier > 1). It excludes basic improved stoves (ISO tier 0-1).

Industry: The sector includes fuel used within the manufacturing and construction industries. Key industry branches include iron and steel, chemicals and petrochemicals, cement, aluminium, and pulp and paper. Use by industries for the transformation of energy into another form or for the production of fuels is excluded and reported separately under other energy sector. There is an exception for fuel transformation in blast furnaces and coke ovens, which are reported within iron and steel. Consumption of fuels for the transport of goods is reported as part of the transport sector, while consumption of fuels by off-road vehicles is reported under the specific sector. For instance, fuels consumed by bulldozers as a part of industrial operations is reported in industry.

International aviation bunkers: Include the deliveries of aviation fuels to aircraft for international aviation. Fuel used by airlines for their road vehicles are excluded. The domestic/international split is determined on the basis of departure and landing locations and not by the nationality of the airline. For many countries this incorrectly excludes fuels used by domestically owned carriers for their international departures.

International marine bunkers: Include the quantities delivered to ships of all flags that are engaged in international navigation. The international navigation may take place at sea, on inland lakes and waterways, and in coastal waters. Consumption by ships engaged in domestic navigation is excluded. The domestic/international split is determined on the basis of port of departure and port of arrival, and not by the flag or nationality of the ship. Consumption by fishing vessels and by military forces is excluded and instead included in the residential, services and agriculture category.

Investment: Investment is the capital expenditure in energy supply, infrastructure, end-use and efficiency. Fuel supply investment includes the production, transformation and transport of oil, gas, coal and low-emissions fuels. *Power sector* investment includes new construction and refurbishment of generation, electricity grids (transmission, distribution and public electric vehicle chargers), and battery storage. *Energy efficiency* investment includes efficiency improvements in buildings, industry and transport. *Other end-use* investment includes the purchase of equipment for the direct use of renewables, electric vehicles, electrification in buildings, industry and international marine transport, equipment for the use of low-emissions fuels, and CCUS in industry and direct air capture. Data and projections reflect spending over the lifetime of projects and are presented in real terms in year-2024 US dollars converted at market exchange rates unless otherwise stated. Total investment reported for a year reflects the amount spent in that year.

Levelised cost of electricity (LCOE)**:** An indicator of the expected average production cost for each unit of electricity generated by a technology over its economic lifetime. The LCOE combines into a single metric all the cost elements directly associated with a given power technology, including construction, financing, fuel, maintenance and costs associated with a carbon price. It does not include network integration or other indirect costs. For a more complete indicator, see value-adjusted levelised cost of electricity (VALCOE).

Light-duty vehicles (LDVs)**:** Include passenger cars and light commercial vehicles (gross vehicle weight < 3.5 tonnes).

Light industries: Include non-energy-intensive industries: food and tobacco; machinery; mining and quarrying; transportation equipment; textiles; wood harvesting and processing and construction.

Lignite: A type of coal that is used in the power sector mostly in regions near lignite mines due to its low energy content and typically high moisture levels, which generally make long-distance transport uneconomic. In this report, data on lignite includes peat.

Liquid biofuels: Liquid fuels derived from biomass or waste feedstock, including ethanol, biodiesel and biojet fuels. Unless otherwise stated, biofuels are expressed in energy-equivalent volumes of gasoline, diesel and kerosene.

Liquid fuels: Include oil, liquid biofuels, synthetic oil products and hydrogen-based fuels, i.e. ammonia and methanol.

Low-emissions electricity: Includes output from renewable energy technologies, nuclear power, fossil fuels fitted with CCUS, hydrogen and ammonia.

Low-emissions fuels: Include modern bioenergy, low-emissions hydrogen and low-emissions hydrogen-based fuels.

Low-emissions gases: Include biogas, biomethane, low-emissions hydrogen and low-emissions synthetic methane.

Low-emissions hydrogen: Includes hydrogen that is produced through water electrolysis with electricity generated from a low-emissions source, e.g. solar, wind and nuclear power. Hydrogen produced from biomass or from fossil fuels with CCUS technology is also counted as low-emissions hydrogen. Production from fossil fuels with CCUS is included only if upstream emissions are sufficiently low, if capture at high rates is applied to all CO_2 streams associated with the production route, and if all CO_2 is permanently stored to prevent its release into the atmosphere. The same principle applies to low-emissions feedstocks and hydrogen-based fuels made using low-emissions hydrogen and a sustainable carbon source of biogenic origin or directly captured from the atmosphere.

B

Low-emissions hydrogen-based fuels: Fuels produced from low-emissions hydrogen. Includes ammonia, methanol and other synthetic hydrocarbons (gases and liquids) made from low-emissions hydrogen when any carbon inputs, e.g. from CO_2, are not from fossil fuels or fossil-derived process emissions.

Low-emissions hydrogen-based liquid fuels: A subset of low-emissions hydrogen-based fuels that includes only ammonia, methanol and synthetic liquid hydrocarbons, such as synthetic kerosene.

Lower heating value: Heat liberated by the complete combustion of a unit of fuel when the water produced is assumed to remain as a vapour and the heat is not recovered.

Marine energy: Mechanical energy harvested from ocean currents, tidal movement or wave motion and exploited for electricity generation.

Middle distillates: Include jet fuel, diesel and heating oil.

Mini-grids: Small electric grid systems, not connected to main electricity networks, linking a number of households and/or other consumers.

Modern energy access: Includes household access to a minimum level of electricity, initially equivalent to 250 kilowatt-hours (kWh) annual demand for a rural household and 500 kWh for an urban household; household access to less harmful and more sustainable cooking and heating fuels, and improved/advanced stoves; access that enables productive economic activity; and access for public services.

Modern gaseous bioenergy: See biogases.

Modern liquid bioenergy: Includes biogasoline, biodiesel, biojet kerosene and other liquid biofuels.

Modern renewables: Include all renewables with the exception of the traditional use of solid biomass.

Modern solid bioenergy: Includes all solid bioenergy products except the traditional use of biomass. It also includes the use of solid bioenergy in intermediate and advanced improved biomass cook stoves (ISO tier > 1), requiring fuel to be cut into small pieces or often using processed biomass such as pellets.

Natural gas: A gaseous fossil fuel, consisting mostly of methane. Occurs in deposits, whether liquefied or gaseous. In IEA analysis and statistics, it includes both non-associated gas originating from fields producing hydrocarbons only in gaseous form, and associated gas produced in association with crude oil production, as well as methane recovered from coal mines. Natural gas liquids, manufactured gas (i.e. produced from municipal or industrial waste, or sewage) and quantities vented or flared are not included. Natural gas has a specific energy content of 44.09 MJ/kg on a higher heating value basis. Natural gas data in cubic metres are expressed on a gross calorific value basis and are measured at 15 °C and at 760 mm Hg (Standard Conditions). Natural gas data expressed in tonnes of oil equivalent, mainly to allow comparison with other fuels, are on a net calorific basis. The difference between the net and the gross calorific value is the latent heat of vapourisation of the water vapour produced during combustion of the fuel.

Natural gas liquids (NGLs)**:** Liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilisation of natural gas. NGLs are portions of natural gas recovered as liquids in separators, field facilities or gas processing plants. NGLs include, but are not limited to, ethane (when it is removed from the natural gas stream), propane, butane, pentane, natural gasoline and condensates.

Network gases: Gaseous fuels transported in a pipeline gas network, either separately or blended together. Include natural gas, biomethane, synthetic methane and hydrogen blended in a gas network.

Non-energy-intensive industries: See other industry.

Non-energy use: The use of energy products as raw materials for the manufacture of non-energy products, e.g. natural gas used to produce fertiliser, as well as for direct uses that do not involve using the products as a source of energy, or as a transformation input e.g. lubrication, sealing, roading surfacing, preservation or use as a solvent. Note that for biofuels, only the amounts specifically used for energy purposes, a small part of the total, are included in energy statistics. Therefore, the non-energy use of biomass is not taken into consideration and the quantities are null by definition.

Non-renewable waste: Non-biogenic waste, such as plastics in municipal or industrial waste.

Nuclear power: Refers to the electricity produced by a nuclear reactor, assuming an average conversion efficiency of 33%.

Off-grid systems: Mini-grids and stand-alone systems for individual households or groups of consumers not connected to a main grid.

Offshore wind: Refers to electricity produced by wind turbines that are installed in open water, usually in the ocean. Includes fixed offshore wind (fixed to the seabed) and floating offshore wind.

Oil: A liquid fuel. Usually refers to fossil fuel mineral oil. Includes oil from both conventional and unconventional oil production. Petroleum products include refinery gas, ethane, liquid petroleum gas, aviation gasoline, motor gasoline, jet fuel, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirits, lubricants, bitumen, paraffin, waxes and petroleum coke.

Other energy sector: Covers the use of energy by transformation industries and energy losses in converting primary energy into a form that can be used in the final consuming sectors. It includes losses in low-emissions hydrogen and hydrogen-based fuels production, bioenergy processing, gas works, petroleum refineries, coal and gas transformation and liquefaction. It also includes energy own use in coal mines, in oil and gas extraction and in electricity and heat production. Transfers and statistical differences are also included in this category. Fuel transformation in blast furnaces and coke ovens are not accounted for in the other energy sector category.

Other industry: A category of industry branches that includes construction, food processing, machinery, mining, textiles, transport equipment, wood processing and remaining industry. It is sometimes referred to as non-energy-intensive industry.

Passenger car: A road motor vehicle, other than a moped or a motorcycle, intended to transport passengers. It includes vans designed and used primarily to transport passengers. Excluded are light commercial vehicles, motor coaches, urban buses and mini-buses/mini-coaches.

Peat: A solid formed from the partial decomposition of dead vegetation under conditions of high humidity and limited air access, i.e. initial stage of coalification. It is available in two forms for use as a fuel, sod peat and milled peat. Peat used for non-energy purposes is not included.

Plastic collection rate: Proportion of plastic that is collected for recycling relative to the quantity of recyclable waste available.

Plastic waste: Refers to all post-consumer plastic waste with a lifespan of more than one year.

Power generation: Refers to electricity generation and heat production from all sources of electricity, including electricity-only power plants, heat plants, and co-generation, i.e. combined heat and power plants. Both main activity producer plants and small plants that produce fuel for their own use, i.e. auto-producers, are included.

Process emissions: CO_2 emissions produced from industrial processes which chemically or physically transform materials. A notable example is cement production, in which CO_2 is emitted when calcium carbonate is transformed into lime, which in turn is used to produce clinker.

Process heat: The use of thermal energy to produce, treat or alter manufactured goods.

Productive uses: Energy used towards an economic purpose: agriculture, industry, services and non-energy use. Some energy demand from the transport sector, for example. freight, could be considered as productive, but is treated separately.

Primary chemicals: Include ethylene, propylene, benzene, toluene, mixed xylenes, ammonia and methanol.

Rare earth elements (REEs): A group of seventeen chemical elements in the periodic table, specifically the fifteen lanthanides plus scandium and yttrium. REEs are vital inputs for key energy technologies, including wind turbines, electric vehicle motors and electrolysers.

Renewables: Include bioenergy, geothermal, hydropower, solar photovoltaics, concentrating solar power, wind and marine (tidal and wave) energy for electricity and heat generation.

Residential: Energy used by households including space heating and cooling, water heating, lighting, appliances, electronic devices and cooking.

Road transport: This refers to all road vehicle types, i.e. passenger cars, two/three-wheelers, light commercial vehicles, buses and medium and heavy freight trucks.

Self-sufficiency: Corresponds to indigenous production divided by total energy supply.

Services: A component of the buildings sector. It represents energy used in commercial facilities, e.g. offices, shops, hotels, restaurants, and in institutional buildings such as schools, hospitals and public offices. Energy use in services includes space heating and cooling, water heating, lighting, appliances, cooking, data centres and desalination.

Shale gas: A type of unconventional natural gas contained within a commonly occurring rock classified as shale. Shale formations are characterised by low permeability, with more limited ability for gas to flow through the rock than is the case within a conventional reservoir. Shale gas is generally produced using hydraulic fracturing. See also tight oil.

Shipping/navigation: This transport mode includes both domestic and international navigation and their use of marine fuels. Domestic navigation covers the transport of goods or people on inland waterways and for national sea voyages (starts and ends in the same country without any intermediate foreign port). International navigation includes quantities of fuels delivered to merchant ships, including passenger ships, of any nationality for consumption during international voyages transporting goods or passengers.

Single-use plastics (or disposable plastics)**:** Plastic items used only one time before disposal.

Solar: Includes solar photovoltaics (PV), concentrating solar power (CSP), and solar heating and cooling.

Solar home systems (SHS)**:** Small-scale photovoltaic and battery stand-alone systems, i.e. with capacity higher or equal to 10 watt peak (Wp) supplying electricity for single households or small businesses. They are most often used off-grid, but also where grid supply is not reliable. Although all SHS are included in the IEA access to electricity definition and historic counting, only solar home systems from 25 Wp in rural areas and 50 Wp in urban areas are deployed in the IEA scenarios for population gaining access. It excludes solar systems smaller than 10 Wp, i.e. multi light systems and solar lanterns.

Solar photovoltaics (PV)**:** Electricity produced from solar photovoltaic cells including utility-scale and small-scale installations.

Solid bioenergy: Includes charcoal, fuelwood, dung, agricultural residues, wood waste and other solid biogenic wastes.

Solid fuels: Include coal, modern solid bioenergy, traditional use of biomass and industrial and municipal wastes.

Stand-alone systems: Small-scale autonomous electricity supply for households or small businesses. They are generally used off-grid, but also where grid supply is not reliable. Stand-alone systems include solar home systems, small wind or hydro generators, diesel or gasoline generators. The difference compared with mini-grids is in scale and that stand-alone systems do not have a distribution network serving multiple costumers.

Steam coal: A type of coal that is mainly used for heat production or steam-raising in power plants and, to a lesser extent, in industry. Typically, steam coal is not of sufficient quality for steel making. Coal of this quality is also commonly known as thermal coal.

Synthetic methane: Methane from sources other than natural gas, including coal-to-gas and low-emissions synthetic methane.

Synthetic oil: Liquid fuels obtained via a process other than the refining of crude oil or bituminous oils. Synthetic oil is produced through Fischer-Tropsch conversion or methanol synthesis. It includes oil products from coal-to-liquids, gas-to-liquids and non-ammonia low-emissions liquid hydrogen-based fuels.

Tight oil: A type of unconventional oil produced from shale or other very low permeability formations, generally using hydraulic fracturing. Sometimes referred to as light tight oil. Tight oil includes tight crude oil and condensate production except for the United States, which includes tight crude oil only. (US tight condensate volumes are included in natural gas liquids).

Total energy supply (TES)**:** Represents domestic demand only, and is equivalent to electricity and heat generation plus the other energy sector, excluding electricity, heat and hydrogen, plus total final consumption, excluding electricity, heat and hydrogen. TES does not include ambient heat from heat pumps or electricity trade.

Total final consumption (TFC)**:** Is the sum of consumption by the various end-use sectors. TFC is broken down into energy demand in the following sectors: industry (including manufacturing, mining, chemicals production, blast furnaces and coke ovens); transport; buildings (including residential and services); and other (including agriculture and other non-energy use). It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector.

Total final energy consumption (TFEC)**:** Is a variable defined primarily for tracking progress towards target 7.2 of the United Nations Sustainable Development Goals (SDG). It incorporates total final consumption by end-use sectors, but excludes non-energy use. It excludes international marine and aviation bunkers, except at world level. Typically this is used in the context of calculating the renewable energy share in total final energy consumption (indicator SDG 7.2.1), where TFEC is the denominator.

Traditional use of biomass: Refers to the use of solid biomass with basic technologies, such as a three-stone fire or basic improved cook stoves (ISO tier 0-2), often with no or poorly operating chimneys. Forms of biomass used include wood, wood waste, charcoal, agricultural residues and other bio-sourced fuels such as animal dung.

Transport: Includes fuels and electricity used in the transport of goods or people within the national territory irrespective of the economic sector within which the activity occurs. This includes: fuel and electricity delivered to vehicles using public roads or for use in rail vehicles; fuel delivered to vessels for domestic navigation; fuel delivered to aircraft for domestic aviation; and energy consumed in the delivery of fuels through pipelines. Energy consumption from marine and aviation bunkers is presented only at the world level and is excluded from the transport sector at a domestic level.

Trucks: Includes all size categories of commercial vehicles: light trucks (gross vehicle weight < 3.5 tonnes); medium freight trucks (gross vehicle weight 3.5-15 tonnes); and heavy freight trucks (gross vehicle weight > 15 tonnes).

Unabated fossil fuel use: Fossil fuels used for energy purposes without carbon capture, utilisation and storage (CCUS). Total fossil fuel use is equal to unabated fossil fuels plus fossil fuels with CCUS plus non-energy use of fossil fuels.

Unconventional natural gas: Includes tight gas, shale gas, coalbed methane, gas hydrates and coal-to-gas products.

Unconventional oil: Includes mining and in-situ extra-heavy oil and bitumen, synthetic crudes made by upgrading bituminous, e.g., oil sands in Canada, or extra-heavy crude oils, light tight oil, kerogen oil, coal-to-liquids (CTL) and gas-to-liquids (GTL) products, additives and natural gas liquids from unconventional natural gas fields.

Useful energy: Energy available to end-users to satisfy their need for energy services. As a result of transformation losses at the point of use, the amount of useful energy is lower than the corresponding final energy demand for most technologies. See energy services.

Value-adjusted levelised cost of electricity (VALCOE)**:** A more complete metric to evaluate the competitiveness of power generation technologies, which includes all direct technology costs (LCOE) combined with the estimated value of three services provided to the system: energy, flexibility and capacity.

Variable renewable energy (VRE)**:** Sources of renewable energy, usually electricity, where the maximum output of an installation at a given time depends on the availability of fluctuating environmental inputs. VRE includes a broad array of technologies such as wind power, solar PV, run-of-river hydro, concentrating solar power where no thermal storage is included, and marine (tidal and wave).

Zero carbon-ready buildings: A zero carbon-ready building is highly energy efficient and either uses renewable energy directly or an energy supply that can be fully decarbonised, such as electricity or district heat.

Zero emissions vehicles (ZEVs)**:** Vehicles that operate without tailpipe CO_2 emissions, i.e. battery electric, plug-in hybrids and fuel cell vehicles.

Regional and country groupings

Advanced economies: Organisation for Economic Co-operation and Development (OECD) regional grouping and Bulgaria, Croatia, Cyprus[1,2], Malta and Romania.

Africa: North Africa and sub-Saharan Africa regional groupings.

Asia Pacific: Southeast Asia regional grouping and Australia, Bangladesh, Democratic People's Republic of Korea (North Korea), India, Japan, Korea, Mongolia, Nepal, New Zealand, Pakistan, The People's Republic of China (China), Sri Lanka, Chinese Taipei, and other Asia Pacific countries and territories.[3]

Caspian: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Central and South America: Argentina, Plurinational State of Bolivia (Bolivia), Bolivarian Republic of Venezuela (Venezuela), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay and other Central and South American countries and territories.[4]

China: Includes (The People's Republic of) China and Hong Kong, China.

Developing Asia: Asia Pacific regional grouping excluding Australia, Japan, Korea and New Zealand.

Emerging market and developing economies: All other countries not included in the advanced economies regional grouping.

Eurasia: Caspian regional grouping and the Russian Federation (Russia).

Europe: European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, Gibraltar, Iceland, Israel[5], Kosovo[6], Montenegro, North Macedonia, Norway, Republic of Moldova, Serbia, Switzerland, Türkiye, Ukraine and United Kingdom.

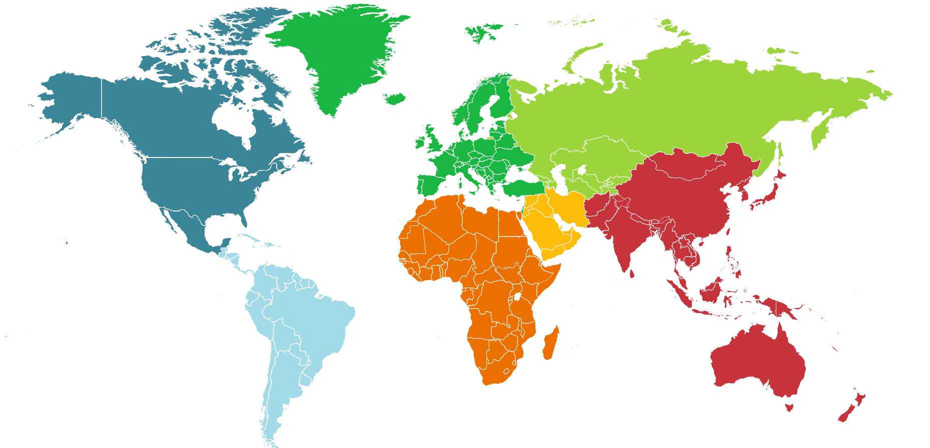
European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus[1,2], Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden.

IEA (International Energy Agency)**:** Australia, Austria, Belgium, Canada, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, The Netherlands, Türkiye, United Kingdom and United States.

Latin America and the Caribbean (LAC)**:** Central and South America regional grouping and Mexico.

Middle East: Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen.

Figure C.1 ▷ Main country groupings



Note: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Non-OECD: All other countries not included in the OECD regional grouping.

Non-OPEC: All other countries not included in the OPEC regional grouping.

North Africa: Algeria, Egypt, Libya, Morocco and Tunisia.

North America: Canada, Mexico and United States.

OECD (Organisation for Economic Co-operation and Development)**:** IEA grouping plus Chile, Colombia, Costa Rica, Iceland, Israel, Latvia and Slovenia.

OPEC (Organization of the Petroleum Exporting Countries)**:** Algeria, Angola, Bolivarian Republic of Venezuela (Venezuela), Equatorial Guinea, Gabon, Iraq, Islamic Republic of Iran (Iran), Kuwait, Libya, Nigeria, Republic of the Congo (Congo), Saudi Arabia and United Arab Emirates.

OPEC+: OPEC grouping plus Azerbaijan, Bahrain, Brunei Darussalam, Kazakhstan, Malaysia, Mexico, Oman, Russian Federation, South Sudan and Sudan.

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. These countries are all members of the Association of Southeast Asian Nations (ASEAN). Timor-Leste joined ASEAN on 26 October 2025 and is not included in this grouping in this publication.

Sub-Saharan Africa: Angola, Benin, Botswana, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo (DRC), Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Kingdom of Eswatini, Madagascar, Mauritius, Mozambique, Namibia, Niger, Nigeria, Republic of the Congo (Congo), Rwanda, Senegal, South Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Uganda, Zambia, Zimbabwe and other African countries and territories.[7]

Country notes

[1] Note by Republic of Türkiye: The information in this document with reference to "Cyprus" relates to the southern part of the island. There is no single authority representing both Turkish and Greek Cypriot people on the island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue".

[2] Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

[3] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga and Vanuatu.

[4] Individual data are not available and are estimated in aggregate for: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Bonaire, Sint Eustatius and Saba, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and Grenadines, Saint Maarten (Dutch part), Turks and Caicos Islands.

[5] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

[6] This designation is without prejudice to positions on status, and is in line with United Nations Security Council Resolution 1244/99 and the Advisory Opinion of the International Court of Justice on Kosovo's declaration of independence.

[7] Individual data are not available and are estimated in aggregate for: Burkina Faso, Burundi, Cabo Verde, Central African Republic, Chad, Comoros, Djibouti, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Malawi, Mali, Mauritania, Sao Tome and Principe, Seychelles, Sierra Leone and Somalia.

Abbreviations and acronyms

AC	alternating current
AFOLU	agriculture, forestry and other land use
APS	Announced Pledges Scenario
BAT	best available technology
BECCS	bioenergy equipped with CCUS
BEV	battery electric vehicles
CAAGR	compound average annual growth rate
CAPEX	capital expenditures
CCGT	combined-cycle gas turbine
CCUS	carbon capture, utilisation and storage
CDR	carbon dioxide removal
CH_4	methane
CHP	combined heat and power; the term co-generation is sometimes used
CLLJ	Caribbean Low-Level Jet

CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-eq	carbon-dioxide equivalent
COP	Conference of the Parties (UNFCCC)
CPS	Current Policies Scenario
CSP	concentrating solar power
CTG	coal-to-gas
CTL	coal-to-liquids
DAC	direct air capture
DACS	direct air capture and storage
DC	direct current
DER	distributed energy resources
DFI	development finance institutions
DRI	direct reduced iron
DSI	demand-side integration
DSO	distribution system operator
DSR	demand-side response
EDGE	excellence in design for greater efficiencies
EHOB	extra-heavy oil and bitumen
EMDE	emerging market and developing economies
ENSO	El Niño-Southern Oscillation
EOR	enhanced oil recovery
ETS	emissions trading system
EU	European Union
EV	electric vehicle
FACTS	flexible AC transmission systems
FAO	Food and Agriculture Organization of the United Nations
FDI	foreign direct investment
FDN	Financiera de Desarrollo Nacional
FEPC	Fondo de Estabilización de Precios de los Combustibles
FID	final investment decision
GEC	Global Energy and Climate (IEA model)
GDP	gross domestic product
GHG	greenhouse gases
GTL	gas-to-liquids
H_2	hydrogen
HDV	heavy-duty vehicle
HEFA	hydrogenated esters and fatty acids
HFO	heavy fuel oil
HVDC	high-voltage direct current
ICE	internal combustion engine
ICZ	Intertropical Convergence Zone
IEA	International Energy Agency

IIASA	International Institute for Applied Systems Analysis
ILO	International Labour Organization
IMF	International Monetary Fund
IMO	International Maritime Organization
IOC	international oil company
IPCC	Intergovernmental Panel on Climate Change
IPF	international public finance
IPT	independent power transmission
IT	information technology
LCOE	levelised cost of electricity
LCV	light commercial vehicle
LDV	light-duty vehicle
LED	light-emitting diode
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULUCF	land use, land-use change and forestry
MEPS	minimum energy performance standards
MER	market exchange rate
NDC	Nationally Determined Contribution
NGLs	natural gas liquids
NGV	natural gas vehicle
NOC	national oil company
NPV	net present value
NO_X	nitrogen oxides
N_2O	nitrous oxide
NZE	Net Zero Emissions by 2050 Scenario
OECD	Organisation for Economic Co-operation and Development
ONI	Oceanic Niño Index
OPEC	Organization of the Petroleum Exporting Countries
OPEX	operating expenditures
PAI PROURE	Plan de Acción Indicativo del Programa de Uso Racional de Energía
PIGCC	Planes Integrales de Gestión del Cambio Climático
PHEV	plug-in hybrid electric vehicles
PLDV	passenger light-duty vehicle
PM	particulate matter
$PM_{2.5}$	fine particulate matter
PNSL	Plan Nacional de Sustitución de Leña
PPA	power purchase agreement
PPP	purchasing power parity
PV	photovoltaics
R&D	research and development
RD&D	research, development and demonstration
RETIQ	Reglamento Técnico de Etiquetado de Equipos que Usan Energía
SAF	sustainable aviation fuel

SDG	Sustainable Development Goals (United Nations)
SEAD	Super-Efficient Equipment and Deployment
SHS	solar home systems
SITP	Sistema Integrado de Transporte Público
SME	small and medium enterprises
SMR	steam methane reforming
SO_2	sulphur dioxide
SOEs	state-owned enterprises
SPI	Standardised Precipitation Index
STEPS	Stated Policies Scenario
T&D	transmission and distribution
TES	total energy supply
TFC	total final consumption
TFEC	total final energy consumption
TPED	total primary energy demand
TSO	transmission system operator
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UPME	Unidad de Planeación Minero Energética
US	United States
USGS	United States Geological Survey
VALCOE	value-adjusted levelised cost of electricity
VRE	variable renewable energy
WACC	weighted average cost of capital
WAMS	wide-area monitoring system
WEO	World Energy Outlook
WHO	World Health Organization
ZEV	zero emissions vehicle
ZCRB	zero carbon-ready building

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Chapter 1: Colombia today

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An Energy Sector Roadmap to Net Zero Emissions in Colombia

World Energy Outlook Special Report

Colombia has set an ambitious goal to achieve net zero greenhouse gas emissions by 2050. The third-largest country in Latin America and the Caribbean by population, it has seen stable economic and population growth over past decades. A large part of its energy mix is made up of fossil fuels, largely oil, while hydropower provides most electricity. Colombia has abundant untapped solar and wind resources and a strong base of clean energy potential.

At the request of the Government of Colombia, the IEA has developed a roadmap to net zero by 2050 for the country. *An Energy Sector Roadmap to Net Zero Emissions in Colombia* charts a possible pathway, but not the only pathway, for Colombia to achieve net zero emissions by 2050 while supporting economic growth and energy security. It examines the current energy mix and emissions trends, the role of clean energy resources such as hydropower, solar, wind, and the technologies needed to transform end-use sectors. It discusses the integration of variable renewables, grid flexibility and the potential for hydrogen and bioenergy. It also addresses investment needs, financing challenges, energy security under climate variability, and the social dimensions of a just transition.