Latin America Energy Outlook

International Energy Agency

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World Energy Outlook Special Report

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Across many indicators, the Latin America and Caribbean region stands out for its extraordinary endowment of natural resources – both fossil fuel and renewable energy – and its history of policy making that has notably delivered one of the cleanest electricity sectors in the world. The expansion of renewable energy technologies such as hydropower and bioenergy, initially driven by an emphasis on energy security, has more recently been propelled by a deepening commitment to sustainability. Sixteen of 33 countries in the region have pledged to reach net zero emissions by mid-century or earlier, and most have presented updated and increasingly ambitious climate targets tied to the 2015 Paris climate agreement.

Our Latin America Energy Outlook, the International Energy Agency's (IEA) first in-depth and comprehensive assessment of Latin America and the Caribbean, builds on decades of collaboration with partners across the region. In support of Latin America and the Caribbean's energy goals, this report explores the opportunities and challenges that lie ahead, providing insights into the ways in which the region's energy future and major global trends are deeply intertwined.

A key asset for region is its low-emissions electricity supply. This lays the groundwork for other key aspects of energy transitions, including extensive clean manufacturing of industrial goods and the production of fuels such as low-emissions hydrogen. Resources and deep expertise in sustainable bioenergy also position the region to lead on sustainable transport fuels – at home and worldwide. Meanwhile, the global electrification of transport and expansion of electricity grids is generating a boom in demand for critical minerals such as copper, lithium, rare earth elements and graphite. The region's ample reserves of these minerals place it in pole position to expand production to supply the needs of the global clean energy transition, with additional potential to move up the value chain into refining and processing.

Reaping these benefits will require clear strategic vision, robust public policies and broad partnerships between governments and other stakeholders. Countries in the region need to design and implement policies and regulations that attract substantial investment, ensure sustainability and deliver just and equitable transitions. This includes overcoming remaining energy access challenges while creating jobs and spurring innovation in emerging clean energy sectors.

Oil and gas remain important in the region. Natural gas balances supply for power systems and is a key fuel for industry, while most vehicles on the road rely on oil, despite the prevalence of biofuels. Latin America and the Caribbean – home to an abundance of oil and gas resources – will continue to play a vital role in supplying international markets, even though global demand for both oil and gas is expected to peak this decade under current policy settings. Managing this transition will require the co-operation of a broad set of stakeholders that are willing to adapt and innovate as local and global needs change in the years ahead.

This report is a testament to the IEA's strong relationships with countries in Latin America and the Caribbean, including five members of the IEA family: Argentina, Brazil, Chile, Colombia and Mexico. Furthermore, this Outlook reflects input from government officials, experts and stakeholders from 17 countries across the region. It also provides a basis for our ongoing collaboration with other international institutions in the region such as the Inter-American Development Bank, the Latin American Energy Organization, and the United Nations Economic Commission for Latin America and the Caribbean.

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The IEA stands ready to support countries across the region as they advance their clean energy transitions, building a more secure and fairer global energy system in the process.

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Annexes

Latin America and the Caribbean is well placed to thrive as the world moves into a clean energy age

How Latin America and the Caribbean uses its vast resources will shape the region's energy future and the role it plays in the global energy system. Latin America and the Caribbean encompasses a region that is both large and diverse in terms of economic development and natural resources. It is rich in fossil fuels and renewable energy, as well as critical minerals. Whether it is harnessing biofuels in Brazil, hydropower in Brazil, Venezuela, Mexico, Colombia, Argentina and Paraguay, or high-quality solar and wind resources in Brazil, Mexico, Chile or Argentina; producing copper or lithium in Chile, Peru and Argentina, minerals essential to clean energy technologies; or tapping the vast oil and natural gas resources in Venezuela, Brazil, Colombia, Argentina, Mexico or Guyana, Latin America and the Caribbean is well placed to thrive as clean energy transitions move forward and to contribute to global energy security and climate goals.

Fossil fuels account for around two-thirds of the region's energy mix, considerably lower than the 80% global average, thanks to the 60% share of renewables in electricity generation. Hydropower alone accounts for 45% of electricity supply in the region. In Costa Rica and Paraguay, almost all electricity supply is from renewable sources. Fossil fuels dominate in many end-use sectors, and oil is notably the primary fuel used in transport. However, the share of biofuels in road transport is twice the global average. Latin America and the Caribbean accounted for 5% of all global energy-related greenhouse gas (GHG) emissions since 1971, while representing 9% of global GDP over the period. Today, the region is a net exporter of crude oil and coal, but a net importer of oil products and natural gas.

Latin America and the Caribbean today represents 8% of the global population and 7% of the global economy, but it can play an outsized role in the new energy economy. With large oil and gas resources, the region can help diversify oil and gas supply in the near term. It is also making strides in developing and exporting advanced biofuels and low-emissions hydrogen, and is ramping up the production of critical minerals essential to clean energy technologies. The region has all the ingredients for secure, affordable and rapid transitions. Moreover, success in Latin America and the Caribbean can bring many benefits to the world.

Clean energy transitions offer opportunities for stronger economic growth

The economy in Latin America and the Caribbean is emerging from a period of sluggish growth over the past ten years. The region's rate of expansion has been a third of the global average during this period. Substantial debt burdens, fiscal deficits, high inflation and the global energy crisis have all put brakes on economic growth. This has generated echoes of the so-called "lost decade" in the 1980s when regional GDP grew slowly amid debt crises and falling investment.

Stronger economic growth can be unlocked with sound energy policies and resource developments. Economic growth is expected to pick up in the next decade to more than twice the rate of economic development observed over the past decade, as countries strengthen their industrial and services sectors, focus on higher value products, and leverage the region's vast energy and mineral resources, which will also boost the economic competitiveness of energy-intensive sectors. A range of measures are needed to attract foreign direct investment, such as implementing clear regulatory frameworks, streamlining administrative procedures and working closely with development institutions.

Our *Latin America Energy Outlook 2023* – the first IEA outlook for the region – contains in-depth country and regional analysis of energy and climate trends, identifying opportunities and key challenges, as more robust growth returns. This report explores three scenarios. It focuses on the Stated Policies Scenario (STEPS), reflecting today's policy settings, and the Announced Pledges Scenario (APS), which assumes all pledges and targets are achieved in full and on time, including climate goals established by Nationally Determined Contributions. The APS also reflects the net zero emissions pledges made by 16 countries – Antigua and Barbuda, Argentina, Barbados, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Grenada, Guyana, Jamaica, Panama, Peru, Suriname and Uruguay – which together cover 60% of energy-related carbon dioxide (CO_2) emissions and two-thirds of GDP in the region. Progress is also benchmarked against the Net Zero Emissions by 2050 (NZE) Scenario, which lays out a pathway to decarbonise the global energy system by mid-century.

Clean electricity provides a springboard for the region's transition

Ample renewable resources present an opportunity to make the electricity sector in Latin America and the Caribbean – already one of the cleanest in the world – even cleaner. Renewable electricity sources outpace electricity demand growth in all scenarios, raising their share of electricity supply from just over 60% today to two-thirds in 2030 and 80% in 2050 with today's policy settings. Hydropower, the foundation of the region's electricity supply for decades, provides the bulk of electricity today in Brazil, Colombia, Costa Rica, Ecuador, Panama, Paraguay and Venezuela. While its growth prospects are more limited in the future due to environmental and social concerns, hydro represents a huge source of flexibility. This will be critical as the share of solar PV and wind in electricity generation doubles by 2030, from 11% today, and reaches 40% by 2050. Brazil, Mexico, Chile and Argentina are leading the way in solar PV and wind development. Natural gas continues to generate about a quarter of electricity to 2030, while coal and oil decline rapidly. In the APS, the region accelerates the shift to renewables, exceeding a 70% share in 2030, 10 years before the STEPS, and over 90% in 2050.

Regional integration offers additional security and cost benefits as the electricity mix evolves. While the benefits are well understood and progress has been made with bilateral interconnections and jointly owned power plants, cross-border electricity trade remains limited today. Our analysis finds that the benefits of stronger regional integration in Latin America and the Caribbean will increase due to several factors: linking countries with different shares of wind and solar PV reduces flexibility needs; tapping a wider set of dispatchable resources improves the flexibility of supply; and linking electricity demand and supply from different climate zones provides more resilience to changing conditions.

Electricity becomes more central to the regional economy and is the fastest growing final form of energy in Latin America and the Caribbean. Electricity demand grows by 90% to 2050 with today's policy settings and by 180% to fulfil all pledges and targets, which doubles the share of electricity in total final consumption. Cheap renewables in the region give electricity a cost advantage in many applications over other fuels, particularly natural gas in importing countries. In the APS, the main driver of electricity demand growth is hydrogen production, followed by buildings (including for appliances and air conditioners), the electrification of transport (with almost 16 million electric vehicles, including buses, on the roads by 2030), and growth in industry to produce cleaner iron and steel, aluminium and chemicals. Peak electricity demand rises even faster than average demand in both scenarios, highlighting the need for dispatchable capacity and storage to maintain electricity security.

Policies determine the path ahead for the energy mix in Latin America and the Caribbean

Today's policy settings set a course for modest growth in fossil fuel use in the region in the long term, complemented by renewable energy. As total energy demand outpaces the growth of fossil fuels, their share of the energy mix falls from 67% today to 63% in 2030 and 54% in 2050. On this path, oil use sees modest growth, remaining far and away the dominant fuel in transport, despite more biofuels use and electric vehicles gaining traction. Natural gas also continues to grow, with new demand from industry producing chemicals, iron and steel in Mexico, Argentina and Brazil adding to growing use in transport and buildings, and stable demand in the electricity sector. Coal remains a small part of the energy mix in the region as demand for it declines, with reductions in the electricity sector in Chile, Brazil and Mexico partly offset by higher use in industry. Despite the growth in fossil fuels, renewables meet the vast majority of new energy demand in the region with today's policy settings – led by the expansion of renewable electricity, plus a doubling of biofuels use in transport and greater use of bioenergy in industry. This raises the share of renewables from 28% in 2022 to over 40% in 2050.

Fulfilling all pledges and targets on time sets out a different pathway for Latin America and the Caribbean, leading to a decline in fossil fuel use in favour of low-emissions sources. On this path, consumption of each fossil fuel peaks this decade and then steadily declines. The use of oil is cut by more than half by 2050, with most reductions in transport due to increased availability of public transit, electric vehicles, efficiency gains and cleaner fuels. Brazil leads the way on expanding sustainable biofuel use, while Chile and Mexico grow their electric vehicle fleets. On this path, natural gas use in the region declines by one-third by 2050, with the largest reductions in the power sector in Argentina, Brazil, Mexico, Chile and Colombia. Decarbonising electricity in these countries to fulfil pledges and targets is also the main driver for deeper coal reductions and faster renewables growth in the region.

Energy efficiency measures in the buildings, transport and industry sectors keep energy demand growth in check while delivering a wide range of social benefits. To date, energy efficiency policies are not widespread in the region. Less than a third of countries have minimum energy performance standards in place for industrial motors or household appliances and few have mandatory building energy codes. Better coverage of performance standards across sectors, tighter fuel economy standards and updated energy-related building codes cut final energy consumption growth by a fifth in 2030. Adopting the best available technologies for products such as air conditioners, moderates energy demand growth at little or no cost to consumers.

Large resources enable a dynamic and diversified traditional and cleaner fuel supply in the region

Latin America and the Caribbean produced over 8 million barrels of oil per day (mb/d) **in 2022, exceeding regional demand with a production value of USD 230 billion, with more resources available to step up production.** The largest producers of oil in the region currently - Brazil, Mexico, Colombia, Venezuela, and Argentina – are at various stages of resource development. In Venezuela oil production has declined by three-quarters since 2010; conventional sources in Argentina show signs of decline; output in Brazil increased by close to 40% since 2010 and production recently started in Guyana after a surge of offshore discoveries. Including those, the region holds about 15% of world oil and gas resources. To 2030, oil production in the region outpaces demand growth, adding about 2 mb/d of net exports. Brazil and Guyana both increase oil production by more than 1 mb/d, giving them two of the top-three largest increases in net exports in the world to 2035. However, any new projects would face major commercial risks if the world is on track to deliver net zero emissions by 2050, as oil demand declines rapidly.

The region produced about 5% of global natural gas in 2022 but was a net importer of gas and it remains so in the outlook despite large resources. Natural gas production declines slightly to 2030 in the region under today's policy settings, raising net imports. If pledges and targets are met in full, including to reduce flaring and methane emissions, natural gas production declines steadily but demand falls faster, particularly after 2030, reducing import needs by 30 billion cubic metres (bcm) in 2050 from the level today. Argentina expands gas production in both cases by exploiting unconventional resources, with most of the gas consumed in the region. Production falls in several other countries, notably Trinidad and Tobago. Argentina, Brazil, Mexico, Colombia and Venezuela all have more gas resources that could be exploited if warranted by higher demand, attractive market prices and lower-than-expected production costs.

Latin America and the Caribbean has huge potential to expand the production of low-emissions fuels. Bioenergy is a growing industry in the region and biofuels, in particular, can help meet both energy security and climate targets. Brazil is a prominent producer and consumer of biofuels, with bioethanol used heavily in road transport. With further policy support, biogas and biomethane use could also expand in electricity generation and transport. Advanced biofuels have significant potential, as an economic competitive export of biojet kerosene. With abundant renewable energy resources, the region has the potential to become a major producer of low-cost and low-emissions hydrogen and related fuels, particularly in Argentina, Brazil, Colombia and Chile. There are already announcements for significant low-emissions hydrogen projects. Beyond traditional applications for hydrogen like refining and chemicals, low-emissions hydrogen would also enable emissions reductions in other industry applications. For example, developing cost-competitive low-emissions iron could provide a major boost to the regional economy and attract foreign investment.

Global transitions open large markets for Latin America and the Caribbean

Significant mineral resources offer opportunities to diversify global supply and deliver economic growth while enabling global clean energy transitions. The region has a third or more of the global reserves for lithium, copper and silver. Revenue from critical minerals production (graphite, bauxite, nickel, zinc, lithium, copper and neodymium) totalled around USD 100 billion in 2022. In the APS, it overtakes revenue from fossil fuel production before 2050. Exports of copper and lithium are set to be especially significant: copper as an essential component of electricity networks, which need to be strengthened and expanded, and lithium to drive the uptake of electric vehicles and battery storage as more variable renewables are integrated into power systems.

The region has resources that position it well for a changing energy system, from tight oil and shale gas to renewables, minerals and metals. Progressing from raw mineral and ore exports up the supply chain to produce refined and processed materials can benefit the region's economy and foster technology development. Producers need to be agile and read markets well to take advantage of new opportunities. In all cases, high standards of environmental, social, governance issues – including attention to methane emissions – will make a huge difference to prospects.

To fulfil national goals and seize global opportunities, the region must close policy gaps, raise investment and put people at the centre of its strategies

There is a significant implementation gap in Latin America and the Caribbean, as today's policy settings lead to rising CO_2 emissions while climate pledges call for deep cuts. Policy gaps need to be filled to bridge the gap between the CO_2 emissions trajectory in the STEPS, which rises from 1 660 million tonnes (Mt) today to 1 850 Mt in 2050, and that in the APS, where emissions fall below 800 Mt by 2050. Our analysis points to renewables, electrification, energy efficiency and other measures to reduce demand as the key areas for more attention from policymakers and stronger implementation measures. Beyond tackling CO_2 emissions, major producers in the region can reduce methane emissions from oil and gas operations by nearly 80% at low cost, and around 40% with no net costs, supporting the Global Methane Pledge that most countries in the region have signed.

Alongside energy, approaches to cut emissions in the region must also give serious attention to land use and agriculture. Today, land use and agriculture produce 45% of regional GHG emissions. After decades of tree cover loss, pledges in the APS lead to an 80% reduction in primary forest deforestation by 2030 and net forest growth of 100 million hectares by 2050. Together with improved resource management practices, land use and agriculture reach net zero greenhouse gas emissions by 2030, with afforestation efforts in Brazil and Mexico playing a key role.

Investment in clean energy needs a major boost to reach the energy-related emissions reductions goals and to pursue international opportunities. In the APS, clean energy investment doubles by 2030 to USD 150 billion and rises fivefold by 2050. The ratio of investment in clean sources to unabated fossil fuels rises from around 1:1 today to 4:1 in the 2030s. Attracting private capital will be critical to achieve this, but challenges include high financing costs, political and regulatory instability, and limited domestic credit capacity. Overcoming these hurdles requires supportive policies, tailored solutions such as hedging instruments, and more concessional financing, especially for energy efficiency and emerging technologies.

A people-centred and inclusive transition calls for universal access to modern energy at affordable prices. Latin America and the Caribbean has one of the highest levels of income inequality, with the richest 10% of the population accounting for 40% of total emissions. About 17 million people remain without access to electricity and 74 million lack access to clean cooking. More needs to be done to achieve universal access on both fronts. Affordable energy is also a key concern. A faster transition to clean energy could reduce energy costs for households, making it easier to end fossil fuel subsidies. However, lower income groups may need support given the higher upfront costs of some clean energy technologies. Clean energy transitions also offer new employment opportunities for workers in the region, with energy jobs set to increase by over 15% to 2030, notably in clean energy technologies and in the critical mineral sector.

State of play

A global clean energy powerhouse – ready to shift gears

S U M M A R Y

- *Latin America Energy Outlook 2023* is the first IEA outlook for the region. It contains in-depth country and regional analysis of the energy outlook, opportunities and key challenges in this vast and diverse region which is home to about 8% of the world population, 7% of global GDP and around 6% of global energy supply and demand.
- Latin America and the Caribbean's (LAC) economy is natural resource intensive, and its high level of dependence on these resources, such as fuels and minerals, exposes its economy to volatility in international markets and price cycles. Pursuing opportunities in the new energy economy could help boost its economic development. Its low-emissions power sector, critical mineral resources and potential for clean energy development mean that the region could play a key role in clean energy transitions. High environmental, social and governance (ESG) standards are needed to sustainably harness this opportunity.
- LAC is rich in energy resources ranging from hydropower to unconventional gas. There is significant potential for further development of bioenergy and high quality solar and wind resources. Brazil, Mexico, Argentina and others are major oil and gas producers. Some producers face declining production, such as Venezuela, while others are seeing a surge of new supply, such as Guyana. Colombia is the main coal supplier in the region, and Chile, Peru, Argentina and Brazil produce large volumes of critical minerals such as lithium, copper and graphite.
- The region accounts for just 5% of global cumulative energy-related greenhouse gas emissions to date. This reflects the longstanding reliance of the electricity sector on hydropower. But fossil fuels are still the main source of energy, and oil remains the dominant fuel in many countries, primarily for use in transport and industry.
- LAC has one of the highest levels of income inequality in the world. This is evident in the energy-related emissions profile in which the richest 10% of the population account for 40% of total emissions while about 17 million people remain without access to electricity. A just transition calls for universal access to modern energy at affordable prices and should involve communities and ethnic groups.
- Half of the countries in the region have pledged to achieve net zero emissions by mid-century or earlier. They represent around 65% of GDP in the region and 60% of its energy-related CO_2 emissions. The region needs to boost investment in clean energy technologies to reach its energy-related emissions reductions goals. Efforts to reduce emissions in the region must also look to agriculture and land-use change, which account respectively for 25% and 20% of its total greenhouse gas emissions. This highlights the importance of tackling deforestation.

1.1 Overview

Latin America and the Caribbean (LAC) is a diverse region which is home to about 8% of the world population and generates about 7% of global gross domestic product (GDP). Around 8% of the population is indigenous. The region covers about 15% of the earth's land surface from Mexico to the southern tip of Patagonia. It includes major and diverse ecosystems such as the Amazon River Basin, Andes mountains, Atacama Desert, Llanos and Pampas grasslands, and the highlands of Brazil and Guyana. It has one of the highest rates of urbanisation in the world, 82%, and most of its cities and economic activity are concentrated along the coasts.

LAC countries are responsible for about 6% of total global energy supply, demand and related emissions. Renewables, mainly hydropower (45%), generate over 60% of its electricity, making its power sector one of the least carbon intensive in the world. In Costa Rica and Paraguay, almost 100% of electricity supply is from renewable sources (Table 1.1). The region has a burgeoning bioenergy industry which expanded by 30% in the last decade.

Renewables present a big opportunity for the region. It has extensive coastlines for wind power, ample sunshine for solar, high geothermal potential along the Andes, and mighty rivers for hydropower. However, making the most of this potential requires renewable power to be transferred over large distances and difficult terrain from the locations of the best renewable resources to the centres of population and economic activity. In the electricity sector, investment in renewables has historically been higher than for fossil fuels, but overall investment in oil and natural gas supply remains higher than all spending in the power sector, although the gap is narrowing.

LAC holds 15% of global oil and gas resources, and less than 1% of global coal resources. It is also home to large unconventional oil and gas resources, such as tight oil and shale gas, which are being actively pursued for development in Argentina. Both net producer and consumer hydrocarbon economies are represented in the region: Brazil, Venezuela and Colombia are among the leading exporters of oil, while Chile, the Dominican Republic and Panama are some of countries that are highly dependent on oil and gas imports to meet domestic energy demand.

LAC is one of the most democratic regions in the world (Economist Intelligence, 2023), however, it has one of the highest levels of income inequality in the world. Over fifteen LAC countries regularly have a Gini coefficient[1] higher than 40, and 17 million people still lack access to electricity. Regional integration schemes, such as MERCOSUR, CAN, OLADE and SICA[2], so far have had limited success in terms of energy with the notable exception of the design and implementation of the Regional Electricity Market in Central America.

[1] The Gini coefficient measures how much the distribution of income among individuals or households deviates from a perfectly equal distribution. A value of 0 represents absolute equality, whereas 100 represents the highest possible degree of inequality. The highest score for any country in the world in 2022 was 63.

[2] MERCOSUR = Mercado Común del Sur (Southern Common Market); CAN = Comunidad Andina (Andean Community); OLADE = Organización Latinoamericana de Energía (Latin American Energy Organization); SICA = Sistema de la Integración Centroamericana (Central American Integration System).

Table 1.1 ▷ Key indicators for selected LAC countries and total indictors for the region, 2022

	Population (million people)	GDP per capita thousand USD (2022, PPP)	Fossil fuels in TES	Renewables in electricity generation	Import dependence ratio	
					Oil	Gas
Argentina	46.0	27	85%	33%	0.07	-0.15
Bolivia	12.2	10	84%	38%	-0.36	0.76
Brazil	215.3	18	46%	88%	0.30	-0.40
Chile	19.8	29	69%	59%	-0.98	-0.81
Colombia	51.9	19	73%	78%	0.63	
Costa Rica	5.2	25	50%	99%	-1.00	
Cuba	11.2	N/A	85%	5%	-0.66	
Dominican Republic	11.2	23	89%	17%	-0.99	-1.00
Ecuador	18.0	13	81%	81%	0.55	
El Salvador	6.3	11	52%	84%	-1.00	-1.00
Guatemala	17.3	11	37%	70%	-0.94	
Guyana	0.8	42	95%	2%	0.67	-0.89
Haiti	11.6	3	25%	13%	-1.00	
Honduras	10.4	7	52%	61%	-0.97	
Jamaica	2.8	12	91%	13%	-1.00	-1.00
Mexico	129.8	23	89%	19%	0.21	-0.56
Nicaragua	6.9	7	42%	69%	-0.96	
Panama	4.4	37	76%	78%	-1.00	-1.00
Paraguay	6.8	16	29%	100%	-0.97	
Peru	34.0	15	73%	62%	-0.42	0.35
Suriname	0.6	18	89%	49%	-0.09	
Trinidad and Tobago	1.5	28	100%	0%	0.72	0.35
Uruguay	3.4	28	44%	85%	-0.93	-1.00
Venezuela	28	9	81%	80%	0.70	
LAC	**658**	**18**	**67%**	**61%**		

Notes: GDP expressed in year-2022 US dollars in purchasing power parity terms (PPP); TES = total energy supply. Renewables includes geothermal, hydropower, marine, modern bioenergy and renewable waste, solar and wind. Import dependence is represented as the ratio of net imports to demand for net importers, and net exports to production for net exporters. For example, for Guyana, a net exporter of oil, its oil import dependence would be net oil exports (3.9 million tonnes of oil equivalent [Mtoe]) divided by oil production (5.9 Mtoe). Import dependence ratio is based on 2021 data.

Sources: IEA population estimates are based on UN DESA (2022); World Bank (2023a); IEA databases and analysis. GDP is based on Oxford Economics (2023a) and IMF (2023a). Fossil fuels in TES and renewables in electricity are estimates based on data from IEA World Energy Balances IEA (2023a).

Of course, challenges vary from country to country, but overall they include pervasive corruption (corruption perception index[3] scores of around 30 and less is no exception), lack

[3] Corruption Perception Index (CPI) for a country is the perceived level of public sector corruption on a scale of 0-100, where 0 means highly corrupt and 100 means very clean. In 2022, Denmark had the highest score of 90, while Somalia had 11 (Transparency International, 2023).

of transparency and open data, and high rates of unemployment and informal employment. These affect energy services and development prospects. For example, despite the risks involved, the theft of copper cables and of oil from pipelines is a common occurrence. Latin America and the Caribbean has suffered from underinvestment in energy for many decades, and high debt constricts government capacity to accelerate clean energy transitions. Enhanced regional and international partnerships can help LAC to overcome many of these challenges and expand its role in the global energy economy.

LAC is in a unique position in which it can become an example of sustainable development and progress if it can overcome the challenges that lie in the way. In particular, the region has significant opportunities to use its natural resources to become a leader in low-emissions hydrogen production and critical minerals development. This in turn could help it to re-industrialise and diversify. Responsible extraction and production practices need to be strengthened to protect the natural environment and local and indigenous communities, and to adequately manage land use and deforestation in the face of ecosystem tipping points, such as savannisation in the Amazon and coral reef die-off.

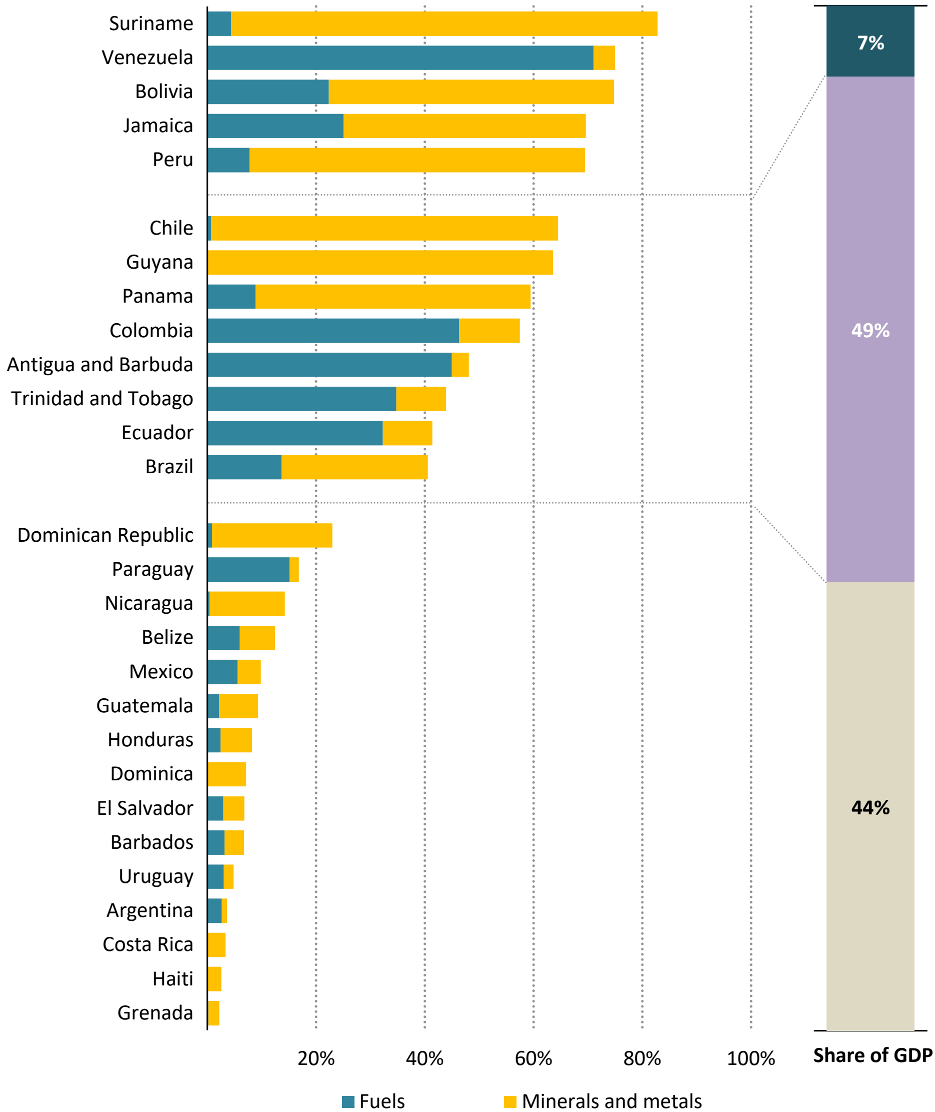
Latin America Energy Outlook 2023 is the IEA's first in-depth analysis of the energy outlook specific for the region. It examines the outlook for energy demand, supply and related emissions and looks at key opportunities to expand its role in the emerging new world energy economy. In accordance with standard international practice, it presents energy data and projections for all of Latin America and the Caribbean. However, the focus of this analysis is on Latin America. The Caribbean is an important sub-region in its own right, with its own specific energy challenges and opportunities (Box 1.5).

This report is structured in five chapters. This initial chapter discusses how Latin America's energy and economic landscape has evolved over the decades and where it stands today. The second presents the outlook for energy demand, electricity generation and energy supply in various scenarios from the IEA *World Energy Outlook (WEO)* (IEA, 2023b). The third details nine important themes for the energy sector. The fourth chapter considers the global implications of the energy outlook for LAC and highlights its importance in terms of energy and climate goals. Chapter five provides an in-depth profile of the region as well as country profiles for Argentina, Brazil, Chile, Colombia, Costa Rica and Mexico. More extensive versions of these profiles are available on the IEA website at: http://www.iea.org.

1.1.1 Economic

Economic strategy in the LAC in the 1950s sought to reduce dependence on imports and to develop rural communities. This brought an expanding middle class, especially in Argentina, Brazil and Mexico, as well as rapid urbanisation. In more recent decades, the regional economy has seen a wave of deregulation and privatisation with the aim to stimulate economic activity and increase exports. Nonetheless, its continuing high degree of dependence on commodity exports means that the region remains exposed to economic shocks (Figure 1.1).

Figure 1.1 ▻ Share of commodities in total merchandise exports and GDP by country in LAC, 2021



LAC economies are highly exposed to commodity exports; those relying on commodities for more than a third of their exports account for 56% of regional GDP

Note: Share of GDP on the right bar refers to the contribution of each group of countries to the total regional GDP.

Sources: IEA analysis based on country merchandise trade data from UNCTAD (2022). GDP data is based on Oxford Economics (2023a) and IMF (2023a).

Today, the region's economy is closely tied to the production of commodities (fuels and minerals), food for export (such as soy and beef) and other raw materials (UNCTAD, 2022). The region is heavily affected by international markets, foreign currency and price cycles. In the region's so-called "lost decade", from around 1980 to 1990, debt crises and falling investment affected industrial production in many LAC countries and regional GDP remained relatively flat at around USD 5 trillion. Since then, the region has seen significant growth and progress: the regional economy has more than doubled in the three decades since 1990 to around USD 12 trillion in 2022. Most of this growth was in the mid-2000s when high commodity prices contributed to increased investment and productivity gains. LAC has historically benefited from global commodity super-cycles, but these have tended to divert attention from the need for major reforms to sustain long-term growth.

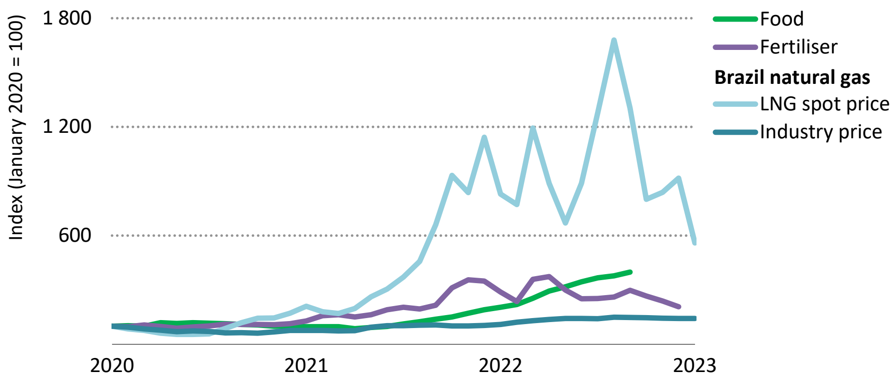
With the onset of the global Covid-19 pandemic in 2020 and the invasion of Ukraine by the Russian Federation (hereinafter Russia) in 2022, the LAC economy is again showing signs of a slowdown, although not in a homogenous way across countries. The year-on-year GDP growth rate for the region fell from 7% between 2020 and 2021 to 4% between 2021 and 2022, and early estimates show a further drop in the growth rate in 2023. While the price pressures that accompanied the 2022 global energy crisis appear to have peaked, underlying inflation remains stubbornly high and its impact on food prices affects the most vulnerable (Box 1.1).

Box 1.1 ▹ Impact of Russia's invasion of Ukraine on food prices in LAC

Countries in LAC export around 10% of their aggregate domestic supply of major cereals (maize, rice, wheat and barley), mostly from Argentina. For oil crops such as soy, and fruits and vegetables, the region is an even richer source of exports, producing 25-60% more than its domestic consumption. And then there is coffee – LAC accounts for nearly 60% of world coffee production – with Brazil and Colombia being particularly large producers. Despite this abundant domestic food supply, many in the region go hungry: 6.5% of people suffered from undernourishment in 2022, 37.5% of people in the region face moderate/severe food insecurity; and a further 13% face severe food insecurity (UN FAO, 2023a).

An important issue in this context is LAC dependence on imports of fertiliser for food production, and in particular on imports of urea and other granular fertilisers, which are commonly used where ease of transport and use are key factors. The significance of this dependence was heightened by the energy crisis related to Russia's invasion of Ukraine. Mineral nitrogen fertiliser prices are closely linked to natural gas prices, with the fuel accounting for 70 to 80% of the cost of production (Figure 1.2). Russia's invasion drove European hub and international liquefied natural gas (LNG) spot prices to all-time highs, which led to huge increases in fertiliser prices on world markets. In first-half 2022, the price of fertiliser imports to LAC increased by almost 190% compared to the same period in 2021, while the volume traded only increased by 4% (IICA, 2023). For example, Mexico experienced up to 300% increase in fertiliser prices (The Economist, 2023). Domestic production of fertilisers was badly affected by natural gas price rises, which led to an increase in reliance on imports. Brazil became the world's largest importer of granular fertilisers for the first time in 2021, while Argentina entered the top-ten largest importers in 2020 (IFA, 2023).

Figure 1.2 ▷ Food, fertiliser and natural gas price indices for LAC



Surging natural gas prices in 2022 drove up fertiliser prices worldwide and in LAC countries it had profound effects on local food prices

Notes: LNG = liquefied natural gas. Fertiliser price benchmark corresponds to Urea Brazil Granular CFR Spot Price (CFR = cost and freight). Food price benchmark corresponds to UN FAO (2023b) food price inflation data for Latin America and the Caribbean. Natural gas (Brazil, industry end-user price) price benchmark corresponds to an average of regulated prices for industrial users of various sizes. Natural gas (Brazil, LNG spot price) price benchmark corresponds to the import price for LNG.

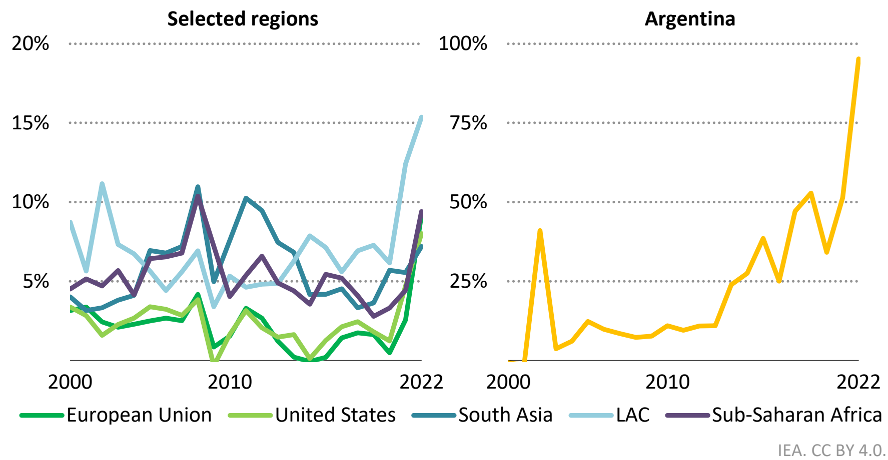
The current global energy and food crises have both short- and medium-term implications. Governments will need to decide how to react. In the near term, policy makers in LAC could focus on designing sustainable support structures for insulating the most vulnerable citizens from high food prices. In the medium term, they could incentivise food growers to increase the efficiency of nutrient use and redouble efforts to replace the use of fossil fuels in the food supply chain with secure, sustainable sources of energy.

These pressures, together with institutional challenges and international competition, threaten to lead to a second lost decade for the region (Figure 1.4) (ECLAC, 2023a). But LAC could yet rebound, especially if it is able to curb high rates of inflation and capitalise on its potential as a key hub for the emerging global clean energy system (Box 1.2). Re-industrialisation of the region to produce value-added and processed or refined goods is one of the main challenges for the region today.

Box 1.2 ▷ Inflation at record highs in LAC

Inflation is a concern for wage and pension earners, whose income and wealth deteriorates in real terms as indexations are slow or partial, as well as investors that look for predictable cash flows and may be wary of taking on debt. High inflation is a recurrent problem in most LAC economies and a key impediment to higher economic growth. LAC (excluding Venezuela) had an average annual inflation rate of 7% between 2000 and 2022, compared with 5.9% in South Asia, 5.4% in sub-Saharan Africa, 2.5% in the United States and 2.3% in the European Union (Figure 1.3). After having risen to about 15% in 2022, inflation in LAC economies is set to slow to below 12% in 2023 (compared with close to 7% at the global level), but this decrease reflects declines in commodity prices rather than progress in bringing down core inflation.

Figure 1.3 ▷ Annual inflation in selected countries and regions, 2000-2022



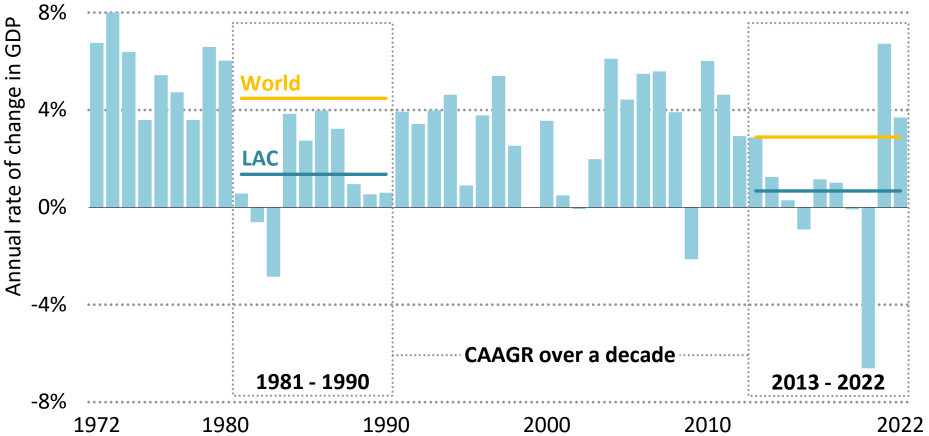
High inflation is a constant challenge for LAC economies, and reached almost 100% in Argentina in 2022

Note: Inflation measured by the Consumer Price Index. In this figure, LAC excludes Venezuela. South Asia includes Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

Sources: ECLAC (2023b); IMF (2023c); World Bank (2023a).

This issue is more acute in some countries than others. It is particularly important in Argentina, where inflation surpassed 50% in 2021 and reached almost 100% in 2022. This was 16-times the annual inflation in Brazil in 2022, 12-times that of Mexico and 7-times that in Colombia. Inflation was lower between the early 2000s and early 2010s, averaging 9% between 2003 and 2013, but reached almost 25% in 2014 and has been consistently above that since then.

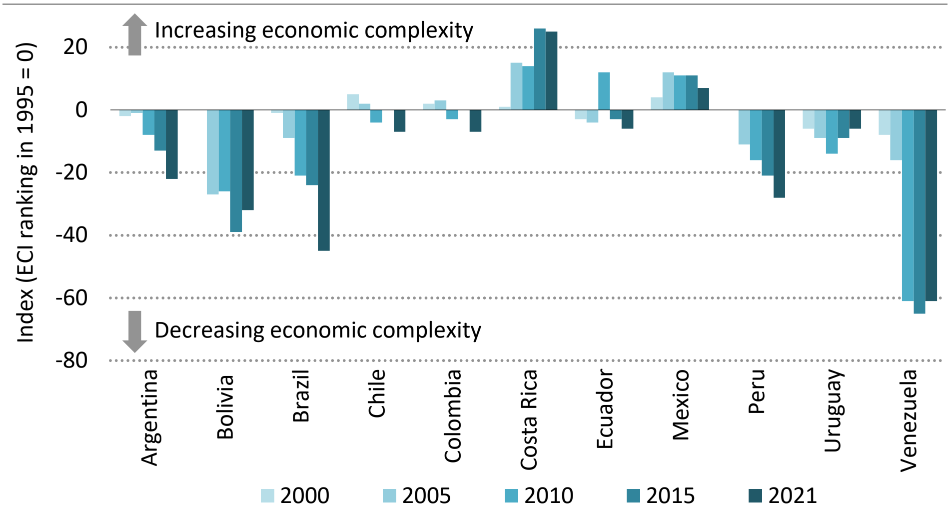
Figure 1.4 ▻ Annual rate of change in GDP in LAC, 1972-2022



Average rate of GDP growth over the last ten years is about half the rate of growth the region had in the "lost decade" of the 1980s

Note: CAAGR = compound average annual growth rate.

Figure 1.5 ▻ Relative change in economic complexity rankings for selected LAC countries, 1995-2021



Many LAC economies have become less complex over time, with a shift in exports from value-added products to raw materials and commodities

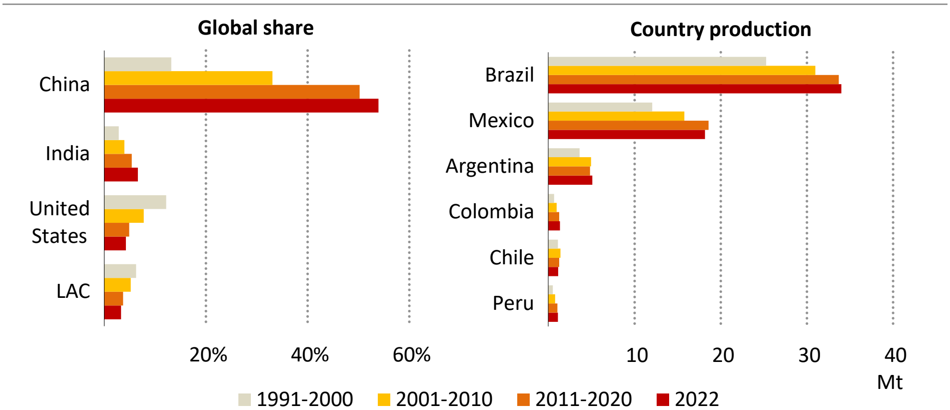
Notes: ECI = economic complexity index, which is an index to rank countries based on the diversification and complexity of their export basket. Each milestone year is depicted as a fall/rise in rankings relative to 1995.

Source: IEA analysis based on data from Harvard University (2023).

LAC's role in the global economy has shifted over time. Some countries are exporting fewer value-added and processed goods than three decades ago. Instead, they have become exporters of raw agricultural produce, crude oil, natural gas and unprocessed minerals and metals, thus reducing the complexity of their domestic economies and significantly hampering their prospects to enter into markets for trading value-added goods (Figure 1.5). With the exception of Costa Rica and Mexico, which have succeeded in diversifying their exports to a certain extent, the result is that most major economies in the region have simplified the nature of goods they export and reduced the complexity of their domestic economies (Harvard University, 2023). This risks trapping them in a core-periphery relationship with more industrialised economies where advanced manufacturing, processing and refining operations are taking place.

Copper exports from Chile provide a case in point. A decade ago, refined copper and copper alloys accounted for around 30% of its export revenues, making it Chile's largest source of export income in 2010. But by 2021, almost 30% of its export revenue came from copper ore and unrefined copper, while the share of higher value refined copper and alloys had fallen to 19% (Harvard University, 2023). Similar trends have been observed in several other LAC countries.

Figure 1.6 ⊳ Annual average global steel production shares of top producers and steel production in LAC countries



Increasing energy costs and competition in the global market have reduced steel market shares of LAC producers and increased import dependency

Note: Mt = million tonnes.

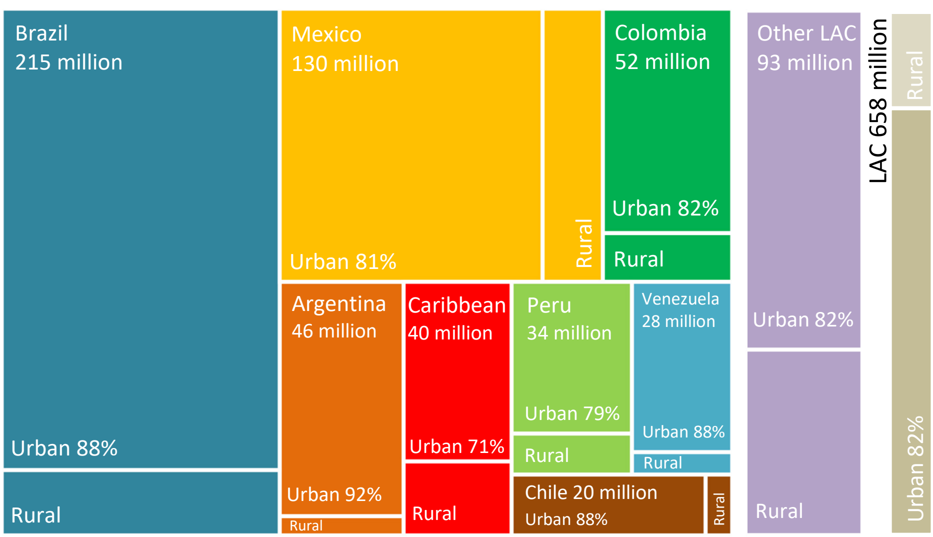
Source: World Steel Association (2023).

A consequence of this shift to less complex economies over time has been a fall in exports of high value goods. Due in part to increasing energy costs, LAC as a whole has been losing global market share for key high value industrial goods such as steel, even though Brazil still ranks as the ninth-largest steel producer in the world (Figure 1.6). As a result, the region has become increasingly dependent on imports of energy-intensive products. The transition to clean energy could help countries in the region to bring about change in their economies and exports. Affordable and clean energy, together with sustainable and responsible mineral production, could support re-industrialisation, boost the region's international competitiveness, and help to reverse recent economic trends.

1.1.2 Demographics

Today just six countries – Brazil, Mexico, Colombia, Argentina, Peru and Venezuela – account for more than three-quarters of the population of 658 million people in Latin America and the Caribbean (Figure 1.7). Its population increased in recent years, but more slowly than in most countries in Africa and Southeast Asia. The population of LAC was 12% larger in 2022 than it was in 2010, compared with an average figure of 16% for emerging market and developing economies over this period. LAC's population is also younger than many advanced economies, with a median age of around 30 years, which is eight to ten years lower than that of the United States and Canada.

Figure 1.7 ▷ Population and urbanisation by country in LAC, 2022



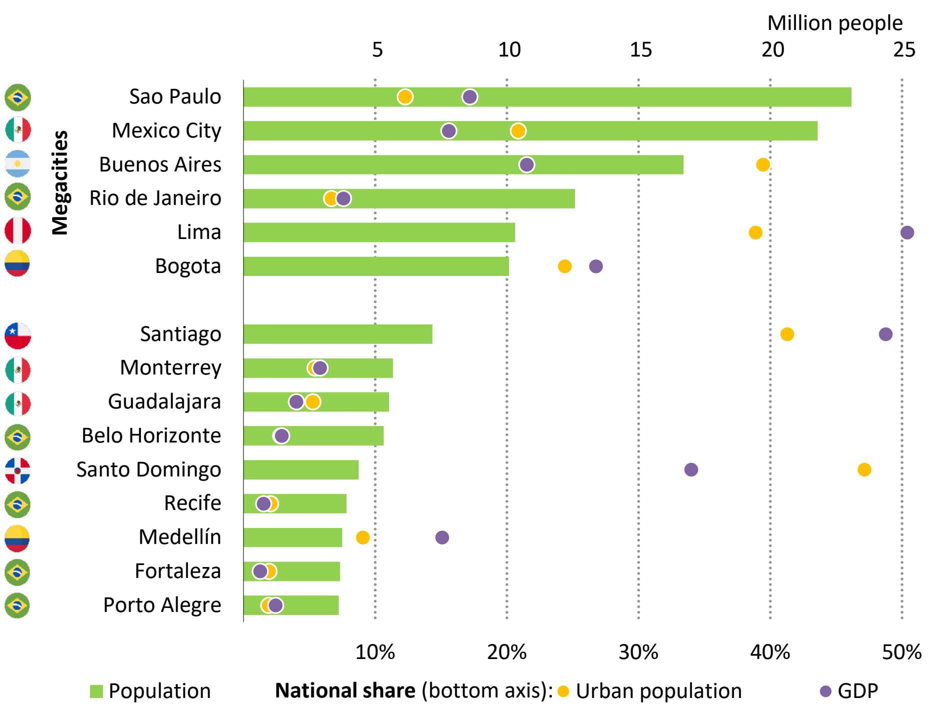
Just six countries account for more than three-quarters of LAC's 658 million people; the region is one of the most highly urbanised in the world

Source: Population estimates are based on World Bank (2023b) and UN DESA (2022) databases.

LAC is one of the most highly urbanised regions in the world, with a regional average of 82% of the population living in cities. Brazil, Mexico, Colombia, Argentina, Chile and Peru are home to many of the largest urban centres in the region, with Brazil alone having six of the fifteen largest cities in LAC, which together account for almost 33% of the GDP of Brazil (Figure 1.8). This makes the role of cities in clean energy transitions in LAC extremely important, and opens the prospect of them acting as hubs for clean energy innovation.

Many of these large urban areas face challenges related to informal housing settlements that lack basic services, have high levels of informal employment and energy poverty. These challenges underline the potential benefits to be gained from investment in electricity distribution networks, waste and water management, construction of safe and sustainable public transit and energy-efficient buildings. They also illustrate the need for work to improve urban planning, create sustainable cities and invest in the infrastructure needed to make them safer, more efficient and more resilient in the face of the impacts of climate change and natural disasters.

Figure 1.8 ▷ Population of the 15 largest cities in LAC and their share in national urban population and GDP, 2022



LAC is home to six megacities, including three cities with a population of over 15 million

Note: Cities in this figure refers to metropolitan areas, which are urban centres consisting of the city and its surroundings.

Sources: The population data for metropolitan areas was taken from Dermographia World Urban Areas (2023). The calculations for the share of the metropolitan area in the national GDP are based on data from Oxford Economics (2023b).

1.2 Investment and financing

Limited fiscal space and macroeconomic problems, governance issues and incomplete investment frameworks have contributed to low investment and slow growth in energy supply in Latin America and the Caribbean and have also affected the development of several infrastructure projects. Resolving issues related to investment and financing needs and boosting investment could play a crucial role in helping the region to rebound.

1.2.1 Investment

Globally, LAC has one of the lowest levels of energy investment as a share of GDP. It stood at below 3% between 2014 and 2022, compared with 5% in Eurasia, the Middle East and North Africa and nearly 4% in sub-Saharan Africa. Several countries in the region face challenges related to energy infrastructure, including outdated and inefficient electricity grids and limited deployment of modern energy storage and distribution systems.

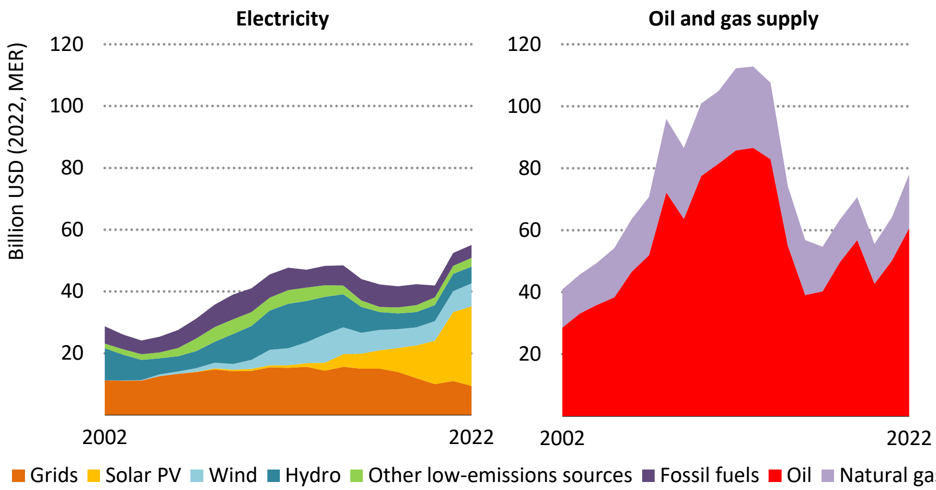
Governments in LAC have spent about USD 14 billion on clean energy transition since 2020, which is about 15% of what has been spent in total in emerging market and developing economies. Most of this has been for clean cooking technologies, low-emissions electricity generation and networks. Since the energy crisis in 2022, the primary focus has been on keeping energy services affordable, with a particular emphasis on transport fuels. As of June 2023, USD 33 billion had been mobilised for this purpose. Refining the scope of the support provided would help to provide more leverage for governments to boost the uptake of clean energy technologies in the region (IEA, 2023c).

Besides limited fiscal space, reduced investment in oil and gas supply globally has played a significant role in the region. Capital spending on oil and gas supply has reduced considerably since the commodities boom ended around 2014. Average annual investment in energy supply in the region was around USD 110 billion between 2010 and 2014. This fell to an average of USD 65 billion in the following seven years after 2014, before jumping to USD 80 billion in 2022 (Figure 1.9). However, investment in the electricity sector has picked up over recent years, rising from an average of USD 45 billion in the first five years of the 2010s to USD 50 billion in the three years to 2022, though this increase was not big enough to match the drop in oil and gas supply investment. Still, prospects for clean energy are showing major signs of improvement, with increased capital spending on solar and wind in particular. Capital investment in renewables has been far higher than in fossil fuel generation during the last decade. It was almost ten-times higher in 2022, with solar photovoltaics (PV) accounting for a major part of this increase in spending.

After languishing for a decade, foreign direct investment (FDI) in LAC rose to almost USD 225 billion in 2022, a massive recovery that surpassed pre-pandemic levels (ECLAC, 2023c). FDI announcements – an indicator of future investments – have had a strong focus on clean energy, especially renewable power generation. Companies in the United States and the European Union have been the major investors in LAC. The United Nations Economic

Commission for Latin America and the Caribbean estimates that investment from the United States and the European Union represented 55% of total FDI in LAC in 2022, and about 50% or more since 2015 (ECLAC, 2023c).

Figure 1.9 ▹ Investment in electricity and oil and gas supply in LAC, 2002-2022



IEA. CC BY 4.0.

Oil and gas supply investment remains higher than investment in electricity supply, but the gap has narrowed in recent years

Note: Other low-emissions sources include other renewables, nuclear, batteries and fossil fuels with carbon capture, utilisation and storage.

Development banks have also been important finance providers in the region, especially for energy-related projects. Multilateral and regional developments banks – notably the World Bank, the Inter-American Development Bank and the Corporación Andina de Fomento – have played a critical role in providing long-term debt as well as technical assistance for project development and policy advice. National development banks, such as the Brazilian Development Bank (BNDES), have also made important contributions, including through the provision of locally denominated loans to energy projects.

The People's Republic of China (hereinafter China) has provided considerable sovereign lending to energy and infrastructure projects in LAC, though its level of lending has declined in recent years (Box 1.3). The China Development Bank and China Export-Import Bank provided more than USD 136 billion in sovereign loans between 2005 and 2020, with Venezuela alone receiving over two-fifths and Brazil more than another fifth (Ray and Myers, 2023).

Box 1.3 ▷ Sovereign lending to LAC by Chinese development banks

Over the last decade, Chinese development banks have been an important source of finance for some governments in LAC (Ray & Myers, 2023). Such lending appears to have peaked in 2010 and has been declining rapidly since 2016. The vast majority of the loans – mainly provided by the China Development Bank and the China Export-Import Bank– have gone towards energy and, in particular, to oil projects.

About 45% of total loans between 2005 and 2020 were to Venezuela, which received roughly USD 60 billion, with agreement that debt repayment would take the form of oil exports. Oil production in Venezuela declined after 2010 and plummeted further 2016, however, and for years China has refused to loan Venezuela any more money, thereby reducing China's overall investment in the region (Boston University Global Development Policy Center, 2022). Brazil and Ecuador, two other major oil producers, were the next biggest recipients of Chinese loans having received USD 31 billion and USD 18 billion respectively since 2007. Argentina has financed some major infrastructure projects, railways and metro lines, with the USD 17 billion it borrowed from China.

At the same time, China has become one of the LAC's largest trade partners. For example, while there has not been mass adoption of electric vehicles (EVs), nearly all electric buses and many electric cars in LAC come from China (Ugarteche, de Leon, & Garcia, 2023). Brazil in particular has significantly strengthened its trade partnerships with China over the last two decades: in 2000, China was the destination for only 2% of Brazil's total exports which increased to 16% by 2010 and to 32% or almost USD 98 billion by 2021 (Harvard University, 2023).

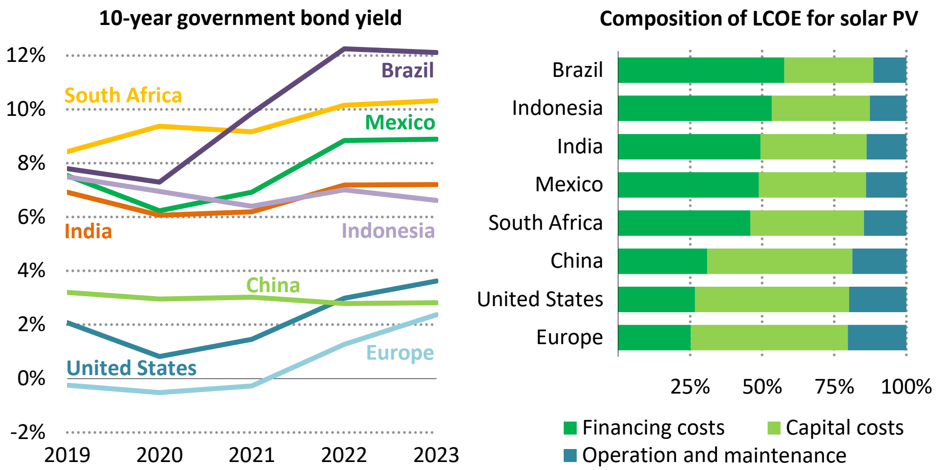
1.2.2 Financing

A significant obstacle that hinders the flow of more money is the region's high cost of capital. Data from the IEA *Cost of Capital Observatory* (IEA, 2023d) shows that the cost of capital for a typical solar PV plant in Brazil was between 12.5% and 13.5% (nominal, after tax) in 2021, which was the highest among a wide set of emerging economies. For Mexico, the same range was between 9.5% and 10%, which was comparable to the range between 9% and 10.5% in India. The cost of capital in Brazil and Mexico was about two-to-three-times higher than in China, Europe and United States.

Economy-wide financing costs are high in LAC. The cost of capital largely depends on an assessment of two sets of risks: those associated with the country and those associated with the sector or project type. These are reflected in a base rate for the country plus a premium for the sector or project. Long-term government bond yields are a benchmark indicator used to estimate a country's base rate. The ten-year government bond yields of LAC countries are generally high. For example, yields of Brazilian bonds in reais were above 12% in 2023 for sovereign and locally denominated bonds, and almost 9% in Mexico (Figure 1.10). These yields are close to those in South Africa (above 10% in 2023), and higher than those in

Indonesia and India for sovereign bonds in domestic currencies (between 6.5% and 7.5% in 2023). They are also two-times or higher than in the United States or European countries.

Figure 1.10 ▷ Long-term government bond yields and composition of levelised cost for a utility-scale solar PV plant with FID in 2021



High lending costs in LAC mean all projects have to reach a high bar to be approved, an obstacle to investment in clean energy assets like solar PV that rely heavily on debt

Note: FID = final investment decision; LCOE = levelised cost of electricity.

Source: IEA analysis based on Refinitiv (2023).

High interest rates, largely stemming from high inflation, in turn tend to lead to a high bar for investment, making it challenging to obtain debt finance (loans or bonds) and to meet the hurdle rates of investors (equity providers). This is a key concern in the region as the energy transition requires a lot of investment in assets such as solar PV and wind which rely heavily on debt, reflecting the fixed element in cost and revenue structures (IEA, 2021). For instance, financing costs accounted for almost 60% of the total levelised costs of a solar PV plant that reached final investment decision (FID) in Brazil in 2021, compared to 30% in China and 25% in Europe.

The ability to obtain low cost domestic capital depends largely on the underlying level of financial system development as measured for example by the capacity to raise debt, the ability to obtain equity from private institutions, the liquidity and depth of domestic capital markets and the scope to access a diverse pool of sources of finance. The share of private bank credit to GDP and the share of stock market capitalisation to GDP – two key indicators of financial sector development – are low in LAC (see Section 3.9). One new source of capital that could be helpful is sustainable finance (Box 1.4). This is a relatively new form of financing, mainly in the form of debt, that is potentially available for projects that embed environmental, social and governance performance indicators. Green bonds are used to finance green projects; sustainability bonds are similar and are used to finance sustainable projects.

Box 1.4 ▹ Green, social, sustainability and sustainability-linked debt in LAC

Emerging market and developing economies other than China have contributed only 10% of the green, social, sustainability and sustainability-linked debt that has so far been issued globally. By September 2023, LAC accounted for above 3% of the global total, about USD 225 billion.

Almost 45% of all issuances in LAC have been in the form of green bonds. Sustainability bonds and loans and sustainability-linked bonds (SLBs), where returns are linked to performance indicators, have been on a rising trend, and each accounts for a fifth of the issuances. Private companies contributed half the issuances, while commercial banks accounted for around 15% (compared with a global average of almost a quarter). On the other hand, the share of issuances by governments in LAC is slightly higher than the global average and has been climbing in recent years. The majority of the sovereign issuance has been through debt defined by the use of proceeds, especially social and sustainability bonds, with Chile and Mexico in the fore in terms of the total amount issued by governments. Chile, Mexico and the government of Uruguay, were the first in the region to issue SLB sovereign bonds.

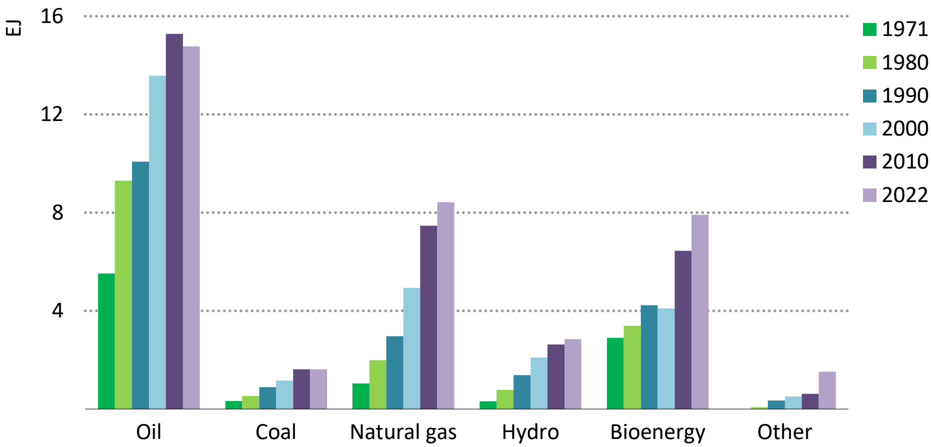
The SLB issued by Uruguay is the first of its kind because it involves both rewards and penalties. Under its terms, the government has to pay a higher level of interest to bondholders (a "step up") if it does not meet its sustainability goals by 2025 and a lower level of interest (a "step down") if it exceeds them. The sustainability goals in question are to reduce the intensity of greenhouse gases per unit of GDP and to maintain native forests. The bond was issued in October 2022 for a total of USD 1.5 billion and was oversubscribed by about three-times, showing strong market interest. SLBs may prove useful in LAC as a source of additional finance for governments that may not be available through conventional bonds.

1.3 Energy and emissions trends

1.3.1 Energy demand

Even with abundant renewable energy resources, including solar, wind, geothermal, hydropower and bioenergy, today most LAC countries rely heavily on fossil fuels to meet their energy needs. On average, oil remains the main fuel used, accounting for 40% of the total energy supply (TES) in Latin America and the Caribbean (Figure 1.11). Demand for oil is driven by the transport and industry sectors.

Figure 1.11 ▷ Total energy supply by source in LAC, 1971-2022



IEA. CC BY 4.0.

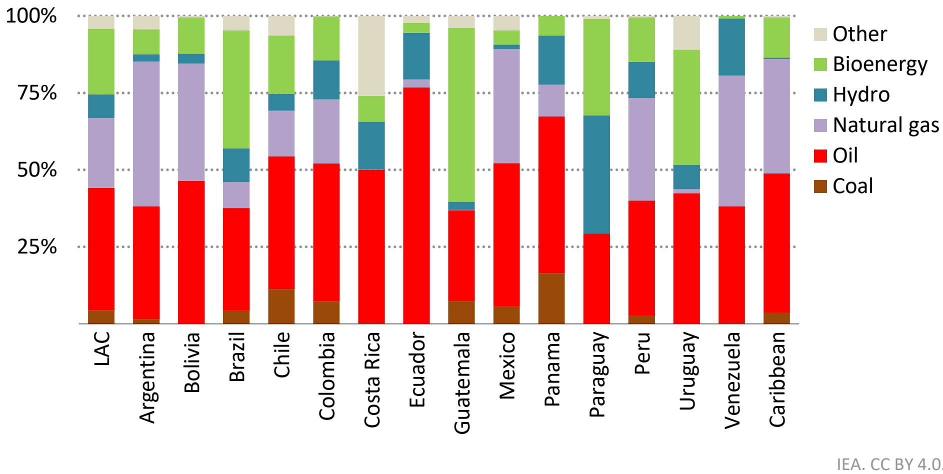
Oil has been the main fuel in LAC's energy mix for over five decades, while natural gas has been the fastest growing fuel

Note: Other includes renewables excluding hydro and bioenergy, nuclear, non-renewable waste and other sources.

While demand for oil appears to be gradually flattening, natural gas has experienced an increase, notably in the electricity sector. Natural gas share in TES has increased from 19% in 2000 to 23% in 2022. Coal demand has been stagnant for the past decade: its use is significant in industry and power generation. Renewables also play a very significant role in electricity generation, particularly hydropower, though the renewables share of TES varies markedly by country. Bioenergy share of TES has been relatively constant in the region since 2010 at around 20%. As with renewables, the quality of bioenergy resources and patterns of use vary widely between countries. Yet, LAC as a whole is the world's second-largest producer of biofuels, thanks to the size of its forests and the scale of its corn and sugarcane production.

While oil is the dominant fuel in the region, there are wide differences in its use, ranging from only 7% of TES in Trinidad and Tobago to 95% in Guyana. This pattern applies to other fuels, with natural gas accounting for less than 5% of TES in countries such as Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Suriname and Uruguay, but over 30% in others such as Argentina, Bolivia, Mexico, Peru and Venezuela. Together Brazil and Mexico account for almost two-thirds of the region's TES. While the share of renewables in TES varies across the region, hydropower is dominant (Figure 1.12). LAC is one of the global leaders in hydropower capacity, although its share in TES has not changed since around 2010. Solar PV and wind are emerging power generation sources in LAC.

Figure 1.12 ▹ Total energy supply mix in LAC and selected countries, 2022



Average share of fossil fuels in the energy mix was around 65% in 2022, but it varied between countries depending on their domestic resource endowments

Note: Other includes renewables excluding hydro and bioenergy, nuclear, non-renewable waste and other sources.

Box 1.5 ▹ Specific energy challenges and opportunities in the Caribbean

The countries in the Caribbean face unique energy challenges related to location, such as lack of energy interconnections, limited infrastructure and climate change vulnerability. Compared with Latin America, the Caribbean has a higher degree of reliance on imported fossil fuels for all energy needs, including electricity generation (Figure 1.14). These factors add to concerns of energy supply security and exposure to volatile price cycles in the global market. In the electricity sector, all ancillary services need to be put in place locally and the fluctuations related to high and low tourist seasons require high reserve power generation capacity. These factors underpin relatively high electricity tariffs which surpass USD 0.40/kWh in certain Caribbean countries. This impedes achievement of universal modern energy access for all and hampers competitiveness of Caribbean counties (Burunciuc, 2022).

Energy systems on islands typically rely on limited grid infrastructure, which makes it difficult to integrate variable renewable energy sources into the grid (Flessa, 2023). In addition, obtaining funding for projects is difficult since most Caribbean countries are categorised as middle or lower middle-income economies, making access to concessional finance challenging (Mohan, 2022). However, Caribbean countries have set themselves ambitious clean energy targets to overcome the "fossil lock-in dilemma" (Kersey, Blechinger, & Shirley, 2021). In 2013, members of the Caribbean Community (CARICOM) agreed on a regional energy policy which aims at achieving set targets for decarbonisation and energy efficiency while enhancing energy security. The Caribbean countries have excellent renewable energy resources which could even allow the region to become a net exporter of energy.

Access to energy remains a challenge in some parts of the Caribbean. In some countries there is still much to be done, and Haiti is an extreme case (Figure 1.22). In others like Jamaica there is already near universal access. In those countries where only a few small pockets of unconnected communities remain, the increasing deployment of distributed generation has the potential to provide access to modern energy for all in the near future.

Hurricanes have severely damaged electricity supply and economic activity in several Caribbean countries in recent years. Investment to improve the resilience of generation – for example by placing some key elements of the network underground, increasing the use of minigrids and boosting storage capacity – could yield net benefits worth over USD 4 billion (IDB, 2020).

The specific and unique challenges and opportunities in the Caribbean are notably different than the rest of LAC and the total energy needs for the Caribbean are relatively small (around 5% of the LAC total in 2022). This report therefore does not attempt cover the Caribbean in great depth, though it does cite Caribbean examples where they are particularly relevant.

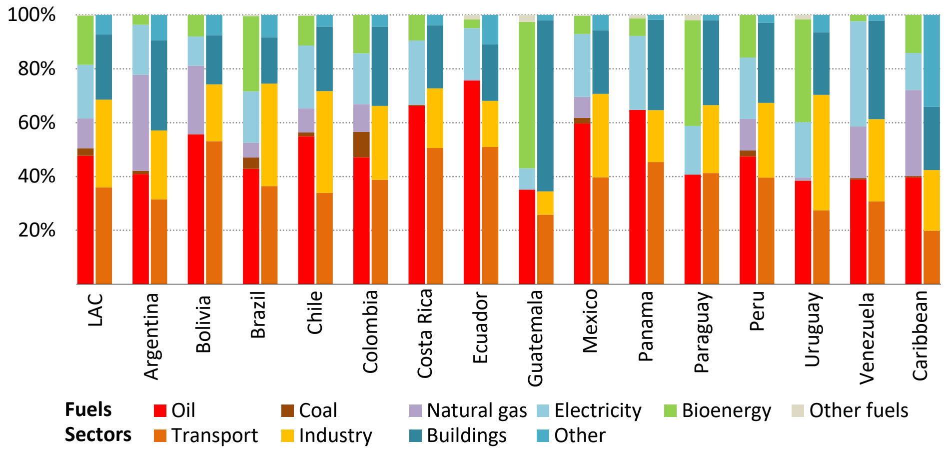
End-use sectors

Transport is the largest source of energy demand in Latin America and the Caribbean, accounting for 36% of total energy consumption from the end-use sectors (Figure 1.13). Road transport accounts for 94% of total transport energy demand, mostly in the form of gasoline (46% of road transport use) and diesel (41%). The car fleet in LAC has expanded around 2.5-times since 2000. Brazil accounted for almost half and Mexico for just over one-fifth of the total car fleet in 2022. Rising incomes and middle class are the drivers of the expanding car fleet, though the lack of adequate public transportation also stimulates growth.

Bioenergy accounts for 10% of energy consumption in transport. Its share varies across the region. It is particularly notable in Brazil, where around 80% of the car fleet consists of flex-fuel vehicles that can operate with high levels of ethanol blending. Rail is relatively less developed in LAC or is used less than in the past in countries where it was once prominent, notably Argentina. The share of rail in total transport energy demand in the region is about half the global average.

Industry is the second-largest sector for end-use energy demand, accounting for 33% of the total. The industry sector is responsible for 31% of LAC's GDP, almost USD 2 trillion of production each year (World Bank, 2022). The chemicals industry has the largest energy demand in the sector. But its share of total energy demand in the industry sector fell from 21% in 2000 to 17% in 2022 as overall energy demand in the sector reflected the declining competitiveness of energy-intensive industries, notably steel and chemicals. On the increase is energy demand in food production and mining activities, with their combined share in total industry energy demand rising from 15% in 2000 to 21% in 2022, much above the global average of 7%. Today, almost half of energy demand in industry in the region is from non-energy-intensive industries compared with 30% globally. This results in low energy intensity in the industry sector compared with other regions or countries.

Figure 1.13 ▷ Total final consumption by fuel and end-use sector in LAC and selected countries, 2022



Oil is the dominant fuel in end-use sectors, mainly in transport and then for industry in most countries

Note: Other fuels include solar thermal and geothermal used directly in end-use sectors. Other includes agriculture and other non-energy use.

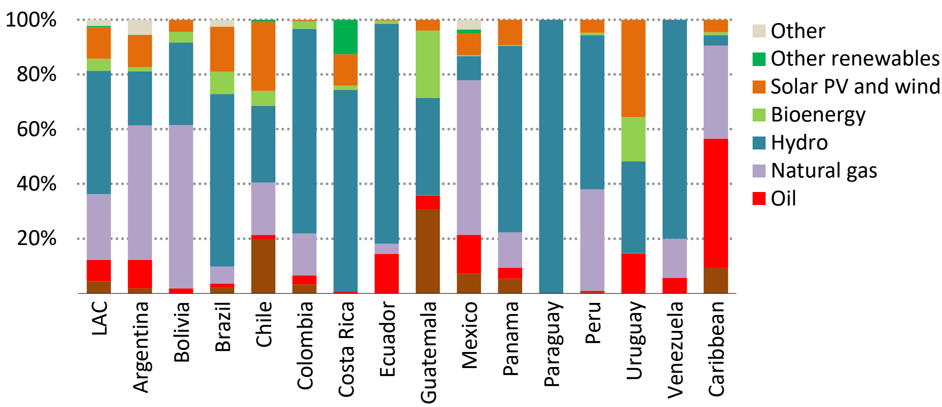
Electricity and bioenergy have supplanted oil as the dominant fuels in industry over the last couple of decades: oil demand declined by more than 0.2 million barrels per day (mb/d) since 2000. Increased natural gas production in the region and the discovery of new gas fields, e.g., Brazil, Colombia and Argentina, together have led to a 58% increase in natural gas use in industry on average in these countries. This increase is mainly in light industries, where natural gas can easily substitute for other fuels such as oil. Natural gas demand has almost doubled in light industries, though its use has made fewer inroads in mining, where oil meets 43% of energy demand while natural gas accounts for 9%.

The **buildings** sector has seen increased energy demand as housing, infrastructure, appliances and amenities have expanded. For example, ownership of appliances and air conditioners went up 20% in the 2010-2022 period, reflecting rising incomes and improving living standards. Space heating energy demand is low compared with colder climate regions and accounts for less than 10% of the buildings sector energy consumption compared with around 50% in North America and Europe. However, space heating energy demand is significant in some countries during cold periods. In Chile, there are now policies to use dry wood to reduce indoor air pollution, while in Argentina, natural gas is the major fuel for space heating. Overall, energy demand in the buildings sector is met mostly by electricity (43%).

1.3.2 Electricity generation

Overall, LAC has one of the lowest emissions electricity systems in the world, with renewables accounting for about 61% of electricity generation in 2022 (Figure 1.14). Hydropower accounted for 45% of total generation, wind for 8%, solar PV for 4% and bioenergy for 4%. Nuclear accounted for 2%. Fossil fuels accounted for 36% of electricity generation in 2022, of which 24% was from natural gas, 8% from oil and nearly 4% from coal. The carbon dioxide (CO_2) emissions intensity of electricity generation in the region was 215 grammes of CO_2 per kilowatt-hour (g CO_2/kWh) in 2022. This is among the lowest levels in the world, and less than half the global average.

Figure 1.14 ▷ Electricity generation by source in LAC and selected countries, 2022



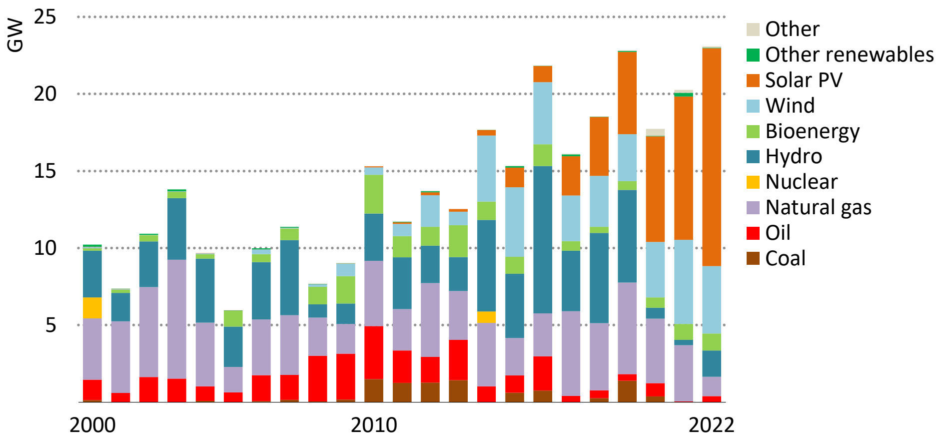
More than 60% share of renewables, mostly hydro, gives electricity generation in LAC one of the lowest emissions profiles in the world

Note: Other renewables include geothermal, concentrating solar power and marine power. Other includes nuclear, non-renewable waste and other sources.

Each country in Latin America and the Caribbean has a unique electricity generation mix. Many are able to draw on vast renewable energy resources. Some countries rely heavily on hydropower. Brazil, Colombia, Costa Rica, Ecuador, Panama, Paraguay and Venezuela each produce at least 60% of their electricity from hydro. Wind and solar PV generally make up a smaller part of the LAC generation mix, though they account for 25-35% of electricity generation in Chile and Uruguay. Only Argentina, Brazil and Mexico have nuclear reactors, which respectively provide 6%, 2% and 3% of generation. Other countries rely more on fossil fuels, which accounted for over 35% of electricity generation in twenty-two countries in LAC including nearly all Caribbean countries. Natural gas is the dominant fuel for electricity generation in Argentina, Bolivia, Dominican Republic, Jamaica, Mexico, Trinidad and Tobago, while coal also plays important role in Chile, Dominican Republic, Guatemala. Oil is used for electricity generation in many countries in the region, though in most continental LAC countries its share of generation is below 20%.

Hydropower accounts for about 45% of total electricity generation in LAC which is higher than more than 110 countries in the world. Countries such as Colombia, Costa Rica, Ecuador, Panama, Paraguay and Venezuela have especially high hydro shares above 60%, and only a handful of countries such as Norway, Canada, Switzerland and Iceland have a comparable level. While hydropower has brought enormous benefits to the region, including providing a large amount of energy storage, countries need to carefully consider the implications of climate change effects on precipitation and temperature on both its existing and planned hydropower projects (see Chapter 2).

Figure 1.15 ▷ Annual power capacity additions by source in LAC, 2000-2022



For decades, LAC looked to hydro, natural gas and oil to meet electricity demand growth, but in the recent years it has turned sharply towards wind and solar PV

Note: GW = gigawatts. Other renewables include geothermal, concentrating solar power and marine power. Other includes non-renewable waste and other sources.

Hydropower maintains its dominant share of renewables electricity generation in LAC, though wind and solar PV capacity additions have been accelerating sharply in recent years which may mark a turning point in the electricity supply mix (Figure 1.15). In the two decades prior to 2019, hydropower, natural gas and oil collectively accounted for more than half of total capacity additions each year. In the last three years, wind and solar PV have been responsible for more than half of annual capacity additions. The share of fossil fuels in total capacity additions has been declining, with almost no construction of coal-fired or oil-fired power plants in recent years and fewer new natural gas-fired plants particularly in the last few years.

1.3.3 Resources and supply

LAC is rich in energy resources from critical minerals to unconventional gas, hydropower, bioenergy and other renewables. Potential areas of growth include solar and wind, advanced ethanol, low-emissions hydrogen and biojet kerosene. Resources and development prospects vary markedly by country. Chile, Brazil and Peru produce substantial volumes of critical minerals such as copper, lithium and graphite, while Bolivia and Argentina are looking to further explore their large lithium resources. Brazil, Mexico and Argentina are the largest of a number of oil and gas producers. Some are seeing their production decline, notably Venezuela, while others like Guyana have scope to provide new supply. Colombia is the main coal supplier in the region, though recent public announcements have indicated it is on a path away from coal as are its main export markets.

LAC plays an important part in energy-related and other global trade reflecting its geographic location, natural resource wealth and trade relationships. Trade agreements such as MERCOSUR, the Pacific Alliance, the US-Mexico-Canada Agreement and bilateral agreements facilitate trade flows between LAC and the United States, Canada, Europe, Asia and Africa. The region is a major supplier of commodities, including oil and gas as well as critical minerals, and is well positioned to contribute to the emerging new global energy economy.

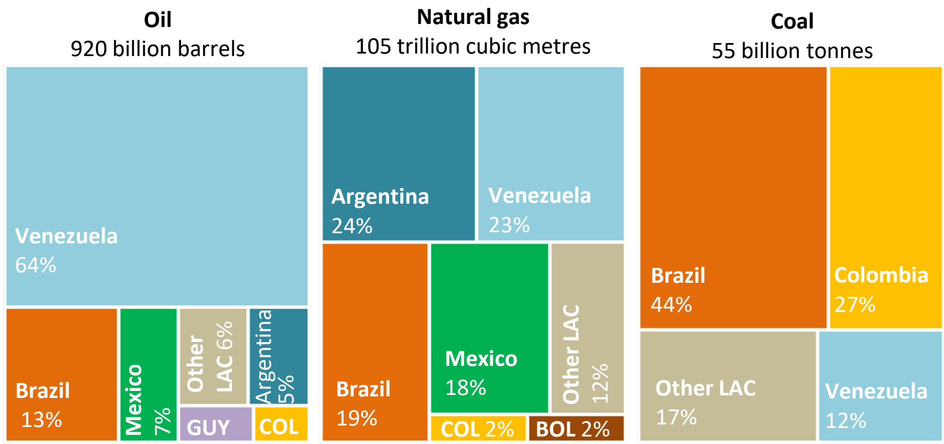
Fossil fuels

Latin America and the Caribbean has substantial oil and gas resources. These resources are spread unequally between countries, and many of them are hard to access and develop at an economic price. It also has some coal resources, mostly in Brazil and Colombia (Figure 1.16). Fossil fuels are currently responsible for two-thirds of total energy supply in LAC, oil (40%), natural gas (23%) and coal (4%).

Guyana and Brazil have increased their oil and natural gas production in recent years and together were responsible for around 15% of the increase in global oil supply between 2019 and 2022 (Figure 1.17). Oil and gas production in LAC rose sharply in 2022, by around 5% as fossil fuel prices surged in response to post-pandemic demand and the energy crisis due to Russia's invasion of Ukraine. Further growth is expected in 2023 in view of market tightness, OPEC+ cuts and new projects coming online. Current major projects include work to develop unconventional production in Argentina as well as new offshore fields in Brazil and Guyana.

Potential sources of new hydrocarbon supply have raised environmental concerns in the region. The development of unconventional resources through fracking has been banned in regions of Brazil and Uruguay, and a moratorium is under discussion in Colombia. Argentina is currently the only country in LAC that has developed tight oil and shale gas at scale. Environmental concerns are not limited to unconventional hydrocarbon production. Following major discoveries by ExxonMobil in Guyana, a court decision required the company to provide unlimited financial guarantees to deal with potential oil spills in its exploration activities, though this has since been limited to USD 2 billion. In a nearby offshore area under Brazil's jurisdiction, a permit for drilling was recently denied, with the environmental agency citing the lack of adequate structures to deal with potential impacts from oil spills as one of the key reasons.

Figure 1.16 ⊳ Fossil fuel resources in LAC, 2022

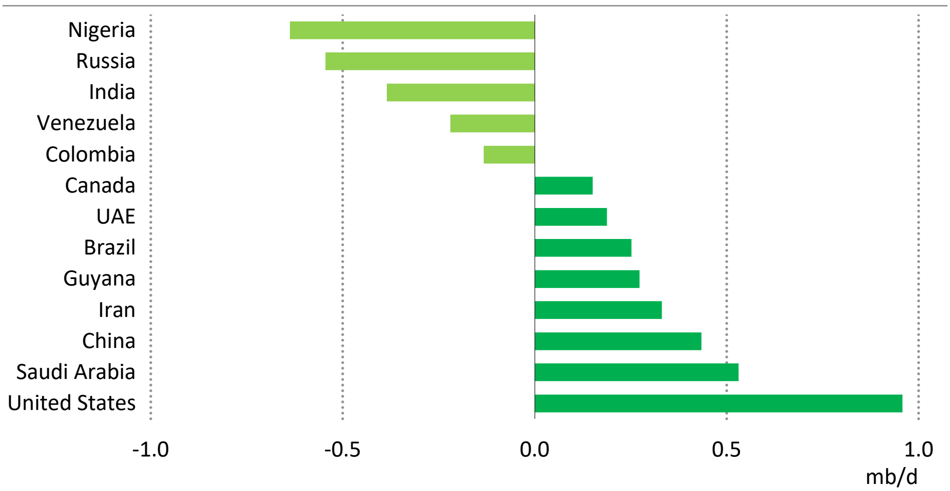


LAC has nearly 15% of global oil and gas resources, and less than 1% of global coal resources

Notes: GUY = Guyana; BOL = Bolivia. COL = Colombia. Resources correspond to the volume of remaining hydrocarbons that could still be produced. This includes volumes already identified as reserves and volumes that are not financially viable to recover for a number of reasons, including price, lack of available technology or resources that are based on geological research but are yet to be discovered.

Sources: BGR (2021); BP (2022); CEDIGAZ (2022); OGJ (2022); US DOE/EIA (2015); US DOE/EIA (2013); USGS (2012a); USGS (2012b); IEA databases and analysis.

Figure 1.17 ⊳ Oil supply changes for selected countries, 2019-2022



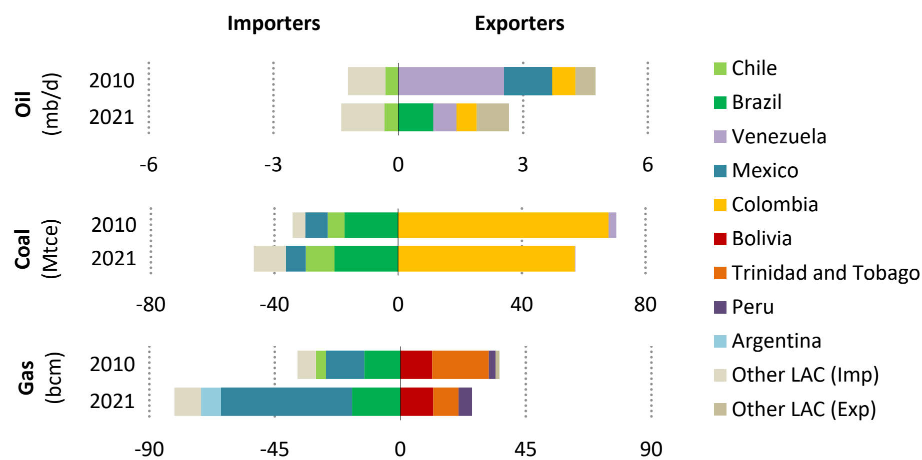
Increased production in LAC accounted for nearly 20% of global growth in oil supply

Note: mb/d = million barrels per day; UAE = United Arab Emirates.

Coal production is relatively small scale, except in Colombia, which accounts for around 90% of supply in LAC. Colombia exported close to 60 million tonnes of coal equivalent (Mtce) in 2022, most of it in the form of steam coal to Europe for the power sector. Production fell from around 80 Mtce to 50 Mtce in 2020 when the Covid-19 pandemic led to a fall in energy demand, and since then it has remained below 60 Mtce.

LAC is a net exporter of crude oil and coal and a net importer of natural gas (Figure 1.18). Brazil, Colombia and Venezuela are the leading net exporters of crude oil with China and the United States as their main customers. Mexico is by far the biggest importer of natural gas, most of which comes from the United States. Argentina is expected to switch from net natural gas importer to exporter as it develops its unconventional gas resources. Colombia is the only significant exporter of coal. Regional trade plays an important role in LAC: for example, coal goes from Colombia to Brazil and Chile; Brazil supplies oil to Chile and other neighbouring countries; and Bolivia delivers natural gas via pipeline to Brazil and Argentina. Some countries, such as Panama and Cuba, rely heavily on imports and are highly vulnerable to price cycles.

Figure 1.18 ▷ Net imports and exports of fossil fuels in LAC, 2010 and 2021



Brazil, Colombia and Venezuela together account for around 70% of net fossil fuel exports in the region

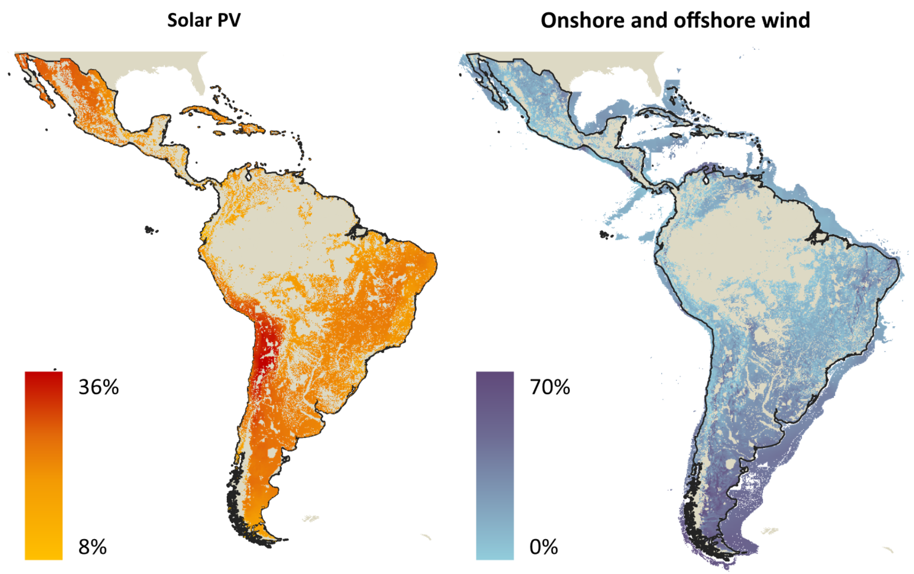
Notes: Mtce = million tonnes of coal equivalent; bcm = billion cubic metres. LNG is included in gas; Imp = Importers; Exp = Exporters.

While the region is a net exporter of crude oil, it is a net importer of oil products, mainly from the United States. Countries with limited domestic oil resources, such as Chile and Uruguay, rely heavily on imports of crude oil and refined oil products to meet their needs. Several of the main producers have substantial refining capacity, including Brazil, Mexico, Venezuela and Argentina, but they also import some oil products to address demand for specific product grades or quality or to bridge temporary mismatches between domestic supply and demand. Venezuela has seen its refining capacity decline due to poor maintenance and underinvestment, leading to shortfalls in the domestic supply of gasoline and diesel.

Renewables

Renewable energy offers a significant opportunity for Latin America and the Caribbean. Hydropower has been a major source of electricity generation in many countries, but much of the remaining potential for hydro is concentrated in the Amazon Basin, which is already suffering from deforestation, climate change and illegal mining. Biofuels also play a significant role, supplying 10% of the energy used for power generation and in transport (compared to less than 5% at a global level). There is potential over time for biofuels to increase productivity, tap into advanced feedstocks, help to decarbonise hard-to-abate sectors and enable net negative energy supply.

Figure 1.19 ▷ Average simulated solar PV and wind capacity factors in LAC



Northern Chile, Peru and Mexico have the best solar PV conditions in the region, while wind potential is highest in Patagonia, Colombia's Guajira and in north-eastern and southern Brazil

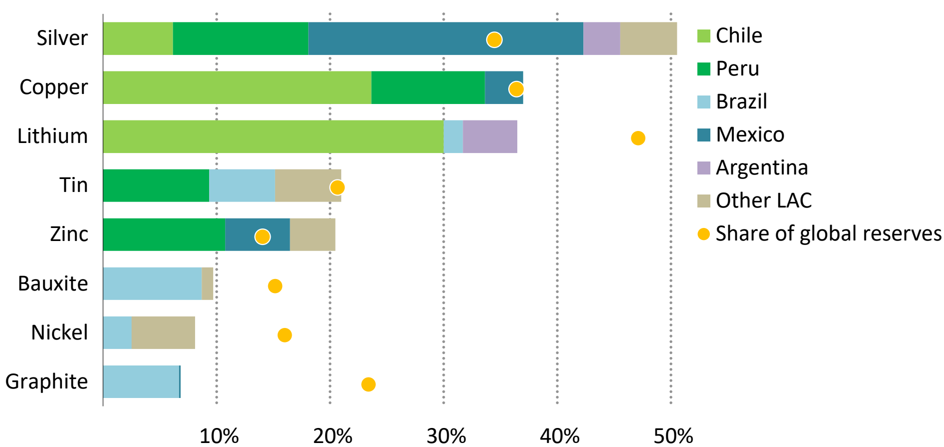
Notes: Solar PV capacity factors are calculated assuming utility-scale solar PV plants with polycrystalline silicon modules (best available technology [BAT] in 2030), single-axis tracking and site adapted tilt angle. Onshore wind capacity factors are calculated based on a wind turbine with a rotor diameter of 160 metres (m), with a hub height of 80-150 m and a capacity of 3-6 megawatts (MW), both site adapted (BAT in 2030). Offshore wind capacity factors are calculated based on a 220 m rotor diameter wind turbine with a hub height of 100-170 m and a capacity of 10-17 MW, both site adapted (BAT in 2030). Solar PV and wind capacity factors are calculated based on average capacity factors for 2000-2019.

The scope for development of solar PV and onshore and offshore wind resources is another enormous opportunity (Figure 1.19). Brazil, Mexico, Colombia, Chile and Peru are driving a wave of new solar PV capacity additions, and have recently added more capacity than Africa, Middle East and Eurasia combined. For wind power, Brazil, Chile, Colombia, Mexico and Argentina are at the forefront of developing new capacity. In the longer term, tapping the wind resource potential could enable LAC countries to become competitive producers of low-emissions hydrogen.

Minerals

Many countries in LAC are major producers of critical minerals (Figure 1.20). Chile is the largest copper producer in the world and accounts for around 30% of global lithium supply today. Brazil is a major bauxite and graphite exporter. Peru and other countries in the region play a key role in the supply of other critical minerals such as nickel and silver. The region also has substantial underexplored reserves, for example lithium in Bolivia and rare earths in Brazil. A strong resource base offers the opportunity to move further along the supply chain to mineral refining and processing, capturing more value, creating jobs and helping to diversify global supply of refined minerals.

Figure 1.20 ▷ Share of LAC countries in global production and reserves of selected minerals, 2022



LAC is highly significant for the production of lithium and other critical minerals required for clean energy transitions

To seize these opportunities, mining activities must adhere to high environmental, social and governance (ESG) standards and benefit local communities. Many of the mineral resources are in sensitive ecosystems that already are subject to a number of stresses. Some of the largest copper mines are in northern Chile, where water scarcity is a critical issue. This is also an area of lithium development, and the water required to produce lithium risks adding to the problem of water scarcity. Several bauxite and rare earths deposits in Brazil lie in the Amazon Basin. Strong ESG performance is of critical importance to safeguard the region's biodiversity, local communities and indigenous peoples (see Chapter 3). There are already some success stories to draw upon. For example, the Los Bronces copper mine upgraded a water transport system and deployed an automated circuit for recirculation to recycle over 78% of the water it uses (Copper Alliance, 2023). More success stories are needed to show the way forward.

1.3.4 Environment

Countries in LAC are some of the most biodiverse in the world and host sensitive ecosystems facing a range of challenges. Limited enforcement capacity and economic pressures make for a delicate path to just transitions. International collaboration can bring major benefits for all involved, help to tackle energy poverty, reduce emissions and accelerate progress towards the Sustainable Development Goals.

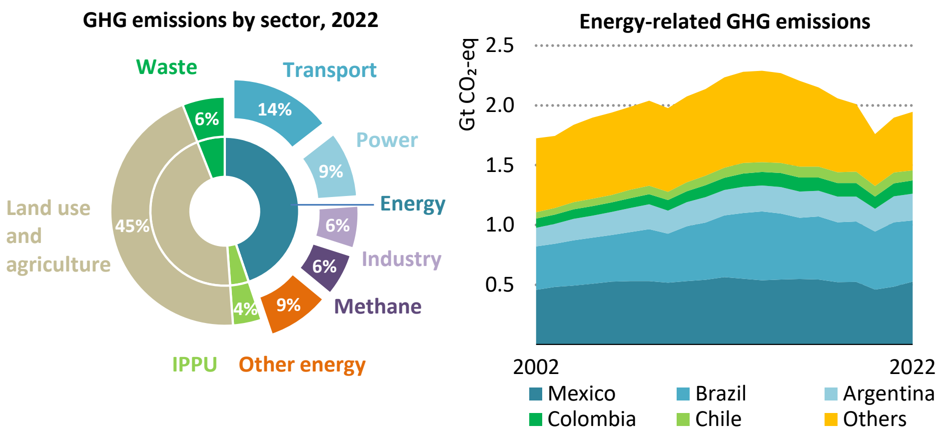
Emissions

LAC was responsible for around 5% of total global energy-related greenhouse gas (GHG) emissions from 1970 to 2022. In 2019, it accounted for around 8% of total economy-wide GHG emissions. At the global level, the energy sector is estimated to be responsible for more than three-quarters of GHG emissions. In LAC, it accounts for less than half of these emissions (Figure 1.21). This underscores the significance of land use and agriculture in the region, which was responsible for around 45% of economy-wide GHGs in 2022.

Low-emissions sources of power have helped to limit the region's historical contribution to climate change, but a clean energy transition will involve tackling emissions in transport and industry as well as making further progress in the power sector. Road transport was the leading source of energy-related CO_2 emissions in 2022 (around 550 million tonnes [Mt] of CO_2, about 33% of the total), followed by power generation (380 Mt CO_2, 23%) and industry (370 Mt CO_2, 22%).

Reducing methane emissions from oil and gas production offers an early and important opportunity to limit near-term global warming. Oil and gas operations in LAC emitted nearly 8 Mt of methane in 2022, equivalent to more than 230 Mt CO_2. We estimate that around 80% of these emissions could be reduced with existing technologies and 40% could be avoided at no net cost because the outlays for the abatement measures are less than the market value of the additional gas that is captured (see Chapter 3).

Figure 1.21 ⊳ GHG emissions by sector in LAC, 2022, and energy-related GHG emissions by country, 2002-2022



Mexico and Brazil account for over half of energy-related GHG emissions, emissions in the region had been falling since 2015, but this trend reversed after 2020

Notes: IPPU = industrial processes and product use; Gt CO_2-eq = gigatonnes of carbon-dioxide equivalent. One tonne of methane is considered to be equivalent to 30 tonnes of CO_2 based on the 100-year global warming potential and one tonne of nitrous oxide is considered to be equivalent to 273 tonnes of CO_2 based on the 100-year global warming potential (IPCC, 2021). Energy combustion-related emissions are included in the energy segment. IPPU corresponds to process emissions, the use of greenhouse gases in products and non-energy uses of fossil fuel carbon. Methane only includes methane emissions from oil, gas and coal operations. Methane emissions from end-use equipment are included in consuming sectors. Other energy covers the use of energy by transformation industries and the energy losses in converting primary energy into a form that can be used in the end-use sectors.

Sources: Emissions for the energy sector are from IEA databases and land use and agriculture emissions are based on modelling by the International Institute for Applied Systems Analysis (IIASA). Estimates of emissions from other sectors are from Climate Watch (2023).

Land use change

Land-use change is a significant source of total GHG emissions in LAC and is a major source of biodiversity loss. Worse could be to come: natural habitats face illegal logging and pressure from agriculture, mining and urban expansion (Box 1.6). Brazil, Colombia, Ecuador and many other countries in the region have pledged to halt deforestation by 2030, but the journey towards this goal is proving to be slow (UNFCCC, 2021). On the other hand, Uruguay, Chile and Costa Rica have managed to reverse deforestation since 2000 through a series of measures, including incentives for afforestation, promotion of protected areas and engagement with local communities. There are potential economic as well as climate change related gains to be had. Restoration of degraded land and productivity gains could allow bioenergy production to keep expanding without affecting forested areas, especially if the region makes progress on the use of waste and advanced feedstocks. Land-use change could turn from emissions sources to sinks.

Box 1.6 ▷ What does the future hold for the Amazon?

The Amazon rainforest is the world's largest tropical rainforest and an ecological hotspot. It is also home to about 400 indigenous ethnic groups, many of which have no contact with modern society, as well as hundreds of local communities with poor access to energy and infrastructure (World Bank, 2019). It spans nine countries and covers an area of approximately 7 million square kilometres, nearly the size of Australia. It plays a major role in sustaining global climate patterns, serving as a carbon sink and regulating regional and global water cycles. Vast rural areas, several urban centres such as São Paulo, and hydropower plants rely on water from the evapotranspiration of the forest carried south by wind currents.

The Amazon Basin is also home to important energy resources ranging from oil and gas reservoirs to deposits of critical minerals and substantial untapped hydropower potential. Developing and using these resources without doing harm has not proved to be straightforward. Ecuador and Colombia have developed hydrocarbon resources within the Amazon region and witnessed the impacts of oil spills on its rivers, forests and people. Brazil has established large-scale mining operations for bauxite extraction and small-scale tin mining in the Amazon which have been the cause of concerns about deforestation and habitat disruption. Brazil's development of the Belo Monte hydropower project, a 11.2 GW plant in the Xingu River, was controversial in its potential impacts on indigenous communities and ecological water flows.

Around 15-20% of the original Amazon Forest has been lost. Most of the deforestation took place on its borders, often following the development of roads and other infrastructure. Faced with multiple stresses – from deforestation to extreme droughts and floods caused by a warming climate – evidence suggests that the Amazon Forest might be nearing a tipping point (Boulton, Lenton, & Boers, 2022). Accordingly, there is risk that the pressures that the Amazon Forest is facing could lead large parts of it to lose the ability to bounce back from drought or recover from deforestation, and as a result to turn into a savannah. This would cause major disruption to the regional and global climate, and bring about irremediable loss of biological diversity.

Much attention is being given to efforts to find synergies between economic development and environmental conservation and to ensure the long-term health of the rainforest and the well-being of its inhabitants. In 2023, Brazil held an Amazon Summit, where ministers from nations in the region agreed on a set of environmental policies and measures to bolster regional co-operation and to stop the rainforest from reaching "a point of no return". A range of initiatives aim to promote sustainable forest management practices, agroforestry plans, payment for ecosystem services, and indigenous and community-led initiatives that explore sustainable production of forest products.

International collaboration has an important role to play in supporting such initiatives. For example, the Amazon Fund created by Brazil and Norway enables countries around the world to contribute to financing projects that reduce deforestation, strengthen protected areas, promote sustainable livelihoods for local communities, or enhance scientific research and monitoring efforts.

Air pollution

Reducing GHG emissions also brings major benefits to air quality. More than 84 000 premature deaths each year in LAC can be attributed to ambient (outdoor) air pollution. Leading sources of air pollution include industry, power generation and road transport. Transport is a major source of air pollution in urban areas. A shift away from internal combustion engine cars to EVs and more mass transit options would do much to improve air quality in cities while also reducing emissions. Infrastructure to support modal changes to rail and waterways for the transport of goods where this is feasible would reduce air pollution as well as cut energy use and GHG emissions. Improvements in household air pollution levels depend on dedicated efforts to expand access to clean cooking and heating, including for isolated communities that still rely on gathering biomass for cooking and/or heating (see Chapter 3).

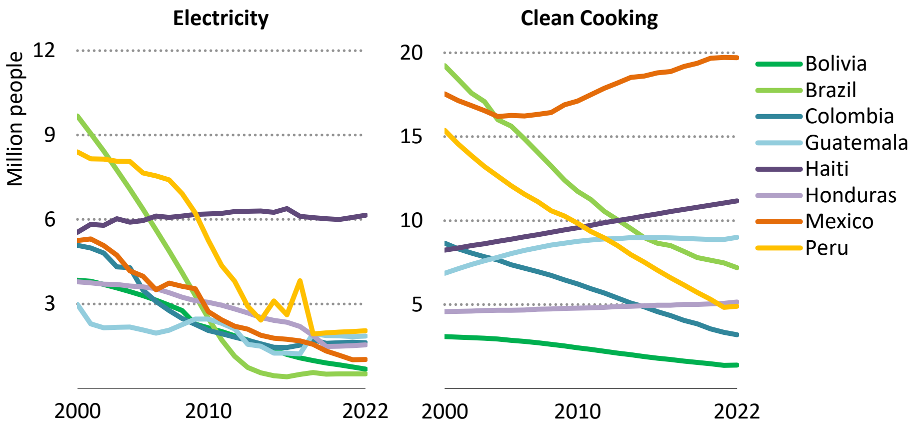
1.4 Energy poverty and affordability

1.4.1 Access to modern energy

Ensuring access to reliable and affordable energy for all remains a crucial challenge for LAC countries, particularly in rural and remote areas. Progress has been made towards achieving universal access to electricity through government policies such as the Luz para Todos programme in Brazil, which has contributed to the 95% reduction of the number of people in Brazil without access to electricity in the last 20 years (Figure 1.22). The increasing availability and use of off-grid technologies has been helpful. Yet, around 3% of the LAC population (17 million people) remain without access to basic electricity services, and this situation has not improved in about a decade. Moreover, quality and reliability of service remains a concern even for those with access.

Meanwhile, the global energy crisis that led to increased natural gas prices has severely hampered the region's progress related to access to clean cooking. About 11% of the population in LAC are without access to clean cooking. In fact, the number of people that lack access to clean cooking has been going up in Mexico, Haiti, Honduras and Guatemala. A lack of access to clean cooking fuels disproportionately impacts the most vulnerable parts of the population such as women and children, and significantly deteriorates indoor air quality.

Figure 1.22 ▷ Population without access to electricity and cleaning cooking solutions in LAC, 2000-2022



While there has been considerable progress in improving access to electricity, nearly one-in-eight people still lacked access to clean cooking in 2022

Source: IEA analysis based on IEA (2023e); OLADE (2022); WHO (2022).

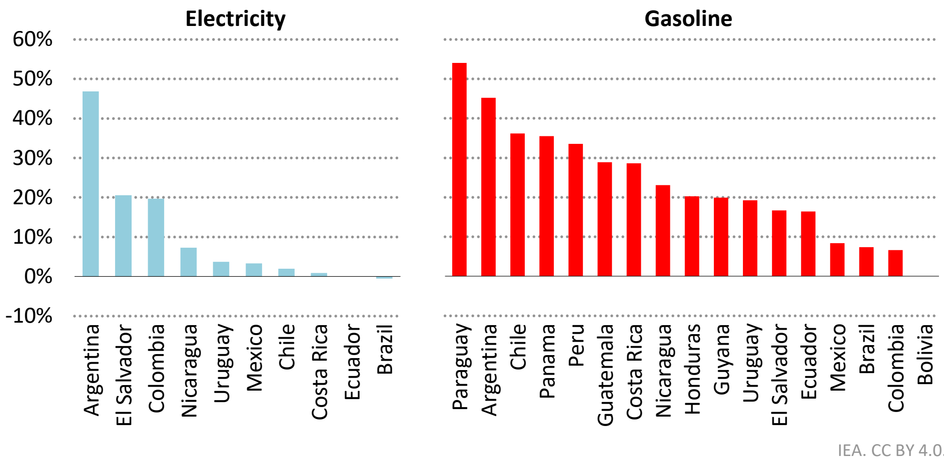
1.4.2 Affordability and inequality

Affordability

Before the energy crisis, high or volatile fossil fuel prices were already a concern, disproportionately affecting the poorest and most vulnerable consumers that spend a higher share of their incomes on energy (IEA, 2022). The energy crisis due to Russia's invasion of Ukraine led to much higher prices and considerable volatility. Natural gas price increased by over 40% in Argentina, Brazil and Uruguay in 2022, while liquefied petroleum gas (LPG) prices rose between 10-20% in most countries. Electricity prices were generally less affected thanks to high levels of hydropower generation in many countries, and replenished dams even brought down electricity prices in Brazil (Figure 1.23). A range of countries responded by introducing vouchers, subsidies and other measures along with existing support schemes to shield consumers from rising household energy bills (IEA, 2023f).

Sharply increased fuel costs for transport put additional pressure on households. Some countries provided protection through existing measures: fuel prices have been frozen for years in Bolivia, for example. Other countries tamed prices by temporarily cutting transport fuel taxes or compensating fuel producers and importers for keeping prices low. Most low income households in LAC do not have the financial means to own a car, though many of those households were affected by the cost of fuel for two-wheelers or by rising bus fares, since two-thirds of all trips in the region are made by public transport (SLOCAT, 2022).

Figure 1.23 ▷ Energy price increases for households in selected LAC countries in 2022 relative to 2021

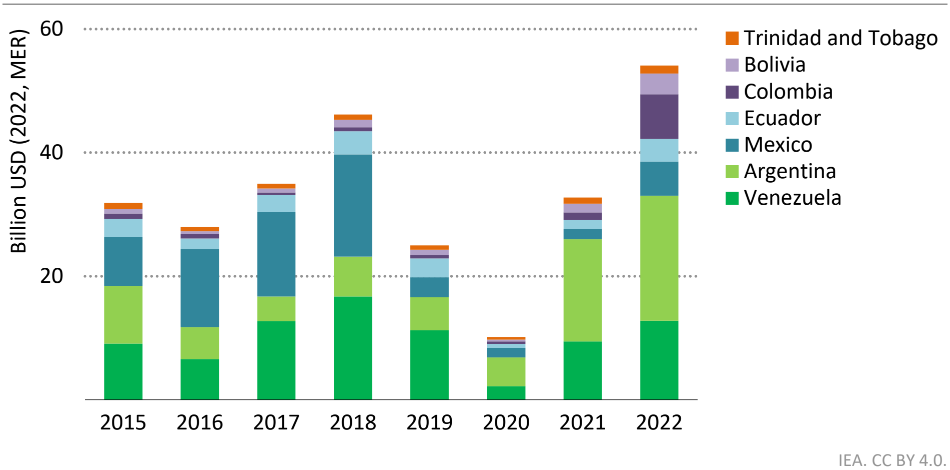


Despite measures intending to dampen gasoline price increases, they increased more sharply than electricity prices in 2022

Notes: Price changes are shown at the nominal rate. Electricity prices in Ecuador and gasoline prices in Bolivia remained stable. Consumer price increases in Argentina were also exceptionally high for other goods (Box 1.2).

Sources: IEA (2023g), IEA estimates and Global Petrol Prices (2023).

Figure 1.24 ▷ Fossil fuel and electricity consumption subsidies in selected LAC countries, 2015-2022



Fossil fuel consumption subsidies increased sharply in 2021 and 2022 in response to rising energy costs

Notes: MER = market exchange rate. Electricity consumption subsidies shown in this figure are only those linked to power generated from fossil fuels.

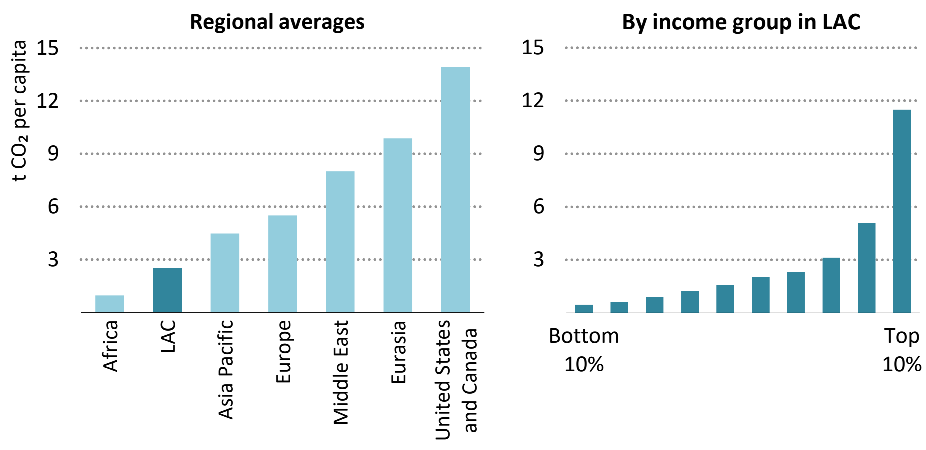
Source: IEA (2023h).

Overall, the Covid-19 pandemic underpinned a tripling of fossil fuel consumption subsides in 2021 relative to 2020, and they rose significantly further in 2022 (Figure 1.24). While they may have provided valuable support in the face of sharp energy price rises, blanket fossil fuel subsidies are not a good long-term solution: they disproportionately benefit the wealthy, and their costs place an additional burden on governments that are already tackling major debt issues. This points to the need to find ways to target subsidies to those that most need them. Despite increasing inflation and global turbulence in energy markets, the subsidies have kept the share of monthly income that average households spend on energy use largely stable at 3-8%, though transport fuel expenditures rose sharply.

Inequality

There are inequalities among regions across the world in terms of CO_2 emissions. On a per capita basis, Latin America and the Caribbean has a comparatively low-carbon footprint, averaging 2.5 tonnes of CO_2 (t CO_2) in 2022, about half the global average of 4.6 t CO_2 per capita. Africa is the only region with lower per capita emissions. There are large inequalities within LAC across income groups. The richest 10% – those earning an average annual income of USD 35 500 – emit close to 12 t CO_2 per capita per year and account for 40% of the region's entire carbon footprint. In other words, the richest 10% emit five-times more than the median individual in LAC. By contrast, the poorest 10% are estimated to emit a mere 0.5 t CO_2 per capita per year (Figure 1.25).

Figure 1.25 ▷ Energy-related CO_2 emissions per capita by region and income group in LAC, 2022



Average per capita emissions in LAC are lower than in any other region except Africa, but its richest 10% are responsible for 40% of regional emissions

These regional inequalities are not unlike those seen at a global level, where the top-emitting decile are responsible for nearly half of global emissions (IEA, 2023i). The largest inequalities are associated with personal transport, particularly aviation and road transport, which are the most income-elastic energy uses. By contrast, residential energy use is generally more equal across income groups, though the use of air conditioners is significantly higher for wealthier households (EPE, 2023).

Low-income households contribute the least to energy-related emissions but spend the highest share of their income on energy bills and are the most likely to lack access to modern energy. To deliver people-centred transitions, governments need to adopt climate policies that also alleviate inequality, such as means-tested incentives for the purchase of clean energy technologies (IEA, 2023j). Getting this right depends on having a good understanding of the employment and equality implications of transitions, plus it requires various agencies across government to co-ordinate effectively. An example is in Panama where an Energy Transition Council has been created to provide accountability and strategic advice on targets including energy access (Republic of Panama Cabinet Council, 2020).

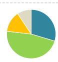
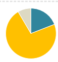
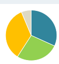
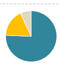
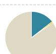
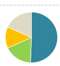
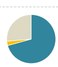
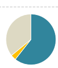
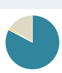
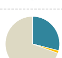
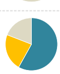
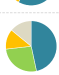
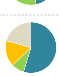
1.5 Energy policies, climate pledges and Nationally Determined Contributions

Mid-term and long-term climate commitments have evolved in Latin America and the Caribbean since the Paris Agreement in 2015. Sixteen of its 33 countries have pledged to meet net zero emissions targets by mid-century or earlier. Together they account for around 65% of the region's GDP and about 60% of its energy-related CO_2 emissions (Table 1.2). Some of these net zero emissions targets are conditional on international support, including increased climate finance using carbon crediting mechanisms like Article 6 and sectoral programmes such as REDD+.[4]

In the context of the Paris Agreement, Nationally Determined Contributions (NDCs) are designed to enable countries to set out their mitigation and adaptation ambitions, policy frameworks, plans and targets with a mid-term horizon. All countries in LAC have submitted their first NDC, and 29 countries subsequently have updated their NDCs to pursue more ambitious mitigation targets or to enhance transparency by providing more details about their policies. The vast majority of the region's current set of NDCs include a quantifiable emissions reduction target. One-third explicitly mention an absolute or relative target, and the rest rely on a counterfactual business-as-usual scenario to specify their potential emission reductions. The aim should be for more countries to adopt absolute emission reduction targets for the upcoming round of NDCs in the lead up to the COP 30 in 2025, including targets for 2035.

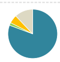
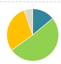
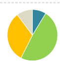
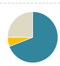
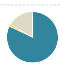
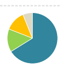
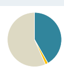
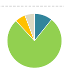
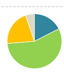
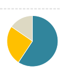
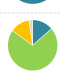
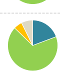
[4] Countries established the REDD+ framework to protect forests as part of the Paris Agreement. REDD stands for reducing emissions from deforestation and forest degradation in developing countries. The + stands for additional forest-related activities that protect the climate, namely sustainable management of forests and the conservation and enhancement of forest carbon stocks.

Table 1.2 ⊳ Mid-term and long-term emissions commitments in LAC

Country	Economy-wide emissions: 2019 share of GHG emissions by sector	Economy-wide emissions: 2030 GHG emissions target	Economy-wide emissions: Net zero target year	Fuel combustion emissions: 2021 (Mt CO_2)	Fuel combustion emissions: 2030 NDC target (Mt CO_2)
Absolute target (max. levels)					
Argentina		349 Mt CO_2-eq	2050	166	168
Chile		95 Mt CO_2-eq*	2050	85	65
Colombia		169.4 Mt CO_2-eq	2050	77	112
Costa Rica		9.11 Mt CO_2-eq	2050	7.5	7.1
Peru		179 Mt CO_2-eq	2050	46	44
Uruguay		0.96 Mt CO_2-eq	2050	7.5	1.3
Relative target					
Brazil		-50% from 2005 levels	2050	439	435
Dominica		-45% from 2014 levels	2030	0.17	0.10
Grenada		-40% from 2010 levels	2050	0.31	0.19
Panama		-11.5%* from 2017 levels	2050	11	11
Saint Kitts and Nevis		-61%* from 2010 levels	-	0.24	0.09
Saint Lucia		-7.2%* from 2010 levels	-	0.51	0.45
Business-as-usual scenario-based target					
Bahamas		-30% from baseline	-	2.4	1.4
Barbados		-70% from baseline	2030	1.3	0.45
Dominican Republic		-27% from baseline	2050	27	32
Ecuador		-11.9% from baseline (in 2025)	-	34	34 (in 2025)
El Salvador		-6% from baseline	-	6.9	8.1

Sectors: ● Energy ● LULUCF ● Agriculture ● Other

Continued on next page…

Country	Economy-wide emissions: 2019 share of GHG emissions by sector	Economy-wide emissions: 2030 GHG emissions target	Economy-wide emissions: Net zero target year	Fuel combustion emissions: 2021 (Mt CO_2)	Fuel combustion emissions: 2030 NDC target (Mt CO_2)
Guatemala		-22.6% from baseline	-	18	17
Haiti		-25.5% from baseline	-	3.1	2.3
Honduras		-16% from baseline	-	9.2	12
Jamaica		-28.5%* from baseline	2050	6.0	5.0
Mexico		-40% from baseline	-	375	474
Nicaragua		-10% from baseline	-	4.8	12
Paraguay		-20% from baseline	-	8.3	6.2
Saint Vincent and the Grenadines		-22% from baseline (in 2025)	-	0.27	0.25 (in 2025)
Trinidad and Tobago		-45%* from baseline	-	13	22
Venezuela		-20% from baseline	-	45	177
No quantifiable target					
Antigua and Barbuda		n.a.	2040	0.64	n.a.
Belize		n.a.	-	0.67	n.a.
Bolivia		n.a.	-	20	n.a.
Cuba		n.a.	-	21	n.a.
Guyana		n.a.	Already net zero	2.8	n.a.
Suriname		n.a.	Already net zero	2.6	n.a.

Sectors: Energy, LULUCF, Agriculture, Other

*Not covering LULUCF in the NDC target.

Notes: LULUCF = land use, land-use change and forestry. Targets reflect unconditional and conditional efforts mentioned in the NDC. LULUCF emission are not displayed when positive. Energy-related CO_2 emissions targets by 2030 are IEA estimates, adjusting the NDC energy or economy-wide targets to IEA historical data.

Sources: Analysis based on data from IEA estimates; Climate watch (2023); Ritchie, Roser and Rosada (2020).

CO_2 emissions from fuel combustion in Latin America and the Caribbean were about 1.5 gigatonnes (Gt) CO_2 in 2022. If all NDCs are fully implemented, including their conditional component tied to international support, the IEA estimates that emissions would rise to 1.7 Gt CO_2 by 2030. If only unconditional NDCs mitigation targets are reached, emissions would rise to 1.8 Gt CO_2, equivalent to an 18% increase compared with 2022. This indicates the need for higher ambition, and for more to be done in countries with longer term net zero emissions goals to put them on course to achieve them. Detailed measures embedded in a well-defined policy framework including financing needs would help to improve transparency and build confidence for the future. This should be seen as essential next steps for the upcoming round of NDCs.

Energy and emissions outlook

From strength to strength?

SUMMARY

- This outlook explores three scenarios for Latin America and the Caribbean (LAC), focussing on the Stated Policies Scenario (STEPS), which reflects current policies and measures, and the Announced Pledges Scenario (APS), which achieves in full and on time all ambitions and pledges by countries and industries, notably in their Nationally Determined Contributions and net zero emissions goals. Where appropriate, progress is benchmarked against the Net Zero Emissions by 2050 (NZE) Scenario.

- Population and economic growth are fundamental factors that influence energy consumption. The LAC population is expected to increase from 658 million today to nearly 700 million by 2030 and 750 million by 2050, along with continuing urbanisation. Emerging from a period of slow growth, the region's GDP growth accelerates due in part to growth in services and re-industrialisation.

- CO_2 emissions in LAC increase slightly from 1 660 million tonnes (Mt) in 2022 to just over 1 690 Mt in 2030 in the STEPS, though they are 200 Mt lower on the track to meet the announced longer term pledges and targets in the APS. Accelerating the deployment of renewables can close nearly 40% of the gap, complemented by electrification, avoided demand and energy efficiency. To 2050, the CO_2 emissions gap widens further, reaching 1 850 Mt in the STEPS, but falling to 800 Mt by 2050 in the APS. Ambient air pollution worsens in the STEPS, but improves to some extent in the APS; household air pollution improves in both scenarios as progress is made in clean cooking.

- While total energy demand increases in each scenario, its composition varies widely. In the STEPS, fossil fuel consumption rises slowly, but they continue to meet the bulk of energy demand, though the fossil fuel share in the energy mix falls from 67% in 2022 to 63% in 2030. In the APS, consumption of all fossil fuels peak in the mid-2020s and their share in the energy mix declines to 57% in 2030. Renewables meet 80% of demand growth to 2030 in the STEPS, raising their share in the energy mix from 28% in 2022 to 33% in 2030, while strong growth in the APS puts renewables on track to overtake fossil fuels in LAC before 2040. In the NZE Scenario, faster uptake of renewables and larger energy efficiency gains push the share of fossil fuels to 50% by 2030.

- Final energy consumption in LAC increases by 1.5% per year to 2030 in the STEPS. The annual rate of increase is 0.8% in the APS reflecting improved energy and material efficiency. Both scenarios see a decline in the share of oil in energy demand, which falls from 48% today to 41% in the STEPS and 23% in the APS in 2050, largely due to the uptake of electric vehicles and use of biofuels. The share of coal in final energy

consumption remains low in the region in all scenarios, mainly used in industry. Countries implement a range of decarbonisation strategies. Brazil leads the way on expanding use of biofuels, for example, while Chile and Mexico promote electric vehicles and Argentina raises the number of compressed natural gas vehicles.

- Electricity demand growth is set to increase its share of total energy demand from 20% today to 21% by 2030 in the STEPS and 23% in the APS. The buildings and industry sectors see demand grow fastest as air conditioner ownership increases by 40% by 2030 and industry is progressively electrified. Minimum energy performance standards and energy-related building codes help to partially offset demand growth, especially in the APS. By 2050, electricity demand in LAC increases by nearly 90% in the STEPS and by 180% in the APS. Peak electricity demand grows even faster.
- Expanding renewable sources of electricity are projected to outpace electricity demand growth in the region and to raise their share in the power mix from just over 60% today to over two-thirds in 2030 in the STEPS and over 70% in the APS. The renewables share continues to rise through to 2050. Today hydropower is the largest source of electricity, but solar PV and wind power installations meet the majority of new demand. Nuclear power accounts for a small amount of generation in some countries, notably Brazil, Argentina and Mexico. Natural gas continues to provide about one-quarter of electricity supply in LAC to 2030, while coal-fired and oil-fired generation decline rapidly, further reducing the emissions footprint of what is already one of the least emissions-intensive power sectors in the world. Power sector investment focusses on renewables, grid expansion and modernisation, and new sources of system flexibility, including batteries and demand-response management.
- The energy production landscape in the region is set to undergo significant changes. In the STEPS, oil production increases through to 2050, with notable jumps in production in Guyana and Brazil, and natural gas production swells strongly after 2030 as Argentina exploits its unconventional reserves. In the APS, oil production in the region declines after 2030 in the face of lower global demand. Natural gas production in the region falls by more than 10% by 2030 and another 20% by 2050 in the APS, despite notable growth in Argentina. In both scenarios, coal production declines rapidly, and bioenergy accounts for a substantial portion of energy supply, with strong growth in liquid biofuels and biogases. Low-emissions hydrogen production growth takes off after 2030 in both scenarios, but it rises ten-times higher by 2050 in the APS relative to the STEPS.

2.1 Introduction

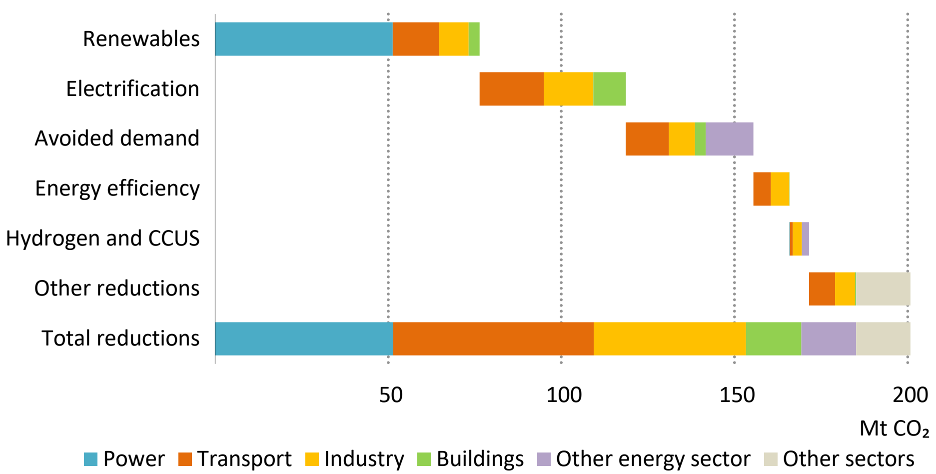
This *Latin America Energy Outlook* builds on the *World Energy Outlook-2023*. It includes three scenarios that explore different pathways for the energy sector to 2050. These scenarios include the latest energy market and cost data and build on the latest projections for economic, population and demographic trends. They consider energy- and climate-related policies and industrial strategies and explore the implications of national plans, targets and Nationally Determined Contributions (NDCs) across Latin America and the Caribbean (LAC) and the world. The variations between the scenarios largely reflect the different policy choices made by governments. The three scenarios are:

- **Stated Policies Scenario** (STEPS) is designed to provide a sense of the prevailing direction of energy system progression, based on a detailed review of the current policy landscape. Outcomes in the STEPS reflect a detailed sector-by-sector review of the policies and measures that are actually in place or that have been announced; aspirational energy or climate targets are not automatically assumed to be met. The STEPS is now associated with a temperature rise of 2.4 °C in 2100 (with a 50% probability).
- **Announced Pledges Scenario** (APS) assumes that governments will meet, in full and on time, all of the climate-related commitments that they have announced, including longer term net zero emissions targets and pledges in 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. Whereas the STEPS looks in detail at what governments are actually doing to reach their targets and objectives across the energy economy, the APS reflects what governments say they will achieve. Since most governments are still very far from having policies announced or in place to deliver in full on their commitments and pledges, this scenario could be regarded as giving them the benefit of the doubt, and very considerable progress would have to be made for it to be achieved. Countries without ambitious long-term pledges are assumed to benefit in this scenario from the accelerated cost reductions that it produces for a range of clean energy technologies. The APS is associated with a temperature rise of 1.7 °C in 2100 (with a 50% probability).
- **Net Zero Emissions by 2050** (NZE) **Scenario** is a normative scenario that portrays a pathway for the energy sector to help limit the global temperature rise to 1.5 °C above pre-industrial levels in 2100 (with at least a 50% probability) with limited overshoot. The NZE Scenario has been fully updated and is the focus of the recently released *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach* (IEA, 2023a). The NZE Scenario also meets the key energy-related UN Sustainable Development Goals (SDGs): universal access to reliable modern energy services is reached by 2030, and major improvements in air quality are secured. Each passing year of high emissions and limited progress towards the SDGs makes achieving the goals of the NZE Scenario more difficult but, based on our analysis, the recent acceleration in clean energy transitions means that there is still a pathway open to achieving its goals.

None of the scenarios should be considered a forecast. Instead, they are designed to explore various courses of action and their implications for energy security, development and the environment.[1] By doing so, they aim to provide policy makers in LAC and elsewhere with insights into the impact of policy choices and a deeper understanding of the levers that could produce different outcomes.

Our analysis finds that current policies would lead to a small increase in total energy-related carbon dioxide (CO_2) emissions in the region from 2022 to 2030, but that there are opportunities to reduce emissions so as to fulfil announced pledges. Closing this implementation gap – the gap between the STEPS and the APS – could save around 200 million tonnes of carbon dioxide (Mt CO_2) by 2030 (Figure 2.1).

Figure 2.1 ▷ Implementation gap of CO_2 emissions reductions by mitigation measure and sector, STEPS relative to the APS, 2030



Increasing the use of renewables through faster deployment of solar PV, wind and biofuels closes nearly 40% of the implementation gap

Notes: Mt CO_2 = million tonnes of carbon dioxide; CCUS = carbon capture, utilisation and storage; solar PV = solar photovoltaics. Other energy sector includes the transformation of energy into another form or the production of fuels. Other reductions includes other fuel switching, process emissions and fugitive emissions. Buildings includes agriculture.

The key actions needed to close the implementation gap in Latin America and the Caribbean by 2030 are:

- The most important mitigation measure is to increase the use of renewables, which accounts for almost 40% of the gap. In the APS, solar PV and wind expand by 35% more

[1] Information on the modelling approach, scenario design and input parameters is available at: IEA (2023b): iea.li/model.

than in the STEPS, reaching 280 gigawatts (GW) of installed capacity and generating almost 30% of electricity. In the transport and industry sectors, stepping up the use of bioenergy also contributes to a higher share of renewables.

- Direct electrification of end-uses closes another 20% of the implementation gap. This entails increasing the share of electric cars and buses in total sales to 20% by 2030 and increasing the use of electricity for low- and medium-temperature heat processes, thus increasing the share of electricity in non-energy-intensive industries from today by three percentage points to 40%. Further electrification becomes increasingly effective as a way of cutting emissions as the share of renewables in power generation expands.

- Measures that reduce demand for energy, i.e. avoided demand, close about 20% of the gap. They include increased use of public transport, material efficiency strategies in industry, and improved access to efficient clean cookstoves.

- Increased energy efficiency closes about 5% of the gap. These savings result from improved fuel economy in vehicles, especially trucks, and increased energy efficiency in industrial processes: the process improvements can be achieved by increasing the stringency and coverage of minimum energy performance standards (MEPS) for motors as well as supporting companies to undertake energy efficiency audits and develop implementation plans.

- The remaining gap is closed by a variety of measures, such as the reduction of fugitive emissions (10 Mt CO_2) and the reduction of industrial process emissions through the use of new methods of production. Carbon capture, utilisation and storage (CCUS) and hydrogen play a minor role (less than 5%) for the rest of the decade but become increasingly important after 2030.

In order to close the implementation gap, countries need to adopt policies that drive emissions reductions in these areas and to underpin those policies with parallel action to strengthen energy systems, for example by adding new grid transmission lines and ensuring adequate systems flexibility in power systems as the use of variable renewables generation increases.

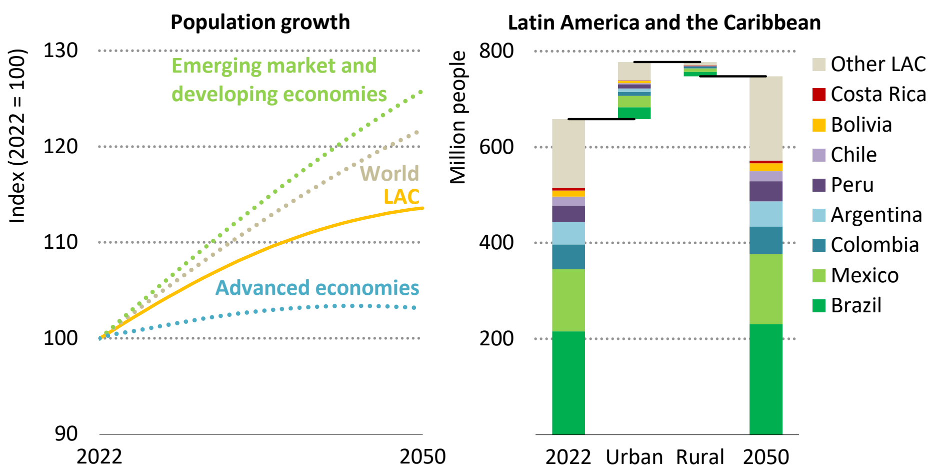
This chapter presents detailed outlooks and analyses for Brazil, Mexico, Argentina, Chile, Colombia and Costa Rica. The first five are the largest economies in the region: together they account for around 80% of LAC gross domestic product (GDP), total energy supply and energy-related CO_2 emissions. Costa Rica is a fast-growing country that already has a fully decarbonised power sector. The remaining Latin America and the Caribbean countries are collectively referred to as *Other LAC* in this chapter.

2.1.1 Population and economic growth

The LAC population is 658 million today. In the coming decade, the population is projected to increase by around 0.7% per year, reaching nearly 700 million by 2030. Growth then continues at a slower rate, with the population reaching almost 750 million by 2050. The rate of population growth is higher than in advanced economies but lower than in other emerging market and developing economies, especially those in Africa (Figure 2.2). Among the LAC countries, Guatemala, Honduras and Bolivia experience the highest population growth rates and Argentina has the highest rate among the focus countries. The population growth rates in Jamaica and Cuba are the lowest in the region while Chile sees the lowest growth among the focus countries in this chapter.

Cities continue to dominate LAC settlements. The rural population shrinks over time, continuing a trend since 1993, while the urban population steadily increases. The percentage of the population living in urban areas rises from 82% today to 83% in 2030 and 88% in 2050, by which time an additional 120 million people live in cities. Of the bigger countries, the shift to cities is particularly pronounced in Guatemala, Bolivia, Mexico and Peru which currently have urbanisation rates below the regional average.

Figure 2.2 ▷ Population growth by economic grouping and in LAC, 2022-2050



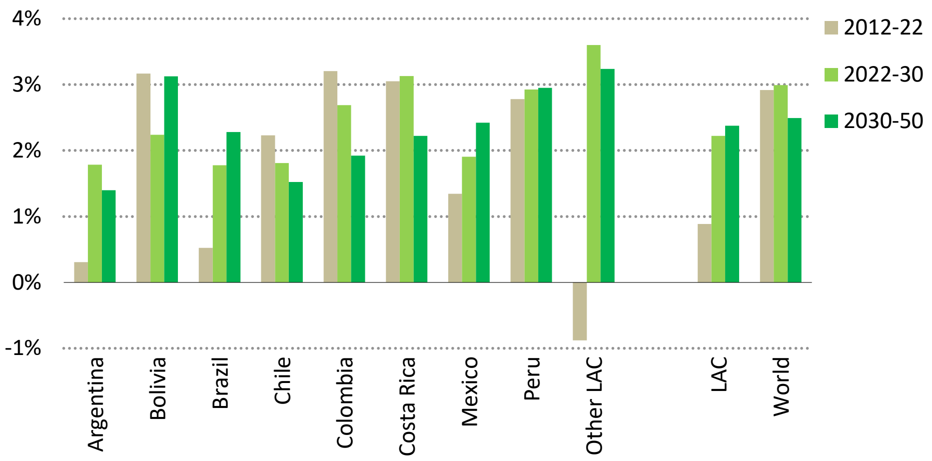
Population growth rate in LAC is between the average in advanced economies and in emerging market and developing economies, with all the growth coming in urban areas

Sources: UN DESA (2018, 2022); World Bank (2023); IEA databases and analysis.

After a decade of relatively low economic growth, economies in LAC are set to overcome the difficulties caused by the current energy crisis and high inflation and to regain momentum. Average GDP growth more than doubles in all scenarios from less than 1% over the last decade to 2.2% in the period to 2030, driven by strong demand growth in the services and industry sectors. GDP growth then edges up to an annual average of 2.4% per year between 2030 and 2050. This steady growth means that the region's GDP rises by 2050 to double current levels. LAC remains a middle-income region, with a level of GDP per capita that is higher than in most emerging market and developing economies but below that in advanced economies.

The rate of GDP growth varies among the LAC countries depending to a large extent on their current income levels and economic structure. The two largest economies, Brazil and Mexico, together account for more than half of GDP in LAC. Their annual GDP growth rate rises to 1.8% in the period to 2030 and then accelerates to around 2.3% per year to 2050 (Figure 2.3). Chile, Colombia and Costa Rica all have relatively high GDP per capita today – above USD 8 000 (2022, purchasing power parity [PPP]) per capita – and their GDP grows at between 1.8% and 3.1% per year over the next decade, driven by expansion in the services sector: it then drops to around 1.5%-2.2% each year to 2050 in line with other advanced economies. Countries with lower income per capita today, including Bolivia and Peru, maintain GDP growth rates of around 3% per year through to 2050.

Figure 2.3 ▷ Average annual GDP growth in LAC and selected countries, 2012-2050



After a decade of slow growth, GDP annual growth rate more than doubles in the coming decade, with strong development projected in Brazil, Costa Rica and Peru

Note: Calculated based on GDP expressed in year-2022 US dollars in purchasing power parity terms.

Sources: IEA analysis based on Oxford Economics (2023) and IMF (2023).

2.2 Total energy supply

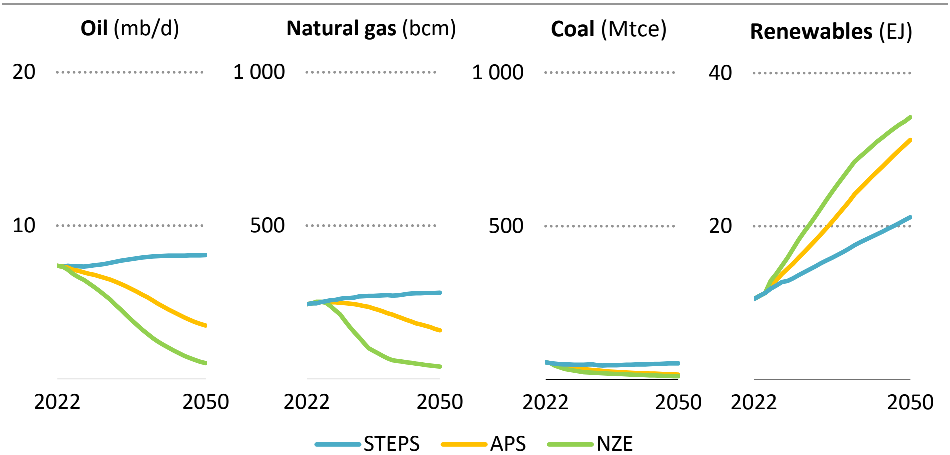
Driven by population and economic growth, total energy supply (TES) in LAC in the STEPS is 10% higher in 2030 than it is today, and 35% higher in 2050. Growth in the less energy-intensive services sector and more efficient end-uses lead to a decrease in the energy intensity of 7% in the period to 2030 and almost 30% by 2050: without this decrease, the growth in demand for energy would be higher. While the absolute demand for fossil fuels increases, its share in the energy mix decreases from 67% today to 63% in 2030 as a result of current policies and the falling costs of renewable sources of energy.

There is a significant gap between the total energy supply in the STEPS and the APS. Reflecting increased climate ambition in net zero emissions pledges and NDCs, total energy supply increases by only 9% in 2030 and 14% by 2050 in the APS. Energy intensity in the APS is 2% lower than in the STEPS by 2030 and 9% lower by 2050. The share of fossil fuels in the energy mix falls to below 60% in 2030 and to only around one-quarter by 2050 in the APS, of which 13% is used as feedstock and 3% is captured by CCUS.

In the NZE Scenario, additional efficiency gains across the energy system limit the growth of total energy supply from current levels to only 2% by 2030 and 6% by 2050. Energy intensity improvements triple by 2030 compared to 2010-2022 and energy intensity is almost halved by 2050. Fossil fuel supply declines to 50% of TES in 2030 and under 10% in 2050, of which almost 40% is used for non-energy purposes and 20% is captured by CCUS. With significant improvements in energy intensity lowering overall demand, renewables energy supply is only 10% higher than in the APS in 2050.

Fossil fuels see varied trajectories over time. Oil remains the largest energy source in the STEPS and until 2040 in the APS, primarily used for transport. Natural gas increases slightly faster oil in the STEPS but declines in the APS as the power sector shifts away more quickly from gas to low-emissions sources (Figure 2.4). Coal demand remains broadly constant in the STEPS, with higher use in the industrial sector roughly offsetting declining use in the power sector, while in the APS it declines in all sectors. However, coal remains the least used fossil fuel in the region and continues to account for less than 5% of total energy supply.

Figure 2.4 ▷ Total energy supply by fuel and scenario in LAC, 2022-2050



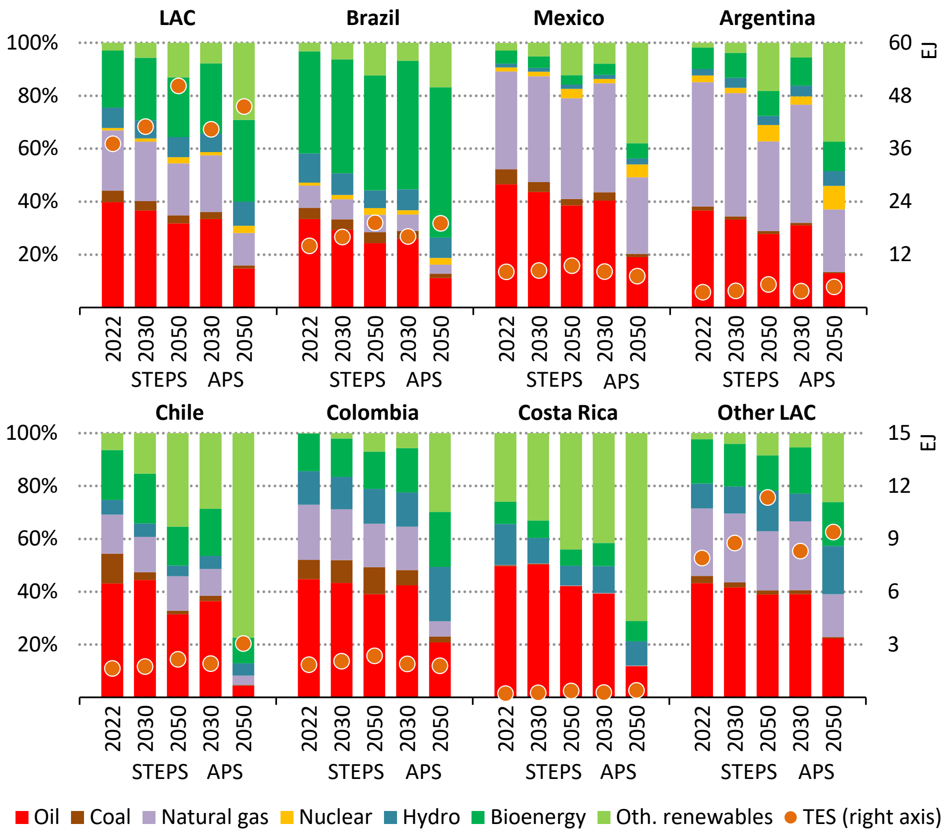
Fossil fuel demand increases in the STEPS, while net zero emissions pledges and NDCs in the APS lead to a decrease from this decade onward; renewables grow strongly

Notes: mb/d = million barrels per day; bcm = billion cubic metres; Mtce = million tonnes of coal equivalent; EJ = exajoule; STEPS= Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario. The Y-axes are scaled to equivalent energetic values.

Renewables, particularly hydropower and bioenergy, already play a significant part in energy supply in LAC, but they make a bigger contribution in the future, mostly from rapid expansion of wind and solar PV and increased use of bioenergy. Current policies lead to a doubling of renewable energy supply by 2050 in the STEPS, with growth even faster in the APS, especially after 2030. In the NZE Scenario, the use of renewables almost doubles by 2030. Renewables are also increasingly used to produce hydrogen and hydrogen-based fuels. While the creation of domestic demand is a priority, several countries in the region export hydrogen-based products to the global market in both the APS and NZE Scenario. Nuclear continues to play a small role in all scenarios, increasing its share slightly to around 3% of TES by 2050.

2

Figure 2.5 ▷ Total energy supply by fuel and scenario in LAC and selected countries, 2022-2050



Renewables displace fossil fuels in all countries, especially after 2030; natural gas sees particularly divergent trends depending on national policies

Note: TES = total energy supply. Oth. Renewables = other renewables.

Shifts in the fuel mix differ among LAC countries according to resource availability, current energy use and government policies (Figure 2.5). In the STEPS, Argentina and Mexico increase natural gas production to meet rising domestic demand and the share of fossil fuels in total energy supply in these countries decreases only by 2-4 percentage points by 2030. Bioenergy helps displace fossil fuels in some countries and makes a particularly large contribution to Brazil's energy transition. Progress in Chile towards targets such as phasing out coal-fired power generation diminishes the share of fossil fuels in its TES from 69% today to 61% in 2030. In the APS, the role of fossil fuel in the primary energy mix in Chile even falls to below 50% by 2030. In Brazil and Costa Rica, it falls from around 50% today to less than 40% by 2030, compared with 40-50% in the STEPS. Without a net zero emissions pledge and with a less ambitious NDC, Mexico is the country that sees the least change in its primary energy mix by 2030.

S P O T L I G H T

Climate resilience of energy infrastructure

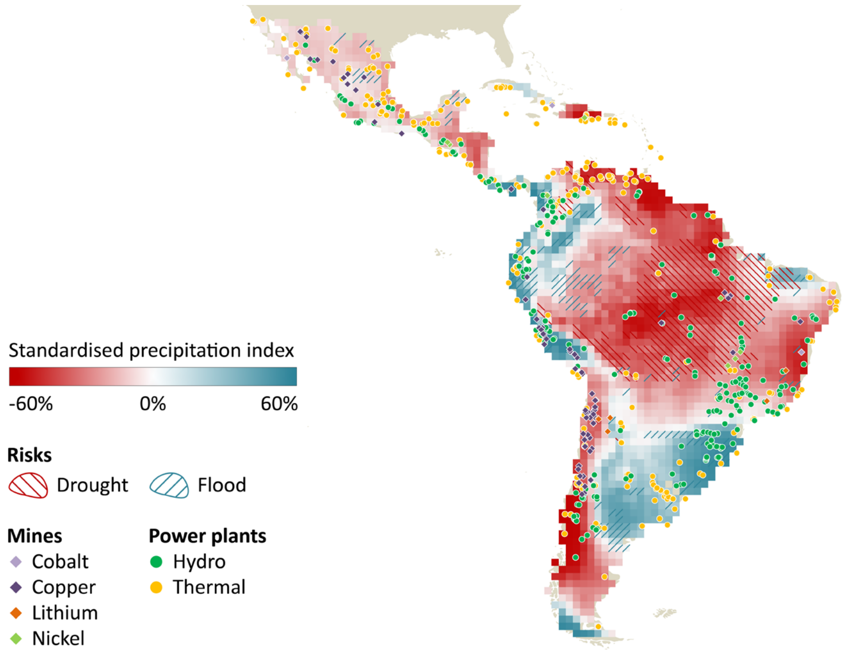
Energy infrastructure in Latin America and the Caribbean is already exposed to climate change impacts. The region has had to contend with changes in precipitation and mean temperatures, as well as increasingly extreme weather events such as floods, droughts, heatwaves and hurricanes. These pose challenges to energy supply, demand and energy infrastructure security. Amid heatwaves in June 2023, electricity consumption in Mexico rose 9% higher than the maximum demand recorded the previous year, and the power system operating reserve margin fell below 6% (Government of Mexico, 2023). During a drought in 2021, which was the worst in 91 years, Brazil's hydropower generation decreased significantly, with dams recording reservoir levels at only 24% of capacity, leading to increased energy prices and a higher level of fossil fuel consumption (The Wall Street Journal, 2021).

Increasing variability in precipitation patterns is a major concern, making some locations wetter and others drier (Figure 2.6). Over 70% of installed hydropower capacity is projected to see a drier climate by mid-century compared with pre-industrial years, and generation from existing plants in the region is projected to be on average 8% lower in the 2020-2060 period than in 1970-2000, with reduced rainfall in many parts of the region only partly offset by increases in the Andean area and some others (IEA, 2021).

Over 65% of installed fossil fuel power capacity is also projected to see a drier climate by mid-century, making it more challenging to secure the cooling water needed for plant operations. Similarly, over 70% of lithium and copper mines could see a drier climate by mid-century, posing risks for water-intensive critical minerals extraction and processing operations (see Chapter 3, section 3.3). The availability of bioenergy could also be affected by droughts which threaten consistent and high crop yields, reduce photosynthesis and change the chemical composition of crops.

Increasing temperatures are also a concern in most parts of LAC, particularly in Brazil, northern Chile and southern Peru. The projected increase in the frequency of hot days could decrease the efficiency of solar PV, wind and thermal power plants, unless additional resilience measures, such as reinforced cooling systems for thermal power plants and improved designs for solar panels and wind turbines, are adopted in good time (IEA, 2022). Rising temperatures are also likely to increase electricity consumption for space cooling. In LAC, cooling degree-days (an index to indicate the excess of temperature above a threshold where cooling is required) are projected to increase by 29-43% in 2041-2060 compared with 1990-2000. Increasing need for cooling is set to add to the demand imposed on electricity grids at a time when higher ambient temperatures are likely to reduce the capacity of transmission and distribution networks.

Figure 2.6 ▷ Precipitation changes in LAC in the SSP2-4.5 scenario, 2040-2060



Over 70% of existing hydropower plants, lithium and copper mines and 65% of fossil fuel power plants need to be prepared to cope with drier climates by mid-century

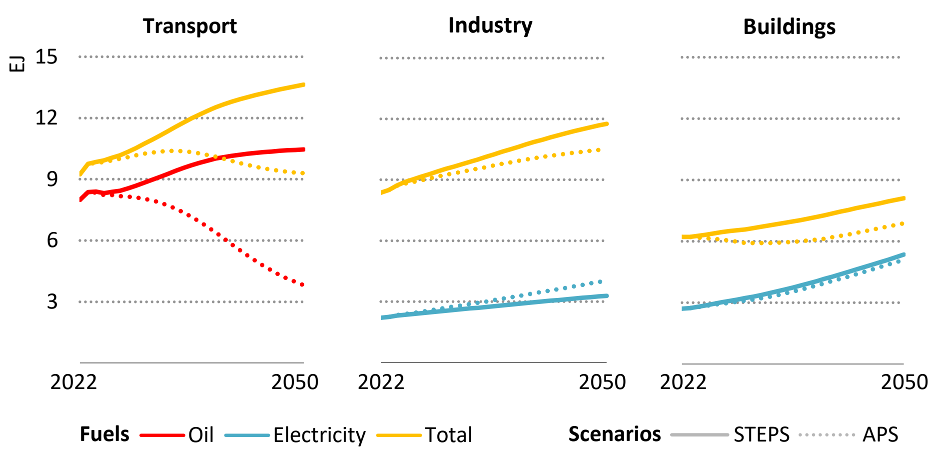
Notes: SSP2-4.5 is an emissions scenario in the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report. Among the IPCC scenarios, it is the one most closely aligned with the STEPS. The Standardized Precipitation Index compares cumulative precipitation over a fixed time against long-term precipitation distribution for the same place and time to characterise meteorological droughts. Only power plants with an installed capacity above 100 megawatts are shown. Drought: increase in consecutive dry days by 10 days or more. Flood: over 10% increase in one-day maximum precipitation.

2.3 Final energy consumption

Final energy consumption in Latin America and the Caribbean is dominated by oil, which accounts for almost half of total final consumption today. The other half is mostly split between electricity (20%), bioenergy (18%) and natural gas (11%). Coal accounts for only 3%. Transport accounts for 36%, industry for 33% and buildings for 24% of final energy consumption. Oil is dominant in transport.

Final energy consumption rises by an annual average of 1.5% to 2030 in the STEPS, with the industry and transport sectors seeing faster growth than the buildings sector (Figure 2.7). After 2030, growth in final energy consumption slows to 1.1% per year as population growth slows and energy efficiency improves even more rapidly. Despite continuous increases in transport energy consumption, current policies in the STEPS lead to a gradual shift from oil to electricity and bioenergy. The share of oil in total final consumption is reduced from 48% today to 46% in 2030 and 41% in 2050.

Figure 2.7 ▹ Total final consumption by main fuel, sector and scenario in LAC, 2022-2050



Electrification and increased use of biofuels lead transport oil consumption to peak in the APS; electrification rises steadily in the industry and buildings sectors

In the APS, meeting the ambitions set out in the NDCs cuts total final consumption growth to 0.8% per year through to 2030. Growth is driven by transport and industry, while improved energy efficiency and access to clean cooking lead buildings energy consumption to plateau by 2030. Increasing bioenergy and electricity use reduce the fossil fuel share in total final consumption to under 60% by 2030 and 35% in 2050, with the share of oil in 2050 falling to one-quarter.

Oil consumption falls sharply in LAC in the APS, with high rates of decline even in some producer economies. This helps governments to deliver on climate-related pledges and, in the case of oil importers, to boost energy security. Meanwhile, natural gas plays an important role as a transition fuel, particularly in producer economies. Gas is primarily used for industrial processes, but in some countries it also provides energy for cooking, heating and transport. Electricity consumption increases in both scenarios, and in all sectors and countries, driven by increased ownership of air conditioners and appliances, and by electrification in industry. Additionally in the APS, accelerated electric vehicle (EV) deployment leads to electricity consumption for transport more than doubling compared to the STEPS in 2030.

The effect of these changes on final energy consumption per capita varies by country. As average incomes increase and households buy more appliances, air conditioners and vehicles, energy consumption per capita rises relatively fast over time in all countries. In some, such as Chile, Brazil, Mexico and Argentina, where industrial production plays a more prominent role, their energy consumption per capita today tends to be higher than in many other LAC countries, but to not rise as fast over time as energy efficiency gains temper energy demand in industry.

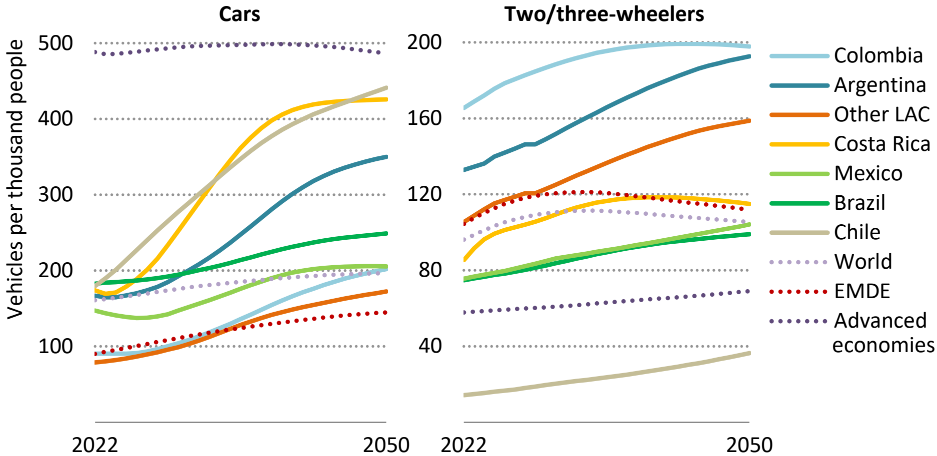
2.3.1 Transport

Road transport accounts for 95% of transport sector energy consumption in LAC. In road transport, cars and light commercial vehicles account for more than 55% of energy demand, with the remainder from heavy-duty trucks (more than 30%), buses (nearly 10%) and two/three-wheel vehicles (less than 5%). On average, 86% of transport in LAC countries depends on oil, which is below the global average of 91%. The remaining 14% of transport demand is met by biofuels (10% of transport demand), natural gas (3.5%) and electricity (less than 0.5%). Brazil has the highest share of biofuels in transport in the world. Argentina and Colombia also have relatively high shares of biofuels and natural gas (mainly Argentina) use in transport. The small size of the contribution made by electricity in the LAC region reflects both the low uptake of EVs so far and the very limited role of rail.

Activity

Higher incomes, high urbanisation rates and relatively limited public transport options in many countries lead to rising ownership levels of cars and two/three-wheelers. Across the region as a whole, car ownership increases from around 140 cars per thousand people today to 230 in 2050 in the STEPS, and ownership of two/three-wheel vehicles rises from nearly 95 per thousand people today to over 130 in 2050. Car ownership rates vary by country: Chile and Costa Rica see fast growth in the region and have a comparably high number of cars per capita by 2050. Two/three-wheel vehicle ownership also varies, with high ownership rates in Colombia and Argentina and low rates in Chile, although ownership rates there still increase 2.5-times between 2022 to 2050 (Figure 2.8).

Figure 2.8 ▷ Car and two/three-wheel vehicle ownership in selected countries/regions in the Stated Policies Scenario, 2022-2050



Ownership of cars and two/three-wheelers expands more rapidly in LAC than the global average; Chile and Costa Rica see high growth rates for cars

Note: EMDE = emerging market and developing economies.

Between different transport modes, aviation sees the fastest growth, followed by rail, private passenger transport and buses. Road freight increases faster than rail freight, with total freight activity more than doubling by 2050.

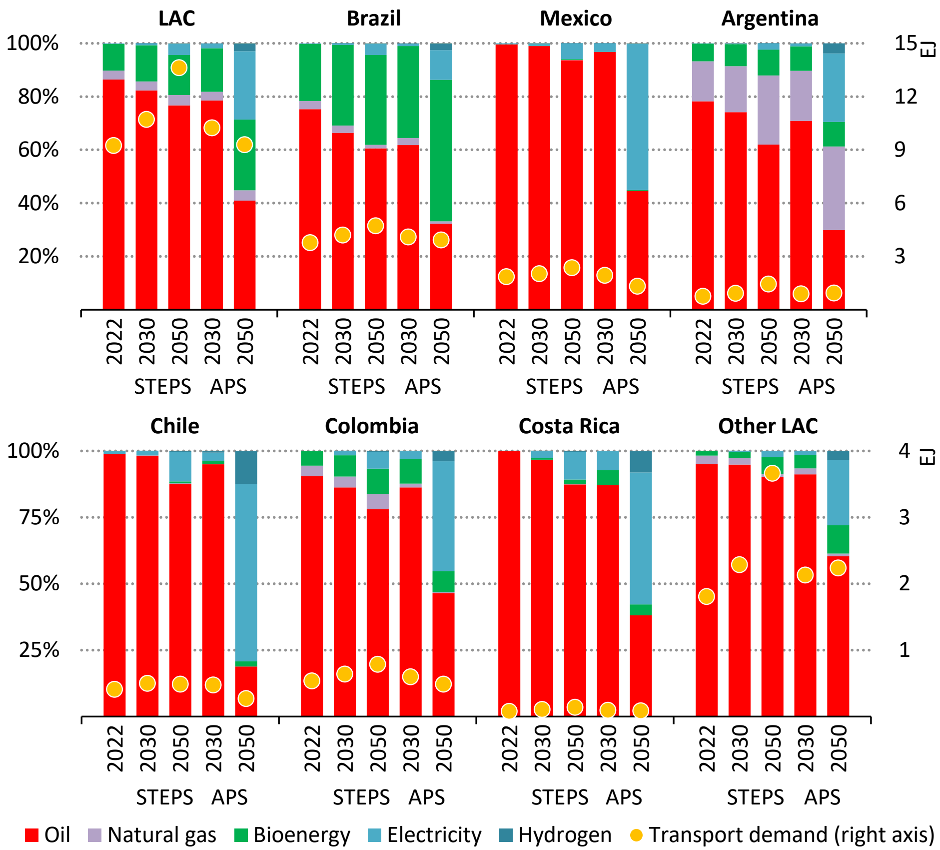
Outlook

Current policies do not lead to fundamental changes in energy demand in transport. In the STEPS, energy consumption rises by 1.9% annually to 2030, driven by more vehicle ownership and increased freight transport. Oil remains the dominant fuel, even as countries deploy various policies to replace oil consumption (Figure 2.9). The share of oil in road transport consumption decreases from 86% today to 82% in 2030, mainly as a result of increased use of biofuels in Brazil and some electrification. Blending mandates cause the share of biofuels to increase in other countries, notably Argentina and Colombia, albeit to a lesser extent than in Brazil. Electricity makes few inroads: by 2030, only 1-in-20 cars and about 1-in-4 two/three-wheelers sold are electric, with electricity accounting for only about 1% of transport energy consumption. Natural gas use in transport in the STEPS is largely unchanged with policy support in Argentina for compressed natural gas vehicles offsetting stagnating demand in other countries.

In the APS, the implementation of more ambitious measures to reach NDCs targets leads to different outcomes. Electrification and higher fuel economy standards reduce energy demand growth in transport to 1.3% per year to 2030. Oil consumption peaks in the mid-

2020s and its share in transport sector demand falls below 80% by 2030, largely due to accelerated EV deployment and biofuel use in major oil consuming countries including Brazil, Mexico, Argentina and Colombia. Two/three-wheel vehicles are the first to be electrified, followed by buses and cars: by 2030, almost every second two/three-wheel vehicle and 1-in-5 cars and buses sold is electric, though only 3% of medium and heavy freight truck sales are electric. The increasing number of electric buses helps to reduce urban air pollution.

Figure 2.9 ▷ Energy consumption in transport by fuel and scenario in LAC and selected countries, 2022-2050



Oil consumption for transport decreases as Colombia, Mexico, Chile and Costa Rica ramp-up EV deployment and Brazil increases its use of biofuels

The difference between the STEPS and the APS widens after 2030. In the STEPS, energy consumption growth in transport tapers to 1.2% per year thanks to fuel economy gains and increased EV deployment. The share of oil in demand falls slightly below 80% by 2050, while the share of electricity rises to 4%. In the APS, EV sales and deployment of biofuels accelerate, leading to a peak in transport energy demand by 2035 and to the share of oil in transport energy consumption nearly halving to 40% by 2050. Around 60% of all cars and buses are electric by 2050, though less progress is made in reducing oil consumption and emissions from the medium and heavy freight trucks and especially in aviation, which require targeted policy support to decarbonise. Hydrogen produced in the region accounts for around 10% of road transport energy consumption in Chile and Costa Rica by 2050.

Policies and decarbonisation strategies

Countries follow various strategies to reduce their dependency on oil products and employ a mix of incentives, targets and carbon taxes, but all strategies have some combination of measures related to:

- **Fuel economy:** Stringent fuel economy standards help to reduce oil consumption in road transport. While current average fuel consumption in LAC is only slightly above the world average, only five countries have fuel efficiency standards for light-duty vehicles and only Argentina, Colombia and Mexico also for heavy-duty trucks (Table 2.1). Tougher fuel economy standards for medium and heavy freight trucks in particular have an impact in the APS leading to an 11% improvement in average fuel consumption of sales by 2030 compared with the STEPS.
- **Electrification:** Mexico, Costa Rica and Chile have the most ambitious EV pledges: in the APS, the market share of electric cars rises in each to 30% or more by 2030, far above the LAC average of 20%. However, EVs do not make up half of the vehicle stock in the region until the late 2040s in the APS, underlining the need to make progress as early as possible and to facilitate the uptake of EVs through policies that aim to build the necessary charging infrastructure and to enhance electricity networks.
- **Biofuels:** Brazil continues to be far above the global average for use of biofuels. Today over 80% of new cars can operate with gasoline blended with high shares of ethanol, even above the current mandate of between 20% and 27% (Bloomberg, 2023). This taps into Brazil's ability to produce ethanol on a large scale. Argentina, Colombia, Peru and Uruguay are among other countries that have biofuel blending targets and consequently increase the share of biofuel in both scenarios.
- **Sustainable aviation fuel** (SAF): Aviation is the fastest growing transport mode in LAC. It is a hard-to-abate sector in terms of emissions due its heavy reliance on oil. In the APS, energy demand for aviation, including international bunkers, doubles by 2050 and oil meets almost 80% of that demand. Biojet kerosene accounts for a further 18%, but its potential is limited by the amount of feedstock that can be sustainably sourced (see Chapter 3, Box 3.3). Synthetic kerosene produced from hydrogen and biogenic or atmospheric CO_2 accounts for only 2% of demand by 2050: it is expensive to produce, and only Brazil has measures in place to support its uptake through its RenovaBio biofuel policy and a SAF mandate planned for 2027. Colombia is just starting consultations on a SAF roadmap linked to its Climate Action Act.

Table 2.1 ▷ Key transport policies in selected countries

	Fuel economy standards for light-duty vehicles	EV policies and targets	Biofuel mandates	Low-emissions aviation fuels support
Brazil	Yes	Yes	Yes	Yes
Argentina, Colombia, Mexico	Yes	Yes	Yes	No
Bolivia, Costa Rica, Ecuador, Panama, Paraguay, Uruguay	No	Yes	Yes	No
Chile	Yes	Yes	No	No
Cuba, Dominican Republic, El Salvador, Nicaragua, Trinidad and Tobago	No	Yes	No	No
Honduras, Peru	No	No	Yes	No

Policy implemented: ○ No ● Yes

Argentina also sees a role for natural gas to reduce oil dependency and increase the use of domestic energy resources. In Argentina, over 10% of trucks run on natural gas by 2050 in the APS. However, betting on natural gas requires careful planning to avoid emissions lock in, including by designing engines that are ready to run on high shares of low-carbon gaseous fuels.

There are also opportunities for modal shifts to public transport to reduce the number of cars and thereby boost emissions reductions:

- Electrified bus rapid transit systems have the potential to serve urban mobility needs in a sustainable way. More than 45 cities in the region have already invested in them. Bogota is the city with the largest electric bus fleet in the world outside China (see Chapter 3, section 3.1).

- Expanding the rail network is another option to cut transport sector emissions, though it requires capital-intensive investment and careful planning, given the challenges presented by the region's geography. The current rail network totals around 95 000 kilometres (km), which accounts for less than 7% of the world's rail network. In the past, parts of LAC had significant rail networks, so there is a possibility of re-opening historical tracks. To reduce complexity and costs, they could potentially be converted to light rail rather than standard heavy rail. Together with bus rapid transit systems, the expansion of urban rail could help reduce congestion and air pollution problems, while the introduction of high-speed rail in the region has the potential to shift demand from aviation, though this potential is limited by geographical constraints in some countries. Increasing the share of passenger-kilometres travelled by rail from 2% currently in LAC closer to the global average of 7% can reduce the dependency on oil products as the region's railways are over five-times less oil-intensive per passenger-kilometre than road transport.

2.3.2 Industry

LAC economies have become less complex over time (see Chapter 1, section 1.1.1), and one result is that the industry sector in the region is less energy-intensive than the global average. Non-energy-intensive industries, or other industry, account for almost half of energy consumption in the industry sector, much above the global average of 30%. The food and mining industries are the most significant, accounting for two-thirds (food) and a quarter (mining) of energy consumption in the light industry sector. Chemicals and iron and steel are the largest energy consumers among the energy-intensive industries. More than half of LAC steel production is in Brazil, followed by Mexico (30%) and Argentina (8%). Brazil also ranks first in high-value chemicals[2] production (70%), while the largest share of ammonia and methanol production is in Trinidad and Tobago (over 70%).

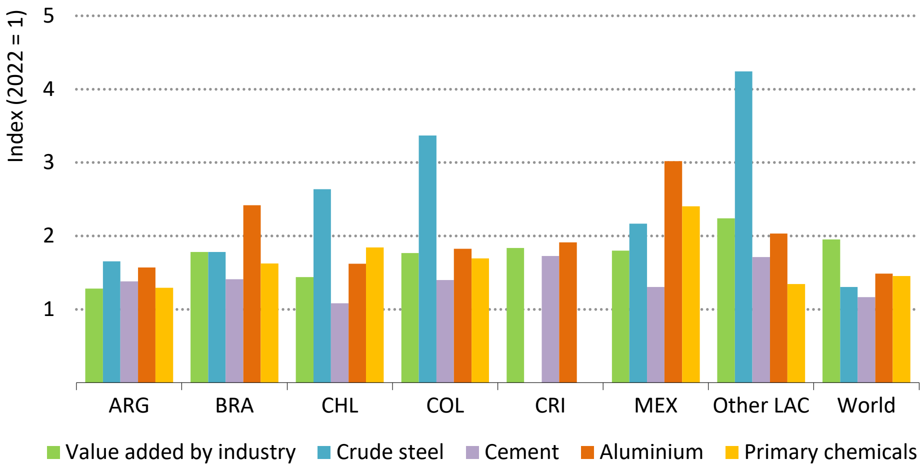
The prevalence of non-energy-intensive industries indicates that the industry sector in LAC can mainly satisfy energy demand with low- and medium-temperature heat, which does not necessarily require fossil fuels. Today a quarter of energy use in industry is electricity and another quarter from bioenergy. Fossil fuels, mostly for high-temperature processes, account for around 50% of energy use in industry in LAC, which is well below the global average of 65%, with oil and natural gas each accounting for around 20% and coal for 10%.

Activity

A resurgence of manufacturing is one of the drivers of economic recovery in LAC, after 20 years of disparity between demand for manufactured goods and the capacity of industry to meet it. In each of our scenarios, industrial value added increases by more than 2% per year through to 2050, almost twice the rate since 2000 but still slightly below the global average. Production of globally traded goods such as steel, aluminium and primary chemicals increases particularly fast, which enables the region to reduce imports (Figure 2.10). Steel production doubles by 2050 in the STEPS, with notable increases in Colombia, Chile and Peru, where, in some cases, production declined in recent years but existing capacity can be tapped to ramp it up. Aluminium production sees particularly rapid growth in Mexico and Brazil, which is facilitated by the availability of scrap that enables lower energy intensity production processes to be used. Primary chemicals production in LAC expands in line with the global average. Cement production increases more slowly, rising at an annual average rate of 1.3% per year to 2050; it rises fastest in Costa Rica and other LAC countries where demand per capita is currently low.

[2] High-value chemicals include ethylene, propylene and aromatics.

Figure 2.10 ▷ Industrial production/output by selected material and country in the Stated Policies Scenario, 2022-2050



Aluminium and steel production increase significantly, reducing the region's import needs; industrial value added growth remains slightly below the global average

Notes: ARG = Argentina; BRA = Brazil; CHL = Chile; COL = Colombia; CRI = Costa Rica; MEX = Mexico. Primary chemicals include ammonia, methanol, ethylene, propylene and aromatics.

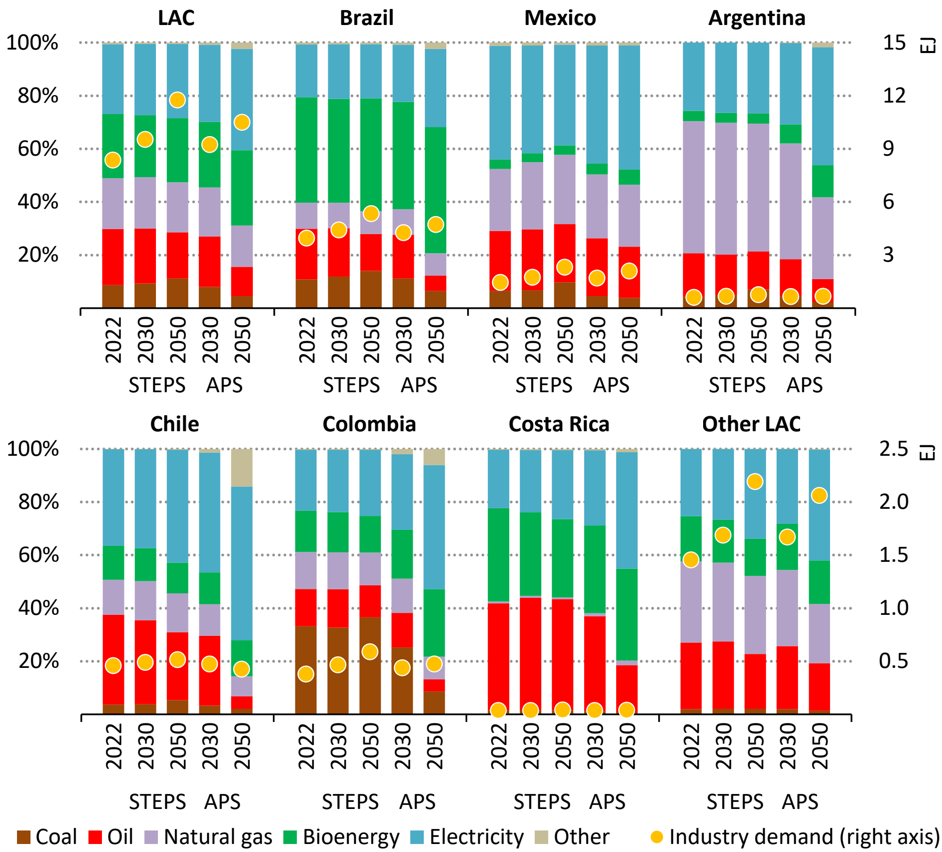
Outlook

In the STEPS, industrial production expands in all sub-sectors with energy consumption increasing by an average 1.7% per year to 2030. The fuel mix remains broadly consistent. Mexico and Colombia see particularly rapid increases in energy demand in industry, driven by strong growth in aluminium, chemicals and steel production. By 2030, Brazil still accounts for almost half of energy consumption in the industry sector.

In the APS, announced pledges result in further action to moderate demand growth in the industry sector and bring about shifts in the fuel mix. Energy and material efficiency measures cut the growth of energy consumption in industry to 1.3% per year to 2030, which is 0.4 percentage points lower than in the STEPS. Additional electrification leads to a reduction in the share of fossil fuel use, mainly in non-energy-intensive industries. Chile electrifies its industry faster than other LAC countries, driven by its target to achieve a 70% reduction in emissions by 2050 relative to 2018 levels, with the share of electricity in industrial energy demand increasing from 36% today to 45% by 2030. Costa Rica and Colombia also see big increases in the electrification of industrial energy demand, rising in both from more than 20% today to almost 30% in 2030. The use of bioenergy increases by more than two percentage points in Argentina and Colombia.

From 2030 onwards, the pathways in the STEPS and APS increasingly diverge. Both scenarios see further growth in energy-intensive industries which decreases the share of non-energy-intensive industries to around 40% of the industry sector total. However, increased energy and material efficiencies lower energy consumption by 10% in the APS compared with the STEPS by 2050 (Figure 2.11). As well, increased deployment of renewables-based sources, such as bioenergy or solar thermal, and electric heating, such as use of heat pumps, in light industries and switching from fossil fuel-based to innovative production routes, such as 100% electrolytic hydrogen-based production of ammonia and iron (H_2-DRI), decrease the share of fossil fuels in industry sector energy demand from 45% in the STEPS to only 30% in the APS.

Figure 2.11 ⊳ Energy consumption in industry by fuel and scenario in LAC and selected countries, 2022-2050



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A mix of electrification, bioenergy and demand reduction is needed to meet announced pledges; some countries aim to use natural gas as a transition fuel for heavy industries

Note: Other includes solar thermal, geothermal, hydrogen and hydrogen-based fuels.

Policies and decarbonisation strategies

LAC countries make use of a range of strategies to boost industrial development while reducing CO_2 emissions by implementing incentives, mandates and, in some cases, carbon taxes.

- **Financial incentives**: Reducing the use of fossil fuels in industrial production requires substantial investment. A number of countries have measures in place to stimulate investment: examples include the exemption of renewable energy equipment from import duties in Costa Rica; the use of decarbonisation credits in the RenovaBio programme in Brazil; and targeted support for decarbonisation in the petrochemical and other strategic industries in Bolivia. In the APS, further measures of this kind mean that cumulative investments are 10% higher in the APS than in the STEPS by 2030.
- **Efficiency**: Increased energy efficiency and material efficiency reduce industrial energy consumption in the APS to 10% below the level in the STEPS by 2050. Important measures for improving energy efficiency in light industries are more stringent MEPS for electric motors, energy management systems and audits. Only less than a third of countries currently have MEPS in place (Table 2.2). Collaboration and knowledge sharing could help to extend coverage of MEPS (see Chapter 3, section 3.2). Material efficiency approaches, such as life extensions of buildings or minimising manufacturing losses, reduce material production, other than aluminium, by 6-9% in the APS and thereby also reduces energy consumption. Chile provides a good example: it has mandated compulsory energy audits and the adoption and implementation of energy management systems for some industrial producers so as to deliver a 4% energy intensity reduction from 2019 levels by 2026.
- **Critical mineral mining:** Mining, especially for critical minerals, is a significant industrial sub-sector in LAC. In the APS, CO_2 emissions from mining in 2030 are reduced by almost 10% compared with the STEPS mainly due to increased electrification. Many producer countries, such as Bolivia and Chile, have already put regulations in place to ensure that the projected increase in critical mineral production in LAC to meet global demand is achieved in a sustainable way (see Chapter 3, section 3.3).
- **Hydrogen strategy**: Low-emissions hydrogen[3] enables the decarbonisation of the industrial sector, especially for applications that cannot be easily electrified. Eight countries in LAC have roadmaps or strategies in place to produce and use hydrogen, although widespread implementation is not expected until after 2030 in the APS. In time, low-emissions hydrogen displaces natural gas-based hydrogen in the chemical industry for ammonia and methanol production (see Chapter 3, section 3.4), and is also used in new applications, such as H_2-DRI in steel making and heavy machinery in mining. In addition, material production based on low-emissions hydrogen create a regional opportunity to export high-value goods and overcome the challenge of transport and

[3] Low-emissions hydrogen is defined in Chapter 3, section 3.4 and the definitions in Annex A.

storage of pure hydrogen (see Chapter 4, section 4.2.2). By 2050, electrolytic hydrogen fuels a third of ammonia production in LAC and around 15% of its iron production in the APS, thanks in part to enhanced funding to advance projects with technologies currently at prototype or demonstration stage (Box 2.1).

Table 2.2 ▷ Key industry policies in selected countries

	Financial decarbonisation incentives	MEPS for motors	Critical mineral mining regulations	Industry-wide efficiency mandates	Hydrogen strategy
Chile, Costa Rica	Yes	Yes	Yes	Yes	Yes
Brazil	Yes	Yes	Yes	No	Yes
Colombia	No	Yes	Yes	Yes	Yes
Mexico	No	Yes	Yes	Yes	No
Bolivia	Yes	No	Yes	Yes	No
Ecuador	No	Yes	Yes	No	Yes
Panama	No	Yes	No	No	Yes
Peru	No	Yes	Yes	No	No
Argentina	No	No	Yes	No	Yes
Uruguay	No	No	No	No	Yes

Policy implemented: ○ No ● Yes

Note: MEPS = minimum energy performance standards.

Electrification of industrial processes is another essential element to achieve the ambitions in the APS. All countries in LAC with net zero emissions pledges are projected in the APS to boost the share of electricity in the energy mix increase by at least ten percentage points by 2050. While natural gas is set to serve as a transition fuel in some countries, it is important to confine its use in the industry sector during energy transitions to energy-intensive industries that require high-temperature heat in order to remain in line with announced climate pledges. Lower temperature processes in light industries offer more immediate scope for non-fossil fuel sources such as heat pumps and bioenergy. In the APS, natural gas consumption in non-energy-intensive industries in LAC declines by 40% by 2050 but increases in energy-intensive industries by 17%, driven by the steel and cement branches.

CCUS, an important technology for the decarbonisation of energy-intensive industries, is another element of the transition. It is mainly used in LAC to reduce combustion and process emissions from cement production.

Box 2.1 ▻ Unlock financing for innovative decarbonisation in industry

In Latin America and the Caribbean, emissions from heavy industries – steel, cement and chemicals – decline by a around quarter by 2050 in the APS, compared with a reduction in overall energy system emissions of 50% over the same period. Heavy industries are the source of some of the region's most stubborn emissions, due in large part to the fact that the technologies needed to tackle them are at early stages of development – with a lower technology readiness level (TRL) – than in other sectors such as power generation and passenger transportation. For heavy industry, these include technologies at the prototype and demonstration phase, such as electrolytic hydrogen-based direct reduced iron (DRI) production, electric steam crackers and cement kilns equipped with CCUS technologies. Government funding for RD&D, provision of enabling infrastructure, policies to create differentiated markets, green public procurement and broad measures like carbon pricing will help to bring these technologies to fruition. Such measures need to be accompanied by de-risked financing in order to mobilise the enormous capital investment required during the early stages of deployment.

Non-reimbursable government funding may well be appropriate in specific instances, but the scale of financing required (billions of dollars for a single commercial-scale plant in many instances) points to a major role for the private sector, particularly given the cash-strapped balance sheets of many LAC countries today. Governments still have a pivotal role to mobilise private sector capital for the investment required, both through the provision of reimbursable finance mechanisms and public-private partnerships that take on some of the financial risk of early projects. Such mechanisms could include concessional and subordinated loans, insurance, debt guarantees, performance-based market and tax incentives, and early-stage equity investment.

International finance has an important role to play to supplement actions taken by individual governments and thus facilitate clean energy transitions in emerging market and developing economies where it is particularly difficult to access affordable public or private sector finance on the scale that is needed. International finance to support industrial decarbonisation can take various forms, including contributions to funds administered by multilateral institutions and development banks, blended finance, bilateral agreements and official development aid. Such funds already exist: the Climate Investment Funds Industry Decarbonisation programme, for example, was announced in 2021 and currently covers more than 100 projects in LAC. But a successful global clean energy transition will require advanced economies to scale up donor support substantially in order to make a significant impact on emerging economy transitions (Climate Investment Funds, 2023).

This box was prepared in collaboration with V. Radaelli, N. Pufal, S. López, G. Cárdenas, P. Henriquez and A. Cathles of the Inter-American Development Bank Group. The opinions expressed in this work are those of the authors and do not necessarily reflect the views of the Inter-American Development Bank, its board of directors or the countries they represent.

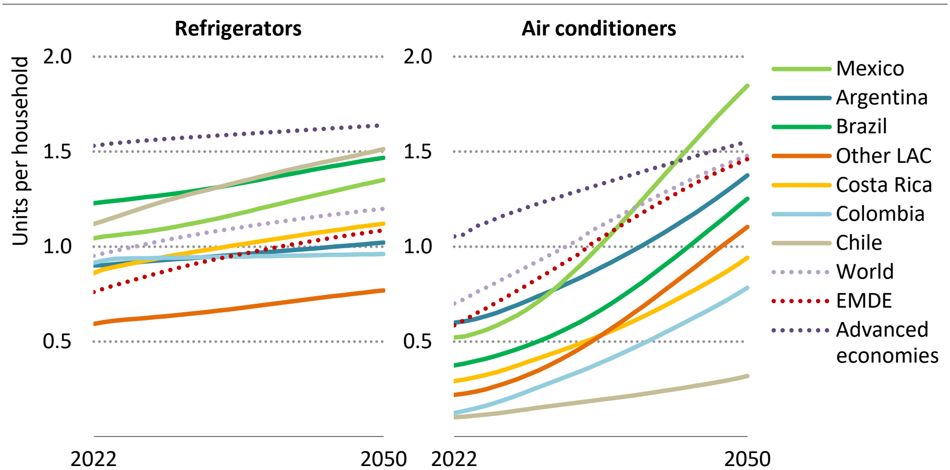
2.3.3 Buildings

Households currently account for three-quarters of energy consumption in the buildings sector, with the remaining quarter used in non-residential buildings. In residential buildings, cooking and appliances each account for almost one-fifth of energy consumption, while water heating consumes around 15%. Space heating and cooling each account for 6-7%, although there is significant variation across countries. In Argentina and Chile, countries with among the highest per capita heating demand in the region, space heating accounts for more than 20% (Chile) and up to 35% (Argentina) of energy consumption in the buildings sector.

Electricity is the most significant energy source, accounting for almost 45% of total consumption in the buildings sector. Costa Rica has a particularly high share of electricity in energy consumption in buildings, at 77%. The traditional use of biomass and oil each account for around one-fifth of energy consumption in the buildings sector, natural gas for 10% and renewables for the remaining 5%. Oil, mostly in the form of liquefied petroleum gas, is mainly used for cooking and, to a less extent, water heating. About 74 million people in LAC, slightly more than 10% of the population, still do not have access to clean cooking facilities and most of them rely on the traditional use of biomass.

Activity

Figure 2.12 ▹ Refrigeration and air conditioner ownership in selected countries/regions in the Stated Policies Scenario, 2022-2050



Ownership of refrigerators increases modestly while air conditioner ownership surges, with the highest growth rates in Colombia and Mexico

Economic progress and rising temperatures increase the significance of air conditioning on energy demand. Today ownership of air conditioners per household in the region is around half of the global average, but it quadruples by 2050 in the STEPS to around the global average, which itself rises over the period (Figure 2.12). The number of cooling degree-days moreover is projected to increase in the coming decades, implying that each air conditioner will be used more often – depending also on progress in climate mitigation. Air conditioner ownership per household doubles even in Argentina, which currently has a relatively high ownership level and sees less growth in air conditioner ownership than almost any other LAC country. Ownership of other appliances, such as dishwashers and refrigerators, increases more modestly across the region, for the most part in line with global trends.

The services sector grows by an annual average of 2.4% to 2050, contributing strongly to GDP growth. GDP growth rates are among highest in countries such as Mexico where economic structures are shifting towards more services-oriented activities, and Costa Rica where well-established services sectors are expanding rapidly.

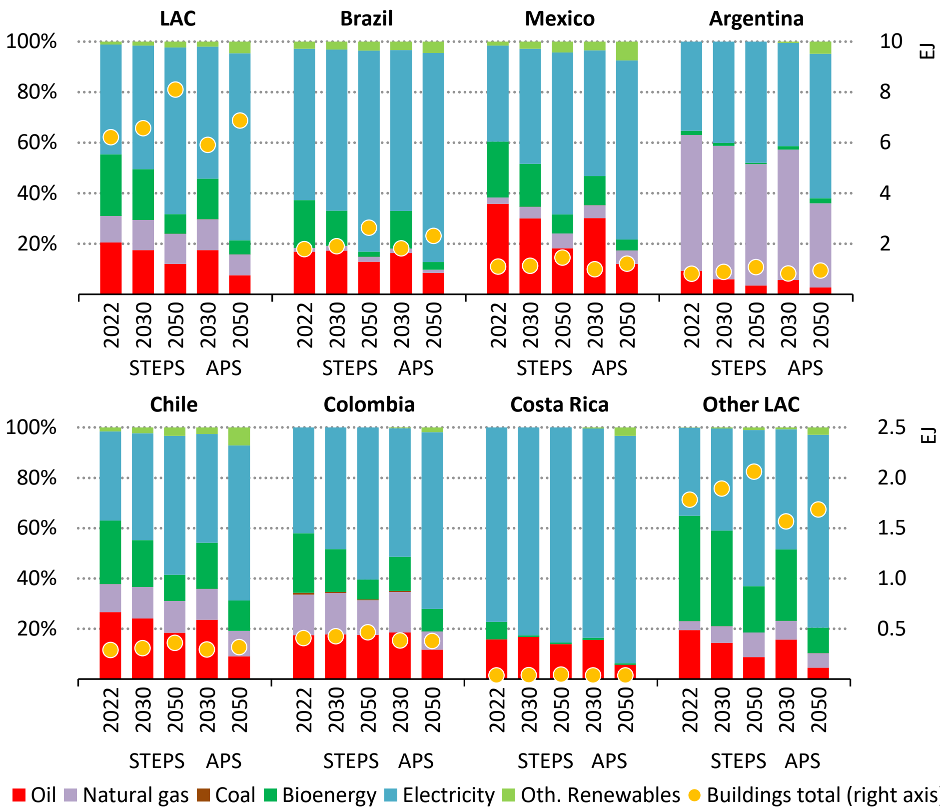
Outlook

In the STEPS, energy consumption in the buildings sector increases by around 0.7% per year to 2030. In residential buildings, progress on clean cooking involves switching from the traditional use of biomass to more efficient alternatives, and this reduces overall demand growth. Nonetheless, around 61 million people remain without access to clean cooking in 2030, falling short of the target in SDG 7.1 to achieve universal access to affordable, reliable and modern energy services (see Chapter 3, section 3.5). Residential electricity demand is driven higher to serve increasing uptake of air conditioners and appliances. Electricity reaches a share of almost 50% of energy consumption in buildings by 2030 as it also displaces the traditional use of biomass and oil for cooking and water heating. Natural gas use also displaces oil use. Mexico and Chile see the biggest increases in electrification: their share of electricity in overall energy consumption in buildings rises from 38% and 36% respectively today to 46% and 42% by 2030.

In the APS, access to clean cooking options accelerates, decreasing energy consumption in the buildings sector by 5% by 2030 compared to today. Electrification also accelerates compared to the STEPS reaching more than 50% by 2030. Argentina and Chile, countries with relatively high buildings sector energy demand per capita today, limit buildings energy consumption growth in this period to only 0.2-0.3% per year in the APS, mainly as a result of using more efficient boilers for space heating and upgrading insulation.

Improvements in clean cooking and energy efficiency reduce annual energy consumption growth to 0.4% per year to 2050 in the APS, compared to 1% in the STEPS. Electricity consumption increases significantly in both scenarios, accounting for two-thirds of all energy used in buildings in the STEPS and three-quarters in the APS. In both scenarios, the rapid expansion of air conditioner ownership leads space cooling to more than double its energy consumption compared to current levels by 2050 and become the second-largest end-use after appliances. Together cooling and appliances account for more than half of total energy consumption in buildings in 2050. Increased electrification in the APS reduces the share of oil and gas to around 15% compared with one-quarter in the STEPS (Figure 2.13). In both scenarios, by 2050 the remaining fossil fuels are mainly used for water and space heating, especially in Argentina, Chile and Mexico, and for cooking. The share of renewables in space and water heating increases in the APS from 11% today to more than a quarter by 2050.

Figure 2.13 ▷ Energy consumption in buildings by fuel and scenario in LAC and selected countries, 2022-2050



Increasing electricity use displaces the use of oil and traditional biomass in buildings, and efficiency gains reduce energy consumption in the APS

Note: Oth. Renewables = other renewables.

Policies and decarbonisation strategies

The energy mix in the buildings sector varies among LAC countries, and so do policies to moderate demand growth and reduce CO_2 emissions. Energy efficiency, however, plays a key part in all the national strategies to counterbalance the upward pressure on demand and to close the implementation gap between the STEPS and APS (see Chapter 3, section 3.2). Given the high level of urbanisation, policy guidelines for cities can play an essential role in clean energy transitions in addition to policies, measures and programmes at the national level. A good example is the target setting for net zero emissions buildings signed by Mexico City as part of the C40 Cities initiative (C40 Cities, 2021).

Two energy efficiency strategies stand out in particular:

- **Minimum energy performance standards:** Many countries already have MEPS and/or labels for domestic appliances which deliver efficiency gains in the STEPS (Table 2.3). Additional efficiency efforts in the APS reduce electricity consumption in end-uses such as appliances, space cooling and lighting from the levels in the STEPS by around 50 terawatt-hours (TWh) by 2030 and 170 TWh by 2050. This has the effect of reducing peak electricity demand by 5% in 2050.

- **Building energy codes:** Improvements in building envelopes and insulation can be incentivised by building codes, which can also increase resilience in case of catastrophic events. Currently, only few LAC countries have mandatory building energy codes, which is a much lower proportion than in most other regions. Some countries such as Brazil and Argentina have established voluntary performance standards, but experience elsewhere suggests that progress depends on mandatory codes that are effectively enforced. Building codes are being developed or improved in a number of countries, with Peru recently updating its code and the Dominican Republic, Guyana, and Trinidad and Tobago currently in the process of developing new codes.

Table 2.3 ⊳ Key buildings sector policies in selected countries

Country	Building codes		Appliances		Cooling	
	Mandatory	Voluntary	MEPS	Labels	MEPS	Labels
Argentina, Ecuador, Peru	●	●	●	●	●	●
Brazil, Costa Rica, Mexico	○	●	●	●	●	●
Chile, Cuba	●	●	○	●	●	●
Colombia	○	●	○	●	○	●
Uruguay	○	○	○	●	●	●
Bolivia	○	○	○	●	○	●
Honduras, Panama, Venezuela	○	○	○	○	●	●
Paraguay	●	●	○	○	○	○
Nicaragua	○	○	○	○	●	○

Policy implemented: ○ No ● Yes

Note: MEPS = minimum energy performance standards.

Electricity and renewable sources help to displace the use of fossil fuels for space and water heating in the buildings sector. In the APS, electricity provides 31% of space heating and 38% of water heating by 2050 and is accompanied by rising sales of heat pumps and other electric heating equipment. Sales of heat pumps surge in Mexico, Brazil and Chile. Solar thermal devices expand to provide almost one-quarter of the energy needed for water heating by 2050 in the APS, compared to 7% today.

Natural gas continues to be used for heating in particular, but its role decreases over time. In Argentina, the share of natural gas in space heating decreases in the APS from 88% today to 73% in 2050. By contrast, in Chile, which also consumes a significant amount of energy for space heating, the share of natural gas increases in the APS from 5% today to 15% in 2050 as it reduces reliance on firewood for heating. This replacement requires political support as the shift from free firewood to natural gas increases cost for households.

Today district heating systems do not play a role in LAC. The region has relatively low space heating needs and district systems require significant investment. Yet, high levels of urbanisation and increasing cooling needs suggest potential for district cooling systems. Recently a number of countries have initiated feasibility studies to assess opportunities. Colombia currently has a few pilot projects: these include the *La Alpujarra* project, which is delivering cooling to several public buildings with the goal of promoting energy efficiency and replacing air conditioners that operate with ozone depleting refrigerants (EPM, 2022). In Trinidad and Tobago, two district cooling pilot projects were launched at the end of 2022 supported by a Global Environment Facility grant (Ministry of Planning and Development Trinidad and Tobago, 2022).

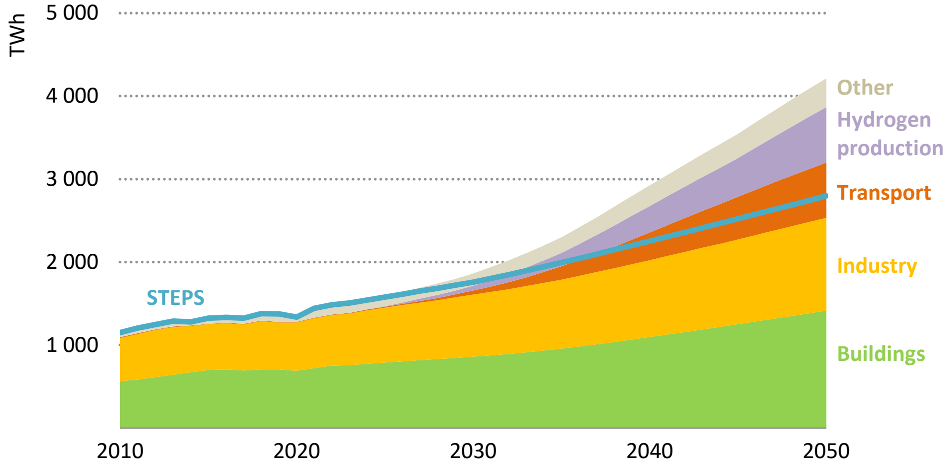
2.4 Electricity sector

2.4.1 Electricity demand

Electricity demand in Latin America and the Caribbean is set to increase by an annual average of 2.3% from 2022 to 2050 in the STEPS compared with just 1.8% over the past decade. In the past ten years, electricity demand grew by 235 TWh. In the STEPS, it increases over the next decade by over 360 TWh, and over the next three decades by over 1 300 TWh, which is equivalent to 2.3-times the total electricity demand in Brazil in 2022. As a result, the share of electricity in total final consumption in the STEPS increases from 20% in 2022 to over 25% by 2050. In the APS, electricity demand rises by more than twice as much in absolute terms to 2050 (Figure 2.14), with more rapid electrification of transport and other end-uses alongside hydrogen production raising the share of electricity in total final consumption to 40% in 2050.

In sectoral terms, total electricity demand growth in the STEPS is driven primarily by the buildings and industry sectors. They account for over 90% of growth by 2030 and continue to account for the majority of growth through to 2050. Buildings alone account for half of total electricity demand growth to 2030, due in large part to increases in demand for cooling and appliances. The electrification of transport and the use of electricity for hydrogen production are less significant: despite rapid growth, they account for a combined 10% of total electricity demand growth to 2030, and 20% to 2050. In the APS, however, demand growth is driven much more heavily by transport and hydrogen production, which ramp up much faster than in the STEPS: they are responsible for 40% of overall demand growth to 2030 and 80% to 2050. Increased demand in buildings, although moderated by improvements in energy efficiency, rises nearly as much as in the STEPS.

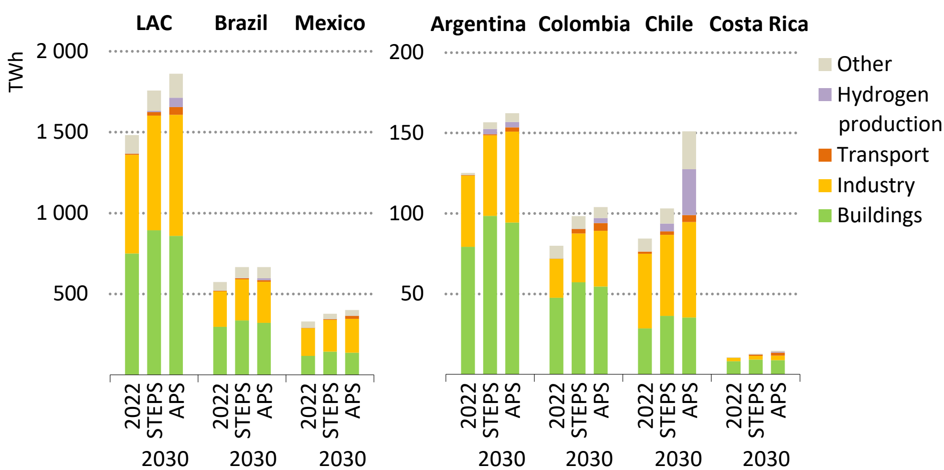
Figure 2.14 ▷ Electricity demand by sector in LAC in the Announced Pledges and Stated Policies scenarios, 2022-2050



Electricity demand increases rapidly in the industry and buildings sectors, and from the 2030s also in transport and hydrogen production

Note: TWh = terawatt-hours.

Figure 2.15 ▷ Electricity demand by sector and scenario in LAC and selected countries, 2022 and 2030

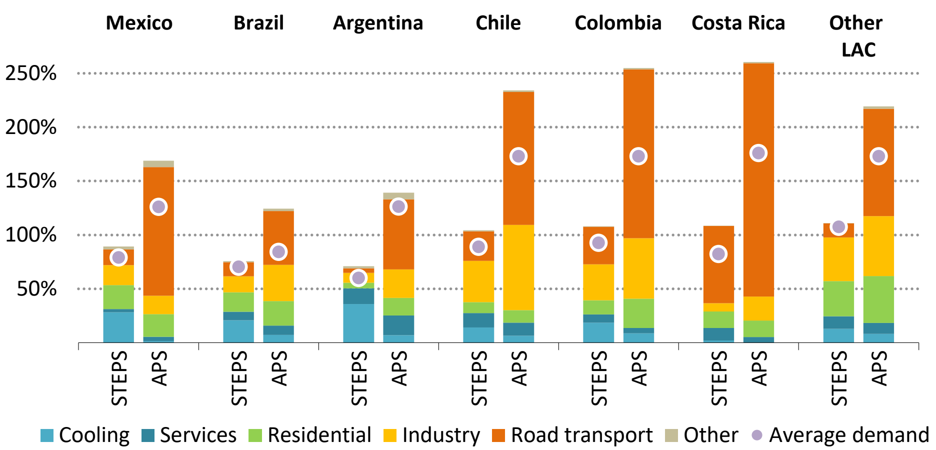


Electricity demand is set for robust growth in both scenarios, in part due to escalating ownership of air conditioning – a key factor in buildings

Within the region, total electricity demand in the STEPS grows fastest in Chile, where it increases by over 20% by 2030 and more than doubles by 2050. This increase is driven largely by hydrogen production, which soars from near zero in 2022 to account for over one-third of Chile's electricity demand growth to 2030 and increases this share to 50% to 2050 (Figure 2.15). However, this increase in electricity demand in Chile represents less than one-tenth of overall LAC electricity demand growth to 2030. Brazil is responsible for a third of all LAC demand growth through to 2050, with most of the demand coming in its buildings and industry sectors. Electricity demand also rises strongly in several other countries, including Costa Rica, Argentina and Colombia, where each averages around 2.2% growth per year from 2022 to 2050. In the APS, demand grows faster in Chile than anywhere else, reaching 6.5-times higher than 2022 levels by 2050; a widening gap compared to the STEPS that mostly reflects a much faster ramp-up of hydrogen production in the APS.

The increase in electricity consumption has a significant impact on annual peak electricity demand in both scenarios. Higher levels of air conditioner ownership make demand more temperature sensitive, and rising EV sales increase the risk of rapid variations in demand caused by uncontrolled charging. As a consequence, peak demand doubles in Chile, Colombia and Costa Rica in the STEPS and more than triples in the APS (Figure 2.16). Peak demand rises faster than average demand in all countries in the STEPS, and even more so in the APS, where electrification moves ahead much faster.

Figure 2.16 ▷ Increase in peak electricity demand by sector and scenario in selected countries in 2050 relative to 2022



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Peak demand rises faster than average demand in each scenario, driven by higher levels of air conditioner ownership and increasing electric mobility

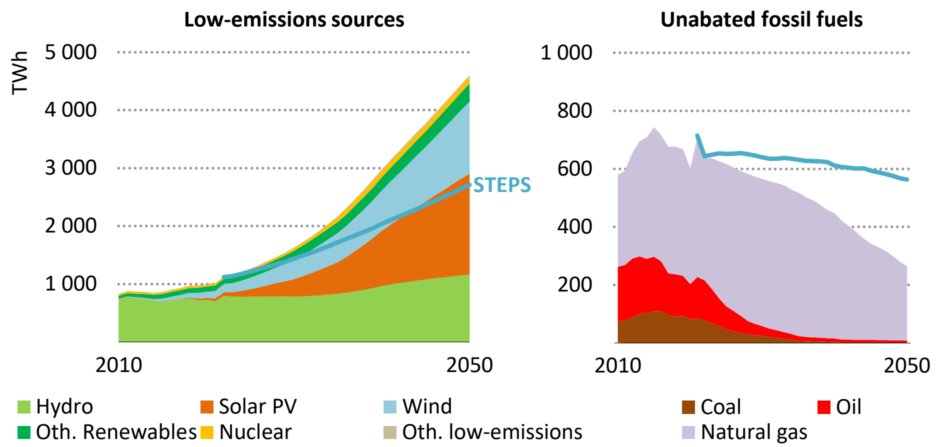
Note: Peak demand is defined as the 500 highest load hours of the year.

Meeting peak demand is a critical test of power system reliability, and energy efficiency has a central part to play in this. In the APS, for example, the contribution of air conditioning to the increase in peak demand is cut in half compared to the STEPS as a result of more stringent MEPS. The increase in peak demand can also be mitigated through demand-response management, given that a large share of the increase is driven by end-uses with significant flexibility potential, such as EVs and air conditioners. For example, finding ways to shift EV charging from the hours with the highest cooling needs in daytime to the evening makes a significant contribution to limiting the daily peak. Demand-response measures enabled by tools such as the use of smart meters in distribution networks are being implemented across several countries in the region.

2.4.2 Electricity generation

The electricity mix in Latin America and the Caribbean is set to be reshaped over the next 30 years in both the STEPS and APS. Most demand growth is met through rapidly rising deployment of wind and solar PV.

Figure 2.17 ▷ Electricity generation from low-emissions sources and unabated fossil fuels in LAC in the Announced Pledges and Stated Policies scenarios, 2010-2050



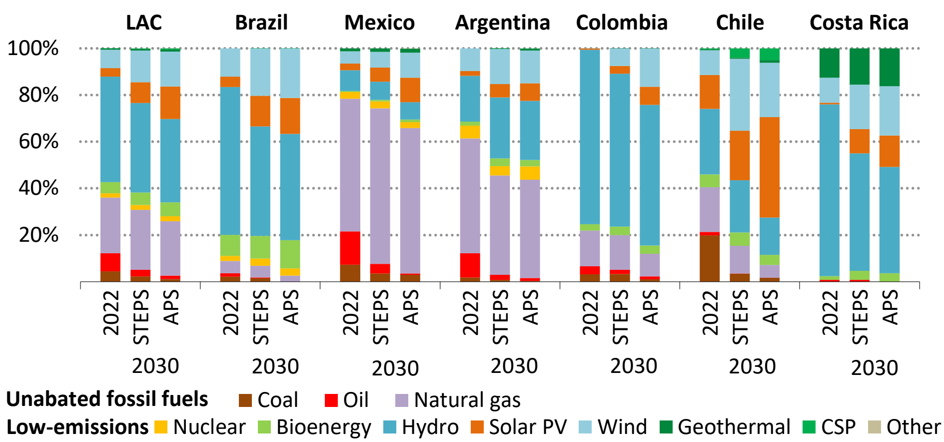
Led by solar PV and wind, renewables expand rapidly to meet all new demand and displace coal and oil in the APS, while natural gas generation continues to decrease

Notes: Oth. = Other. Solar PV includes both utility-scale and distributed projects.

In the STEPS, the share of low-emissions sources in total generation rises from 63% in 2022 to over 80% in 2050, with more than two-thirds of the increase coming from solar PV and wind. Hydropower output rises by 260 TWh to 2050, but it increases more slowly than demand. The share of hydropower in total generation falls from 45% today to less than 35% by 2050 (Figure 2.17). The use of unabated fossil fuels falls significantly: they were responsible for 36% of generation in 2022 but are reduced to half that share by 2050. Oil and coal use falls sharply, while demand for natural gas, which is already the fossil fuel with the largest share in generation, increases by one-quarter to 2030, peaks around 2040 and falls back to around the 2030 level in 2050. The average CO_2 emissions intensity of electricity generation drops by two-thirds from 216 grammes of carbon dioxide per kilowatt-hour (g CO_2/ kWh) in 2022 to about 70 g CO_2/kWh in 2050.

In the APS, deployment of solar PV and wind accelerates, and their share of total generation rises to 30% by 2030 and reaches 60% in 2050. Hydropower continues to be the foundation of electricity supply in LAC and provides one-quarter of electricity in 2050. Taken together low-emissions sources account for 95% of total electricity generation by 2050, and the share of unabated fossil fuels falls to 5%. While natural gas continues to serve as an important dispatchable source of generation, coal and oil are nearly phased out by 2040. The share of fossil fuels in power generation falls in most countries in the region: in Mexico, Argentina and some others it falls by 50% from the 2022 level. The net result of the changes is that the CO_2 emissions intensity of electricity generation drops to one-tenth of 2022 levels by 2050.

Figure 2.18 ▷ Electricity generation mix by source and scenario in LAC and selected countries, 2022 and 2030



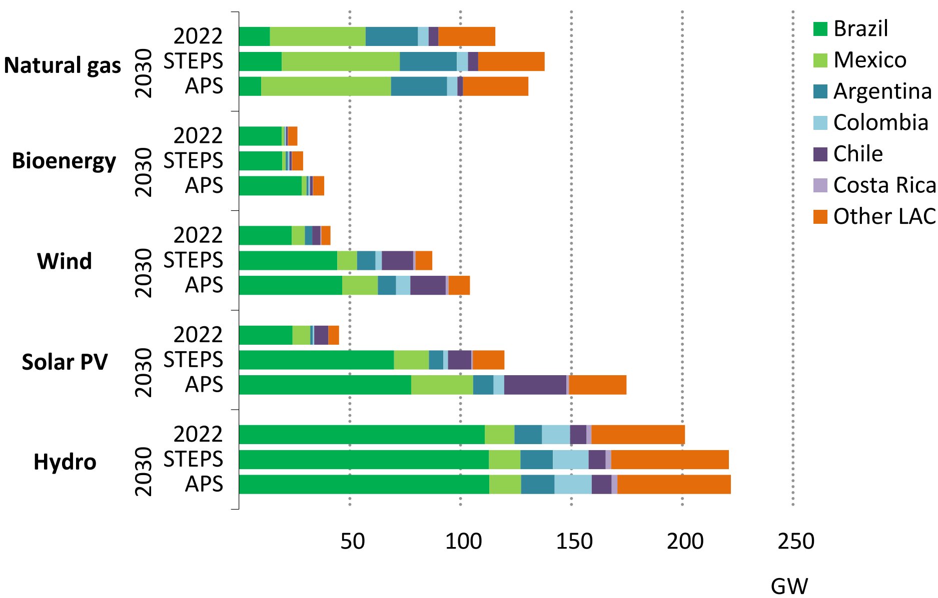
Hydro continues to be the largest source of generation, but an expanded suite of renewables leads to higher shares of low-emissions electricity generation

Each country in Latin America and the Caribbean aims to decarbonise generation while making use of natural resources and existing infrastructure in the way that best suits their electricity needs. For several, including Brazil, Colombia, Costa Rica and Paraguay, this means that hydropower continues to be the main source of electricity. It provides over 40% of total power generation in LAC in 2030 in both scenarios (Figure 2.18). In Costa Rica, geothermal maintains a 15% share of total generation through to 2050 in the APS. In Mexico and Argentina, natural gas continues to provide far more generation than any other source through to 2030. The speed of change varies among countries in the region, with some shifting more quickly than others to low-emissions sources of electricity. Change happens particularly quickly in Chile, where coal constituted 20% of generation in 2022 but is almost entirely phased out by 2030. In the STEPS, 85% of generation needs in Chile are met by low-emissions sources by 2030. In the longer term, concentrating solar power provides additional system flexibility. In the APS, solar PV generation in Chile rises by 2030 to triple the level in the STEPS to meet rapidly rising energy demand for hydrogen production.

2.4.3 Installed power capacity

In both scenarios, renewables capacity accounts for 80% of new additions in the period to 2030. Solar PV and wind are responsible for over 60% of all capacity additions to 2030 in the STEPS and nearly 70% in the APS, but other renewables including hydropower, bioenergy and geothermal also increase. Natural gas is the only fossil fuel source that sees any significant increase in capacity to 2030, although it represents just 15% of new capacity additions in the STEPS and over 10% in the APS. Coal and oil capacity additions are less than 1% in both scenarios. Nuclear power capacity increases, concentrated in Brazil, Mexico and Argentina, which have existing nuclear power programmes, with additions to 2050 less than 2% of total additions in both scenarios. In the APS, more renewables capacity is installed across the region and there are less additional natural gas-fired capacity additions than in the STEPS.

Figure 2.19 ▷ Installed capacity by selected sources and countries in the Stated Policies and Announced Pledges scenarios, 2022 and 2030



Hydropower's foundation is bolstered by strong growth for solar PV and wind, complemented by bioenergy, while the dispatchability of natural gas has an ongoing role

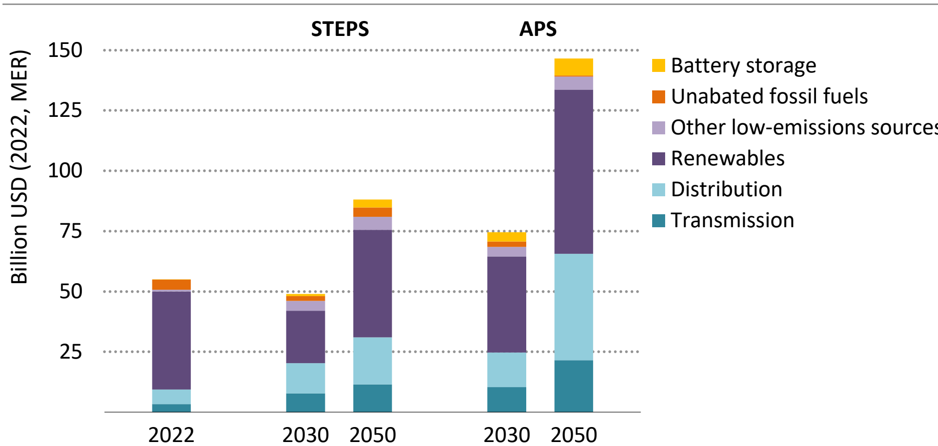
Note: GW = gigawatt.

In the STEPS, hydropower continues as the base in installed power capacity, though solar PV capacity expands rapidly. By 2030, hydropower and solar PV together account for 50% of installed capacity (Figure 2.19), with natural gas and wind accounting for 20% and 13% respectively of total capacity. In the APS, the electricity mix is entirely reshaped by 2050, with solar PV alone comprising over 40% of all installed capacity in the region. Wind also expands, and together solar PV and wind account for 60% of total installed capacity in 2050, which is nearly four-times as much as hydropower. Natural gas-fired capacity remains broadly flat to 2050. Coal capacity falls by 90% and oil by two-thirds: the overall decline in unabated fossil fuels is around 25%.

2.4.4 Power sector investment

Power sector investment increases in each scenario to meet rising electricity demand and to modernise and expand grid infrastructure. In the STEPS, after remaining broadly stable to 2030 and benefiting from declining costs for solar PV and wind, power sector investment rises to 60% above the level in 2022 (Figure 2.20). Investment in renewables and grids accounts for the majority, complemented by smaller amounts for other low-emissions sources and unabated fossil fuels. In the APS, power sector investment increases much more rapidly to deliver faster clean energy transitions and meet higher demand. By 2050, it rises to over 2.5-times the level in 2022, with a 70% increase in investment in renewables, and is two-thirds higher than in the STEPS. Scaling up investment in both scenarios means mobilising more private capital and developing innovative business models (see Chapter 3, section 3.9).

Figure 2.20 ▷ Investment in the power sector by category and scenario in LAC, 2022, 2030 and 2050



Power sector investment continues to climb in both scenarios, propelled by renewables capacity additions and grid expansion

Note: MER = market exchange rate.

Investment in grids increases in the STEPS from 17% of total power sector investment in 2022 to around 35% in 2050, and spending well over triples from 2022 levels to around USD 30 billion by 2050. In the APS, grid investment increases even more dramatically by 2050. Investment in transmission networks increases nearly 6.5-fold from 2022 levels to reach over USD 20 billion while investment in distribution networks increases more than 7-times to USD 45 billion. Investments are driven by the need to meet increases in demand, integrate renewable capacity additions and modernise existing grid infrastructure, including through digitalisation.

Rapidly increasing demand for electricity and additions of renewables power capacity boost the need for significant expansion of the supporting grids. In the STEPS, the electricity network in LAC expands from around 9 million km of lines and cables in 2022 to 10 million km in 2030 and 13.6 million km in 2050. In the APS, the LAC electricity network grows to 17 million km of lines and cables by 2050. The expanded network helps to make grids more robust and to enhance regional integration while enabling grids to support energy transitions throughout Latin America and the Caribbean.

2.4.5 Power system flexibility

Power system flexibility[4] needs in Latin America and the Caribbean are projected to increase considerably over the outlook period. They are met by a combination of hydropower, thermal power plants, batteries and demand response.

Increasing shares of variable wind and solar PV electricity generation and changes in electricity demand profiles are the primary drivers of power system flexibility needs. The expanding share of generation from non-dispatchable wind and solar PV increases the variability of the residual load (the load that remains after removing wind and solar production from electricity demand). On the supply side, hydropower is a significant source of power system flexibility, but is subject to variations in precipitation between seasons and across years. On the demand side, the increasing adoption of air conditioning in many LAC countries, increased use in industry, and electrification of transport together push higher peaks in demand for electricity and increase the hourly, daily and seasonal variability of electricity consumption, though they also provide additional opportunities for demand response.

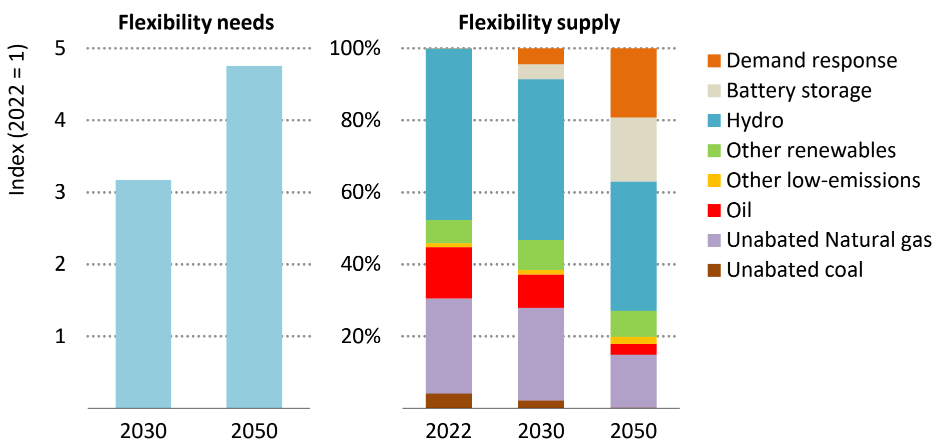
Grids also play a vital role in enhancing system flexibility across all timescales. By connecting different power sources across large areas within and across countries, grids and interconnections help to balance variations in demand and supply of weather-dependent variable renewables. This reduces the need for flexibility from other sources while at the same time increasing efficiency and reducing costs. Although seasonal and inter-annual variations play an increasingly important role in systems characterised by high shares of

[4] Flexibility is defined as the ability of a power system to reliably and cost effectively manage the variability of demand and supply. It ranges from ensuring the instantaneous stability of the power system to supporting long-term security of supply.

variable renewables and hydropower, the change in residual load from one hour to the next remains a useful indicator for flexibility needs, and is used in this analysis. The impact of seasonal and inter-annual variability and the potential role of grids and regional integration in meeting these and other flexibility challenges is discussed in more detail in Chapter 3 (see section 3.6).

The APS projects a more significant rise in the share of variable renewables in power systems across the region than the STEPS. The combined share of wind and solar PV in the electricity mix rises from 11% today to nearly 30% by 2030 and exceeds 60% by 2050 in the APS. Electricity demand for space cooling more than doubles over the outlook period which increases variability by raising the temperature sensitivity of total electricity demand. This in turn increases the need for system flexibility to balance supply and demand continuously and to maintain grid stability. In the APS, flexibility needs across the region triple by 2030 and rise almost fivefold by 2050 (Figure 2.21).

Figure 2.21 ▹ Flexibility needs and flexibility supply in LAC in the Announced Pledges Scenario, 2022, 2030 and 2050



Hydropower remains a key source of power system flexibility, increasingly complemented by batteries and demand-response measures

Hydropower is an essential provider to meet hour-to-hour flexibility needs in many LAC countries, notably Brazil, Colombia and Argentina. In 2022, it accounted for half of the flexibility supply, with most of the remainder provided by thermal power plants burning natural gas and fuel oil. While the hydropower contribution to meet flexibility needs is projected to increase in absolute terms in the APS as its capacity increases, its share in the flexibility supply mix drops to around a third by 2050 as electricity demand rises faster than hydropower capacity.

After 2030, hydropower, as a source of flexibility in power systems, is increasingly complemented by demand-response measures and battery storage. These emerging sources of power system flexibility are projected to contribute in a significant manner to power system flexibility and to their enhanced security through to 2050. Batteries are well suited to smooth daily variations in solar PV feed-in, while demand-response technologies have the potential to decouple energy service demand and electricity consumption. For example, they are able to do this by scheduling the charging of EVs through smart charging or by adjusting the operation of air conditioners or electric heaters in response to signals from the grid through smart controls. In addition to digital tools, making the most of the significant demand-response potential that exists requires an effective regulatory framework and adequate price signals. A variety of measures are already being implemented in several countries across the region, which provides a base to build upon.

While the share of flexibility provided by thermal power plants decreases, they remain an important source of flexibility over longer timescales in the APS. They retain a valuable role in countries that face seasonal fluctuations in demand, for example. In absolute terms, natural gas-fired power plants in LAC provide about as much flexibility in 2050 as they do today. Coal is almost phased out from the electricity mix. Low-emissions thermal power plants, including bioenergy and nuclear, remain important sources of flexibility.

2.5 Energy production

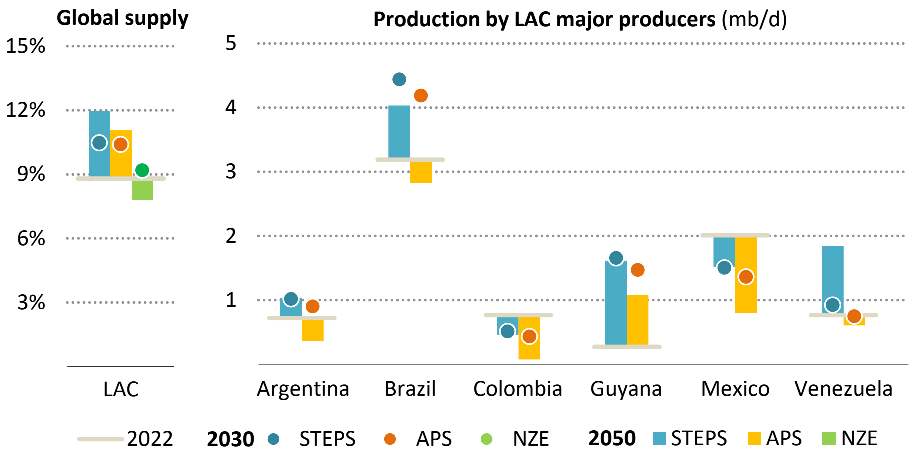
2.5.1 Fossil fuels

The outlook for fossil fuel supply in Latin America and the Caribbean varies significantly by fuel. The region is a net crude oil exporter. Exports should increase in tandem with production in the coming years as new offshore developments in Brazil and Guyana come online. On the other hand, the region is a net importer of natural gas, and many countries are looking to use gas as a relatively low-emissions fuel. Coal production plays a minor role in the region, and one that is likely to diminish further. Colombia is the key coal producer, though most of its production currently is used to generate power in markets where renewables are increasingly the preferred choice for new capacity.

Oil

LAC countries produced more than 8 million barrels of oil per day (mb/d) in 2022, which amounted to just under 10% of global oil supply. Most was used to meet demand in the region. While the outlook varies from producer to producer, overall oil output in LAC rises in the STEPS to 2030 and then increases further through to 2050. In the APS, it declines after 2030 as domestic and global oil demand contracts (Figure 2.22). In the NZE Scenario, oil supply starts to decline before 2030 and the region mostly maintains its share of global production up to 2050.

Figure 2.22 ▷ Share of LAC in global oil supply, and LAC oil production by country and scenario in 2030 and 2050 relative to 2022



Most major LAC oil producers increase output to 2050 in the STEPS, while production declines in the APS in all countries except Guyana

The value of oil production in LAC in 2022 totalled around USD 230 billion, which equates to around 2% of the region's GDP. Brazil was the main producer, accounting for over 35% of supply. Mexico was the second-largest producer with nearly 25%, followed by Colombia, Venezuela and Argentina, each responsible for slightly less than 10%. Other producers include Ecuador and Guyana. LAC producers are at various stages of resource development. In Venezuela, oil production dropped from around 3 mb/d in 2010 to below 1 mb/d in 2022 and is projected to remain around this level for the rest of the decade. In Brazil, production increased by nearly 45% from 2010 to 2022. Guyana started oil production recently, experiencing a surge in offshore discoveries (Box 2.2), and it could see its 2022 output increase over five-times by 2030. Conventional oil resources in Argentina are showing signs of decline, with production falling from 2010 to 2022, but the development of unconventional resources might provide new avenues of growth, and investments are being made to increase export capacity in view of this potential development.[5]

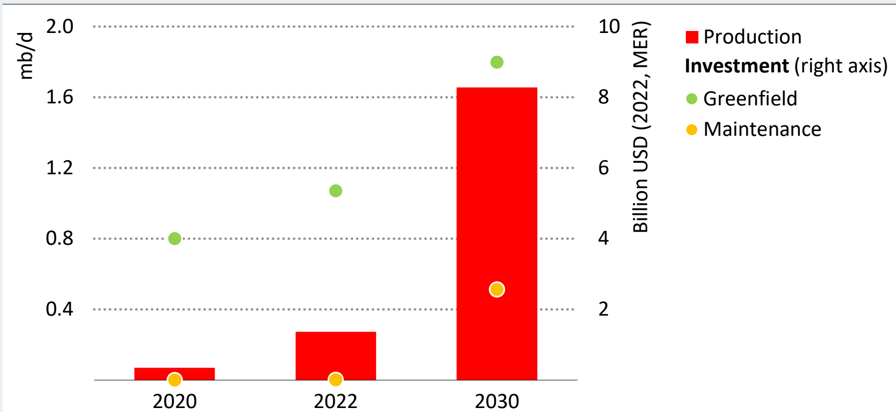
The outlook for oil supply shows overall potential for growth, especially in the near term, though this does not hold true for all for producers. In the STEPS, the LAC share of global oil supply increases gradually to 2050. In the APS, the region's share of global oil supply increases more slowly, staying around 10% throughout the outlook period.

[5] Unconventional oil resources generally include: extra-heavy oil and bitumen, kerogen oil and tight oil; unconventional gas resources usually include: shale gas, tight gas, coal bed methane and gas hydrates.

Box 2.2 ▷ New oil discoveries abound in Guyana

Guyana has emerged as one of the main sources of new global oil supply due to major offshore developments. Exploration activity started to accelerate with the discovery of the Liza field in 2015, which is around 190 km offshore. Since then, several discoveries in the Stabroek Block have followed, including the Payara, Liza Deep, Snoek, Ranger, Longtail, Tilapia, Yellowtail, Redtail, Whiptail and Sailfin fields. Oil and gas discoveries have brought substantial investment and transformed Guyana's economic prospects. Production from the Liza Phase 1 project began in December 2019, with Liza Phase 2 following in February 2022 (Exxon, 2023). Together they increased Guyana's oil output to nearly 0.3 mb/d in 2022. In the STEPS, investment to develop oil and gas supply increases to over USD 10 billion by 2030 (Figure 2.23).

Figure 2.23 ▷ Oil production and investment spending in Guyana in the Stated Policies Scenario, 2020, 2022 and 2030



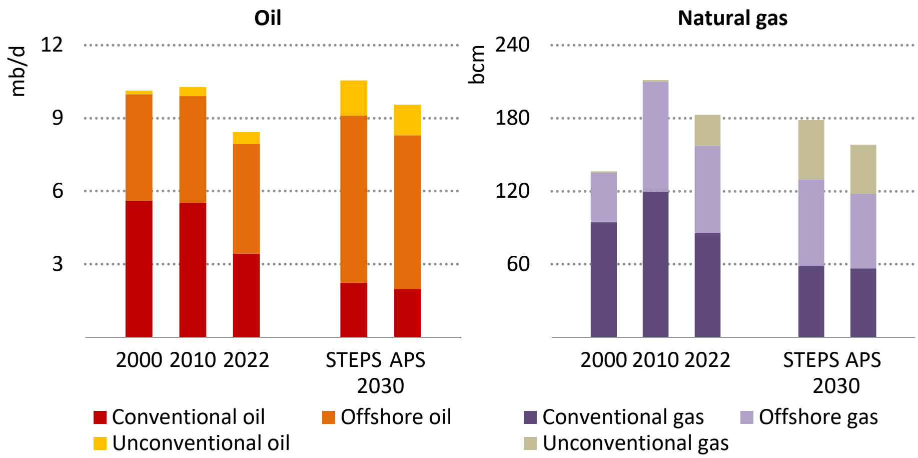
Oil production surges to reach over 1.6 mb/d by 2030, with annual investment in greenfield operations increasing to just under USD 10 billion

The surge in oil and gas activity comes with challenges, including the need to ensure high standards of transparency and environmental protection. There is also the question of how Guyana chooses to use its oil and gas revenue. This could play a key part in determining how the country adjusts to the global energy transition and in shaping the course it sets for its development.

Oil supply in LAC countries increases from 2022 to 2030, reaching around 11 mb/d in the STEPS and 10 mb/d in the APS, and net exports increase by nearly 2 mb/d in both scenarios. This reflects production increases of more than 1 mb/d to 2030 in both Brazil and Guyana. Argentina adds less than 0.5 mb/d to its production, and oil supply slowly declines in Mexico, Colombia and Ecuador.

Supply trends start to diverge in the STEPS and APS after 2030. In the STEPS, production continues to rise, reaching nearly 12 mb/d by 2050. Venezuela doubles its oil production from 2030 to 2050. In the APS, oil supply decreases by more than 35% from 2030 to 2050. All producers cut output due to lower demand for oil both domestically and internationally. In line with its net zero emissions pledge, Brazil reduces its oil demand by more than 45%, and its production falls by almost 1.5 mb/d from 2030 to 2050.

Figure 2.24 ▷ Oil and natural gas production by source and scenario in LAC, 2000-2030



Offshore fields are the main source of new supply, but unconventional oil and natural gas resources also increase their share of production to 2030

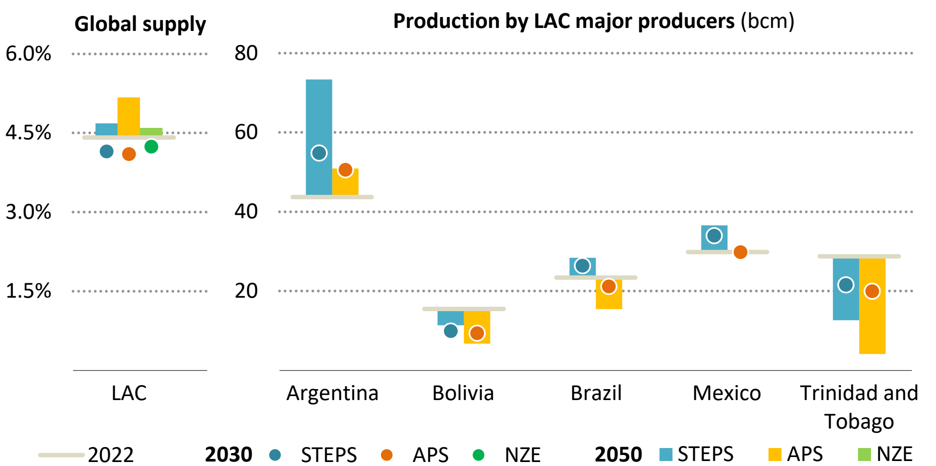
Natural gas

LAC countries produced just under 185 billion cubic metres (bcm) of natural gas in 2022, representing slightly less than 5% of global supply. In the STEPS, output declines slightly in the region to 2030. After that, the development of unconventional gas reserves in Argentina leads to a rebound in production (Figure 2.24). In the APS, regional natural gas demand falls substantially in the long term. As a result, fewer new fields are developed, and production continues to drop over the outlook period.

Argentina is the main natural gas producer in the region, accounting for nearly 25% of supply, with close to 60% of its production coming from unconventional resources (up from less than 2% in 2010). Mexico is the second-largest producer with over 15%, closely followed by Trinidad and Tobago with a similar share, and by Brazil with just under 15%. Bolivia, Venezuela and Peru each account for another 5-10%. Supply has increased in the last decade in some countries, notably Brazil, Peru and Argentina, but in general it has been on the decline. LAC natural gas production in 2022 was more than 15% lower than in 2010.

Over 90% of natural gas supply is consumed in the region in the power, industry, transport and buildings sectors. Trinidad and Tobago is the main exporter of liquefied natural gas (LNG): it shipped around 12 bcm to importing countries in 2022. Natural gas production is a major driver of the economy in Trinidad and Tobago, and extraordinary prices pushed up the value of its exports to around USD 12 billion in 2022, such that gas export revenues were equivalent to nearly 40% of its GDP. Bolivia is another key exporter of natural gas, sending around 11 bcm by pipeline to Brazil and Argentina in 2022. Many other countries in the region import natural gas to meet domestic demand. Mexico is the major importer: it brought in more than 45 bcm from the United States via pipelines in 2022.

Figure 2.25 ▹ Share of LAC in global natural gas supply and production by country and scenario in 2030 and 2050 relative to 2022



LAC natural gas production declines slowly to 2030 in the STEPS and then picks up considerably as new unconventional resources are developed in Argentina

Natural gas supply in the region peaked in the mid-2010s and there is little prospect for growth in the period to 2030. Production falls to less than 180 bcm by 2030 in the STEPS, and to just under 160 bcm in the APS. Many of the major producers are facing declining reserves and production, including Colombia, Bolivia, Venezuela and Trinidad and Tobago, though decreases in these countries are somewhat offset by increased output in Argentina, Mexico and Brazil (Figure 2.25). After 2030, Argentina is set to develop substantial unconventional natural gas fields. In the STEPS, it increases its production by over one-third from 2030 to 2050, causing aggregate regional natural gas production to rebound and rise above the current level to 195 bcm in 2050. In the APS, natural gas production in LAC continues to decrease after 2030, dropping to 125 bcm by 2050. Output plateaus in Mexico and declines in all other countries except Argentina, where production increases by around 15% to 2030 and then remains mostly stable through to 2050. This surge in production enables Argentina to become a net exporter of natural gas.

Some LAC countries see natural gas as a relatively low-emissions fuel that may contribute to meeting higher demand and provide important energy services such as power generation during demand peaks. However, increased natural gas production carries the risk of stranded assets, including underutilised pipelines or LNG facilities (see Chapter 3, section 3.7).

Coal

The region produced around 65 million tonnes of coal equivalent (Mtce) in 2022, representing just 1% of global coal supply. Colombia is the dominant producer, accounting for around 90% of production, and its coal exports reached over USD 20 billion in value in 2022. The second- and third-largest coal producers, Mexico and Brazil, produced just over 3 Mtce each in 2022. Except for Colombia, coal production mainly serves domestic demand. More than 90% of the coal produced in Colombia is steam coal that is primarily used for power generation, of which over 95% is exported. Today Europe is the main market for Colombian coal exports, but close to 30% is exported to other LAC countries.

Coal production declines in all scenarios. Production drops by over 45% between 2022 and 2030 in the STEPS, and by nearly 60% in the APS. From 2030 to 2050, coal production plateaus in the STEPS, while it is almost completely phased out in the APS. Shrinking export markets for steam coal are the main driver of this decline. Many countries have pledged to decarbonise their electricity sectors to achieve net zero emissions targets. In Europe – the main destination for Colombian coal cargoes – most countries are already taking steps to replace coal-fired power plants with cleaner alternatives such as wind and solar. The same trend holds for other advanced economies. Coal growth is also set to decrease over time in many emerging market and developing economies as renewable generation becomes increasingly cost competitive, especially in the APS. Domestic resource and climate policy objectives also drive the shift away from coal: Colombia recently announced a halt to new coal exploration permits in a move to support the emerging new clean energy economy.

2.5.2 Bioenergy and hydrogen

Bioenergy and low-emissions hydrogen, as potential substitutes for fossil fuels in hard-to-abate sectors of the economy, are essential building blocks of a low-emissions energy system.

Bioenergy

Bioenergy provided around one-fifth of the energy used in Latin America and the Caribbean in 2022, and it is projected to remain a significant contributor. This underscores the necessity of stringent parameters that define what counts as *sustainable* bioenergy.

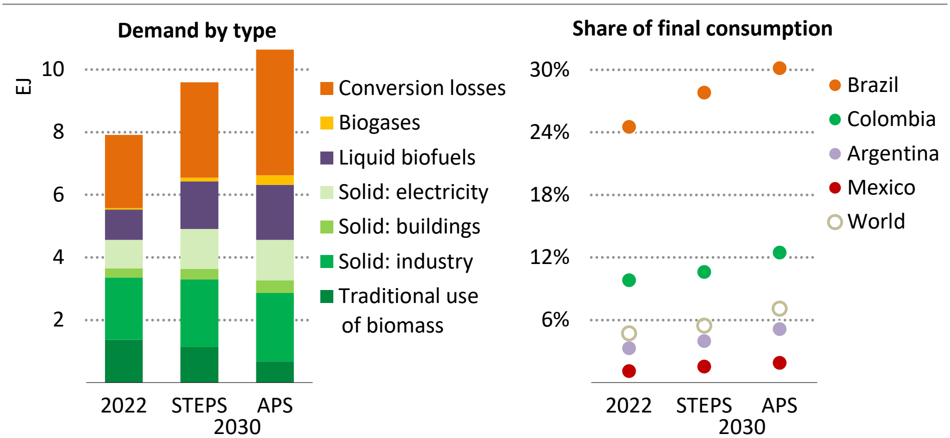
In 2022, about one-sixth of bioenergy production in LAC was traditional biomass for use in household heating and cooking, a proportion that has nearly halved since 2000. Traditional use of biomass is inefficient and causes household air pollution that has been linked to an over 80 000 premature deaths in the region. Replacing traditional biomass use with modern solid bioenergy alternatives is more energy efficient and avoids negative health and environmental impacts.

Over 35% of demand for modern solid bioenergy is for use in manufacturing, mostly in light industry such as food and tobacco production. Yet some bioenergy use in manufacturing can also be inefficient and polluting, for instances brick making. Around one-sixth of modern solid bioenergy in LAC is used to generate electricity, and the remainder is used in the agriculture and buildings sectors.

Demand for liquid biofuels was almost 1 000 petajoules (PJ) in 2022, about three-times the global average on a per capita basis. Around 95% is used in road transport. Most of the remainder is used in chemicals feedstocks or agricultural production.

The STEPS and the APS both project growth in modern bioenergy demand (about 20% and 35% respectively) by 2030 compared with 2022, but this masks differences in the underlying mix of fuels and uses (Figure 2.26). In the STEPS, the traditional use of biomass decreases moderately (around 15%) by 2030, whereas in the APS it drops by half. Conversely, demand growth for liquid biofuels is stronger in the APS than in the STEPS, driven mostly by road transport and in part by new fuels for use in shipping and biojet kerosene in aviation.

Figure 2.26 ▷ Bioenergy demand by type, and modern bioenergy in final consumption by scenario in selected LAC countries, 2022 and 2030



Stronger demand growth in liquid biofuels and biogases in the APS than the STEPS, especially driven by Brazil expanding its leading position of bioenergy uses

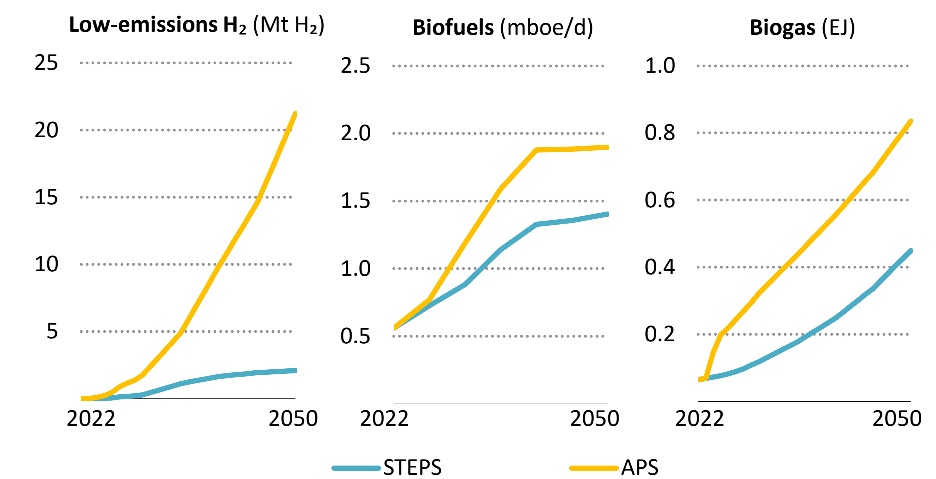
Notes: Buildings includes agriculture. Bioenergy demand excludes exported biofuels but includes the conversion losses associated with biofuels production for export.

The share of modern bioenergy in the energy mix increases only slightly (3%) in the region by 2030 in the STEPS, but more significantly in the APS (7%). However, trends differ among countries. Brazil – already the world leader in use of modern bioenergy – continues to expand its use to decarbonise, in particular, the transport sector. Biofuel mandates in Argentina and Colombia increase the share of modern bioenergy in their overall energy supply mixes: use of liquid biofuels ramps up significantly, and, to a lesser extent, so does the use of biogases. Production of modern bioenergy increases across the region to meet both domestic and export demand. The availability of bioenergy resources within the region, the competitiveness of liquid biofuels and the scope to blend biomethane into natural gas all help to stimulate demand and to displace oil products and natural gas (see Chapter 3, section 3.8).

Hydrogen

Today, hydrogen production consumes around 1.5% of the region's total energy supply. Hydrogen is mainly used in refining and chemicals production such as ammonia and methanol. Natural gas steam reforming without CCUS fuels about 80% of current hydrogen production. There is potential for electrolytic hydrogen to be produced cheaper in the region than in most other parts of the world (see Chapter 3, section 3.4).

Figure 2.27 ▷ Low-emissions hydrogen and bioenergy production in LAC by scenario, 2022-2050



Modern bioenergy use increases significantly in both scenarios; low-emissions hydrogen production rises strongly in the APS

Note: $Mt H_2$ = million tonnes of hydrogen; mboe/day = million barrels of oil equivalent per day.

In the STEPS, hydrogen production in the region increases by almost 40% from its 2022 level by 2030 and doubles by 2050. In the APS, it increases two-thirds by 2030 and six-times by 2050. Low-emissions hydrogen increases in the STEPS from almost zero to 5% of total hydrogen production in 2030 and 25% in 2050, but most of this is still fuelled by unabated natural gas. Conversely, in the APS scenario, vigorous upswing in hydrogen production stems from a rapid ramp-up of low-emissions hydrogen, particularly electrolytic hydrogen. Low-emissions hydrogen accounts for more than 25% of total production in 2030 and more than 85% in 2050 in the APS (Figure 2.27). By 2050, the proportion of total energy supply in LAC used for hydrogen production increases from 1.5% today to 2.5% in the STEPS and over 8.5% in the APS. The boost in low-emissions hydrogen production reflects its role in decarbonising hard-to-abate sectors such as iron and steel, heavy freight transport, aviation and shipping, together with its traditional use in oil refining and chemicals production. It also reflects the export potential of low-emissions hydrogen. In the APS, some low-emissions hydrogen displaces hydrogen produced from unabated natural gas in the region, but much of the increase in production is driven by its export potential (see Chapter 4, section 4.2.2).

2.6 Emissions and air pollution

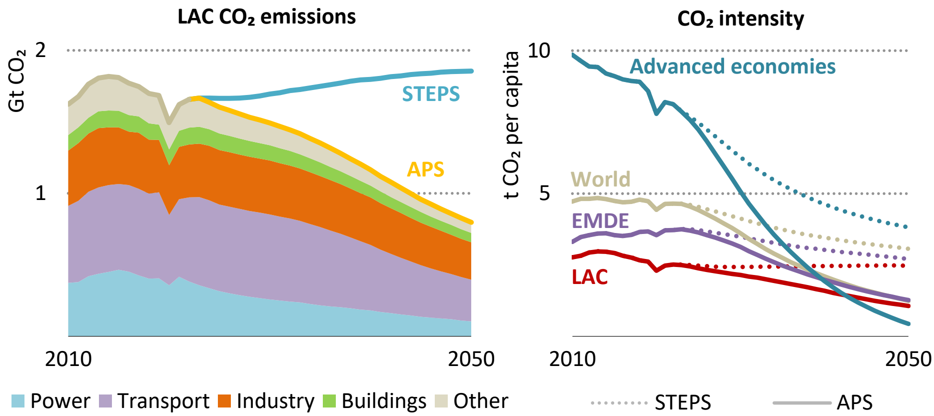
2.6.1 Energy-related CO_2 emissions

Energy-related CO_2 emissions from LAC totalled 1 660 million tonnes of CO_2 (Mt CO_2) in 2022. In the STEPS, they increase by 2% to 2030, driven by projected economic growth (Figure 2.28). The power sector, which currently accounts for around a quarter of total energy-related CO_2 emissions, sees emissions continue to decline with the accelerated deployment of renewables. By contrast, increasing industrial activity and mobility lead to higher emissions from end-use sectors, with increases of more than 10% in transport and industry. Emissions continue to rise after 2030 in the STEPS, although it is moderated by increasing electrification of end-uses and by energy efficiency gains. Total emissions reach 1 850 Mt CO_2 by 2050, a level very close to the peak seen in 2014.

Steps taken in relation to announced net zero emissions pledges and NDCs are already starting to decouple LAC economic growth from increases in CO_2 emissions by accelerating renewables expansion and the electrification of end-use sectors. In the APS, emissions decrease by almost 10% to 1 490 Mt CO_2 in 2030, which is 200 Mt CO_2 less than in the STEPS. The power sector, in which emissions decline by one-third, contributes three-quarters of the total emissions reduction. Buildings sector emissions decline with progress on electrification, while transport emissions remain close to current levels as higher EV sales and more use of biofuels almost offset rising emissions from additional internal combustion engine vehicles sales. Emissions rise 2% in the industry sector as energy-intensive production expands.

The implementation gap widens after 2030 as countries with pledges reach net zero emissions. Total energy sector CO_2 emissions in the APS subsequently almost halve from their 2030 level to just below 800 Mt CO_2 by 2050, putting them roughly 1 000 Mt CO_2 below where they are in the STEPS. This progress is driven by rapid decarbonisation of the power sector and further electrification of end-uses. Increased EV deployment reduces transport emissions by 50%, and increased electrification of light industries cut industry emissions by 30%. Emissions-intensive sectors, including energy-intensive industries, heavy freight trucks, shipping and aviation, account for more than half of remaining emissions in 2050. Many countries have pledged to offset remaining emissions outside the energy sector. In the NZE Scenario, total energy sector emissions in the region approach zero by 2050, and remaining emissions in hard-to-abate areas are offset by carbon capture in biofuel production (BECCS) and to a smaller extent by direct air capture.

Figure 2.28 ▷ CO_2 emissions by sector and scenario in LAC, and CO_2 intensity by economic grouping and scenario, 2010-2050



Implementing announced pledges leads to decreasing CO_2 emissions; emissions per capita in LAC remain below the global average in the STEPS and APS

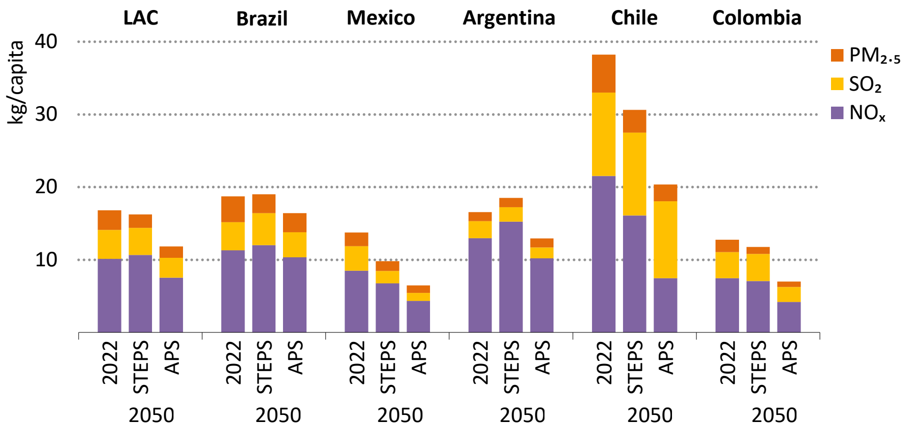
Note: Gt CO_2 = gigatonne of carbon dioxide; t CO_2 = tonne of carbon dioxide.

CO_2 intensity in LAC – currently the world's second-lowest of main regions at around half of the global average – remains below this average in each scenario. In the STEPS, CO_2 emissions per capita remain roughly constant to 2050 at around 2.5 tonnes of CO_2 (t CO_2) per capita compared to a global average of 3.1 t CO_2 per capita by 2050. Full delivery of announced pledges and NDCs in the APS leads to emissions intensity in the region decreasing to 1.1 t CO_2 per capita in 2050, which is about 0.2 t CO_2 per capita below the global average in that scenario. All countries in the region contribute to closing the implementation gap, with Costa Rica, Brazil, Colombia and Chile accelerating emissions reductions as declared in their ambitious NDCs.

2.6.2 Air pollution

Air pollution remains a concern in Latin America and the Caribbean, most notably in big cities. Although pollutant emissions on a per capita basis vary considerably by country, road transport – the leading source of nitrogen oxide (NO_X) emissions – is a common denominator. In some countries, sulphur dioxide (SO_2) emissions (mainly from coal use in electricity generation and industry) and emissions of fine particulate matter known as $PM_{2.5}$, often from the use of biomass in buildings, are also significant.

Figure 2.29 ▷ Air pollution emissions by pollutant in LAC and selected countries in 2022 and by scenario in 2050



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Air pollution does not significantly improve in the STEPS to 2050 despite progress in some countries; reductions in the APS are driven mainly by lower NO_X emissions than in the STEPS

Notes: kg/capita = kilogrammes per capita; NO_X = nitrogen oxides; $PM_{2.5}$ = fine particulate matter; SO_2 =sulphur dioxide. Data for 2022 are estimated.

Source: IEA analysis based on IIASA modelling.

Exposure to ambient air pollution led to around 85 000 premature deaths in LAC countries in 2022, largely as a result of the emission of pollutants by the buildings, industry and transport sectors. Breathing polluted indoor air also caused around 84 000 premature deaths, principally due to the traditional use of biomass for cooking and heating in households. In the STEPS, the current limited level of regulation and continued heavy reliance on oil-based products in the transport sector means that there is no significant reduction in ambient air pollutant emissions by 2050 (Figure 2.29). The APS shows a mixed picture: in some countries a concerted effort to accelerate the uptake of EVs and mandate tailpipe standards, particularly for trucks, helps to bring about notable reductions in NO_X and $PM_{2.5}$ emissions. Limited progress is projected and an increasingly urban and ageing population mean that premature deaths linked to ambient air pollution continue to rise to 2050 (see Chapter 3, section 3.1.2). In contrast, reduced reliance on biomass for heating homes and progress on clean cooking results in fewer premature deaths from exposure to household air pollution by 2050 in both scenarios (see Chapter 3, section 3.5.1).

Key areas for policy action

Opportunities and challenges in equal measure?

SUMMARY

- In Latin America and the Caribbean (LAC), each country faces specific challenges and has particular opportunities to evolve its energy sector. Yet there are some energy issues that are relevant to many, if not all, LAC countries which are critical to the energy outlook for the region and to prospects for socioeconomic progress. Nine cross-cutting themes in this regard are examined in detail in this chapter.
- Public transport and road infrastructure in LAC have not kept pace with rapid urbanisation, resulting in increased traffic congestion, CO_2 emissions and air pollution. Promoting low-carbon urban mobility through investment in public transport systems, electrification of cars and buses and cleaner fuels such as biofuels, offers scope to improve the outlook: in 2030, the average specific CO_2 emissions from road passenger transport is 17% lower than today's levels in the Stated Policies Scenario (STEPS) and 25% lower in the Announced Pledges Scenario (APS). The percentage of the population breathing clean air is larger in both the APS and the Net Zero Emissions by 2050 (NZE) Scenario than in the STEPS.
- Energy efficiency measures in buildings, industries and transport in the APS cut energy consumption growth by 20% in 2030 compared with the STEPS. In the transport sector, reaching the fuel economy levels of the European Union in all LAC countries would save around 0.5 million barrels per day of oil demand in 2030. In the buildings sector, analysis shows that the most efficient appliances and air conditioners are not necessarily the most expensive.
- Its endowment of significant critical mineral resources offers LAC countries the opportunity to diversify and deliver economic growth while supporting global clean energy transitions. Estimated total revenue in LAC was around USD 100 billion in 2022 from the production of critical minerals. Revenue from critical minerals overtakes combined revenues from fossil fuel production in the APS and the NZE Scenario by 2050. Success depends on adhering to high environmental, social and governance standards and on bringing benefits to local communities. By moving up the supply chain to produce refined and processed materials, the region can boost its economy.
- Abundant renewable resources in LAC offer excellent potential to produce low-emissions hydrogen. Announced low-emissions hydrogen projects in the region could produce up to 3.5 million tonnes of hydrogen (Mt H_2) in 2030, mostly from water electrolysis, and up to 6 Mt H_2 if projects currently at a conceptual stage materialise. This would account for 15% of announced projects worldwide. In the APS, hydrogen use in LAC in 2030 is mostly confined to traditional applications such as chemicals and refining, but it expands significantly by 2050, with most additional production exported in the form of hydrogen-based fuels.

- The success of the energy transition hinges on improving outcomes for people. In LAC, around 3% of the population still lack electricity access, and 11% lack access to clean cooking options. The cost of inaction is huge in terms of energy poverty, health and development. Affordable energy remains a key concern: a faster transition to clean energy technologies reduces the costs of energy for households, making it easier to end fossil fuel subsidies, but lower income groups are likely to need support with the higher upfront costs of some clean technologies. The global energy transition also offers new employment opportunities. Energy jobs stand to expand by 1 million to 2030 in the APS, notably in the electricity sector and in critical mineral mining and processing, as well as in oil and gas sectors as the region increases its production.
- Electricity systems in LAC are shifting towards high shares of variable renewables, which require increased system flexibility. Regional electricity integration offers benefits that include enhanced security of supply and lower costs. There has been progress with bilateral interconnections and jointly owned power plants, but cross-border electricity trade remains limited. Taking advantage of the opportunities provided by a broader scale requires sustained political will, infrastructure development, harmonisation of technical standards, effective market design and institutional co-ordination.
- Some LAC countries host major fossil fuel producers, particularly of oil and natural gas, and there is much they can do to support the clean energy transition. They can make an important contribution to reducing greenhouse gas (GHG) emissions by tackling flaring and methane emissions from their operations. There are also opportunities for hydrocarbon producers to diversify into low-emissions technologies, such as offshore wind, carbon capture, utilisation and storage (CCUS), and geothermal. Collaboration between governments and companies is crucial to facilitate this.
- Bioenergy, particularly biofuels, can help LAC countries to meet both energy security and emissions targets. Brazil is a prominent producer and consumer of biofuels, with bioethanol fuelling a significant portion of energy used in road transport. Advanced biofuels have considerable potential in LAC which could become a major global exporter of biojet kerosene, building on its current production capacity. Biogas and biomethane have untapped potential, but supportive policies are needed to spur their deployment in power generation and transport.
- Energy investment in LAC as a share of GDP was 2.5% between 2015 and 2022. In the NZE Scenario, this rises to 4.1% by 2030, with a massive reallocation of capital towards clean energy assets, especially in the electricity and end-use sectors. Private sector participation is essential, and efforts are needed to attract more private capital. The challenges include high financing costs, political and regulatory instability, and limited domestic credit capacity. Better policies are necessary to accelerate investment and to tailor solutions, such as hedging instruments or more concessional financing especially for newer technologies and energy efficiency.

Each country in Latin America and the Caribbean (LAC) faces specific challenges and has particular opportunities to evolve its energy sector. Yet there are some energy issues that are relevant to many, if not all, LAC countries which are critical to the energy outlook for the region and to prospects for socioeconomic progress. This chapter delves into the nine cross-cutting topics:

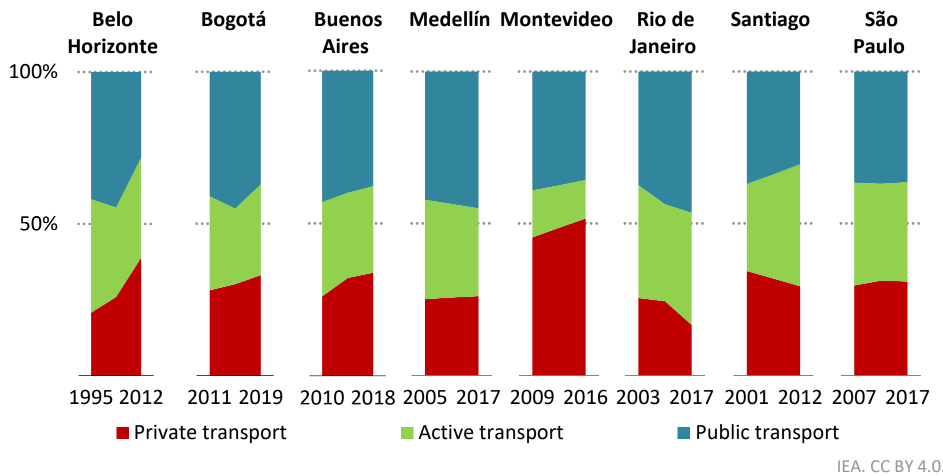
- Sustainable urban transport and cities
- Tap into energy efficiency potential
- Critical minerals: A major contributor to global mineral security and economic growth
- Hydrogen: A new energy frontier
- People-centred transitions
- Energy security and regional power integration
- Transitions in producer economies
- Bioenergy: A sustainable opportunity
- Achieve net zero emissions: Investment and finance

3.1 Sustainable urban transport and cities

Latin America and the Caribbean is home to six megacities, three of which have a population over 15 million (São Paulo, Mexico City and Buenos Aires). The region is highly urbanised: 82% of its population live in cities. LAC faces the difficult challenge of improving urban transport systems to make them efficient, safe, accessible and sustainable for all the inhabitants of its sprawling urban centres (IDB, 2022). The rapid and often unplanned growth of LAC cities, limited financial resources and a lack of strategic urban planning have all hindered the development of public transit systems. Ten capital cities in the region lack underground rail systems. For every million inhabitants, Europe has 35 kilometres (km) of mass transit infrastructure, while LAC has only 10 km (World Bank, 2021a), and cities such as Bogotá and Monterrey rank as among the most congested in the world (INRIX, 2022).

Between 2000 and 2022, the region experienced a more than tripling of the fleet of private modes of transport and a declining reliance on public transport (Figure 3.1). Today, the car ownership rate in LAC is comparable with the global average, though 3.5-times lower than the average of advanced economies. Despite the rise in private modes of transport, many lower income households do not have the financial means to own a car. On a regional basis, more than one-third of all trips are made by public transport. Many cities in the region offer accessible public transport, but the layout of the routes and a low frequency and reliability often mean longer journey times (IDB, 2021). Active mobility – mainly walking and cycling – are other options for getting about, and cities such as Santiago, Rio de Janeiro and Bogotá have seen increases in active mobility. Santiago stands out with an increase in the share of non-motorised active transportation from nearly 30% in 2001 to around 40% in 2012, coinciding with significant government investment in the development of cycle paths in the city between 2007 and 2010 (Metropolitan Regional Government of Santiago, 2010).

Figure 3.1 ▹ Transport modes in selected LAC cities over time



Share of public transport has been declining in six of the eight major cities, as private transport has been increasing

Note: Active transport includes mainly walking and cycling.

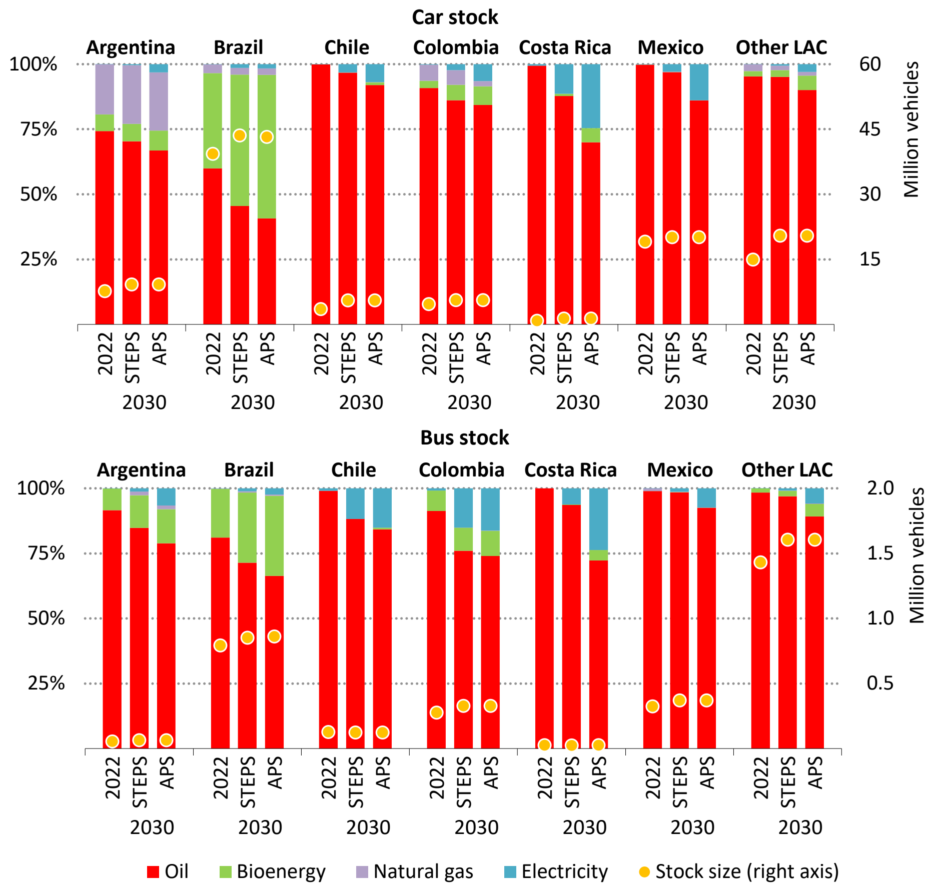
Sources: IEA analysis based on mobility surveys for: *Belo Horizonte* (Belo Horizonte City Hall, 2022); *Bogotá* (Bogota City Hall, 2019); *Buenos Aires* (BA Data, 2018), (Gutierrez, 2020), (Anapolsky, 2020); *Medellín* (OPPCM, 2018), (Aburrá Valley Metropolitan Area, 2009); *Montevideo* (Ministry of Transportation and Public Works of Uruguay, 2017), (CAF, 2017); *Rio de Janeiro* (Codatu, 2019), (Government of the State of Rio de Janeiro, 2017); *Santiago* (Ministry of Transport and Telecommunications of Chile, 2014) and (Government of Chile, 2001); *São Paulo* (São Paulo Metro, 2017), (São Paulo State Government, 2012).

3.1.1 Develop low-carbon urban mobility

The transport sector is responsible for over 35% total energy-related CO_2 emissions in LAC. This compares with the global average of slightly over 20% in the transport sector. By the end of this decade, the urban population in LAC is set to increase by nearly 10%, in line with the trend of increasing urbanisation. Against this background, making the development of public transport a priority during city planning would not only significantly alleviate congestion and reduce travel time, but also lower energy consumption and emissions per passenger-kilometre (pkm). On average, meeting a given set of mobility needs in the region produces passenger car emissions around three-times higher than those that use buses and more than seven-times higher than those from passenger rail. Today, over 45 LAC cities have embraced bus rapid transit systems whose benefits include faster travel, energy-efficient commuting, reduced traffic congestion and lower emissions: the city of Curitiba in Brazil is widely heralded as a bus rapid transit pioneer. The adoption of low-emissions buses that operate on electricity or biofuels is gaining momentum in the region. For example, cities such as Bogotá and Santiago are global leaders in electric buses, while Argentina and Brazil are increasing the use of compressed natural gas (CNG) in urban transport. Bus rapid transit systems and electrified bus fleets together can provide sustainable and affordable mass transit solutions that address mobility needs while reducing congestion and air pollution.

In the scenarios to 2030, two/three-wheelers expand by 20% as a convenient mode of urban transport and passenger car fleets expand by over 15% as more people enter the middle-income category. The fleet of buses expands by more than 30% while activity from metro systems rises by a third to 2030.

Figure 3.2 ▷ Car and bus fleets by fuel type and scenario in selected countries, 2022 and 2030



With growing car and bus fleets, the adoption of EVs is essential to limit air pollution in city centres and reduce emissions from road transport

Notes: STEPS =Stated Policies Scenario; APS = Announced Pledges Scenario. Electricity represents both electric and hydrogen fuel cell electric vehicles. Bioenergy represents internal combustion engine vehicles that operate with biofuel blends.

In the STEPS, nearly 10% of new buses and 5% of new cars in the region are electric by 2030. The share of electric vehicles (EVs) varies by country depending on the current electrification rate and on policy support for their uptake (Figure 3.2). Colombia and Chile lead the way in terms of policies and regulations to support electrification of bus fleets: in 2022, over 10% of new buses in both countries were electric, placing them in the top-ten countries worldwide with electric bus fleets. Bogotá's electric buses now account for around 15% of the total city bus fleet, and demonstration projects to use hydrogen in buses are underway.

In the APS in 2030, the fleet of electric two/three-wheelers is nearly 100-times bigger and for electric cars is over 60-times bigger than in 2022. The market share of both electric buses and electric cars in LAC reaches 20% by 2030 as charging infrastructure development intensifies. Brazil is the global frontrunner in biofuel blending, matching domestic production of bioethanol with the largest fleet of flexible fuel vehicles in the world.

3.1.2 Urban air pollution

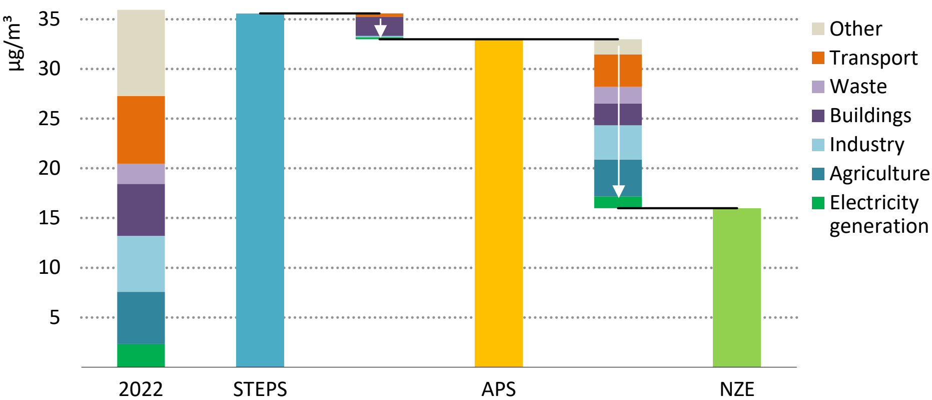
Most city-dwellers in Latin America and the Caribbean breathe polluted air on a daily basis. Annual average concentrations of fine particulate matter ($PM_{2.5}$) in 2022 exceeded the World Health Organization (WHO) air quality guideline of 5 microgrammes per cubic metre (μg/m³) in more than 90% of cities in the region, with concentrations exceeding 12 μg/m³ in cities such as Mexico City, Buenos Aires, Guatemala City and Bogotá. In some cases, concentrations were five- to eight-times higher than the WHO guidelines, with particularly high values in Santiago and its surroundings and in many urban areas of Peru (WHO, 2021; IQAir, 2022).

Road transport is one of the leading causes of $PM_{2.5}$ emissions in many large cities, together with emissions from industry and buildings sectors (Figure 3.3). In some cities, emissions originating from activities outside the city have a significant effect on air quality inside the city. For example, modelling done by the International Institute for Applied Systems Analysis (IIASA) indicates that over half of $PM_{2.5}$ emissions in Santiago (Chile) come from outside the city, mainly from livestock, fertiliser use and industry.

Imposition of stricter vehicle emissions standards has brought some recent improvements in urban air quality, although the adoption and stringency of the standards vary among LAC countries. Out of 33 countries, only nine have emissions standards for both cars and trucks (see section 3.2.1). The increasing use of biofuels for road transport may also have contributed to cleaner air, with studies indicating a 10 - 47% drop in particulate emissions for older more polluting vehicles, though much depends on the blending ratio (EEA, 2019).[1] However, biofuels are likely to have a much smaller impact in reducing pollution from vehicles compliant with high emissions standards.

[1] Biofuel blending can reduce particulate emissions by 10% (for B10 blending ratio) to 47% (for B100 blending ratio) from vehicles with emissions standards less stringent than Euro-IV.

Figure 3.3 ⊳ Average $PM_{2.5}$ concentrations in large LAC cities in 2022, and reductions by sector and scenario in 2030



Transport and buildings are leading causes of $PM_{2.5}$ concentrations in large cities; in 2030 these are halved in the NZE Scenario compared to the STEPS

Notes: μg/m³ = microgrammes per cubic metre. NZE = Net Zero Emissions by 2050 Scenario. Large cities included have a population of more than 5 million. Other includes anthropogenic sources such as from the use of solvents or tobacco smoke and natural sources such as soil dust and wild fires.

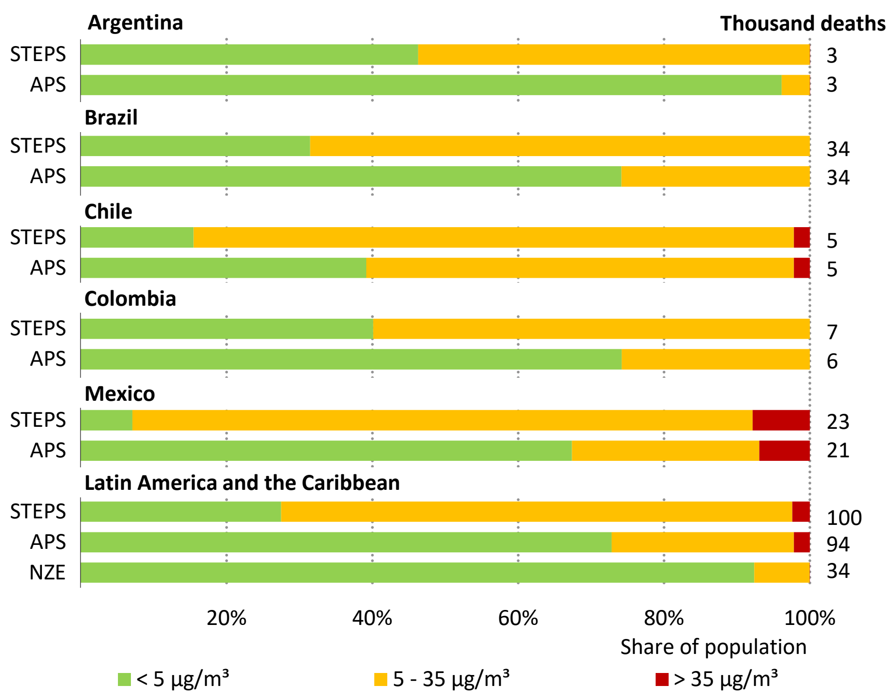
Source: IEA analysis based on IIASA modelling

In the STEPS, $PM_{2.5}$ concentrations associated with pollution from transport in cities of more than 5 million people increase by only 3% in 2030 relative to 2022, with this modest growth more than offset by reduced emissions from electricity generation and buildings. These concentrations remain stubbornly high due to factors including slow progress on adopting or improving emissions standards, slow uptake of EVs (which are used for only around 3% of journeys in LAC countries in 2030), and persistent emissions from trucks (both from exhaust gases and non-combustion sources such as brake wear). In the APS, urban air quality improves modestly by 2030 relative to the STEPS, with the buildings sector responsible for three-quarters of this improvement, transport a further 15% and electricity generation and industry the remainder. However, the most significant reductions are projected in the NZE Scenario, with annual average $PM_{2.5}$ concentrations in 2030 in large cities falling by more than half compared to the STEPS. The lion's share of improvements compared to the APS are from reduced emissions from transport, industry and agriculture sectors. The sharp drop in transport-related pollution in the NZE Scenario is due to factors including a progressive shift to EVs (the use of which in 2030 increases more than fourfold compared to the STEPS), a 10% reduction in emissions from trucks, largely due to improved emissions standards, and increased use of buses and electrified urban rail that reduce the use of private cars.

As LAC is highly urbanised, many people breathe the heavily polluted air that permeates cities, which has grave consequences for public health. Around three-quarters of people living in LAC in 2022 were exposed to ambient $PM_{2.5}$ concentrations exceeding 5 µg/m³, resulting in about 85 000 premature deaths, mainly in Brazil and Mexico.

In the STEPS, the percentage of people exposed to polluted air in 2030 hardly changes from 2022 levels, but population growth, urbanisation and a relatively higher number of elderly and more vulnerable people mean that premature deaths increase by almost one-fifth to just under 100 000. In the APS, despite a reduced percentage of people being exposed to high $PM_{2.5}$ concentrations, particularly in Mexico and Colombia, the number of premature deaths from ambient air pollution continues to rise to 2030, albeit less than in the STEPS (Figure 3.4). In the NZE Scenario, concentrations of $PM_{2.5}$ decline dramatically from current levels, reducing the number of premature deaths from ambient air pollution in 2030 by around two-thirds compared with the STEPS.

Figure 3.4 ▷ Population exposed to various $PM_{2.5}$ concentrations and premature deaths from ambient air pollution in LAC and selected countries by scenario, 2030



More people breathe cleaner air in the APS and the NZE Scenario than in the STEPS, but only in the NZE Scenario does this translate into a significant drop in premature deaths

Note: µg/m³ = microgrammes per cubic metre.

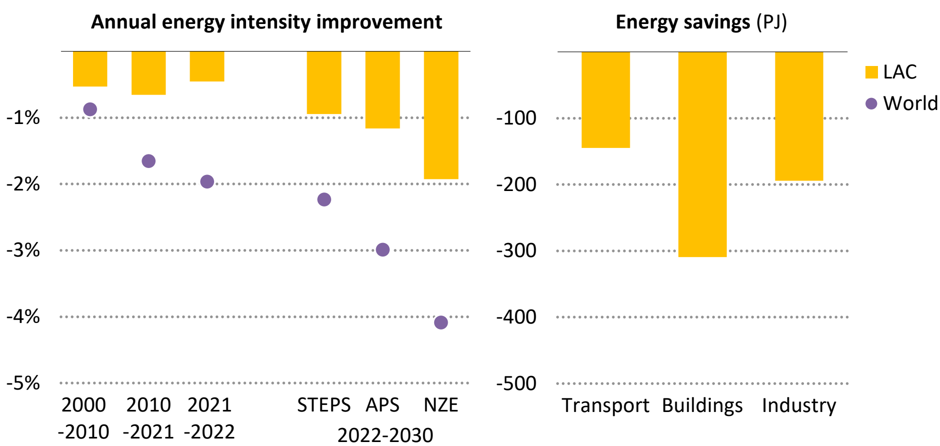
Source: IEA analysis based on IIASA modelling.

3.2 Tap into energy efficiency potential

Concerted efforts to boost energy efficiency in Latin America and the Caribbean offer multiple benefits. Energy efficiency improvements lead to reductions in energy consumption and related emissions, enhance energy security, and create employment opportunities (IEA, 2023a). Digitalisation has the potential to make a significant contribution to improve energy efficiency in the region. Digital solutions can enhance competitiveness, lower operational costs and accelerate the transition to clean energy.

The NZE Scenario calls for a doubling of the annual rate of energy intensity improvement by 2030 (IEA, 2023b). Over the last two decades, annual intensity improvements in LAC countries have hovered around 0.6%. This is below the global average, which almost doubled from the first to the second decade of the 2000s from 0.9% to 1.7%. In the STEPS, the rate in LAC rises to an average of 0.9% in this decade until 2030 (compared to 2.2% globally). In the APS, the rate of energy intensity improvement rises to 1.2% for the same period but remains well below the global average of 3% in this scenario. The rate rises in the APS as a result of additional energy efficiency measures in all three end-use sectors, i.e. buildings, industry and transport. These reduce the increase in energy demand stemming from economic and population growth and avoid an additional 650 petajoules (PJ) of energy consumption by 2030, which accounts for almost 20% of the growth in energy consumption to 2030 in the STEPS (Figure 3.5).

Figure 3.5 ▷ Energy intensity improvement by scenario in LAC, and energy savings by sector in the APS relative to the STEPS in 2030



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Energy efficiency improvements need to increase in this decade: measures across end-use sectors lower energy demand in the APS by 20% relative to the STEPS in 2030

Note: PJ = petajoules.

Making energy efficiency gains need not lead to significant extra cost. Energy efficiency measures can reduce energy bills and are often more cost effective than increasing energy supply to meet higher demand. Bundling projects to achieve scale is one route to secure investment, although it is also important to improve building codes and certifications to reduce the perceived risks sometimes associated with investment in energy efficiency (see section 3.9). Thorough cost-benefit analyses for new programmes are also essential to ensure that investments meet their goals. Energy efficiency programmes also need to be designed considering subsidy programmes: while subsidies for low-income households are important to reduce the share of income spent on energy (see section 3.5.2), many of these programmes undermine incentives for energy efficiency.

There are ready examples of successful programmes. In Mexico, for instance, a lighting replacement programme had a payback period of four years (Government of Mexico, 2022). In Brazil, the Energy Efficiency Programme (PEE) operated by the Electricity National Regulatory Agency (ANEEL) has led to savings of 9 terawatt-hours (TWh) per year and reduced peak demand by 2.8 gigawatts (GW): a reduction in demand of up to 32 TWh is anticipated by 2031 (Ministry of Mines and Energy of Brazil, 2023). In Uruguay, the Energy Efficiency Certificates (CEE) programme provides support to the efficiency projects with the highest savings potential: it delivered energy savings of 160 terajoules per year (TJ/year) in 2022, equivalent to the average annual electricity consumption of 17 000 households. Argentina just launched the Iluminar programme, in which low energy consumption lamps are planned to be distributed free of charge to low-income households to reduce energy bills and thereby also reduce the burden of the current high electricity subsidy load (Government of Argentina, 2023).

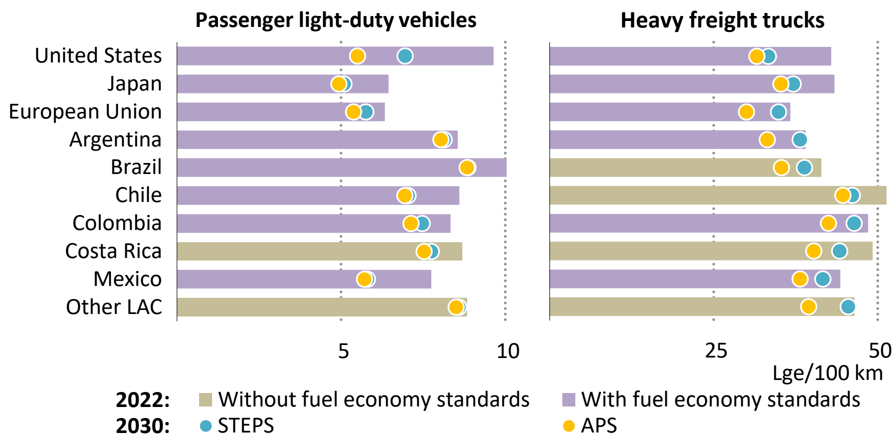
In terms of energy security, strengthening energy efficiency reduces the level of dependence on imported oil products, most of which are used in transport and industry. This is relevant to a number of producer countries as well as to importers, given the lack of refineries in the region (see section 3.7).

3.2.1 Potential of fuel economy to reduce transport oil demand

Many LAC countries, including oil producers, aim to reduce their imports of oil and oil-derived products. Achieving this requires a suite of measures that include the imposition of stricter fuel efficiency standards, particularly for trucks, the adoption of alternative fuels and EVs, and action to discourage the imports of older, less efficient second-hand cars (Figure 3.6). If all LAC countries were to reach the fuel economy levels that apply to light-duty and heavy-duty vehicles in the European Union today, it would save around 0.5 million barrels per day (mb/d) of oil demand in 2030 (6% of the total oil demand in the region in the STEPS).

The reliance on second-hand cars plays its part in reducing average fuel economy in the region because they are less efficient. Between 2015 and 2020, approximately 2 million used light-duty vehicles were exported to LAC countries, accounting for almost 10% of the global fleet of used vehicle exports (UNEP, 2021). In 2020, the region imported around 300 000 second-hand light-duty vehicles (LDV), which accounted for around 5% of all new registrations in LAC countries, although this share varies greatly by country. Some countries in the region have taken steps to address the issue. For instance, Argentina, Brazil, Chile, Colombia, Ecuador, Uruguay and Venezuela have imposed import bans on used vehicles, 11 countries have adopted LDV Euro-4 emissions standards for used cars and/or imposed an age limit of four or five years, and four countries have adopted LDV Euro-3 emissions standards and/or imposed an age limit of six to eight years. Some countries have gone further: Chile and Colombia have adopted Euro-6 emissions standards (the current EU pollutant standard) and Peru is doing the same from 1 January 2024; Argentina and Brazil (PROCONVE L-7) have opted for similar to Euro-6 standards.

Figure 3.6 ▷ Average fuel consumption of new ICE vehicles in 2022 in selected countries and by scenario in 2030



Stricter fuel economy standards, particularly for trucks, offer a significant opportunity to improve energy efficiency in road transport

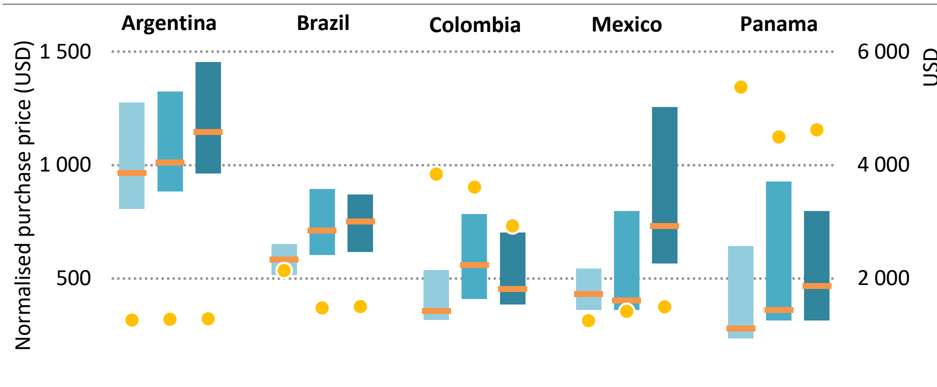
Note: Lge/100 km = litres of gasoline equivalent per 100 kilometres; ICE = internal combustion engine.

3.2.2 Building energy codes and minimum energy performance standards for appliances

Improving the efficiency of appliances and cooling systems is key to improving efficiency in the buildings sector. In the APS, stricter minimum energy performance standards (MEPS) and energy labels help avoid almost 40 TWh of electricity consumption from appliances and air conditioners by 2030 compared to the STEPS (5% of buildings electricity consumption in the STEPS). The efficiency of appliances and air conditioners used in homes on average is around 10% higher by 2030 in the APS than in the STEPS. Energy efficiency gains can also reduce both overall energy demand and peak demand (see Chapter 2).

A rising number of countries (23 out of 33) have recognised the substantial cost-effective energy savings potential and other benefits offered by MEPS and energy labels for appliances and already have policies in place. Several countries have taken significant steps to adopt or strengthen MEPS and to ensure that they are properly enforced. For example, Argentina, Brazil, Chile, Colombia and Mexico successfully phased out incandescent lamps between 2010 and 2016, demonstrating their commitment to energy efficiency. Each of these countries has established its own MEPS for general service lights (GLS), though none has yet reached the standard of 90 lumen/Watt seen in countries such as South Africa or India.

Figure 3.7 ▷ Purchase price and life cycle cost versus efficiency for air conditioners in selected countries, 2023



More efficient air conditioners do not necessarily involve higher upfront costs or higher life cycle costs

Notes: Argentina: Lower, moderate and higher efficiency corresponds to ratings A/B, A+, and A++/A+++; Brazil: efficiencies below 5 W/W, between 5-6 W/W, and above 6 W/W; Colombia: ratings D/E, C, and B/A; Mexico: efficiencies below 3.5 W/W, between 3.5-4 W/W, and above 4 W/W; Panama: efficiencies below 4 W/W, between 4-5 W/W, and above 5 W/W. The normalised purchase price represents the air conditioner price normalised with a cooling capacity of 12 000 British thermal units per hour. The analysis assumes a ten-year lifespan for air conditioners and uses residential electricity tariffs from September 2022.

Cooling is a vitally important area for MEPS. Despite the availability of energy-efficient air conditioners on the market, MEPS in the region remain below those in other major markets. For refrigerators, each LAC country follows a different performance standard for the various refrigerator models, e.g. EU EcoDesign or US Energy Conservation Standards. Harmonising appliance energy efficiency policies across LAC countries could unlock energy savings and sustainable growth across the region (Box 3.1). Analysis from countries shows that opting for a more efficient model does not always come with a significantly higher price tag, especially in Argentina, Brazil and Colombia (Figure 3.7). When considered over the lifetime of the equipment, more efficient equipment is often more cost effective than less efficient alternatives as a result of lower daily operating costs. In formulating policies to enhance the efficiency of air conditioners and refrigerators, governments should also incorporate guidelines for the proper installation, recycling and final disposal of refrigerants to minimise GHG emissions and to ensure environmental sustainability.

Box 3.1 ▷ Institutional collaboration and support can accelerate energy efficiency improvements

Institutional collaboration has a crucial part to play to improve energy efficiency. A good example at the global level is the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative.[2] SEAD is a voluntary collaboration among governments working to promote the manufacture, purchase, and use of energy-efficient appliances, lighting, and equipment worldwide. The SEAD Call to Action urges governments to commit to fast, ambitious action on appliance and equipment energy efficiency (CLASP, 2021). It aims to double the rate of efficiency improvement in four key areas by 2030: lighting, air conditioning, refrigeration and electric motors. Fourteen countries signed the Call to Action at the Conference of the Parties (COP) 26 in 2021, including three LAC countries: Brazil, Chile and Colombia.

LAC countries can collaborate to establish minimum energy performance standards that apply across the region and can deliver benefits by creating a larger market area. For instance, the Central American Integration System (SICA) set unified standards for air conditioners. This type of action does not necessarily require the national government to be the only actor: they can support initiatives from regional governments and local municipalities to promote collaboration on best practice among regional programmes. Industry associations can be key partners to advance energy efficiency in industry.

More than half of the floorspace in buildings that will be in use in 2050 has yet to be built. This makes new construction a key priority, with a focus on establishing effective building energy codes and standards. Application of effective codes and standards also applies to renovation and re-fitting of existing buildings. Today, only 13 of 33 countries in the region have mandatory or voluntary building codes in place. It is fundamental that existing codes be enhanced and the range of coverage extended to more LAC countries in order to temper growing demand for space cooling and to enhance resilience to climate change impacts. Significant progress is likely to require a shift from voluntary to mandatory building codes, action to ensure that regulations are monitored and enforced, and a drive to adopt passive and affordable construction design strategies to reduce reliance on active cooling and heating systems.

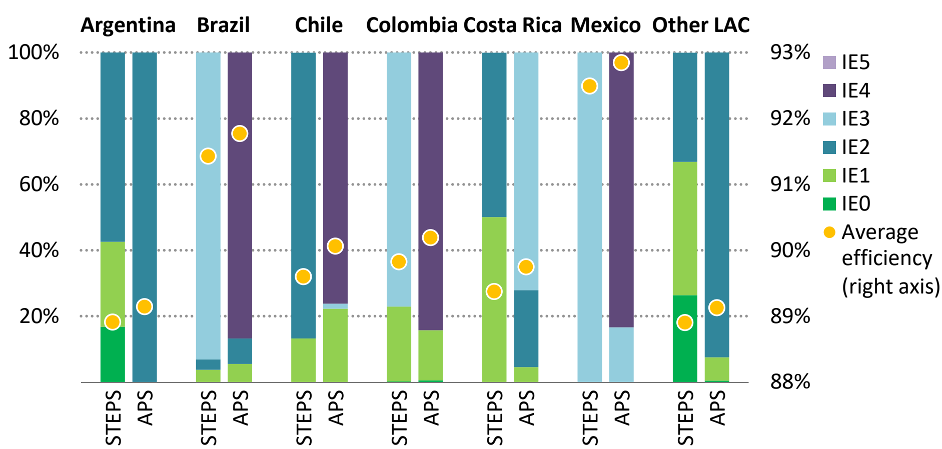
[2] Please find more information on SEAD under: https://www.cleanenergyministerial.org/initiatives-campaigns/super-efficient-equipment-and-deployment-sead-initiative/?_years=2021.

3.2.3 *Increase efficiency in non-energy-intensive industries*

Non-energy-intensive industries (other industry), with most energy needs characterised by low and medium temperature heat for processing and motors, account for almost half of energy demand in the industry sector in LAC countries. Strengthening MEPS for motors, implementing energy management systems and switching to sustainable fuels or electric heat pumps are significant levers for decarbonisation in these industries. Only nine LAC countries have MEPS for industrial motors in place today, and only five have industry-wide efficiency mandates (see Chapter 2, table 2.2).

A key measure to improve the efficiency of industrial motors is to put MEPS in place or, where they exist, to make them more robust. In the APS, enforced energy efficiency measures including electrification save more than 60 petajoules (PJ) in other industry, with motors representing a large portion. The SEAD Call to Action to accelerate motor standards is supported by Brazil, Chile and Colombia and leads to projected electricity savings of 1.9 TWh by 2030 in the APS. In Chile, upping the MEP motor standard from International Efficiency Class (IE)2 to IE4 saves almost 1 terawatt-hour in 2030 in the APS (Figure 3.8). In the APS, 80% of new motors sold across the region by 2030 meet IE3 standard or higher.

Figure 3.8 ⊳ Industrial motor sales by International Efficiency Class and average efficiency in selected countries by scenario, 2030



Increased efficiency in industrial motors could boost overall efficiency and save 1.9 TWh in non-energy-intensive industries in the LAC countries participating in the SEAD Call to Action

Note: Based on the International Electro-technical Commission International Efficiency (IE) standards for electric motors that range from low (IE0) to ultra premium (IE5).

Programmes that provide information and support for audits and project execution can play a big part in helping with the adoption of energy efficiency measures, especially for the small and medium enterprises (SMEs) that dominate light industries. The "Transformative Investment for Energy Efficiency in Industries (PotencializEE)" initiative in Brazil is a good example: it supports the certification of energy auditors, funds audits for and helps SMEs to acquire financing for energy efficiency measures.

3.3 Critical minerals: a major contributor to global mineral security and regional economic growth

Latin American and the Caribbean countries have a well-established mining sector from which to further develop their significant mineral reserves and broaden their mineral production profile. Doing so will boost their economies: it will also help the global economy to avoid supply bottlenecks that could threaten clean energy transitions. Three key opportunities exist: scaling up production of both existing and so far undeveloped resources; improving practices for responsible and sustainable supply; and moving from the production of ores to processed products.

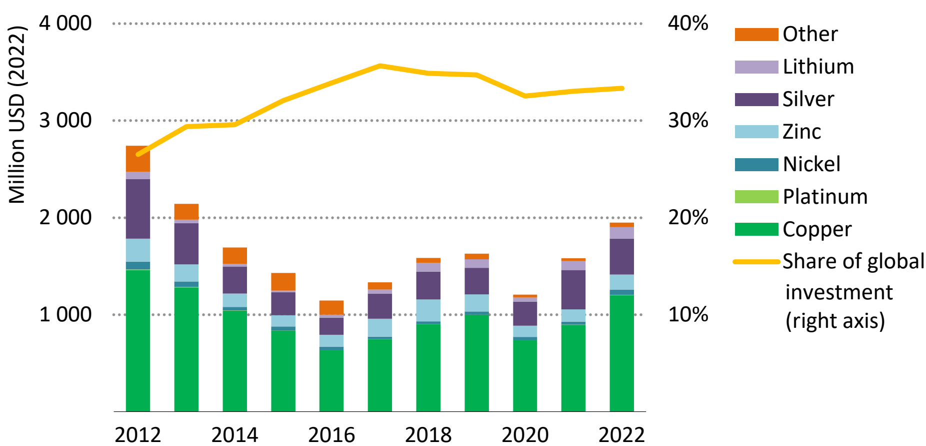
The region already produces large quantities of lithium, which is needed for batteries, and copper, which underpins the expansion of renewables and electricity networks. But LAC countries could expand into a range of other minerals, including rare earth elements that are required for EV motors and wind turbines, and nickel, a key component in batteries and electrolysers used to produce hydrogen. To reap this potential, mining activities must adhere to high environmental, social and governance (ESG) standards and benefit local communities. Countries can maximise the benefits to their economies by integrating mineral processing into local supply chains.

3.3.1 Supply prospects

LAC countries account for almost 40% of global production of copper, led by Chile (24%) and Peru (10%). Copper production started to pick up in 2022 after several flat years. The Quellaveco mine in Peru and the Quebrada Blanca mine in Chile have contributed to recent production growth, and other expansion projects are underway. A mega port is under construction in Peru (Terminal Portuario de Chancay) to facilitate exports. Chile's national mining plan includes a copper production target of 7 million tonnes (Mt) by 2030, up from 5.7 Mt today, and 9 Mt by 2050, alongside a doubling in annual investment in greenfield exploration. The region's share of global copper exploration expenditure has gone up from around 30% in 2012 to nearly 45% in 2022 – indicating the potential for further production increases. Existing operations are however facing challenges: declining ore grade, water shortages and protests from local communities could disrupt supply.

The region also supplies just over 35% of the world's lithium and holds around half of global lithium reserves. It is home to the so-called lithium triangle, a lithium-rich region that spans Argentina, Bolivia and Chile. Chile and Argentina are respectively the second (30%) and fourth (5%) top global producers. Bolivia also has substantial resources, but lack of infrastructure has so far hindered them from being economically attractive. LAC countries predominantly produce lithium carbonate from brine, which generates fewer emissions than mining from hard rock. Lithium exploration spending in LAC almost doubled over the last decade to reach nearly USD 120 million in 2022, and there is scope to further scale up activities (Figure 3.9). So far, lithium mining has been concentrated in Chile's salt flats, but there have been notable developments in Argentina, where the Kachi project is expected to start in 2027, and Brazil, where the Grota do Cirilo mine has just started production. In Bolivia, the Chinese firm CATL plans to invest over USD 1 billion in two lithium plants that will extract minerals from the country's Uyuni and Coipasa salt flats.

Figure 3.9 ▷ Investment in exploration for selected minerals in LAC, 2012-2022



LAC is responsible for an expanding share of global exploration spending in critical minerals, most of which is linked to copper

Note: Excludes gold and diamonds.

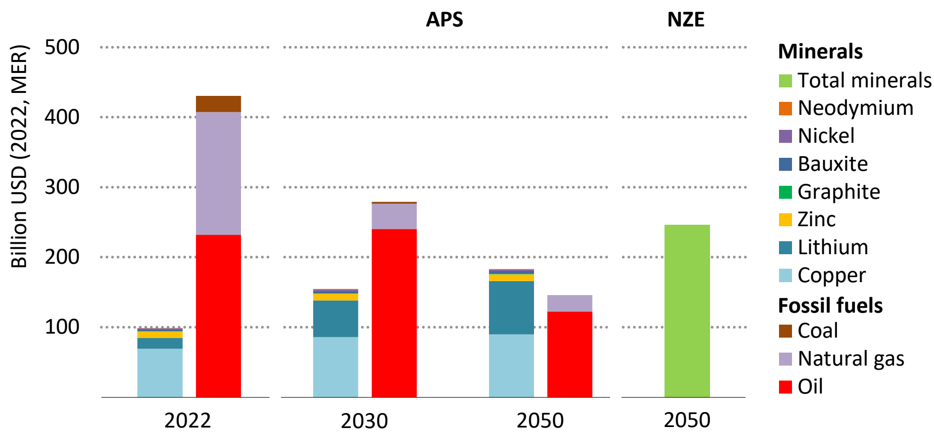
Source: IEA analysis based on data from S&P Global (2023a).

In addition to copper and lithium, LAC has significant potential to supply graphite, nickel, manganese and rare earth elements. Brazil alone holds around one-fifth of the global reserves of each of these resources, but it currently produces only small to moderate amounts of them: production ranges between less than 1% of global production of rare earth elements and 7% of graphite. Brazil also has major reserves of bauxite (used for aluminium production) and is a leading producer and recycler of aluminium, which is increasingly being used in electricity networks. However, LAC countries have not yet attracted investment in line with their potential: for example, less than 10% of the global exploration budget for nickel is allocated to the region (S&P Global, 2023a).

Governments can help by establishing long-term frameworks to attract investment in mining and processing activities, setting clear regulations and incentives, and ensuring compliance with ESG standards. Dialogue with stakeholders, investors and communities as well as increased international co-operation is also needed. Exploration campaigns could benefit from updated national geological surveys as current geological information does not always cover energy-related critical minerals. Some countries are taking steps in this direction. Chile's geological service provides detailed open-source geological data with regional and mineral focal points, Brazil has established a division on critical minerals under its geology department (DIPEME) to facilitate access to related geological data, and Colombia has launched a strategic roadmap, called Copper & Phosphates Route, to expand this industry.

Revenue from the production of critical minerals found in the region (graphite, bauxite, nickel, zinc, lithium, copper and neodymium) are estimated to have totalled around USD 100 billion in 2022 – close to 30% of the global market. With rising demand for these minerals, the LAC revenue from their sales increases over 1.5-times by 2030 in the APS. By 2050, critical minerals production revenue almost doubles compared to 2022 and overtakes combined revenue from fossil fuel production in the region, which fall to under USD 145 billion as countries around the world deliver on announced pledges to limit the impacts of climate change. In the NZE Scenario, revenue from critical minerals production rises further to over USD 245 billion by 2050 (Figure 3.10).

Figure 3.10 ▷ Revenue from production of selected critical minerals and fossil fuels in LAC in 2022 and by scenario, 2030 and 2050



Revenue from production of critical minerals increases over 1.5-times by 2030 in the APS, and surpasses the combined revenue from fossil fuels by 2050 in both scenarios

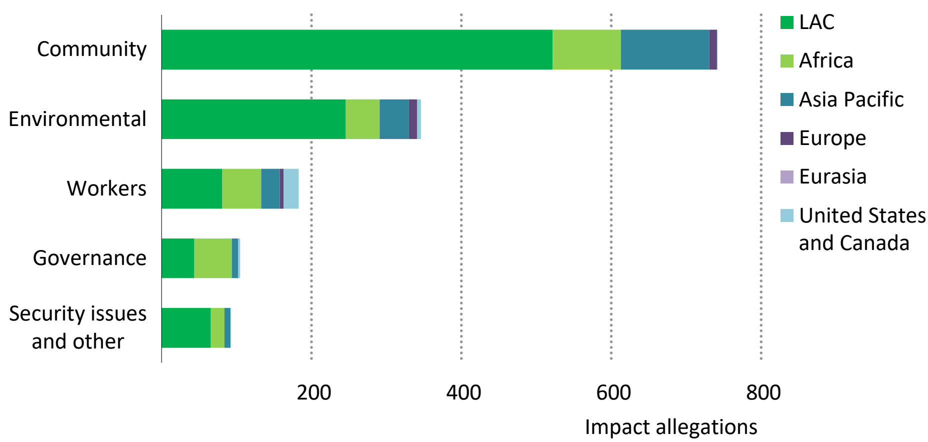
Notes: Revenue is total proceeds from domestic sales and exports. Assumes average 2022 prices for minerals in 2030 and 2050, and that the region maintains its current market share of global minerals production.

Sources: IEA analysis based on price data from S&P Global (2023b); Wood Mackenzie (2023); BMO Capital Markets (2023); KOMIS (2022).

3.3.2 Responsible and sustainable mining

Mining comes with a risk of environmental degradation and adverse impacts on local communities. It has been associated with a host of negative ESG impacts, including human rights violations, environmental contamination, deforestation and other harms (Figure 3.11). Mining has also historically accounted for around 10-20% of foreign direct investment in LAC, and it has provided some good examples of environmental stewardship. In 2021, for example, Escondida and Spence copper mines shifted to 100% renewable energy power purchase contracts after early termination of a coal-fired power contract (BHP, 2021). In July 2023, Brazil exported to China the world's first cargo of "green lithium", which was produced in its Jequitinhonha Valley following the so-called "triple zero" standard: without carbon, tailings and harmful chemicals.

Figure 3.11 ▷ Allegations of ESG impacts linked to critical minerals by region, 2010-2022



LAC has the highest number of tracked ESG impact allegations associated with the production of critical minerals

Notes: Allegations refer to publicly reported environmental and human rights abuses at mine sites of large-scale companies mining cobalt, copper, lithium, manganese, nickel and zinc. ESG = environmental, social and governance. Other includes security issues, such as abuses by private security, and impacts related to the Covid-19 pandemic, such as violations of containment measures.

Source: IEA analysis based on the Transition Minerals Tracker, Business & Human Rights Resource Centre, (2023).

The development and enforcement of ESG standards is crucial to protect both the environment and local communities. ESG issues are a growing concern for mining companies, customers, investors and other stakeholders. Major environmental disasters during the last decade have fed anti-mining sentiment among local communities. Prominent examples include the 2014 spill of 40 000 cubic metres of copper sulphate into the Sonora River in

Mexico, which affected the water supply of over 24 000 people, and the 2019 tailings dam disaster at Brumadinho, Brazil, which killed 270 people. Mining activities are often located near sensitive and biodiverse ecosystems, many of which are home to vulnerable or indigenous communities, and they frequently involve intensive use of land and water resources and the deployment of heavy machinery. All this raises the likelihood of conflicts and makes it challenging for companies to obtain a "social licence to operate".

A number of countries in the region have put in place environmental licensing frameworks and regulations to improve ESG standards. In 2023, Brazil led a task force to evict illegal mining from indigenous lands in the Amazon, driving thousands of illegal miners out of the area. Chile's national mining strategy includes targets to reduce water use in the mining industry, achieve carbon neutrality in the sector by 2040 and stop tailings dumping by 2050. However, there is still room to improve enforcement and compliance standards (IDB, 2020). Thorough risk and tailings management and monitoring can prevent accidents and contamination, and improved efficiency and recycling can reduce waste and increase supply. Technologies are available to reduce water use, improve effluent quality and curtail emissions. Many companies also aim to improve gender equality in mining operations, to support local development and to increase transparency across their activities. Robust regulatory regimes with sufficient permitting and compliance staff are needed as well as reliable and accessible public information. ESG standards can also ensure mining operations are prepared for the changing climate and contribute to overall regional climate resilience.

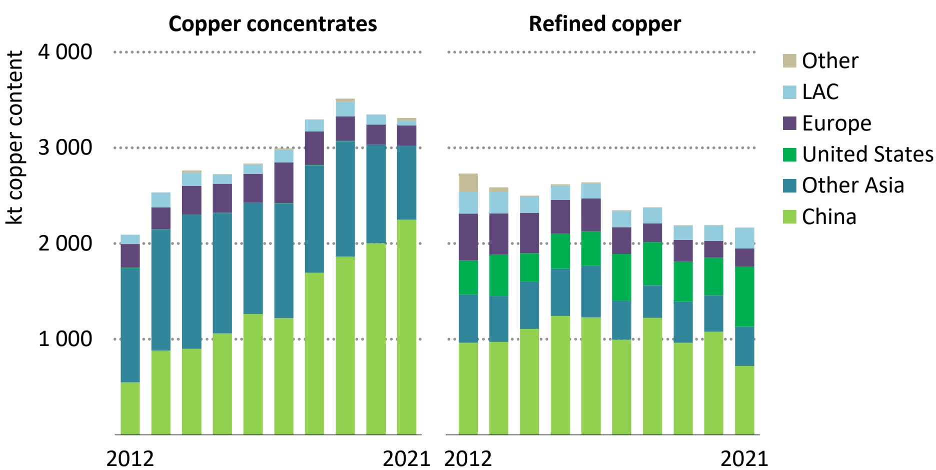
In the last two decades, many governments in LAC have reshaped royalty redistribution models with the aim to bring higher benefits to areas affected by mining activities. This aim was at the centre of the royalties reform in Colombia in 2020 and guided the creation of a special contribution for regional development in Chile in the same year. In 2023, Chile also enacted the Mining Royalty Law to support regional economic development. More widespread action will be needed to ensure that mining brings tangible benefits to local communities, for example by promoting higher value-added activities such as processing or making improvements to local infrastructure. Actions should be designed to make the most of synergies where they exist, for example by reprocessing tailings or using wastewater from geothermal plants for lithium production.

3.3.3 Moving along the supply chain

LAC can help ensure a reliable supply of the critical minerals required for global energy transitions by moving up the supply chain beyond mining. The refining industry has relatively shorter lead times and generates more employment and added value than the extractive sector. Additional investment in this sector could open avenues for economic growth and diversification, such as the development of local processing and the production of clean energy technology components. Some LAC countries are taking steps in this direction, such as by providing public funding for research and development related to lithium industrialisation (ECLAC, 2023). Potential growth avenues include the preparation of cathode active materials for batteries, conversion of lithium into its hydroxide form, or the treatment and separation of rare earth ore into oxides. However, there are challenges to developing critical minerals refining and transformation such as limited access to technology and skills, lack of cost competitiveness and market barriers for new entrants.

The existing clean electricity mix in the region gives LAC countries a competitive advantage in building a low-carbon processing sector. Countries such as Chile and Brazil already have smelters and export oxides and refined alloys. However, trends in recent years are not encouraging. From 2012 to 2021, Chile's exports of refined copper and copper alloys fell by around 20%, whereas exports of copper ore and concentrates increased by almost 60% (Figure 3.12). In 2023, Chile's national mining company, Codelco, closed the Ventanas smelter, which had been associated with environmental pollution affecting the coastal communities nearby. In the same year, Chile launched a National Strategy for Smelters and Refineries with recommendations to strengthen the sector and improve its ESG practices.

Figure 3.12 ▷ Copper exports from Chile by type and destination, 2012-2021



IEA. CC BY 4.0.

Copper exports have grown, but exports of refined products have fallen by more than 20%; China has increased its market share from around 30% to nearly 55%

Notes: kt = thousand tonnes. Other includes Australia, Canada, Namibia, South Africa and other small importers as reported by the Chilean Copper Commission.

Source: IEA analysis based on data reported by Chile Ministry of Mining, COCHILCO (2023).

There are reasons to think that the trends in recent years could change. In 2023, Chile also announced a National Lithium Strategy to increase domestic wealth and support a global green economy. It outlines a long-term vision that stretches from exploration to value chain expansion and mentions regulations to ensure sustainability and reinvestment in the country's development. The strategy provides for the participation of various stakeholders, including private companies, and proposes the creation of a National Lithium Company and of a Public Technological and Research Institute of Lithium and Salt Flats.

Argentina, Brazil and Chile have many of the elements needed for midstream and downstream development, including resources of minerals such as lithium, nickel, cobalt, manganese and phosphate rock. They also have mining expertise, renewable potential (often close to mineral deposits) and key infrastructure. These factors could facilitate midstream operations, e.g., lithium hydroxide refineries, and a downstream segment for battery components. The Chinese auto giant BYD is set to invest over USD 620 million to make Brazil its first EV and lithium iron phosphate (LFP) battery manufacturing hub outside Asia, and to invest USD 290 million to install a lithium cathode plant in the Antofagasta region of Chile with a production capacity of 50 000 tonnes of LFP cathodes.

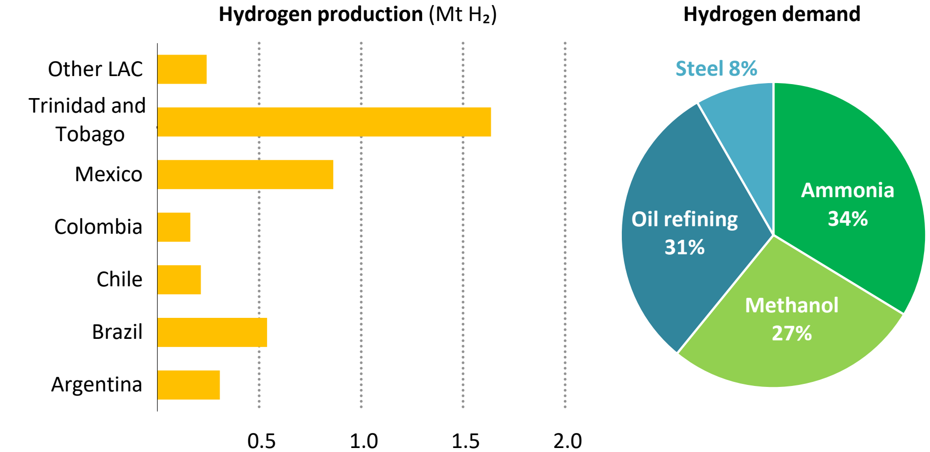
Building strategic partnerships with consumers could bring enormous benefits. Support in the form of long-term off-take agreements, grants or preferential loans could be paired with performance standards. Many importers are now also looking at how to build partnerships to improve the diversity of supply in response to concerns about the current high level of geographic concentration in the refining of critical minerals. Off-take agreements with importers could help spur the development of local supply chains and promote stronger resilience of the global mining and processing industry. An enabling regulatory framework with stable rules would facilitate long-term investment and could create synergies between ore production and processing. It could also involve tailored industrial policies and regional co-operation to encourage new operations and facilitate the consolidation of industry clusters.

3.4 Hydrogen: A new energy frontier

Hydrogen consumption in Latin America and the Caribbean today is concentrated in the five largest economies (Argentina, Brazil, Chile, Colombia and Mexico) and in Venezuela and Trinidad and Tobago (Figure 3.13). In 2022, total hydrogen consumption in the region stood at 4 million tonnes of hydrogen (Mt H_2), about 4% of the global total of 95 Mt H_2. Almost 90% of this hydrogen was produced from steam reforming of natural gas, resulting in annual emissions [3] of more than 35 million tonnes of carbon-dioxide equivalent (Mt CO_2-eq), comparable to about half of Chile's CO_2 emissions from fossil fuel combustion. Trinidad and Tobago is the largest hydrogen consumer in the region: its chemicals industry uses hydrogen to produce large volumes of ammonia and methanol for export. In other LAC countries, oil refineries are the largest consumers. A decline in oil refining over the last decade has reduced total hydrogen consumption, and so have difficulties in recent years in securing natural gas at competitive prices for ammonia production in some countries: these led to a complete shutdown of ammonia production in Mexico and to only one plant operating in Brazil in 2019 (IEA, 2021a).

[3] This includes direct emissions from the steam methane reforming process as well as average upstream and midstream emissions from natural gas production, processing and transport. This also includes captured CO_2 utilised in the synthesis of urea and methanol, the majority of which is latter emitted.

Figure 3.13 ▷ Hydrogen production by country and consumption by industrial sector in LAC, 2022



Hydrogen consumption was 4 Mt in LAC, about 4% of global demand, with most used in oil refining and chemicals manufacturing, particularly in Trinidad and Tobago

With its abundant renewable resources, the region has the potential to produce low-emissions hydrogen at a lower cost than most other parts of the world.[4] This hydrogen could be used both at home and overseas to help decarbonise hard-to-abate sectors where there are few alternative technologies. Seizing this opportunity would support domestic decarbonisation efforts, enhance industrial competitiveness and create new jobs. It would also boost energy and food security, given that most LAC countries currently rely heavily on imports of ammonia and urea. LAC countries are starting to move forward in this area. Chile became the first country in the region to publish a national hydrogen strategy in 2020, followed by Colombia in 2021, Uruguay in 2022 and Argentina, Brazil, Costa Rica, Ecuador and Panama in 2023. Other countries are currently working on national hydrogen strategies and are expected to publish them soon.

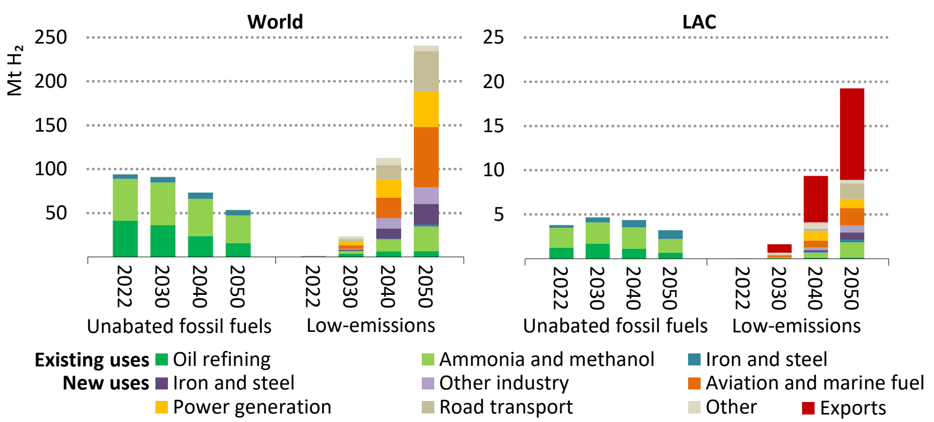
3.4.1 Demand outlook for low-emissions hydrogen and hydrogen-based fuels

In the STEPS, global hydrogen demand increases about 15% by 2030 and 45% by 2050 compared with 2022, but this growth is driven by increased demand for hydrogen in

[4] In this report, low-emissions hydrogen includes hydrogen produced from water electrolysis where the electricity is generated from a low-emissions source, such as solar, wind or nuclear. Hydrogen produced from biomass or from fossil fuels with CCUS technology is also considered as low-emissions hydrogen. However, production from fossil fuels with CCUS should have low upstream emissions, high capture rates in all CO_2 streams, and permanent CO_2 storage to be considered as low-emissions hydrogen. 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). (IEA, 2023c).

traditional applications. In LAC countries, demand rises more quickly than the global average, but it remains concentrated in traditional applications, as it does elsewhere. In the APS, global hydrogen demand increases faster than in the STEPS, rising more than 20% by 2030 and tripling by 2050 compared to 2022. Low-emissions hydrogen displaces hydrogen from unabated fossil fuels in existing applications and finds new uses in hard-to-abate sectors such as long distance trucking, aviation, shipping and heavy industry, as well as in the power sector: these new uses account for 70% of global hydrogen demand by 2050 (Figure 3.14). In LAC, domestic consumption of hydrogen increases around 35% by 2030 and more than triples by 2050. The share of consumption accounted for by new applications is 10% in 2030 and 55% by 2050, which is lower than the global average. Demand for hydrogen in LAC is driven not only by increased domestic consumption but also by increasing exports, mostly in the form of hydrogen-based fuels: around 15% of low-emissions hydrogen production in the APS in 2030 and about 45% in 2050 is intended for the production of hydrogen-based fuels for export.

Figure 3.14 ▷ Hydrogen and hydrogen-based fuels demand and exports by sector globally and in LAC in the Announced Pledges Scenario, 2022-2050



In LAC, demand for low-emissions hydrogen rises in existing and new uses, but the big driver of growth is hydrogen-based fuels for export

Notes: International bunkering is included in aviation and marine fuel. Exports and demand for road transport, aviation and marine fuel, and power generation include hydrogen that is converted to hydrogen-based fuels. For hydrogen-based fuels, the equivalent hydrogen amount (Mt H_2-eq) corresponds to the stoichiometric hydrogen inputs needed to produce these fuels.

Seize near-term opportunities: Catalyse domestic demand

While a few countries in LAC are net exporters of ammonia and nitrogen fertilisers, many countries spend millions of dollars each year to import large quantities of them, mainly from Russia, China, Qatar and Oman as well as from other countries in the LAC region, particularly from Trinidad and Tobago. The production of ammonia using low-emissions hydrogen provides an opportunity to reduce import dependency and market volatility risks and to minimise the use of natural gas in existing ammonia plants (see Chapter 1, Box 1.1). In Brazil, Unigel is building the region's largest low-emissions hydrogen project. It will be able to produce 10 000 tonnes of hydrogen per year equivalent to around 60 000 tonnes of ammonia per year, with the potential to expand utilising dedicated new renewable energy generation. The aim is to supply electrolytic hydrogen from grid-connected electricity for use in an existing ammonia plant to displace current natural gas consumption. In Chile, the HyEx project aims to use electrolytic hydrogen in the country's first ammonia plant (26 MW, equivalent to a capacity of 5 kt H_2 per year) by 2025, with the aim of reducing ammonia imports and the carbon footprint of explosives used in mining.

Ammonia from low-emissions hydrogen could improve food security and the resiliency of the agricultural sector in the region. However, cost considerations are critical as most farmers will not be able to afford a price premium (if any) unless supported by customers such as large agribusinesses with ESG objectives. The agricultural sector in LAC is heterogeneous, with half of the regional production coming from small farmers (J.P.Morgan, 2022), even though large, export-oriented farmers dominate in countries such as Argentina, Brazil and Uruguay (OECD and FAO, 2019). Policies should be differentiated, prioritising measures that protect small farmers while promoting regional food security and sustainability. More ambitious targets could be set for large farms, which will also have to take account of targets in their export markets.

Diesel fuel used by machinery in the mining sector represents an important share of energy consumption in mining. Several projects in Chile, such as Kura H_2 and AndesH2, envisage the use of hydrogen-fuelled trucks in place of diesel trucks. Chile and Peru are also considering the use of hydrogen-fuelled machinery. The mining sector commitment to meet ESG targets and minimise emissions could provide initial demand for low-emissions hydrogen in the region, with other drivers of demand increasing over time. For example, as governments award mining concessions, they are likely to incorporate increasingly ambitious sustainability criteria that seek to minimise all potential GHG emissions from mining operations.

Currently, oil refining dominates hydrogen consumption in LAC countries, except for Trinidad and Tobago, where ammonia and methanol production are the largest consumers. Oil refining accounts for about 1.2 Mt H_2 today, and this is set to rise to 1.7 Mt by the end of this decade in the APS as a result of increased refining demand and stricter sulphur content requirements for oil products. Some LAC national oil companies are pursuing emissions reduction strategies that consider low-emissions hydrogen (S&P Global, 2022). For example, Ecopetrol in Colombia launched an electrolytic hydrogen pilot project at its Cartagena refinery in 2022, has started feasibility studies to scale electrolytic hydrogen production there and in Barrancabermeja refinery by 2026, and has set ambitious targets for emissions reduction including carbon neutrality by 2050. The company also plans to expand the use of hydrogen for other applications and exports (Ecopetrol, 2022). In Argentina, the national oil company YPF is leading the consortium H2ar, a collaborative working group of companies seeking to innovate and promote the development of hydrogen supply chains (CONICET, 2020). The engagement of national oil companies plays a key role in driving demand for low-emissions hydrogen in the short term, reducing downstream emissions and building up valuable expertise that could help them to diversify in the future.

New uses for low-emissions hydrogen and hydrogen-based fuels

In the road transport sector, low-emissions hydrogen and hydrogen-based fuels could support the decarbonisation of segments that are difficult to electrify, such as heavy-duty trucks and long-distance buses. Biofuels and electrification decarbonise most trucks and buses in LAC, but hydrogen also plays a role in the APS, accounting for 6% of the energy consumption by buses in LAC by 2050 and more than 3% for trucks. Ambitious decarbonisation targets in Chile and Costa Rica mean that hydrogen is likely to fuel a larger proportion of freight trucks in these countries than in others in the region. There are already a few projects in the region involving hydrogen buses. Costa Rica has had a bus running on electrolytic hydrogen since 2017 (Portal Movilidad, 2021), and Transmilenio unveiled a public transport bus operating on electrolytic hydrogen in Bogotá in 2023. Transmilenio already has a fleet of more than 1 400 EVs, and the pilot project aims to assess the feasibility of using hydrogen on some routes with longer ranges (Transmilenio, 2023). Uruguay recently announced funding for the H24U project (Ministry of Industry, Energy and Mining of Uruguay, 2023), in which 17 trucks for the forestry industry will run on electrolytic hydrogen with an expected driving range of 450-500 km.

Hydrogen and hydrogen-based fuels, such as ammonia, methanol or synthetic fuels, could play a key role in the decarbonisation of the maritime and aviation sectors as well. Panama, one of the world's largest bunkering port, adopted a hydrogen strategy in July 2023 that sets ambitious consumption targets for its maritime sector. It wants 5% of its bunkering supply to consist of hydrogen and hydrogen-based fuels by 2030, rising to 30% by 2040 and 40% by 2050. In addition, Panama and Uruguay are both members of the international Clean Energy Marine Hubs initiative, which aims to mitigate the risks associated with investment in infrastructure for the transport and bunkering of hydrogen and hydrogen-based fuels in ports. Such infrastructure is very capital intensive, has long lead times, and may require the use of technologies that are still at a demonstration phase. This initiative underscores the value of international co-operation and public-private partnerships in sharing risk, aggregating demand, creating dedicated corridors and facilitating the exchange of experience in the deployment of new technologies.

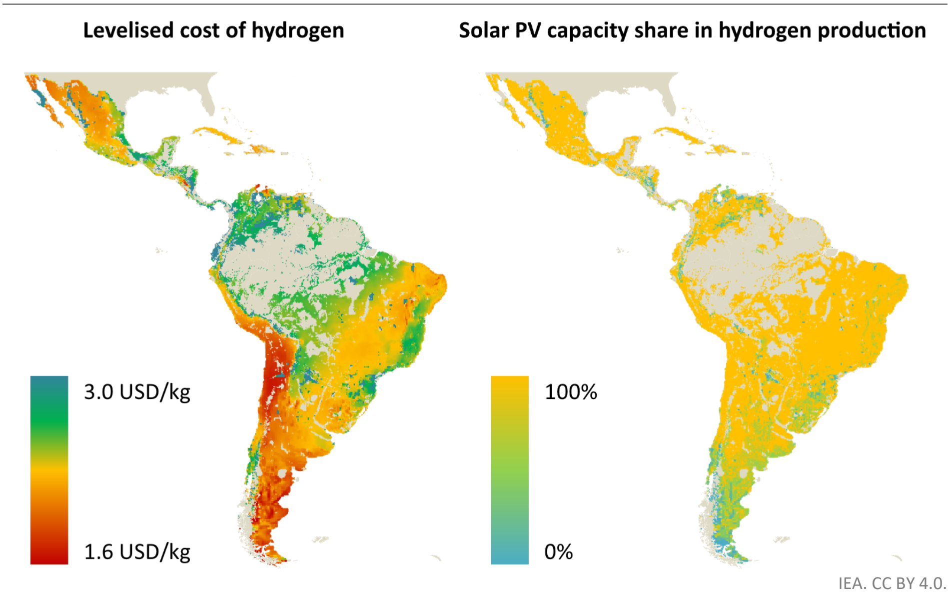
Hydrogen could also play an important role to decarbonise iron and steel production. This could start with the use of low-emissions hydrogen in facilities that already use hydrogen and in place of natural gas in fossil fuel-based direct reduced iron (DRI) with blended hydrogen. The only project in the region that is currently being developed is CAP's H2V in Chile, where a pilot plant is testing the use of hydrogen as a partial substitute for coal in its blast furnaces. Industrial policies need to find ways to promote the production of low-emissions steel and incentivise its use, while safeguarding the competitiveness of domestic steel producers in comparison to potential imports of foreign steel and in international markets. In time, the production of low-emissions steel will create export opportunities if countries start to demand low-emissions steel regardless of whether it involves a cost premium (see Chapter 4).

In the APS, the use of hydrogen for power generation is one of the main drivers of low-emissions hydrogen demand, although its share in the power mix is less than 1% in LAC by 2050, in large part because of the ready availability of renewable resources in the region. Low-emissions hydrogen has a high value as a clean, storable and flexible fuel that can help balance electricity networks. A micro-grid in Cerro Pabellón, Chile has been using hydrogen since 2017 to provide continuous clean electricity, and other projects at the scale of few megawatts are being assessed in Mexico and Barbados. Countries such as Mexico are also considering blending hydrogen in their combined-cycle gas turbines from 2033.

3.4.2 Low-emissions hydrogen production

In the STEPS, global hydrogen production increases to 110 Mt in 2030 and 140 Mt in 2050, with low-emissions hydrogen accounting for only 6% of the total in 2030 and 22% in 2050. In the APS, global hydrogen production reaches about 120 Mt in 2030 and 300 Mt in 2050, and low-emissions hydrogen accounts for 21% of the total in 2030 and 82% in 2050. Both fall far short of what is required in the NZE Scenario, which sees global hydrogen production rise to 150 Mt in 2030 and 430 Mt in 2050, of which 46% is low-emissions hydrogen in 2030 and 97% in 2050.

Figure 3.15 ▷ Levelised hydrogen production costs and share of solar PV from hybrid solar PV and wind systems in LAC, 2030



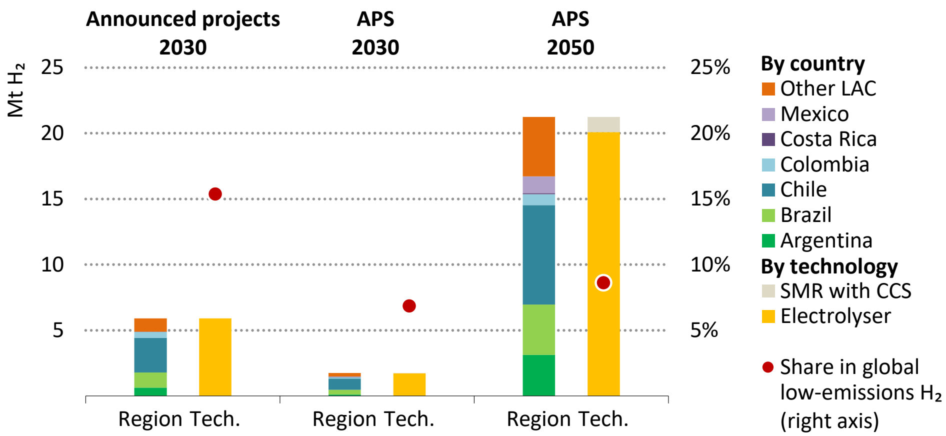
LAC region has some of the lowest renewable hydrogen production costs in the world

Notes: USD/kg = US dollars per kilogramme of hydrogen. For each location, production costs are determined by optimising the mix of solar PV, onshore wind, electrolyser and battery, resulting in the lowest costs. Technological costs reflect 2030 values in the Net Zero Emissions by 2050 Scenario.

Source: Analysis by IEK-3, Research Centre Jülich using the ETHOS model suite.

The LAC region is well positioned to become a leader in low-emissions hydrogen production because its abundant renewable energy resources mean that it has the potential to produce low-emissions hydrogen more cost effectively than many other regions of the world (Figure 3.15). In the APS, hydrogen production in LAC countries is more than 50% higher by 2030 than it was in 2022, and the share of low-emissions hydrogen is 25% higher than the global average, highlighting the scope for rapid growth in the production of low-emissions hydrogen in the region.

Figure 3.16 ▻ Low-emissions hydrogen production from announced projects in LAC and in the Announced Pledges Scenario, 2030-2050



If all announced low-emissions hydrogen production projects in LAC proceed, the region will account for 15% of announced global production by 2030

Notes: Announced projects are those that plan production by 2030, including those at early stages of development (such as those in which only a co-operation agreement among stakeholders has been announced). SMR with CCS = steam methane reforming with carbon capture and storage; Tech. = technology type to produce low-emissions hydrogen.

Source: Hydrogen Projects Database, IEA (2023d).

According to the IEA hydrogen production project tracking (IEA, 2023d), LAC countries have so far mostly announced low-emissions hydrogen projects based on water electrolysis, although other technologies are being considered, with Brazil exploring bioethanol reforming to hydrogen in a demonstration project, for example (Toyota, 2023). If all the announced projects are realised, annual production of low-emissions hydrogen could reach around 6 Mt H_2 in 2030, accounting for more than 15% of the global total (Figure 3.16). However, the status of these projects varies, with only 0.1% in operation, under construction or with a final investment decision, compared with more than 6% globally. Most projects in operation or under construction are relatively small (<1 kt H_2/year), but some LAC countries are pioneering a few larger scale projects, one of which has been in operation for nearly six decades. This project, *Industrias Cachimayo* in Peru, uses 25 MW alkaline electrolysers (equivalent to a capacity of 4.2 kt H_2/year) connected to the grid to produce hydrogen for ammonium nitrate for explosives in its mining operations, and has agreed with Engie to provide certification that only renewable energy sources would power the electrolysers (ENGIE, 2022).

As a result of uncertainties about actual deployment and a lack of policies to incentivise demand for low-emissions hydrogen, production is only 0.3 Mt H_2 in 2030 and 2.1 Mt H_2 in 2050 in the STEPS, rising in the APS to 1.7 Mt H_2 in 2030, which is around 40% of today's fossil fuel-based production, and to 21.2 Mt H_2 in 2050, which is five times as much (Figure 3.16). This results in a mismatch between announced projects and scenario results, unless resolved. If production is to speed up, governments need to tackle regulatory uncertainties at a national and international level, boost domestic demand and seek to develop export off-take agreements. It will be especially important to secure international co-operation on hydrogen certification to avoid market fragmentation and provide certainty to export-oriented projects.

Boost LAC competitiveness with low-emissions hydrogen production

Scaling up the production of low-emissions hydrogen to make the region a leading supplier will require investment, national and international support, appropriate policies and regulations, human capital development, and a co-ordinated effort to boost hydrogen production and demand simultaneously. It will also require the development of the transport and storage infrastructure needed to support international trade.

Trade opportunities could arise from the export of low-emissions hydrogen, but they could also flow from the export of products manufactured with low-emissions hydrogen. The export of products of this kind would not require hydrogen transport and storage, whereas the export of pure hydrogen would require technologies that are still at a demonstration phase (see Chapter 4). While some countries plan to jump-start low-emissions hydrogen production to cover their own demand, others may heavily rely on exports. Active participation in global hydrogen trade holds immense potential for LAC countries, which could make use of their abundant renewable energy resources to create value and secure additional sources of revenue.

Despite the LAC region being a hub for low-emissions hydrogen production projects, there has been a notable lack of announcements regarding manufacturing plants of hydrogen-related technologies. This could hinder industrialisation and value creation. In the first-half 2023, Chile's CORFO sought to identify companies interested in electrolyser manufacturing projects in the country and received nine responses, which it plans to follow up with a request for proposals (CORFO, 2023). Argentina's draft Hydrogen Law (as of July 2023) includes local content requirements, but there are some doubts about the scope for meeting them in the short term. When assessing the potential for hydrogen in the region, countries should at the same time develop a strategy for creating a robust manufacturing sector that maximises domestic innovation and wealth creation along the entire value chain.

3.5 People-centred transitions

The global energy transition is ultimately for and about people. Whether it is supporting rising standards of living, ensuring energy is secure and affordable, or reducing harmful air pollution and GHG emissions, it should improve outcomes for society. The energy transition is also dependent on people, whether it be skilled energy sector workers building the new energy economy, households adopting new technologies and practices, or the general public that has a say in how and how fast these transitions occur. Governments should therefore balance the need to transition with economic and political considerations, and engage civil society in the process of defining the pathway forward.

The IEA Global Commission on People-Centred Clean Energy Transitions delivers recommendations aimed at ensuring that the energy transition is for and about people. These are organised around four guiding pillars: decent jobs and workers protection; social and economic development; equity, social inclusion and fairness; and people as active participants (IEA, 2021b). Many Latin American and Caribbean countries have placed strong emphasis on connecting the sustainability agenda to the social agenda, and are looking for ways for clean energy progress to provide better outcomes for citizens. Their efforts to achieve this are taking varied forms across the region, but the four pillars are relevant to many of their policies. Affordability remains a particular concern in the wake of the energy crisis, especially for those that remain without access to electricity and clean cooking. The accelerated transition to clean energy also holds promise to reduce consumer spending on energy, improve air quality and create new jobs. Governments need to bear in mind those that may be adversely affected, such as low income households, indigenous communities and those working in fossil fuel sectors.

3.5.1 Energy access

Electricity

Progress in recent decades means that most countries in LAC are close to achieving universal electricity access. Yet, 3% of the LAC population – around 17 million people – do not have access to electricity. Almost three-quarters of them are concentrated in rural areas and in countries that have witnessed little progress in the last decade, notably in Haiti where over a third of those without access live. However, even large countries like Brazil and Mexico that have access rates of over 99% are home to over 1.5 million people without access. Poor communities remain disproportionately affected not just by a lack of access but also by unreliable connections. For instance, over a fifth of residents in the favelas in Brazil report suffering black-outs at least once a month (CLASP, 2023). Reliable and affordable access to electricity remains key to other important social agendas, such as improved access to safe drinking water, education and health services.

Universal access by 2030 is within reach in the region but requires stronger efforts in countries where progress has remained slow. In the STEPS, roughly 1 million people are set to gain access each year between now and 2030. Countries such as Mexico, Brazil and Peru currently have policies in place that aim to deliver universal access, but other countries are only on course to slightly reduce the number of those without access. Reaching universal access requires doubling the rate of progress seen in the STEPS, so that around 2 million people gain access each year. Bolivia, Ecuador, Guatemala, Honduras, Panama, and other countries not set to reach universal access in the STEPS have targets to close the gap to 2030, but those targets need to be supported by concrete plans and policies.

If universal access is to be achieved by 2030, electricity access investment needs to reach around USD 1.6 billion per year, equal to just around 2% of today's clean energy investments in the region. Unlike in Africa, attracting the investment needed is less of a problem than working out how best to provide power to remote communities and informal settlements. Mini-grid and off-grid systems are now playing a larger part in providing access to remote communities around the world, helped by continued cost declines and technical improvements. In the LAC region, a number of notable mini-grid projects in the mining sector have fostered a local developer base that can be scaled up. Off-grid solutions can also play a role in regions that face significant risks of disruption as a result of climate change.

Clean cooking

Nearly 75 million people in LAC lack access to clean cooking today, which is around 11% of the region's population.[5] While some countries are approaching universal access to clean cooking, others still have a large share of their population without access, including Haiti (95%), Honduras (50%), Guatemala (50%), Mexico (15%), Peru (15%) and Bolivia (12%). Those without access mostly rely on solid biomass as firewood and charcoal, but some households still use coal and to a lesser extent kerosene (IEA, 2023e). Energy price spikes and rising inflation have added to pre-existing affordability concerns and are making the switch to modern cooking fuels more difficult, as are a variety of cultural and culinary norms.

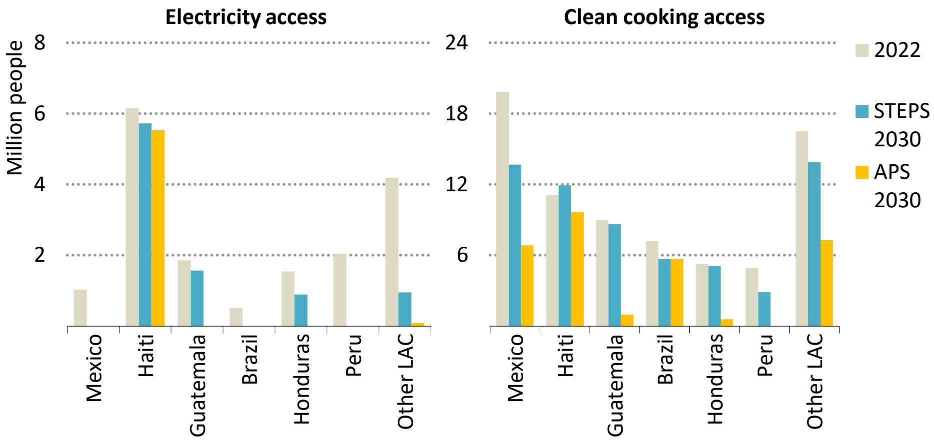
If universal clean cooking access is to be achieved by 2030, current efforts need to be stepped up (Figure 3.17). Since 2010, more than 20 million people have gained access to clean cooking in the region. Progress will continue at a similar pace in the STEPS, with measures in Brazil, Mexico, Nicaragua and Peru compensating to some extent for countries that do not have robust policy frameworks in place. In the STEPS there will still be around 60 million people without access to clean cooking in 2030. However, if all national targets for clean cooking are met this will be halved to around 30 million.

As in the last decade, liquefied petroleum gas (LPG) represents the preferred fuel to extend clean cooking access, followed by electricity and improved biomass stoves. Around two-thirds of households gain access either through LPG or electricity on the road to universal access by 2030. These improvements deliver marked health improvements by reducing household air pollution, delivering meaningful time savings, and reducing GHG emissions

[5] In some parts of LAC, notably the Andean region and southern territories, firewood and other forms of unsustainable biomass are used as a source of heating in addition to cooking.

(methane emissions released as a result of incomplete combustion of biomass energy sources and related deforestation).

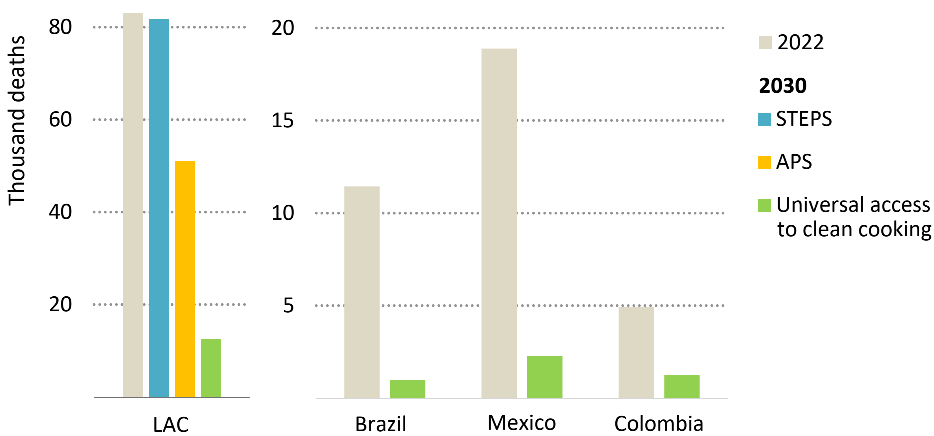
Figure 3.17 ⊳ Population lacking electricity and clean cooking access by country in 2022, and by scenario in 2030



IEA. CC BY 4.0.

Countries with stronger access policy frameworks continue to make good progress towards universal access to electricity by 2030, while access to clean cooking lags

Figure 3.18 ⊳ Premature deaths from exposure to household air pollution in LAC and selected countries in 2022, and by scenario in 2030



IEA. CC BY 4.0.

Complications from household air pollution contributed to over 80 000 premature deaths in 2022; reaching universal access by 2030 reduces premature deaths by 85%

Source: IEA analysis based on modelling by IIASA.

Premature deaths from household air pollution amount to over 80 000 per year in the region, mostly in rural areas (Figure 3.18). Lack of progress in clean cooking access contributes to keeping this figure almost unchanged to 2030 in the STEPS. Reaching universal access to clean cooking by 2030 reduces annual premature deaths related to household air pollution by 85%. Urban households face higher ambient air pollution, which also has major health impacts. The cost of health damage from $PM_{2.5}$ alone in 2019 was around USD 40 billion, equivalent to 0.8% of the region's 2019 GDP (World Bank, 2022). Women and children bear the brunt of the impact of household air pollution as they typically spend more time exposed to harmful smoke and polluting stoves (IEA, 2023e).

3.5.2 Energy affordability

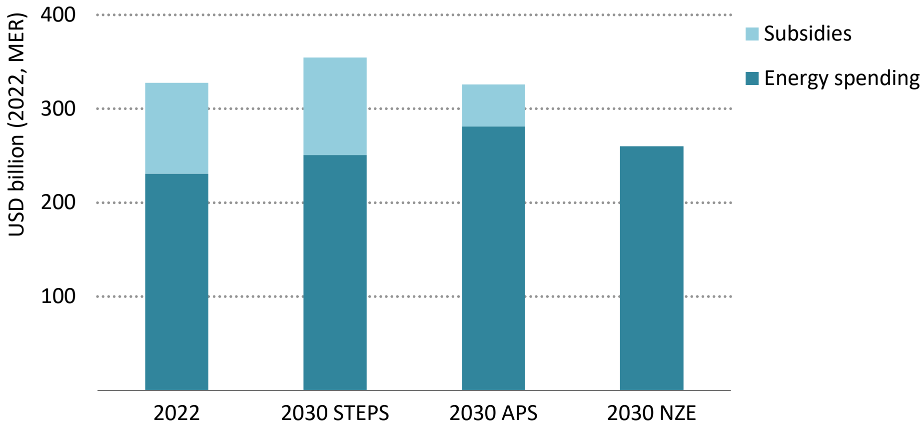
Keeping energy affordable remains a key priority for governments in the region, but the costs incurred by governments in pursuit of this objective are climbing. During the energy crisis, governments implemented additional price support measures on top of subsidies already in place. These helped to keep the share of monthly income that the average LAC household spends on energy use in the home at 3-10%, despite increasing inflation and global turbulence in energy markets. They also caused fossil fuel subsidies for consumer energy consumption to rise from 1.3% of GDP in 2021 to 1.7% of GDP in 2022 in the region: this share of GDP is fifty percent higher than the global average.

A number of ideas for subsidy reform have been explored in the past, but reform remains difficult to balance with near-term impacts on consumers, particularly those with low incomes. Low-income households spend a significantly higher share of their income on energy than higher income groups and are particularly vulnerable to price shocks (IEA, 2023a). These challenges are often concentrated in remote areas or in informal settlements where around one-in-five people in the region live (ECLAC, 2021). However, wealthier segments of the population typically consume more energy, and disproportionately benefit from the current subsidy schemes. Subsidy reforms would alleviate fiscal burdens and correct price signals while allowing governments to introduce more targeted support measures for low income households.

An important point in this context is that faster transitions to clean energy help reduce the challenges of fossil fuel subsidy removal. In the STEPS, where emergency affordability measures are removed but broader fossil fuel subsidy reforms remain limited by 2030, the total cost of providing energy rises from current levels (Figure 3.19). In the APS and the NZE Scenario, higher levels of efficiency and reduced spending on fuels help to curb the rise in energy supply costs. In the NZE Scenario, these reductions are large enough to keep consumer spending on energy roughly equal to that in the STEPS in 2030, even after the removal of all fossil fuel subsidies.

The NZE Scenario also relies on households switching to clean energy technologies. These often involve higher upfront costs than less efficient alternatives but which are more than offset over time by lower operating costs. Many low income consumers find it difficult to afford this upfront cost premium, even though the size of the premium continues to decline to 2030. Incentives or novel financing structures could be implemented to help price-sensitive consumers adopt these clean technologies (see section 3.2).

Figure 3.19 ▷ Economy-wide cost of household energy in LAC in 2022, and by scenario in 2030



Phasing out fossil fuel subsidies reduces the economy-wide cost of household energy and opens the door to more targeted government support

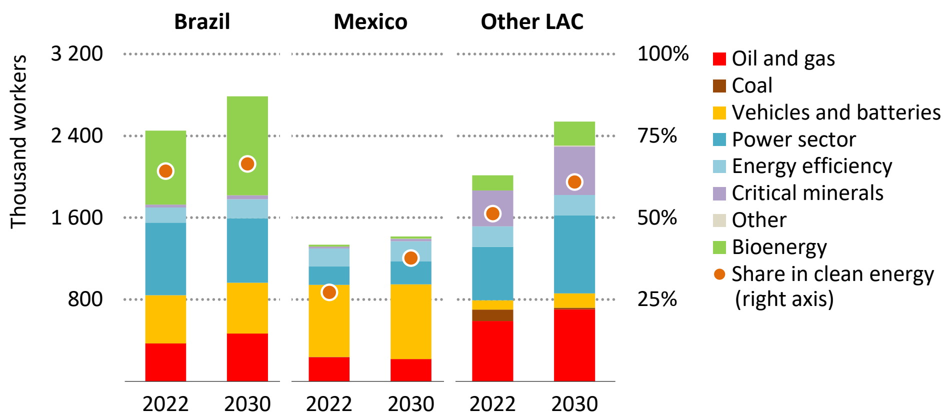
Notes: MER = market exchange rate; NZE = Net Zero Emissions by 2050 Scenario. Subsidies are fossil fuel consumption subsidies based on the IEA price-gap approach. Energy spending includes transport energy spending as well as taxes and levies, such as carbon pricing.

3.5.3 Employment in the energy sector

Today, the energy sector plays a significant role in the economies of several LAC countries. Energy sector employment accounts for around 2% of the LAC workforce, including around 6 million jobs in energy supply, electricity sector, energy efficiency and vehicles (Figure 3.20). These jobs are evenly split between fossil fuel industries and clean energy, and their composition varies widely across the region. There are a number of producer economies with large workforces in oil and gas supply. Brazil, home to the largest biofuels industry, has also the most jobs in the power sector, employing around 700 000 people, mostly related to renewables and grids; Mexico has a strong vehicle manufacturing industry which is largely focussed on exports to the United States and Canada. The critical minerals sector is an important and increasing source of employment across the region.

In the APS, jobs in the energy sector increase by 15% in 2030. Most of this increase is concentrated in clean energy, where the number of jobs reaches 4 million, up from 3 million today. Except in Mexico, where workforce numbers stay broadly level, the power sector is the largest driver of increased employment. Mexico's vehicle manufacturing workforce also grows to 2030, but regulations in the United States and the targets set by vehicle manufacturers themselves mean that production lines increasingly shift to EV manufacturing.

Figure 3.20 ▷ Energy sector employment in LAC in 2022 and in the APS in 2030



IEA. CC BY 4.0.

Clean energy jobs could increase significantly if the existing large vehicle manufacturing base transitions towards electric vehicles

Notes: Other includes nuclear and hydrogen supply. Vehicles refer to all road vehicles. Critical minerals includes both extraction and processing activities. Power sector includes grids.

The critical mineral sector is also an important source of jobs in the region and employs close to 400 000 people in LAC today. Chile has more jobs in critical minerals than any other country in the region: its extraction and processing of copper alone accounts for almost half of all the jobs in critical minerals in the region. In the APS, the region maintains its current share of global production, and surging global demand for critical minerals means that the number of jobs increases by a third by 2030. Today the region exports most of the critical minerals it mines, but countries have announced ambitions to use the indigenous minerals to manufacture value-added goods, notably lithium-ion batteries, which could contribute to rising energy employment (Government of Argentina, 2021a).

Fossil fuel supply jobs also increase through to 2030 in the APS as the region picks up some of the oil and gas demand previously met by imports from Russia. New oil and gas projects create additional jobs, increasing jobs in fossil fuel supply by around 100 000 from just over 1.3 million today. Over 100 000 of those 1.3 million jobs are in the coal industry, mostly in Colombia, with some of these jobs shifting to other sectors by 2030. However, new opportunities may emerge that need the skills honed in coal production such as operation of heavy machinery and expertise in safety protocols relevant in critical mineral mining and processing.

Shifts in employment present opportunities to formalise and diversify the current workforce and reinforce broader policy objectives in the region. While informal employment in the energy sector is relatively limited in the region, it accounts on average for around 50% of employment in the wider economy across the region (ECLAC and ILO, 2023). Job growth in areas like bioenergy, mining and energy efficiency, which rely on or interface with informal sectors, could contribute to bring workers into the formal economy, for instance through requirements on training and certification, thus becoming a catalyst to ensure access to social protection systems such as health care, pension schemes and unemployment benefits.

Today, women make up around a quarter of the energy workforce in the region (IDB, 2023). In the energy sector, the share of women in senior leadership roles sits around 15% today, higher than in the broader economy. There are several programs in LAC that aim to address gender imbalances in the sector, with some countries in the region rolling government-led initiatives to reduce the gender participation gap. For example, Argentina has created the *Comisión Tripartita para la Igualdad de Oportunidades-Género* (Tripartite Commission for Equal Opportunities-Gender) to promote gender equality by incorporating gender issues in job sector policies, while Chile has implemented the *Mujer + Energia* (Woman + Energy) programme to promote the inclusion of historically underrepresented groups in the energy sector and to provide skills training for women.

Box 3.2 ▹ Community engagement

Public participation and community engagement are just as vital to ensuring successful people-centred energy transitions in Latin America and the Caribbean as they are in the rest of the world. Such engagement builds public support, incorporates local perspectives, stimulates innovative ideas from a variety of stakeholders, and helps create energy transition plans that are sustainable, locally appropriate and feasible. Several LAC countries, such as Chile and Colombia, have drawn up extensive public consultation processes to develop their national energy transition strategies. Their central element of is the selection at random of representative groups of citizens to learn, deliberate and make recommendations on how to respond to climate change.

Consultation and citizen engagement processes also represent an opportunity to develop inclusive plans with grassroots input from women, youth, indigenous communities and vulnerable groups which, historically, may have been less likely to be represented in policy-making processes. The inclusion and active participation of these communities is not just a matter of simply securing their support: it also creates opportunities to draw on their understanding of local ecosystems in considering climate change adaptation and mitigation. In Peru, the process of prior consultation with indigenous communities regarding the Framework Law on Climate Change has led to the establishment of the Indigenous Peoples Platform to Address Climate Change which is used to manage, develop, and monitor climate change mitigation and adaptation proposals put forward by indigenous groups.

It is also essential to involve younger generations that will have to live with the long-term outcomes of policy decisions taken today. One example is Panama's SDG 7 academy for young people in energy, which aims to develop skills and increase capacity building while developing an active network of young leaders to support the implementation of its energy transition agenda.

Citizens also have important roles to play in the shift to clean energy. Countries including Mexico and Chile have developed awareness campaigns to reduce energy use, and community-based energy projects are increasingly being implemented across the region. These have shown clear benefits in driving effective renewables deployment and increasing efficiency while reducing bills, supporting access, helping to ensure reliable power supply and creating local jobs. For instance, the RevoluSolar programme in Brazil has successfully deployed solar energy technologies in some of the favelas through co-operative models that involve training favela residents in the installation and maintenance of solar PV systems, and so far, 80% of those trained are women.

3.6 Electricity security and regional power integration

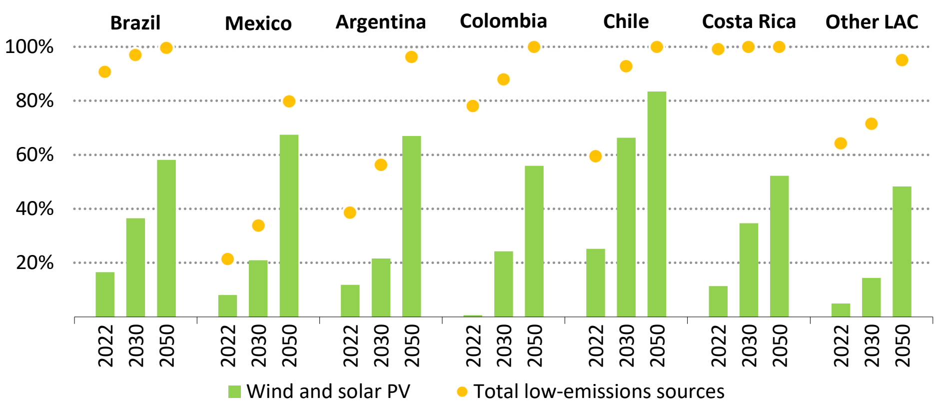
Power systems across Latin America and the Caribbean are set for a major shift from a base of hydropower and thermal power plants to one increasingly reliant on wind and solar photovoltaics (PV). This will require new sources of flexibility and system operation changes to maintain electricity security. Deeper regional power integration in LAC is important in this context: it could enhance system reliability, reduce electricity costs and support expansion of renewables sources. This section discusses the rationale for LAC countries to pursue more regional power integration, and the benefits and challenges that this could bring.

At the Community of Latin American and Caribbean States (CELAC) Summit in Buenos Aires in January 2023, presidents of LAC nations underlined how crucial regional power interconnections are and called for action to take advantage of the complementarities between countries (CELAC, 2023). LAC countries have made varying degrees of progress towards regional power integration through multilateral trade arrangements, bilateral interconnection power trade settlements and jointly owned power plants. For example, Central American countries have had an integrated secondary market – for trading deficits and excesses of electricity – since the SIEPAC interconnector was completed in 2013 (IEA, 2019a). In South America, a number of interconnections were established in the past decades, for instance between Brazil and Argentina, Colombia and Ecuador, Argentina and Uruguay, and Chile and Argentina, and various new projects are being studied (CIER, 2022). There are three jointly owned hydropower plants in the region. The most notable example is the Itaipu plant at 14 GW – the third-largest hydropower plant in the world – being owned by Brazil and Paraguay. Nonetheless, cross-border electricity trade remains limited compared to other regions in the world.

3.6.1 Rationale for higher regional power integration

Electricity systems in LAC are set to see large increases in flexibility needs to 2050 in the APS as wind and solar PV increase their share of electricity generation to over 60% in some countries (Figure 3.21). LAC flexibility needs in 2050 reach almost five-times the level in 2021 in the APS. Different levels of renewables in the generation mix and differing resource endowments provide opportunities for increased multilateral trading, with countries that have an excess of renewables providing flexibility to those that need it. In most cases, flexibility needs could technically be met without recourse to cross-border trading or regional power integration through the use of dispatchable units, the expansion of domestic transmission, new energy storage and demand-response measures, but higher levels of cross-border trade have the potential to meet these needs at lower costs.

Figure 3.21 ⊳ Low-emissions electricity in grid-connected generation mix in selected LAC countries in the APS, 2022-2050

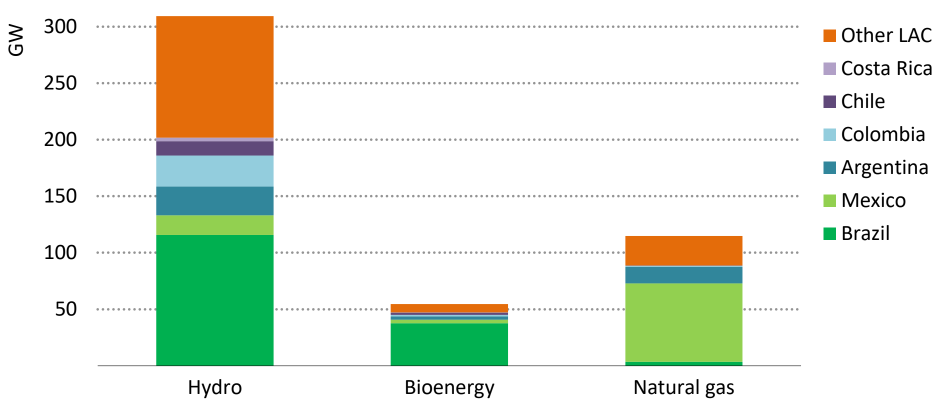


Solar PV and wind are set to play increasing roles in the LAC electricity mix

Dispatchable power capacity that is distributed across countries in the region also provides opportunities for increased cross-border trade. If domestic flexibility is either not available or too costly, regional integration offers countries the ability to tap into dispatchable capacity from other systems. In the APS, over 300 GW of hydropower capacity is operational across various countries by 2050, creating significant opportunities for trade (Figure 3.22). Other key flexible generation sources such as bioenergy and natural gas-fired plants could also provide cost-effective flexibility output across borders.

Long-term complementarities across zones can create incentives for increased cross-border trade, as expanding electrification and higher renewable shares will result in both electricity demand and supply being more weather dependent. The Köppen-Geiger classification (Beck et al., 2018) distinguishes between five main climate zones (temperate, tropical, arid, continental and polar), all of which are found in LAC. Differences between zones result in variations in temperature, precipitation, wind strength and solar radiation patterns, which give rise to complementarities related to electricity demand and to hydropower, solar PV and wind output (IEA, 2023g). For example, tropical climate zones, such as in parts of Brazil, see their highest hydropower availability in the rainy season towards the end of the year, which results in lower wind and solar PV output. At the same time, countries such as Peru and Chile have dry periods over those months, combined with high solar PV output. Moreover, differences in weather patterns across zones means that, although some zones may experience peak demand in summer as a result of cooling needs, others could see peak demand in winter due to heating requirements, while inter-annual climate phenomena such as the El Niño-Southern Oscillation could affect some countries to have drier seasons while others have an extended wetter season (Ochoa, Dyner, & Franco, 2013) as well as affecting wind and solar PV output, creating further incentives for cross-border electricity exchanges.

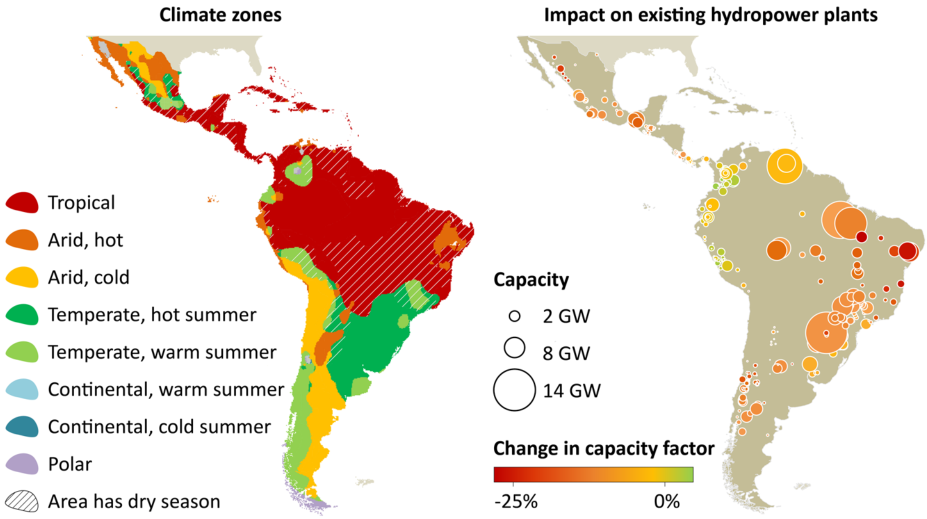
Figure 3.22 ▷ Main dispatchable power capacity by type in selected countries in the APS, 2050



A number of LAC countries command significant amounts of hydropower and other flexible sources of electricity generation

Climate change could also exacerbate zonal differences in hydropower availability. IEA analysis based on the Intergovernmental Panel on Climate Change (IPCC) RCP 2.6 scenario shows that, while some hydro facilities in the region could see minor, or even slightly positive, long-term effects on their annual output, others could see their capacity factor fall by more than 20% of its 1970-2000 average level (Figure 3.23). This could lead to some areas needing to compensate for a lack of hydropower output with other local resources or through cross-border imports. Weather pattern disruptions caused by climate change could also exacerbate differences in temperatures, wind patterns and solar radiation, possibly increasing complementarities across zones in terms of electricity supply and demand. While there have been a range of potential impacts found in other studies, for example on hydropower in Brazil (IEA, 2021c), deeper regional integration would provide benefits.

Figure 3.23 ▷ Present-day climate zones (left) **and operational changes for existing hydropower plants in 2040-2060 relative to 1970-2000, IPCC RCP 2.6 scenario** (right)



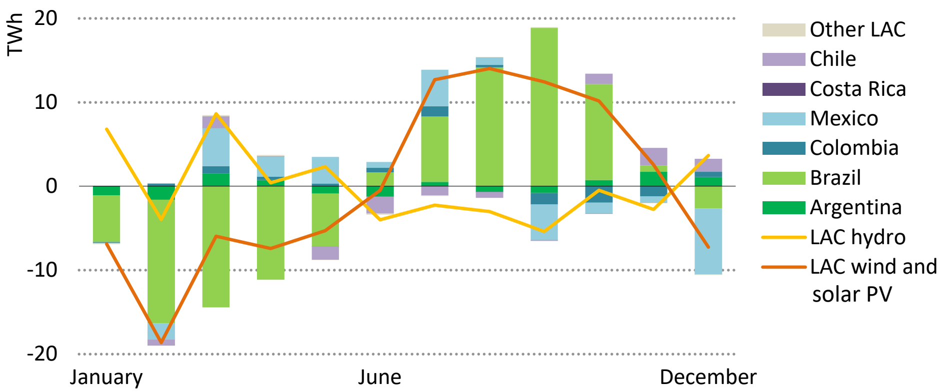
Varying climate zones and potential climate change impacts on hydropower plants point to benefits of increased cross-border power trading

Note: RCP2.6 is an emissions scenario considered in the IPCC Fifth Assessment Report (IPCC,2014). Among IPCC scenarios, it is the one most aligned with the APS.

Sources: Climate zones adapted from Beck et al. (2018). Hydropower analysis based on IEA (2021c).

All these characteristics could translate into complementarities over short-term (hourly/daily) and longer (monthly/seasonal) timescales. At the shorter end of the scale, for example, reductions in output from wind and solar in one system could be compensated by trading with a neighbouring system experiencing an instantaneous surplus in wind and solar PV. Over a longer timeframe, trading could take advantage of complementarities at the seasonal level. For instance, the aggregate output of wind and solar PV in the region tends to be highest in the third quarter of the year, whereas hydropower tends to peak towards the end of the year and the first quarter of the next one (Figure 3.24). Monthly declines in renewables output in some countries could be partially offset by trading with countries where there are increases. For example, wind and solar PV output declines in March and April in Brazil could partially be offset by increases in Argentina, Chile and Colombia. Furthermore, complementarities for hydropower across different climate zones, as is the case across Brazil, Argentina and Paraguay, can provide benefits via expanded trading and co-ordination.

Figure 3.24 ▷ Deviations in monthly output of wind and solar PV and hydropower in selected LAC countries in the APS, 2050



Renewable sources of electricity in LAC complement each other, with monthly swings for wind and solar PV matching well with seasonal patterns for hydropower

Notes: Values reflect differences between monthly generation and the average annual generation. Capacity factors are based on historical data for 2015-2022 for hydropower and 2018-2022 for wind and solar PV.

3.6.2 Benefits and challenges to enhance regional power integration

Benefits

Potential benefits of greater regional power integration include electricity security, affordability and renewables integration. The degree to which these benefits can be obtained will depend on the level of market integration achieved, ranging from early stage integration measures such as bilateral power trade agreements (already in place, for example, between Paraguay and Brazil) to deep integration as in the European Union Internal Market or the PJM market in the United States.

First, higher regional integration can bring enhanced electricity security. Access to a wider range of resources across different areas can help countries to cope with domestic resource variability or supply shortages, for example, in the case of periods of low renewables output or infrastructure outages. For instance, when Brazil was affected by low hydropower output, Uruguay increased its power exports to Brazil from 0.4 TWh in 2020 to 2.2 TWh in 2021 (ADME, 2021). As phenomena such as dry seasons become more intense and frequent, higher regional integration could make an increasing contribution to ensure that systems are more climate resilient and to enhance electricity security.

Second, higher regional integration can make power supply more affordable. It allows resources to be pooled over larger areas and to be used more efficiently, taking advantage of larger markets and economies of scale. This provides scope to reduce operational costs. For example, studies suggest that Central American countries participating in the Central American Electricity Market have seen economic benefits as a result of trading in a common power market (IDB, 2017a). In the long term, it also leads to a reduced need for investment in capacity. For example, the World Bank estimated that 20 countries in the region, considering their current power plants and demand patterns, could save almost USD 2 billion per year if there were unlimited cross-border trade between their power systems (World Bank, 2021b). Similarly, the Inter-American Development Bank (IDB, 2017b) estimated that higher interconnection in the region would result in lower annual costs and capacity investment needs by 2030.

Third, deeper regional integration can support integration of renewables, reduce reliance on fossil fuels and contribute to decarbonisation ambitions. For example, the rationale behind the integrated Central American power market was to optimise the use of geothermal energy and hydropower resources (IDB, 2017a), and thus to reduce the need for high priced fossil fuel imports. As the use of solar PV and wind expands, and as weather patterns show more variation due to climate change, deeper regional integration can help countries to manage local variability in renewables supply by providing access to more resources, and contribute to lowering renewables curtailment as well.

Challenges

Various barriers will need to be overcome by interested countries in the region to unlock the benefits of deeper power system integration. Previous IEA analysis suggests a set of common minimum requirements (political, technical and institutional) that need to be met if progress is to be made towards multilateral power trading and deeper levels of market integration (IEA, 2019b). Strong and effective political leadership is a crucial prerequisite for agreements that are sustained and improved over time. So too is a holistic perspective, given the nature of the challenges. This means that regional integration cannot be a matter for energy ministries and regulators alone, and recognition is needed that it can take a long time to agree. For instance, the Central American Electricity Market Framework Treaty was signed in 1996, after years of carrying out feasibility studies and the market did not start operation for about 17 years.

Domestic improvements will be critical to improve the efficiency of operating each electricity system. This includes several areas that are under discussion today in the region, such as market design improvements, streamlining permitting processes, and improving the planning process and development of transmission and distribution networks.

Beyond domestic improvements, multilateral agreements on matters such as harmonisation of technical specifications, commercial trading and market design, and planning and investment co-ordination are necessary to unlock the full benefits of deeper regional power integration. Regulators and domestic utilities will play crucial roles in resolving most of the issues involved. Harmonisation of technical aspects includes agreeing on grid operation and security assessment criteria, together with grid codes and technical requirements, such as the interconnection capacity calculation methodology for power exchanges. Commercial trading and market design include issues such as defining the allocation between participating countries of transmission costs, power purchase agreements and the level of market coupling. At advanced stages of integration, countries could benefit from co-ordinated financing for priority projects, and from some degree of co-ordinated system planning instead of standalone country plans.

The deployment of more physical cross-border infrastructure is essential and needs to be accompanied by investment in domestic grid infrastructure that enable best use to be made of national resources. The region already has some interconnection capacity and some jointly owned hydropower plants. However, capacity for cross-border trade remains limited compared to other regions, so LAC has substantial opportunity to do more to increase the available cross-border trade infrastructure.

In addition, creating strong and stable regional institutions is vitally important, as is making related changes to their domestic counterparts. The Latin America Energy Organisation (OLADE) was created in 1973 in part to promote the integration, conservation and rational use of the region's energy resources: it has a potentially very significant role to play in the years ahead. The creation in 1993 of the Central American Integration System (SICA) as a regional and political organisation facilitated regional dialogue and thus enabled integration initiatives to materialise in later years. The creation of the Regional Commission on Electrical Interconnection (CRIE) of Central America was also critically important: its responsibilities include co-ordinating with the six national regulators of participating countries and regulating the operation of the Regional Electricity Market (MER).

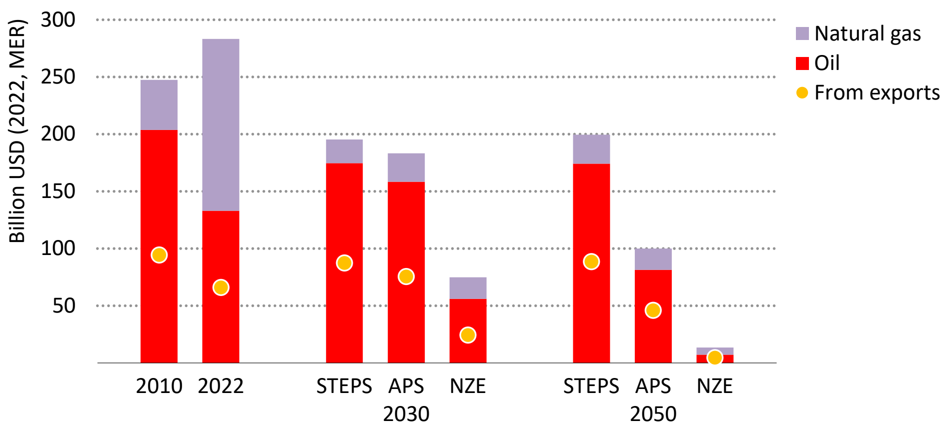
3.7 Transitions in producer economies

Fossil fuel production is a key part of the economy of many countries in Latin America and the Caribbean and an important source of external currency. Net income from fossil fuel supply in the region totalled around USD 300 billion in 2022, of which oil and gas accounted for close to 95%. Some countries are highly dependent on the oil and gas industry: in Trinidad and Tobago, petrochemicals and the oil and natural gas industry provide over 35% of GDP (Government of Trinidad and Tobago, 2023); in Venezuela, oil accounts for around 90% of exports by value (OPEC, 2023). Coal supply is concentrated in Colombia, where coal exports brought an inflow of over USD 10 billion to the national economy in 2022 and, together with oil, accounted for 55 % exported goods (IMF, 2023a). These producers are important for both domestic and international markets. Well over 60% of oil and gas produced in LAC stays within the region. While oil and gas prices have a large impact on national balance sheets, citizens are often cushioned from international swings due to domestic policies. The remaining share of oil and gas production is exported to some of the main global demand centres, including the United States, China, the European Union and India.

3.7.1 Balance short- and long-term demand outlook

Our scenarios indicate that, even if decarbonisation makes rapid progress, oil and natural gas will play important albeit declining roles in the energy system for many years to come. Natural gas can help deliver services that are difficult to provide cost effectively with low-carbon alternatives, such as high-temperature heat for industry, and it will take time to substitute oil in aviation, navigation and petrochemicals. The outlook for fossil fuel production to 2030 varies markedly by scenario, with an increase of nearly 15% in the STEPS, plateauing in the APS and a reduction of more than 20% in the NZE Scenario. All the scenarios feature a decline from 2022 levels in terms of the value of net income associated with the fossil fuel industry (Figure 3.25). This is the result of a decrease in prices from the record levels seen in 2022 and a reduction in global demand for these fuels. Many producer economies are looking to transition away from fossil fuels over time in view of the declining role of these fuels in the global energy sector. Colombia, for example, has announced it will no longer award new fossil fuel exploration contracts.

Figure 3.25 ▷ Net income from oil and gas supply in LAC, 2010-2050



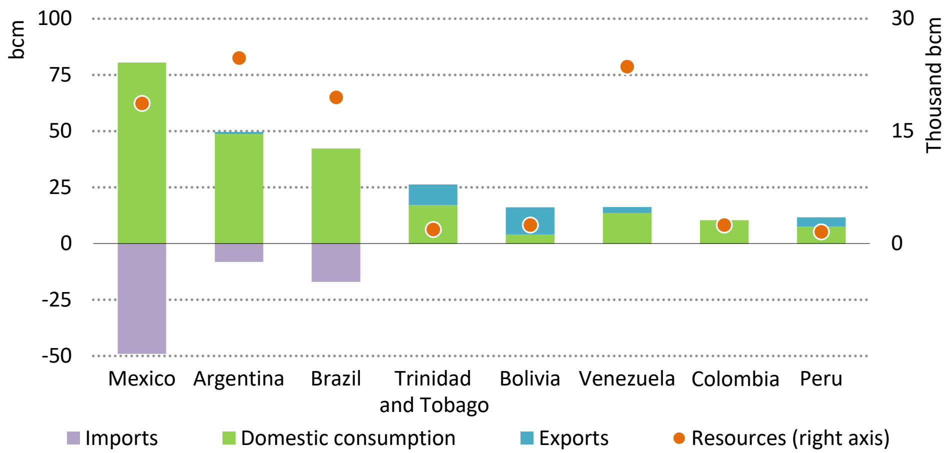
As prices slide from historic highs, net income from oil and gas declines in each scenario to 2030; exports surpass 2022 levels by 2030 in the STEPS and APS

Notes: MER = market exchange rate; NZE = Net Zero Emissions by 2050 Scenario. Net income, i.e. the difference between revenue and costs, is shown for exports and total supply.

The region has both well-established and new producers, and development prospects vary markedly from country to country. Oil production has been rising in Brazil and Guyana, while it is in decline in Venezuela and Mexico. Increased demand and prices for liquefied natural gas (LNG) in 2022 have made occasional importers such as Argentina and Colombia look for alternatives to natural gas: it has also shone a spotlight on the important role played by exporters such as Trinidad and Tobago and Peru in easing market tightness (Figure 3.26).

While the region has long been a net exporter of oil, it remains a net importer of oil products (Figure 3.27). All major producers have oil refineries, but these meet only about half of demand in LAC for diesel and gasoline. Historically, the United States has been the main supplier filling that gap, but comparatively lower prices have led to Russian products making an appearance in the market. Several countries are now looking to expand their downstream segments. Colombia completed expansion works at a refinery in 2022, and Brazil has announced plans to increase Petrobras refining capacity, including capacity for biofuels. Mexico intends to increase the refining capacity of Pemex, including by investing in the Olmeca refinery, and in the medium-term Pemex intends to refine all its production locally.

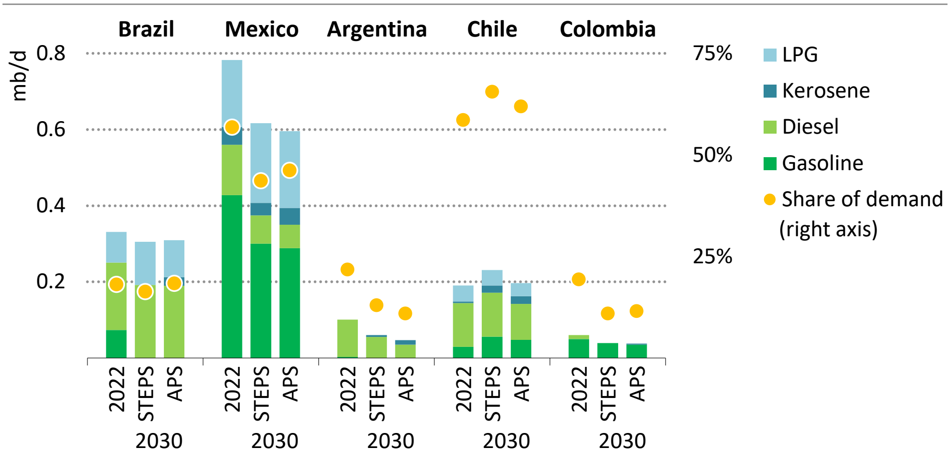
Figure 3.26 ▷ Natural gas demand, imports, exports and resources in selected countries, 2021



Some countries that currently import natural gas have large, underexplored resources

Note: bcm = billion cubic metres.

Figure 3.27 ▷ Net imports of oil products by type in selected countries in 2022 and by scenario in 2030



Countries in LAC remain a net importer of refined oil products

Producer economies are also planning investments in the natural gas industry. Brazil has taken steps to facilitate private participation in its midstream sector, where new investment in processing capacity is expected. New investment decisions for LNG projects have come through in Suriname, and Mexico is currently considering developing a series of terminals.

Although the outlook varies by scenario, these producer economies face the risk that new projects are not cost-competitive or result in stranded assets (IEA, forthcoming). LNG and refinery projects have particularly high capital costs. New refining capacity will face fierce competition from existing refiners in other regions, which are seeking export outlets. With around 250 billion cubic metres (bcm) of annual liquefaction capacity under construction, global LNG markets look amply supplied in the STEPS until at least 2040. In the APS, LNG trade peaks before 2035 and projects under construction today are sufficient to meet demand. In the NZE Scenario, LNG projects currently under construction are not necessary.

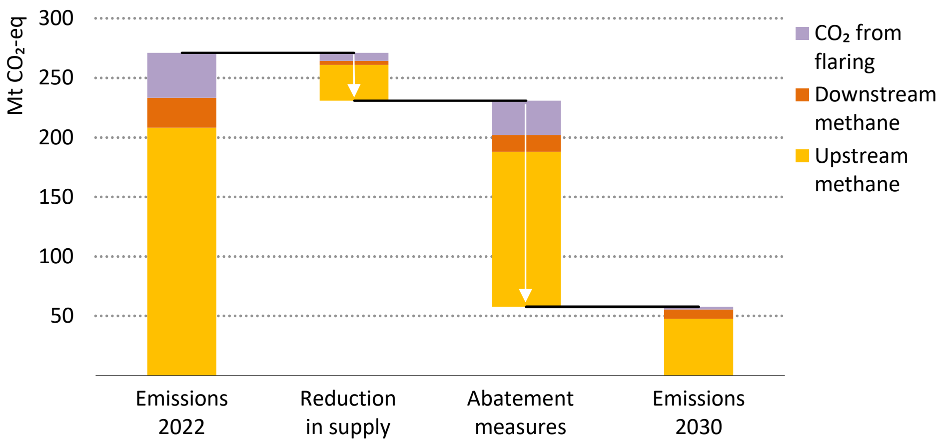
3.7.2 Reduce greenhouse gas emissions

Producers in the region need to balance a short-term push for increased fossil fuel production while prices are high against declining long-term demand for fossil fuels. This could favour the development of resources that can maintain a competitive price in scenarios with GHG emissions pricing or carbon border adjustment mechanisms. Efforts to curtail flaring and methane emissions are crucial in this context.

Flaring and methane leaks are a leading source of emissions in Venezuela, Mexico, Argentina and other oil and gas producers in the region. The methane emissions intensity of oil and gas operations in Venezuela is five-times the world average, and their flaring intensity is over seven-times higher the global average. Producer economies can work with trading partners to reduce scope 1 and 2 emissions from oil and gas activities by tackling methane emissions; eliminating non-emergency flaring; electrifying upstream facilities with low-emissions electricity; equipping oil and gas processes with carbon capture utilisation and storage (CCUS); and expanding the use of low-emissions electrolysis hydrogen in refineries. These five actions are the key to making rapid progress.

Tackling methane emissions is the single most important way of reducing emissions from oil and gas operations. In 2022, oil and gas operations in the region emitted around 8 Mt of methane, with about one-third of these emissions coming from Venezuela. Apart from Venezuela, all major producers in the region have signed the Global Methane Pledge, thereby committing to work together collectively to reduce global methane emissions to at least 30% below 2020 levels by 2030. Argentina and Mexico also participate in the Global Methane Pledge Energy Pathway, which calls for taking all possible cost-effective actions to abate methane emissions in the oil and gas sector, and for the elimination of routine flaring as soon as possible and no later than 2030. There is plenty of scope for early action. We estimate that existing technologies could reduce methane emissions in the region by nearly 80% at low cost (IEA, 2023f), and that around 40% of methane emissions from oil and gas operations could be avoided at no net cost because the outlays for the abatement measures would be less than the market value of the additional gas that is captured, based on average natural gas prices from 2017 to 2021.

Figure 3.28 ▷ Methane and flaring reductions in LAC in the NZE Scenario, 2022-2030



IEA. CC BY 4.0.

Emissions from flaring, venting and methane leaks fall nearly 80% by 2030 largely as a result of targeted and widespread abatement measures

Notes: Mt CO_2-eq = million tonnes of carbon-dioxide equivalent. One tonne of methane is considered to be equivalent to 30 tonnes of CO_2 based on the 100-year global warming potential (IPCC, 2021).

Colombia and Mexico are the only countries in the region directly regulating methane emissions from their oil and gas sector through equipment standards, leak detection and repair requirements and other means. Argentina, Brazil and Ecuador have mostly focused so far on restricting flaring, with mixed success. From 2012 to 2022, flared volumes nearly doubled in Argentina reaching 1.2 bcm, increased around 60% in Ecuador to 1.3 bcm and fell from 1.6 bcm to 0.9 bcm in Brazil. Colombia, Ecuador and Mexico have endorsed the World Bank Zero Routine Flaring by 2030 Initiative, as have several companies that operate in LAC countries, including Petrobras and Ecopetrol.

Stopping all non-emergency flaring and venting is the single most impactful measure countries can take to reduce methane emissions from oil and gas operations. It would also reduce CO_2 emissions in the region by around 35 Mt and bring benefits to health and safety. There are many options for using the natural gas that is currently flared: these include bringing it to consumers via new or existing gas networks, using it to generate electricity, reinjecting it to support reservoir pressure, and converting it to CNG or LNG, as some small LNG and CNG operations in Argentina are already doing.

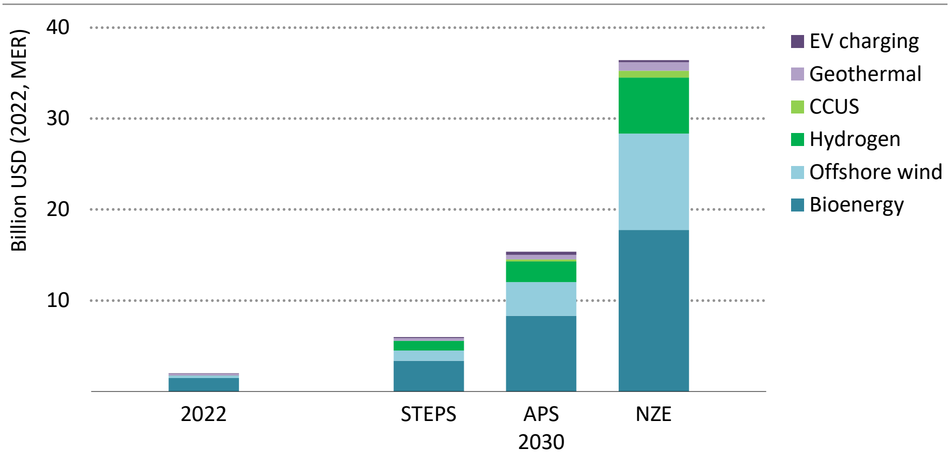
The integration of renewable energy into oil and gas operations also has a part to play in reducing emissions. A large portion of the energy required at upstream facilities is needed to power electrical equipment or to produce heat in boilers, with onsite natural gas generators often producing the required power and heat. Electrifying operations through onsite renewables or grid connections could reduce CO_2 emissions from upstream energy use by more than one-third by 2030.

The use of low-emissions hydrogen can help reduce emissions too. Over 1 Mt of hydrogen is used to refine and upgrade oil in LAC today, releasing around 10 Mt of CO_2 into the atmosphere. Switching to low-emissions electrolysis hydrogen would significantly reduce these emissions: it could also boost demand for this fuel, potentially supporting local industrial development.

3.7.3 Diversify economies

A successful transition in producer countries depends on them managing fossil fuel revenue to promote future prosperity, including through investment in clean energy technologies. Oil and gas companies could choose to diversify by investing in offshore wind, CCUS, advanced bio-refineries, geothermal and other market opportunities. These technologies could be a good match for these companies because they often require similar expertise in handling liquids and gases, large financial resources, extensive R&D and complex engineering projects (Figure 3.29) though none of these technologies is a perfect fit for all oil and gas companies and all of them differ in a variety of ways from traditional oil and gas operations.

Figure 3.29 ▷ Investment in clean energy technologies suited to oil and gas industries in LAC in 2022 and by scenario in 2030



Investment in clean energy technologies triple to 2030 in the STEPS, and reach around USD 15 billion in the APS and over USD 35 billion in the NZE Scenario

Currently, oil and gas companies in the region account for a small share of total investment in clean energy technologies. While some are developing CCUS projects, bioenergy and renewables, overall spending on these technologies is still quite low and there is scope for investment to be stepped up. CCUS could be paired with LNG terminals or oil refineries when suitable sites for geological storage are available, and suitable sites could include depleted oil and gas fields. Offshore oil and gas exploration could share infrastructure and support bases with new wind developments, and refineries could be adapted to process bioenergy and use low-emissions hydrogen. Oil and gas companies could also invest in the production of bioethanol, biodiesel, biomethane and other sources of bioenergy, capitalising on their capacity to refine and distribute products. Brazil has long established blending requirements that ensure biofuels substitute part of the demand for diesel and gasoline. Other areas of potential synergy and diversification include geothermal, plastic recycling and EV charging (IEA, forthcoming).

If oil and gas companies choose not to get involved, these technologies will still be deployed, but it may take longer for them to reach the level of maturity where they can be supplied cost competitively. Existing policy frameworks and industry strategies can be further developed to support clean energy transitions: R&D requirements can be attuned to drive emissions reduction technologies or hydrogen development, and decommissioning plans may consider the integration of new renewables or CCUS opportunities.

3.8 Bioenergy: A sustainable opportunity

3.8.1 Liquid biofuels

The introduction of sugar cane into mainland Latin America from the Caribbean during the 16th century has had far-reaching consequences for economic development in the region, global trade and, more recently, energy supply. In response to the 1973 oil crisis, Brazil introduced the *Pró-Álcool* programme to produce bioethanol from sugar cane in order to reduce reliance on gasoline imports and bolster domestic supply security. In the early 1980s, car makers in Brazil first started manufacturing cars which could run on pure bioethanol, and subsequently during the 2000s they began producing flex-fuel cars which can run on both bioethanol and gasoline at arbitrary blending ratios. Today flex-fuel cars account for over 80% of car sales in Brazil.

The progress of biodiesel – mostly produced from fatty acid methyl esters (FAME) – is closely linked to policies in the region that promote the development of renewable energy and mandatory blending mandates.

By far, Brazil remains the largest producer and consumer of biofuels in the region and the second-largest producer worldwide - accounting for about one-fifth of global production – with biofuels meeting one-quarter of Brazil’s energy demand for road transport in 2022. Argentina and Colombia are also emerging as prominent suppliers.

Table 3.1 ▷ LAC countries with biofuel blending mandates in force in 2023

	Bioethanol share (in volume)	Biodiesel share (in volume)
Argentina	12%	7.5%
Bolivia	12%	-
Brazil	27.5%	12%
Colombia	4-10%	10%
Costa Rica	0-8%	0-5%
Ecuador	-	5%
Jamaica	10%	-
Paraguay	24-27%	5%
Peru	7.8%	2-20%
Uruguay	8.5%	-

Notes: In September 2023, Brazil's Future Fuel Program Bill, which will increase the maximum bioethanol blending to 30%, was signed by the president. Brazil also intends to ratchet biodiesel blending to 15% by 2026. In Panama, a 5% biofuels blending mandate will come into force in 2024.

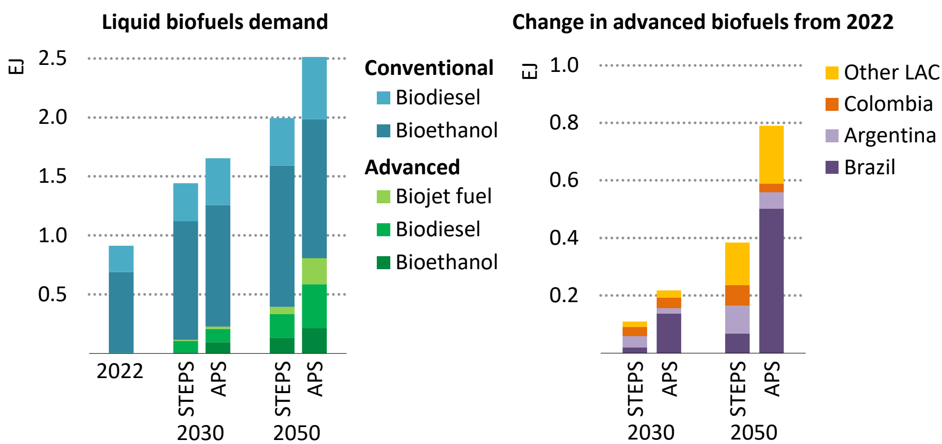
Sources: *Argentina* (Government of Argentina, 2021b); *Bolivia* (Government of Bolivia, 2018); *Brazil* (Government of Brazil, 1997), (Government of Brazil, 2023); *Colombia* (Government of Colombia, 2021); *Costa Rica* (Government of Costa Rica, 2012); *Ecuador* (Government of Ecuador, 2012); *Jamaica* (NREL, 2020); *Panama* (Government of Panama, 2023), (Government of Panama, 2011); *Paraguay* (Government of Paraguay, 2018), (Government of Paraguay, 2020); *Peru* (Government of Peru, 2007); *Uruguay* (Government of Uruguay, 2007).

In the STEPS, biofuel demand increases by 520 PJ, or 270 thousand barrels of oil equivalent per day (kboe/d), between 2022 and 2030, with conventional bioethanol, mostly used in cars, accounting for over 60% of this demand growth (Figure 3.30). In the APS, demand for biofuels is 15% higher in 2030 than in the STEPS, with half the extra demand supplied by advanced biofuels, much of it for use in road freight. Though small in absolute terms (producing just 14 PJ by 2030 in the STEPS, or 5% of global biojet kerosene demand, and 7% in the APS) a nascent industry in biojet kerosene production begins to take off, paving the way for a potentially major export industry by 2050 (Box 3.3). Both scenarios see continued growth in demand for biofuels by 2050, but in the APS advanced biofuels reach almost twice the level of the STEPS, while conventional biofuels stay roughly equal in the two scenarios. Over 70% of the demand growth in advanced biofuels between 2022 and 2050 in the APS is in Brazil, with advanced biodiesel for trucks responsible for most of this.

Advanced biofuels are produced from non-food crop feedstocks and wastes and residues. They can result in significantly fewer GHG emissions than fossil fuels while not competing with food for agricultural land and avoiding adverse sustainability impacts. Feedstocks can include residue fats, oils and grease such as used cooking oils, agricultural residues such as manure and crop residues, the organic portion of municipal solid waste, forestry and wood processing residues and short-rotation crops such as miscanthus and poplar (see section 3.8.3). While residue fats, oils and grease can be used in existing biofuel production processes today, they are ultimately limited in supply. Other wastes and residues are more abundant but require advanced conversion technologies to process into liquid biofuels. Wastes and residues also tend to be dispersed, and to require a lot of co-ordination to collect, sort and distribute.

Yet, there are opportunities for early movers: conventional crop-based bioethanol production can be integrated with advanced cellulosic bioethanol from crop residues such as sugarcane bagasse or corn stover. Brazil is leading the way, with several bioethanol plants already converting bagasse into bioethanol and more plants in the pipeline (Biofuels International, 2022), (Bioenergy International, 2023). Policy mechanisms could be introduced to support a more extensive uptake of advanced biofuels. Examples include financial incentives such as loan guarantees for first-of-a-kind commercial plants, production tax credits and advanced biofuels blending mandates.

Figure 3.30 ▷ Liquid biofuels demand by type and scenario in selected countries, 2030 and 2050



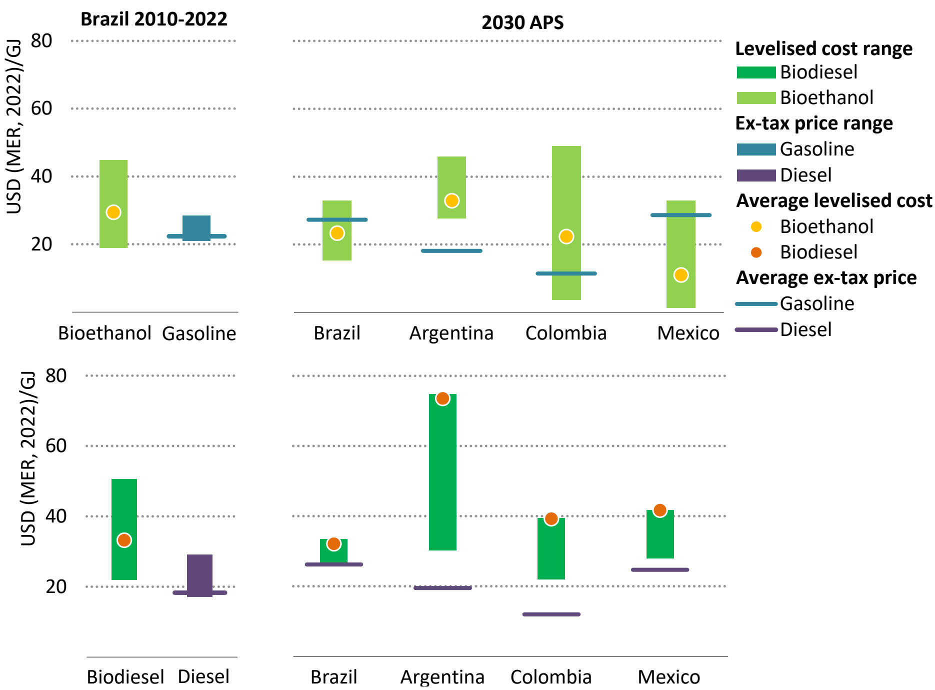
Advanced biofuels growth is particularly strong in the APS, underpinned by rapid expansion in production facilities in Brazil

Notes: EJ = exajoules. Biodiesel in this figure refers to both FAME biodiesel and renewable diesel from hydro processed esters and fatty acids (HEFA) or biomass gasification and Fischer-Tropsch synthesis (bio-FT).

The average levelised cost of bioethanol production in Brazil was higher than the ex-tax gasoline price between 2010 and 2022. However, the pump price of bioethanol was often lower than that of gasoline, as Brazil, in common with other countries in the region, deployed a mix of blending mandates, financial support (including reduced tax rates and fixed pricing) and other measures such as trade policy and technical standards to drive production and demand. Brazil also implemented the RenovaBio Program in 2021 to further incentivise the use of all biofuels and biogases in the transport sector in order to reduce GHG emissions (Government of Brazil, 2021).

Biodiesel, on average, was more than 10% more costly to produce than bioethanol over this period. Much of this cost premium was due to feedstock cost differences, with soybean oil (used to make biodiesel) around 30% more expensive than sugar cane (used to make bioethanol) between 2010 and 2022. The costs of bioethanol and biodiesel production do experience wider fluctuations year-on-year than their fossil counterparts as a result of yield and harvest conditions, markets dynamics, and the price of fuels used for process energy (Figure 3.31).

Figure 3.31 ▷ Levelised cost of biofuels and ex-tax price of gasoline and diesel in Brazil, 2010-2022, and in selected countries in the APS in 2030



Following Brazil's lead, bioethanol becomes cost competitive with fossil fuel alternatives by 2030, particularly in Colombia and Mexico

Notes: USD/GJ = US dollars per gigajoule. Ex-tax price of gasoline and diesel represents domestically used gasoline and diesel price and includes trading, transportation and storage, but excludes taxes and subsidies.

In the APS, bioethanol becomes more cost competitive and is cheaper than gasoline in Brazil and Mexico by 2030. Biodiesel does not reach cost parity with its fossil fuel counterpart due to increasing feedstock costs. However, there is a significant range in production costs across countries depending on domestic feedstock prices, the mix of feedstocks used and production technology costs. For example, high wholesale prices of starchy feedstocks such as cassava in Colombia mean that the highest levelised production costs for bioethanol could reach 50 USD/GJ; at the other end of the cost spectrum, Colombia's comparatively steep carbon price (by regional standards) further reduces the cost floor associated with cheaper feedstocks, such as sugar cane, in production facilities using CCUS.

Box 3.3 ▹ LAC as a biojet kerosene exporter

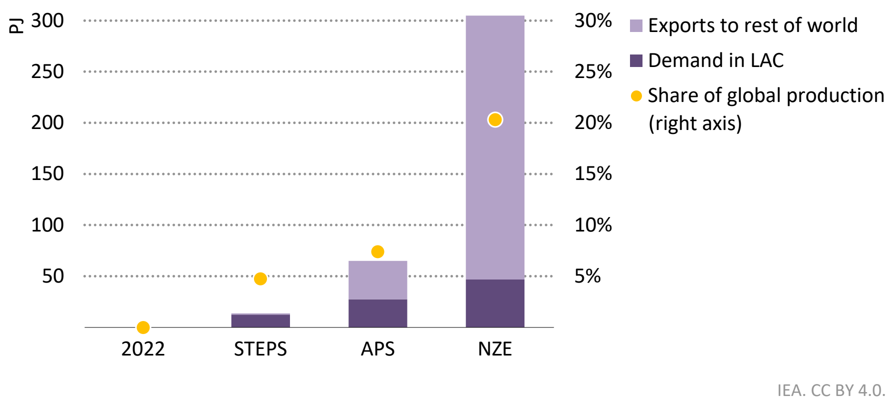
Sustainable aviation fuels (SAF), of which biojet kerosene is one type, has been gaining increasing global attention as a major pathway to decarbonise the aviation sector (ICAO, 2022), (European Parliament, 2023), (IATA, 2021). LAC is taking notice. For example, Brazil's government submitted its Fuel of the Future bill to congress in September 2023, which includes an ambition to increase the production of SAF as a means to reduce domestic transport emissions, and there is increasing interest in building biojet kerosene production plants to take advantage of the biomass resources in the region (S&P Global, 2023c), (Reuters, 2022). A critical benefit of biojet kerosene is that it is a drop-in fuel, requiring little to no modification to existing fleet of aircraft. While the ASTM standards currently limit biojet fuel blending to 50%, tests have shown that 100% blending is possible (Airbus, 2023), and the increasing demand for SAF provides an opportunity for LAC to become a major exporter of biojet kerosene.

Today biojet kerosene is produced in very small quantities, making up about 0.1% of global aviation demand. However, all our scenarios see global demand growth for sustainable aviation fuels, and at present biojet kerosene is one of the most promising SAF candidates. LAC is well placed to extend its existing biofuels production industry to include biojet kerosene by taking advantage of its industry know-how, workforce, infrastructure, bio-refineries and biomass resources. In the STEPS, APS and NZE Scenario, biojet kerosene demand in LAC rises from near zero today to around 10, 25 and 50 PJ respectively by 2030 (Figure 3.32). In the NZE Scenario, LAC capitalises on huge global demand growth for biojet kerosene and production ramps up to about seven-times the level of domestic demand as the region becomes a major global exporter of biojet kerosene, meeting one-fifth of global demand for aviation biofuels.

Biojet kerosene can be produced with several different combinations of feedstock and conversion pathways (ANP, 2021). Currently, the HEFA pathway, using vegetable oils, waste and residue oils, is the only one that has been commercialised. However, bioethanol can also be used as a pre-cursor to biojet kerosene via the alcohol-to-jet (ATJ) pathway, which is at demonstration scale today. Given the scale of bioethanol production in the region, and its integration with sugar mills in Brazil, ATJ could provide a future biofuel pathway as demand for bioethanol in road transport decreases with increasing electrification. LAC is also rich in advanced feedstock resources, such as crop residue, forestry residue and the organic part of municipal solid waste. These advanced feedstocks can be converted to biojet kerosene via routes such as biomass gasification and Fischer-Tropsch synthesis. As with the ATJ pathway, this technology is currently at demonstration scale. Despite these various advances, in LAC the levelised cost of biojet kerosene remains over twice as high as that of conventional kerosene to 2030.

Various challenges need to be overcome in relation to feedstock supply and conversion technology. Policy mechanisms to support the deployment of advanced conversion technologies – which are often more expensive than current biofuel production technologies – will be important to develop biojet kerosene production in the region, while incentivising the lowest GHG emissions SAF pathways will help to ensure that biojet kerosene produced in LAC can maximise its contribution to decarbonise aviation across the world.

Figure 3.32 ⊳ Biojet kerosene supply and demand in LAC in 2022 and by scenario in 2030



LAC becomes a major exporter of biojet kerosene in the NZE Scenario

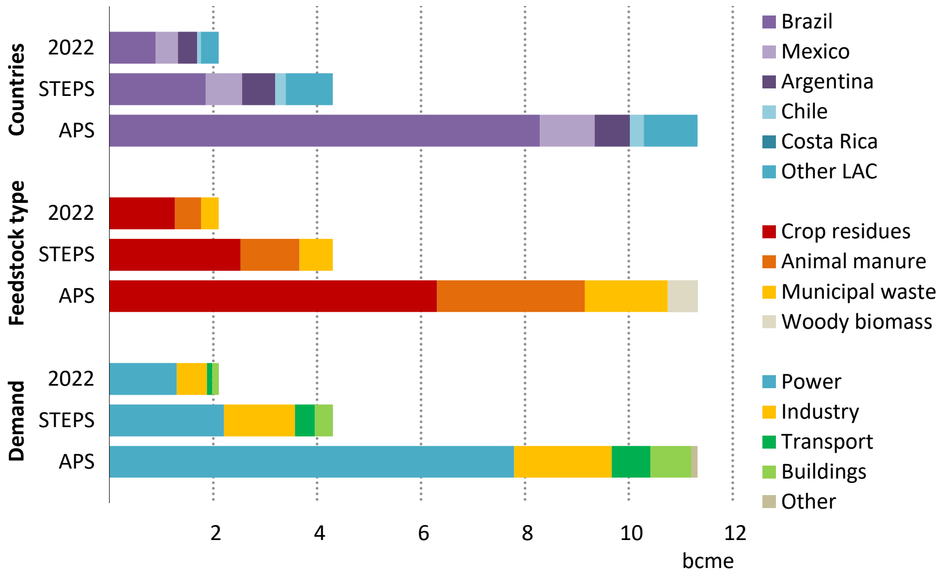
Note: PJ = petajoules; NZE = Net Zero Emissions by 2050 Scenario.

3.8.2 Biogas and biomethane

Biogas and biomethane potential is largely untapped in LAC. A detailed geospatial analysis of agricultural wastes and residues reveals a potential of just under 200 billion cubic metre-equivalent (bcme). Around 10% of this lies within 20 km of major gas pipeline infrastructure, and could be suitable for large-scale production and injection into gas grids. Around half is near a road network, an indicator of the potential for feedstocks to be collected and brought to centralised biodigesters to produce biogas for local heat and power requirements or to be upgraded to biomethane for use in transport.

Harnessing a portion of the biogas potential in LAC raises production from just over 2 bcme in 2022 to 4 bcme in the STEPS and over 10 bcme in the APS by 2030 (Figure 3.33). Brazil, which is already the biggest producer of biogas and biomethane in the region, increases its current production by more than ninefold in the APS: production rises above 8 bcme by 2030 and accounts for nearly three-quarters of total supply of gaseous bioenergy in LAC. The remaining production is concentrated in Mexico, Argentina, Chile, and Costa Rica.

Figure 3.33 ▷ Biogas and biomethane deployment by country, feedstock and end-use in 2022 and by scenario in 2030



Biogas demand in LAC doubles in the STEPS to 2030, and even more in the APS as available feedstocks are more fully exploited

Today, most biogas is produced from maize, sugar cane, and soybean crops, with a small share from animal manure and the organic portion of municipal waste. While the respective shares of these feedstocks remain relatively stable between now and 2030, policy support leads to crop residues and wastes becoming a more competitive and commercially viable feedstock in the APS by 2030. The ninefold increase in gaseous bioenergy deployment in the APS depends on significant investment in feedstock supply chains to increase overall supply and to transition from food crops to sustainable alternatives that do not have negative social and environmental consequences. Currently, many countries lack comprehensive waste management policies, but countries such as Brazil and Argentina have already approved national waste strategies designed to increase the availability of feedstock for biogas production.

Thanks in part to the inclusion of biogas in support schemes that promote electricity generation from renewable sources, the power sector is currently the main user of gaseous bioenergy in LAC, and this is set to continue in the STEPS and APS. Argentina and Chile, for example, over the course of the last decade, have approved laws that provide benefits and incentives for biogas-based power plants. In parallel, several countries have taken steps to encourage the use of biomethane as a transport fuel. This has been achieved through its inclusion in biofuel support schemes like Brazil's Rota 2030, RenovaBio and Fuel of the Future program, as well as Argentina's biofuels law and its RenovAr Renewable Energy Programme. Nonetheless, the use of gaseous bioenergy in transport remains limited in both the STEPS and the APS in the face of growing competition from liquid biofuels and electrification. Conversely, the lack of viable low-carbon alternatives in the near term implies that the industry sector remains an important destination for biogas and biomethane in the APS.

3.8.3 Bioenergy supply

Bioenergy supply in LAC was 8 EJ in 2020, around 15% of the global total. Four sources of bioenergy accounted for about 90% supply: the traditional use of biomass, mainly for heating and cooking; forestry planting, much of it to make wood pellets for electricity generation; conventional biofuel crops to produce liquid biofuels; and forest and wood residues used, for example, to make bio-crude.[6]

Bioenergy supply increases by about 35% in 2030 from 2020 levels in the STEPS, mostly associated with the planting of short-rotation woody crops. Growth in the APS is stronger: a rapid increase in the use of organic waste streams (such as biogenic municipal solid waste, wastewater sludge, manure and crop residues) supplies an extra 2.2 EJ of bioenergy by 2030. The tapping of organic waste streams to provide bioenergy requires no dedicated land use, thereby avoiding any impact on biodiversity and any potential conflict with food production, as well as minimising impacts on soil health.

By 2050, bioenergy supply in the STEPS is two-thirds higher than in 2020 and doubles in the APS. It outstrips the growth in total energy supply in both scenarios. Much of the additional growth in the APS is for production of bioethanol, bio-based diesels and biojet kerosene for export. There are a number of key differences between the sources of bioenergy in the two scenarios. In the STEPS, the traditional use of biomass falls by 70% relative to current levels by 2050; in the APS, it drops by 90%. In the STEPS, the use of organic waste streams rises; in the APS, it expands rapidly to almost three-times the level in the STEPS in 2050. The expansion in the APS depends on investment in waste collection and sorting systems because organic waste streams tend be more dispersed than other sources of biomass.

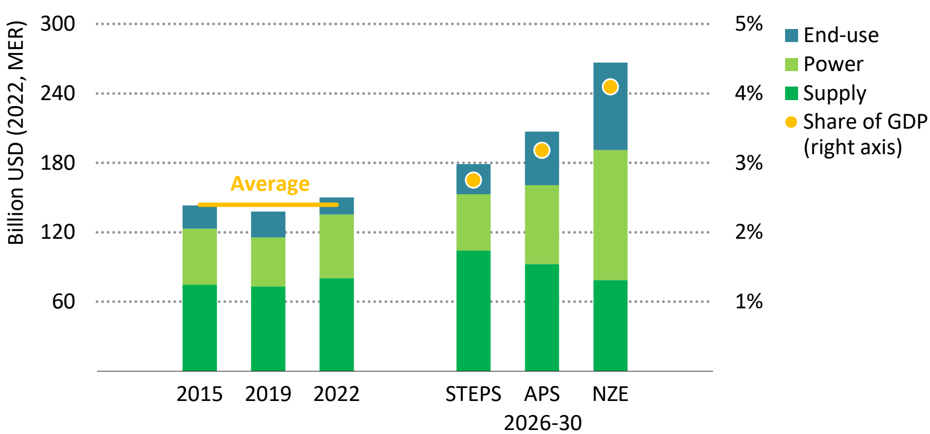
Brazil and several countries in the region signed a deforestation pledge during COP21 in 2015, which has been reflected in the bioenergy supply and land-use modelling undertaken in co-operation with the International Institute for Applied Systems Analysis (IIASA) (see Chapter 4, section 4.1.3). In both the STEPS and the APS, the expansion of bioenergy is not a driver of deforestation, as no bioenergy crops are established on forested land.

[6] Liquid biofuel produced by liquefaction of biomass at high temperatures, often further refined before use.

3.9 Achieve net zero emissions: Investment and finance

Energy investment in Latin America and the Caribbean totalled USD 150 billion in 2022, the highest level since 2014. Investment in the power sector reached a record USD 55 billion, while fossil fuel supply accounted for USD 80 billion, having recovered from the global drop that occurred after the end of the commodity price cycle in 2014 and later during the Covid pandemic. On the other hand, investment in energy end-use has been low and has not picked up in recent years: it accounted for only one in in every ten USD invested in energy in LAC in 2022.

Figure 3.34 ▹ Annual energy investment in LAC by sector, 2015-2022, and by scenario to 2030



Higher investment in energy in LAC is needed to 2030 in all scenarios, the NZE Scenario requires a large reallocation of capital towards power and end-uses

Note: MER = market exchange rate.

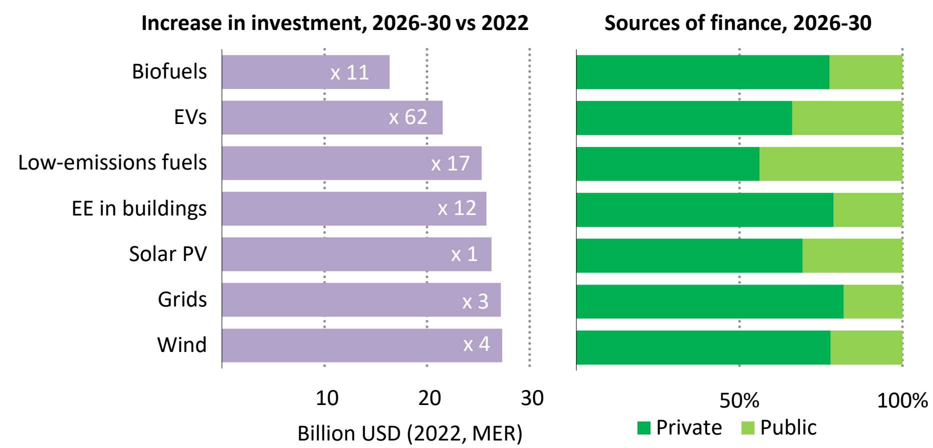
Investment in the region needs to increase further in all scenarios (Figure 3.34). It increases by 20% from the 2022 level, reaching an annual average investment of around USD 180 billion in the STEPS between 2026 and 2030, and it needs to increase by almost 80% to deliver what is needed over the same period in the NZE Scenario. The effort required to bridge this gap will sizable large, especially given the region's low starting point. Energy investment in LAC as a share of GDP was 2.5% between 2015 and 2022, lower than the average share in India or sub-Saharan Africa during the same period. Meeting the requirements of the NZE Scenario would require energy investment to rise to 4.1% of the region's GDP by 2030. Investment in the APS by the end of the 2020s covers above three-quarters of the needed investment in the NZE Scenario over that period.

The NZE Scenario also requires a massive reallocation of capital among sectors. Current policy settings are headed towards a return to past trends, with investment concentrated on expanding oil and gas: investment in supply accounts for almost three-fifths of total energy investment in the STEPS in the late 2020s, compared to around half in recent years. In contrast, energy supply accounts for 30% of the investment in the late 2020s in the NZE Scenario, while the power sector accounts for over 40% and end-use sectors for almost 30%.

3.9.1 Sources of finance

Getting on track for the NZE Scenario requires financing a variety of clean energy assets from utility-scale solar PV plants to consumer-owned appliances and EVs and complex large-scale hydrogen projects. The effort required varies by sector. For example, average annual investment in solar PV and wind in LAC in the late 2020s is above USD 25 billion for each technology. In the case of solar PV spending, this amount is similar to that invested in 2022; in the case of wind, it is four-times the amount invested in 2022 (Figure 3.35). Spending on electricity networks also needs to reach above USD 25 billion over the same period, which is three-times the current annual investment. Some of the most significant increases are needed in end-use sectors, given the very low market share of EVs and the lack of MEPS for appliances and air conditioners in many LAC countries today. Annual average investment to improve efficiency in buildings needs to increase 12-fold; in the case of EVs, it needs to expand 60-times.

Figure 3.35 ▷ Annual energy investment in clean energy and sources of finance in LAC in the NZE Scenario, 2030



Investment in clean energy needs to increase from 2022 levels, particularly in end-uses, and private sector finance plays a significant role

Notes: EVs = electric vehicles; MER = market exchange rate. EE in buildings includes the incremental investment for new or renovated buildings, such as the change in cost for services (design, delivery, installation) and products (lighting, appliances, equipment and materials) that deliver better energy efficiency performance. In the left chart, the bars represent the annual average investment needs in 2026-2030 in the NZE Scenario. The values in the bars show how the average investment in 2026-2030 compares with investment in 2022.

The NZE Scenario also calls for the mobilisation of much more private capital: private investment doubles by 2030, driven by policy and regulatory reforms. About 85 cents for every dollar invested in energy in 2030 is spent on clean energy assets, of which about 70% comes from private providers. Each asset type is financed through various business models, and increasing investment in clean energy means mobilising a wide variety of sources of finance and instruments to match the capital structure of the different energy projects and companies (Table 3.2).

Table 3.2 ▷ Business models and private sector participation in main clean energy assets

Clean energy assets	Most common business model and financing structure	Private sector participation	Level of development in LAC
Solar PV and onshore wind	• Feed-in tariff or long-term physical power purchase agreement, financed on a project finance basis.	High	Growing to mature
Offshore wind	• Long-term physical power purchase agreement or contract for differences. Recently more projects developed with hydrogen production.	High	Nascent
Grids	• Whole-of-grid concessions managed by public or private entity.	Low to high	Mature
	• Independent power transmission projects (used in various LAC countries).	High	Mature
Low-emissions fuels	• With underlying long-term contracts for export or domestic use, usually financed on balance sheets.	High	Nascent
Electric mobility	• EVs financed by households or (public or private) transport companies through savings and consumer finance.	Mid to high	Nascent to growing
	• Enabling infrastructure financed mostly by public entities or utilities, financed on balance sheets.	Mid to high	Nascent to growing
Energy efficiency	• Funded on balance sheets by developer or tenant, mostly using equity financing.	Low to high	Nascent to growing

LAC has attracted a higher share of financing from private sources than many emerging market and developing economies. The region led the way in to establish long-term auctions for independent power producers (IPPs), which were predominantly taken up by private companies, and to privatise distribution (IEA, 2021d). Various countries, notably Colombia, Brazil, Peru and Chile, have also been successful in mobilising private sector investment in transmission grids through a business model similar to the IPP used for generation, with national and international development finance institutions playing a critical supporting role. In Brazil, the development of utility-scale solar PV and wind was catalysed by the BNDES – the national development bank – which provided concessional, long-term debt for IPPs. In Argentina, the RenovAR auction programme, supported by the World Bank Group, has attracted USD 7 billion in almost 154 new renewable energy projects totalling almost 5 GW, despite private sector doubts about investment risks (Energy Green Map, 2023). The programme included a fund to extend loans as well as a guarantee covering risks of delay or non-payment by the utility and termination, and an additional World Bank guarantee to provide a backstop for the fund in case of shortfalls risk. Today, solar PV and wind contribute 12% to the power generation mix in Argentina, up from about 1% in 2016.

Energy efficiency improvements can be a very cost-effective way of tempering energy demand growth and reducing emissions, but it tends to be challenging to finance such improvements because they are generally small-scale and therefore involve relatively high transaction costs. The lack of stringent and enforced building codes is also a major impediment to investment. Despite some successes, this is still a relatively nascent sector in LAC. Colombia was a first-mover in the region to develop mechanisms to reduce risks and lower financing costs, though in general, efficiency investment still faces significant barriers (CEFIM, 2023).

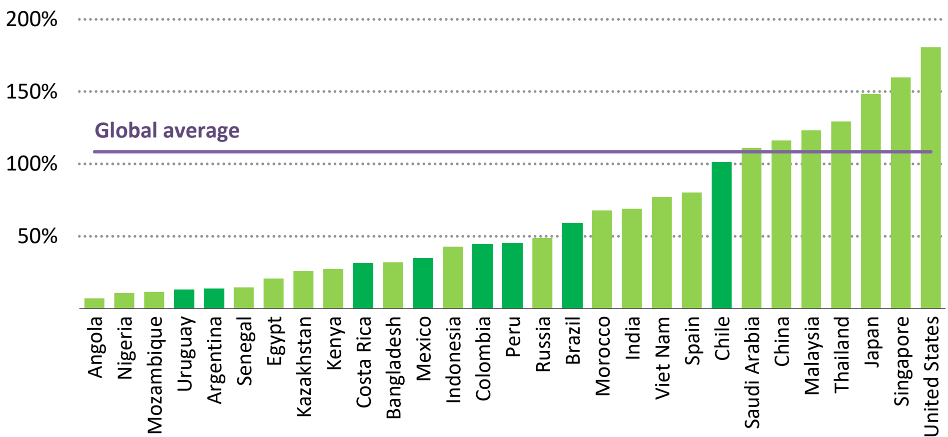
3.9.2 Challenges and ways to mobilise more investment

The LAC region offers various advantages for investors compared to other emerging market and developing economies. On average, LAC scores relatively well in international democracy indices. The region also ranks above many emerging market and developing economies in terms of rule of law, governance and political stability, though still below most advanced economies. On the energy front, various LAC countries have undergone important reforms since the 1990s to unbundle the power sector, introduce more regulatory independence, and increase competition. A number of countries have also privatised power utilities. In general the region has secured a high level of private financing for energy assets and companies compared to emerging market and developing economies in Asia and Africa.

A particular challenge for LAC is its high inflation history and the related high interest rates and cost of capital (see Chapter 1). This has two important implications for the region. First is that interest rates are very high, making it more difficult than it would otherwise be for any project to become profitable. Second is that high inflation comes with exchange rate instability and high hedging costs which add to the challenge of securing predictable cashflows in hard currency. Worries about debt distress and low economic growth domestically also discourage investors and financiers in a region that has generally been perceived as suffering from a high degree of political instability.

On top of these issues, the availability of domestic credit in the region is low: it is hard for citizens to save money, and capital markets are neither very deep nor liquid. The level of financial system development varies, but most LAC countries have capital markets and banking sectors that are relatively less well developed than the global average (Figure 3.36). Access to finance in Chile, one of the highest income countries in the region, is similar to the world average, but this is the exception rather than the rule. In general, LAC countries rank better than African countries, but worse than Southeast Asian nations, a region that is closer to LAC in terms of GDP per capita. With the exception of utility-scale renewables, local banks sometimes lack the ability to undertake risk analysis of clean energy projects. In addition, credit for final consumers and small and medium enterprises (SME) is generally constrained, and credit ratings are generally absent. This all makes for high interest rates for SME. For instance, the interest rate differential between larger companies and SME tops 12% in Brazil and Peru (IEA, 2021d).

Figure 3.36 ▹ Financial system development indicator for selected countries as share of GDP, 2017-2022



Most LAC countries have capital markets and banking sectors that are less well developed than the global average

Notes: Financial system development indicator shows the average of the share of private credit to GDP and the share of stock market capitalisation to GDP over the most recent five years. Global average is weighted by GDP.

Source: IEA analysis based on IMF (2023b), World Bank and World Federation of Exchanges (2023).

Closing the investment gap requires solutions to reduce cross-cutting as well as project or sector specific risks. The cost of capital reflects these two groups of risks and can be split into a base rate (incorporating risk perceptions of the general investment conditions in a country) and a premium (covering risk perceptions of the specific investment). Reducing the base rate is a long-term project going well beyond the energy sector which may demand long-term structural reforms. However, improving the availability and affordability of hedging instruments could be a quick solution to help reduce currency risk and attract more foreign capital investment in energy. These instruments help fix the exchange rate between, for example, the local currency denominated cash flows and hard currency lending (or capital investment) over a defined period, in exchange for a protection fee paid by the investors. Hedging alternatives in the region tend to be for short maturities, not very liquid – especially for some currencies – and costly. Extending alternatives like the Currency Exchange Fund (TCX) would be a good start: this is a global currency hedging facility that helps reduce currency risk in low- and low-middle-incomes countries (including various countries in LAC).

In terms of project specific risks, solutions vary depending on the stage of development of the sector. In some mature sectors, the challenge is to get projects moving fast, so improving permitting and licensing processes and approvals is critical. Governments and corporations could also start or expand the use of sustainable finance instruments to attract debt in domestic currency and from local and international sources. For example, the government of Colombia released two green bonds in 2021, followed by a National Green Taxonomy in 2022. The green bonds had estimated "greeniums" (an interest rate lower than a standard bond) of 7 and 15 basis points each. About 40% of the investors were domestic, demonstrating their comfort with this type of instrument and indicating that there is scope for further use of green bonds (IEA, 2023h).

Concessional financing is needed for less mature sectors as well as for low income countries and those with perceived high levels of political risk. About 5% of the investment needed in LAC in the NZE Scenario by the early 2030s takes the form of concessional funds (IEA, 2023i). Together with India, LAC is the second-largest recipient of this type of funding. In Africa, which is the largest recipient, clean energy markets are less developed, and concessional funds are needed to kick-start these markets through de-risking and project development. In LAC, the situation is different, with these funds being needed primarily to play a catalytic role to promote newer technologies such as low-emissions fuels, large-scale storage or electric mobility. Of course, concessional funding alone will not solve all problems; scaling up private investment depends on policy and regulatory certainty, and countries also need clear targets, procurement processes and contract frameworks to ensure bankability in nascent sectors like offshore wind and green hydrogen production.

Tailored solutions are also required to scale up investment in energy efficiency. Building codes and performance standards are key to improve project bankability, but so are certification schemes that provide an independent evaluation of building energy performance, bringing confidence to investors. Pooling projects together to achieve scale and expanding green consumer finance, e.g., green mortgages, are other ways of securing investment. Initiatives like the Infonavit Green Mortgage Programme in Mexico or the Energy Savings Insurance model in Colombia are good examples on which other programmes could be modelled. Colombia's programme was implemented by Bancoldex, a national development bank, and then replicated by the Inter-American Development Bank, a regional bank.

In addition, data availability and reliability are critical to improve project bankability. Without easily accessible, granular and reliable data, banks, equity investors and developers may find it difficult to undertake proper due diligence and may not approve – or even consider – otherwise viable projects. Governments play a key role in providing this information and building investor confidence, especially among foreign investors. For example, the Federation of Industries of the State of Ceará in the northeast of Brazil produced a highly granular wind-solar atlas in 2019 that helped to attract a large volume of investment, positioned the state as a hub for green hydrogen production, and stimulated other Brazilian states to make similar data available (IEA, 2023i).

Implications for global transitions and energy security

SUMMARY

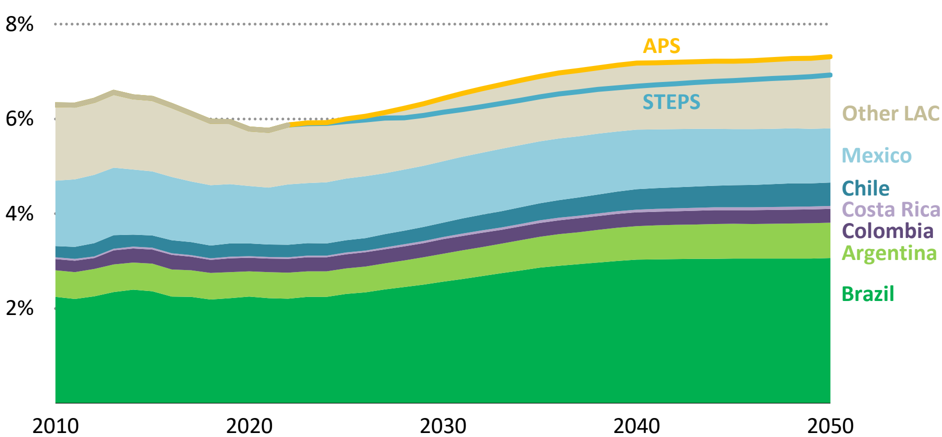
- Latin America and the Caribbean (LAC) currently accounts for just 6% of global energy demand, rising to 7% in 2050 in the Announced Pledges Scenario (APS). Yet it has an outsized role in renewable energy. LAC accounts for 14% of global renewable energy use, relying heavily on hydropower and bioenergy. Its ample solar and wind resources enable it to contribute 8% of the global increase in renewables to 2050 in the APS.
- LAC is set to make a significant contribution to the global clean energy transition. In the APS, it accounts for almost 10% of the global reduction in oil demand to 2050 and about 5% of the decline in natural gas demand. Reducing fossil fuel use in LAC cuts energy-related CO_2 emissions by about 860 million tonnes (Mt) from 2022 to 2050. This reduction means halving its emissions when compared to 2022 levels, further lowering its already less than average emissions intensity.
- Forests and land use in LAC have a vital role to contribute to climate mitigation, carbon storage and biodiversity preservation. The region witnessed significant tree cover loss between 2000 and 2020. In the APS, pledges lead to an 80% reduction in primary forest deforestation by 2030 and net forest growth of 100 million hectares by 2050. The near cessation of deforestation accounts for more than two-thirds of the reduction in emissions from land use and agriculture by 2030, and land use becomes a net greenhouse gas sink by 2030, removing about 1.6 billion tonnes of carbon dioxide equivalent annually by 2050, with the near halting of deforestation and afforestation in Brazil and Mexico playing key roles.
- LAC plays a crucial role to enhance global energy security with diversified fossil fuel supply. Recent oil discoveries and expansion plans lead Guyana and Brazil to see particularly strong increases in production, as they are projected to make the two largest increases in the world to 2035 in the APS. Argentina has the potential to significantly expand its natural gas production, compensating for reduced output in several other LAC countries, notably Trinidad and Tobago.
- Excellent renewable energy resources in the region mean that LAC has the potential to become a major low-emissions hydrogen producer and exporter. It is projected to increase its share in global hydrogen production, becoming a major net exporter of low-emissions hydrogen and hydrogen-based fuels by 2050 in the APS. Developing cost-competitive low-carbon iron and low-emissions ammonia production could further boost the region's re-industrialisation and attract foreign investment.
- LAC has further opportunities to enhance its economic development and support global clean energy transitions by supplying critical minerals such as copper, nickel, lithium and rare earth elements. Copper and lithium exports are projected to be particularly important in the years ahead.

4.1 Role of Latin America and the Caribbean in shaping global energy trends

4.1.1 Energy demand

Latin America and the Caribbean (LAC) represents a relatively small share of world energy demand, yet the region has the potential to play an important part in global energy transitions. Today it accounts for 6% of global energy demand. LAC energy demand is projected to rise about 1% a year on average to 2050 (Figure 4.1). As a result, its share of total primary energy demand rises to around 7% in 2050 in both the Stated Policies Scenario (STEPS) and the Announced Pledges Scenario (APS). Brazil, Mexico and Argentina are the largest energy consumers in the region: their combined energy demand rises from 4% of global primary energy supply in 2022 to around 5% in both scenarios in 2050.

Figure 4.1 ▷ LAC share in global total energy supply by country and scenario, 2010-2050



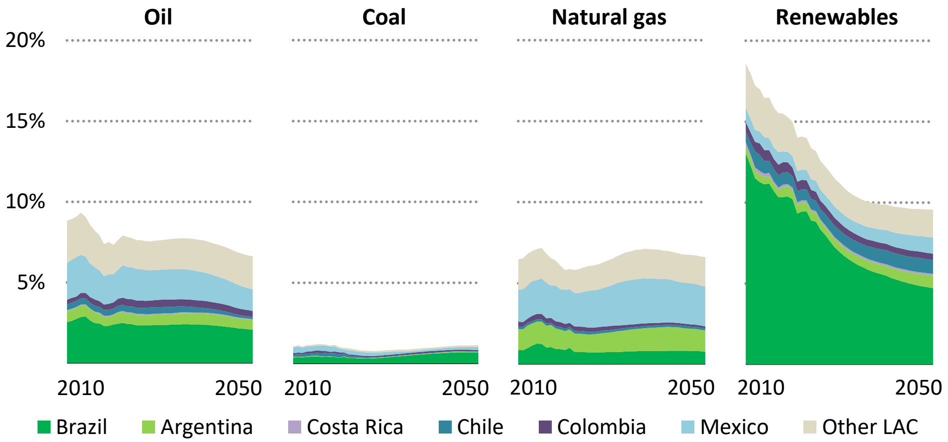
LAC countries account on average for 6% of the world's total primary energy supply, with the largest consumers being Brazil and Mexico, which represent 60% of the region

Note: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

LAC has abundant natural resources to meet this demand. These include significant natural gas reserves in Argentina and Venezuela, oil reserves in Venezuela, Brazil, Mexico, Argentina and Guyana, and coal reserves in Brazil and Colombia. In addition, there are varied and extensive renewable energy resources. LAC has long made extensive use of renewable energy, accounting for 14% of global renewable energy supply in 2022, relative to just 6% of global total primary energy supply. Bioenergy and hydropower have been cornerstones of the LAC energy mix, and home to four of the world's ten-largest hydro facilities. LAC accounted for 18% of global electricity generation from hydropower and 22% of bioenergy production in 2022. The region also has significant potential wind resources to exploit, notably in Patagonia and the north of Brazil, and solar resources in Chile and elsewhere.

Renewable energy will continue to be critically important in the region, and in the APS, renewable energy supply triples from 2022 to 2050. While inherent limits to its sustainable use mean that hydropower growth is set to be more limited than in the past, low-cost wind and solar energy are rapidly gaining momentum and bioenergy stays on a steady growth track. Clean energy transitions are rapidly increasing the use of renewables around the world, so the LAC share of global renewable energy supply declines from 14% today to about 9% in the STEPS and 10% in the APS by 2050 (Figure 4.2). In either case, it is set to be a more important player in global renewable energy than the size of its regional economy would suggest.

Figure 4.2 ⊳ LAC share in global total energy supply by source and country in the Announced Pledges Scenario, 2010-2050



LAC plays a significant role in global renewable energy supply, though the share declines as other regions in the world rush to catch up

Despite fossil fuel resource endowments, the share of their use in LAC total energy demand is relatively modest. Today, fossil fuels account for two-thirds of the LAC energy mix. In the APS, this falls to 57% in 2030 and to 28% in 2050. In the Net Zero Emissions by 2050 (NZE) Scenario, LAC relies on fossil fuels for 50% of its energy needs in 2030, which drops to less than 10% in 2050.

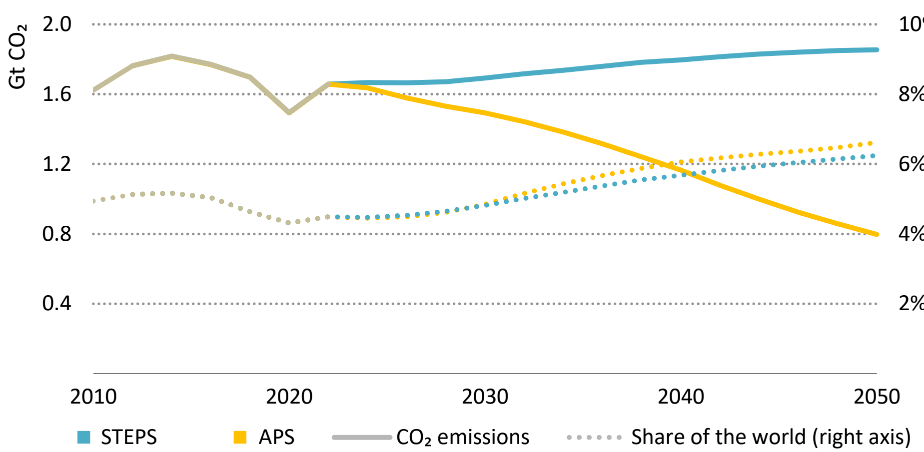
In 2022, LAC accounted for nearly 8% of global oil use and 6% of the global total natural gas use. Brazil and Mexico are the two largest oil consumers in the region, primarily reflecting their robust economies and road transport fuel demand. Mexico and Argentina are the two main natural gas consumers accounting for 2% and 1% of global natural gas demand respectively. In the STEPS, natural gas demand in LAC increases in the years ahead and stabilises in the long term at a level more than 15% higher than 2022, keeping a steady share of around 7% of the global total. In the APS, natural gas demand gradually declines to 65% of the level of demand in 2022 by 2050, accounting for over 6% of the global total.

Today, coal consumption in LAC is 1% of total global demand. Coal has a minor role in the energy landscape of the region, relative to the rest of the world. Brazil has the highest share of coal demand in the region, mainly for steel production, which increases in both the STEPS and the APS. However, the region still has a marginal impact at world level in terms of global share of coal consumption.

4.1.2 Energy-related CO_2 emissions

Total CO_2 emissions in LAC drop by more than 50% in the APS between 2022 and 2050 due to increased electrification in end-use sectors and a continued rapid rise in the renewables share of the electricity generation mix. Yet, the LAC share of global energy-related CO_2 emissions increases from less than 5% today to nearly 7% in 2050 as other parts of the world decarbonise faster (Figure 4.3), reflecting the challenge of striving for decarbonisation while simultaneously trying to deliver economic growth. The LAC share of global emissions nevertheless remains smaller than its share of the global population. In the STEPS, emissions in the region continue to rise both in absolute terms and as a share of global emissions, but average annual growth is less than 0.5%, and emissions per capita remain broadly constant at around 2.5 tonnes of carbon dioxide (t CO_2) per year between 2022 and 2050.

Figure 4.3 ▷ Energy-related CO_2 emissions in LAC and share in global CO_2 emissions, 2010-2050

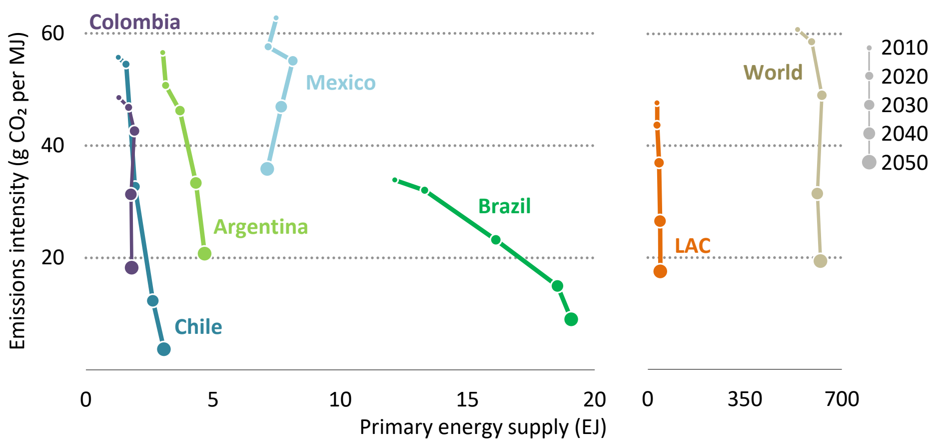


LAC accounts for less than 7% of global energy-related CO_2 emissions between 2022 and 2050 in both scenarios; in the APS, CO_2 emissions drop by more than 50% by 2050

Note: Gt CO_2 = gigatonnes of carbon dioxide.

As a region, LAC is already one of the least emissions-intensive economies in the world. The CO_2 intensity of its energy consumption was 24% below the world average in 2022, and this trend continues to 2030 in both the STEPS and the APS. By 2050, LAC is 10% below the world average. Brazil, which is already the least emissions-intensive country in the region, achieves a further 30% reduction by 2030 in the APS (Figure 4.4). Meanwhile, Chile delivers a 35% reduction, the largest in the region: this reflects the implementation of a series of effective energy efficiency measures, electrification and a substantial decrease of 85% in coal-fired power generation with a coal phase-out target of no later than 2040. Mexico and Colombia reduce their emissions intensity by 7% and 8% respectively by 2030, which is below the average of 17% in the region. Argentina makes steady progress to reduce emissions intensity, with steeper reductions in emissions per unit of energy used than in Colombia and Mexico to 2030, though less steep than in Chile.

Figure 4.4 ▷ CO_2 intensity of primary energy supply in LAC in the Announced Pledges Scenario, 2010-2050



Emissions intensity improvements achieved in most LAC countries are in line with or better than the global average

Note: g CO_2 = grammes of carbon dioxide; MJ = megajoule; EJ = exajoule.

4.1.3 Greenhouse gas emissions from land use and agriculture

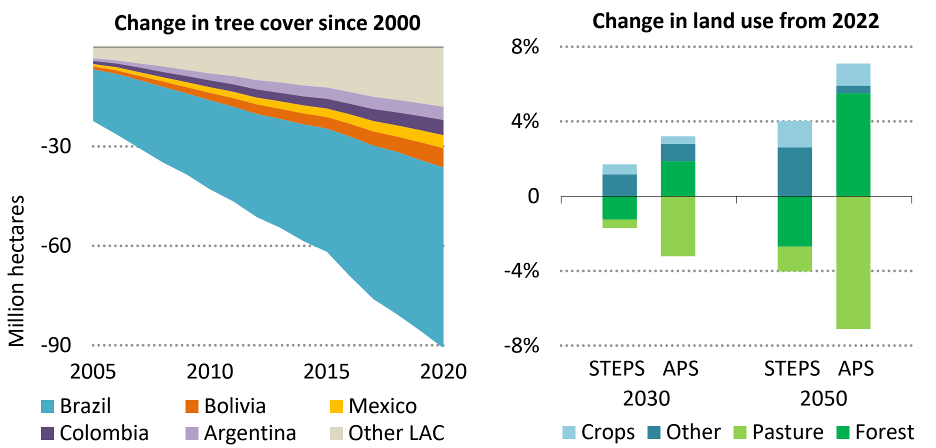
Land use and agriculture play a pivotal role in the contribution of Latin America and the Caribbean to global climate mitigation efforts. This is because the land use sector in LAC – currently responsible for around one-quarter of global land use CO_2 emissions – has the potential to become a substantial carbon sink in the future.

Around one-quarter of the world's forests are in LAC, of which almost 40% is primary rainforest.[1] Primary forest is particularly significant on many fronts. From a climate

[1] Primary forest is naturally regenerated forests of native tree species where there are no clearly visible indications of human activity and the ecological processes are not significantly disturbed.

perspective, it can store 30-70% more carbon per unit area than logged and degraded forests, and losses are especially dangerous: deforestation and degradation of primary rainforest could trigger irreversible changes in local weather patterns, leading to the complete collapse of forest ecosystems, which in turn could push the climate towards a tipping point (Keith et al., 2014); (International Action for Primary Forest, 2017); (Armstrong McKay et al., 2022). The Amazon rainforest is of irreplaceable value in terms of biodiversity – it contains around one-quarter of all terrestrial species – as well as being home to indigenous communities (Barlow et al., 2018).

Figure 4.5 ▷ Change in tree cover since 2000 by country and change in land use by scenario



IEA. CC BY 4.0.

Tree cover loss, mainly of primary rainforest, has accelerated since 2015; in the STEPS deforestation continues; in the APS pasture is converted to secondary forest and cropland

Note: Tree cover represents 50% canopy density.

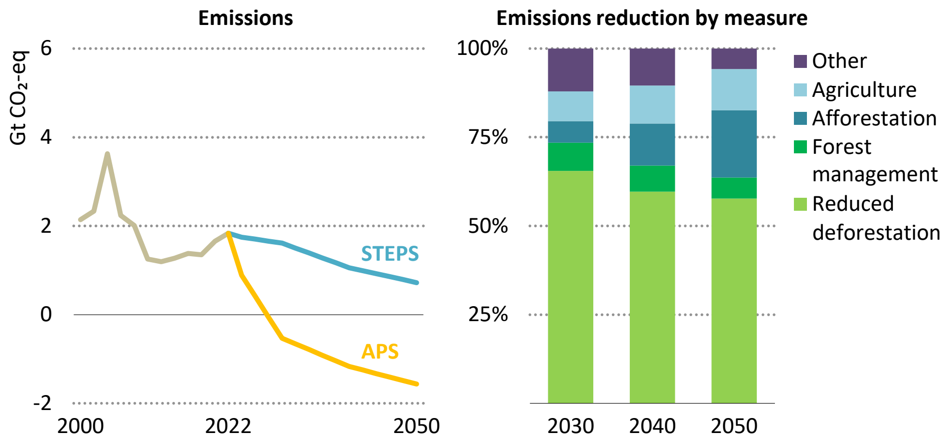
Sources: Global Forest Watch (2023) and International Institute for Applied Systems Analysis (IIASA) modelling for the IEA.

Tree cover in LAC fell by 90 million hectares (Mha) – about the size of France and Germany combined – between 2000 and 2020. Tree clearing in Brazil accounts for about 60% of the total area lost, but there have also been significant losses in Bolivia and Colombia (Figure 4.5). Deforestation has accelerated in recent years, particularly in Brazil, where it reached a 15-year peak of 11 Mha in 2022, equivalent to about 30 football fields every minute. About 40% of previously forested land in LAC has been converted to pasture, and 35% to cropland, almost half of which is used to grow grain crops to feed animals (OECD-FAO, 2022). Much of this is for beef exports to the rest of the world, which have quadrupled since 2000 and now account for one-quarter of beef production in LAC (OECD-FAO, 2022).

In the STEPS, net deforestation continues at an average rate of around 1.7 Mha per year to 2050, with around half of the land cleared used for additional crops and other land uses, and half for cattle ranching, mining and illegal logging. The outlook is very different in the APS. Around 85% of LAC forests are in countries whose governments have signed the Glasgow Leaders Declaration on Forests and Land Use, which aims to halt and reverse deforestation and land degradation by 2030 (United Kingdom Government, 2021).[2] These signatories to the declaration account for almost 90% of the total area deforested in LAC since 2000 (Global Forest Watch, 2022). The APS assumes that they will deliver on their commitments in full and on time, and as a result the deforestation of primary forest is reduced in this scenario by almost 80% by 2030; this is accompanied by afforestation and reforestation, with net growth in forests of 100 Mha by 2050 relative to 2022, much of it on former pasture land.

The different outlooks for land use depicted in the STEPS and the APS make for significant differences in greenhouse gas (GHG) emissions in the scenarios. GHG emissions from land use and agriculture currently account for just under half of the LAC economy-wide GHG emissions on average, but in some countries that value rises to two-thirds (SIRENE, 2023). In the STEPS, land use and agriculture emissions fall slightly to 2030; their decline is more pronounced thereafter, due mainly to an easing in deforestation, emissions from which decline by one-third in 2050 relative to 2022 levels (Figure 4.6).

Figure 4.6 ⊳ GHG emissions from land use and agriculture in the STEPS and APS, and emissions reductions by measure in the APS, 2022-2050



Emissions from land use and agriculture reach net zero by 2030 in the APS, mostly from reduced deforestation

Notes: Gt CO_2-eq = gigatonnes of carbon-dioxide equivalent. Other = bioenergy crops and other land use conversion.

[2] There is ambiguity regarding whether the Glasgow Leaders Declaration on Forests and Land Use aims to halt gross or net forest loss. The projections in this section are consistent with halting net deforestation by 2030 among the signatory countries.

By contrast, the APS sees a steep fall in land use and agriculture GHG emissions in LAC, which reach net zero by 2030. This reflects multilateral commitments, notably the Glasgow Leaders Declaration on Forests and Land Use. It also takes account of the role of land use in the Nationally Determined Contributions of some countries. For instance, the Framework Law on Climate Change in Chile, and legislation such as the National Policy for the Control of Deforestation and Sustainable Management of Forests in Colombia, which targets a reduction in deforestation rates (Government of Chile, 2022); (Government of Colombia, 2020).

A range of improved land use practices combine to bring about GHG emissions reductions in the APS. The most important of these is the near cessation of deforestation, which accounts for two-thirds of the land use-related GHG emissions reductions to 2030, with most of the remaining reductions deriving from improved forest management, other land use changes (such as pasture converted into cropland), and better practices and technologies in agriculture (such as improved rice production, better manure management, crop nutrient management and improved composition of animal feeds). By 2050 the land use and agriculture sector removes about 1.6 billion tonnes of carbon-dioxide equivalent (Gt CO_2-eq) from the atmosphere each year. Avoided deforestation accounts for more than half of the reduction in the GHG emissions from land use between 2022 and 2050, but afforestation efforts in the 2030s and 2040s start to pay dividends in terms of CO_2 removals by 2050, accounting for around 20% of the reductions in the APS by 2050.

Afforestation and reforestation schemes have been established in Peru, Mexico, Ecuador and elsewhere, supported by a mix of non-governmental organisation funding and government backed programmes such as those set up under the Bonn Challenge, which is a global goal to bring 150 Mha of degraded and deforested landscapes to restoration by 2020 and 350 Mha by 2030. An average of 3.3 Mha is afforested per year in the 2022-2050 period in the APS. Over 85% of afforestation takes place in Brazil and Mexico, most of it on land that was previously used for pasture and made possible by improvements in husbandry and pasture management.

4.2 Role of LAC in achieving global clean energy transitions and supporting energy security

4.2.1 Diversity of fossil fuel supply

Diversity of fossil fuel supply has long been a central concern for energy security. A more diverse set of suppliers bolsters energy security by making energy markets more resilient to disruptions of all kinds. Russia’s invasion of Ukraine and the subsequent turmoil in global energy markets has underlined the importance of this point. Energy security is a crucial issue for all countries, and the recent disruption and price spikes in fossil fuel markets have led to renewed interest on the part of importing countries in the potential to develop a more diverse range of suppliers.

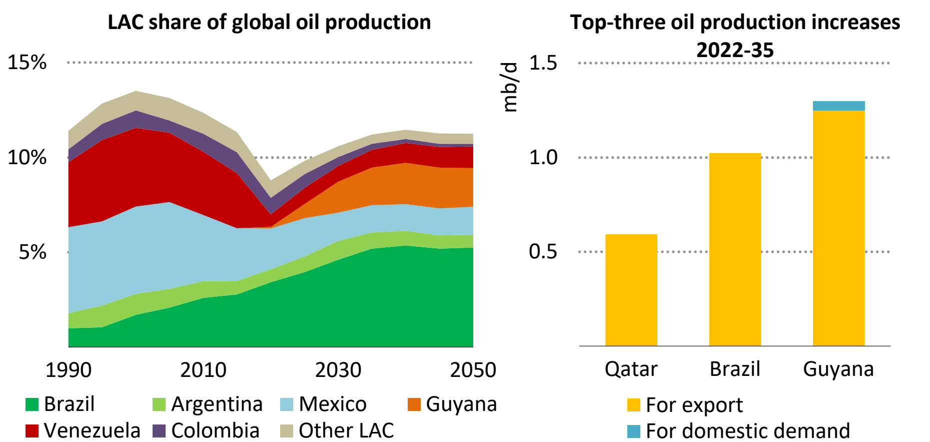
This provides a major opportunity for LAC countries to boost their economies by using recent resource discoveries, in particular oil, to diversify global supply. However, the possibility of additional oil and gas projects comes with important caveats and qualifications. Future demand for fossil fuels varies by scenario, but no new conventional long lead time oil and gas projects are approved for development after 2023 are needed if the world is successful in bringing down fossil demand quickly enough to reach net zero emissions by 2050, as in the NZE Scenario. Any new projects would face major commercial risks, and any countries or companies choosing to undertake them need to recognise that they might fail to recover their upfront costs.

4

Oil

In the APS, fossil fuel demand levels and market conditions put LAC countries in a position to play an increasing role in global oil production and trade. Brazil and Guyana see the second-largest and third-largest increases in oil net exports in the world to 2035 in this scenario, behind only the United States. LAC is already a net oil exporter, sending 0.6 million barrels per day (mb/d) to overseas markets in 2022, which represents around 0.6% of global oil production. Growth in oil production and exports in the APS fall short of what is projected in the STEPS, in which the region increases net exports to nearly 3 mb/d to 2035, but it is still significant: LAC oil production increases outpace regional oil demand growth in the APS, boosting net exports to over 2 mb/d in 2035, or around 3% of global oil supply.

Figure 4.7 ▷ LAC share of global oil production, 1990-2050, and global top-three oil production increases in the APS, 2022-2035



Guyana and Brazil are the top-two countries in the world in oil production growth to 2035: their combined output rises by about 2.5 mb/d, most of which is exported

Guyana increases oil production by over 1 mb/d from 2022 to 2035 in the APS. This is the largest increase in the world over that period and is nearly equivalent to the overall increase in United Arab Emirates oil production over the past 12 years (Figure 4.7). It is made possible by a massive discovery of oil reserves offshore since 2015 by virtue of which Guyana accounts for around 20% of total global crude oil discovered from 2015 to 2023. With a population of less than 1 million, nearly all of Guyana's expanded oil production will be available for export. The boost in oil exports will improve the diversity of oil supply in the world and provides a major opportunity for the country's development. Guyana's net oil exports quadrupled in from 2020 to 2022, with about half of delivered cargoes in 2022 going to the Europe to help replace Russian oil, plus destinations in the United States and importers in LAC.

Brazil accounts for the second-largest increase in oil production in the world to 2035 in the APS. Brazil increases oil production by 1 mb/d over this period, which is nearly 75% more than in Qatar (ranked third in terms of production growth). All of this additional production in Brazil is for export. Brazil has been the largest oil producer in LAC since 2016, after overtaking both Venezuela and Mexico, and it continues to be so through to 2050 in the APS, accounting for about 5% of global production from 2030 to 2050. Brazil has exported oil for many years, and in 2022 its main export markets outside LAC were the European Union, United States and China.

Argentina could potentially increase its oil production, depending on market conditions and production costs for tight oil. Venezuela could also do so if there is meaningful progress in normalising the current international situation.

Natural gas

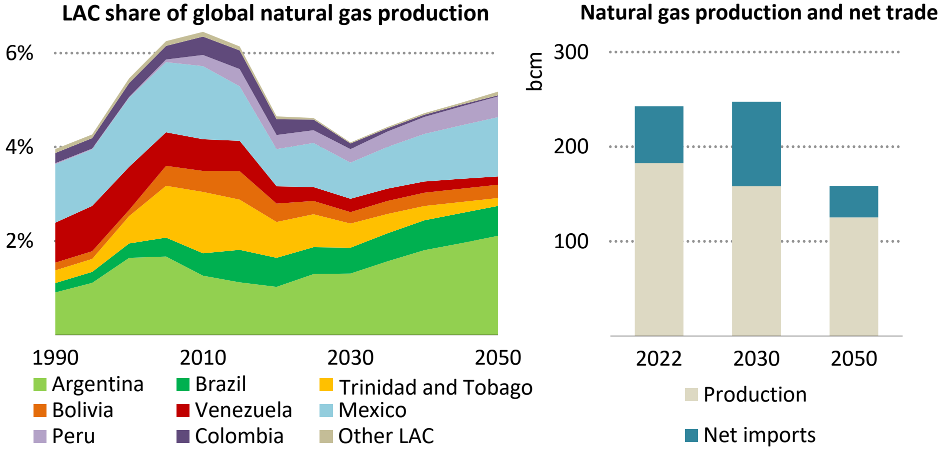
In the APS, LAC remains a net importer of natural gas, though volumes decline sharply after 2030, reducing imports by more than 50 billion cubic metres (bcm). Natural gas demand in the region decreases on average by 1.5% per year to 2050, and production falls over time from almost 185 bcm in 2022 to 125 bcm in 2050. Since global natural gas production also falls over this period, the region's share of the global total is stable at around 5% through to 2050.

Between 2022 and 2030, Argentina increases production by around 15% in the APS while most other LAC countries reduce their output (Figure 4.8). Trinidad and Tobago is the third-largest natural gas producer in the region and a major exporter of liquefied natural gas (LNG), with cargoes going to Europe, importers in LAC and other markets, but its 2022 production was 20% below a recent high in 2019, and it falls by another 30% to 2030. The reduced volume of LNG exports from Trinidad and Tobago in the years ahead presents a challenge for the country's development. Brazil natural gas output plateaus in the near term in the APS, while gas production declines in Colombia.

Between 2030 and 2050, net imports of natural gas in LAC fall sharply in the APS as demand falls more steeply than production. Argentina and Mexico are the only significant producers in the region to see a boost in production over this period.

In the STEPS, natural gas demand in the region continues to rise by an average of 0.5% per year and regional net imports increase by half to 2050. LAC mainly meets its additional demand with imports rather than higher production within the region, in particular as there is a significant decline in output in Trinidad and Tobago. Argentina increases its output by about 70% by 2050, while Brazil increases its production by 20%, more than the increase of domestic demand. Peru has broadly stable output, while other producers like Venezuela and Bolivia see significant declines.

Figure 4.8 ▷ LAC share in global natural gas production, 1990-2050, and natural gas production and net trade in the APS, 2022-2050



Natural gas production increases in Argentina, partially offsetting reductions elsewhere in the region, with LAC share of global output remaining at about 5%

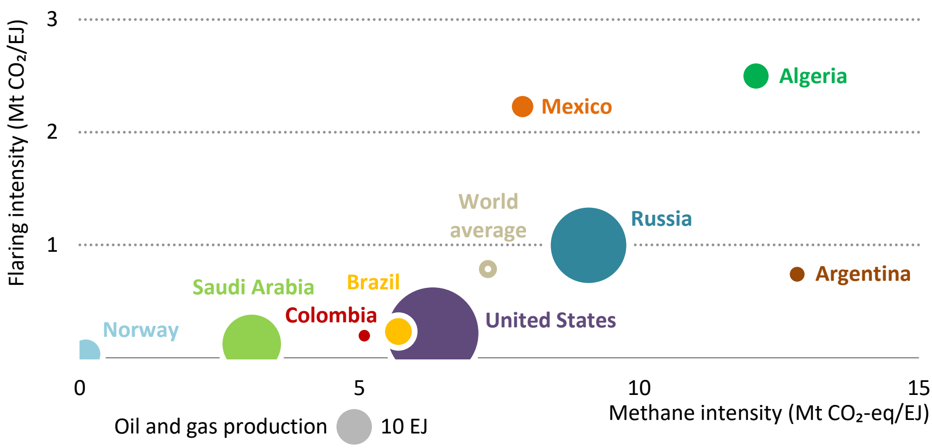
Note: bcm = billion cubic metres.

Emissions from methane and flaring

Methane emissions related to oil and natural gas operations in LAC accounted for around 10% of the industry's global total in 2022. The LAC share of global methane emissions was higher than its share of global oil and gas supply, which totalled 7%. Several major producers in LAC have high methane emissions intensities. Compared with the global average methane intensity of about 7 million tonnes of carbon-dioxide equivalent per exajoule (Mt CO_2-eq/EJ) of oil and gas production, Venezuela was five-times higher in 2022 and Argentina around 75% higher (Figure 4.9). Flaring is also a source of emissions in the region. Compared with the global average for oil and gas operations of 0.8 Mt CO_2/EJ in 2022, Mexico was almost three-times higher and Venezuela eleven-times higher. Colombia and Brazil are notable exceptions: they perform relatively well on both metrics, comparing favourably with the world average.

All major producers in LAC, apart from Venezuela, have signed the Global Methane Pledge, signalling their commitment to tackle methane emissions. Mexico and Argentina also participate in the Global Methane Pledge Energy Pathway, which encourages all nations to capture the maximum potential of cost-effective methane mitigation in the oil and gas sector, and to eliminate routine flaring as soon as possible, and by 2030 at the latest. If all countries in the region heeded this call, they could cut more than 6 Mt of methane emissions and around 35 Mt CO_2 emissions each year. In addition to the emissions benefits, this would make over 25 bcm of natural gas available that could help boost energy security and reduce the region's reliance on natural gas imports. There are a number of steps that producers can take to achieve these reductions (see Chapter 3, section 7).

Figure 4.9 ▷ Oil and gas production for selected producers with associated methane and flaring intensities, 2022



There is scope for major emissions reductions in the oil and gas industry in LAC, by reducing flaring and implementing methane mitigation measures

Notes: Mt CO_2 / EJ = million tonnes of carbon dioxide per exajoule. One tonne of methane is considered to be equivalent to 30 tonnes of CO_2 based on the 100-year global warming potential (IPCC, 2021).

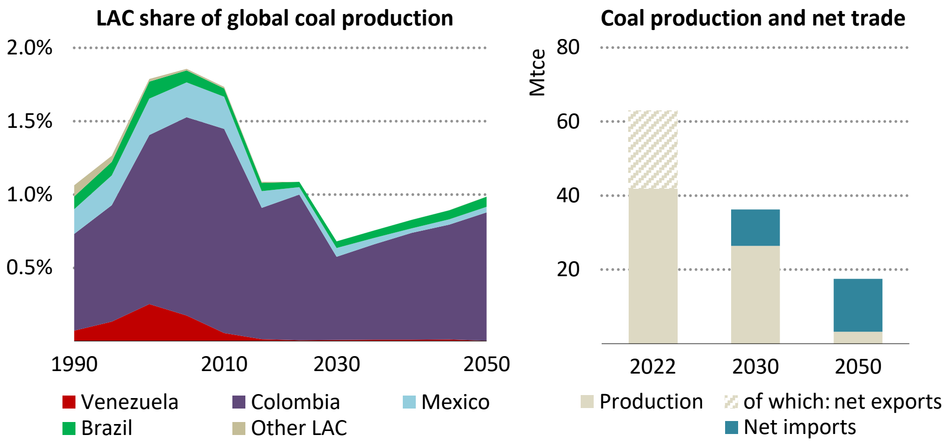
Coal

LAC is not a significant user of coal at the global scale, and this remains the case over the outlook period (Figure 4.10). In 2022, LAC accounted for 1% of total global coal production (measured in energy terms) and coal demand. Coal consumption is projected to decrease marginally in the STEPS, with growth in demand from steel and cement production partly offsetting declining demand in the power sector, but LAC's share of global coal consumption by 2050 remains near or around 1%. Consumption declines in the APS by slightly less than the global average, and it drops by 80% by 2050 in the NZE Scenario. Coal production in LAC declines faster than the global average in the APS, dropping to about 0.2% in the APS.

By far, Colombia is the biggest LAC coal producer. In 2022 it produced around 55 million tonnes of coal equivalent (Mtce), about 90% of the region's total, making it one of the world's top-ten largest coal producers. The vast majority of the coal is destined for export, mostly to Europe. Colombia is currently the world's sixth-largest exporter of coal. In 2022, about 60% of its exports went to Europe, about a quarter to other LAC countries, and smaller amounts to many other markets.

In the STEPS, LAC coal production is set to drop by nearly half to about 35 Mtce by 2030, and then stabilises. It falls faster and further in the APS, dropping to 3 Mtce in 2050. The projected decline in production in both scenarios is primarily due to a fall in steam coal consumption in Colombia's main export markets. The Colombian government recently announced that it would not permit the opening of new coal mines.

Figure 4.10 ▷ LAC share in global coal production, 1990-2050, and coal production and net trade in the APS, 2022-2050



IEA. CC BY 4.0.

Colombia accounts for the bulk of regional coal production; LAC coal production falls by 95% from today to 2050, more than demand in the APS, raising net imports in the long term

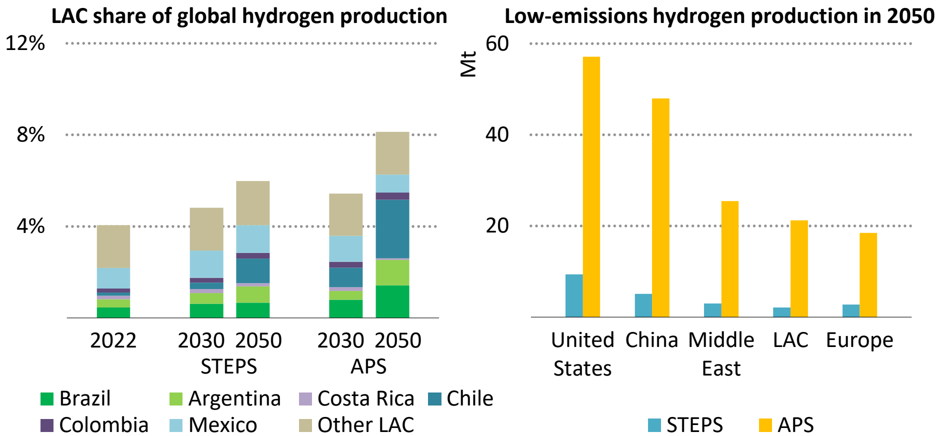
Note: Mtce = million tonnes of coal equivalent.

Other than Colombia, most LAC coal is produced in Mexico and Brazil, primarily for industry and power generation. Production in both countries declines in the STEPS, with a steeper drop in the APS due to an accelerated phase out of coal-fired power generation. The sharp decline in Colombian coal production turns the region into a net importer of coal by 2030 in both scenarios.

4.2.2 Low-emissions hydrogen, hydrogen-based fuels and related products

The share of global hydrogen production in the LAC region rises from around 4% (around 4 Mt) today to 6% (about 8 Mt) in the STEPS and 8% (around 25 Mt) in the APS in 2050 (Figure 4.11). Nearly 50% of the growth in the region in the STEPS comes from low-emissions hydrogen. In the APS, all of the additional production is low-emissions, with electrolysis being used for most of it. Excellent renewable energy resources lead to relatively low production costs for electrolytic hydrogen in the region, which becomes a major producer of low-emissions hydrogen both for use within the region and for export, particularly in the APS.

Figure 4.11 ▷ LAC share of global hydrogen production and top producers of low-emissions hydrogen by scenario in 2050



LAC becomes a significant producer of low-emissions hydrogen in the Announced Pledges Scenario

Note: Mt = million tonnes. STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario.

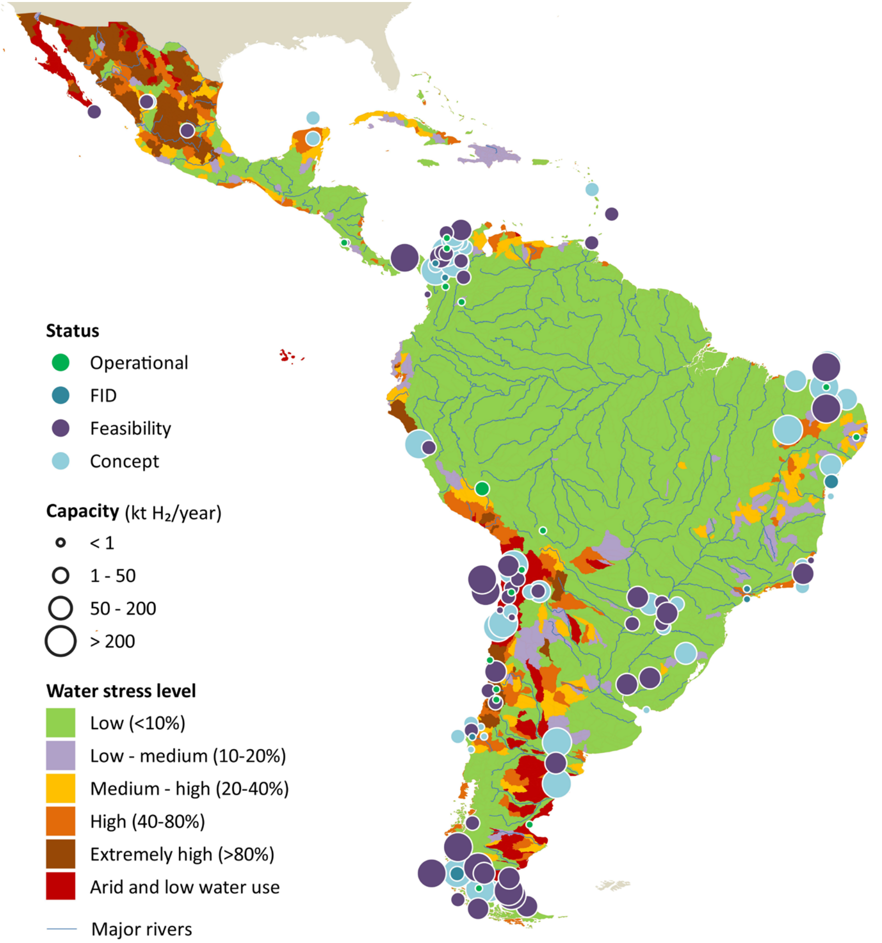
SPOTLIGHT

Ensuring that hydrogen production does not exacerbate competition for water in water-stressed and arid regions

Most of the announced projects in LAC for low-emissions hydrogen production rely on water electrolysis. This requires approximately 10 litres per kilogramme of hydrogen (L/kg H_2) of feedstock water and an additional 30-70 L/kg H_2 of process water for cooling, with exact requirements depending on the cooling technology used and on the ambient conditions. Based on these projects, the production of 5.9 million tonnes of hydrogen (Mt H_2) in 2030 would require around 250-500 million cubic metres (m^3) of water, not including the water used in the maintenance of the renewable energy power plants, for example to clean solar panels. In 2019, the region's annual freshwater withdrawals for agriculture, industry and municipal waste amounted to approximately 420 billion m^3 of water (Ritchie and Roser, 2023). Electrolytic hydrogen production would therefore consume around 0.06%-0.12% of the total amount of current water withdrawals. This percentage might seem small, not least because South America is the region with the largest renewable freshwater resources per capita in the world, but it could still exert additional pressure on water-stressed areas, especially since water availability is already affected by seasonal rainfall variations, recurring droughts and the effect of climate change.

Regardless of its location, proposed hydrogen production projects should assess the feasibility of sites to check whether production could place unmanageable pressure on water supplies. For this reason, most of the announced electrolytic hydrogen projects in the LAC region are planned in coastal areas or close to large bodies of water (Figure 4.12).

Figure 4.12 ▷ Announced electrolytic hydrogen production projects and water stress levels in the LAC region, 2030



Around half of the capacity of announced electrolytic hydrogen projects is in water-stressed areas, requiring additional desalination plants

Notes: The water stress level is a measure of the ratio of total water demand to available renewable surface and groundwater supplies.

Sources: WRI (2023); Hydrogen projects database IEA (2023a); IEA (2023b).

There are several options to supply the water needed for hydrogen electrolysis:

- *Desalination* of seawater or brackish groundwater. In 2022, total operating desalination capacity in the LAC region was 4.2 million m^3/day, equivalent to around 1.5 billion m^3/year (Global Water Intelligence, 2023). If most electrolytic hydrogen production relies on desalinated water, the region may need to expand its desalination capacity by up to 30% by 2030. The largest announced hydrogen projects in LAC, with an expected annual production of 500 kilotonnes (kt) on average, would consume 20-40 million m^3 of water each year, which translates to 55 000-110 000 m^3/day. Although the region has over 1 300 desalination plants, only ten exceed a capacity of 55 000 m^3/day and only one surpasses 110 000 m^3/day. Electrolytic hydrogen projects therefore will often require the construction nearby of some of the largest desalination plants in the region, and these must avoid environmental damage during water intake and brine discharge. These desalination projects also have the potential to contribute to improve water availability and quality. For example, the Marengo I project in Mexico is planning to provide 2 000 m^3/day to nearby communities.
- *Sustainable use of freshwater resources*. When hydrogen production relies on water from freshwater sources, including surface water and groundwater, assessments should be carried out to ensure that production will not encroach on other water needs or jeopardise the viability of future economic activities in the area.
- *Wastewater use*. Wastewater has significant potential to reduce the strain on water resources, and there are opportunities to promote the circular economy by using the oxygen and waste heat that are by-products from the electrolytic process for the wastewater treatment process.

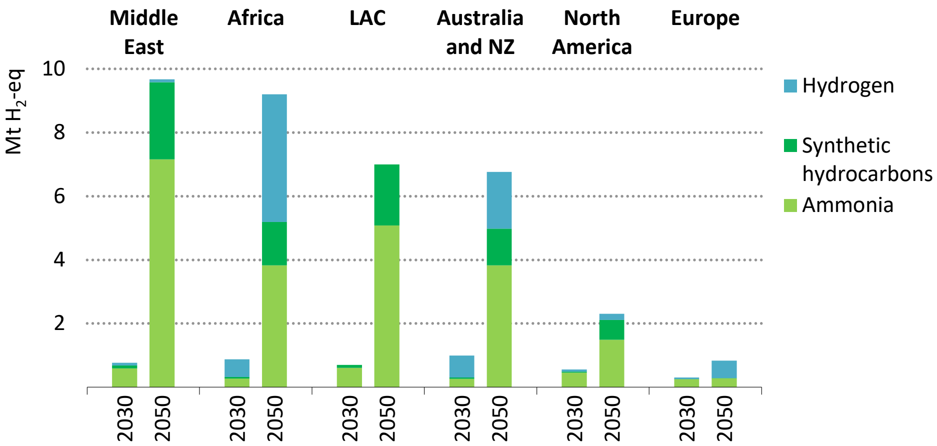
Export opportunities for hydrogen, hydrogen-based fuels and related products

At a global level, around 5 million tonnes of hydrogen equivalent (Mt H_2-eq)[3] are traded inter-regionally[4] in the APS by 2030, rising to nearly 50 Mt H_2-eq by 2050. This is equivalent to around 20% of global low-emissions hydrogen production, which increases about tenfold between 2030 and 2050. LAC is a major exporter of low-emissions hydrogen in the APS, along with the Middle East, Africa and Australia and New Zealand. It is responsible for around 20% of global exports, making it the third-largest exporter of hydrogen and hydrogen-based fuels (Figure 4.13).

[3] For hydrogen-based fuels and feedstocks, the equivalent hydrogen amount corresponds to the stoichiometric hydrogen inputs needed to produce these fuels and feedstocks, assuming a 2% hydrogen loss in the reaction. The hydrogen requirements are 0.18 kg H_2 per kg ammonia; 0.13 kg H_2 per kg of methanol; 0.52 kg H_2 per kg of Fischer-Tropsch synfuel; and 0.55 kg H_2 per kg of methane.

[4] Inter-regional trade refers to the transport of hydrogen and hydrogen-based fuels among regions covered by the IEA Global Energy and Climate Model, but not among countries within the same region.

Figure 4.13 ▷ Exports of low-emissions hydrogen and hydrogen-based fuels by region in the Announced Pledges Scenario, 2030 and 2050



LAC becomes one of the world's largest exporters of low-emissions hydrogen-based fuels

Note: Mt H_2-eq = million tonnes of hydrogen equivalent. Australia and NZ = Australia and New Zealand. North America excludes Mexico, which is included in the Latin America and the Caribbean aggregate. Hydrogen can be traded as gaseous hydrogen through a pipeline or as liquefied hydrogen in a tanker.

Growing interest in trading low-emissions hydrogen and hydrogen-based fuels has already led to a flurry of project announcements. Announced export-oriented projects around the world suggest that about 16 Mt H_2-eq could be exported by 2030, of which almost 2.5 Mt H_2-eq could come from the LAC region. Almost all of these export-oriented projects have been announced in the last three years, however, most of them are still at an early stage of development and only three projects have reached a final investment decision, none of them in LAC (IEA, 2023b). Announced LAC projects accounting for 40% of potential production in the region have identified northwest Europe as their potential export destination, while other announced projects are considering exports to Japan and Korea.

International hydrogen trade is at a very early stage. It is currently limited to a few hydrogen pipelines in northern Europe. In contrast, ammonia and methanol are already traded globally as feedstocks for the chemical industry. The infrastructure to handle and store ammonia and methanol at ports, is already available, including in LAC, and the tankers needed to transport them are operational. However, there is no commercially available technology for shipping pure hydrogen, which requires storage and transport at extremely low temperatures. As a result, most near-term exports are expected to be in the form of ammonia, as there is also a demand for ammonia today. Based on announced projects around 45% of the exports from the region by 2030 are expected to be made in the form of ammonia, and another 5% in the form of synthetic liquid hydrocarbons; the rest remains undefined.

One potential difficulty is that available ammonia storage infrastructure may not align with hydrogen project locations. For instance, Brazil and Chile have announced projects to export 1.1 Mt H_2-eq as ammonia by 2030. This translates into 6.2 Mt of ammonia, which would require a storage capacity of around 400 kt.[5] Currently, Brazil and Chile only have storage capacity of around 110 kt. Therefore, by the end of the decade they need at least four-times as much storage as they currently have. However, the lead times for such facilities can be up to nine years. Early planning and construction of deep water port infrastructure, dedicated jetties and ammonia storage tanks therefore is essential if existing ammonia export plans are to be realised.

Some projects announced in Chile and Uruguay specifically target synthetic hydrocarbons. A good example is the Haru Oni synfuels project in southern Chile, which currently is in its demonstration phase and in early 2023 shipped 2 600 litres of synthetic gasoline produced from low-emissions hydrogen to a refinery in the United Kingdom. Trade of synthetic hydrocarbon liquid fuels can be carried out using existing fossil fuel infrastructure.

Box 4.1 ▷ Could low-emissions hydrogen propel the industry sector in LAC?

While LAC comprises some net exporting countries, the region as a whole is currently a net importer of steel and nitrogen fertilisers. In 2021, it imported iron and steel worth USD 37 billion, 25% of which came from China, 17% from the United States and 8% each from Japan and Korea. In the same year it also imported nitrogen fertilisers and their pre-cursors worth USD 8 billion, 21% of which came from Russia, 16% from China and about 8% each from Oman and Qatar. Trade between countries in LAC also plays an important role in both industries.

This import dependency results from relatively high steel and fertiliser production costs in LAC, which in turn are due to relatively high energy prices. These factors hamper the region's competitiveness, especially compared with developing Asia. Energy accounts for a large fraction of the cost of producing both steel and nitrogen fertilisers, and the current levelised cost of production (LCOP) is estimated to be on average 35% and 5% higher than in developing Asia for iron and ammonia production respectively.

The potential for lower hydrogen production costs in LAC compared with other regions – combined with the region's existing infrastructure and mineral resources – constitutes an opportunity to phase-out domestic fossil fuel-based production and become an important player in the global clean energy transition by boosting industrial output and reducing import dependency in the process (IEA, 2023c).

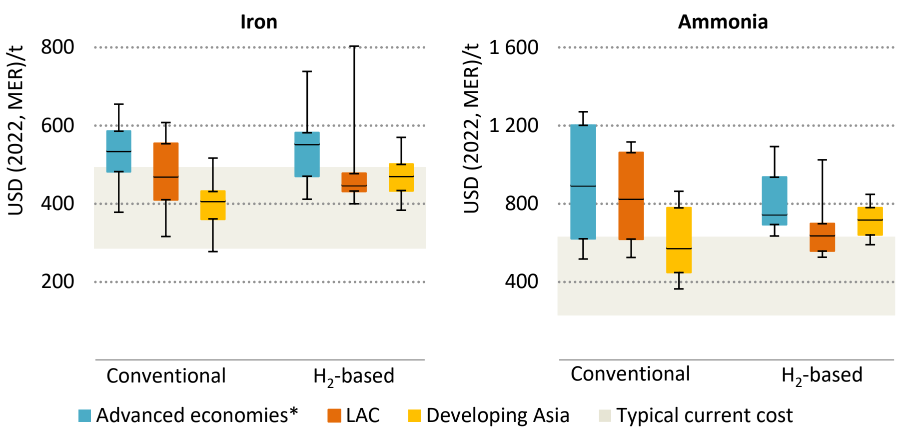
Globally, nearly 45% of iron-based steel production and virtually all ammonia production is based on low-emissions hydrogen routes in the NZE Scenario by 2050. Our analysis shows that countries in the LAC region could be attractive partners for other countries

[5] Assuming that the ammonia storage tanks are loaded and unloaded between 15 and 20 times per year.

looking to reduce their energy transition costs through the import of energy-intensive intermediate products. The import of iron or ammonia produced more competitively in LAC than is possible in other regions could reduce input costs for their industries, while at the same time keeping certain steps in the value chain, such as steel production and finishing, and downstream chemical production, close to their final customers.

Producing iron is the most energy-intensive and most expensive part of steel production. Our analysis highlights the LAC potential to become a globally competitive 100% electrolytic hydrogen-based iron producer based on its vast renewable energy resources and high-quality iron ore deposits. Low-emissions iron could either be used for local steel production or shipped to other countries. By 2030 in the NZE Scenario, the average LCOP of iron produced through low-emissions hydrogen-based routes reaches USD 450 per tonne (USD/t) in LAC, which makes the region competitive with developing Asia, and almost 20% cheaper than the average cost in other advanced economies (Figure 4.14). According to our country-level hydrogen production cost estimates, steel production will be particularly competitive in Chile, Mexico and Argentina. Brazil's significant hydrogen potential, iron ore resources and existing industry infrastructure put it in a good position too.

Figure 4.14 ▷ Levelised cost of production of iron and ammonia by process type in selected regions in the NZE Scenario, 2030



Wind and solar potential for hydrogen production makes LAC a competitive low-emissions iron and ammonia producer in a global decarbonisation scenario

* Advanced economies do not include LAC countries classified as such.

Notes: H_2-based = hydrogen-based. Conventional routes include blast furnaces and direct reduction for iron production and steam methane reforming and coal-based production for ammonia production. Levelised cost of production calculation is based on the NZE Scenario assumptions for fuel prices and carbon prices as well as typical investment and operational costs.

Ammonia is the starting point for all mineral nitrogen fertilisers, with around 70% of the ammonia produced worldwide being used in fertiliser production. Given this, ammonia production costs are particularly relevant for agricultural regions such as LAC. The average LCOP of ammonia produced through low-emissions hydrogen-based routes in the region reaches USD 640/t by 2030 in the NZE Scenario, which is 11% cheaper than in developing Asia and 14% cheaper than in advanced economies. Ammonia production with electrolytic hydrogen is also cost competitive with conventional process routes, where low-emissions hydrogen can be produced at low-cost, as it is for example in Chile, Argentina and Brazil.

LAC can reduce its fossil fuel, iron, steel and fertiliser import dependencies by developing cost-competitive industrial production based on low-emissions hydrogen. The stringency of policies addressing industrial CO_2 emissions – whether carbon pricing, border adjustments or subsidies for alternative production processes – must increase if economies are to fully decarbonise, which means that the costs of production using low-emissions hydrogen and other innovative technologies will decrease relative to incumbent technologies still in use in the medium term.

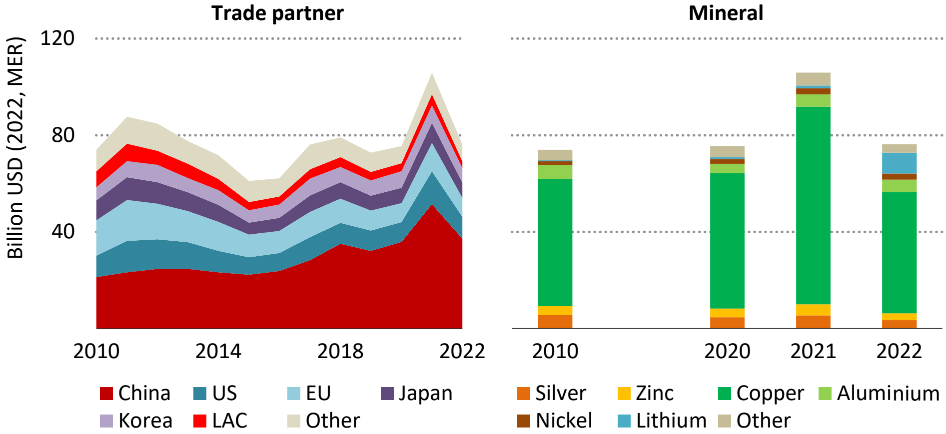
In the longer term, global supply chains for many industries are likely to be shaped based on cost competition between regions all using innovative technologies. Low hydrogen production costs in several LAC countries could result in a competitive advantage in global low-emissions iron and ammonia markets. Further opportunities lie downstream in the supply chain with the potential to export higher value-added derivative products, thus potentially boosting export revenues and adding more jobs in the region, particularly in countries such as Brazil, Mexico, Argentina and Trinidad and Tobago that already have industries and supply chains in place across a variety of sectors. To realise these opportunities sustainably, policy makers will need to take steps to ensure that such developments preserve forests and biodiversity, respect constraints on water and land use, and that proper account is taken of the views and interests of local populations.

4.2.3 Critical minerals

LAC has another major opportunity to enhance regional economic development through the supply of critical minerals, while at the same time helping to support global clean energy transitions and to diversify clean energy supply chains. Critical minerals – including copper, lithium, rare earth elements, nickel, cobalt and graphite – are essential to the deployment of many clean energy technologies and to building tomorrow's sustainable energy systems. As recently detailed in the IEA *Critical Minerals Market Review* (IEA, 2023d), demand for critical minerals is already increasing rapidly as clean energy transitions surge around the world, yet today the supply of many critical minerals is highly concentrated, with 70% or more of the production of rare earths, graphite, lithium and cobalt in the hands of the top-three producing countries.

Over the past decade, LAC has earned an average of over USD 75 billion per year from the export of critical minerals (Figure 4.15). Copper accounts for over 70% of these exports, but lithium is gaining ground. The region also has significant untapped potential for rare earth elements and other critical minerals. Being home to these minerals means that LAC can play an increasingly important role in the global energy transition as a major supplier for the rest of the world.

Figure 4.15▷ Revenue from LAC critical mineral exports, 2010-2022



China imports nearly half of all critical mineral exports from LAC, up from around 30% in 2012; copper remains dominant, but lithium exports are gaining ground

Notes: US = United States; EU = European Union. Other trade partners include India, Canada, United Kingdom, Norway, Thailand and other smaller importers. Other minerals include tin, platinum, graphite, rare earths, tungsten, silicon, cobalt, manganese and lead.

Source: IEA analysis based on the United Nations Comtrade Database (2023).

China is LAC's largest trading partner in this area: in 2022, China purchased about half of the critical minerals exported from the region by value. The United States and the European Union were the next largest markets, each accounting for about 10% of the LAC exports in 2022; Korea and Japan were also important destinations for critical minerals originating in LAC.

In the APS, copper continues to be the largest source of revenue from critical minerals in LAC and lithium becomes a close second. Copper is essential for electricity transmission and distribution grids, and lithium for the global production of electric vehicle and stationary storage batteries. The rollout of these technologies will play a leading role in determining the fate of the global energy transition. Reflecting this key role in energy transitions, copper production remains a mainstay in terms of absolute revenue for LAC, but only expands modestly from current levels to 2030 and 2050. Meanwhile, the production of lithium increases sharply, bringing nearly as much additional revenue as copper by 2050 (see Chapter

3.3). Harnessing LAC's mineral resource endowments in a sustainable and responsible manner will therefore be crucial to foster the region's economic and social development while facilitating the rapid deployment of clean energy technologies.

Regional and country energy profiles

Introduction

This chapter highlights the scenario results to 2050 for Latin America and the Caribbean (LAC), and it focusses on selected countries: Argentina, Brazil, Chile, Colombia, Costa Rica and Mexico. Together these six countries in 2022 accounted for more than 80% of the region's gross domestic product (GDP), over 70% of its population and nearly 80% of its energy demand. The scenarios are the Stated Policies Scenario (STEPS) and Announced Pledges Scenario (APS). The policy landscape, technology preferences and economic assumptions that underpin both scenarios are discussed in Chapter 2. The profiles aim to provide decision makers with data-rich information on potential energy pathways that reflect the unique energy demand patterns and energy supply options of LAC and the six selected countries.

Structure of the profiles

A standard format is used to present the LAC and country profiles. Each profile presents a set of figures and tables that include:

- Key characteristics of the LAC or country's energy system.
- Major macroeconomic indicators, including population, GDP (expressed in year-2022 US dollars in purchasing power parity [PPP] terms) and GDP per capita growth to 2050.
- Energy-related CO_2 emissions, energy-related CO_2 emissions per capita, energy intensity (calculated as units of energy per unit of GDP in PPP terms) and data for trade of commodities (2021).
- Overview of how primary energy demand and the share of low-emissions sources evolve to 2050 in the STEPS and APS.
- Key energy-related policy initiatives, including specific targets and projects.
- Final energy consumption by scenario and sector, showing energy consumption avoided by efficiency gains and fuel switching and how the fuel mix evolves for each sector.
- Average electricity daily load profile by scenario, showing demand by sector in each hour, without implementation of any demand response measures.
- Electricity supply mix changes over time to meet increasing electricity demand.
- Trajectories for demand and production of oil, natural gas and hydrogen, highlighting trade balances.
- Average annual energy supply investment required to meet growth in energy demand and to fulfil policies and pledges in both scenarios.

The units, terms and acronyms that are used in the figures, tables and text of the profiles are defined at the end of this chapter.

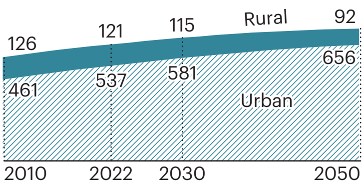
Latin America and the Caribbean

HIGHEST
share of renewables in electricity generation in the world

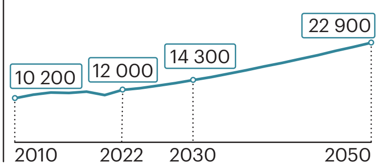
15%
of global oil and gas resources

OVER 1/3
of global silver, copper and lithium reserves

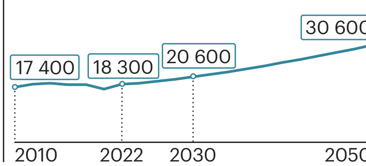
Population Million people



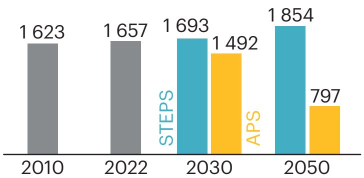
GDP Billion USD (2022, PPP)



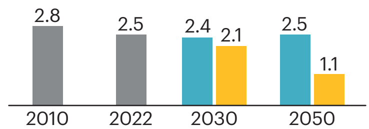
GDP per capita USD per capita (2022, PPP)



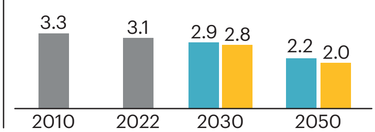
CO_2 emissions Mt CO_2



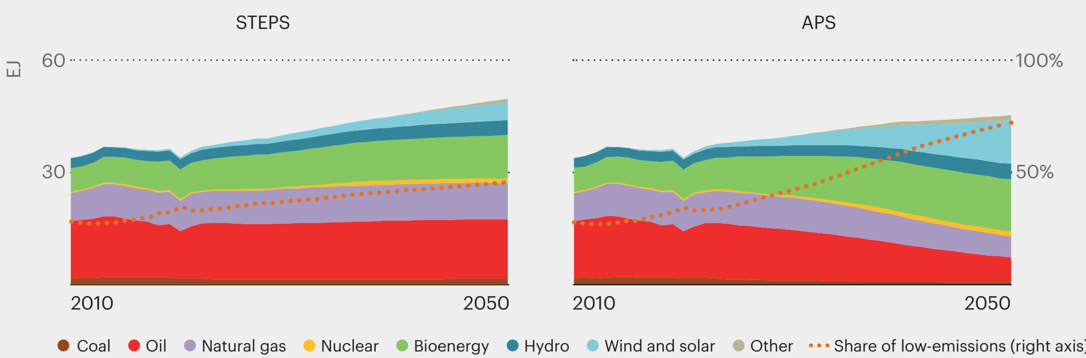
CO_2 emissions per capita t CO_2/capita



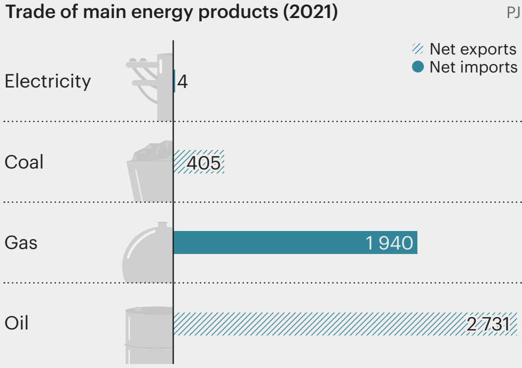
Energy intensity GJ per thousand USD (2022, PPP)



Primary energy supply and share of low-emissions sources



Trade of main energy products (2021) PJ



Trade of non-energy products (2021) Billion USD

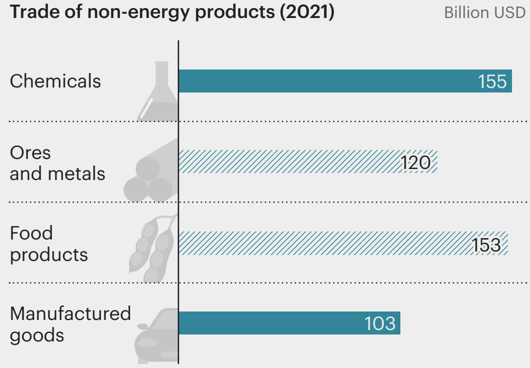


Table 5.1 ▷ Recent policy developments in Latin America and the Caribbean

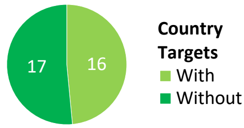
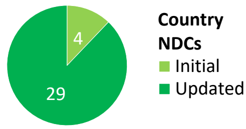
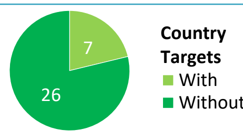
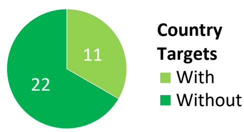
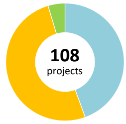
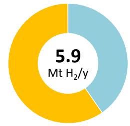
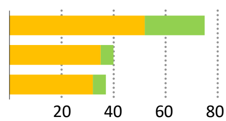
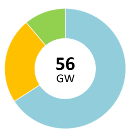
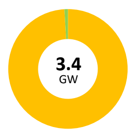
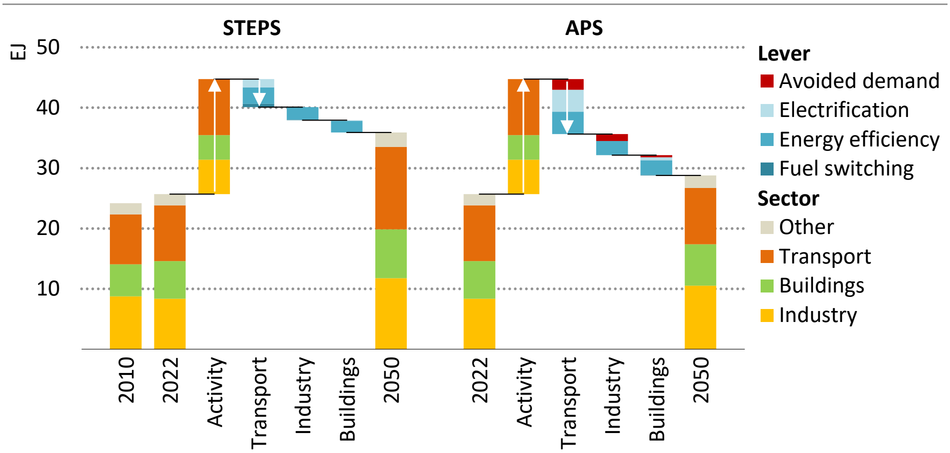
Policy			
Economy-wide measures	Climate commitments: Net zero emissions target		Represents 60% of total CO_2 emissions from fuel combustion and 65% of total GDP Target for mid-century (or earlier)
	Climate commitments: Nationally Determined Contribution (NDC)		1.7-1.8 Gt CO_2 emissions from fuel combustion by 2030 (+13-18% increase from 2022) Target for 2030
Access (SDG7)	Clean cooking		11% of the LAC population lacks clean cooking access (12 out of 33 countries have already reached 95% access rate)
	Electricity access		3% of the regional population lacks electricity access (24 out of 33 countries have already reached 95% access rate)
AFOLU	Eight countries with targets to end or to mitigate deforestation (Brazil, Chile, Colombia, Costa Rica, Dominica, Guatemala, Mexico and Suriname).		
Environmental governance	Fifteen countries ratified the Escazú Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters (Antigua and Barbuda, Argentina, Belize, Bolivia, Chile, Ecuador, Grenada, Guyana, Mexico, Nicaragua, Panama, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines and Uruguay).		
Hydrogen	Eight countries have a hydrogen strategy (Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Panama, Uruguay), and four countries have announced a hydrogen strategy but are still in the preparation phase (Bolivia, Paraguay, Peru, Trinidad and Tobago).		
Power	Twenty-four countries have renewables targets (Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Peru, Saint Lucia, Uruguay and Venezuela).		
Transport	Sixteen countries have electric vehicle policies (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Mexico, Nicaragua, Panama, Paraguay, Trinidad and Tobago and Uruguay).		
Buildings	Thirteen countries have energy-related building codes (Antigua and Barbuda, Argentina, Barbados, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Jamaica, Mexico, Paraguay and Peru). Seventeen countries have minimum energy performance standards (MEPs) for air conditioning (Argentina, Brazil, Chile, Costa Rica, Cuba, Ecuador, El Salvador, Honduras, Jamaica, Mexico, Nicaragua, Panama, Peru, Saint Lucia, Trinidad and Tobago, Uruguay and Venezuela).		

Table 5.2 ▷ Major infrastructure projects in LAC

	Projects		Countries
Low-emissions hydrogen	Announced projects 	2030 Production 	Argentina, Barbados, Brazil, Chile, Colombia, Costa Rica, Dominica, Mexico, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay.
Oil and gas	Number of projects 		Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago.
Dispatchable low-emissions power plants	128 hydro projects 	4 nuclear projects 	**Hydro**: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru. **Nuclear**: Argentina, Brazil, Mexico.
Large-scale CCUS	1 BECCS project in Brazil: Lucas do Rio Verde (0.4 Mt CO_2 removal per year).		
Interconnections	Four projects under construction or in financing phase: Argentina-Paraguay (270 MW); Peru-Ecuador (600 MW addition); SIEPAC expansion (from 300 MW to 600 MW); SIEPAC-Colombia high voltage direct current (400 MW).		

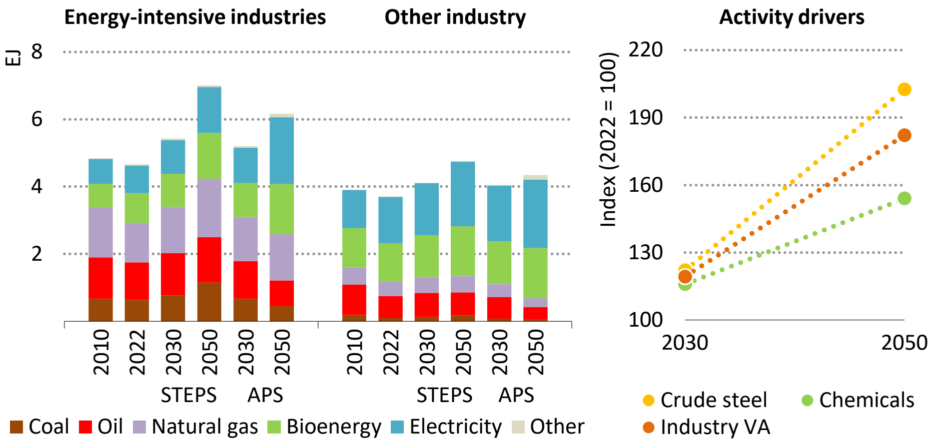
Status Concept Feasibility study Under construction

Figure 5.1 ▷ Final energy consumption by scenario in LAC



- Rising transport demand and re-industrialisation push total final energy consumption up by 40% in the STEPS and over 10% in the APS by 2050.
- In both scenarios, energy efficiency moderates this growth in all sectors. In the APS, electrification plays a key role in tempering this growth in the transport sector.

Figure 5.2 ▷ Fuel consumption in industry by type and scenario in LAC



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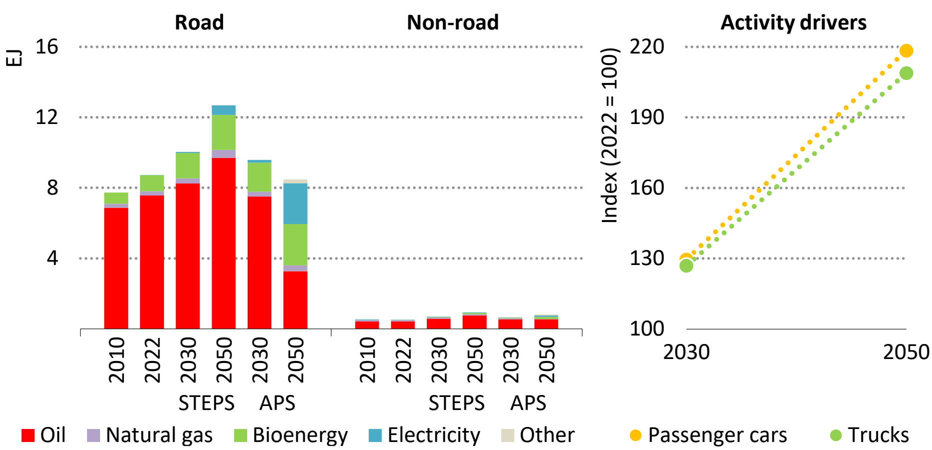
- Re-industrialisation boosts growth, with the aluminium, iron and steel, and chemicals sub-sectors leading the way. This increases energy consumption in the sector.
- Bioenergy plays a key role in both scenarios and electricity use also rises. The share of natural gas remains constant at just below 20% in the STEPS and declines in the APS.

Figure 5.3 ▷ Fuel consumption in transport by type and scenario in LAC



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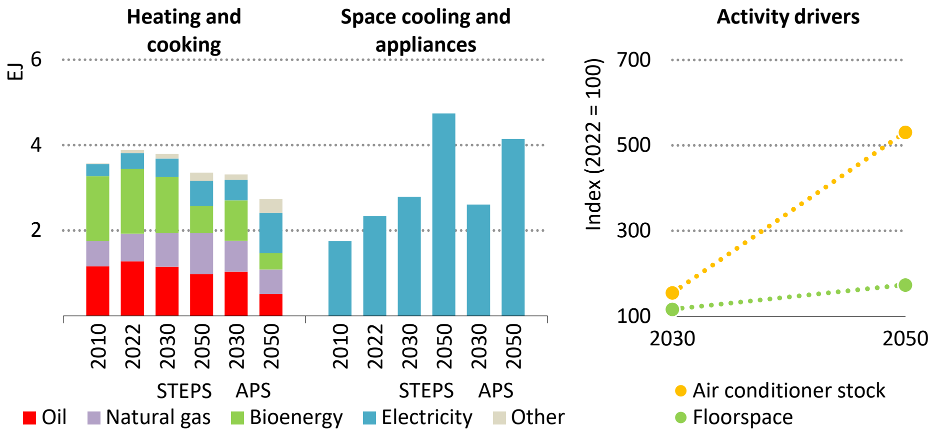
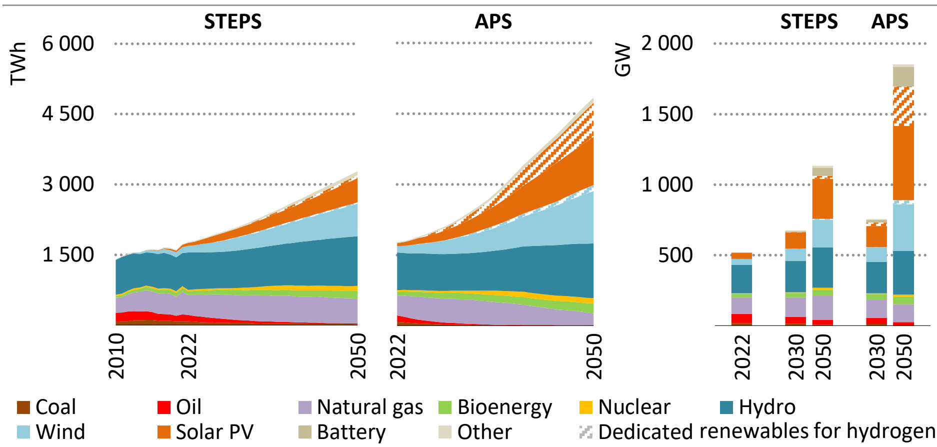
- Oil accounts for 86% of energy consumption today in the transport sector, compared with 91% globally.
- Road activity doubles by 2050. In the APS, growing use of electricity and bioenergy leads the share of oil in road transport to decline below 80% by 2030 and around 40% by 2050.

Figure 5.4 ▷ Fuel consumption in buildings by type and scenario in LAC



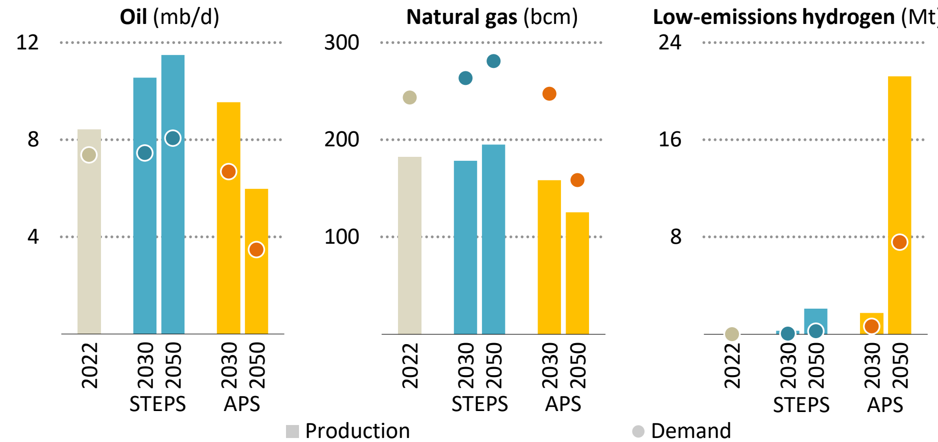
- Over 10% of the LAC population lacks access to clean cooking today. Their reliance on bioenergy for cooking is a major cause of household air pollution and leads to nearly 82 000 premature deaths per year.
- Rising incomes prompt increases in the ownership of appliances and air conditioners, which are the main drivers of electricity consumption growth in the buildings sector.

Figure 5.5 ▷ Electricity generation and capacity by fuel in LAC



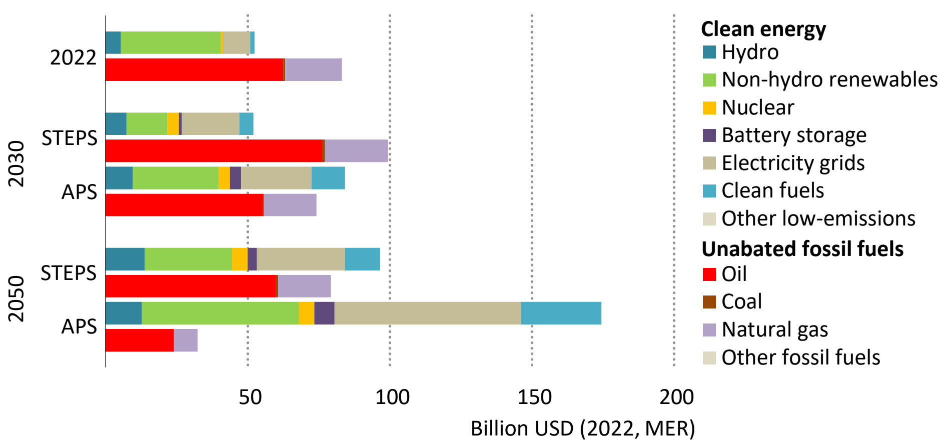
- Today, most electricity in the region is from hydropower and natural gas, but solar photovoltaics (PV) and wind provide the bulk of capacity additions in both scenarios.
- In the APS, renewables meet all new electricity demand, reducing the need for natural gas and displacing almost all generation from coal and oil.

Figure 5.6 ▷ Fuel demand and production by scenario in LAC



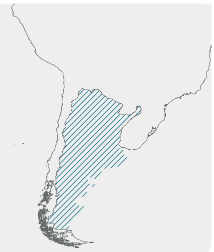
- In the STEPS, oil production outstrips demand and net oil exports triple to 2030. The region remains a net importer despite natural gas production increasing in the long run.
- In the STEPS, low-emissions hydrogen production sees modest growth from near zero. In the APS, it reaches nearly 2 million tonnes (Mt) in 2030 and more than 20 Mt in 2050.

Figure 5.7 ▷ Annual investment in energy supply by type and scenario in LAC



- In the STEPS, fossil fuels account for most energy supply investment in 2030. In the APS, investment in clean energy supply overtakes those for fossil fuels by 2030.
- Investment in clean energy supply reaches 0.8% of GDP in the STEPS and over 1% in the APS by 2030, increasing to nearly 0.9% and 1.6% respectively by 2050.

Argentina

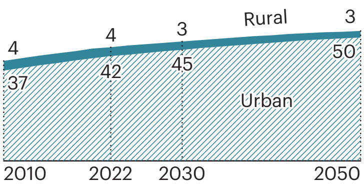


LARGEST
natural gas producer in Latin America and the Caribbean

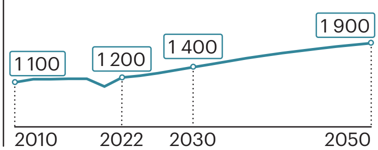
2ND
largest lithium producer in Latin America and the Caribbean

6TH
largest CNG vehicle fleet in the world

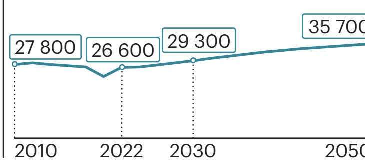
Population Million people



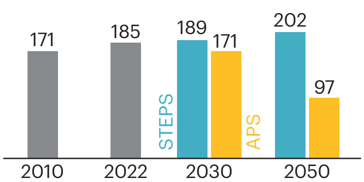
GDP Billion USD (2022, PPP)



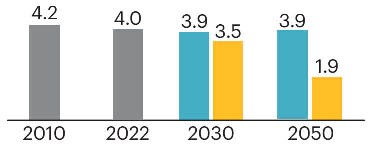
GDP per capita USD per capita (2022, PPP)



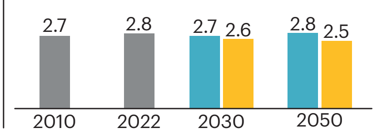
CO_2 emissions Mt CO_2



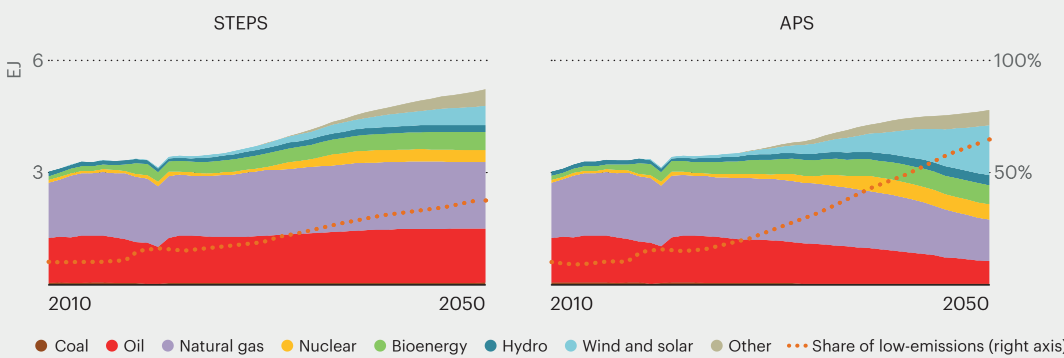
CO_2 emissions per capita t CO_2/capita



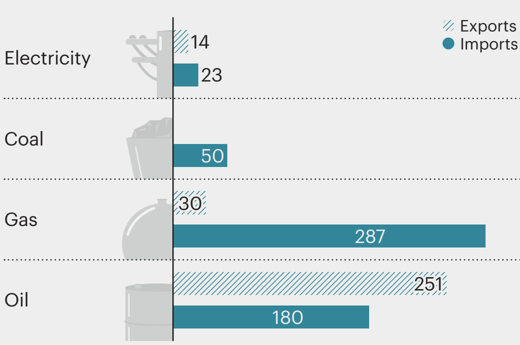
Energy intensity GJ per thousand USD (2022, PPP)



Primary energy supply and share of low-emissions sources



Trade of main energy products (2021) PJ



Trade of non-energy products (2021) Billion USD

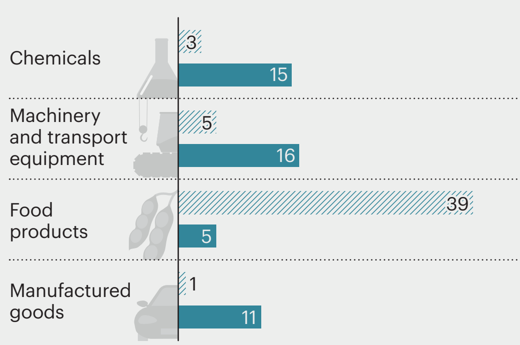


Table 5.3 ▻ Recent policy developments in Argentina

	Policy	Publication year
Economy-wide measures	• NDC: maximum absolute target of 349 Mt CO_2-eq in 2030.	2021
	• Long-term strategy: GHG neutrality by 2050.	2022
	• National Energy Transition Plan to 2030 includes 8% reduction of energy demand, at least 50% of renewable electricity generation.	2023
	• Decree N° 332/2022: Energy Subsidy Segmentation Plan.	2022
Just transition policies	• Green Employment Programme.	2023
	• Resolution No 255/2021: Federal Network of Argentinian Mining Women.	2021
AFOLU	• Pilot programme of payments based on REDD+ results (reduction of deforestation emissions and degradation of forests) - target 2027.	2020
	• Law 27.487 to promote investment in forest plantations.	2019
Producer economies	• Decree N° 892/2020: "Plan Gas.Ar" - subsidies to the hydrocarbon industry.	2020
Hydrogen	• 2023-2050 National Strategy for the Development of the Hydrogen Economy.	2023
Power	• Law 27.424 incentivises the integration of distributed generation to the public electricity network (net metering scheme) - 1 GW distributed solar PV by 2030.	2017
Industry	• National plan for industrial development: Recommendations to leverage financial support and tax credits of more than USD 3 billion.	2022
Transport	• National Plan for Sustainable Transportation: Reduce GHG emissions to minimum 5.84 Mt CO_2-eq below a business-as-usual scenario by 2030 - target 15% of vehicles to run on natural gas.	2022
Buildings	• National Housing Labelling Programme (PRONEV) to unify energy efficiency labelling system.	2023

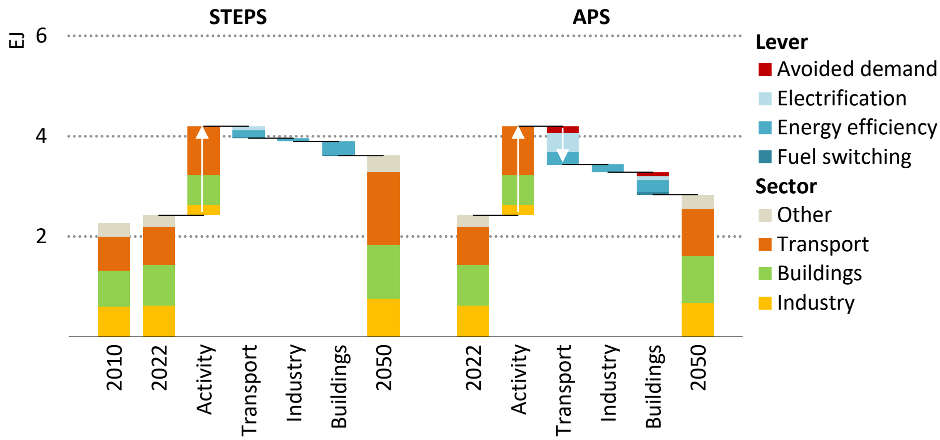
Table 5.4 ▻ Major infrastructure projects in Argentina

	Project	Size	Date online	Status	Description
Hydrogen/ ammonia	Pampas	35 kt H_2/year (production)	2024	🟡	Dedicated renewables
	Rio Negro (phase 1)	104 kt H_2/year (capacity)	2024	🟡	Dedicated renewables
Nuclear	CAREM project	32 MW	2027	🟢	Small modular reactor
Hydro	Néstor Kirchner and Jorge Cepernic hydroelectric plant	1 310 MW	2025	🟢	Southernmost hydroelectric dams
Oil and gas	Néstor Kirchner natural gas pipeline phase 2	20 bcm/d	2024	🟡	470 km natural gas pipeline
Transmission, interconnections	AMBA I	500/220/132 kV	-	🟡	Substations and high voltage lines (+ 500 km)

Status 🟡 Feasibility study 🟢 Under construction

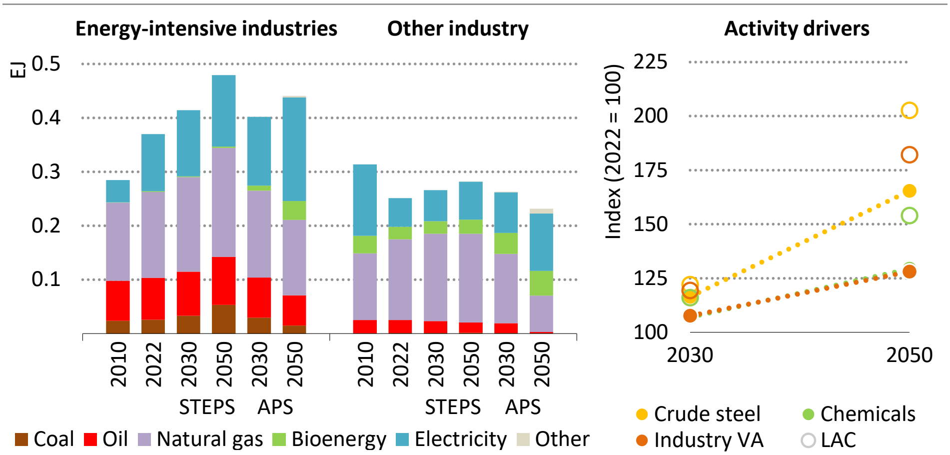
5

Figure 5.8 ⊳ Final energy consumption by scenario in Argentina



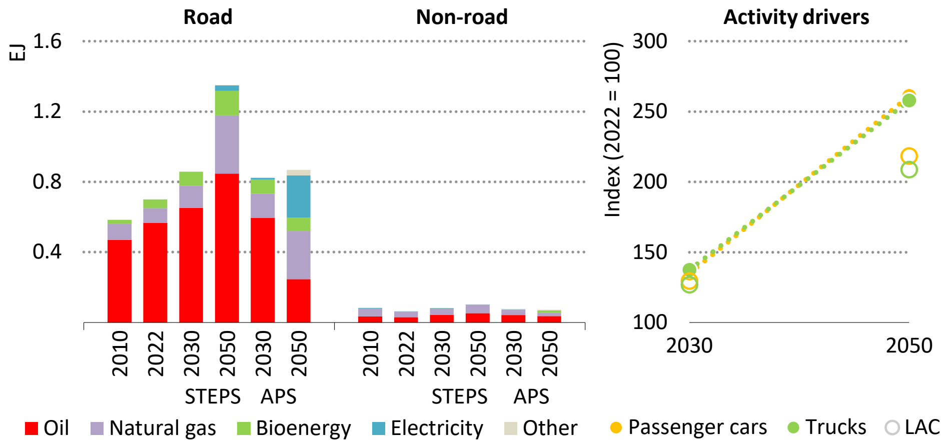
- Today, transport and buildings account for two-thirds of total final energy consumption. In both scenarios, transport energy consumption rises the most through to 2050.
- In the STEPS, total final consumption increases 50% by 2050. In the APS, final energy consumption rises by only 17% thanks to electrification and energy efficiency gains.

Figure 5.9 ⊳ Fuel consumption in industry by type and scenario in Argentina



- Today, around 45% of energy used in energy-intensive industries is natural gas: energy-intensive industries account for 60% of total energy demand in industry in Argentina.
- Industrial activity in Argentina sees less growth than the average in the region. Most of this modest increase is met by natural gas and electricity in the STEPS. In the APS, most of the increase is met by electricity while gas and oil consumption decline.

Figure 5.10 ▷ Fuel consumption in transport by type and scenario in Argentina



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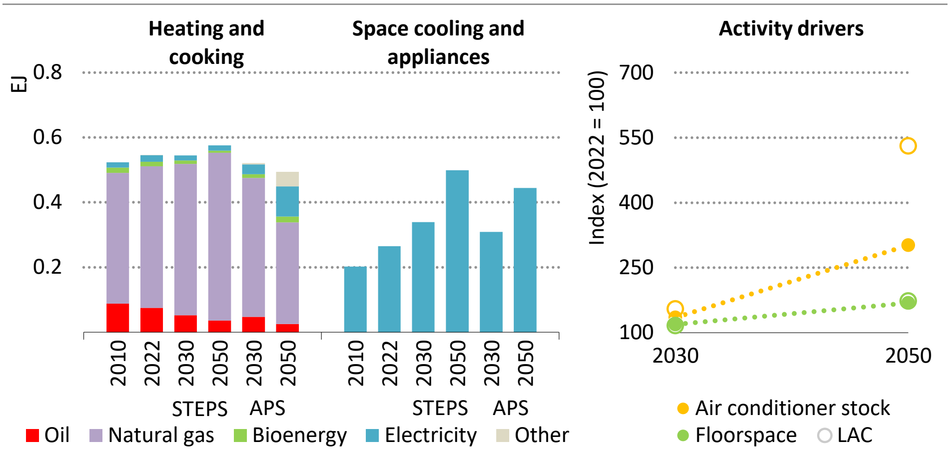
- Oil accounts for nearly 80% of transport energy consumption today. Natural gas sees its current share rise in both scenarios; EV sales rise rapidly, especially in the APS.
- Road freight and passenger car activity both increase by 160% between 2022 and 2050.

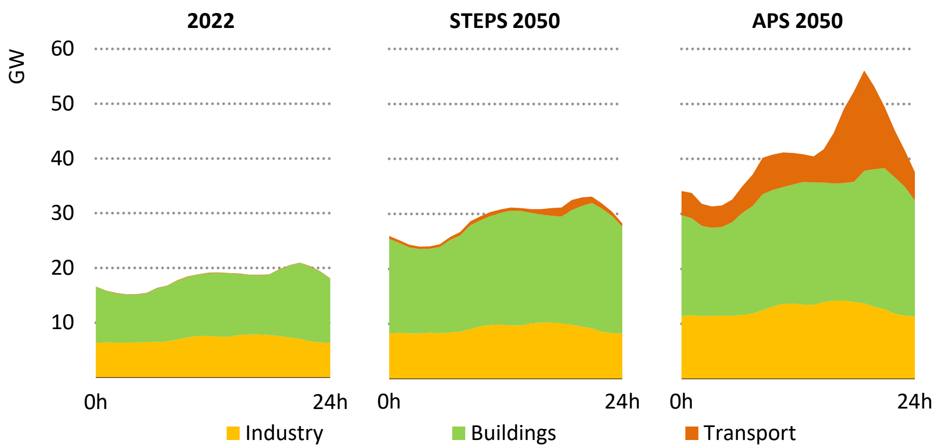
Figure 5.11 ▷ Fuel consumption in buildings by type and scenario in Argentina



IEA. CC BY 4.0.

- Natural gas currently meets 80% of heating and cooking needs. Energy efficiency gains temper increases in demand for heating in both scenarios.
- Demand for space cooling rises by over 25% by 2030 in the STEPS and more than 15% in the APS. Appliances account for most growth in electricity consumption in buildings in both scenarios.

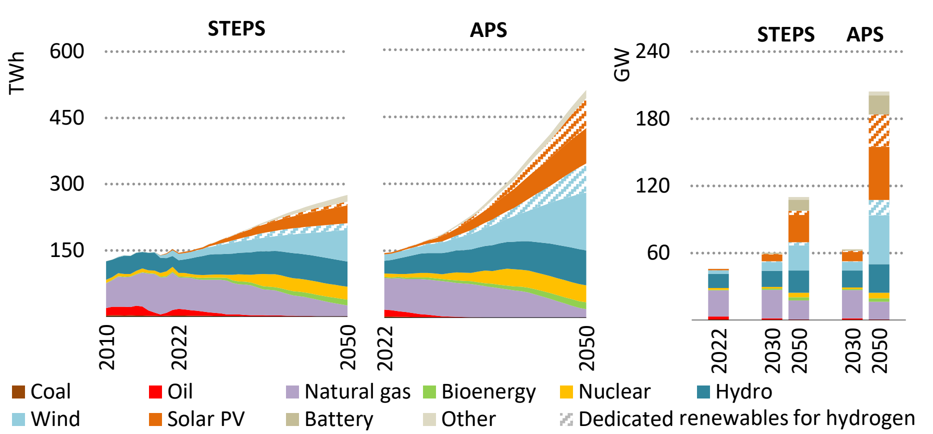
Figure 5.12 ⊳ Average electricity daily load profile by scenario in Argentina



IEA. CC BY 4.0.

- Between 2022 and 2050, peak electricity demand increases by 70% in the STEPS and more than doubles in the APS: mainly driven by cooling needs and rising fleet of EVs.
- In the APS, smart charging of EVs could play a central role in peak demand management.

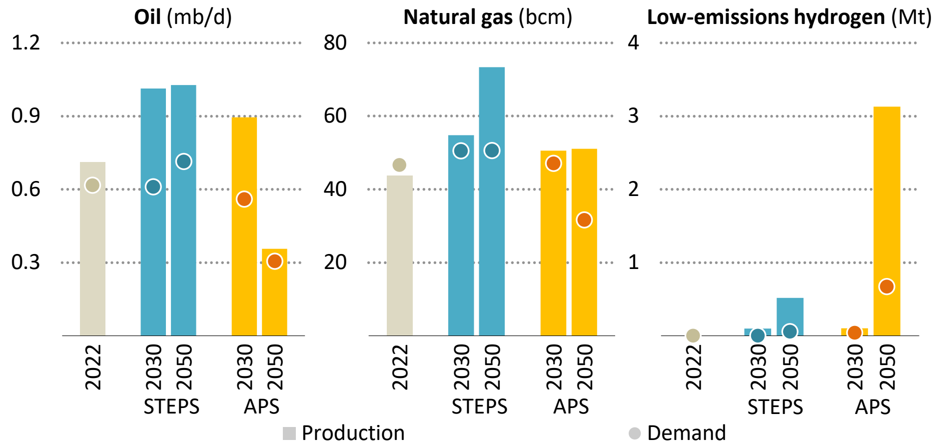
Figure 5.13 ⊳ Electricity generation and capacity by fuel and scenario in Argentina



IEA. CC BY 4.0.

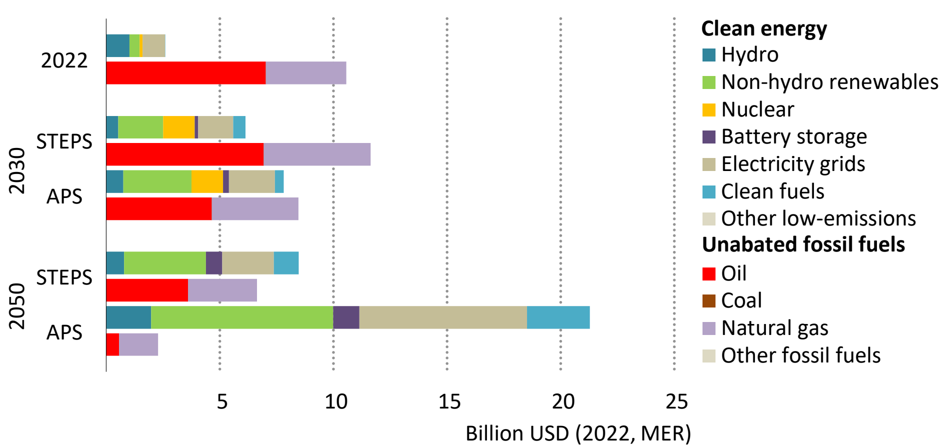
- Natural gas supplies 50% of electricity today, but wind and solar PV meet most of the demand growth in both scenarios, driven by the significant wind potential in Patagonia.
- In the APS, solar PV and wind produce 67% of electricity generation by 2050, up from 12% today. Nuclear generation also increases. Gas-fired generation falls steadily.

Figure 5.14 ⊳ Fuel demand and production by scenario in Argentina



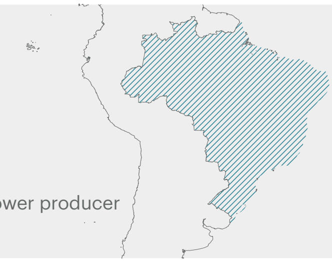
- In the STEPS, oil production increases by 40% to 2030 and then plateaus. Argentina becomes a natural gas exporter as gas production increases by 25% to 2030.
- In the APS, abundant renewable energy potential (wind in the south and solar in the north) enables low-emissions hydrogen production to reach over 3 Mt in 2050.

Figure 5.15 ⊳ Annual investment in energy supply by type and scenario in Argentina



- In the STEPS, investment in clean energy supply increases from 0.4% of GDP today to 0.9% by 2050. In the APS, it reaches eight-times the current level.
- In the APS, most remaining fossil fuel investment is for natural gas by 2050.

Brazil

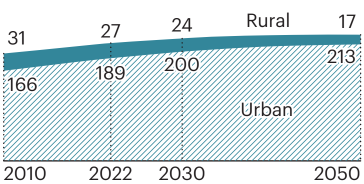


LARGEST
economy in Latin America and the Caribbean

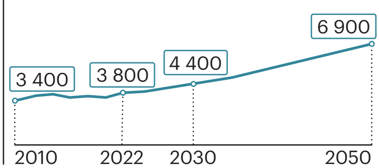
2ND
largest biofuels producer in the world

2ND
largest hydropower producer in the world

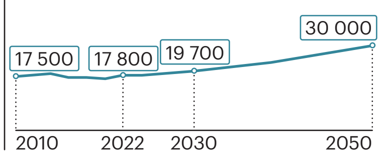
Population Million people



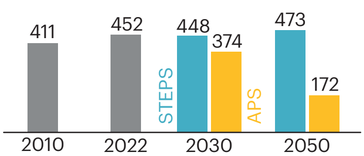
GDP Billion USD (2022, PPP)



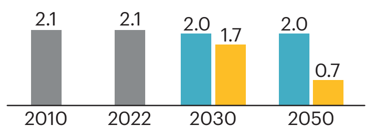
GDP per capita USD per capita (2022, PPP)



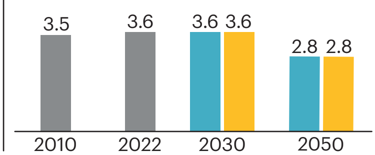
CO_2 emissions Mt CO_2



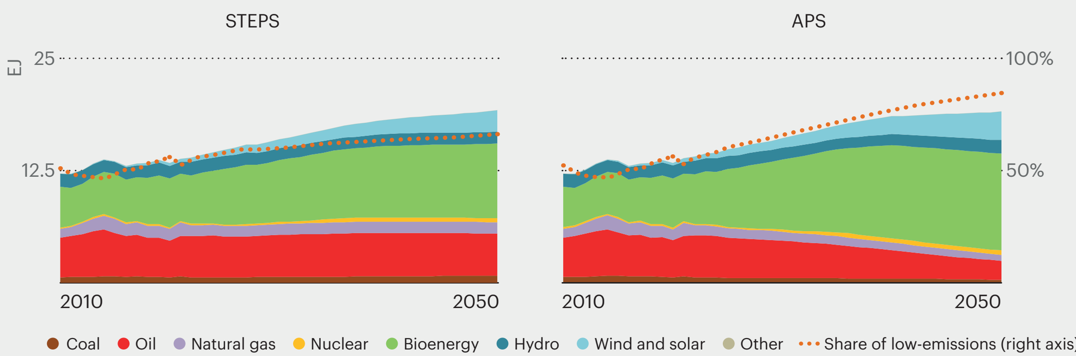
CO_2 emissions per capita t CO_2/capita



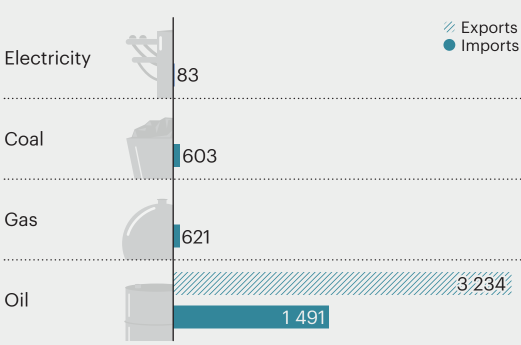
Energy intensity GJ per thousand USD (2022, PPP)



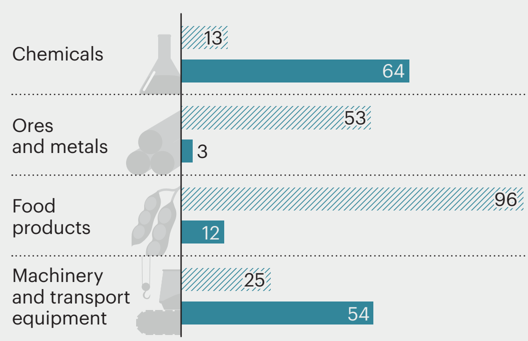
Primary energy supply and share of low-emissions sources



Trade of main energy products (2021) PJ



Trade of non-energy products (2021) Billion USD



5

Table 5.5 ▷ Recent policy developments in Brazil

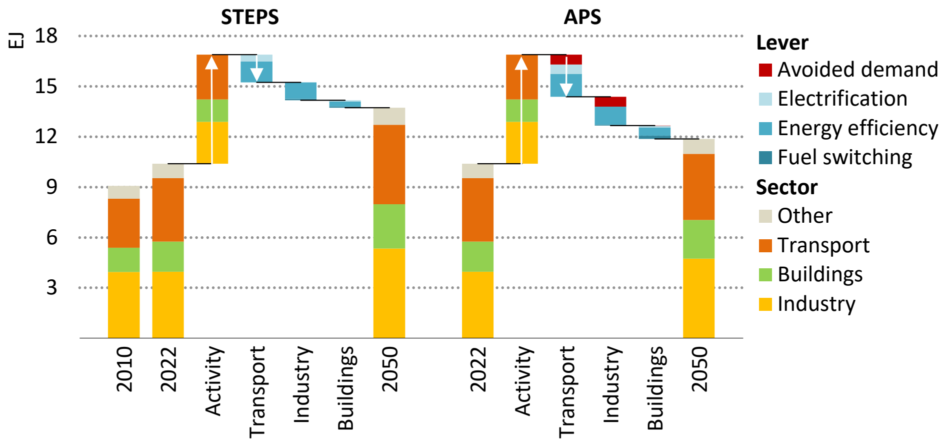
	Policy	Publication year
Economy-wide measures	• NDC: 50% reduction of GHG emissions by 2030 from 2005 levels.	2022
	• Net zero emissions by 2050 target.	2022
	• Guidelines for a National Strategy for Climate Neutrality: between 45% and 50% of renewable energy in the national energy mix by 2030.	2022
	• Decennial Energy Expansion Plan 2032 (PDEE 2032) (indicative).	2023
Just transition policies	• Amazon Decarbonisation Programme: Reduce diesel power plant generation in the Amazon region by 40% by 2026, USD 1 billion.	2023
	• *Luz para todos* programme (initially launched in 2003): To bring electricity to 500 000 families that lack access by 2026.	2023
	• *Novo PAC*: USD 105 billion for the energy transition and energy security.	2023
AFOLU	• Action Plan: Zero deforestation by 2030 (5th phase).	2023
Environment and water resources	• *Metano Zero* programme: 25 new biomethane plants (2.3 mcm/d in 2027).	2022
	• Hydropower Reservoir Recovery Plan: Improve water management.	2022
Hydrogen	• 2023-2025 Working Plan of the National Hydrogen Programme.	2023
Power	• Revised subsidies for distributed generation (net billing scheme).	2022
Industry	• Energy Efficiency Programme: Public funds (about USD 117 million in 2020).	2020
Transport	• RenovaBio Programme - National Biofuel Policy.	2017
	• National Bio Kerosene Programme: Promotes R&D for biofuel for aviation.	2021
	• *Combustível do Futuro* programme: Targets 30% bioethanol and 15% biodiesel blending rate.	2021

Table 5.6 ▷ Major infrastructure projects in Brazil

	Project	Size	Date online	Status	Description
Oil and gas	Pre-salt (Etapa 3 & 4)	+0.5 mb/d (target 2.2 mb/d)	2027	Under construction	Oil and gas
Hydrogen/ ammonia	Port of Pecem - Base One	600 kt H_2/year (production)	2025	Feasibility study	Dedicated hydro
	Unigel, phase I	10 kt H_2/year (capacity)	2023	Under construction	Dedicated wind
Nuclear	Angra 3	1 405 MWe	2028	Under construction	Nuclear reactor
CCUS	Lucas do Rio Verde, FS Bioenergia	0.4 Mt CO_2/year	2030	Feasibility study	BECCS
Transmission, interconnections	Graça Aranha–Silvânia (HVDC)	800 kV	2028	Feasibility study	1 440 km

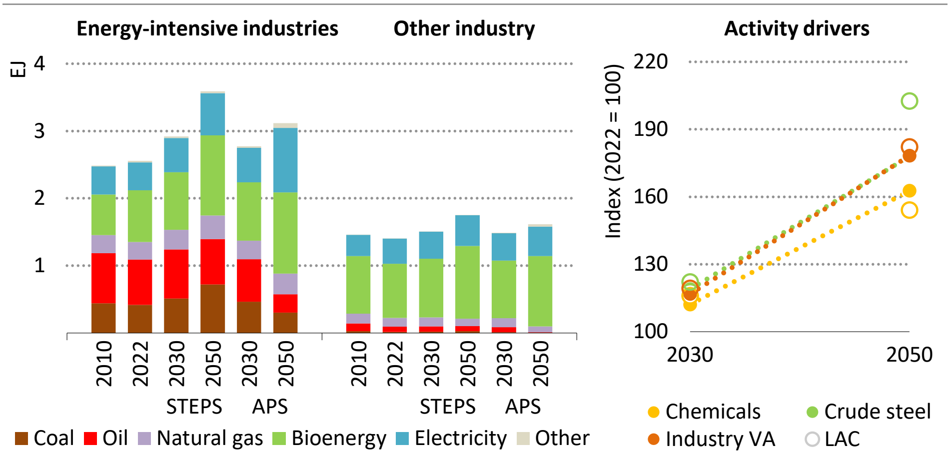
Status ● Feasibility study ● Under construction

Figure 5.16 ▷ Final energy consumption by scenario in Brazil



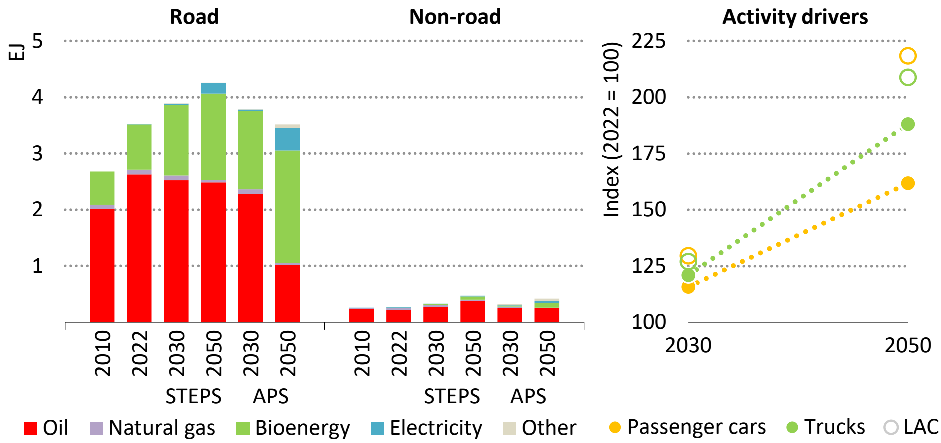
- Today, transport and industry account for 75% of final energy consumption in Brazil.
- In the STEPS, total final consumption increases over 30% by 2050, with the most growth coming from industry. In the APS, energy efficiency gains and avoided demand mean that final consumption grows nearly 15% less than in the STEPS.

Figure 5.17 ▷ Fuel consumption in industry by type and scenario in Brazil



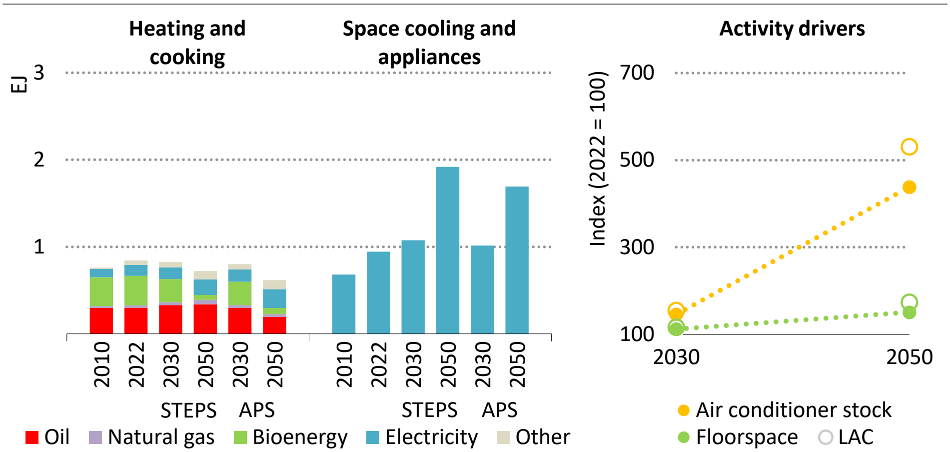
- Brazil is the region's industry heavyweight, especially for ethylene, steel and aluminium production. Energy-intensive industries make up 65% of total industry energy demand.
- Bioenergy meets 40% of industrial energy consumption today: by 2050, its share expands to 42% in the STEPS and nearly 50% in the APS.

Figure 5.18 ▷ Fuel consumption in transport by type and scenario in Brazil



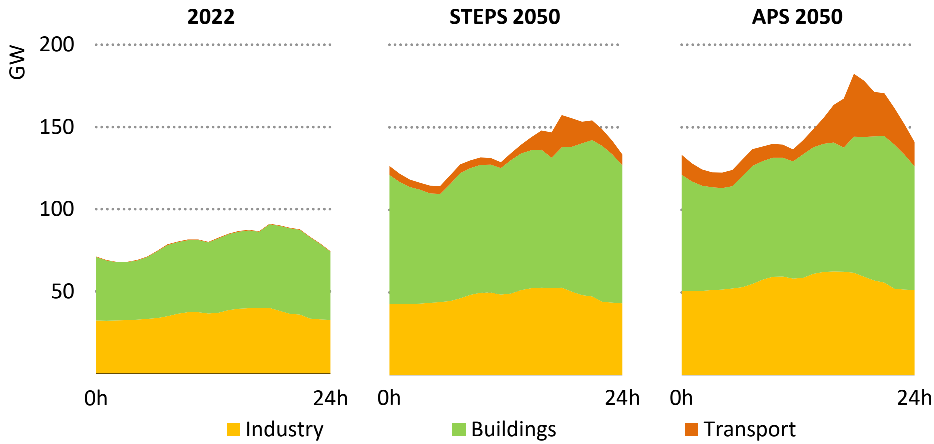
- Today, oil accounts for 75% of energy consumption in transport. The share of oil declines in both scenarios, with bioenergy being the dominant fuel in the APS by the early 2040s.
- By 2050, road freight activity increases by around 90% from today's level; passenger cars activity increases by over 60%.

Figure 5.19 ▷ Fuel consumption in buildings by type and scenario in Brazil



- Heating and cooking needs currently are met by bioenergy (40%) and oil (36%). Higher access to clean cooking and electrification reduces the traditional use of biomass.
- Electricity demand for cooling almost triples by 2050 in the STEPS. In the APS, minimum energy performance standards and more efficient buildings cut this growth by 35%.

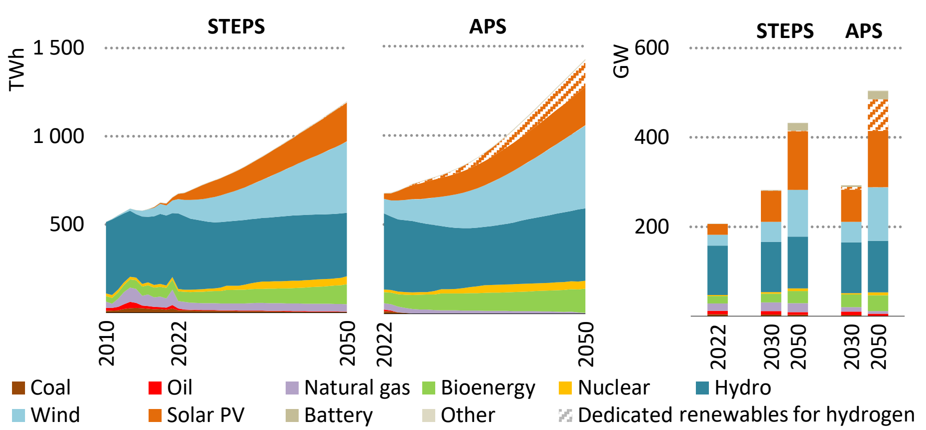
Figure 5.20 ⊳ Average electricity daily load profile by scenario in Brazil



IEA. CC BY 4.0.

- Peak electricity demand rises by more than 75% in the STEPS by 2050 and more than doubles in the APS, where peak increases much faster than average electricity demand.
- The increase in daily peak demand is mainly driven by higher use of electricity in buildings. Demand-response and load shifting measures could flatten the load curve.

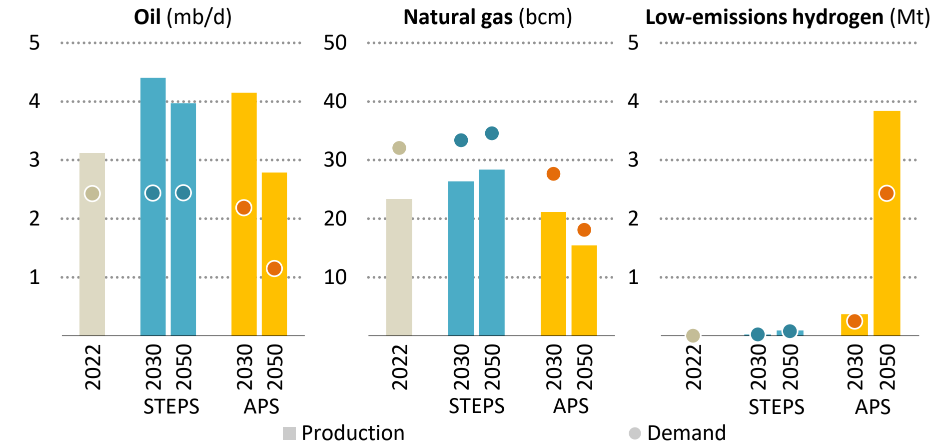
Figure 5.21 ⊳ Electricity generation and capacity by fuel and scenario in Brazil



IEA. CC BY 4.0.

- Hydropower dominates the current power mix, but its expansion in both scenarios is constrained by inherent resource limits and social acceptance concerns.
- Wind and solar PV meet nearly all electricity demand growth. In the APS, they account for nearly 60% of electricity generation in 2050 compared with 17% today.

Figure 5.22 ▷ Fuel demand and production by scenario in Brazil



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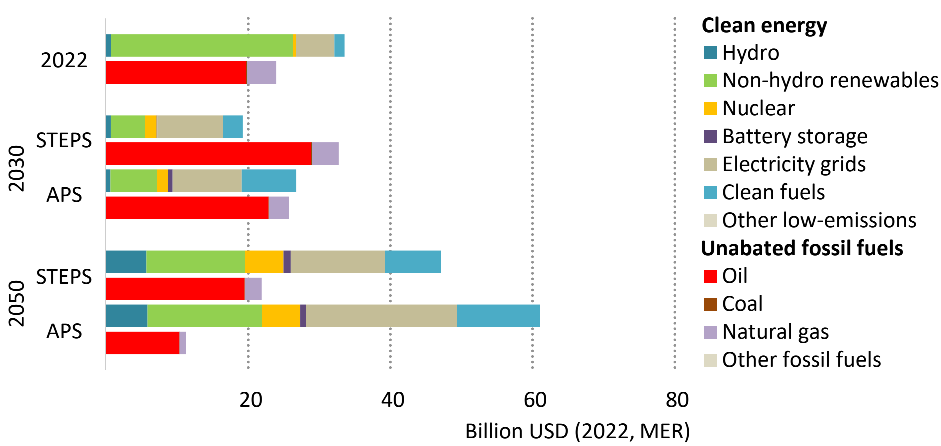
- Oil production in the STEPS increases from 3 mb/d to just over 4 mb/d by 2030; natural gas production grows in response to rising demand in the STEPS but declines in the APS.
- In the APS, hydrogen production reaches 4 Mt in 2050 boosted by the national strategy.

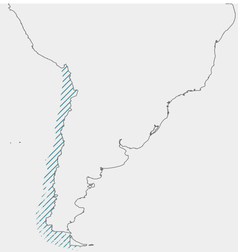
Figure 5.23 ▷ Annual investment in energy supply by type and scenario in Brazil



IEA. CC BY 4.0.

- Investment in clean energy supply accounts for 1.4% of Brazil's GDP in the STEPS in 2050 and 1.8% in the APS.
- By 2050, investment in clean energy supply is more than double the level of investment for fossil fuels in the STEPS and more than five-times their level in the APS.

Chile

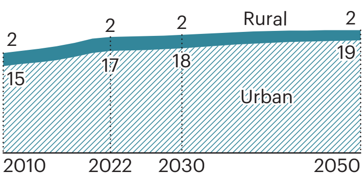


6TH
largest share of solar in electricity generation in the world

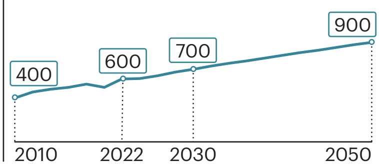
TOP
copper producer in the world

2ND
largest lithium producer in the world

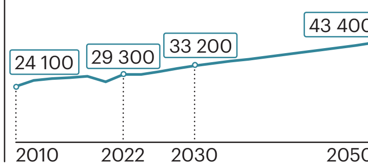
Population Million people



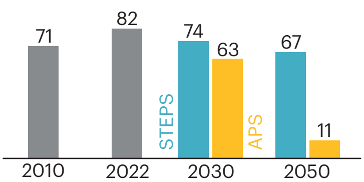
GDP Billion USD (2022, PPP)



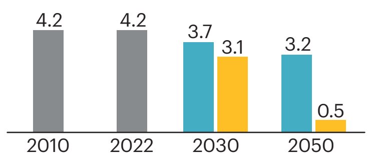
GDP per capita USD per capita (2022, PPP)



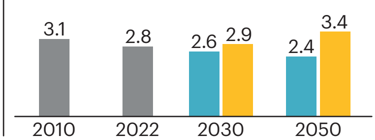
CO_2 emissions Mt CO_2



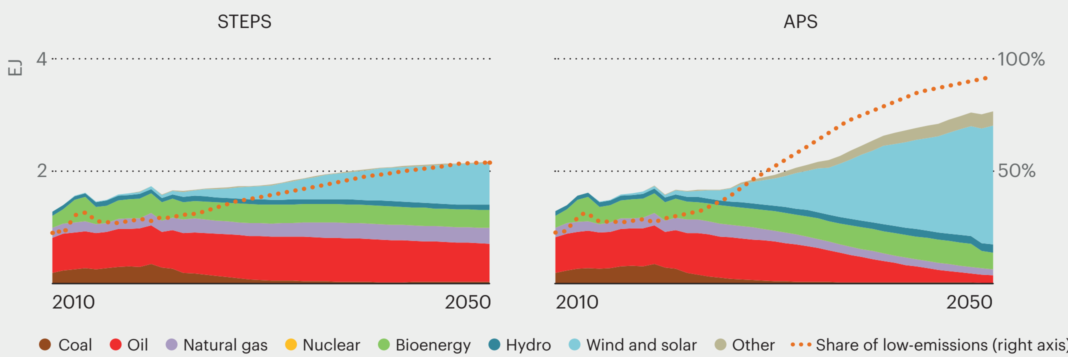
CO_2 emissions per capita t CO_2/capita



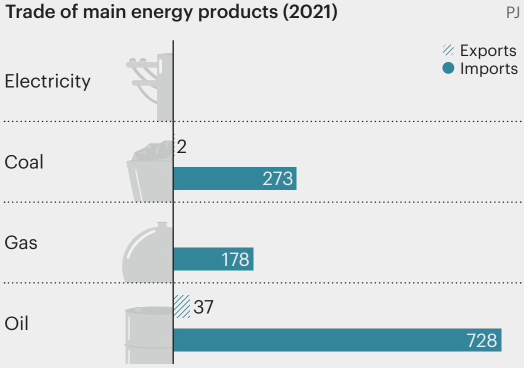
Energy intensity GJ per thousand USD (2022, PPP)



Primary energy supply and share of low-emissions sources



Trade of main energy products (2021) PJ



Trade of non-energy products (2021) Billion USD

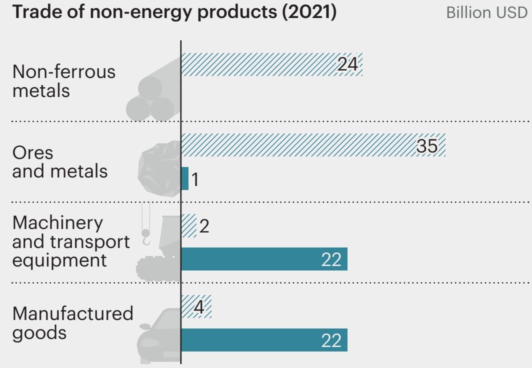


Table 5.7 ▷ Recent policy developments in Chile

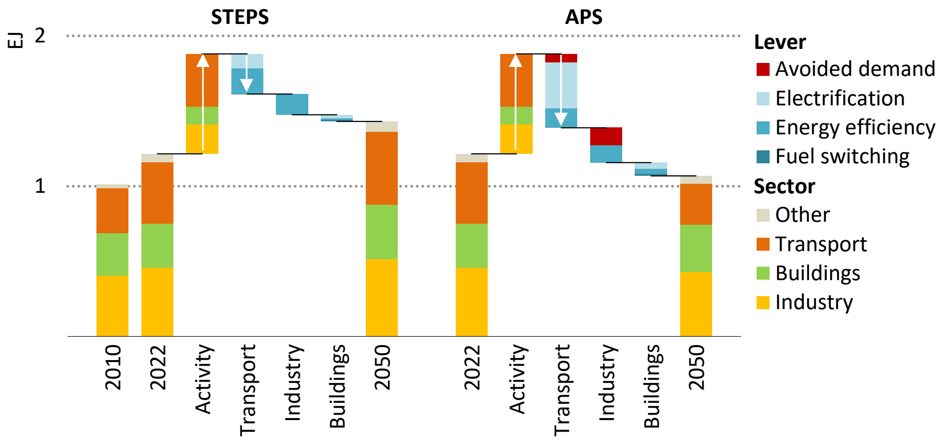
	Policy	Publication year
Economy-wide measures	• Climate Change Law 21455: Binding 2050 net zero GHG emissions target.	2022
	• NDC (update): GHG emissions peak no later than 2025 and reach 95 Mt CO_2-eq by 2030.	2021
	• 2022-2026 National Energy Efficiency Plan: Reduce energy intensity on a national basis of at least 13% by 2030 relative to 2019.	2022
	• Industry and power: CO_2 tax of USD 5/t CO_2.	2017
Critical minerals	• National Lithium Strategy: Aims to increase public participation and public-private partnerships in the lithium supply chain; proposes the creation of research institutes and a national lithium company (announced).	2023
	• National Mining Policy 2050: Reach carbon neutrality in mining by 2040.	2022
Hydrogen	• National Hydrogen Strategy: Electrolysis capacity targets (operating and under development) of 5 GW by 2025 and 25 GW by 2030. Aim to reach USD 2.5 billion/year from exports of hydrogen and derivatives by 2030.	2020
Power	• Phase out or retrofit coal-fired power plants no later than 2040.	2019
Industry	• Energy Efficiency Law 21305: By 2023, mandatory energy management system for large energy consumers (consumption of over 50 T cal/year).	2021
Transport	• Law 21505 promoting electricity storage and electromobility introduced an eight-year gradual tax exemption scheme for electric and hybrid vehicles.	2022
	• National Electromobility Strategy 2035 targets: 100% of new light-duty and medium-duty vehicles, and new urban public transport vehicles to be zero emissions.	2021
Buildings	• National Energy Policy 2050 target: 100% low-emissions heating and cooking in urban centres in 2040, and 100% of new buildings are net zero energy use by 2050.	2022

Table 5.8 ▷ Major infrastructure projects in Chile

	Project	Size	Date online	Status	Description
Hydrogen/ ammonia	H_2 Magallanes	1 400 kt H_2/year (capacity)	2025	Feasibility study	Dedicated wind
	Gente Grande Magallanes	630 kt H_2/year (production)	2028	Feasibility study	Dedicated wind
	Faraday	180 kt H_2/year (production)	2027	Feasibility study	Grid + dedicated
Synfuels	Haru Oni (phase 2)	75 mill. litres synfuel/year	2025	Feasibility study	Dedicated renewables
Transmission, interconnections	Kimal-Lo Aguirre high voltage direct current transmission line	3 000 MW- 600 kV	2029	Feasibility study	1 500 km at permitting stage

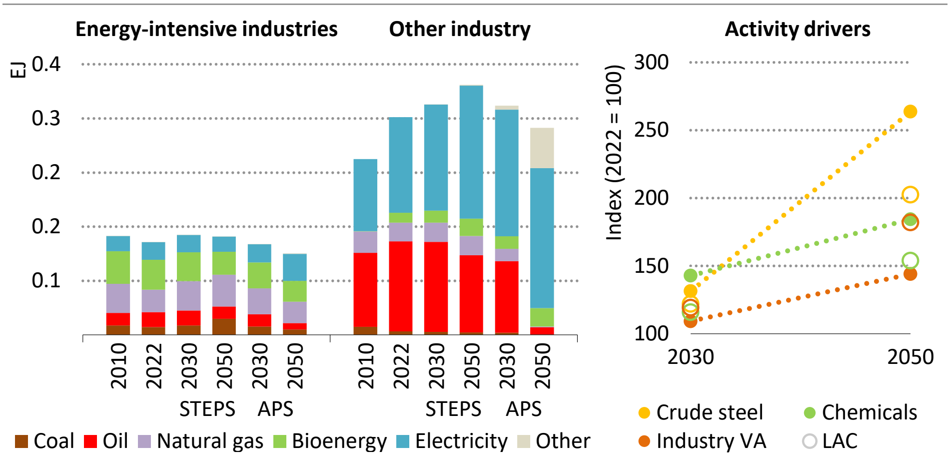
Status ● Feasibility study ● Under construction

Figure 5.24 ▷ Final energy consumption by scenario in Chile



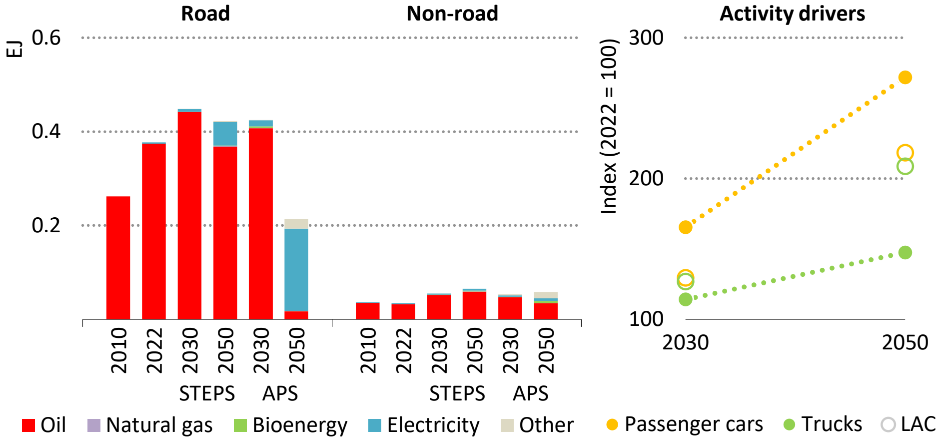
- Industry and transport account for 72% of final energy consumption today. Transport and industry drive up final energy consumption by nearly 20% in the STEPS by 2050.
- In the APS, final energy consumption in 2050 is 25% lower than in the STEPS due to electrification and energy efficiency gains in transport.

Figure 5.25 ▷ Fuel consumption in industry by type and scenario in Chile



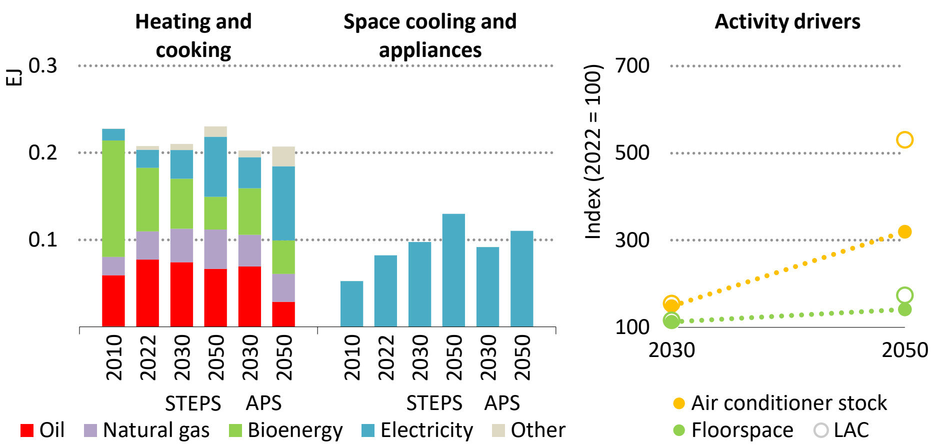
- Light industries, mostly mining, currently account for over 50% of energy consumption in industry in Chile. By 2050, steel industry output is above 2.5-times higher than today.
- In the APS, accelerated electrification and adoption of hydrogen-fuelled trucks in the mining sector bring about steep declines in emissions.

Figure 5.26 ⊳ Fuel consumption in transport by type and scenario in Chile



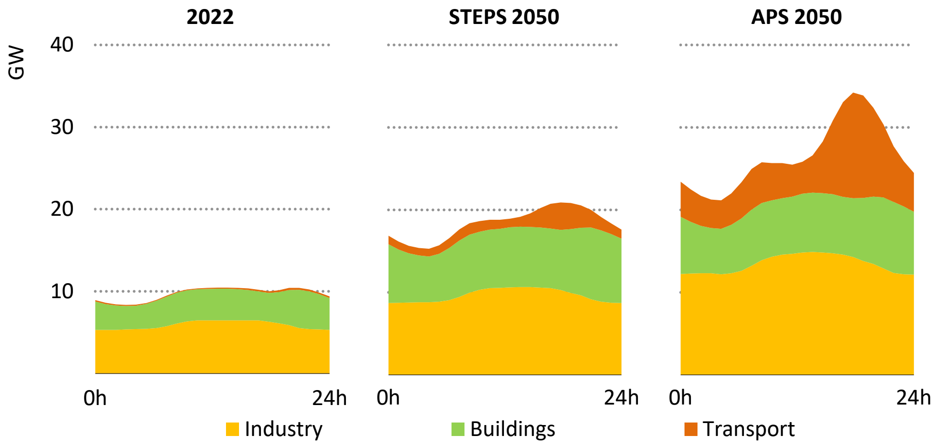
- Chile's geography means that most passengers and freight travel by road. Fuel consumption for transport is dominated by oil use in road transport.
- Chile has the ninth-largest electric bus fleet in the world. In the APS, its ambitious fuel economy and electromobility plans boost EV sales.

Figure 5.27 ⊳ Fuel consumption in buildings by type and scenario in Chile



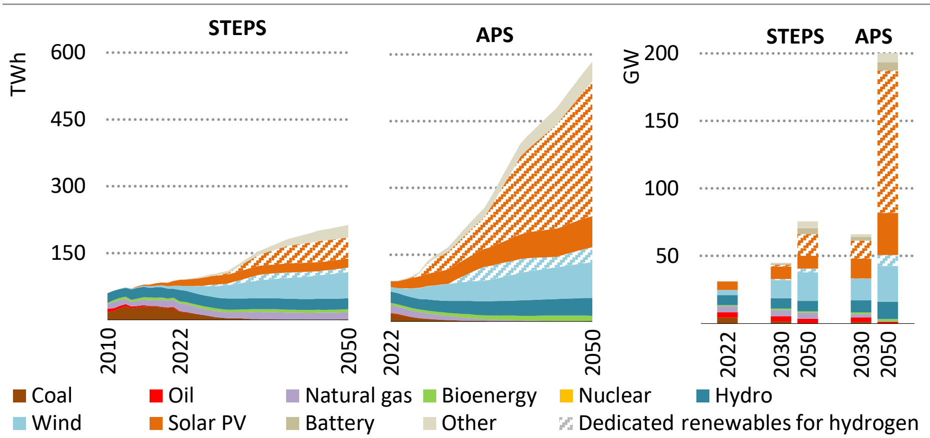
- Oil and bioenergy meet most heating and cooking needs today. By 2050, firewood use for heating, relevant in the central and southern regions, is dramatically lower in both scenarios.
- The shift away from oil and firewood use in heating and cooking and rising sales of household appliances are the drivers of additional electricity demand.

Figure 5.28 ⊳ Average electricity daily load profile by scenario in Chile



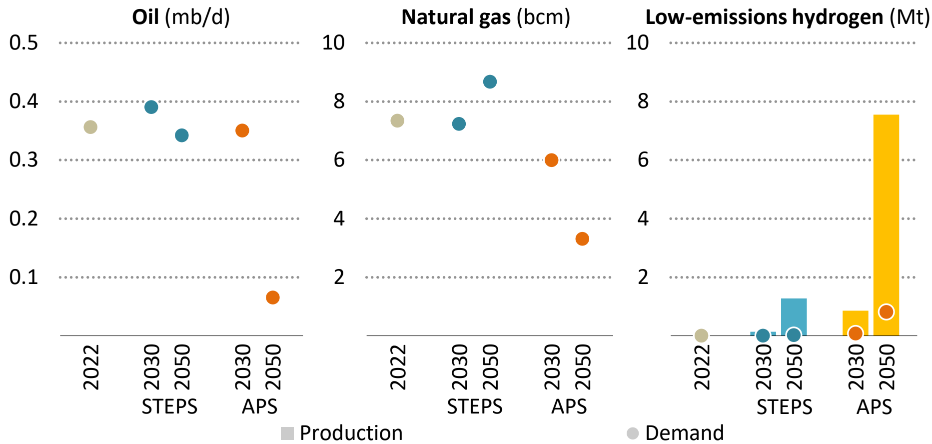
- By 2050, peak electricity demand doubles in the STEPS and triples in the APS; it grows by up to 15% (STEPS) and 60% (APS) faster than average electricity demand.
- The increase in daily peak demand is mainly driven by light industries (mining) and the uptake of EVs. Demand management could help to smooth evening peak demand.

Figure 5.29 ⊳ Electricity generation and capacity by fuel and scenario in Chile



- Coal accounted for 20% of electricity generation in 2022. A big increase in wind and solar PV generation leads to coal being phased out of the electricity mix in both scenarios.
- Chile's solar potential is the third-largest in the world. In the APS, dedicated solar PV for hydrogen production leads total installed capacity to rise to three-times the level in the STEPS.

Figure 5.30 ▷ Fuel demand and production by scenario in Chile



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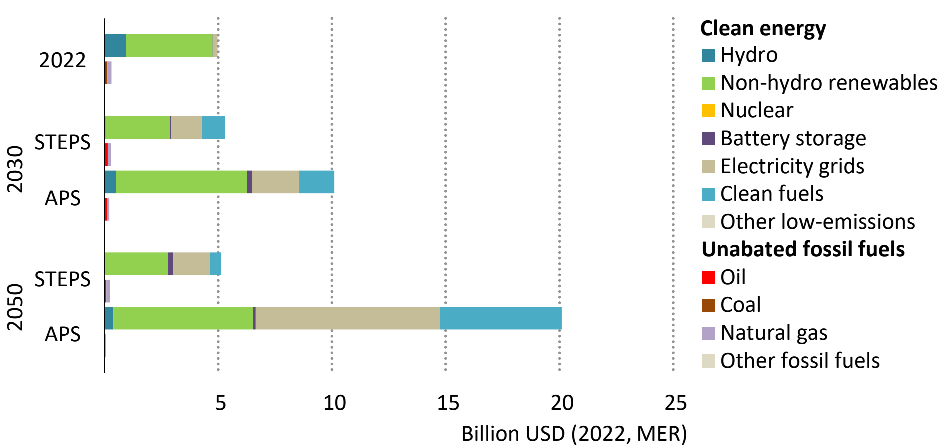
- In the STEPS, oil demand stagnates, while natural gas demand increases due to fuel switching in buildings and higher activity in energy-intensive industries.
- Hydrogen production is projected to reach around 7.5 Mt in 2050 in the APS, driven by domestic demand, particularly in transport and mining, and by international trade.

Figure 5.31 ▷ Annual investment in energy supply by type and scenario in Chile



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- Investment in clean energy supply accounts for over 1% of GDP in Chile in the STEPS in 2050 and 4% in the APS.
- In the APS, 40% of investment goes by 2050 to grids and 20% to hydrogen supply.

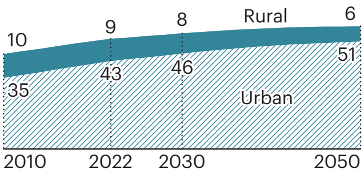
Colombia

6TH
largest city (Bogota) in Latin America and the Caribbean

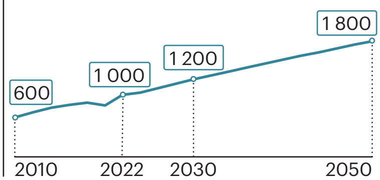
8TH
largest e-bus fleet in the world

6TH
largest coal exporter in the world

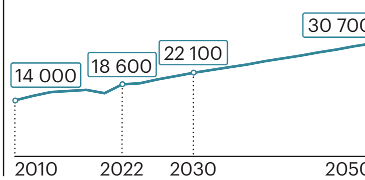
Population Million people



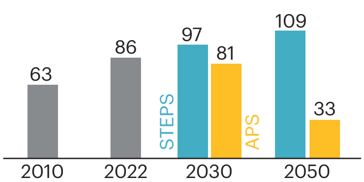
GDP Billion USD (2022, PPP)



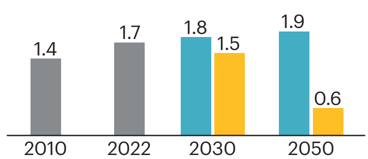
GDP per capita USD per capita (2022, PPP)



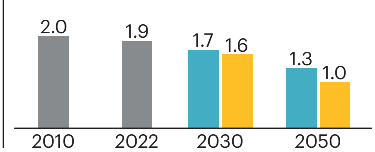
CO_2 emissions Mt CO_2



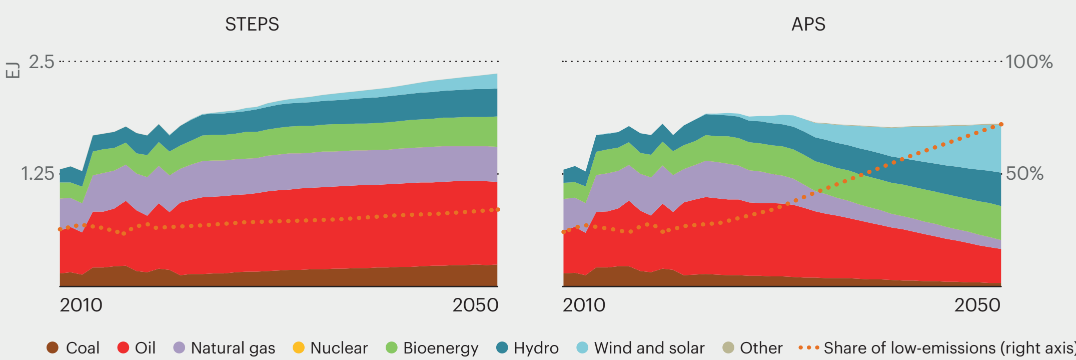
CO_2 emissions per capita t CO_2/capita



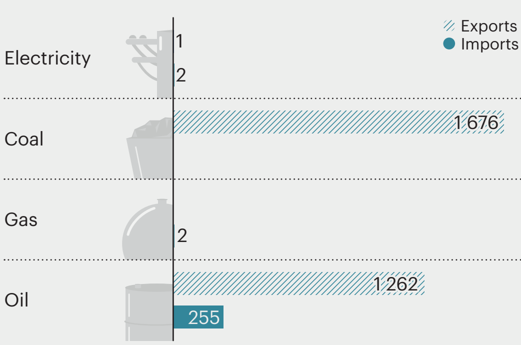
Energy intensity GJ per thousand USD (2022, PPP)



Primary energy supply and share of low-emissions sources



Trade of main energy products (2021) PJ



Trade of non-energy products (2021) Billion USD

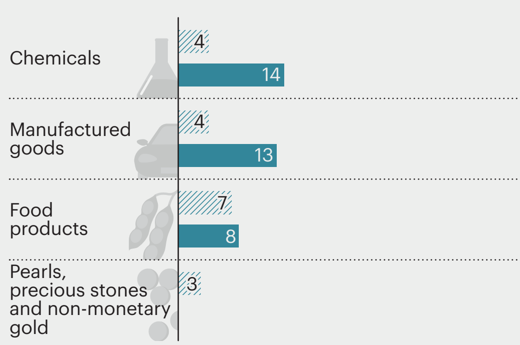


Table 5.9 ▻ Recent policy developments in Colombia

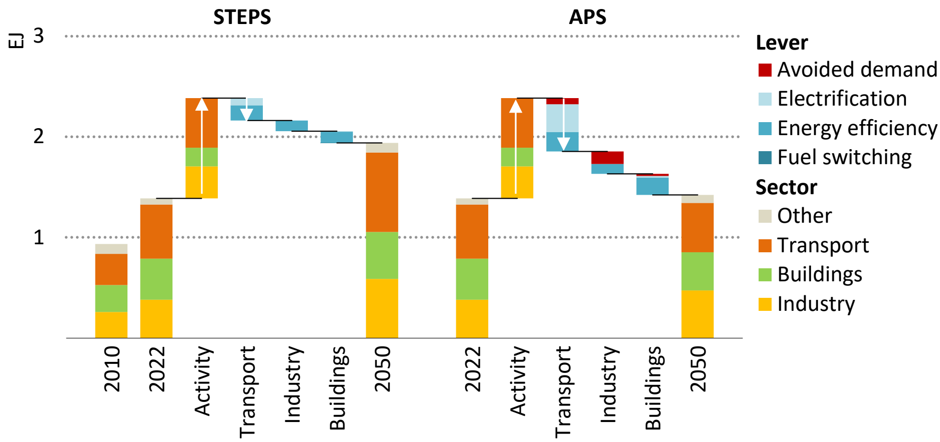
	Policy	Publication year
Economy-wide measures	• Climate Action Law: Net Zero GHG emissions by 2050.	2021
	• NDC: Unconditional target to reduce GHG emissions 51% below business-as-usual by 2030.	2021
	• Carbon tax for petroleum derivatives and gas used for combustion (USD 5/t CO_2-eq). Carbon tax for coal will be increased gradually to reach USD 12/t CO_2-eq by 2028.	2016
	• New National Energy Plan which will include the Just Energy Transition roadmap by 2050 (announced).	2023
Just transition policies	• Law 2056 to regulate the organisation and functioning of the general system of royalties.	2020
AFOLU	• Climate Action Law: Reduction of deforestation to 50 000 ha/year and zero deforestation by 2030.	2021
Oil and gas production	• Legislation to ban fracking (announced).	2022
	• Halt on new fossil fuel exploration licences (announced).	2023
Hydrogen	• National Hydrogen Strategy: 40% low-emissions hydrogen in total consumption in industry sector by 2030.	2021
Power	• Promotion of renewables integration through long-term auctions.	2021
	• E2050 strategy: Quantitative targets for clean electricity generation (10 GW offshore wind by 2050).	2021
Transport	• National Electric Mobility Strategy: 600 000 EV stock (excluding two/three-wheelers) by 2030.	2019
Energy efficiency	• Product Efficiency Call to Action at COP-26: Double the efficiency of air conditioners, refrigerators, lighting and industrial electric motors by 2030.	2021

Table 5.10 ▻ Major infrastructure projects in Colombia

	Project	Size	Date online	Status	Description
Hydrogen/ ammonia	Cartagena refinery	9 kt H_2/year (capacity)	2026	● Feasibility study	Dedicated renewable
	Barrancabermeja refinery	9 kt H_2/year (capacity)	2026	● Feasibility study	Dedicated renewable
	BEAUTY Ammonia	170 kt H_2/year (capacity)	2027	● Feasibility study	Grid
Oil and gas	Sebastopol refinery	150 000 b/d	2022	● Under construction	Crude oil derivatives Delayed due to COVID
Public transport	Bogota Metro Rail, Line 1	72 000 passengers per hour	2028	● Under construction	-

Status ● Feasibility study ● Under construction

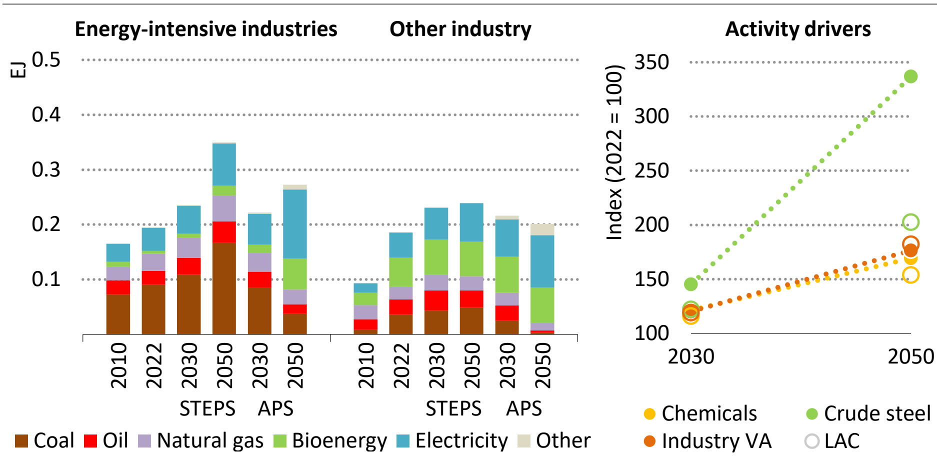
Figure 5.32 ⊳ Final energy consumption by scenario in Colombia



IEA. CC BY 4.0.

- Today, the transport and buildings sectors account for 68% of final energy consumption.
- Total final consumption increases 40% by 2050 in the STEPS, led by transport and industry. In the APS, only the industry sector consumes more energy in 2050 than in 2022.

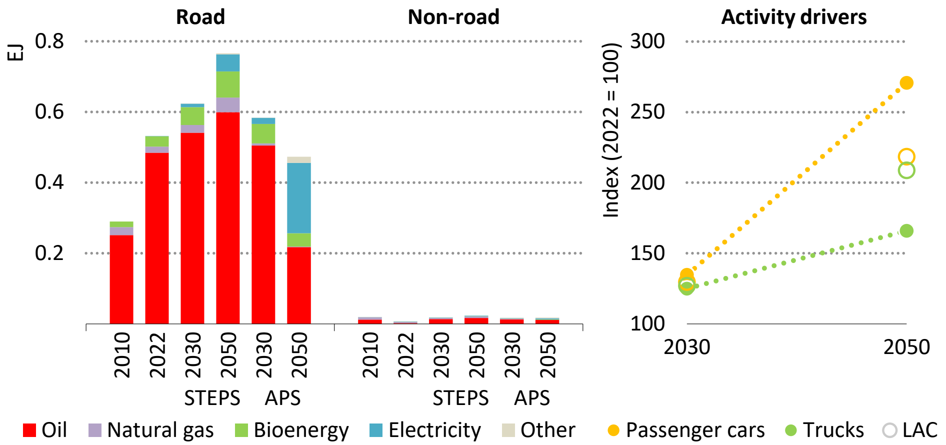
Figure 5.33 ⊳ Fuel consumption in industry by type and scenario in Colombia



IEA. CC BY 4.0.

- Coal currently meets a third of energy consumption in industry, and it remains the main fuel in the STEPS for energy-intensive industries as steel production more than triples by 2050.
- In the APS, the roll-out of heat pumps and processes based on electrolytic hydrogen lead to electricity demand displacing coal in most industrial sectors.

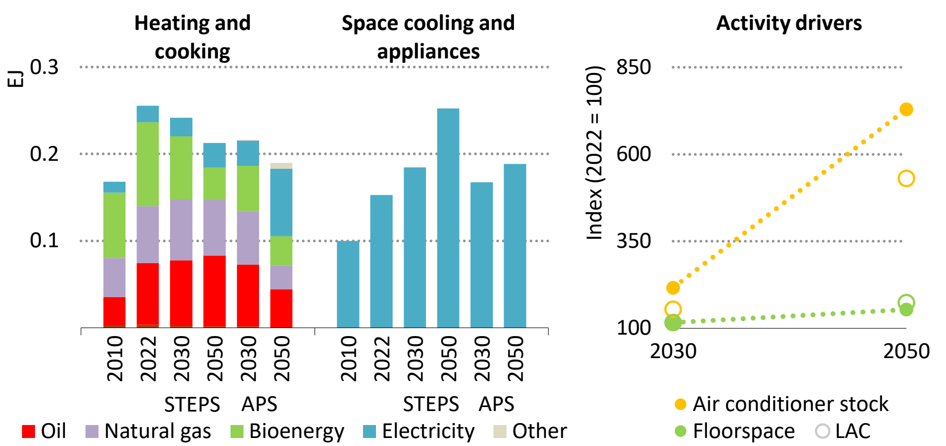
Figure 5.34 ▷ Fuel consumption in transport by type and scenario in Colombia



IEA. CC BY 4.0.

- Colombia has the world's eighth-largest electric bus fleet today. In the APS, nearly 80% of the bus fleet is electric by 2050.
- In the APS, passenger activity increases by 170% from 2022 levels by 2050, but oil use in road transport falls by 55% as the share of electricity in consumption rises to over 40%.

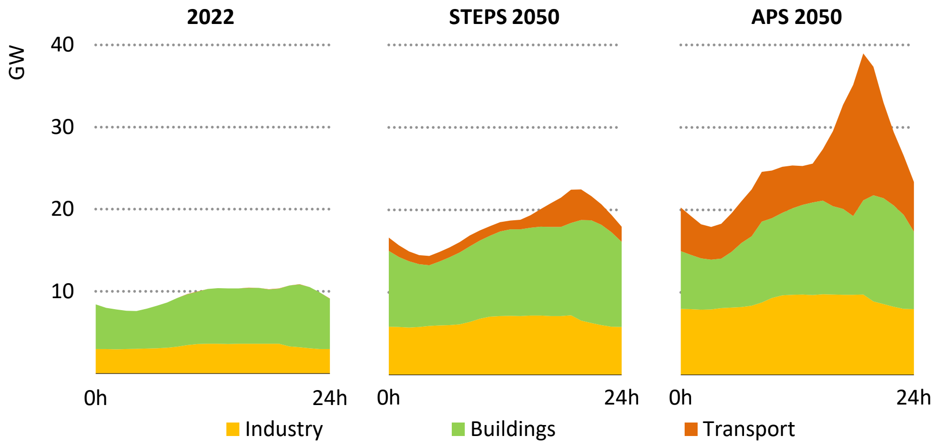
Figure 5.35 ▷ Fuel consumption in buildings by type and scenario in Colombia



IEA. CC BY 4.0.

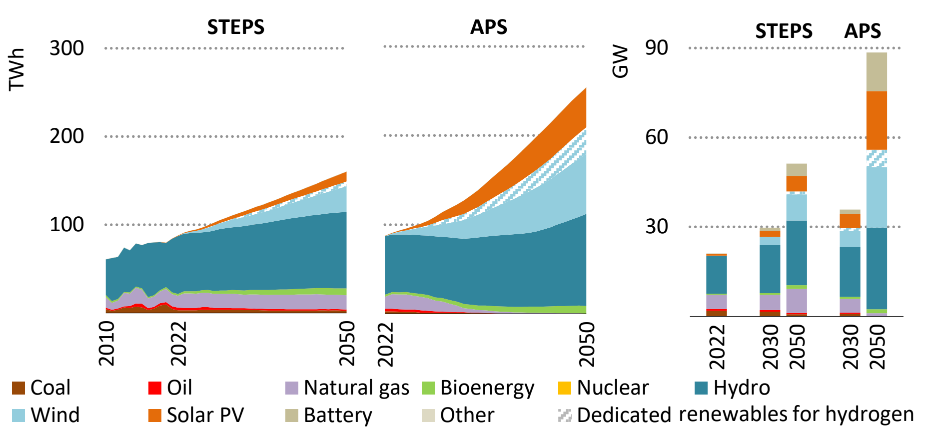
- Most heating and cooking needs in Colombia are met by bioenergy, oil and natural gas. In the APS, the share of oil declines as electrification increases.
- Increased use of household appliances and space cooling drives electricity demand growth in buildings. In the APS, more stringent MEPS cut the growth by nearly 15% compared to STEPS.

Figure 5.36 ▷ Average electricity daily load profile by scenario in Colombia



- By 2050, peak electricity demand doubles in the STEPS and more than triples in the APS, outpacing growth in average electricity demand.
- In the APS, smart charging of EVs could smooth the evening peak in demand.

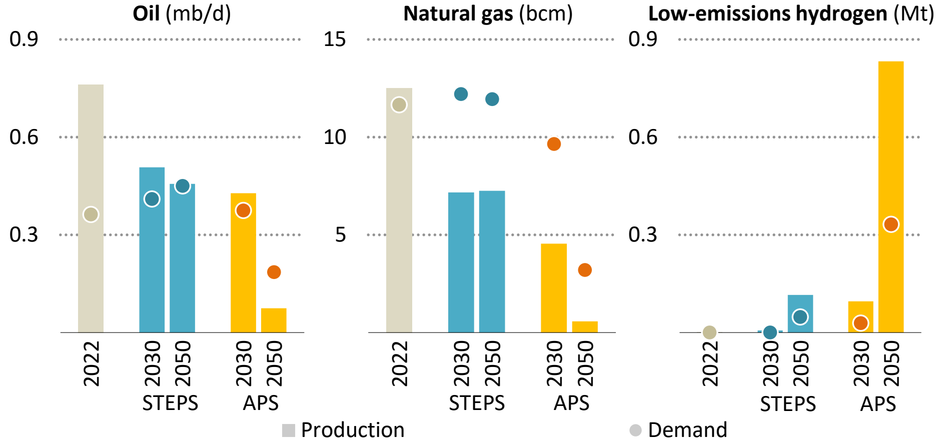
Figure 5.37 ▷ Electricity generation and capacity by fuel and scenario in Colombia



- Today's power mix is dominated by hydropower (75%), with natural gas and oil accounting for most of the rest.
- Rising demand for electricity is met primarily by wind and solar PV generation. In the APS, solar PV and wind generation increases from 1% today to almost 60% in 2050.

5

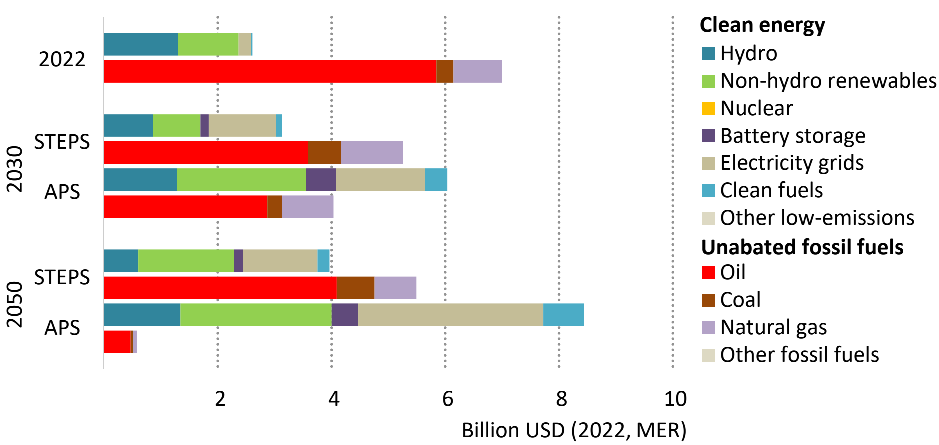
Figure 5.38 ⊳ Fuel demand and production by scenario in Colombia



IEA. CC BY 4.0.

- Oil and gas production decline in both scenarios, but the decline is much starker in the APS as Colombia delivers on its pledge of no new oil and gas exploration contracts.
- In the STEPS, low-emissions hydrogen production rises to 0.1 Mt by 2050. In the APS, it increases to almost 1 Mt.

Figure 5.39 ⊳ Annual investment in energy supply by type and scenario in Colombia



IEA. CC BY 4.0.

- Investment in clean energy supply accounts for 0.6% of GDP in Colombia in the STEPS by 2050 and 1.4% in the APS.
- More than a third of overall investment for clean energy supply supports grid development in both scenarios in 2050.

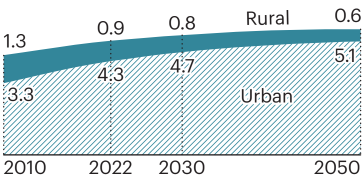
Costa Rica

3RD
largest producer of geothermal energy in Latin America and the Caribbean

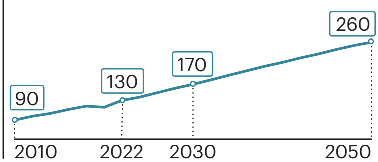
100%
share of renewables in electricity generation

HIGHEST
electrification in buildings in Latin America and the Caribbean

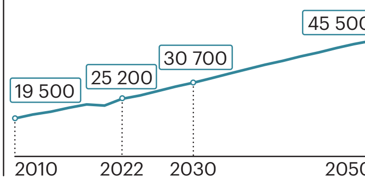
Population — Million people



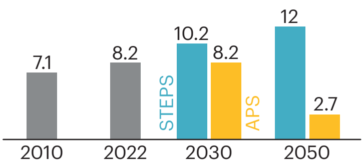
GDP — Billion USD (2022, PPP)



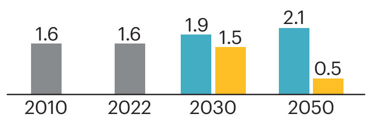
GDP per capita — USD per capita (2022, PPP)



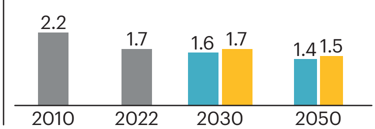
CO_2 emissions — Mt CO_2



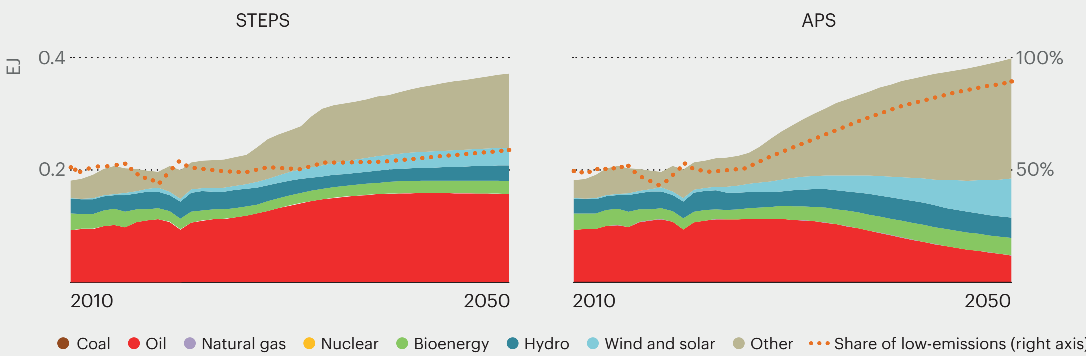
CO_2 emissions per capita — t CO_2/capita



Energy intensity — GJ per thousand USD (2022, PPP)

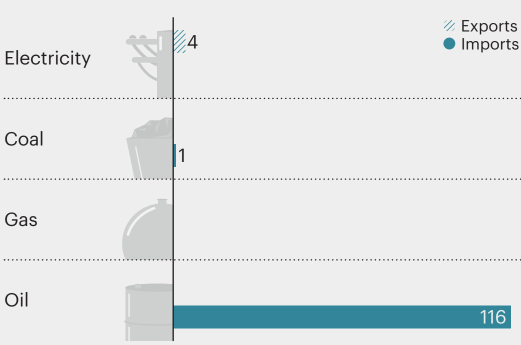


Primary energy supply and share of low-emissions sources



Trade of main energy products (2021)

PJ



Trade of non-energy products (2021)

Billion USD

Table 5.11 ▹ Recent policy developments in Costa Rica

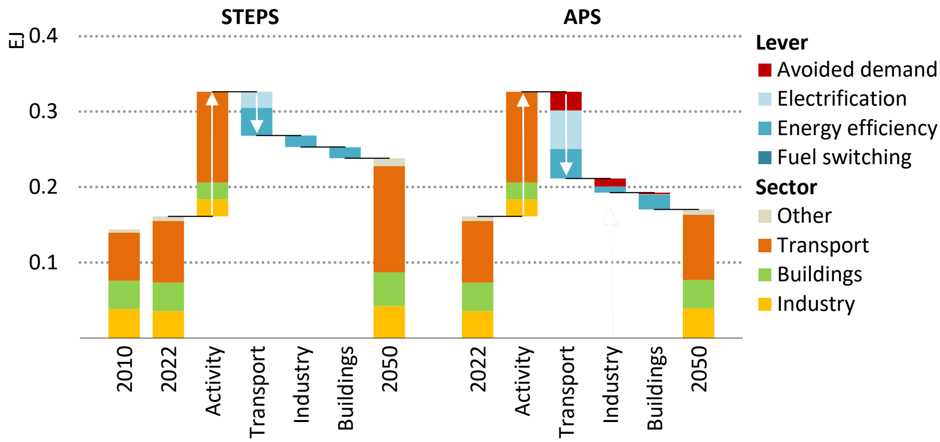
	Policy	Publication year
Economy-wide measures	• NDC (revised in 2020): Commitment to a maximum of 9.11 Mt CO_2-eq of net emissions by 2030 and to reach net zero emissions by 2050.	2020
	• Net zero emissions target (target reiterated in NDC in 2020): General commitment to net zero emissions goal by 2050 in its National Decarbonisation Plan 2018-2050.	2019
	• National Adaptation Plan (2022-2026): Roadmap to strengthen resilience to the impacts of climate change.	2022
AFOLU	• Implementation Plan for the National REDD+ Strategy: Increase forest cover by recovering 254 923 hectares of agricultural land by 2025.	2017
Oil and gas production	• Decree No. 41578: extends the national moratorium on activities related to oil exploration and exploitation from 2021 to 2050.	2019
Hydrogen	• National Hydrogen Strategy 2022-2050. Three key strategies: use green hydrogen to decarbonise the transport and industry sectors; develop a technology hub; and foster the conditions to facilitate hydrogen exports.	2022
Power	• Generation Expansion Plan 2022-2040: Install 1 775 MW of solar PV and wind capacity.	2023
Industry	• Decarbonisation National Plan 2018-2050: Industry to shift energy sources to reduce emissions while increasing activity.	2019
Transport	• Decarbonisation National Plan 2018-2050: 60% of the light-duty vehicle fleet and 100% of the public transport fleet will be zero emissions, with electricity as the main power source.	2019
	• *Plan Nacional de Desarrollo en Inversión Pública 2023-2026*: *Rogelio Fernández Güell*: Implements a blending target of 8% of renewable components in fossil fuels sold in the domestic market.	2022
Buildings	• Agreement 09- MINAE. Creates the National Environmental and Energy Efficiency Labelling Programme of Costa Rica and the Technical Committee for Environmental and Energy Labelling.	2023

Table 5.12 ▹ Major infrastructure projects in Costa Rica

	Project	Size	Date online	Status	Description
Hydrogen/ammonia	Costa Rica Transportation Ecosystem Project	0.2 kt H_2/year (capacity)	2025	Feasibility study	Dedicated renewables
Hydropower	Fourth Cliff	61 MW	2029	Feasibility study	Hydropower
Geothermal	Borinquen I	55 MW	2027	Under construction	Geothermal
	Borinquen II	55 MW	2031	Under construction	Geothermal

Status ● Feasibility study ● Under construction

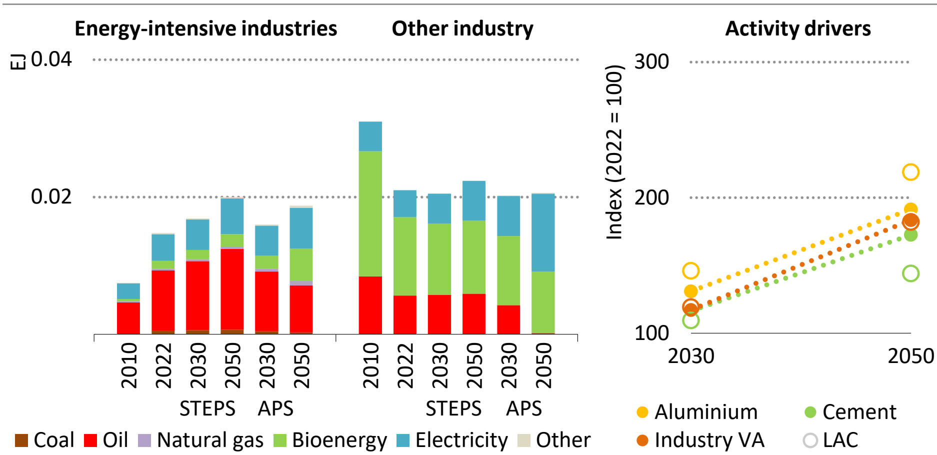
Figure 5.40 ⊳ Final energy consumption by scenario in Costa Rica



IEA. CC BY 4.0.

- Today, transport alone accounts for more than half of final energy consumption.
- In the STEPS, total final energy consumption increases by 50% by 2050, mainly driven by increased transport demand. In the APS, final energy consumption increases by only 6% thanks in part to accelerated electrification that tempers 33% of the increase in activity.

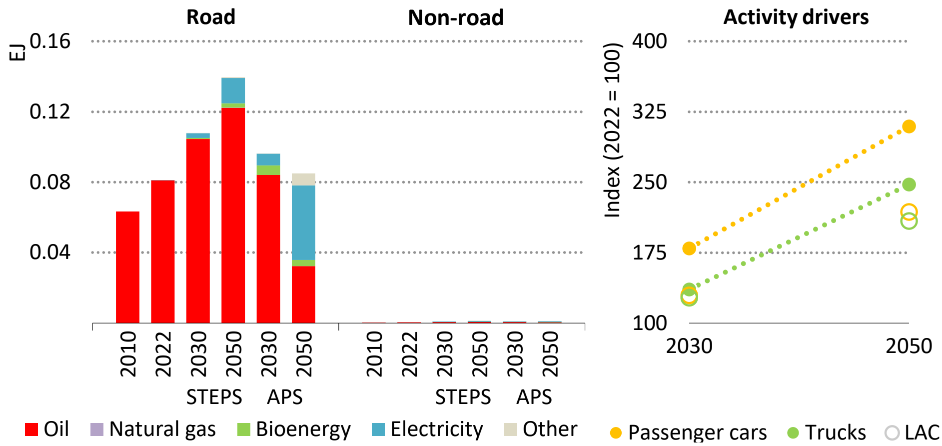
Figure 5.41 ⊳ Fuel consumption in industry by type and scenario in Costa Rica



IEA. CC BY 4.0.

- Energy-intensive industries account for over 40% of energy demand in industry today.
- In the APS, bioenergy continues to play a key role, and electricity use rises as industrial heat pumps supply low-temperature heat. Oil use in industry is halved by 2050 compared to today.

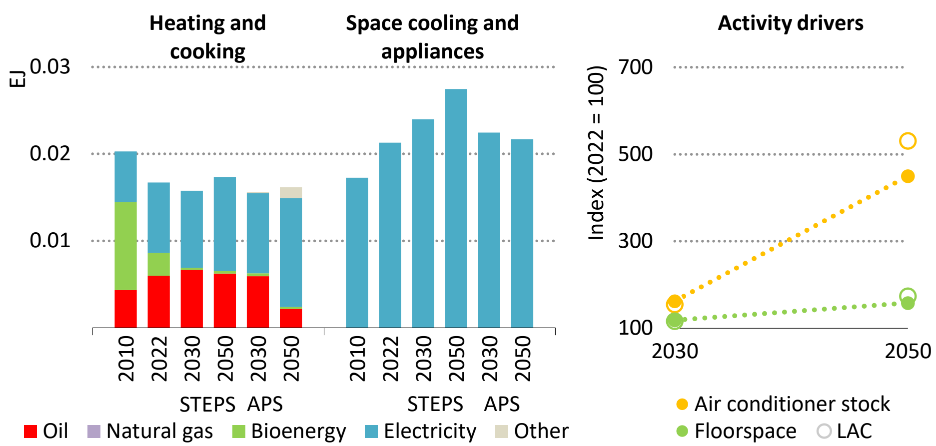
Figure 5.42 ⊳ Fuel consumption in transport by type and scenario in Costa Rica



IEA. CC BY 4.0.

- The transport sector is the largest source of energy-related CO_2 emissions in Costa Rica. Electrification plays a key role to decarbonise transport in future years.
- In the APS, electricity is 50% of consumption in 2050, curbing energy demand growth.

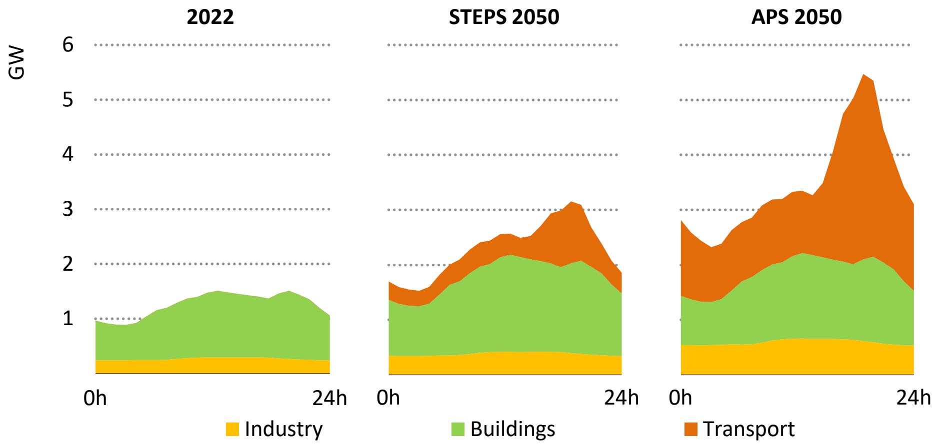
Figure 5.43 ⊳ Fuel consumption in buildings by type and scenario in Costa Rica



IEA. CC BY 4.0.

- Most cooking needs today are met by electricity. In the APS, the share of oil in heating and cooking declines as the share of electricity rises 1.4-times from its 2022 level.
- In the STEPS, the increase in demand for appliances and space cooling is responsible for 60% of the increase in electricity consumption in the buildings sector.

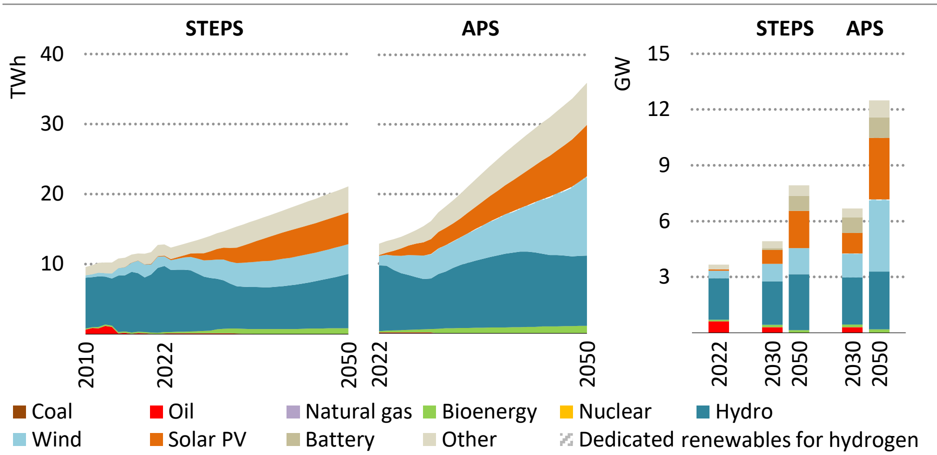
Figure 5.44 ⊳ Average electricity daily load profile by scenario in Costa Rica



IEA. CC BY 4.0.

- Peak electricity demand doubles by 2050 from current levels in the STEPS and increases more than 3.5-times in the APS. It rises over 80% more than average electricity demand.
- Electricity for transport is the main driver of the increase in electricity peak demand.

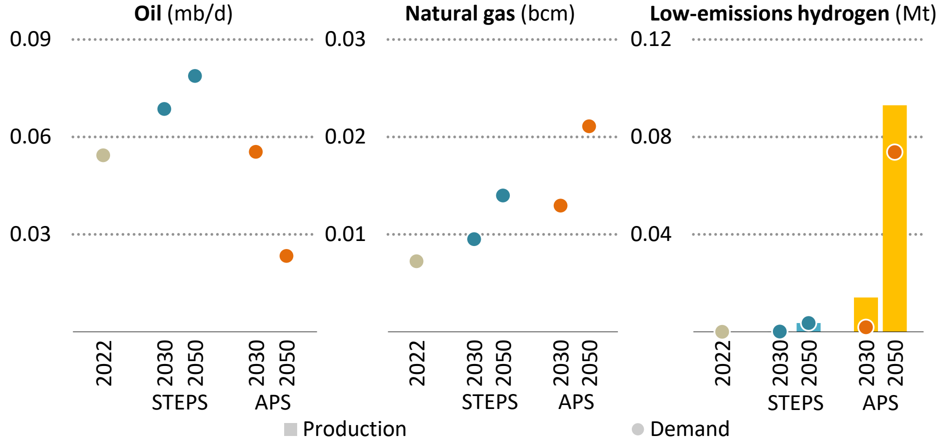
Figure 5.45 ⊳ Electricity generation and capacity by fuel and scenario in Costa Rica



IEA. CC BY 4.0.

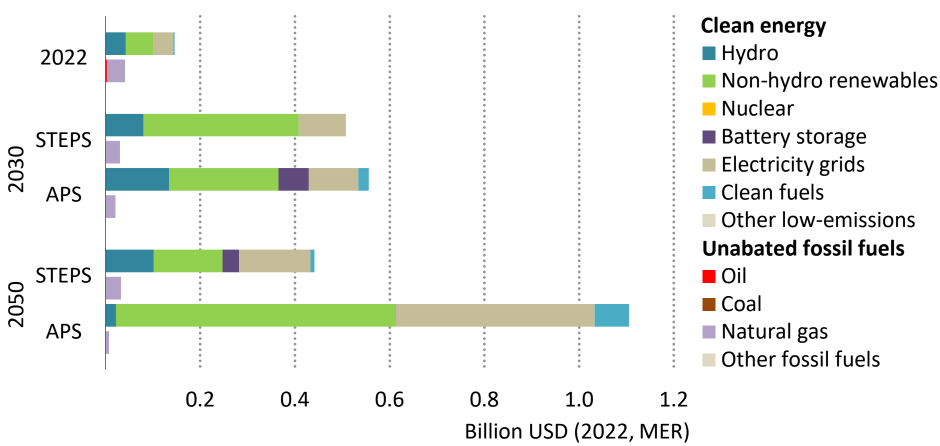
- Hydropower dominates the current power mix. It continues to play a key role to 2050 in both scenarios. Geothermal plays an important role both today and in the future.
- Wind and solar PV meet most of the electricity demand increase in both scenarios. In the APS, their share of total generation rises from 10% today to more than 50% in 2050.

Figure 5.46 ▷ Fuel demand and production by scenario in Costa Rica



- After 2030, demand for oil plateaus in the STEPS and decreases significantly in the APS.
- Low-emissions hydrogen production and demand is around 0.1 Mt by 2050 in the APS.

Figure 5.47 ▷ Annual investment in energy supply by type and scenario in Costa Rica



- Investment in clean energy supply accounts for 0.3% of GDP in Costa Rica in the STEPS in 2050 and 0.8% in the APS.
- In the APS, investment in clean energy supply increases fourfold by 2030 from current levels, and over USD 0.6 billion is invested in renewables in 2050.

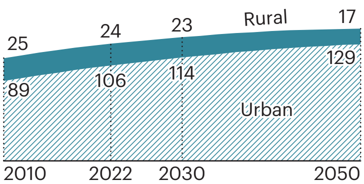
Mexico

2ND
largest economy in Latin America and the Caribbean

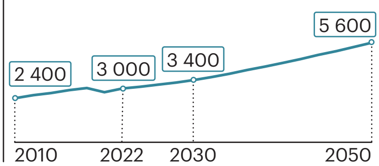
2ND
largest steel producer in Latin America and the Caribbean

11TH
largest oil producer in the world

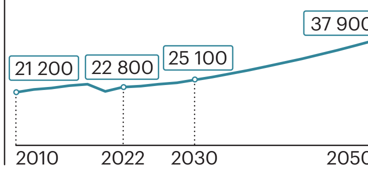
Population Million people



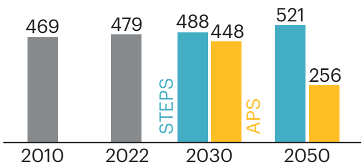
GDP Billion USD (2022, PPP)



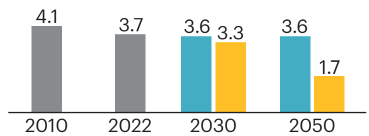
GDP per capita USD per capita (2022, PPP)



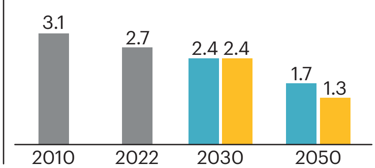
CO_2 emissions Mt CO_2



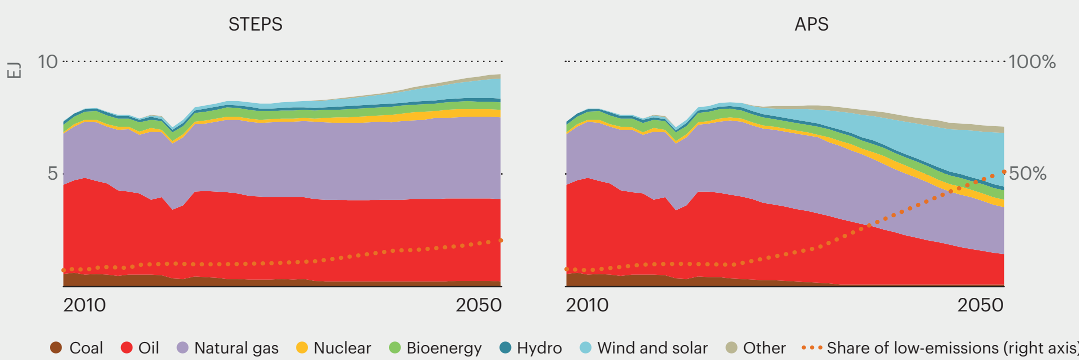
CO_2 emissions per capita t CO_2/capita



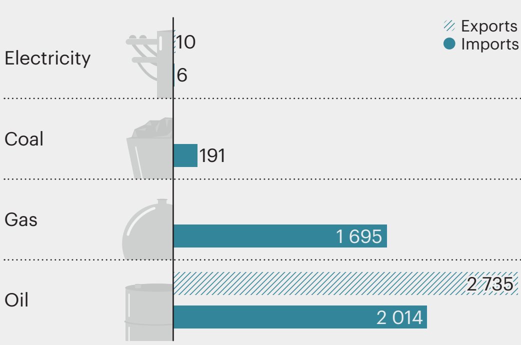
Energy intensity GJ per thousand USD (2022, PPP)



Primary energy supply and share of low-emissions sources



Trade of main energy products (2021) PJ



Trade of non-energy products (2021) Billion USD

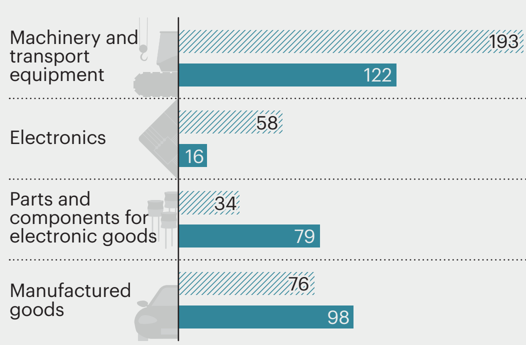


Table 5.13 ▷ Recent policy developments in Mexico

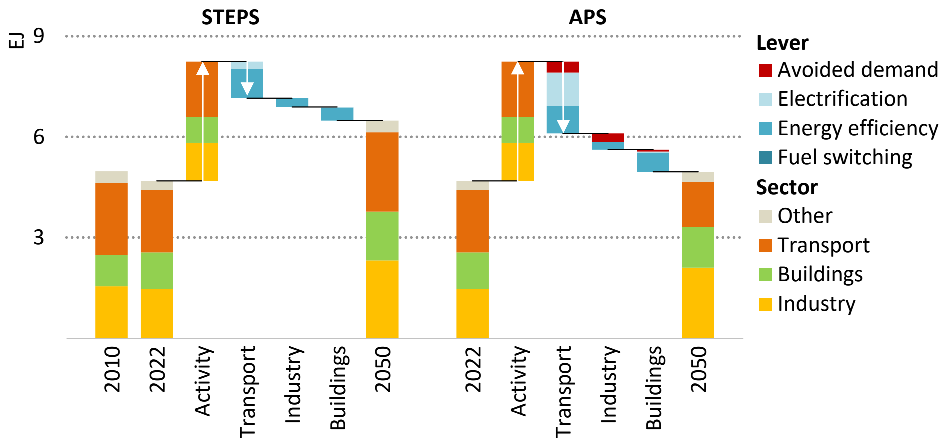
	Policy	Publication year
Economy-wide measures	• NDC: Conditional target of GHG emissions reduction of 40% from business-as-usual by 2030.	2022
	• Carbon Tax: Special Tax Law on Production and Services was amended to levy a tax on the carbon content of fuels from 2014. The carbon tax is updated annually. So far, natural gas is excluded.	2012
AFOLU	• National strategy for REDD+ 2017-2030: Goal of net zero deforestation by 2030.	2017
Critical minerals	• A decree granted the federal government the rights to explore, exploit and export lithium through the state-owned company LitioMx.	2022
Oil and gas production	• Global Methane Pledge: Mexico joined the initiative to reduce global anthropogenic methane emissions by 30% from 2020 levels by 2030.	2021
	• General Administrative Provisions on methane from the hydrocarbon sector: Regulated entities must submit plans to prevent methane emissions, including actions and targets.	2018
Power	• *Ley de Transición Energética*: Sets a target for clean energy to have a 35% share in electricity generation by 2024.	2015
Industry	• Provisions of *Ley de Transición Energética* define the procedure for voluntary agreements on energy efficiency for large industrial consumers.	2017
Transport	• Energy efficiency of light-duty vehicles: Mexico published the standard project PROY-NOM-163-SEMARNAT-SCFI-2023 to update the existing fuel efficiency standard for new light-duty vehicles from 2025.	2023
	• Draft National Strategy for Electric Mobility: Sets targets for 100% of passenger vehicle sales to be electric or plug-in hybrid by 2040 and 100% to be electric by 2050.	2023
Buildings	• Energy efficiency requirements for home appliances: NOM-028-ENER-2017 for light bulbs, NOM-015-ENER-2018 for household refrigerators and freezers, NOM-023-ENER-2018 for air conditioners.	2018

Table 5.14 ▷ Major infrastructure projects in Mexico

	Project	Size	Date online	Status	Description
Hydrogen/ ammonia	Mexican Green Hydrogen Hub, phase 1	10 kt H_2/year (capacity)	2025	Feasibility study	Dedicated solar PV
	Energía Los Cabos	4 kt H_2/year (capacity)	2024	Feasibility study	Dedicated solar PV
	Delicias Solar	6 kt H_2/year (capacity)	2026	Feasibility study	Dedicated solar PV
Oil and gas	Energía Costa Azul Liquefaction plant	3 Mt/year	2024	Under construction	Build liquefaction capacity to export LNG
	Olmeca refinery	340 000 b/d	2023	Under construction	Increase national refining

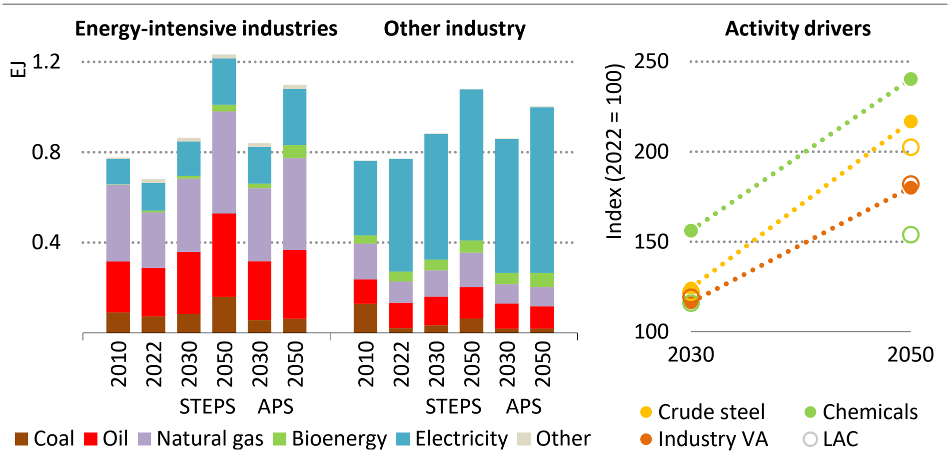
Status ● Feasibility study ● Under construction

Figure 5.48 ▷ Final energy consumption by scenario in Mexico



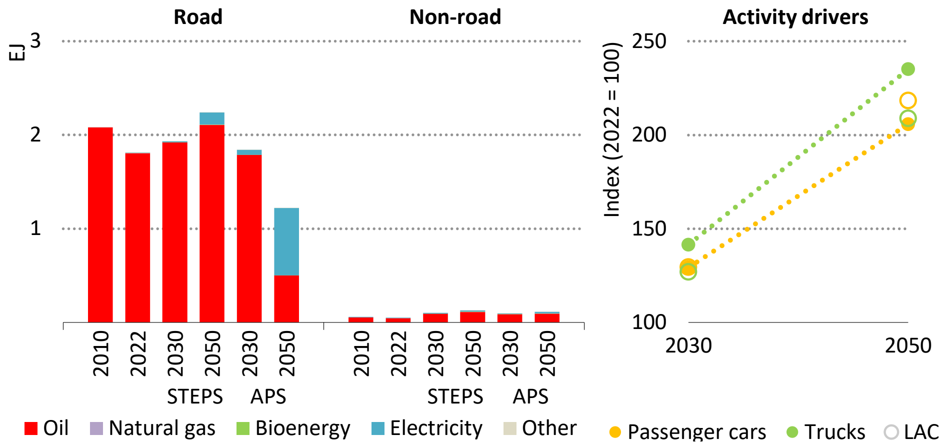
- Today, transport accounts for around 40% of total final energy consumption in Mexico.
- Total final energy consumption increases nearly 40% in the STEPS by 2050. Accelerated energy efficiency gains and electrification reduce this to 6% in the APS.

Figure 5.49 ▷ Fuel consumption in industry by type and scenario in Mexico



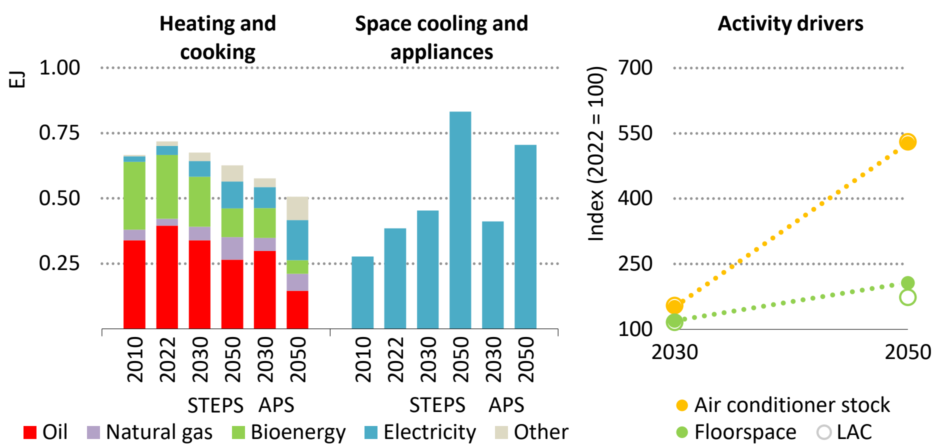
- With strong cement and steel industries, Mexico accounts for 20% of industrial energy use in the region, and for a quarter of the increase in demand by 2050 in the STEPS.
- In both the STEPS and APS, the share of fossil fuels in energy consumption in industry in Mexico remains high. In the APS, the share of bioenergy remains low compared to other LAC countries.

Figure 5.50 ⊳ Fuel consumption in transport by type and scenario in Mexico



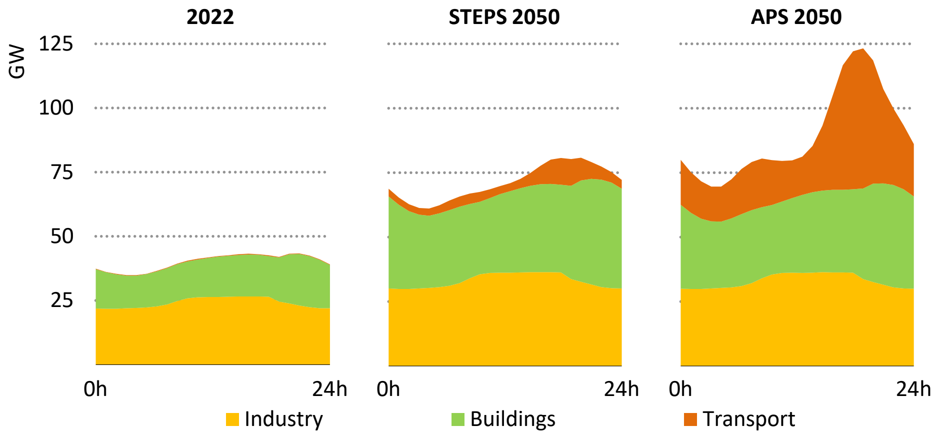
- Electrification increases in road transport after 2030 in both scenarios. In the APS, electricity accounts for over half of energy consumption in transport by 2050.
- A drop in oil demand in the APS is mainly driven by a shift to electromobility and by efficiency gains from more stringent fuel economy standards.

Figure 5.51 ⊳ Fuel consumption in buildings by type and scenario in Mexico



- Oil-derived fuel consumption slowly decreases in buildings as the use of electricity and natural gas increases. Electrification helps reduce the traditional use of biomass.
- Ownership of air conditioners more than triples by 2050, and is responsible for more than 40% of the increase in electricity consumption in Mexico's buildings sector in the STEPS. Energy-efficient appliances limit the size of the increase in the APS.

Figure 5.52 ⊳ Average electricity daily load profile by scenario in Mexico



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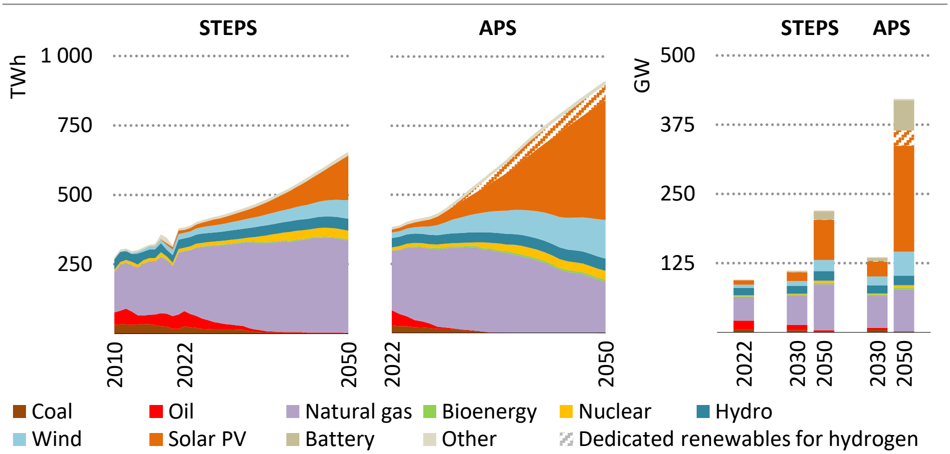
- In both scenarios, electricity consumption in buildings almost doubles from current levels. It contributes to a total peak demand increase of 40% in the APS by 2050.
- The gap between peak demand in the STEPS and APS reflects higher uptake of EVs which account for nearly 45% of daily peak in the APS. Smart charging could smooth the peaks.

Figure 5.53 ⊳ Electricity generation and capacity by fuel and scenario in Mexico



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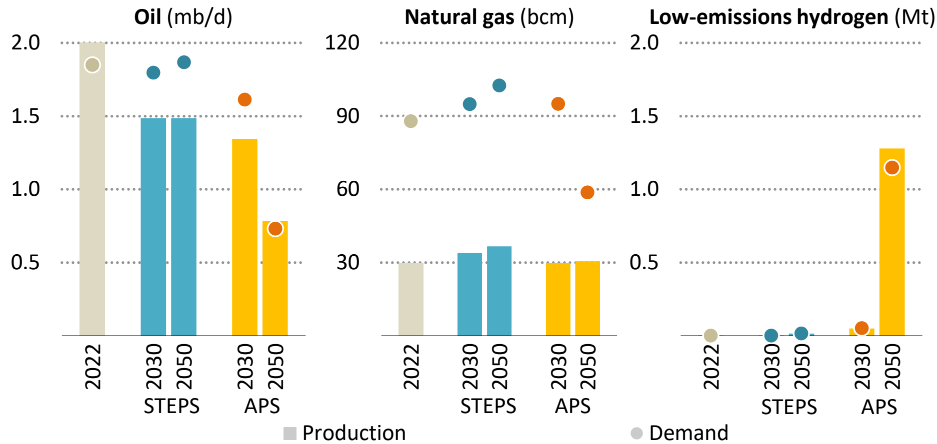
- Natural gas dominates the power mix in Mexico today. In the STEPS, natural gas and solar PV together meet over 95% of electricity generation growth to 2050.
- The APS sees much higher electricity demand by 2050 than the STEPS, with solar PV and wind meeting almost all the additional demand.

Figure 5.54 ▷ Fuel demand and production by scenario in Mexico



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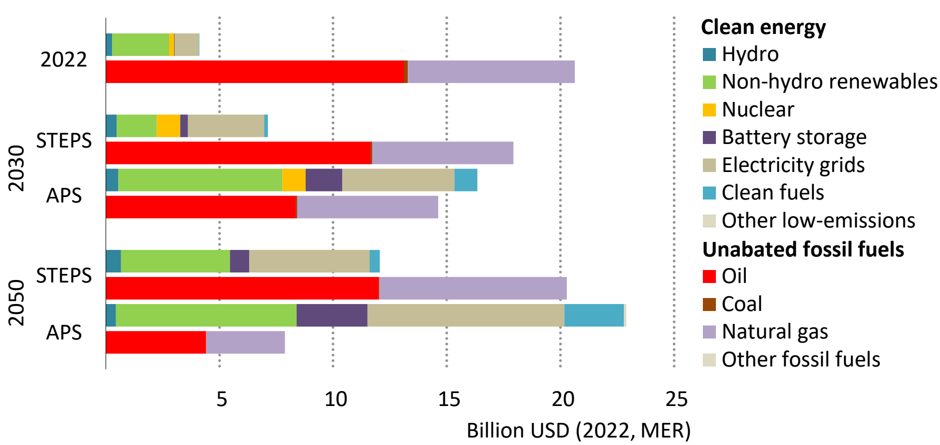
- In the STEPS, natural gas production increases nearly 25% by 2050, but the gap with demand widens; oil production falls, then plateaus as demand remains steady.
- In the APS, natural gas demand drops sharply after 2030 as use in the power sector declines; oil production follows demand downwards and falls by 60%.

Figure 5.55 ▷ Annual investment in energy supply by type and scenario in Mexico



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- Investment in clean energy supply accounts for 0.5% of GDP in Mexico in the STEPS in 2050 and 0.9% in the APS.
- In the STEPS, most investment is still directed to fossil fuels in 2050. In the APS, investment in clean energy is 3-times higher than investment in fossil fuels by 2050.

Notes

Units

Area	ha	hectares
Distance	km	kilometre
Emissions	Gt CO_2	gigatonnes of carbon dioxide
	Mt CO_2	million tonnes of carbon dioxide
	Mt CO_2-eq	million tonnes of carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
	t CO_2-eq	tonnes of carbon-dioxide equivalent
Energy	EJ	exajoule (1 joule x 10^{18})
	PJ	petajoule (1 joule x 10^{15})
	TWh	terawatt-hour
	Tcal	teracalorie (1 calorie x 10^{12})
Gas	bcm	billion cubic metres
	bcm/d	billion cubic metres per day
	mcm/d	million cubic metres per day
Mass	kg	kilogramme
	kt	kilotonnes (1 tonne = 1 000 kg)
Monetary	USD million	1 US dollar x 10^6
	USD billion	1 US dollar x 10^9
Oil	mb/d	million barrels per day
	b/d	barrels per day
Power	GW	gigawatt
	MW	megawatt
	kV	kilovolt

Terms

Activity drivers for industry include production levels (Mt) and value added (USD 2022, PPP); for transport, vehicle-kilometres (km) for passenger cars and tonne-km for trucks; for buildings, air conditioning (million units) and floorspace (million square metres). The activity numbers presented correspond to the Stated Policies Scenario (STEPS) indexed on the 2022 value.

Bioenergy refers to bioenergy and waste.

Clean fuels refers to biofuels, hydrogen and hydrogen-related fuels.

Daily average electricity load profiles do not factor in electricity demand generated by dedicated renewable sources connected to electrolysers, and they also do not consider the influence of demand-response mechanisms.

Energy-intensive industries include chemicals, iron and steel, non-metallic minerals (cement and other), non-ferrous metals (aluminium and other) and pulp, paper and printing.

Heating and cooking in buildings refers to energy demand for space and water heating, and cooking.

Hydrogen demand excludes both hydrogen exports and the hydrogen used for producing hydrogen-based fuels which are exported.

Investment data are presented in real terms in year-2022 US dollars.

Large-scale CCUS projects refer only to facilities with a planned capture capacity higher than 100 000 tonnes of CO_2 per year.

Low-emissions hydrogen projects considered are those with an announced capacity for 2030.

Non-road transport includes rail, domestic navigation, domestic aviation, pipeline and other non-specified transport.

Other for power generation and capacity refers to geothermal, concentrated solar power, marine, non-renewable waste and other non-specified sources.

Other for final consumption in sectors refers to non-renewable waste, hydrogen, solar thermal and geothermal.

Other in a sector category refers to agriculture and other non-energy uses.

Other fossil fuels in energy supply investment refer to non-renewable waste and other supply sources.

Other fuel shifts include bioenergy, nuclear, solar thermal, geothermal and natural gas.

Other industry refers to the construction, food and tobacco, machinery, mining and quarrying, textile and leather, transport equipment, wood industry branches and remaining industry.

Other low-emissions in energy supply investment include heat pumps, CCUS, electricity generation from hydrogen, electricity generation from ammonia and direct air capture.

Road transport includes six vehicle categories (passenger cars, buses, two/three-wheelers, light-duty vans and trucks, and medium and heavy trucks).

SDG 7 refers to Sustainable Development Goal (SDG) 7: "ensure access to affordable, reliable, sustainable and modern energy for all", adopted by the United Nations in 2015.

Solar potential data is calculated based on the average potential at national level assessed in kilowatt-hour per kilowatt peak per day (2020).

Total final consumption includes consumption by the various end-use sectors (industry, transport, buildings, 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.

Acronyms

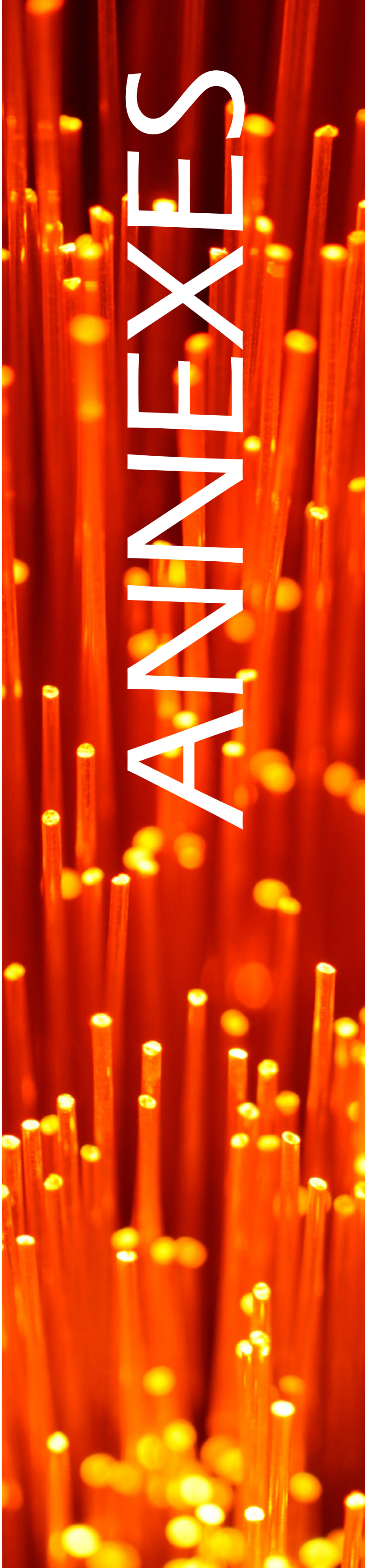
Scenarios: **STEPS** = Stated Policies Scenario; **APS** = Announced Pledges Scenario.

AFOLU	agriculture, forestry and other land use
BECCS	bioenergy with carbon capture and storage
CCUS	carbon capture, utilisation and storage
CNG	compressed natural gas
EV	electric vehicle
GDP	gross domestic product
GHG	greenhouse gases
H_2	hydrogen
HVDC	high voltage direct current
ICE	internal combustion engine
MEPS	minimum energy performance standards
MER	market exchange rate
NDC	Nationally Determined Contribution
PPP	purchasing power parity
PV	photovoltaics
SDG	Sustainable Development Goals
VA	value added
ZEV	zero emissions vehicle

The policy tables include existing policies and announcements as of the end of September 2023. The same applies to the tables of existing and announced projects.

The IEA does not use colours to refer to the various hydrogen production routes. However, when referring to specific policy announcements, programmes, regulations and projects where an authority uses colour to define a hydrogen production route, e.g. green hydrogen, we use that terminology to report developments in this review.

ANNEXES



Tables for scenario projections

General note to the tables

This annex includes historical and projected data by scenario for the following five datasets:

- A.1: Latin America and the Caribbean energy supply
- A.2: Latin America and the Caribbean final energy consumption
- A.3: Latin America and the Caribbean electricity sector: gross electricity generation and electrical capacity.
- A.4: Latin America and the Caribbean CO_2 emissions: carbon dioxide (CO_2) emissions from fossil fuel combustion and industrial processes.

Each dataset is given for the following scenarios: (a) Stated Policies Scenario (STEPS) [Tables A.1a. to A.4a] and (b) Announced Pledges Scenario (APS) [Tables A.1b. to A.4b].

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

Abbreviations/acronyms used in the tables include: CAAGR = compound average annual growth rate; CCUS = carbon capture, utilisation and storage; PJ = petajoule; 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 2023.

The formal base year for this year's projections is 2021, 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 2022 estimates for energy production and demand in this annex. Estimates for the year 2022 are based on the IEA *CO_2 Emissions in 2022* 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.

Historical data for gross power generation capacity (Table A.3) are drawn from the S&P Global Market Intelligence World Electric Power Plants Database (March 2023 version) and the International Atomic Energy Agency PRIS database.

Definitional note: Energy supply and transformation tables

Total energy supply (TES) is equivalent to *electricity and heat sectors*, plus 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.

Annex A licencing

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Table A.1a: Latin America and the Caribbean energy supply

				Stated Policies Scenario (PJ)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Total energy supply	**34 083**	**35 960**	**37 117**	**41 010**	**43 871**	**46 293**	**50 210**	**100**	**100**	**100**	**1.3**	**1.1**
Renewables	8 043	9 929	10 492	13 621	15 547	17 522	21 192	28	33	42	3.3	2.5
Solar	21	246	311	826	1 174	1 612	2 637	1	2	5	13	7.9
Wind	17	456	501	1 013	1 361	1 743	2 600	1	2	5	9.2	6.1
Hydro	2 632	2 520	2 853	2 843	3 034	3 296	3 792	8	7	8	-0.0	1.0
Modern solid bioenergy	4 440	5 445	5 528	6 816	7 417	7 825	8 249	15	17	16	2.7	1.4
Modern liquid bioenergy	659	950	961	1 516	1 746	1 945	2 188	3	4	4	5.9	3.0
Modern gaseous bioenergy	6	51	57	116	169	240	419	0	0	1	9.3	7.4
Traditional use of biomass	1 347	1 365	1 369	1 141	1 018	840	416	4	3	1	-2.3	-4.2
Nuclear	301	409	362	477	883	1 117	1 159	1	1	2	3.5	4.2
Unabated natural gas	7 465	8 538	8 325	9 118	9 327	9 352	9 657	22	22	19	1.1	0.5
Natural gas with CCUS	-	108	103	121	156	172	193	0	0	0	2.0	2.3
Oil	15 280	13 910	14 766	15 050	15 527	15 807	15 976	40	37	32	0.2	0.3
Non-energy use	1 301	962	1 047	1 180	1 190	1 188	1 135	3	3	2	1.5	0.3
Unabated coal	1 629	1 629	1 627	1 418	1 346	1 413	1 529	4	3	3	-1.7	-0.2
Coal with CCUS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Electricity and heat sectors	**8 982**	**10 946**	**10 747**	**11 724**	**13 017**	**14 391**	**17 151**	**100**	**100**	**100**	**1.1**	**1.7**
Renewables	3 371	4 375	4 812	6 400	7 510	8 895	12 125	45	55	71	3.6	3.4
Solar PV	-	174	230	671	954	1 288	2 097	2	6	12	14	8.2
Wind	17	456	501	1 013	1 361	1 743	2 600	5	9	15	9.2	6.1
Hydro	2 632	2 520	2 853	2 843	3 034	3 296	3 792	27	24	22	-0.0	1.0
Bioenergy	454	961	943	1 339	1 428	1 540	1 995	9	11	12	4.5	2.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Ammonia	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Nuclear	301	409	362	477	883	1 117	1 159	3	4	7	3.5	4.2
Unabated natural gas	2 766	3 948	3 395	3 749	3 823	3 756	3 500	32	32	20	1.2	0.1
Natural gas with CCUS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Oil	1 755	1 296	1 293	575	448	315	137	12	5	1	-9.6	-7.7
Unabated coal	788	897	864	503	332	285	192	8	4	1	-6.5	-5.2
Coal with CCUS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Other energy sector	**5 981**	**6 797**	**7 040**	**7 841**	**8 280**	**8 419**	**8 923**	**100**	**100**	**100**	**1.4**	**0.9**
Biofuels conversion losses	-	1 561	1 590	2 253	2 652	2 838	2 619	100	100	100	4.5	1.8
Low-emissions hydrogen (offsite)												
Production inputs	-	-	-	46	189	275	336	100	100	100	n.a.	n.a.
Production outputs	-	-	-	32	133	196	249	100	100	100	n.a.	n.a.
For hydrogen-based fuels	-	-	-	29	125	182	212	-	91	85	n.a.	n.a.

Table A.2a: Latin America and the Caribbean final energy consumption

				Stated Policies Scenario (PJ)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Total final consumption	**24 166**	**24 432**	**25 702**	**28 951**	**31 031**	**32 999**	**35 900**	**100**	**100**	**100**	**1.5**	**1.2**
Electricity	4 052	4 981	5 124	6 077	6 777	7 624	9 499	20	21	26	2.2	2.2
Liquid fuels	12 603	12 392	13 206	14 799	15 764	16 508	17 060	51	51	48	1.4	0.9
Biofuels	659	950	961	1 516	1 746	1 945	2 188	4	5	6	5.9	3.0
Ammonia	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Synthetic oil	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Oil	11 945	11 442	12 244	13 283	14 018	14 563	14 872	48	46	41	1.0	0.7
Gaseous fuels	3 115	2 656	2 862	3 393	3 690	3 983	4 439	11	12	12	2.2	1.6
Biomethane	1	19	22	55	87	131	267	0	0	1	12	9.3
Hydrogen	-	-	-	-	2	4	15	-	-	0	n.a.	n.a.
Synthetic methane	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Natural gas	3 114	2 637	2 840	3 336	3 598	3 843	4 151	11	12	12	2.0	1.4
Solid fuels	4 374	4 334	4 433	4 571	4 666	4 728	4 696	17	16	13	0.4	0.2
Solid bioenergy	3 492	3 561	3 653	3 632	3 624	3 565	3 322	14	13	9	-0.1	-0.3
Coal	865	730	736	896	998	1 117	1 326	3	3	4	2.5	2.1
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Industry	**8 742**	**8 183**	**8 365**	**9 539**	**10 121**	**10 742**	**11 758**	**100**	**100**	**100**	**1.7**	**1.2**
Electricity	1 875	2 152	2 199	2 552	2 732	2 924	3 283	26	27	28	1.9	1.4
Liquid fuels	2 149	1 817	1 791	2 017	2 068	2 128	2 183	21	21	19	1.5	0.7
Oil	2 125	1 794	1 767	1 980	2 002	2 036	2 040	21	21	17	1.4	0.5
Gaseous fuels	2 009	1 555	1 615	1 881	2 024	2 164	2 376	19	20	20	1.9	1.4
Biomethane	1	14	16	37	57	83	155	0	0	1	11	8.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Unabated natural gas	2 008	1 541	1 600	1 844	1 968	2 081	2 221	19	19	19	1.8	1.2
Natural gas with CCUS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Solid fuels	2 710	2 655	2 757	3 085	3 292	3 521	3 910	33	32	33	1.4	1.3
Modern solid bioenergy	1 838	1 891	1 987	2 156	2 259	2 367	2 545	24	23	22	1.0	0.9
Unabated coal	854	720	726	886	988	1 107	1 316	9	9	11	2.5	2.1
Coal with CCUS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Chemicals	1 718	1 409	1 423	1 629	1 710	1 798	1 929	17	17	16	1.7	1.1
Iron and steel	1 303	1 177	1 194	1 478	1 674	1 911	2 405	14	15	20	2.7	2.5
Cement	498	581	578	605	632	662	708	7	6	6	0.6	0.7
Aluminium	328	225	231	359	404	433	456	3	4	4	5.7	2.5

Table A.2a: Latin America and the Caribbean final energy consumption

				Stated Policies Scenario (PJ)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Transport	**8 262**	**8 578**	**9 246**	**10 731**	**11 784**	**12 668**	**13 637**	**100**	**100**	**100**	**1.9**	**1.4**
Electricity	26	23	23	76	156	272	581	0	1	4	16	12
Liquid fuels	7 941	8 253	8 906	10 279	11 196	11 893	12 447	96	96	91	1.8	1.2
Biofuels	633	905	916	1 447	1 640	1 805	1 984	10	13	15	5.9	2.8
Oil	7 307	7 349	7 989	8 832	9 556	10 087	10 463	86	82	77	1.3	1.0
Gaseous fuels	294	301	318	376	432	503	610	3	4	4	2.1	2.4
Biomethane	-	2	3	10	19	29	69	0	0	1	16	12
Hydrogen	-	-	-	-	2	4	15	-	-	0	n.a.	n.a.
Natural gas	294	299	315	365	411	469	525	3	3	4	1.9	1.8
Road	7 733	8 119	8 727	10 030	11 032	11 855	12 692	94	93	93	1.8	1.3
Passenger cars	3 332	3 463	3 732	4 302	4 995	5 549	5 864	40	40	43	1.8	1.6
Heavy-duty trucks	2 524	2 606	2 752	3 261	3 556	3 849	4 404	30	30	32	2.1	1.7
Aviation	669	534	769	1 048	1 176	1 318	1 619	8	10	12	3.9	2.7
Shipping	773	623	692	821	850	895	1 075	7	8	8	2.2	1.6
Buildings	**5 324**	**6 040**	**6 218**	**6 579**	**6 900**	**7 274**	**8 103**	**100**	**100**	**100**	**0.7**	**1.0**
Electricity	2 035	2 602	2 701	3 219	3 639	4 159	5 345	43	49	66	2.2	2.5
Liquid fuels	1 155	1 238	1 273	1 150	1 078	1 030	976	20	17	12	-1.3	-0.9
Biofuels	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Oil	1 155	1 238	1 273	1 150	1 078	1 029	976	20	17	12	-1.3	-0.9
Gaseous fuels	598	619	655	796	870	929	1 014	11	12	13	2.5	1.6
Biomethane	1	3	3	7	12	19	42	0	0	1	11	9.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Natural gas	597	616	651	787	855	905	967	10	12	12	2.4	1.4
Solid fuels	1 515	1 514	1 516	1 309	1 187	1 011	577	24	20	7	-1.8	-3.4
Modern solid bioenergy	166	147	143	166	167	170	160	2	3	2	1.9	0.4
Traditional use of biomass	1 347	1 365	1 369	1 141	1 018	840	416	22	17	5	-2.3	-4.2
Coal	3	2	3	2	2	1	1	0	0	0	-4.9	-3.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Residential	4 099	4 632	4 748	4 881	5 073	5 284	5 768	76	74	71	0.3	0.7
Services	1 225	1 408	1 470	1 698	1 827	1 990	2 335	24	26	29	1.8	1.7

Table A.3a: Latin America and the Caribbean electricity sector

				Stated Policies Scenario (TWh)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Total generation	**1 404**	**1 727**	**1 771**	**2 084**	**2 358**	**2 656**	**3 281**	**100**	**100**	**100**	**2.1**	**2.2**
Renewables	798	969	1 089	1 395	1 640	1 937	2 605	61	67	79	3.1	3.2
Solar PV	0	48	64	186	265	358	583	4	9	18	14	8.2
Wind	5	127	139	281	378	484	722	8	14	22	9.2	6.1
Hydro	739	705	798	797	850	923	1 060	45	38	32	-0.0	1.0
Bioenergy	43	79	78	111	118	129	166	4	5	5	4.5	2.8
of which BECCS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
CSP	-	0	0	5	9	19	37	0	0	1	41	19
Geothermal	10	9	10	15	19	25	37	1	1	1	5.1	4.8
Marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Nuclear	28	38	33	44	81	102	106	2	2	3	3.5	4.2
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	579	715	643	640	631	612	564	36	31	17	-0.1	-0.5
Coal	74	84	79	46	32	28	19	4	2	1	-6.5	-5.0
Natural gas	317	487	427	533	553	551	531	24	26	16	2.8	0.8
Oil	188	143	137	61	47	33	14	8	3	0	-9.7	-7.7

				Stated Policies Scenario (GW)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Total capacity	**323**	**499**	**521**	**676**	**775**	**886**	**1 133**	**100**	**100**	**100**	**3.3**	**2.8**
Renewables	171	292	314	460	542	638	847	60	68	75	4.9	3.6
Solar PV	0	31	45	120	160	206	305	9	18	27	13	7.1
Wind	2	37	41	87	113	142	203	8	13	18	9.8	5.9
Hydro	156	199	201	221	234	250	285	39	33	25	1.2	1.3
Bioenergy	11	23	24	29	31	33	41	5	4	4	2.5	2.0
of which BECCS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
CSP	-	0	0	1	2	4	7	0	0	1	32	16
Geothermal	2	2	2	3	3	4	5	0	0	0	2.9	3.6
Marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Nuclear	5	5	5	6	12	14	14	1	1	1	2.3	3.5
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	147	201	202	202	205	206	214	39	30	19	0.0	0.2
Coal	13	19	18	14	10	9	7	4	2	1	-3.0	-3.6
Natural gas	77	117	118	138	148	156	175	23	20	15	1.9	1.4
Oil	57	65	65	50	46	41	33	12	7	3	-3.3	-2.4
Battery storage	-	0	0	6	15	27	57	0	1	5	53	22

Table A.4a: Latin America and the Caribbean CO_2 emissions

				Stated Policies Scenario (Mt CO_2)				CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2030	2050
Total CO_2*	1 623	1 621	1 657	1 693	1 749	1 797	1 854	0.3	n.a.
Combustion activities (+)	1 504	1 457	1 495	1 532	1 584	1 626	1 661	0.3	0.4
Coal	153	154	152	126	116	119	123	-2.3	-0.8
Oil	961	884	936	953	996	1 025	1 040	0.2	0.4
Natural gas	388	410	398	443	463	472	486	1.4	0.7
Bioenergy and waste	3	9	9	9	9	10	12	0.5	1.1
Other removals (-)**	-	-	-	-	-	-	-	n.a.	n.a.
Biofuels production	-	-	-	-	-	-	-	n.a.	n.a.
Direct air capture	-	-	-	-	-	-	-	n.a.	n.a.
Electricity and heat sectors	373	416	382	309	286	267	232	-2.6	-1.8
Coal	84	94	90	53	35	30	20	-6.5	-5.2
Oil	134	99	99	44	34	24	10	-9.7	-7.8
Natural gas	155	220	190	210	214	210	196	1.2	0.1
Bioenergy and waste	0	3	3	3	3	3	6	2.0	2.7
Other energy sector**	151	103	114	124	127	129	146	1.1	0.9
Final consumption**	1 080	1 064	1 123	1 238	1 322	1 394	1 469	1.2	1.0
Coal	69	60	61	73	80	89	103	2.2	1.9
Oil	766	752	803	869	922	962	987	1.0	0.7
Natural gas	143	121	128	150	162	173	187	2.0	1.4
Bioenergy and waste	3	6	6	6	6	6	6	-0.2	0.1
Industry**	387	366	370	421	449	479	523	1.6	1.2
Chemicals**	52	38	39	46	48	51	53	1.9	1.1
Iron and steel**	71	63	63	76	85	96	115	2.4	2.2
Cement**	93	114	114	121	128	136	148	0.8	1.0
Aluminium**	15	12	12	17	19	21	22	4.8	2.3
Transport	539	542	589	652	706	747	777	1.3	1.0
Road	504	512	554	605	657	695	718	1.1	0.9
Passenger cars	205	203	221	238	275	302	305	0.9	1.2
Heavy-duty trucks	175	175	185	212	229	245	274	1.7	1.4
Aviation	48	38	55	74	83	92	110	3.8	2.5
Shipping	59	48	53	61	62	65	76	1.9	1.3
Buildings	108	113	119	118	117	117	117	-0.1	-0.1
Residential	89	94	99	96	95	94	92	-0.4	-0.3
Services	19	19	20	22	22	23	24	1.5	0.8
Total CO_2 removals**	-	-	-	-	-	-	-	n.a.	n.a.
Total CO_2 captured**	-	9	9	10	12	14	15	1.5	2.1

*Includes industrial process and flaring emissions.

**Includes industrial process emissions.

Table A.1b: Latin America and the Caribbean energy supply

				Announced Pledges Scenario (PJ)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Total energy supply	34 083	35 960	37 117	40 380	42 291	43 924	45 548	100	100	100	1.1	0.7
Renewables	8 043	9 929	10 492	15 919	19 754	24 162	31 285	28	39	69	5.3	4.0
Solar	21	246	311	1 322	2 345	3 987	7 198	1	3	16	20	12
Wind	17	456	501	1 185	1 823	2 513	4 479	1	3	10	11	8.1
Hydro	2 632	2 520	2 853	2 788	2 972	3 444	4 155	8	7	9	-0.3	1.4
Modern solid bioenergy	4 440	5 445	5 528	7 905	9 099	10 063	10 431	15	20	23	4.6	2.3
Modern liquid bioenergy	659	950	961	1 752	2 160	2 412	2 675	3	4	6	7.8	3.7
Modern gaseous bioenergy	6	51	57	306	405	512	735	0	1	2	23	9.6
Traditional use of biomass	1 347	1 365	1 369	676	492	345	141	4	2	0	-8.4	-7.8
Nuclear	301	409	362	513	901	1 226	1 247	1	1	3	4.5	4.5
Unabated natural gas	7 465	8 538	8 325	8 539	8 081	7 175	5 291	22	21	12	0.3	-1.6
Natural gas with CCUS	-	108	103	135	174	200	276	0	0	1	3.4	3.6
Oil	15 280	13 910	14 766	13 480	12 014	10 050	6 745	40	33	15	-1.1	-2.8
Non-energy use	1 301	962	1 047	1 134	1 110	1 092	985	3	3	2	1.0	-0.2
Unabated coal	1 629	1 629	1 627	1 059	807	677	430	4	3	1	-5.2	-4.6
Coal with CCUS	-	-	-	-	7	30	84	-	-	0	n.a.	n.a.
Electricity and heat sectors	8 982	10 946	10 747	12 085	14 189	17 188	22 458	100	100	100	1.5	2.7
Renewables	3 371	4 375	4 812	7 306	9 497	12 700	19 281	45	60	86	5.4	5.1
Solar PV	-	174	230	1 098	1 968	3 431	6 277	2	9	28	22	13
Wind	17	456	501	1 185	1 823	2 513	4 479	5	10	20	11	8.1
Hydro	2 632	2 520	2 853	2 788	2 972	3 444	4 155	27	23	19	-0.3	1.4
Bioenergy	454	961	943	1 500	1 626	1 817	2 275	9	12	10	6.0	3.2
Hydrogen	-	-	-	6	63	120	126	-	0	1	n.a.	n.a.
Ammonia	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Nuclear	301	409	362	513	901	1 226	1 247	3	4	6	4.5	4.5
Unabated natural gas	2 766	3 948	3 395	3 639	3 454	2 965	1 702	32	30	8	0.9	-2.4
Natural gas with CCUS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Oil	1 755	1 296	1 293	313	172	122	72	12	3	0	-16	-9.8
Unabated coal	788	897	864	287	79	34	16	8	2	0	-13	-13
Coal with CCUS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Other energy sector	5 981	6 797	7 040	8 712	9 643	10 539	11 402	100	100	100	2.7	1.7
Biofuels conversion losses	-	1 561	1 590	3 242	4 229	4 998	4 727	100	100	100	9.3	4.0
Low-emissions hydrogen (offsite)												
Production inputs	-	-	-	276	755	1 500	2 977	100	100	100	n.a.	n.a.
Production outputs	-	-	-	190	531	1 073	2 203	100	100	100	n.a.	n.a.
For hydrogen-based fuels	-	-	-	126	340	709	1 516	-	66	69	n.a.	n.a.

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Table A.2b: Latin America and the Caribbean final energy consumption

				Announced Pledges Scenario (PJ)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Total final consumption	**24 166**	**24 432**	**25 702**	**27 465**	**28 066**	**28 281**	**28 796**	**100**	**100**	**100**	**0.8**	**0.4**
Electricity	4 052	4 981	5 124	6 214	7 310	8 813	11 905	20	23	41	2.4	3.1
Liquid fuels	12 603	12 392	13 206	13 841	13 227	11 886	9 192	51	50	32	0.6	-1.3
Biofuels	659	950	961	1 752	2 160	2 412	2 675	4	6	9	7.8	3.7
Ammonia	-	-	-	7	10	12	18	-	0	0	n.a.	n.a.
Synthetic oil	-	-	-	-	-	2	7	-	-	0	n.a.	n.a.
Oil	11 945	11 442	12 244	12 081	11 057	9 459	6 491	48	44	23	-0.2	-2.2
Gaseous fuels	3 115	2 656	2 862	3 199	3 349	3 480	3 687	11	12	13	1.4	0.9
Biomethane	1	19	22	81	127	183	333	0	0	1	18	10
Hydrogen	-	-	-	13	40	101	360	-	0	1	n.a.	n.a.
Synthetic methane	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Natural gas	3 114	2 637	2 840	3 091	3 155	3 153	2 931	11	11	10	1.1	0.1
Solid fuels	4 374	4 334	4 433	4 059	3 962	3 810	3 572	17	15	12	-1.1	-0.8
Solid bioenergy	3 492	3 561	3 653	3 270	3 206	3 113	3 054	14	12	11	-1.4	-0.6
Coal	865	730	736	752	719	661	486	3	3	2	0.3	-1.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Industry	**8 742**	**8 183**	**8 365**	**9 247**	**9 620**	**9 999**	**10 508**	**100**	**100**	**100**	**1.3**	**0.8**
Electricity	1 875	2 152	2 199	2 694	2 998	3 340	4 023	26	29	38	2.6	2.2
Liquid fuels	2 149	1 817	1 791	1 805	1 681	1 566	1 307	21	20	12	0.1	-1.1
Oil	2 125	1 794	1 767	1 759	1 608	1 469	1 161	21	19	11	-0.1	-1.5
Gaseous fuels	2 009	1 555	1 615	1 756	1 838	1 914	1 952	19	19	19	1.1	0.7
Biomethane	1	14	16	51	80	117	214	0	1	2	16	9.7
Hydrogen	-	-	-	4	17	47	110	-	0	1	n.a.	n.a.
Unabated natural gas	2 008	1 541	1 600	1 699	1 707	1 676	1 441	19	18	14	0.8	-0.4
Natural gas with CCUS	-	-	-	2	34	74	187	-	0	2	n.a.	n.a.
Solid fuels	2 710	2 655	2 757	2 966	3 059	3 117	3 133	33	32	30	0.9	0.5
Modern solid bioenergy	1 838	1 891	1 987	2 186	2 311	2 428	2 621	24	24	25	1.2	1.0
Unabated coal	854	720	726	742	703	622	394	9	8	4	0.3	-2.2
Coal with CCUS	-	-	-	-	7	30	84	-	-	1	n.a.	n.a.
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Chemicals	1 718	1 409	1 423	1 588	1 636	1 713	1 804	17	17	17	1.4	0.9
Iron and steel	1 303	1 177	1 194	1 426	1 567	1 720	1 997	14	15	19	2.2	1.9
Cement	498	581	578	589	625	659	708	7	6	7	0.2	0.7
Aluminium	328	225	231	314	344	359	361	3	3	3	3.9	1.6

Table A.2b: Latin America and the Caribbean final energy consumption

				Announced Pledges Scenario (PJ)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Transport	**8 262**	**8 578**	**9 246**	**10 246**	**10 372**	**10 002**	**9 302**	**100**	**100**	**100**	**1.3**	**0.0**
Electricity	26	23	23	173	573	1 193	2 390	0	2	26	29	18
Liquid fuels	7 941	8 253	8 906	9 708	9 386	8 340	6 234	96	95	67	1.1	-1.3
Biofuels	633	905	916	1 655	2 013	2 219	2 399	10	16	26	7.7	3.5
Oil	7 307	7 349	7 989	8 046	7 364	6 107	3 810	86	79	41	0.1	-2.6
Gaseous fuels	294	301	318	364	413	470	678	3	4	7	1.7	2.7
Biomethane	-	2	3	20	32	42	72	0	0	1	27	12
Hydrogen	-	-	-	9	22	55	249	-	0	3	n.a.	n.a.
Natural gas	294	299	315	335	359	373	356	3	3	4	0.8	0.4
Road	7 733	8 119	8 727	9 574	9 673	9 265	8 477	94	93	91	1.2	-0.1
Passenger cars	3 332	3 463	3 732	4 106	4 281	4 108	3 518	40	40	38	1.2	-0.2
Heavy-duty trucks	2 524	2 606	2 752	3 093	3 184	3 259	3 421	30	30	37	1.5	0.8
Aviation	669	534	769	1 038	1 154	1 283	1 552	8	10	17	3.8	2.5
Shipping	773	623	692	784	743	701	721	7	8	8	1.6	0.1
Buildings	**5 324**	**6 040**	**6 218**	**5 918**	**5 947**	**6 124**	**6 879**	**100**	**100**	**100**	**-0.6**	**0.4**
Electricity	2 035	2 602	2 701	3 092	3 444	3 946	5 095	43	52	74	1.7	2.3
Liquid fuels	1 155	1 238	1 273	1 035	858	711	523	20	17	8	-2.6	-3.1
Biofuels	-	-	-	1	3	4	6	-	0	0	n.a.	n.a.
Oil	1 155	1 238	1 273	1 034	856	707	517	20	17	8	-2.6	-3.2
Gaseous fuels	598	619	655	748	753	736	667	11	13	10	1.7	0.1
Biomethane	1	3	3	10	16	24	47	0	0	1	16	10
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Natural gas	597	616	651	726	715	677	566	10	12	8	1.4	-0.5
Solid fuels	1 515	1 514	1 516	924	729	517	276	24	16	4	-6.0	-5.9
Modern solid bioenergy	166	147	143	247	236	172	135	2	4	2	7.1	-0.2
Traditional use of biomass	1 347	1 365	1 369	676	492	345	141	22	11	2	-8.4	-7.8
Coal	3	2	3	2	1	-	-	0	0	-	-4.9	n.a.
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
Residential	4 099	4 632	4 748	4 294	4 229	4 280	4 761	76	73	69	-1.2	0.0
Services	1 225	1 408	1 470	1 624	1 718	1 845	2 118	24	27	31	1.3	1.3

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Table A.3b: Latin America and the Caribbean electricity sector

				Announced Pledges Scenario (TWh)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Total generation	**1 404**	**1 727**	**1 771**	**2 194**	**2 691**	**3 426**	**4 862**	**100**	**100**	**100**	**2.7**	**3.7**
Renewables	798	969	1 089	1 575	2 075	2 842	4 460	61	72	92	4.7	5.2
Solar PV	0	48	64	305	547	953	1 744	4	14	36	22	13
Wind	5	127	139	329	506	698	1 244	8	15	26	11	8.1
Hydro	739	705	798	781	832	963	1 159	45	36	24	-0.3	1.3
Bioenergy	43	79	78	131	143	160	207	4	6	4	6.8	3.6
of which BECCS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
CSP	-	0	0	9	20	32	58	0	0	1	53	21
Geothermal	10	9	10	19	27	34	44	1	1	1	8.6	5.4
Marine	-	-	-	-	0	1	3	-	-	0	n.a.	n.a.
Nuclear	28	38	33	47	83	112	114	2	2	2	4.5	4.5
Hydrogen and ammonia	-	-	-	1	10	19	20	-	0	0	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	579	715	643	566	518	447	264	36	26	5	-1.6	-3.1
Coal	74	84	79	25	7	3	1	4	1	0	-13	-14
Natural gas	317	487	427	508	494	432	256	24	23	5	2.2	-1.8
Oil	188	143	137	32	17	12	7	8	1	0	-17	-10

				Announced Pledges Scenario (GW)				Shares (%)			CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2022	2030	2050	2030	2050
Total capacity	**323**	**499**	**521**	**756**	**969**	**1 271**	**1 857**	**100**	**100**	**100**	**4.8**	**4.6**
Renewables	171	292	314	544	733	1 007	1 548	60	72	83	7.1	5.9
Solar PV	0	31	45	175	292	476	807	9	23	43	18	11
Wind	2	37	41	104	152	207	360	8	14	19	12	8.0
Hydro	156	199	201	222	239	266	310	39	29	17	1.2	1.6
Bioenergy	11	23	24	38	42	46	53	5	5	3	6.2	2.9
of which BECCS	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
CSP	-	0	0	2	4	6	11	0	0	1	42	18
Geothermal	2	2	2	3	4	5	6	0	0	0	6.3	4.3
Marine	-	-	-	-	0	1	1	-	-	0	n.a.	n.a.
Nuclear	5	5	5	6	12	15	15	1	1	1	2.3	3.8
Hydrogen and ammonia	-	-	-	0	2	4	4	-	0	0	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	147	201	202	186	183	178	152	39	25	8	-1.0	-1.0
Coal	13	19	18	11	7	4	2	4	2	0	-5.9	-8.5
Natural gas	77	117	118	131	136	140	127	23	17	7	1.3	0.3
Oil	57	65	65	44	40	34	24	12	6	1	-4.8	-3.5
Battery storage	-	0	0	19	39	66	137	0	2	7	76	26

Table A.4b: Latin America and the Caribbean CO_2 emissions

				Announced Pledges Scenario (Mt CO_2)				CAAGR (%) 2022 to:	
	2010	2021	2022	2030	2035	2040	2050	2030	2050
Total CO_2*	**1 623**	**1 621**	**1 657**	**1 492**	**1 351**	**1 164**	**797**	**-1.3**	**n.a.**
Combustion activities (+)	**1 504**	**1 457**	**1 495**	**1 353**	**1 218**	**1 036**	**681**	**-1.2**	**-2.8**
Coal	153	154	152	86	59	47	27	-6.9	-5.9
Oil	961	884	936	846	756	631	409	-1.3	-2.9
Natural gas	388	410	398	413	396	355	249	0.5	-1.7
Bioenergy and waste	3	9	9	8	6	4	- 4	-0.6	n.a.
Other removals (-)**	**-**	**-**	**-**	**5**	**6**	**8**	**7**	**n.a.**	**n.a.**
Biofuels production	-	-	-	4	5	6	5	n.a.	n.a.
Direct air capture	-	-	-	1	1	1	2	n.a.	n.a.
Electricity and heat sectors	**373**	**416**	**382**	**258**	**217**	**181**	**104**	**-4.8**	**-4.5**
Coal	84	94	90	28	8	3	1	-14	-14
Oil	134	99	99	24	13	9	5	-16	-9.8
Natural gas	155	220	190	203	193	166	95	0.9	-2.4
Bioenergy and waste	0	3	3	3	3	3	2	2.0	-0.9
Other energy sector**	**151**	**103**	**114**	**105**	**91**	**71**	**46**	**-1.1**	**-3.2**
Final consumption**	**1 080**	**1 064**	**1 123**	**1 120**	**1 039**	**910**	**648**	**-0.0**	**-1.9**
Coal	69	60	61	58	52	44	26	-0.7	-3.0
Oil	766	752	803	786	712	598	391	-0.3	-2.5
Natural gas	143	121	128	137	138	135	115	0.9	-0.4
Bioenergy and waste	3	6	6	5	3	0	- 6	-1.8	n.a.
Industry**	387	366	370	377	357	332	261	0.2	-1.2
Chemicals**	52	38	39	42	41	38	24	0.7	-1.8
Iron and steel**	71	63	63	66	64	61	47	0.5	-1.0
Cement**	93	114	114	115	108	102	86	0.1	-1.0
Aluminium**	15	12	12	15	14	10	2	2.8	-6.1
Transport	539	542	589	594	546	457	292	0.1	-2.5
Road	504	512	554	551	504	415	252	-0.1	-2.8
Passenger cars	205	203	221	214	195	151	69	-0.4	-4.1
Heavy-duty trucks	175	175	185	194	190	181	148	0.6	-0.8
Aviation	48	38	55	72	77	81	85	3.5	1.6
Shipping	59	48	53	55	47	39	29	0.5	-2.1
Buildings	108	113	119	107	95	83	65	-1.3	-2.2
Residential	89	94	99	88	78	68	52	-1.5	-2.3
Services	19	19	20	19	17	15	12	-0.2	-1.6
Total CO_2 removals**	**-**	**-**	**-**	**5**	**8**	**11**	**17**	**n.a.**	**n.a.**
Total CO_2 captured**	**-**	**9**	**9**	**18**	**34**	**53**	**108**	**9.9**	**9.5**

*Includes industrial process and flaring emissions.

**Includes industrial process emissions.

A

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
Batteries	Wh/kg	watt hours per kilogramme
Coal	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
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
Energy	EJ	exajoule (1 joule x 10^{18})
	PJ	petajoule (1 joule x 10^{15})
	TJ	terajoule (1 joule x 10^{12})
	GJ	gigajoule (1 joule x 10^{9})
	MJ	megajoule (1 joule x 10^{6})
	boe	barrel of oil equivalent
	toe	tonne of oil equivalent
	ktoe	thousand tonnes of oil equivalent
	Mtoe	million tonnes of oil equivalent
	bcme	billion cubic metres of natural gas equivalent
	MBtu	million British thermal units
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
	Gcal	gigacalorie
Gas	bcm	billion cubic metres
	tcm	trillion cubic metres
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}
	USD/t CO_2	US dollars per tonne of carbon dioxide
Oil	barrel	one barrel of crude oil
	kb/d	thousand barrels per day
	mb/d	million barrels per day
	mboe/d	million barrels of oil equivalent per day
Power	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})

General conversion factors for energy

		Multiplier to convert to:					
		EJ	Gcal	Mtoe	MBtu	bcme	GWh
Convert from:	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 IEA balances due to the use of country-specific energy densities. Lower heating values (LHV) are used throughout.

Currency conversions

Exchange rates (*2022 annual average)*	Argentinian peso (ARS)	Brazilian real (BRL)	Chilean peso (CLP)	Colombian peso (COP)	Mexican peso (MXN)
1 US dollar (USD) equals:	130.62	5.16	873.31	4 256.19	20.13

Source: OECD Data (database): Exchange rates (indicator), https://data.oecd.org/conversion/exchange-rates.htm, accessed October 2023.

Definitions

Advanced bioenergy: Sustainable fuels produced from wastes, residues and non-food crop feedstocks (excluding traditional uses of biomass), which are capable of delivering significant life cycle greenhouse gas emissions savings compared with fossil fuel alternatives and of minimising adverse sustainability impacts. Advanced bioenergy feedstocks either do not directly compete with food and feed crops for agricultural land or are only developed on land previously used to produced food crop feedstocks for biofuels.

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

Agriculture, forestry and other land use (AFOLU) **emissions:** Includes greenhouse gas emissions from agriculture, forestry and other land use.

Ammonia (NH_3)**:** Is a compound of nitrogen and hydrogen. It can be used as a feedstock in the chemical sector, as a fuel in direct combustion processes in fuel cells, and as a hydrogen carrier. To be considered a low-emissions fuel, ammonia must be produced from hydrogen in which the electricity used to produce the hydrogen is generated from low-emissions generation sources. 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 kilowatts. 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 and release electricity on demand.

Biodiesel: Diesel-equivalent fuel made from the transesterification (a chemical process that converts triglycerides in oils) of vegetable oils and animal fats.

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.

Biogases: Include both biogas and biomethane.

Biogasoline: Includes all liquid biofuels (advanced and conventional) used to replace 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.

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

Capacity credit: Proportion of the capacity that can be reliably expected to generate electricity during times of peak demand in the grid to which it is connected.

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: Energy vectors used as raw materials to produce chemical products. 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 (such as a three-stone fire), coal or kerosene. This 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 aviation bunkers and 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: Includes 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)**:** Process in which coal is first turned into syngas (a mixture of hydrogen and carbon monoxide) and then into synthetic methane.

Coal-to-liquids (CTL)**:** Transformation of coal into liquid hydrocarbons. One route involves coal gasification into syngas (a mixture of hydrogen and carbon monoxide), which is processed using Fischer-Tropsch or methanol-to-gasoline synthesis. Another route, called direct-coal liquefaction, involves reacting coal directly with hydrogen.

Coking coal: 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 liquid biofuels: Fuels produced from food crop feedstocks. Commonly referred to as first generation biofuels and include sugar cane ethanol, starch-based ethanol, fatty acid methyl ester (FAME), straight vegetable oil (SVO) and hydrotreated vegetable oil (HVO) produced from palm, rapeseed or soybean oil.

Critical minerals: A wide range of minerals and metals that are essential in clean energy technologies and other modern technologies and have supply chains that are vulnerable to disruption. Although the exact definition and criteria differ among countries, critical minerals for clean energy technologies typically include chromium, cobalt, copper, graphite, lithium, manganese, molybdenum, nickel, platinum group metals, zinc, rare earth elements and other commodities, as listed in the Annex of the IEA special report on the *Role of Critical Minerals in Clean Energy Transitions* available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

Decomposition analysis: Statistical approach 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. The *World Energy Outlook* 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 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: Refers to technologies whose power output can be readily controlled, i.e. increased to maximum rated capacity or decreased to zero in order to 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 comprise of battery electric vehicles (BEV) and plug-in hybrid vehicles.

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-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 the *World Energy Outlook* 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 dioxide (N_2O) emissions from the energy and industry sectors.

Energy services: See useful energy.

Ethanol: Refers to bioethanol only. Ethanol is produced from fermenting any biomass high in carbohydrates. Currently ethanol is made from starches and sugars, but second-generation technologies will allow it to be made from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter.

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

Fossil fuels: Include coal, natural gas and oil.

Gaseous fuels: Include natural gas, biogases, synthetic methane and hydrogen.

Gases: See gaseous fuels.

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

Geothermal: Geothermal energy is heat from the sub-surface of the earth. Water and/or steam carry the geothermal 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 fuels or renewables, direct geothermal or solar heat systems, exothermic chemical processes and electricity (through resistance heating or heat pumps which can extract it 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 vehicles (HDVs)**:** Include both medium freight trucks (gross weight 3.5 to 15 tonnes) and heavy freight trucks (gross weight >15 tonnes).

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: See low-emissions hydrogen-based fuels.

Hydropower: Refers to the electricity produced in hydropower projects, with the assumption of 100% efficiency. It excludes output from pumped storage and marine (tide and wave) plants.

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, chemical and petrochemical, 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 by off-road vehicles is reported under 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-2022 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)**:** 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.

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. Data on lignite in the *World Energy Outlook* include peat.

Liquid biofuels: Liquid fuels derived from biomass or waste feedstock, e.g. ethanol, biodiesel and biojet fuels. They can be classified as conventional and advanced biofuels according to the combination of feedstock and technologies used to produce them and their respective maturity. Unless otherwise stated, biofuels are expressed in energy-equivalent volumes of gasoline, diesel and kerosene.

Liquid fuels: Include oil, liquid biofuels (expressed in energy-equivalent volumes of gasoline and diesel), synthetic oil and ammonia.

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: Hydrogen that is produced from water using electricity generated by renewables or nuclear, from fossil fuels with minimal associated methane emissions and processed in facilities equipped to avoid CO_2 emissions, e.g. via CCUS with a high capture rate, or derived from bioenergy. In this report, total demand for low-emissions hydrogen is larger than total final consumption of hydrogen because it additionally includes hydrogen inputs to make low-emissions hydrogen-based fuels, biofuels production, power generation, oil refining, and hydrogen produced and consumed onsite in industry.

Low-emissions hydrogen-based fuels: Include ammonia, methanol and other synthetic hydrocarbons (gases and liquids) made from low-emissions hydrogen. Any carbon inputs, e.g. from CO_2, are not from fossil fuels or 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: Represents the mechanical energy derived from tidal movement, wave motion or ocean currents 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 uses of renewable energy with the exception of the traditional use of solid biomass.

Modern solid bioenergy: Includes all solid bioenergy products (see solid bioenergy definition) 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 in small pieces or often using processed biomass such as pellets.

Natural gas: Includes gas occurring in deposits, whether liquefied or gaseous, consisting mainly of methane. 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 (colliery gas). Natural gas liquids, manufactured gas (produced from municipal or industrial waste, or sewage) and quantities vented or flared are not included. 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). Gas data expressed in exajoules are on a net calorific basis. The difference between the net and the gross calorific value is the latent heat of vaporisation of the water vapour produced during combustion of the fuel (for gas the net calorific value is 10% lower than the gross calorific value).

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: 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 fuels as feedstocks for chemical products that are not used in energy applications. Examples of resulting products are lubricants, paraffin waxes, asphalt, bitumen, coal tars and timber preservative oils.

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.

Oil: Includes both conventional and unconventional oil production. Petroleum products include refinery gas, ethane, liquid petroleum gas, aviation gasoline, motor gasoline, jet fuels, 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 the 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: Peat is a combustible soft, porous or compressed, fossil sedimentary deposit of plant origin with high water content (up to 90% in the raw state), easily cut, of light to dark brown colour. Milled peat is included in this category. Peat used for non-energy purposes is not included here.

Plastic collection rate: Proportion of plastics 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 combined heat and power plants. Both main activity producer plants and small plants that produce fuel for their own use (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, e.g. freight, could be considered as productive, but is treated separately.

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

Renewables: Include bioenergy, geothermal, hydropower, solar photovoltaics (PV), concentrating solar power (CSP), wind and marine (tide 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: Includes all road vehicle types (passenger cars, two/three-wheelers, light commercial vehicles, buses and medium and heavy freight trucks).

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

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

Shale gas: Natural gas contained within a commonly occurring rock classified as shale. Shale formations are characterised by low permeability, with more limited ability of gas to flow through the rock than is the case within a conventional reservoir. Shale gas is generally produced using hydraulic fracturing.

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 both solar photovoltaics and concentrating solar power.

Solar home systems (SHS)**:** Small-scale photovoltaic and battery stand-alone systems, i.e. with capacity higher than 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. Access to electricity in the IEA definition considers solar home systems from 25 Wp in rural areas and 50 Wp in urban areas. It excludes smaller solar lighting systems, e.g. solar lanterns of less than 11 Wp.

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: Synthetic oil produced through Fischer-Tropsch conversion or methanol synthesis. It includes oil products from CTL and GTL, and non-ammonia low-emissions liquid hydrogen-based fuels.

Tight oil: Oil produced from shale or other very low permeability formations, generally using hydraulic fracturing. This is also 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 broken down into electricity and heat generation, other energy sector and total final consumption.

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 0-1), 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: 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. Fuel delivered to international 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: Consumption of fossil fuels in facilities without CCUS.

Useful energy: Refers to the energy that is available to end-users to satisfy their needs. This is also referred to as energy services demand. As 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. Equipment using electricity often has higher conversion efficiency than equipment using other fuels, meaning that for a unit of energy consumed, electricity can provide more energy services.

Value-adjusted levelised cost of electricity (VALCOE)**:** Incorporates information on both costs and the value provided to the system. Based on the LCOE, estimates of energy, capacity and flexibility value are incorporated to provide a more complete metric of competitiveness for power generation technologies.

Variable renewable energy (VRE)**:** Refers to technologies whose maximum output at any time depends on the availability of fluctuating renewable energy resources. 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 are capable of operating without tailpipe CO_2 emissions (battery electric and fuel cell vehicles).

Regional and country groupings

Advanced economies: 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.

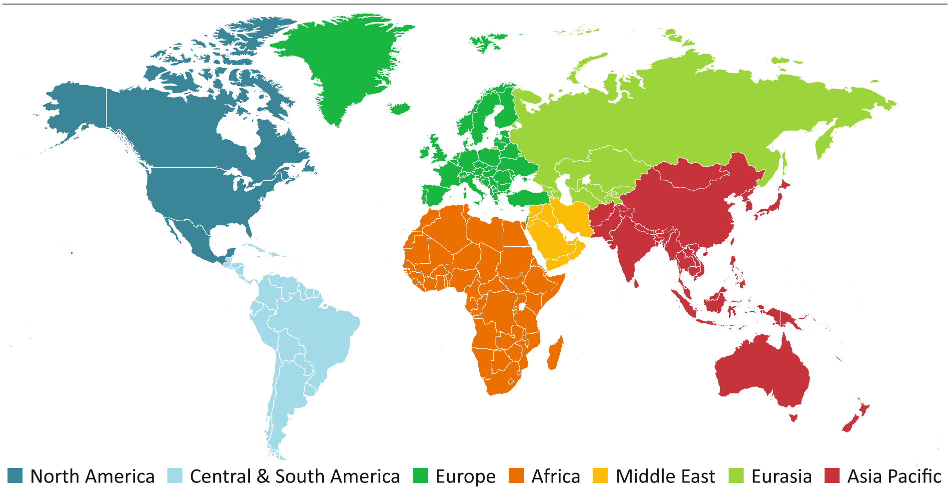
Central and South America: Argentina, Plurinational State of Bolivia (Bolivia), Bolivarian Republic of Venezuela (Venezuela), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, 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.

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.

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, 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)**:** OECD regional grouping excluding Chile, Colombia, Costa Rica, Iceland, Israel, Latvia and Slovenia.

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.

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)**:** Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom and United States.

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 (Russia), 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).

Sub-Saharan Africa: Angola, Benin, Botswana, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, 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.[6]

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] 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

ACEEE	American Council for an Energy Efficient Economy
ADME	Administración del Mercado Eléctrico (Electricity Market Administration)
AFOLU	agriculture, forestry and other land use
ANEEL	Agência Nacional de Energia Elétrica (Electricity National Regulatory Agency, Brazil)
ANP	Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (National Agency for Petroleum, Natural Gas and Biofuels, Brazil)
APS	Announced Pledges Scenario
ARI	Asset Revitalization Initiative
ASEAN	Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
ATJ	alcohol-to-jet
BECCS	bioenergy equipped with CCUS
BEV	battery electric vehicles

BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources, Germany)
BP	Beyond Petroleum
CAAGR	compound average annual growth rate
CAF	Corporacion Andina de Fomento (Development Bank of Latin America)
CAN	Comunidad Andina (The Andean Community)
CARICOM	Caribbean Community
CCUS	carbon capture, utilisation and storage
CEE	Certificados de Eficiencia Energética (Energy Efficiency Certificates)
CELAC	Comunidad de Estados Latinoamericanos y Caribeños (Community of Latin American and Caribbean States)
CEPAL	Comisión Económica para América Latina y el Caribe (ECLAC - United Nations Economic Commission for Latin America and the Caribbean)
CFR	Cost and freight
CH_4	Methane
CHP	combined heat and power; the term co-generation is sometimes used
CIER	Comisión de Integración Energética Regional (Regional Energy Integration Commission)
CLASP	Collaborative Labelling and Appliance Standards Program
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2-eq	carbon-dioxide equivalent
CONICET	Consejo Nacional de Investigaciones Científicas y Técnicas de Argentina (National Scientific and Technical Research Council, Argentina)
COP	Conference of the Parties (United Nations Framework Convention on Climate Change)
CORFO	Corporación de Fomento de la Producción (Economic Development Agency, Chile)
CPI	Corruption Perception Index
DIPEME	Divisão de Projetos Especiais e Minerais Estratégicos (Special Projects and Strategic Minerals Division)
DRI	direct reduced iron
ECI	Economic Complexity Index
ECLAC	United Nations Economic Commission for Latin America and the Caribbean (CEPAL - Comisión Económica para América Latina y el Caribe)
EIA	United States Energy Information Administration

EMDE	emerging market and developing economies
EPE	Empresa de Pesquisa Energética (Energy Research Company, Brazil)
EPM	Empresas Públicas de Medellín (Public Companies of Medellín)
ESG	environmental, social and governance
EU	European Union
EV	electric vehicle
FAME	fatty acid methyl ester
FDI	foreign direct investment
GDP	gross domestic product
GEC	Global Energy and Climate (model)
GHG	greenhouse gases
H_2	hydrogen
HEFA	hydrogenated esters and fatty acids
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICE	internal combustion engine
IDB	Inter-American Development Bank
IE	International Efficiency classification
IEA	International Energy Agency
IFA	International Fertilizer Association
IIASA	International Institute for Applied Systems Analysis
IICA	Instituto Interamericano de Cooperación para la Agricultura (Inter-American Institute for Co-operation on Agriculture)
ILO	International Labour Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
KOMIS	Korea Mineral Resources Information Services
LAC	Latin America and the Caribbean
LCOE	levelised cost of electricity
LCOH	levelised cost of hydrogen
LCOP	levelised cost of production
LDV	light-duty vehicle
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
MERCOSUR	Mercado Común del Sur (The Southern Common Market)
MINAE	Ministerio de Ambiente y Energía de Costa Rica (Ministry of Environment and Energy, Costa Rica)
NDC	Nationally Determined Contribution
NGV	natural gas vehicle
NO_x	nitrogen oxides
N_2O	nitrous oxide
NZE	Net Zero Emissions by 2050 Scenario
OECD	Organisation for Economic Co-operation and Development
OGJ	Oil and Gas Journal
OLADE	Organización Latinoamericana de Energía (Latin American Energy Organization)
OPEC	Organization of the Petroleum Exporting Countries
PHEV	plug-in hybrid electric vehicles
PLDV	passenger light-duty vehicle
PM	particulate matter
$PM_{2.5}$	fine particulate matter
PPP	purchasing power parity
PV	photovoltaics
R&D	research and development
RD&D	research, development and demonstration
REDD+	Reducing emissions from deforestation and forest degradation in developing countries. The '+' stands for additional forest-related activities that protect the climate.
SAF	sustainable aviation fuels
SDG	Sustainable Development Goals (United Nations)
SEAD	Super-Efficient Equipment and Appliance Deployment initiative
SENER	La Secretaría de Energía, México (Secretariat of Energy, Mexico)
SICA	Sistema de la Integración Centroamericana (Central American Integration System)
SIEPAC	Sistema de Interconexión Eléctrica para Países de América Central (Central American Electrical Interconnection System)
SLB	sustainability-linked debt
SME	small and medium enterprises

SO_2	sulphur dioxide
STEPS	Stated Policies Scenario
T&D	transmission and distribution
TES	total energy supply
TFC	total final consumption
TRL	Technology Readiness Level
UAE	United Arab Emirates
UN DESA	United Nations Department of Economic and Social Affairs
UN FAO	Food and Agriculture Organization of the United Nations
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US DOE	United States Department of Energy
US	United States
USGS	United States Geological Survey
VRE	variable renewable energy
WEO	World Energy Outlook
WHO	World Health Organization
WRI	World Resources Institute

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Chapter 1: State of play

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Latin America Energy Outlook 2023

World Energy Outlook Special Report

Latin America and the Caribbean is a region that stands out in the global energy sector. It boasts extraordinary natural resources – both fossil fuels and renewable energy – and a significant share of the world's critical minerals. It also has a history of ambitious policy making in pursuit of stronger energy security and greater sustainability that has delivered one of the cleanest electricity mixes in the world. As the region emerges from a period of sluggish economic growth, countries in Latin America and the Caribbean now stand to leverage these resources to revitalise their economies and improve the security and sustainability of energy around the world.

The *Latin America Energy Outlook*, the International Energy Agency's first in-depth and comprehensive assessment of Latin America and the Caribbean, builds on decades of collaboration with partners. In support of the region's energy goals, the report explores the opportunities and challenges that lie ahead. It provides insights on the ways in which the outlook for the region and the biggest global energy trends are deeply intertwined – as well as recommendations on policies that could allow Latin America and the Caribbean to take full advantage of its great potential.