Colombia 2023

Energy Policy Review

International Energy Agency

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1. Executive summary

Colombia has emerged as a leader in clean energy transition policy making and is an inspiring example of a fossil fuel producing country committed to climate action, based on a long-term decarbonisation pathway and a policy of energy and economic diversification and a just transition.

In the context of the National Energy Plan 2020-2050, launched in 2016, Colombia started a journey to diversify its energy resources and ensure a reliable energy supply by promoting wind, solar and geothermal in the country's electricity mix.

At COP26, Colombia presented a net zero target and an ambitious Nationally Determined Contribution (NDC), aiming at a 51% reduction in greenhouse gas (GHG) emissions by 2030. These ambitions are reflected in the long-term strategy, the E2050 Strategy, the Energy Transition Law and the Climate Action Law. To implement its targets, Colombia uses a robust system of climate change management plans across government with targets assigned to each sector, including for energy (PIGCCme). The Energy Transition Law expanded policy actions and tax benefits to energy efficiency and low-carbon energy technologies, including geothermal, carbon capture and storage (CCS), and hydrogen. Colombia's national oil company, Ecopetrol (Empresa Colombiana de Petroleos), is supporting the shift to low-carbon energy with investment plans for clean energy technology.

In 2023, Colombia's energy transition policy is at another crucial turning point, as the government targets the gradual shift to net zero, shifting away from an extractive industry model heavily dependent on oil and coal exports towards a more diversified clean energy economy based on investments in renewable energy sources, critical minerals and hydrogen.

Colombia enjoys a strong natural resource base. Renewables accounted for more than a third of total final energy consumption in 2020, thanks to the significant role of conventional hydropower and bioenergy. In 2021, renewable energy accounted for 25% of Colombia's total energy supply and for 29% of final consumption, substantially above the IEA average of 14% and made up 75% of electricity generation (compared to the IEA average of 30%).

The government continues to expand non-conventional renewable energy, largely through long-term auctions for large-scale solar and wind developments. Extensive renewables potential in the La Guajira region should help advance rural electrification and close the energy access gap. Concentrated in the northern regions, which has a 50 gigawatt (GW) offshore wind potential, renewables can also provide the clean energy needed to jump-start Colombia's hydrogen production. Colombia's geothermal development also enjoys substantial potential along the Pacific ring of fire.

In 2023, work is under way on updating the National Energy Plan (PEN) towards 2050, in line with Colombia's new National Development Plan 2022-2026 (PND) and energy and

climate goals towards decarbonisation. The new PEN is an opportunity to build greater coherence of policy planning and set clear energy efficiency and clean energy technology targets for 2030. Based on the different long-term energy scenarios for the energy sector, the PEN should confirm the possible targets and investment needed for the technology shift towards a more digital, decentralised and decarbonised energy sector as an enabler of broader sustainable development. The PEN should also identify the needed investments in energy research, development and innovation in Colombia.

Greater competition in energy markets is important to attract needed investments. Ecopetrol continues to account for two-thirds of the activity in the oil and gas sector. Colombian energy market design and policy have followed a fundamentally market-driven approach since the mid-1990s, when the power sector was unbundled and opened to private investment. However, market power persists in the electricity sector due to the integration of generation and retail. Power system planning, new grids and regulation will be required to accompany the shift from today's hydro-dominated power market to a more flexible and diverse market design. An initial auction for battery storage was successful to optimise the use of the transmission grid.

Colombia has a largely decarbonised power sector thanks to the significant role of hydropower and bioenergy. Electricity demand is expected to increase as a result of economic growth and the electrification of end-use sectors, an opportunity to decarbonise the transport sector over time. A stronger focus on energy efficiency is needed to reduce emissions and support affordable clean energy. A diversified mix of generation technologies will emerge and opportunities for efficiency need to be harvested.

Clarity is also needed on the targets and policies for different new clean energy technologies, for example the deployment of CCS and geothermal, in line with long-term plans. Technology road maps for these areas would provide clarity for policy actions. Clarifying responsibilities and consistently applying them in planning documents, especially in energy efficiency, where responsibilities are widely dispersed would improve implementation.

Colombia's high degree of income inequality influences energy policy making. Despite recent progress, in 2021, 3% of the population did not have access to electricity. Colombia still has 1 million families, or 6% of households, relying on firewood for cooking, lacking access to modern cooking fuels. Around 45% of the country's population lives under the poverty line. This is most evident for La Guajira, where indigenous groups make up 42% of the total population. Over time, the government has developed energy pricing and subsidy mechanisms covering gasoline and diesel, electricity, natural gas, and liquefied petroleum gas (LPG). These arrangements need to be structured to avoid discouraging energy efficiency while boosting the uptake of clean energy and targeting the needs of vulnerable groups.

When preparing the PND in 2022, the government placed a strong focus on engaging the entire society in the country's energy transition to generate consensus. This is critical to translate policy goals into support for infrastructure projects on the ground, ensure social justice and support vulnerable communities. The IEA supports Colombia's agenda for a just energy transition. Experience from the IEA's Global Commission on People-Centred Transitions provides useful learnings for the government of Colombia, helping to boost local economic benefits and the transition to clean energy and new job opportunities.

These include suggestions on job development and skills shifts, notably for employment in fossil sectors, and the range of new jobs in such future industries as renewables, hydrogen and critical minerals.

Colombia's transition will involve ramping up investments in clean energy while compensating for declining oil/gas/coal export revenues. The oil sector has contributed an annual average of close to 2% of gross domestic product (GDP) and 13% of the total income of the national government in the last ten years, from tax revenues, dividends and royalties. The government's reliance on this income will have to be taken into account in elaborating transition pathways for the hydrocarbon sector. Drawing on the experience of clean energy transition leaders such as Norway, it will be critical to communicate the role of oil rents to be used to support investments in the clean energy transition. The government aims to create a fund from fossil fuel sector royalties and taxes to finance clean energy initiatives. Colombia has extensive reserves of copper, nickel and cobalt, all critical to the global energy transition. Colombia can build on its well-established mining sector to diversify into new minerals. To reap this potential, mining activities must adhere to high environmental, social and governance standards and generate tangible benefits for affected local communities.

Security of supply should be a priority for the government during the transition. Continued attention is needed to ensure the resilience of the country's electricity and natural gas/oil supplies, including during periods of seasonal droughts and in isolated areas. Colombia's hydropower has low runoff storage capacity but good flexibility for balancing higher shares of variable renewables. There is high interannual variability from extreme weather events (droughts or rainfall). Availability needs to be ensured with sufficient dispatchable capacity.

Key recommendations

The government of Colombia should:

- Define the general vision for Colombia's energy transition policy and set out practical actions needed to reconcile the affordable and secure energy growth required to support Colombia's economic development with its net zero emissions target.
- Ensure consistency in policies, targets and ambitions contained in the various laws, decrees, plans and sectoral policy plans for energy and climate change, and track progress of the milestones in Colombia's energy transition.
- Set out a medium- to long-term energy security road map, defining specific actions for securing oil, gas, electricity and the critical minerals needed for the country's energy transition.
- Develop a people-centred transition strategy together with Colombia's territories and industry, building on existing initiatives. This would include social guidelines; retraining programmes; and supporting access to energy, employment and economic development opportunities arising from clean energy deployment at the local level.

- Improve engagement and co-operation among national, regional and territorial government departments and the private sector to ensure that local communities receive tangible economic and social benefits from the expansion of essential energy-related projects in their locations.

2. General energy policy

Key data (2021)

Total energy supply (TES): 1 775 PJ (oil 45.4%, natural gas 22.4%, bioenergy and waste 12.5%, hydro 12.3%, coal 7.2%, solar 0.1%), +35% since 2011

TES per capita: 35.5 GJ/capita (IEA average: 166.7 GJ/capita) +21% since 2011

TES per unit of GDP: 2.497 MJ per USD PPP, +1.5% since 2011 (IEA average: 3.737 MJ per USD PPP)

Energy production: 4 105 PJ (oil 40.5%, coal 39.1%, natural gas 9.7%, bioenergy and waste 5.4%, hydro 5.3%, solar 0.03%), -21% since 2011

Total final consumption (TFC): 1 319 PJ (39.5% transport, 35.5% industry, 25.1% buildings)

Colombian peso (COP): COP 1 000 = USD 0.27 = EUR 0.24 (5 April 2022)

Country overview

Colombia has maritime borders in the north with the Caribbean Sea and in the west with the Pacific Ocean. Its main neighbours include Panama in the north-west, Ecuador and Peru in the south, and the Bolivarian Republic of Venezuela and Brazil in the east and south-east. In 2020, Colombia had a population of 49 million, 20% of which live in Bogota, the capital. Population growth has slowed down to 1.1% per year (OECD). Spanish is the official language along with over 70 indigenous languages.

Colombia's geography is diverse, with small islands along the coasts of the North Pacific Ocean and the Caribbean Sea; areas located in the ring of fire, with earthquakes and volcanic eruptions; the Amazon Rainforest region shared with Brazil, Ecuador, Peru and Venezuela; and the Andes mountains in the interior.

Economy

From 2015 to 2019, GDP grew annually by 2-3% (+3.3% in 2019). However, it dropped by 6.8% in 2020 due to the Covid-19 pandemic. Revenues from the production and export of oil, gas and coal remain important for the country's GDP. The oil sector has contributed an annual average of close to 2% of GDP and 13% of total government revenue in the last ten years from tax revenues, dividends and royalties. Almost 90% of Colombia's coal production is exported, securing a large part of the state budget.

Due to Covid-19, investment in the oil/gas sectors fell to the lowest level in history. The economic recovery plan "New Compromise for Colombia" and major privatisations led the economy to recover at a rate of 10% during the second half of 2020 and throughout 2021, supported by a significant fiscal response from the government. The OECD projects GDP

growth to recover and to grow by 6.1% in 2022 and 2.1% in 2023 (OECD, 2022), thanks to increasing private consumption and growing employment.

Political system

Colombia is a presidential republic under the Constitution of 1991. The president, Gustavo Petro, was elected in June 2022 and officially inaugurated in August 2022. The Minister of Mines and Energy is Omar Andrés Camacho Morales.

As a result of growing decentralisation since the 1980s, today, the administrative structure of the country builds on the national government and territorial entities: 32 regional departments (and Capital District of Bogota); districts; around 1 100 municipalities, with the mayors with an important role; and indigenous territories. In the dual system of decentralised and delegated responsibilities, the majority of competences are shared between all levels of government. The 1991 Constitution gives a special status to the 817 indigenous territories, home to 1.4 million inhabitants, and six metropolitan areas. Over the past decades, the authority of the national government has been challenged by rebel and paramilitary groups' control over areas, notably remote regions.

Colombia is a member of the United Nations, the World Trade Organization, the Organization of American States, the Pacific Alliance, the Andean Community, and a global partner of the North Atlantic Treaty Organization since 2017. Colombia became a member of the OECD in April 2020 and started the process of accession to the IEA in 2021.

Political priorities

The political priorities of the Petro government evolve around the shift towards a new economic model based on climate and social justice and the protection of vulnerable communities. President Petro has pledged a "gradual phase down of the extractive industry model" by halting any new mining and oil/gas exploration concessions and shifting away from oil and coal dependency in terms of exports and budget revenues. Existing exploration licenses will remain effective and the government aims to improve oil and gas production from existing fields.

The president proposed that the fiscal shortfall resulting from the phase down of the extractive industries be compensated by promoting the tourism and agricultural sectors. To diversify the mining industry, Petro's programme supports the production of hydrogen and critical minerals as part of the country's energy transition. President Petro proposed creating a fund that would use royalties and taxes from the fossil fuel sector to finance clean energy initiatives.

The government also prioritises continued support for further integrating non-conventional renewable energy sources, working with indigenous groups for investment in large-scale solar and wind developments and ensuring that benefits accrue to local communities to improve livelihoods and jobs. The National Development Plan (PND) 2022-2026 announced a strategy for jobs from the energy transition. President Petro has also pledged to advance rural electrification to close the energy access gap.

Over the next 15 years, NOC Ecopetrol is expected to play a pivotal role in shifting the country to a low-carbon economy, with a strong role in research, science and technology development for clean energy.

Main energy policy institutions

The National Planning Department (Departamento Nacional de Planeación, DNP) promotes a strategic vision of the country in terms of social, economic and environmental outcomes through the guidelines for and evaluation of public policies, national development plans and programmes, the management and allocation of public funding, as well as the definition of frameworks for the performance of the private sector.

Under the DNP operates the National Council on Economic and Social Policy (Consejo Nacional de Política Económica y Social, CONPES). CONPES is chaired by the president and composed of all ministers and the DNP director. CONPES is the highest national planning authority and serves as an advisory body to the government in all aspects related to the economic and social development of the country. It issues reports and general policy guidelines for the government, such as inputs to the National Development Plan.

The Ministry of Mines and Energy (Minenergia, MME) is in charge of energy policy across mining, electricity and gas, and other energy sectors. The entities attached to the MME are the National Agency of Hydrocarbons, the National Mining Agency, the Mining and Energy Planning Unit, the Energy and Gas Regulatory Commission, the Institute for Planning and Promotion of Energy Solutions for Non-Interconnected Zones, and the Colombian Geological Survey, which are described below.

The Mining and Energy Planning Unit (Unidad de Planeación Minero Energética, UPME) supports the policy-making process through energy data and analysis and the planning of mining and energy resources (electricity, coal, gas, oil, etc.). The UPME works with energy sector stakeholders and produces and disseminates information, including monthly and annual supply/demand data and projections. UPME prepares the National Energy Plan 2020-2050.

The National Agency of Hydrocarbons (Agencia Nacional de Hidrocarburos, ANH) was created after the restructuring of Colombia's oil and gas industry in 2003 and is a key pillar of national energy security. Ecopetrol's regulatory tasks for oil/gas upstream contracts were transferred to the ANH, which today administers Colombia's hydrocarbon reserves and resources (through contracts, agreements and royalties, allocation of production areas), including their optimal and environmentally safe use.

The National Mining Agency (Agencia Nacional de Minería, ANM) manages the mineral resources (coal and critical minerals) owned by the state, with a view to promote their optimal, environmentally sustainable and safe use. The ANM also co-ordinates the National Mining Rescue System.

The Colombian Geological Survey (Servicio Geológico Colombiano) supports the ANH and the ANM by surveying and mapping the subsoil, establishing areas with mining and hydrocarbon potential, and providing technical and scientific support to the sector.

The Institute for Planning and Promotion of Energy Solutions for Non-Interconnected Zones (Instituto de Planificación y Promoción de Soluciones Energéticas para las Zonas No Interconectadas) supports local energy technology solutions to support off-grid rural communities with universal access to energy.

The Energy and Gas Regulatory Commission (Comisión de Regulación de Energía y Gas, CREG) is part of the MME and regulates wholesale and retail markets and the public

utilities for electricity, natural gas, LPG and liquid fuels with a mandate to ensure service reliability and competition, through measures to prevent abuse of dominant position. The CREG adopts the methodologies for calculating electricity and gas tariffs (or oversees tariff setting by discoms) and for the rates and margins for liquid fuels (except producer revenues). CREG does not have legal status but administrative, technical and financial autonomy under MME.

The Superintendence of Public Utilities (Superintendencia Servicios Públicos Domiciliarios) oversees the Colombian power market and is in charge of enforcing and supervising regulations. XM is the pool market operator for electricity; it also runs the National Dispatch Center. XM is fully controlled by the transmission company ISA which, in turn, is government owned. In 2021, Ecopetrol (88.49% state-owned) signed an agreement with the Colombian Ministry of Finance and Public Credit to acquire the 51.4% state-owned stake in ISA. The UPME is in charge of transmission and generation planning for the interconnected zone and the wholesale energy market. The national operation councils for gas and power ensure the safe technical system operation.

The Ministry of the Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible, MADS) guides policies and regulations for the protection of the environment and natural resources. The National Environmental Licensing Agency (Autoridad Nacional de Licencias Ambientales) ensures that energy projects comply with environmental regulations and sustainable development through environmental licensing and permitting. Biofuels policy is set by an inter-sectoral commission of the Ministry of Agriculture and Rural Development; the Ministry of Transportation; the Ministry of Commerce, Industry and Tourism; the director of the DNP; the MADS; and the MME. The Institute of Hydrology, Meteorology and Environmental Studies (Instituto de Hidrología, Meteorología y Estudios Ambientales) manages the National Information System on Climate Change.

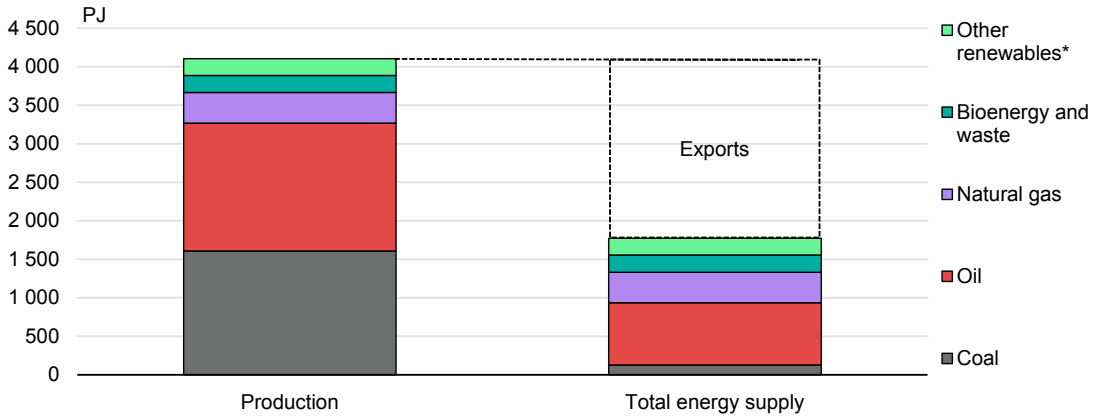
In 2016, Colombia created the national climate change governance (SISCLIMA), headed by an Intersectoral Council on Climate Change, which consists of seven bodies (MADS; the MME; the DNP; the National Unit for Disaster Risk Management; and the Institute of Hydrology, Meteorology and Environmental Studies) and nine climate change regional nodes. The 2018 Law on Climate Change made the SISCLIMA with the National Council on Climate Change and Adaptation a permanent consultative body, including representatives of academia, government and civil society.

Energy supply and demand

Colombia is an oil and coal net exporting country. In 2021, Colombia exported 59% of its domestic energy production (Figure 2.1).

Energy production in Colombia is dominated by fossil fuels and mainly directed to exports. In 2021, fossil fuels accounted for 89% of total production (3 578 petajoules [PJ]), mostly consisting of oil (41%), coal (38%) and natural gas (10%). Fossil fuels accounted for 71% of total energy supply (TES). Oil was the largest energy source of TES in 2021 (39.7%), followed by natural gas (24.9%). TES also consists of significant shares of renewable energy sources, mostly bioenergy and waste (16%) as well as hydro (13%) and a small share of solar and wind (0.1%). Coal accounts for 6.3%.

Figure 2.1 Overview of energy production and supply in Colombia, 2021



Colombia exports a large share of the energy it produces, mainly oil and coal.

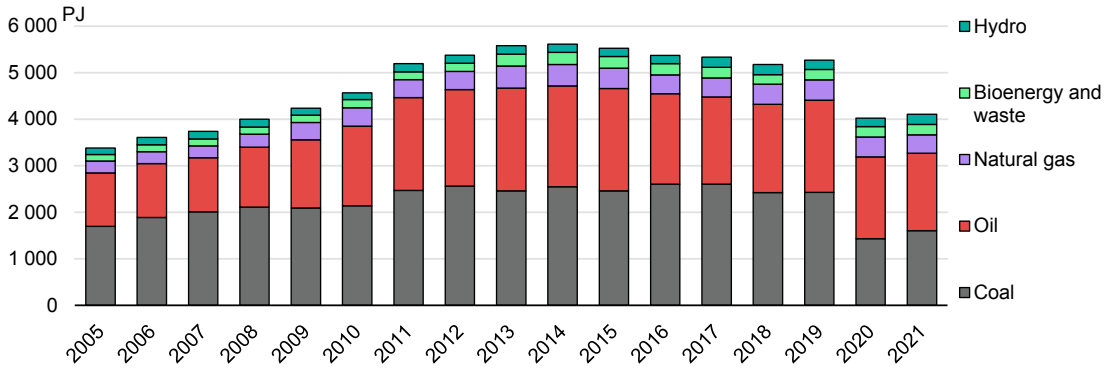
* Other renewables include hydro, wind and solar.

Source: IEA (2023).

Energy production and supply

Total energy production increased steadily and peaked in 2014 (5 610 PJ), with coal production at its highest level in 2017 (2 604 PJ), oil in 2013 (2 208 PJ) and natural gas in 2019 (438 PJ). In 2020, total energy production dropped by 24% compared to 2019.

Figure 2.2 Energy production by source in Colombia, 2005-2021

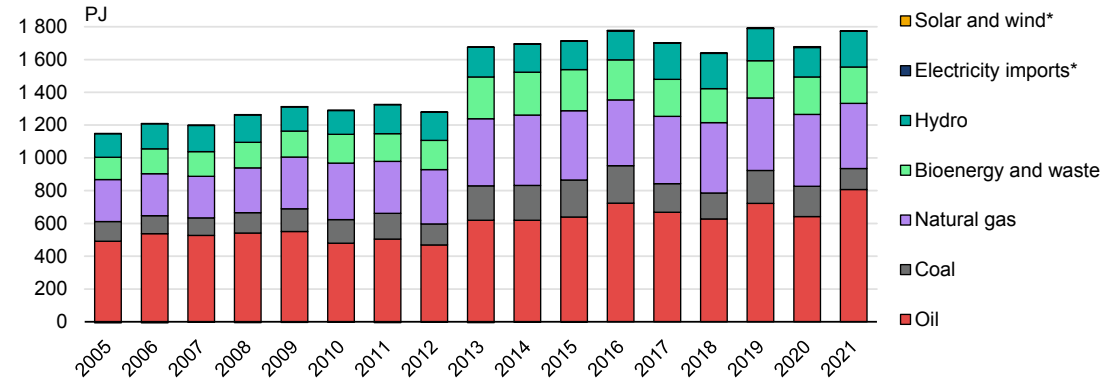


Colombia's energy production consists of oil (41%), coal (39%) and natural gas (9.7%).

Source: IEA (2023).

As a result of the global crisis triggered by the Covid-19 pandemic, coal production decreased by 41% from 2019 to 2021, following mine closures due to lockdowns and industrial action. Oil and gas production was less affected by the pandemic. Between 2005 and 2012, Colombia's TES rose from 1 141 PJ to 1 276 PJ with a sharp increase to 1 671 PJ in 2013, driven by an increased supply of fossil fuels (Figure 2.3). TES rose to a record high in 2019 (to 1 792 PJ) but dropped by 1% in 2021 (1 774 PJ).

Figure 2.3 Total energy supply by source in Colombia, 2005-2021



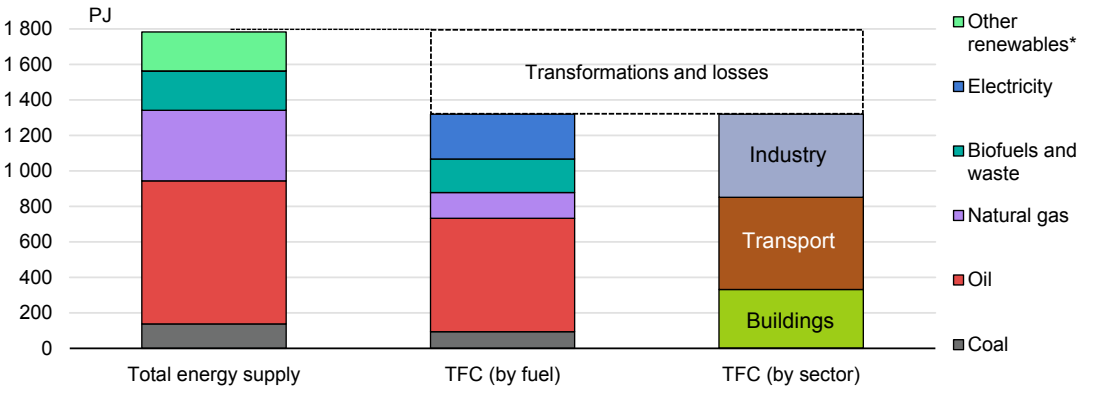
Since 2013, Colombia's TES has increased with a rising supply and exports of fossil fuels.

* Figures for solar and wind (1.4 PJ in 2021) and electricity imports (0.4 PJ) are not visible on this chart.
Source: IEA (2023).

Energy demand

In 2021, Colombia's total final consumption (TFC) was 1 319 PJ. Fossil fuels represented 67% of TFC, with oil being the first energy source (49%), followed by natural gas (11%) and coal (7.1%). Electricity (mostly hydro power) was the second-most consumed energy source, contributing 19% in TFC, followed by biofuels and waste (14%).

Figure 2.4 Colombia's total energy supply and total final consumption, 2021



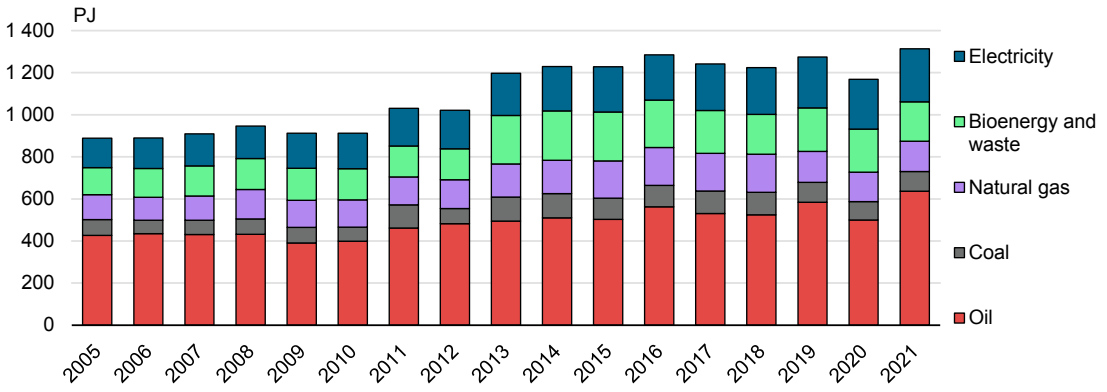
Transport and industry activities drive Colombia's total final consumption.

* Other renewables include hydro, wind and solar. Total final consumption (TFC) includes non-energy use.
Source: IEA (2023).

Transport accounted for the largest share of TFC (39.5%), followed by industry (35.5%) and buildings consumption (25.1%). TFC increased moderately between 2005 and 2015, from 893 PJ to 1 234 PJ (Figure 2.5). As of 2011, growth accelerated, reaching 1 276 PJ in 2019. In 2013, Colombia experienced its largest year-on-year increase of TFC, mostly due to a significant increase of bioenergy consumption (from 148 PJ to 231 PJ in one

year). Such an increase was the result of the rapid development of bioethanol from sugar cane crops and biodiesel (Fedebiocombustibles, 2021).

Figure 2.5 Total final consumption by fuel in Colombia, 2005-2021

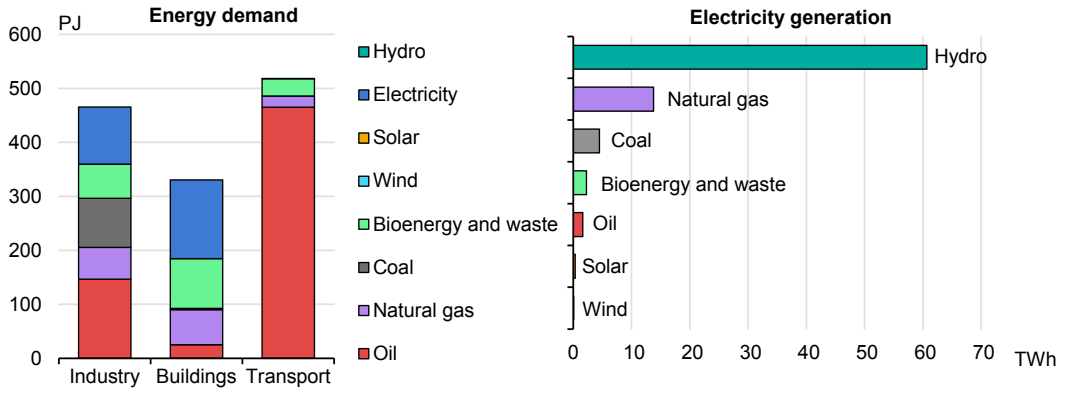


Colombia's total final consumption has experienced a rapid increase since 2011, with significant growth in bioenergy consumption since 2013.

Source: IEA (2023).

Industry relies on fossil fuels, with oil as the main energy source. Buildings rely on electricity and biomass, and together with industry account for 72%. Transport is dominated by oil (90%). Colombia has a highly decarbonised electricity mix thanks to abundant hydropower (72%). Natural gas is the second source of electricity (16%), followed by coal (5.3%), biofuels (2.7%), oil (1.9%), solar (0.4%) and wind (0.1%).

Figure 2.6 Energy demand and electricity generation by fuel in Colombia, 2021



The energy consumption mix varies greatly across sectors. Hydropower accounts for 72% of Colombia's electricity generation. Biomass and electricity drive consumption in buildings.

Source: IEA (2023).

Energy strategies and targets

National Development Plan

Colombia's energy strategy is aligned with the sustainable development agenda of the nation. The latest National Development Plan (PND) for the period 2022-2026, under the theme of "Colombia, World Power of Life (Colombia Potencia Mundial de la Vida)", was presented in November 2022 for a country-wide consultation process with Congress, the unions and civil society, including binding regional dialogues across the national territory.

The PND supports five socio-economic transformations: 1) territorial planning in line with the availability of water; 2) human security and social justice, 3) human right to food, 4) productive transformation, internationalisation and climate action and 5) regional convergence. The implementing PND law was adopted in May 2023 (GoC, 2023).

The PND sets priorities for investments in the country's energy transition under the dedicated pillar on 'Productive transformation, internationalisation and climate action' with the following priorities: diversification of exports (a targeted share of 56.3% to come from non-mining exports), reindustrialisation and technology investment (with a targeted share of 0.5% in the GDP dedicated to research and development), the promotion of new mechanisms for the generation of 2 GW of non-conventional renewables, sustainable transportation, a 20% reduction of deforestation, and the restauration of the country's ecosystems.

Over the past decade, Colombia's energy transition policy was shaped by the PND 2018-2022, PEN 2050, electricity generation and transmission expansion plans, the country's long-term development strategy (E2050 Colombia), the Energy Transition Law (2099/2021), the Climate Action Law (2169/2021) and sectoral climate change management plans (so-called PIGCC), including for the energy sector (PIGCCme).

Energy transition laws

Law 1715 of 2014 laid the ground for the promotion of non-conventional renewable energy and energy efficiency projects, mainly through tax incentives and benefits. This regulation was complemented by Law 1955 of 2019 (PND 2018-2022), which increased existing tax benefits and created an obligation for energy utilities to buy at least 10% of their total power purchase from non-conventional renewables. In July 2021, the Energy Transition Law (2099/2021) expanded actions and tax benefits for a broad range of energy efficiency and low-carbon energy technologies, including geothermal, CCS and hydrogen. The law also created a new fund – the Fondo Único de Soluciones Energéticas, or FONENERGIA – to improve quality of supply and energy access.

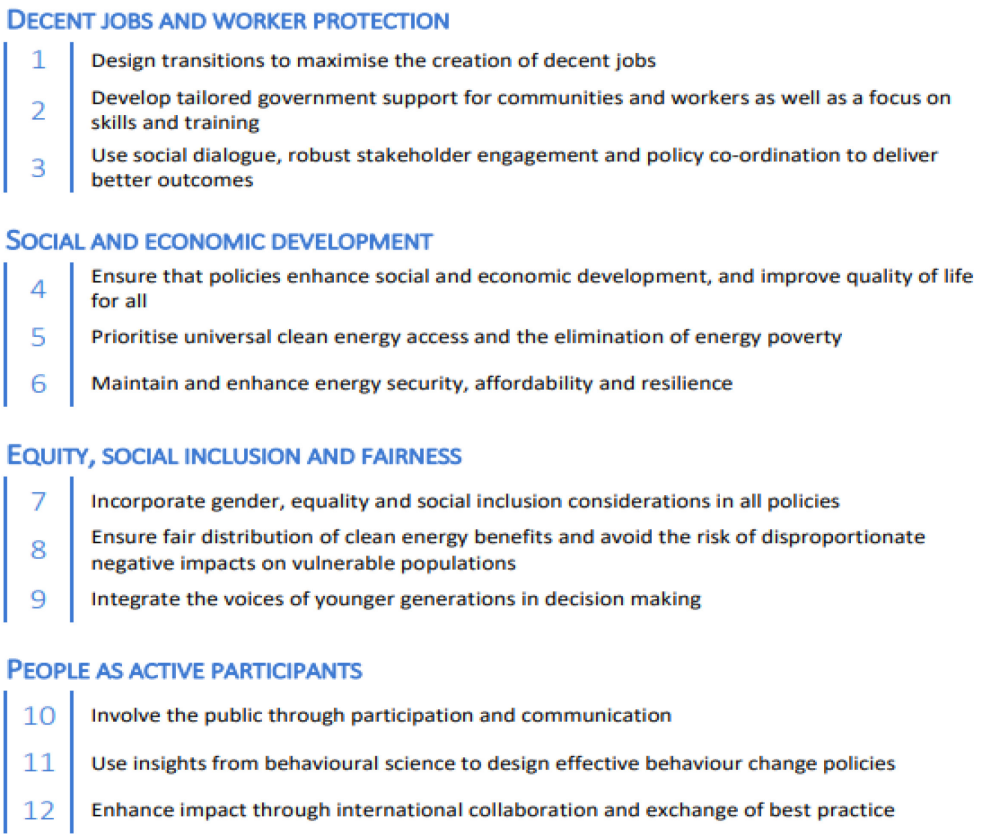
Just energy transition road map

Colombia is pursuing a reindustrialisation policy with the aim to shift from an extraction economy to a productive and sustainable knowledge economy. In parallel to the elaboration of the PND, the government is preparing a national just energy transition road map. The road map will set out the actions needed to achieve energy access for all, a fair and just transition, engaging the regions and citizens in the energy transition, and expand its economic benefits, including by supporting the creation of energy communities.

Colombia's road map confirms that the transition will be gradual and rely on a broad portfolio of energy sources, including solar photovoltaics (PV), wind, geothermal, bioenergy, hydrogen and others. It will be knowledge-intensive and be based on reskilling and training, to prepare and educate the country and professionals. A new Colombian Energy Institute will be created to support training, reskilling and analysis of the energy transition.

In 2021, the IEA Global Commission on People-Centred Clean Energy Transitions adopted a set of actionable recommendations for governments, industry and citizens by drawing on recent experiences and best practices from around the world (IEA, 2021).

Figure 2.7 Principles for just energy transitions



Source: IEA (2021).

Drawing on the work of the IEA Global Commission on People-Centred Clean Energy Transitions, several best practices could be of interest to Colombia as the government develops the just energy transition road map.

- The United States has introduced new geothermal tax credits under the Inflation Reduction Act, focused on energy communities (defined as those that have typically depended on coal/fossil fuels for economic activity).
- The Spanish government is using just transition agreements between government, companies and labour councils to provide for a range of investment and strategic development at the regional level.

- Poland is undertaking intensive engagement with coal regions to create regional plans to direct investment in coal communities to support the transition, in line with the government's social dialogue with unions and coal companies and subsequent agreement to phase out coal mining by 2049.
- Brazil has used biomass gasification to expand electricity access in rural areas, and the RevoluSolar, a community-based organisation, to install solar panels in favelas and trains residents as electricians or entrepreneurs.
- Indonesia supports micro hydropower plants to expand energy access in Indonesia.

Universal energy access

Colombia is highly urbanised, with 75% of the 11.5 million households living in urban areas. Thanks to rapid economic growth, today it is an upper middle-income country. But growth is not evenly shared; over 45% of the population lives below the national poverty line.

In 2021, 3% of Colombia's population, or 500 000 users, did not have access to electricity and 1 million families used wood for their heating and cooking needs. By 2030, the government aims to half this lack of coverage: 100 000 families shall be connected per year and 200 000 families provided with clean cooking. Under the PND 2018-2022, the government proposed to reach 100 000 new users by 2022. Progress towards the target was good. By March 2022, 73 046 new users had gained access to electricity, and of these, 26 899 through solar PV. There is no consolidated national subsidy programme in place for clean cooking; efforts are scattered and driven by international aid programmes, notably by the United States Agency for International Development (GACC, 2021).

The new PND 2022-2026 reiterates the government's commitment to achieving universal access to clean energy. It aims at enhancing community-owned energy projects and deploying a clean cooking programme to substitute firewood.

Since the National Rural Electrification Plan of 2017, the government has been working to offer energy solutions to users either by connecting them to the electricity interconnected system or through self-generation, with a range of funding programmes, which were consolidated in the FONENERGIA (Law 2099 of 10 July 2021).

The Social Energy Fund has played a key role in financing universal access, largely financed (80%) from the congestion income of the market operator, XM. This fund guarantees up to COP 46 per kilowatt hour (kWh) of the value of electricity used for residential users (strata 1 and 2 of rural areas of low development and low-income neighbourhoods). Since 2021, the value of these subsidies averaged COP 13-18 billion.

The Solidarity Fund for Subsidies and Income Redistribution also supported low-income users, with resources from the national budget to cover the subsidies for the public electricity service to lower income users.

The Financial Support Fund for the Energisation of Interconnected Rural Areas allows the territorial entities, with the support of the electricity service providers, to support investment in new electricity infrastructure. The Financial Support Fund for the Energisation of Non-Interconnected Zones finances investment in energy infrastructure in non-interconnected zones.

In 2021, the government introduced a pilot programme for subsidising the consumption of LPG cylinders with programmes to replace firewood, coal, waste, kerosene, ethanol and diesel use (Law 2128, MME Resolution 40342/2021).

With limited fiscal space, the government relies on leveraging private investment, notably for investment in smart grids which can be included in the tariffs charged by network operators. This offers also co-benefits for the economic local development in rural areas.

The government plans large-scale renewables and green hydrogen deployment, which are expected to generate USD 2.5 billion in investment and 400 000 jobs. The dedicated Fund for Renewable Energy and Energy Efficiency (Fondo de Energías No Convencionales y Gestión Eficiente de la Energía, FENOGE) is the main support programme in energy efficiency (including cash transfers) and unconventional energy sources, financing research, studies, energy audits, modernisation, and final disposal of replacement of equipment.

Energy subsidies

The government subsidised energy consumption for a total of USD 564 million in 2018 based on a national housing classification system (so-called strata)[1]. Sixty per cent of the subsidy is allocated to residential users (strata 1), 50% to strata 2 and 15% to strata 3. The subsidy is paid by commercial users (strata 5 and 6) who pay a 20% electricity surcharge as contributions.

Table 2.1 Energy subsidies and contributions by strata, 2018, in COP million

	Strata 1	Strata 2	Strata 3	Irrigation districts	Total subsidies
No. of users	3 929 877	4 580 166	2 666 078	581	**11 176 703**
Subsidy/ contribution	1 306 332	1 196 864	234 673	18 971	**2 756 840**

	Strata 5	Strata 6	Commercial and others	Total contributions
No. of users	373 441	216 923	1 072 407	**1 662 772**
Subsidy/ contribution	75 869	67 604	1 027 562	**1 171 035**

Sources: Ministry of Mines and Energy, Ministry of Finance.

The Covid-19 pandemic led to increased support for the production and consumption of fossil fuels. Despite the collapse of the global oil price in April 2020, subsidies increased in 2020 in Colombia. These include the 10% increase in natural gas subsidies for users of strata 1 and 2. Strata 1 users will increase to 70%, while strata 2 will increase to 60% for an additional billing cycle. Direct government transfers to reduce fuel prices decreased the

[1] The national classification identifies groups with similar socioeconomic characteristics for the strata composition. Housing characteristics, such as a garage, a front yard, and quality of the neighborhood, are the main criteria used for defining strata in Colombia. Depending on the diversity and quality of housing, there could be six strata: level one is lower-low, two is low, three is upper-low, four is medium, five is medium-high, and six is high. Most cities have all six, but there are towns that have only three.

price of gasoline by COP 1 200 (-13%), from an average price of COP 9 159 per gallon to COP 7 958 per gallon; diesel decreased by COP 800 (-9%) from an average of COP 8 952 per gallon to COP 8 152 per gallon (OECD/IEA, 2021).

From 2020 to 2022, the government allocated USD 1.11 billion in support of oil and gas consumption and production (not the coal sector) through a range of regulatory roll-backs and easing of procedures in the hydrocarbon sector alongside tax refunds. The main public funding commitments included USD 373.77 million for fossil fuel consumption, through increased income support for electricity and gas consumers, economic aid to retail fuel distributors, and support to permitting of oil/gas/mining infrastructure projects through reduced royalty payments. Ecopetrol's new investments in the Barrancabermeja refinery of USD 730.75 million also aim to improve the reliability of the water segregation system and the SOx emissions control.

This compares with the clean energy investment, including:

- USD 4.41 million for clean energy through tax incentives for non-conventional renewable energies (solar, wind).
- USD 31.8 million for investment in electrical networks in the departments of Magdalena, Meta, Atlántico, Arauca and La Guajira.
- USD 881 million of investments mobilised by the state in the auction of 26 October 2021 for 11 solar projects (800 megawatts [MW] and 4 800 green jobs).

Energy data and statistics

The UPME is responsible for energy data for planning purposes. It is a special technical administrative unit attached to the MME, with its own legal status, assets and budgetary autonomy, subject to a special procurement regime. The UPME interacts frequently with other institutions and governmental bodies.

Colombia joined the OECD on 28 April 2020 and is currently an IEA accession country. As such, it has energy data reporting requirements to fulfil and will have additional ones once it becomes a member of the IEA.

In terms of energy data submitted to the IEA, the UPME uses data that are already made available to other institutions and the general public. It does not have the ability to request data directly from the companies or users.

The legislative landscape for collecting and publishing energy data is complex, with diverse specifications depending on the area covered (fuel or sector). In addition, there is no legislation allowing for the collection of emergency data in an oil supply disruption setting (this particular item is being discussed as part of the IEA accession process). The National Administrative Department of Statistics (Departamento Administrativo Nacional de Estadística) is the only institution that has the legal authority to request any type of data from any member of society for the purpose of producing official statistics.

Energy data collection and analysis are currently scattered among several different institutions and not all inter-institutional exchanges of information are handled through formalised agreements. There is no centralised system to make energy data available in a harmonised manner.

With the support of the Intern-American Development Bank, the administration is currently working on a project, Intégrame, a data portal that supports the integration and interoperability of data and analysis for the energy and mining sector in Colombia. The portal will provide centralised access to different users. The scope of Intégrame will be adapted to the needs of the MME.

Assessment

For two decades, the energy transition has been a stated policy goal for Colombia and the country has made progress towards achieving it. It has also a very good resource endowment: Colombia has abundant natural renewable energy sources, a highly decarbonised electricity mix, with 72% from hydropower, and consumes more renewable energy in its final consumption than many other OECD countries.

In 2016, Colombia launched the PEN to diversify energy supply by promoting wind power plants, solar PV and geothermal energy generation in the country's electricity mix. A range of strategies and plans are adopted, but not always well aligned or co-ordinated, stifling progress of the transition on the ground. While the Indicative Action Plan of Energy Efficiency (PAI PROURE) 2022-2030 does set targets for energy efficiency by 2030, there are none for non-conventional energy sources beyond 2022, which means consumers and businesses have little visibility of the country's medium-term energy transition objectives.

Colombia is a producer economy which is still struggling with economic diversification ambitions and social development gaps and poverty. The Petro government takes these concerns seriously and acknowledges that the transition will require substantial financial resources to wean the country off fossil fuels, which still account for more than 75% of the country's energy mix. The PND aims at increasing the share of non-mining exports to 56.3% by 2026.

Financial resources will also have to come from resource-related export revenues in the short to medium term. Oil revenues continue to account for over 30% of the total value of Colombian exports. As a major producer and exporter of both oil and coal, Colombia is generating around USD 20 billion in annual foreign exchange earnings from both sources. In 2022, Colombia's industry was benefitting from high export revenues in the context of the high energy price environment. Meanwhile, new rounds of licenses for greenfield oil/gas/mining development brought to Colombia commitments of new foreign direct investment of USD 7.6 billion in 2020.

When evaluating Colombia's energy transition policy to date, some have suggested that any plan for greater coal and oil production to fund social development projects may contradict Colombia's climate commitments of reducing 51% of its emissions by 2030 and reaching net zero by 2050. To address such criticism, a clear vision is necessary to define the future pathway and long-term transformation of the country's energy production sectors (oil, gas and coal). This also includes involving international actors, as Colombia remains a major energy exporter and relies on global energy markets.

A people-centred just transition will be an essential prerequisite for the success of Colombia's transition. Colombia should prioritise the provision of universal access to electricity and clean cooking while preparing for job shifts, reskilling and reconversion of traditional coal-mining regions to the future economic opportunities stemming from the transition.

Despite a range of funding programmes, in 2021, 3% of the population still did not have access to electricity and 1 million families did not have access to clean cooking. Around 45% of the country's population lives under the poverty line. Clean energy projects face opposition from local communities, who raise concerns of a lack of consultation, assessment of environmental and social impacts, and a lack of understanding of the relationship between communities and their lands. This is most evident for La Guajira, whose population is 42% indigenous, with high levels of poverty and limited access to electricity, but with enormous potential for wind and solar energy.

The energy transition is a key policy priority of the new Petro government, with a strong focus on social justice, local ownership of resources and support to vulnerable communities to achieve energy access and clean energy investment across all of the country's regions. In 2023, the government adopted the implementing law for the PND 2022-2026 and is preparing a Just Energy Transition Roadmap to achieve a common vision across the entire country on the need for boosting clean energy for all, notably in isolated areas; to reduce the high financial dependence on exports from extractive industry; and to boost employment and reskilling. Experience from the IEA's Global Commission on People-Centred Transitions provides useful learnings for the government of Colombia, helping to boost local economic benefits and the transition to clean energy and new job opportunities. Building on the PND, the Just Energy Transition Roadmap and subsidy reform can support the energy sector response to climate change, in line with the overall 2050 decarbonisation objectives.

Recommendations

The government of Colombia should:

- Define Colombia's energy transition policy and set out practical actions needed to reconcile the affordable and secure energy growth required to support Colombia's economic development with the country's ambitious climate targets. Building on the PND 2022-2026 process, complete a broad consultation with a wide range of stakeholders with a view toward gaining support for that general vision.
- Prioritise and ensure consistency in policies, targets and ambitions contained in the various laws, decrees, plans and sectoral policy documents involving energy and climate change and track progress of the milestones in Colombia's energy transition.
- Establish a plan to address existing data gaps for robust tracking of energy supply and demand sectors and international energy data requirements, including the IEA. The plan should identify the institutional, legal and resource needs to formalise data access, automate energy data collection and complete data centralisation systems as well as collaboration across institutions, including through the Integrame data hub.

- Agree an energy transition strategy with a people-centred focus, jointly with Colombia's territories and industry, building on existing initiatives. This would include social guidelines; local retraining programmes; and supporting access to energy, employment and economic development opportunities arising from clean energy deployment at the local level. Join IEA efforts globally to advance people-centred transitions.
- Improve co-operation among national, regional and territorial government departments and the private sector to ensure that local communities receive tangible economic and social benefits from the expansion of essential energy-related projects in their areas.

References

Fedebiocombustibles (2021), Statistics, https://fedebiocombustibles.com/statistics/.

GACC (Global Alliance for Clean Cookstoves) (2021), Colombia Market Assessment, https://cleancooking.org/wp-content/uploads/2021/07/206-1.pdf.

GoC Government of Colombia (2023), National Development Plan 2022-26, https://www.dnp.gov.co/plan-nacional-desarrollo/pnd-2022-2026; https://colaboracion.dnp.gov.co/CDT/portalDNP/PND-2023/Ley_2294_del_19_de_mayo_de_2023.pdf.

IEA (International Energy Agency) (2023), IEA World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

OECD (2022), Economic Forecast Summary, https://www.oecd.org/economy/panorama-economico-colombia.

OECD/IEA (2021), G20 Fossil Fuel Subsidies Reform Update Report, https://www.oecd.org/fossil-fuels/publicationsandfurtherreading/OECD-IEA-G20-Fossil-Fuel-Subsidies-Reform-Update-2021.pdf.

3. Energy and climate change

Key data

GHG emissions (2018): 302.9 Mt CO_2-eq, +35% since 1990

Energy-related CO_2 emissions (2021):

CO_2 intensity per capita: 1.55 t CO_2 /capita (IEA average: 6.7 t CO_2 /capita)

CO_2 emissions from fuel combustion: 79.7 Mt CO_2, +24% since 2011, +67% since 1990

CO_2 emissions by fuel: oil 60.2%, natural gas 22.1%, coal 17.7%

CO_2 emissions by sector: transport 45%, industry 31%, electricity 16% and buildings 8%

CO_2 intensity per GDP: 0.109 kg CO_2/USD (IEA average: 0.185 kg CO_2/USD)

Overview

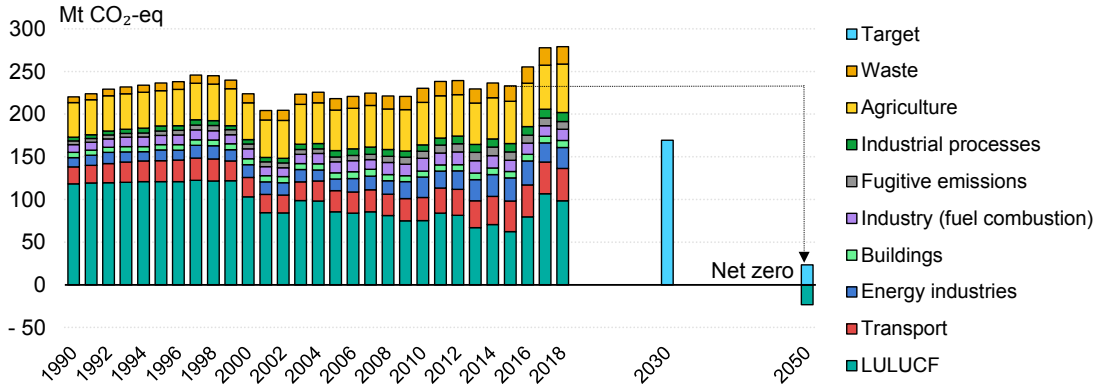
Colombia's GHG emissions were 303 million tonnes of carbon dioxide equivalent (Mt CO_2-eq) in 2018 (Figure 3.1), a 35% increase since 1990.

In the case of Colombia, agriculture, forestry and land use are not a sink but a net source of emissions, accounting for 56% of the total. Emissions from land-use change have increased with growing deforestation, which alone accounted for 35% of total GHG emissions in 2018. During 2019-20, the deforested area was 171 685 hectares (ha), 23% more than in 2018-19 (158 893 ha), according to the country's Third Biennial Update Report to the United Nations Framework Convention on Climate Change (UNFCCC) (GoC, 2021a). In 2018, the emissions from fossil fuel combustion (transport, industry, energy industries, buildings, etc.) accounted for 31% of total GHG emissions, followed by waste (6.5%) and industrial processes and product use (3.5%).

Showing a clear commitment to act on climate change, Colombia raised its climate pledge at COP26 in 2021 with an unconditional and ambitious reduction target of 51% for 2030 below the business-as-usual scenario and introduced a cap on total emissions of 169.44 Mt CO_2-eq in 2030. An emissions reduction from 300 Mt CO_2-eq in 2018 to 169.4 Mt CO_2-eq in 2030 implies a reduction of 43% in 12 years, compared, for instance, with the -55% European Union (EU) target over 40 years.

Colombia plans to achieve net zero emissions by 2050 by reducing the country's GHG emissions by 90% from 2015 levels and have the remaining 10% balanced with land use, land-use change and forestry (LULUCF).

Figure 3.1 Greenhouse gas emissions by sector in Colombia, 1990-2018 and targets



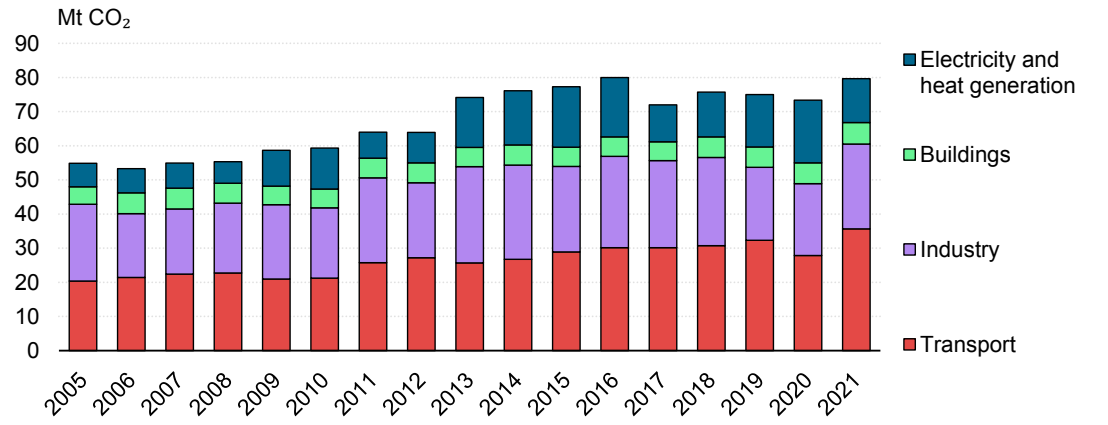
Colombia's GHG emissions increased by 35% from 1990 to 2018. Agriculture, forestry and land use account for 56% of GHG emissions while 33% stem from fossil fuel combustion.

Notes: LULUCF includes emissions and absorption from land use, land-use change and forestry.
Source: GoC (2021a), IEA (2023).

Energy-related CO_2 emissions

Emissions from fossil fuel combustion have been increasing, reaching a historic high of 80 Mt CO_2 in 2016. In 2021, Colombia emitted 79.7 Mt CO_2 from energy, a 9% increase with respect to 2020. The increase was mainly due to emission growth in the transport sector of 28% from 2020 to 2021. Meanwhile, electricity and heat generation dropped from 18.4 Mt CO_2 to 12.9 Mt CO_2 over the same period. Transport was the largest emitter in the energy sector (45% of total emissions), followed by industry (31%), electricity and heat generation (16%), and buildings (7.9%) (Figure 3.2).

Figure 3.2 Energy-related CO_2 emissions by sector in Colombia, 2005-2021

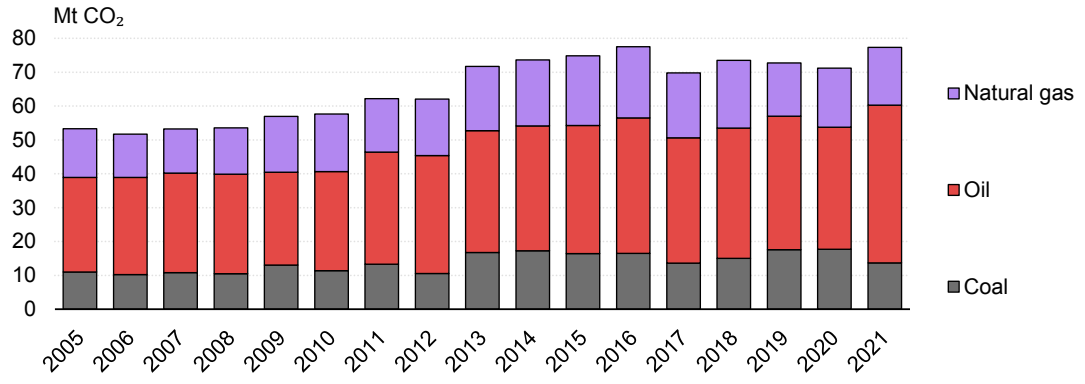


Colombia's energy-related CO_2 emissions increased until 2016 but have remained flat since.

Source: IEA (2023).

Domestic consumption of oil is responsible for the largest share of energy-related CO_2 emissions in Colombia, accounting for 60% of the total in 2021, followed by natural gas at 22% and coal at 18% (Figure 3.3).

Figure 3.3 Energy-related CO_2 emissions by fuel in Colombia, 2005-2021



Oil makes up the largest part of energy-related CO_2 emissions in Colombia, followed by natural gas and coal. Oil emissions increased by 9% in 2021 compared to 2020.

Source: IEA (2023).

CO_2 emissions drivers and carbon intensity

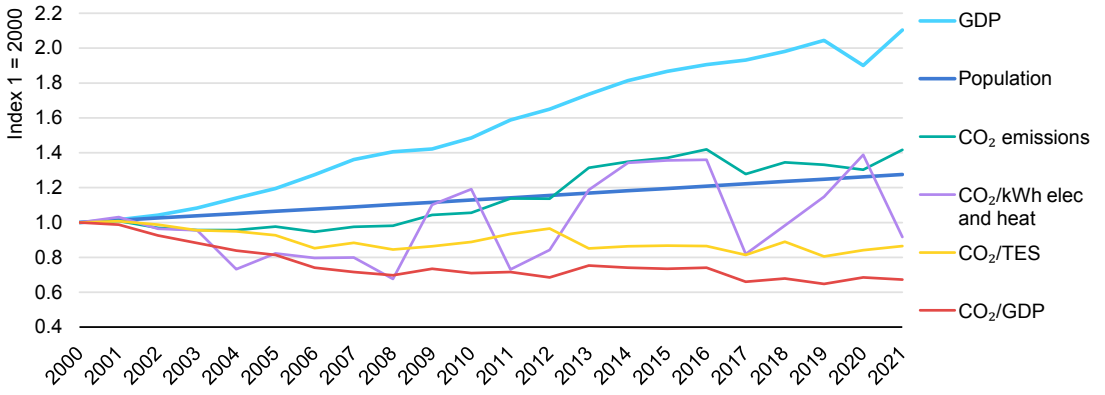
Colombia has a low carbon intensity of GDP compared to the IEA average, with CO_2 emissions per GDP equivalent of 0.09 kilogrammes (kg) of CO_2/2015 USD PPP, less than half the IEA members' weighted average (0.2 kg CO_2) in 2021.

From 2000 to 2021, total energy-related CO_2 emissions in Colombia increased by 42%, while GDP roughly doubled (Figure 3.4), showing a relative decoupling from economic and population growth.

Overall, there was a reduction in the CO_2 intensity of the economy (CO_2/GDP) by 33%, along with a reduction of 29% in the energy intensity of the economy (TES/GDP). This can be explained by the 14% decline in the carbon intensity of the energy supply mix (CO_2/TES) over the same period.

The carbon intensity of Colombia's electricity generation is fluctuating in line with the share of hydropower, reflecting annual and seasonal variability of the electricity generation mix during dry and wet years. In 2021, the carbon intensity decreased to 144.2 g CO_2/kWh, from 229.3 g CO_2/kWh in 2020, as the share of coal in electricity generation dropped by more than half (-58%) while the share of hydropower increased to 72%.

Figure 3.4 Energy-related CO_2 emissions and main drivers in Colombia, 2000-2021



Colombia's CO_2 intensity of GDP has decreased since 2000 as economic growth was higher than energy-related CO_2 emissions growth, showing a slight decoupling.

Note: GDP = gross domestic product; CO_2 = carbon dioxide; kWh = kilowatt hour; TES = total energy supply.
Source: IEA (2023).

Climate change targets

Colombia is a non-Annex I Party to the UNFCCC. In 2018, Colombia presented its first NDC, with GHG emissions reduction targets of 20% (unconditional) and 30% (conditional on technology transfer and climate finance) below the business-as-usual scenario in 2030.

At the United Nations Climate Action Summit in September 2019, Colombia announced its pledge to reach carbon neutrality by 2050. In December 2020, the government presented an updated NDC with a more ambitious reduction target of 51% for 2030 (unconditional) below the business-as-usual scenario (GoC, 2020), which was followed up by the Carbon Neutrality and Climate Resilience Strategy of Colombia (E2050). For the first time, Colombia introduced a cap on total emissions of 169.44 Mt CO_2-eq in 2030, compared to 345.8 Mt CO_2-eq in the business-as-usual scenario and is committed to peak GHG emissions, ideally by 2027, but well before 2030. The government announced its intention to adopt a carbon budget approach for the period 2020-30. By 2030, Colombia targets the reduction of the deforestation rate to 50 000 ha/year and beyond the NDC efforts, it aims to reduce to zero deforestation and black carbon emissions by 40% by 2030, compared to 2014 emissions levels, excluding forest fires.

The country's NDC relies on the largest emissions reductions to come from the agriculture and forestry sector, today the largest source of emissions.[1] The actions planned for this sector represent a potential reduction of 100.6 Mt CO_2-eq. Outside of the sector, the targets and actions envisaged have a mitigation potential of 27.1 Mt CO_2-eq (21.22% of total potential mitigation).

[1] The land-use sector comprises LULUCF and agriculture, sometimes referred to collectively as agriculture, forestry and other land use (AFOLU).

Table 3.1 Overview of Colombia's climate mitigation measures and their potential

Mitigation action	Mitigation potential by 2030 (CO_2-eq)	Sector
Energy efficiency	0.96-1.21 Mt	Mines and energy
Fugitive emissions	0.39-3.24 Mt	Mines and energy
Demand management	0.22-2.01 Mt	Mines and energy; industry; residential and commercial
Diversification of electricity generation	4.74-7.99 Mt	Mines and energy
Integrated solid waste management	1.31 Mt	Sanitation; mines and energy
Domestic wastewater management	0.02 Mt	Sanitation
Sustainable construction	0.09 Mt	Residential and commercial
NAMA sustainable cattle farming	11.15 Mt	AFOLU; mines and energy; transport
Forest plantations for commercial purposes and capture of greenhouse gas (GHG) emissions	10.37 Mt	AFOLU
Strategies for reducing GHG emissions in the life cycle of cacao production	0.16 Mt	AFOLU
Reduction of GHG emissions in rice production through adoption of technology (AMTEC 2.0)	0.08 Mt	AFOLU
NAMA* coffee	0.36 Mt	AFOLU; mines and energy; sanitation
NAMA panela**	0.1 Mt	AFOLU; mines and energy; sanitation
Promotion of energy management and energy efficiency projects in the industry sector	1.67 Mt	Industry; mines and energy
Development of a low-carbon bricks industry	0.19 Mt	Industry; mines and energy
Implementation of technologies to reduce N_2O emissions in the production of fertiliser raw materials	0.6 Mt	Industry
Sustainable cement production processes	0.71 Mt	Industry
Improvement of logistics and product management	1.48 Mt	Industry; transport
Electric mobility	4.04 Mt	Transport
Performance-based navigation	0.01 Mt	Transport
Programme for the modernisation of cargo trucks	1.03 Mt	Transport
Change from road to fluvial freight (Magdalena River)	0.2 Mt	Transport
NAMA active transport and demand management	0.13 Mt	Transport
NAMA development oriented to transport	0.16 Mt	Transport
Rehabilitation of the railway corridor La Dorada-Chiriguaná-Santa Marta	0.11 Mt	Transport
Ecological restoration	16.94 Mt	AFOLU
Replacement of wood stoves with efficient stoves	2.29 Mt	AFOLU; residential
Substitution of products with HFCs	0.85 Mt	Industry; residential; commercial
NAMA domestic refrigeration (energy efficiency)	3.14 Mt	Industry; residential; commercial
Promotion of thermal districts for the replacement of cooling systems in cities (energy efficiency)	0.02 Mt	Industry; residential; commercial
Intersectoral reduction of deforestation (REDD+)	59.18 Mt	AFOLU
Carbon pricing mechanism	0.73 Mt	Mines and energy; transport

* NAMA refers to low-carbon sustainable production.

** Panela is raw cane sugar.

Note: CO_2-eq = carbon dioxide equivalent; Mt = million tonnes; AFOLU = agriculture, forestry and other land use.

Climate Change Law

The 2018 Climate Change Law created the legal and institutional framework for climate change mitigation and adaptation policy and governance in Colombia. It requires each ministry to prepare and implement a comprehensive sector climate change management plan (PIGCCS) with binding targets. Colombia has a whole-of-government approach to implementing its NDC through the PIGCCS. The latest 2021 PIGCCS presented specific actions to achieve the goals of Colombia's 2020 updated NDC and the E2050 under the Climate Action Law (2169/2021). For the period 2020-30, Colombia seeks to mitigate 176 Mt CO_2-eq under its NDC. Table 3.2 shows the government allocated binding emissions mitigation targets by ministry under the interministerial PIGCCS process.

Table 3.2 Colombia's greenhouse gas mitigation targets by sector

Leading ministry	Emissions mitigation potential/target by 2030 (Mt CO_2-eq)	Share of potential emissions mitigation (%)
Ministry of Mines and Energy	11.2	6.3
Ministry of Housing, City and Territory	1.42	0.8
Ministry of Agriculture and Rural Development	21.22	12.4
Ministry of Commerce, Industry and Tourism	4.67	2.6
Ministry of Transport	5.68	3.2
Ministry of Environment and Sustainable Development	23.24	13.1
Intersectoral (Deforestation)	59.18	33.5
Ministry of Finance and Public Credit	0.73	0.4
Local government	49	27.7
Total	**176.34**	**100**

Source: GoC (2020), Annex M1 and the annex of the complementary mitigation portfolio.

For the energy and mining sector, the PIGCCME co-ordinated and developed the energy sector's commitments (MME, 2021a). Given Colombia's overall GHG profile, it is well understood that energy sector action is not the main plank of action, with LULUCF sectors being asked to lead the short- to medium-term emissions mitigation action. Under the PIGCCME, the mitigation target for the energy sector is 11.2 Mt CO_2-eq, with strong reductions expected to come from actions relating to electrification of transport and improvements in energy efficiency (see Chapter 4) (MME, 2021a). The government expects half of the emissions reductions to come from the so-called intersectoral approach, which relates to actions combating deforestation.

As for the transport sector, the government aims to add 600 000 electric vehicles (EVs) to the transport fleet by 2030 under the 2019 National Strategy of Electric Mobility (GoC, 2019a). The transport sector is the principal contributor to air pollution, which is reported to have significant effects on people's health (see the section on air pollution below). Implementing mitigation policies in the transport sector will not only be beneficial for the climate, but will also yield important immediate benefits to air quality.

At the central government level, agreed mitigation actions represent a reduction of 127.7 Mt CO_2-eq; local government action will contribute 28% in the share of emissions reductions alongside fighting deforestation.

Long-term strategy towards carbon neutrality by 2050

The E2050 Colombia (E2050C) strategy was presented by the government during the COP26 in Glasgow (GoC, 2021b) as the country's long-term strategy under the UNFCCC.

The strategy was elaborated with an extensive process of expert consultation, technical analysis and public engagement, including civil society workshops and dialogues, and intersectoral committees. The whole process is guided by a central committee of experts.

To achieve carbon neutrality by 2050, GHG emissions are planned to be reduced by 90% from 2015 levels while the remaining 10% would be balanced with LULUCF. Based on the NDC, the government aims to reduce GHG emissions from around 300 Mt CO_2-eq in 2018 to 169.4 Mt CO_2-eq in 2030.

To achieve full carbon neutrality, the strategy aims to turn the LULUCF sector from a net emitting sector (at present) into a net sink, by protecting forests (stopping deforestation and land conversion) and encouraging restoration. Protecting forests, developing agricultural land, afforestation and ecological restoration are intended to develop an absorption capacity for the country of potentially up to 508 Mt CO_2-eq per year.

The technical analysis underpinning the E2050 strategy was undertaken with the Global Change Analysis Model, which allows the integrated assessment of the economy, energy system and land use. Complementary modelling was done with other models, including the CAPRA model on climate change.

The E2050 developed different scenarios based on variations in economic growth; population; and the cost of electric mobility, renewable energy and carbon capture technologies, as well as different global climate change scenarios impacting the Colombian hydrological system. Through a system of nine "stakes", the E2050 strategy presents a set of actions and technology choices to achieve the decarbonisation of Colombia's economy. E2050 presents policies related to environmental education, a just transition and the circular economy.

By 2050, the E2050 scenario achieves a reduction of gross emissions to around 25 Mt CO_2-eq, with the remainder offset by removals from the land-use sector. Total energy-related CO_2 emissions are reduced from about 70 Mt CO_2 in 2020 to about CO_2 in 2030 and 12 Mt CO_2 in 2050. This is in line with Colombia's NDC.

The E2050 outlines several major milestones to achieve the net zero emissions by 2050 target.

In the energy field, it also proposes lines of action to promote operational carbon-neutral buildings, develop thermal districts and promote self-generation to cover up to 15% of energy demand. It also promotes the use carbon capture systems in thermal power plants, the digitalisation of the distribution system, and estimates that 70% of the demand for passenger mobility could be met by public transportation by 2050, of which 80-100% must operate with low-emission technologies.

The E2050 envisages doubling the share of renewable energy in the total energy supply by 2050 (from 25% in 2020 to 50% in 2050) mainly through substantial increases in the use of bioenergy and solar.

The E2050 envisages 70% of final consumption to be met through electricity, and around 20% by liquid fossil and bioenergy-based fuels. In the power sector, it envisages that by 2050, more than 60% of electricity generation will be met through solar and wind power, while hydro accounts for most of the rest. Coal and natural gas are phased out of the electricity system in the 2030s and 2040s, respectively. Total electricity generation grows from around 75 terawatt hours (TWh) in 2020 to around 480 TWh, driven by both economic growth and electrification of energy demand.

Wind and solar energy are set to see a significant growth, notably as the role of hydropower declines (from around 70% today). According to the Reference Generation and Transmission Expansion Plan 2020-2034, Colombia would have a total installed capacity of 7 330 MW of onshore wind energy, 2 000 MW of offshore wind energy and 10 909 MW of solar energy by 2050 (UPME, 2021). Natural gas also plays a role. While hydrogen is identified as a fuel for the future, notably green hydrogen, there are no quantitative plans for blending hydrogen into natural gas networks.

Long-term energy scenarios

The National Development Plan (PND) 2022-26 will set the guidelines, actions and funding programmes needed to close the energy access gap, boost regional equality and equity, employment and clean energy production and use. A new PEN would follow the PND. The PEN is updated every two years, with the next revision due for adoption in 2023.

The energy sector's main long-term scenario planning is done by the UPME. The previous PEN 2020-2050 was adopted in 2021 (MME, 2021b). It was developed using the LEAP model (Low Emissions Analysis Platform), a widely used and well-established energy system modelling platform.

The PEN highlights the structural challenges facing the Colombian energy sector. First, the declining availability of domestic energy resources and the possibility of a regime change to net imports in oil and gas. Second, predominance of inefficient energy technologies, particularly in the end-use sectors, which creates substantial excess costs to the energy system. Third, mitigation and adaptation to climate change are becoming more significant. Fourth, disruptive technological trends of decentralisation and digitalisation are gaining importance in the system. Building on those challenges, the PEN is developed to serve four key policy objectives: 1) security and reliability of supply; 2) mitigation and adaptation to climate change; 3) competitiveness and economic development; and 4) management of knowledge and innovation. In line with this, the PEN develops four key scenarios for Colombia's energy future: updating, modernisation, decline and disruption.

The PEN is explicitly framed as an exercise in energy system scenario analysis; it is not intended to provide predictions. Intended as an indicative and exploratory scenario exercise, the PEN 2020-2050 also predates the adoption of the goal of reaching net zero emissions in 2050. As such, it expected energy sector CO_2 emissions of 59-75 Mt in 2030 and 53-90 Mt in 2050 (compared to 12 Mt in E2050).

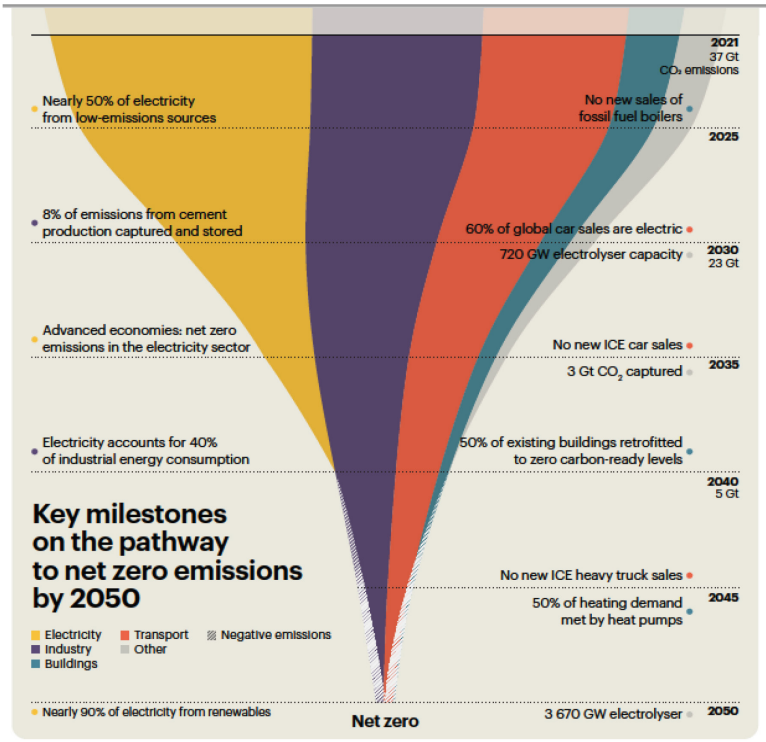
The long-term energy scenarios of the PEN 2020-2050 were devised to meet the goal of reducing emissions by 20% with respect to the baseline of the NDC proposed in 2015 to be achieved in 2030 (the reference document for the preparation of the PEN 2020-2050).

The PEN increases the ambition to 40% in the scenario with the highest ambition. The update of the NDC goal in 2020 was not available at the time the PEN 2020-2050 was constructed.

The PEN envisages a growth in energy demand of 21-48% between now and 2050 (a relatively modest average annual growth rate of around 0.5-1.3% per year, implying a very substantial improvement in energy intensity given the assumed long-run GDP growth rate of 3.1-3.5% per year). Under the PEN, oil and oil products are expected to continue to play an important role and the transport sector is considered the main transition sector. The PEN envisages a share of oil products in TES of 34-44% in 2050 (compared to 40% in 2020); 16-27% for natural gas (22% in 2020); 11% for hydrogen; and 15-20% for wind, solar and other non-hydro renewables (14% in 2020).

The PEN also estimates total energy system costs of the four scenarios presented, including capital costs of supply technologies, capital costs of end-use technologies and fuel costs. It finds that total energy system costs are the highest in the Disruption scenario (which also leads to the lowest emissions in 2050), at 13% higher than in the Updating scenario. The key driver of the high costs are the modelled high capital cost of low emissions and efficient end-use technologies, while assumed fuel savings are not sufficient to cancel out the higher capital costs. For example, the PEN assumes that EVs will achieve cost parity with internal combustion engine vehicles only around 2035, and that the long-run oil price is around USD 45/barrel (it should be noted that the PEN was elaborated in the middle of the Covid-19 crisis in 2020).

Figure 3.5 Global milestones under the IEA Net Zero Emissions Roadmap



Note: Gt = gigatonne; GW = gigawatt; ICE = internal combustion engine; Gt CO_2 = gigatonnes of carbon dioxide.
Source: IEA (2022).

As the PEN was designed before the adoption of Colombia's E2050 strategy, it is not necessarily aligned with net zero by 2050 goals, while the E2050 is a decarbonisation pathway. The PEN 2020-2050 (Ministry of Mines and Energy) and the E2050 (Ministry of Environment and Sustainable Development) have similar assumptions, but differ in many others, such as economic drivers and the share of the energy sector in the economy.

When updating the PEN, it will be worthwhile examining Colombia's E2050 against the global benchmark, the IEA's Net Zero Emissions Roadmap and its milestones for the global energy sector to achieve net zero emissions by 2050 (Figure 3.5).

Climate change mitigation policies

Carbon pricing

Since 2016 Colombia levies a national carbon tax on the sale, import or consumption of liquid fuels. The tax is levied on the final price of regular motor gasoline, regular oxygenated motor gasoline, diesel and diesel mixed with biofuel for use in diesel engines (Resolution 40112/2021).

The carbon tax (Article 221 of Law 1819/2016) is set according to the carbon content of fossil fuels, including all petroleum derivatives and all types of natural gas used for energy purposes, provided they are used for combustion.

Table 3.3 presents the carbon tax rates as of 1 February 2023 based on Resolution 12/2023.

Table 3.3 Carbon tax rates in Colombia, 1 February 2023

	Rate/unit
Liquefied petroleum gas	COP 152.92/US gal
Kerosene and jet fuel	COP 224.82/ US gal
Coal	COP 59.587/tonne
Fuel oil	COP 271.61/US gal
As of 2024	
Natural gas	COP 36/m^3
Diesel oil (ACPM)	COP 191/US gal
Gasoline	COP 169/US gal

Note: COP = Colombian peso; gal = gallon.

Source: https://www.dian.gov.co/normatividad/Normatividad/Resoluci%C3%B3n%20000012%20de%2031-01-2023.pdf.

The annual revenue from the carbon tax contributes to around 0.5% of GDP and resources are administered by the Colombia in Peace Fund for expenditure on key issues, such as rural development, the fight against coastal erosion, support to protected areas and the National Peace Accord.

Colombia's carbon tax covers around 19% of the country's GHG emissions, according to the OECD effective carbon rates assessment (OECD, 2021), mainly pricing emissions in the transport sector.

The national fuel tax has existed for over 25 years and is applied to gasoline, diesel and all other liquid motor fuels used in vehicles and stationary combustion engines.

In April 2021, the government announced a major tax reform, which planned to extend the coverage of carbon taxation to coal and natural gas. This reform would have resulted in a gradual increase in the prices of coal, natural gas and LPG for electricity generation, assigning different rates for residential and industrial users.[2] Major protests erupted (known as *Paro Nacional*) and the tax reform was withdrawn by the then president.

In August 2022, the Ministry of Finance and Public Credits presented the tax reform plan as President Petro started his term, which was adopted by Congress in November 2022. As of 1 February 2023, a carbon tax at COP 23 394.60 or EUR 5.28/t CO_2-eq, is imposed on all petroleum derivatives and natural gas used for combustion as well as coal. A gradual increase will occur for the tax on coal over time: 0% in 2023 and 2024; 25% in 2025, 50% in 2026, 75% in 2027 and as of 2028 the full rate of COP 59 587/t or EUR 13.46/t.

As fossil fuel exports are exempt from the carbon tax, the reform imposes a 10% tax on income from oil and coal exports that exceed the designated price threshold (USD 48/barrel and USD 87/t respectively).[3]

Colombia's NDC announced the creation of a national emissions trading mechanism (ETS), which could have a reduction potential of 0.73 Mt CO_2 in 2030 (see Table 3.1). The Climate Action Law (2169/2021) consolidates the commitments presented in Colombia's NDC and announces to fully implement the ETS by 2030.

Colombia has a certified mechanism for using GHG reduction and removals offsets to receive an exemption from the national carbon tax. Around 75% of offsets stem from offset activities in forestry and agriculture.

In 2018, the government presented the national programme of tradable GHG emissions quota (PNCTE), but the project is still in the preparatory phase.

The private sector developed a voluntary carbon market, in which each of the carbon bonds exchanged represent one metric tonne of CO_2 that was reduced or neutralised through the development of a GHG emissions mitigation project. These carbon bonds are deductible from the total emissions of the companies and, therefore, from the national carbon tax.

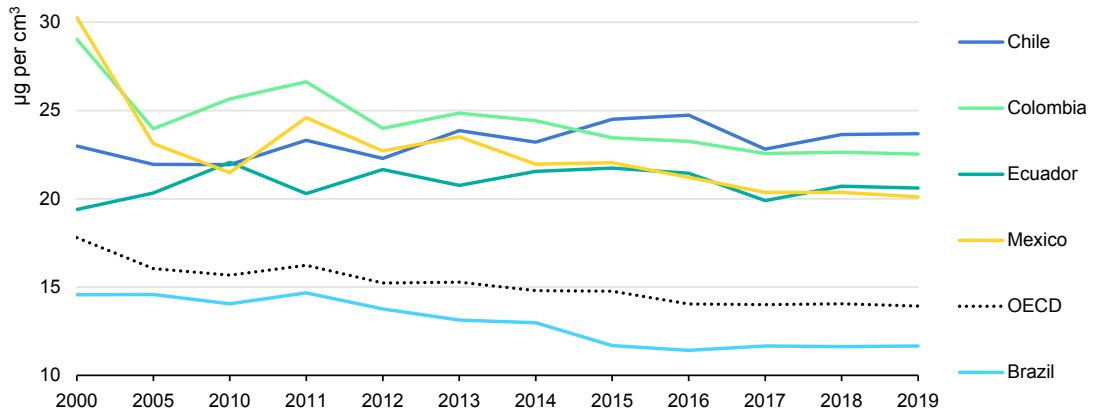
Air pollution

In 2019, Colombia released its National Air Quality Strategy. Colombia has 175 air quality monitoring stations across the territory (MADS, 2021). According to the air quality index,[4] air quality in Colombia, notably in Bogota, has decreased. The major sources of air pollution relate to deforestation, agriculture activity, vehicle and industrial emissions, and construction activity in growing urban areas.

[2] https://www.larepublica.co/economia/pese-a-politica-de-transicion-energetica-la-reforma-tributaria-gravaria-la-energia-solar-3158474.
[3] https://carbon-pulse.com/169353/?utm_source=ground.news&utm_medium=referral.
[4] https://www.iqair.com/colombia.

The OECD highlights that the exposure to pollution in Colombia is higher than the OECD average and of most countries in Latin America. In 2019, the year of the latest data available, the mortality rate associated with air pollution was 260 per million inhabitants, slightly lower than the OECD average (275 per million inhabitants) (OECD, 2020a). Exposure to air pollution in Colombia has been relatively constant since 2000, with 22.53 micrograms per cubic metre (µg/m^3) of fine particles ($PM_{2.5}$) in 2019, higher than the OECD weighted average (14 µg/m^3) (OECD, 2020b).

Figure 3.6 Air pollution in Colombia and selected countries, 2000-2019



Exposure to air pollution in Colombia was 22.53 µg/m^3 of fine particles ($PM_{2.5}$) in 2019, higher than the OECD weighted average (19.93 µg/m^3).

Source: OECD (2020b).

In 2012, Colombia became partner with the Climate and Clean Air Coalition (CCAC) and participates in the Supporting National Action and Planning (SNAP), Bricks, Urban Health and Mineral Methane initiatives from this coalition. Within the framework of the SNAP programme, Colombia developed a National Strategy for the Mitigation of Short-Lived Climate Pollutants in 2018 (MADS, 2020).

The strategy includes the following targets for 2030, which are part of Colombia's NDC:

1) Reduce the consumption and emissions from hydrofluorocarbons by 10% in 2029, 30% in 2035, 50% in 2040 and 80% in 2045, compared to 2020-22 levels. Colombia committed to promoting the replacement of high global warming potential (GWP) refrigerants with low GWP refrigerants.

2) Reduce methane emissions by around 170 000 tonnes by 2030 by capturing methane emissions from open-pit mines and burning biogas recovered from sewage and landfills. The Ministry of Agriculture and Rural Development promotes other measures for the agricultural sector, such as pasture renovation or enteric fermentation.

3) Reduce black carbon emissions by 40% compared to 2014 levels. Targets for $PM_{2.5}$ are under preparation.

Other administrative objectives are included in the strategy for 2022, such as the creation of at least five trained environmental authorities acting in urban and industrial zones; the

integration of a national inventory of black carbon emissions in the forthcoming updated submissions to the UNFCCC; the integration of a monitoring system and the development of a portfolio of actions to mitigate black carbon emissions.

Climate adaptation and resilience

Colombia is highly vulnerable to extreme climate events, such as droughts and floods, especially during phenomena such as El Niño and La Niña, respectively. Over the last 50 years, 90% of the climate disasters in Colombia were associated with hydro meteorological events (GoC, 2012). Particularly heavy rains in 2010-11 associated with La Niña affected 3 million people and costed around 2% of GDP (GoC, 2012), as the First National Adaptation Plan of 2012 outlined.

According to the Institute of Hydrology, Meteorology and Environmental Studies, during the second half of the 20th century, several regions of the country experienced an increase of the average air temperature at a rate of 0.1-0.2°C per decade. The maximum temperatures of the *páramos* mountains, an ecosystem in the Andes mountains above the continuous forest line, yet below the permanent snowline, have been increasing by 1°C per decade. Storms and heavy precipitations are also increasing in most of the country, mainly in the areas of Caribe, Orinoquía, North and South Pacific, and northern Andean region. During the period 1945-85, eight mountain glaciers melted; only four remained in 2018. It is estimated that all Colombian glaciers will have disappeared by 2030.

The average temperature is projected to increase from 1.3°C to 1.8°C by 2050 and annual average rainfall from 0.8% to 1.6%. Extreme rainfall days are also expected to increase from 27% to 37% by 2050 (USAID, 2017). The rise in ocean levels from 0.4 to 0.7 metres threatens cities such as Cartagena and could potentially cause a loss of key ecosystems like coral reefs and fisheries, which are critical to livelihoods.

There has been an upward trend in deforestation for agriculture and urbanisation in Colombia. In 2018, the government implemented a Payment for Ecosystem Services system,[5] which remunerates people who provide environmental services, such as the conservation of a water basin or a forest.

Climate change also represents a risk for the Colombian power sector, as 70% of electricity generation is based on hydroelectric energy. As explained in more detail in Chapter 6, Colombia has implemented a range of reliability mechanisms to ensure back-up capacity for years with low hydropower availability.

According to the IEA special report *Climate Impacts on Latin American Hydropower* (IEA, 2021), the regional mean hydropower capacity factor in Latin America is expected to decline. However, in the Andean region (Colombia, Ecuador and Peru), the increase in annual average rainfall and in the average runoff volume project a slight increase in the hydropower capacity factor. Current climate projections for Colombia suggests a relative maintenance of the hydropower capacity factor by 2100 compared to 1970-2000, but the increase in extreme precipitation events will add stress to operation. The report

[5] https://www.metropol.gov.co/ambiental/Paginas/consumo-sostenible/pagos-por-servicios-ambientales.aspx.

recommended building and strengthening climate risk resilience and public insurance. The private insurance usually covers the damage to physical assets and lost revenue, but not the damage to society, the national economy or attendant costs.

Given its high vulnerability to climate risks, adaptation is a priority for Colombia. Particular attention has been paid to climate change adaptation since the 2010 La Nina event. The Adaptation Fund[6] (Fondo Adaptación) was created in 2011 to face the risks and consequences of natural disasters. This intersectoral entity is in charge of developing projects for climate change adaptation at the regional level. Colombia implemented a national adaptation plan (PNACC) in 2012, which establishes general guidelines for sectoral and territorial entities to include adaptation actions in their planning strategies (GoC, 2012).

The PIGCCME, adopted in 2018 and updated in 2021, sets out four strategic areas for future work on adaptation (MME, 2021a):

1) Resilient infrastructure: integrates the risk management of climate change and climate variability, which may affect the country's energy security; in particular, the transportation of hydrocarbons, coal and inputs for the energy mining activity on the country's highways and the transmission of electricity. Includes climate risk in pipelines and transmission lines, and co-ordination with road and port authorities.

2) Short- and long-term planning to promote the progressive incorporation of climate risk management at all levels of planning and decision making in the mining and energy system, both at the sectoral and corporate levels. This aims to strengthen resilience and competitiveness in the face of the effects of climate variability and change. It encompasses the inclusion of risk variables in planning instruments, generating a climate risk assessment and a warning system, and influencing long-term corporate planning with climate change plans.

3) Environment management to support the co-ordination of efforts of public and private actors in the sector for managing climate risks that may occur in the territories with mining and energy development. This includes the use of nature-based solutions to contribute to the conservation of reservoirs and biodiversity.

4) Information for adaptation supports research and updated and accurate information on the threats and impacts of climate change on mining and energy systems, as well as on all those elements involved in the energy transition. This is an important input for short- and long-term decision making.

To reduce climate vulnerability and guarantee energy generation in extreme climate events, the PIGCCme aims to identify the best nature-based solutions to be implemented in a hydropower plant watershed and modelling the hydropower plant energy potential after implementing the nature-based solutions.

The PND 2018-2022 "Pact for Colombia, Pact for Equity" (GoC, 2019b), set a target for the four-year period to reach 100% of departments that implement climate change

[6] https://www.fondoadaptacion.gov.co/index.php/fondo-adaptacion/quienes-somos.html.

adaptation initiatives. The plan acknowledged that climate change adaptation analysis and action are not co-ordinated efficiently and there are no mechanisms to monitor their implementation and effectiveness.

Colombia included adaptation targets for 2025-30 in its 2020 updated NDC (GoC, 2020). The E2050C strategy sets out plans to develop an Integrated Public Health Surveillance and Control System (SIVCSP) and Early Warning Systems (SAT) which would include climatic and non-climatic factors to calibrate the response within and across sectors.

Assessment

Colombia has a less carbon-intensive economy than IEA countries and intensity levels have decreased despite continuous economic growth. From 2000 to 2021, total energy-related CO_2 emissions in Colombia increased by 42%, as GDP per capita had grown by 65%.

In 2021, Colombia emitted almost 80 Mt CO_2 from energy sector activities (fossil fuel combustion). In 2021, transport was the largest emitter in the energy sector, followed by industry, power generation and buildings. The energy sector is not the main driver of GHG emissions; agriculture and deforestation account for around 60% of emissions.

Colombia has increased its government's ambition with respect to climate mitigation. Colombia cannot easily be compared with higher income OECD countries due to its high emissions from deforestation. Nonetheless, a -51% target is a very ambitious goal and it is unconditional, a rare commitment by non-Annex I parties of the UNFCCC. An emissions reduction from around 300 Mt in 2018 to 169.4 Mt in 2030 implies a reduction of 43% in 12 years, compared, for instance, with the -55% EU target over 40 years.

Colombia seeks to mitigate 176 Mt CO_2-eq by 2030 compared to the baseline, through mitigation actions set out under the updated NDC, presented at COP26 and legally enshrined in the Climate Action Law and PIGCCS, with a major contribution estimated from the LULUCF sector (100 Mt) and actions at the territorial level.

Long-term strategy and energy sector response

While important first steps have been taken to legislate the 2030 and 2050 targets in the Climate Action Law, the 2050 net zero target is not yet fully reflected in near-term policy making.

Colombia has a range of high-quality medium- to long-tem scenario-based strategies and several voluntary and mandatory instruments for setting mitigation targets and policy approaches, including the PEN, PIGCCme 2050, E2050 and NDC. Greater consistency is needed among those plans and strategies in terms of scenarios, visibility of action and derived mitigation targets.

In November 2021, Colombia presented its long-term development strategy at COP26 in Glasgow following a broad range of consultations with experts, industry and academia at large, securing the overall buy-in from Colombian society on a pathway to net zero emissions by 2050. The IEA is impressed by the degree of public engagement in the technical analysis supporting the E2050. Both the E2050 and the PEN display a high

degree of sophistication in terms of the technical modelling analysis, as well as the carefully considered scenario design that allows an evaluation of key policy goals, drivers and uncertainties.

The E2050 highlights a number of challenges of moving towards net zero by 2050. These include the low level of electrification of final energy consumption; the need to ensure continued economic growth and the provision of services to the Colombian population; the challenge of stopping illegal deforestation; and uncertainty in the future costs and performance of some low emissions technologies such as carbon capture, utilisation and storage (CCUS), advanced biofuels and low-emission hydrogen.

The latest PEN was elaborated prior to the adoption of the E2050 and based on the NDC. The E2050 explicitly acknowledges that the PEN is not yet aligned with the goal of net zero by 2050. The next update to the PEN will be carried out after the PND 2022-2026 is finalised.

Colombia's NDC states that it would establish carbon budgets for the 2020-30 period no later than 2023. Carbon budgets have been useful frameworks for medium- and long-term climate policy making in IEA countries. In Colombia, more specifically, they could be used to bridge the relatively concrete 2030 approach and the yet more indicative approaches for reaching the 2050 ambition. It would also be an opportunity to better align the E2050, PEN and NDC scenarios with the implementing framework of the PIGCCME.

For instance, the IEA noted a disconnect between the energy scenarios and plans underpinning the NDC target of a 51% emissions reduction by 2030 and the net zero goal by 2050. None of the PEN scenarios presents a pathway for the energy sector to fully contribute to this target and there is no clarity on the sectoral pathway for Colombia's oil/gas production and coal mining under the net zero by 2050 goal.

Colombia could benefit from the development of a normative energy system scenario that is consistent with the legislated goal of net zero emissions by 2050, set out in the Climate Action Law (2169/2021). Such a normative scenario would help orient all actors around this goal, ensure consistency between short- and long-term actions, and reveal the actions needed to achieve the goal. This normative scenario could co-exist alongside regularly updated reference scenarios, similar to the IEA's approach of combining reference and normative scenarios.

The PEN is framed as a living document. A regular scenario exercise with continually updated fuel price and technology assumptions could reveal interesting evolutions. For example, the IEA's analysis shows a much earlier point of competitiveness of EVs (already today in many vehicle markets). It also shows that more ambitious decarbonisation scenarios need not have excess energy system costs in the longer term compared to a reference scenario, due to the substitution of investment costs and fuel costs.

The energy system results of the E2050 display a number of possible weaknesses that are sometimes common to the results of integrated assessment models such as the Global Change Analysis Model. For example, the very high share of electricity in final consumption (around 70%) is substantially higher than in the IEA's Net Zero Emissions by 2050 Scenario, which sees a 50% share of electricity globally. In the IEA's experience, integrated assessment models sometimes do not represent end uses at a sufficient level

of granularity to reveal the barriers to deep electrification (for example, in very high-temperature process heat; long-distance, heavy-duty road transport; or fossil fuel feedstocks to industry).

These analyses still do not address a number of important policy areas related to the energy transition to net zero emissions. These include the energy security implications of the scenarios studied in terms of imports and exports; international linkages in fuel and technology markets; and socio-economic considerations such as affordability, job creation, subsidy regimes and fiscal implications. Addressing these questions may require building new modelling tools or modules over time, as it is unlikely that a single model would be able to adequately represent these different issues.

The consistency of the long-term scenarios and the medium-term oil, gas and coal projections will be an important part of the net zero analysis (modelling and sectoral pathways). President Petro aims to reduce Colombia's reliance on fossil fuels and change the economic approach. By switching to an economy based on critical minerals production and exports, Colombia could expand its revenues and make up for lower revenues from coal mining and exports.

Alongside the analysis of socio-economic implications, the goal of net zero emissions raises new questions for policy and energy modelling and analysis. Particularly important among them is the issue of sector coupling and its implications for energy security, energy system operation and energy costs.

Climate change mitigation

Representatives of Colombia's energy associations, non-governmental organisations and universities reached an overall broad agreement with the ambitions of the Climate Action Law. Stakeholders called for a comprehensive clean transport policy, greater cost effectiveness in implementation and a stable policy framework while acknowledging that the energy sector emits less than a third of total GHG emissions. Furthermore, they observed that Colombia's energy transition has just begun. The government has developed important policy instruments, but a balance between different policy instruments and energy policy goals still needs to be found. The government needs to provide more guidance and direction on the role of energy efficiency, renewables (non-conventional) and other technologies.

Colombia currently does not have an ETS but plans to introduce one, as stipulated in the NDC. There are already some voluntary schemes (a tradable GHG emissions quota programme, a voluntary private sector carbon market) in conjunction with the carbon tax. Colombia levies a national carbon tax on liquid fuels and natural gas used by refineries or the petrochemical industry. Coal and other solid fuels are covered from 2023 onwards. In November 2022, the new government's tax reform was adopted, which will see the introduction of a 10% tax on coal and gas exports.

Although the volume of this voluntary CO_2 market is relatively small, Colombia has seen positive results from its carbon tax exemption mechanism and wholesale energy distributers' voluntary carbon credits projects, mainly for projects in forestry. International validators have contributed to a system in which the energy sector contributes to reducing deforestation. It would be very useful to expand this to a system of reforestation.

Coal is Colombia's second-largest export product, contributing 13.7% of total exports and 0.74% of GDP. Coal production is of significant importance in two regions in particular, accounting for more than one-third of regional GDP (see Chapter 7). Some 90% of coal production is for export; only 10% is for national consumption – coke, electricity and cement being the biggest consumers. Coal is important for the Colombian economy and the country has large reserves. Coal exports are not part of the national emissions reduction target, consistent with the production-based emissions accounting approach followed in international climate negotiations. However, exported fuels also contribute to global emissions and global warming is a joint problem of consuming and producing countries.

The IEA believes the government also has a responsibility to make credible approaches in this regard to become a real global frontrunner in climate policy. Several actions are under way to improve the efficiency of production, to shift to mining of critical minerals needed for the global energy transition (see Chapter 7). The introduction of a carbon tax on coal consumption is a welcome step but will need to be accompanied with policy measures to boost clean energy investment in the coal-using sectors, such as power generation and industry.

However, more action is needed to understand and plan for Colombia's role in global coal markets. Indeed, in a world aiming at "holding the increase in the global average temperature to well below 2°C and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels," as formulated in the 2015 Paris Agreement, coal use has to be largely phased out before 2050, unless its GHG emissions are fully captured and stored. Imposing a tax on coal exports is another welcome reform the government is undertaking.

Colombia could engage globally on technology development for CCS, notably in developing economies where the coal power fleet is still young and such investment economical. The new 10% tax on income from coal exports that exceed the designated price threshold (USD 87/t) could help raise funding for the coal industry's transition and technology development and investment, including in developing economies.

Air quality and climate resilience

Air quality in Colombian cities remains a pressing issue, notably fine particulate matter, and levels are higher than the OECD average. In 2019, Colombia released its National Air Quality Strategy. Currently, the country has 175 air quality monitoring stations across the territory.

Colombia's NDC also contains targets for climate adaptation, a novelty internationally. The energy sector's climate risks relate to water shortage, flooding, sea-level rise and storms. The government has conducted a robust climate resilience risk evaluation, identified concrete adaptation actions for 2025-30 under its NDC and four areas of action under PIGCCme. In particular, the increasing effect of El Niño, which leads to lower availability of important hydropower, poses a huge risk. The government approaches this by diversifying the electricity mix and concluded voluntary agreements with the generation sector. The Carbon Neutral Electricity Sector was the first example of such an agreement and should be expanded to also include thermal generators.

A particular challenge for Colombia is the phenomenon of El Niño and the resulting low hydro availability. Analysing these kinds of issues in the context of a net zero road map

would require subannual modelling combining an integrated analysis of the electrical, natural gas and end-use systems. Colombia should continue to invest in modelling and analytical tools, which would enable a more detailed analysis of the high degree of sector coupling implied by net zero as well as the impacts of increasing climate change.

Another critical area of climate resilience is the analysis of the robustness of an electricity system based almost entirely on hydro, wind and solar power in 2050. A detailed modelling of electricity system capacity expansion and subannual operation could possibly find the need for more dispatchable flexibility sources, particularly if stress-tested against the low hydro availability in an El Niño year. These considerations demonstrate the importance of complementing the integrated assessment used to develop the E2050 with dedicated energy sector modelling, using more disaggregated tools to develop an energy sector road map to achieve net zero emissions.

Recommendations

The government of Colombia should:

- Ensure greater co-ordination, consistency and readability of medium-term mitigation targets, for instance by adopting a carbon budget approach and just energy transition analysis and ensuring the net zero target serves as a clear benchmark for near-term policy making in the energy sector, including for updating the Nationally Determined Contribution, the PIGCCme and the National Energy Plan and the Just Energy Transition and Net Zero Roadmaps.
  - Review and update the PEN into an energy sector road map to achieve net zero emissions, including by developing a framework with normative and reference scenarios, to enhance its role as a guide for policy making in all energy sub-sectors, notably mining and oil/gas.
  - Regularly update the PEN with the latest global technology, innovation and energy market trends and improve related domestic data collection. Updates to the PEN should also take existing policies and near-term sectoral plans and socio-economic implications of pathways to net zero emissions into account.
- Translate the energy-sector emissions reduction goals for 2030, as stipulated in the NDC and the Climate Action Law, into clear energy transition targets for different supply and demand sub-sectors. Develop a solid policy package for their implementation.
- Devise a comprehensive economy-wide implementation process to reach Colombia's significant climate ambition, building on the PIGCCS. Prioritise all cost-effective measures to meet the 2030 targets, taking the 2050 net zero ambition into account and monitoring progress.

- Based on consultations, define sectoral net zero transition pathways for Colombia's oil/gas production and mining sectors, considering its domestic end use and exports, economic contribution, especially to mining regions, global coal consumption trends and the need to meet the targets under the Paris Agreement. Support global technology collaboration on investment in carbon capture, utilisation and storage in developing economies.

References

GoC (Government of Colombia) (2021a), Third Biennial Update Report (BUR3) (in Spanish), https://unfccc.int/sites/default/files/resource/BUR3%20-%20COLOMBIA.pdf#page=15.

GoC (2021b), E2050, Colombia's Long-Term Strategy, https://unfccc.int/sites/default/files/resource/COL_LTS_Nov2021.pdf.

GoC (2020), Colombia's Updated Nationally Determined Contribution (NDC) (in Spanish), https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20actualizada%20de%20Colombia.pdf.

GoC (2019a), National Electric Mobility Strategy, https://archivo.minambiente.gov.co/images/AsuntosambientalesySectorialyUrbana/pdf/Estrategia-Nacional-de-Movilidad-Electrica-enme-minambiente.pdf.

GoC (2019b), National Development Plan 2018-2022, https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=93970.

GoC (2012), First National Adaptation Plan (in Spanish), https://www4.unfccc.int/sites/NAPC/Documents/Parties/Colombia%20NAP%20Spanish.pdf.

IEA (International Energy Agency) (2023), IEA World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

IEA (2022), An updated roadmap to net zero by 2050, https://www.iea.org/reports/world-energy-outlook-2022/an-updated-roadmap-to-net-zero-emissions-by-2050.

IEA (2021), Climate Impacts on Latin American Hydropower, https://www.iea.org/reports/climate-impacts-on-latin-american-hydropower.

MADS (Ministry of the Environment and Sustainable Development) (2021), "Colombia has 175 air quality monitoring stations", press release, https://www.minambiente.gov.co/asuntos-ambientales-sectorial-y-urbana/colombia-tiene-175-estaciones-de-monitoreo-de-calidad-del-aire.

MADS (2020), Progress report, National strategy for the mitigation of short-lived climate pollutants (in Spanish), https://www.minambiente.gov.co/wp-content/uploads/2022/02/Informe-Avances-ENCCVC_2020_V3.pdf.

MME (Ministry of Mines and Energy) (2021a), Integrated Climate Change Management Plan for the Mining and Energy Sector 2050 (in Spanish), https://www.minenergia.gov.co/documents/6393/PIGCCme_2050_vf.pdf.

MME (2021b), National Energy Plan 2020-2050 (in Spanish) https://www1.upme.gov.co/DemandayEficiencia/Paginas/PEN.aspx.

OECD (2021), Effective Carbon Rates, Colombia 2018-2021, https://www.oecd.org/tax/tax-policy/carbon-pricing-colombia.pdf.

OECD (2020a), Air pollution effects, https://data.oecd.org/air/air-pollution-

effects.htm#indicator-chart.

OECD (2020b), Air pollution exposure, https://data.oecd.org/air/air-pollution-exposure.htm#indicator-chart

UPME (2021), Plan de Expansion de Referencia Generación, Transmisión 2020-2034, https://www.upme.gov.co/Docs/Plan_Expansion/2021/Volumen2_Generacion.pdf#page=107.

USAID (2017), Climate Risk Profile Colombia, Factsheet, https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20CCIS_Climate%20Risk%20Profile_Colombia.pdf.

4. Energy efficiency

Key data (2021)

Total final consumption (TFC): 1 319 PJ (oil 48.5%, electricity 19.2%, bioenergy and waste 14.3%, natural gas 11%, coal 7.1%), +28% since 2011

TFC by sector: transport 39.5%, industry 35.5%, buildings 25.1%

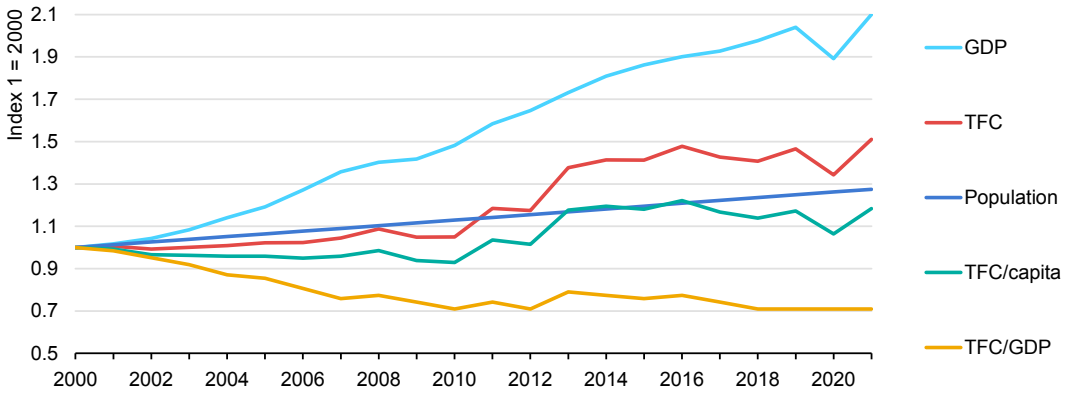
TFC per capita: 0.6 toe/capita (IEA average: 2.9 toe/capita), +14% since 2011

TFC per GDP: 44 toe/USD million (IEA average: 65 toe/USD million), -4.3% since 2011

Overview

Colombia's energy demand is strongly driven by economic and population growth. From 2011 to 2021, Colombia's TFC increased by 28% to 1 319 PJ, driven by a 33% increase in GDP and an increase in population to 50 million in 2021. Energy demand per capita (TFC/capita) rose by 14%.

Figure 4.1 Energy demand and drivers in Colombia, 2000-2021



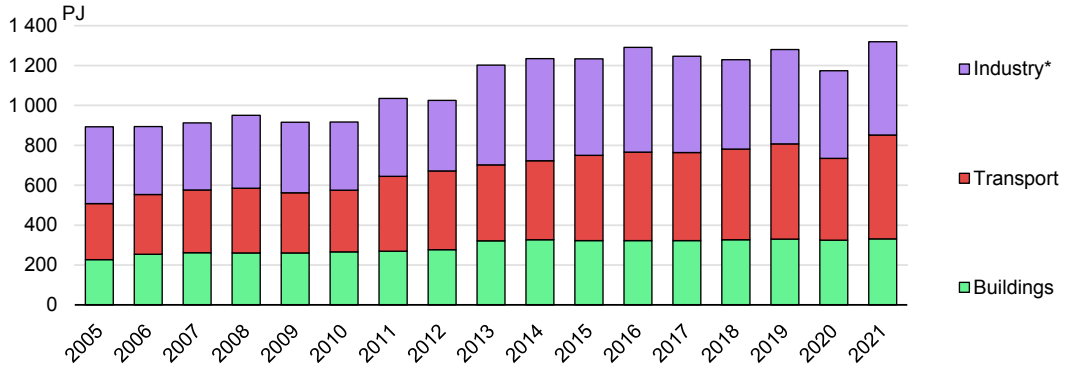
From 2011 to 2021, Colombia's GDP and energy consumption both grew by 28%.

Notes: GDP = gross domestic product; TFC = total final consumption. GDP data are in billion USD 2015 prices and PPPs (purchasing power parities).

Source: IEA (2023).

In 2021, transport accounted for 40% of TFC, followed by industry (36%) and buildings (25%). Between 2011 and 2021, the largest increase in TFC was observed in the transport sector, which rose by 27%. In the same time frame, energy consumption in industry increased by 20% and that in buildings by 23%.

Figure 4.2 Total final consumption by sector in Colombia, 2005-2021



Transport is the largest energy-consuming sector, followed by industry and buildings.

* *Industry* includes non-energy use.

Source: IEA (2023).

Energy efficiency targets and strategies

The National Development Plan 2022-2026 includes energy efficiency actions as part of its productive transformation and climate action priority.

In 2018, the Colombian government commissioned the "useful energy balance study" (BEU) to identify the energy efficiency potential by sector (UPME, 2018). The BEU indicated that useful energy is only 31% of total energy consumed, with a consumption inefficiency of around 67% (including inefficient energy and losses). It found that best available technologies (BAT) could reduce these inefficiencies by 38-62%.

The MME holds the main responsibility for determining energy efficiency policy in Colombia. CIURE (Intersectoral Commission for Rational and Efficient Use of Energy and the Use of Non-conventional Energy Sources), created in 2003, advises and assists the ministry in co-ordinating energy efficiency policies.

Law 697/2001 created the legal framework for the support of rational and efficient use of energy and clean energy sources (solar, wind, geothermal, biomass and small hydro) and introduced the Programme for the Rational and Efficient Use of Energy (PROURE) with minimum efficiency levels. The government implemented this programme through the Action Plan of Energy Efficiency (PAI PROURE) for the period 2017-22. There is no analysis available about the progress or results of the programme with regard to meeting energy efficiency targets.

In 2021, the MME adopted an Indicative Action Plan of Energy Efficiency (PAI PROURE) for the period 2022-30. The objective is to achieve energy savings of approximately 10% compared to a business-as-usual scenario, equivalent to total energy savings of 1 688 PJ. The highest contribution to total energy savings would come from the transport sector, followed by residential buildings and industry (Table 4.1). The plan also includes a target of decreasing the energy intensity of the economy from 2.23 terajoules (TJ)/USD million in 2019 to 1.79 TJ/USD million in 2025 and 1.6 TJ/USD million in 2030, with respect to a business-as-usual scenario (UPME, 2021).

Table 4.1 Colombia's energy savings targets by 2030

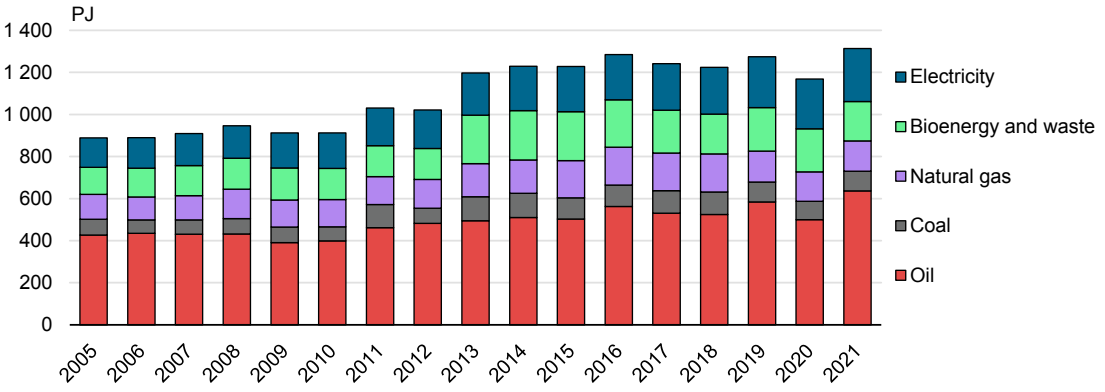
Sector	Energy savings goal (PJ)	Energy savings goal (%)
Transport	673.33	4.00%
Residential buildings	523.07	3.11%
Industry	256.36	1.52%
Service buildings	131.71	0.78%
Others	104.07	0.15%
Total	**1 688**	**10%**

Source: Indicative Action Plan of Energy Efficiency 2022-30 (PAI PROURE).

Industry

Industry demand had been relatively stable until 2013, when it experienced a sudden jump driven by increased mining and coal production. Demand has fluctuated since 2013 and reached 466 PJ in 2021. Oil covers the largest share of industry energy demand (31% of industry TFC in 2021), followed by electricity (23%), coal (19%), bioenergy and waste (14%), and natural gas (13%). The main industrial sectors are food and tobacco (28% in 2021); non-metallic minerals (16%); chemical and petrochemical (14%); mining and quarrying (13%); paper, pulp and print (7%); iron and steel (5%); textile and leather (2%); and others (15%).

Figure 4.3 Total final consumption in industry by source in Colombia, 2005-2021



Colombia's industry energy demand surged in 2013 due to higher fossil fuel production.

Notes: PJ = prtajoule. Includes non-energy use in the chemical and petrochemical sector.
Source: IEA (2023).

Policies and measures in the industry sector

According to the BEU, one of the most important challenges in the industry sector is the optimisation of heat processes, as they account for 88% of the energy consumed. An improvement in the energy efficiency of boilers and furnaces would yield a 20% improvement in efficiency in the sector, according to the study.

Industrial companies can benefit from a tax discount of 25% on investments improving energy efficiency. In addition, value-added tax (VAT) is excluded on machinery and equipment for energy efficiency projects. A 50% tax deduction is granted to investments for a period of up to 15 years.

Energy-intensive companies can undertake energy audits on a voluntary basis. The audits highlighted that the benefits of implementing the measures identified are 93 times higher than the costs. A regulatory impact analysis conducted in February 2022 identified the need for making energy audits in large industries mandatory.

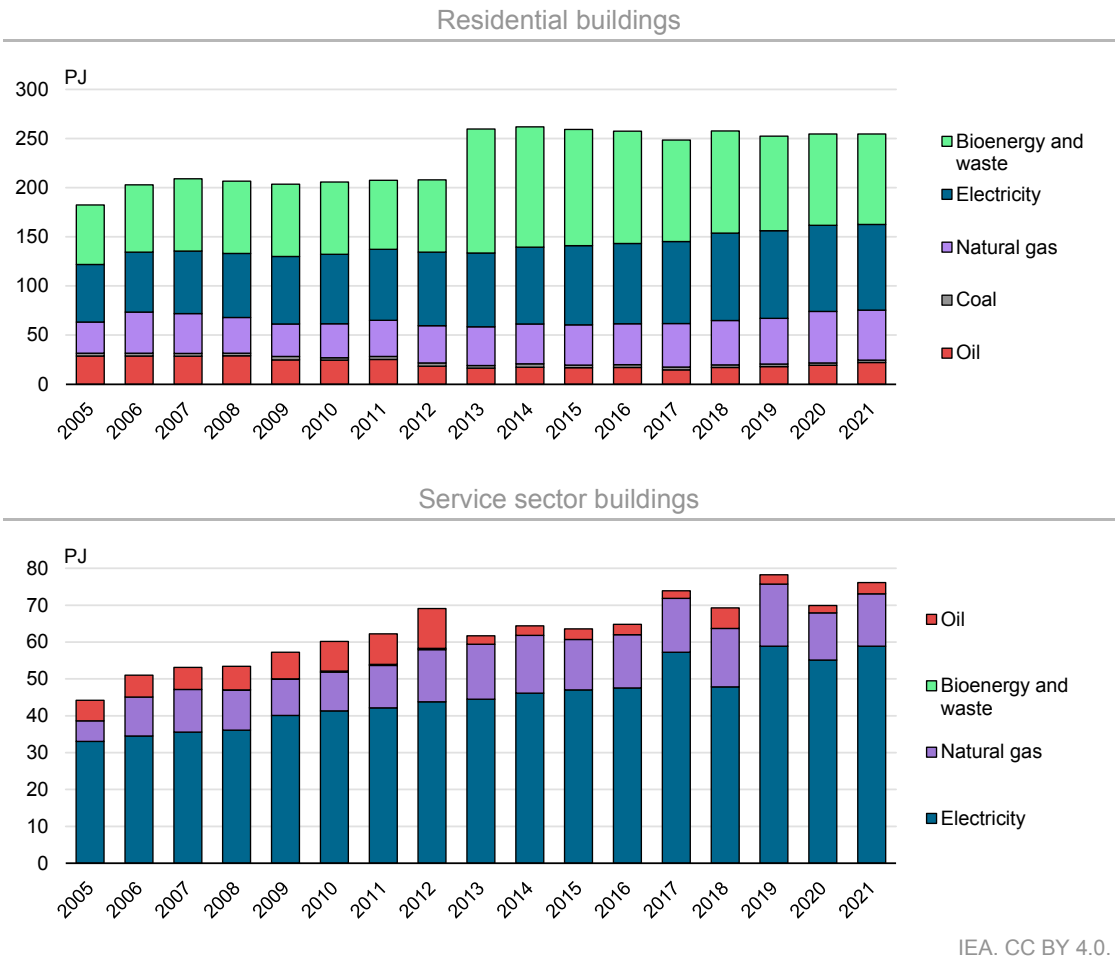
The government also organises training programmes to improve knowledge about potential energy savings. Between 2015 and 2019, training was completed on energy management systems (including design and implementation of ISO 50001 standards), optimisation of energy end-use systems and certification of competences for implementers.

Buildings and district heating

Energy demand from buildings reached a maximum of 331 PJ in 2021. Energy demand in the sector stems mostly from residential buildings (78% of buildings TFC in 2021), while service sector buildings (including both commercial and public services) accounted for 22%. Energy demand from buildings was relatively stable until 2013, when it increased significantly, with bioenergy and waste in residential buildings accounting for most of the increase (Figure 4.4).

Bioenergy and waste (mainly firewood) is the main energy source for residential buildings (36% in 2021), followed by electricity (34%), natural gas (20%), oil (9%) and coal (1%). In contrast, electricity is the main energy source for service sector buildings (77% in 2021), followed by natural gas (19%) and oil (4%). Cooking is responsible for most residential building energy demand (67% in 2015), followed by residential appliances (16%), cooling and refrigeration (12%), and water heating (5%). Cooking is mainly fuelled by natural gas (in cities), LPG (the main fuel in unconnected areas) and firewood (used by half of the rural population).

Figure 4.4 Total final consumption in buildings by source in Colombia, 2005-2021



Energy demand in buildings increased by 23% between 2011 and 2021, with residential buildings covering more than three-quarters of building energy demand.

Notes: Bioenergy and waste figures are not visible in the service sector buildings chart.
Source: IEA (2023).

Policies and measures in the buildings sector

The BEU estimates a potential for energy efficiency improvements in the residential sector of around 30% if BATs at the national level are used. Most of the energy efficiency improvement potential in the sector relates to improvements of cooking appliances, as the use of firewood for cooking is common in rural areas in Colombia. Clean cooking has been a priority under the Sustainable Development Goals (SDGs) as part of energy access. The integration of energy efficiency and renewable energy use is consistent with the SDG agenda.

In the residential sector, the 2017-2022 PAI PROURE promoted the substitution of wood in rural areas, the replacement of natural gas cookers with electric induction cookers and the installation of better performing cookers. It also refers to the replacement of refrigeration appliances (UPME, 2016).

The PND 2022-2026 provides for the creation of a clean cooking programme for the substitution of firewood, charcoal, and waste by transition sources, including renewables, LPG and natural gas.

The Energy Labelling System for Buildings establishes standard procedures to certify the energy performance of buildings in their design and operational stage.

Regulation 549/2015 regulates the parameters and guidelines of sustainable construction. Colombia also has a guide for saving water and energy in buildings.

The PND 2022-2026 requires an energy audit of all government administrative facilities every four years and energy saving targets to be achieved through energy efficiency measures and the deployment of non-conventional renewables (GoC, 2023). UPME will be in charge of establishing the baselines and reporting of progress. The year after the energy audits each entity shall implement strategies for savings in energy consumption of at least 15% with respect to the consumption of the previous year. From the second year, objectives defined by the audit shall be implemented and achieved by 2026 at the latest.

Appliances, equipment and lighting

Since 2016, the RETIQ regulation made energy efficiency labels mandatory for refrigerators, indoor air conditioners, induction motors, lighting, washing machines, heaters and food cooking equipment. RETIQ also established progressive minimum energy efficiency standards, which are currently in place for industrial engines and household refrigerators.

Since 2018, VAT has been reduced from 19% to 5% for the purchase of high-efficiency refrigeration equipment, provided an older appliance is scrapped. Similarly, VAT is excluded for the purchase of high-efficiency air conditioning equipment.

Local governments have implemented policies providing the replacement of incandescent and fluorescent bulbs with LED bulbs. LED bulbs are provided for free to low-income consumers if they return their older bulbs. For example, from 2020 to 2022, FENOGE replaced more than 197 000 light bulbs and 7 900 refrigerators and air conditioners with high-efficiency models.

Thermal districts

In 2013, Colombia developed a thermal district strategy, with the aim of promoting the creation of thermal districts providing district cooling to groups of buildings. There are currently four thermal districts in Colombia providing district heating or (mainly) cooling. Co-generation plants using natural gas have been operating in Medellin since 2016 and in Montería and Cartagena since 2018. In the same year, an industrial thermal district operated by Air Liquide started operation in the suburbs of Bogota, using electricity and natural gas. Four additional projects are currently under study, including the potential use of renewable energy sources.

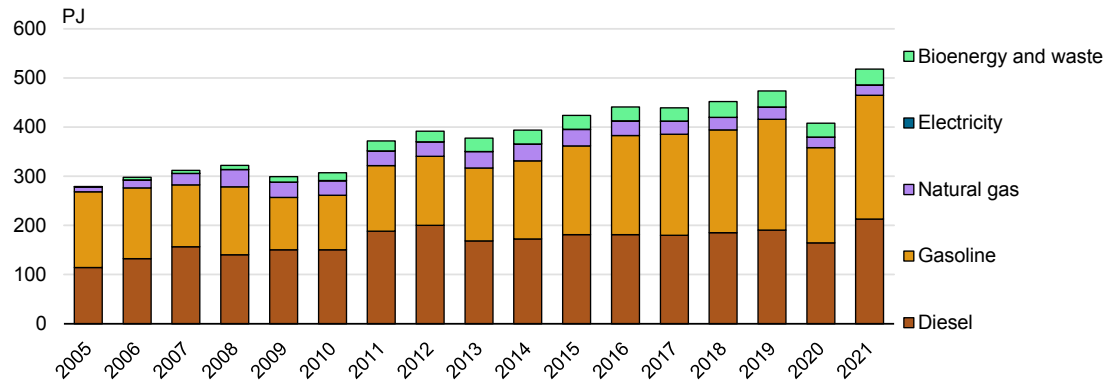
Transport

Transport sector energy demand consistently increased until 2019, when it reached 474 PJ. In 2020, demand from the sector dropped to 409 PJ due to the Covid-19 pandemic and increased again to 518 PJ in 2021 (Figure 4.5). Most transport energy demand is

covered by oil products, mainly gasoline (49% of transport TFC in 2021), and diesel (41%). Biofuels accounted for 6.2% of transport TFC in 2021 and natural gas accounted for 4%. From 2011 to 2021, transport sector demand for biofuels increased from 20 PJ to 32 PJ. Biofuels in Colombia consisted mainly of biodiesel (74%) and bioethanol (26%) in 2021. Most energy demand in the transport sector comes from road transport (99%), with small shares of pipeline transport (0.7%), domestic navigation (0.2%) and aviation (0.1%).

The deployment of EVs has seen strong growth, from 1 695 in 2018 to 7 537 in March 2022, overachieving the government's target of 6 600 EVs for 2022 (Figure 4.6).

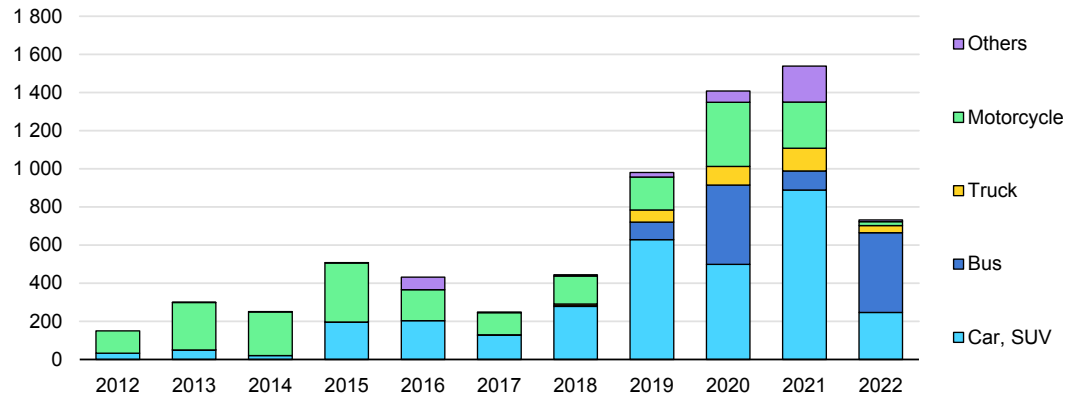
Figure 4.5 Total final consumption in transport by fuel in Colombia, 2005-2021



Since 2011, Colombia's transport sector energy demand increased by 39%, half of which is covered by gasoline.

Notes: Transport sector demand excludes international aviation and navigation.
Source: IEA (2023).

Figure 4.6 Newly registered electric vehicles in Colombia each year, 2012-2022



By March 2022, in total, there were 7 537 electric vehicles in Colombia, surpassing the government's target of 6 600 registered vehicles in 2022.

Source: Ministry of Transport of Colombia.

In 2021, there were 11.2 million registered vehicles using gasoline and 715 000 using diesel. Motorcycles are the most common type of vehicle in Colombia (7.7 million), followed by automobiles (2.4 million). As of March 2022, there were 7 537 registered EVs in Colombia, including cars, motorcycles, trucks and buses (Figure 4.6).

Policies and measures in the transport sector

The transport sector, according to the BEU, has the highest end-use inefficiency (69%). Technological improvements, adopting BATs at the national level, correspond to potential efficiency improvements of 50%.

The 2018-2022 PND "Pact for Colombia, Pact for Equity" (GoC, 2019a) included an update of the energy labelling regulations and schemes, including vehicle labelling and the introduction and definition of energy efficiency standards for new and used light and heavy vehicles.

In 2019, the Colombian government introduced measures to promote electric mobility, including the liberalisation of imports of EVs under Decree 2051 (abolishing the existing unit limits), no import tariffs (rate of 0%), discounts on the vehicle tax (which cannot exceed 1% of the market price of the vehicle) and a reduction from 35% to 5% of the tariff levy for the import of natural gas vehicles without any unit limit. Law 1819/2016 decrees that electric and hybrid vehicles have a reduced VAT rate of 5%. Decree 1116/2017 establishes temporary import duties of hybrid vehicles for a maximum of 26 400 units between 2017 and 2027. There is also a 10% discount on mandatory insurance and technical check-ups, promotion of charging infrastructure, exclusive parking spaces in public places and access to limited traffic areas. Colombia also presented an air quality improvement policy (CONPES 3943/2018), which proposes promoting low-emission vehicles through labelling, tax incentives and systems for the disposal of internal combustion vehicles.

These policies have allowed the number of EVs (battery and plug-in hybrid) to increase quickly. From 2 165 in 2018 to 7 537 in 2022. The government aimed to reach a total of 600 000 registered EVs by 2020 as part of the National Electric Mobility Strategy of 2019 (GoC, 2019b).

There are practically no passenger trains in Colombia and the only metro system in the country is in Medellín. Buses are the most popular means of public transport. In 2018, with the largest bus delivery ever, the public transport company of Bogota (TransMilenio) acquired 481 Euro VI gas fuelled buses. In 2021, there were 1 485 electric buses in operation in Bogota (Transmilenio), 69 in Medellin (Metroplus) and 35 in Cali (MIO).

As part of the 2022-2026 PND, the government makes sustainable transport a key plank of its programme pillar 'Productive transformation, internationalisation and climate action'. It has plans to establish new incentives and mechanisms to finance sustainable mobility and low-carbon transport.

Under the Hydrogen Roadmap, the MME has an objective to increase hydrogen use in freight, heavy and long-distance transport, with 1 000-1 500 heavy vehicles and 1 500-2 000 light fuel cell vehicles running on hydrogen and 50-100 public hydrogen stations.

Assessment

Colombia's energy consumption is still increasing and fully driven by economic and population growth; there has not yet been a decoupling. From 2011 to 2021, Colombia's GDP and energy consumption both grew by 28%. Transport accounts for the largest part of TFC (40%), followed by industry (36%) and buildings (25%). However, Colombia's TFC per capita is 57% lower than the IEA average and TFC per GDP is 37% lower.

The government estimates that the country's demand could grow by 21-48% to 2050, assuming different economic growth scenarios. Its 2020 NDC estimates that energy demand mitigation will deliver savings of 13.81 Mt CO_2. This demonstrates the huge challenge and opportunity ahead for energy efficiency.

In 2018, the government commissioned the "useful energy balance study" to identify the energy efficiency potential by sector. The BEU indicated that useful energy is only 31% of the total energy consumed, highlighting great potential for energy efficiency.

In 2021, the government adopted the PAI PROURE for the period 2022-30, setting goals to achieve energy savings of approximately 10% compared to a business-as-usual scenario. The greatest contribution to total energy savings is required from the transport sector (4%) and residential buildings (3%), while savings in industry (1.5%), commercial and services sector and others (1.5%) are not priorities.

The Colombian government has identified the opportunities for reducing energy demand and the importance of energy efficiency to its economy and the energy sector. It has also introduced energy efficiency strategies and policies, making good progress against its goals in EV deployment, for example. However, the lack of detailed data and policy evaluation of energy efficiency progress from the action plans and programmes mean that the potential or actual benefits of those policies are not clear in many cases, and it is not evident that the goals for 2030 are realistic.

As Chapter 2 described, Colombia maintains a system of subsidies for electricity, gas and, in practice, transport fuels. The Fuel Price Stabilisation Fund, while theoretically fiscally neutral, has been in deficit since 2011, acting as a fuel subsidy. These subsidies undermine incentives for reducing demand. This means that certain energy efficiency policies and incentives are hampered by price subsidies, increasing the fiscal burden on the state as well as slowing demand reduction.

Price support for certain demographic groups is understandable, as social policy and such support will not be removed rapidly. However, significant demand reduction requires investment and behavioural change and becomes more difficult once the most cost-effective measures are installed and the pool of early adopters exhausted. Colombia will not make the necessary progress in energy efficiency over the longer term until it has the right price signals in place.

Industry

Industry energy demand has slightly increased since 2013, reaching its highest level in 2016. Oil covers the largest share of industry energy demand, followed by coal, electricity, bioenergy and waste, and natural gas.

The BEU identified the optimisation of heat processes as a key opportunity for energy efficiency in industry, as they account for 88% of the energy consumed in the sector. According to the study, improving the energy efficiency of boilers and furnaces would yield a 20% improvement in efficiency in the sector.

There are several tax incentives for industry to invest in energy efficiency, namely: a 25% tax discount on investments in energy efficiency; no VAT on machinery and equipment for energy efficiency projects; and a 50% corporation tax deduction on investments in energy efficiency for a period of up to 15 years. On a voluntary basis, energy-intensive companies can undertake energy audits, which could save 574 gigawatt hours (GWh) per year (with a cost-benefit ratio of 93), according to a recent study for the MME, which is considering making the audits mandatory.

While the above policies should be effective in incentivising cost-effective demand reduction, awareness of them is not universal among potential beneficiaries and accessing them can be complex and time consuming, including for businesses having to deal with multiple government bodies. Improving information provision and working with industry to simplify processes would be a low-cost method of driving more energy efficiency investments.

The government has identified the lack of knowledge about energy efficiency potential as one of the key barriers to deployment and intends to introduce mandatory energy audits for large consumers as a way of ensuring businesses are informed about the cost-effective measures they could take. To ensure that businesses are empowered to follow through with the recommended actions, the government should require auditors to provide information on incentives and how to access them. Moreover, the government should introduce requirements to improve industrial efficiency over time, with training programmes to help develop skills among industrial energy consumers to deliver energy savings. This way, requirements can work with training and incentives to build capacity and deliver savings over time.

Colombia has already adopted minimum energy performance standards for industrial electric motors at the level of IE3. Given the importance of industrial electric motors in electricity consumption in Colombia, complementing minimum energy performance standards with a replacement programme for old motors can further advance energy savings in the country.

Transport

According to the BEU study, the transport sector has the highest potential for savings. The study highlights that adopting best available technologies at the national level would lead to energy efficiency improvements of 50%.

Improving the energy efficiency of transport is part of the 2022-2026 PND. The national urban and regional mobility policy and national logistics policy are intended to encourage the decarbonisation of multiple modes of transport and save an additional 2.14 $MtCO_2$. The government is currently formulating a national strategy for active transport. It should continue to clarify its vision for the transport sector to be fulfilled by the implementation of specific policies.

The government is due to implement energy labelling for new and used light-duty vehicles, as identified in the PAI-PROURE and the National Electric Mobility Strategy. The MME

intends to define minimum energy efficiency standards for vehicle technologies based on regulatory impact analysis, but has not yet introduced mandatory efficiency standards. However, given the growing energy demand in the transport sector it should maximise its policy levers to improve efficiency and this should include the adoption of fuel economy standards for domestically assembled and imported cars aligned to high international standards.

The government has introduced a National Electric Mobility Strategy, accompanied by specific laws and tax incentives, including discounts on the vehicle tax and mandatory insurance check-ups, reduced VAT rate of 5%, promoting charging infrastructure, and advantages for parking and access to limited traffic areas. This has led to a rapid increase in the number of EVs (both cars and motorcycles), from 1 695 in 2018 to 7 537 in March 2022, exceeding the government's goal of 6 600 for 2022 and making it a leader in Latin America. For 2030, the government has a goal of 600 000 registered EVs.

While progressing rapidly in recent years from a low base, the adoption of EVs and other low-emission vehicles will take a long time and there are short- and medium-term opportunities to complement that shift with more efficient fossil fuel vehicles. However, the pricing of fuels and costs of car ownership disincentivise that shift. Annual car taxes and insurance requirements are more costly for more expensive and, therefore, newer cars, leading to an old and inefficient vehicle fleet.

A review of existing subsidies should be undertaken to ensure continued support for low-income households while facilitating the shift towards more efficient vehicles. Aggressive fuel economy standards, once introduced, will lower the fuel cost of driving over the next several years, making it important to ensure the uptake of new, more efficient vehicles. The government has a policy for modernising the heavy-duty transport fleet, which includes fiscal incentives for scrapping the oldest heavy-duty vehicles. It should introduce such a scheme for all vehicles, prioritising the oldest and most polluting ones.

Another important focus should be on alternatives to personal vehicles. Better public transport infrastructure and enabling walking and cycling will reduce the need for personal vehicles while improving air quality and helping to meet climate objectives. Therefore, as part of its transport strategies, the government should focus on providing convenient and viable alternatives to vehicle ownership.

Buildings

Energy demand in buildings increased by 23% from 2011 to 2021. Residential buildings account for three-quarters of building energy demand. The remainder comes from the services sector. Bioenergy (mainly firewood) is the main source of energy for residential buildings (36%), followed by electricity (34%) and natural gas (20%). Cooking is responsible for most residential buildings' energy demand and in rural areas it is mainly fuelled by firewood. Conversely, three-quarters of the energy demand in service sector buildings is covered by electricity.

The BEU estimates that energy efficiency improvements can reduce energy consumption in the residential sector by 30%, mostly by replacing firewood – used by around 1 million rural households – with natural gas, LPG and electricity. In addition to reducing energy demand, this would improve indoor air quality with the consequent improved health outcomes, making it a wider social as well as an energy issue. However, the wood being replaced is gathered for free, so users will face higher costs, especially in the absence of

a subsidy. Furthermore, while electric induction cooking is likely to be the most efficient and lowest emissions solution, there are issues with the capacity of the electricity connections, necessary change to cooking vessels and more expensive operation than natural gas or LPG under current prices.

Reducing the use of wood burning in the residential sector is necessary. However, the government should ensure that short-term costs and pricing are not the key drivers and that it does not lock in consumers in expensive, higher carbon-intensive infrastructure and appliances.

Colombia is a member of the Super-efficient Equipment and Appliance Deployment Initiative, a global coalition focused on advancing the energy efficiency of appliances. Colombia signed the Product Efficiency Call to Action at COP26, with a commitment to double the efficiency of four key appliance categories by 2030: air conditioners, refrigerators, lighting and industrial electric motors. Colombia has already made important progress in introducing minimum energy performance standards and labelling for each of these appliance categories. While more efficient appliances save costs over time, they are not always the cheapest option in the market. To help bring down the upfront cost of efficient appliances, the government should consider bulk purchase programmes to accompany existing appliance replacement programmes, particularly for low-income consumers. The government should also continue to lead regional discussions on advancing a shared vision for appliance efficiency in the region, which can help ensure that efficient appliances are available at scale – and therefore at a lower cost to consumers.

The government intends to implement a road map for the energy labelling of buildings and has tax incentives for certain measures to reduce energy demand. The ambition here is commendable and the government is considering best practices to introduce a labelling system, which is fit-for-purpose. Given the high degree of informal construction and complexity in the residential sector, the government should prioritise its initial focus on non-residential buildings. The road map should not stop at labels but consider regulations (such as minimum energy performance of existing buildings at lease or sale) and incentives that work with labels to ensure that efficiency improvements happen. The government should develop a national space cooling road map to address rising energy demand for cooling in buildings.

Since 2016, regulation makes energy efficiency labels mandatory for appliances; the range of appliances included is due to be expanded. In 2017, VAT was removed for the purchase of high-efficiency air conditioning equipment, and in 2018, a reduced-VAT refrigerator scrappage scheme was introduced for households in strata 1-3. Local governments have implemented policies providing the replacement of older light bulbs with LED bulbs, again, based on strata. Despite the lack of data, it nevertheless appears that these policies have been successful; as well as reducing demand, they reduce the need for price subsidies.

The government has an ambitious goal for smart meter deployment, which is important to advance demand-side flexibility and grid efficiency. It will be important that this vision is implemented with opportunities for periodic review and adjustment to ensure that consumers benefit from opportunities associated with grid integration of solar PV, air conditioners and EVs and other flexible end uses, as well as from business opportunities

for metered energy savings programmes. Colombia should consider lessons learnt from other countries and include consumer engagement and reskilling of staff in its roll-out plans.

Since 2019, Colombia has been implementing energy districts for heating and cooling with the objective of reducing the emissions from air conditioning, the demand for which is forecast to grow. Indicators from phase 1 of the programme are positive, including 25% energy and 35% emissions reductions. The Energy Cities and Smart Cities are pilot projects with broad goals including more efficient use of energy. Given the lack of market-wide data, the government should focus on the comprehensive evaluation of the projects, disseminate data and implement the learnings in energy efficiency policies more widely. These projects are all consistent with the four strategic axes of a fair, sustainable and resilient economic recovery post-Covid. The government should therefore aim to provide maximum support for their success and wider deployment.

Recommendations

The government of Colombia should:

Across sectors

- Improve the delivery of policies and tax incentives through better provision of information to intended beneficiaries through simplified and accelerated administrative processes.
- Improve data gathering, public data provision, evaluation and awareness to support policy development and enable all market actors to take informed decisions about energy efficiency.
- Reform energy subsidies and pricing mechanisms to incentivise more efficient use of energy.

Transport

- Adopt ambitious fuel economy standards for imported and domestically assembled vehicles, aligned with international standards.
- Reform vehicle taxation policy to remove disincentives for new vehicles. In addition, introduce a light vehicle scrappage scheme, prioritising the oldest and most polluting vehicles.
- Prioritise electrification of motorcycles to improve air quality in cities. Expand public transport infrastructure and active mobility (walking and cycling) as convenient and viable alternatives to vehicle ownership.

Buildings

- Prioritise energy labelling for non-residential buildings and consider regulations and incentives linked to labels to ensure that efficiency improvements happen.
- Develop a national space cooling road map to address rising energy demand for space cooling in buildings.

- ☐ Implement the commitment to double the efficiency of key appliances by 2030 in line with the COP26 Product Efficiency Call to Action and consider programmes, such as the bulk purchase of appliances, to reduce the upfront cost of new efficient appliances.
- ☐ Maximise support for energy districts and, once evaluated, disseminate the learnings from the Energy Cities and Smart Cities pilots and continue to lead regional discussions to advance a shared vision of appliance efficiency.

Industry

- ☐ Set energy performance requirements for industries, accompanied by training and incentives to help meet these requirements.
- ☐ Introduce a replacement programme for the oldest industrial electric motors to accelerate the penetration of efficient motors.
- ☐ Require energy auditors to supply information to clients on available incentives and how to access them.

References

GoC (Government of Colombia) (2019a), National Development Plan 2018-2022, https://dapre.presidencia.gov.co/normativa/normativa/LEY%201955%20DEL%2025%20DE%20MAYO%20DE%202019.pdf.

GoC (2019b), Estrategia Nacional de Movilidad Eléctrica (National Electric Mobility Strategy), https://archivo.minambiente.gov.co/images/AsuntosambientalesySectorialyUrbana/pdf/Estrategia-Nacional-de-Movilidad-Electrica-enme-minambiente.pdf.

GoC (2023), National Development Plan 2022-2026, General website: https://www.dnp.gov.co/plan-nacional-desarrollo/pnd-2022-2026; Implementing Law 2294 of 19 May 2023: https://colaboracion.dnp.gov.co/CDT/portalDNP/PND-2023/Ley_2294_del_19_de_mayo_de_2023.pdf; Consolidated Text: https://colaboracion.dnp.gov.co/CDT/portalDNP/PND-2023/2023-05-05-texto-conciliado-PND.pdf.

IEA (International Energy Agency) (2023), IEA World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

UPME (Mining and Energy Planning Unit) (2021), Plan de Acion Indicativo PAI PROURE 2022-2030, https://www1.upme.gov.co/DemandayEficiencia/Documents/PROURE/Resumen_ejecutivo_PAI-PROURE_2022-2030_v2.pdf.

UPME (2019), Balance Energia (Energy Balance), https://www1.upme.gov.co/Documents/Balance_energia_util.pdf.

UPME (2016), Plan de Acción Indicativo de Eficiencia Energética PAI PROURE 2017-2022, https://www1.upme.gov.co/Documents/PAI_PROURE_2017_2022.pdf.

5. Renewable energy

Key data (2021)

Renewables in TES: 25% (IEA average: 14%)

Renewables in TFEC: 378 PJ, or 29% of TFEC (IEA average: 14%), hydro (14%), solid biomass (12%), liquid biofuels (2.5%), biomass for electricity (0.5%), solar (0.1%) and wind (0.01%)

Renewables in electricity generation: 63.3 TWh, 74% of electricity generation (IEA average: 30%) hydro (72%), biofuels (2.7%), solar (0.4%) and wind (0.1%)

Overview

Colombia uses substantially more renewable energy than the IEA average. In 2021, renewable energy accounted for 25% of Colombia's total energy supply (TES) and for 29% of total final energy consumption (TFEC), substantially above the IEA average of 14%, three-quarters of which is electricity generation (compared to the IEA average of 30%), thanks to the strong role of hydro and bioenergy.

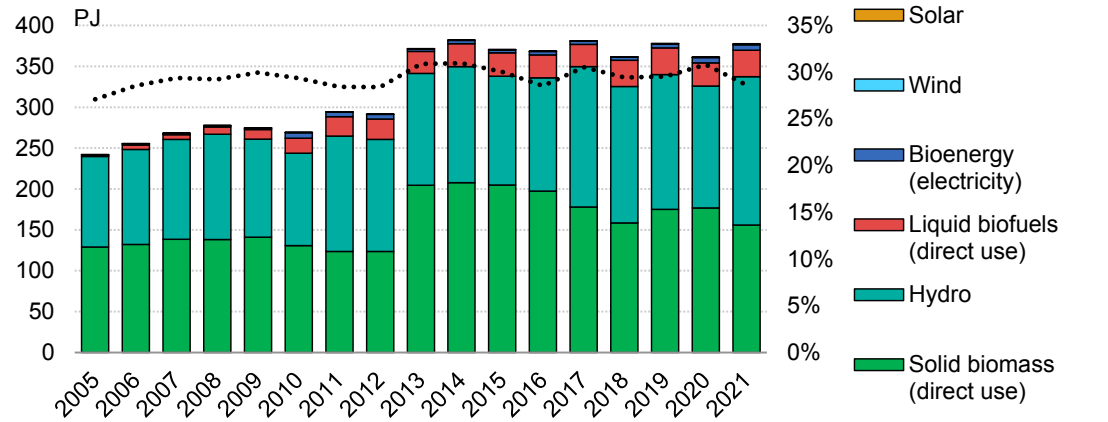
With the commissioning of the Hidroituango mega hydropower plant in 2022, Colombia's installed hydroelectric capacity increased by 1.2 GW. Colombia's position as a large producer of sugar cane and palm oil allowed it to have a relatively high share (6%) of bioethanol and biodiesel in transport final consumption in 2019 (above the IEA average of 4.7%). Biomass remains a key energy source for electricity and heating. Bioenergy and waste (largely firewood) accounted for 28% of Colombia's TFC in the buildings sector in 2021. Solid biomass, mostly bagasse and wood, is used for cooking and heating in off-grid regions. Colombia still has 1 million families, or 6% of households, relying on firewood for cooking, lacking access to modern cooking fuels.

Colombia's hydropower has low storage capacity and extreme weather events (droughts or rainfalls) put stress on the hydropower availability. The policy aim for decades has been to diversify the power generation mix towards a portfolio of non-conventional renewable energy sources (FNCER, or fuentes no convencionales de energía renovable). By 2022, Colombia targeted a share of 12% from non-conventionals in its electricity mix, up from 3.2% in 2021. Since the opening of the first solar PV power plant in 2017 and the relaunching of wind energy in 2022 after a 17-year pause, the PND provides for 2 GW of renewables deployment by 2026. Concentrated in the northern regions, the country has a strong offshore wind potential (50 GW). Despite the large potential along the Pacific ring of fire, Colombia's geothermal development is only just beginning, with two projects and the adoption of a new legal framework.

Trends in renewable energy by sector

Colombia has consistently increased its renewable energy consumption. The overall share of renewables in TFEC increased modestly, from 27% to 29% in the same period. Renewable energy consumption increased sharply in 2013, mostly due to higher solid biomass consumption. Between 2005 to 2021, liquid biofuels increased from 0.6 PJ to 32 PJ.

Figure 5.1 Renewables in total final energy consumption in Colombia, 2005-2021

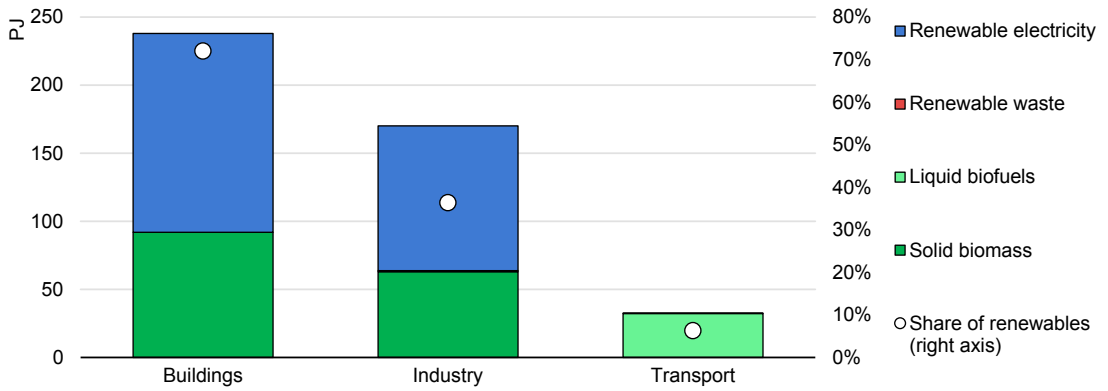


Accounting for 89%, hydropower and solid biomass are the pillars of Colombia's energy use.

Notes: Solar, wind and bioenergy (electricity) figures are very small and not visible on this chart.
Source: IEA (2023).

Colombia stands out among IEA countries for having a large share of renewable energy in TFEC (29% above the IEA average of 14%). They are concentrated in buildings and industry sectors, where renewables represent 72% and 36% of energy consumption, respectively. Renewable energy accounted for 6.3% of transport energy consumption.

Figure 5.2 Renewable energy by sector in Colombia, 2021



In Colombia, hydropower and biomass dominate energy use in buildings and industry.

Notes: Renewable waste is negligible.
Source: IEA (2023).

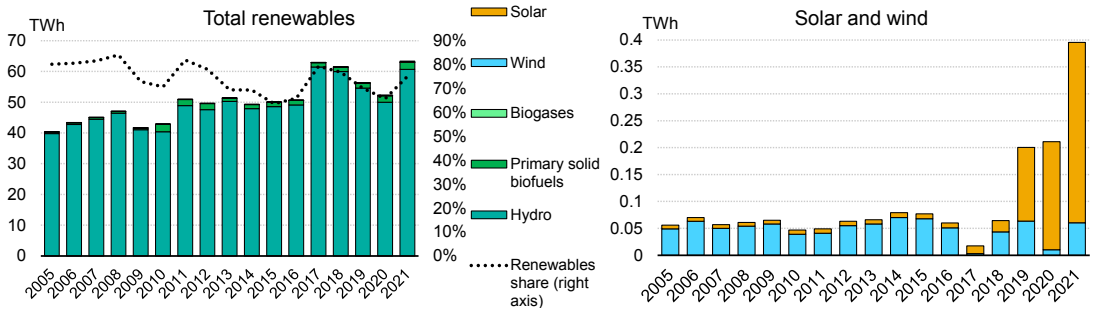
Renewable electricity

From 2011 to 2021, renewable electricity generation increased from 51 TWh to 63 TWh, and the share of renewables in total electricity production increased to 75%, with a peak of renewables electricity production (of 63 TWh) in 2021. In 2021, hydro was the largest electricity production source, accounting for 72% of total production. Wind and solar only accounted for 0.07% and 0.4%, respectively.

At the end of 2022, Colombia had a hydroelectric installed capacity of 12 265 MW and an installed capacity of 570 MW of solar PV and 38.4 MW of wind.

Colombia has unique potential to expand hydropower thanks to its ample river water resources. Colombia has also powerful wind and solar resources, with areas of the La Guajira province having annual average wind speeds of more than 12 m/s and large parts of the country exhibiting solar insolation of more than 5 kWh/m^2.

Figure 5.3 Renewables in electricity generation in Colombia, 2005-2021



Hydropower is the leading source of electricity in Colombia and dominates electricity generation. Electricity from solar has been increasing since 2019.

Notes: Solar photovoltaics, wind and biogases figures are not visible in the left panel.
Source: IEA (2023).

Renewable electricity targets

Under the Energy Transition Law (2099/2021), the 2018-22 National Development Plan (GoC, 2019) and the PEN (MME, 2021), the government targets a share of 12% of non-conventional renewables in the electricity mix by 2022 (mostly wind and solar), a large jump from today's 1.4% (with biofuels [1%], solar [0.3%] and wind [0.09%]).

Beyond 2022, medium-term targets of renewable energy are not legislated nor quantified, but indicative based on forecasts according to planned renewable energy auctions set out in the Reference Generation and Transmission Expansion Plan 2020-2034 (UPME, 2020).

By 2024, Colombia intends to scale-up renewables, with additions of 2 GW of wind and 1.4 GW of solar PV. By 2034, Colombia expects to have a total installed capacity of 24.15 GW of renewable energies for electricity generation. Hydro would still be the leading source, with 15.3 GW, followed by wind (4.56 GW), solar PV (4 GW), biomass (350 MW) and biogas (11 MW). This would raise the share of renewables in Colombia's electricity mix to 79%, according to government estimates.

On biofuels, the government has established pilots to test the blending of bioethanol up to 20%, but there are currently no plans for increasing the blending rate. Expanding the biorefinery sector is a target in the government's innovation strategy, aiming for five export-oriented biorefinery companies in 2030.

Under the E2050 strategy (GoC, 2021), the government aims at 2 GW of offshore wind by 2050 alongside 7.3 GW of onshore wind and 10 GW of solar energy.

The PND 2022-2026 announced the development of new road maps for bioenergy (biomass, biogas, biofuels) and the promotion of research and development on advanced biofuels.

Progress towards the targets

According to the 2022 IEA market forecast, Colombia's renewable capacity is forecast to expand by more than 5 GW (+44%) between 2022 and 2027 (IEA, 2022). Past auctions will lead to the commissioning of over 1.1 GW of capacity for each solar PV and onshore wind by 2027. The Long-Term Auction Programme awarded more than 2 GW of wind and solar capacity combined, with additional auctions planned for 2023.

These will help meet national targets under the PEN (MME, 2021) and enlarge the onshore wind and utility-scale solar PV share to 17% by 2027. In 2022, solar PV was the fastest growing renewable energy source. Hydropower will see the largest increase with the progressive commissioning of Hidroituango capacities between 2022 (1.2 GW) and 2024 (potential second stage of 1.2 GW to be confirmed) and other minor projects.

Finally, wind power capacities are expected to be added up to 2027, including two offshore wind projects (550 MW).

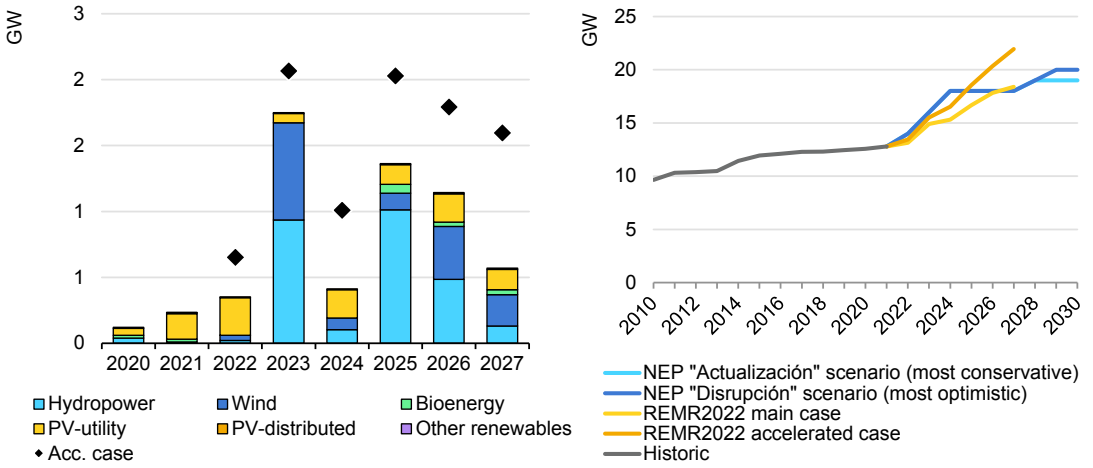
The IEA considers an accelerated case of +60% capacity increase if barriers to renewable deployment are lifted. These barriers include slow transmission infrastructure development and permitting delays due to community acceptance concerns.

On 5 April 2022, the MME published a road map for the deployment of offshore wind energy in Colombia. The road map was designed and prepared with support from the World Bank. A large offshore wind development in the north would require major transmission investment but could also be an enabler of hydrogen production.

The Offshore Wind Roadmap 2022 estimates that there is a potential for 50 GW in Colombia, of which around 27 GW would be in shallow water and about 21 GW would require floating infrastructure (MME, 2022).

The government will open tendering in 2023. Offshore wind capacity will not be commissioned within the forecast period and is not included in the IEA's forecast. Government plans for green hydrogen also boost the renewable outlook and include 1-3 GW of electrolysis in 2030.

Figure 5.4 Colombia's renewable capacity additions, 2020-2027 (left) and installed renewable capacity in IEA forecast vs. National Energy Plan (right)



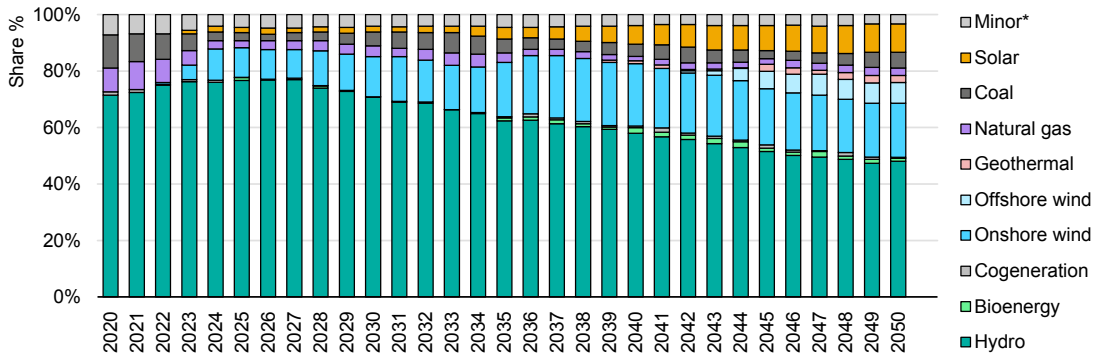
Colombia plans to accelerate renewable capacity additions in the coming years, mostly accelerating the deployment of solar PV and wind power installations.

Notes: GW = gigawatt; PV = photovoltaics; Acc. case = accelerated case; NEP = National Energy Plan.
Sources: right: UPME (2020); IEA (2022).

The renewable energy project pipeline in Colombia is significant and the deployment managed by the MME's planning department, the UPME. For solar PV and wind, there are already 25 projects committed under auctions for a total capacity of 2 879 MW (UPME, 2021) expected to be commissioned in the coming years. Beyond that, there are 221 solar PV projects, according to March 2022 data by UPME, with a cumulative capacity of 11.4 GW (UPME, 2022): 73 of them are in the pre-feasibility (phase 1); and technical, economic, financial and environmental feasibility studies are being undertaken for 148 projects (phase 2). These could be commissioned between 2023 and 2026. In the wind sector, there are 23 wind projects in preparation with a cumulative capacity of 4.5 GW; eight of them are in phase 1 and 15 are in phase 2. These projects could be commissioned between 2023 and 2026.

Colombia's long-term strategy towards 2050 (E2050C; GoC, 2021) expects onshore and offshore wind to come second in electricity generation after hydropower (Figure 5.5). Hydroelectricity would only represent half of electricity generation by 2050, compared to 70% in 2022. The share of biomass is expected to drop significantly by 2025, including in co-generation, where biomass combustion represents a large share today. Geothermal energy use for electricity generation is expected to contribute to the electricity mix, with some relevance by 2039, acquiring a greater role until 2050.

Figure 5.5 Outlook for electricity generation by source in Colombia, 2020-2050



By 2030, wind energy becomes the main source of electricity production after hydropower.

* Refers to power generation with effective capacity of less than 20 MW.

Source: UPME Electricity Generation Expansion Plan of Colombia for 2021-2034 as part of GoC (2021).

Policies and support schemes

The PND 2022-2026 provides for the continuous support of non-conventional renewables with an investment scheme for 2 GW by 2026 and the creation of energy communities, which will be defined by UPME and regulated by the CREG.

The government started to financially support the development of non-conventional renewable energies in 2014, when Congress adopted Law 1715. The law was amended in 2018 to reflect the new targets under the PND 2018-2022 of 12% in the power generation mix.

The government promotes the scale-up of renewables through long-term auctions, income from the reliability charge (CXC), renewable obligations and tax incentives.

The regulatory framework setting the guidelines for renewable expansion is laid out in Law 1715/2014 and the Climate Action Law (2169 of 2021) as well as the Energy Transition Law (2099/2021), which maintains and expands existing tax incentives projects (exemption of sales tax, VAT and deduction of investments from income tax).

Colombia introduced renewable obligations under Law 1955/2019 and MME Resolution No. 40060/2021, requiring power traders to source 10% of their annual energy purchases from the FNCER. Besides this purchase obligation, a number of policies support the growth of non-conventional renewables, including 15-year long contracts; gradual reduction of income tax; exemptions of VAT for the purchase of solar panels, inverters and charge controllers; and other tax credits. In 2021, tax incentives amounted to COP 4.8 trillion (USD 126 million), according to the latest government data.

Since 2019, wind and solar PV developers (around 20 projects) have secured around 3 GW of capacity through three auctions (auctions of long-term energy agreements), introduced by Resolution 40791/2018.

The auction's power purchase agreement contract price includes the CERE payment,[1] which is paid back to generators to reward them for the reliability or "firmness" of their supply to the system (IRENA, 2021). Bids in renewable energy auctions can therefore be influenced by parallel participation in "firm" energy auctions (CXC) because generators may retain the CERE payment in their renewable auction bid (valued at USD 17.88/MWh in October 2019) and consider it additional power purchase agreement revenue. Hence, the lowest wind bids in the auction came from three projects that were also awarded through firm energy auctions (OEF). Systematic auctions that reflect a commitment to a longer term schedule may attract a larger number of bidders, leading to increased penetration of non-hydro renewable energy. In 2019, eight solar and wind projects with a total capacity of 1.4 GW were awarded OEF. To complement the payments and processes and ensure longer term visibility for renewable investors, there are plans to hold joint auctions in the future for both the CXC and the renewable power purchase agreement contract. Future auctions could also include offshore wind projects.

Beyond price discovery, auctions offer the potential to engage communities, contribute to subnational development, foster the development of local industries and create jobs; in this case, in the historically marginalised and energy-poor La Guajira region of Colombia.

Special mechanisms exist for the connection of self-generation and smaller scale projects (<5 MW), regulated under Resolution CREG 174/2021. This resolution was made to ease the conditions for approving and installing self-generation projects, enforce the reporting of small-scale projects in the country, boost the interaction of final consumers with retailers, and improve the legislation on the delivery of surpluses. Such regulation led to a fast increase in solar PV installations at the distributed level.

Direct subsidies are assigned to producers and residential consumers to promote the installation of generation capacity in non-interconnected zones (not covered by the national grid), mainly renewable energy. These subsidies are implemented through five funds (the Financial Support Fund for the Energisation of Interconnected Rural Areas, the Financial Support Fund for the Energisation of Non-Interconnected Zones, PRONE, the SGR and FENOGE). Financial support is allocated directly to producers, either through tax reductions and exemptions, direct transfer for capital expenditure investment, or subsidised loans.

Barriers to renewable energy deployment

Colombia lacks transmission capacity to evacuate power from the north of the country, notably La Guajira, towards load centres. Wind projects encounter substantial barriers as development of transmission networks in la Guajira, the region where most wind projects are aimed for, is slow and cannot keep up with the current project pipeline (FITCH, 2021). Permitting delays due to community acceptance concerns have resulted in project deferments of up to three years (IEA, 2022).

The project developer has to ensure the connection of the project to the transmission system, but the transmission network is the responsibility of the transmission system operator. An additional transmission line is being constructed, but there are concerns about its timely completion as well as that its capacity will soon be insufficient.

[1] Real Equivalent Cost of Energy.

A second challenge relates to the development of projects in remote areas, where access to infrastructure is low and projects need to get buy-in from local communities. The first Energy Transition Law of 2019 required that companies with FNCER projects spend a share of project revenues within the municipality hosting the project.

A third challenge relates to the issue of adapting electricity market design to variable renewable energy. the CREG is consulting on proposals with regard to intraday market and ancillary services markets that would boost the integration of FNCER in the wholesale market (see Chapter 6). Adequately valuing the volume and timing of the reliability contribution of variable renewable energy in the context of the reliability charge auctions will be critical. Future joint auctions can be a welcome mechanism to better integrate the reliability contribution of renewables in the long-term contracts.

Colombia's peak load is currently in the early evening hours right after sunset, which creates challenges for solar PV integration ("duck curve"), requiring greater investment in new grid management services, including batteries. A first storage auction was carried out in 2021 with promising results. The PND 2022-2026 provides for the creation of regulations for electricity storage.

Hydropower

Hydropower is the main renewable energy source of electricity generation. Owing to its large water resources, Colombia intends to keep expanding its hydroelectric capacities in the coming years. Coastal regions of Andean countries, such as Colombia, are projected to have more rainfall in the coming years, which would potentially increase these resources while also posing security issues. Average annual rainfall in Colombia is projected to increase from 0.8% to 1.6% overall, with some areas of the country suffering from decreasing precipitation (IEA, 2021).

Most of Colombia's resources are run-of-river and only 8% have a storage function. Dams are able to provide important storage capacity, such as the new Hidroituango dam, which is 225 metres high with installed capacity of 2 400 MW. Construction began in October 2012 and was commissioned in late 2022. It was expected to be online by the end of 2018. The Hidroituango dam, located on the Cauca River, in Antioquía, was damaged in 2018 as a result of heavy rainfall and landslides. Three tunnels were built to divert the river during the construction phase. During construction, by the end of April-May 2018, one of the tunnels was clogged and later collapsed due to internal landslides, storms and heavy rains. The project initially cost USD 4 billion, but the landslide and heavy rains caused damages, elevating costs by USD 2.5 billion in recovering infrastructure and equipment and USD 628 million in lost profits.

There are 34 new hydroelectric projects with a cumulative capacity equivalent to around 1 GW, according to the last update in March 2022: 25 of them are in phase 1; the remaining nine are in phase 2, but the addition has not been confirmed. If confirmed, these projects could be commissioned between 2024 and 2029 (UPME, 2022).

Bioenergy

Biomass plays a minor role in electricity generation. Out of a total of 84 TWh, Colombia generated 2.2 TWh from biomass in 2021, being the second-most relevant renewable energy source of electricity. Colombia has 192 MW of installed biomass co-fired power

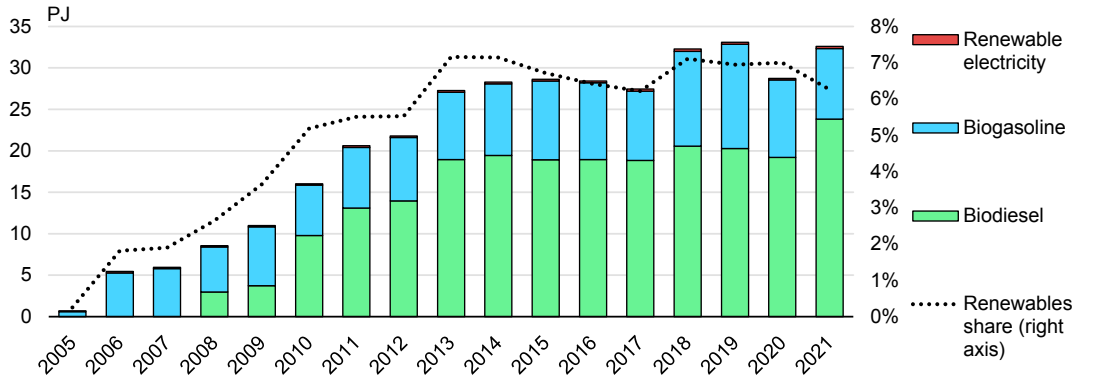
capacity, which could increase to 202.7 MW when adding projects in commercial operation and newly built projects. Biomass is also used for co-firing in diesel generators (1 GW of diesel/fuel oil/jet capacity installed).

Renewables in transportation

Biofuels

Colombia's biofuels production includes biodiesel, produced from palm oil, and bioethanol, produced from sugar cane. The production of liquid biofuels began in 2005 (0.6 PJ) and reached 32 PJ in 2021. From 2011 to 2021, liquid biofuels production grew by 37%.

Figure 5.6 Renewables in transport in Colombia, 2005-2021



After a rapid increase at the beginning of the century, the share of renewables in transport plateaued between 2013 and 2021.

Source: IEA (2023).

In 2020, average sales of bioethanol were 360 000 barrels per month,[2] while average sales of biodiesel were 314 000 barrels.[3] Since mid-2021, biodiesel sales have surpassed bioethanol sales. In the month of December 2021, 408 756 barrels of biodiesel were sold compared to 203 701 barrels of bioethanol.[4]

The government supports the price of palm oil through the Price Stabilisation Fund for palm kernel, palm oil and others. Colombia's total production of biofuels grew strongly after the mid-2000s but has stagnated in recent years. Higher cost compared to domestically produced gasoline and diesel are a major challenge to further growth of the share of biofuels in the transport energy mix. In recent years, the production cost of bioethanol and biodiesel in Colombia has typically been in the order of 40-50% higher than that of fossil fuels. As of December 2021, the production cost of bioethanol was about

[2] https://datastudio.google.com/embed/u/0/reporting/aaa5887f-4536-4143-a57c-535df24d78a8/page/EC3CC.
[3] https://datastudio.google.com/embed/u/0/reporting/aaa5887f-4536-4143-a57c-535df24d78a8/page/YC3CC.
[4] https://www1.upme.gov.co/DemandayEficiencia/Paginas/observatorio-info-energetica.aspx.

COP 9 000/gallon to COP 10 000/gallon (USD 2.25/gallon to USD 2.5/gallon). This compares to a pump price of gasoline of in the order of COP 9 500/gallon.

If biofuel production prices are high, the price of fossil fuel gasoline or diesel is lowered by a corresponding amount to maintain a stable end user price. If the end user price of fossil gasoline or diesel is below the international market price, the difference is paid out of the Fuel Price Stabilisation Fund (see Chapter 9).

Colombia has several regulations making the use of biofuels in the transport sector mandatory. Compulsory use of biofuel blending has been implemented for gasoline under Law 693/2001 and for diesel under Law 939/2004. The mandatory blending percentage is 10% for both. Biodiesel blending is obligatory for refiners and importers, which have to blend at least 2% in the fuels they deliver to transport agents and wholesalers. In turn, the wholesaler is in charge of blending the fuel, until reaching a share of 10%.

The government is working on methodologies to assess the emissions footprint of biofuels. There are currently no certification schemes in place to ensure the sustainability of biofuels produced in Colombia.

Blending mandates are adapted in response to high prices and ethanol production. In 2021/22, the government lowered blending mandates for gasoline and diesel, with the mandatory ethanol blending share set to drop to 6% from February to June 2022. It rose to 8% in July and 10% from August 2022. The share of biodiesel dropped from 12% in December 2021 to 11% in January 2022 before falling again to 10% since March 2022.

Since 31 July 2022, distributors have had to start works to prepare for compliance with the limits on sulphur content of 50 ppm for oxygenated gasoline and of 10 ppm for diesel and its mixtures that are going to enter into force by 2031.

Renewables in residential and industry sectors

Buildings account for 27% of final energy consumption, and the sector is the second-fastest growing demand after transport. Direct renewables use also accounted for about 30% of TFC in 2019. The share is higher in the residential sector at 38%, largely due to the dominance of firewood for cooking in households without access to modern cooking fuels. Indeed, all renewables in the buildings sector come from the consumption of primary solid biofuels (i.e. firewood): there is no consumption of alternative renewable sources such as biogases, renewable municipal waste or solar thermal. In IEA countries, on average, renewables other than primary solid biofuels account for more than 15% of the total renewables consumption in the buildings sector.

In the industry sector, bagasse represented 20% of final energy consumption in 2018. This source was mostly used for direct heat in production chains (UPME, 2020). The industrial sector that uses the most bagasse is the agro-industrial sector. In the industry sector, direct renewables accounted for about one-fifth of TFC in 2019 (this is higher than the IEA average of around 9%). Almost all of this was primary solid biofuels and the large majority of consumption occurred in the light manufacturing sectors, in particular the food processing industry. Renewable consumption in the heavier industries such as pulp and paper or cement is negligible. However, industry in Colombia is increasingly investing in renewables for heat processes, notably with solar PV projects for own consumption in the mining and metals sectors as well as coking production.

With the government's electrification plans, the share of biomass in residential heating is expected to decrease in the coming years, giving room mostly to natural gas and electricity.[5]

According to the UPME's long-term scenarios of the National Energy Plan 2020-2050 (UPME, 2019), the share of biomass in the industry sector energy use is likely to remain relatively stable at around 16-17% up to 2050. In industry, the share of coal in total energy use is expected to decline over the coming years and be replaced by electrification and hydrogen.

Colombia's carbon tax (Law 1819 of 2016) exempts industry use of fuels such as coal, coke crude oil and refinery gas. Natural gas is only subject to the tax if used by refineries or in the petrochemical industry (see also Chapter 2).

Assessment

Renewable sources of energy accounted for around 25% of Colombia's total energy supply in 2021, substantially above the IEA average of 14%, thanks to abundant hydropower (72% of total electricity generation) and a significant role of bioenergy, sugar cane and palm oil. In 2019, biofuels accounted for about 6% of total transport energy consumption (4.7% in IEA countries).

Renewables in electricity

Since 2014, Colombia has developed its framework for renewable energy which attracts significant investment, as it complements its excellent renewable resources. However, three key challenges impede the smooth development of the sector and if overcome could strongly accelerate Colombia's progress.

The country lacks transmission lines and progress in realising them is slow, is increasingly experiencing low public acceptance of new infrastructure projects by the local population. There are insufficient incentives for renewable energy in the electricity market design.

Colombia does not have renewable energy targets set for after 2022. The new National Development Plan 2022-2026 should include more plans for greater clean energy deployment. Up to now, the estimates of future renewable electricity installations are based on the Electricity Generation Expansion Plan. The plan is permanently updated and only computes projects but does not entitle the government to reach a specific threshold of renewable installations in the years up to 2050. In this sense, investors lack an instrument to clearly envision Colombia's level of ambition on renewable energy deployment. Setting specific renewable targets would also allow monitoring compliance with energy transition goals by multilateral organisations concerned by the topic.

Colombia failed to reach its non-conventional renewable energy target of 12% by 2022. The Covid-19 pandemic has generated negative impacts on the installation of new projects but the pipeline of registered projects shows that a high share of non-conventional energy can be achieved in the medium term. To close the gap, the government has to address

[5] https://www1.upme.gov.co/DemandayEficiencia/Documents/PEN_2020_2050/Plan_Energetico_Nacional_2020_2050.pdf#page=91.

the significant challenges regarding the expansion of transmission and the management of the social and environmental licensing of projects, including for generation plants. In particular for wind projects, which are located mostly in the La Guajira peninsula, there is an additional challenge for the transportation and logistics of the components due to the weakness of the port infrastructure.

The challenges facing end users are related to finding schemes for conveying the greatest number of benefits from these technologies. Another possibility is to change the consumer trend and turn them into prosumers, where distributed renewables and community ownership will be the key to achieving this. In terms of rural electrification, achieving the universalisation of the service is the greatest challenge and distributed energy is a key element to achieving it, given the geographical dispersion of many users and the great distance from the nearest grid.

One of the key areas of potential is offshore wind. In May 2022, the government launched the Offshore Wind Roadmap, which includes 50 GW of potential and also shows the economic benefits from the regions in the north of the country. Offshore wind energy auctions are planned, possibly together with the next round of auctions for onshore wind and solar, in co-ordination with the reliability charge auctions.

Despite the large potential along the Pacific ring of fire, Colombia's geothermal development is only just starting up, with two pilot projects and a new legal framework being prepared. The government does not address the specific risks of geothermal investment but has included the technology under the Energy Transition Law 2099/2021 and its tax incentives. The Inter-American Development Bank has begun a programme to offer loans to Colombian companies to address the exploration risk of geothermal.

In the context of the reliability of electricity supply in Colombia, the government should indeed review the current mechanisms under the electricity market design to foster the deployment of low-emission dispatchable generation in the coming years, including bioenergy, geothermal and ammonia (from green hydrogen) to secure back-up capacity during dry years.

Renewables in transport

To support biofuels, the government has undertaken several measures. Biofuels are exempt from sales tax, and the blending mandate ensures a stable demand. The government mitigates the price gap between biofuels and oil products by managing a cross-subsidy between them while maintaining a fixed price for the end user.

The government carried out pilots to test the blending of bioethanol up to 20%, but there are currently no plans to generalise this by increasing the blending rate. Expanding the biorefinery sector is a target of the government's innovation strategy, aiming for five export-competitive biorefinery companies in 2030.

The government is working on methodologies to assess the emissions footprint of biofuels, but there are currently no certification schemes in place to ensure the sustainability of biofuels produced in Colombia. A robust framework to certify the environmental quality of biofuels would help increase Colombia's production and its competitiveness in global markets.

Renewables in industry

The government has no plans for bioenergy, despite the large potential of bagasse and other waste available for co-generation. Agricultural residues and waste streams from industrial and municipal activities are abundant and policy action is needed to encourage clean energy generation from waste and residues, particularly as these projects can be more difficult given the complex chain of sourcing, sorting and treating waste (OECD, 2022). Experience from India and the People's Republic of China (hereafter, "China") shows that policy action is most effective through an ETS or an energy-efficiency scheme for targeted industrial sectors complemented by dedicated support schemes for co-generation to switch industrial production heat processes from coal to bioenergy and waste. Abolishing the exemptions of industry from carbon taxes will encourage the phase down of fossil fuel use in industry.

Recommendations

The government of Colombia should:

- Provide additional predictability to investment in renewable electricity by establishing mid-term targets by technology and a defined schedule and framework of auctions for long-term power purchase agreements.
- Ensure that electricity system development provides both additional capacity and increased flexibility from low-emission dispatchable sources to support the secure integration of renewables.
- Keep subsidies for renewable electricity projects under review to take into account the competitiveness of wind and solar in Colombia and revise methodologies to calculate the reliability contribution of wind, solar and related storage projects in the reliability charge.
- Reduce barriers to the development of renewables and related electricity grid projects, in particular by strengthening stakeholder engagement, local ownership and the localisation of benefits within the regions hosting projects.
- Create incentive frameworks to promote the uptake of untapped renewable energy sources, for example geothermal and concentrated solar power in electricity generation, solar thermal and biogases in buildings, and solid biomass in industry.
- Adopt a sustainability certification framework for domestically produced biofuels.

References

FITCH (2021), Colombia, https://www.fitchratings.com/research/corporate-finance/government-auctions-to-boost-colombian-non-conventional-renewable-energy-24-02-2021.

GoC (Government of Colombia) (2021), E2050, Colombia's Long-Term Strategy, https://unfccc.int/sites/default/files/resource/COL_LTS_Nov2021.pdf.

GoC (2019), National Development Plan 2018-2022, https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=93970.

IEA (International Energy Agency) (2023), IEA World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

IEA (2022), Renewables 2022, https://iea.blob.core.windows.net/assets/64c27e00-c6cb-48f1-a8f0-082054e3ece6/Renewables2022.pdf.

IEA (2021), Climate impacts on Latin American hydropower, https://iea.blob.core.windows.net/assets/8fa86b9d-470c-41a6-982e-70acd3fbdda4/ClimateImpactsonLatinAmericanHydropower_WEB.pdf.

IRENA (2021), Renewable Energy Auctions in Colombia, https://www.irena.org/publications/2021/March/Renewable-energy-auctions-in-Colombia.

MME (Ministry of Mines and Energy) (2022), Offshore Wind Roadmap, https://www.minenergia.gov.co/documents/5859/Colombia_Offshore_Wind_Roadmap_VE_compressed.pdf.

MME (2021), National Energy Plan (Plan Energetico Nactional 2020-2050) (in Spanish), https://www.eltiempo.com/uploads/files/2021/09/23/Plan_Energetico_Nacional_2020_2050.pdf.

OECD (2022), Enabling Conditions for Bioenergy Finance and Investment in Colombia, https://www.oecd-ilibrary.org/docserver/20f760d6-en.pdf?expires=1672402418&id=id&accname=ocid177496&checksum=F940D082918C08D8B8AD745739B96EE6.

UPME (Mining and Energy Planning Unit) (2022), Informe sobre proyectos de generación de electricidad (Report on electricity generation projects), https://www1.upme.gov.co/siel/Seguimiento_proyectos_generacion/Informe_Avance_proyectos_Generacion_Diciembre_2022.pdf.

UPME (2020), Plan de Expansión de Referencia Generación – Transmisión 2021-2034 (Reference Generation and Transmission Expansion Plan 2021-2034), http://www.upme.gov.co/Docs/Plan_Expansion/2021/Volumen2_Generacion.pdf.

6. Electricity

Key data (2021)

Electricity generation: 84.4 TWh (hydro 71.9%, natural gas 16.3%, coal 5.4%, bioenergy and waste 2.7%, oil 1.9%, solar 0.4%, wind 0.1%)

Electricity net imports: 0.12 TWh

Electricity consumption: 77.0 TWh in 2021 (industry 47%, residential buildings 31%, services sector buildings 21%)

Installed capacity: total 17.8 GW: hydro 12 GW, combustible fuels 5.4 GW (coal 1.6 GW, oil 1.1 GW, gas 2.5 GW, biomass 0.2 GW), solar 0.12 GW and wind 0.02 MW.

Overview

Colombia's power system consists of an interconnected grid (the National Interconnected System, SIN in its Spanish abbreviation), covering 97% of the total electricity demand, and the non-interconnected zones, which are supplied by local small electricity generation plants, running mainly on liquid fuels, such as diesel (IMF, 2019).

The Colombian Wholesale Energy Market (MEM) operates across the SIN. The MEM was created following the restructuring of the power sector in 1994 (Electric Laws 142 and 143), which brought about vertical unbundling of network and generation activities, open access to transmission/distribution and the end of the regional electricity supply monopolies. Generators and distribution companies can both retail. The 1991 Constitution considers electricity supply a universal service. The state is responsible for guaranteeing secure access to and quality of electricity supply.

Colombia's hydropower-based electricity system has seen periods of low availability of hydropower resources, which led to frequent price spikes and power supply disruptions, notably in the El Niño disaster in 1992. To deal with this main challenge, the government has implemented several capacity remuneration mechanisms over the past decade. The new hydropower storage project, Hidroituango, came online at the end of 2022, which will offer significant flexibility to the power system.

To strengthen the reliability of Colombia's electricity system, the road map for the transformation of Colombia's energy sector, presented in 2019, envisaged significant reforms to make Colombia's electricity sector fit for the energy transition by boosting competition, modernising the way subsidies are allocated to support vulnerable households, expanding the coverage of distributed generation and flexibility sources. As part of the just transition, the government is investing in self-consumption and distributed renewables, notably solar PV, in non-interconnected remote areas.

To operate a hydropower system with rising shares of variable renewable energy in a net zero world, the government will need to examine options for securing low-emission dispatchable capacity during periods when hydropower is less available. The reliability of the system could remain costly and fossil fuel intensive, hampered by gas availability constraints. At the same time, pumped hydro storage can play a role in providing peak load and flexibility services. The government needs to evaluate opportunities for managing the interannual and seasonal variability of hydropower resources through technological diversification of the security of supply mechanisms.

Electricity supply and demand

Electricity generation

In 2021, Colombia had a total of 5.3 GW of thermal power generating capacity, with gas (2.6 GW), coal (1.6 GW) and oil products (1.1 GW), including 800 MW of diesel generation (centrally dispatched). Solar is much larger than wind but not centrally dispatched. Coal and natural gas have been the main back-up capacity for hydropower.

Table 6.1 Installed generating capacity in Colombia 2021 (MW)

Energy source	2021 (MW)	Share (%)
Centrally dispatched resources		
Hydro	**11 043**	**62.17%**
Thermal	**5 295**	**29.81%**
Gas	2 550	14.36%
Coal	1 626	9.15%
Fuel oil	268	1.51%
Diesel	807	4.54%
Jet	44	0.25%
Non-centrally dispatched resources		
Minor	**1 106**	**6.23%**
Hydro	869.6	4.90%
Thermal	102.2	0.58%
Biogas	3.95	0.02%
Coal	16	0.09%
Gas	82.3	0.46%
Wind	18.4	0.10%
Solar	115.5	0.65%
Co-generation (biomass)	192.5	1.08%
Large-scale self-generators	122.9	0.69%
Small-scale self-generators	2.5	0.01%
Total National Interconnected System	**17 762**	**100.00%**

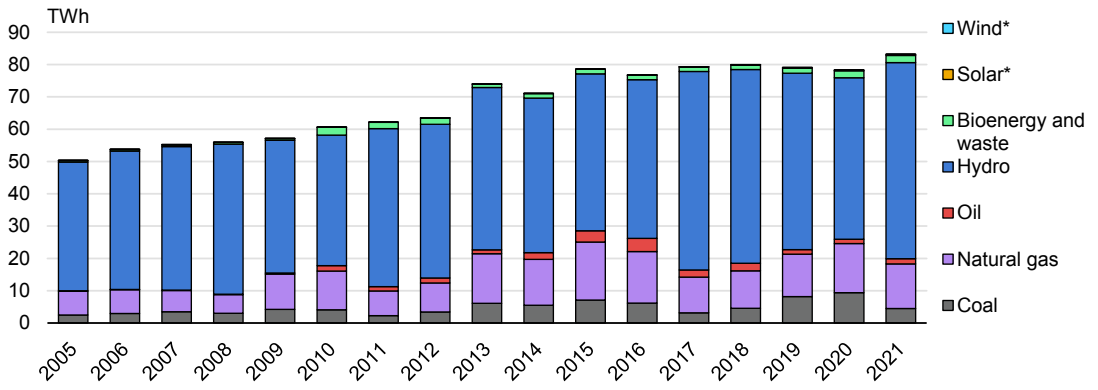
Note: MW = megawatt.

Source: Government of Colombia 2022.

Electricity generation was 84 TWh in 2021, 36% higher compared to 2011 (Figure 6.1). Hydropower is the main source of electricity generation. Colombia's installed hydropower capacity was 12 GW in 2021, the 4th largest capacity in Latin America (IEA, 2021). Electricity generated from hydro has increased by 24% over the last decade. On average,

the share of hydro was 70% of total electricity production, with a historic peak in 2008, when it accounted for 82.9% (or 46.4 TWh).

Figure 6.1 Electricity generation by source in Colombia, 2005-2021



Dominated by hydro, accounting 70% on average, Colombia's power system experiences annual fluctuations depending on water availability during periods of droughts or flooding.

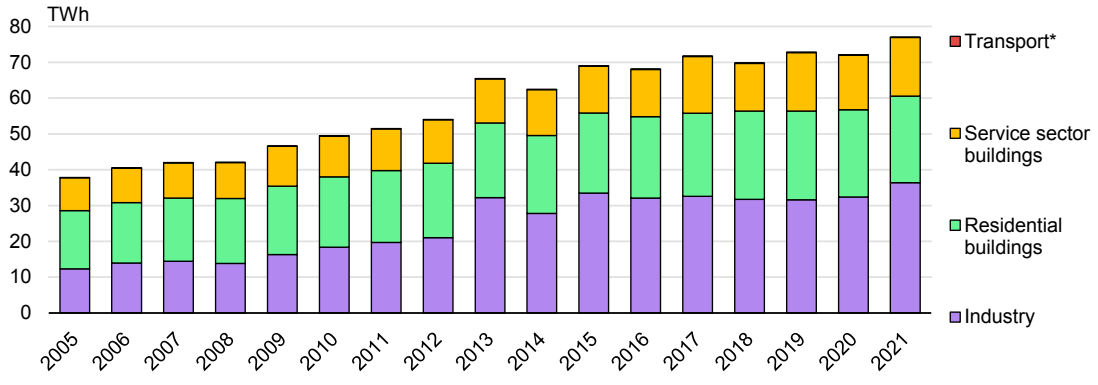
* Wind and solar are not negligible. They accounted for 0.06 and 0.33 TWh in 2021, respectively.

Source: IEA (2023).

Electricity demand

Electricity consumption almost doubled from 2005 to 2021, driven by industrial demand (paper and pulp, car manufacturing, petrochemicals and mining), and a rising population gaining access to electricity as well as the development of the first railway sections.

Figure 6.2 Electricity demand by sector in Colombia, 2005-2021



Electricity consumption increased mainly in the industry sector.

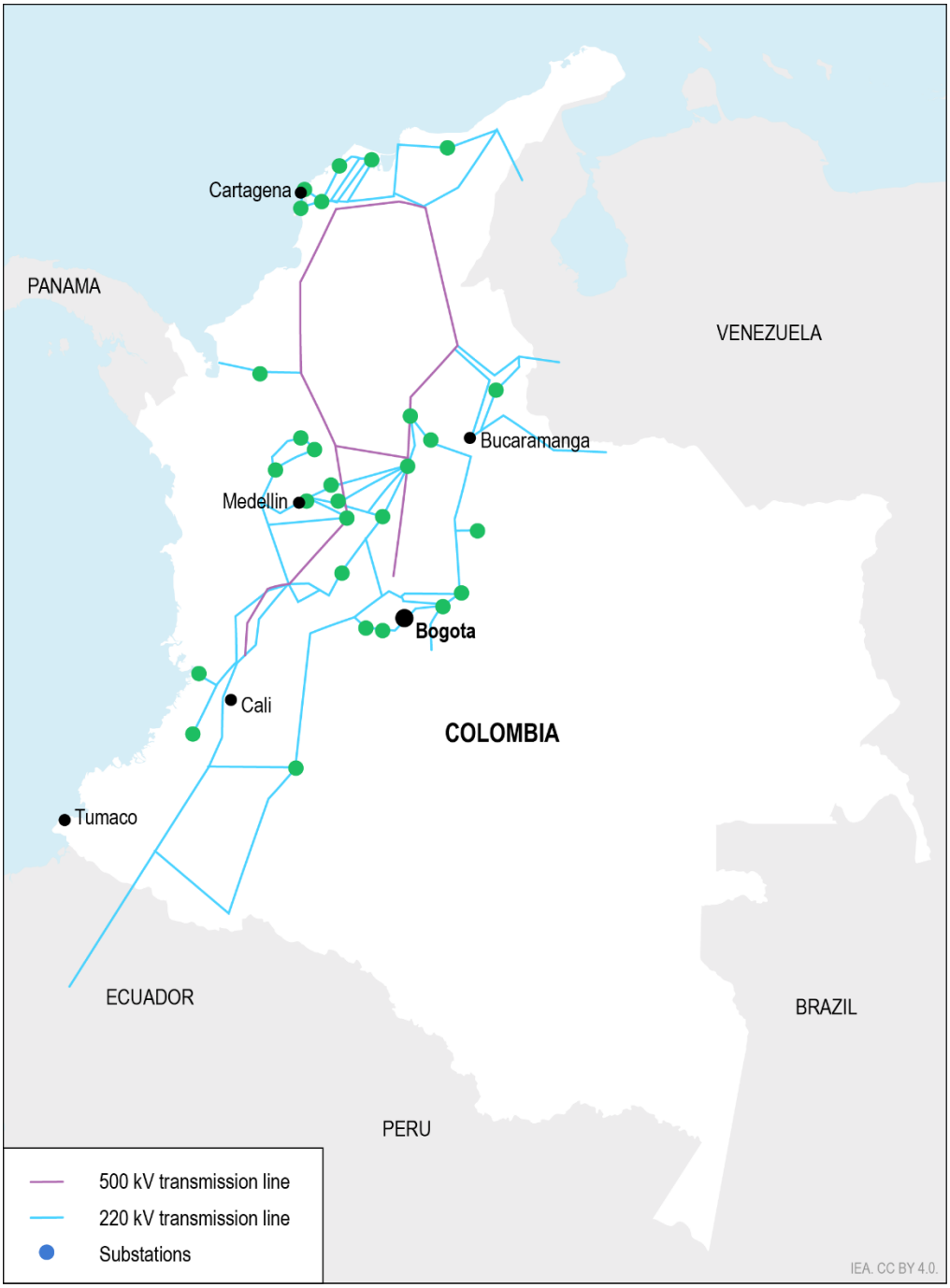
* *Transport* demand for electricity rose from 0.06 TWh in 2010 to 0.09 TWh in 2021 (negligible).

Source: IEA (2023).

Transmission and distribution

The national transmission system consists of around 28 000 km of transmission lines. There are 16 transmission system operators (transcos), which own and operate the transmission networks. The largest part of the network, 70%, is owned and operated by the state-owned Transco ISA. All transmission lines built before 2001 are regulated. Since 1999, Colombia organises auctions for new transmission projects to which both new entrants and incumbent transcos can participate.

Figure 6.3 Colombia's electricity network



Colombia has transmission constraints between the centre and the north of the country and in the transmission and distribution networks of Distco Electricaribe (at or below 110 kV). Market decoupling can occur during congestion. The weak transmission infrastructure is also a major barrier to the development and system integration of renewable energy, notable wind power in the north of the country. There are 37 distribution companies in Colombia, which own and operate distribution networks as a regulated natural monopoly. Open access to the distribution network is established.

Cross-border interconnections

Colombia is interconnected with Ecuador and Venezuela. Colombia was a net exporter of electricity until 2015, when imports from neighbouring countries started to increase over exports, notably from Ecuador. Electricity trade with Venezuela stopped on 3 May 2019. Trade flows are largely the result of hydropower availability in Colombia. During water scarcity, Colombia imports and in periods of water abundance, Colombia exports electricity.

Colombia has five interconnections with Ecuador with a total capacity of 395 MW for imports and 535 MW for exports. Colombia has three interconnectors with Venezuela with a total capacity of 205 MW for imports and 336 MW for exports, but they have not been in operation since May 2019.

A new interconnection is planned with Panama. In July 2021, both countries signed an agreement to establish the framework for the interconnection project. Colombia's CREG and Panama's National Authority of Public Services will develop the regulatory harmonisation scheme, which will set the administrative and remuneration system for electricity exchanges.

Supported by the United States Department of Energy and the Council of Ministers of the Andean Electrical Interconnection System, plans are being developed for a regional interconnection project of Ecuador, Colombia and Peru, as the backbone for a common Andean electric power market. The construction of a 500 kV Ecuador-Peru transmission line is planned for commissioning in 2024-25. Once operational, it will enable the synchronous operation of the Colombia-Ecuador-Peru power systems.

Market structure and regulation

The operation of the Colombian electricity (and gas) market is based on Law 142 (public utilities) and Law 143 (Energy Law). The national government, through different entities and organisations, has the oversight of the electricity market, with electricity supply considered an essential right under the Constitution.

The MME is responsible for setting the electricity policy reforms and guidelines for electricity security of supply. The Ministry of Finance supervises the budgets for the electricity subsidies and investments. The UPME is in charge of the mandatory transmission planning and also provides for indicative plans for power generation expansion. The Superintendence of Public Utilities oversees and monitors the market.

The CREG regulates the end user prices (tariffs), transmission tariffs, and the entry of new competitors to both the wholesale and the retail market (Resolutions 054/1994 and 024/1995). The MEM is managed by the market and system operator, XM, which is a subsidiary of the major transmission company, Transco ISA. Two committees, the National Operation Council and the Market Operation Committee, work to ensure market governance and market surveillance. The National Operation Council is the technical system operation committee formed by representatives of the generation, transmission and distribution segment. The Market Operation Committee supports the CREG in overseeing the functioning of the market and the system, notably XM's work. The Market Operation Committee can propose market rule changes to CREG.

Since liberalisation in the 1990s, Colombia's market model has not changed much. The MEM was created in 1994 as a result of the restructuring of Colombia's electricity sector. Market power has been an issue for several decades, reflected in periodical sharp increases in power prices, given the integration of supply/retail and generation. The CREG made several attempts to mitigate market power with regulated market shares imposed. Gentailing remains a reality and full ownership unbundling is not implemented.

In 2004, XM was set up as market and system operator. XM remains a subsidiary of Transco ISA. Major market design changes were introduced following the 1992 blackout to ensure backup capacity for hydropower, with capacity remuneration schemes, mainly for thermal power capacity. Obstacles remain for generation investment and market entry, including regulatory uncertainty, gas supply scarcity, weakness of power and gas transport networks, complicated and lengthy processes for permits and licenses, and public opposition to new generation projects.

A 2019 World Bank study highlighted structural weaknesses in the Colombian power market: generation and contract prices have been steadily increasing; the reliability charge shows dysfunctionalities; the Colombian electricity and natural gas markets lack the integration necessary for ensuring a reliable and efficient supply; and demand participation is very limited in the power market (World Bank, 2019).

Demand response mechanisms have historically focused on critical conditions, such as El Niño seasons. In January 2022, Colombia launched a public consultation on a demand response road map and is placing more emphasis on demand response in the market rules. This is fully supported by Colombia Inteligente, a collaborative network involving utilities, technology providers and public actors (including the ministry) to support capacity building and knowledge sharing on smart grids deployment, promotion of pilot projects, contribution to policy, regulation, and standardisation processes.

A voluntary reduction of consumption is done in exchange for a payment by generators that cannot comply with production schedule. Demand reductions are incentivised in the daily market, in which retailers can make offers to reduce their users' consumption for daily dispatch. The rationing system "Apagar Paga" was put in place for the first time in 2016 (see the section below on electricity security). There is no dynamic electricity pricing for retail consumers, which could incentivise demand response.

Box 6.1 The Energy Transformation Mission

The road map for the transformation of the electricity sector recommends a range of market design improvements, which are in line with economic best practices and learnings from market reforms across the globe.

Their introduction will, however, require the reinforcement of political and institutional governance and strong stakeholder commitment. The road map includes several recommendations in this regard, notably the review of the unbundling rules, ending vertical and horizontal integration, the introduction of a ten-year National Energy Plan, the Energy and Gas Regulatory Commission as the central energy regulator (to include gas and petroleum products), stronger market oversight and monitoring by the Superintendence of Public Utilities, increased capacity of the planning bodies (the Mining and Energy Planning Unit, the Superintendence of Public Utilities, XM, etc.), and an energy co-ordination committee across government with stakeholder participation.

For the wholesale electricity market design, the road map calls for several critical improvements to activate all sources of flexibility. This includes the introduction of nodal pricing to foster locational investment signals alongside intraday and balancing markets, improved risk allocation of bilateral contracts, and improved design of the reliability charge, including bilateral contracts with non-conventional renewables, the participation of distributed energy sources and demand response in wholesale markets for energy and capacity, improved transmission planning across national and regional networks, and the creation of an exchange for international electricity trade along the major interconnections. Strong co-ordination mechanisms across gas and electricity dispatch and planning are vital for the Colombian market in the future.

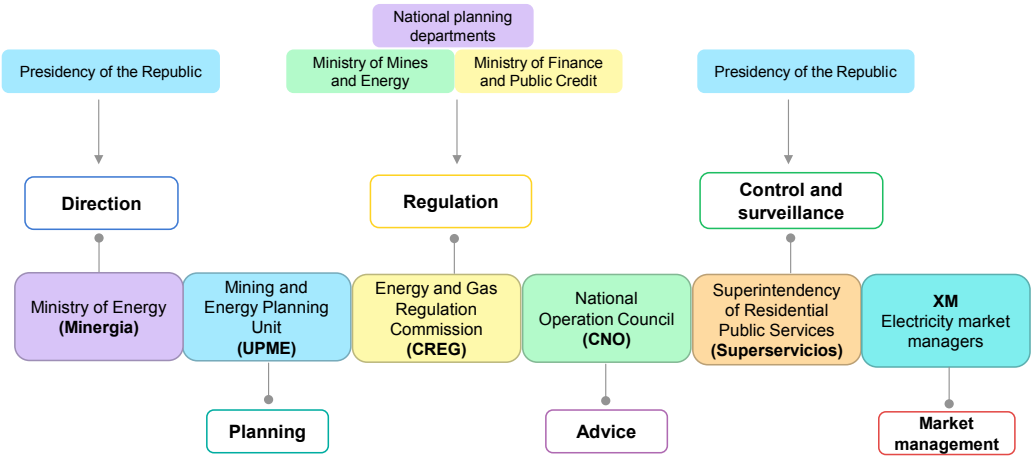
At the distribution network level, the road map calls for the structural deregulation of distribution networks and supply activities, creating independent distribution system operators (DSOs); the transition to a new regulatory regime (using the TOTEX approach); a new data transparency regime for distributors, which should be accompanied by contract models for the greater integration of demand response; electric vehicles; and the introduction of more dynamic components in regulated electricity prices.

New models are suggested for achieving cost-effective universal access (to electricity and natural gas/liquefied petroleum gas for cooking to replace wood burners) across Colombia's regions and improving the quality of supply, the greater rationalisation of subsidy programmes with a merger of funds, while undertaking a gradual subsidy reform and ending subsidies as access is achieved.

The reform of the natural gas market is a key priority of the road map, which includes recommendations for the introduction of a ten-year gas supply/demand adequacy plan, a ten-year gas infrastructure planning process of priority gas network projects and open access regime to liquefied natural gas regasification terminals. The gas market should be transformed to a common carrier system, based on entry-exit tariffs and greater separation of supply and transport activities, with the creation of an independent gas system operator and a gas hub.

Source: ETM (2020).

Figure 6.4 Regulatory governance of Colombia's electricity market



Wholesale electricity market

Colombia's MEM has three main markets: 1) the spot day-ahead market with a single node mandatory power pool (*bolsa*); 2) the bilateral contract market (long-term); and 3) the capacity market with reliability options.

The spot market for electricity is a day-ahead market in which each unit submits single bids (unique price for 24 hours and declared quantity). A firm can own a portfolio of power generation plants with different technologies. The economic dispatch occurs on a merit order basis (i.e. according to bid price) following principles of efficiency and does not allow for dispatching by technological differences. The CREG's regulation requires a security-based dispatch, a minimum cost dispatch with electric and energy restrictions. The spot market is administered and operated by XM. These dispatch rules involve co-ordination in case of electricity exchange with other countries.

There is no forward and no intraday market and no real demand response in the spot market (only in the secondary market and under critical market conditions). The CREG has not yet developed a futures derivatives market for hedging. The private company Derivex developed energy commodity futures, but participation to this market remains limited. The power pool price does not take into account transmission constraints and congestion.

Spot transactions are hedged by a reliability option during tight supply conditions. Demand does not participate in the wholesale energy market in Colombia. Firm energy auctions are conducted to ensure reliability during dry hydrological conditions.

Colombia's wholesale electricity market is highly concentrated, with three main players (Emgesa, EPM and Isagen) each holding around 20% of total generating capacity and five companies holding less than 10% shares (Table 6.2).

Table 6.2 Concentration in Colombia's wholesale electricity generation

Firm	Share in total generating capacity
Emgesa	19.8%
EPM	19.5%
Isagen	17.9%
Celsia	7.8%
Aes Chivor	5.7%
T. Barranquilla SA	5.1%
Gecelca	4.1%
Prime	3.4

Source: CREG (2022).

Colombia's measures for structural participation are set by Resolution CREG 60 of 2006, which requires surveillance if the share of a company is between 25% and 30% and below a Herfindahl-Hirschman Index (HHI) of 1 800. If the share goes above 30% and the HHI above 1 800, the firm is subject to special enforcement rules in bidding and a participation "bandwidth" to prevent merger integration above uncompetitive levels (Resolution CREG 101 of 2010). General competition rules of behaviour are set out in Resolution CREG 80 of 2019.

Retail electricity market

The residential sector had 91% of total users in 2020, or approximately 15 million. Eight per cent of users belong to the commercial sector and the remaining 1% to other, industrial, sectors, but account for 30% of sales.

Colombia has introduced retail competition, but in practice distributors are the main suppliers. Twenty-nine retailers are integrated with distribution companies and there are more than 20 retailers without an integrated structure.

Retail prices and taxes

Households and small businesses connected to distribution networks are supplied with electricity based on regulated prices. Customers with a peak consumption of over 100 kilowatts (kW), mainly industry, can opt for direct and liberalised long-term contracts with suppliers.

Electricity retail tariffs are cost-based, as calculated by the CREG (Resolution CREG 199/2007). The CREG establishes the formula for calculating the cost of the service on a monthly basis. The cost of the service is considered as the maximum cost retailers can pass on to their users. The cost formula (service provision unit cost) is made up of the costs of generation, transmission, distribution and marketing; recognised losses; and restrictions. The unit cost is a flat cost for each kWh consumed. Costs have almost doubled in ten years to reach almost USD 700/MWh.

In 2021, the cost of generation made up the lion's share (USD 231/MWh). The retail tariff is composed of the generation cost (36%), the cost of transmission (6%) and distribution (38%), with a retail margin (8%) and losses (7%) alongside the costs of supply restrictions (5%).

Financial assistance to vulnerable households (the so-called social strata 1-3) is allocated through price subsidies. In 2021, the MME made more than COP 1.6 trillion to cover electricity subsidies that benefit approximately 13 million households in strata 1-3 across the country. Of the total, COP 1.49 trillion are subsidies that benefit users connected to the SIN and more than COP 118.8 billion went to companies that serve 222 000 families living in non-interconnected zones of 13 departments.

Eligible households are entitled to a price subsidy for the provision of electricity of 60%, 40% and 15% of the cost-recovery tariff. This price subsidy only applies to consumption levels below a "subsistence" threshold, which is set according to the altitude of the residence – the subsistence threshold is 130 kWh in municipalities that are 1 000 metres above sea level or more and 170 kWh in municipalities less than 1 000 metres above sea level. Consumption above this threshold is priced at cost recovery of electricity supply. Households classified in stratum 4 pay the cost-recovery tariff; households in strata 5 and 6, along with commercial users, pay a contribution of 20% of the cost-recovery tariff over their entire consumption. This cross-subsidisation of the retail cost is a key feature of Colombia's retail rate design.

The 20% contribution is allocated to the Solidarity Fund, which is complemented by direct transfers to shoulder the entire subsidy payment for strata 1-3. The Solidarity Fund for Subsidies and Income Redistribution allocates the retail payments to retailers according to their subsidy-contribution balance. The remaining substantial deficit of some 60%, or well over USD 1.5 billion per year, is covered by the state budget. The Social Energy Fund provides an additional flat support of COP 46/kWh to residential consumers in strata 1 and 2 in areas with sub-standard electricity service.

Stratum allocation is based solely on the neighbourhood of the household dwelling and does not take into account variables associated with the household income. Municipalities are responsible for updating the stratum system, but many fail to do so, either because they do not have the capacity or because they do not have sufficient incentives to graduate households from subsidised strata to unsubsidised ones. There are municipalities whose stratum allocation dates back to 1997. Furthermore, the government does not audit the electricity retailer clientele's mapping to the stratum system – to ensure that it correctly maps a municipality stratum allocation as reported in its cadastre – before compensating distributors and retailers. This results in approximately one-third of total electricity price subsidies currently benefiting households in the top 4 income deciles.

Low electricity tariffs encourage over-consumption by households and decrease incentives to adopt energy-saving behaviours. According to the International Monetary Fund, the fiscal cost of electricity price subsidies was, on average, relatively constant at about 0.3% of GDP per year over the period 2016-18.

As of March 2022, there were around 450 000 advanced meters installed in Colombia, still far from the targeted penetration of 75% of retail consumers by 2030 (11 million meters).

Quality of supply

The quality of service is improving, but losses at the distribution level were still about 14-16% in 2018. By 2022, the government targets the average duration of outages to go down to 27 hours per year (from 38) and the average number of outages per year to reach 35 (from 49). Progress is well under way to reach these targets.

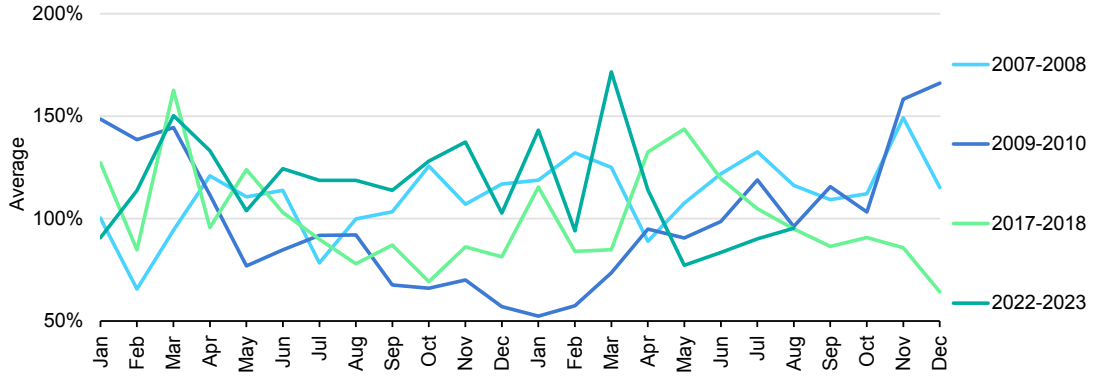
The sum of the last two years' electricity demand amounted to 143 257 GWh. The demand not served in the same period amounted to 110 GWh. Therefore, on average over the last two years, the percentage of demand not served was 0.077%.

Electricity security and emergency response

As most countries relying on hydropower for their electricity supply (Australia, Canada, New Zealand and Norway), Colombia's electricity security needs to ensure fuel diversity, preparedness for varying hydropower availability over seasons and years, and adequate dispatchable fuel supply for the back-up capacity, which is today mainly natural gas.

Colombia's hydropower capacity has limited storage capacity – only 6% of the total capacity has reservoirs (most of the plants are run-of-river) that can provide seasonal storage (6 months). Besides, storage capacity is very much affected by extreme weather events, either droughts or floods in an interannual perspective. Colombia's power system has to deal with the large variability of water inflows to its run-of-river plants. The power system is divided into five hydro regions. The monthly hydro inflows in Colombia's rivers significantly vary around the historic medium of all aggregated river basins in the interconnected power system (100%).

Figure 6.5 Monthly water inflows of Colombia, in % change from historic medium



Source: XM Sinergox (2023).

Historic supply disruptions

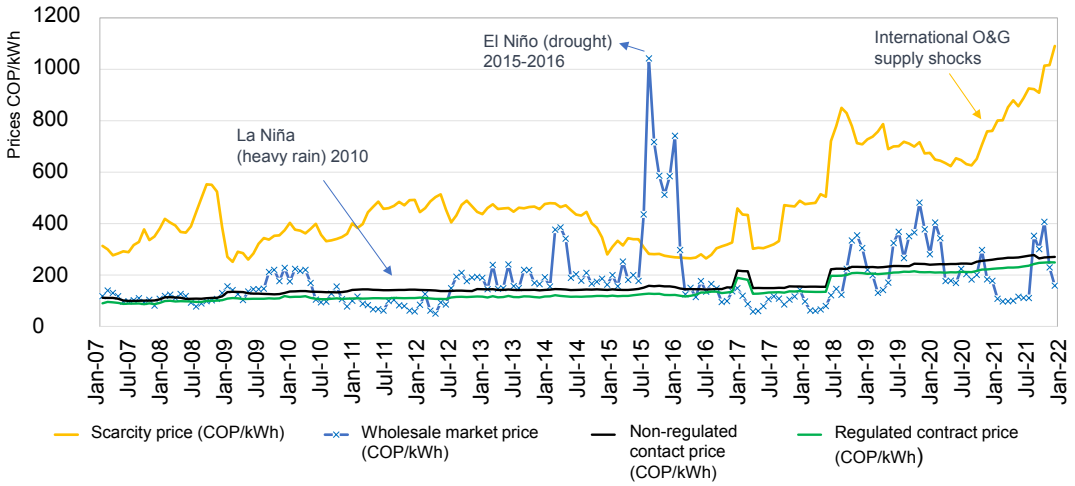
Colombia experienced a major blackout in 1992, which gave rise to a re-evaluation of the electricity system and a major market reform. Since then, electricity security has been at risk a few times. In 2015-16, Colombia experienced severe droughts caused by El Niño. To secure the power supply, energy reserves were mobilised, electricity was imported from Ecuador, and the government worked to deploy a strategic plan to increase the supply of natural gas and ensure backup generation from thermal power plants.[1]

[1] https://www.eltiempo.com/opinion/columnistas/alejandro-riveros-gonzalez/apagar-paga-segunda-parte-columna-de-alejandro-riveros-312480.

In February 2016, a transmission line of one of the largest hydropower plants of the country, the Guatapé dam, caught fire, causing the plant to be out of service for more than four months. Low gas and diesel availability also contributed to the risk of rationing.

The 2015-16 El Niño crisis had exposed some important shortcomings of the MEM: during a period of fuel shortage, the variable costs of thermal generators and the spot price can be higher than the firm energy scarcity price set in the auction, and therefore effective enforcement is essential to ensure that generators meet their obligations resulting from the auction. This led to several reforms of the scarcity price calculation. Today, guarantees and compliance checks are included, and the demand side can participate. To ensure firm gas supply, the system operator co-optimises gas and electricity markets within the dispatch of energy, which considers constraints of natural gas supply and transport schedules.

Figure 6.6 Spot price versus scarcity price in Colombia, 2007-2022



Note: Joint scarcity-price time series between 2007 and 2017 with scarcity price series by Resolution CREG 140 of 2017.

Source: CREG (2022), calculation based on XM.

Colombia has two main demand response programmes: an incentive-based voluntary demand response and a price-based demand response. The voluntary disconnectable demand was created as a security backup in the secondary market (with reforms in 2006, 2010 and 2018), and the price-based demand response introduced after the El Niño power crisis in 2015 (through Resolution CREG 29 of 2016 and Resolution CREG 51 of 2016).

To avoid a power outage, from February to April 2016, the government had implemented a successful reward and punishment policy called "Apagar paga" ["Turn off pays"], to reduce the demand of electricity (Rodríguez Hernández, 2017). Over two months, the scheme penalised electricity consumption above historical means and rewarded customers with low consumption. The campaign resulted in a reduction of 1 179 GWh, much above the targeted reduction of 400 GWh (World Bank, 2019).

Power system adequacy and flexibility

Investment in non-conventional sources is the government's main priority for increasing electricity security and reliability.

The Network Code (Resolution CREG 025/1995) requires the system and market operator XM to carry out the planning of the SIN, with an indicative long- and medium-term energy operational planning and a mandatory planning of system operations, economic dispatch and redispatch.

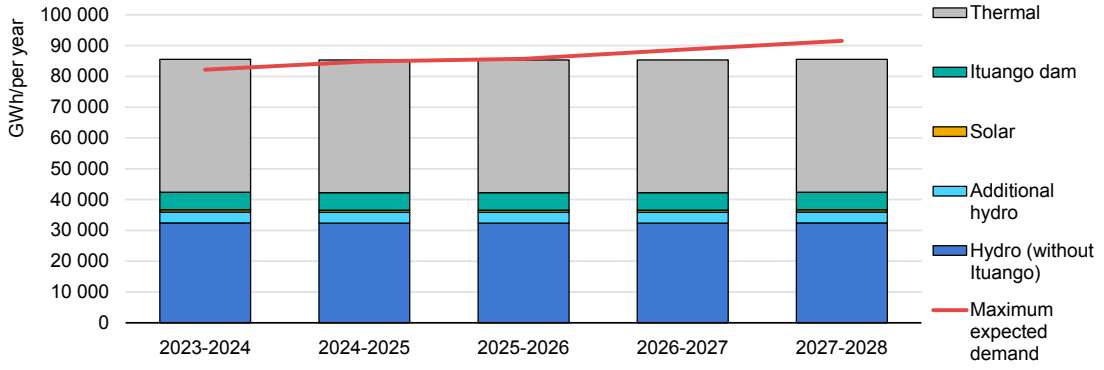
In 2022, XM released its latest demand/supply adequacy assessment for the medium term, according to which it does not foresee any deficit in the system adequacy and no particular challenges for renewables integration into the system (XM, 2022). The National Operation Council is issuing guidelines for system operation and the National Dispatch Center co-ordinates dispatch and takes action during supply deficit situations.

The main back-up capacity is natural gas. However, fuel availability is difficult to secure, with domestic gas production in decline, tight global LNG markets and limited contract certainty for generation as gas demand is fluctuating in the power sector to make up for interannual variability. The co-ordination of gas and electricity systems and markets has become a stronger feature of Colombia's market. This is necessary due to limited gas transportation capacity due to the radial gas network and limited production from gas fields.

Beyond 2030, variable renewables (wind and solar, VRE) will become important for the system operation, when the projects in the pipeline will come online, while gas and coal will not see growth in their supply; the role of coal is expected to decline strongly.

CNE studies several scenarios for high penetration for 2025 with 8 GW of VRE in the system – 2.5 GW of wind capacity and 5.6 GW of solar capacity – adding to the current capacity of 18 GW to meet a maximum historical demand of 10.5 GW. Run-of-river plants are a good source of flexibility to balance seasonal variability and integrate renewables. With higher shares of VRE and considerable interannual variability, traditional resources (thermal) will need to be flexible enough to adjust their production to support interannual variability of hydropower generation. Even under net zero constraints, thermal plants are a cost-efficient source of backup; given their limited use they do not raise the emission intensity of the power generation. To date, the flexibility contribution from electricity imports is negligible and demand response limited.

Figure 6.7 Firm energy balance by technology in Colombia, 2023-2028



Source: CREG (2022).

Security of electricity policy

Colombia operates a reliability charge based on four elements.

The first is a call option for firm energy contribution, activated when the spot price exceeds a monthly scarcity price set by the regulator. The call option allows load to hedge price spikes and the system operator to identify hours of tight supply.

Second, generators with firm energy obligations (FEOs) must deliver on the energy committed by their obligations in these hours. FEOs are awarded through centralised auctions, which provide long-term revenues to secure investment in generation, paid by all consumer categories. FEOs are to ensure enough generation capacity is available to supply demand, even under dry hydrological conditions. Generators are compensated for the availability of their installed generation capacity with a fixed USD amount per kW/hour, paid monthly during the awarded OEF period, regardless of whether any energy is effectively delivered into the system.

Third, a safety net designed to further ensure generators can supply the committed FEOs during hours of tight supply. Moreover, adjustment mechanisms in the safety net allow market participants and the regulator to update their FEO positions.

Fourth, guarantees to ensure compliance with the reliability mechanism for all generation technologies (hydro, fossil fuel-based power plants, solar PV, wind farms, geothermal, biomass). Such compliance includes: starting operation of a new or special generation plant or unit by a deadline committed; contracting fuel supply and natural gas transportation required; and continuous fuel availability during the commitment period for thermal generation plants and units.

In 2019, the CXC saw participation of renewables in the reliability charge, with 8 (solar and wind) projects for a total 1 389 MW participating in the auction.

The demand side can participate to support and back-up firm energy obligations. In 2021, contracted demand side for the reliability charge was approximately 3% of annual electricity demand.

The reliability charge has enabled significant investments in new capacity. The third firm energy auction held in 2019 for the period 2022-23 assigned energy at a price of USD 15.1/MWh, resulting in a value for firm energy availability in 2021 of approximately USD 1.5 billion.

Assessment

Electricity generation was 84 TWh in 2021, around 50% higher compared to 2009. During the Covid-19 pandemic, generation fell to 80 TWh in 2020 but rebounded thereafter.

Hydropower is the main source of electricity generation, accounting for around 72% in 2021. With a total installed hydropower capacity of 12 GW in 2021 (out of a total of 17.8 GW), Colombia has the fourth-largest hydro capacity in Latin America.

Electricity consumption more than doubled from 2000 to 2020, driven by demand in industry, a rising population gaining access to electricity and industrial development.

Today, industry is the main electricity consumer, with major industrial users being paper and pulp, car manufacturing, petrochemicals, and mining.

Colombia only has a few small cross-border interconnections with some trade with Ecuador (trade with Venezuela stopped in 2019). Colombia was a net exporter of electricity until 2015, when imports from neighbouring countries started to increase over exports, notably from Ecuador. Trade flows are largely the result of hydropower availability in Colombia. During water scarcity periods, Colombia imports and in periods of water abundance it exports electricity.

Electricity wholesale market

Colombia's power system spans across the interconnected grid (the SIN). The Colombian wholesale energy market covers 97% of the total electricity demand in the country. The MEM was created as a result of the restructuring of the power sector in 1994 (Electric Laws 142 and 143), which brought about vertical unbundling of network and generation activities, open access to transmission/distribution, and partly ended the regional electricity supply monopolies.

Generators and distribution companies can both generate and retail electricity. Such a "gentailing" structure (see below) also creates the risk of concentrated market power. The wholesale market is dominated by three companies, which represented about 60% of the installed generation capacity: EMGESA, EPM and ISAGEN, with around 19% each. As of 2022, there were 29 integrated and 20 non-integrated retailers in Colombia. That said, the retail market is *de facto* dominated by two companies, also generators, EPM and ENEL, which meet around 70% of total demand.

Since 2019, vertical integration of generation, retail and distribution (gentailing) has been allowed again to create a level playing field between newcomers and companies established before the 1994 reform that according to a court ruling were exempt from unbundling.

The regulator, CREG, is in charge of promoting competition, while the Superintendence of Industry and Commerce exercises inspection, oversight and control functions. It shares these oversight functions with the Superintendence of Public Utilities. Ensuring co-ordination and avoiding overlaps or gaps between the competences of both entities is key to ensuring the competitive and transparent functioning of the wholesale market.

The independence of the superintendences is very much needed to police market power, which is high in both the gas and electricity markets. CREG Resolution 080/2019 aims to improve market oversight amid the highly vertically integrated energy markets in Colombia.

Colombia's market design has remained in place since the 1990s, despite small reforms being carried out on the margins. All bids are made in the mandatory pool on the spot market (MEM), which is the only one in Latin America. To mitigate market power, bids have the same price for the whole day. An economic dispatch determines one single market for the country. In addition to the spot market, there is an over-the-counter market of bilateral financial contracts between generators and traders without commitment to physical delivery. These contracts are a hedge mechanism against spot price volatility, which varies according to hydraulic conditions, fuel prices and demand. Finally, considering the energy from the spot market (including from the financial contracts) and

the energy from the reliability scheme, the operator solves all transmission constraints and creates the feasible programme for the day ahead.

There is work underway to modernise the wholesale market by introducing new market segments such as intraday and system operation services by 2024. If properly designed, this will help to increase the efficiency in the dispatching of generation (including co-ordination with the gas system) and to better integrate the expected increasing amounts of variable generation resources, such as solar and wind, while progressing in bringing competition to the market. The framework has to encourage the participation of demand-side response.

The Energy Transformation Roadmap produced by the Inter-American Development Bank in 2019 suggested significant reforms to make Colombia's electricity sector fit for the energy transition by boosting competition, modernising the way subsidies are allocated to support vulnerable households, while expanding the coverage of distributed generation and flexibility sources.

With regard to transmission and distribution, integrated capacity expansion and network development plans are important to support the co-ordinated expansion of the grids in line with generation investment, in particular in the current context of increasing new non-conventional renewable projects. The UPME is in charge of, among others, preparing and updating the national plans, including expansion plans for the SIN and co-ordinating the execution of infrastructure projects together with stakeholders.

The UPME is also in charge of the challenging co-ordination of permitting processes of both generation facilities and the related transmission grids. The UPME has a 15-year forward planning which assumes that everything planned arrives on time, but this is not always the case. In case of delays, the SIN system operator, XM, carries out a separate planning exercise and if constraints are detected, they are communicated to the UPME to speed up the planning work. To make this process more efficient and avoid a negative impact on new generation projects, one alternative would be to re-evaluate the long-term plan every three years under the co-ordination of both entities.

To deliver on the government's decarbonisation ambitions in an efficient and co-ordinated manner, there is a need to ensure coherence of electricity planning exercises with other plans (PEN and PIGCCme) in all time horizons (short, medium and long term). Moreover, the co-ordination of the authorities at different administrative levels (local, regional and central government) has to be improved to better integrate their policies and actions to enlarge the social benefits in the territories where the different transition projects are to be developed.

Electricity retail markets

The nominal electricity retail tariff has almost doubled in ten years, driven by increases in the "cost of service". In March 2022, the cost of service depended on the distribution company and was on the average between COP 650/kWh and COP 750/kWh, with USD 0.151/kWh for households and USD 0.145/kWh for businesses. In 2020, the cost of service was composed of the cost of generation (36%), transmission (6%) and distribution (36%), with a retail margin (8%) and losses (7%), alongside costs of supply restrictions (5%, cost of the reliability charge). Distribution costs are very high due to non-technical losses and higher distribution investments in recent years, driving up network charges at the different regional distribution areas.

Electricity retail prices are heavily subsidised for low- and middle-income households (strata 1-3) and partly cross-subsidised for more wealthy households (strata 5 and 6) and industry users; any remaining deficit is covered by the state. Some 80% of households (strata 1-3) benefit from substantial subsidies (up to 60% of the retail price) up to the level of the subsistence consumption. The government acknowledges that the strata classification system is flawed, as it is not linked to income but to housing and regions. A short-term fix to improve the targeting of the subsidies would be to reform the strata system so that only vulnerable households enjoy subsidised prices. But in the longer term, a more fundamental change is needed, and support should be targeted through other means than the electricity price to ensure prices reflect costs for everyone, and provide incentives for energy saving and efficiency.

The MME and the CREG have been promoting massive deployment of advanced metering infrastructure, which integrates hardware, software and communications networks for the operation of the distribution system. The MME set a goal for advanced metering infrastructure that by 2030, 75% of system users would have advanced meters, equivalent to approximately 11 million meters. As of March 2022, there were 446 055 advanced meters installed in the country. Advanced metering infrastructure is considered a fundamental component for the digitisation of the system and the implementation of smart networks, as well as for distributed energy resources. Despite this, further work is needed to address the cost and benefits of the roll-out of smart meters considering the experience of the pilot projects already developed.

Outside the SIN and the MEM, Colombia has non-interconnected zones (3% of demand), which are supplied by small local electricity generation plants, running mainly on liquid fuels, such as diesel. Access to electricity remains a challenge in these areas. As part of the just transition, the government is investing in self-consumption and distributed renewables, notably solar PV, in non-interconnected remote areas.

Electricity security

The 1991 Constitution considers electricity supply a universal service. The state is responsible for guaranteeing secure access to and the quality of electricity supply.

Electricity security is strongly determined by Colombia’s resources. Colombia's hydropower-based electricity system has seen periods of low availability of hydropower resources (most of the resources are run-of-river and only 8% have a storage function), which led to frequent price spikes and power supply disruptions, notably during the El Niño disaster in 1992. To deal with this challenge, the government approved a large hydro-reservoir project, the Hidroituango, that came online in 2022 with 1.2 GW (possibly another 1.2 GW in a second phase by 2024), and has implemented several capacity remuneration mechanisms over the past decade. The government’s main task is providing security with sufficient flexibility, notably during times of El Niño (which is about every four to five years).

International interconnections are weak in Colombia, but projects are underway to have sufficient electricity imports available in the medium term. A new interconnection is planned with Panama and there are plans for a regional interconnection project with Ecuador, Colombia and Peru, as the backbone for a common Andean electric power market. The commissioning of the 500 kilovolt (kV) Ecuador-Peru transmission line planned for 2024-25 will enable the synchronous operation of the Colombia-Ecuador-Peru power systems.

Today, natural gas plays a critical role in the security of the Colombian power system, notably during El Niño periods. The link between the gas and electricity systems is growing. In 2021, Colombia had a total of 5.3 GW of thermal power generating capacity, with gas (2.6 GW), coal (1.6 GW) and oil products (1.1 GW), including 800 MW of diesel generation (centrally dispatched). Solar is much greater than wind but not centrally dispatched.

According to government forecasts, hydroelectricity will only represent half of electricity generation by 2050, compared to 70% in 2022. Colombia's geothermal development is only just starting, with two pilot projects and a new legal framework being adopted. Expanding the country's dispatchable capacity beyond gas and coal to pumped hydro and other storage (battery storage) as well as ammonia will be critical to ensure a secure and affordable, clean and climate-resilient power system.

The main mechanism to ensure security of electricity supply is Colombia's reliability charge, which has also seen increasing participation from renewable energy capacity since 2019. The scarcity pricing formula was reformed in 2015/16 and today reflects the cost of the oldest diesel generator. The CXC was activated several times and reliability energy was delivered by market participants. The CXC is an expensive mechanism but is still below the cost of a government price cap or a prolonged shortage over eight months due to low hydropower availability.

The regulatory authority, the CREG, is carrying out an assessment on how to adapt the reliability scheme to better fit the electricity system needs at all times while adapting to the decarbonisation pathway. The update and evolution of the reliability system has to be aligned with the introduction of new wholesale market segments, such as intraday and ancillary services, in a way that orders price signals and ensures generation adequacy and flexibility in a cost-efficient way. In doing so, aspects such as the complementarity of variable non-conventional renewable energy sources to provide firmness should be assessed.

Today, natural gas is a relevant fuel to ensure security of electricity supply in scarcity situations. For efficient market operation amid tight gas supply, it is key to ensure an adequate interface between the operation of the electricity and the gas systems in the short-term horizons. In the day-to-day dispatching, there is close co-ordination between both system operators to guarantee gas supply for the following day, which is called the gas nomination programme. However, further co-ordination and forecasts for weeks or months ahead would be positive to anticipate system needs.

Colombia suffers from very frequent outages, with 35 hours per year interruptions (SAIFI), much above the average of 10 hours per year in IEA countries. Quality of service must improve for industrial competitiveness and a more digitalised power system will be needed with higher shares of VRE.

Recommendations

The government of Colombia should:

- Strengthen and streamline the institutional governance of the electricity sector through structured co-operation of the different authorities and entities playing a role in the regulation, planning and supervision of the activities in the sector to ensure smooth and co-ordinated action in the energy system transformation process.
- Ensure effective integration and coherence of all electricity planning instruments within the different time horizons (short, medium and long term), based on the electricity demand projections of different sectors with sufficient granularity, and periodically update these electricity plans in a co-ordinated manner while closely monitoring and communicating their progress so as to avoid, for example, the negative impact of delays in permitting.
- Strengthen the independence and competences of market and competition authorities so they have the capacity to jointly take actions to enforce the efficient functioning of the electricity market, promote effective competition and preserve a high level of consumer protection.
- Reform the wholesale market by designing and implementing the envisaged new intraday and system operation services markets by 2024 with the objective of having a more technically and economically efficient dispatching and system integration of variable renewable energy sources. In doing so, take a holistic approach to ensure a proper fit with other markets, such as the day-ahead market and the reliability scheme.
- Guarantee that the expected roll-out of smart metering systems delivers benefits in a balanced manner from both the consumer and network operator perspectives, helping to improve flexibility and demand-side response.
- At the retail level, promote competition and establish a road map for the reform of price subsidies, stratum allocation and the cost-of-service calculation to support greater quality of electricity service, consumer choice and supplier switching.

References

CREG (2022), CREG presentation during the review week, April 2022 Bogota.

ETM (2020), Final report of the Energy Transformation Mission, https://efinetico.org/en/energy-transformation-mission-in-colombia.

IEA (International Energy Agency) (2023), IEA World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

IEA (2021), Climate Impacts on Latin American Hydropower, https://www.iea.org/reports/climate-impacts-on-latin-american-hydropower.

IMF (International Monetary Fund) (2019), Colombia – Technical Assistance Report Reforming Energy Pricing, https://www.imf.org/en/Publications/CR/Issues/2019/11/18/Colombia-Technical-Assistance-Report-Reforming-Energy-Pricing-48819.

Rodríguez Hernández, R. (2017), Apagar Si Pagó, UPME, www.cidet.org.co/sites/default/files/documentos/art_9_0.pdf.

World Bank (2019), Learning from developing country power market experiences, https://documents.worldbank.org/en/publication/documents-reports/documentdetail/898231552316685139/learning-from-developing-country-power-market-experiences-the-case-of-colombia.

XM Sinergox. (Accessed: August 2, 2023). Hidrología del SIN. https://sinergox.xm.com.co/hdrlg/Paginas/Informes/HidrologiaSIN.aspx.

7. Coal

Key data (2021)

Coal production: 1 606 PJ (38 Mt) (1 467 PJ thermal, 139 PJ metallurgical), -38% since 2011

Coal exports: 1 595 PJ (40 Mt), -27% since 2011

Stock changes: 198 PJ (5 Mt)

TES of coal: 209 PJ (3.1 Mt) (production – exports + stock changes), -10% since 2011

Share of coal: 39% of domestic energy production, 7.2% of TES, 5.4% of electricity generation, 7% of TFC

Coal demand by sector: power generation 50.3%, industry 48.3%, buildings 1.4%

Overview

For more than two decades, coal has been the largest source of energy production in Colombia. Colombia is the fifth-largest coal exporter in the world. In 2021, almost all the coal produced in the country was exported.

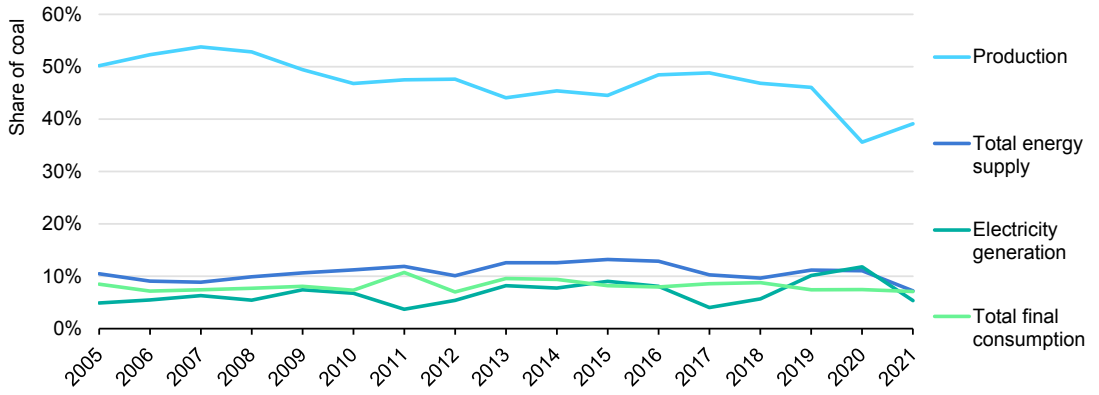
However, due to a significant reduction in global energy demand provoked by Covid-19 pandemic-related lockdowns, Colombia's coal production and exports decreased by 41% from 2019 to 2020. In 2021, coal production slightly rebounded by 12%. In the domestic mix, in 2021, coal accounted for 39% of domestic energy production, 7.2% of Colombia's total energy supply and 5.4% of electricity generation (Figure 7.1).

The share of coal in the Colombia's energy mix increased from 2000 to 2019. With a larger openness to international markets and the development of the coal industry over the last two decades, coal production increased by 121% between 2000 and 2019. TES of coal also increased, by 72%, during the same period. Electricity generation from coal increased by 271%, while the direct use of coal in TFC, mainly in the industry sector, slightly decreased, by 4%. Coal is used for electricity generation to guarantee security of electricity supply during seasons of water scarcity, such as when climate phenomena like El Niño occur. From 2019 to 2021, domestic energy supply of coal decreased by 36% and the use of coal for electricity generation fell by 45%.

Coal resources belong to the state and their exploitation is controlled by the MME. Colombia's energy and climate policy strategies do not include specific phase-out targets for coal production or consumption. In the short term, demand for Colombian coal increases amidst EU member states' ban on Russian coal. However, Colombian energy plans recognise the potential longer term reduction of international demand for coal in the context of the energy transition. The Petro government has banned investment in new coal

mines and introduced a tax on coal use for combustion as of 1 January 2023. The creation of mining districts under the PND 2022-2026 places new emphasis on the socio-economic and environmental transition and diversification of the mining regions.

Figure 7.1 Share of coal the energy system in Colombia, 2005-2021



Coal represents almost half of national energy production in Colombia, while it only accounts for 7% of total final consumption.

Source: IEA (2023).

Coal production and supply

Reserves

Colombia had 5 985 million tonnes (Mt) of coal reserves as of 2019, with 80% of reserves concentrated in the La Guajira (3 436 Mt) and Cesar (1 388 Mt) regions, in the north-east part of the country (UPME, 2021). Colombian reserves are the largest in South America and are mainly composed of anthracite and bituminous coal (ANM, 2021). Colombian coal has high calorific values: the coal from La Guajira and Cesar reaches calorific values between 6 600 kcal/kg and 7 100 kcal/kg. Colombian coal also has a low sulphur content. As of January 2022, there were 1 955 coal mining titles in the country, of which 192 were in the construction and assembly stage, 166 in the exploration stage and 1 597 in the exploitation stage (ANM, 2021).

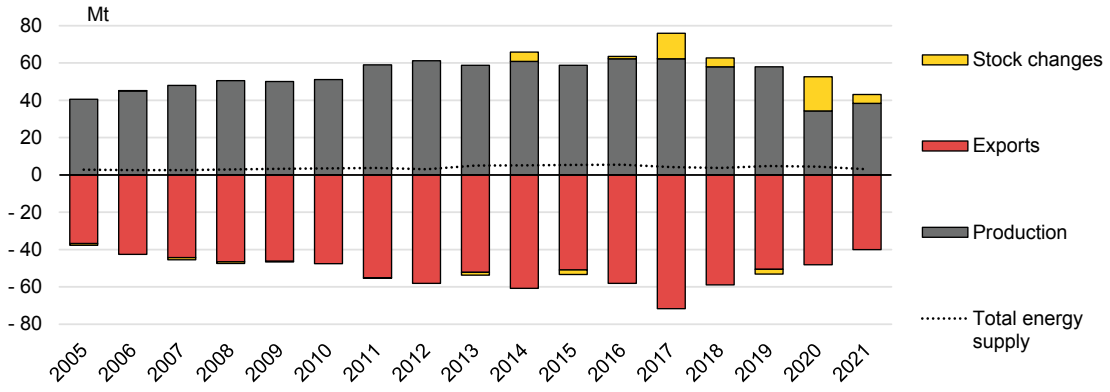
Production

Large-scale mining in the two coastal departments of Cesar and La Guajira accounts for 91% of the country's production. All coal produced in these regions is exported. Coal produced in the interior of the country is thermal coal, which is consumed locally for power generation and in the cement, paper, textile and food sectors.

Colombian coal production grew rapidly in the first decade of 2000s. Between 2000 and 2011, production increased from 38 Mt to 85 Mt (UPME, 2021). Since then, it stabilised but decreased because of the pandemic in 2020 and only slightly rebounded in 2021. Most Colombian production is exported. The country is the fifth-largest thermal coal exporter in the world after Indonesia, Australia, the Russian Federation and South Africa (IEA, 2021).

In 2020, coal production fell by 42%, from 84 Mt the year before to 50 Mt (IEA, 2021). This was the result of low coal prices, plummeting demand in the Atlantic basin and interruptions due to Covid-19, alongside a strike at El Cerrejón, the country's (and Latin America's) largest open pit coal mine in the La Guajira region. Cerrejón production dropped from 27 Mt in 2019 to 13 Mt in 2020. Production of mines in the Magdalena region fell from 15 Mt in 2019 to only 4 Mt in 2020, as the company managing the mine, Prodeco, (subsidiary of Glencore) stopped extraction due to low prices and (relatively) high production cost in the La Jagua and Calenturitas mines. Preliminary data for 2021 show a 6.4% increase in production.

Figure 7.2 Coal balance in Colombia, 2005-2021



Colombia exports most of the coal it produces. Imports are marginal as reserves in the country are abundant and enough to satisfy local demand.

Note: Mt = million tonnes.
Source: IEA (2023).

Trade

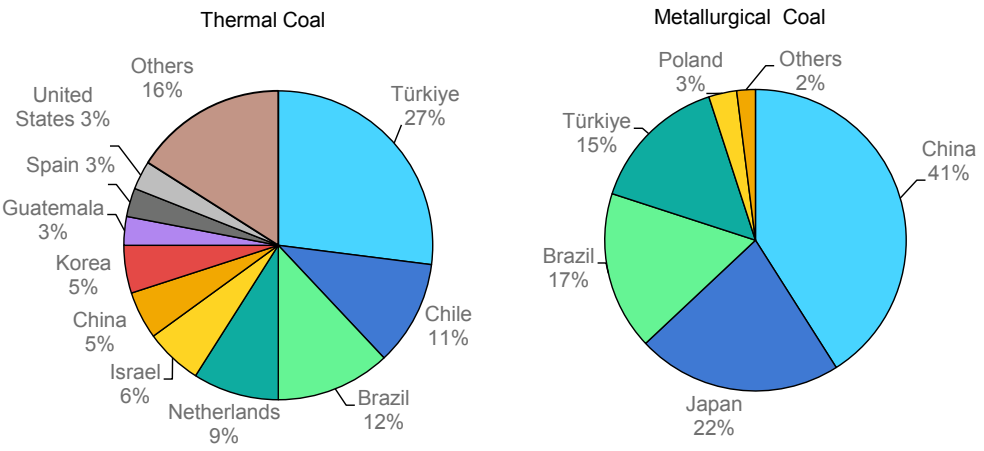
Coal in Colombia is mainly produced for exports. Exports peaked at 72 Mt in 2017, slightly decreased to 51 Mt in 2019 and dropped to 40 Mt in 2021, the lowest amount since 2005. In 2021, thermal (bituminous) coal accounted for 91% of total production and metallurgical coal for 9%.

Colombian coal trade reaches across the globe. Trade partners vary depending on the type of coal.

For thermal coal, the large majority of Colombia's coal exports are directed to the Republic of Türkiye (27% in 2021), followed by Brazil (12%), Chile (11%), the Netherlands (9%) and Israel (6%).

For metallurgical coal, Colombia exports mainly to China (41% in 2021), Japan, Brazil and the Republic of Türkiye, according to government statistics. Even if marginally, Colombia is also a coal importer. In 2020, the country imported almost 80 kilotonnes (kt) of coal, of which 86% came from Ireland and Spain (UPME, 2021).

Figure 7.3 Coal exports by type of coal in Colombia, 2021



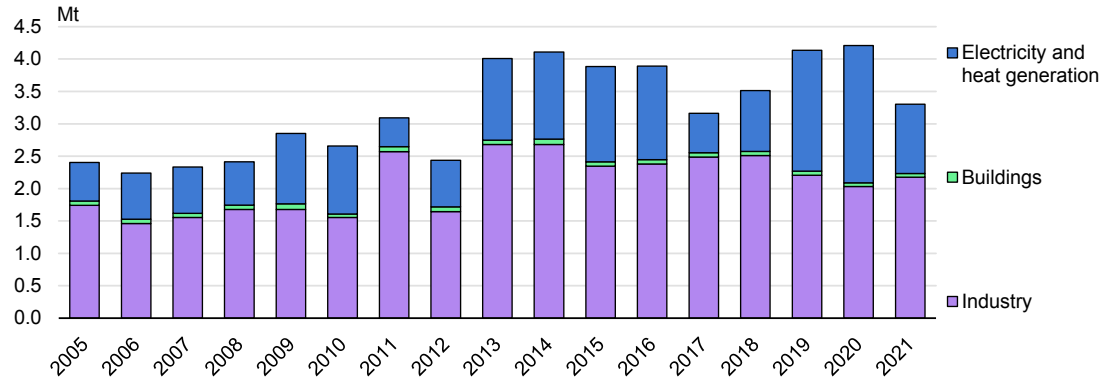
Colombia's thermal coal exports are diversified. China is a major importer of coking coal.

Source: Government of Colombia 2022.

Coal demand

In 2021, only 9% of the total production was consumed domestically. Colombia's coal supply was 136 PJ in 2020 and has decreased by 28% since 2011. It is composed of metallurgical coal (61%) and thermal coal (39%). In 2021, 50.3% of coal consumption stemmed from the industry sector, using coal for the production of coking coke, followed by electricity generation (48.3%) and residential buildings (1.4%).

Figure 7.4 Coal demand by sector in Colombia, 2005-2021



Source: IEA (2023).

Coal is used for electricity generation, especially when drought periods lower the availability of electricity generation from hydro. In 2013, when the El Niño phenomenon reduced precipitations, coal demand jumped by 60% year-on-year. It remained until the drop by 20% during 2016 and 2017, when the La Niña phenomenon brought heavy rains

across the country. In the residential sector, coal is mostly used for space heating, particularly in the less developed regions of the country.

Coal demand and supply outlook

In 2022, European demand for Colombian thermal coal was on the rise, following the Russian invasion of Ukraine and the planned phase outs of coal-fired power generators being postponed.

In 2022, the country's coal production was forecast to decrease by almost 4%, according to the IEA's latest global coal market report (IEA, 2022a). This was caused by lower production in Colombia's large mines due to rainfall and export barriers for small inland miners due to protests by the local population and port blockages.

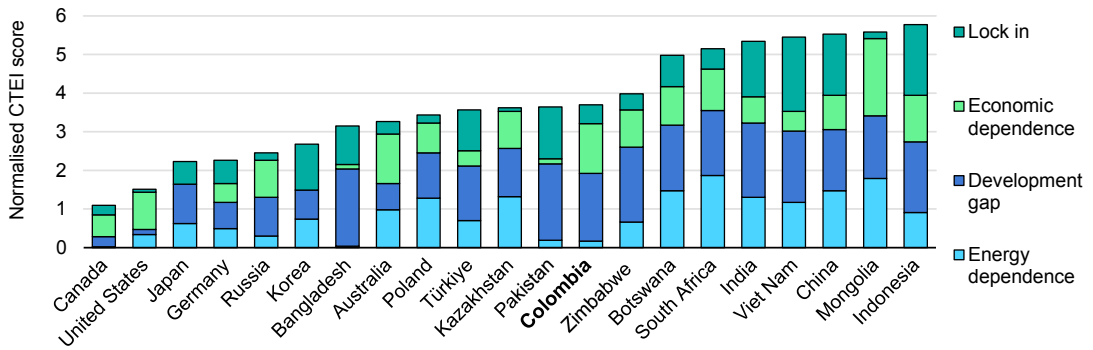
The medium-term outlook for coal in Europe to 2025 points to the fact that Russia's invasion of Ukraine is accelerating the energy transition. The IEA expects Colombian coal production to decline by 2025, due to reduced thermal coal production in response to lower domestic demand and reduced demand from key importers (IEA, 2022a).

Coal transitions

According to the IEA Coal Transition Exposure Index (CTEI), Colombia's energy transition has to face several country-specific issues related to the role of coal production and consumption. Colombia does not highly depend on coal use for its domestic energy needs, but the coal sector is critical for its economic development, as almost 90% of total coal production is exported.

Coal accounts for 39% of domestic energy production, 7.2% of TES, 5.4% of electricity generation and 7% of TFC.

Figure 7.5 The IEA Coal Transitions Exposure Index



Source: IEA (2022b).

However, Colombia's energy demand is still on the rise as economic development drives up energy consumption. To satisfy rising future energy demand, clean energy supply needs to expand as fast as demand to avoid increased coal use, and faster than demand growth to cut into existing coal use.

The potential lock-in from Colombia's coal mining is relatively small, as coal-fired power generation assets are already aged and so are the mines. However, Colombia's coal production is concentrated in specific regions and any transition away from coal translates into job and economic losses in those regions.

The CTEI typology employs two indicators for each of the four categories: 1) energy dependence on coal is quantified by its share in TES and in electricity generation; 2) the development gap is quantified by GDP per capita measured at purchasing power parity and TFEC per capita; 3) economic dependence is measured by the share of coal in total goods exports and the share of coal produced domestically compared with total coal consumption. Domestic production of a sizeable share of coal demand is likely to see coal playing a larger role in the economy than for a country that imports coal; 4) lock-in aims to quantify the challenge of potential early retirement of assets that have not been fully depreciated through the capacity-weighted age of a country's integrated steel mills and its coal-fired power plants. To generate the index, the raw data for each of the eight indicators was normalised to assign a total score. For each indicator, the country with the highest value was allocated a one and the country with the lowest value received zero. Normalised scores were added together to give an aggregate score.

Coal policies

The Colombian state is the owner of the natural resources (Article 332 of the 1991 Constitution). The MME (and the UPME) is the main authority for the Colombian mining sector. Attached to the MME, the ANM acts as mining authority and is tasked with managing the mineral resources of the state and is responsible for granting rights for their exploration and exploitation. It also designs, implements and discloses strategies to promote the exploration and exploitation of minerals.

In the last ten years, three operators (Drummond, Prodeco and Cerrejón) have contributed around 86% of coal production and 96% of coal royalties. Four new mines are included in the priority investment projects and new thermal coal investment is contained in the National Generation and Transmission Plan. Glencore acquired Anglo American's and BHP's respective 33.3% interests in Cerrejón in 2021.

As the state is the owner of the mines, coal exploiters have to pay royalties to the state. The holders of mining licences pay a fee to the state during the exploration, construction and assembly stages, and royalties during the production stage. The ANM defines the terms and conditions for the base prices of royalties and compensations for coal exploitation. The total amount of coal royalties was estimated in 2019 at COP 2 trillion (USD 532 million) per year, which accounts for 1.1% of GDP.[1]

[1] https://www.minenergia.gov.co/documents/10192/24311177/documento+carbon%284%29.pdf#page=14.

Coal exploration and exploitation must be carried out under mining concession agreements, with a term of 30 years, extendable for an additional 30 years. They include a 3-year exploration stage, extendable for 11 years. The construction and assembly stage lasts three years and can be extended by one year. The mining exploitation stage, which is the time remaining to complete 30 years, includes the closing and decommissioning stage. Mining titleholders are obliged to carry out an environmental impact study prior to the start of construction, assembly and production works. There are no incentives or subsidies for coal production, but coal is exempt from the national carbon tax.

Adopted in 2016, the National Mining Policy is the main framework for mining (Resolution No. 40391). The policy promotes dialogue with territories, compliance with the environmental obligations of mining titleholders and co-ordination with environmental authorities for the monitoring of mining activities. A legal obligation to have an environmental insurance exists to cover damages caused to property owned by third parties as a result of environmental pollution, deterioration or damages. However, there is no environmental license required for the exploration stage (which can last 11 years).

Colombia's coal policy under President Duque

According to the government (ANM, 2022), in 2021, the coal mining industry accounted for 130 000 employees, of which 30 000 are employed by large-scale mining in the Cesar and La Guarjira regions, and 100 000 in small and medium-sized mines in the central regions of Norte de Santander, Santander, Cundinamarca, Boyacá, Córdoba, Antioquía, Cauca and Valle del Cauca. These numbers do not include workers in coal-related industries and there is a large informal mining sector, notably in smaller mines.

Illegal mining remains a significant issue in Colombia. There is no updated mining census, but it is estimated that more than 70 000 people are engaged in small-scale mining in the country, exploiting gold, precious metals and coal.[2] The MME has proposed to legalise 27 000 miners (all sectors included). In the coal sector, only a small portion – 1 917 miners according to government statistics – have been formalised; the government expects another 1 873 more illegal coal miners yet to be formalised.

A financial inclusion strategy, entitled "Building Trust", promoted mechanisms for the inclusion of mining entrepreneurs in the financial system and in the capital market. Regarding credit solutions, the MME entered into an agreement with the Fund for the Financing of the Agricultural Sector (FINAGRO), contributing COP 2 763 million for the creation of a Special Credit Facility to facilitate loans to small mining titleholders.

Colombia did not include any targets or guidelines for coal production and export in its NDC. Under the E2050 strategy, Colombia expects the international coal market to remain stable, with no fundamental changes in coal demand from the main importers (UNFCCC, 2021). The E2050 strategy did not include any ambition to phase out coal production or consumption, as long as international demand is sustained. The country's net zero goal under the Climate Action Law (2169/2021) has not yet defined specific energy and mining sector targets.

[2] https://www.semana.com/mejor-colombia/articulo/asi-avanza-la-formalizacion-del-sector-minero-colombiano/202200.

In October 2021, the then Minister of Mines and Energy Diego Mesa presented the Coal Agenda, a road map to develop Colombia's coal sector. The government at the time considered that a better position for Colombia in the international coal market could favour the financing of coal-related projects, including investment in energy self-sufficiency of small mines and improved coal trade infrastructure, particularly rail. To promote a just transition in the medium and long term in coal-producing regions, the government launched a number of diversification strategies. In the regions of Cesar and La Guajira, local actors promote tourism and other service activities.

Concerning carbon capture, utilisation and storage (CCUS), the government identified four clusters of potential areas for carbon storage in the country to compensate for polluting activities. A cluster was identified between Santander, Antioquía and Norte de Santander, where most of small-scale coal mining is located. This cluster has a CO_2 capture potential of 4.3 Mt CO_2/year that was mostly linked to the oil, power generation and cement industries. However, coal is not being addressed. Nonetheless, the government estimates that CCS could eventually remove 25 Mt CO_2 per year, which could, for a large part, offset the 33.5 Mt per year emissions from the mining and energy sectors.

Colombia's coal policy under President Petro

The Petro government seeks to address the issues related to coal mining in Colombia, including paramilitary violence, deforestation and environmental destruction. It imposes a carbon tax on coal consumption. In August 2022, the Ministry of Finance and Public Credits released the draft tax reform plan as President Petro started his term, which was adopted by Congress in November 2022. As of 1 February 2023, a carbon tax at COP 23 394,60, or EUR 5.28/t CO_2-eq, is imposed on all petroleum derivatives and natural gas used for combustion as well as coal. A gradual increase will occur for the coal tax over time: 0% in 2023 and 2024; 25% in 2025, 50% in 2026, 75% in 2027 and as of 2028 the full rate of COP 59 587/t or EUR 13.46/t.

As coal exports are not subject to the carbon tax, the Petro government announced plans to introduce a 10% income tax on coal exports above a threshold of USD 87/t.

The Petro government seeks to overhaul the way concessions are granted in mineral mining. In December 2022, the Petro government committed to ban investment in new coal mines and announced plans for the gradual phase out of coal exports in the coming decades and to diversify the economy of the country. As long as agriculture and renewable energy production do not generate more income than coal mining, the government aims to purchase the coal that is produced and ensure a transition for the coal mining sector.

In addition, the Petro government aims to provide former coal miners of the La Guajira and Cesar regions with the ownership of the non-conventional renewable energy sources that are expected to be massively deployed in these departments.

Critical minerals

Colombia's energy transition towards climate neutrality is expected to provide employment and social benefits and shift Colombia's producer economy to a new energy economy. The Colombian government wants the mining sector to focus on the exploration and development of minerals critical for the energy transition.

Colombia has reserves of copper, nickel and cobalt, and its mining industry is well developed and guided by the National Mining Policy of 2016 (as a framework for competition and good governance). The demand for critical minerals is going to evolve in step with the pace of the global and regional energy transitions in Latin America, technology developments, improvements in recycling and substitution as well as the outlooks for domestic minerals production and demand in North America and Europe.

Colombia has a list of critical minerals that it considers strategic. In 2012, as part of a national plan to foster the development of the mining industry, the MEM seeks to promote a rational, technical and responsible use of its mineral resources to attract foreign and national investment and foster national economic and regional development.

Energy enacted Resolution No. 180102 declared certain minerals as being in the strategic interest for the development of the Colombian mining industry due to their worldwide demand and significance: gold, platinum, copper, phosphate minerals, magnesium minerals, metallurgical and thermal coal, uranium, iron, niobium and tantalum minerals, and/or black sands. The MME can reserve areas in which these minerals are present and impose special minerals licensing conditions. In the bases for the PND 2022-2026, the government announces the definition of a new mining policy with measures to improve geological knowledge about Colombia's mineral resource base.

Based on court rulings, mining in areas deemed to be environmentally sensitive, such as high-altitude wetlands, is restricted and there are many environmentally protected zones in Colombia. Colombia's environmental authority cancelled Minesa's environmental application for its Soto Norte gold project in October 2020 and AngloGold Ashanti's application for its Quebradona copper project in October 2021.

Assessment

Coal is an important asset for the Colombian economy, notably in some regions that have limited alternative economic activities. The high quality of its coal reserves and its relatively low costs of production make Colombian coal very attractive for exports. Today, almost 90% of Colombia's coal production is exported, securing a large part of the state budget and employment at the local level.

The eventual decline of global coal demand will have an impact on Colombia. In this context, the opening of new large coal mines needs to be re-evaluated to avoid stranded assets in the future. In 2022, the new Petro government banned investment in new mines.

A gradual transition of the coal sector in Colombia is a key priority, notably for the country's economic development.

Coal is important domestically, as an energy source for industry and electricity generation; in existing government projections, this importance is there to stay, even in the 2030 and 2050 time frame. In this sense, there would be a disparity between those projections and the stated goals of the government to reduce GHG emissions by 51% in 2030 and to have a carbon-neutral society by 2050. The Coal Agenda announces some initiatives to reduce emissions from the coal sector, but these are not yet detailed, and are unlikely to contribute its share of the 51% emissions reduction by 2030 and carbon neutrality by 2050.

Moreover, a renewable expansion has been slow over the past years, coal has seen a stronger use and a few new coal-fired power plants are planned to be built, without any

requirement for a carbon removal technology. A carbon tax has been introduced and will gradually increase to the full rate of EUR 13.46/t on coal consumption in Colombia until 2028 but not exports. The new tax proposed on coal export income above a certain threshold could be a basis for government investment in abatement technologies.

While CCUS is set as an abatement technology for power generation and the production of hydrogen from coal, the country does not have a CCUS programme for developing and implementing this technology, nor is there a regulatory framework for CO_2 storage that would allow for providing permits for sites where CO_2 storage could be allowed.

Concerning the substantial use of coal in industry (steel, paper, cement), there is no policy for these industries to either move away from coal through electrification or the use of non-emitting energy sources, or to apply CCUS on their processes.

Despite the government's goals to plant trees as an option to compensate for remaining GHG emissions from the use of coal, Colombia currently faces a significant deforestation challenge, responsible for about a third of the country's GHG emissions. If deforestation is not properly addressed, planting trees might not be effective as a mitigation measure to reduce GHG emissions from coal use. It is important to halt deforestation to also address illegal mining in the country, which usually comes with much higher emissions per unit produced than regulated mining, and harmful working conditions.

To date, Colombia was relying on continued exports of coal, also in a situation where most countries have stated goals for net zero emissions or carbon neutrality. This comes with a risk, notably for those regions in Colombia that rely heavily on coal exports. The government is to be commended for starting an economic diversification programme for those regions. These programmes focus on tourism and culture, agroindustry, and renewable energy; notably, renewable energy seems to be a promising option for the mining regions in the north, which have a high wind and solar resource.

The PND 2022-2026 provides for the increase in the share of non-mining activities in the country's exports and includes the creation of mining districts to support the diversification in each district depending on its socio-economic situation and coal transition. Such an approach is also broadly consistent with global approaches, such as the coal regions in the EU and other regional programmes in Brazil or Indonesia.

What seems to be lacking is making use of the skilled mining labour force to develop an industry for critical minerals, which are in high demand globally to enable the energy transition. The Petro government announced plans for clean energy projects in Colombia's coal regions, which is a good step forward; however, new funding programmes are needed for reskilling and industrial transformation. To prepare Colombia's mining sector for this transition, there is a need to strengthen standards to mitigate environmental impacts on water and biodiversity, foster the consultation with affected communities, and agree on the distribution of socio-economic benefits.

Recommendations

The government of Colombia should:

- Develop concrete policies, measures and funding to accompany a people-centred transition of the coal sector in Colombia's coal regions in line with Colombia's climate and energy transition goals.
- Design a carbon capture, utilisation and storage road map to develop and apply this technology in the country, and implement a comprehensive regulatory framework for licencing underground storage and transportation of CO_2.
- Steer industry to reduce CO_2 emissions from coal use by applying the national carbon tax on the use of coal; or providing incentives to invest in improved, lower emissions production processes.
- Explore the potential for mining of critical minerals in the country, and, together with industry and communities, identify pathways and adapt mining policies to set up a profitable critical minerals industry in Colombia, aligned with environmental, social and governance criteria.

References

ANM (National Mining Agency) (2022), Coal, the mining godfather of Colombia, https://www.anm.gov.co/?q=carbon_el_padrino_minero_de_colombia_boletin_prensa.

ANM (2021), El future del carbón en Colombia no termina, se fortalece con las ruedas de negocio [Colombia's coal future doesn't end, it is strengthened by business roundtables], https://www.anm.gov.co/?q=rueda-de-negocios-carbon-termico-en-colombia.

IEA (International Energy Agency) (2023), IEA World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

IEA (2022a), Coal 2022, https://www.iea.org/reports/coal-2022.

IEA (2022b), Coal in Net Zero Transitions, https://iea.blob.core.windows.net/assets/4192696b-6518-4cfc-bb34-acc9312bf4b2/CoalinNetZeroTransitions.pdf.

IEA (2021), Coal Market Report 2021, https://www.iea.org/reports/coal-2021.

UPME (Mining and Energy Planning) (2021), Carbon, Cifras Sectorales, https://www1.upme.gov.co/simco/Cifras-Sectoriales/Paginas/carbon.aspx.

UNFCCC (United Nations Framework Convention on Climate Change) (2021), E2050 Colombia, https://unfccc.int/sites/default/files/resource/COL_LTS_Nov2021.pdf#page=50.

8. Natural gas

Key data (2021)

Domestic production: 12.4 bcm, +0.5% since 2011

Imports: 0.05 bcm

Share of gas: 10% of domestic energy production, 22% of TES, 16% of electricity generation, 11% of TFC

Gas consumption: 12.4 bcm (industry 42.5%, electricity and heat generation 31.9%, residential buildings 15.1%, transport 6.2%, services buildings 4.2%)

Overview

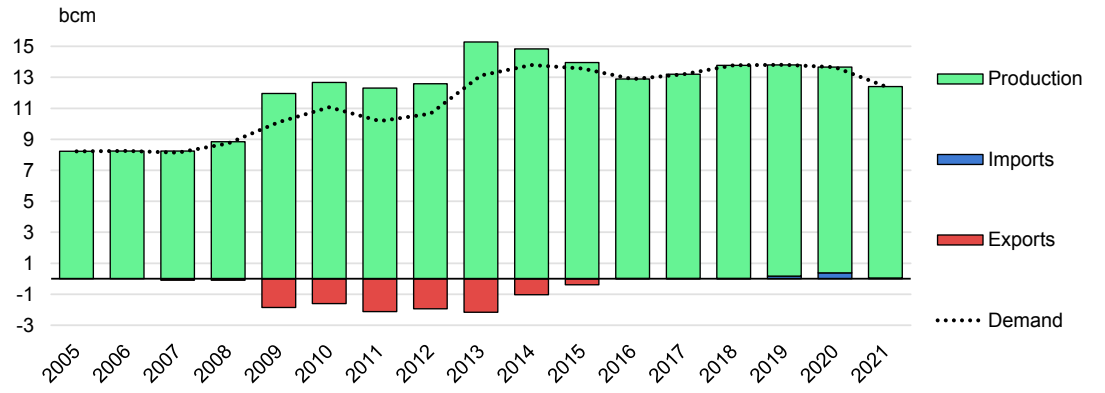
Since the 1990s, the role of natural gas has grown in Colombia. Building on the CONPES "Gas Plan and Programme for Gas Mass Consumption", Colombia has invested in developing a natural gas sector. To encourage the use of natural gas and LPG, the government offers subsidies to the population and collaborates with the private sector to finance the expansion of gas infrastructure. The shift to gas has accelerated over the last two decades, which was reflected in a significant increase in both consumption and production. From 2005 to 2016, the number of natural gas users increased by 122%, from 3.72 million to 8.11 million household consumers, or two-thirds of households in Colombia. In the urban areas of municipal districts, this share surpassed 80% of households, while in populated and rural areas, around 12% of households had access to this service.

However, Colombia's proven gas reserves are declining. At the end of 2022, reserves were around 80 billion cubic metres (bcm) or 7.2 years of reserves to production ratio (ANH, 2022).

In 2021, gas consumption was 12.4 bcm, which was covered by 12.36 bcm was domestically produced and 0.05 bcm imported. Colombia's domestic production only just covers regular domestic supply needs (Figure 8.1), not periods of high gas demand when hydropower is unavailable. Then, Colombia's domestic demand can become higher than production, so the country needs to import natural gas to cover the deficit.

Natural gas demand across the residential and transport sectors has been on the rise and gas demand in the power sector experiences strong variations with the period of severe droughts. While Colombia was a net exporter of natural gas between 2007 and 2015, this trend reversed in 2016, when the country commissioned its first LNG regasification terminal and began importing gas, mainly from Trinidad and Tobago. To maintain flexibility in the power sector, investment in a second LNG regasification terminal is being considered. Gas security policies are becoming a major priority for Colombia.

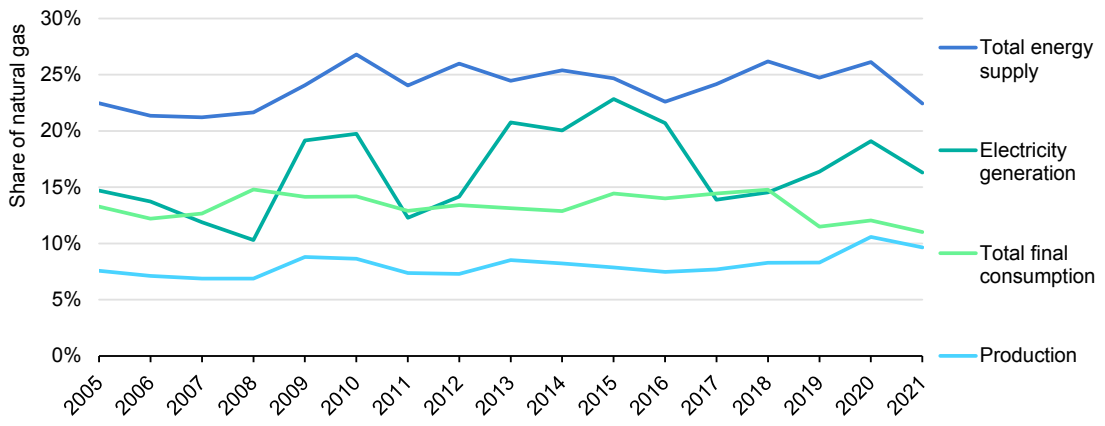
Figure 8.1 Natural gas consumption and production in Colombia, 2000-2021



Notes: Demand is calculated based on the energy balance.
Source: IEA (2023).

Power generation in Colombia is dominated by hydro but backed up with gas-fired and coal-fired power generation. Natural gas flexibility is critical for energy security in Colombia, mainly due to its role in supporting electricity supply but also strong industry demand. Consequently, during periods of drought, mainly caused by El Niño, the demand for natural gas grows. Any natural gas disruption or deficit of supply can have severe impacts on the power system reliability. For example, during the last El Niño event in 2015, gas-fired electricity generation increased from 14 bcm in 2014 to 18 bcm in 2015, accounting for 23% of electricity generation in 2015 (Figure 8.2).

Figure 8.2 Shares of natural gas in the Colombian energy system, 2005-2021



Source: IEA (2023).

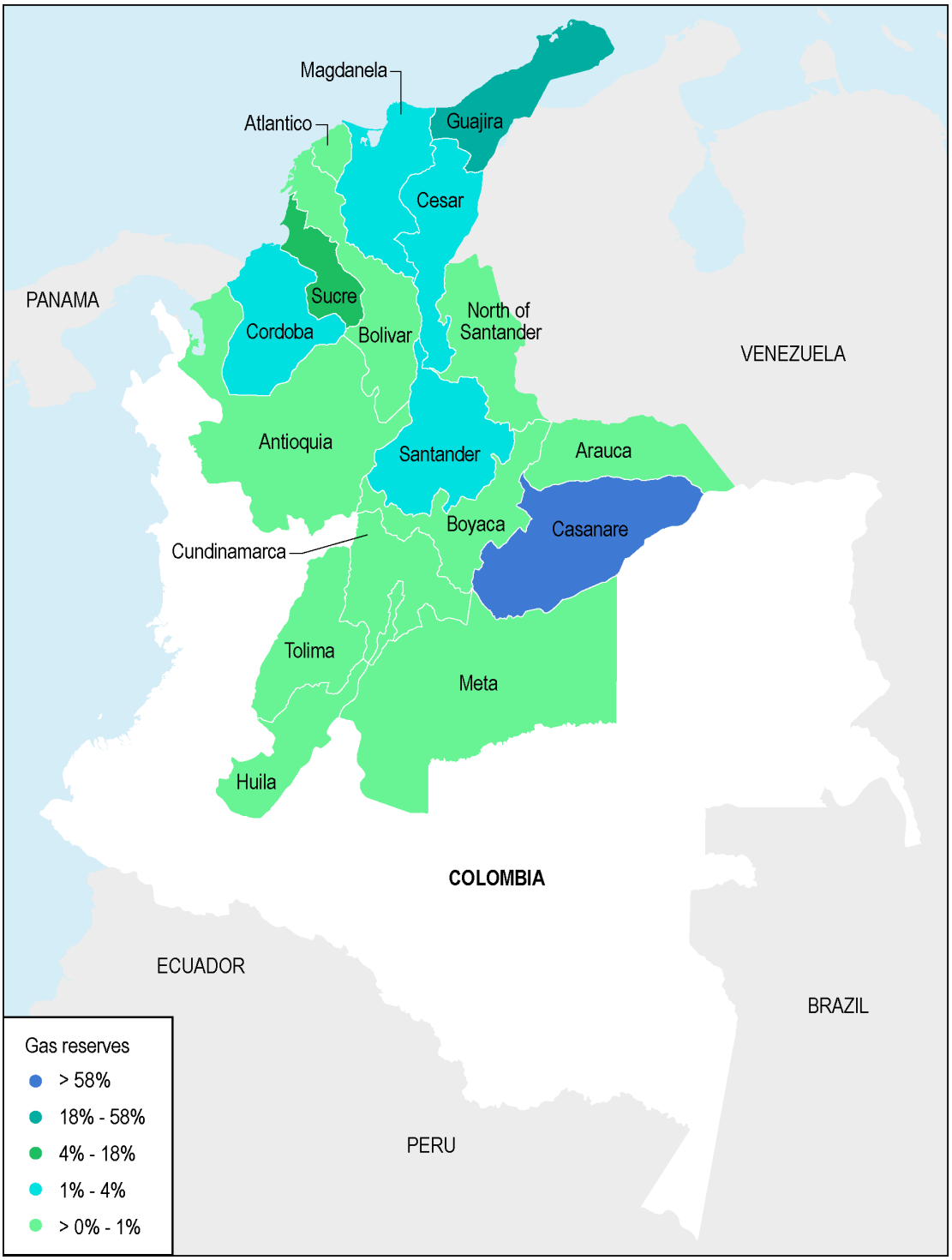
Supply and demand

Reserves

In 2021, Colombia's 337 hydrocarbon fields produced 84% of associated gas and 16% of dry gas. Sixty per cent of Colombia's gas reserves are located in the Llanos Orientales

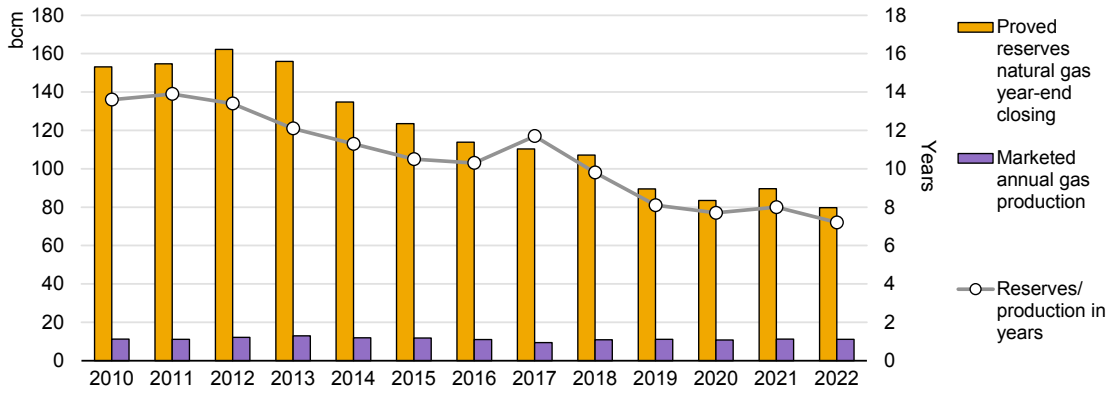
region (UPME, 2020). The most productive sites were located in La Guajira. However, the productivity of these sites decreased while production from other sites in the Llanos Orientales and Magdalena increased their supply.

Figure 8.3 Natural Gas reserves in Colombia



Note: Regional split of 1P reserves of natural gas by administrative department in Colombia (% of total reserves).
Source: ANH (2020).

Figure 8.4 Production of natural gas in Colombia, 2010-2020



Source: ANH (2023).

Despite an expected slight increase in domestic production up to 2028, Colombia's gas fields are in overall decline: at the end of 2021, proven reserves were at 89.6 bcm but at the end of 2021, falling to around 80 bcm at the end of 2022 or 7.2 years (ANH, 2023). Between 2010 to 2020, reserves declined by 45%.

In 2021, annual marketed gas production increased by 4%. In the latest 2021 license rounds, 30 new projects were awarded a license.

Colombia has important unconventional gas resources. Unconventional fields in Valle Medio del Magdalena could have a potential of 62.3-189.7 bcm (UPME, 2020). The Colombian Oil Association claimed fracking could add 198.2 bcm of gas to proven reserves[1] in the next 25 years. As of 2021, four permits had been issued for unconventional oil/gas production to Ecopetrol, Drummond, Tecpetrol and ExxonMobil.

The local population continues to oppose fracking (see Chapter 9). The Petro government is considering fully banning it and has no plans to develop new oil/gas reserves (apart from the ones that received approvals in the last licensing round). The anti-fracking bill, after being debated and approved by the Senate, has moved to the lower house of Congress for review, inching Colombia ever closer to prohibiting fracking.

Supply

The share of natural gas in TES in Colombia increased from 24% in 2009 to 27% in 2019. Historically, Colombia's natural gas needs were covered by domestic production, but amid decreasing availability of reserves and increasing demand, the country started importing gas from Trinidad and Tobago in 2016.

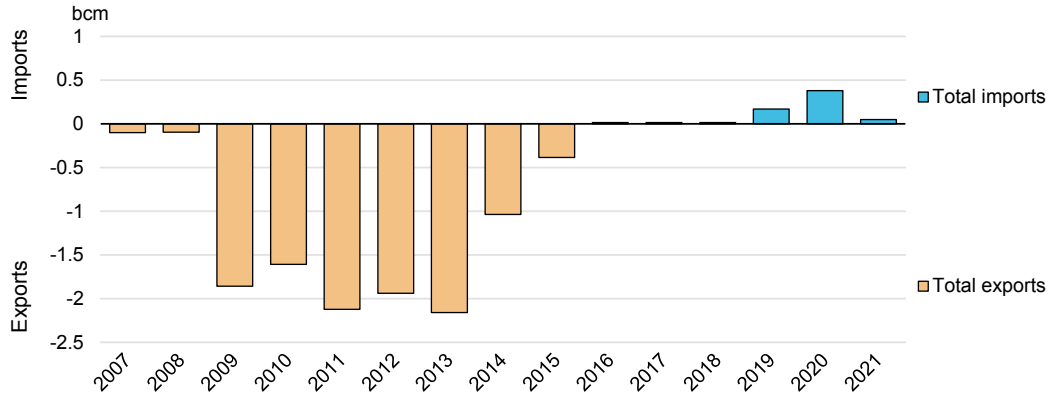
Trade

From 2007 to 2015, Colombia exported natural gas to Venezuela through the Trans-Caribbean gas pipeline. Today, Colombia no longer exports natural gas. Amid risks of energy supply disruptions, Colombia suspended exports and instead started receiving

[1] https://acp.com.co/web2017/es/todo-sobre-el-fracking/826-cuales-son-los-beneficios-del-fracking.

import cargos of LNG from Trinidad and Tobago in 2016. It is expected that the United States will become a major supplier of South America in the coming years, ahead of Trinidad and Tobago, which offers opportunities for Colombia to import US LNG.

Figure 8.5 Colombia's imports and exports of natural gas, 2007-2021



Source: IEA (2023).

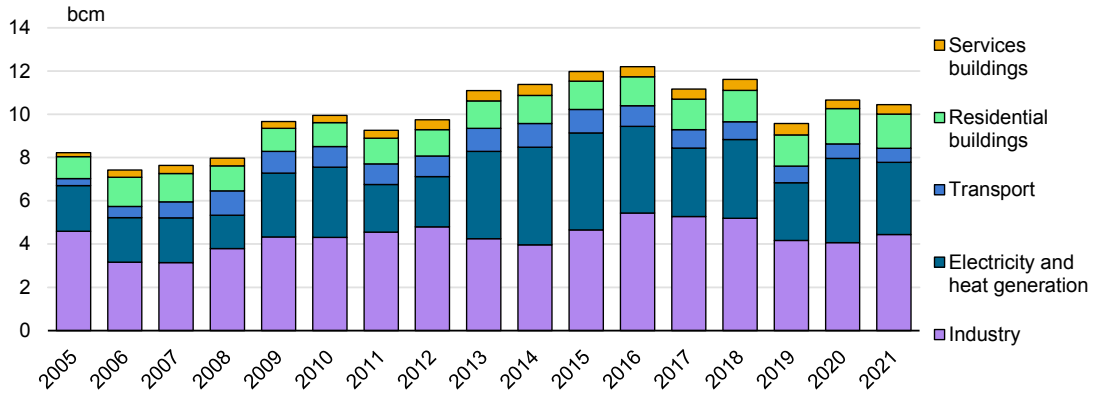
Demand

Demand for natural gas has almost doubled in two decades, driven by the growing demand in the power generation sector and the buildings sector. Natural gas demand was 12.4 bcm in 2021, up by 13% from 2011. Colombia's gas demand is not seasonal – there are no substantial increases in demand during winter/summer, but demand alters between the weekdays and the weekend and is driven by El Niño phenomenon, which occurs roughly every four years.

During the first half of 2020, for instance, hydro reservoir levels were very low (30-45%), pushing gas demand up with power generation from thermal plants going from 361 GWh (month of March) to 453 GWh in June.

In the power sector, 24 natural gas-fired power plants operated in 2021 (7 combined-cycle gas turbines, 17 normal, of which three with fuel-switching and co-firing capability).

Figure 8.6 Natural gas final consumption by sector in Colombia, 2005-2021



Source: IEA (2023).

The industry sector is the largest consumer of natural gas, accounting for 43% of demand in 2021, followed by power generation (32%), residential buildings (15%), transport (6%) and services buildings (4%). Industry demand for natural gas decreased by 2% between 2011 and 2021, with notable yearly fluctuations. The use of natural gas for power generation increased by 51% from 2011 to 2021, and experienced a notable increase between 2013 and 2016, mainly related to the El Niño episode that severely affected hydropower generation availability.

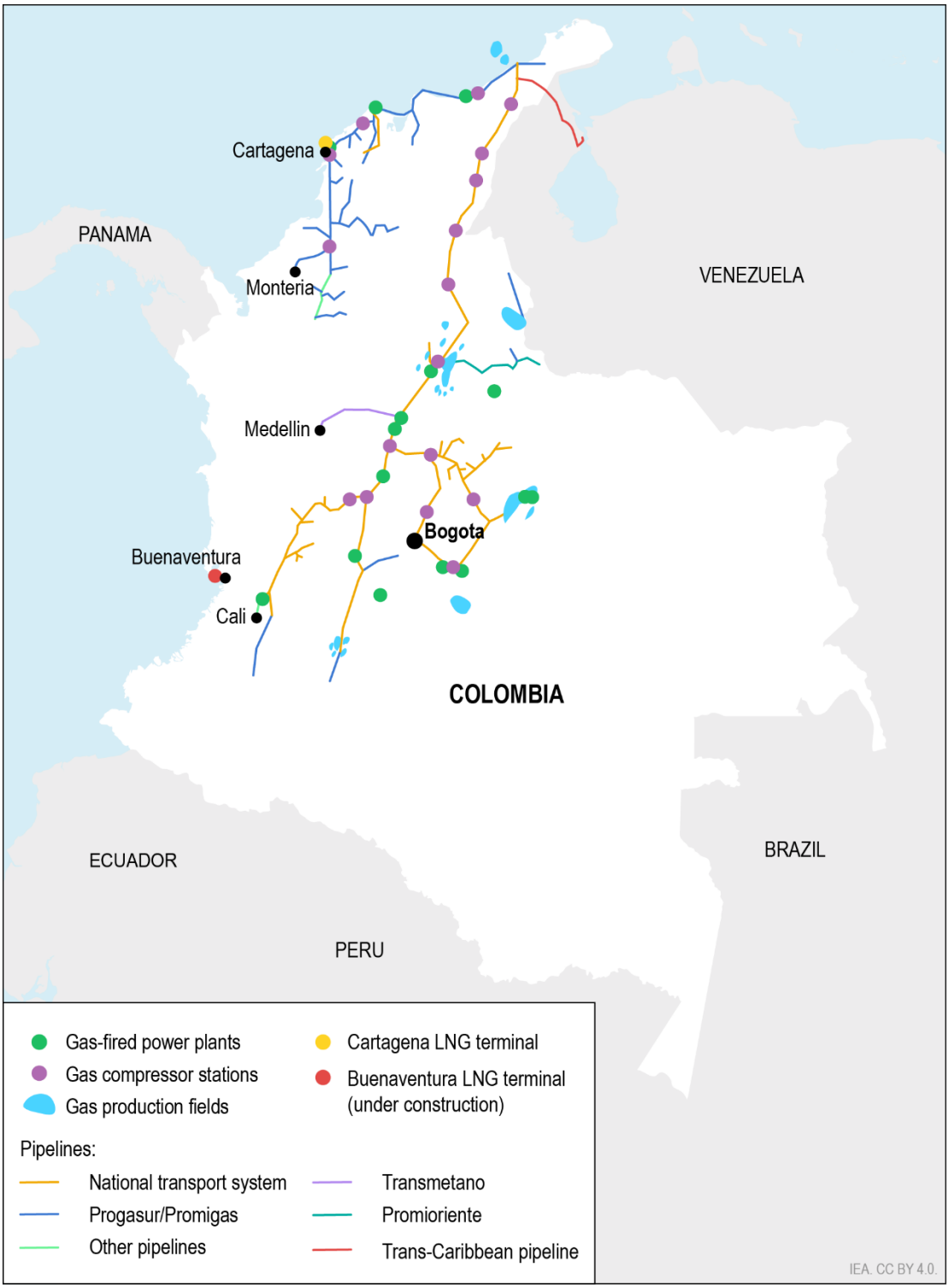
Transport consumption of natural gas consists of compressed natural gas (CNG) for vehicles. There are 433 service stations that supply this fuel to vehicles, located in 21 of the country's 32 departments, with 184 419 natural gas vehicles in Colombia.

Gas infrastructure

The gas network (national transport system, NTS) is radial and connects production and import areas with consumption sites. It consists of two large but non-interconnected systems: the coastal gas pipeline system owned by Promigas in the Caribbean Coast region, including the Cartagena Regasification Plant (Sociedad Portuaria El Cayao, LNG) and the mainland pipeline system (Figure 8.7 in orange), owned by Transportadora de Gas Internacional (TGI, 2023). TGI is affiliated to GEB (Grupo Energía Bogotá) and operates 4 000 km of pipelines with a transmission capacity of 23 675 cm/d.

Colombia has one LNG regasification plant and investment in two additional LNG terminal projects is planned.

Figure 8.7 Gas infrastructure in Colombia



In 2013, the government initiated a tendering procedure to build the first regasification plant in Barú, in Cartagena de Indias. The floating storage regasification unit (FSRU) "El Cayao" started operations in December 2016 (Sacyr Industrial, 2021). El Cayao has a storage capacity of 170 000 m^3 of LNG and regasification capacity of 11.3 mcm/d.[2] The contract for the FSRU is held for a ten-year period up to November 2026 by Grupo Térmico and SPEC (Sociedad Portuaria el Cayao), which is affiliated to pipeline owner Promigas. Promigas announced plans to expand the terminal to a capacity of 24 mcm/d by 2027.

Aside from the FSRU storage capacity, Colombia's natural gas network does not have underground gas storage. Linepack of the NTS and gas stored in completed oil/gas fields can be counted as storage.

The NTS has little network redundancy that could ensure the reliability of the supply in case of planned or unplanned maintenance of the production or transportation facilities. In 2008, the CREG created incentives for distribution and marketing companies to invest in projects ensuring network reliability, but none of the proposals materialised.

Natural gas regulation

The Superintendence of Industry and Commerce (SIC) is in charge of ensuring that the gas market is competitive and can take actions against monopolistic behaviour. The CREG is the regulatory agency for energy, gas and fuels, but it does not regulate access to gas infrastructure. Colombia's market framework is similar to the US scheme, based on gas transportation long-term agreements (contract carriage). The policy that is applicable depends on the type of facility:

- The installation of looping pipelines or compressors in the existing conduits must be carried out by the same transporter through an expansion contract. For the remuneration, the CREG fixes charges based on the average costs of the facility.
- For network extensions, the CREG opens a tendering process in which the participants depend on the type of infrastructure: for high-pressure lines only, transporters can participate and for low-pressure pipe networks, transporters and distributors can present their offers. In this case, the CREG guarantees remuneration through a revenue cap regulation, based on the offer that was selected.
- Regarding the pipelines that connect production or regasification sites to the NTS, the producer or importer can make the investments themselves or can open a public tender to transporters. For the last case, the charges must be approved by the CREG.

Overall, the framework tends to ensure the participation of the transport operator in the network expansion investments. However, when the transport operator refuses the costs set by the CREG, the project is carried out through a tendering process, which is then allocated regardless of the costs initially proposed to the transporter. This has led to ever rising network costs for consumers.

Gas market reforms

Liberalisation of the gas sector was enacted with Law 142 (in parallel to electricity), which ended Ecopetrol's gas monopoly over supply, transport and distribution and unbundled its production assets from transportation activity, thus creating the Colombian gas company,

[2] http://www.speclng.com/Es/El-Puerto/Paginas/GNL-para-generadores-termicos.aspx.

Ecogas. Natural gas distribution was free, not requiring concession agreements with the government. During the 2000s, the La Guajira gas field was connected to the gas network and started supplying the country. From 2010 onwards, the government carried out a range of reforms to boost competition, transparency and market performance, based on a number of the CREG's resolutions, all supporting the creation of a more liquid primary and secondary market, to allow for greater availability of gas and more efficient pricing in the primary and secondary market.

Today, there is a large number of contracts with varying degrees of firmness of supply.

LNG imports are directly tied to meet the firm energy obligations of the CXC mechanism due to the important role of gas in the power system. The LNG plant serves the shortages in the thermal plants during the year of a gas deficit; it does not participate in the main gas market.

The road map for the transformation of the energy system (ETM, 2020) had a focus area on natural gas, security and reliability of supply, which recommended the need for greater co-ordination between the CREG and the SIC with regard to the gas market regulation.

The ETM suggested a gas planning mechanism, spanning over ten years, based on the forecasted gas demand and not only supply availability, which has been the focus of the UPME to date. The ETM road map also called for major infrastructure build-out, with projects classified as "strategic". This could help to consider network redundancy projects as strategic and a matter of security and prioritised projects could benefit from special funding. The ETM also recommended the extension or substitution of the El Cayao FSRU by the end of the current contract (November 2026).

Another area of concern is the untransparent access and pricing regime. The ETM recommended switching to a common carriage regime, compatible with the "entry-exit" model and a revenue cap regulation scheme for existing transmission networks alongside the market-based regime for new transmission (tenders). The entry-exit regime and the related gas market merger are still being studied in 2023.

Gas market structure

Colombia's natural gas production is dominated by three companies: state-owned company Ecopetrol holds most of the market, followed by Equion Energia (a partnership between Ecopetrol and Talisman Energy) and Chevron.[3]

Wholesale market

Colombia has a primary and secondary gas market. The primary market covers natural gas producers, marketers and traders of imported gas, which offer natural gas. Natural gas transporters can also offer their transport capacity. In the secondary market, market participants with gas supply rights and/or with secondary available capacity can negotiate their contractual rights. All market participants can participate in the secondary market.

[3] https://www.eia.gov/international/content/analysis/countries_long/Colombia/background.htm.

The gas market manager is responsible for the provision of primary market and secondary market management services. The gas market manager designs, implements and administers the central gas bulletin (BEC, Boletín Electrónico Central), which centralises transactional and operational information, manages the auction mechanism in the primary natural gas market, the marketing mechanisms of the secondary natural gas market, runs the auction mechanism envisaged for contracts with interruptions in the natural gas wholesale market and reports information for monitoring the wholesale natural gas market.

Retail market

The main players in the distribution of natural gas are Vanti S.A. E.S.P., Gases Del Caribe S.A. E.S.P., Gases De Occidente S.A. E.S.P. and Empresas Públicas de Medellín E.S.P. Colombia has unbundled network and supply activities; however, supply, retail and production can be integrated, according to Resolution CREG 057/1996, if the company was created before liberalisation (Law 142/1994). Companies that carry out production, sale or distribution activities can market their gas freely.

Retail prices and taxation

Gas prices in Colombia are calculated at each level of the value chain by the respective companies in line with the tariff methodologies established by the regulator, the CREG. Production, transportation, distribution and marketing activities each have a different price regulation.

The marketing price of gas from the country's gas fields has been free for several years.

In 2020, the CREG implemented price mechanisms (Resolution CREG 186/2020). The CREG determines how the supply price is transferred to regulated users based on the cost of gas based on the volume of physical supply agreements, which are denominated in dollars (multiplied by the exchange rate on the last day of the month).

Service providers, based on the general tariff methodologies established by the CREG, calculate the cost of the service, according to the characteristics of the market served by each of them.

Subsidies

As with electricity, industrial users and consumers in strata 5 and 6 subsidise household consumers in strata 1 and 2, through the Solidarity Fund for Subsidies and Income Redistribution Crosssubsidisation Fund (under Law 142/1994) based on two principles established under the law for gas utility tariffs: 1) the principle of solidarity and redistribution; and 2) the principle of financial sufficiency.

Similar to the electricity sector, the same stratification system applies with users in strata 1 and 2 as beneficiaries of fuel gas subsidies, while those in strata 5 and 6 and commercial users make contributions through a surcharge. The subsidy is granted only on the basic subsistence consumption, established by the UPME, which is equal to 20 m^3 of natural gas per month. The subsidy is a maximum of 60% of the cost of providing the service for stratum 1 and a maximum of 50% for stratum 2. Gas users belonging to strata 3 and 4 are not eligible for the subsidy, and they are exempt by law to pay the contribution. The contribution factor that residential users of strata 5 and 6 must pay is 20% of the value of the service; it is 8.9% for commercial users.

Currently, the distribution of the Solidarity Fund for Subsidies and Income Redistribution does not comply with a basic principle of targeting, according to which the proceeds from subsidies must be directed to the lowest income population. Rate subsidies are granted to almost 60% of households connected to the gas grid.

Nationally, an average monthly natural gas bill considering a consumption of 20 m^3 is equal to USD 43.43.

Gas policy

Past governments have promoted the use of natural gas as a key transition fuel across the economy. The National Energy Plan 2018-2022 indicated a significant and growing role for natural gas, based on long-term energy scenarios. With a view to decrease emissions, governments have promoted natural gas use, including in the residential sector to replace firewood and solid fuels; in industry to switch away from coal; and in the transport sector with an increase in public transport (buses), freight (heavy-duty vehicles and trucks) and maritime transport.

In August 2021, Law 2128 created provisions to boost the reliability and coverage of natural gas in the country, alongside new subsidy programmes to support the policy objectives of greater gasification and incentives to increase exploration and exploitation activities. The PND 2022-2026 provides for the continued public support of the grid expansion to connect more users to the grid.

Security of gas supply

Colombia expects natural gas import needs to rise by 2024. The timing of current investment in the exploration and production of conventional and unconventional gas may not be able to mitigate the short-term gas deficit; it could, however, reverse the trend of declining reserves in the medium term. In 2021, the MME published a road map with actions on security and reliability of gas supply, building on the UPME's gas supply and demand report (UPME, 2020).

Historic gas supply disruptions

Colombia has experienced gas supply disruptions in recent years. In 2021, social protests and demonstrations (28 April and 21 May 2021), including road blockages, affected the transportation of fuels, including LPG and CNG. This situation created the risk of a gas supply storage, mainly in the south-western part of the country: Nariño, Cauca, Putumayo, Caquetá, Huila and Valle del Cauca.

A cold snap in August 2021 produced a landslide along the Chitamena River, in the department of Casanare, which resulted in a disruption of the gas pipeline Cusiana-El Porvenir-La Belleza. The incident caused a drop in pressure and forced the shutdown of the Cusiana gas field, which covers 31% of the country's demand.

Such gas supply issues can become particularly difficult when gas supply is high in the power sector during the El Niño seasons. In 2021, Colombia adopted a security of gas supply framework with a demand restraint mechanism, following several domestic gas supply disruptions.

Security of gas policy and regulation

In 2011, the government issued a Decree aimed at guaranteeing the national supply of natural gas, reflecting the urgency of preparing the country for a risk of a supply shortage caused by the increasing demand or the depletion of domestic reserves. The government prioritised the development of infrastructure to increase gas imports. Colombia's first regasification plant was inaugurated in 2016 in Cartagena. In 2015, Decree 1073/2015 set the regulatory framework for preventive action, planning and emergency response measures, including scheduled rationing.

It is interesting to note that in Colombia, gas producers and marketers are required to submit their production plan each year to the MME for each field for a ten-year period. They can update this information during the year.

The UPME prepared the 2019-2028 Natural Gas Supply Plan, based on the MME resolution (40304/2020). The technical evaluation and risk assessment provided by the UPME takes into account the forecast of a moderate episode of El Niño during 2021-24 which would result in a considerable gas supply deficit in 2024-25. To address this gap, the timely commissioning of the regasification plant of Buenaventura by December 2024 is considered essential. The Gas Supply Plan aims to interconnect the two systems, facilitate the integration of LNG supplies from the south-west into the system and make most pipeline sections bidirectional.

The plan includes investment in new and upgrades of existing gas infrastructure, with the following projects.

Projects for upgrades of existing infrastructure:

- Expansion of the transportation capacity in the Mariquita-Gualanday section to 20 million cubic feet per day (mcf/d) in Guandalay, by December 2022.
- Bidirectional transportation capacity of 100 mcf/d in Ballena, in the Barrancameja-Ballena section, by December 2022.
- Bidirectional transportation capacity of 170 mcf/d in Ballena, in the Barranquilla-Ballena section, by December 2022.
- Bidirectional interconnection between the sections of Barranquilla-Ballena and Ballena-Barrancabermeja with a transportation capacity of 170 mcf/d, by December 2022.
- Expansion of transportation capacity of the Jamundí branch in Valle de Cauca to 3 mcf/d to supply the demand in the Popayán node, by December 2022.
- Bidirectional transportation capacity of 250 mcf/d in Mariquita, in the Yumbo-Mariquita section. The execution of this project is subject to the selection of investors by the UPME. Commissioning should be no later than December 2024.

Projects for new infrastructure:

- Regasification plant in the south-west at the Pacific Coast, in Buenavetura (Costa Pacifico) with a regasification capacity of at least 400 mcf/d and a storage capacity of 170 000 m^3, to be commissioned no later than December 2024, preferably by 2022.

- Gas pipeline connecting the Buenaventura LNG plant to the NTS in Yumbo, with a transportation capacity of at least 400 mcf/d, to be commissioned no later than December 2024.
- The government is also considering another regasification plant, Costa Caribe. The La Guajira project would have a capacity for 200 MBTU/d.

Demand restraint programme

In 2021, the Colombian government adopted new security of gas supply rules. Resolution 40280 of 30 August 2021 updated the framework for the MME to regulate gas demand constraints and rationing of the supply of natural gas to satisfy essential demand of priority consumers.

According to the resolution, essential or protected demand includes four categories of gas users:

- operators of natural gas transport and related compressor stations
- residential users and small commercial users which are part of the distribution network
- CNG for massive public transportation systems
- refineries.

After that, Colombia will protect non-essential industrial demand. This includes by order of importance:

- Transportation of crude oil destined for refining to guarantee the supply of regulated liquid fuels in the country (which has contracts in force and registered with the natural gas market manager with guaranteed supply without interruptions established).
- Contracts in force and registered with the natural gas market manager with guaranteed supply without interruptions established.
- Other contracts in force and registered in the natural gas market manager will be attended to, and "finally, exports agreed upon in firm will be attended to".

In these cases, "the volume will be assigned by the trading producers, the traders and the transporters in accordance with the contractually agreed upon supply conditions. In the event of a tie, the highest supply priority must be given to the user with the highest rationing cost, and so on", the resolution specifies.

Assessment

The shift to natural gas in Colombia has accelerated over the past two decades, with a significant increase in both consumption and production. In 2021, natural gas accounted for 10% of domestic energy production, 22% of total energy supply, 16% of electricity generation and 11% of TFC.

Colombia has more than 10 million natural gas consumers, distributed among the domestic, commercial, industrial and transportation segments. This includes 8 million households; more than 90% of the users are connected to the gas grid. In 2021, gas consumption was 12.41 bcm, of which 12.36 bcm was domestically produced and 0.05 bcm imported. Industry was the main consumer of natural gas (43%) and considered

a priority customer in a gas supply crisis, followed by electricity and heat generation (32%), residential (15%), transport (6%), and services (4%).

Colombia's domestic production just covers regular domestic demand but not during the periods of high gas demand when hydropower is less available. In 2022, Shell and Ecopetrol lead offshore gas development, which could also serve the domestic market. However, the scale and timing of current upstream investment may not be able to fully mitigate the short-term gas deficit up to 2024 but could reverse the trend of declining reserves in the medium term.

Subsequent governments have been promoting natural gas as a key transition fuel across the residential and transport sectors to reduce pressing concerns of air pollution while maintaining gas as a source of flexibility and back-up to hydropower, varying with the period of severe droughts. Under Colombia's long-term E2050 strategy, natural gas is only phased out in electricity by the 2040s.

In 2016, Colombia started importing gas from Trinidad and Tobago and the United States, through its first FSRU LNG terminal in Cartagena. These LNG imports are mostly tied to serve additional gas needed in the power sector during years of low hydro availability.

Gas consumption and production centres are not well interlinked. Colombia still has two separate gas networks, the Promigas network along the Caribbean Coast with the Cartagena LNG terminal and the mainland grid (TGI). The UPME's 2019-2028 Natural Gas Supply Plan is a critical plan to interconnect the two systems in the northern part of the country, integrating a new LNG terminal on the Pacific Coast and facilitating bidirectional flows in most gas pipeline sections. A second LNG terminal, currently planned for 2027 commissioning at the Pacific Coast (Buenaventura), would allow Colombia to also arbitrage between Atlantic and Pacific Basin supplies and related LNG prices.

Colombia's gas market is built on a variety of bilateral contracts, mostly firm agreements (70%); only 23% of all agreements are interruptible. The market system is highly regulated and allows for little contractual flexibility. For instance, the LNG contract is tied to the electricity market and its reliability charge.

Improvements have been made to the gas market over the past decade thanks to the regulator and the creation of a primary and secondary gas market, administered by the gas market manager, who conducts gas auctions and promotes data transparency through monitoring, collecting and publishing wholesale natural gas data. To alleviate the situation of the looming gas deficit, the government needs to identify and remove important barriers.

Colombia's gas market suffers from market concentration in the two regional gas systems. The government is taking the role of a *de facto* system operator, requiring gas producers to nominate gas production for the year ahead to match demand. In the northern system, the lack of transparent access and persistence of market power due to vertical integration hampers the connection of new supply sources, artificially tightening the gas supply and pushing up prices. In light of the looming gas deficit, the government has to take urgent action to enforce competition and should consider introducing an independent gas system operator.

First, transportation and trade remain significant bottlenecks. The connection to the two gas systems depends on access granted by two main regional pipeline companies, Promigas and TGI. This is also the result of remaining vertical integration of transport and

retail/distribution. Transportation costs remain high by international standards, accounting for 22% of the total cost, due to the distance-based tariff methodology applied in a radial system. Two major transmission companies hold the regional monopoly, alongside five smaller pipeline companies. As the two gas systems become interconnected, the need arises to reconsider the natural gas transportation model. Studies are being conducted to migrate to an entry-exit scheme after 2026, but no details are known or presented to the market. The CREG allows for some flexibility under the current tariff methodology, which will be in place until at least 2026.

Second, in the medium term, the CREG plans to adjust the role of the gas market manager from centralising contractual information to new operational and transactional functions, in harmony with a possible future entry-exit scheme, which is in the planning for 2026. As interim steps, the CREG plans to move to a commercial balance and shorter contracts (less than one year, likely quarterly).

Third, gas pricing and commercialisation is very complex due to unharmonised contracts. There is no gas price marker across Colombia and gas is partly subsidised for households (strata 1 and 2), paid by other households (strata 5 and 6) and commercial and industrial users, and ultimately the state budget. The gas cost of service includes 43% production, 22% transport, 35% distribution, and the gas price for the final consumers is around USD 0.05/m^3. Gas in road transport is very price-sensitive and the regulation for price stabilisation of diesel and gasoline undercuts the goal of expanding gas use in transport.

In the light of the future physical interconnection of the two gas markets, the government should prepare a regulatory road map for the creation of liquid and competitive regional gas areas and their merger into one gas market, which would allow for greater competition and trade of gas.

Gas security

In recent years, Colombia has experienced several gas supply disruptions, notably in 2021 when social protests caused road blockages and disrupted the transportation of CNG/LPG and supply to 3.4 million consumers in the south-western part of the country. A cold snap in August 2021 produced a landslide along the Chitamena River, which resulted in a disruption of the gas pipeline Cusiana-El Porvenir-La Belleza. The incident caused a drop in pressure and forced the shutdown of the Cusiana gas field, which covers 31% of the country's demand. In the light of the tight margins, such gas supply disruptions can quickly cause a crisis for industry and households.

Colombia does not have underground gas storage and relies only on the storage capacity of its LNG terminal, which can deliver gas within 12 hours. In a more meshed gas system, the use of gas storage can be a relevant source of flexibility. The MME and the CREG should study gas storage when considering the entry-exit system.

Many gas-fired power plants still have fuel-switching capacity and can use oil products, coal or bagasse. The government should examine other options of ensuring better interlinkages for gas and power system reliability (see Chapter 6). The co-ordinated dispatch of electricity and gas administered by the CREG is a good option to deal with the current constraints. However, with new additions in hydro, geothermal and the emergence of battery storage, there are new opportunities to enlarge the electricity reliability options to cleaner and more cost-competitive sources beyond natural gas.

The government has evaluated the annual declaration by gas producers to the MME (in the future also LNG importers) and anticipates matching demand with increased domestic production from existing fields. The contract held by SPEC at the LNG terminal is to be extended beyond 2026. The UPME, the CREG and the MME developed a competitive tender mechanism for investment in LNG storage capacity. In 2021, Colombia adopted a security of gas supply framework with a demand restraint mechanism, following gas supply disruptions, the El Niño rationing mechanism. The government is strengthening regulations on the quality of natural gas supply to final users. The MME issued a new Decree on Reliability for consultation, which envisages setting a reliability standard for the gas system and an annual gas supply plan up to 2024.

Recommendations

The government of Colombia should:

- Devise an action plan for gas supply and demand flexibility by promoting demand response for gas, investing in gas storage, enhancing production from existing fields, reducing flaring and venting of methane emissions, and diversifying the country's gas supply options through additional LNG terminals.
- Support the creation of a competitive gas market by completing the physical interconnections between the two networks, promoting more harmonised gas contracts, flexible trading of gas, independent transportation and system operation, and efficient transportation tariff regulation.
- Ensure the gas system is built with clear reliability criteria to ensure its ability to withstand the disruption of its single largest piece of gas infrastructure (gas field or LNG terminal) during periods of peak gas demand and enlarge the availability of LNG storage or local underground storage in depleted fields.

References

ANH (2023), Informe de recursos y reservas 2022, Informe_de_Reservas__y_Recursos_Contingentes_de_Hidrocarburos_2022_pfMyhzQ.pdf (anh.gov.co).

ETM (2020), Final report of the Energy Transformation Mission, https://efinetico.org/en/energy-transformation-mission-in-colombia.

IEA (International Energy Agency) (2023), IEA World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

Sacyr Industrial (2021), Sacyr Industrial website, www.sacyrindustrial.com/es_es/Actividad/Petroleo-gas/Colombia/proyecto1/default.aspx.

TGI (2023), Gas Supply Chain, Infraestructura - Transportadora de Gas Internacional (tgi.com.co) .

UPME (Mining and Energy Planning Unit) (2020), Estudio técnico para el plan de abastecimiento de gas natural, https://www1.upme.gov.co/Hidrocarburos/publicaciones/PAGN_2019-2028.pdf .

9. Oil

Key data (2021)

Domestic crude oil* production: 767 kb/d (-17% since 2011)

Net exports of crude oil:* 471 kb/d (-25% since 2011)

Domestic oil products production: 415 kb/d (+32% since 2011)

Net imports of oil products: 19 kb/d (-205% since 2011)

Share of oil: total energy production 40%, TES 45%, TFC 48%, electricity generation 3.3%

Oil demand by sector: transport 61%, industry 23%, international bunkers 5%, buildings 11%, electricity and heat generation 0.1%

* "Crude oil" includes crude, natural gas liquids and feedstocks.

Overview

Oil is the second-largest energy source in Colombia, after coal, and earns 2% of the country's GDP (13% of direct revenues of the state budget). Total crude oil production reached historic peaks of around 1 million barrels per day (mb/d) in 2011-15 but has decreased since to reach 767 kb/d in 2021. Further declines in production are expected, possibly turning Colombia into a net importer within the next decade.

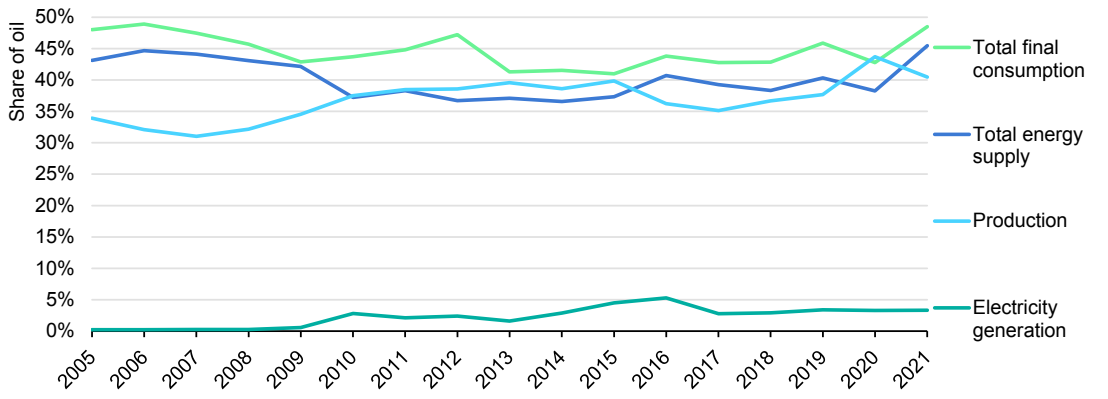
Oil is the first source of energy production in Colombia: 40% of the country's total domestic energy production in 2021, followed by coal (39%). Around one-third of the produced crude oil is transformed in domestic refineries into oil products and two-thirds is exported, mainly to the United States, China and neighbouring Latin American countries. Decreased production levels have led to declining exports. Net exports accounted for 61% (or 471 thousand barrels per day [kb/d]) of the total oil production in 2021, but are projected to decrease to 36% in 2028, according to the latest IEA estimates.

Oil is the largest energy source in TES, accounting for 45% in 2021, up from 37% in 2010. Oil's contribution to TFC was 48% in 2021.

Transport and industry are the largest consuming sectors of oil products in Colombia. As Colombia does not have a railway network, mobility is dominated by coaches, buses, cars and motorcycles.

In 2021, oil covered 90% of transport energy demand and 31% of industry energy demand. Oil is marginally consumed in electricity generation in Colombia (1.8% in 2021), despite the upward trend since 2010, with a notable peak during El Niño in 2016 (4.4%).

Figure 9.1 Shares of oil in the energy system of Colombia, 2005-2021



Oil accounts for around 45% of Colombia's TES and TFC.

Source: IEA (2023a).

Supply and demand

Crude oil production

Colombia's crude oil production (including natural gas liquids and feedstocks) was 767 kb/d in 2021, 17% lower than in 2011 and 25% lower than the peak of 2013 (1 016 kb/d) (Figure 9.2). The government has a crude oil production target of 865 kb/d in 2023.

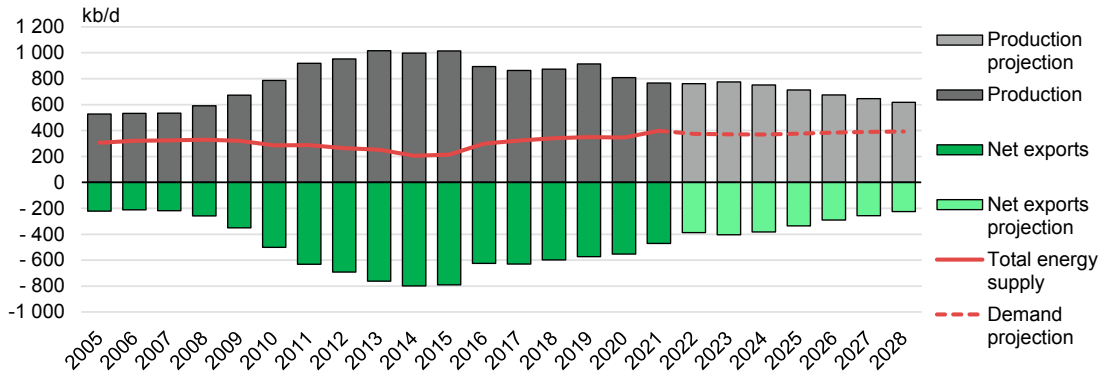
Colombia's total proven, probable and possible reserves were 3.4 billion barrels at the end of 2022. Proven oil reserves were 2.0 billion barrels, equivalent to a useful production life of 7.5 years in 2022 (ANH, 2023).

Crude oil trade

Colombia's net crude exports peaked in 2014 at 799 kb/d, and have decreased since, amid lower reserve availability and growing domestic demand. Colombia's crude oil net exports decreased to 471 kb/d in 2021, or 61% of crude production.

The main destination for Colombia's exports of crude oil are: the United States (37%), for which it is the fifth-largest crude oil exporter; followed by China (32%), Panama (14%), Brazil, Ecuador, India and Spain.

Figure 9.2 Crude oil production and oil demand outlook in Colombia, 2005-2028



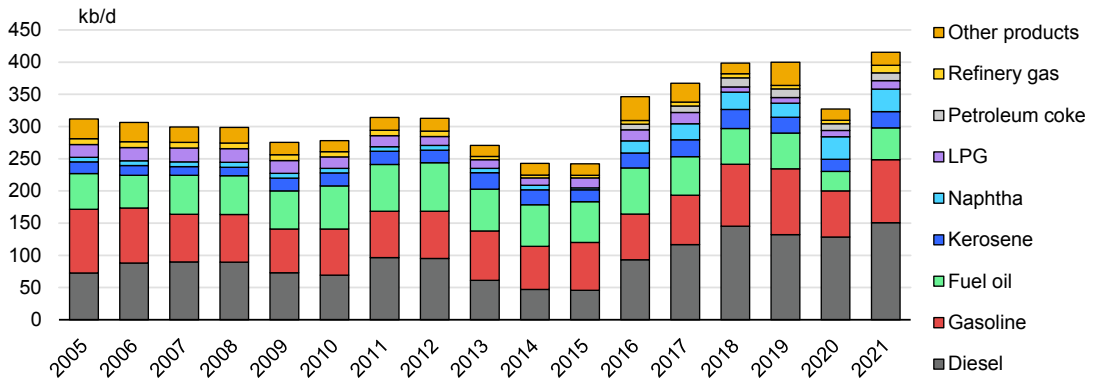
Colombia is expected to remain a net exporter through 2028, yet net exports are projected to decline to around 200 kb/d by 2028.

Sources: IEA (2023b).

Oil products production

Colombia's total net domestic oil products production reached 415 kb/d in 2021, up from 400 kb/d in 2019 (Figure 9.3). Over the past decade, diesel dominated production growth, with additions from 97 kb/d in 2011 to 151 kb/d in 2021, followed by gasoline, which saw increases in production from 72 kb/d in 2011 to 98 kb/d in 2021. Production of diesel dropped to 128 kb/d in 2020 (-3% compared to 2019), while gasoline production decreased to 72 kb/d in the same year (-30%).

Figure 9.3 Oil products production in Colombia, 2005-2021



Colombia's total net domestic oil products production increased from 314 kb/d in 2011 to 415 kb/d in 2021, dominated by the production growth of gas/diesel oil and gasoline.

Note: LPG = liquified petroleum gas.

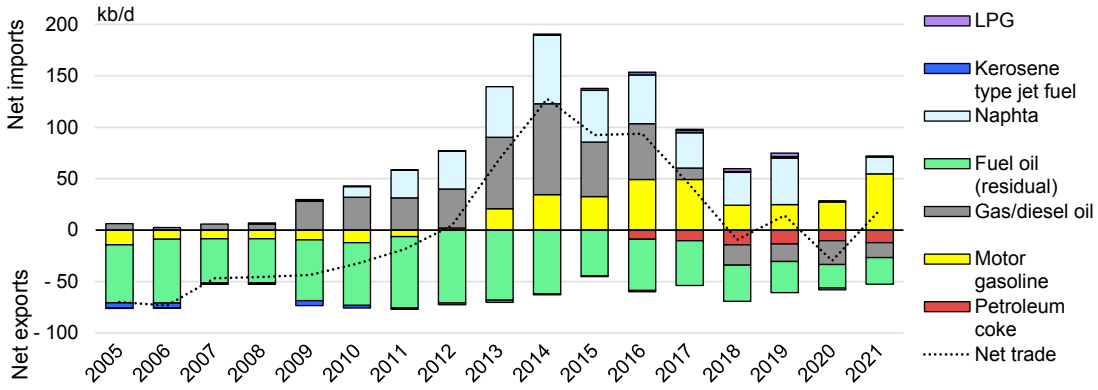
Source: IEA (2023c).

Fuel oil production has fluctuated over time and slightly decreased from 73 kb/d in 2011 to 50 kb/d in 2021 and 30 kb/d in 2020. Kerosene production has been relatively stable, with a recent increase from 21 kb/d in 2011 to 25 kb/d in 2021 yet saw decrease in production to 19 kb/d in 2020. Naphtha increased from 7 kb/d in 2011 to 35 kb/d in 2021, and was stable from 35 kb/d in 2020. LPG production decreased from 17 kb/d in 2011 to 13 kb/d in 2021 (10 kb/d in 2020), and refinery gas from 8 kb/d in 2011 to 12 kb/d in 2021. Other oil products accounted for 20 kb/d in 2011, 20 kb/d in 2021 and 18 kb/d in 2020. Production of petroleum coke started in 2016 with 9 kb/d, increased to 13 kb/d in 2019 then decreased to 12 kb/d in 2021.

Oil products trade

Colombia is a net exporter of crude oil and as such an important regional supplier. However, national crude oil refining capacity is not enough to satisfy domestic oil product demand, so oil products are imported (Figure 9.4). Over the period 2019-21, Colombia imported most of its gasoline, diesel and naphtha needs from the United States. Overall, Colombia was a net importer of gasoline, diesel and LPG in 2021. In recent years, imports have slightly decreased due to the expansion of Ecopetrol's refining capacity (IMF, 2019). Most of the imported oil products in Colombia are naphtha and motor gasoline, which represented 77% and 23% of imported fuels in 2021, respectively.

Figure 9.4 Oil products net trade in Colombia, 2005-2021



With high fluctuations by product, Colombia switched from being a net exporter of oil products to a net importer in 2013. It had net exports again in 2018 and 2020.

Note: LPG = liquified petroleum gas.
Source: IEA (2023c).

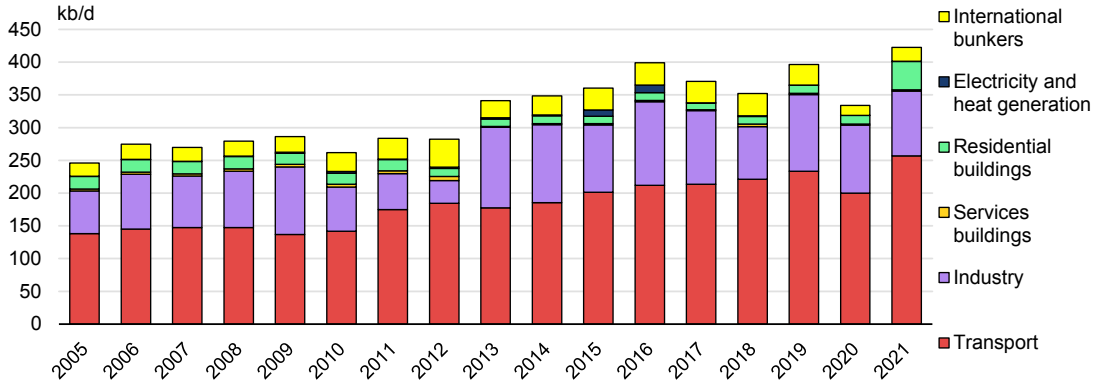
Colombia's product exports are destined for the US market, but diesel exports also go to Puerto Rico. Colombia is a net exporter of fuel oil, gas/diesel oil and petroleum coke. Historically, most of Colombia's oil products exports consisted of fuel oil, but have decreased significantly (by 81%) since 2011. In 2021, Colombia's exports consisted of gas/diesel oil (45%), naphtha (27%), fuel oil (12%), petroleum coke (11%) and motor gasoline (4%). In volumetric terms, oil product exports have fluctuated over the past decades, totalling 106.7 kb/d in 2021, while total oil products imports were 122.2 kb/d. In 2013, Colombia switched from being a net exporter of oil products to a net importer but became a net exporter again in 2018 and 2020.

Oil demand

Oil consumption has been on the rise for decades, mainly driven by the increasing oil demand in transport, industry and electricity generation (Figure 9.5). Total demand was 422 kb/d in 2021, 50% higher than in 2011, a rebound from 334 kb/d in 2020, which had seen decreased demand in transport due to the pandemic-related lockdowns.

The transport sector is the largest oil consumer, accounting for 61% of total oil consumption in 2021. Road transport consumes the most oil in the sector, but international aviation and marine transport are also important consumers, accounting for 5% of total demand. Industry is the second-largest consumer, representing 23% of total demand, of which almost half is for non-energy use. Oil consumption in buildings represented 11% of total demand, followed by electricity generation (0.1%). Oil demand in the electricity sector has decreased over the past decade, from 11.8 kb/d in 2016 to 0.4 kb/d in 2021, but can increase during periods of low water availability, as seen during El Niño in 2016, when high oil demand in electricity coincided with a spike in total demand.

Figure 9.5 Oil demand by sector in Colombia, 2005-2021



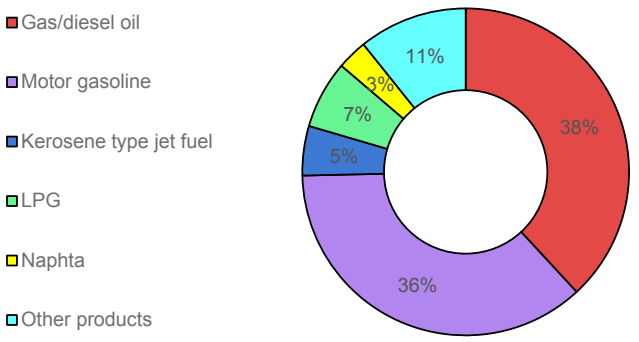
In Colombia, the transport sector accounts for 61% of total oil consumption.

Note: kb/d = thousand barrels per day.

Source: IEA (2023a).

Gas/diesel oil is the oil product with the highest domestic consumption in Colombia (38%), followed by motor gasoline (36%), both used in road transport. LPG, which is mainly used in residential buildings and industry, accounted for 11% of total consumption. Transport is the largest diesel-consuming sector (63%), followed by industry (15%).

Figure 9.6 Oil demand by product in Colombia, 2021



Both used in road transport, gas/diesel oil (38%) and motor gasoline (36%) are the most consumed oil products in Colombia.

Note: LPG = liquefied petroleum gas.
Source: Government of Colombia 2022.

Oil policy

Institutional responsibilities for the oil sector in Colombia are divided between policy making exercised by the MME and those related to extraction and supply stability, for which the National Hydrocarbons Agency (ANH) is responsible. The main legislative framework for the sector is the Petroleum Code.

Under Colombia's Constitution, ownership of the subsoil and the natural resources found in it belong to the state. The ANH can grant national or international companies with exploration and production rights over a determined area in exchange for a royalty based on the type of hydrocarbons that are commercially exploited. To be awarded such rights, companies need to comply and meet a number of minimum requirements of legal, financial, operational and good socio-environmental practices.

As a net exporter, Colombia's oil sector has contributed an annual average of close to 2% of GDP and 13% of the total national government revenues in the last ten years from taxes, dividends and royalties. The government's reliance on this income will have to be taken into account when elaborating transition pathways.

In November 2022, Congress approved the tax reform bill that allowed raising an additional COP 200 trillion (USD 4 billion) annually, largely through higher taxes on oil producers. Oil producers will be taxed an additional 5% when international crude prices are between USD 67.3 and USD 75 per barrel. The tax rises to 10% when prices range between USD 75 and USD 82.2 per barrel, and 15% when they are higher. President Petro proposed a tax reform to increase revenue for social programmes.

The Petro government has ruled out signing new oil and gas exploration contracts beyond the recently signed licenses,[1] and aims to instead concentrate on enhancing oil and gas production from existing fields. To date, several jurisdictions have committed to ending

[1] In 2022, the Colombian Association of Petroleum and Gas had estimated that cutting new oil contracts could cost the government around USD 4.5 billion in tax revenue by 2026.

oil/gas production by 2050 and rule out investment in major new fields (Costa Rica, Denmark, France, Greenland, Ireland, Quebec [Canada], Sweden and Wales) and are part of the Beyond Oil and Gas Alliance. Canada has imposed a cap on oil and gas sector emissions but not on oil/gas production.

As production in existing fields is declining, Colombia held two bidding rounds in 2019 and awarded 26 contracts with an estimated investment of USD 2.7 billion. Another round occurred in 2020 and awarded four areas. In 2021, the government completed another bidding round for 32 blocks, of which the MME assigned 30; 25 were to foreign investors.[2] Canada's Parex Resources made proposals for 18 areas, mainly in the Orinoquía area, followed by national Ecopetrol (four), Lewis Energy (three) and CNE (two). Frontera, Hocol and Maurel & Prom presented one offer each. In 2021, the ANH signed 13 offshore hydrocarbon exploration and production contracts, six of which were signed with Ecopetrol, four with Anadarko, two with Shell and one with Repsol. Eight of these contracts are in execution while the contract with Repsol is in the process of being finalised; the four Anadarko contracts are in the process of being converted from evaluation to exploitation and production contracts.

The development of shale oil reserves in Colombia has been of interest to oil majors but faces political, legal and regulatory uncertainties (Atlantic Council, 2020). After the 2013 production peak, the government adopted a regulatory framework for the exploration and production of unconventional fields (Decree 3004 of 2013, Resolution 90341 of 2014). In 2014, ConocoPhillips and Canacol Energy signed an agreement on joint unconventional exploration in the municipality of San Martín.[3] The project faced local resistance and was denied environmental licenses.[4] In 2018, Colombia's State Council suspended the decisions of 2013 and 2014. In 2020, it specified that this suspension does not prevent exploration and exploitation pilot projects from going ahead. The Duque government promoted pilot projects for fracking. In December 2019, the MME published a regulatory framework for these pilot projects (PPIIs)[5], and in early 2021, awarded projects of four companies (Ecopetrol, ExxonMobil, Drummond and Tecpetrol). The ANH planned to start pilot fracking projects in 2020. Many projects were delayed due to the Covid-19 pandemic.

Under Colombia's long-term strategy (E2050), oil continues to play a role for exports but declines strongly in the domestic energy system. For 2050, the strategy targets an increase in electrification of final energy consumption of 40-70% of final energy use, multiplying by a factor of 7 the 2015 electricity consumption. The share of liquid fuels in the energy sector will drop to around 25% (from today's 42%), with a substantial share of biofuels. Around 70% of the demand for passenger mobility would be met by public transportation by 2050, using low-emission technologies. Under the National Energy Plan, oil and oil products consumption is expected to continue to play an important role up to 2050 (34-44% of TFC).

[2] https://www.minenergia.gov.co/en/historico-de-noticias?idNoticia=24268578.

[3] http://canacolenergy.com/es/newsroom/news/canacol-energy-ltd-and-conocophillips-sign-agreement-for-shale-oil-exploration-project-in-colombia/.

[4] https://www.reuters.com/article/us-colombia-fracking-idUSKCN1R12CR

[5] https://www.minenergia.gov.co/en/foros;jsessionid=YTXcjncTt8qB6IHSFq28XRAp.portal2?idForo=24162581.

Oil infrastructure

Ports

The main ports in Colombia are Buenaventura, Cartagena, and Tumaco and Coveñas, which specialised in the export of crude oil and import of refined products from abroad. The Port of Tumaco is situated on the Pacific Coast in Tumaco Bay, close to the border with Ecuador and south of the Panama Canal.

In April 2021, a new bidirectional single buoy mooring was inaugurated in Coveñas with a load capacity between 50 000 and 60 000 barrels per hour. It is expected to strengthen crude oil exports but can also load imports.

Cartagena oil terminal is for importing oil products. The Pozos Colorados terminal in Santa Marta receives liquid fuels and naphtha from the international market, which are then transported via pipeline to the interior of the country. Refined products are received through Puerto Bolívar in La Guajira for the operation of the Cerrejón Complex.

Pacific Buenaventura handles the largest volume of cargo in the country for the Asian market. It also has a terminal for receiving refined products that meet the demand of the south-west of Colombia.

Pipelines

Colombia's crude oil pipeline network has a length of 6 100 km, with 16 transportation companies responsible for a network of 55 pipelines.

Pipelines connect isolated oil production areas with refineries (Cartagena and Barrancabermeja plants) or export ports in the Caribbean Atlantic (Coveñas, Cartagena, Barranquilla, Santa Marta, Puerto Bolívar and San Andrés) and the Pacific (Buenaventura and Tumaco).

The majority of the oil product pipeline system in Colombia is owned by Cenit Transporte y Logística de Hidro-carburos S.A.S., a subsidiary of Ecopetrol, and consists of a radial network that connects Pozos Colorados station, with several end stations, such as Buenaventura, Neiva and Puente Aranda. Only one line belongs to a third party and moves refined products between Medellín and Rionegro.

On several occasions, crude oil pipelines have been attacked by rebel groups, causing damage to infrastructure and the environment, as well as economic losses. The Coveñas pipeline located in the north-east of the country is the most frequently targeted and was not operational for almost half a year in 2018.

Figure 9.7 Oil Infrastructure in Colombia

Refining

Colombia has five refineries with a combined crude processing capacity of around 420 kb/d. Owned by the state company Ecopetrol, Colombia's two main refineries are located in Barrancabermeja and Cartagena, which produce all of the national diesel and jet fuel (ACP, 2020). They process around 250 kb/d of light and medium-light crudes and 165 kb/d of heavy crudes, respectively. The other refineries are smaller and their product output does not comply with quality specifications required for the national pipeline system. Ecopetrol pursues a large-scale public investment programme of USD 777 million in the Barrancabermeja refinery scheduled until 2023 to ameliorate fuel quality and reduce emissions.[6] Equally, Ecopetrol invests in the Cartagena refinery by boosting its interconnection with the pipeline network, reliability and output growth. The country's first private refinery is being planned in the municipality of Puerto Berrío, Magdalena, and is expected to start processing up to 150 kb/d in 2023.[7]

Storage

Colombia's 400 hydrocarbon fields have a total of 15 000 wells and around 250 production facilities. According to the administration, on the upstream supply chain, Colombia has a total storage capacity of 3.5 mb, compared to total production of 761 kb/d in 2021. Colombia has a crude oil storage capacity of around 7 mb (Table 9.1) and oil product storage capacity of around 3 mb (Table 9.2), according to the data compiled by Cenith.

Table 9.1 Crude oil and oil product storage capacity in Colombia

Location	kB	Crude oil							Total
		Caño Limón	Mezcla Castill	Mezcla Vasconia	Castilla Norte	Mezcla Magdalena	Mezcla Liviana	Mezcla Rubiales	
	Altos de Porvenir	0	341	0	0	0	0	0	**341**
	Aplay	0	265	0	0	0	0	0	**265**
	Araguaney	0	0	201	0	0	0	0	**201**
	Ayacucho	221	0	0	226	93	0	0	**540**
	Caño Limón	1 128	0	0	0	0	0	0	**1 128**
	Coveñas Cenit	0	0	1 688	0	214	0	107	**2 009**
	Coveñas GCX	0	0	804	0	0	0	0	**804**
	Monterrey	0	0	40	0	0	0	20	**60**
	Orito	0	0	246	0	0	0	0	**246**
	San Fernando	0	602	0	0	0	0	0	**602**
	Vasconia Cenit	0	0	106	0	0	222	0	**328**
	Tumaco	0	0	434	0	0	0	0	**434**
	Total	**1 349**	**1 208**	**3 518**	**226**	**307**	**222**	**127**	**6 957**

Note: kB = thousand barrels.

Source: Cenit (2023)

[6] https://www.ecopetrol.com.co/wps/portal/Home/es/?page=detalleNoticias&urile=wcm:path%3A%2FEcopetrol_WCM_Library%2FAS_es%2FNoticias%2FNoticias%2B2021%2Frefineria-barrancabermeja-desarrollara-plan-actualizacion-reposicion-tecnologica.

[7] https://www.larepublica.co/economia/refineria-sebastopol-estara-lista-antes-de-finalizar-2023-2892568.

Wholesale oil distributors are obliged to guarantee a regular and stable supply of fuels to consumers. They have to hold a minimum of oil tank capacity at all times corresponding to 30% of monthly volume of dispatches from each supply plant owned. For ethanol and biodiesel, distributors must have sufficient storage and inventory capacity to cover demand for a minimum of ten working days. These obligations are for storage capacities, not for oil products to be stored.

Table 9.2 Oil product storage capacity in Colombia

Location	kB	Oil products				Total
		Gasolina	Diesel	Jet fuel	Nafta	
	Pozos Colorados	206	393	–	205	805
	Sebastopol	133	130	38	190	492
	Salgar	248	158	113	–	518
	Mansilla	168	167	140	–	475
	Tocancipá	150	150	–	–	300
	Medellín	0	25	–	–	25
	Cartago	0	–	–	–	-
	Apiay	0	–	–	81	81
	Yumbo	82	29	–	–	111
	Buenaventura	29	96	–	–	125
	Total	**1 016**	**1 149**	**291**	**476**	**2 933**

Note: Storage sites Neiva, Gualanday and Mulaló are not included as no data were available.
Source: Government of Colombia, ANH, 2022.

Prices and taxation

Retail prices

Prices of gasoline, diesel and biofuels are regulated by the government, with the MME determining monthly prices for diesel and gasoline. The MME's other responsibilities in regulating liquid fuels have been reassigned to the CREG (IMF, 2019).

Created in 2006, the extra-budgetary Fuel Price Stabilisation Fund (Fondo de Estabilización de Precios de los Combustibles, FEPC) is used as a framework for smoothing fuel price variations and containing large price volatility on the international market.

In 2021, the FEPC costed USD 12 billion from the public budget. There is substantial controversy over the need to reform the FEPC, but many want to maintain it as they see the continuous need for the fund to support low-income households and keep inflation low. Although social aid to the poor is necessary, the FEPC lowers fuel prices for all inhabitants, which may raise concerns of overreliance on cheap fuels across society.

Originally, the government allowed for a price band with a maximum and minimum price. When international prices rose above the set maximum price, consumers paid the maximum price and the state used the funds from the FEPC to pay the difference. When the international price was below the minimum price, the consumer paid the minimum price and the difference was paid into the FEPC.

However, during periods of rising oil prices, disbursements were greater than income and the state acquired a large debt with the refineries. A new price band was created under Emergency Decree No. 027-2010. It is adjusted every two months – provided that the international price is outside the current band – within a maximum of 5% of the variation in the final consumer price of each product (except for LPG, whose band update will be equivalent to 1.5%). FEPC subsidies are targeted, since compensation to cement, mining and fishing companies, the largest consumers of fuel, has been reduced to only one-tenth compared to other sectors. The subsidy for LPG has been increased, notably for low- and middle-income consumers, to facilitate access to cheaper cooking and heating options.

To encourage the use of LPG, the government offers subsidies to the population. Colombia has reached its goal of providing 1 million new families with gas, with was the objective of the PND 2018-22, partly thanks to LPG programmes. The government supports 100 000 households in clean cooking and subsidises 70% of the purchase cost of the cylinder and up to 50% of the consumption.

Oil security

Despite being a significant oil producer and important regional supplier, Colombia suffers from numerous conditions that undermine its security of oil supply. Among them, resilience of the infrastructure, complicated fuel logistics and uncertainty about the future of exploration are the most prominent and entail the need for government action.

Historic disruptions

During 2018, bombings of oil infrastructure caused an average of 11 kb/d of oil supply being disrupted. The Caño Limón-Coveñas crude oil pipeline is the most frequent target of militant attacks. In 2017, as a result of bombings attributed to the Colombian National Liberation Army, the pipeline had outages equivalent to half a year of its operations. During 2017-18, the oil pipeline had been attacked over 80 times. In 2020 alone, 29 attacks were carried out, some of which polluted rivers and streams and caused fires.[8] The Bicentenario crude oil pipeline was reversed in 2018 to transit crude oil displaced by the attacks. Following the attack of the oil pipelines, the National Army announced a new strategy to monitor the country's oil pipelines via drones.

Additionally, in early 2018, Ecopetrol suspended production at the Castilla, Chichimene and CPO-9 fields because of violent labour protests.

Colombia does not have a domestic security of oil regulation or framework, unlike for natural gas, but is contemplating creating a domestic co-ordination mechanism with a demand restraint programme to tackle domestic disruptions to the oil supply.

The Petroleum Code regulates activities of the sector alongside the laws and decrees that establish the functions for the MME and the National Hydrocarbons Agency, giving them policy-making functions and ensuring the supply, respectively.

[8] https://www.reuters.com/article/colombia-oleoducto-ataque-idLTAKBN29R2LB.

The UPME's forecasts foresee measures to improve oil supply security, notably investment in refining capacity. The UPME conducted a reliability analysis of the national oil supply chain. The PND 2022-2026 highlights security of the fuels' value chain as a priority area for the government.

Colombia has a permanent liquid fuel supply committee which evaluates all early warnings and measures and takes corrective actions to facilitate the assessment of strategies for ensuring the continuity of the fuel supply.

Oil stocks and accession to the IEA

Colombia does not have any oil stockholding system and does not collect stock data. Colombia is currently a net exporting country, meaning that its stockholding obligation towards the IEA would be zero. However, to be part of the IEA, the country has to prove that it is able to meaningfully contribute to an IEA collective action to pledge oil to the global market during a severe global oil supply disruption.

Colombia does not have an obligation for industry to hold stocks (although existing regulations impose an obligation on wholesalers to have tank storage capacity at minimum levels). The government does not have a system in place to monitor the level of oil stocks held in the country and according to anecdotal evidence, some companies only have two or three days of stocks to optimise cash flow.

The hydrocarbons regulator (ANH) is working on a strategic stockholding system of 1.2 million barrels to be created with in-kind royalties that the ANH collects from upstream companies and currently sells to the market via Ecopetrol.

A legal review of this option is currently underway to understand if this solution would enable Colombia to contribute to an IEA collective action in the future. Preliminary ideas include Colombia renting storage capacity for the strategic reserves, the Ministry of Finance agreeing to use a part of oil royalties for this purpose and including a "trigger" embedded into emergency legislation to enable these stocks to be used in the case of an IEA collective action.

Assessment

Oil is the largest energy source in TES in Colombia, accounting for 45% in 2021. In addition, the sector plays a significant role in the Colombian economy, as the country remains a net exporter. The oil sector has contributed an annual average of close to 2% of GDP and 13% of the total income of the national government in the last 10 years from tax revenues, dividends and royalties.

Under Colombia's long-term strategy (E2050), oil continues to play a role for exports but declines strongly in the domestic energy system. By 2050, the country targets an increase in electrification of final energy consumption of 40-70% of final energy use, multiplying by seven the electricity consumption in 2015. Overall, the share of liquid fuels in the energy sector will drop to around 25%, with a substantial share of biofuels. Around 70% of the demand for passenger mobility would be met by public transportation by 2050, using low-emission technologies. Under the PEN, which is not yet aligned with the E2050, oil and oil products are expected to continue to play an important role (34-44% of TFC).

However, no road map for the oil sector has been prepared. Other countries have devised a net zero pathway for the oil sector, identifying a cap on oil emissions of 40-45% by 2030, like, for instance, the government of Canada. Such a pathway would see a reduction of oil consumption in transport and power generation (notably in the non-interconnected zones) and a switch to gas, renewables and hydrogen, together with massive electrification.

While the target of crude oil production is set to 865 kb/d in 2023, production was 761 kb/d in 2021, 17% lower than in 2019 and 25% lower than the peak in 2013 (1 016 kb/d). Proven oil reserves were 2.0 billion barrels in 2022, which is equivalent to a useful production life of 7.5 years. Such production reserves are very low and, given their declining trend, Colombia's future oil production is at a crossroads if no new reserves are developed.

Decreased production levels have also led to declining exports. Net exports stood at 471 kb/d, or 61% of total oil production, in 2021. Net exports peaked in 2014 at 799 kb/d and have decreased since, amid lower reserve availability and growing domestic demand.

New potential areas that would reverse the decline of reserves and production are limited to offshore development, shale formations and enhanced oil recovery. The shale development has been of interest to oil companies, but faces political, legal and regulatory uncertainties. The use of hydraulic fracking for shale development remains restricted to pilot projects. The Petro government has ruled out signing new oil and gas exploration contracts and aims to instead concentrate on enhancing oil and gas production from existing fields.

As Colombia implements its long-term strategy, the government has indeed clarified plans for the oil sector in the medium term, related to its ambitions to fully decarbonise the country's economy by 2050. The government stopped opening up licenses for new oil fields. However, no road map for the oil sector has been prepared. Such a pathway would see a reduction of emissions from oil production; reduced oil consumption in transport and power generation (notably in the non-interconnected zones); and a switch to gas, renewables and hydrogen, together with massive electrification.

Colombia has a fuel price stabilisation policy. Created in 2006, the FEPC is used for mitigating price volatility of gasoline and diesel on the international market. However, in practice, since 2020, international prices are no longer reflected in national prices. National gasoline prices increased marginally, diesel prices not at all. This led to a significant subsidisation of diesel and gasoline consumption; as of May 2022, subsidised gasoline was half the price of premium gasoline, which is not subsidised. Net costs of the fuel stabilisation policy amounted to 1% of GDP in 2021, or USD 12 billion. The government felt obliged to act due to a combination of the Covid-19 situation, followed by high price inflation. Without the stabilisation policy, actual inflation would have been considerably higher.

The fuel price stabilisation policy is a fiscal and environmental concern for the country. It not only creates a large deficit for the state budget (owed to Ecopetrol), but heavily subsidised fuel prices undermine efforts to reduce GHG emissions and switch to low-carbon fuels and technologies. While the government may want to protect consumers and combat inflation, the Ministry of Finance has already considered ways to reform this policy instrument. The IEA understands the political sensitivity of such a reform. However, taking a longer term view, the IEA strongly recommends implementing a reform to shift revenues from the oil rent gradually to support vulnerable consumers, and a clean energy transition, technology and innovation at large.

Oil security

Based on the IEA's medium-term oil market forecasts, Colombia is expected to remain a net oil exporter through 2028, but net exports decline by over 75% to around 200 kb/d by 2028. The IEA expects Colombia to become a net importer by 2030 at the latest. The government should review the implications of this change in its energy security position and introduce policy changes, notably regarding the security of the liquid fuel supply chain and storage obligations.

Colombia has crude oil storage (7 mb) and oil product storages (3 mb), alongside upstream storage capacity of 3.5 mb, or 4 days of production. These are, however, operational storage capacities dedicated to conduct production activity. Potentially, some of these capacities will be available for stockholding purposes as production declines.

Wholesale oil distributors are obliged to guarantee a regular and stable supply of fuels. They have to hold a minimum of oil tank capacity at all times, corresponding to 30% of their monthly volume of sales. However, these distributers are not obliged to actually store oil. In addition, there is no government oil stockholding in Colombia. According to the MME, Colombia's fuel distribution chain is tight regarding the supply and demand balance, with limited spare refining and transportation capacities.

Domestic oil disruptions are a major issue at the local level. On several occasions, crude oil pipelines have been attacked by rebel groups, causing damage to infrastructure, the environment and economic losses. The Coveñas pipeline located in the north-east of the country is the most frequent target. But industrial actions, labour protests, and manifestations blocking roads or refineries also impact local fuel supplies.

The government acknowledges that Colombia's fuel distribution chain is experiencing serious stress with regard to the supply and demand balance, due to limited refining and transportation capacities.

Colombia's National Development Plan proposed measures to improve oil supply security, notably investment in refining capacity. The UPME conducted a reliability analysis of the national oil supply chain. In recent years, major investment in Colombia's refining sector have been completed and government incentives and recovery funds are allocated to the oil sector.

Colombia has a permanent liquid fuel supply committee which evaluates all early warnings and measures and takes corrective actions immediately for ensuring the continuity of the fuel supply. The IEA strongly encourages the government to reinforce all domestic frameworks on oil security, including storage obligations, demand restraint and efficiency, as well as greater transparency of oil security data, its monitoring and data collection.

The government adopted several decrees on oil security in 2022 in this regard, which are pending implementation. The ANH plans to set aside 1.2 million barrels to guarantee Colombia's ability to contribute to collective actions. Planned changes to the oil policy and management of both the MME and the ANH raise the question on the direction the government will be headed in terms of oil security, on which the IEA accession process hinges.

Recommendations

The government of Colombia should:

- Formulate a net zero pathway for emissions from Colombia's oil production and refining sectors to ensure a clear vision as a responsible oil producer and exporter, given the importance of oil revenue to its economy and the need to meet domestic oil demand in the medium term.
- Develop comprehensive policy measures to ensure an adequate level of domestic oil production and efficient oil consumption to address core energy security, fiscal and economic development requirements.
- Reinforce oil security by imposing an obligation on industry to hold a minimum level of oil stocks, which can be lowered during domestic oil supply disruptions.
- Devise a mechanism that gradually shifts resources currently used for fuel price stabilisation to targeted programmes that directly support vulnerable groups in Colombia, and that promote clean energy technology development, including energy efficiency.

Reference

ACP (2020), Evolución y perspectivas 2020-2021 del mercado de combustibles líquidos, en Colombia, https://acp.com.co/web2017/en/informes/690-informe-economico-avances-y-perspectiva-para-la-exploracion-de-petroleo-y-gas-2020-2021/file.

ANH (2023), Informe de recursos y reservas 2022, Informe de recursos y reservas con corte diciembre de 2022, insumo para la Transición Energética Justa en Colombia (minenergia.gov.co).

Atlantic Council (2020), Atlantic Council Shale Report, https://www.atlanticcouncil.org/wp-content/uploads/2020/11/AC_shale-report-Final.pdf.

CENIT (2023), Oil infrastructure, https://cenit-transporte.com/que-hacemos.

IEA (International Energy Agency) (2023a), IEA World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

IEA (2023b), OIL 2023, Oil 2023 – Analysis - IEA.

IEA (2023c), Oil Information, Oil Information - Data product - IEA.

IMF (2019), Colombia, Technical Assistance Report, Reforming Energy Pricing, https://www.imf.org/en/Publications/CR/Issues/2019/11/18/Colombia-Technical-Assistance-Report-Reforming-Energy-Pricing-48819.

10. Energy research, development and innovation

Overview

The government of Colombia last defined its priorities for clean energy technology and innovation in 2019, building upon the Commission of Experts Colombia with the consultation of the private sector. These priorities include digitalisation, biorefining, smart cities, efficiency, hydrogen and CCUS.

Hydrogen has been identified as an important technology for Colombia, with the Hydrogen Strategy setting out ambitious actions. Colombia has been active in international dialogues with the objective of positioning itself as a potential exporter for the largest markets (Japan, Korea and Europe) and signed agreements with European ports.

Since 2019, Colombia has set out ambitious energy and climate goals, notably the Energy Transition Law and the E2050 strategy as well as the Climate Action Law. The Offshore Wind Roadmap and new strategies have been presented since.

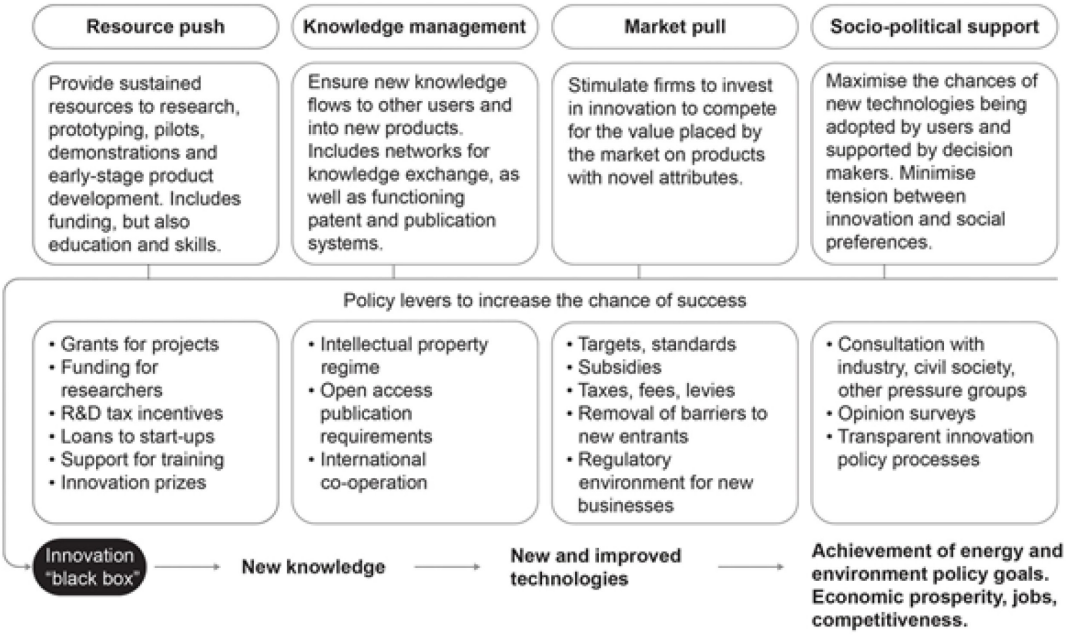
The government has a critical role to play in defining the priorities, strategy, policy and incentive frameworks required to boost the role of energy research, development and demonstration (RD&D) in Colombia's clean and just transition as well as the tracking of results and progress. The Petro government has the stated objective of making Ecopetrol a key player for investment in clean energy technology RD&D.

The PND 2022-2026 will be an important basis for programming efforts and investment in the area of energy RD&D. The government targets a share of 0.5% of R&D spending in the GDP by 2026. The government has a unique opportunity to identify the benefits of a strong energy technology and innovation policy for boosting a competitive industrial sector in Colombia and its economic development.

This chapter is structured according to the IEA framework for energy innovation policies (Figure 11.1). Technology innovation processes are complex and decision makers must pay attention to a variety of elements. The IEA groups these elements into four core functions: A) resource push; B) knowledge management; C) market pull; and D) socio-political support. Successful energy innovation ecosystems have effective policies in each of the four areas. In some cases, the policies might operate at different levels, such as local, national or municipal.[1]

[1] https://www.iea.org/reports/tracking-clean-energy-innovation.

Figure 10.1 The IEA's four functions of a successful innovation ecosystem for energy



Successful innovation systems involve a wide range of actors and a wide variety of functions, each of which can be enhanced by public policy. Such a system will need to have action under each of these four headings to successfully translate research into technological change.

A sustained flow of RD&D funding, a skilled workforce (e.g. researchers and engineers) and research infrastructure (laboratories, research institutes and universities) are required: these resources can come from private, public or even charitable sources, and can be directed to specific problems or basic research (resource push).

Knowledge should be exchanged easily between researchers, academia, companies, policy makers and international partners (knowledge management).

The expected market value of the new product or service must be high enough to make the RD&D risks worthwhile, and this is often a function of market rules and incentives established by legislation. If the market incentives are high, then much of the risk of developing a new idea can be borne by the private sector (market pull). There needs to be broad socio-political support for the new product or service, despite potential opposition from those whose interests might be threatened (socio-political support).

Strategies and priorities for energy research, development and innovation

Adopted in 2021, the PND 2018-2022 included an overall ambition to increase public and private investment in technology and innovation to 1.5% of GDP by 2022 (as a pact for science, technology and innovation). The PND 2022-2026 includes a priority of

reindustrialisation and public technology investment with a targeted share of 0.5% in the GDP dedicated to research and development. It announces the creation of a dedicated agency.

In September 2021, Presidential Directive No. 6/2021 launched a pact for science, technology and innovation across sectors. The mining and energy sector is considered a "benchmark sector", which would need to invest 10% above the average percentage of investment in science, technology and innovation over the period 2014-19, or a total of 7% of sector total investments from 2022 onwards.

In 2019, the national government convened a Commission of Experts with the purpose of drawing up a road map to 2030 for the development of science, technology and innovation. For the energy sector, the commission's recommendations (which the government has adopted) included three energy programmes towards a new competitive and sustainable productive model:

- Create an instrumentation, control and equipment industry for the energy transition, focused on the development of equipment adapted for tropical conditions, with a goal of creating five technology-based companies by 2030.
- Create a biorefinery industry with a view to exporting biofuels and the goal of creating five biorefinery companies by 2030.
- Support the transfer and implementation of technologies for smart and sustainable cities through the creation of two national laboratories in the short term and five smart cities by 2030.

In addition to the priorities identified by the Commission of Experts, under Law 2099/2021, the national government was tasked to design policies to promote technology RD&D for the production, storage, distribution, electrification, energy and non-energy uses of hydrogen and other low-carbon technologies. Based on this mandate, the Ministry of Science, Technology and Innovation together with the MME, is developing guidelines for the development of programmes for innovation in the field of hydrogen and CCS.

Colombia has recently been very active in the development of technology road maps. In September 2021, the government released its Hydrogen Roadmap and in February 2022 its Offshore Wind Energy Roadmap.

A. Public funding for energy RD&D and innovation

Colombia supports energy RD&D through the following general (non-energy specific) funding instruments:

- National financing fund for science, technology and innovation "Francisco José de Caldas Fund". This fund is the main financing mechanism for science, technology and innovation and provides financial support for the development of RD&D projects aimed at developing and validating new technologies for the energy transition. The fund is sourced by the general government budget, as well as resources from other public and private entities, donations, and international co-operation.
- The Science, Technology and Innovation Fund, which is funded by using 10% of the royalties from the exploitation of energy and mining resources.

- Tax benefits granted by the National Council of Tax Benefits to companies that carry out science, technology and innovation projects, in association with an actor acknowledged by the Ministry of Science, Technology and Innovation.
- Fiscal credits for small and medium-sized enterprises.
- The Fund for Unconventional Energies and Efficient Energy Management (FENOGE), created in 2014 (although in operation since 2018), which can finance projects across all the technology development stages, including research, innovation and demonstration. The fund was developed to support projects to improve energy efficiency and develop unconventional energy sources, but Law 2099/2021 allows the fund to support hydrogen projects as well.

In addition, as a response to the Commission of Experts, the Ministry of Science, Technology and Innovation; the MME; and Ecopetrol have established a co-operation agreement within the Francisco José de Caldas Fund to develop science, technology and innovation activities to address energy transition issues. The first call (USD 1 million) to develop projects on renewable hydrogen and CCUS has been already announced.

Presidential Directive No. 6/2021, which defined the mining-energy sector as a benchmark sector and established that the sector must make an investment in R&D of at least 7% of the total investment from 2022, also established that the National Planning Department and the Ministry of Science, Technology and Innovation will provide technical assistance to entities for defining the investments for them to fulfil this investment goal in accordance with their competencies. Currently, the DNP; the Ministry of Finance and Public Credit; and the Administrative Department of Science, Technology and Innovation (Colciencias) are working on a new multiannual framework with a new public spending programme for government entities, based on: investment needs; tax restrictions; and financing sources that guarantee the stability of investments in science, technology and innovation in accordance with the medium-term fiscal framework and the medium-term spending framework. The new framework will establish the specific annual actions for the fulfilment of the investment goals.

B. Knowledge management

The Ministry of Science, Technology and Innovation is the governing body of science, technology and innovation policy in Colombia at the national level. It is responsible for the government's policy in this area. In addition, at a territorial level, the departments of science, technology and innovation; of economic development; and the departmental councils of science, technology and information play an important role in defining departmental policies and plans in science, technology and innovation.

Energy RD&D projects in Colombia are mainly executed by research groups in universities, centres of technology development and the private sector, although the research community on energy technologies is quite small (around 100 research groups).

In 2019, the government inaugurated the Center for the Fourth Industrial Revolution of Colombia. It aims to maximise the benefits of the fourth industrial revolution for the inclusive and sustainable development of Latin America, seeking to strike a balance between technological governance, data use and the implementation of emerging technologies. The MME announced the creation of a technological training and

transparency centre in association with the German government to promote training in renewable energy regionally and encourage technology transfer between the two countries.

Colombia, with the support of the World Bank, has developed the Seneca and Energetica alliances, which involved universities and the private sector to facilitate knowledge sharing and develop training programmes. These programmes ended in 2022 and the government is looking for alternatives to give them continuity given that the funding from the World Bank will not be renewed.

In terms of international co-operation in RD&D, Colombia has a very limited participation in international fora and is not a member of the Clean Energy Ministerial, nor of Mission Innovation. However, it is a full member of one IEA technology collaboration programme (TCP), the Enhanced Oil Recovery TCP (in which Ecopetrol is a member of the implementation agreement) and is a sponsor of the Industrial Energy-Related Technologies and Systems TCP.

C. Public support for business innovation and market creation

In the private sector, RD&D is driven mainly by large players in the energy sector (such as Ecopetrol, Empresas Públicas de Medellín, ISA, XM and CELSIA). The National Administrative Department of Statistics collects and consolidates information on RD&D activities in the private sector through the Technological Development and Innovation Survey, although the latest information available comes from 2018 and does not present information specific for the energy sector (DANE, 2018).

Public support for business innovation in energy is quite limited to certain tax benefits for companies developing RD&D projects on energy, which have been projected to reach COP 2.1 trillion for 2022. In addition, fiscal credits are available for small and medium-sized enterprises, although there is a very limited number of energy technology start-ups in Colombia. Presidential Directive No. 6/2021 established a target of 7% of sector total investments to be dedicated to RD&D activities from 2022.

On the other hand, as part of the Ecopetrol Group's strategy "2040 Strategy, Energy to Transform", more than USD 240 million will be allocated to innovation, technology and digital transformation projects as part of the goals to 2024. This investment will cover a wide range of topics, including cybersecurity, supply chain optimisation, sustainable water production and management, and CO_2 capture. In addition, the plan includes resources to boost human resources and skills.

D. Monitoring and evaluation

Colombia does not have a system to track public spending on energy RD&D. The National Administrative Department of Statistics collects information from companies through the Technological Development and Innovation Survey, but the latest published version is from 2018 and the information is not disaggregated, so no energy-specific information is available from these surveys. The Colombian government does not have a system to track and evaluate progress in energy technology RD&D in relation to policy objectives.

Special focus: Hydrogen

According to the Colombian government, annual hydrogen demand in Colombia is around 150 kt, mostly concentrated in refining, with some demand in fertiliser production, glassmaking and the food industry. Most of this demand is met with hydrogen produced using natural gas without CCUS, with very small contributions of electrolysers powered with grid electricity.

The production of hydrogen in Colombia emits around 1.5 Mt CO_2 per year. These emissions could be minimised by switching current production to low-emission technologies, such as electrolysis using renewable energy or fossil fuels coupled with CCUS. The Colombian government considers that low-emission hydrogen can also play an important role supporting the decarbonisation of the industrial and transport sectors, helping to balance the electric grid and creating economic income through exports.

The first step Colombia took to tap into the opportunity that hydrogen can offer for the country's clean energy transition was the Energy Transition Law, which defines "green" and "blue" hydrogen,[2] extends tax benefits already in use for non-conventional renewables (FNCR) to "blue" and "green" hydrogen projects, and gives FENOGE competence to finance and execute projects in hydrogen and CCUS.

In September 2021, the government presented its Hydrogen Roadmap, which was developed with support from the Inter-American Development Bank (GoC, 2021). The road map analyses low-emission hydrogen competitiveness and demand and export potential; defines a series of goals for the development of a low-emission hydrogen market in Colombia; and establishes actions to implement in the short, medium and long term.

The road map establishes a series of goals for 2030:

With regard to production:

- Production of green hydrogen at a price of USD 1.7 /kg, competitive compared to countries like Chile or Australia.
- Production of 50 kt of blue H_2 through CO_2 capture in small modular reactor plants and between 1 GW and 3 GW of installed electrolysis capacity to produce green H_2 in regions with high renewable resources such as La Guajira.

With regard to demand:

- Target of around 3 500 fuel cell vehicles in the light and heavy categories.
- A network of at least 50-100 publicly accessible hydrogen stations for refuelling vehicles.
- Consumption of 40% of low-emission hydrogen in the industrial sector compared to the total hydrogen currently consumed in the sector.

The road map's overall objectives include:

[2] 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.

- The development and demand for hydrogen will allow the reduction of 2.5-3 Mt CO_2 in the next decade in the country, making it possible to decarbonise hard-to-abate sectors, such as heavy transport, long-distance or industrial processes.
- Investments in this type of project can attract resources between USD 2 500 million and USD 5 500 million by 2030.

The road map also identifies a series of measures to facilitate the development of a low-emission hydrogen market in Colombia, distributed in four main areas of action (regulatory framework, market mechanisms, infrastructure development and technology development) and divided into three temporal phases: laying the groundwork for hydrogen development (1-2 years), enabling the development of a hydrogen market (3-5 years) and periodic monitoring.

The government of Colombia has prioritised a series of actions from the road map for the:

- Development of a regulatory framework for low-emission hydrogen, reconsidering the current definitions of “blue” and “green” hydrogen and defining hydrogen as an energy carrier.
- Implementation of regulatory sandbox for the development of pilot projects.
- Adoption of a system of guarantees of origin and certifications comparable with those being adopted in other countries.
- Development of technical regulations for the production, use and transport of hydrogen.
- Identification of best financial mechanisms for low-emission hydrogen projects.

Law 2099 of 2021 established a series of provisions for the energy transition in Colombia, with a view to modernise current legislation and boost the energy market through the use, development and promotion of non-conventional sources of energy, to integrate the concepts of green hydrogen and blue hydrogen into the regulatory framework for non-conventional energy sources. CONPES 4075 of 2022 targets the sustained deployment of hydrogen as a lever for a greater diversification of the Colombian energy matrix and reducing emissions.

This activity is already bearing fruits. Two demonstration projects for the production of low-emission hydrogen and its use in refining and grid blending became operational in 2022 and Ecopetrol announced plans for the development of two projects to create low-emission hydrogen production capacities at industrial scale (Table 10.1).

More announcements for the development of projects are expected to come soon since FENOGE launched the programme “+H2 Colombia” in March 2022 to promote “blue” and “green” hydrogen, identify players and projects across the value chain, improve knowledge management, and implement financing mechanisms. A call for interest is open to identify projects and a following stage will provide investment and financing mechanisms for pre-feasibility and feasibility studies.

The MME is preparing regulation to include new definitions of renewable energy sources, which will include hydrogen. Through the ANH, the state will also go through a public procurement process to choose a contractor to carry out studies to assess the viability of various hydrogen projects in Colombia.

Ecopetrol has already started various studies in relation to hydrogen as part of its projections for the next five to ten years.

Table 10.1. Low-emission hydrogen production projects in Colombia

Project	Lead developer	Year	Capacity (kt H_2/yr)	Use	Status
Ecopetrol pilot	Ecopetrol	2022	0.007	Refining	Operational
Promigas pilot	Promigas	2022	0.003	Grid blending	Operational
Cartagena refinery	Ecopetrol	2026	10.4	Refining	Feasibility study
Barrancabermeja refinery	Ecopetrol	2026	10.4	Refining	Feasibility study

With these pilot projects, it is planned to move to new applications, in which the challenge is to replace the current fuels used in their industrial processes with low-emission hydrogen. To this end, studies are being developed to identify and promote hydrogen hubs in the country, production of derivatives (PtX), analysing new financing schemes, as well as the opportunities that Colombia has to develop hydrogen hubs in regions that concentrate supply, demand and infrastructure, considering the geographical advantages and ways to optimise proximity to distribution networks and massive industrial centres.

Colombia has been active in international dialogues with the objective of positioning itself as a potential exporter for the largest markets (Japan, Korea and Europe). The government has signed a memorandum of understanding with the Port of Rotterdam, which it aims to replicate with other European ports, and is working to establish co-operation agreements with Australia, Chile and Germany. Colombia is currently exploring its accession to the International Partnership of Hydrogen and Fuel Cells in the Energy.

Assessment

Colombia has identified RD&D and energy technology and innovation as an important policy priority going forward.

Colombia has defined its priorities for energy RD&D by adopting the recommendations from the 2019 Commission of Experts Colombia and through consultation with the private sector. These priorities include digitalisation, biorefining, smart cities, efficiency, hydrogen and CCUS, broadly aligned with the country's energy and climate goals.

Other clean energy technologies, such as electrification of end uses in transport or industry, should be added to help align energy technology development efforts with long-term decarbonisation goals. At the same time, it will boost opportunities for the creation of high-skilled jobs that can also play an important role in enabling a just transition.

The definition of these priorities has not taken into account the role that RD&D in energy technologies can play in building a competitive industrial sector in Colombia and its impact on economic development. This assessment is also something the representatives from the industrial sector have called for.

Past policy, programmes and commitments tried to improve resourcing for the RD&D system and introduce some benchmarks for private investment. Achieving the goal of

dedicating 7% of the total investment of the sector in energy RD&D can significantly boost the development of energy technologies in the country. However, the IEA considers that it will be difficult to verify the achievement of such a goal without an appropriate system to track public and private expenditure in RD&D. Without this tracking, it is not possible to evaluate how RD&D policies perform and whether they deliver on their objectives.

Colombia increased its RD&D resources, including through the creation of new research centres and the streamlining of funds. However, its RD&D system still lacks adequate structures and resources. There is, for instance, a lack of human capital in key technologies for the energy transition in Colombia (such as electric mobility, hydrogen, CCUS, geothermal or smart cities).

Stakeholders suggest that there are not enough incentives to stimulate innovation in the private sector to develop novel and improved technology products to compete in the global market. In addition, innovators face significant administrative challenges when applying for these incentives (tax benefits or fiscal credits) and for permits for demonstration processes, putting at risk the successful completion of these projects.

The government has made important efforts to improve knowledge management in Colombia, including the creation of the Seneca and Energetica alliances. However, there is no continuity in these efforts and the knowledge transfer networks are scarce and involve a limited number of stakeholders (11 universities and three private companies are involved in the Energetica alliance). The government needs to support the creation of stable knowledge transfer networks and encourage greater participation from stakeholders.

Colombia lacks public awareness of the environmental, social and economic benefits of clean energy technologies, particularly in small cities and rural areas. The adoption of these technologies is critical to put Colombia on the right path to enable the clean and just transition that the country aims to achieve. There is a need for more action in engaging communities through the development of consultations, outreach and communication programmes to ensure that public opposition does not become a significant barrier for the deployment of these technologies. Greater involvement of universities as independent scientific institutions can help to avoid suspicion among the population about vested interests of government and private companies.

Special focus on hydrogen

Colombia has made impressive progress in recent years to develop a vision for the role of hydrogen in its energy system, especially since hydrogen was recognised as a key energy carrier in the Energy Transition Law (2021). Low-emission hydrogen can significantly contribute to Colombia's just transition to net zero and the Hydrogen Roadmap constitutes a very encouraging first step.

The first policies implemented (in the form of tax breaks and support to project developers through FENOGE's "+H2 Colombia" programme) and the strong interest in the industrial sector have facilitated the development of the first demonstration projects.

The government priorities for action for the development of hydrogen are properly oriented but there is a need for accelerated action if Colombia is to realise the potential of low-emission hydrogen for the country's energy transition. The current policies to support low-emission hydrogen production projects seem insufficient to move beyond small demonstrators. The use of instruments that are already bearing fruits in other countries

(carbon pricing, grants, loans) and the use of regulatory sandboxes to test new business models can help derisk investments from the private sector and bridge the competitiveness gap.

There is a need to define an appropriate regulatory framework to enable the development of a low-emission hydrogen market in the country in line with the latest international developments. The government should reconsider the current definitions of “green” and “blue” hydrogen, which can be a barrier to tap into the full potential of low-emission hydrogen. The government should evaluate the adoption of a low-emission hydrogen definition based on life cycle GHG emissions for the production of hydrogen. This will favour the adoption of those production technologies with real potential to abate emissions, including the use of the FNCR, but also hydropower and ensuring that the use of fossil fuels is limited to those projects that incorporate CCUS with high capture rates and upstream emissions abatement measures. The road map has strong targets and objectives for the final use of hydrogen like energy, fuel or industrial products and supplies as ammonia and urea.

It is a welcome step that the MME is preparing a regulation to include new definitions of renewable energy sources, which will include hydrogen. Through the ANH, the state will also go through a public procurement process to choose a contractor to carry out studies to assess the viability of various hydrogen projects in Colombia. Ecopetrol has already started various studies in relation to hydrogen as part of its projections for the next five to ten years.

In the case of CCUS-based hydrogen production, as highlighted in Chapter 7, there is no programme to support the implementation of this technology, there is no regulatory framework for CO_2 storage, and there is no plan for developing the necessary infrastructure for transporting and storing CO_2.

Most of the measures defined in the national Hydrogen Strategy, if properly implemented, can help hydrogen to play its envisaged role in Colombia’s energy transition. However, some actions should be re-evaluated to ensure consistency with the long-term net zero goal. Blending low-emission hydrogen in the gas network could be a way of creating demand in the short term but presents a limited environmental benefit at a high cost for end users, which may not be aligned with the objective of delivering an affordable or just transition in the country. Also, the development of new hydrogen production capacities with coal and CCUS (given that unabated coal is currently not used for producing hydrogen) seems to have limited competitiveness and risks locking in significant residual emissions that will require undertaking significant removal efforts in the long term.

The development of low-emission hydrogen production capacities is not only a matter of a supportive policy framework. It also depends on the creation of demand. The first signals in the form of targets for its use in industry and transport point in the right direction. In addition, the large concentration of demand in Ecopetrol refining activities along with its decarbonisation plans can provide a strong demand-pull. However, targets will not be realised on their own without the implementation of policies that support end users to adopt low-emission hydrogen as a clean feedstock and energy vector. Policies such as carbon contracts for difference, quotas and mandates can help create this demand. Public procurement can also help create demand by requiring its use for public transport (waste collection, trucks, ferries and barges) and by stipulating the use of low-emission steel and cement in infrastructure projects.

Colombia's active role in international engagement is commendable. However, there is potential for the government to boost its potential through key multilateral fora, such as the International Partnership for Hydrogen and Fuel Cells in the Economy, the Hydrogen Energy Ministerial, the Clean Energy Ministerial, and Mission Innovation. They all present great opportunities for knowledge sharing of best practices in policy making. More importantly, they are critical platforms to position Colombia in the international dialogue.

This will allow the country to present itself as a potential exporter and so that the development of an international hydrogen market adequately benefits the local communities where large production projects will emerge. Although the government considers the opportunity to export low-emission hydrogen within the time frame to 2030, securing a place in this market requires early engagement with the potential future partners, all of which are active members in these platforms.

Recommendations:

The government of Colombia should:

Energy technology and innovation

- Establish an independent monitoring system to regularly track progress in energy technology research, development and demonstration (RD&D) to evaluate the effectiveness of RD&D policies against their objectives and identify areas for improvement. Develop a system for regular data collection of public and private spending on energy RD&D to evaluate alignment of spending with strategic priorities.
- Simplify administrative procedures for innovation projects to reduce barriers for technology development. For instance, adopt regulatory sandboxes and improve co-ordination among government institutions.
- Develop a public engagement strategy and communication programmes on clean energy technologies to inform communities about the benefits that they can deliver and their critical role in a clean and just energy transition.

Hydrogen

- Adopt definitions for low-emission hydrogen, based on the life cycle greenhouse gas emissions of hydrogen production. This should be complemented by the adoption of a standard for the quantification of those life cycle emissions and a certification scheme to ensure that public support is only channelled to projects producing hydrogen below a carbon intensity threshold that is compatible with the net zero target.
- Develop a supporting policy framework, using instruments such as carbon pricing, grants, loans or regulatory sandboxes, to mobilise investments in low-emission hydrogen production projects.
- Stimulate demand for low-emission hydrogen both in existing applications and for adoption in those sectors where it can make the greatest contribution toward meeting Colombia's CO_2 reduction targets for the long term, including heavy transport and industrial applications.

- Enhance international co-operation through participation in multilateral fora to exchange experience and best practices in supporting the development of low-emission hydrogen markets and amplify Colombia's voice in international dialogues as a champion on the role of low-emission hydrogen in the just transition.

References

GoC (2021), National Hydrogen Roadmap, https://www.minenergia.gov.co/documents/5862/Colombias_Hydrogen_Roadmap_2810.pdf.

DANE (2018), Encuesta de Desarrollo e Innovación Tecnológica Industria Manufacturera – EDIT IX (Survey of Technological Development and Innovation in the Manufacturing Industry – EDIT IX), https://www.dane.gov.co/files/investigaciones/boletines/edit/boletin_EDIT_manufacturera_2017_2018.pdf.

ANNEX A: Review team and supporting stakeholders

Review criteria

The Shared Goals, which were adopted by the International Energy Agency (IEA) Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the IEA's in-depth reviews. The Shared Goals are presented in Annex C.

Review team and preparation of the report

The IEA's in-depth review visit of Colombia took place from 25 April to 2 May 2022. The review team met with government officials, energy suppliers, market participants, interest groups, consumer associations, research institutions and other stakeholders. The report was drafted based on information obtained in these meetings, the review team's assessment of Colombia's energy policy, the Colombian government's response to the IEA energy policy questionnaire and information on subsequent policy developments from the government. The members of the team were:

IEA member countries

Paul Simons, United States (team leader)

Pieter Boot, Netherlands

Maria Jimenez Navarro, Spain

Andrej Miller, United Kingdom

Daisuke Harada, Japan

International Energy Agency

Sylvia Beyer, Senior Energy Policy Analyst (IDR co-ordination)

Jose Bermudez, Energy Technology Analyst

Aad Van Bohemen, Consultant, Energy Policy and Security Division

Thomas Spencer, Power Sector Analyst

Joerg Husar, Programme Officer, Accession Co-ordinator

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Sylvia Beyer managed the review and is the main author of the report. The report has benefited from the guidance and review of Aad van Bohemen. Milosz Karpinski prepared the chapters on oil and natural gas. Jose Bermudez prepared the chapter on energy technology research and development. Alessio Scanziani, Clémence Lizé, Anders Caratozzolo, Elisa Hittner, Pablo Fons D'Ocon, Eléonore Carré, Su Min Park and Han Young Chang prepared and drafted the sections relating to energy data contained in each chapter. Helpful comments, chapter reviews and updates were provided by the following IEA staff: Joerg Husar, Alejandra Bernal, Edith Bayer, Toril Bosoni, Carlos Fernandez, Diana Perez Sanchez, Luca Lo Re, Thomas Spencer, Rachael Boyd and Jason Elliott.

Special thanks to the IEA secretariat with regard to the data, publication and editing. Astrid Dumond and Isabelle Nonain-Semelin managed the editing, layout and publication. Eléonore Carré, Poeli Bojorquez and Charner Ramsey prepared the maps. Roberta Quadrelli, Stève Gervais and Dionysia Lyngopoulou provided support on statistics. Jennifer Allain was the editor.

Meetings held with the following organisations

ACM

Agency of National Hydrocarbon Colombia (ANH)

BP

CENIT

Carbomax

Cerrejón

CNR

Drummond

ECP

Ecopetrol

Energy and Gas Regulatory Commission (CREG)

Fenalcarbón

ICP

MILPA COQUECOL

MINERCONDOR

Ministry of Mines and Energy

Mining and Energy Planning Unit (UPME)

Ministry of Environment and Sustainable Development

Ministry of Finance

Ministry of Science, Technology and Innovation (MINCIENCIAS)

National Hydrocarbons Regulatory Authority

National Mining Agency (ANM)

National Planning Department

Non-Conventional Energy Fund and Efficient Energy Management (FENOGE)

Superintendence of Industry and Commerce (SIC)

XM

ANNEX B: Key statistical data and notes

Unit: PJ

SUPPLY		1975	1990	2000	2010	2019	2020	2021
TOTAL PRODUCTION		**714.8**	**2050.3**	**3087.5**	**4567.8**	**5266.7**	**4023.7**	**4105.6**
Coal		101.1	614.8	1099.8	2138.3	2425.7	1433.2	1606.3
Peat		-	-	-	-	-	-	-
Oil		346.7	964.1	1500.1	1713.4	1983.9	1758.7	1661.9
Natural gas		53.7	141.3	228.5	394.6	437.7	426.0	396.5
Biofuels and waste[1]		181.3	231.1	143.6	175.9	222.1	225.1	220.9
Nuclear		-	-	-	-	-	-	-
Hydro		32.0	99.0	115.5	145.4	196.5	179.9	218.5
Wind		-	-	-	0.1	0.2	0.0	0.2
Geothermal		-	-	-	-	-	-	-
Solar/other		-	-	0.0	0.0	0.5	0.7	1.2
TOTAL NET IMPORTS[2]		**-64.7**	**-936.6**	**-2035.3**	**-3275.5**	**-3419.2**	**-3315.6**	**-2724.2**
Coal	Exports	0.8	390.8	1022.7	1994.0	2120.4	2018.4	1675.8
	Imports	-	-	-	-	-	0.0	-
	Net imports	-0.8	-390.8	-1022.7	-1994.0	-2120.4	-2018.4	-1675.8
Oil	Exports	53.9	571.1	995.4	1306.6	1471.9	1450.8	1261.8
	Imports	9.4	51.1	19.4	138.2	230.6	168.7	254.6
	Int'l marine and aviation bunker	-19.4	-26.5	-36.8	-60.2	-64.1	-31.2	-43.1
	Net imports	-63.8	-546.5	-1012.8	-1228.6	-1305.4	-1313.2	-1050.3
Natural gas	Exports	-	-	-	50.1	-	-	-
	Imports	-	-	-	-	5.5	12.2	1.6
	Net imports	-	-	-	-50.1	5.5	12.2	1.6
Electricity	Exports	-	-	0.1	2.9	0.0	0.9	1.3
	Imports	-	0.7	0.3	0.0	1.1	4.7	1.7
	Net imports	-	0.7	0.1	-2.8	1.1	3.8	0.4
TOTAL STOCK CHANGES		**-3.8**	**-92.0**	**31.0**	**-6.1**	**-60.7**	**966.8**	**392.9**
TOTAL SUPPLY (TES)[3]		**646.3**	**1021.7**	**1083.2**	**1286.2**	**1791.8**	**1677.8**	**1774.6**
Coal		91.7	136.4	116.9	144.3	200.5	185.3	128.3
Peat		-	-	-	-	-	-	-
Oil		287.6	413.2	478.6	479.0	722.7	642.2	806.4
Natural gas		53.7	141.3	228.5	344.6	443.2	438.2	398.1
Biofuels and waste[1]		181.3	231.1	143.6	175.6	227.0	227.6	221.4
Nuclear		-	-	-	-	-	-	-
Hydro		32.0	99.0	115.5	145.4	196.5	179.9	218.5
Wind		-	-	-	0.1	0.2	0.0	0.2
Geothermal		-	-	-	-	-	-	-
Solar/other		-	-	0.0	0.0	0.5	0.7	1.2
Electricity trade[4]		-	0.7	0.1	-2.8	1.1	3.8	0.4
Shares in TES (%)								
Coal		*14.2*	*13.3*	*10.8*	*11.2*	*11.2*	*11.0*	*7.2*
Peat		-	-	-	-	-	-	-
Oil		*44.5*	*40.4*	*44.2*	*37.2*	*40.3*	*38.3*	*45.4*
Natural gas		*8.3*	*13.8*	*21.1*	*26.8*	*24.7*	*26.1*	*22.4*
Biofuels and waste[1]		*28.0*	*22.6*	*13.3*	*13.7*	*12.7*	*13.6*	*12.5*
Nuclear		-	-	-	-	-	-	-
Hydro		*5.0*	*9.7*	*10.7*	*11.3*	*11.0*	*10.7*	*12.3*
Wind		-	-	-	-	-	-	-
Geothermal		-	-	-	-	-	-	-
Solar/other		-	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*
Electricity trade[4]		-	*0.1*	-	*-0.2*	*0.1*	*0.2*	-

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: PJ

DEMAND							
FINAL CONSUMPTION	**1975**	**1990**	**2000**	**2010**	**2019**	**2020**	**2021**
TFC	**520.4**	**796.5**	**873.4**	**916.6**	**1279.8**	**1173.3**	**1319.0**
Coal	49.6	70.9	99.3	67.4	95.0	87.5	93.5
Peat	-	-	-	-	-	-	-
Oil	244.1	366.4	450.2	400.5	586.9	501.7	639.5
Natural gas	11.1	38.3	68.0	129.9	147.0	141.4	145.2
Biofuels and waste[1]	176.3	224.2	136.0	148.9	207.8	205.4	188.2
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	-	-	-	-
Electricity	39.2	96.7	120.0	169.9	243.0	237.3	252.6
Heat	-	-	-	-	-	-	-
Shares in TFC (%)							
Coal	*9.5*	*8.9*	*11.4*	*7.4*	*7.4*	*7.5*	*7.1*
Peat	-	-	-	-	-	-	-
Oil	*46.9*	*46.0*	*51.5*	*43.7*	*45.9*	*42.8*	*48.5*
Natural gas	*2.1*	*4.8*	*7.8*	*14.2*	*11.5*	*12.0*	*11.0*
Biofuels and waste[1]	*33.9*	*28.2*	*15.6*	*16.3*	*16.2*	*17.5*	*14.3*
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	-	-	-	-
Electricity	*7.5*	*12.1*	*13.7*	*18.5*	*19.0*	*20.2*	*19.2*
Heat	-	-	-	-	-	-	-
TOTAL INDUSTRY[5]	**142.8**	**236.1**	**330.0**	**270.9**	**410.0**	**337.1**	**380.0**
Coal	42.9	65.4	96.2	65.0	92.3	85.1	91.1
Peat	-	-	-	-	-	-	-
Oil	52.5	70.9	122.4	69.2	110.8	75.8	94.6
Natural gas	11.1	33.2	40.9	54.9	58.9	54.5	59.2
Biofuels and waste[1]	21.5	37.9	29.5	30.9	66.5	47.8	51.1
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	-	-	-	-
Electricity	14.9	28.6	41.1	50.9	81.5	73.8	84.0
Heat	-	-	-	-	-	-	-
Shares in total industry (%)							
Coal	*30.0*	*27.7*	*29.1*	*24.0*	*22.5*	*25.3*	*24.0*
Peat	-	-	-	-	-	-	-
Oil	*36.8*	*30.0*	*37.1*	*25.5*	*27.0*	*22.5*	*24.9*
Natural gas	*7.8*	*14.1*	*12.4*	*20.3*	*14.4*	*16.2*	*15.6*
Biofuels and waste[1]	*15.0*	*16.1*	*8.9*	*11.4*	*16.2*	*14.2*	*13.4*
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	-	-	-	-
Electricity	*10.4*	*12.1*	*12.5*	*18.8*	*19.9*	*21.9*	*22.1*
Heat	-	-	-	-	-	-	-
TRANSPORT[3]	**132.9**	**233.5**	**263.5**	**309.0**	**476.2**	**410.4**	**520.7**
OTHER[6]	**244.7**	**326.9**	**280.0**	**336.7**	**393.6**	**425.8**	**418.3**
Coal	6.5	5.4	3.1	2.3	2.7	2.4	2.4
Peat	-	-	-	-	-	-	-
Oil	59.0	62.6	66.8	68.1	57.8	65.8	77.7
Natural gas	0.0	4.5	24.8	45.3	63.5	65.4	65.2
Biofuels and waste[1]	154.8	186.3	106.5	102.2	108.5	129.1	104.7
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	-	-	-	-
Electricity	24.4	68.1	78.7	118.8	161.1	163.1	168.3
Heat	-	-	-	-	-	-	-
Shares in other (%)							
Coal	*2.7*	*1.7*	*1.1*	*0.7*	*0.7*	*0.6*	*0.6*
Peat	-	-	-	-	-	-	-
Oil	*24.1*	*19.1*	*23.9*	*20.2*	*14.7*	*15.5*	*18.6*
Natural gas	*-*	*1.4*	*8.9*	*13.5*	*16.1*	*15.4*	*15.6*
Biofuels and waste[1]	*63.2*	*57.0*	*38.0*	*30.4*	*27.6*	*30.3*	*25.0*
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	-	-	-	-
Electricity	*10.0*	*20.8*	*28.1*	*35.3*	*40.9*	*38.3*	*40.2*
Heat	-	-	-	-	-	-	-

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: PJ

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1975**	**1990**	**2000**	**2010**	**2019**	**2020**	**2021**
ELECTRICITY GENERATION[7]							
Input (PJ)	78.3	204.1	226.5	341.5	417.6	452.5	428.0
Output (PJ)	46.6	130.9	155.3	218.3	289.5	286.4	304.0
Output (TWh)	12.9	36.4	43.1	60.6	80.4	79.5	84.4
Output shares (%)							
Coal	*10.4*	*10.2*	*5.1*	*6.8*	*10.2*	*11.8*	*5.4*
Peat	-	-	-	-	-	-	-
Oil	*1.9*	*1.0*	*0.2*	*2.8*	*3.4*	*3.3*	*3.3*
Natural gas	*17.4*	*12.4*	*19.1*	*19.7*	*16.4*	*19.1*	*16.3*
Biofuels and waste[1]	*1.5*	*0.8*	*1.1*	*4.0*	*2.0*	*2.7*	*2.7*
Nuclear	-	-	-	-	-	-	-
Hydro	*68.8*	*75.6*	*74.4*	*66.6*	*67.9*	*62.8*	*71.9*
Wind	-	-	-	*0.1*	*0.1*	-	*0.1*
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	-	*0.2*	*0.3*	*0.4*
TOTAL LOSSES	**134.2**	**230.8**	**235.9**	**377.5**	**323.2**	**436.1**	**386.3**
of which:							
Electricity and heat generation[8]	31.7	73.3	71.3	123.2	128.1	166.1	124.0
Other transformation	54.7	52.6	13.6	104.7	73.2	150.9	108.7
Own use and transmission/distribution losses	47.8	105.0	151.1	149.6	121.9	119.1	153.6
Statistical differences	**-8.2**	**-5.7**	**-26.2**	**-7.9**	**188.8**	**68.4**	**69.2**
INDICATORS	**1975**	**1990**	**2000**	**2010**	**2019**	**2020**	**2021**
GDP (billion 2015 USD)	66.37	120.41	157.43	233.25	321.09	297.80	330.61
Population (millions)	24.06	33.18	39.17	44.22	48.91	49.43	49.94
TES/GDP (MJ per 2015 USD)[9]	9.74	8.49	6.88	5.51	5.58	5.64	5.37
Energy production/TES	1.11	2.01	2.85	3.55	2.94	2.40	2.31
Per capita TES (GJ per capita)	26.87	30.79	27.65	29.09	36.63	33.94	35.53
Oil supply/GDP (MJ per 2015 USD)[9]	4.33	3.43	3.04	2.05	2.25	2.16	2.44
TFC/GDP (MJ per 2015 USD)[9]	7.84	6.62	5.55	3.93	3.99	3.94	3.99
Per capita TFC (GJ per capita)	21.63	24.01	22.30	20.73	26.17	23.74	26.41
CO_2 emissions from fuel combustion ($MtCO_2$)[10]	28.2	46.3	54.6	57.6	72.7	71.2	77.3
CO_2 emissions from bunkers ($MtCO_2$)[10]	0.5	0.3	0.7	2.0	0.4	0.4	0.4
GROWTH RATES (% per year)	**75-90**	**90-00**	**00-10**	**10-18**	**18-19**	**19-20**	**20-21**
TES	3.1	0.6	1.7	3.1	9.3	-6.4	5.8
Coal	2.7	-1.5	2.1	1.1	26.9	-7.6	-30.8
Peat	-	-	-	-	-	-	-
Oil	2.4	1.5	0.0	3.4	15.1	-11.1	25.6
Natural gas	6.7	4.9	4.2	2.8	3.3	-1.1	-9.2
Biofuels and waste[1]	1.6	-4.6	2.0	2.1	9.5	0.3	-2.7
Nuclear	-	-	-	-	-	-	-
Hydro	7.8	1.6	2.3	5.1	-8.9	-8.5	21.4
Wind	-	-	-	1.4	45.8	-84.0	497.6
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	2.9	12.8	554.0	46.6	66.8
TFC	2.9	0.9	0.5	3.7	4.1	-8.3	12.4
Electricity consumption	6.2	2.2	3.5	3.4	9.1	-2.3	6.5
Energy production	7.3	4.2	4.0	1.6	1.8	-23.6	2.0
Net oil imports	..	..	..	..	..	..	..
GDP	4.1	2.7	4.0	3.7	3.2	-7.3	11.0
TES/GDP	-0.9	-2.1	-2.2	-0.6	6.0	1.0	-4.8
TFC/GDP	-1.1	-1.7	-3.4	0.1	1.0	-1.2	1.3

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Footnotes to key statistical data

1 Biofuels and waste comprise solid biofuels, liquid biofuels, biogases and municipal waste. Data are often based on partial surveys and may not be comparable between countries.

2 In addition to coal, oil, natural gas and electricity, total net imports also include biofuels.

3 Excludes international marine bunkers and international aviation bunkers.

4 Total supply of electricity represents net trade. A negative number in the share of TES indicates that exports are greater than imports.

5 Industry includes non-energy use.

6 Other includes residential, commercial and public services, agriculture/forestry, fishing, and other non-specified.

7 Inputs to electricity generation include inputs to electricity. Output refers only to electricity generation.

8 Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 100% for hydro, wind and solar photovoltaic.

9 MJ per thousand US dollars at 2015 prices and exchange rates.

10 "CO_2 emissions from fuel combustion" have been estimated using the IPCC Tier I Sectoral Approach methodology from the *2006 IPCC Guidelines.* Emissions from international marine and aviation bunkers are not included in national totals.

Statistical notes for data used in the report

- Unless otherwise noted, all GDP data are in USD 2015 prices and PPPs (purchasing power parities).
- *Total energy supply (TES)* comprises production + imports – exports – international marine and aviation bunkers ± stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (e.g. electricity generation and refining) or in final use.
- *Total final consumption (TFC)* is the final consumption of energy (electricity, heat and fuels, such as natural gas and oil products) by end users, not including the transformation sector (e.g. power generation and refining).
- *Total final energy consumption (TFEC)* excludes non-energy use which is counted in total final consumption (TFC). TFEC provides a more accurate assessment of the share of energy demand covered by renewable energy and is better aligned with the European Union's gross final energy consumption metric, which is used to set EU member states' renewable energy targets.
- The shares of renewables in total final energy consumption, electricity generation, heating and cooling, and transport differ if computed with IEA or Eurostat methodologies. The Eurostat methodology includes multiplying factors and normalisation procedures.
- *Bioenergy* refers to solid and liquid biofuels, renewable waste, and biogas and excludes non-renewable waste.
- *Buildings* includes the energy use of the residential sector (residential buildings) and commercial and public service sectors (service sector buildings).
- *Transport* excludes international aviation and navigation.
- *Industry* includes both energy and non-energy use of the industry sector, agriculture, forestry and fishing.
- *Non-energy use* refers to fuels used as raw materials, and not used as fuel or transformed into another fuel. This typically comprises raw materials used in the chemical and petrochemical sector.
- "IEA average" is the equivalent of a weighted average of IEA member countries.

ANNEX C: International Energy Agency "Shared Goals"

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. Diversity, efficiency and flexibility within the energy sector are basic conditions for longer term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydropower, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases, this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. The environmentally sustainable provision and use of energy are central to the achievement of these Shared Goals. Decision makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the polluter-pays principle where practicable.

4. More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle, from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. Co-operation among all energy market participants helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA ministers at the meeting of 4 June 1993 in Paris, France.)

* Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States.

ANNEX D: Glossary and list of abbreviations

In this report, abbreviations and acronyms are substituted for a number of terms used within the International Energy Agency. While these terms generally have been written out on first mention, this glossary provides a quick and central reference for the abbreviations used.

Acronyms and abbreviations

ANH	Agency of National Hydrocarbon
ANM	National Mining Agency
BAT	best available technology
BEU	useful energy balance study
CCS	carbon capture and storage
CCUS	carbon capture, use and storage
CNG	compressed natural gas
CONPES	National Council on Economic and Social Policy
COP	Colombian peso
CREG	Energy and Gas Regulatory Commission
CTEI	Coal Transition Exposure Index
CXC	reliability charge
DNP	National Planning Department
DSO	distribution system operator
ETS	emissions trading system
EU	European Union
EV	electric vehicle
FENOGE	Fund for Renewable Energy and Energy Efficiency
FEO	firm energy obligation
FEPC	Fuel Price Stabilisation Fund
FNCER	non-conventional renewable energy source
FSRU	floating storage regasification unit
GDP	gross domestic product
GHG	greenhouse gas
HHI	Herfindahl-Hirschman Index
IEA	International Energy Agency
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULUCF	land-use, land use change and forestry
MADS	Ministry of the Environment and Sustainable Development
MEM	Wholesale Energy Market
MME	Ministry of Mines and Energy

NDC	Nationally Determined Contribution
OECD	Organisation for Economic Co-operation and Development
PEN	National Energy Plan
PIGCC	sectoral climate change management plan
PIGCCME	energy sector climate change management plan
PIGCCS	comprehensive sector climate change management plan
PND	National Development Plan
PPP	purchasing power parity
PROURE	Programme for the Rational and Efficient Use of Energy
PV	photovoltaics
RD&D	research, development and demonstration
SIC	Superintendence of Industry and Commerce
SIN	interconnected grid
TCP	technology collaboration programme
TES	total energy supply
TFC	total final consumption
TFEC	total final energy consumption
UNFCCC	United Nations Framework Convention on Climate Change
UPME	Mining and Energy Planning Unit
USD	United States dollar
VAT	value-added tax

Units of measure

b/d	barrels per day
bcm	billion cubic metres
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
GJ	gigajoule
GW	gigawatt
GWh	gigawatt hour
ha	hectare
kb/d	thousand barrels per day
kcal	kilocalorie
kg	kilogramme
kg CO_2	kilogramme of carbon dioxide
kt	kilotonne
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour

m²	square metre
mb	million barrels
mcm	million cubic metres
MJ	megajoule
Mt	million tonnes
Mt CO_2-eq	million tonnes of carbon dioxide equivalent
MW	megawatt
MWh	megawatt hour
PJ	petajoule
t CO_2	tonne of carbon dioxide
TJ	terajoule
toe	tonne of oil equivalent
TWh	terawatt hour

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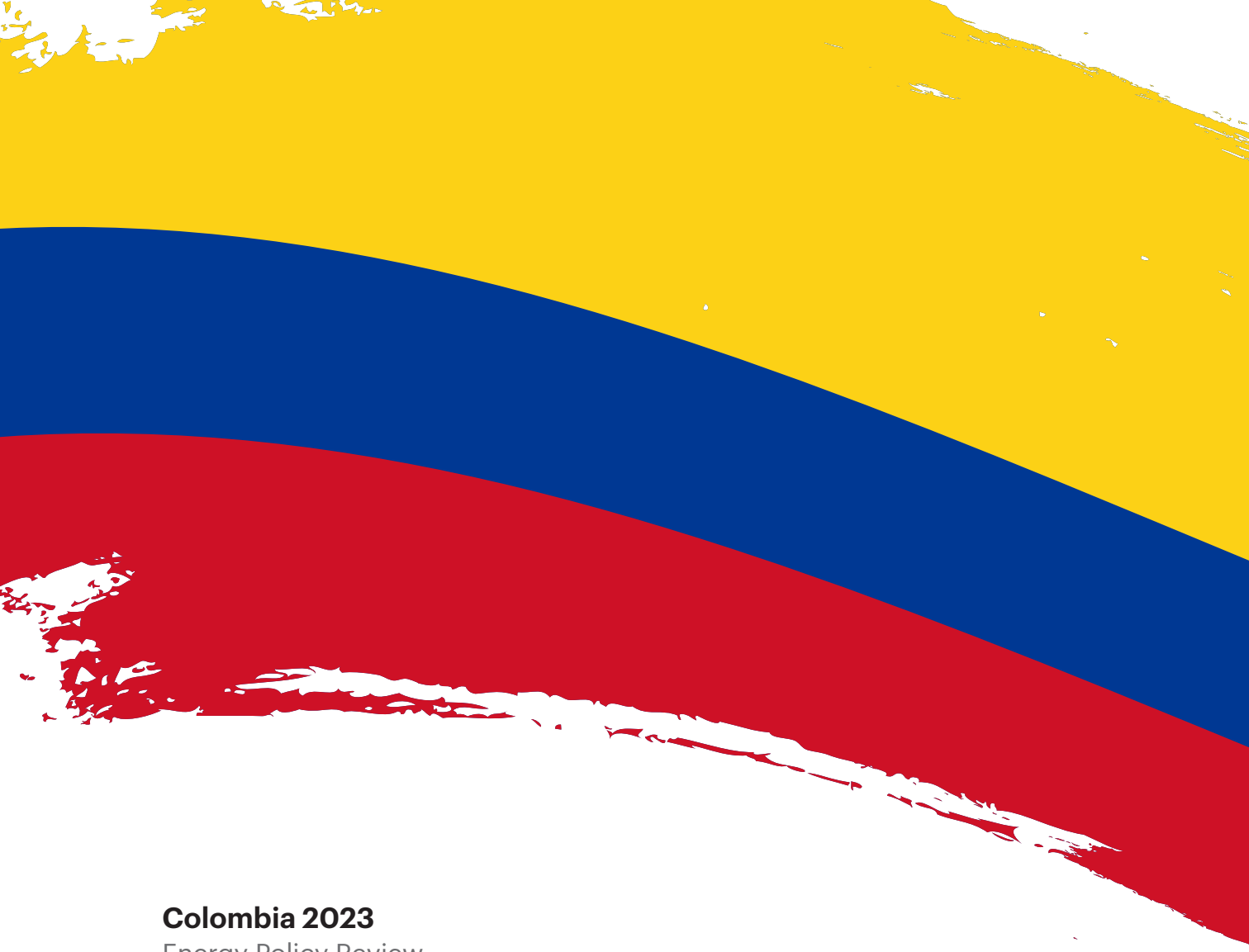

Colombia 2023

Energy Policy Review

The International Energy Agency (IEA) regularly conducts in-depth peer reviews of the energy policies of its member, accession and association countries. This process supports energy policy development and encourages the exchange of international best practices and experiences.

This first energy policy review of Colombia's energy policies examines the country's achievements in developing its energy sector as well as the challenges it faces in ensuring a sustainable energy future.

Colombia's energy transition policy making is an inspiring example of a fossil fuel producing country committed to climate action, based on a long-term decarbonisation pathway and a policy of energy and economic diversification and a just transition.

This report provides insights into Colombia's unique energy system transformation, which is linked to expanding access to electricity and clean cooking for its citizens and swiftly deploying renewable energy technologies. It analyses the full breadth of the country's energy sector and presents recommendations for strengthening the country's people-centred, secure and clean energy transition. These include clean energy technology and innovation, adapting energy market rules, notably in power and gas markets; integrating higher shares of variable renewables; addressing air quality; and reducing vulnerability to the impacts of climate change.