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IS NATURAL GAS A GOOD INVESTMENT FOR LATIN AMERICA AND THE CARIBBEAN?

FROM ECONOMIC TO EMPLOYMENT AND CLIMATE IMPACTS OF THE POWER SECTOR

aecid

ISBN No: 978-92-807-3980-0
Job No: LAC/2478/PA

Published by the United Nations Environment Programme (UNEP), October 2022.

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Suggested citation

United Nations Environment Programme (2022). Is Natural Gas a Good Investment for Latin America and the Caribbean? From Economic to Employment and Climate Impacts of the Power Sector

Production

United Nations Environment Programme (UNEP)

Acknowledgements

The United Nations Environment Programme (UNEP) would like to thank the external contributors of the coordinating review committee and the lead and contributing authors for their contribution to the preparation of this assessment report.

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Micro-site development

Javier Bianchet, UNEP, Latin America and the Caribbean Office.

Thanks also to:

Finally, UNEP would like to thank the Spanish Agency for International Development Cooperation (AECID) for supporting the work of the United Nations Environment Programme in line with the Paris Agreement on climate change in Latin America and the Caribbean.

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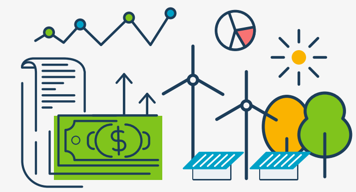
Executive Summary

Latin America and the Caribbean (LAC) has over 650 million inhabitants; it is responsible for 8.1 per cent of global greenhouse gas (GHG) emissions and 6.7 per cent of the world's gross domestic product (GDP). Its energy sector – including the power sector, industry, and transport – is responsible for 35.2 per cent of regional GHG emissions (UNEP, 2019). Almost 25 per cent of those emissions are from the power sector, and about 70 per cent are on the demand side (primarily from transportation).

The region holds less than 5 per cent of global natural gas reserves, and accounts for 7 per cent of production (OLADE, 2019). Mexico, Brazil and Argentina are increasing their fossil fuel investments and exploitation, particularly of natural gas, while many other countries are planning new natural gas infrastructure projects (UNEP, 2021). This happens in the midst of a global disruption of the energy market because of Russia's Ukraine invasion. Prices of oil and gas have recently peaked because of the conflict, raising concerns over energy security.

The International Energy Agency (IEA) has argued exploitation and development of new oil and gas fields must stop now in order to meet the Paris Agreement targets (IEA, 2021). Fossil fuel infrastructure, both existing and planned, would release enough emissions over its lifetime to exceed 1.5ºC of warming compared to pre-industrial times, one of the goals included in the Paris Agreement on climate change, according to the Intergovernmental Panel on Climate Change (IPCC). To meet these targets overall greenhouse gas emissions would have to be reduced 43 per cent by 2030 and 100 per cent by 2050 (IPCC, 2022). Specifically, methane emissions, the second biggest contributor to global warming after carbon dioxide, would have to be reduced by 33 per cent by 2030. Measured over a century, methane has a global warming potential around 30 times that of CO_2.

Why are then so many LAC countries considering increasing their investments in fossil fuels, especially of natural gas? What would be the consequences of this in terms of benefits to their economies, job creation opportunities and GHG emissions? What would happen if governments instead decided to boost renewable energy rather than natural gas as part of an energy transition away from fossil fuels?



Latin America and the Caribbean:

+650 million inhabitants

8.1 % of global GHG emmissions

6.7 % of the world's GDP

>5 % of global natural gas reserves

accounts for 7 per cent of production

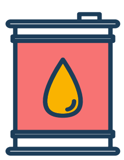
The International Energy Agency (IEA) has argued that the exploitation and development of new oil and gas fields must stop now in order to meet the Paris Agreement targets

This report seeks to understand the implications of an expansion of natural gas in LAC. It deep-dives into the power sector to investigate the effects of meeting future electricity demand through different electricity mixes. Other sectors such as natural gas for heating, also relevant in LAC for their extensive use in several countries, weren't considered for the analysis. However, the recommendations apply transversally for all sectors.

To assess the implications in emissions, costs and job creation of different power sector options, three scenarios have been analyzed.

This report also seeks to contextualize regional findings in specific countries of the region. To do so case studies for three countries are also included as part of the report. Argentina, in South America, with the shale gas and oil reservoir Vaca Muerta and plans for offshore fossil fuels extraction. Panama, the first country in Central America to inaugurate a natural gas power plant. And Grenada, a Caribbean country currently at crossroads over the future of its energy sector after the failure of a system based on diesel generators.

Business-as-usual (BAU)

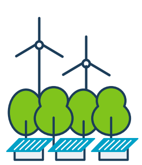


The power sector continues supplying electricity following recent trends, including coal and oil-based power plants. Hydropower is developed until identified potential is reached. This is the reference scenario used to compare the next two scenarios.

Natural gas (NG)

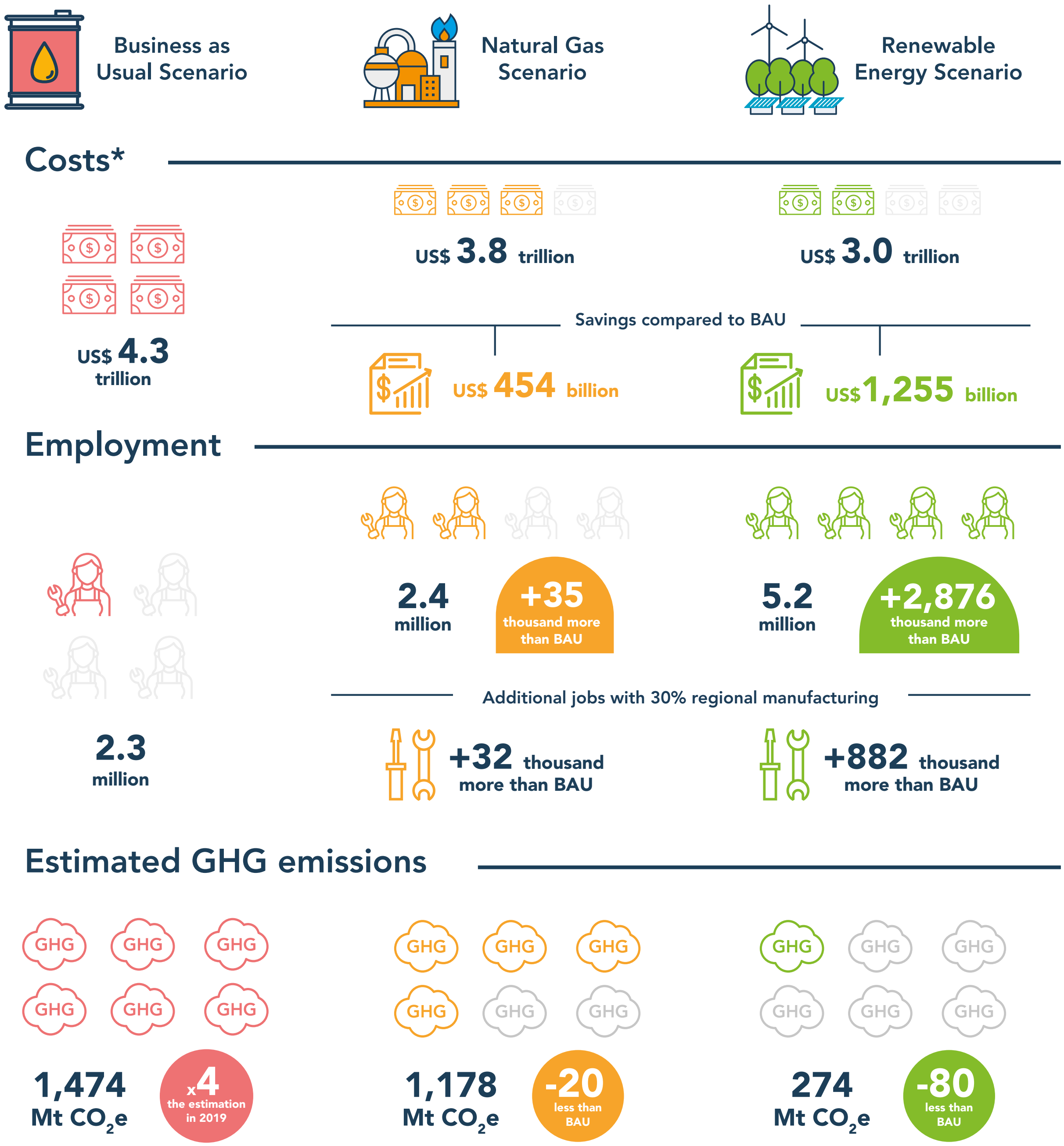
The power sector supplies electricity prioritizing natural gas power plants to meet expected demand increases and as a replacement for coal and oil power plants. Hydropower is developed until identified potential is reached.

Renewable Energy (RE)



The power sector supplies electricity primarily through wind and solar power plants coupled with energy storage. Existing hydropower plants remain operational, no new plants are developed due to social and environmental impact.

Figure R1. Key results of the report by 2050



*Results are cummulative values to 2050 for costs. Other results are yearly values in 2050

Source: Author's elaboration

Results: costs and benefits

The natural gas scenario requires almost the same capital investments as the business-as-usual pathway, with a reduction on fixed and variable operational costs. In this scenario, the region would perceive a net benefit of US$454 billion by 2050 (about 7 per cent of the 2019 regional GDP) compared to the business-as-usual scenario.

Meanwhile, moving to a renewable power system coupled with energy storage reduces investments in power plants, saving US$448 billion in construction of capacity in the region compared to the business-as-usual case. The switch to renewable energy also brings a significant reduction of US$790 billion in variable operation costs, which over-compensates for a US$24 billion increase in fixed operational costs caused by a larger installed capacity.

The variability of renewable energy generation is expected to require larger investments in the transmission and distribution grid including storage and grid services, accounting for extra costs estimated at US$49 billion by 2050. Lowering the use of fossil fuels also brings an important reduction on the climate change impact of the region (US$74 billion) and reduced impact on health (US$19 billion). The reduction on income for exporter countries related to lowering the use of natural gas for electricity generation in LAC was also accounted for and estimated in US$3 billion by 2050.

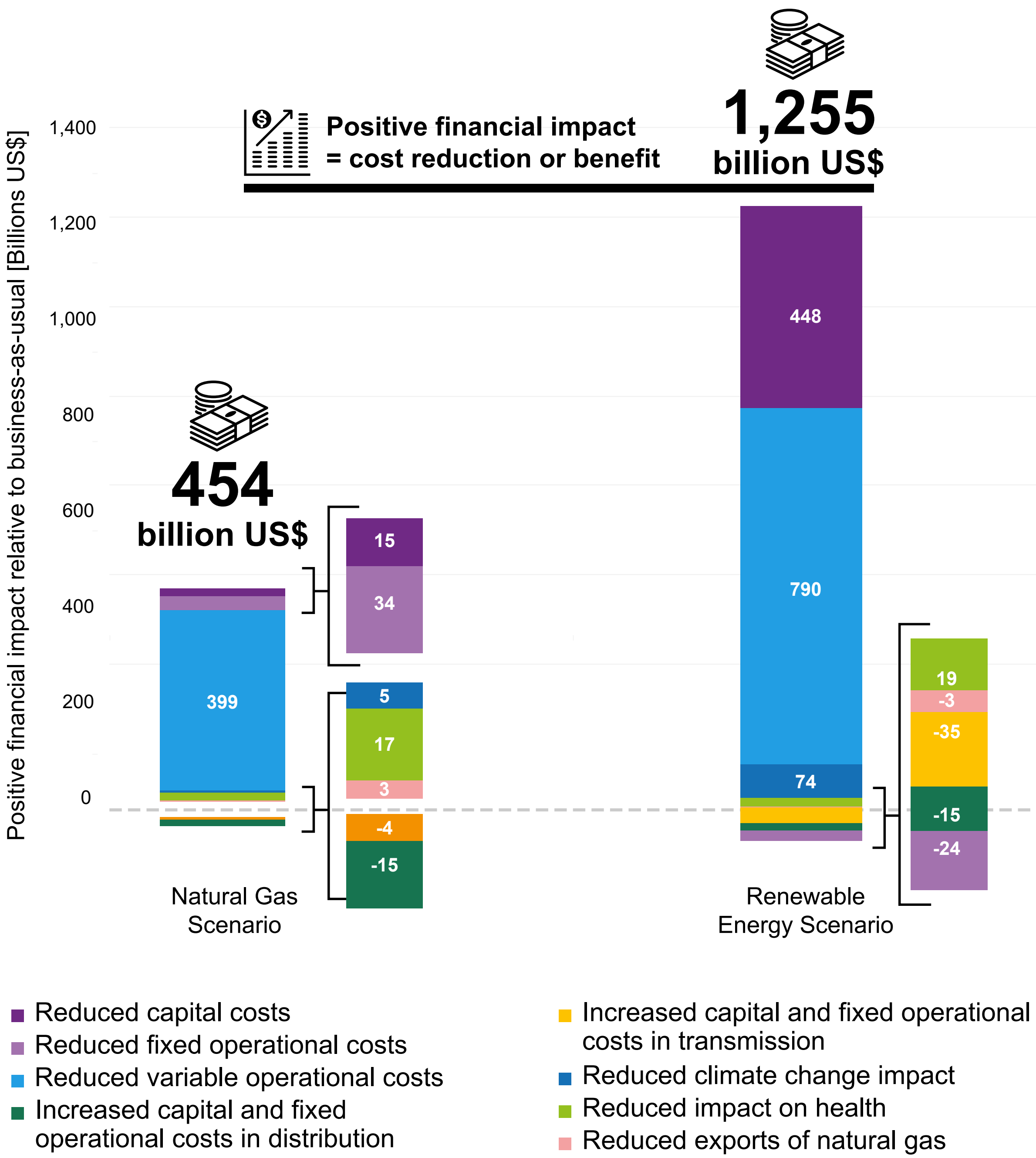
The switch towards a renewable power system would bring the LAC region a net benefit of US$1,255 billion by 2050 (about 20 per cent of the 2019 regional GDP). Figure RE2 shows the net benefits of the natural gas and renewable energy strategies compared to the business-as-usual scenario.

The switch towards a renewable power system would bring the LAC region a net benefit of US$ 1.25 trillion by 2050 (about 20 per cent of the 2019 regional GDP)

ARGENTINA CASE STUDY RESULTS

For example, in Argentina, one of the countries analyzed by this report the business-as-usual scenario would have a total estimated cost of US$263.3 billion. Meanwhile, the natural gas scenario would reduce costs by US$14 billion and the renewable energy scenario would save US$31 billion by 2050.

Figure RE2. Positive financial impact and other benefits of the natural gas and renewable energy scenarios relative to the business-as-usual scenario



Source: Authors' own research.

Results: Job creation

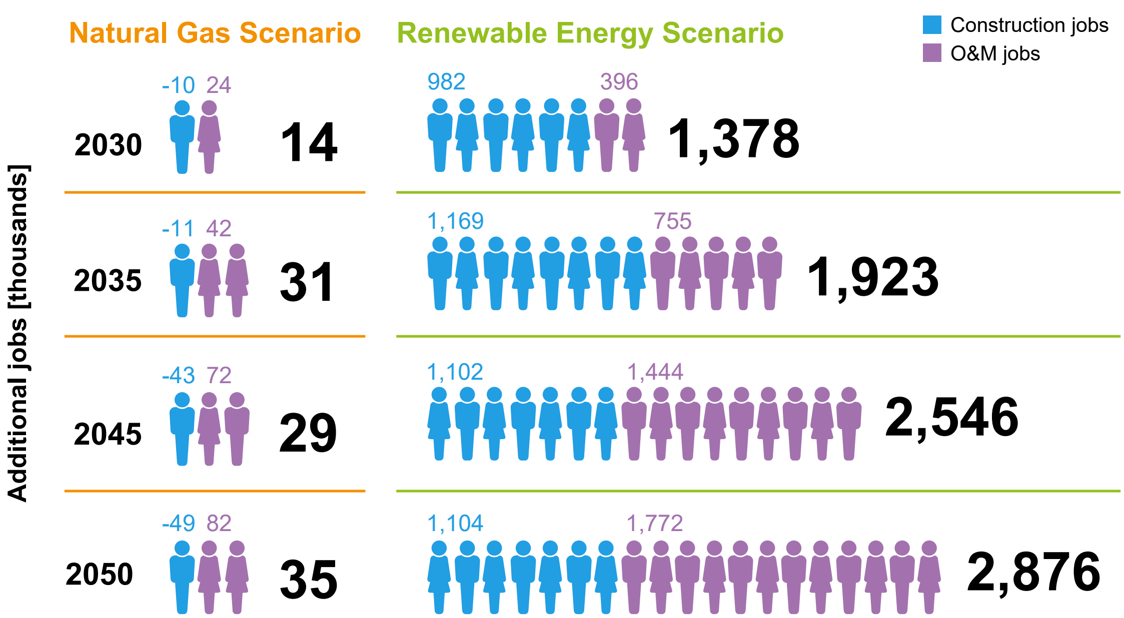
In 2050, the natural gas scenario would create 35 thousand more jobs than the business-as-usual scenario in LAC. This figure could increase to 38 thousand if we consider the jobs created by a higher production of this fuel and using similar values referred to Argentina (Romero, 2018). Replacing coal and oil by natural gas results in a loss of 132 thousand jobs in 2050 and creates 167 thousands new jobs in 2050.

In 2050, the renewable energy scenario would create around 3 million new jobs compared to the business-as-usual one. The switch to renewables overcompensates the loss of 132 thousand jobs from the phase out of coal and oil plants, and the 5 thousand jobs loss from the production of natural gas in the region according to (Romero, 2018).

In Panama, one of the countries reviewed by this report, the natural gas scenario doesn't generate additional jobs compared to the business-as-usual scenario, while the renewable energy path would create 93 thousand jobs by 2050. Figure RE3 shows the net effect (relative to the business-as-usual scenario) of deploying the natural gas and renewable energy scenarios.

The renewable energy scenario far outstrips natural gas in terms of job creation. 3 million versus 167,000 respectively would be created by 2050

Figure RE3. Job creation under a natural gas and renewable energy scenario relative to the business-as-usual one



Source: Authors' own research.

The previous results on job creation consider construction, operation and maintenance related jobs in the power sector. These results are conservative as they do not account for manufacturing in the region. If 30 per cent of the components were to be manufactured in the region, the total job creation figure of the renewable energy scenario would ascend to 3.7 million net jobs by 2050.

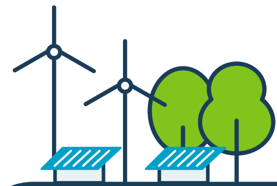
Results: GHG emissions

On the business-as-usual scenario, annual GHG emissions in LAC in 2050 are four times higher (390 per cent) than those estimated in 2019.

The natural gas scenario results in a modest 20 per cent reduction in GHG emissions compared to the business-as-usual pathway in 2050. The reduction comes from the decommissioning of diesel and coal power plants. In addition, fugitive emissions would grow due to higher natural gas production and imports.

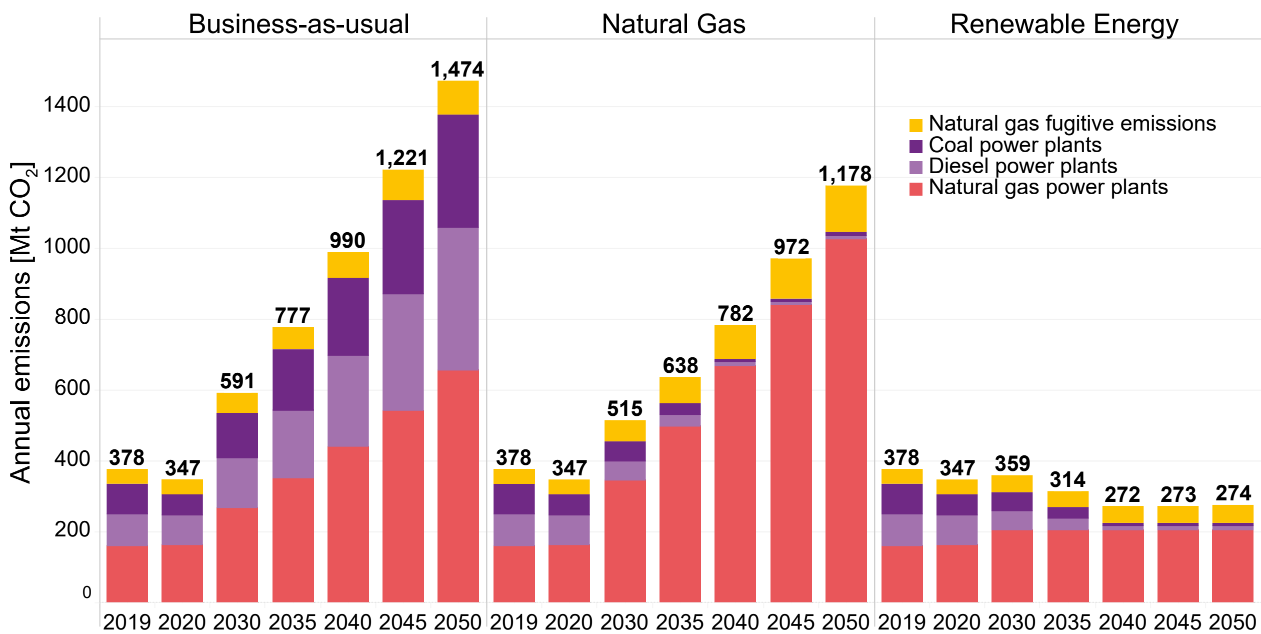
The renewable energy scenario results in 75 per cent lower GHG emissions than natural gas by 2050, as well as 80 per cent lower than the business-as-usual scenario. Adopting a renewable energy scenario reduces mid-century GHG emissions by 30 per cent compared to 2019 levels.

In Grenada, one of the countries included in this report, emissions would grow 20 per cent by 2030 under a BAU scenario and decline 20 per cent under a natural gas expansion. However, they would decline 31.7 per cent compared to BAU under a renewable energy scenario, closing the gap to meet the country's Nationally Determined Contribution, NDC. Figure RE4 shows the annual GHG emissions trajectory for each scenario and type of fuel, including fugitive emissions.



The renewable energy scenario results in 80 per cent lower GHG emissions by 2050 than those in the business-as-usual scenario, and 75 per cent lower than the natural gas scenario.

Figure RE4. Annual emissions trajectory per strategy from the power sector



Source: Authors' own research.

Key take-aways

The findings of the present study suggest the following key takeaways:

Business-as-usual (BAU) = high climate and socio-economic risk

Countries can use fossil fuels, as they have in the past, to meet the higher demand described above; i.e., a business-as-usual scenario, which keeps using high levels of hydropower, coal, and oil (diesel and fuel oil) in the electricity matrix.

- The business-as-usual scenario would have a total estimated cost of US$4.3 trillion.
- Lower competitiveness due to higher electricity costs. Potential restrictions on regional exports due to carbon footprint.
- Ecosystems are stressed increasing vulnerability to climate change.
- GHG: Emissions increase 390 per cent by 2050. There are no reductions on demand side either.
- The installed capacity of fossil power plants (diesel, coal and natural gas) increases from about 170 GW to nearly 725 GW.

Natural Gas = climate risk and lost opportunities

- The cost reduction relative to the BAU scenario would be US$0.450 billion.
- This scenario produces few net jobs relative to the BAU scenario. Replacing coal and oil plants for natural gas does not produce significant job generation in the power sector, nor does it generate the emissions reductions needed to achieve the goals of the Paris Agreement and avoid deepening the climate crisis.
- GHG: Emissions are only 20 per cent lower than the business-as-usual scenario.

Renewable energy = climate action, higher employment and economic outcomes

Considering the falling cost of renewables and batteries, which can provide short-term power and energy storage solutions to power grids, the cost reduction of a renewable energy scenario is US$1.25 trillion.

There are several avoided costs mainly from diesel, coal and natural gas, as they are not used as an option for the transition.

If countries start pursuing non-conventional renewables decisively, emissions for the energy sector in 2050 could be 80 per cent lower than those in the BAU scenario, and 30 per cent lower than those estimated for 2019.

Wind and solar over hydro can decrease construction costs, adapt more quickly to demand changes (i.e., with smaller projects), and be closer to demand centers in the case of distributed solar generation.

There is a reduction of the risk and variability of international fuel prices, therefore also allowing for higher predictability and energy security.


Photo: CCU

A significant number of net jobs are created in the power sector: 2.8 million by 2050 in construction, operation, and maintenance jobs. If components for renewables are partially manufactured in the region, this figure could increase to 3.7 million net jobs by the same year.

A renewable energy scenario, unlike the analyzed alternatives, provides a clear pathway to achieving emission reduction targets, as established in the countries' NDCs, and fulfilling the region's climate change mitigation ambitions.

Investments in natural gas may currently be competitive in some countries, but with an increasing risk of establishing stranded assets which would hamper the options to meet or increase emission reduction ambitions in the future. In addition, half of LAC's natural gas reserves are at risk of becoming stranded assets, leading to billions in losses (IDB, 2021). No short or long-term economic, social or climate benefits were found by this report that would justify the investments that governments are currently making on natural gas instead of renewables.

Is natural gas a good investment for Latin America and the Caribbean? No, it is not.

This report shows that natural gas is neither a cheap nor a low-emission alternative. Instead, the expansion of renewable energy will bring the economic recovery the region needs in the midst of the COVID-19 pandemic, saving US$ 1,250 billion and creating three million jobs by 2050, among other greater benefits.

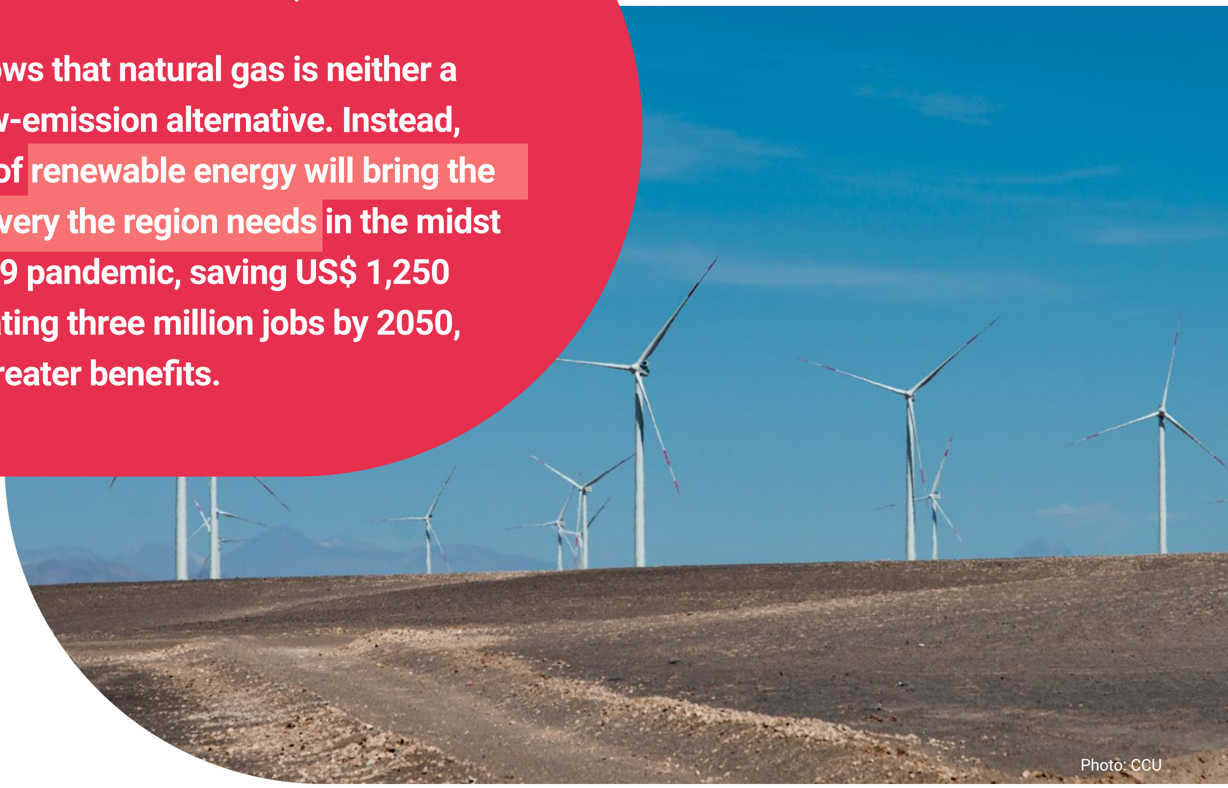


Photo: CCU

1. Introduction

The effects of climate change are already perceivable in Latin America and the Caribbean (LAC), with consequences ranging from increased droughts to floods and hurricanes. Climate change has impacted the health of the region's ecosystems and the livelihoods of millions of people, who are also affected by high levels of poverty and inequality across the region (WMO, 2021; IPCC, 2021). The mitigation of greenhouse gas (GHG) emissions is a critical component of combating such effects, but current efforts are not yet fully in line with the Paris Agreement's goal of limiting the global average temperature increase to "well below 2ºC" or ideally 1.5ºC (UNEP, 2019; United Nations, 2015).

Achieving these targets requires net-zero carbon dioxide (CO_2) emissions between 2050 and 2070 (or earlier) and probably net-negative emissions after that (IDB & DDP-LAC, 2019). Similarly, significant targets apply to all GHG emissions: methane (CH_4) and black carbon must fall by half or more by 2050 and nitrous oxide (N_2O) by at least a third (IPCC, 2018, 2021; Waisman et al., 2019). Net-zero emissions means that remaining anthropogenic CO_2 emissions are balanced globally by CO_2 removals through activities such as afforestation or carbon capture (IPCC, 2021). The Intergovernmental Panel on Climate Change (IPCC) indicates that a systemic transformation is needed in the energy, transportation, agriculture, and land-use sectors (IPCC, 2021) to reach net-zero CO_2 emissions. Hence, Latin America and the Caribbean must identify the most appropriate transformative changes needed to reduce its emissions by 2050 while increasing resilience and maximizing the net benefits for its society.

The effects of climate change are already perceivable in Latin America and the Caribbean (LAC), with consequences ranging from increased droughts to floods and hurricanes.

Photo: CCU

The energy sector (including electricity, industry, and transport) accounts for 35 per cent of GHG emissions in Latin America (UNEP, 2019). Therefore, a transformation towards zero and low carbon technologies of the energy sector is crucial to enable decarbonization. Beyond that, this transformation will unlock the benefits of more sustainable energy and transport systems, such as economy diversification, health improvements, operational cost reductions, job creation, reduced congestion, and a lower number of accidents, among others.

A recent study estimates that the committed emissions of the power sector in Latin America (i.e., expected carbon emissions if existing energy infrastructure, such as coal-fired power plants, runs for its forecasted lifetime) at 6.9 $GtCO_2$ (González-Mahecha et al., 2019). This estimate is higher than the average emissions included in scenarios reviewed by the IPCC for the LAC power sector, which are consistent with limiting temperature increases to 2°C or 1.5°C CO_2 (approximately 6.5 $GtCO_2$ and 5.4 $GtCO_2$ respectively). If countries in the region build all of their planned or announced fossil fuel power plants then the committed emissions will increase by 6.7 $GtCO_2$, totaling 13.6 $GtCO_2$ - double the current number of committed emissions.

Remarkably, natural gas has found its place at the heart of the debate around the power sector's transition. Multiple alternatives have been discussed regarding the role that this fossil fuel could play in the decarbonization process. The region holds less than 5 per cent of global natural gas reserves, and accounts for 7 per cent of current production (OLADE, 2019).

Mexico, Brazil, and Argentina are significantly increasing their fossil fuel investment and exploitation. Brazil's Energy Plan foresees an increase in oil and gas production of 60 per cent and 110 per cent, respectively, between 2020 and 2030. In Mexico, substantive tax credits and other beneficial fiscal schemes have been launched to promote oil and gas, which would increase production 66 per cent and 89 per cent respectively by 2032. (UNEP, 2021). In Colombia, Ecuador, Bolivia, Venezuela, Trinidad and Tobago, and, more recently, Guyana, fossil fuels are a primary export. Multiple natural gas infrastructure projects are planned or in construction in Argentina, Brazil, Colombia, El Salvador, Jamaica, Mexico, Nicaragua, Panama, and Peru.

This happens in the midst of a global disruption of the energy market because of Russia's invasion of Ukraine. Russia is one of the leading exporters of natural gas and oil. Prices of both fossil fuels have peaked because of the conflict.

The International Energy Agency has argued that the exploitation and development of new oil and gas fields must stop now in order to meet the Paris Agreement targets (IEA, 2021). However, fossil fuel infrastructure, both existing and planned, will release enough emissions over its lifetime to exceed 1.5ºC of warming, one of the goals included in the Paris Agreement on climate change. To meet these targets, overall greenhouse gas emissions would have to be reduced 43 per cent by 2030. Specifically, methane emissions (the second biggest contributor to global warming after carbon dioxide) would have to be reduced by 33 per cent by 2030. (IPCC, 2022)

Natural gas already represents 52 per cent and 63 per cent of committed emissions from existing and planned power plants in the region, respectively

Natural gas already represents 52 per cent and 63 per cent of committed emissions from existing and planned power plants in the region, respectively (González-Mahecha et al., 2019). Nevertheless, this fossil fuel has been presented as an abundant resource that can support a growing electrical production while more polluting sources like coal and diesel are phased out. It has been estimated that replacing planned coal plants with natural gas plants would reduce committed emissions by around 10 per cent (González-Mahecha et al., 2019). Even though it has been proven that these transformations by themselves have the potential to still lead to substantial committed emissions (UNEP, 2019, IDB & DDPLAC, 2019), natural gas has been presented as an effective transition alternative, with the potential to reduce its committed emissions in the future.

On the other hand, some argue that to avoid carbon lock-in, governments need to act early on emission reductions and focus on options consistent with a rapid transition to net-zero emissions, such as zero-carbon electricity. Switching from fossil fuels to renewable energy sources will help countries to lower their CO_2 emissions and achieve net-zero targets. It will also make use of the vast renewable energy potential available in the region to sustain its path towards higher economic development (IDB, 2014a, 2014b; IRENA, 2016). Renewable energy sources are currently cheaper than any other energy source. Their deployment in 2020 was the fastest, beating prior years, despite the COVID-19 pandemic (IEA, 2021).

There are multiple benefits associated with a net-zero economy, for instance, the International Renewable Energy Agency (IRENA, 2019a) found that a large-scale shift to electricity from renewable energy would boost gross domestic product (GDP) by 2.5 per cent and total employment by 0.2 per cent globally in 2050. The International Labor Organization (ILO, 2018) indicates that efforts to reduce emissions could result in the net creation of 24 million jobs globally by 2030. A study for the LAC region estimates that a green economy could lead to 15 million jobs by 2030 (Saget et al., 2020), while another study suggests 35 million jobs by 2050 (UNEP, 2019). This situation calls upon the need to understand the impacts of deploying pathways that consider natural gas in the power sector versus the effects of a renewable-based energy system.

Many countries in the LAC region are pushing towards decarbonization and are setting net-zero targets by or around 2050 (Bataille et al., 2020; Benavides et al., 2021; Groves et al., 2020; IDB & DDP-LAC, 2019; Quirós-Tortós et al., 2021). Many NDCs and LTS from Latin American countries also make a reference to expanding renewable energy, with some including specific targets. This is the case of The Bahamas (30 per cent by 2030), Guyana (100 per cent by 2025, conditional to finance), Haiti (47 per cent by 2030), Costa Rica (100 per cent by 2030), El Salvador (50 per cent by 2030), Nicaragua (60 per cent by 2030), Panama (77 per cent by 2030), Saint Lucia (7 per cent by 2030), and Suriname (35 per cent by 2030), for example.

The RELAC initiative, a platform created at the end of 2019 within the framework of the United Nations Climate Action Summit (UNCAS), has the objective of reaching at least 70 per cent of renewable energy participation in the region's electricity matrix by 2030. This is the first time a group of countries in the region has agreed to promote renewables with a concrete goal, a monitoring scheme, and an operating structure designed to support countries in the process. So far, 15 countries are participating, including Bolivia, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama, Paraguay, Peru, and Uruguay.

This report sheds light on the implications of moving forward with the usage of natural gas in the region's power sector and contrasts those effects with a scenario that deploys renewables instead. Both scenarios are contrasted against a current trend's scenario. Consequently, three scenarios are built. Other sectors such as natural gas for cooking are also relevant in LAC for their extensive use in several countries, but weren't considered for the analysis.

In November 2021, Energy Ministers grouped in OLADE (Latin American Energy Organization composed of 27 member countries in LAC) signed a declaration considering natural gas a "viable, affordable and reliable option to accelerate decarbonization" (OLADE, 2021).

Photo: CCU

The first scenario, **Business-As-Usual (BAU)**, is based on current and past trends and assumes that the power sector continues to supply electricity in the way that it has done historically. The second scenario, called **natural gas (NG)**, considers that future power plants will primarily use this fuel while existing diesel and coal power plants are retrofitted to use natural gas as their primary energy source. The third scenario, called **renewable energy (RE)**, considers that future power plants are based only on renewable energy sources. The scenarios are analyzed using an OSeMOSYS-inspired (Howells et al., 2011) accounting model (see Appendix A).

Three key metrics for each scenario are estimated: the emissions trajectory of the power sector, the total discounted costs, and the number of jobs created. Emissions trajectory includes combustion emissions and gas leaks. The costs include capital expenses, operational expenses (fixed and variable), and environmental costs. The analysis base year is 2019 to avoid COVID-19 distortion in demand and production of electricity. The calculation horizon extends to 2050, with costs discounted at a 10 per cent yearly rate. Two externalities resulting from fuel combustion are explored: local pollution and global warming (described in detail in Appendix B). The estimate of the number of jobs uses a simple approach based on multipliers per power plant type (Dominish et al., 2019). The analysis can answer these questions on a per-country basis, although the discussion is carried out at the regional level.

The model is calibrated using energy-related information from the Latin American Energy Organization (OLADE), the International Energy Agency (IEA), the IRENA, data from the World Bank Group (WBG), and National Renewable Energy Laboratory (NREL) databases, and country-based information when possible. The model is based on country-level energy balances. **It includes all sectoral energy needs and scenarios that can be studied with higher electrification in demand.** Power plant investments of all types of generation units per country are included. While the power grid (transmission and distribution) is not modeled, its expansion costs are mapped using estimation costs per type of power plant and power plant capacities. The analysis can help understand the emissions, costs, and effects on employment in LAC countries if they increasingly adopt natural gas as a decarbonization alternative versus a strategy based on renewable technologies.

For the purpose of this work, the region is structured into six subregions: Mexico, Central America, Caribbean, Andean, Brazil, and Southern Cone (Figure 1). Figure 1 shows the countries belonging to each subregion.


Photo: CCU

The report is structured into four additional chapters. Chapter 2 presents the energy status in LAC, describing the supply and consumption of energy in 2019 and detailing the production of electricity and installed capacity per energy carrier for the same year. Chapter 3 describes the status of natural gas: its supply chain, demands, as well as ongoing and future developments. Chapter 4 presents the assumptions considered in each scenario and the results of the analysis of this work in terms of their emissions, the different costs estimates, and the benefits of switching towards renewables by 2050 in terms of net economic benefits and jobs creation. Chapter 5 five looks specifically at three countries as case studies.

Figure 1. Geographic grouping of LAC countries considered in this work.

Source: Authors' own research.

2. Energy Status in Latin America and the Caribbean

2.1 Gross Domestic Product

For the last decade, LAC countries' economies have grown at a moderate pace. According to World Bank data, GDP in the region increased from US$5.354 trillion in 2010 to US$6.216 trillion in 2019 (World Bank Data, 2021). Although it dropped to US$5.824 trillion in 2020 due to the COVID-19 pandemic, a recent report from the Economic Commission for Latin America and the Caribbean (ECLAC) has estimated a 2021 GDP growth for the LAC region of 5.2 per cent. This figure reflects a rebound from the deep contraction of 6.8 per cent recorded in 2020 (ECLAC, 2021). The same study projects a GDP growth of 2.9 per cent in 2022.

Figure 2 shows the GDP of LAC countries in 2019 (OLADE, 2020) in 2010 constant US$. South American countries (Andean, Brazil, and Southern Cone) accounted for almost 70 per cent of the regional GDP, while Mexico represented about 23 per cent. Caribbean countries together made up for 3.9 per cent of the regional GDP, and Central American countries were 0.2 percentage points (pp) below (3.7 per cent).

From a country perspective, Brazil represented about 41 per cent of the region's GDP in 2019. Mexico was the second-largest economy with its 23 per cent share, followed by Argentina (7.6 per cent), Colombia (6.8 per cent), and Chile (5 per cent).

Photo: CCU

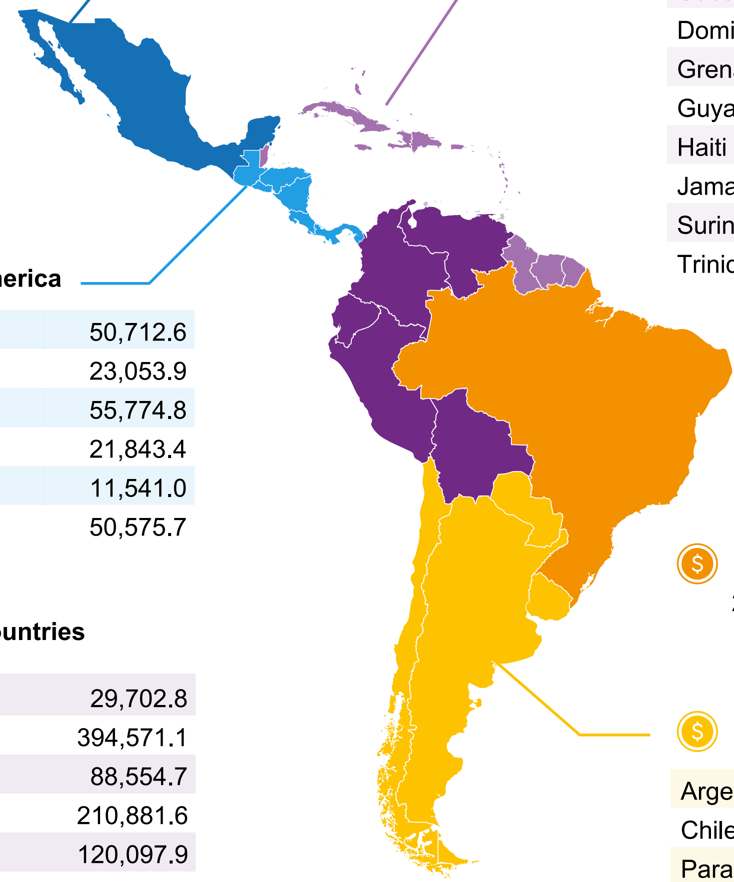
Figure 2. GDP in LAC countries in 2019.

GDP [Constant M US$ 2010]

Mexico
1,306,700.8

Caribbean

Barbados	4,621.0
Belize	1,583.3
Cuba	77,680.9
Dominican Republic	85,811.7
Grenada	1,045.0
Guyana	4,780.6
Haiti	8,170.2
Jamaica	14,377.7
Suriname	4,759.7
Trinidad & Tobago	21,048.8



Central America

Costa Rica	50,712.6
El Salvador	23,053.9
Guatemala	55,774.8
Honduras	21,843.4
Nicaragua	11,541.0
Panama	50,575.7

Brazil
2,347,202.3

Andean Countries

Bolivia	29,702.8
Colombia	394,571.1
Ecuador	88,554.7
Peru	210,881.6
Venezuela	120,097.9

Southern Cone

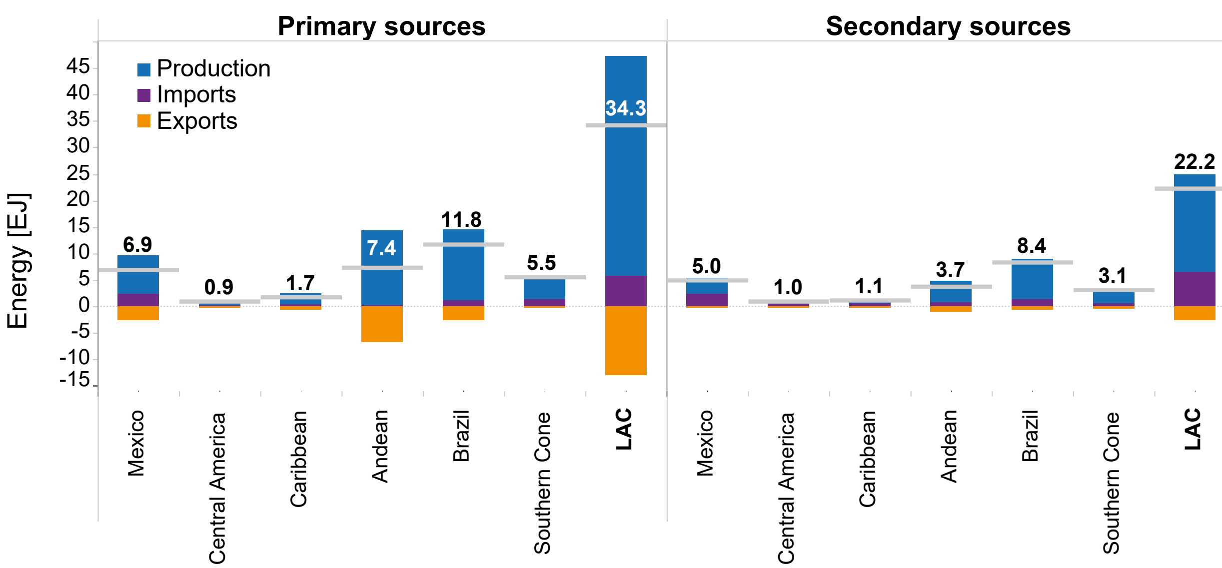
Argentina	440,769.2
Chile	286,013.8
Paraguay	37,260.6
Uruguay	50,532.1

Source: Authors' own research using (OLADE, 2020).

2.2 Energy Supply

The region's primary energy supply was 34.3 EJ in 2019 (Figure 3). Brazil accounted for 34 per cent, followed by Andean countries (22 per cent), Mexico (20 per cent), Southern Cone (16 per cent), Caribbean (5 per cent), while Central American countries had the lowest primary energy supply (3 per cent). The region's secondary energy supply was estimated at 22.2 EJ. Brazil accounted for the most prominent secondary energy supply in the region, followed by Mexico, Andean countries, Southern Cone, Caribbean, and Central American countries.

Figure 3. Energy supply in 2019 per source.

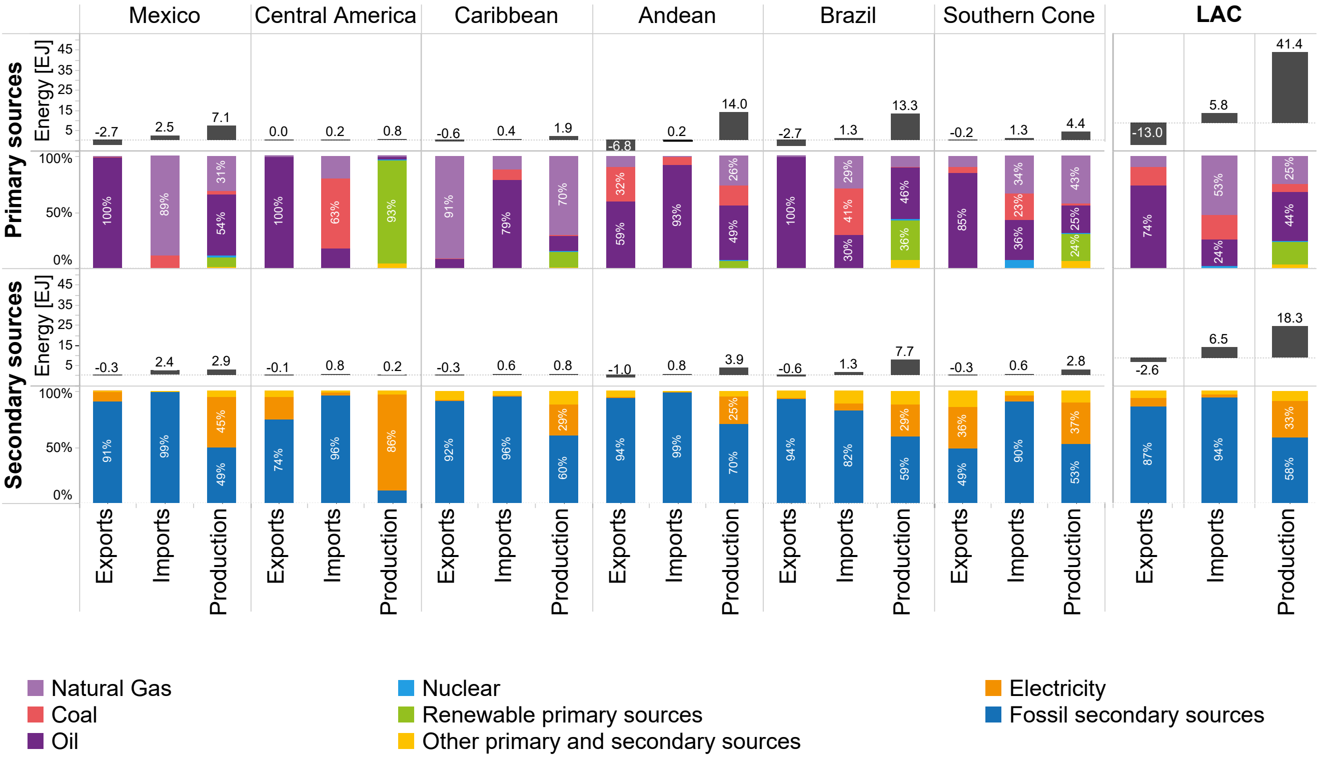


Source: Authors' own research using (OLADE, 2020).

Note: Horizontal lines represent the total energy supply (production plus imports minus exports).

In 2019, primary energy production in the region (Figure 4) was split between oil (44 per cent), natural gas (25 per cent), renewables (20 per cent), coal (7 per cent), and other primary energy sources (4 per cent). Secondary energy production was mainly divided between fossil fuel derivatives (58 per cent) and electricity (33 per cent). More than 50 per cent of primary imports in the region were from natural gas (53 per cent), followed by oil (24 per cent), coal (21 per cent), and a small fraction of nuclear (2 per cent). About 94 per cent of secondary energy imports were fossil fuel derivatives, 3 per cent from electricity, and 3 per cent from other secondary sources. Nearly three-quarters of the primary energy exports were oil, complemented by coal (17 per cent) and natural gas (9 per cent). About 87 per cent of secondary energy exports were fossil fuel derivatives, a small proportion of electricity (7 per cent), and other secondary energy sources (6 per cent).

Figure 4. Energy supply in 2019 per energy carrier.



Source: Authors' own research using (OLADE, 2020).

Primary energy production in the Andean subregion was the highest (14.1 EJ), followed by Brazil, Mexico, Southern Cone, Caribbean, and Central America (Figure 4). About half of the primary production in Andean countries came from oil, 26 per cent natural gas, and only 7 per cent renewables. In Brazil, primary energy production was divided between oil and renewables: 46 per cent and 36 per cent, respectively, complemented by 9 per cent natural gas and other primary sources (7 per cent). More than half of the primary energy production in Mexico was from oil, while 31 per cent was from natural gas and about 8 per cent from renewables. Southern Cone countries produced 4.4 EJ; 43 per cent natural gas, 25 per cent oil, 24 per cent renewables and 7 per cent from other primary sources. Caribbean countries had the highest share of primary energy production based on natural gas in the region at 72 per cent, while 14 per cent was from renewables and 12 per cent from oil. A total of 93 per cent of the primary energy production in Central America came from renewables, the highest share in the region, while only 3 per cent came from oil.

Secondary production in the region was primarily from fossil fuel derivatives and electricity. Brazil had the most significant secondary energy production (7.7 EJ): 59 per cent from fossil fuel derivatives and 29 per cent from electricity. Secondary production in Andean countries was equal to 4 EJ, and the split was 70 per cent and 25 per cent, respectively. Secondary production in Mexico (2.9 EJ), Southern Cone countries (2.8 EJ), and Caribbean countries (0.7 EJ) were divided almost half and half between the two energy carriers. Secondary energy production in Central America was mostly from electricity (86 per cent) with 11 per cent from fossil fuels.

Mexico had the largest primary energy import in the region (2.5 EJ), with 89 per cent composed of natural gas. Southern Cone and Brazil had the second largest primary energy imports in the region. At least 90 per cent of secondary energy imports in all countries (except Brazil with 82 per cent) were associated with fossil fuels.

Exports vary significantly across subregions. Oil exports covered the vast majority in Mexico, Brazil, Southern Cone, and Andean countries. Primary energy exports in the Caribbean countries were mainly from natural gas (93 per cent). Exports of fossil fuel derivatives as secondary sources were predominant across the region (except for Southern Cone countries), exporting a bit more than a third of electricity.

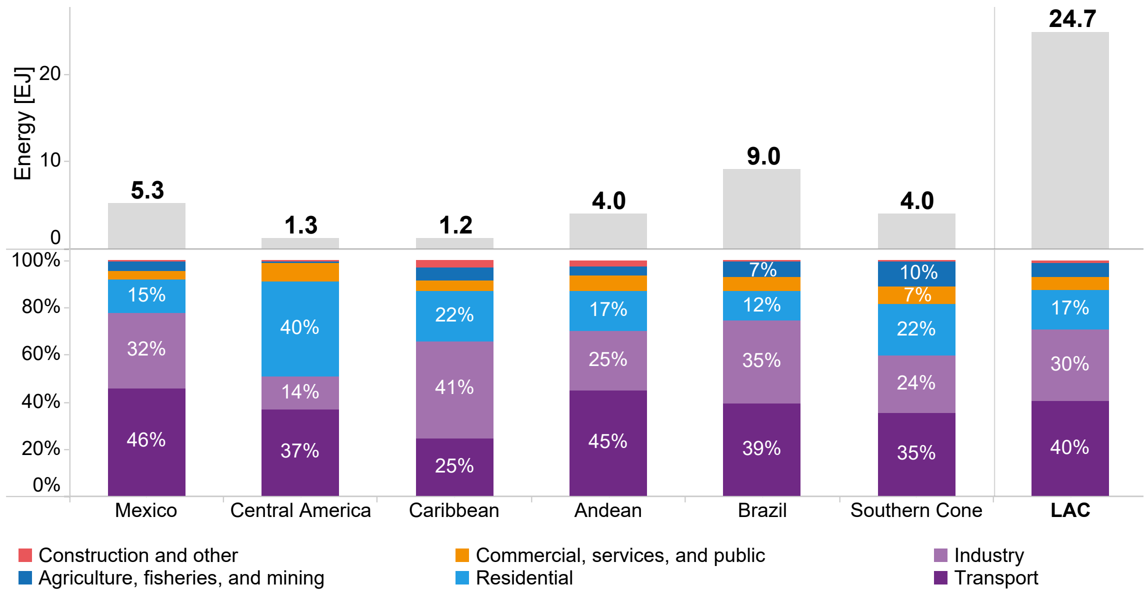
2.3 Energy Consumption

In 2019, total energy consumption in the region was 20.7 EJ (Figure 5). Brazil had the most significant consumption (9 EJ), followed by Mexico (5.3 EJ), Andean (4.1 EJ), Southern Cone (4.0 EJ), Central American (1.3 EJ), and Caribbean countries (1.1 EJ).

Most of the energy consumed in the region was used in transportation (39 per cent), industry (31 per cent), and households (17 per cent). Mexico and Andean countries had the largest share in the transport sector. Most of the energy consumed in Caribbean countries was used in industry, primarily driven by industrial activities in Trinidad & Tobago. Similarly, most of the energy consumed in Central America was used in the residential sector and only 14 per cent in the industrial sector. As a share of its total, Brazil had the lowest consumption in the residential sector. Similarly, Southern Cone countries consumed most of their share in agriculture, fisheries, and mining, followed by Brazil.


Photo: CCU

Figure 5. Energy consumption in 2019 per sector.



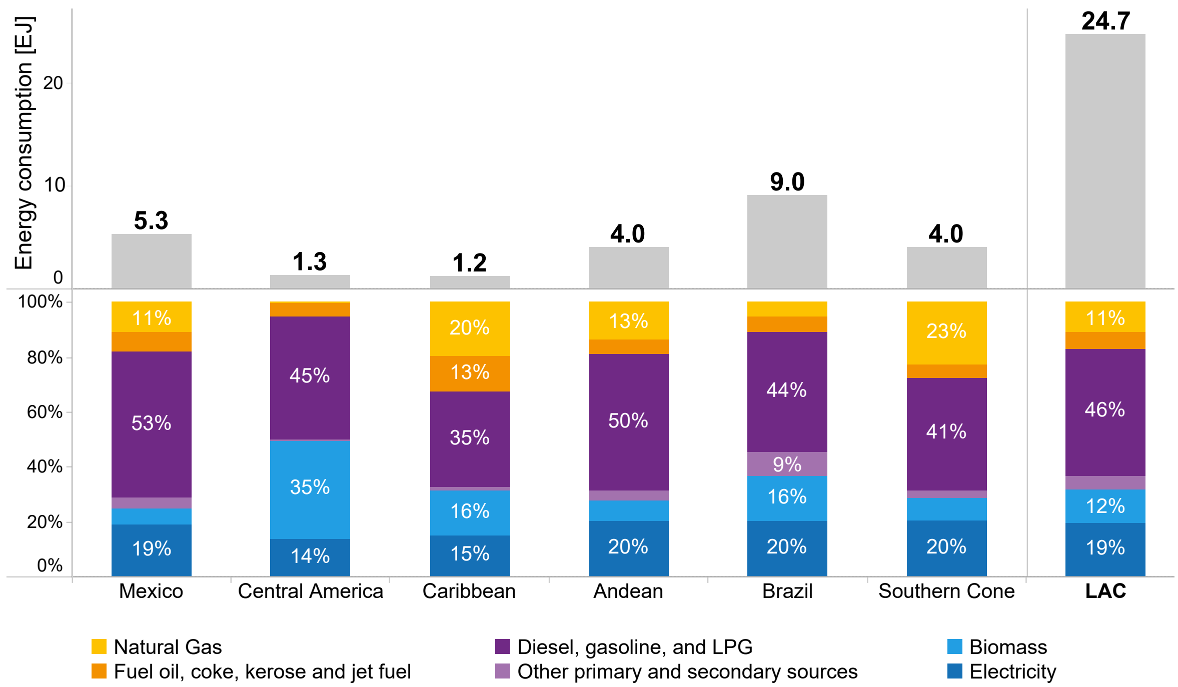
Source: Authors' own research using (OLADE, 2020).

From the perspective of the fuels used in that year (Figure 6), 45 per cent of the total energy consumption in the region came from diesel, gasoline, and liquified petroleum gas (LPG). A fifth was from electricity; 13 per cent from biomass; a tenth from natural gas; 6 per cent from fuel oil, coke, kerosene, and jet fuel; and 5 per cent from other sources. At least a third of the total consumption within each subregion was from diesel, gasoline, and LPG, with Mexico presenting the largest share at 53 per cent. Central America had the highest percentage of biomass consumption. Countries in the Southern Cone and the Caribbean had the highest share of natural gas in their energy consumption with 23 per cent, and 21 per cent, respectively.

Figure 7 disaggregates the energy consumption of 2019 per subregion, energy carrier, and for the three main sectors. The transport sector in all subregions except the Caribbean consumed the most energy in 2019: 9.9 EJ in total. Consumption in the industry was the second largest in all subregions except in Central America. Regardless of the subregion, energy consumption in the transport sector was met primarily with fossil fuel derivatives (including those carriers used in road, rail, air, and maritime transport).

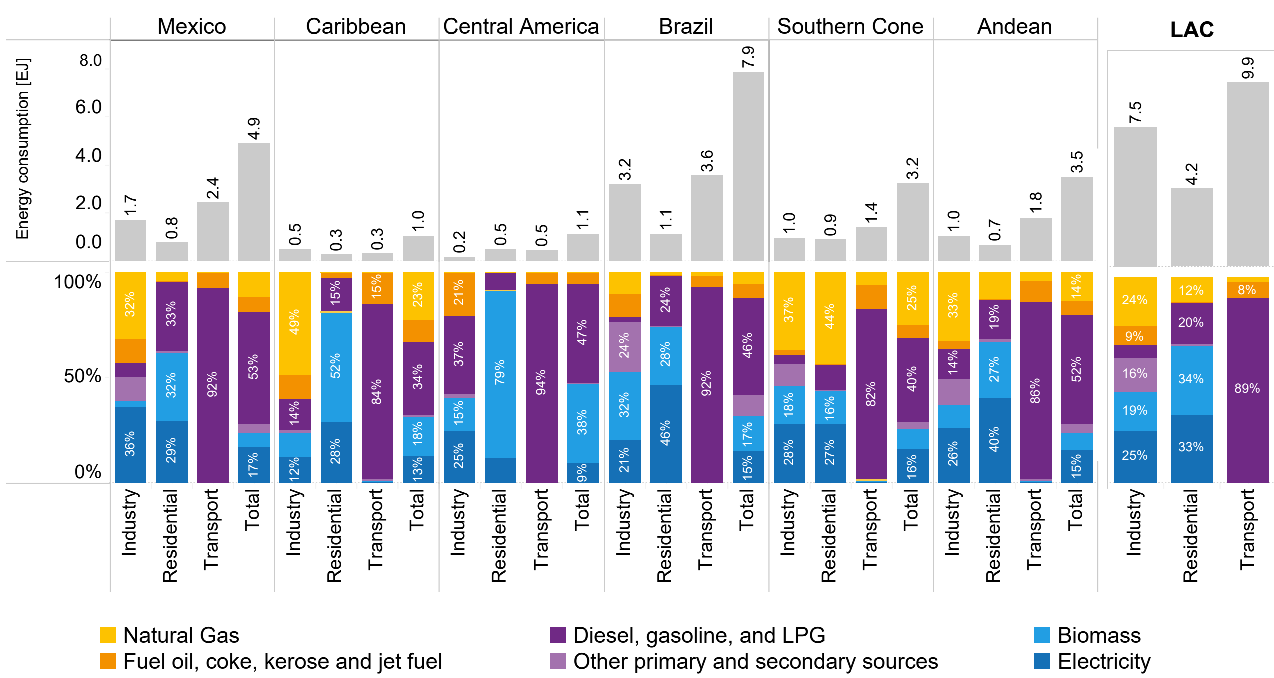
Brazil, Andean, and Southern Cone countries consumed a small fraction of natural gas for transportation (a share of 2 per cent, 4 per cent, and 6 per cent of their consumption, respectively). Energy consumption in the industrial and residential sectors was more diverse. Electricity (25 per cent), natural gas (24 per cent), biomass (19 per cent), and fossil fuel derivatives (16 per cent) were primarily used in the region to meet the demand of 7.5 EJ from the industrial sector. Electricity and biomass were equally used in 2019 to cover two-thirds of the regional energy consumption in the residential sector. LPG (20 per cent) and natural gas (12 per cent) complemented the regional energy consumption in this sector in 2019.

Figure 6. Energy consumption in 2019 per energy carrier.



Source: Authors' own research using (OLADE, 2020).

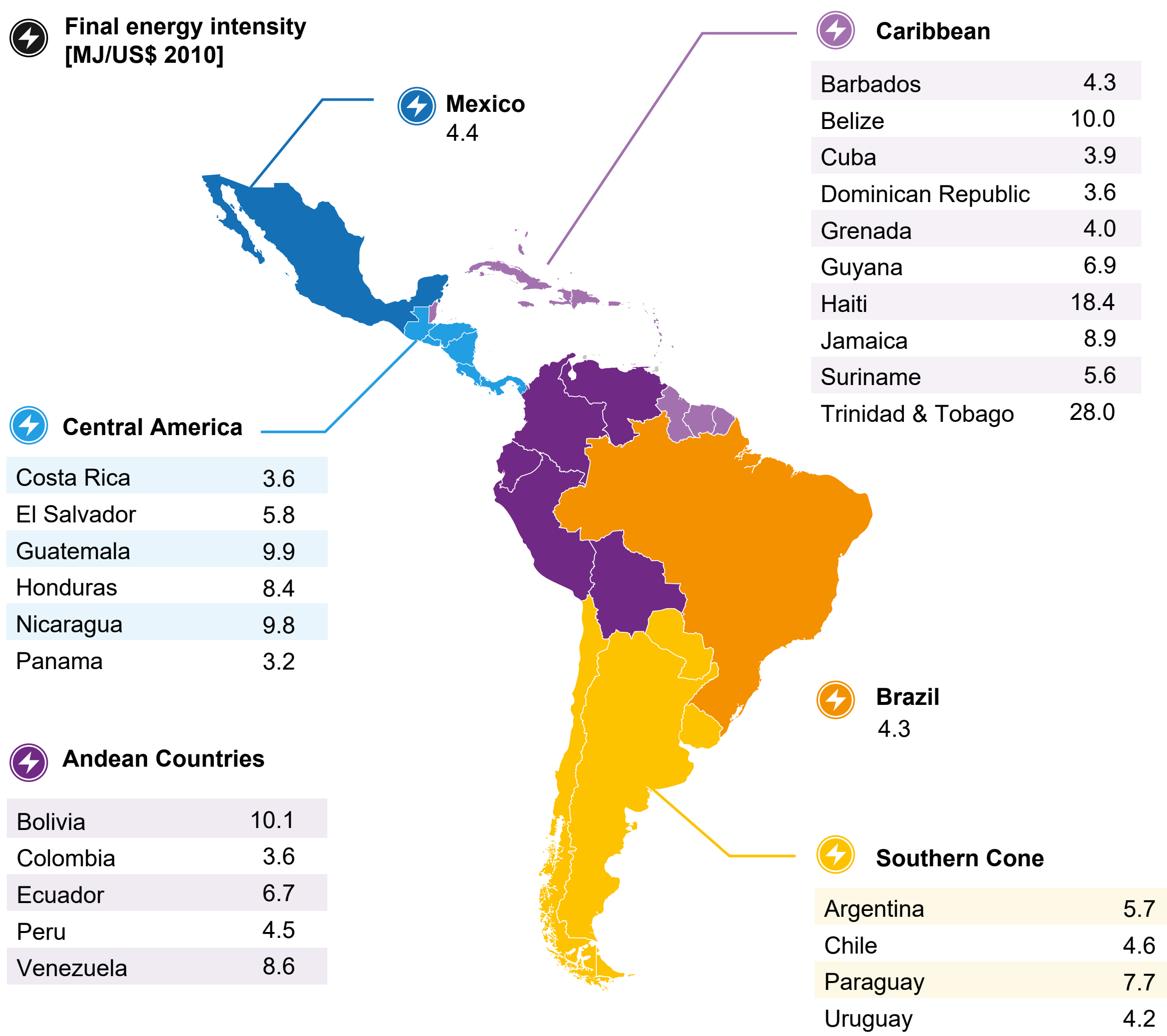
Figure 7. Energy consumption in 2019 in technology by energy carrier.



Source: Authors' own research using (OLADE, 2020).

The energy intensity of each country in the region in 2019 is shown in Figure 8. Panama had the lowest energy intensity in the region, while Trinidad & Tobago had the highest. The average energy intensity of the region was 7.4 MJ/US$ in 2010. From a subregion perspective, Brazil had the lowest value, followed by Mexico, Southern Cone (5.5 MJ/US$ of 2010), Andean (6.7 MJ/US$ of 2010), Central America (6.8 MJ/US$ of 2010), and the Caribbean (9.3 MJ/US$ of 2010).

Figure 8. Energy intensity in 2019 in LAC countries.



Source: Authors' own research using (OLADE, 2020).


Photo: CCU

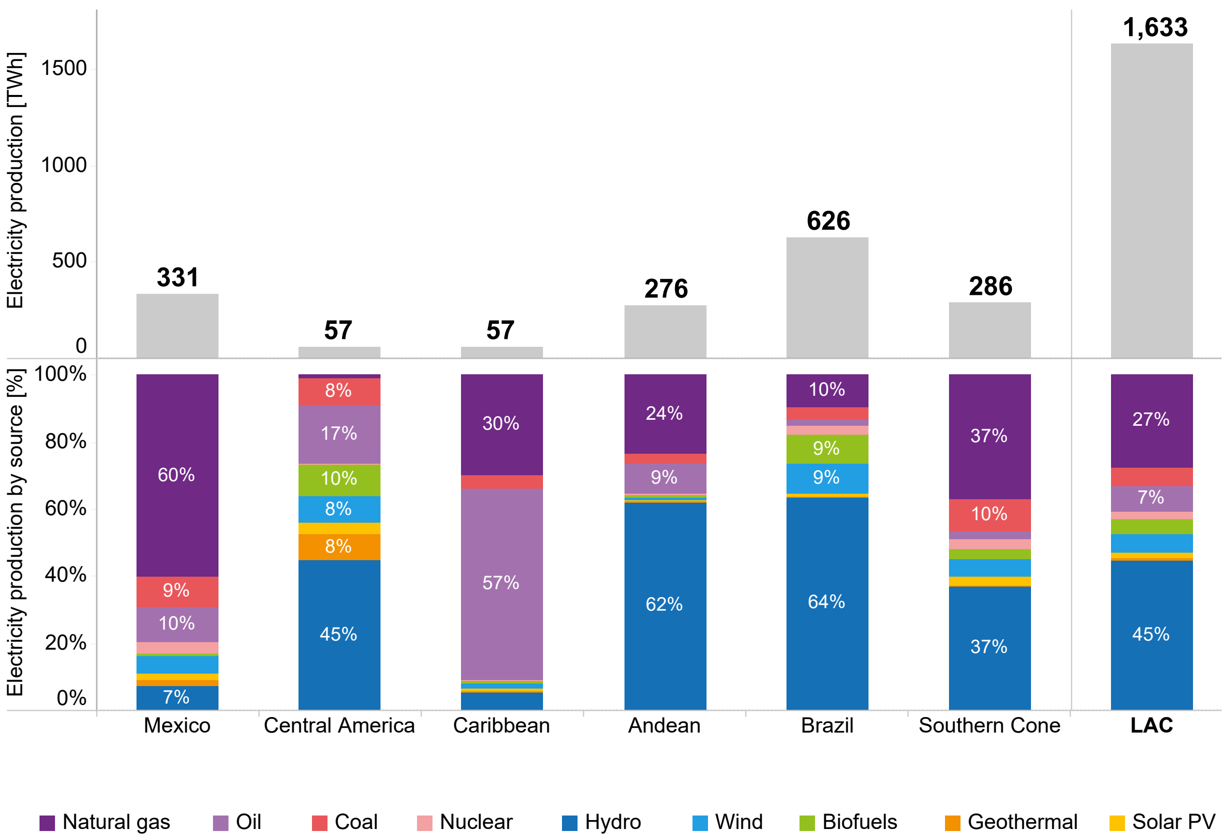
2.4 Electricity Production

Currently, most of the installed capacity in the region is in hydropower. However, since 2012 the installed capacity for non-conventional renewables has doubled its participation in the regional matrix. Some countries in the region have reached or are in the process of attaining 100 per cent renewable power and more are aligning actions and policies toward this goal. The increase in participation of renewables has clipped the carbon intensity of the sector, from an already low starting point of 285 tCO_2 /GWh in 2015 to 243 tCO_2 /GWh in 2018, making the region a world leader in low-carbon power generation. The decarbonization of the energy matrix is now being challenged by the expansion of natural gas, a fossil fuel that generates greenhouse gas emissions.

In 2019, Electricity production in the region was primarily based on hydropower and natural gas (Figure 9). From the 1,633 TWh produced, 45 per cent was from hydro and 27 per cent from natural gas. Oil accounted for 7 per cent, followed by coal 6 per cent, wind 6 per cent and biofuels 5 per cent. The remaining 4 per cent was based on nuclear, solar, and geothermal technologies. Mexico had the second smallest production from renewables (17 per cent) and the most significant production from natural gas (60 per cent) in the region. Central American countries had the second-largest share of renewables: a total of 73 per cent, 45 per cent from hydro, 10 per cent biofuels, 8 per cent wind, 8 per cent geothermal, and 3 per cent solar.

Central America had the region's largest share of geothermal and solar as well as the lowest production from natural gas. Electricity production in Caribbean countries was primarily based on non-renewable sources. Over 90 per cent of the production came from natural gas, coal, and oil, with oil accounting for more than half of its production. Andean countries produced 62 per cent of their electricity from hydro power plants, almost a quarter from natural gas and the rest from oil, coal, and other sources. In Brazil, about two-thirds of electricity was produced with hydro power plants, 10 per cent with natural gas, 9 per cent with wind, 9 per cent with biofuels and the rest in small proportions with solar, nuclear, oil, and coal. Three-quarters of the electricity in Southern Cone countries were equally produced with hydro and natural gas. This generation was complemented with production from coal and small participation of other sources such as wind, solar, nuclear, oil, and biofuels.

Figure 9. Electricity production in 2019 in LAC countries.



Source: IEA databases.

2.5 Installed Capacity

By December 2019, the installed capacity in the region was equivalent to 438 GW (Figure 10). Most installed power plants were based on hydro (45 per cent) and natural gas (26 per cent). Diesel or oil power plants' installed capacity reached 8 per cent in 2019. This figure was around 7 per cent of onshore wind, 6 per cent coal, 5 per cent biomass, 3 per cent solar and 1 per cent nuclear power plants. More than half of the installed capacity in Mexico (79.6 GW) was based on natural gas, while only a third was based on renewables. Coal (8 per cent) and oil – diesel or fuel oil – (9 per cent) power plants complemented Mexico's installed capacity. Two-thirds of the installed capacity in Central America was based on renewables, the majority being from hydro power plants complemented by biomass, solar and wind farms.

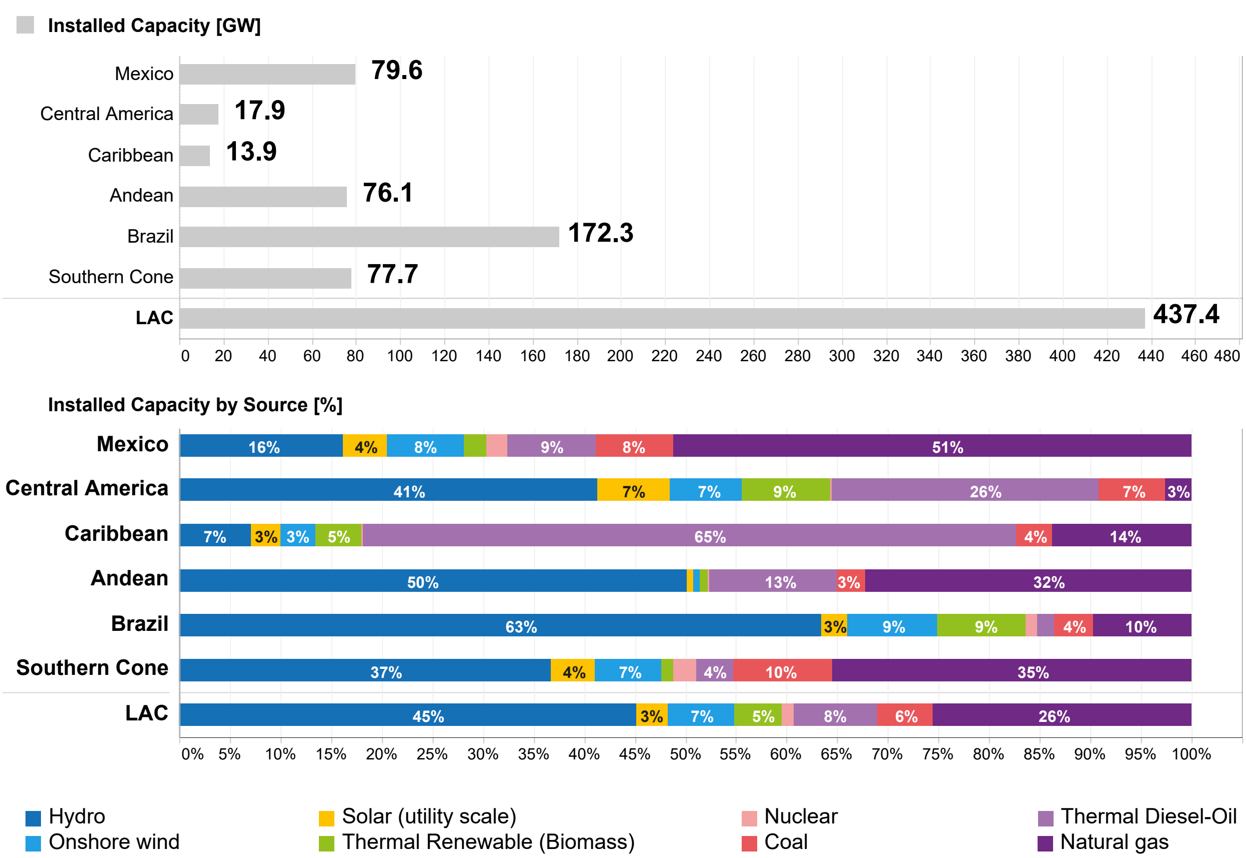
Caribbean countries had the least renewable installed capacity with only 17 per cent. Almost two-thirds of installed capacity was based on oil power plants, 15 per cent natural gas and 4 per cent coal power plants.

Andean countries nearly split the installed capacity between renewables (52 per cent) and non-renewables (48 per cent).

Hydro power plants in Brazil represented 63 per cent of the installed capacity. When complemented by solar, wind, and biomass power plants, the installed capacity of renewables in the country reached 84 per cent. Non-renewable power plants accounted for 16 per cent of the country's installed capacity in 2019 with the majority from natural gas at 10 per cent.

The installed capacity in Southern Cone countries (77.7 GW) was split between hydro power plants (37 per cent) and natural gas power plants (35 per cent). Coal, thermal, and nuclear power plants represented 16 per cent of the installed capacity. Solar, wind, and biomass power plants accounted for 12 per cent of the installed capacity in the subregion.

Figure 10. Installed capacity in 2019 in LAC countries.



Source: Authors' own research using (OLADE, 2020).

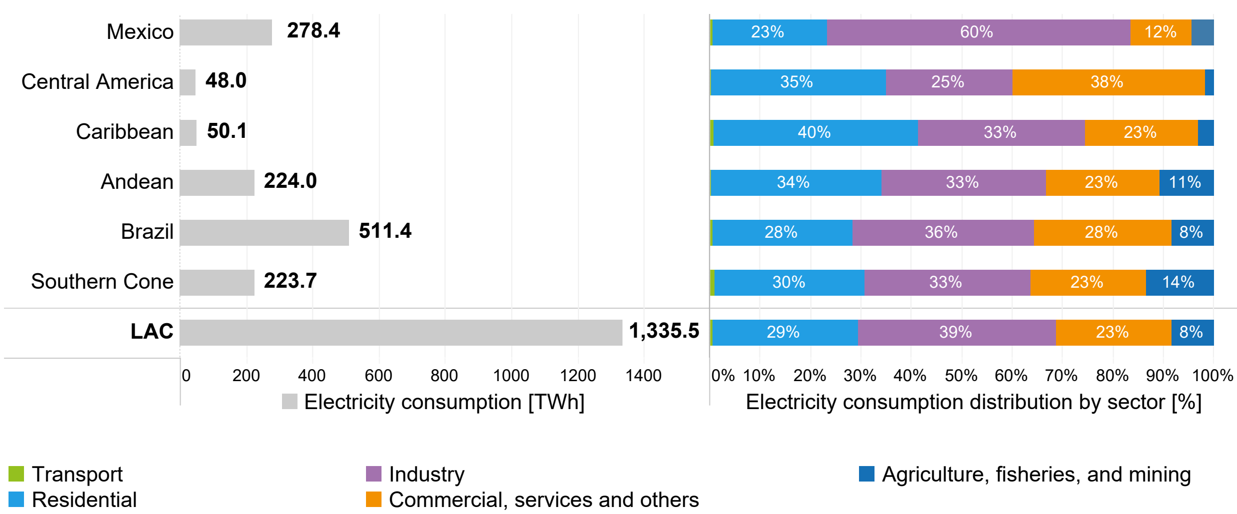
2.6 Electricity Demand Per Sector

Demand for electricity is growing at a moderate pace across the region, driven by demographics, gross domestic product (GDP) increases, improved access, and increases in the overall standard of living. However, it has been relatively flat since 2016. Electricity is used in various degrees in the residential and commercial sectors in the region, in part, addressing a growing demand for space cooling, but mainly for cooking, refrigeration, lighting, and water heating, and in the industrial sector for heating, cooling and pumping, but only very marginally in the transport and agriculture sectors. The electricity used in transport did increase by a factor of 10 between 2012 and 2018, reflecting growing deployment of subway, light-duty, and passenger electric vehicles.

In 2019, the electricity demand in the region equaled 1,336 TWh (Figure 11). The industry sector was the largest consumer (39 per cent), followed by the residential sector (29 per cent), then commercial, services, and others (23 per cent), and agriculture, fisheries, and mining (8 per cent).

In Mexico, more than half of the electricity was consumed in the industry and almost a quarter in the residential sector. In Central America, commercial, services, and others consumed about 38 per cent of the electricity of the subregion, followed by the residential sector with 35 per cent, and industry with a quarter of the total consumption. In Caribbean countries, the majority (41 per cent) was used in the residential sector, a third was consumed in the industrial sector. Only 22 per cent in commercial, services, and others. In Andean, Brazil, and Southern Cone countries, electricity consumption was almost equally divided between the residential, industrial, and commercial, public services, and others.

Figure 11. Electricity consumption in 2019 in LAC countries per sector.



Source: Authors' own research using (OLADE, 2020).

3. Status of Natural Gas in LAC

3.1 The Natural Gas Supply Chain

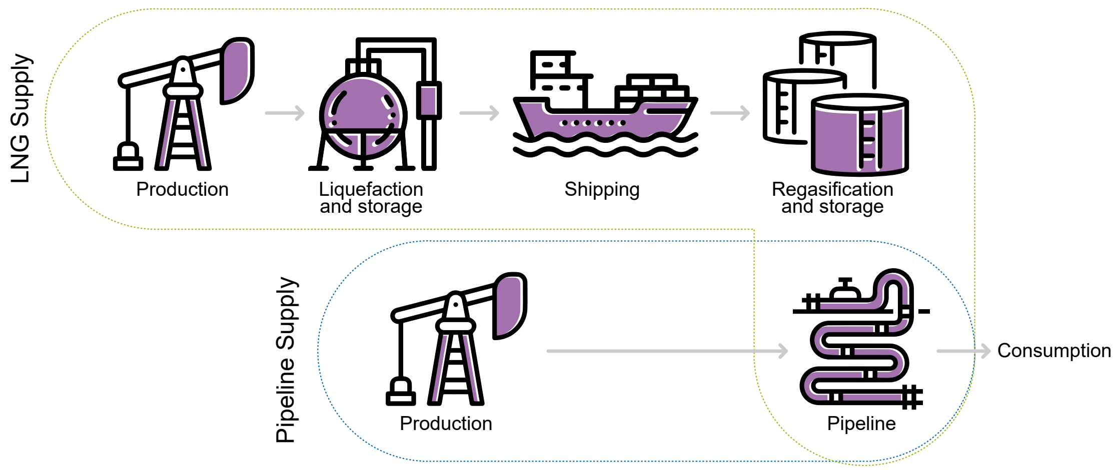
The region used natural gas to supply 25 per cent of primary energy consumption in 2019. The main consumers were Argentina, Brazil, Bolivia, Colombia, Mexico, Trinidad and Tobago, and Venezuela. Venezuela is estimated to have around 70 per cent of the proven reserves in the region. Argentina holds a sizable worldwide shale reserve called Vaca Muerta. In 2019, Trinidad and Tobago had the largest share of natural gas in primary energy production (91 per cent) and the most significant consumption share (76 per cent). In the power sector in 2019, Mexico, Argentina, Brazil, and Trinidad and Tobago used natural gas to produce 200 TWh, 91 TWh, 60 TWh, and 9.2 TWh; about 60 per cent, 65 per cent, 10 per cent, and 100 per cent of their total electricity production, respectively.

Almost all subregions plan to expand their generation capacity in the future by including natural gas (to a larger extent), diesel fuel, or carbon in their energy matrix. Under BAU, this report argues that natural gas would maintain its current 26 per cent share of the energy matrix, while under a natural gas expansion the fossil fuel would reach 38 per cent, almost overcoming hydro. Apart from the increase in GHG emissions this will create a technology lock-in for many years ahead and likely put the region in a difficult scenario to comply with the Paris Agreement goals.

Photo: CCU

Supply of natural gas in the region is done through Liquefied Natural Gas (LNG) and pipelines. The former includes the liquefaction and storage of natural gas in the exporter country, followed by its shipping to the regasification plant, generally in the importer country. The supply chain then continues to pipelines. Pipelines are also used as a simpler direct procedure to import natural gas between neighboring continental countries. Figure 12 presents these two mechanisms.

Figure 12. Supply chain of natural gas for electricity production.



Source: Authors' own research.

The process of bringing LNG to countries for final use in electricity generation requires the following steps:

1. Acquire required gas volumes through a purchase agreement.
2. Transport the gas from the production facility to an export facility.
3. Liquefy the gas to make shipping easier by bringing down the volume.
4. Transport the LNG to the country.
5. Store the LNG – done in vacuum-insulated tanks or floating storage units.
6. Regasify the LNG at an import facility.
7. Transport the gas to the generation facility.
8. Burn the gas for electricity.

As a reference, Table 1 breaks down the cost of each key stage, including shipment and pipeline transportation to countries. Liquefaction, the gas itself, and shipping account for three-quarters of the whole process. The costs vary per country; thus, this table presents upper and lower limits for each expense.

Table 1. Cost structure for potential LNG import to countries.

	Index Price of Natural Gas	Pipeline Transportation	Liquefaction	Shipping	Storage and Vaporization	Land Transport	Generator* Retrofit
$/MMBTU	$ 3,77	$ 0,38	$ 3,85	$ 2,00	$ 1,65	$ 0,38	$ 0,83
upside error	$ 1,50	$ 0,05	$ 0,40	$ 1,00	$ 1,00	$ 0,20	$ 0,40
downside error	$ 1,00	$ 0,05	$ 0,40	$ 1,00	$ 0,50	$ 0,20	$ 0,40

* Retrofit applicable where needed

Source: Summary of natural gas projects from Rocky Mountain Institute.

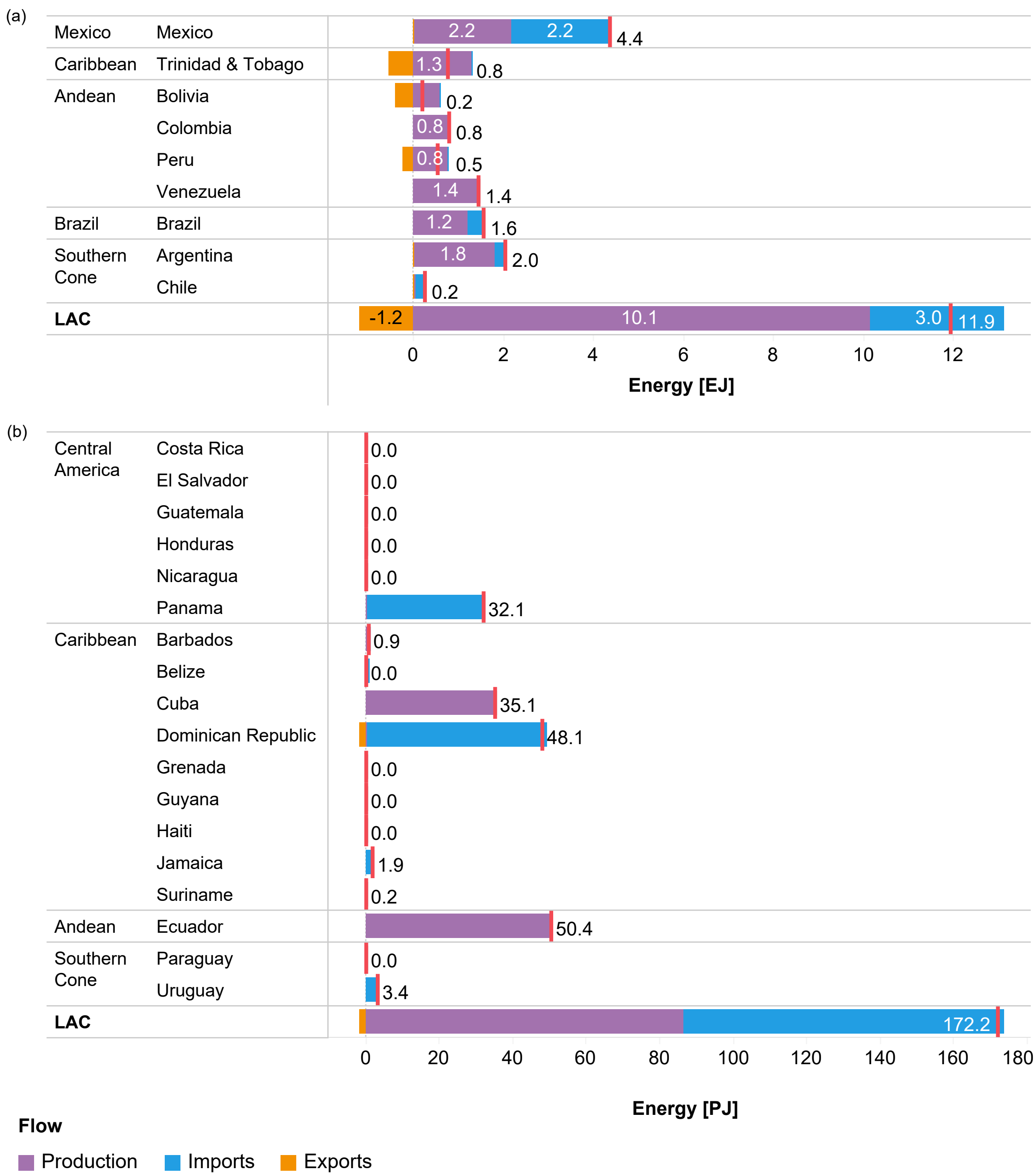
Note: This cost structure was originally provided for Caribbean islands.

3.2 Supply and Demand

Figure 13 shows the natural gas supply in LAC by country, measured as net local supply (production plus imports minus exports). Figure 13(a) shows the countries with the largest net local supply, which equals the natural gas demand (ignoring inventories and unused quantities). Mexico is the largest natural gas consumer (almost 31 per cent of the total LAC demand). Trinidad and Tobago is the largest exporter, followed by Bolivia and Peru. Figure 13(b) shows the countries with the least demand: 10 countries have zero natural gas demand (mainly in Central America and the Caribbean).

Photo: CCU

Figure 13. Natural gas supply by country in 2019. a) for countries with over 100 PJ of net local supply, b) for countries with under 100 PJ of net local supply.



Source: Authors' own research using (OLADE, 2020).

Table 2 shows the demand for natural gas in Latin America and the Caribbean: 13.4 per cent is exported, 56.1 per cent is transformed into other forms of energy, and 30.5 per cent is directly consumed.

Each region uses natural gas differently. Mexico mainly uses it for electricity production in power plants with 45 per cent, followed by self-producers with 20.2 per cent (i.e., energy producers for their consumption or other consumer but is not their core business) and industry with 19.7 per cent of demand participation (García et al., 2017).

Central America has a minimal natural gas demand. Only Panama uses it for electricity production. In contrast, Trinidad & Tobago in the Caribbean is a significant natural gas user: half of its natural gas production is used in the country and the remainder is exported. Andean countries export almost as much natural gas as they use for power generation. Despite being the largest energy consumer in the region, Brazil has a relatively low natural gas demand (13.5 per cent), which is mainly used for power generation and industry. The Southern Cone exports little natural gas, almost 40 per cent of it is used for power generation and stands out with 20.5 per cent of consumption for the residential sector (the highest among regions, related to its colder climate and heating requirements).

Table 2. Natural gas energy demand in 2019.

Sector			Mexico	Central America	Caribbean	Andean	Brazil	Southern Cone	LAC
Disaggregation [per cent]		Exports	0.3	0.0	51.8	31.6	0.0	0.9	13.4
	Transformation	Power plants	45.0	100.0	15.2	30.6	32.8	33.8	34.5
		Refineries	0.0	0.0	2.6	0.0	0.0	0.0	0.3
		Gas centers	13.1	0.0	6.1	7.2	9.6	10.4	9.9
		Other centers	0.0	0.0	1.4	0.0	9.4	1.2	1.7
		Self-producers	20.2	0.0	0.1	3.7	10.3	5.7	9.7
	Consumption	Agriculture, fisheries, and mining	0.0	0.0	0.0	0.6	1.1	0.7	0.4
		Commercial, services, public, construction and other	0.4	0.0	0.0	1.5	0.5	3.3	1.2
		Industry	19.7	0.0	22.7	16.6	27.9	18.9	20.2
		Residential	1.2	0.0	0.0	4.3	1.4	20.5	5.9
		Transport	0.1	0.0	0.1	3.8	7.0	4.6	2.8
Total [per cent]			100	100	100	100	100	100	100
Total demand [PJ]			2,724	32	1,028	2,004	1,195	1,872	8,855

Source: Authors' own research using (OLADE, 2020).

Table 3 shows LNG imports in LAC countries and the corresponding exporter country. In 2019, Mexico, Chile, Argentina, Panama, Jamaica, and Colombia imported more than half of their LNG from the USA. The Dominican Republic imported about 70 per cent of its LNG from Trinidad and Tobago. While the USA accounted for 45 per cent of the total imports in LAC, Trinidad and Tobago was responsible for 35 per cent of regional imports.

Table 3. Liquefied natural gas imports by country and exporter in 2019 [MT].

Country	Angola	Argentina	Cameroon	Egypt	Equatorial Guinea	Indonesia	Nigeria	Norway	Trinidad & Tobago	USA
Mexico					0.35	0.18	1.03		0.44	2.89
Chile					0.14				0.63	1.68
Brazil	0.07	0.05	0.10		0.13		0.20	0.25	0.42	1.09
Argentina			0.03						0.44	0.73
Dom. Rep.							0.06	0.06	0.85	0.22
Panama				0.03				0.12	0.05	0.21
Jamaica									0.08	0.17
Colombia							0.06		0.03	0.14
Total	0.07	0.05	0.13	0.03	0.62	0.18	1.35	0.43	2.94	7.13

Source: Authors' own research using (GIIGNL, 2021).

Table 4 presents natural gas reserves in the region. About 70 per cent of proven reserves in the region are in Venezuela. Argentina holds about 18 per cent of probable reserves in the region. Bolivia is known to have around 40 per cent of possible reserves. Although Mexico holds a small proportion of proven reserves (~4 per cent), it has about 30 per cent of probable reserves.

Table 4. Natural gas reserves by country in 2019 [10^9 m^3].

Country	Proven offshore	Probable offshore	Possible offshore	Proven in continent	Probable in continent	Possible in continent
Argentina	81.43	75.88	60.09	318.80	114.37	74.58
Barbados				0.14		
Bolivia				253.46	347.2	485.12
Brazil	295.91			68.08		
Chile				6.97		
Colombia	7.76			81.81	18.7	10.26
Cuba				67.82		
Ecuador	4.37	4.54	3.31			
Guatemala				5.60		
Guyana	369.00					
México	109.37	102.74	109.53	164.01	213.56	217.34
Perú	2.35			296.64		
Trinidad & Tobago		183.21	184.29	298.06		
Venezuela				5,595.02		

Source: Authors' own research using (OLADE, 2020).

3.3 Ongoing and Future Developments

Figure 14 presents key natural gas infrastructure in LAC countries. There are 17 regasification terminals in the region with five in Brazil and three in Mexico. Peru and Trinidad and Tobago hold the four operating liquefaction terminals in LAC. Neighboring countries trade natural gas through pipelines as this mechanism is usually cheaper. There are 15 pipeline trades in the region between neighboring countries, seven of them between Argentina and Chile.

Figure 14. Schematic representation of regasification terminal, liquefaction terminal, pipeline trades and liquefy natural gas trades.

Source: Authors' own research using (Sabbatella, 2018; Sbroiavacca et al., 2019; Viscidi et al., 2015).
Note: The name indicated in any line refers to the country of natural gas origen.

The region holds four operating liquefaction plants (Table 5). Trinidad and Tobago holds three liquefaction plants for 26.6 meta tons per annum (MTPA) of nominal capacity. Peru is the only continental country with an operating liquefaction plant, with a nominal capacity of 4.45 MTPA. A fifth liquefaction plant with a capacity of 3.25 MTPA is expected to be built in Baja California, Mexico, starting operations by late 2024. The Tango plant, in the Port of Bahía Blanca, Argentina, ceased operations in 2020. The project was designed to produce 0.5 MTPA.

Table 5. Liquefaction plants in LAC.

Country	Name	Number of trains	Nominal Capacity (MTPA)	Number of tanks	Total capacity (liq m³)	Start-update
Argentina	Tango (stopped; no vessel chartered) (FLNG)	-	-	-	-	2019, Stopped in 2020
Trinidad and Tobago	Atlantic LNG T1	1	16.50	1	102,000	1999
	Atlantic LNG T2 - T3	2	3.30	2	262,000	T2: 2002 T3: 2003
	Atlantic LNG T4	1	6.80	1	160,000	2006
Peru	Peru	1	4.45	2	260,000	2006

Source: Authors' own research using (GIIGNL, 2021).

Regasification plants in the region are found in multiple countries (Table 6). Argentina leases two regasification terminals, although only one was in operation in 2020. The Bahía Blanca facility was reinstated in 2021. The capacity of this was increased by 6.1 MTPA in early 2020. Brazil accounts for five of the total regasification terminals of the region, but one of them is not operating at the moment. In total, the Brazilian capacity adds up to 21 MTPA. Chile currently holds two regasification plants with a total of 8.9 MTPA.

Colombia plans to increase its 3.8 MTPA capacity by considering plans for additional regasification terminals. The proposed onshore Buenaventura terminal on the Pacific coast could be operating by 2023. El Salvador is working on an LNG-to-power project including a 378 MW power plant. The plan includes converting the 137,000 m^3 Moss LNG carrier Gallina to a floating storage regasification unit (FSRU) named BW Tatiana. The project will use LNG to produce electricity in El Salvador. It is expected to be operational in 2022. In Jamaica, Golar Freeze FSRU with 125,000m^3 capacity is expected to be replaced by Hoegh Gallant FSRU, a 144,300m^3 facility.

Progress was made during 2021 on the Baja California project, Mexico, where a 0.8 MTPA regasification facility with a 135 MW power plant and truck loading bays was under development. LNG will be delivered to the terminal via small scale LNG carriers loaded from a large-scale LNG carrier moored nearby. Commercial operations are expected to begin in 2022, after delays in late 2021. A 0.4 MTPA LNG-to-power project in Nicaragua is currently being developed. It includes a 300 MW gas-fired power plant and an offshore LNG receiving, storage, and regasification terminal off the coast of Puerto Sandino.

In Panama, the 2.6 MTPA Sinolam LNG terminal may also start to operate in 2022. Associated with a 441 MW gas-to-power plant, the terminal will consist of a floating storage unit (FSU) and onshore regasification facilities. If environmental approval is received, the project could start up in 2022.

Table 6. Regasification plants in LAC.

Country	Site	Number of tanks	Nominal capacity (liq. m^3)	Number of vaporizers	Total capacity (MTPA)	Start-up date
Argentina	Bahia Blanca No vessel chartered					2008
	GNL Escobar Excelerate Expedient (FSRU)		151,000	6	6.1	2011
Brazil	Bahia No vessel chartered					2013
	Guanabara Bay Excelerate Experience (FSRU)		173,400	6	6.0	2009
	Pecem Golar Winter (FSRU)		137,000		3.8	2009
	Port of Açu BW Magna (FSRU)		173,400		5.6	2020*
	Sergipe Golar Nanook (FSRU)		170,000		5.6	2020
Chile	Mejillones	1	480,000	8	7.4	2009
	Quintero	3	187,000	3	1.5	2010
Colombia	Cartagena Höegh Grace (FSRU)	4	170,000	4	3.8	2016
Dom. Rep.	Andrés	1	160,000	3	1.7	2003
Jamaica	Montego Bay	7	7,000		0.5	2016
	Old Harbour Golar Freeze (FSRU)		125,000		3.6	2019
Mexico	Altamira	2	300,000	5	5.7	2006
	Energía Costa Azu	2	320,000	6	7.6	2008
	Manzanillo	2	300,000		3.8	2012
Panama	Costa Norte	1	180,000		1.5	2018

Source: Authors' own research using (GIIGNL, 2021).

*Commercial operation from 2021

Pipelines are used for trading natural gas between neighboring countries (Table 7). Argentina and Chile have the most significant number of connections at seven. The connection with the largest flow of natural gas is located between Mexico and the USA. Peru is currently developing the *Sur peruano* pipeline , now named the Integrated System for Natural Gas Transport, expected to be operational in 2025. An additional 1430 km long pipeline to connect the Vaca Muerta shale reservoir in Argentina to Brazil is being discussed between both countries, although several aspects regarding its benefits remain unclear in regard to insufficient demand, natural gas production costs, and access to required financing.

Table 7. Pipelines in LAC.

Countries	Infrastructure	Location	Start-up year	Capacity (10^6 m^3/day)
Arg-Chile	Methanex PA	San Sebastián-Bandurrias	1997	2.0
Arg-Chile	Methanex YPF	El Cóndor - Posesión	1999	2.0
Arg-Chile	Methanex SIP	Cabo Vírgenes -Dungeness	1999	1.3
Arg-Chile	Atacama	Cnel. Cornejo -Mejillones	1999	9.0
Arg-Chile	Pacífico	Loma La Lata -Talcahuano	1999	3.5
Arg-Chile	Gas Andes	La Mora -San Bernardo	1997	10.0
Arg-Chile	Norandino	Pichanal -Tocopilla	1999	5.0
Arg-Brazil	Uruguayana (TGM)	Aldea Brasileira -Uruguayana	2000	2.8
Arg-Urug	Petrouruguay	Colón -Paysandú	1998	1.0
Arg-Urug	Cruz del sur	Ensenada -Montevideo	2002	6.0
Bol-Arg	Yabog/Juana Azurduy	Santa Cruz-Campo Durán	1972/2011	27.0
Bol-Brazil	Gasbol	Santa Cruz-Corumba	1999	30.0
Bol-Brazil	Gas oriente boliviano	San José de Chiquitos-San Matías	2002	4.0
Col-Ven	Transcaribeño (Antonio Ricaurte)	Yacimiento Ballena-Maracaibo	2008	17.0
USA-Mex	Wahalajara pipeline	Texas-Guadalajara		209.5

Source: Authors' own research using (Sabbatella, 2018; Sbroiavacca et al., 2019)

4. Transformations, Emissions, Costs, and Socioeconomics

The modeling tool aims at considering the complexity of the power sector by representing individually the diversity of power plants in the region (i.e., offshore wind, onshore wind, utility solar, distribution solar, geothermal, hydro, nuclear, thermal renewable, coal, fuel oil, diesel, and natural gas). The simulation encompasses a 2019-2050 timeframe and is performed by country, however, results are analyzed aggregated by region. The scenarios consider i) data that describes the current state of multiple energy variables in LAC countries and ii) assumptions related to their future evolution. Specifically:

i) The energy variables include the total installed capacity for electricity generation in each country by source, total electricity produced by source, fossil fuel production, imports and exports, and energy demands by fuel and sector. The model uses 2019 as its base year and includes the COVID-19 effect in terms of consumption and production of energy. The data to characterize the base year is compiled from diverse databases from renowned institutions such as OLADE, IEA, IRENA, data from the WBG and NREL databases, and country-specific information when possible.

ii) The model evaluates three scenarios that consider different assumptions to the evolution of the variables mentioned in i). Section 4.1 describes all these assumptions for each scenario.

The model provides insights in terms of three metrics: *i)* emissions, *ii)* costs, and, *iii)* job creation. The above metrics are estimated multiplying coefficients by energy variables (e.g., energy production or installed capacities). These metrics are estimated as follows:

i) Total emissions are calculated by using emission factors associated with each fuel. Consumption is multiplied by the emission factors to obtain emissions per fuel.

ii) Capital, operational, maintenance, and variable costs associated with installation and usage of power plants and transmission and distribution infrastructure are calculated using capacities and production. These costs vary according to the type of power plant. While the power grid (transmission and distribution) is not modeled, its expansion costs are also mapped using estimation costs per type of power plant and power plant capacities. There are externality costs in global warming and air pollution associated with the consumption of fossil fuels which are calculated using coefficients and fuel consumption.

iii) The model estimates the potential job creation in the power sector for each scenario with coefficients that represent the number of jobs generated with each additional unit of installed capacity. This process includes the construction, manufacturing, operation, and maintenance stages of power plants.

For further information on the modeling tool, please refer to Appendix A.

There are limitations of the analysis that are worthy of acknowledgment:

While operational aspects of the power system are not modeled, the use of batteries is considered to address stability issues of the grid under conditions of high penetration of renewables. Moreover, residual 2020 capacity will provide backup power.

It is assumed that the power plant capacity investments occur to exactly match the estimated demand in a given year (overnight costs). In practice, power plants are built with the expectation to meet more demand in future years relative to the construction year.

Extraction or refining costs for natural gas or any other fossil fuel derivative are not considered; only final prices are multiplied by the consumed amount to obtain gas expenses. This approach considers that the final price includes all the costs associated with fuel production.

Only the final energy demand of fossil fuels is considered, i.e., production requirements from transformation losses (i.e., refining processes) are not captured.

Demand-side costs are not discussed, only the effects of demand changes on the power sector. Since the three scenarios consider the same demand changes, the corresponding costs will have no effect on the results presented.

The land-use requirements for any power plant construction are not accounted for.

A single future cost trajectory for fuels is considered, which is a subject of deep uncertainty. Future work should address the impact of higher or lower strategy costs, as well as the effect of other uncertainties in the results.

Emerging technologies such as hydrogen, concentrated solar power and tidal are not considered in this work due to limited information of their cost, maturity and full understanding of their potential in the region.

4.1 Assumptions in Terms of GDP, Demand Growth, and the Grid

The scenarios share assumptions in terms of the GDP growth, energy intensity reduction by 2050, electrification of end uses, energy losses reduction in the grid (transmission and distribution) by 2050, net capacity factors of power plants, and planned construction and phase out of units by 2030[1].

This work uses a regional GDP growth of 2.6 per cent obtained as the average GDP growth in the LAC region in the 2000-2019 period (World Bank Data, 2021). However, GDP values for 2020 were only used for calibrating the model to capture the effects of the pandemic in energy demands and electricity production.

The scenarios consider a reduction in sectoral energy intensities resulting from the deployment of energy efficiency programs, the technology evolution, the electrification of uses, and customer awareness to lower their consumption. Values from 2019[2] are assumed to linearly drop 27 per cent by 2050. This is based on the IEA sustainable development scenario (IEA, 2020). Figure 15 shows the resulting sectoral energy intensity in MJ/US$ in 2050. A less aggressive policy, such as the stated policies scenario will result in higher demand needs, and thus higher requirements from the power sector.

Photo: CCU

1. This report focuses on the power sector. It discusses environmental and socioeconomic effects of meeting the electricity demand growth with natural gas or renewables. Therefore, identical measures are considered in the demand side for all scenarios to focus the analysis on the production of electricity.
2. Figure A.2 in Appendix A shows the estimated intensities for 2019.

Figure 15. Energy intensity in MJ/US$ by sector in 2050 (BAU scenario).

Subregion	Country	Agriculture, fisheries, and mining	Commercial, services, public, construction and other	Industry	Residential	Transport
Mexico	Mexico	0.11	0.06	0.89	0.42	1.15
Central America	Costa Rica	0.04	0.13	0.42	0.26	1.36
	El Salvador	0.05	0.12	0.86	0.88	1.92
	Guatemala	0.00	0.13	0.62	4.12	1.84
	Honduras	0.07	0.27	0.78	2.32	2.04
	Nicaragua	0.16	0.41	0.80	3.00	1.96
	Panama	0.01	0.19	0.44	0.35	1.04
Caribbean	Barbados	0.00	0.23	1.30	0.25	0.95
	Belize	0.02	0.29	1.19	1.16	3.67
	Cuba	0.06	0.22	1.01	0.46	0.28
	Dominican Republic	0.06	0.09	0.56	0.51	0.92
	Grenada	0.19	0.18	0.17	0.72	1.37
	Guyana	1.26	0.08	0.70	0.54	1.98
	Haiti	0.00	0.06	0.63	5.38	1.08
	Jamaica	1.62	0.24	0.42	0.71	2.88
	Suriname	0.58	0.14	0.64	0.52	1.47
	Trinidad and Tobago	0.00	0.06	8.87	0.40	1.23
Andean Countries	Bolivia	0.29	0.18	1.62	1.02	3.76
	Colombia	0.13	0.12	0.60	0.48	1.02
	Ecuador	0.05	0.33	0.72	0.61	2.50
	Peru	0.30	0.10	0.59	0.56	1.42
	Venezuela	0.00	0.16	2.45	0.97	2.41
Brazil	Brazil	0.20	0.08	0.99	0.34	1.10
Southern Cone	Argentina	0.25	0.15	0.94	0.95	1.30
	Chile	0.60	0.11	0.58	0.45	1.18
	Paraguay	0.00	0.18	1.34	1.43	2.16
	Uruguay	0.10	0.09	1.15	0.47	0.75

Source: Authors' own research.

Sectoral energy demand per country is considered to grow with the national GDP. Yearly values per sector are calculated using the corresponding energy intensity and the national GDP. The scenarios consider the effect of COVID-19 in 2020 energy demands. Energy balances available in (OLADE, 2021) were used to calibrate the model in 2020.

Figure 16 (first row) shows the resulting energy demand by sector. Sectoral demand from 2019 will grow on average 60 per cent by 2050. The scenarios also consider electrification of end uses.

The following are the key considerations in terms of the demand of fuels:

No changes in the energy carriers are assumed in the agriculture, fisheries, and mining sector. Their energy demand is always met using the same share of energy carriers as in 2019, about 53 per cent using diesel and around 28 per cent through electricity.

No changes in the energy carriers are assumed in the commercial, services, and public sectors, where around three-quarters of the total demand is met using electricity throughout the years.

Industry, residential, and transport sectors reduce liquid fossil fuel derivatives due to end-use electrification.

By 2050, the industrial sector is assumed to replace charcoal, coal, diesel, and fuel oil with electricity. This results in an increment of the electricity share, growing from 28 per cent in 2019 to 45 per cent in 2050. The participation of coke, firewood, LPG, natural gas, and sugar cane in this sector remains practically constant throughout the years.

By 2050, the use of firewood in the residential sector is assumed to be reduced to a maximum of 10 per cent per country. Countries with lower shares remain constant. The share of LPG and natural gas remains constant. The electrification of end uses in the residential sector increases demand, and its share of electricity grows from 33 per cent in 2019 to 59 per cent in 2050.

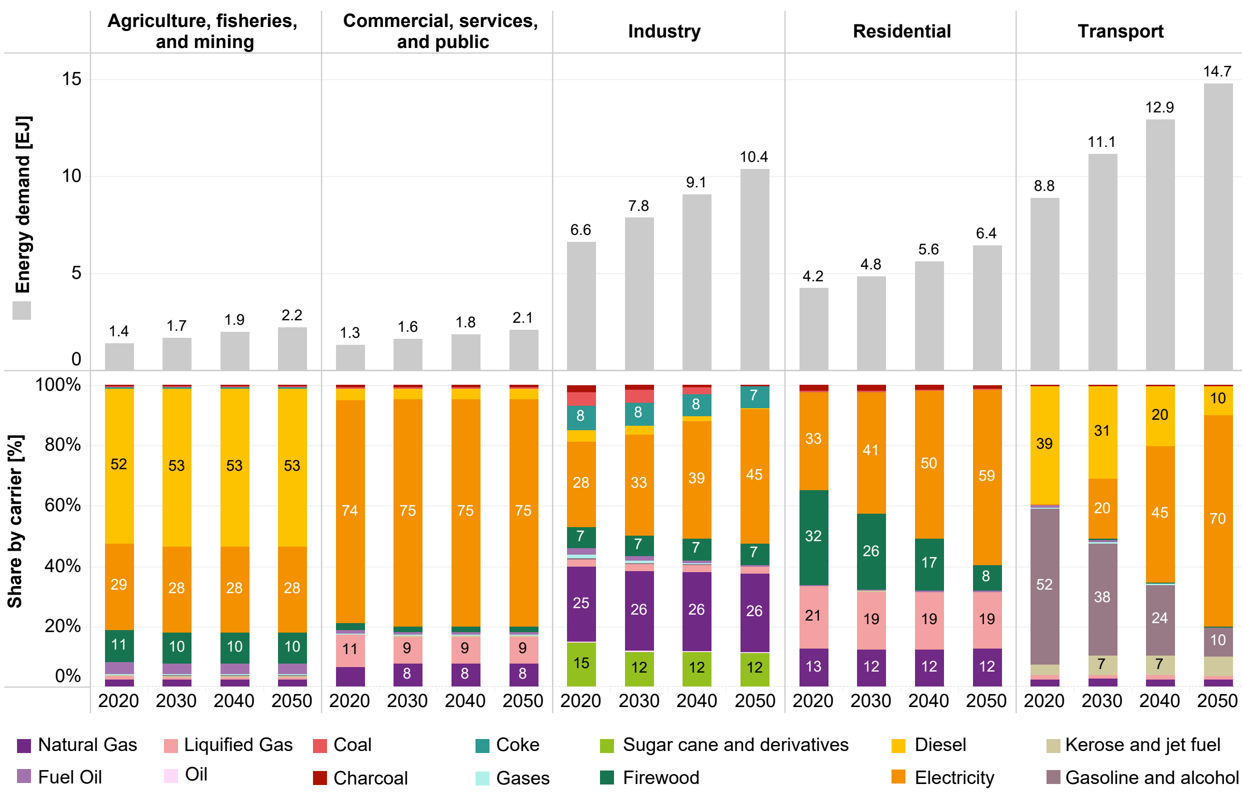
The demand of diesel and gasoline in the transport sector is assumed to lower in time as a result of the electrification of the transport fleet. By 2050, their share is 10 per cent maximum per country. The participation of kerosene and jet fuel in the transport sector remains constant, assuming no interventions on aviation. The use of LPG and natural gas remains constant through the years. By 2050, 70 per cent of the energy demand in the transport sector will be supplied by the power sector[3].

3. This work does not model the transport sector in detail. Future work can characterize the sector and understand the regional stock of electric and fuel-based vehicles.

All scenarios consider that energy losses in the electricity grid– transmission and distribution– drop linearly per country starting from current values to a 10 per cent maximum by 2050. Countries with lower values remain constant. Net capacity factors per power plant type and country are based on their average value from the 2015-2019 period. Historical values are obtained from OLADE's database (OLADE, 2022). Planned construction and phase-out of power plants per country by 2030 are also based on (OLADE, 2018).

All scenarios consider the same evolution of natural gas and fossil fuel prices. The final natural gas price is obtained from Table 1 considering index price, liquefaction, storage, vaporization, and transport (pipeline or land) costs. Based on (IEA, 2021b), they increase 1.8 per cent annually. Fossil fuels per subregion are based on (*Global Petrol Prices*, 2021), and their annual growth is 2.6 per cent according (IEA, 2021b).

Figure 16. Sectoral energy consumption and share by energy carriers.



Source: Authors' own research.

4.2 Scenario Results

4.2.1 Electricity Production and Installed Capacity

4.2.1.1. Business-As-Usual

The Business-As-Usual (BAU) scenario represents a power sector in which future electricity consumption is met using traditional energy sources: hydropower, natural gas, oil, coal, wind, biofuels, and a small amount of solar. There are investments to keep up with expected energy demand but not to decarbonize the energy sector.

Figure 17 shows the total production of electricity (first row) and the share per energy carrier (second row). By 2030, electricity production will grow 75 per cent relative to its 2019 value.

Unplanned power plants per country are based on trends. The average electricity generation mix per country of the 2015-2019 period is used to proportionally define future power plants requirements per country until the maximum potential of a power plant type is reached. No more power plants of a given type are installed when its maximum potential is reached in a country. The maximum potential per type of power plant per country is obtained from (OLADE, 2022).

The regional electricity mix based on this assumption is shown in Figure 17 (second row). The following is the expected evolution of production under the Business-As-Usual scenario:

Existing coal and diesel power plants end their life cycle by 2040, assuming a minimum operational life of 20 years. They are replaced by new diesel or coal power plants. Their production grows in time passing from a 15 per cent share in 2019 to a 16 per cent share in 2050.

The share of electricity production from natural gas remains in the range of 26 per cent during the entire scenario.

The share of electricity production from hydro power plants decreases in time as some countries in the region reach maximum capacity, passing from a 45 per cent share in 2019 to a 41 per cent share in 2050.

The production of electricity from wind and solar power plants remains in the range of an 8 per cent share over the entire period.

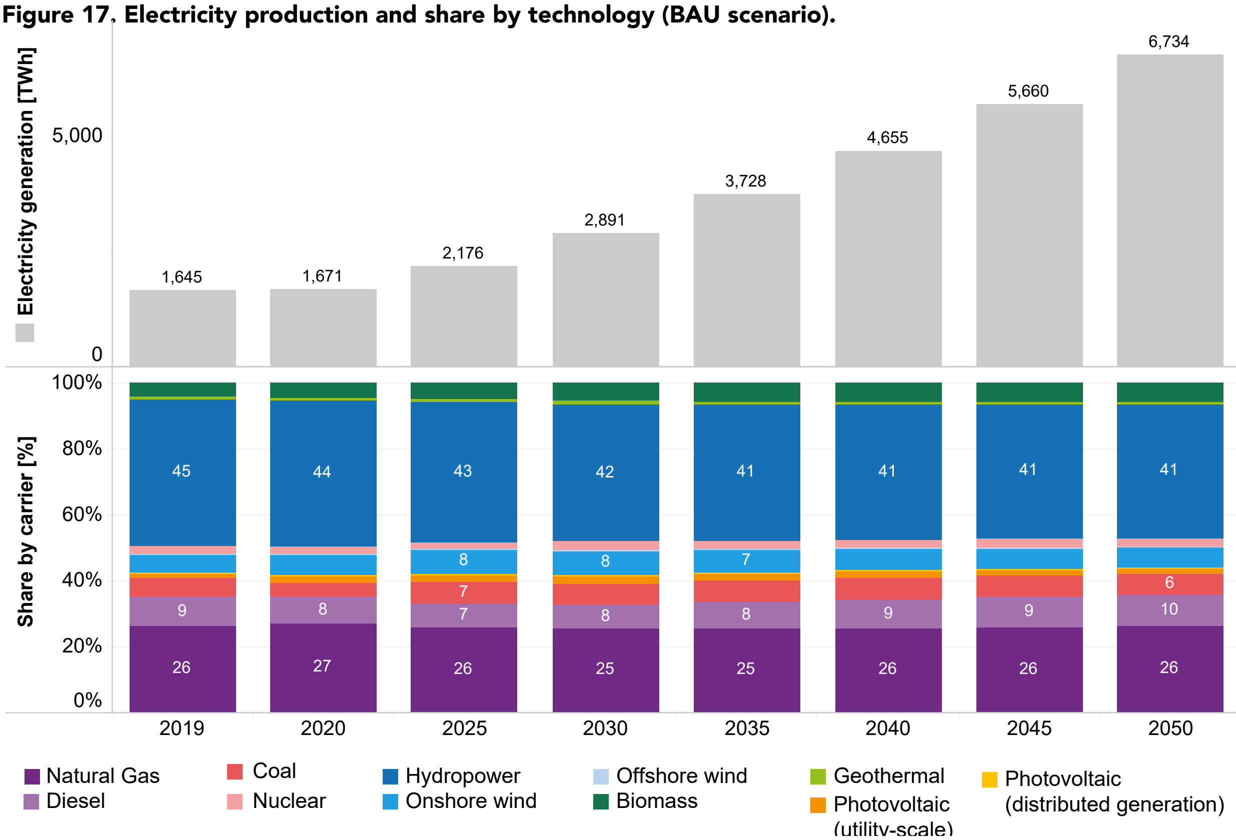
Photo: CCU

The regional production of electricity from biomass power plants increases slightly from historical levels. By 2050, the 2019 share of electricity produced using this fuel will grow 2 pp, reaching 6 per cent.

Electricity production from geothermal power plants remains in the range of 1 per cent share. Only countries with reported potential are considered to install new geothermal power plants.

The share of electricity produced from nuclear power plants increases only 1 per cent by 2050, passing from 2 per cent in 2019 to 3 per cent in 2050.

Figure 17. Electricity production and share by technology (BAU scenario).



Source: Authors' own research.

In a BAU pathway, the regional installed capacity will reach around 1,800 GW by 2050 (Figure 18), about four times the value from 2019. The following is the expected evolution of installed capacity under the BAU scenario:

The installed capacity of non-renewable power plants (coal, diesel, and natural gas) increases, representing 41 per cent of the total capacity in the region by 2050.

The installed capacity of hydro power plants increases in countries with more potential until it reaches maximum potentials according to (OLADE, 2022). The share of hydro power plants decreases from 45 per cent in 2019 to 39 per cent by 2050.

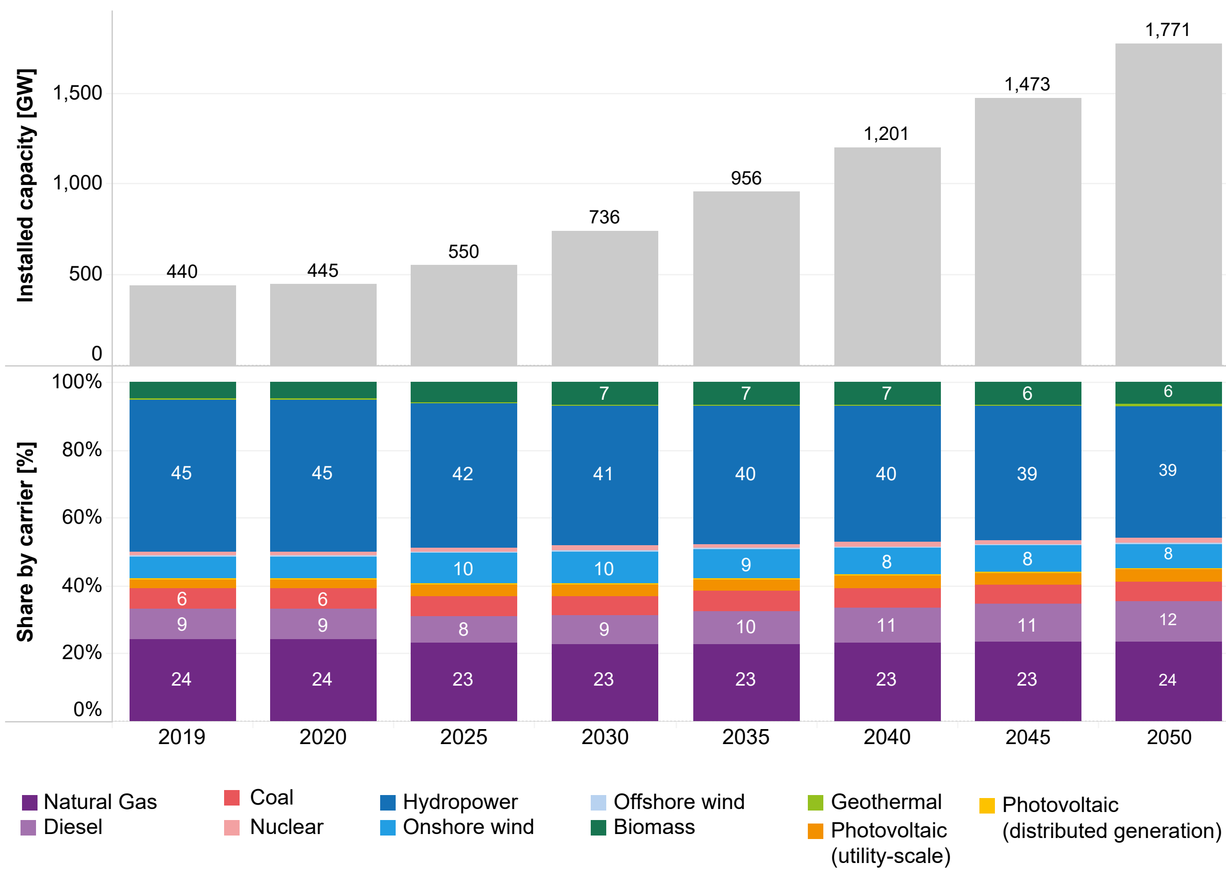
The share of installed capacity of non-conventional renewables (wind and solar) grows 2 per cent, passing from a 10 per cent in 2019 to 12 per cent in 2050.

The share of biomass power plants remains in the range of 6 per cent in the entire period.

The installed capacity of geothermal power plants grows by 2050. However, the share of regional installed capacity remains around 1 per cent in the entire period.

The installed capacity of nuclear power plants remains constant throughout the entire period.

Figure 18. Total installed capacity and share by energy carrier (BAU scenario).



Source: Authors' own research.

4.2.1.2. Natural Gas

The natural gas (NG) scenario prioritizes the deployment of natural gas power plants to meet the growing demand.

The scenario considers that Bolivia and Trinidad and Tobago -current suppliers in the region- continue to provide natural gas to LAC countries. Their proven reserves are accounted for in the scenario by limiting their exports. Once the limit is achieved, all needs are assumed to be provided by Europe, Russia, Africa and the United States.

The share of imports in 2019 is kept constant for all countries. If a country had not used natural gas before, it is assumed that it will import all of it. Mexico, Brazil, and Argentina import natural gas through pipelines; the rest of the countries import it liquified.

Unplanned power plants are based on the average electricity mix of the 2015-2019 period replacing coal, diesel and fuel oil for natural gas; 2020 is not included in this average to avoid COVID-19's impact. No more power plants of a given type are installed when its maximum capacity is reached in a country.

Figure 19 shows the total production (first row) and the share per energy carrier in the natural gas scenario (second row). By 2030, electricity production will reach 2.900 TWh. By 2050, it will quadruple the production from 2019 (1645 TWh).

The following is the expected evolution of production under the natural gas scenario:

- Existing coal and diesel plants end their life cycle by 2040, assuming a minimum operational life of 20 years. Their production is replaced by natural gas power plants.

- The production of electricity from natural gas grows in time and its 26 per cent share in 2019 becomes 44 per cent in 2050.

- The electricity production percentage from hydropower plants decreases over time as some countries approach maximum potential. The share of electricity production from this source decreases from 45 per cent in 2019 to 41 per cent by mid century.

- Total electricity production from wind and solar increases in time. However, its share remains constant at a 8 per cent in the entire scenario.

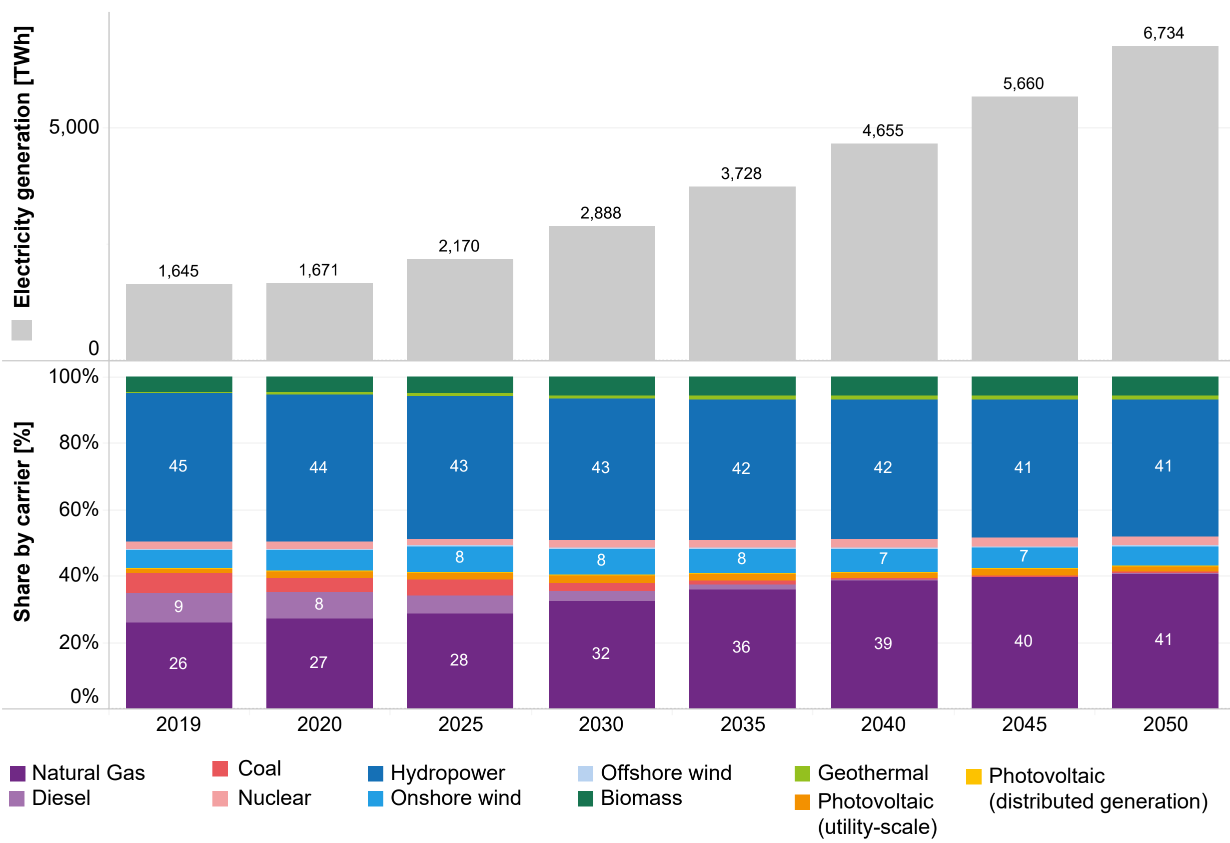
Photo: CCU

The production from biomass power plants increases slightly. Its participation in the electricity mix grows 2 per cent by 2050, from 4 per cent in 2019 to 6 per cent by mid-century.

Production from geothermal power plants is constant throughout the horizon at a 1 per cent share of the total production in the region. Geothermal power plants are considered only on countries with potential.

Output from nuclear energy remains constant throughout the entire scenario.

Figure 19. Electricity production and share by energy carrier (Natural Gas scenario).



Source: Authors' own research.

The increased production of electricity is possible thanks to the installation of additional power plants. The installed capacity in the region will reach about 1,700 GW by 2050, almost four times the value from 2019. Figure 20 shows the total installed capacity and the share per energy carrier.

The following is the expected evolution of installed capacity under the natural gas scenario:

The deployment of coal and diesel power plants is limited to projects currently under development. Beyond 2030, no more power plants of these types are constructed, and they are replaced by natural gas power plants at the end of their lifetime. Consequently, the installed capacity from both sources decreases from 15 per cent in 2019 to zero by 2050.

The installed capacity of natural gas power plants increases. The 24 per cent share in 2019 grows to 38 per cent of the total by 2050.

The share of hydro power plants' installed capacity is reduced as some countries reach maximum capacity. The share decreases from 45 per cent in 2019 to 41 per cent in 2050.

The installed capacity of non-conventional renewables (wind and solar) grows over timefrom 10 per cent in 2019 to 12 per cent in 2050.

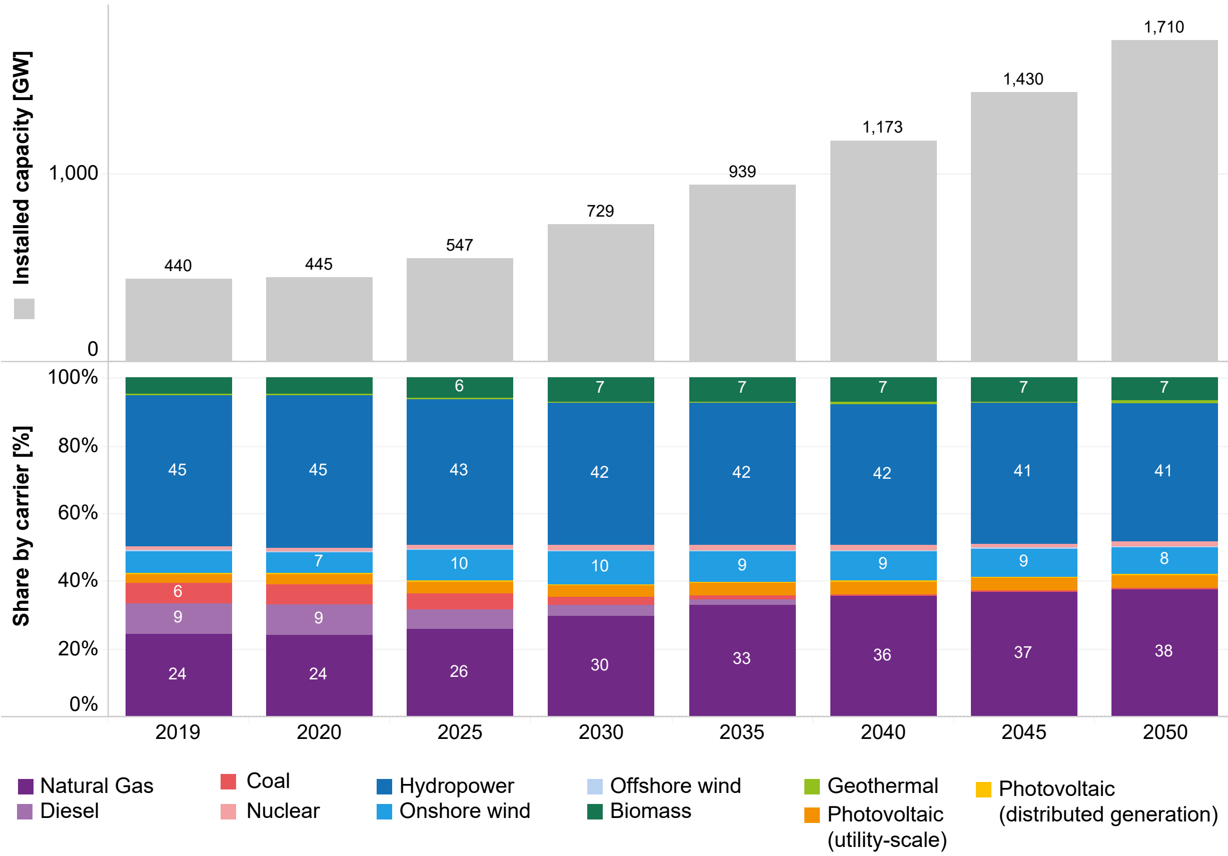
Biomass power plants' installed capacity grow from a 5 per cent share in 2019 to 7 per cent in 2050.

The installed capacity of geothermal power plants remains constant throughout the period at a 1 per cent share.

The installed capacity of nuclear power plants remains practically constant throughout the period.


Photo: CCU

Figure 20. Total installed capacity and share by energy carriers (NG scenario).



Source: Authors' own research.

4.2.1.3. Renewable Energy Scenario

The renewable energy scenario represents a power sector in which countries meet their future electricity demand using conventional and non-conventional renewables.

Planned projects are executed accordingly, and new developments are primarily based on wind and solar power plants, along with geothermal plants in countries with reported potential, and small-scale hydro power plants (mainly run-of-river units).

Unplanned power plants are based on conventional and non-conventional renewables. The shares of unplanned power plants per country are obtained from (UNEP, 2019). Differences are made between countries without and with reported geothermal potential. The former deploys only wind (62 per cent), solar (34 per cent) and hydro (4 per cent). The latter deploy wind (56 per cent), solar (31 per cent), hydro (3 per cent), and geothermal (10 per cent).

The share between onshore and offshore wind power plants is defined based on historical shares (IRENA, 2019b); 77 per cent and 23 per cent, respectively. The share of utility-scale photovoltaic systems and distributed generation (at customer premises) is also defined based on historical shares (IRENA, 2019c); 80 per cent and 20 per cent, respectively.

Variability of solar units is accounted for by assuming utility-scale solar with energy storage units starting in 2023. Due to the costs of domestic-scale batteries, distributed photovoltaic generation is assumed to be without storage until 2035. After that, it is assumed that all distributed photovoltaic systems are installed with battery storage systems considering the falling costs of the technology.

Figure 21 shows the total production (first row) and the share per energy carrier in time (second row). By 2030, it will reach almost 2,900 TWh. By 2050, it will reach about 6,700 TWh.

The following is the expected evolution of production under the renewable energy scenario:

Existing diesel and coal power plants are decommissioned by 2040, assuming a minimum operational life of 20 years. They are replaced by renewable units. No electricity is produced by 2050 using diesel or coal power plants.

The production of electricity from natural gas will decrease from a 26 per cent share in 2019 to a 8 per cent share by 2050.

Electricity production from hydropower plants lowers in time as this type of units are not developed further due to social and environmental impacts. Its share decreases from 45 per cent in 2019 to 11 per cent by 2050.

Electricity production from wind and solar technologies grows. By 2050, the share of offshore and onshore wind power plants is 7 per cent and 39 per cent, respectively. The share of distributed photovoltaic generation and utility-scale photovoltaic units by mid-century will be 5 per cent and 20 per cent, respectively.

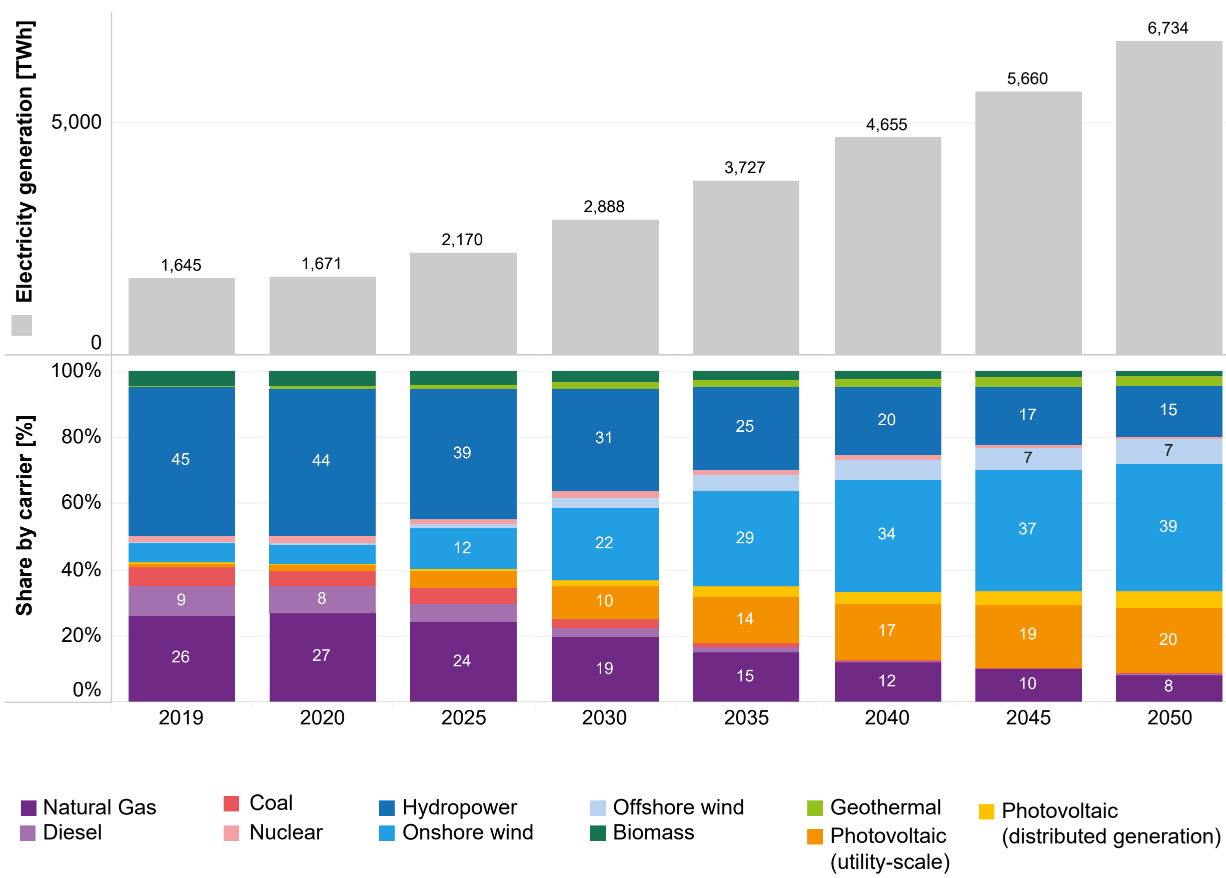
The share of electricity production from biomass power plants is reduced over time. It decreases from a 4 per cent share in 2019 to a 2 per cent share by 2050.

Photo: CCU

The further development of geothermal power plants in countries with potential leads to a larger participation in the region. The share of electricity from geothermal power plants increases over time reaching 3 per cent by 2050.

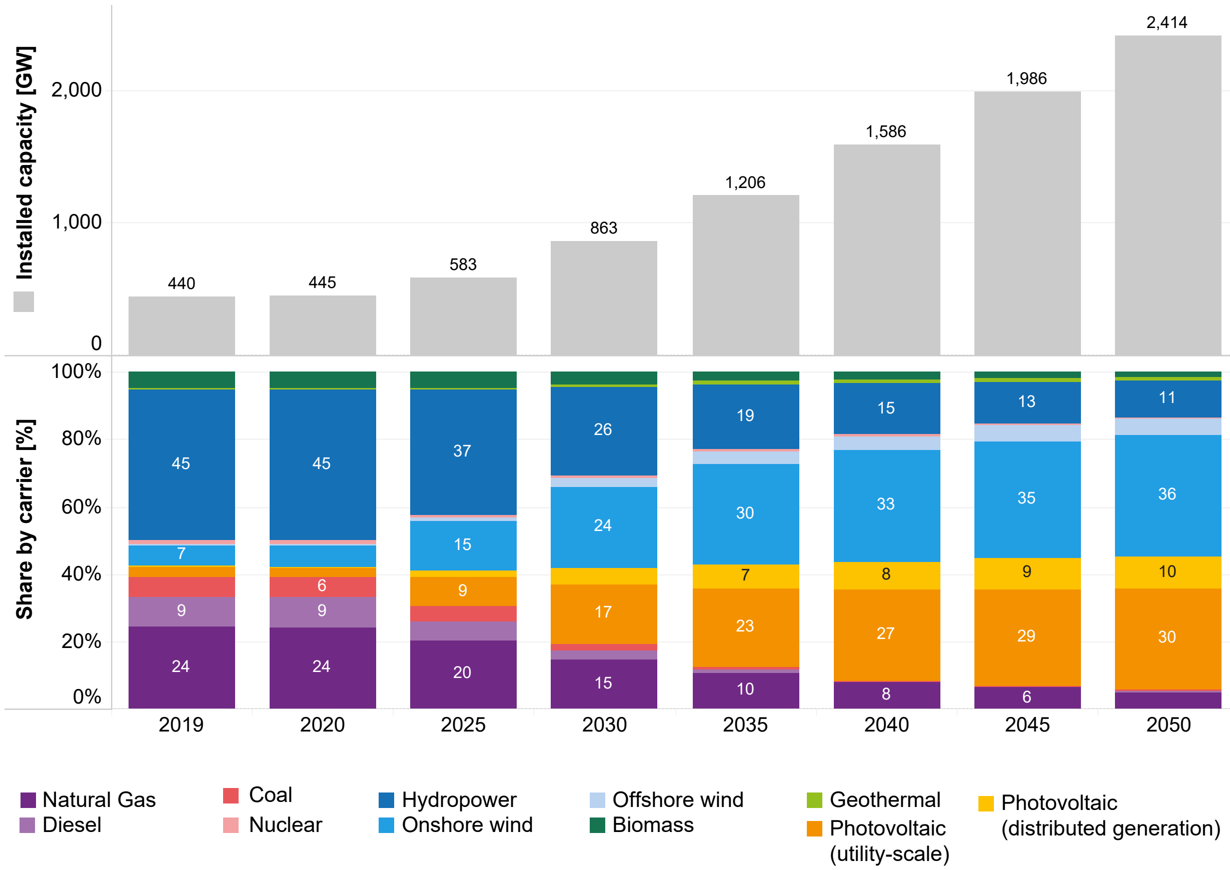
The share of electricity production from nuclear power plants lowers in time as no more units are developed in the region. By 2050, its share will be reduced to 0.85 per cent from its 2.2 per cent share in 2019.

Figure 21. Electricity production and share by energy carriers (renewable energy scenario).



Source: Authors' own research.

Figure 22. Total installed capacity and share by energy carrier (renewable energy scenario).



Source: Authors' own research.

A decarbonization of the power sector will require a larger installed capacity, which will reach 2,400 GW by 2050; about five times 2019 values (Figure 22). The following is the expected evolution of installed capacity under the renewable energy scenario:

Coal and diesel's installed capacity in 2050 is limited to projects currently under development. Existing units in 2019 are phased-out by 2040 assuming a minimum operational life of 20 years. The share of electricity production from coal, diesel, and natural gas power plants decreases in time from 39 per cent in 2019 to 5 per cent by 2050.

The share of non-conventional renewables grows from 10 per cent in 2019 to 81 per cent in 2050. Wind power plants account for a 41 per cent of the total installed capacity by mid-century. The penetration of utility-scale photovoltaics grows in time accounting for 30 per cent by 2050; more than 95 per cent of it is coupled with energy-storage systems. Distributed photovoltaic generation accounts for a 10 per cent share in 2050; about two-thirds of which is coupled with battery energy storage units.

The share of hydro power plants installed capacity is reduced over time decreasing its share from 45 per cent in 2019 to 11 per cent in 2050.

The net installed capacity of biomass power plants grows slightly by 2030 based on planned projects. It then remains constant by 2050. However, its share reduces from 5 per cent in 2019 to 1 per cent by 2050.

The installed capacity of geothermal units grows in countries with reported potential, reaching a 1 per cent share by 2050.

The installed capacity of nuclear power plants remains constant throughout. Its share lowers slightly because of the growth in the total regional capacity.

4.2.2. Emissions

Regional emissions from the production of electricity and fugitive emissions in 2019 are estimated at 378 MtCO_2e. A BAU scenario will make them grow. A natural gas scenario will marginally reduce them by 2050, and a renewable energy pathway will pave the way for countries to meet their NDCs. Figure 23 shows the annual emissions trajectory for each scenario disaggregated into fugitive and emissions per type of fuel.

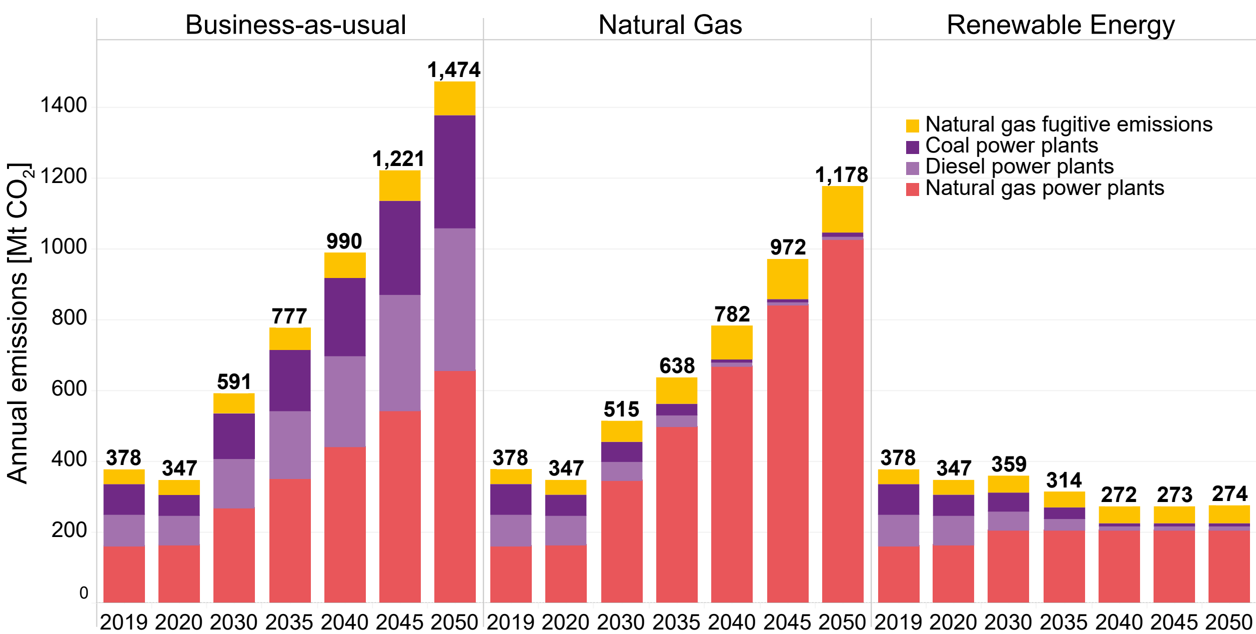
In a BAU scenario, total emissions from the power sector in 2050 will be equivalent to almost four times the estimate in 2019. Emissions from electricity generation will increase significantly caused by higher electricity production with fossil fuels and natural gas growing from 336 MtCO_2e in 2019 to 1,376 MtCO_2e by 2050. Fugitive emissions from production and imports of natural gas in the region will also increase due to the higher use of this fuel, growing from a few megatons to 98 MtCO_2e by mid-century.

Photo: CCU

Emissions from the production of electricity will decrease slightly by 2050 in the natural gas scenario. Using natural gas to supply growing demand will only reduce emissions by about 20 per cent compared to the BAU scenario; reaching 1,178 $MtCO_{2e}$ by 2050. Emissions from natural gas power plants will surpass 1,000 $MtCO_{2e}$ by 2050. Emissions from remaining diesel and coal power plants will reduce to 18 $MtCO_{2e}$ as a result of the decommissioning of these plants. Fugitive emissions will increase in this scenario caused by a larger use of this resource, reaching 133 $MtCO_{2e}$ by 2050.

The renewable energy scenario demonstrates that increasing electricity production through renewable technologies will lower emissions at large. Switching from fossil fuels to renewable energy will significantly reduce emissions by 2050, lowering them to 274 $MtCO_{2e}$. By 2050, emissions from power plants will be reduced to 224 $MtCO_{2e}$. Fugitive emissions will also be reduced to 50 $MtCO_{2e}$ by 2050. This scenario will help countries meet their NDC targets and bring important socioeconomic benefits as discussed later. It will also enable the electrification of the transport sector at the lowest emissions possible.

Figure 23. Annual CO_{2e} emissions from the power sector by source of emission in LAC.



Source: Authors' own research.


Photo: CCU

4.2.3. Costs and Economic Benefits

Different costs associated with electricity generation have been estimated in this work.

Investments in power plants are calculated using the installed capacity of each type multiplied by the cost per unit of capacity. Fixed operational costs in power plants are estimated similarly, i.e., using the capacity and a cost per unit of capacity. Variable operational costs in power plants refer to those from fossil fuels or natural gas and are quantified using the production.

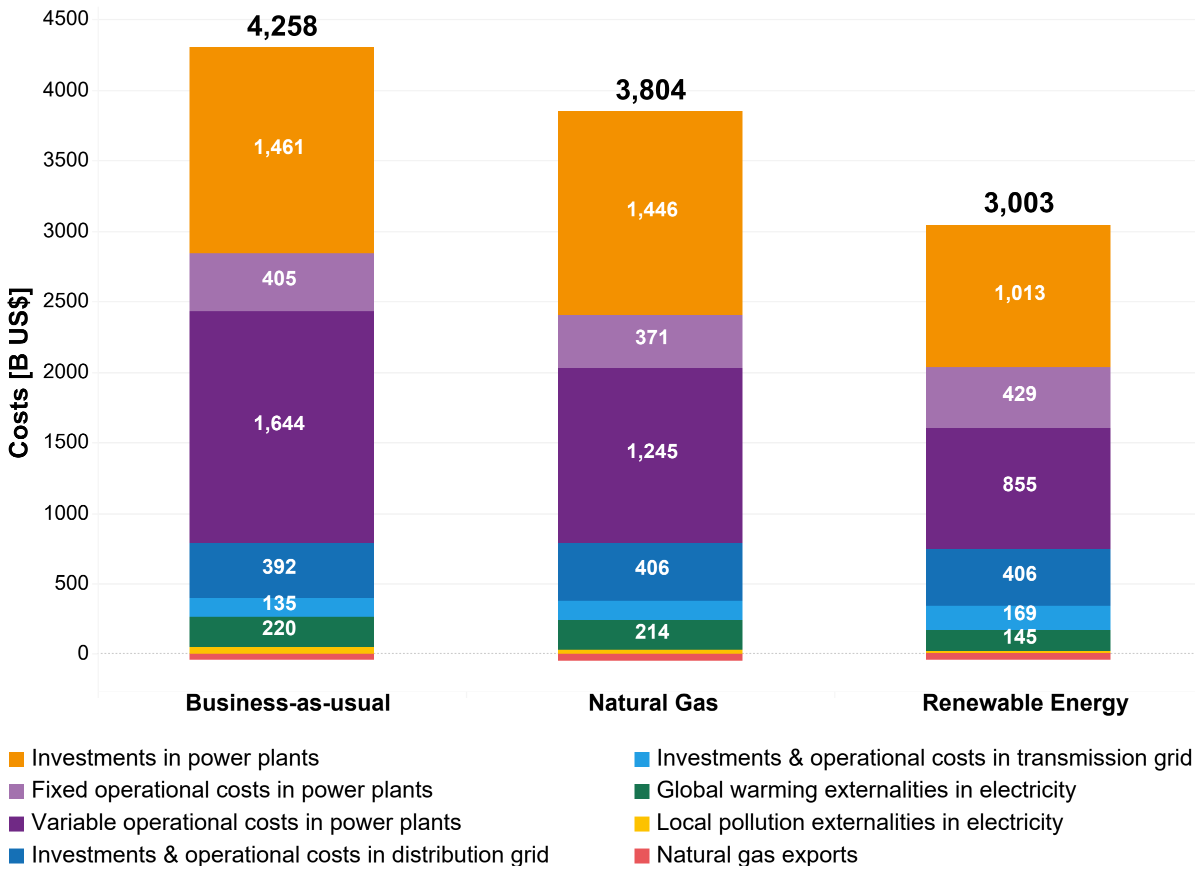
Investments and fixed operational costs in the transmission and distribution grid required to enable the connection of power plants are also captured using the production and a cost per type of power plant.

Two externality costs for the electricity sector, global warming –also related to the social cost of carbon– and local pollution, are quantified using information from the IMF and the corresponding GHG emissions[4].

Costs related to natural gas exports are incorporated to understand the potential effects of changes in the natural gas demand in some countries (primarily producers). All costs are discounted to 2019 using a 10 per cent annual discount rate. Figure 24 shows the total system costs per scenario.

4. Appendix B shows details of the externalities of fossil fuels, which are based on (Coady David et al., 2019).

Figure 24. Electricity generation discounted costs to 2021 with a 10 per cent discount rate in LAC.



Source: Authors' own research.

The BAU scenario requires investments in power plants of around US$1.5 trillion by 2050. Operational cost (fixed and variable) will add about US$2.0 trillion. Investments in transmission and distribution will account for an additional US$0.5 trillion, while externality costs will represent almost US$0.3 trillion. Countries with natural gas exports will perceive a marginal benefit estimated at less than US$0.1 trillion by 2050 (represented as negative values as they are an income for producers). The BAU scenario will have a total cost estimated at US$4.3 trillion by 2050.

The natural gas scenario shows that meeting growing electricity demands with natural gas power plants will require investments in power plants estimated at US$1.4 trillion by 2050. Fixed and variable operational costs will add US$1.6 trillion. Investments in transmission and distribution are estimated at nearly US$0.6 trillion, while externality costs are estimated at almost US$0.3 trillion by 2050. Exporter countries increase their revenue as the region uses more natural gas for electricity generation. However, this increment was estimated to be less than US$0.1 trillion by 2050. The natural gas scenario has a total cost estimated at US$3.8 trillion by 2050.

In the renewable energy scenario, deploying renewables in the power sector will require investments of around US$1.0 trillion by 2050: the lowest of the three scenarios as renewables are cheaper in their lifetime. Fixed and variable operational costs are also the lowest of the three scenarios, totaling about US$1.3 trillion by 2050. Investments in the transmission and distribution grid will increase in this scenario as more variable energy sources will penetrate the power sector accounting for around US$0.6 trillion (equal to the natural gas scenario), while externality costs are the lowest among the three scenarios accumulating by 2050 less than US$0.2 trillion. The reduction in income for exporter countries related to lowering the use of natural gas for electricity generation in LAC was estimated to be less than US$0.1 trillion by 2050. The renewable energy scenario will have a total cost of US$3.0 trillion by 2050, much lower than the other two scenarios.

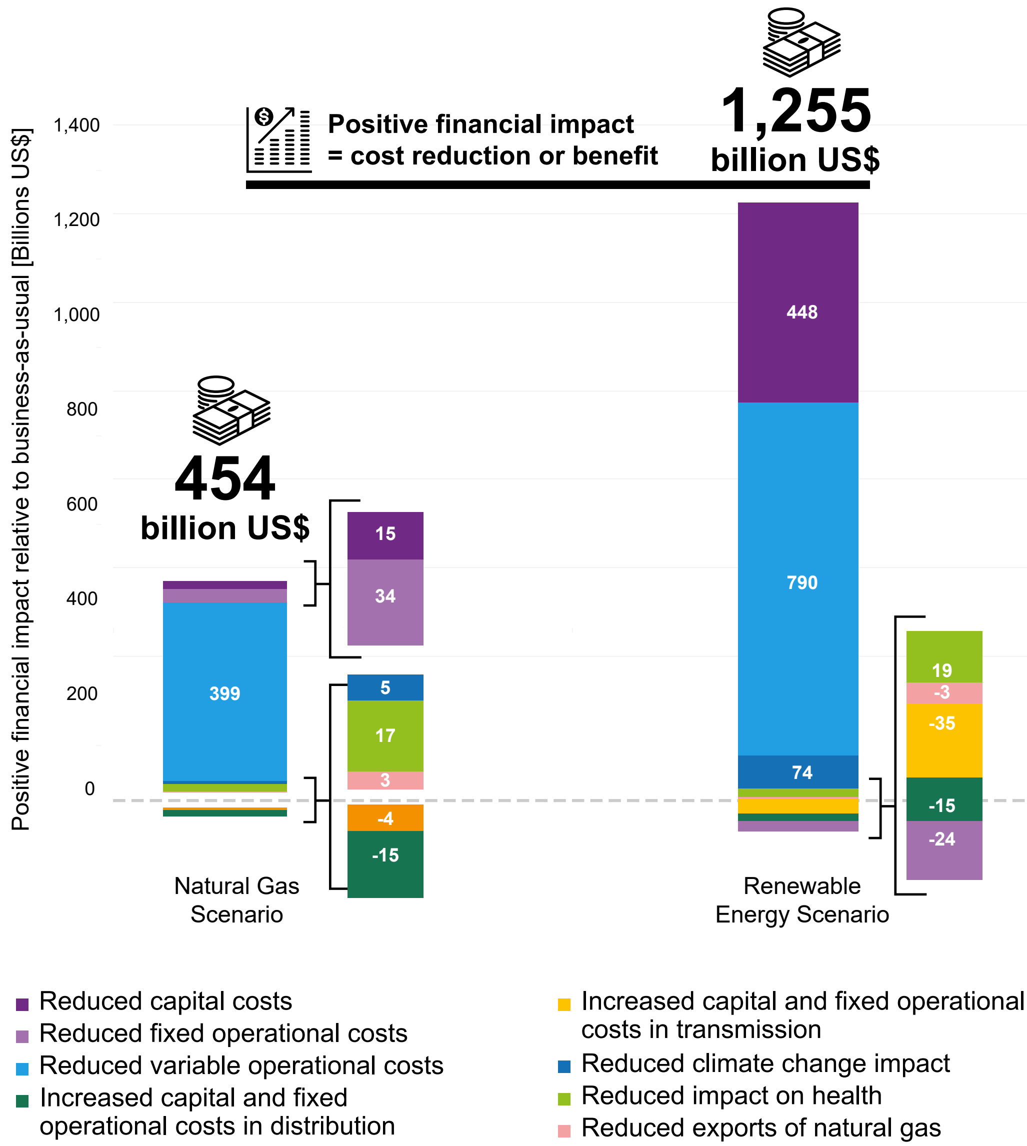
The economic impact is calculated for the natural gas and the renewable energy scenarios relative to the BAU one. The results are presented in Figure 25.

The natural gas scenario requires almost the same investments and less fixed operational costs than the BAU pathway. It has a lower installed capacity as these power plants have higher capacity factors. Thus, it is possible to meet growing demand with fewer units. Their adoption will also lead to significantly lower variable operational costs compared to the BAU scenario utilizing coal and diesel power plants. If future electricity needs are met with natural gas, the region will perceive a net benefit of US$454 billion by 2050 (about 7 per cent of 2019 regional GDP).

Compared to the BAU scenario, switching to a renewable power system will reduce investments in power plants saving US$448 billion in construction of capacity in the region. This switch will bring a significant reduction of US$790 billion in variable operation costs, with a smaller increase of US$24 billion on fixed operational costs. The deployment of more variable energy will require larger investments in the transmission and distribution grid accounting for extra costs estimated at US$49 billion by 2050. Lowering the use of fossil fuels will bring an important reduction on the climate change impact of the region (US$74 billion) and reduced impact on health (US$19 billion). Lowering the use of natural gas will result in an extra cost in terms of fuel exports estimated at US$3 billion by 2050. All in all, the switch towards a renewable power system will bring a net benefit of US$1,255 billion by 2050 (about 20 per cent of 2019 regional GDP).

Photo: CCU

Figure 25. Financial impact of natural gas and renewable energy scenarios.



Source: Authors' own research.

4.2.4. Benefits on Jobs

The transformations in the power sector will also have an effect on the number of jobs in the region. The net number of jobs is estimated here for the natural gas and renewable energy scenarios relative to the BAU pathway. Two types of jobs are considered first: those from the construction of power plants and those from their operation and maintenance. They are estimated using a simplified approach presented in (Dominish et al., 2019). This first analysis considers that all manufacturing capacity will remain out of the region as it has been over the last few years (IRENA & ILO, 2021). The estimating is then extended to evaluate the impact of manufacturing part of the power plant components in the LAC region.

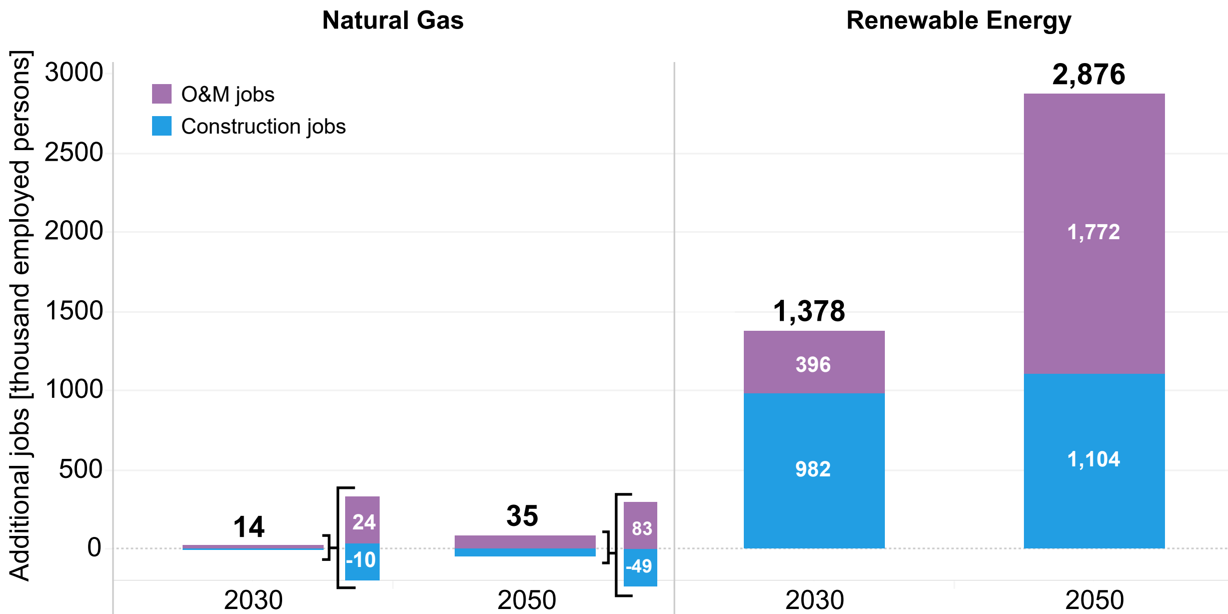
Figure 26 shows the net effect of deploying the natural gas and renewable energy scenarios if 100 per cent of the power plant components are imported in the region. A natural gas scenario will result in 14 thousand more jobs by 2030. By 2050, this figure increases to 35 thousand new jobs. Meeting future electricity demand with renewables will significantly increase the number of jobs in the region. By 2050, a renewable energy scenario will create 2.9 million net green jobs. A third of these are created in the near term, 1.3 million additional jobs by 2030 which could help the region on its post-COVID recovery.

There is a potential to increase the number of net green jobs in the region. If countries in LAC manufacture power plant components, particularly for solar and wind technologies, instead of importing them from other regions, the total number of jobs will grow. If 30 per cent of power plant components in future units are manufactured in the region (Figure 27), the number of additional jobs in the renewable energy scenario will increase to 3.8 million by 2050, 2.2 million of which occur in the near term (2030).

Direct job generation and losses were estimated exclusively for the power sector as a function of installed capacity and electricity generation. If jobs associated to grid maintenance, digital services, assembly and manufacturing of electric drives, storage systems, electric vehicles, as well as indirect jobs associated with the industry and infrastructure related to the latter were considered, total additional jobs could reach almost 35 million, as stated in UNEP's "Zero Carbon LAC" report.

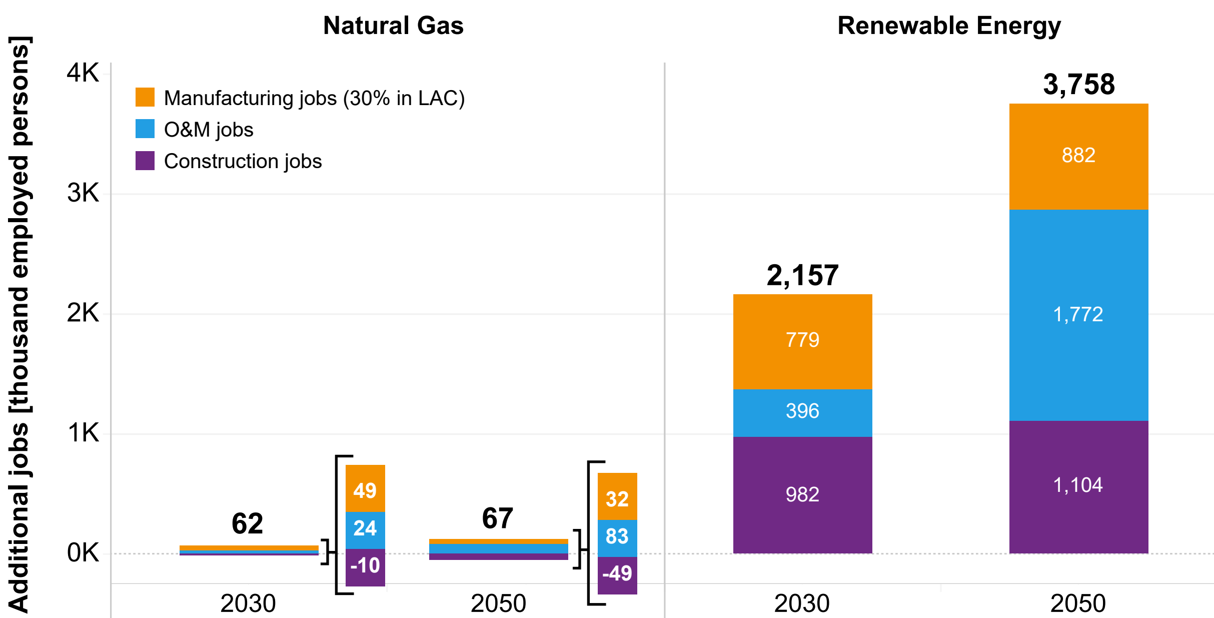
Local manufacturing of renewable energy technologies has the potential to generate more jobs where market development and appropriate incentives are present. According to "Study on the Development of the Renewable Energy Market in Latin America and the Caribbean" (IDB), Latin America and the Caribbean as a region already has complete clean energy value chains for biofuels, biomass, waste, and hydropower. Solar, wind, and geothermal also have near-complete value chains. Argentina, Brazil, Chile, and Mexico have the most complete clean energy value chains in the region.

Figure 26. Net effect on employment from natural gas and renewable energy scenarios excluding manufacturing in the region.



Source: Authors' own research.

Figure 27. Net effect on employment from natural gas and renewable energy scenarios considering 30 per cent manufacturing in the region.



Source: Authors' own research.

4.2.5. Green Economy and Just Transition

While limiting fossil fuel use will likely foment an array of societal benefits — related to reduced climate risks, sustainable economic growth, air quality and human health — it is essential to recognize that not everyone will benefit equally from a transition to a low-carbon economy. Important to note as well, renewable energy will not create fairer and more equal societies if governments do not apply and implement appropriate measures and guidelines. In the last few decades, and even more notably in the last few years, increasing evidence suggests that transitioning to a green economy has solid political, social, and economic gains that justify the need to complement sustainable development efforts with the pursuit of getting the economy right.

A green economy is a low carbon system with resource efficiency and social inclusivity. More precisely, UNEP defines a green economy as one that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2011; 2017). The shift towards a green economy, by definition, includes a degree of economic restructuring. The system needs to be guided by effective policies and measures designed in dialogues with workers, employers, and communities, to ensure a "just transition" for affected workers, families, and communities.

Thus, a just transition is a socio-technical shift that demands structural changes in the long-term towards reconfigurations in technology, policy, infrastructure, scientific knowledge, and social and cultural practices, which meet sustainable ends (Newell and Mulvaney 2013). On the way to this transition, the process also calls to address existing environmental inequalities, such as exposure to ill-health and localized degradation,

Photo: CCU

so that they are not reproduced or exacerbated. The International Labor Organization perceives the energy transition as a window of opportunity to improve social, environmental, and economic outcomes for all members of society. If managed well, the ILO argues that “transitions to environmentally and socially sustainable economies can become a strong driver of job creation, job upgrading, social justice, and poverty eradication”(ILO 2015).

This socially inclusive emphasis is imperative as governments acknowledge the limits of market-based solutions that do not usually address the increased inequalities and consequent social justice (or injustice) issues arising from our economies’ distributional aspects. The transition can still reinforce existing inequalities such as the under-representation of women and other marginalized groups in fossil fuel governance and employment. The renewable energy sector can transfer biases from the fossil fuel industry and avoid addressing the underlying norms and practices that drive inequality.

Governments have a choice to make regarding the paths toward a low-carbon economy. Overall, the policies they opt for fall into three broad categories: compensatory policies, adjustment assistance, and holistic, adaptive support (Piggot et al. 2019). Compensatory policies compensate workers for lost wages and pensions, and companies for lost asset value. Adjustment assistance helps workers and communities transition to new roles through re-training or economic diversification programs. Holistic support typically includes both categories of support and broader social assistance.

The research on historical fossil fuel transitions shows that proactive, holistic policies are rare since most policymaking tends to react to a transition that is already underway, leading to a tendency for compensatory measures to cover losses rather than forward-looking adjustment assistance or holistic, adaptive support for a post-fossil-fuel economy. (Spencer et al. 2018). Overall, transition planning must include a broader set of actors and issues and attend to both the distributive and procedural justice dimensions of planning. The policy development process should be participatory and designed to ensure the representation of historically marginalized voices, interests, and issues.

The governance of energy shapes matters of distributive justice. Patterns of uneven development pose key governance challenges like energy access and the provision of energy to those living in poverty; energy security to supply energy in a regular, fair, and predictable manner to communities and the promotion of energy and climate justice by minimizing the environmental externalities and unequal burdens of energy extraction, provision, and consumption (Newell and Mulvaney 2013). To understand energy and environmental justice, governments must ask themselves questions about security, violence, and production structures; energy relates so closely to economic growth and security that it has a prominent place in our region’s geopolitical and economic strategies that must not be neglected.

Chapter 5.
Case Study Findings

In order to dig deeper into the implications of a natural gas expansion in LAC, this report also includes case studies on three selected countries, Argentina, Grenada and Panama. While each country has a different energy matrix, they are all expanding or considering expanding natural gas use and infrastructure. The three case studies show the implications this would have in terms of emissions, jobs, and economic costs.

5.1 Argentina

In 2017, more than 53 per cent of Argentinian GHG emissions came from the energy sector (including energy industry, transport, manufacturing and construction industry, fugitive emissions, residential, agriculture, commercial, and public services). Multiple research projects have shown alternatives to mitigate emissions in the energy sector. These alternatives range from moving towards energy carriers other than fossil fuels to more slight structural changes (Deloitte, 2019, Lallama, 2021).

Argentina has been proposing natural gas as a bridging fuel option to accelerate the energy transition in the country and the region. Natural gas plays a crucial role in the energy sector of Argentina since it satisfies 58 per cent of the country's primary energy demand (more than double the LAC regional average). Argentina is also the largest natural gas market in South America, with a comprehensive infrastructure of gas distribution network

Argentina has pledged to reduce its GHG emissions by 19 per cent by 2030 compared to the 2007 peak, according to its Nationally Determined Contribution (NDC) submitted to the Paris Agreement. However, the country doesn't present actions that result in the fulfillment of such a pledge, with more investments in fossil fuels. A new natural gas pipeline is now being discussed to connect the Vaca Muerta shale gas area with the rest of the country and also with Brazil.

Photo: CCU

The BAU scenario used for this work would have a cost of US$263.3 billion (discounted by 10 per cent to 2021), with a more than double increase in emissions by 2050 compared to 2019. The natural gas scenario would result in a 6% reduction in emissions compared to the BAU scenario by 2050, as well as cost reductions of US$ 14 billion, 13,000 jobs created by 2030 and no additional jobs by 2050. Meanwhile, the renewable energy scenario would cut emissions by 59 per cent compared to BAU, save costs for a total of $31 billion and create 133 thousand jobs, which would increase to 149 thousand if components for renewables are partially manufactured in Argentina.

If Argentina increasingly deploys non-conventional renewables (wind and solar), constituting a renewable energy strategy, there are significant emission reduction, cost-saving, and job creation advantages to capitalize. On the other hand, increased investments in natural gas exploitation will have an increased risk of establishing stranded assets which will hamper the options to meet or increase emission reduction ambitions in the future.

Investments in natural gas exploitation will have an increased risk of establishing stranded assets which will hamper the options to meet or increase emission reduction ambitions in the future

5.2 Grenada

Climate change is an existential threat to Grenada. Increasing frequency and intensity of coastal storms threatens infrastructure and livelihoods, as do increased risk of coastal flooding and drought. Grenada has recognized this by placing climate resilience at the center of its policy making and forging strategic alliances with key global climate finance providers. However, the country now faces difficult choices in terms of the future of its energy matrix.

Photo: CCU

Grenada's installed power generation capacity is 57.8 MW with about 5.8 per cent from renewable energy sources and the remainder from diesel generation. In October 2020, a catastrophic failure of a baseload 8 MW diesel generator occurred. Grenada's power utility company GRENLEC leased a 6 MW diesel unit as a temporary solution, and in 2021 they installed an additional 9.7 MW diesel unit. After the generator failure, the government received proposals from private sector companies interested in retrofitting or replacing its existing diesel generating units with natural gas-fueled units.

As part of its climate commitments, the country has agreed to a set of targets in recent years, with a special focus on the energy sector. These include reducing the country's greenhouse gas emissions by 40 per cent by 2030, a 30 per cent reduction in emissions through electricity production by 2025 with 20 per cent from energy efficiency (EE) measures, EE actions to reduce emissions include retrofitting of all buildings and the establishment of policies for EE building codes for all building sectors.

The BAU scenario used for this study would result in an increase in emissions from the energy sector of 20 per cent by 2030 compared to emissions in 2018, creating 18 new jobs in the power generation sector. The implementation of the natural gas scenario would reduce emissions by 20 per cent compared to BAU, cost US$1,101 million to be implemented and create 35 jobs. Meanwhile, the renewable energy scenario would reduce emissions 31.7 per cent compared to BAU, cost US$1,033.2 million and create 91 jobs.

The renewables-based scenario has the highest economic benefit and emission reduction when compared to all other scenarios. This scenario is the only power generation pathway that reduces emissions in the power industry by over 60 per cent by 2030 when compared to the BAU scenario. Investing in renewables would not only result in the most emission reduction but also generate the most jobs in the power sector by 2030. The number of new jobs in the renewables-based scenario is five times greater than those created in the BAU scenario by 2030 and 2.6 times greater than in the natural gas scenario by 2030.

Photo: CCU

5.3 Panama

In 2018 Panama inaugurated a natural gas power plant. This milestone made Panama the first country in Central America to have this type of infrastructure. Since then, the use of natural gas for power generation in the country has been increasing, rising from 5.6 per cent in 2018 to 24.1 per cent in 2019 (Secretaría de Energía, 2019b).

Panama pledged to reduce its emissions 24 per cent by 2050 and 11.5 per cent by 2030 in its NDC, updated in 2020. The country also committed to having 15 per cent of its energy matrix from renewable sources by 2030. Expanding its energy matrix with natural gas may put those pledges at risk, as seen in this case study.

Under the BAU scenario, Panama would exploit all its available resources to meet the expected crescent electricity consumption produced by the electrification of the demand side. This BAU scenario would cost $65.89 billion with 43.3 $MtCO_2e$ in electricity generation emissions. If natural gas is expanded, the scenario would drive emissions down 24 per cent compared to BAU and reduce costs by 18 per cent. Meanwhile, under a renewable energy scenario Panama would cut emissions by 91.6 per cent reduce costs by US$22 billion and create 93 thousand jobs by 2050, which would reach 133 thousand if components are partially built in Panama.

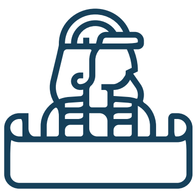
The renewable energy scenario provides a clear pathway to achieve emission reduction targets, as established in the country's NDC, and fulfilling the country's climate change mitigation ambitions. On the other hand, increased investments in natural gas exploitation for incorporation into the power generation mix will have an increased risk of establishing stranded assets which will hamper the options to meet or increase emission reduction ambitions in the future.

Under a renewable energy scenario Panama would cut emissions by 91.6 per cent reduce costs by US$22 billion and create 93 thousand jobs by 2050, which would reach 133 thousand if components are partially built in Panama.

Photo: CCU

In closing...

This report compares three possible scenarios to answer the question of whether or not natural gas is a good investment for electricity generation in Latin America and the Caribbean (LAC). In doing so, it presents evidence proving that **if the energy transition is led by non-conventional renewable energies in LAC then the economic savings for the region would be three times larger by 2050 than doing so through developing natural gas.**



Additionally, when comparing the renewable energies versus natural gas scenarios, **the number of jobs generated by the deployment of the renewable energies are 98 times higher in the short term and 82 times higher by 2050.**

Finally, compared to the BAU scenario, the emission reduction achieved by transitioning to natural gas by the year 2050 is four times lower, standing at 20 per cent compared to the 80 per cent achieved by deploying renewables.

It should be noted that the actual difference between these results may be even greater given that the methodology of the report considers fugitive emissions in the transport and production process. However, fugitive emissions from the transport process could be underestimated.

Going ahead with natural gas expansion would prevent the region from meeting the Paris Agreement, driving up global temperatures and deepening the climate crisis.

However, **several countries in the LAC region are currently accelerating investments to increase the capacity of current plants and/or to start operating new gas plants.** In fact, this is not only happening in this part of the world. There is a world-wide trend currently pushing the expansion of natural gas, especially in developing countries[5].

5. IEA (2020) 2021-2025: Rebound and beyond.

Looking through a magnifying glass

The report took a deep dive into LAC countries and proved that these regional results could also be replicated at the national level.

Grenada

A Caribbean Island highly dependent on fossil fuels and where climate change presents an existential threat, the renewables-based scenario has been proven to have the highest economic benefit and emission reduction when compared to all other scenarios.

Panama

A Central American country that imports fossil fuels and is looking to commercialize gas, has the possibility to cut emissions of its electric sector by 91.6 per cent, reduce costs by US$ 22 billion, and create 93 thousand jobs by 2050 under the renewable energy scenario vs BAU. This number would rise to 133 thousand if components were partially built domestically.

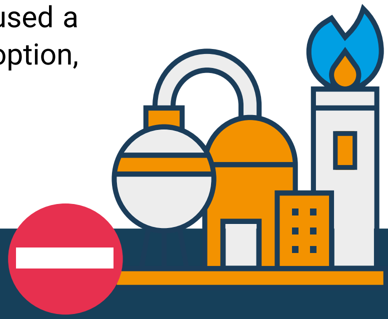
Argentina

An oil and gas producing country, renewables would reduce costs of electric generation by US$ 31 billion and generate 149,000 new jobs by 2050 when compared to BAU, while natural gas would only reduce economic costs by US$ 14 billion without increasing jobs.

Results: All results are in comparasion to the BAU scenario in the year 2050.

The hidden truth of natural gas

Natural gas releases GHG, which is mainly methane and has a warming potential 86 times higher than CO_2[6]. After decades of continuous rise in carbon emissions, there is no longer room for more fossil fuels of any type if we are to keep global warming under control[7]. Methane leaks are poorly controlled, and emissions are vaguely reported.[8] Methane emissions have already caused a 0.5°C temperature increase.[9] Far from being a clean or sustainable option, **decisions in favor of natural gas accelerate the climate crisis.[10]**



In many countries in the region, gas investments are being proposed as an engine for economic recovery and low-cost energy. This report proves that if the same funds that are being invested in the generation of electricity from natural gas were instead directed towards renewable energies then better economic results would be obtained and the region could recover faster and strengthen from the post-pandemic crisis, being in a better position to tackle climate change.

The global energy crisis we are experiencing at the time of publication of this report has sharply increased the price of natural gas. However, this could change in the medium term as countries seek to decarbonise their energy sector. On the other hand, the costs of renewables have fallen dramatically over the last decade and continue to fall year on year. Renewables now present cheaper options than fossil thermal generation in most LAC countries.

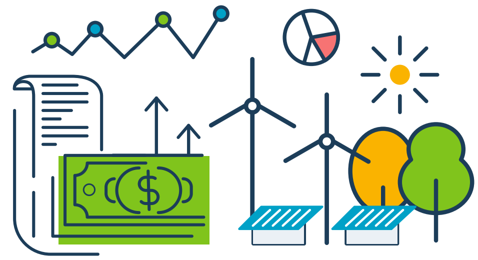
This report demonstrates that there are better options for electricity generation than the use of natural gas. Renewables provide greater social, economic and environmental benefits.

Natural gas is not a transition technology, but a regression.

6. UNEP (2021), An Eye on Methane, International Methane Emissions Observatory 2021 ReportFacts about Methane.
7. IEA (2021) Net Zero by 2050.
8. UNEP, (2021) Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions.
9. IPCC (2022) Sixth Assesment Report.
10. IPCC (2022) Figure SPM.2 in IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

The great opportunity

The benefits are not only economic. **Renewable energy would provide energy access to rural and remote areas that are currently marginalised.** Their inhabitants would benefit directly by replacing the use of fossil fuels for electricity generation, water heating, lighting and other uses, reducing the risks of fire and air pollution.



The burning gas is toxic to breathe.

Although it is not the objective of this report, it is worth mentioning that other studies have shown that at least 21 toxins were identified in unburned natural gas, including bezene, a carcinogen that harms white and red blood cells in the human body. Gas stoves emit much higher levels of methane than initially thought, even while they're switched off. Cooking with gas also releases toxic substances that affect health and are even linked to causes of cancer[11]. While natural gas is installed in many LAC households, there is sufficient evidence to urgently begin an orderly transition to renewables for electricity generation, including for cooking and heating.

This report analyses electricity generation, but there are other uses of gas that are being promoted, such as transport, heating and household cooking. It is worth considering what the impact of natural gas in these sectors would be compared to renewable energies.

Wind and solar power may require balancing with other energy sources, but gas is not the only, nor the best, resource available to do so. Other sources are available, such as hydropower. Battery storage is also starting to become competitive to bring stability to the system. It is important to take these factors into account as any new investment in fossil generation built today is designed to run for decades, with the risk of becoming stranded assets for countries.

In the face of the evidence analysed, this report has found that natural gas is not the best investment for electricity generation in LAC. **The use of renewable energies represents a great opportunity for the region to obtain greater economic, social and climate benefits in the coming decades.**

This report offers concrete evidence for LAC countries to consider in their national energy and climate debates and planning processes. This evidence may prove useful amid the economic, climate, and social crisis the region – and the world – are currently going through.

11. EOS (2022) Hazardous Air Pollutants Found in Cooking Stove Gas.

The road ahead is clear: all sectors must collaborate and enable an economic, sustainable, and technological development of the region that will establish the foundation for the impetus of the fourth industrial revolution.

In this sense, the public sector has a fundamental role to create the conditions for renewable energies to roll out much faster. This means changing the flow of funds that currently subsidize fossil fuels, accelerating the legal frameworks for renewable energies, securing the proper functioning of energy grids, and the responsible use of the land for renewable energy projects. The renewable energy scenario allows governments to reach energy independence, reduce the outflow of foreign exchange from the country, and thereby decrease energy imports and improve public finances.

Governments should also work side by side with the private sector. This includes securing the proper legal framework and facilitating company investments with contracts and guarantees for them to focus their investments in the renewable sector.

This report also has concrete evidence for the private sector. The costs of renewable energy have been drastically reduced over the last few years. This is an opportunity to work hand in hand with governments by contributing to technological development free of the risk of stranded assets. Solar and wind have already reached cost parity – and in several countries overcome – hydrocarbon-based generation, making the renewable energy pathway a no regret option. **These technologies are year by year winning the race to be the cheapest sources of new generation.** The region also has some of the world's best conditions in terms of solar radiation and wind power[12].

"Climate activists are sometimes depicted as dangerous radicals, but the truly dangerous radicals are the countries that are increasing the production of fossil fuels. Investing in new fossil fuels infrastructure is moral and economic madness. Such investments will soon be stranded assets,"

UN Secretary General Antonio Guterres, April 2022[15] .

This report answered one question, but raised others: what's stopping a significant expansion of renewable energy across LAC? Will governments redirect their efforts on natural gas to support renewable energy technologies instead? Or will they continue on their current path, with the possibility of natural gas infrastructure becoming a stranded asset in the medium term and ultimately failing to deliver on their climate targets?

12. UNEP (2019) Carbono Cero.
13. UNEP (2022) Secretary-General Warns of Climate Emergency, Calling Intergovernmental Panel's Report 'a File of Shame', While Saying Leaders 'Are Lying', Fuelling Flames.

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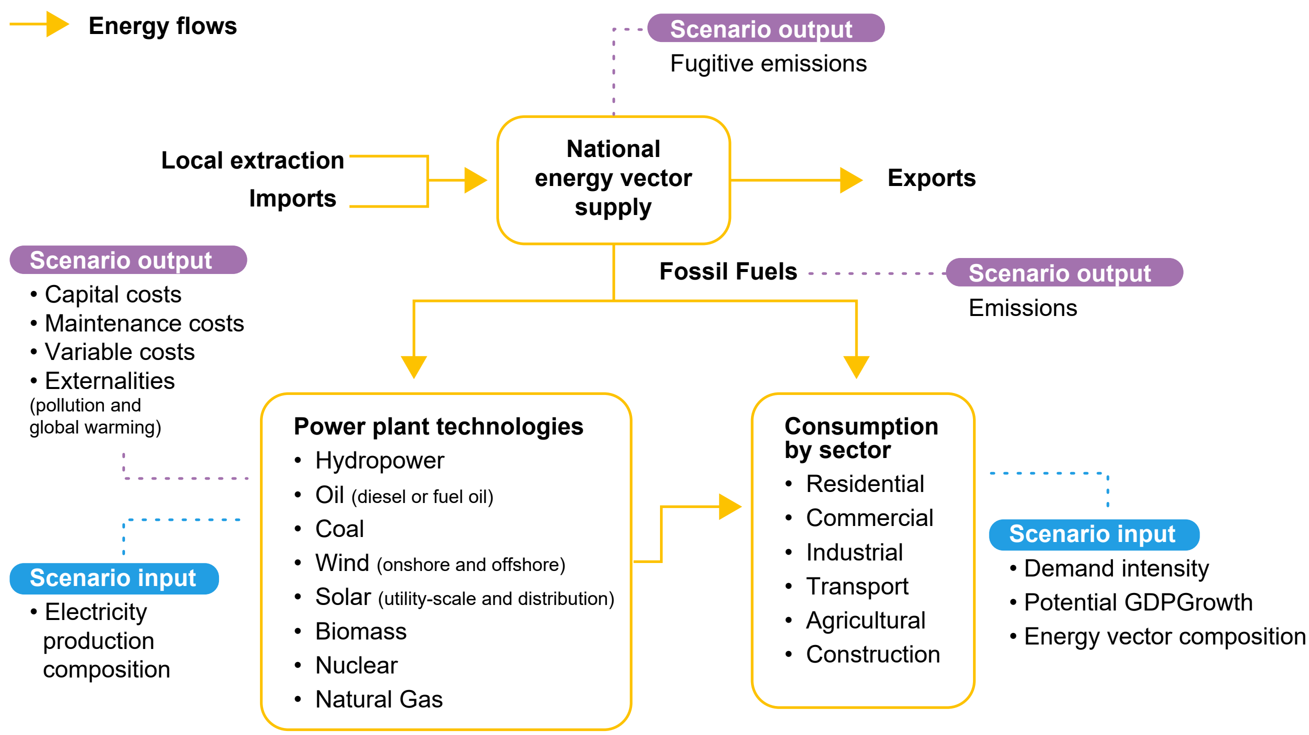
Appendix A: Model assumptions

The model consists of a Python simulation tool using an OSeMOSYS-inspired (Howells et al., 2011) accounting model that creates energy demand and supply scenarios. Figure A.1 shows the overview of the modeling approach. Although 2020 databases are available, to avoid anomalies caused by the COVID-19 pandemic, the model uses 2019 as its base year. To specify demands, energy consumption by sector (i.e., residential, commercial, industrial, transport, agricultural, and construction sectors) and exports per energy carrier are included. The model includes the consumption and production per energy carrier. The flexibility of the model allows creating multiple scenarios to answer almost any policy question of the type "what if".

Figure A.1. Modeling approach overview.



Source: Authors' own research.

The assumptions per scenario of general demand elements are in Table A.1. Figure A.2 shows the energy intensities in 2019 per country and sector. The assumptions of energy vector composition per sector demands are in Table A.2., which are equal across the scenarios described in Chapter 4.

One of the consumption energy vectors is electricity. The higher the electrification share of total energy consumption or the higher the overall demand, the more production requirement. Planned and phased-out power plants modify 2019 existing electricity generation capacity. The modeling criteria for unplanned production is defined for each power generation technology and is aligned with each scenario's narrative. The assumptions of the unplanned power generation composition are in Table A.3.

Table A.1. General assumptions for all countries and scenarios.

	Assumption
GDP growth	The model includes the assumption of a 2.6 per cent constant potential GDP growth throughout the 2019-2050 simulation horizon.
Energy intensity	Energy intensity decreases 27 per cent by 2050 relative to 2019 following the IEA's Sustainable Development scenario for South America. This assumption is made in the model for all LAC. The IEA defines primary energy intensity changes but this modeling assumes the same change for final energy intensity.
Discount rate	10 per cent

Source: Authors' own research.

Figure A.2. Energy intensity per country and sector in 2019

Subregion	Country	Agriculture, fisheries, and mining	Commercial, services, public, construction and ..	Industry	Residential	Transport
Mexico	Mexico	0.15	0.08	1.22	0.58	1.57
Central America	Costa Rica	0.06	0.17	0.57	0.36	1.87
	El Salvador	0.06	0.16	1.18	1.20	2.63
	Guatemala	0.00	0.18	0.85	5.64	2.51
	Honduras	0.10	0.36	1.07	3.18	2.80
	Nicaragua	0.22	0.56	1.09	4.12	2.69
	Panama	0.02	0.26	0.60	0.48	1.42
Caribbean	Barbados	0.00	0.32	1.79	0.34	1.30
	Belize	0.03	0.40	1.63	1.60	5.02
	Cuba	0.09	0.30	1.39	0.63	0.39
	Dominican ..	0.08	0.12	0.77	0.70	1.27
	Grenada	0.26	0.25	0.23	0.99	1.88
	Guyana	1.73	0.11	0.96	0.73	2.71
	Haiti	0.00	0.09	0.86	7.37	1.48
	Jamaica	2.22	0.33	0.57	0.97	3.94
	Suriname	0.79	0.19	0.87	0.71	2.01
	Trinidad and..	0.00	0.09	12.16	0.55	1.68
Andean Countries	Bolivia	0.39	0.25	2.22	1.39	5.15
	Colombia	0.18	0.16	0.82	0.65	1.39
	Ecuador	0.07	0.45	0.98	0.83	3.43
	Peru	0.41	0.14	0.81	0.76	1.94
	Venezuela	0.00	0.22	3.36	1.32	3.30
Brazil	Brazil	0.27	0.12	1.35	0.47	1.50
Southern Cone	Argentina	0.35	0.21	1.28	1.30	1.79
	Chile	0.82	0.15	0.79	0.62	1.62
	Paraguay	0.00	0.25	1.83	1.96	2.96
	Uruguay	0.14	0.12	1.58	0.64	1.02

Source: Authors' own research using (OLADE, 2020)

Table A.2. Demand energy vector composition rules for countries and scenarios.

Sector	Assumption
Transport	The proportion of kerosene/jet fuel, LGP, and natural gas is kept constant. Diesel and gasoline reach 10 per cent each. The remaining demand is electrified.
Residential	The scenarios include the assumptions of a decrease in firewood use to 10 per cent participation as a maximum (countries with lower shares are kept constant). The percentage of LPG and natural gas are held constant. The scenario includes the electrification of the rest of the demand.
Commercial and construction	Without change relative to the base year.
Industrial	The scenarios keep the proportion of LGP or natural gas. They also hold the participation of coke, sugar cane, and firewood constant. The rest of the demand is electrified.

Source: Authors' own research.

Table A.3. Unplanned power generation composition rules for countries.

Scenario	Assumption
Business-as-usual	In this scenario, the distribution per power plant is the same as the 2015-2019 total electricity generation mix average.
Natural gas	The only difference relative to the business-as-usual scenario is that the share of diesel and coal power plants generation are substituted with natural gas.
Renewable energy	The shares of unplanned power plants per country are obtained from (Vergara et al., 2019). Differences are made between countries without and with reported geothermal potential. The former deploy only wind (62 per cent), solar (34 per cent) and hydro (4 per cent). The latter deploy wind (56 per cent), solar (31 per cent), hydro (3 per cent), and geothermal (10 per cent). The countries with geothermal potential according to (Gishclear et al., 2020) are Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, Peru, Bolivia, Chile, and Argentina. The share between onshore and offshore wind power plants is defined based on historical shares (IRENA, 2019b); 77 per cent and 23 per cent, respectively. The share of utility-scale photovoltaic systems and distributed generation (at customer premises) is also defined based on historical shares (IRENA, 2019c); 80 per cent and 20 per cent, respectively.

Source: Authors' own research.

The outputs of each scenario are emissions, costs, and power sector jobs. The modeling tool quantifies three types of emissions: energy consumption, power sector, and fugitive emissions of the natural gas value chain. The natural gas value chain is different across countries. Thus, there are different imports and exports proportions, which link to future demand. Table A.4. shows the assumptions for natural gas production, imports, and exports.

Table A.4. Natural gas production, imports, and exports for all scenarios.

	Assumption
Fugitive emissions	The production of natural gas generates fugitive emissions with an estimated emission factor of 7.36 Gg/PJ, which is about 13 per cent of the combustion emission factor of natural gas. For countries with only natural gas imports, an estimation of 3.72 Gg/PJ is included in the model. These estimations are based on a compilation of greenhouse gas inventories across LAC, linking reported emissions of specific value chain components with production and consumption statistics. Therefore, it is vulnerable to underestimation issues if these are present in the inventories.
Imports	The assumption that Panama, the Dominican Republic, Jamaica, and Uruguay import 100 per cent of their natural gas throughout the period is part of the model. Other import shares are: Mexico (33 per cent), Guyana (97 per cent), Venezuela (2 per cent), Brazil (32 per cent), Argentina (17 per cent), and Chile (78 per cent). The unnamed countries only import natural gas for power generation in the Natural Gas scenario. Although there are differences between pipeline and liquified gas prices, we assume power plants pay the same price regardless of how the country transports its gas (see Table A.5.). The countries with pipeline imports are Mexico (59 per cent), Brazil (51 per cent), and Argentina (80 per cent). The rest of the imports are through liquified petroleum gas.
Exports	For exports, in the model, Trinidad and Tobago, Bolivia, Peru, and Argentina are the LAC suppliers to the rest of the countries. In 2019, only Trinidad and Tobago, Bolivia, and Argentina exported natural gas to LAC: 18.8 per cent, 21.3 per cent, and 0.27 per cent of total LAC demand, respectively. The model includes the assumption that Trinidad and Tobago and Bolivia will maintain exports compatible with their proven reserves. Considering that Trinidad and Tobago and Bolivia exported 4.5 per cent and 9.6 per cent of LAC imports in 2019, the exports drop to 1.6 per cent and 0 per cent by 2035. The share decreases because the LAC demand increases and exports remain relatively constant or decline. We assume Argentina's export share remains constant at 0.27 per cent of LAC natural gas demand. 100 per cent of Bolivian and Argentinian exports are via pipeline.

Source: Authors' own research.

The costs include capital expenses (CAPEX), fixed operational expenditures (OPEX), and variable OPEX of power plants. They also quantify global warming and local pollution externalities associated with electricity generation. Besides power generation costs, the model includes transmission and distribution costs, CAPEX, and OPEX. Finally, natural gas exports are computed as revenue and compared across scenarios (see Table A.4. for natural gas trade assumptions). The costs are discounted to 2021 (see Table A.1. for the rate). Table A.5. presents the assumptions for each cost component.

Table A.5. Power sector characterization.

	Assumption
Capital and fixed operational costs of power plants	One of the main data sources is the National Renewable Energy Laboratory's (NREL) Annual Technology Baseline (ATB). We include the Wind Speed Class 1 option for offshore wind for costs and land-based wind, an average of all classes. A storage cost ratio is obtained by dividing utility-scale solar with storage and without storage costs, which are used to increase the cost of wind. An average of the residential and commercial options for distributed solar plus the storage cost coefficient is used from 2035 onwards. We incorporate the natural gas combined cycle plant characteristics from the database, costing 1,053.7 MUS$/GW in 2019 and 906.8 MUS$/GW in 2050. Combustion power generation relies on heat rates to calculate how much fuel is needed. In turn, the variable OPEX can be computed with fuel cost data. Heat rates in MMBtu/MWh in 2019 for coal, natural gas, and diesel at 8.55, 6.36, and 7.96, respectively, are used. The ATB database assumes a slight heat rate improvement for coal by 2050, placing the value at 7.41 MMBtu/MWh (i.e., a decrease of 13.33 per cent achieved by 2030).
The capacity factors of power plants	They derive from each country's statistics and remain constant throughout the period. Suppose the a country does not have power generation of a specific type. In that case, a simple average of all net capacity factors suggested by NREL's ATB is included. The default net capacity factors for geothermal, biomass, natural gas, coal, and diesel power plants is 0.9 for countries where these plants did not exist in 2019. For offshore wind, it is 0.46; for land-based wind, it is 0.41; for distributed solar, it is 0.156; for utility-scale solar with battery storage, it is 0.204; for nuclear, it is 0.934. For hydropower, the value is 0.44, although it is only used if hydropower plants are planned but not previously installed in a country.

Planned power plants	These values are based on the NDC assessment for LAC in 2018 report from OLADE.
Phased-out power plants	The model includes values from the NDC assessment for LAC in 2018 from OLADE. The BAU scenario only has the planned phase-out capacity. However, the natural gas and renewable energy scenarios include the assumption of eliminating the existing capacity (i.e., the 2019 capacity) of coal and diesel plants by 2040. This assumption is made with a minimum life of 21 years. However, many coal and diesel plants have been in operation for longer.
Variable and fuel costs for power plants	The model includes scenario trajectories for fossil fuel projections from the 2021 World Energy Outlook (WEO). It follows the WEO's Stated Policies scenario for all scenarios: oil increases 2.6 per cent, natural gas 1.8 per cent, and coal remains constant (author's estimation is based on Table 2.2. of the 2021 WEO). Three primary data sources are part of the scenarios for the base year prices. The price of natural gas is from RMI at 9.15 MUS$/PJ, which includes liquefaction and transport costs. The model includes the assumption that the natural gas price from pipeline transport avoids the liquefaction stage. With a natural gas price of 4.15 MUS$/PJ to account for country exports, exports of liquified natural gas are priced at 7.62 MUS$/PJ for this effect. The coal price is from the IMF's commodity indices and is at 2.84 MUS$/PJ in 2019. The diesel price is a simple subregional average of prices on the Global Petrol Prices website, including taxes. The prices are the following: for Mexico, it is 24.93 MUS$/PJ; for Central America, it is 19.47 MUS$/PJ; for the Caribbean, it is 31.15 MUS$/PJ; for Andean Countries, it is 16.19 MUS$/PJ; for Brazil, it is 19.73 MUS$/PJ; and for the Southern Cone, it is 23.35 MUS$/PJ. We assume these costs are applicable for oil-based electricity generation.
Power sector losses	All scenarios consider that energy losses in the electricity grid– transmission and distribution– drop linearly per country starting from current values to a 10 per cent maximum by 2050. Countries with lower values remain constant.
Power transmission and distribution costs	The data is from OSeMOSYS starter kits for LAC for unit transmission and distribution costs. The units of costs are converted from MU$ per unit of capacity to MU$ per unit of energy (assuming transmission and distribution lines transport energy the entire year) and multiplied by the electricity generation of each power plant type. An additional assumption is that the fixed operating costs are 2 per cent of the CAPEX. In sum, the model includes 23.66 M US$/PJ for CAPEX (based on new electricity generation) and 0.473 M US$/PJ for OPEX (based on total electricity generation).

Externalities	Externalities are taken from the International Monetary Fund. The global warming externalities per unit of consumption are 0.111 US$ per liter for gasoline, 0.127 US$ per liter for diesel, 4.37 US$ per GJ for coal, and 2.586 US$ per GJ for natural gas. Local air pollution values are different per country and are based on individual willingness to pay to cover their insurance.

Source: Authors' own research.

Not all transmission costs apply equally for a given power plant in the model. As presented in Table A.6, the cost percentage is assigned to each power plant technology. Distributed solar does not have transmission costs, whereas we assume fossil fuel power plants have only 30 per cent of the total transmission capital costs, considering they are closer to the end-uses.

Table A.6. Percentage of transmission costs per power plant.

Tech	Transmission costs
Offshore Wind	100 %
Onshore Wind	100 %
Utility-scale Solar	100 %
Distributed Solar	0 %
Geothermal	100 %
Hydro	100 %
Nuclear	30 %
Biomass	100 %
Thermal Coal	30 %
Thermal Natural Gas	30 %
Thermal Diesel	30 %

Source: Authors' own research.

To estimate jobs, we include the coefficients of Table A.7. Construction, installation, and manufacturing jobs depend on new capacity, whereas operations and maintenance jobs depend on installed capacity.

Table A.7. Jobs multiplication factors.

Tech	Construction and installation (Job years/ MW)	Manufacturing (Job years/ MW)	Operations & maintenance (Jobs/MW)
Thermal Coal	11.4	5.1	0.14
Thermal Natural Gas	1.8	2.9	0.14
Nuclear	11.8	1.3	0.6
Biomass	14.0	2.9	1.5
Hydro	7.5	3.9	0.2
Onshore Wind	3.0	3.4	0.3
Offshore Wind	6.5	13.6	0.15
PV Utility+Battery Solar	13.0	6.7	0.7
PV DistResi Solar	13.0	6.7	0.7
Geothermal	6.8	3.9	0.4
CSP Solar	8.9	4.0	0.7

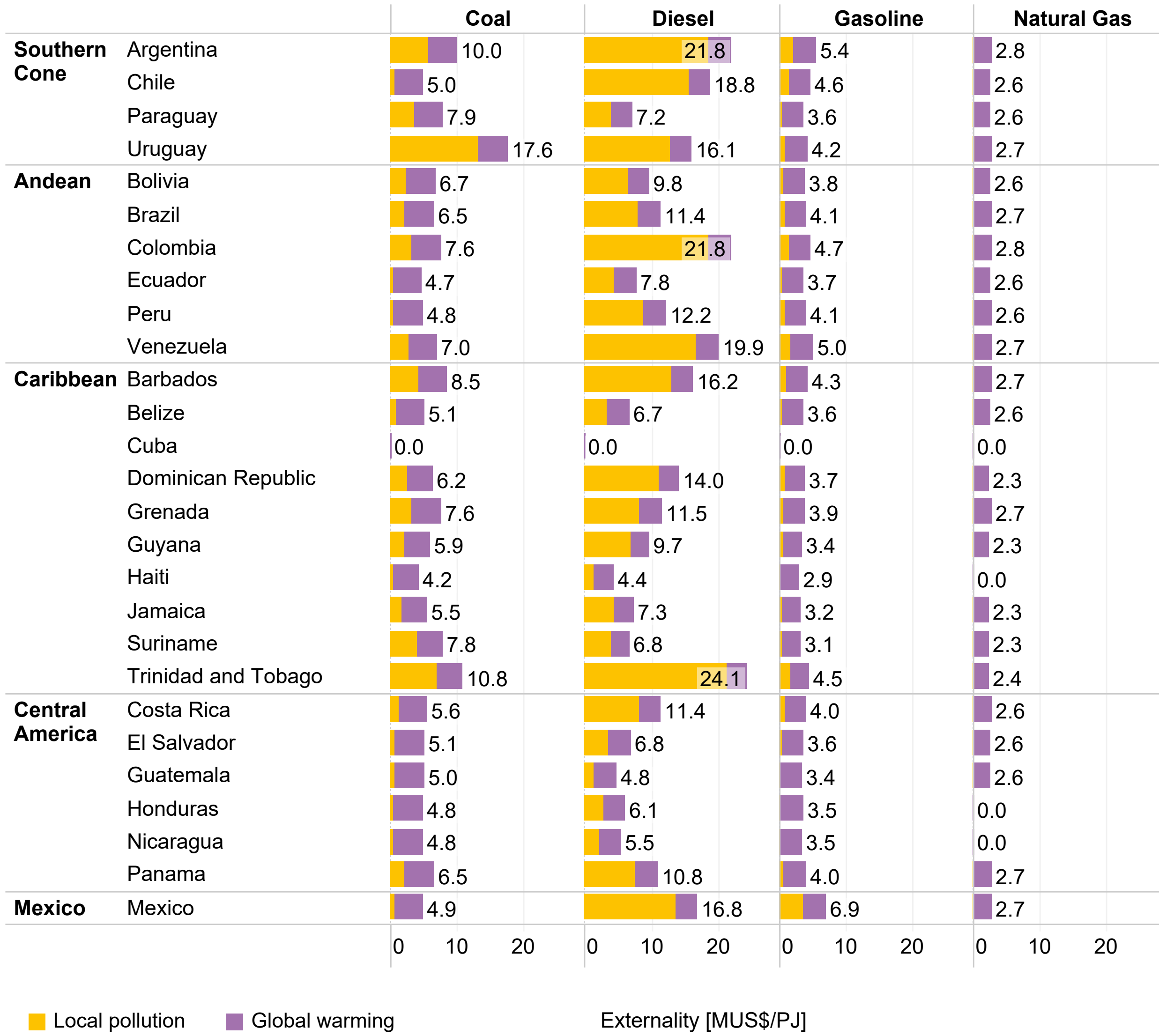
Source: (Dominish et al., 2019).

Appendix B: Externalities of fossil fuels

Fossil fuels prices have subsidies and they do not reflect the complete supply and environmental costs. The International Monetary Fund (IMF) estimated efficient prices (i.e., prices without subsidies) for 191 countries (Coady David et al., 2019). They estimated the value of environmental costs, or externalities, associated with fossil fuels for different elements: transport, impacts of local air pollution on health, and global warming. The externality estimates have considerable uncertainty but are as real as supply costs. Notwithstanding possible parametric differences, the IMF offers country-specific estimates. This study considers local pollution and global warming externalities to focus on power generation effects with fossil fuels. Figure A.3 shows the values used in this work for LAC countries. The authors recognize there are unaccounted externalities, like energy security or system stability, because they are harder to quantify.

Local pollution externalities depend on the population exposure to particulate matter and its incidence in causing premature cardiovascular and pulmonary disease deaths. Health impacts convert into a monetary component through the willingness to pay to reduce health risks by country. Global warming externalities relate to the damages caused by climate change. Although there are multiple options to measure global warming costs, the authors define an illustrative value of $40 per ton of 2015 emissions that rises 3 per cent in real terms. Other options include the social cost of carbon (associated with future climate change damages with an additional ton of current emissions) and the cost of emissions to cost-effectively meet temperature stabilization goals (Coady David et al., 2019).

Figure A.3. Modeling approach overview.



Source: Authors' own research using (Coady David et al., 2019)

Fugitive emissions must also be accounted for when understanding fossil fuel externalities. Table A.8 shows the venting and fugitive emissions for five countries in LAC according to the latest GHG inventory submitted to the United Nations Framework Convention on Climate Change (UNFCC). Panama did not estimate fugitive emissions on their latest inventory. Ecuador, Brazil, Uruguay, and the Dominican Republic present their fugitive emissions as an aggregated category of oil and gas fugitive emissions, corresponding to 50.61 Gg CO_2eq in 2015, 15,443 Gg CO_2eq in 2016, 2.51 Gg CO_2eq in 2019, and 60.26 Gg CO_2eq in 2019, respectively. There are no available inventories for Trinidad & Tobago, Cuba, Jamaica, Bolivia, and Venezuela on the UNFCC website.

Table A.8. Fugitive emissions by country according to their latest GHG Inventory [Gg CO_2eq].

Country		Mexico	Argentina	Colombia	Chile	Peru
Year		2015	2016	2019	2018	2014
Venting		4,759.99	2,978.70	129.84	12.30	228.07
Fugitive	Production	1,049.86	3,398.76	3,072.94	380.90	
	Processing	1,997.59	258.57	3.56	32.50	1483.80
	Transport and storage	1,270.13	523.57	184.57	82.10	218.02
	Distribution	1,384.47	1,868.80	455.67	234.00	282.60

Source: Authors' own research with GHG inventories from countries.

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