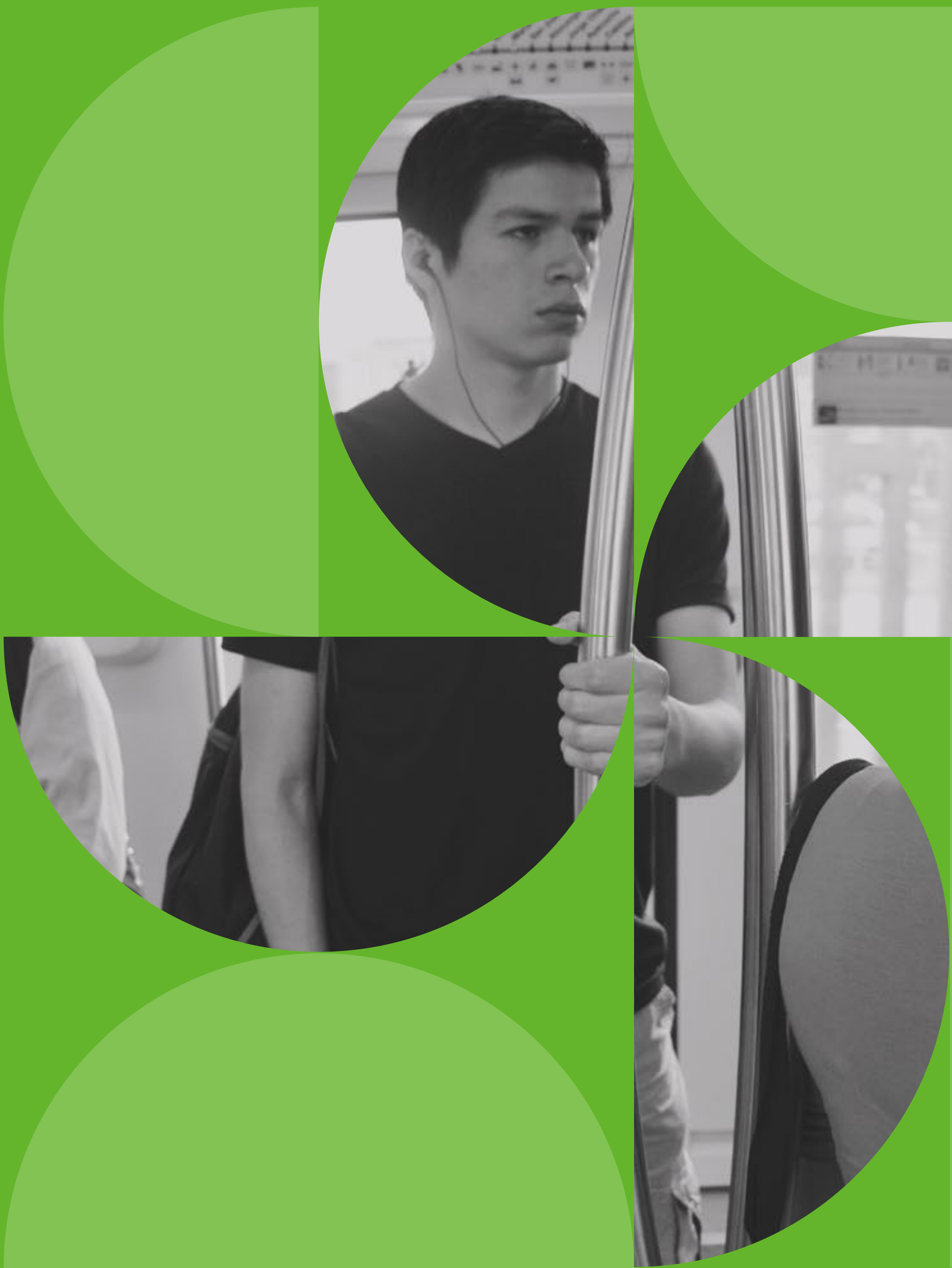
JUST ENERGY TRANSITION

Scenarios Peru



IDFC International Development Finance Club
FACILITY

CAF DEVELOPMENT BANK OF LATIN AMERICA AND THE CARIBBEAN

Just Energy Transition / Scenarios Peru

CORPORACION ANDINA DE FOMENTO- Av. Luis Roche, Torre CAF Urb.
Altamira, Caracas (Chacao) Miranda 1060, Venezuela. RIF: G200015470

Contribution of CAF to the Climate Facility of the International Development Finance Club

Report coordinated by the Climate Action and Positive Biodiversity Management, the Knowledge Management and the Physical Infrastructure and Digital Transformation Management.

Edgar Salinas, principal executive, Direction of GreenOperationsandFinance.
Walter Cont, senior executive, Direction of Sectoral Analysis.
Juan Ríos, principal executive, Direction of Transport and Energy.

Authors
The GME team (in alphabetical order) included Agustín Ghazarian, Coline Champetier, Darío Quiroga, Francisco Baqueriza, Nicolás Barros, Laura Souilla, Ramón Sanz and Roberto Gomelsky.
The authors thank Edgar Salinas, Walter Cont and Juan Ríos for their comments, suggestions and support for the development of this document.

Editor
CAF
Direction of Strategic Communication

Graphic design
https://cleiman.com
Universal neuroinclusive graphic design, with principles of accessibility and visualization for neurodivergent readers

Photography
Portrait: ©AdobeStock
Internal: © CAF - © Pexels

Just Energy Transition

Scenarios Peru

INDEX

Chapter 1 Diagnosis and base line

26-88

Chapter 2 Energy projection methodology

89-105

Chapter 3 Transition scenarios

106-164

TABLES AND GRAPHICS

List of abbreviations

AFOLU agriculture, forestry and other land use

BAU business as usual

CAGR compound annual growth rate

CAPEX capital expenditures

CCUS carbon capture, use, and storage

CEPAL Economic Commission for Latin America and the Caribbean

CNG compressed natural gas

COES Committee for the Economic Operation of the System (*Comité de Operación Económica del Sistema*)

EE energy efficiency

FISE social energy inclusion fund

ENCC national strategy on climate change

FOSE electric social compensation fund

GCRI global climate risk index

GDP gross domestic product

GDPpc gross domestic product per capita

GHG greenhouse gases

HDI human development index

IEA International Energy Agency

ISIC International Standard Industrial Classification

JET just energy transition

LEAP SEI's low emissions analysis platform

LNG liquefied natural gas

LPG	liquefied petroleum gas
MINEM	Ministry of Energy and Mines
MUSD	millions of dollars
UNFCCC	United Nations Framework Convention on Climate Change
NCRE	non-conventional renewable energy
NDC	nationally determined contributions
NZ	net zero
OLADE	Latin American Energy Organization
OSINERGMIN	Regulatory Agency for Investment in Energy and Mining
PJ	petajoule (10^{12} J)
PNER	National Rural Electrification Plan
PPP	purchasing power parity
SEI	Stockholm Environment Institute
SHW	sanitary hot water
sieLAC	Energy Information System for Latin America and the Caribbean
TJ	terajoule
UNDP	United Nations Development Programme

Foreword

1. General objective

The general objective of the project was to develop a methodological approach to define the concept of just energy transition (JET) in a national context, with potential application in the CAF – development bank for Latin America and the Caribbean – member countries and to evaluate the proposed approach in Brazil, Colombia, Mexico, Peru, and the Dominican Republic.

2. Specific objectives

The specific objectives of this report are the following:

1. to define a methodological approach to address the just energy transition in the region in a comprehensive way;
2. to diagnose the national energy systems (target countries) – in particular, the power systems – in the context of the energy transition process;
3. to define national scenarios for the low-carbon development model of the energy transition in the target countries, including those elements to be electrified in energy sectors that are currently not being served by the power sector, within the prospective requirements;
4. to model the viable energy transition alternatives in the previously defined context.

3. Organization of the Just Energy Transition series

In order to meet the objectives indicated above, the study was conducted between October 2022 and October 2023. The series was organized into seven reports.

1. Just Energy Transition / Conceptual framework for the region. Analysis in the national context
2. Just Energy Transition / Projection assumptions
3. Just Energy Transition / Scenarios for Brazil
4. Just Energy Transition / Scenarios for Colombia
5. Just Energy Transition / Scenarios for Mexico
6. Just Energy Transition / Scenarios for Peru
7. Just Energy Transition / Scenarios for the Dominican Republic

The reports were organized following the alphabetical order of their names.

4. Organizational aspects

This report has been financed by CAF and is published to communicate the results and conclusions obtained to the community interested in Latin American development. Therefore, the document has not been prepared following the procedures of an official document. Some of the sources cited in this report could be informal documents that are difficult to obtain.

The conclusions and opinions expressed herein are exclusively those of their authors and should not be attributed to CAF or GME, their affiliates, or executive directors, and do not necessarily reflect their points of view.

CAF and GME do not guarantee the accuracy of the data included in this publication and accept no liability whatsoever for the consequences of its use. The colors, borders, names, and classifications of any map in this report do not imply any judgment by CAF on the legal or otherwise condition of the territories, or the approval or acceptance of such borders.

The reports in this series are documents for debate; therefore, they are subject to the same copyright as other publications by CAF.

CAF promotes the dissemination of its papers and authorizes their immediate reproduction for free as long as they are not used for commercial purposes.

Edgar Salinas, Juan Ríos, and Walter Cont from CAF formed a working team that established the terms of reference and supervised the development of the abovementioned reports by GME consultants.

The GME team – in alphabetical order – was composed of Agustín Ghazarian, Coline Champetier, Darío Quiroga, Francisco Baqueriza, Nicolás Barros, Laura Souilla, Ramón Sanz, and Roberto Gomelsky.

5. Scenarios: Peru

This report contains the analysis of the energy transition for Peru and is organized into four chapters.

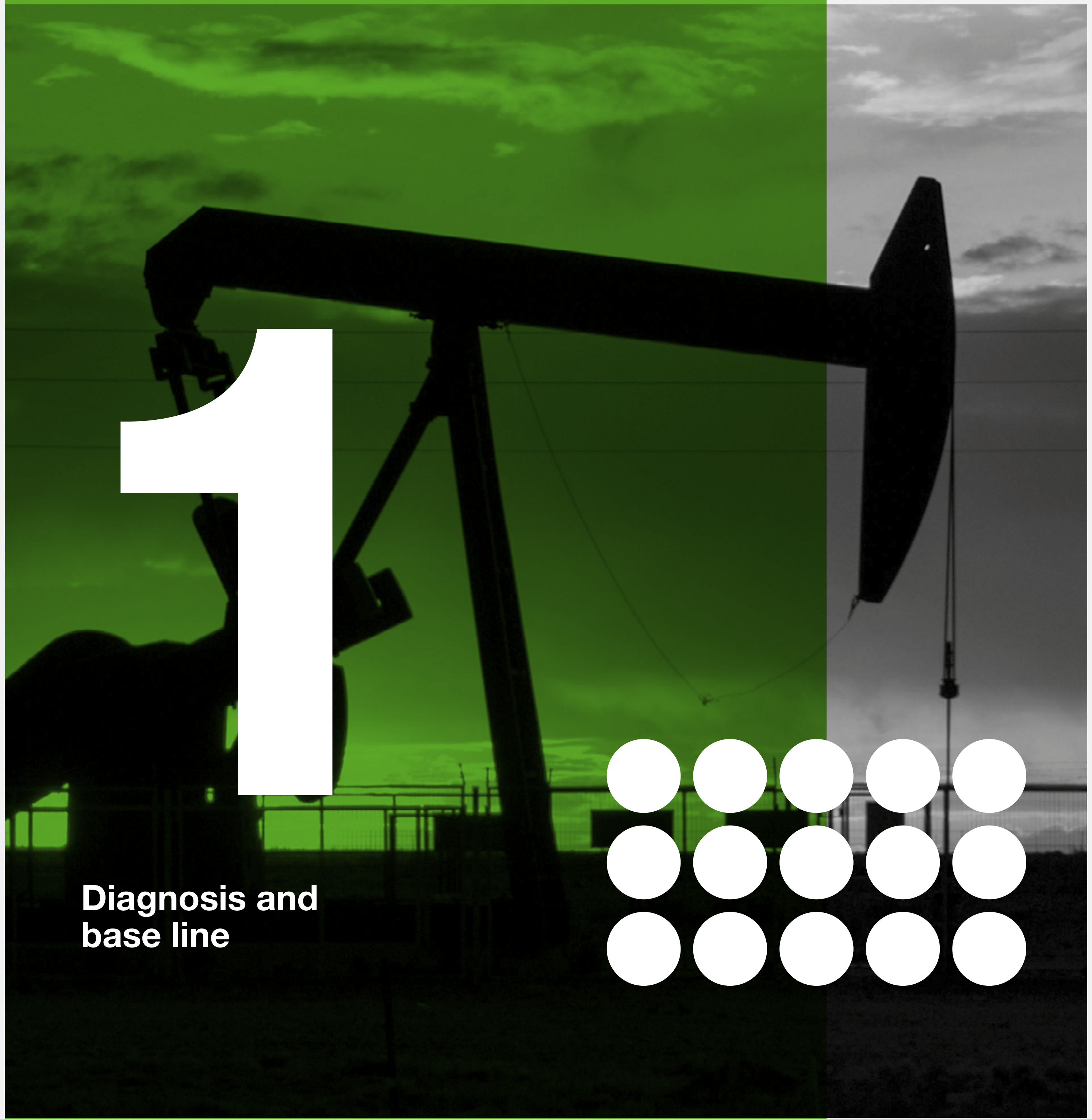
- **Diagnosis and base line.** This chapter establishes the diagnose of the base line in terms of sources and energy uses, characteristics of the power sector, environmental aspects (greenhouse gas (GHG) inventories, commitments), and institutional, regulatory, and public policy aspects, among others. It allows us to present the starting point of the energy projections and to identify the main characteristics that may condition the just energy transition strategy.

- **Energy projection methodology.** This chapter summarizes the low-emissions analysis platform (LEAP) model and its use to model emissions in the energy sector[1]. Energy demand projection methodologies are presented by sector, subsector, use, and source, as well as the power generation modeling. It also describes the three projection scenarios contemplated and the main assumptions considered.

- **Transition scenarios.** This chapter presents the projections in terms of emissions and energy demand for the three scenarios previously defined (Business as Usual (BAU), Net Zero 2050 (NZ 2050), and Net Zero 2060 (NZ 2060)). It details the results by sector and the main explanatory assumptions, and presents the needs in terms of energy transition investment related to the power sector and its end uses. It concludes with the starting point and the end point of the main transition indicators by scenario.

1 More specifically, the LEAP (Low Emissions Analysis Platform) model was used to model the emissions related to burning fuel.

- **Proposal for the roadmap for a just energy transition.** The roadmap describes the public policies to be developed and the segments that require concessional finance or support to accompany the just energy transition scenarios previously presented.



1. General characterization

Socio-economic aspects

Peru has a population of over 33 million people, with a population density of 26 inhabitants per square km; 79 % of its population lives in urban areas.

Table 1 Socio-economic indicators

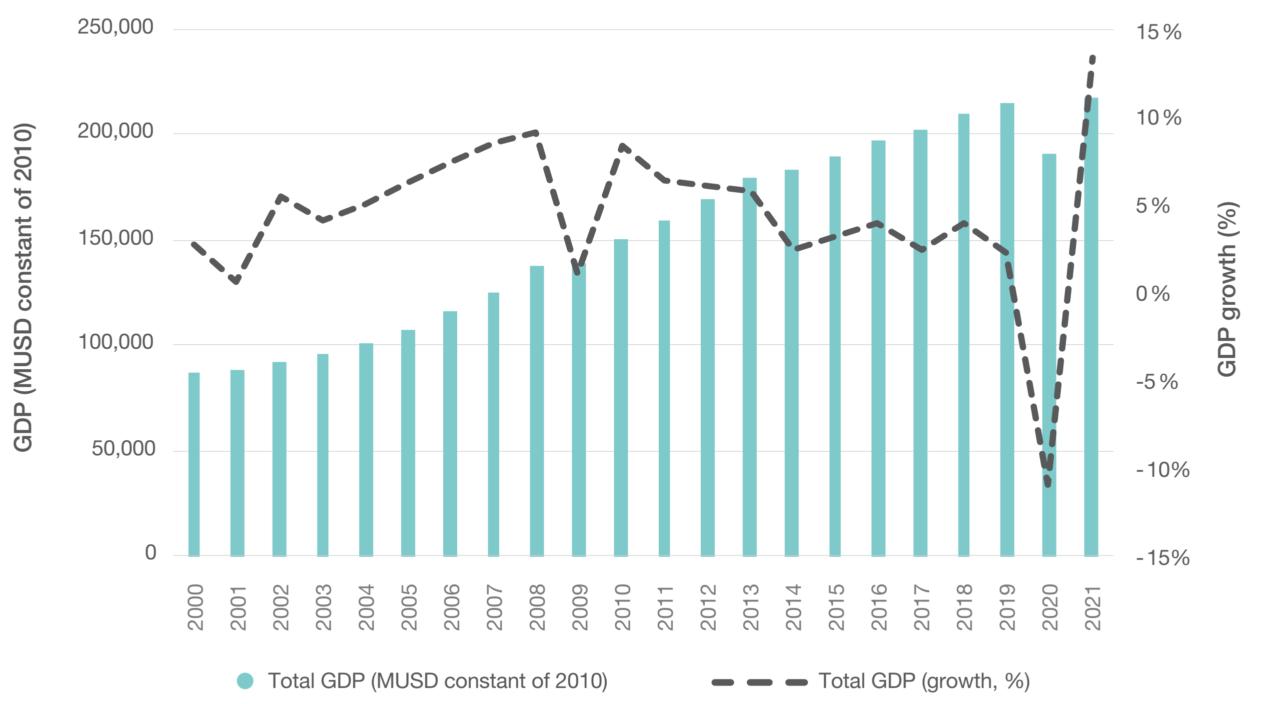
Indicator/Country	Peru
Total population (2021, million)	33.36
Population density (inhab./km^2)	26
Urban population (%)	79 %
GDP per capita 2021 (USD at constant 2010 prices)	6,506
Extreme poverty index 2020	8.6 %

Source: Own preparation con base en datos del Banco Mundial y CEPALSTAT.

In the last decades, Peru's gross domestic product (GDP) experienced solid economic growth, with an annual figure of around 5% (between 2000 and 2019). More recently, in the last five years, Peru's economic growth slowed down; in

2020, the impact of the COVID-19 pandemic on the Peruvian economy was significant, like in many other countries in the region.

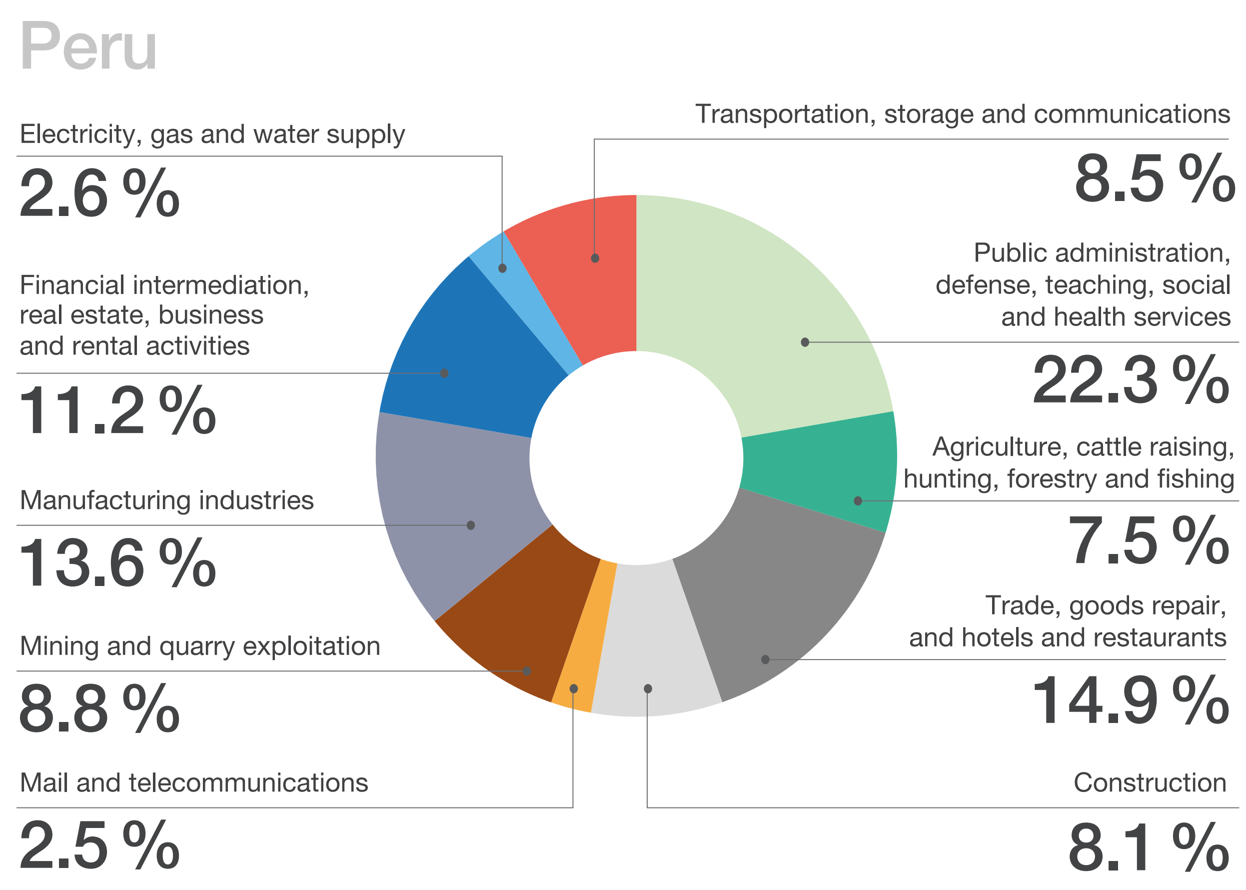
Graphic 1 GDP and annual growth rate, MUSD constant of 2010 and %



Source: Own preparation based on data from the World Bank.

The public administration is the sector with the largest share in the GDP (22.3% of GDP), followed by the commercial sector (14.9%), the manufacturing industry (13.6%), and financial intermediation (11.2%).

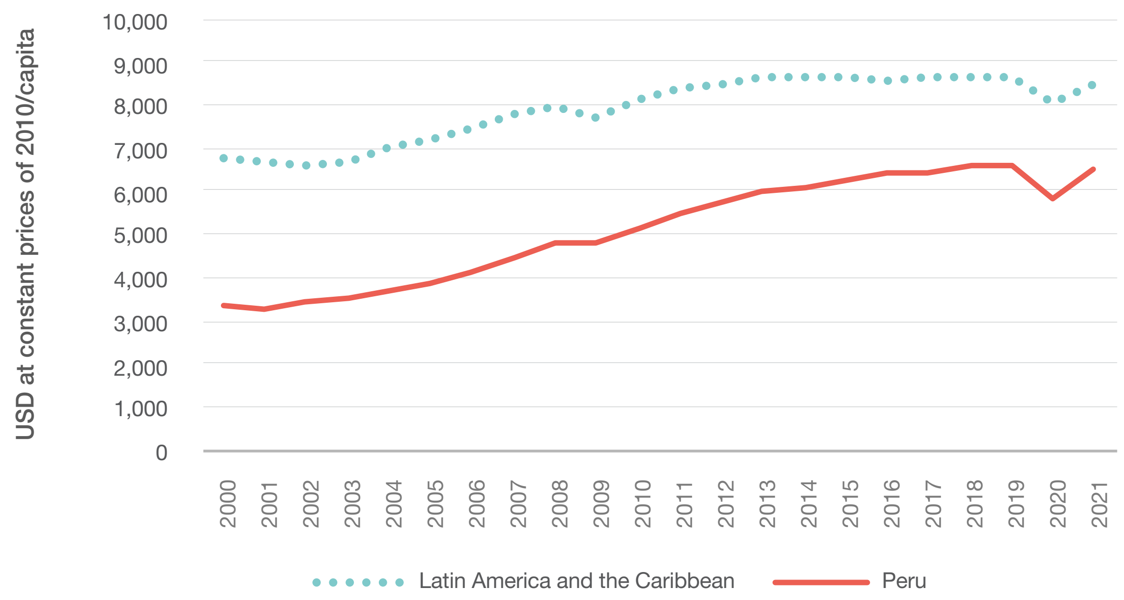
Graphic 2 GDP by sector, 2021, %



Source: Own preparation based on data from CEPAL.

Except for certain particular years, the GDP per capita has shown a growing trend in the last 20 years. In 2021, it was 6,506 constant US dollars (USD) of 2010 per capita, below the regional average.

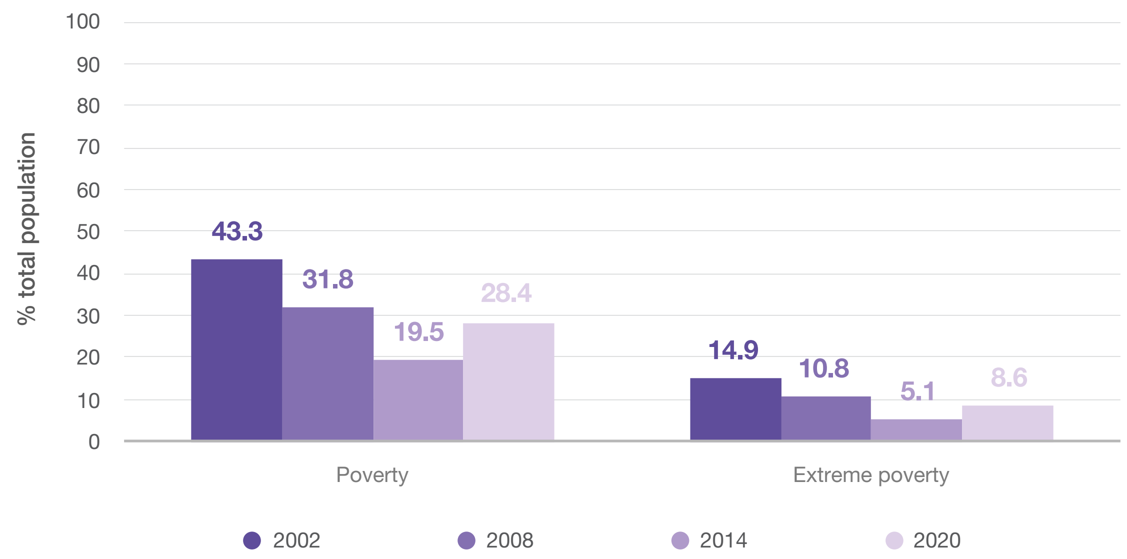
Graphic 3 GDP per capita, constant USD of 2010



Source: Own preparation based on data from the World Bank.

At present, Peru's poverty levels are around 30%, and 8.6% extreme poverty. The country had been reducing its poverty levels since 2002; however, poverty and extreme poverty levels have worsened significantly, according to data from 2020.

Graphic 4 Incidence of poverty and extreme poverty by year, %



Source: Own preparation based on data from CEPALSTAT.

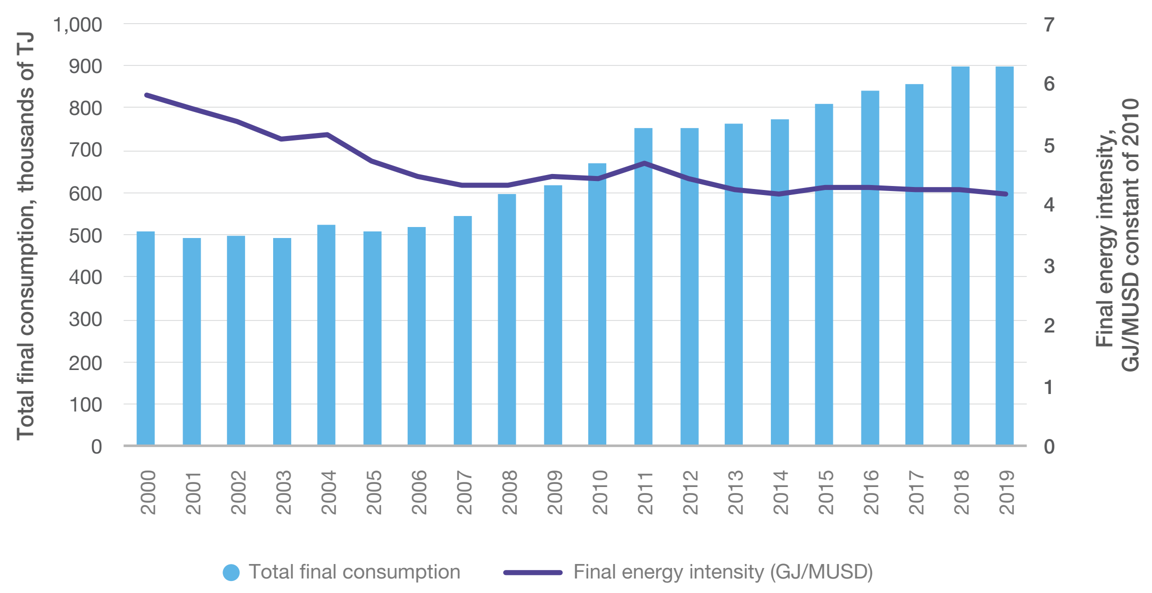
Socio-economic and energy indicators

Energy intensity of the economy

Final energy intensity[2] decreased significantly in the period 2020-2019 (-27.8% cumulative, -1.4% annual average) whereas total final consumption grew by an annual average of 3.9%.

2 It is defined as the relation between final energy consumption and GDP at constant USD of 2010.

Graphic 5 ▶ Total final consumption versus final energy intensity, 103 TJ and GJ/MUSD constant of 2010



Source: Own preparation based on data from OLADE[3].

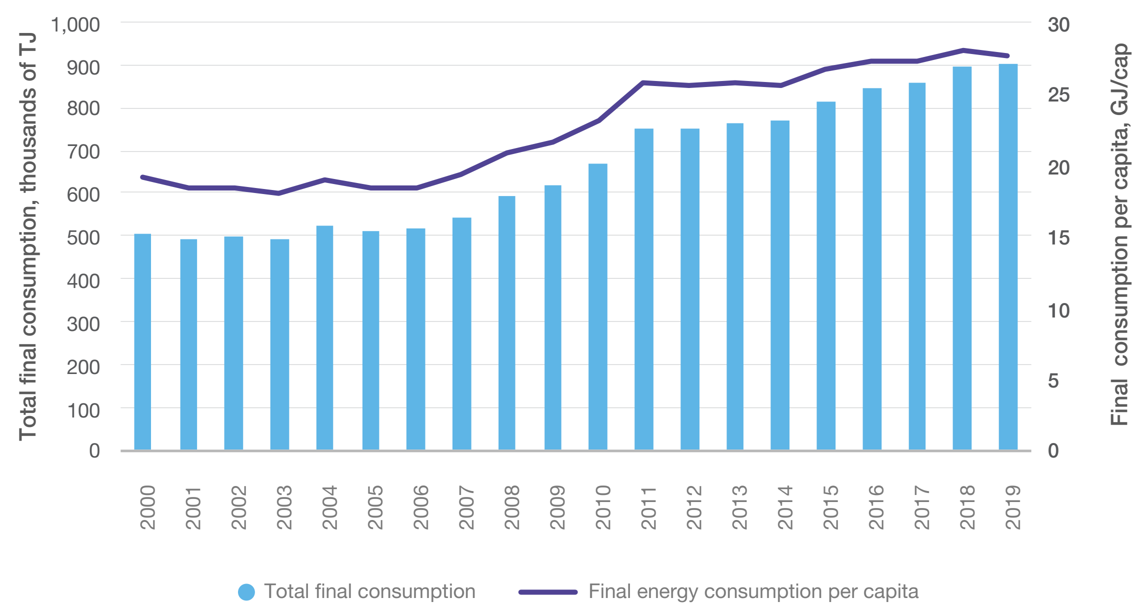
Consumption per capita

The growth in final energy consumption per capita was lower than that of total final consumption in the period 2000-2019 (2.2% vs. 3.9%) and slowed down until it stabilized in the period 2016-2019.

3 Data on energy intensities calculated internally in the system with data from the World Bank and the energy consumptions in the national energy balances.

Diagnosis and base line

Graphic 6 ▶ Total final consumption versus final consumption per capita, 10^3 TJ and GJ per capita



Source: Own preparation based on data from sieLAC, OLADE.

Local prices

The following end user prices refer to Peru. Regardless of the fact that they refer to electricity, natural gas, or other fuels, these prices are close to the average in the region, except in the case of diesel and fuel oil, which have higher prices, like in Uruguay.

Table 2 Prices of the main energy products in Peru, cut-off year 2020

Energy product	VAT %	Special taxes	Price
LPG (residential)	-	Yes	1.18 USD/kg
Regular gasoline	-	Yes	0.93 USD/l
Premium gasoline	-	Yes	1.14 USD/l
Diesel (transportation)	-	Yes	1.01 USD/l
Fuel oil (industrial)	-	Yes	0.61 USD/l

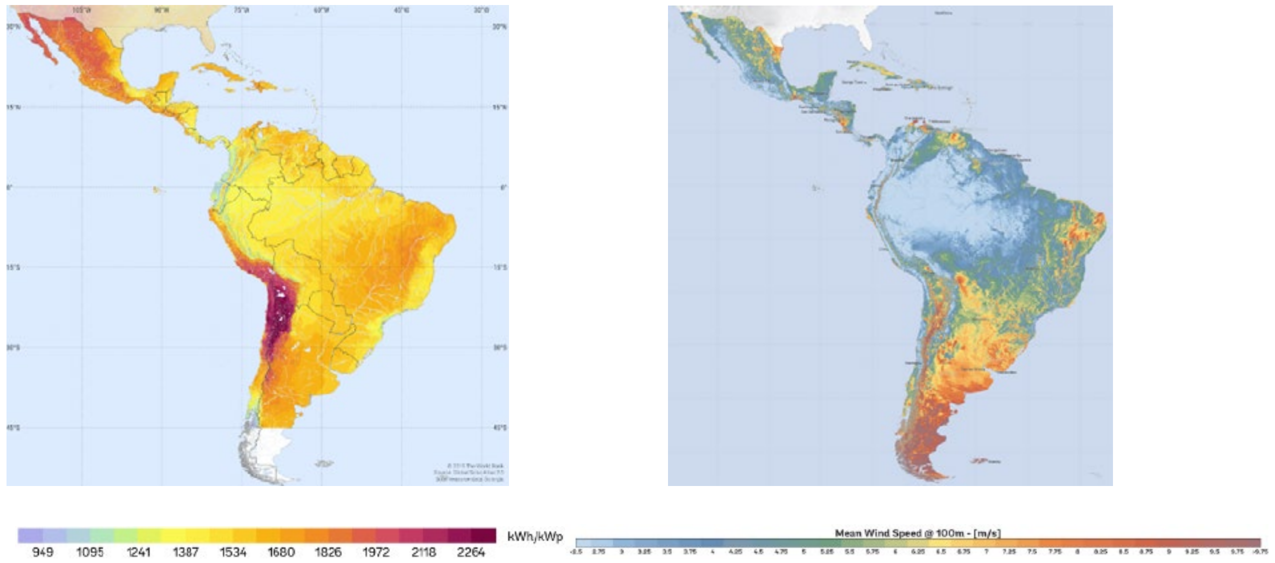
Source: OLADE - https://www.olade.org/publicaciones/precios-de-la-energia-en-america-latina-y-el-caribe-informe-anual-abril-2021/

Energy aspects

Reserves and total fuel supply (production, imports and exports)

Peru is characterized by a large amount of energy resources, among which we can mention its natural gas reserves and hydraulic potential. As to its solar resource, according to the Global Solar Atlas, Peru shows a value of 1,967 kWh/kWp in 10% of the areas with greater photovoltaic production, and an average of 1,789 kWh/kWp. As a reference, the global resource for 10% of the areas with more irradiation has been established at 1,736 kWh/kWp and the average global resource is 1,576 kWh/kWp. The greatest concentration of solar resource is located in the northwest of the country. The areas with more potential are in the south coast of the country, in Arequipa, Ica, Tacna, and Moquegua. On the other hand, its wind resource for 10% of the areas with more wind is equal to or greater than 235 W/m², where the mean wind speed at 100 meters is 6.1 m/s or more.

Graphic 7 Potential solar resource (kWh/kWp) and average wind speed at 100 m (m/s)



Source: Global Solar Atlas (Banco Mundial)[4] and Atlas Eólico Mundial (Banco Mundial)[5].

Peru's availability of resources is evidenced both in its power generation mix and in the final demand by fuel. Hydroelectric energy and natural gas account for a significant portion of its electricity production.

4 Global Solar Atlas, World Bank Group, https://globalsolaratlas.info/download/latin-america-and-caribbean

5 ws_LAC.pdf

Table 3 ▶ Fuel reserves, hydroelectric potential, and infrastructure, 2019

Reserves				Potential	Installed capacity	
Oil	Natural gas	Coal	Uranium	Hydro	Refining	Power generation
345	299	7	0	69.4	215	15.1
Mbbl	Gm³	Mt	10^6 bep	GW	kbbl/día	GW

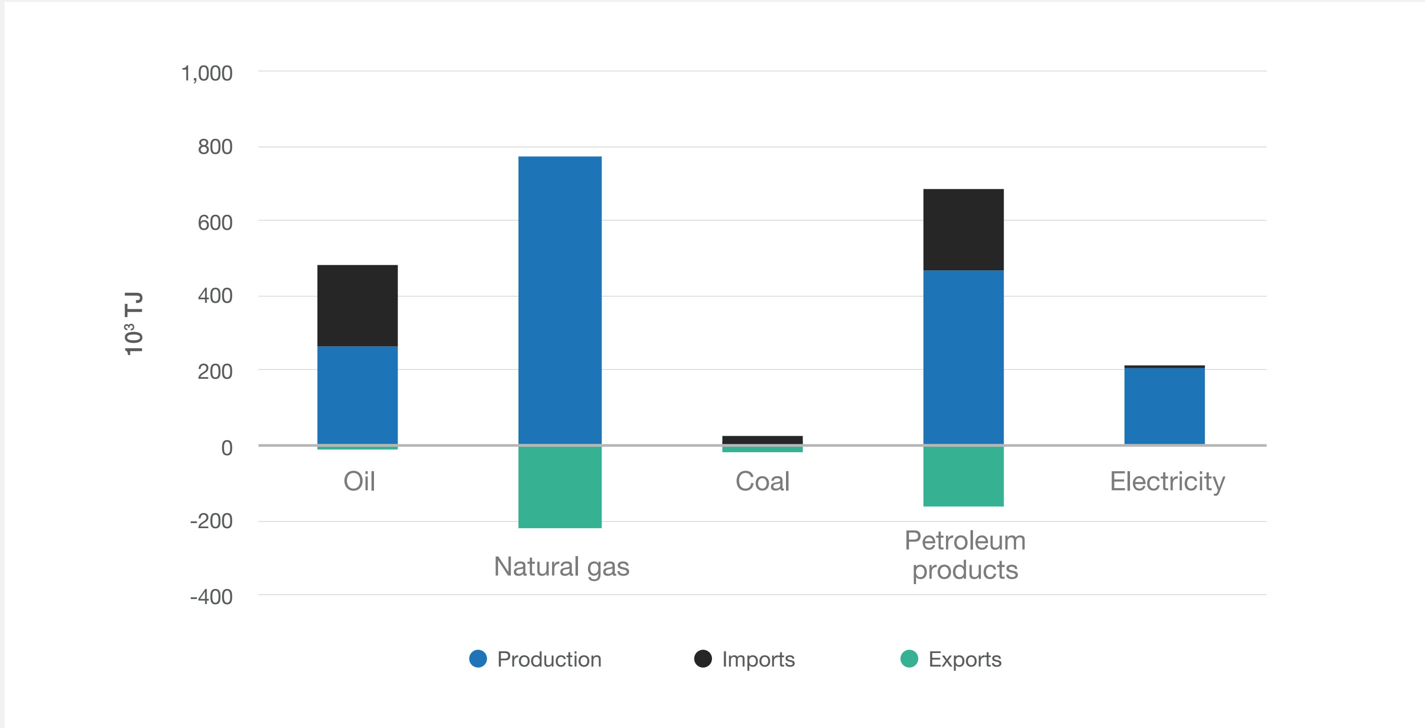
Source: sieLAC, OLADE.

Table 4 ▶ Wind and solar resources

Resources		
Wind (10 % of the areas with more wind)	Solar (average)	Solar (10 % largest production)
6.05	1,789	1,967
m/s	kWh/kWp	kWh/kWp

Source: Own preparation based on Global Solar Atlas and Global Wind Atlas.

Graphic 8 ▶ Production, imports and exports by main sources, 2019, 10^3 TJ

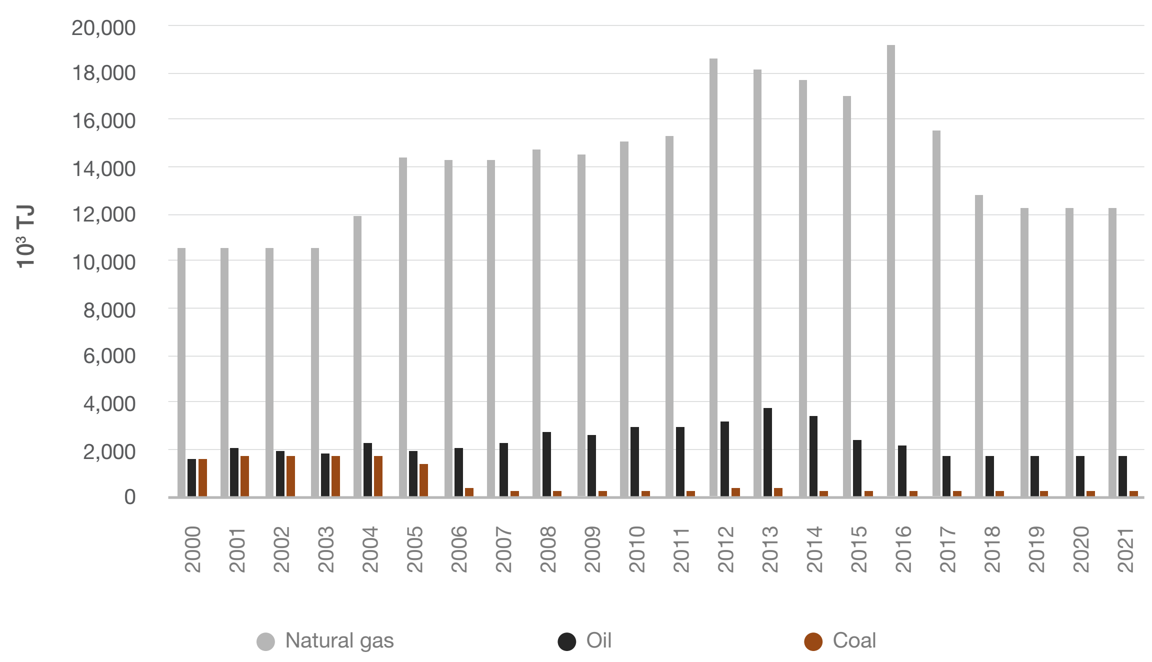


Source: Own preparation based on data from sieLAC, OLADE.

In 2019, Peru was the seventh natural gas producer in Latin America and the Caribbean (after Argentina, Trinidad & Tobago, Mexico, Brazil, Venezuela, and Bolivia). As to its oil production, it was in the same position, after Brazil, Mexico, Venezuela, Colombia, Argentina, and Ecuador. It imports a large amount of oil (an average 80% during the analyzed period; it was 84% in 2019). As regards natural gas, it exported approximately 30% of its production from 2011 to 2019.

Peru's oil and natural gas proven reserves have remained high in recent years whereas its coal reserves have diminished slightly. In 2020, the horizon of its oil, natural gas, and coal reserves was 8, 16, and 47 years, respectively.

Graphic 9 Evolution of proven oil, natural gas, and coal reserves, 10^3 TJ

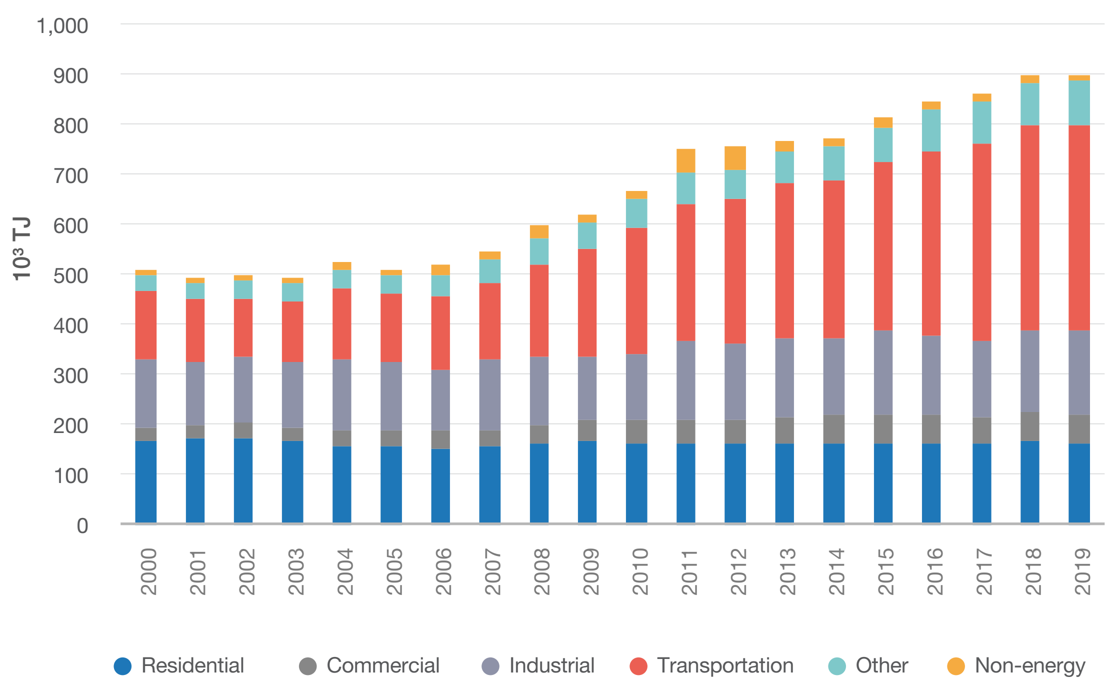


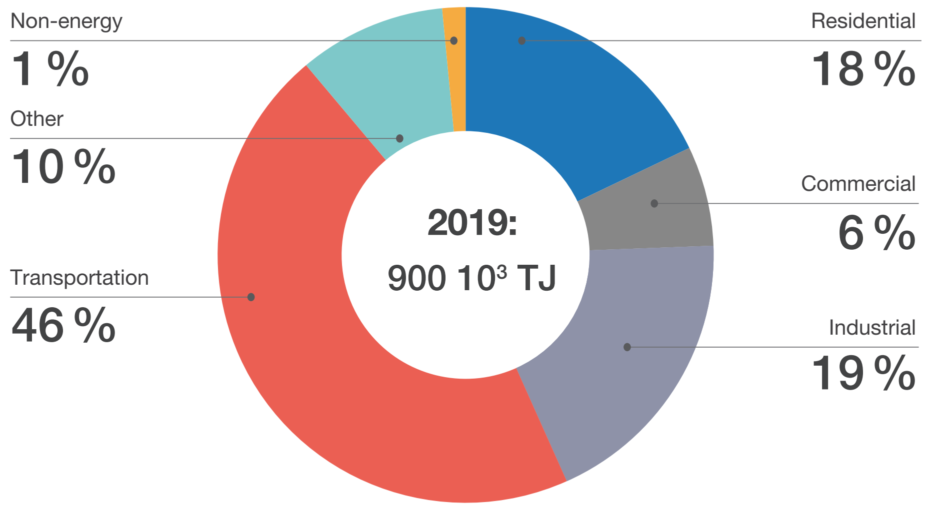
Source: sieLAC, OLADE.

Final consumption by source and sector

Transportation was the sector with the most consumption in 2019, and its relative weight has increased significantly in the last 20 years (from 27% to 46%). On the other hand, residential demand remains quite stable and even falls slightly. If we focus on its participation, we can notice a strong reduction from 36% in 2000 to 18% in 2019. The industrial sector grows by an annual average of 1.2%.

Graphic 10 Final consumption by sector, 10^3 TJ

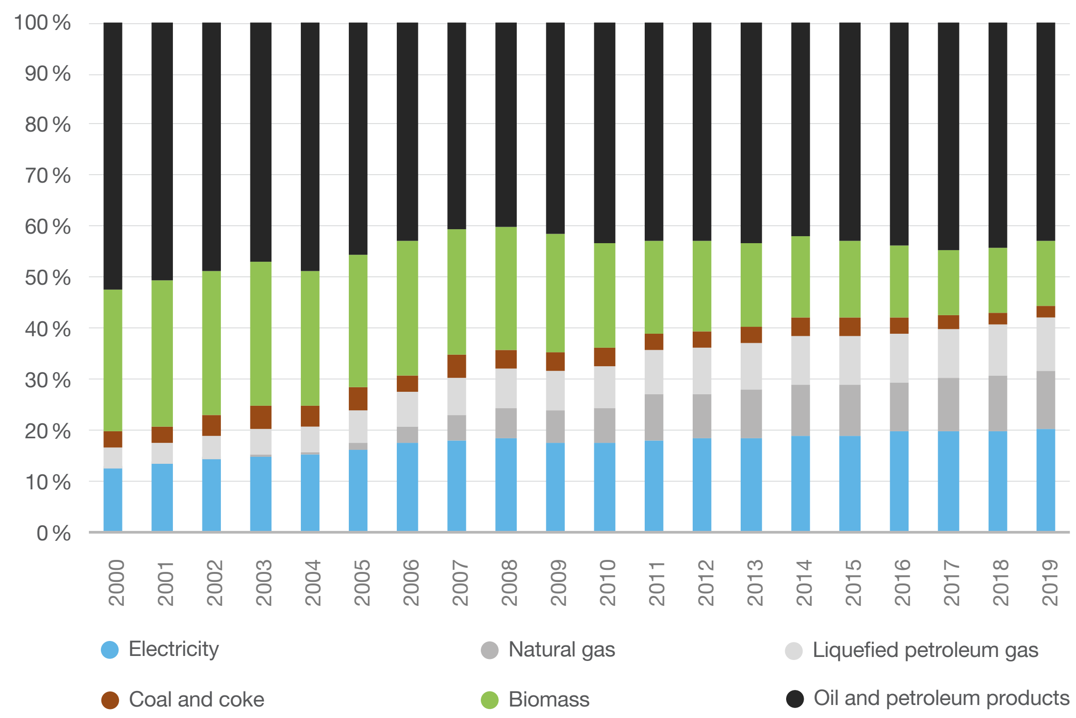




Source: Own preparation based on data from sieLAC, OLADE.

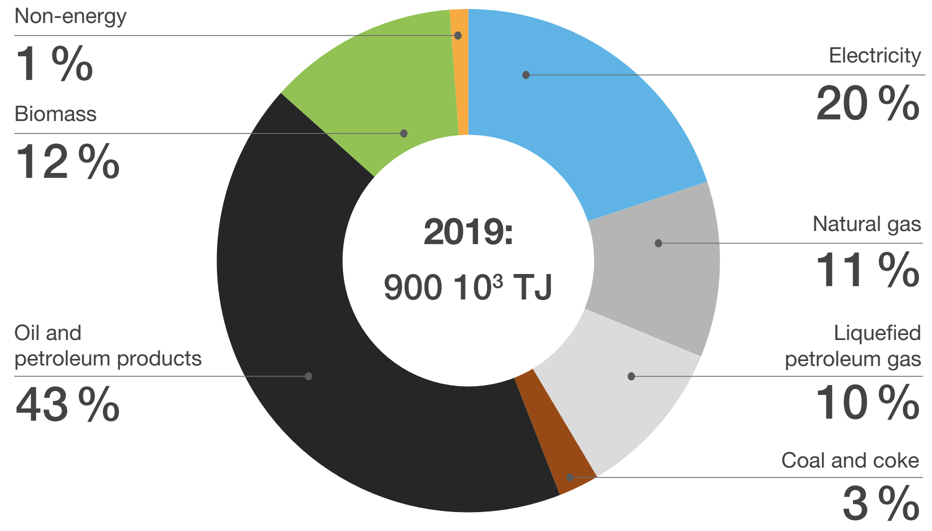
By source, electricity, natural gas, and liquefied petroleum gas (LPG) are the fuels that gain more importance in the matrix, to the detriment of biomass, oil, petroleum products, coal, and coke. The role of natural gas has grown since the start of operations at Camisea field in 2004.

Graphic 11 A ▶ Final consumption by source



Source: Own preparation based on data from sieLAC, OLADE. The "non-energy" category is not included in the historical evolution.

Graphic 11 B ▶ Final consumption by source



Source: Own preparation based on data from sieLAC, OLADE. The "non-energy" category is not included in the historical evolution.

Climate profile

Climate change scenarios and risks to the energy sector

Peru is located in a region that is highly vulnerable to extreme climate events[6]. In the rainy season between December and March, there is heavy rainfall that can

6 In addition to extreme events associated with the rainy season, Peru is also prone to experiencing earthquakes due to its location in the so-called Ring of Fire in the Pacific. These earthquakes can be very destructive and affect both structures and people.

cause floods in several areas in the country, especially on the coast and in the Amazon and Andean regions.

In the study *La economía del cambio climático en el Perú*[7], the effect of the climate change on the country's hydroelectric production was analyzed. The analysis was conducted on a large number of the existing hydroelectric plants, some of which increase their production factor while others decrease it. In said study, it was established that "the aggregate effects show that the climate change would cause less electricity production due to less water availability in the basins".

On the other hand, the other potential risks to the energy sector associated with climate change include a rise in energy demand for climate control, an eventual reduction in solar and wind production in some regions in the country, and eventual risks to energy infrastructure related to extreme climate events (storms, floods, etc.), among others.

The global climate risk index (GCRI)[8] indicates the level of exposure and vulnerability to extreme climate phenomena. In the period 2000-2019, Peru occupied the 45th position among 180 countries (the first position is the position with the greatest exposure and vulnerability).

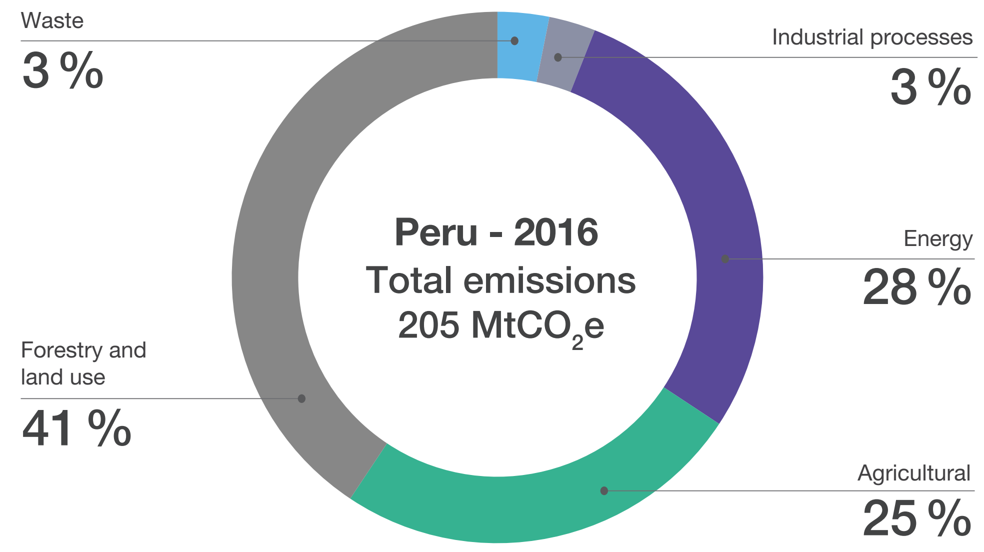
GHG contributions in the base year

According to the latest National Greenhouse Gas Inventory (INGEI), net total emissions in 2016 were 205 $MtCO_2e$; a small portion of them (28%) was related to the energy sector, (that is, emissions from burning fuels and fugitive emissions from fuel leaks), 25% to the agricultural sector, and 41% to forestry and other land uses sector.

7 https://repositorio.cepal.org/bitstream/handle/11362/37419/1/S1420992_es.pdf

8 The GCRI comprises four indicators: number of deaths, number of deaths per 100,000 inhabitants, sum of losses in USD at PPP, and losses per GDP unit. The final ranking considers these indicators with different weights and in a 20-year period. https://www.germanwatch.org/en/19777

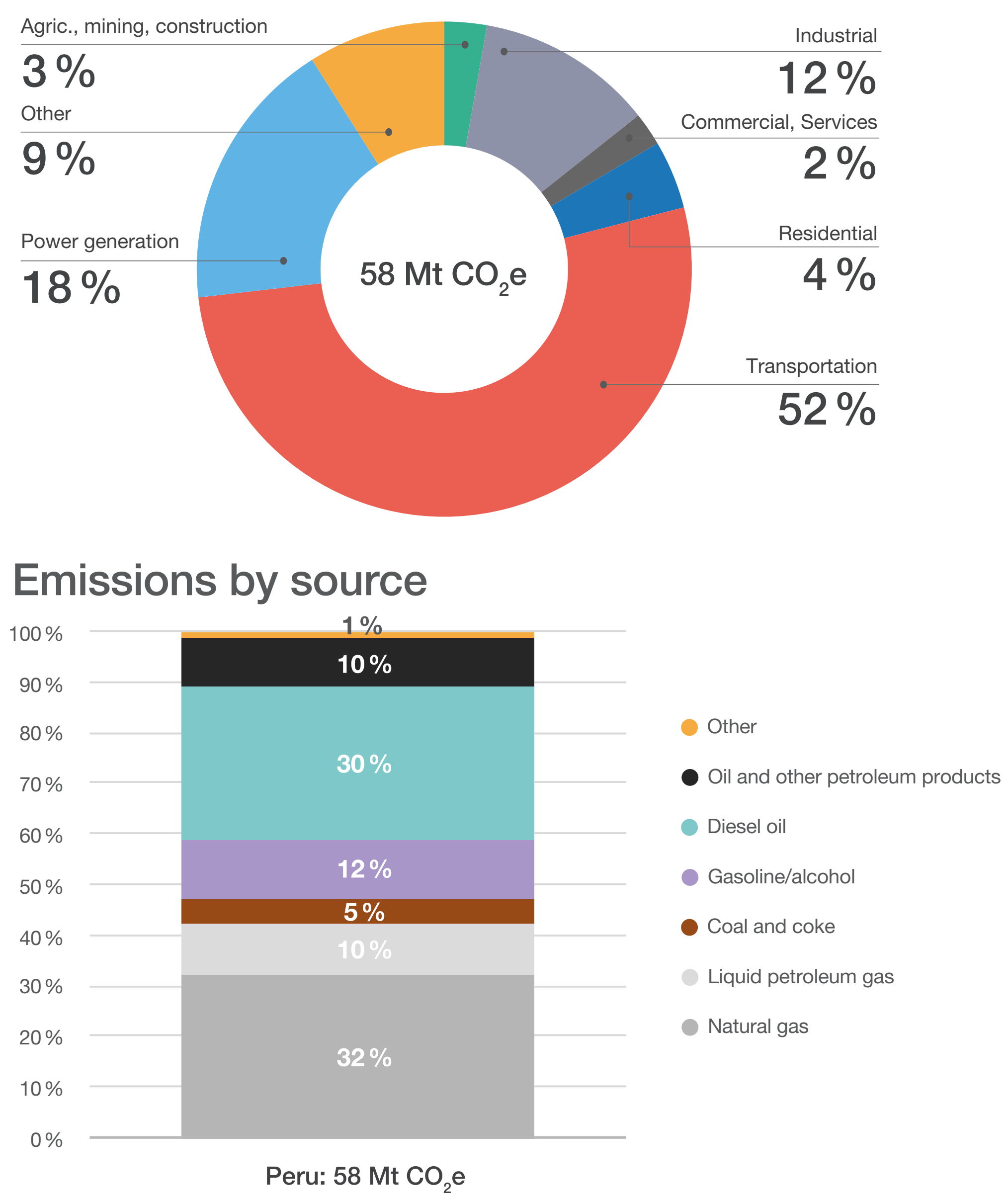
Graphic 12 ▶ Net total emissions, $MtCO_2e$



Source: Own preparation based on the national GHG emissions inventory (MINAM, 2016).

When specifically analyzing the energy sector (emissions resulting from burning fuels and fugitive emissions), it is possible to analyze the emissions by sector and by source. The data in Graphic 13 is based on the estimation of CO_2 emissions conducted by the Latin American Energy Organization (OLADE) (sieLAC).

Graphic 13 Estimated emissions from the energy sector, by sector and by source, $MtCO_2e$, 2019



Source: Own preparation based on data from sieLAC, OLADE.

The transportation sector accounts by itself for half of the emissions from the energy sector. The main fuels consumed by the sector are diesel and gasoline. In the second and third positions, power generation and industry account for 18% and 12% of the sector's emissions, mainly due to natural gas burning (and coal for industrial purposes).

National commitments (NDC and Paris Agreement)

With reference to CO_2 emission reduction commitments, two elements can be pointed out:

- The Peruvian State has pledged to limit its net greenhouse gas emissions to 208.8 $MtCO_2e$ (an unconditional goal, nationally determined contributions (NDC) 2030)[9] and 179 $MtCO_2e$ (conditional goal) by 2030, based on the availability of international external financing and the existence of favorable conditions.

- Peru signed the Paris Agreement; therefore, it is committed to "substantially reducing the greenhouse gas emissions to limit the increase in global temperature in this century to 2 °C and make efforts to limit this increase to even more, only 1.5 °C".

Climate policy in Peru has had its ups and downs.

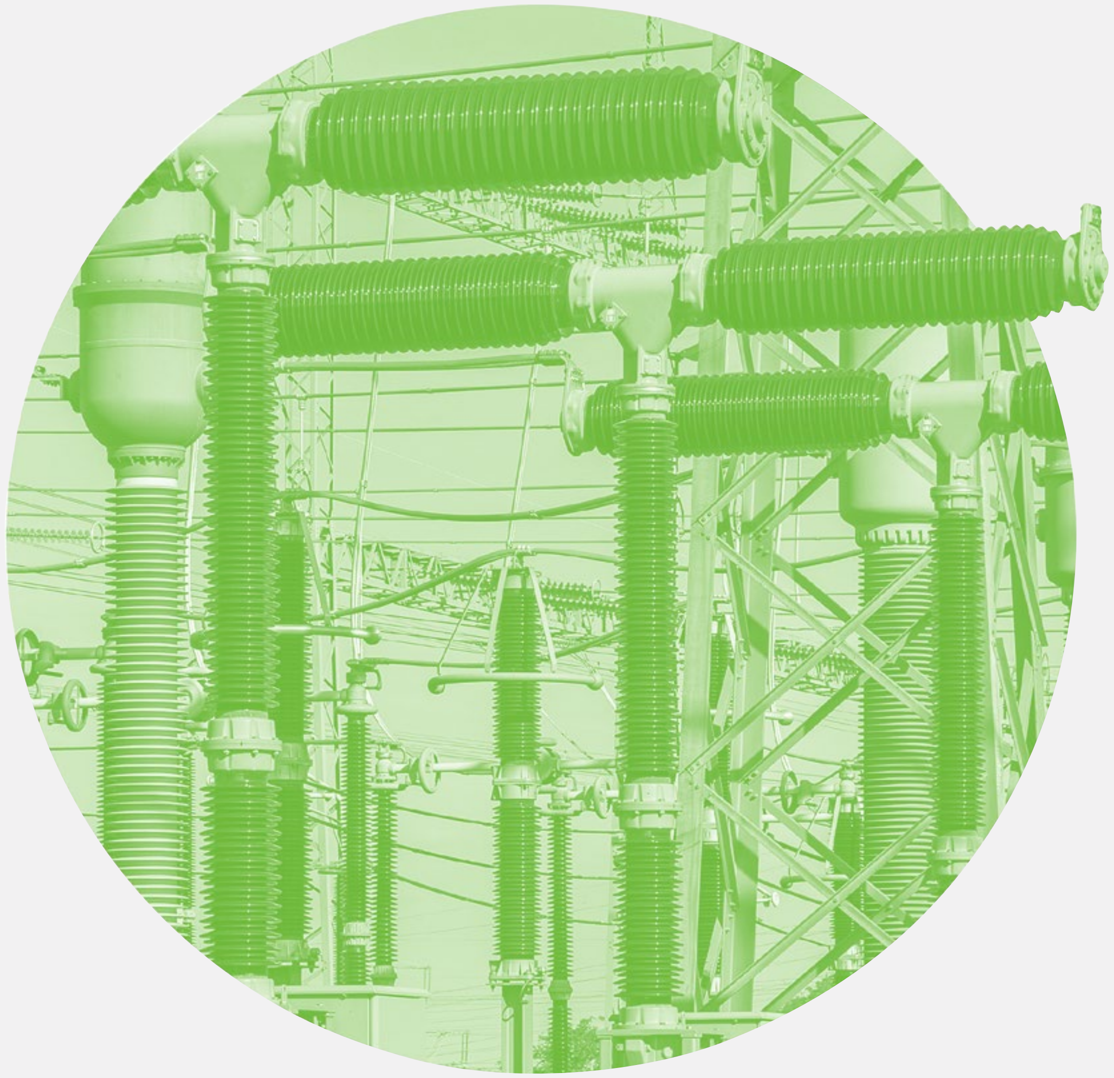
- The share of renewable energy continues rising in spite of new investment in fossil fuels. The government has prepared new renewable auctions and in 2022 it agreed to implement the first green hydrogen project in the country.

- However, the Government also approved a new license contract for the most important oil extraction asset in Peru, which is located in the center of the Amazon region. Investors in oil extraction do not agree to a national

9 NDC by country (https://unfccc.int/NDCREG)

strategy on climate change (ENCC) with a net zero target for 2050.

The forestry and land uses sector continues being the largest source of emissions in the country. In 2021, the National Forestry Program reported the highest deforestation rate in the last two decades, mainly due to illegal activities.



2. Institutional, regulatory, and public policy aspects

Sectoral government

Table 5 lists the principal institutions in the energy sector.

Table 5 Mapping of institutions in the energy sector

Institution	Function
Ministry of Energy and Mines (MINEM)	• Definition of policies and planning for the oil, gas, and electricity sectors.
Regulatory Agency for Investment in Energy and Mining (*Organismo Supervisor de la Inversión en Energía y Minería*, OSINERGMIN)	• Expansion of the gas and electricity sectors. • Regulation of the oil, gas, and electricity sectors.
Committee for the Economic Operation of the System (*Comité de Operación Económica del Sistema*, COES)	• Electricity market administrator.

Source: Own preparation.

Main regulatory concepts

Table 6 indicates whether there is price regulation and a competitive market with free access for each energy sector and segment.

Table 6 Main regulatory concepts by sector and segment

Sector	Segments	Price regulation	Market
Electricity	• Generation • Distribution • Transmission	• Transmission • Distribution and • retail commercialization	• The market is competitive in generation. There is free access in all the segments of the chain.
Natural gas	• Exploration and exploitation • Distribution • Transmission	• The price of gas production, transmission, distribution, and retail commercialization is regulated.	• Free access
Oil	• Exploration and exploitation • Refining • Distribution and commercialization	• Reference prices for the whole chain.	• The market is competitive in GLP storage and refining.
Coal	• Exploitation • Commercialization		• Free pricing.

Source: Own preparation.

Public policy aspects

Energy efficiency policies

In 2000, Law No. 27345 (Efficient Use of Energy Promotion Act) declared the promotion of the efficient use of energy (UEE, in Spanish) of national interest to ensure energy supply, protect consumers, foster competitiveness in the national economy, and reduce the negative environmental impact of the use and consumption of energy products.

The main energy efficiency policies, measures, and programs are briefly described in Table 7.

Table 7 ▶ Energy efficiency in Peru

Aspect	Concept	Country progress
Labeling regulation	Sector	Commercial and industrial.
	Commercial and industrial	The law stipulates that equipment and devices requiring energy supply must include information on energy consumption relative to energy efficiency standards on their labels, packaging, and advertising.
	Minimum energy efficiency standards (MEPs)	Doesn't have MEPS.
Sectoral policies	Public sector	√
	Transportation	√
	Residential	√
	Commercial and industrial	√
Energy efficiency fund	Type	
	Name	
	Other	Specific financial resources to implement energy efficiency measures.
Promotion and cultural change	Labeling	√
	Training programs and workshops for the public and private sectors	
	Development of programs, and dissemination and demonstration campaigns	√
	Social participation, consultations, and public access to information	
	Inclusion of energy efficiency in syllabuses	√
	Energy efficiency awards, honors, and/or recognition	√

Source: Document *Leyes de eficiencia energética en América Latina y el Caribe*, OLADE.

Pricing, subsidy, and incentive policies

Subsidies and taxes on fuel prices

Subsidies

The existing subsidies to be considered are indicated below.

a. **Electricity.** Law No. 27510 creates an electric social compensation fund (FOSE, in Spanish) to apply discounts to users with consumptions equal to or lower than 140 kWh/month and incorporate exclusion criteria for power utilities to apply the FOSE. The FOSE is a cross subsidy created to benefit regulated users with lower incomes. Specifically, the FOSE seeks to favor access to the electricity service and permanence in it to all residential users of the public service of electricity with monthly consumptions equal to or lower than 100 kWh/month that are within the residential tariff options.

   The FOSE is financed through a charge in the electricity bills of users of the electricity service of the interconnected systems that do not qualify as FOSE beneficiaries.

b. **Natural gas and LPG.** E Access to LPG by vulnerable sectors and the connection to the natural gas network are financed through the social energy inclusion fund (FISE, in Spanish), created under Law No. 29852. The economic resources of the FISE come from large electricity consumers, the natural gas transportation service (Camisea gas), and fuel production and imports.

c. **Gasolines.** Even though the market fixes the prices, in Peru there is a fuel price stabilization fund (FEPC, in Spanish). At present, liquified petroleum gas (LPG) destined to be bottled (domestic use), vehicle diesel, gasoline with 84 and 90 octanes, LPG in bulk, and 84-octane gasohol are included in this fund.

Taxes

The taxes applied on fuel prices are indicated below.

a. **Vehicle tax (*impuesto al rodaje*).** This tax on fuel consumption is applied in the vehicle transportation sector, except for diesel. The rate is 8% on the net price of the fuel ex-refinery.

b. **Selective tax on consumption.** This tax is applied differentially on the consumption of each fuel through a rate per unit (soles per gallon).

c. **General sales tax. (*impuesto general a las ventas, IGV*).** This is a general tax on consumption that is applied on chattels, the import of goods, the provision or use of services in the country, etc. The general rate of the IGV is 18%. As from July 2003, VAT is 19%.

Incentives to renewable energy

Main laws

Since 2008, with the enactment of Decree No. 1002, there has been a specific regulation that seeks to promote investment in small-scale renewable energy projects (RER, in Spanish), offering dispatch priority and preferential tariffs awarded through public tenders[10], among other things.

Recognition of capacity

Decree No. 144/2019 authorizes the recognition of firm capacity for renewable energy. This recognition grants economic advantages to non-conventional renewable energy to enter into contracts with free and regulated users without having to sign a back-up contract with another generator to purchase firm capacity.

10 Long term auctions: Since the implementation of the promotional regime for RER projects in 2008, Osinergmin has carried out four public tenders: in 2009, 2011, 2013 and 2015, and has announced 2 auctions for 2022.

Distributed generation

The first time that measures to promote distributed generation were contemplated was in 2006, through Law 28832, to ensure the efficient development of power generation. However, this law has not been implemented.

Creation of a carbon market

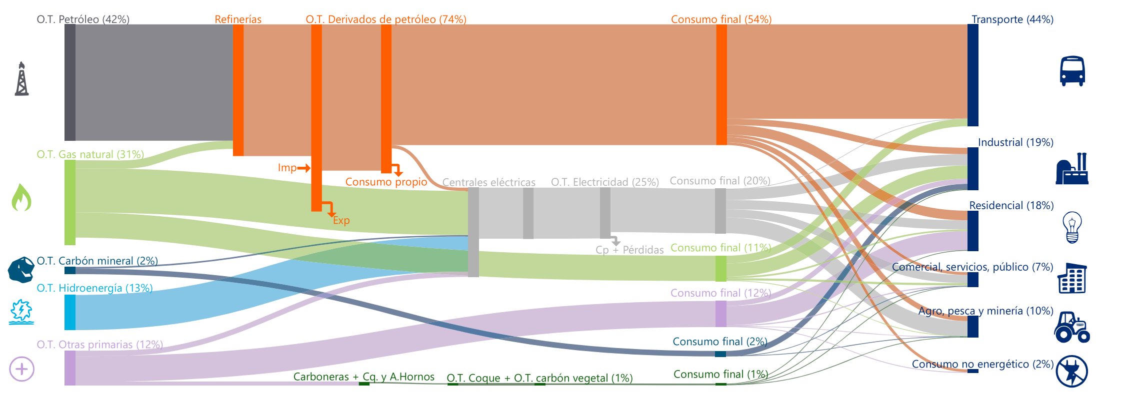
In addition to the carbon tax, the Peruvian State is developing a set of economic and market instruments.

It has developed different technical blocks of its national GHG data management system and its monitoring, reporting and verification (MRV) systems, and has launched its national carbon footprint program. There is currently no carbon pricing instrument.

3. Energy balance, 2019 and 2022

The energy balance records energy flows from production, energy imports and exports, and transformation to final consumption in the different socio-economic sectors for a certain period (one year). Graphic 14 is a graphic representation (Sankey diagram) of the year 2019, considered as the base year for this study.

Graphic 14 Energy balance, 2019



Source: *Panorama energético de América Latina y el Caribe 2020*, OLADE, November 2020.

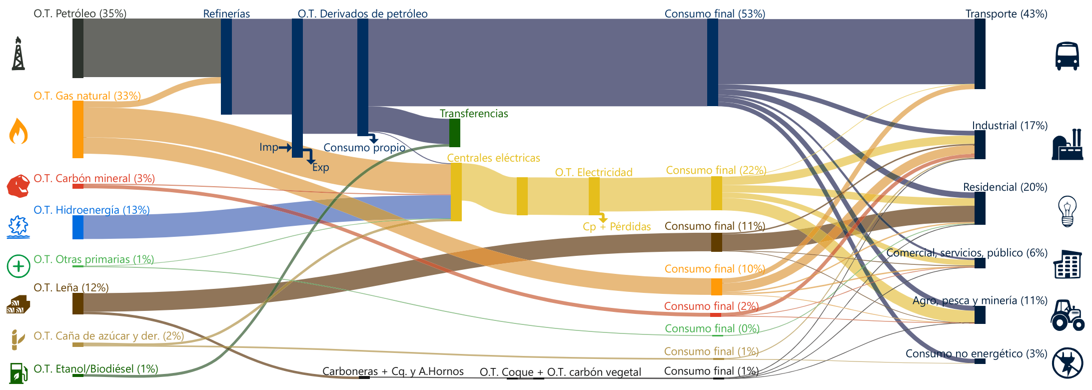
The energy balance allows us to summarize some of the main characteristics of the Peruvian energy sector:

- The prevailing role of oil (42%) and natural gas (31%);
- A large portion of electricity is generated from natural gas or hydro;
- The role of electricity in final consumption is still limited (20%);
- The sectors with the greatest final consumption are transportation (44%), industry (19%), and residential (18%);

The latest energy balance available (2022), showing some slight differences with the energy balance of 2019, is also presented:

- Greater weight of natural gas (33% versus 31%) and less weight of oil (35% versus 42%) in terms of primary energy supply;
- Greater weight of the residential sector (20% versus 18%) and less weight of the industrial sector (17% versus 19%) in terms of final consumption;

Graphic 15 Energy balance, 2022



Source: *Panorama energético de América Latina y el Caribe 2023*, OLADE, December de 2023.

4. Evolution of energy demand by sector and source

The national energy balance allows us to visualize the dynamics of the energy sector over time through the analysis of time series of the main variables that are part of the country's energy matrix and a comparison of the structures and indicators in different years of a historical period.

The following paragraphs include, in addition to the energy demand by source, additional data required to characterize this demand, such as the share of demand by energy use (useful energy balance), the description of the vehicle fleet, sectoral energy intensity, etc.

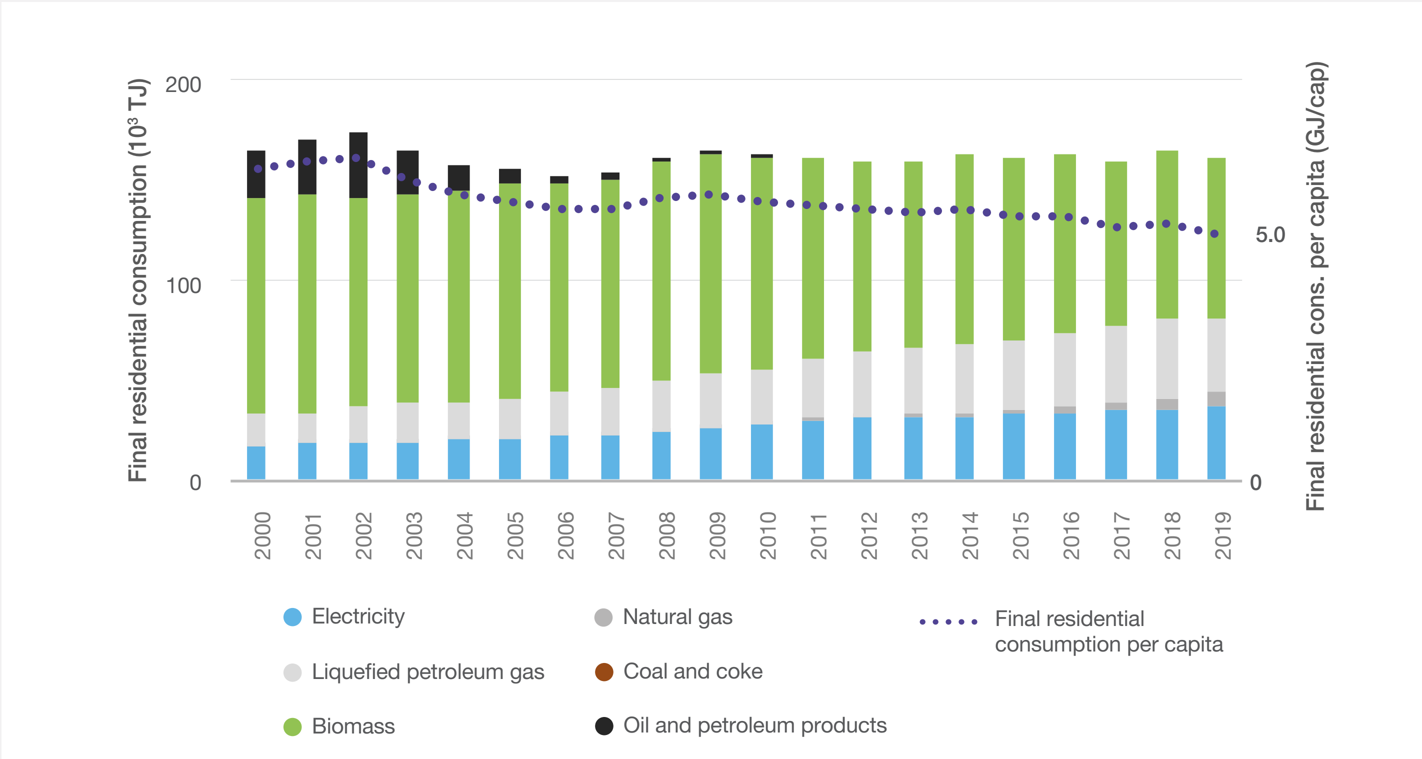
Residential sector

Final residential consumption has remained relatively constant in the last 20 years. We can observe a sharp fall of 1.2% annual average per capita, which evidences the changes in energy sources that result in less use of final energy for one same use. By source, we can mention the following characteristics:

Diagnosis and base line

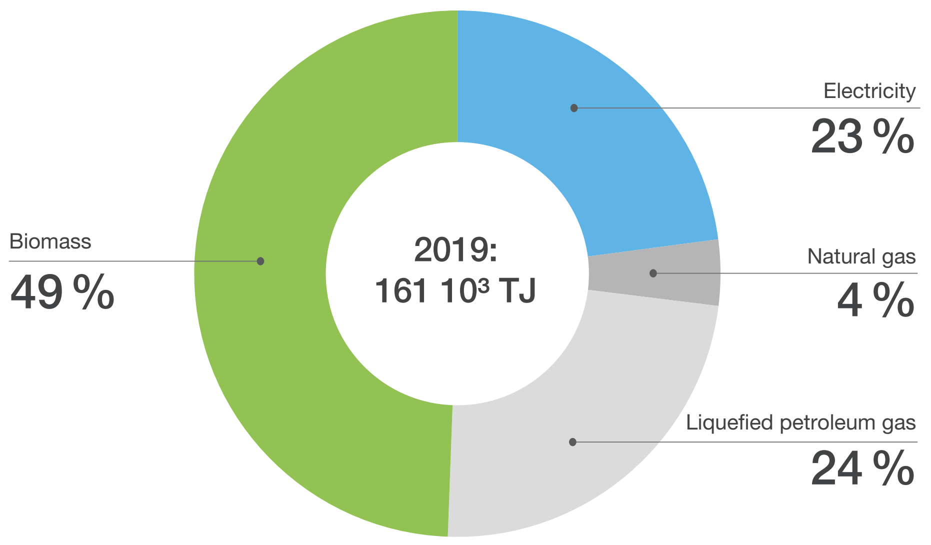
- high biomass consumption (firewood), although its volume and proportion have decreased significantly in the last two decades. In 2000, biomass consumption amounted to 108 PJ and accounted for 65% of total consumption, whereas such values were 80 PJ and 49% in 2019;
- increase in final electricity and LPG consumption from 18 PJ and 15 PJ in 2000 to 37 PJ and 38 PJ in 2019, respectively.

Graphic 16 A Residential sector: evolution of final consumption by source, 10^3 TJ and final residential consumption per capita (GJ per capita)



Source: Own preparation based on data from del sieLAC, OLADE.

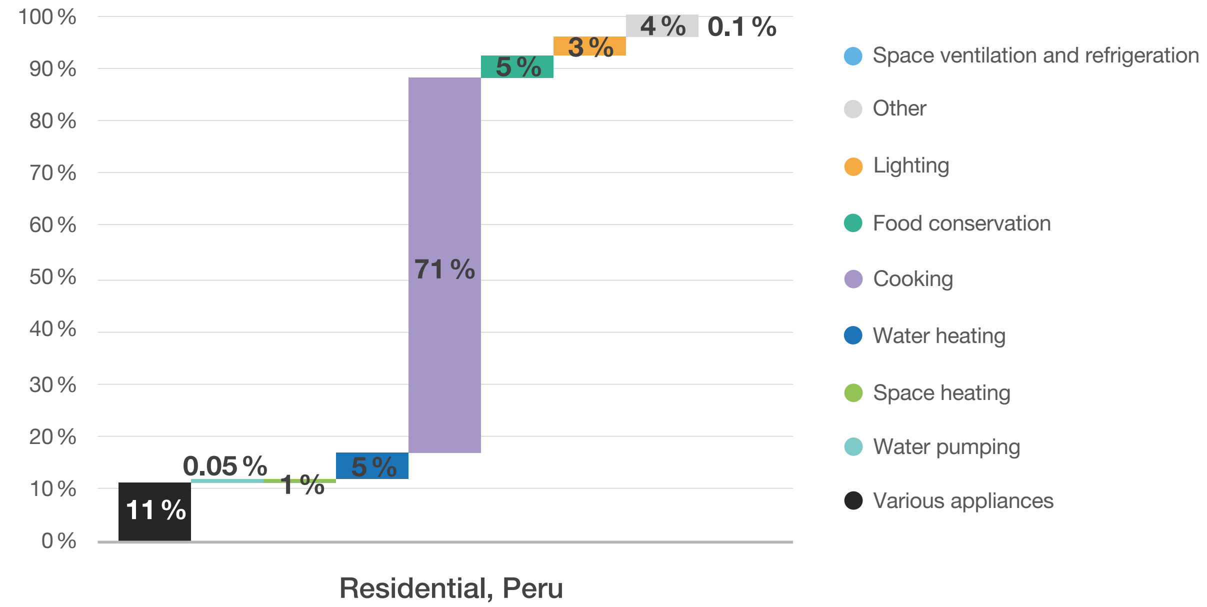
Graphic 16 B ▶ Residential sector: evolution of final consumption by source, 10^3 TJ and final residential consumption per capita (GJ per capita)



Source: Own preparation based on data from del sieLAC, OLADE.

In terms of energy consumption for end uses, 71% of the total is cooking, especially based on firewood and LPG. Exclusively electrical uses include lighting, food conservation, and various appliances.

Graphic 17 ▶ Residential sector: energy consumption for end uses, 2013



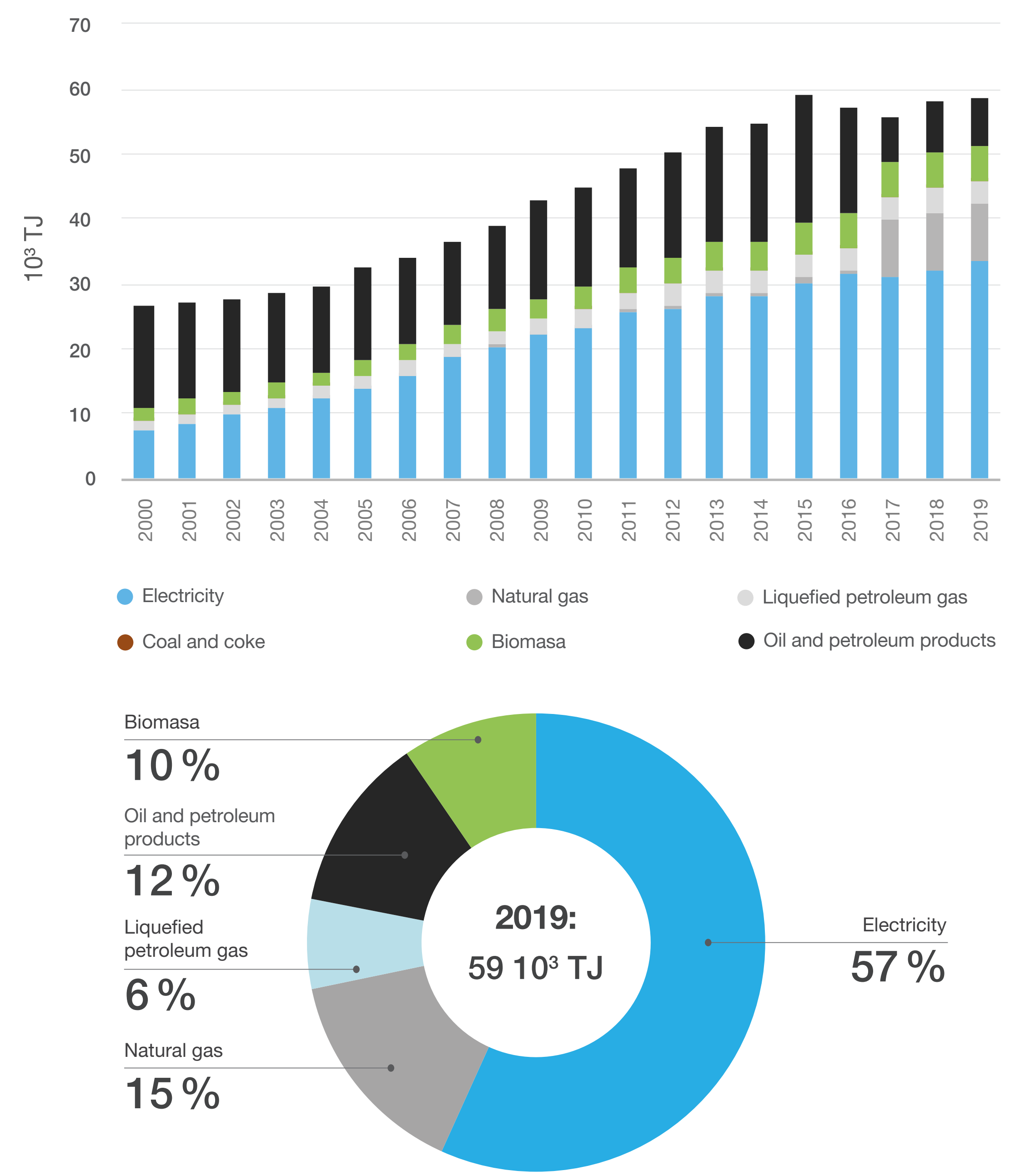
Source: Own preparation based on data from the useful energy balance, 2015, ENERINTER-Mercados energéticos consultores, Datum Internacional.

Commercial, services, and public sector

The final consumption of the commercial, services, and public sector has increased in the last 20 years (annual average, 4.2%). By source, the following characteristics can be pointed out:

- a high share of electricity in total consumption (57 % in 2019);
- supply of the rest of the demand with natural gas, oil, petroleum products, biomass and LPG. Natural gas consumption has increased strongly since 2017 and has replaced oil and petroleum products.

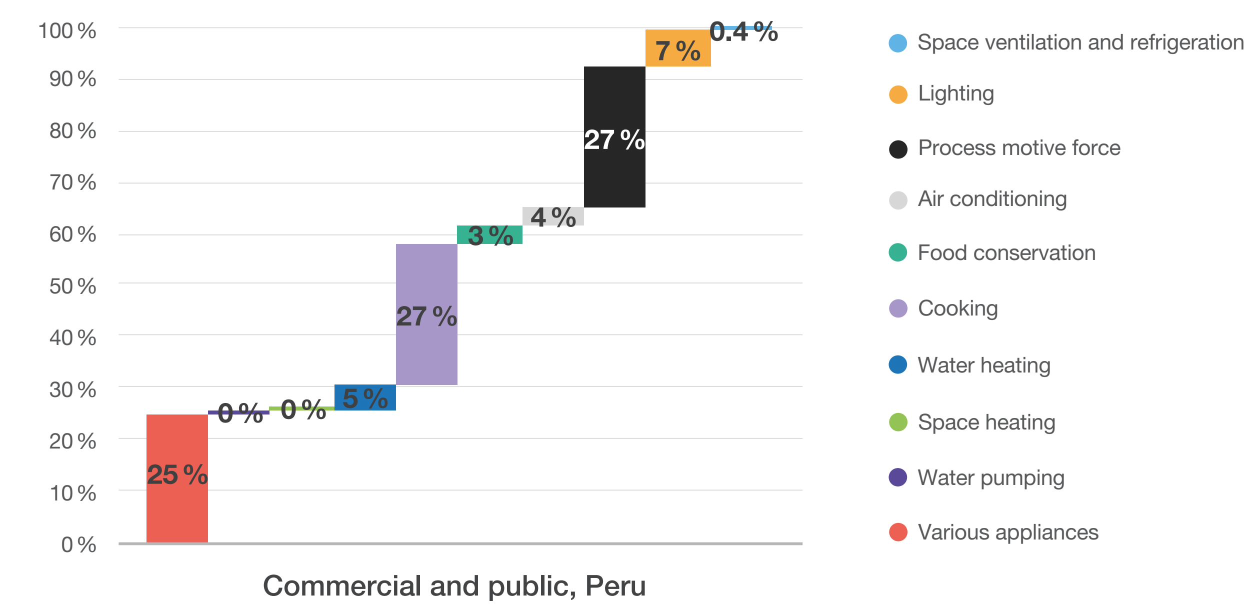
Graphic 18 Commercial and public sector: evolution of final consumption by source, 10^3 TJ



Source: Own preparation based on data from sieLAC, OLADE.

In terms of energy consumption for end uses, motive force, cooking, and several appliances are the uses with the most consumption. As to motive force, the public sector prevails, where mainly gasohol, turbo, and gasoline are used. The use of several appliances shows an exclusively electrical use, and food cooking prevails in the commercial sector, with mainly piped gas and firewood consumption.

Graphic 19 Commercial and public sector: energy consumption by end use, 2013



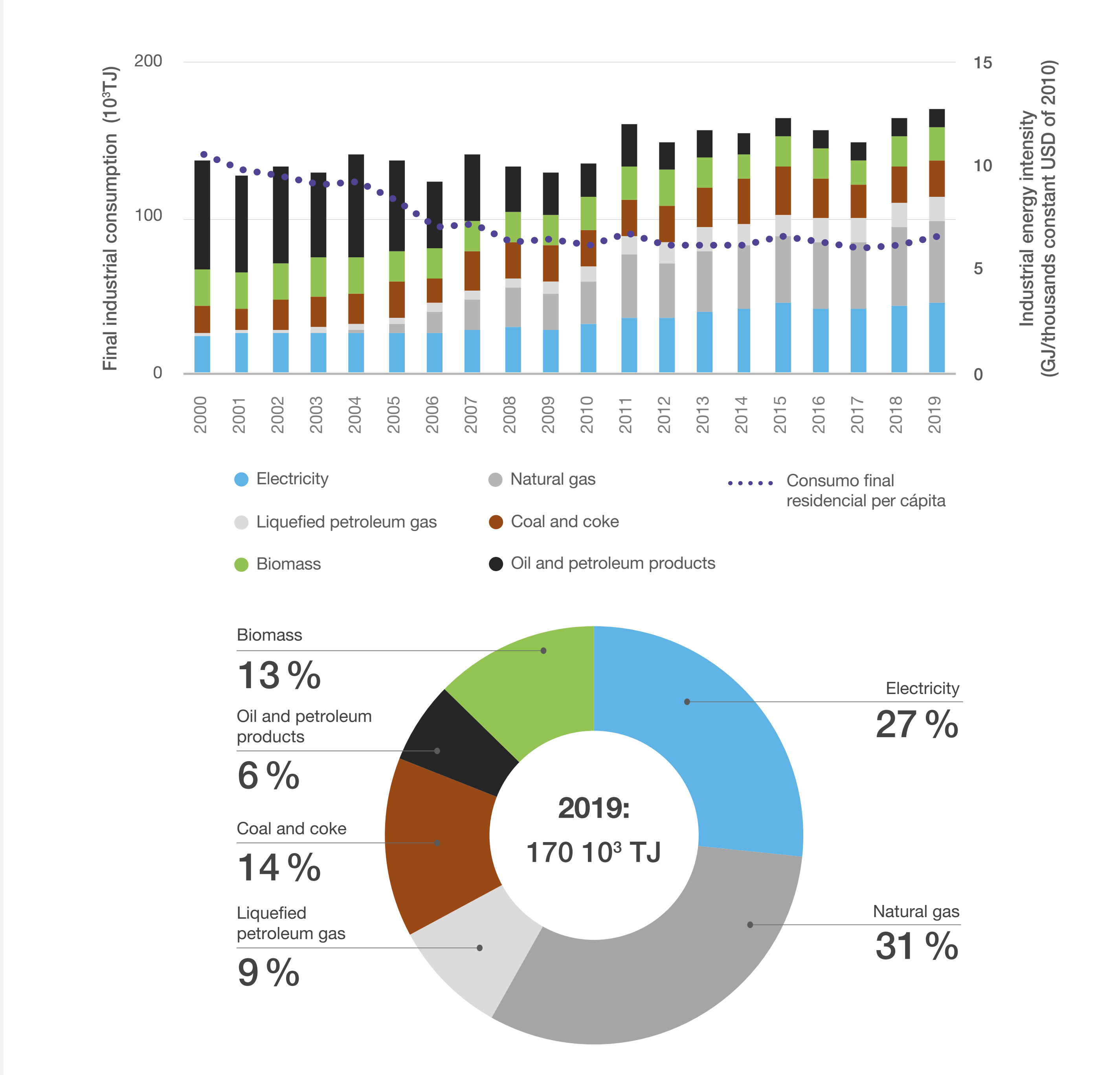
Source: Own preparation based on data from the useful energy balance, 2015, ENERINTER-Mercados energéticos consultores, Datum Internacional.

Industrial sector

Final industrial consumption has increased in the last 20 years (annual average growth of 1.2%). By GDP unit, the energy intensity of the industrial sector has decreased dramatically in the period, especially in 2000-2008; since then, it has remained relatively constant. By source, the following characteristics can be pointed out:

- the natural gas share is relevant. It started growing in 2004 and reached 31% of the final energy consumed today;
- the use of oil and petroleum products is lower and has diminished;
- electricity has increased its share from 18% in 2000 to 27% in 2019;

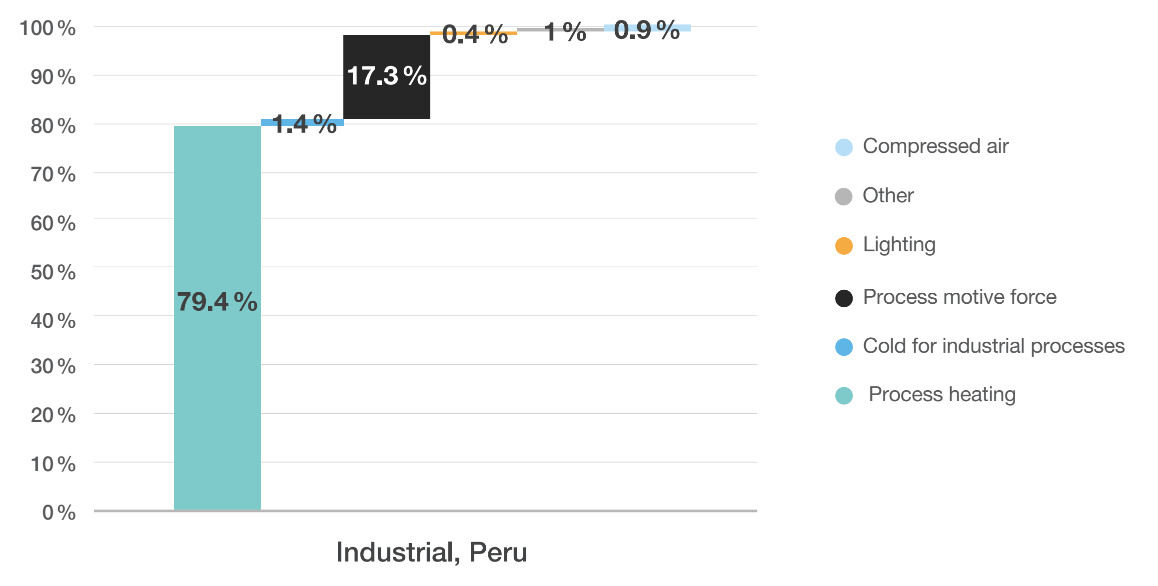
Graphic 20 Industrial sector: evolution of final consumption by source, 10^3 TJ



Source: Own preparation based on data from sieLAC, OLADE.

In terms of energy consumption for end use, process heat accounts for a large portion of consumption (79.4 %), followed by motive force with 17.3 %.

Graphic 21 Industrial sector: energy consumption for end use, 2013



Source: Own preparation based on data from the useful energy balnace, 2015, ENERINTER-Mercados energéticos consultores, Datum Internacional.

Transportation sector

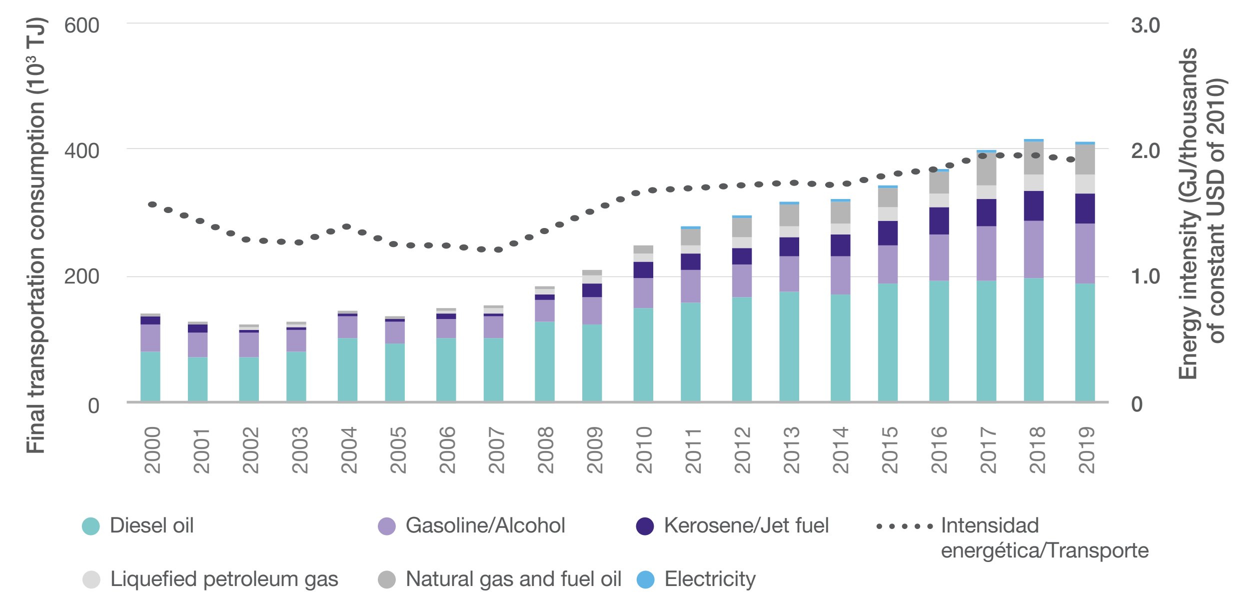
Demand by source

Final consumption in the transportation sector has increased steadily in the last 20 years (annual average 5.9%). By GDP unit, the energy intensity of the

transportation sector[11] increased in the period, although less significantly. By source, the following characteristics can be pointed out:

- high consumption of diesel (46%), followed by gasoline/alcohol (22%);
- increase in consumption of kerosene/jet fuel and natural gas/fuel oil, reaching 12% in both cases.

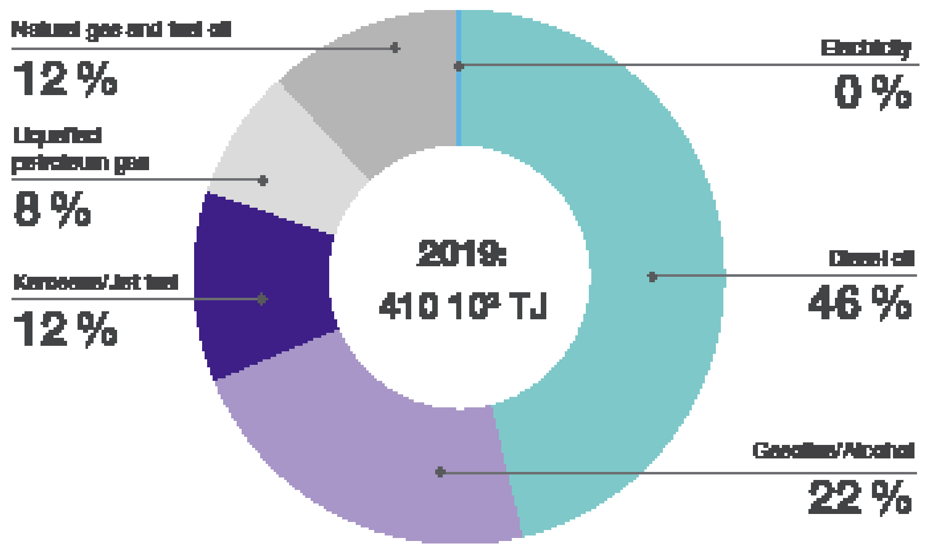
Graphic 22 A Transportation sector: evolution of final consumption by source, and year 2019, 10^3 TJ



Source: Own preparation based on data from sieLAC, OLADE.

11 The energy intensity of the transportation sector is calculated as transportation energy consumption/ total GDP. The GDP of the transportation sector alone is not considered. Transportation consumption involves all the economy.

Graphic 22 B ▶ Transportation sector: evolution of final consumption by source, and year 2019, 10³ TJ



Source: Own preparation based on data from sieLAC, OLADE.

Vehicle fleet and consumption by type

Table 8 shows total road vehicles and their share by type. The car and light truck fleet accounts for 78% of the total fleet, against 9% motorcycles and 7% freight vehicles.

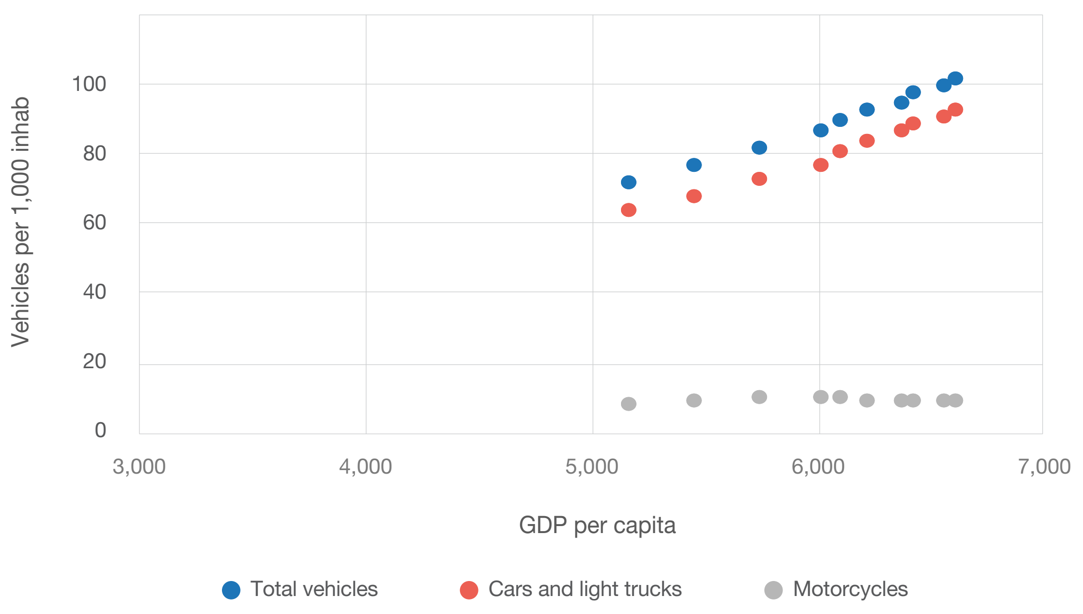
Table 8 ▶ Number of road vehicles, total and by type, 2019

	2019
Cars	55%
Light trucks	23%
Motorcycles	9%
Buses	3%
Freight	7%
Heavy machinery + dump	4%
Total	3,287,413

Source: Own preparation based on data from the useful energy balance, 2013, ENERINTER-Mercados energéticos consultores, Datum Internacional.

Peru develops its vehicle fleet along with the increase in GDP per capita; in particular, the number of cars and light trucks grows more than that of motorcycles, which seems to remain constant..

Graphic 23 Vehicle fleet versus GDP per capita, 2010-2019



Source: Own preparation based on *Anuario Estadístico 2019*, Ministry of Transportation and Ministry of Communications.

Table 9 shows fuel consumption by transportation type and by fuel.

Table 9 Consumption by type of transportation and by fuel type, 10^3 TJ and %, 2019[12]

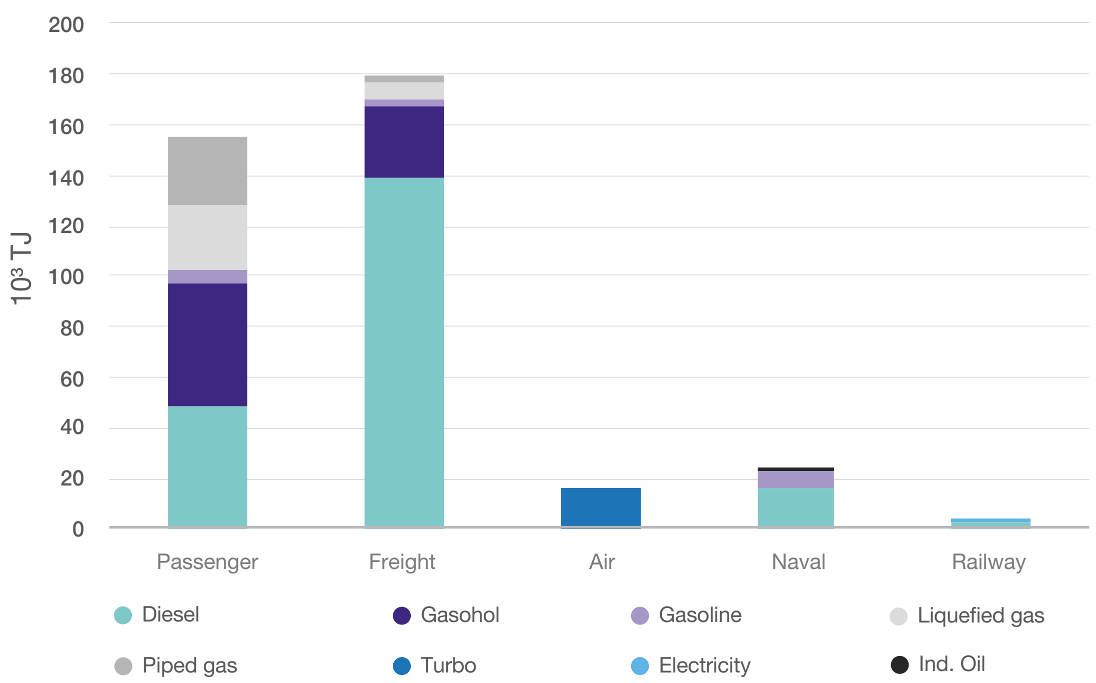
	Total consumption (10^3 TJ)	Diesel	Gasohol	Gasoline	Liquefied gas	Piped gas	Turbo	Electricitydad	Oil
Passengers	156	31%	32%	3%	16%	18%	-	-	-
Freight	180	77%	16%	1%	4%	1%	-	-	-
Air	16	-	-	-	-	-	100%	-	-
Naval	24	67%	-	29%	1%	-	-	-	3%
Railway	2	89%	-	-	-	-	-	11%	-

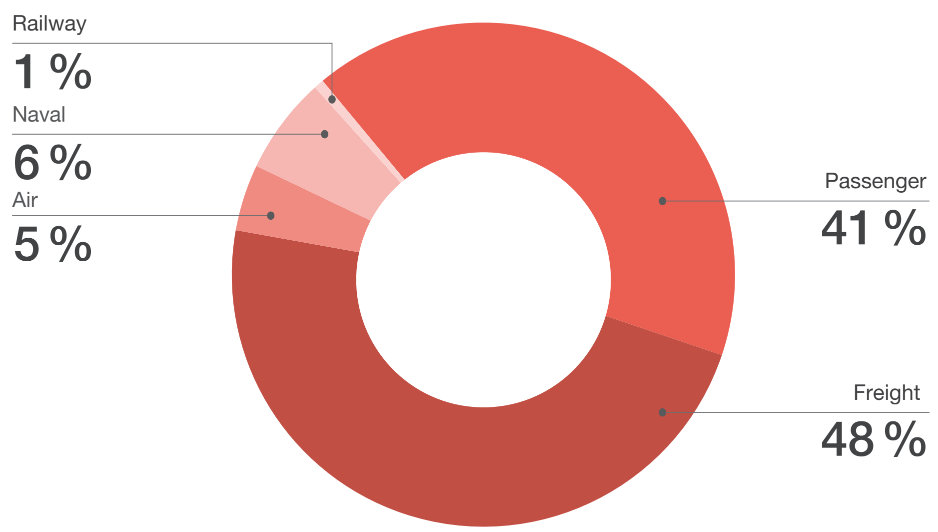
Source: Own preparation based on data from the useful energy balance, 2013, Mercados energéticos consultores, Datum Internacional.

Freight transportation consumes the most energy (48% of the total) and uses mainly diesel, followed by passenger transportation (41%). In terms of consumption by fuel, passenger transportation consumes mainly gasohol, diesel, piped gas, and LPG.

12 The differences observed between the energy balance published by OLADE and the National energy balance are due to the accounting of energy consumption of international transport. For the energy projections in the following chapter, data from the national energy balance was used.

Graphic 24 Transportation sector: Final consumption by type and by fuel, 10^3 TJ





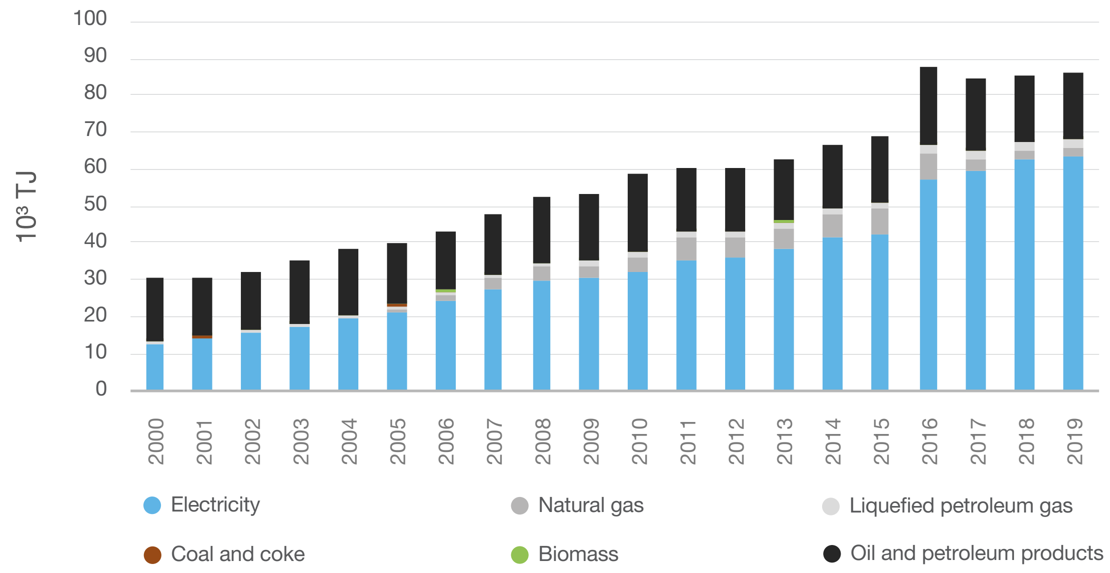
Source: Own preparation based on data from the useful energy balance, 2013, Mercados energéticos consultores, Datum Internacional.

Agricultural, fishing, mining, and construction sector

Final consumption in the sector has increased irregularly in the last 20 years (5.7% annual average)[13]. By source, the following characteristics can be pointed out:

- large share of electricity (74%);
- participation of oil and petroleum products (close to 21%);
- supply of LPG and natural gas in the rest of the demand.

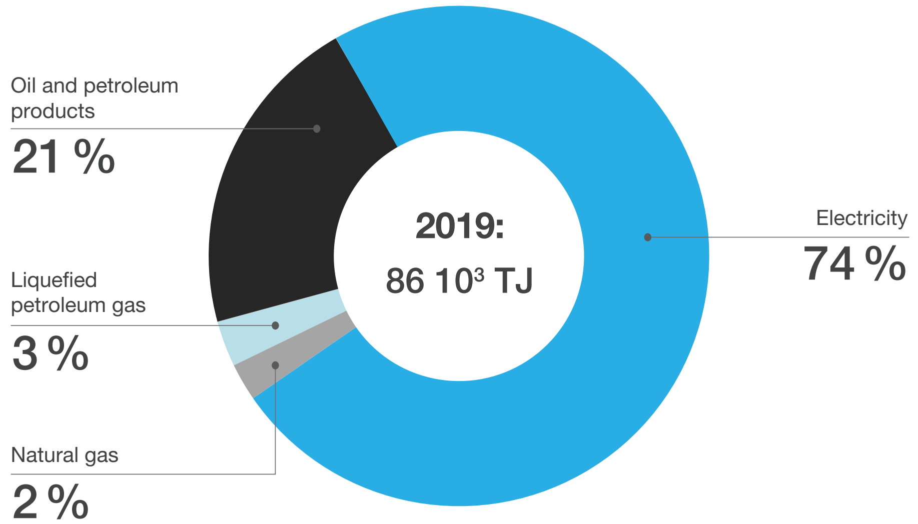
Graphic 25 A Other sectors: evolution of final consumption by source, 10^3 TJ



Source: Own preparation based on data from sieLAC, OLADE.

13 The increase in power consumption since 2016 could be the result of a change in the statistics counting methodology or a new additional demand in the sector.

Graphic 25 B ▶ Other sectors: evolution of final consumption by source, 10^3 TJ



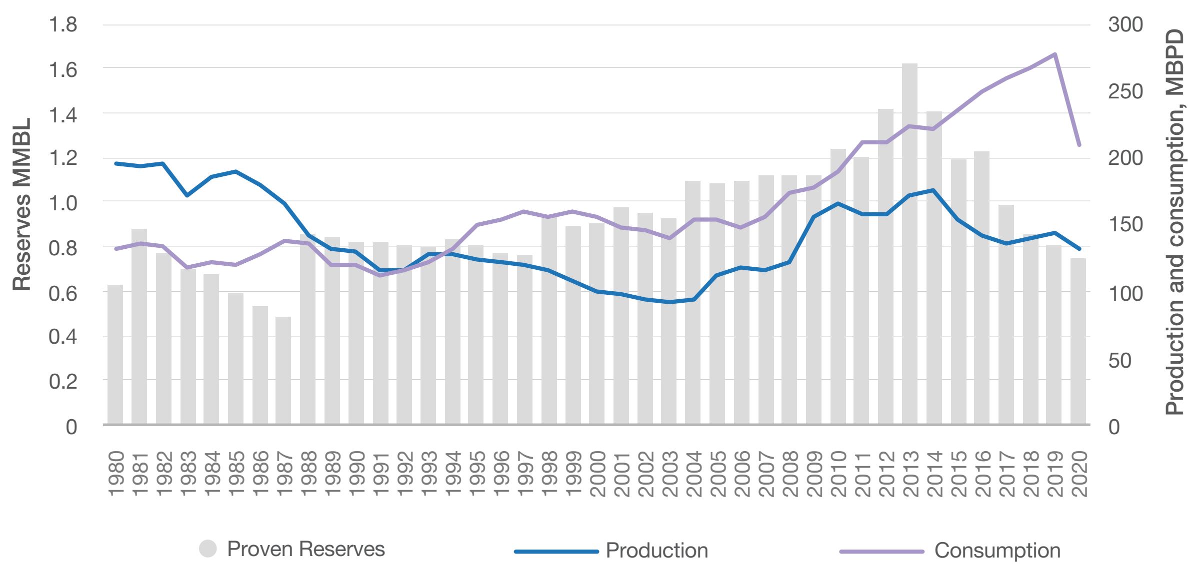
Source: Own preparation based on data from sieLAC, OLADE.

By subsector, we can mention that the mining sector adds up most of the demand (89%) and the agricultural and fishing sectors cover the rest (8% and 4%, respectively).

5. International trade

Peru is a net oil importer. Even though in the 1980s the country was a net exporter – it produced more oil than its refineries required –, this situation changed in the 1990s. Since then, Peru has become a net importer, notwithstanding the growth of its reserves, which started to decline rapidly as from 2013.

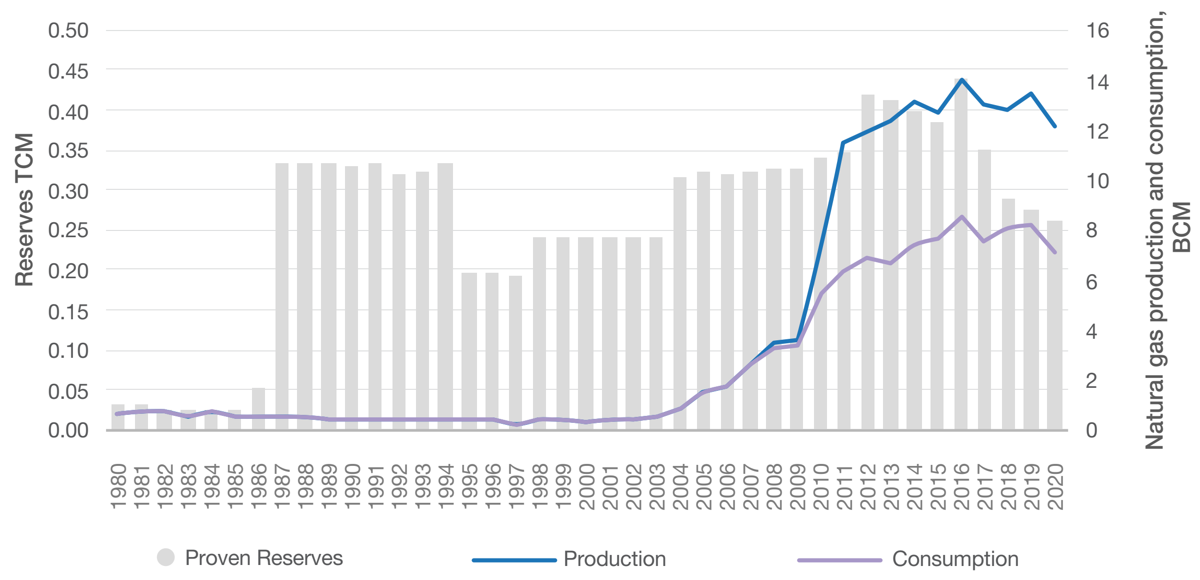
Graphic 26 ▶ Oil reserves, production and consumption, MMBL



Source: Own preparation based on data from *BP Statistical Review of World Energy 2022*.

As regards natural gas, the development of the Camisea field was a turning point that led to the characterization of the country as a net natural gas exporter.

Graphic 27 Natural gas reserves, production and consumption, TCM



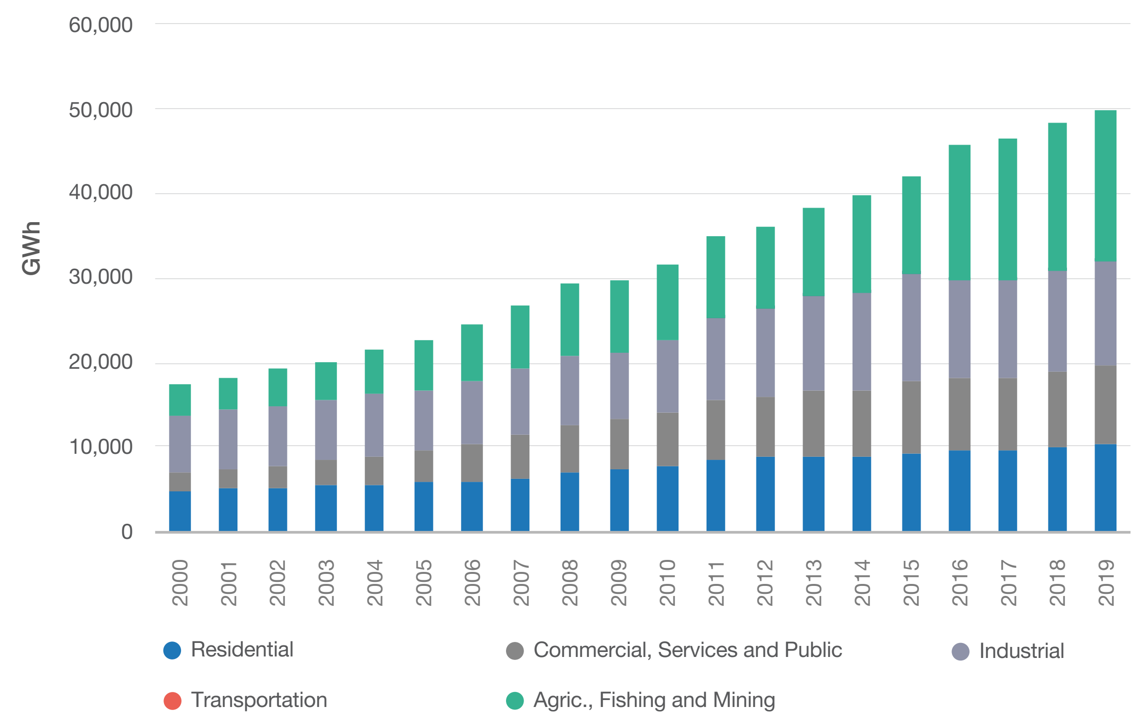
Source: Own preparation based on data from *BP Statitiscal Review of World Energy 2022.*

6. Power sector

Electric demand

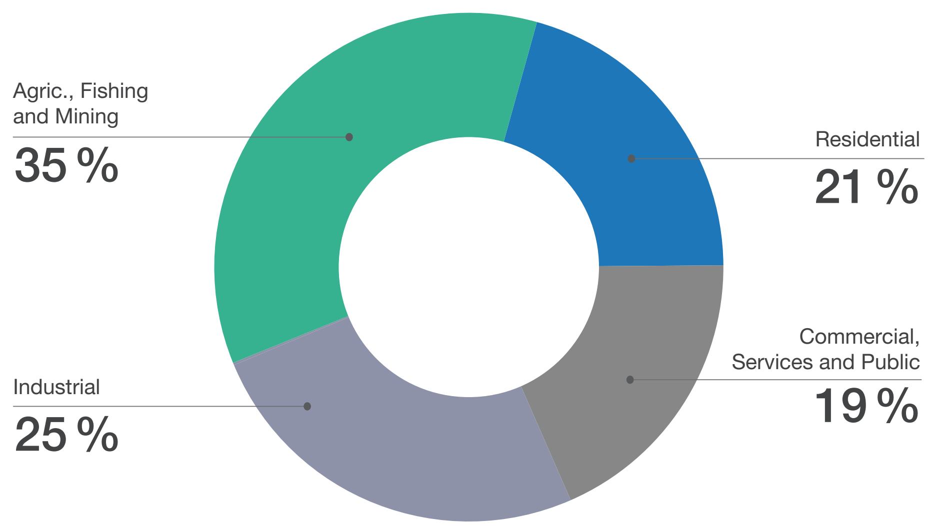
Graphic 28 shows final power consumption broken down into the different sectors of the economy.

Graphic 28 A Final electricity consumption by sector, 2000-2019, and year 2019, GWh



Source: Own preparation based on data from sieLAC, OLADE.

Graphic 28 B ▶ Final electricity consumption by sector, 2000-2019, and year 2019, GWh



Source: Own preparation based on data from sieLAC, OLADE.

Historically, power demand in Peru maintained a direct relation with economic growth, which is largely explained by the industrial sector (mining, construction), and the population growth. Short and long-term growth trends were as follows:

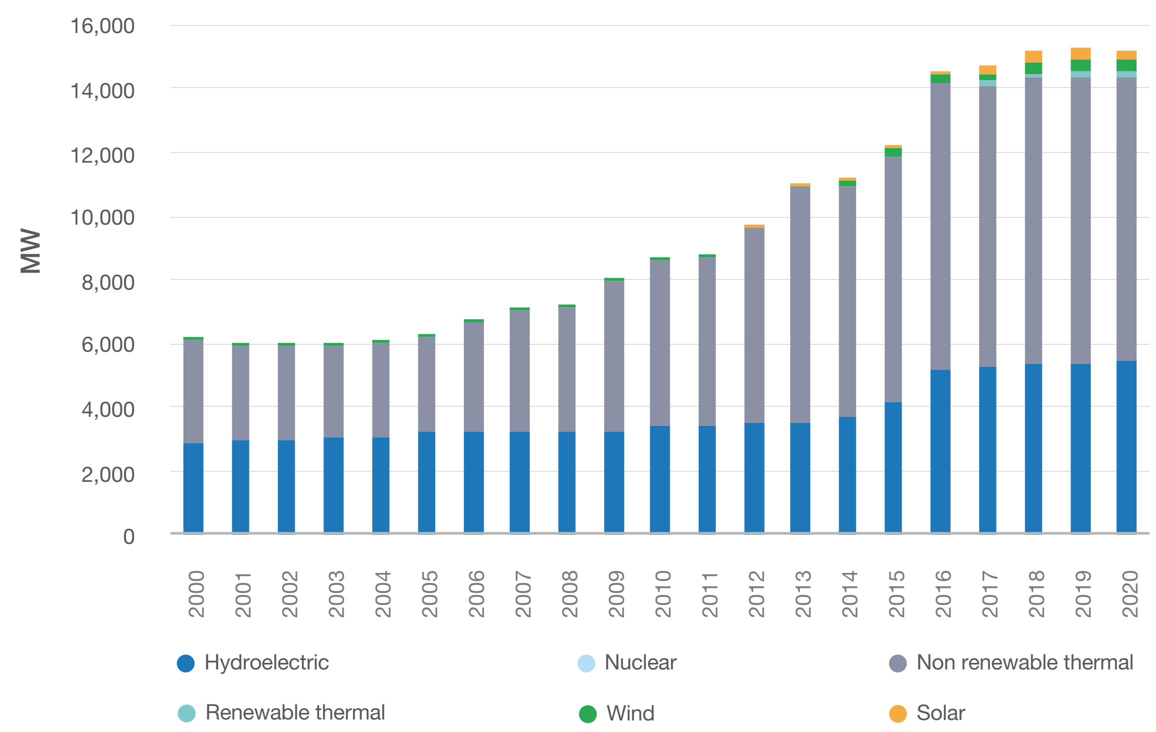
- 5.7% in the long term (between 2000 and 2019), and
- 4.6% in the short term (between 2014 and 2019).

In 2019, the average composition of electric consumption in Peru included the agricultural, fishing, and mining sector (35%) in the first place, followed by the industrial sector (25%) and the residential sector (21%). In the last 20 years, the share of the residential sector in total power consumption has decreased from 28% in 2000 to 21% nowadays.

Installed capacity

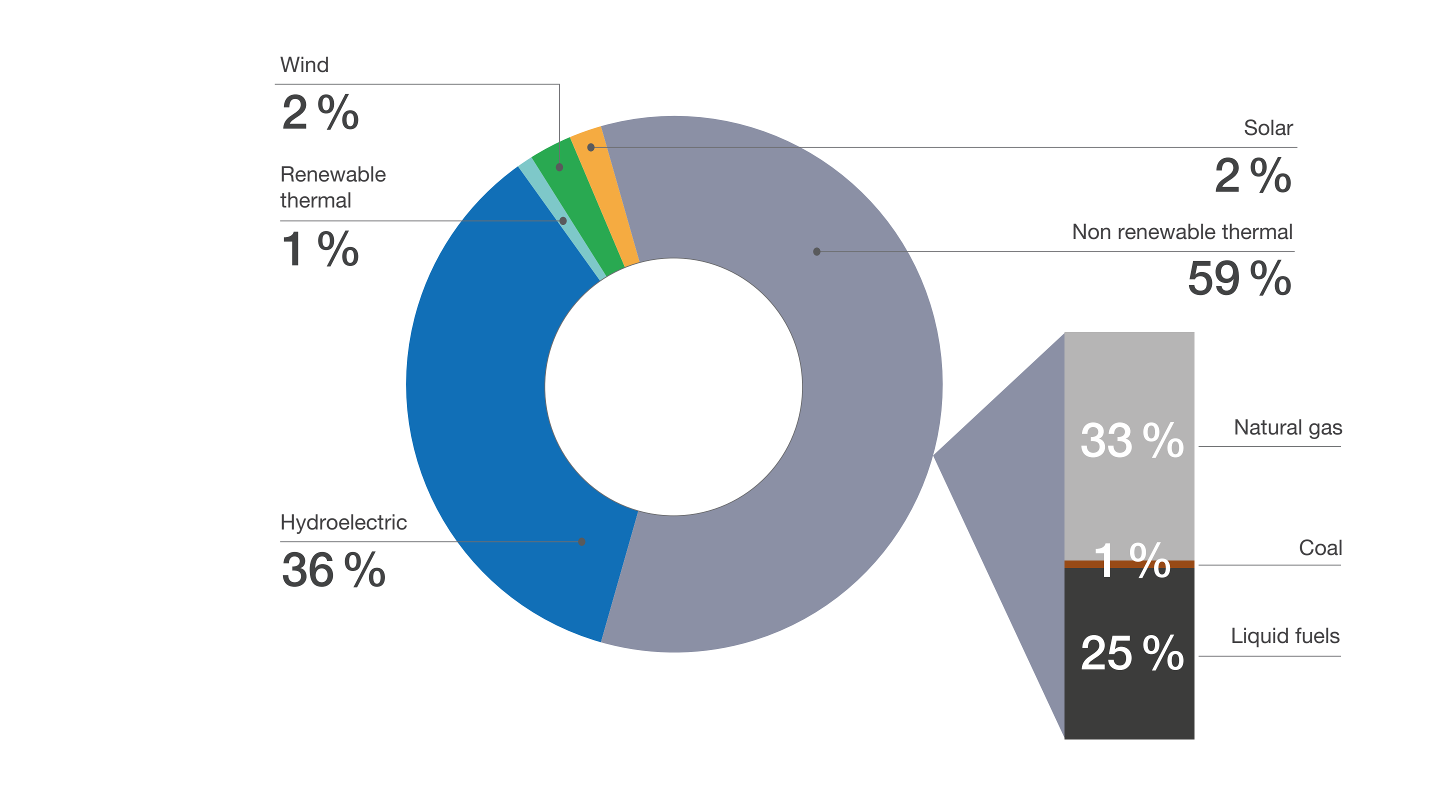
Installed capacity in Peru was about 15 GW in 2019 (including isolated systems). Around 59% of the installed capacity was related to non-renewable thermal plants (mainly gas-fired or running on liquid fuels) whereas hydro plants accounted for 36% of the installed capacity.

Graphic 29 ▶ Installed capacity, 2000-2020, MW



Source: Own preparation based on data from sieLAC, OLADE. It includes isolated systems (SS AA, in Spanish).

Graphic 30 Installed capacity by source, 2019, %



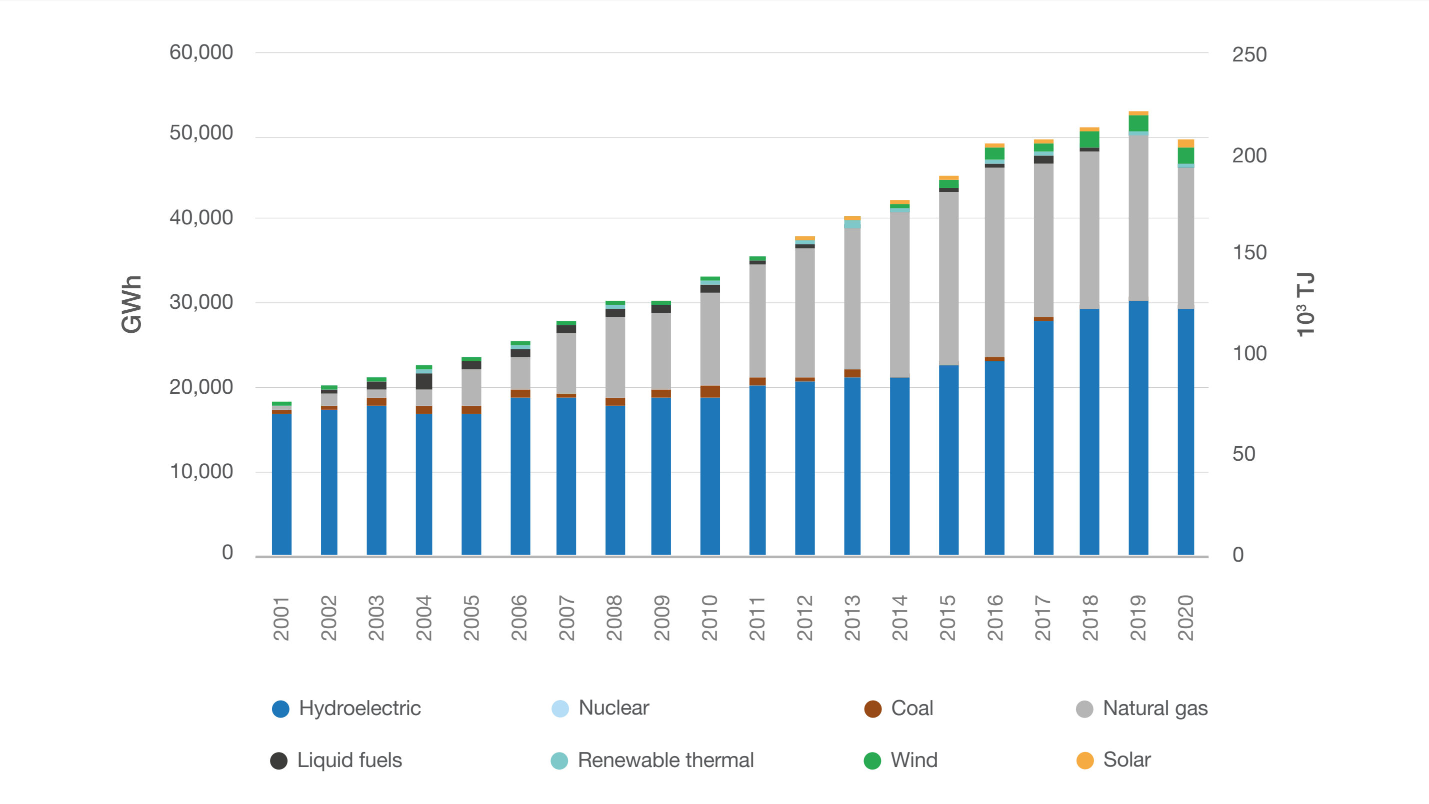
Source: Own preparation based on data from COES and MINEM. It includes isolated systems (SS AA, in Spanish).

In the last decade, many gas-fired plants were installed (around 40% of the current total), which implies a young generation fleet. In recent years, wind and solar projects have started developing to diversify the generation matrix; 1,655 MW of wind energy and 763 MW of solar energy were installed by 2019.

Power generation

In the period, we can observe a large increase in generation based on natural gas, which reached a share of 37% in 2019 and was in a second position only after hydroelectricity (57%). Natural gas was introduced in 2004 when the Camisea field[14]. started operating. Petroleum products (bunker and diesel) currently have a very low participation. Hydro generation shows a growing trend in the period at an annual average rate of 3.3%.

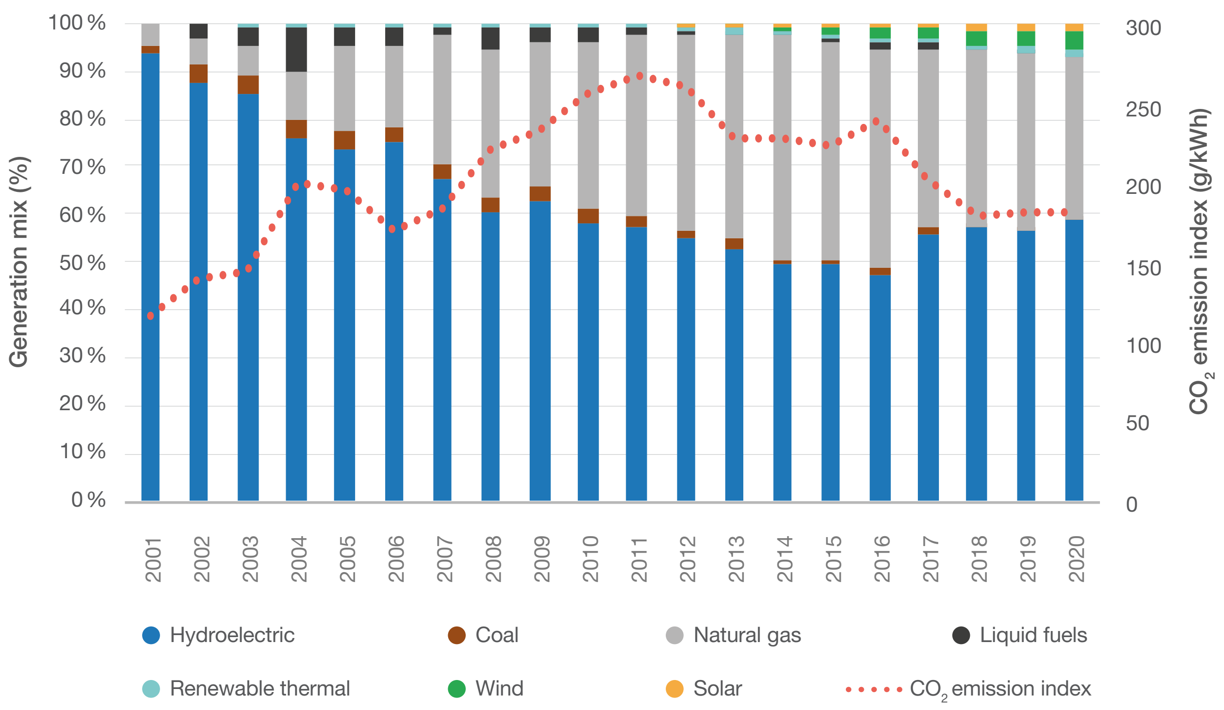
Graphic 31 Power generation by source, 2001-2020, GWh and 10^3 TJ



Source: Own preparation based on data from COES (system operator) and sieLAC, OLADE.

14 Camisea is one of the most important conventional natural gas reservoirs in South America.

Graphic 32 Power generation by source 2001-2020, %, and CO_2 emissions index of the power sector, g/kWh



Source: Own preparation based on data from COES and sieLAC, OLADE.

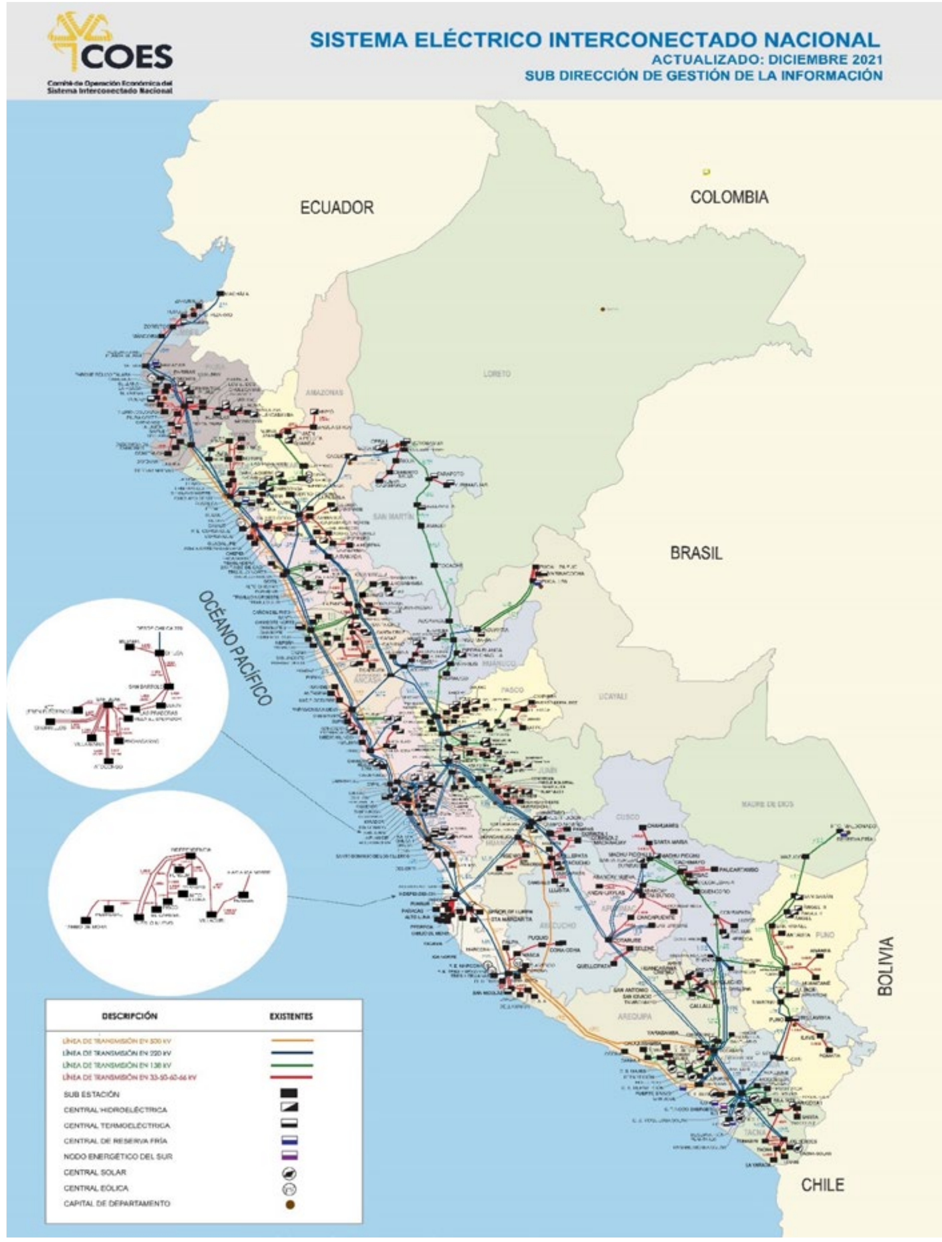
Natural gas supplied a large portion of the demand increase, which led to a rise in the CO_2 emissions index in the period.

Finally, due to the significant share of hydroelectricity in the generation composition, the Pool prices reflect certain volatility in the Peruvian system. They also show seasonality (rainy season from May to November and dry season from December to April). Recently, prices have been low because of relative market oversupply.

7. Existing power grids and gas pipelines

Peru currently has 29,000 km of power transmission lines (2020, COES) and 730 km of gas transportation networks (2022, OSINERGMIN).

Graphic 33 National Interconnected Electricity System, 2021, Peru



Source: COES.

Graphic 34 Natural gas transportation network - Lima and Callao, 2022, Peru

Source: OSINERGMIN.

Peru has great potential for hydroelectric, onshore and offshore wind, solar, and geothermal energy, all of which are favorable resources for developing a low-emission power generation park. The south of the country enjoys one of the best solar radiation indices in the world.

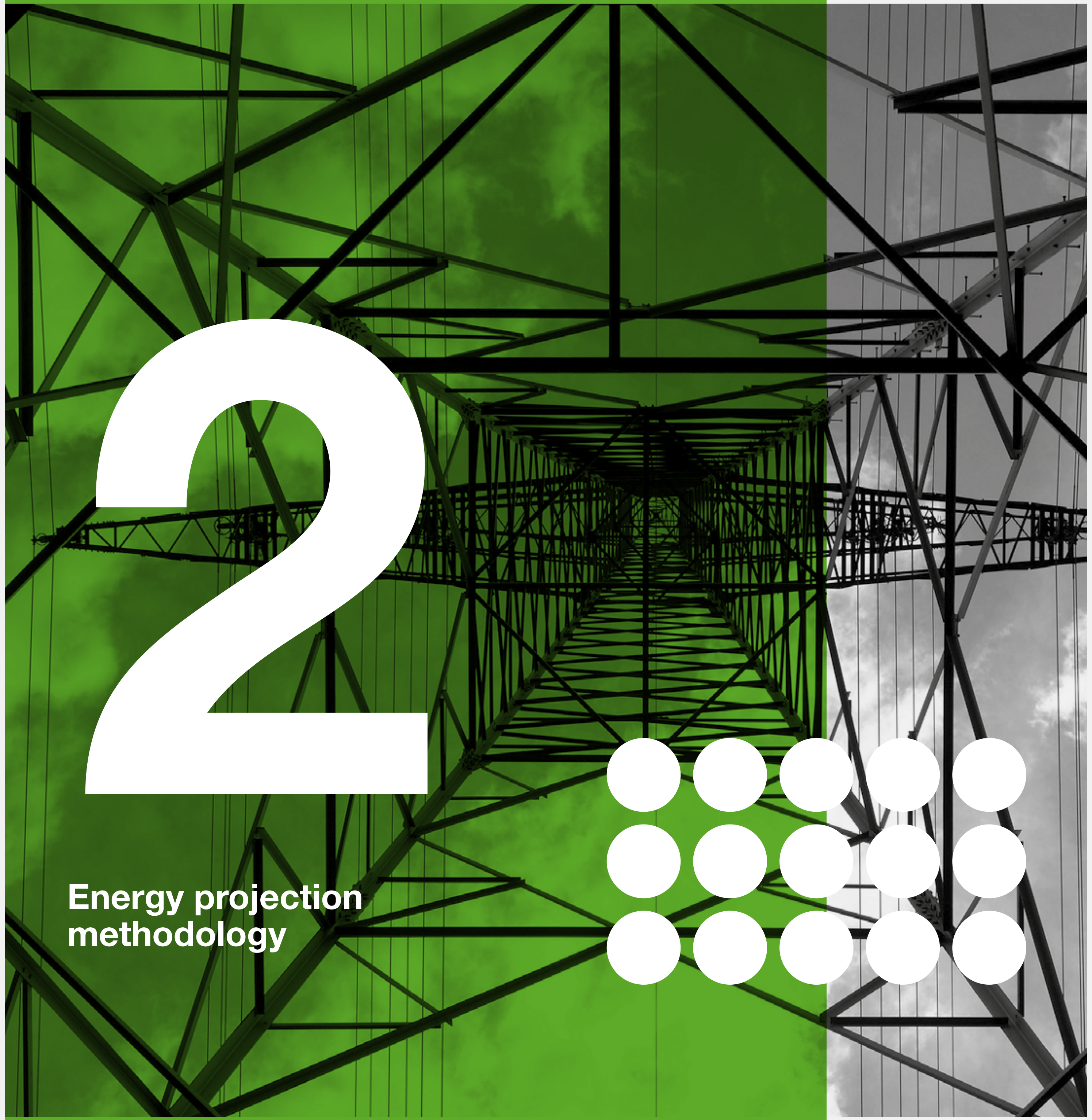
8. Conclusions

Peru shows a current reality with certain relevant characteristics as a base line to face the energy transition towards carbon neutrality.

- The performance of the Peruvian economy has shown a sustained historical economic growth that may favor an energy transition process.
- However, in spite of the economic growth, we must consider that there is a high degree of informality in the country, with a very important fraction of the population that is outside the economic circuit.
- Even when the incidence of poverty and extreme poverty is high, its reduction, which will necessarily take place as part of the transition (the United Nations' definition of sustainability refers to three main areas: social, economic, and environmental) will imply a growth in energy demand. This energy demand growth will not only increase investment requirements but also – simultaneously – will allow opening up markets, which can increase competitiveness in order to introduce new low-emission technologies.
- The country has a hydroelectric potential of around 70 MW, only 8% of which is exploited. This allows for its expansion. Most of this hydroelectric potential is from the Atlantic basin, which requires reservoirs in the jungle, which may bring about environmental problems.
- It also has great onshore wind potential (20 MW) as well as offshore wind, solar (25 MW) and geothermal (3 MW) potential. All these resources are favorable to develop a generation fleet with low emissions. In particular, the south of Peru is benefitted by one of the best solar radiation indices in the world.
- Peru has important natural gas reserves; it is a net exporter and has a reserves/production horizon of about 25 years. This is a positive aspect for the country, since natural gas is internationally accepted as a sustainable

fuel for energy transition in the medium term, as established by the European Parliament.

- The prices of energy products are highly subsidized through a cross subsidy (price of electricity) and direct subsidies (LPG). At present, the price of diesel and of certain gasolines is subsidized.
- There is no detailed regulation for distributed generation.
- Different policies have been developed in connection with energy transition, for example:
    - Renewable energy auctions to generate electricity; and
    - RER legislation for non-conventional renewable energy in power generation.



2

Energy projection methodology

1. Base year and planning horizon

The base year considered for the projection, and previously described in the chapter “Diagnosis and base line”, is 2019. The planning horizon starts in 2019 and ends in 2060.

2. Projection modeling

General description

In order to conduct the study, a low-emissions analysis platform (LEAP) model, developed by the Stockholm Environment Institute (SEI), was used. The LEAP model is a (software) tool used to analyze energy policies and assess climate change mitigation. In this case, it was used to model the emissions from the energy sector relating to burning fuel in Mexico.

In terms of modeling methodologies, the LEAP model is particularly versatile.

- It starts from the information from the energy balances, which guarantee the integrity of the data used.
- Energy demand can be projected by using methodologies:
    - bottom-up, from specific detailed data to a total projection, or
    - top-down.

    In this study, bottom-up modeling was selected and the demand was divided into sectors (residential, industrial, transportation, etc.) which, in turn, were subdivided into subsectors and uses.
- Energy supply offers a wide range of simulation methodologies that allow us to estimate an annual power generation dispatch or incorporate the results of other more specialized optimization models.

The modeled demand sectors are projected according to an activity level and an explanatory variable, summarized in Graphic 33 in a simplified manner.

Graphic 35 Sectors, activity levels, and explanatory variables.

Sector	Activity level	Explanatory variable
Residential	Population	Consumption per capita
Road transportation	Target variable, vehicle fleet	Average consumption per vehicle
Non-road transportation	Total GDP	Energy intensity
Industrial	Sectoral GDP	Energy intensity by subsection and use
Commercial, Services, and Public sector	Sectoral GDP	Energy intensity
Agricultural, Fishing, Mining, and Construction sector	Sectoral GDP	Energy intensity

Source: Own preparation.

The sectoral GDP is one of the main drivers of energy demand growth, particularly for production sectors, while the evolution of the population plays an important role in the energy demand growth of the residential sector. The road transportation sector depends on the evolution of the number of vehicles which, in turn, is related to the GDP per capita in the case of passenger transportation and the GDP in the case of freight transportation. Non-road transportation is projected on the basis of the global GDP.

The modeling adopted for this study is described below in more detail by demand sector and for the power sector. Given that the decarbonization strategy seeks to replace fossil fuels (coal, oil, and petroleum products, natural gas, etc.), the value chain associated with these fuels was not analyzed in detail, assuming that there will be enough supply.

Energy projection methodology

Demand by sector

Residential sector

In order to analyze and project energy consumption in the residential sector, the **projection of the population and of unitary consumption** are estimated by use and by source per capita.

Residential consumption has two kinds of energy uses: heat uses (mostly cooking, sanitary hot water (SHW), space heating), which use different fuels with substitution potential, and electrical uses (lighting, refrigeration, etc.). The following analyses apply to each group.

- **Heat uses**
  - **Cooking.** The historical consumption trends used for future projections are analyzed in terms of useful energy[15] per 1,000 inhabitants. Fuel substitution assumptions by scenario are presented (replacement of firewood with electric appliances or others running on natural gas).
  - **SHW and space heating.** Given that these sectors are incipient and this type of consumption takes place with the increase in GDP per capita, the current consumption observed in Spain and Portugal (countries with similar climate conditions to the region) is extrapolated as target consumption[16]. A broader implementation of energy efficiency measures and assumptions on the types of fuel to be used are also presented.

15 According to OLADE, IADB, 2017, final energy is "the amount of energy source consumed in each economic and social sector in the country". On the other hand, useful energy is "the amount of energy actually used to perform the productive task of the consuming equipment or device, for example, the necessary heat that food must absorb to be cooked".

16 It is assumed that the increase in purchasing power (GDP per capita) entails an increase in the demand due to the higher levels of comfort enjoyed by the individuals. This implies an increase in current consumption to international levels compatible with a decent standard of living.

- **Other electrical uses.** Electrical uses (lighting, refrigeration, air conditioning, water pumping, electronics, etc.) are projected based on a historical regression against the GDPpc, which reflects the increase in electrical uses as the standard of living increases. In addition, energy efficiency enhancements are considered.

Commercial, services, and public sector

In order to estimate the energy consumption of the commercial sector, we started from its consumption in 2019 and projected it **based on the GDP growth and energy intensity obtained for the base year**, by source, without discriminating by end use. Different assumptions are presented in terms of energy efficiency and fuel substitution.

Industrial sector

Industry was projected with information on energy consumption from 2019, broken down with an International Standard Industrial Classification (ISIC) digit, additional to that of the sector's GDP, that is, **by activity subsector**. Eight subsectors were modeled, of which food, cement, and other industries were the most relevant in terms of energy consumption. In turn, for each industrial subsector, consumption is broken down by end use (direct heat, indirect heat, motive force, etc.) and by source.

Expected GDP growth, together with energy intensity by subsector and use obtained for 2019 are used for the energy consumption projection, mainly based on the final and useful energy balances available. The assumption was that the subsectors will maintain their share of the total industrial GDP during the planning horizon[17]. Energy

17 This assumption implies that no structural changes are modeled within the industrial sector and the same GDP growth rate is applied to all the subsectors.

Energy projection methodology

efficiency is modeled through a reduction in energy intensity while fuel substitutions are performed in terms of useful energy, with annual rates of participation.

Transportation sector

The transportation sector is projected pursuant to the following structure to reflect the main drivers that vary in each segment:

- road passenger transportation (cars, motorcycles, buses, etc.);
- road freight transportation (trucks, truck tractors);
- other (air, maritime/river, railway).

Road passenger transportation

To estimate the energy consumption level or the activity level of road passenger transportation, the following were estimated:

- **evolution of the vehicle fleet** (number of motorcycles, cars, light trucks, buses, etc.; and
- **average consumption by vehicle** calculated as the average annual distance traveled, divided by performance in km by energy unit.

Projection of the passenger vehicle fleet

- Private transportation (motorcycles, cars, light trucks)

In the first place, the countries with high development levels were identified and the average number of cars and motorcycles per 1,000 inhabitants in these countries was estimated. Such average was used as a long-term **saturation point**

(2060), and projections were made using a logit function[18] to estimate the number of future private transportation vehicles.

In addition, to calculate the number of vehicles by type (motorcycles/cars), Law's conclusions (Law, 2015) on the relation between **the number of motorcycles per 1,000 inhabitants and GDP per capita** shaped like an **inverted "U"**[19]. were used. This implies that, at first, the number of motorcycles per 1,000 inhabitants has a positive relation to GDP per capita until it peaks; from there on, as the development level of the countries increases, the number of motorcycles starts to fall and the number of cars increases.

- Public transportation (bus)

Like in the case of private transportation, the average number of passenger vehicles per 1,000 inhabitants in developed countries was considered as an expected saturation point for developing countries in the long term. A logistic function was also used.

Road freight transportation

To estimate the energy consumption level or the activity level of the freight transportation sector, the following were estimated:

- **evolution of the vehicle fleet** (number of trucks + truck tractors), and
- **average consumption per vehicle** calculated as the annual average distance traveled divided by performance in km per energy unit.

18 The logit function or logistic curve or S-shaped curve is a mathematical function used in population growth models, product introductions, etc. Such function is a refinement of the exponential model for magnitude growth. In product introduction, growth is initially exponential; after some time, the growth rate decreases; finally, at maturity, growth stops.

19 Law, Hamid & Goh (2015), *The motorcycle to passenger car ownership ratio and economic growth: A cross-country analysis.*

Projection of the freight vehicle fleet

In order to estimate the future evolution of the freight vehicle fleet, the freight transportation fleets were projected with the linear regression method using the total GDP (measured at PPP of 2017) as an independent variable.

Freight transportation is segmented into two types of trucks: trucks and truck tractors; the latter are heavy-duty trucks with trailers. The shares of each type of truck were projected as constant.

Air, maritime/river, and railway sector

Energy consumption for the sector was projected based on the global GDP growth and the energy intensity obtained for 2019, for each type of transportation, by source and without discriminating by end use.

Agricultural, fishing, mining, and construction sector

Energy consumption for this sector was **projected based on the GDP growth and energy intensity** obtained for 2019, by source and without discriminating by end use. The transition measures considered were enhancements in terms of energy efficiency and fuel substitution..

Power sector

The starting point was the current composition of installed capacity and generation. To cover the growth of the sector in the short and medium terms, the development of the power sector considers the projects under construction with a high degree of certainty and progress.

In the future, the expansion of the generation fleet will depend on:

- the relative competitiveness of the expansion options (renewable projects, particularly solar and wind, are believed to become more and more competitive due to the projected reduction in construction and development costs);
- the maximum project development potential by technology, as published at national level. This potential is considered a maximum limit;
- energy policy decisions included in the generation expansion plan;
- the local context regarding the development of projects by type.

The expansion of the generation fleet considers aspects such as:

- the average production factor, by technology and by country, for renewable projects;
- the firm energy or capacity that each technology can provide;
- the minimum production factor from which new thermal projects are developed;
- the estimation of power demand[20], including losses and own consumption.

20 The projections presented in this report do not include the power demand associated with the electrolysis process to produce green hydrogen for local consumption and/or export, nor the related electrical capacity.

The analysis is carried out on an annual basis (that is, it is not a detailed hourly simulation exercise but a 'high-level' estimation, as a first estimation in the context of a long-term energy transition analysis).

Even though most countries will need flexibility means (storage, demand management) to accompany the development of non-conventional renewable energy (NCRE), a high-level estimation was carried out in the chapter on financing[21].

21 Current technologies are not competitive and productivity enhancements are expected, which prevents us from establishing with certainty the degree of penetration they could reach.

Detailed modeling of energy demand, broken down by sector, branches, end uses, and fuel types, along with the projection of energy supply by technologies, enables the analysis of a wide variety of transition scenarios.

3. Scenarios and global framework

Definition of the scenarios

Three scenarios were studied to characterize different pathways towards a just energy transition. See the detailed description in the chapter “Methodological section and assumptions”, *Just Energy Transition / Projection Assumptions* report.

The **Business as Usual (BAU)** scenario represents the expected evolution **following national public policy guidelines and the current trends**. The assumptions are based on the analysis of recent historical trends in terms of energy transition in each analyzed country, as well as the paths traveled by more developed countries, to identify mitigation measures that can be rapidly implemented. Even though no disruptive changes are expected in this scenario and it is not possible to meet the net zero emissions target during the planning horizon, investment is required to continue the energy transition policies that are being carried out in Peru.

On the other hand, **the Net Zero 2050 (NZ 2050) and Net Zero 2060 (NZ 2060) scenarios** are based on the terms established in Article 4 of the Paris Agreement[22]. Both scenarios focus on reducing GHG emissions from the

22 Paris Agreement, paragraph 4.1: “achieve a balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of the century”.

energy sector[23] to a permissible minimum[24], so that the country can manage the absorption of CO_2 in the general balance of the national GHG inventor[25].

These scenarios require major investment and addressing different topics to **transform the current energy sector deeply**. Such topics include, for example, strengthening the technological bases, training human resources, energy planning, regulatory commissioning, infrastructure expansion, and instruments to develop the market for the new energy resources, as well as **changes** – in some cases disruptive – in the energy matrix, among others.

Projections of the socio-economic variables

GDP per capita and GDP

In line with the grounds for a **just energy transition (JET)**, the scenarios presented are accompanied by similar socio-economic development in the region, **reaching sufficient GDP per capita levels to be considered high-income countries**. In the case of Peru, the GDP per capita stands at approximately USD 41,500 per capita at PPP in 2060, with a 2.9% annual growth rate in the period.

23 The analysis performed focuses on the emissions related to burning fuel, both in energy demand processes by sector and in power generation. GHG emissions from other sectors (e.g., industrial processes, waste, fugitive emissions, etc.) are not detailed in this study, but are broadly estimated and are subtracted to estimate the national reduction potential.

24 It is assumed that emission reduction must be achieved through an effective combination of regulatory measures, promotion of market efficiency, technology transfer, and investment.

25 It is assumed that CO_2 absorptions will result from measures implemented in the agricultural, cattle-raising, forestry, and other land uses (AFOLU) sectors or via the adoption of CO_2 capture, use, and storage technologies (CCUS).

Table 10 Socio-economic indicators and CAGR 2019-2060 (%)

		2019	2030	2040	2050	2060	CAGR period
GDP per capita	USD per capita	12,753	18,020	24,297	32,147	41,563	2.9 %
Total GDP	MUSD	418,610	661,382	965,078	1,350,929	1,807,592	3.6 %
Population	1,000 inhabitants	32,825	36,702	39,720	42,023	43,490	0.7 %

Source: Own preparation.

The GDP by sector is projected assuming that the share of each sector is maintained pursuant to 2021 values. This results in a GDP growth rate by sector equal to the total GDP growth rate.

Population

As to the projection of the population, information from CEPALSTAT[26] was used. A deceleration in population growth is expected in Peru in the future.

26 https://statistics.cepal.org/portal/cepalstat/dashboard.html?theme=1&lang=es

4. Main assumptions of the energy sector

The general framework of the study covers the definition of assumptions for **five target countries**. Even though each country has its own characteristics, the study **standardizes, whenever possible, the assumptions used** and assumes that the countries will undergo similar processes for the just energy transition. The particularities inherent in each country were considered, such as the coal industry in Colombia, biofuels in Brazil, natural gas at very competitive prices in Mexico, gas in Peru, and fossil natural resource shortage in the Dominican Republic, among others.

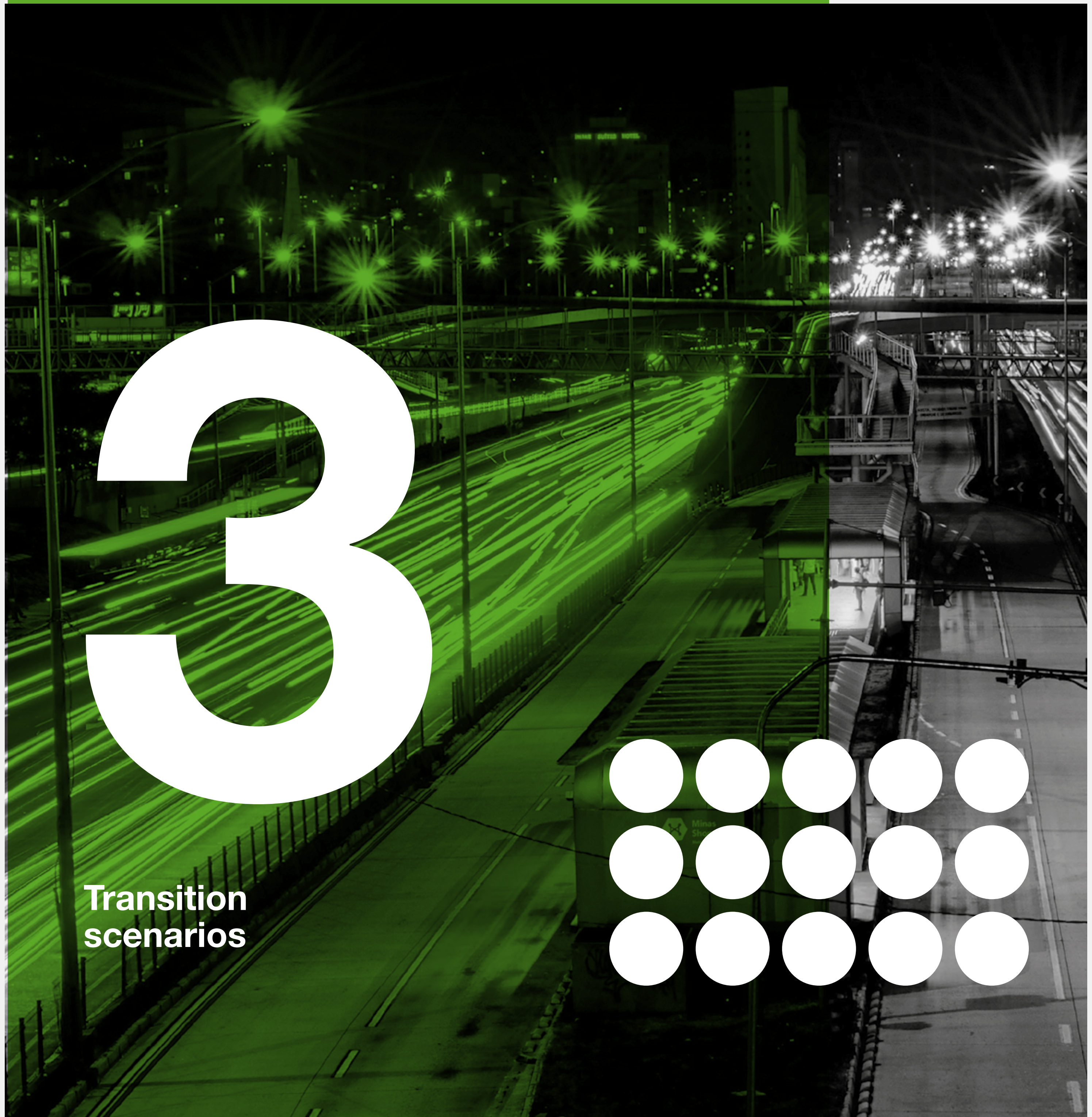
In order to meet the decarbonization targets set in each scenario, the assumptions considered were more ambitious in the case of the net zero (NZ) scenarios. The main assumptions are based on the measures described below.

- **Energy efficiency enhancements.** This is applied in all sectors, with equipment replacements, more thermal efficiency in homes, optimization of the use of energy in industrial processes, and technological replacements

to more efficient appliances and facilities, more efficiency in transportation vehicles, etc.

- **Behavior changes.** This refers, in particular, to the reduction in average distances traveled by vehicle (km/vehicle) as a result of digitalization in society (remote work, etc.), the development of public transportation, logistics enhancements, and the shift from freight transportation by truck to the railway system.
- **Fuel substitution.** In most of the sectors, there is a trend towards further electrification of energy uses, except for industrial uses or subsectors where there are low electrification possibilities. In these cases, the replacement of fuels with more CO_2 emissions by natural gas or the use of CO_2 capture and storage technologies are the projected options. Hydrogen and low-emission derivatives may also contribute to the decarbonization of the industrial sector (fertilizers, refining) and of heavy road, maritime, and air transportation (synthetic fuels).
- **Power generation matrix with non-fossil technologies.** A very significant development of renewable energy and, in some cases, nuclear energy, is incentivized, as well as the phase-out of coal-fired plants and plants running on liquid fuel. It is important to remember that power generation composition is a key element in scenarios where a strong electrification of the consumption matrix is proposed to guarantee that this substitution will have the expected effect in terms of GHG reduction. This integration of renewable energy must be accompanied by the development of grid infrastructure, smart grids, and batteries to facilitate the integration of variable power generation.

The assumptions detailed by sector are presented in the chapter “Results and assumptions by sector”. It is important to point out that the sectors with the most emission reduction potential in absolute values are the transportation and industrial sectors, which nowadays are responsible for around two thirds of the emissions from the energy sector.



1. Global results

The global results presented below reflect the sum of the assumptions adopted by each sector.

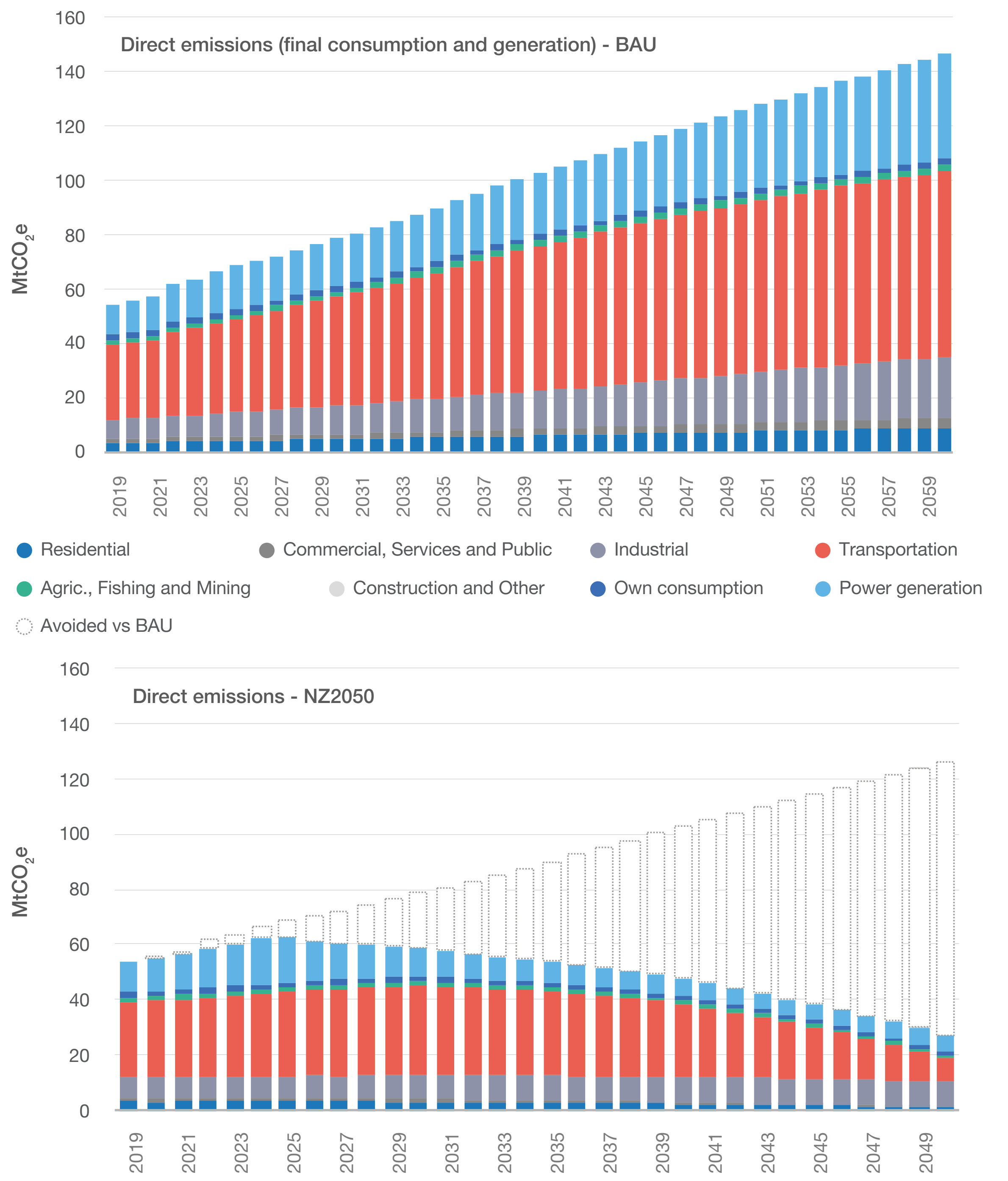
Emissions by sector

In the **BAU scenario**, the emissions related to burning fuels grow at an average annual rate of 2.5%, from 54 MtCO_2e in 2019 to 147 MtCO_2e in 2060. Even though this **increase** is sustained, it is **lower than the expected GDP growth**, which shows a certain environmental improvement in the economy. The transportation sector continues being the greatest polluter in Peru, followed by the power generation and industry segments. This scenario is well above the country's CO_2 absorption capacity, estimated at 37.4 MtCO_2e per year[27].

In the **NZ scenarios**, emissions fall to 28 MtCO_2e in 2050 (NZ 2050 scenario) and up to 33 MtCO_2e in 2060 (NZ 2060 scenario), thus meeting **the net zero emissions target**. The average annual emission reduction pace is -2.2% in the NZ 2050 scenario and -1.2 % in the NZ 2060 scenario. The industrial and transportation sectors are the ones with the most emissions.

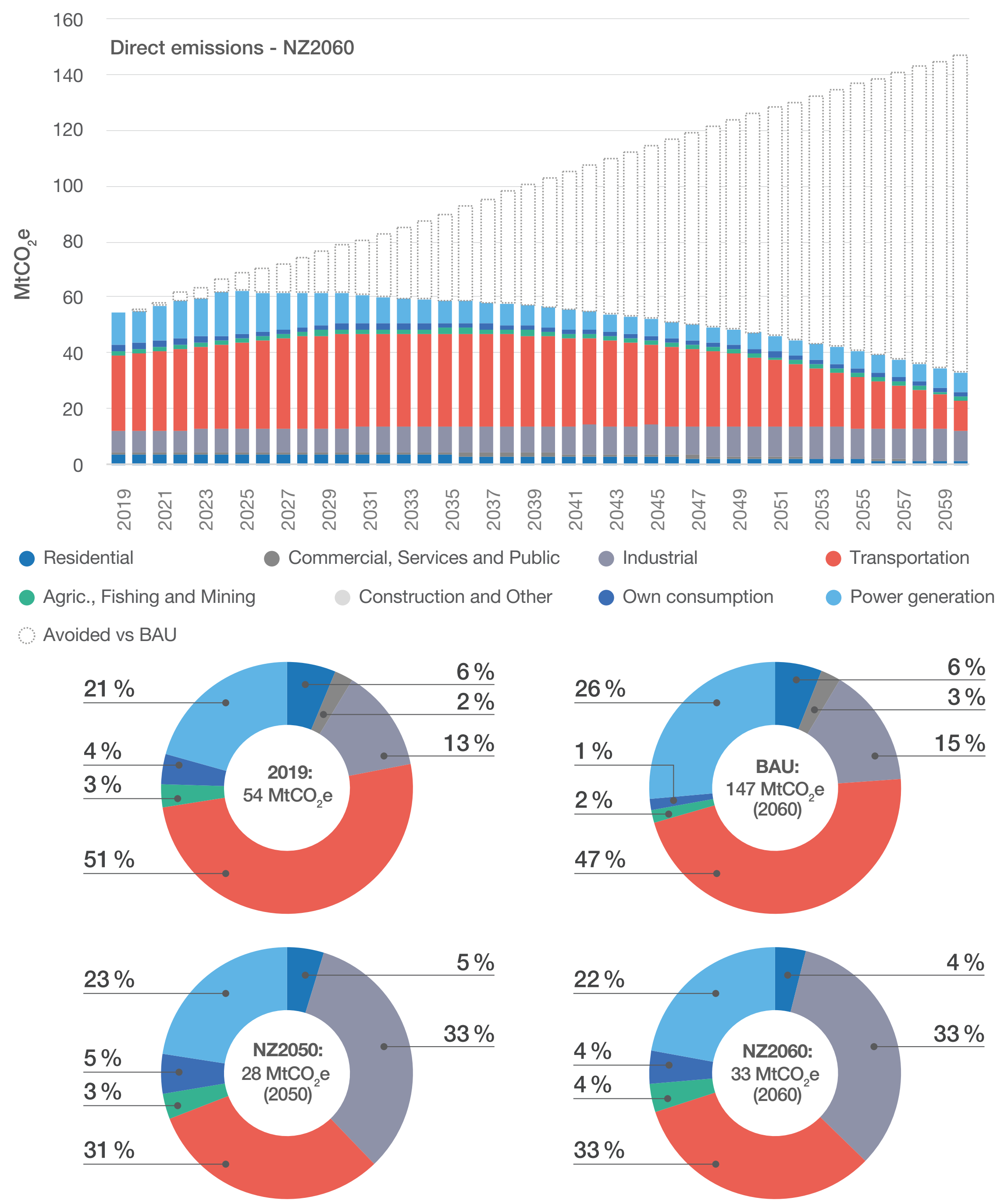
27 https://climateactiontracker.org/countries/peru/. Absorptions must cover not only the energy sector but also the industrial processes and use of products (IPPU) sector, residues, etc.

Graphic 36 A ▶ Direct emissions (final consumption and generation) by sector ($MtCO_2e$)



Source: Own preparation.

Graphic 36 B ▶ Direct emissions (final consumption and generation) by sector ($MtCO_2e$)



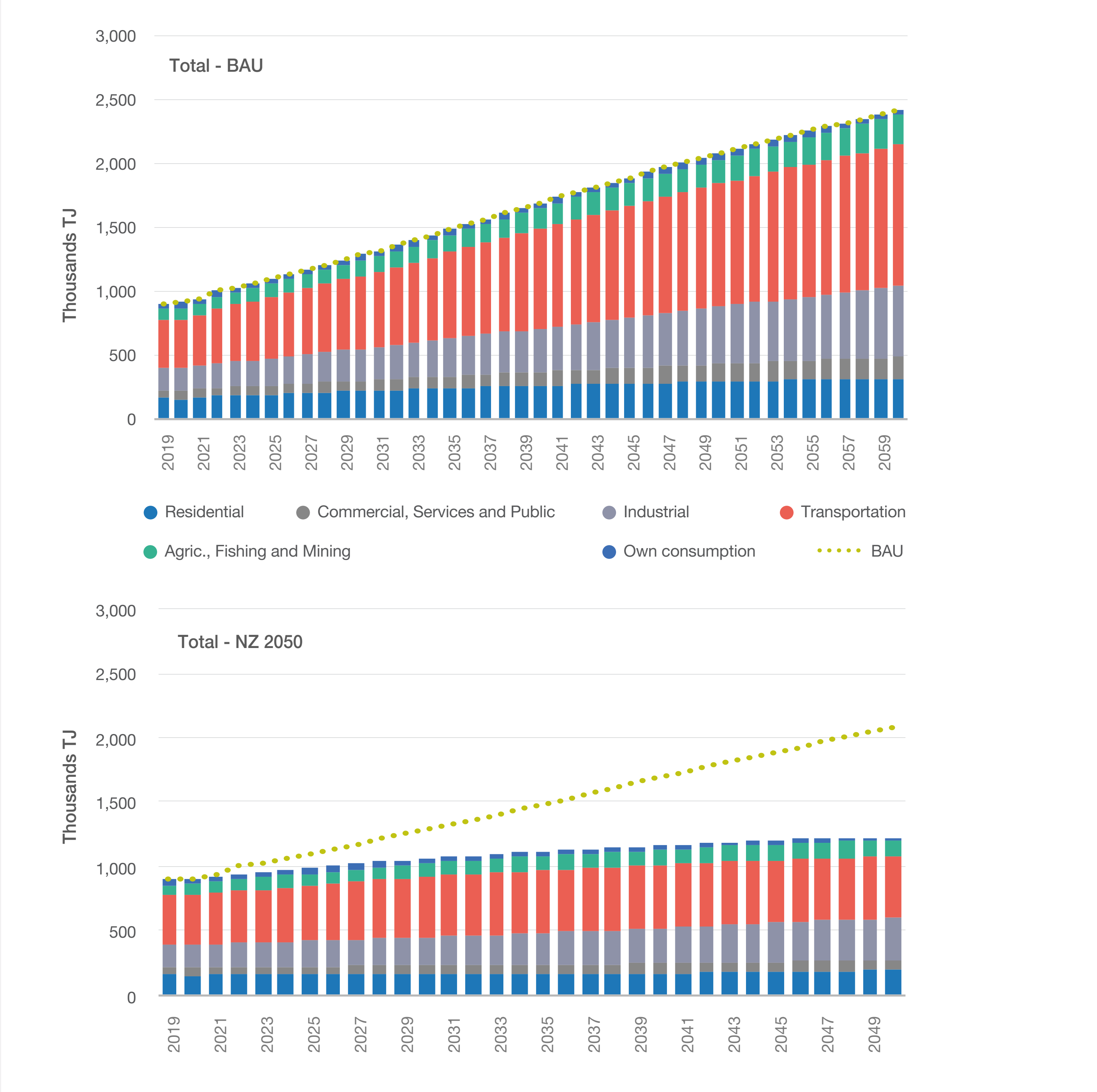
Source: Own preparation.

To meet the net zero emission target, **total emissions should reduce by two thirds during the planning horizon**, compared to current emissions.

Energy demand by sector

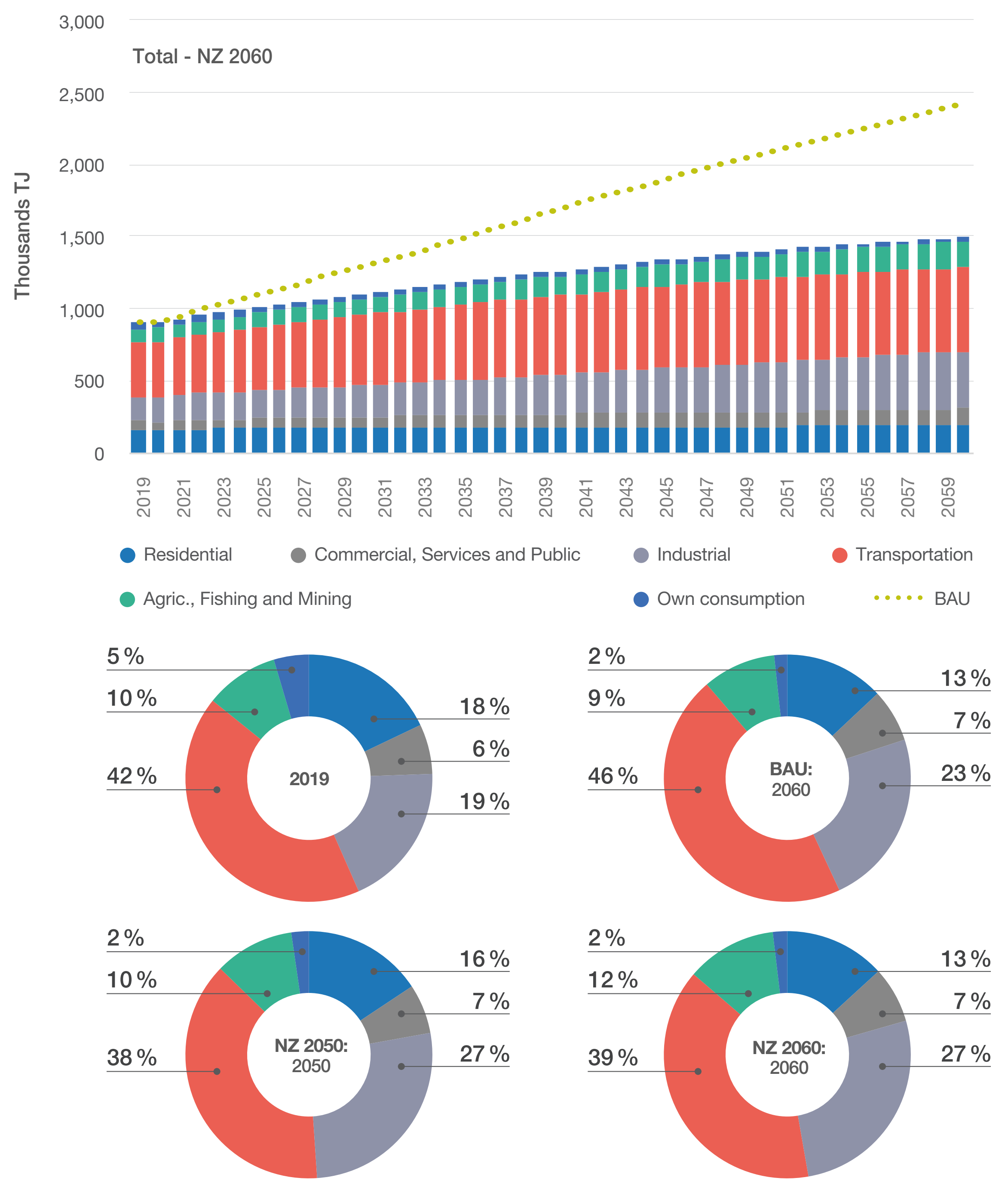
In the BAU scenario, the demand grows by 168% during the analyzed period and reaches around 2,400 thousand TJ in 2060. In the NZ scenarios, the demand grows slightly due to the stronger effects of efficiency and fuel substitution.
In all the scenarios, **the demand growth is greater than the growth in GHG emissions**.

Graphic 37 A Final consumption and own consumption, by sector and scenario (thousands of TJ)



Source: Own preparation. Non-energy consumption is not included.

Graphic 37 B Final consumption and own consumption, by sector and scenario (thousands of TJ)



Source: Own preparation. Non-energy consumption is not included.

Table 11 Final and own consumption by scenario, thousands of TJ and CAGR (%)

Demand (thousands of TJ)	2019	2030	2040	2050	2060	CAGR (%)
BAU	898	1,284	1,692	2,074	2,416	2.4 %
NZ 2050	898	1,063	1,158	1,226		1.0 %
NZ 2060	898	1,104	1,260	1,394	1,489	1.2 %

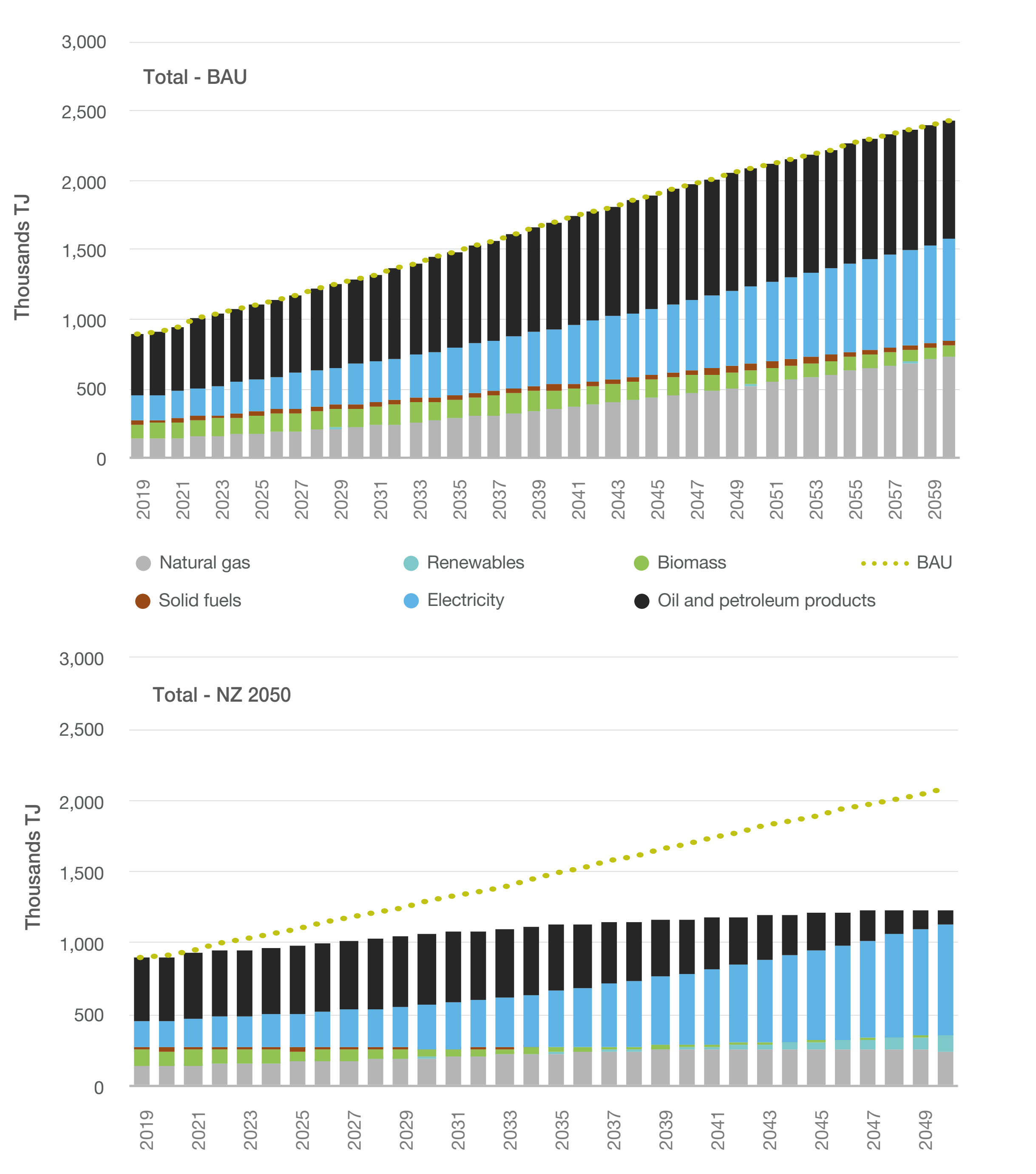
Source: Own preparation. Non-energy consumption is not included.

In all the scenarios, the relative participation of the demand by sector does not vary much and the transportation, industry, and residential sectors continue adding up to around 80% of the demand. Most of the sectors have similar growth rates, which evidences that **all the sectors participate in the transition efforts**.

Energy demand by source

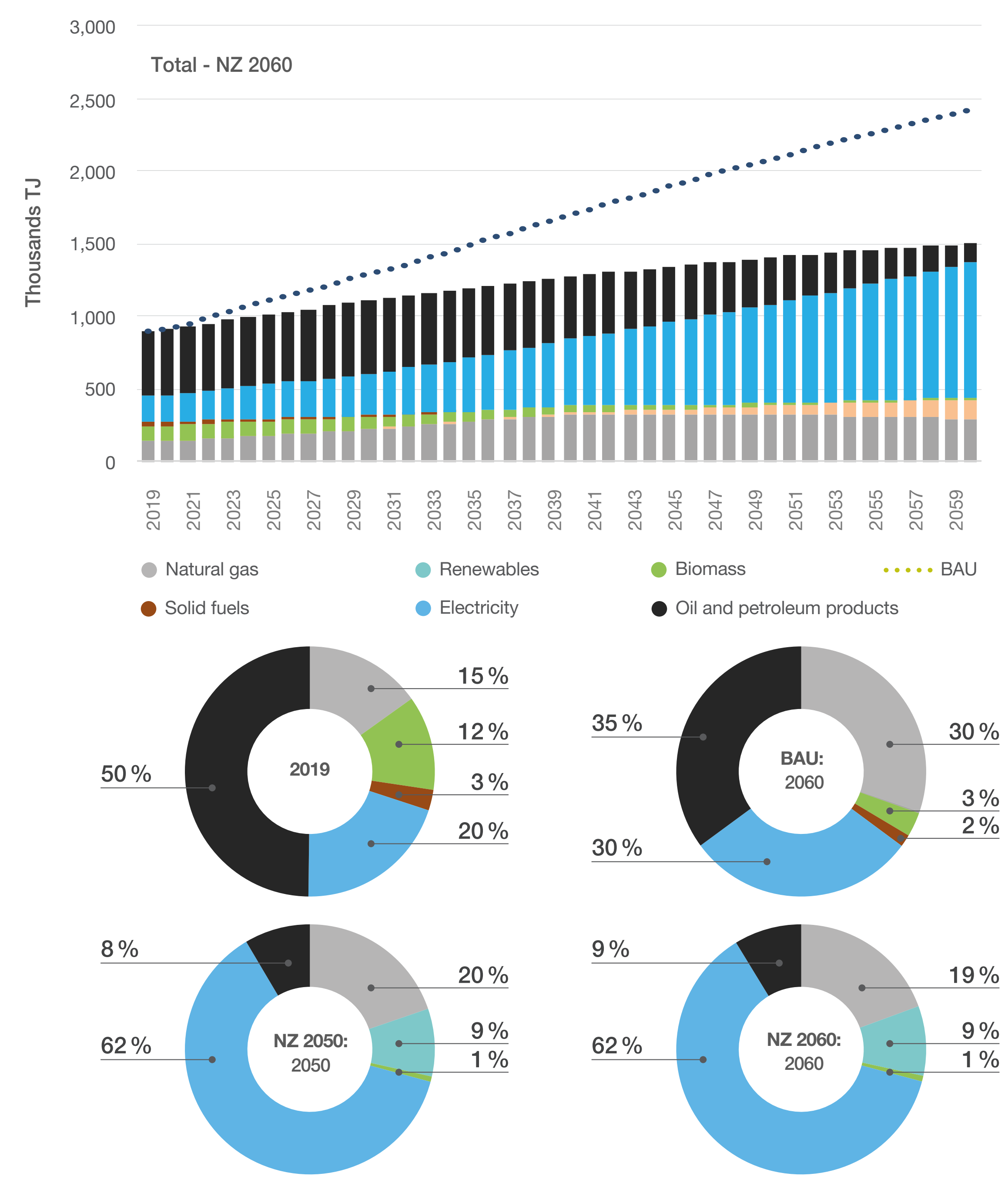
By fuel, **a strong trend towards electrification** of the demand can be observed in all the scenarios, though it is stronger in the NZ scenarios. The BAU scenario reflects stability in coal and biomass consumption while the increase in demand is covered by electricity, natural gas, and – to a lesser degree – oil and petroleum products (mainly LPG). The NZ scenarios present stronger electrification hypotheses (62% of total final consumption) and total substitution of coal and biomass. Hydrogen derivatives and solar thermal energy are developing in the long term near the end of the planning horizon.

Graphic 38 A Final consumption and own consumption, by source and scenario, (thousands of TJ)



Source: Own preparation. Note: The renewables category refers to solar thermal energy or hydrogen derivatives. The oil and petroleum products category includes LPG.

Graphic 38 B Final consumption and own consumption, by source and scenario, (thousands of TJ)



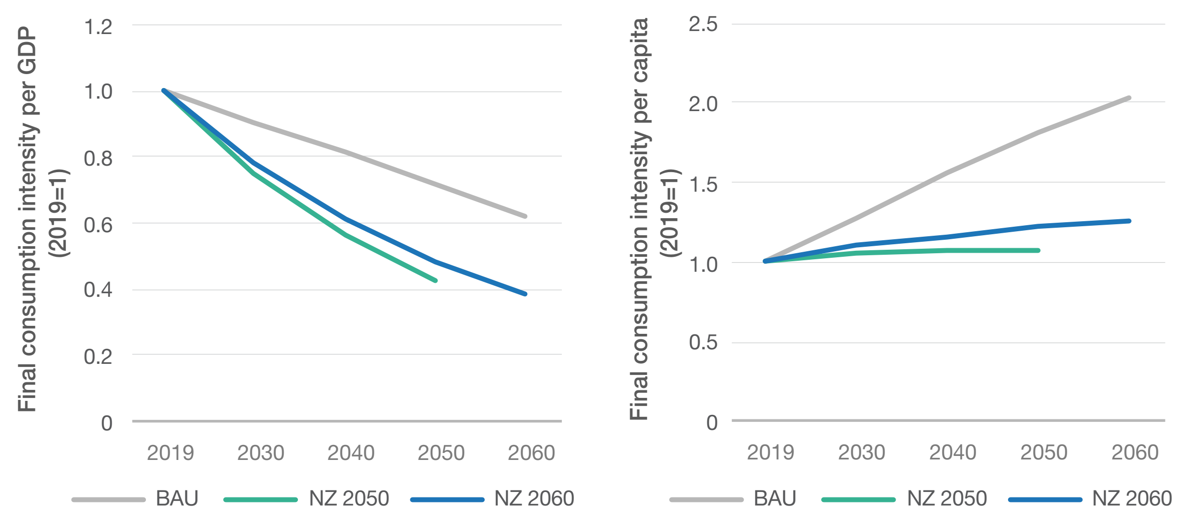
Source: Own preparation. Note: The renewables category refers to solar thermal energy or hydrogen derivatives. The oil and petroleum products category includes LPG.

Energy and environmental intensity

In the BAU scenario, energy intensity, measured in economic terms, (final consumption/total GDP) is reduced by about 40% in the period (annual -1.1 %), whereas in the NZ 2050 and NZ 2060 scenarios, it is reduced by over 60 % (-2.7 % and -2.3 % p.a., respectively).

Measured in terms of population (final consumption per capita), total unitary consumption grows by around 100% in the BAU scenario whereas in the NZ scenarios it remains quite stable. These figures evidence the necessary evolution of final consumption to fulfill the country's economic development and cover the current consumption gaps.

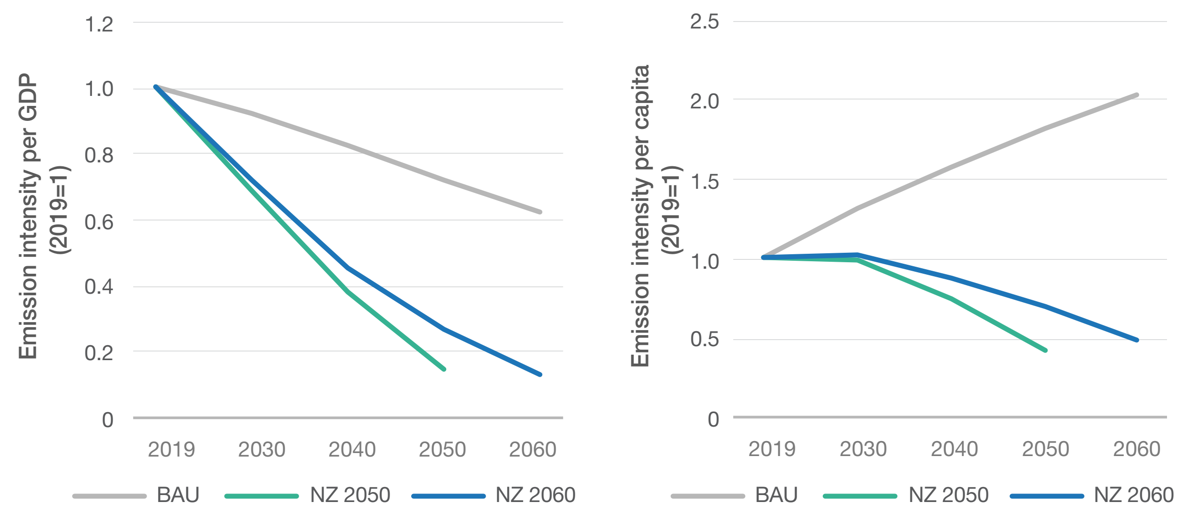
Graphic 39 Unitary energy intensity (2019=1), thousands of TJ/MUSD PPP 2017 (left) and thousands of TJ/capita (right)



Source: Own preparation.

A significant reduction in energy intensity is required to meet the Paris Agreement targets. This reduction reflects the **decoupling between economic growth and energy consumption**. The assumptions adopted to implement the proposed solutions (see *Just Energy Transition / Projection Assumptions* report) for energy transition in Peru allow the country to reach a high future decarbonization level and **promote a more developed and efficient economy**.

Graphic 40 Unitary environmental intensity (2019=1), tCO_2e/thousands of USD PPP 2017 (left) and tCO_2e/capita (right)



Source: Own preparation.

Unitary environmental intensity, measured in terms of economy (GHG emissions/ total GDP), is more significantly reduced than energy intensity for all the scenarios and shows the emission reduction by energy unit consumed. To achieve net zero emissions, the emissions by GDP unit of the base year should be reduced by 85%. Unitary environmental intensity, measured in terms of population (GHG emissions/capita), has a very similar evolution to energy intensity measured per capita in the BAU scenario, and falls in the NZ scenarios.

2. Results and assumptions by sector

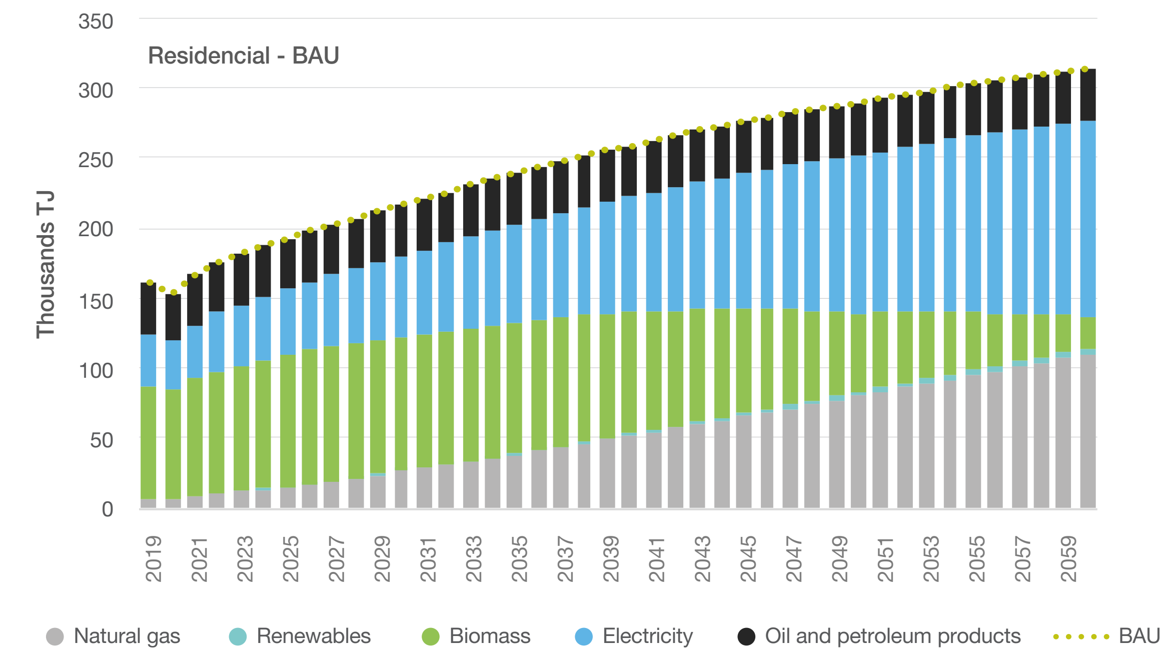
Residential sector

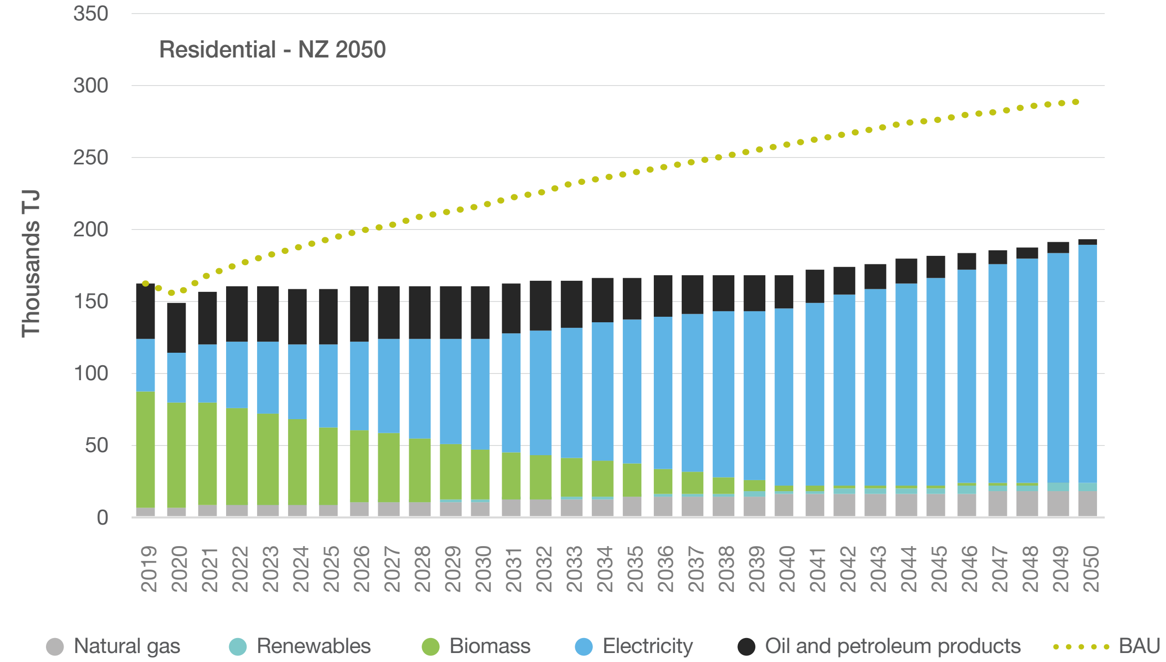
The residential sector is the third sector in terms of energy demand (18% in 2019). It is responsible for a limited volume of GHG emissions (3 Mt CO_2e), but there is potential to reduce them even further with energy transition measures. This sector is characterized by:

- high biomass consumption, with great electrification potential (and, in turn, large efficiency gains[28]). This biomass consumption (49% of the sector's final consumption) relates to the most vulnerable sectors of the population; that is, its replacement is possible in a context of higher standards of living and support programs for the sector. The cooking use accounts for around 70% of the sector's final consumption, one of the highest rates in the region;
- other uses (SHW, home appliances, air conditioning, etc.) with growth potential as the standard of living improves and in line with what was observed in developed countries.

28 It is estimated that the use of electricity or natural gas instead of firewood for cooking allows for very significant final energy savings.

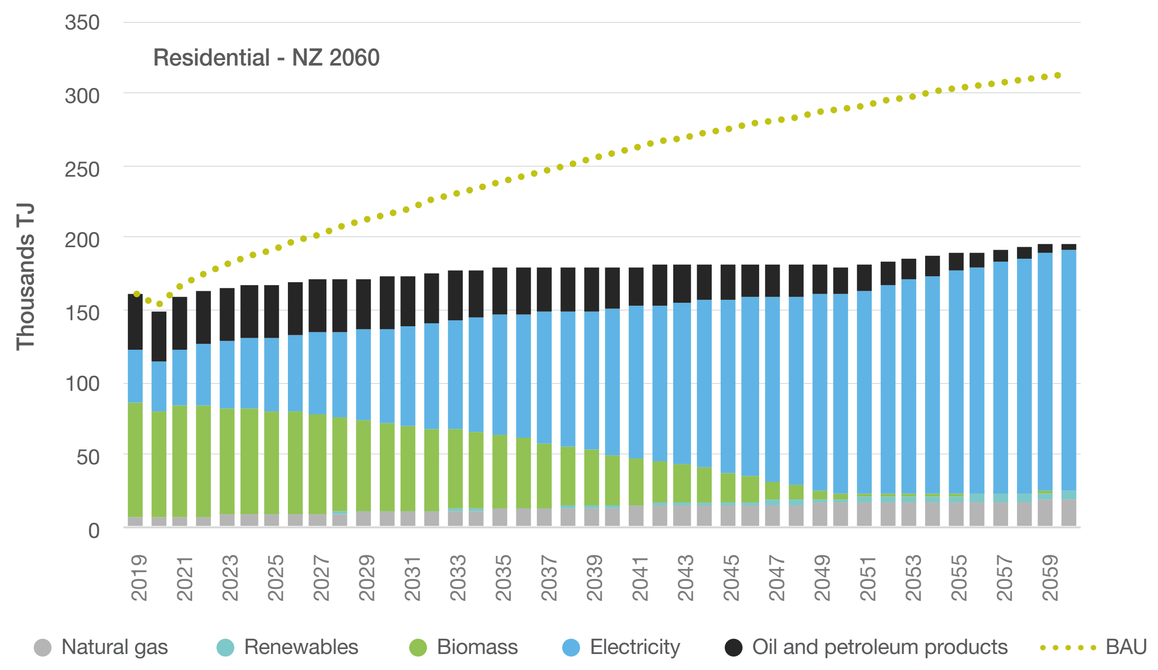
Graphic 41 A Residential sector: results by fuel and by scenario (10^3 TJ)





Source: Own preparation. **Note:** The renewables category refers to solar thermal energy. The oil and petroleum products category includes LPG.

Graphic 41 B Residential sector: results by fuel and by scenario (10^3 TJ)

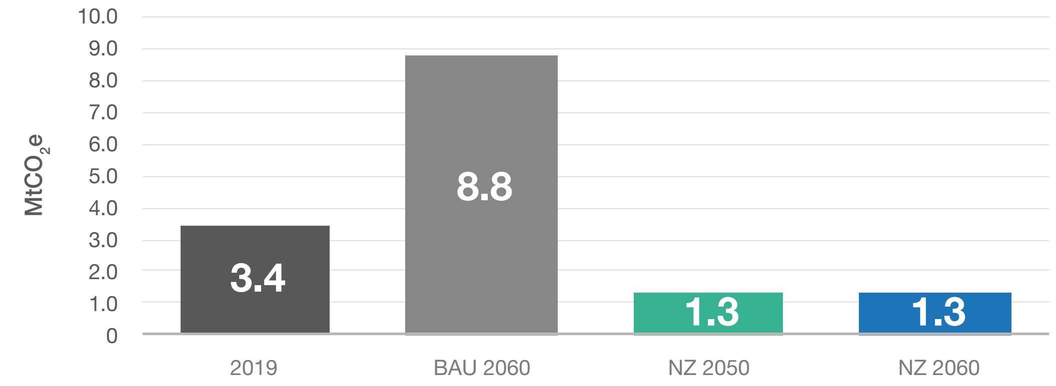


Source: Own preparation. **Note:** The renewables category refers to solar thermal energy. The oil and petroleum products category includes LPG.

In the BAU scenario (graphic on the left), we can see a 95% increase in residential energy demand in the period (annual 1.6%), mainly driven by the new electrical uses (including air conditioning) of water heating and space heating that are expected to accompany the increase in the projected standard of living. This growth is higher than that of the population (32% in the period). Firewood is replaced almost completely towards the end of the period, following historical trends. Natural gas consumption grows considerably whereas LPG remains relatively constant. Electric consumption grows both for electric cooking and for other uses.

In the NZ 2050 and NZ 2060 scenarios, power consumption covers a large part of final consumption (88 % for both scenarios); there is a natural gas surplus, and solar thermal energy is introduced to heat sanitary water. In turn, biomass replacement takes place faster. More energy efficiency efforts[29], both for appliances and buildings, allow compensating for the new uses that accompany the increase in GDP per capita to a large extent (the energy intensity of the sector, measured as demand per capita, is quite stable in the period).

Graphic 42 Residential sector: direct emissions by scenario ($MtCO_2e$)



Source: Own preparation.

29 There are only two lines of action to increase energy efficiency in all sectors: technological change and good energy use practices. For example, the replacement of incandescent bulb lighting with discharge units (bulbs to save energy) and later with LED bulbs, which took place in most countries, produces, by itself, a reduction in installed lighting capacity of up to 80%. However, this would result in a similar reduction in terms of energy consumption only if the same patterns of use previous to replacement were maintained. Or else, it may be higher if there is more care in the use of lights (with motion sensors, for instance); instead, it may be lower if all the lights are left on more time when switching for LED. Changing the technology is not enough; what is known as "good practices in the use of energy and operation and maintenance of facilities and equipment" should be applied.

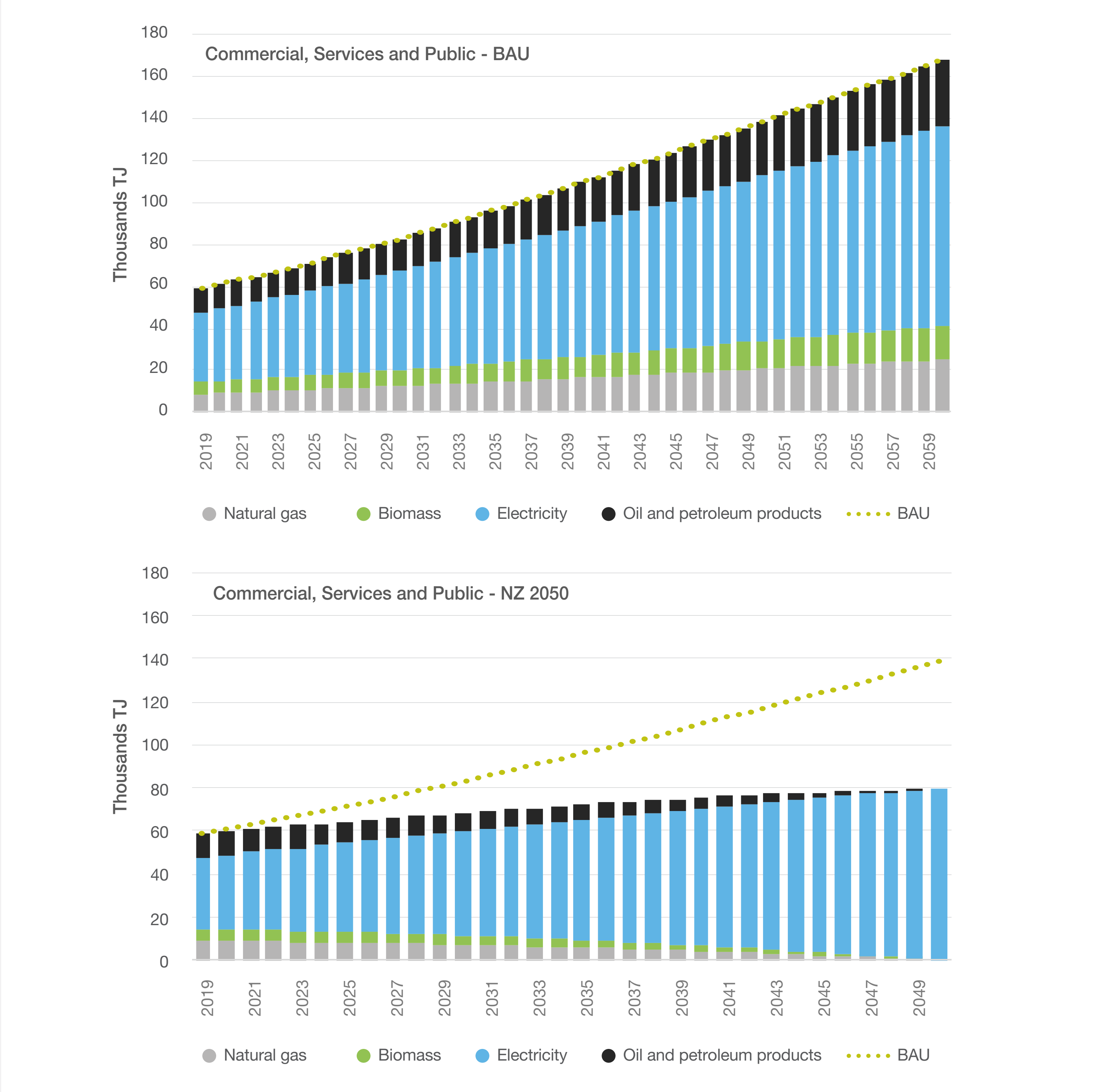
CO$_2$e emissions grow by 159 % in the BAU scenario and fall by 62% in the NZ scenarios in the long term as a result of the energy efficiency and electrification measures from clean generation sources.

In practice, the energy transition measures required to limit GHG emissions in the residential sector relate to mature technologies (electric ovens, more efficient electrical appliances, heat pumps for space heating or climate control, more thermal efficiency in the home, etc.). However, their implementation entails a massive effort from all households and covering consumption gaps for lower-income households, thus ensuring a just transition.

Commercial, services, and public sector

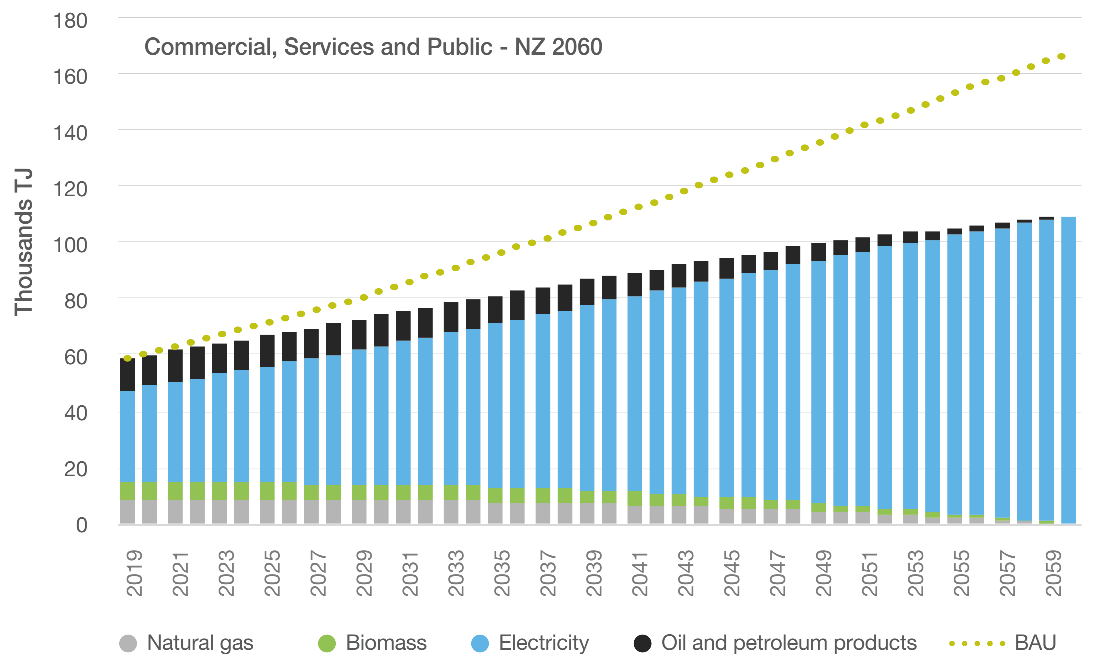
The commercial, services, and public sector (CSP) is composed of the public administration, hospitals, hotels, and stores, etc. It is a sector with little weight in terms of energy consumption (6% of the total, in 2019) compared to the transportation, industrial, and residential sectors. It starts with an electrification rate of 57% in 2019 and energy uses with electrification potential (SHW, space heating, motive force, cooking, etc.), as in the case of the residential sector. There is also potential for more energy efficiency, both in equipment and in the buildings themselves (thermal renovation of existing buildings, application of strict thermal regulations for new buildings).

Graphic 43 A CSP sector: results by fuel and by scenario (10³ TJ)



Source: Own preparation. **Note:** The renewables category refers to solar thermal energy. The oil and petroleum products category includes LPG.

Graphic 43 B ▶ CSP sector: results by fuel and by scenario (10^3 TJ)



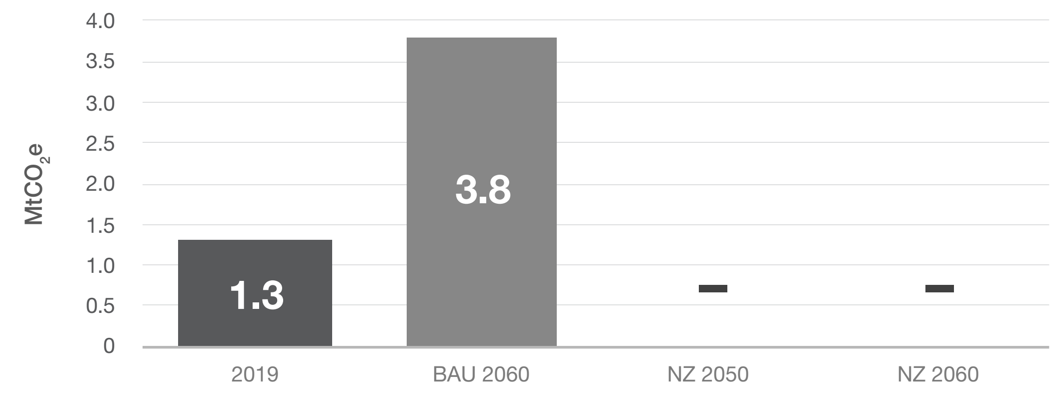
Source: Own preparation. **Note:** The renewables category refers to solar thermal energy. The oil and petroleum products category includes LPG.

In the BAU scenario, the fuel share remains relatively constant. Even though the sector's GDP is expected to grow by over 300%, the energy demand grows by around 185% due to energy efficiency measures.

For the NZ scenarios, there is almost total electrification of the sector. A 35% demand reduction is achieved for 2060 and 43% for 2050 in the NZ 2050 scenario, compared to the BAU scenario. Efficiency enhancements account for a large part of this phenomenon.

Transition scenarios

Graphic 44 ▶ CSP sector: Direct emissions by scenario, ($MtCO_2e$)



Source: Own preparation.

CO_2e emissions grow in the BAU scenario, but at a slower pace than that of GDP, whereas they are zero in the NZ scenarios.

The energy transition measures required to limit GHG emissions in the commercial, services, and public sector include mature technologies related to refrigeration, lighting, and direct or indirect heat uses; therefore, electrification must be prioritized and the efficiency of the appliances should be enhanced. Although it has little weight at energy level, the sector itself is heterogeneous, with consumption related to cooking and refrigeration uses in restaurants, IT equipment and lighting in offices, mixed uses in hospitals or schools, etc.

Industrial sector

The industrial sector is composed of several industrial subsectors and is the second with the largest energy demand (19% in 2019) after the transportation sector. Its starts with low penetration of electricity (27%), conditioned by several sectors that are difficult to electrify, such as the steel and cement industries.

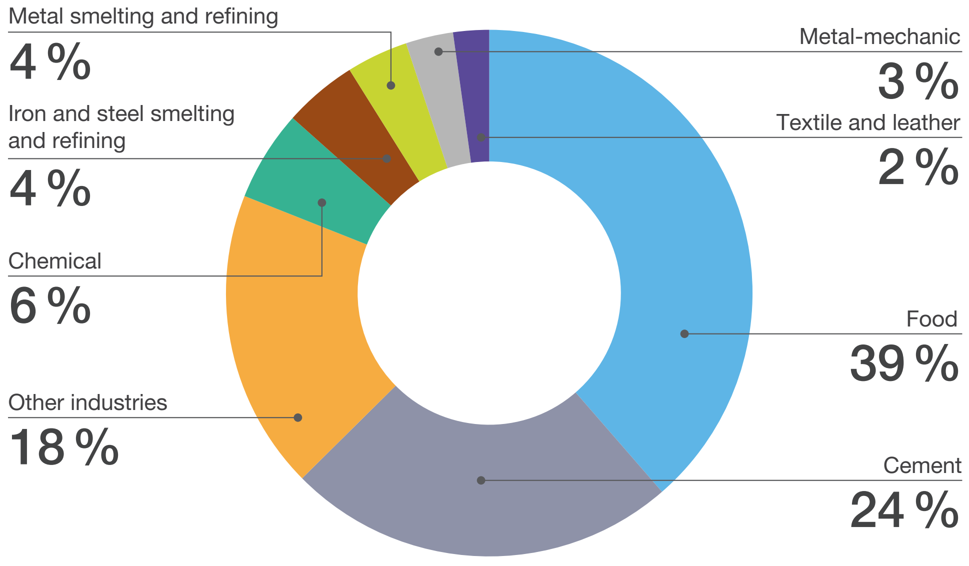
It is important to remember that fuel substitution possibilities may vary considerably from one industrial subsector to another, given the variety of existing industrial processes. To make the projections, the industrial subsectors were grouped together into a limited number of subsectors. The analysis focused more in detail on the subsectors with the greatest consumption and their associated uses.

Projections by subsector

The information on the industrial sector contained in Peru's National Energy Balance is divided into eight subsectors.

Transition scenarios

Graphic 45 Industrial sector: energy consumption by industrial subsector, 2019 (%)

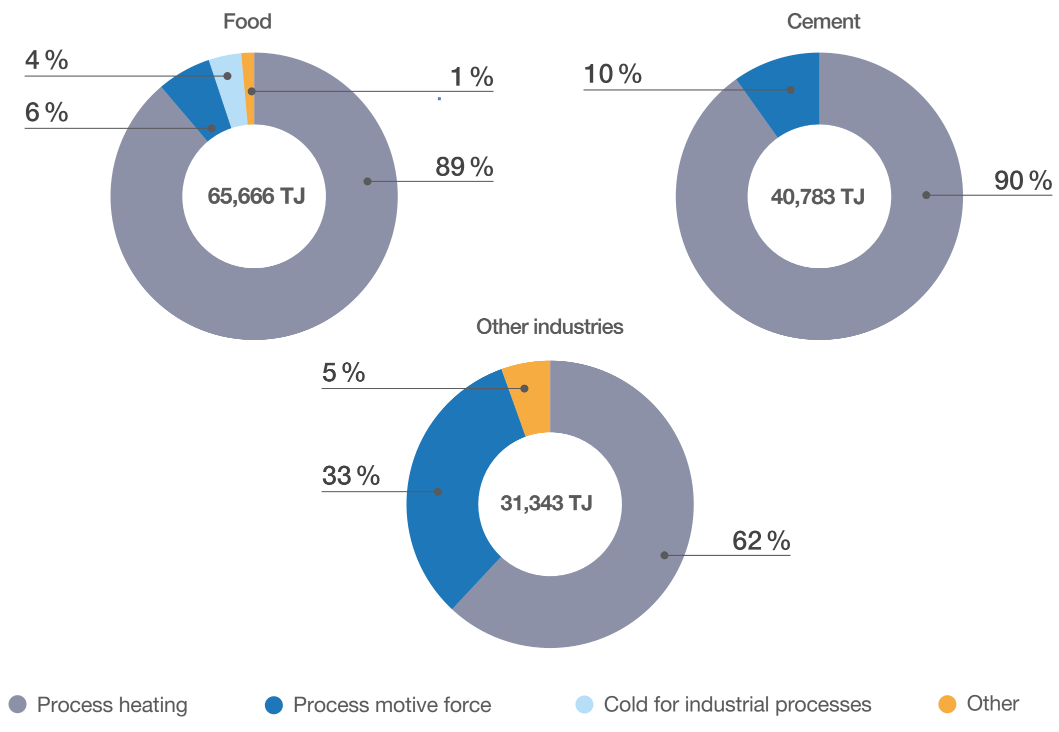


Source: Own preparation based on data from Peru's energy balance.

The food, cement, and other industries subsectors account for 81% of the energy consumption in the sector. The process heat use prevails in the food, cement and other industries subsectors (89%, 90%, and 62%, respectively).

Just Energy Transition - Scenarios Peru

Graphic 46 Industrial sector: energy consumption of fossil fuels by use for the main subsectors (%)



Source: Own preparation based on data from Peru's useful energy balance.

Transition measures focus on **enhancements in terms of efficiency and fuel substitution**. Energy efficiency is achieved thanks to the optimization of energy use in industrial processes and technological replacement to more recent and efficient appliances and facilities.

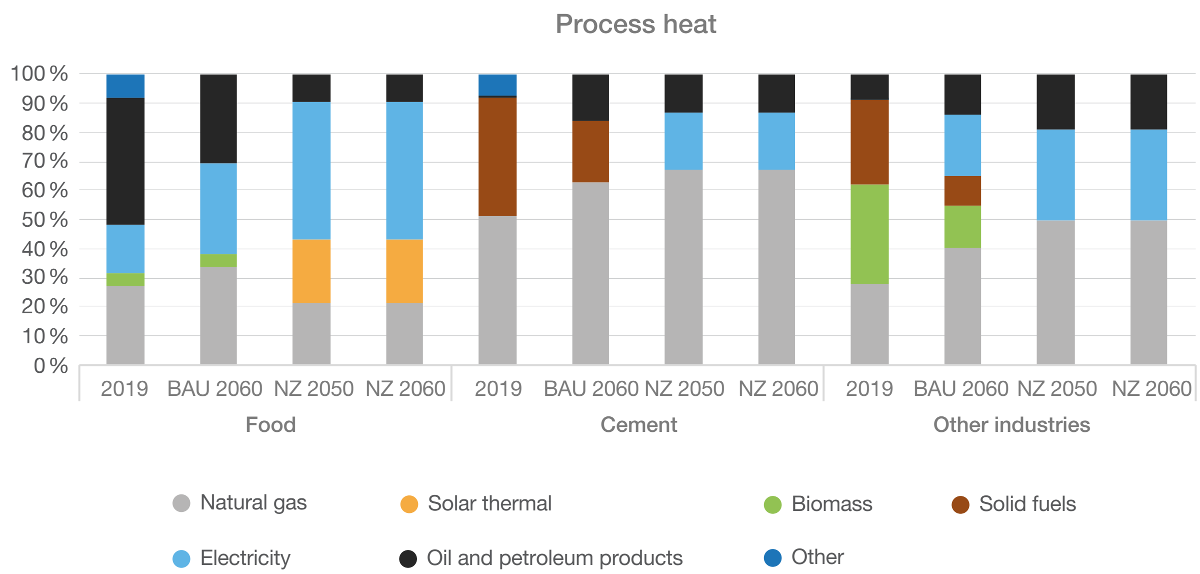
The substitution assumptions considered for Peru are as follows.

- A strong reduction in consumption (deeper for the NZ scenarios) was considered for the industrial subsectors with high coal penetration and substitution potential. Natural gas partially replaces coal.

- Natural gas and LPG fully replace fuel oil and diesel in the next decade and a progressive penetration of solar thermal energy is assumed in some sectors for indirect heat.

Graphic 47 shows the evolution of final consumption by fuel for the main uses in the different scenarios.

Graphic 47 Industrial sector: evolution by scenario for the main uses in the most relevant industrial subsectors (%)

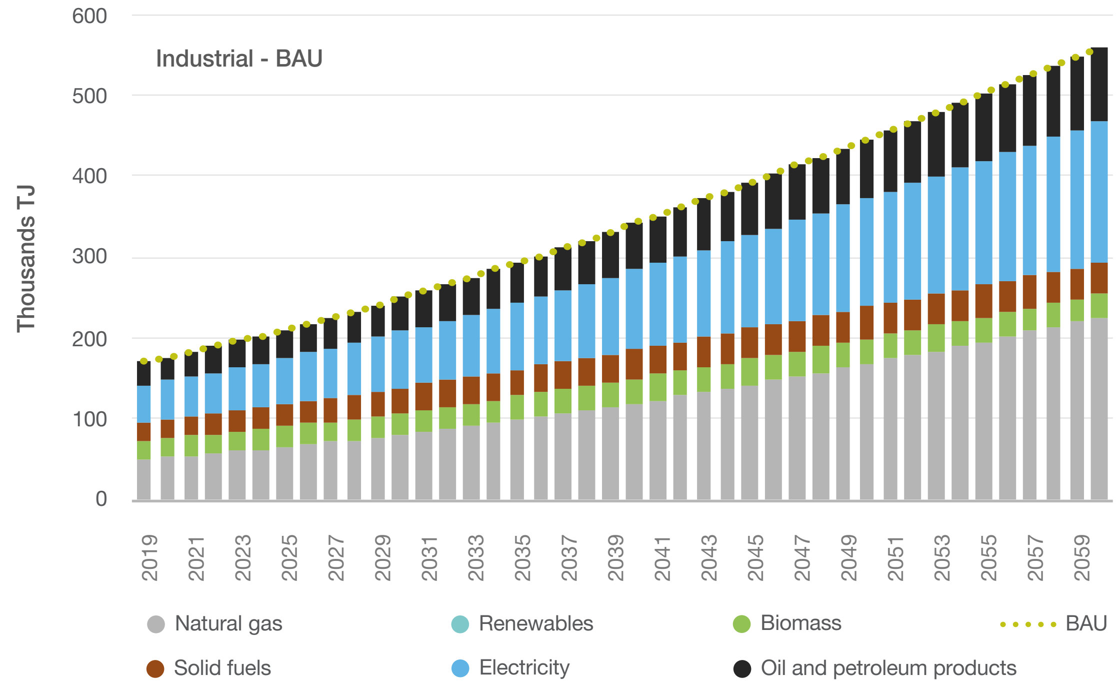


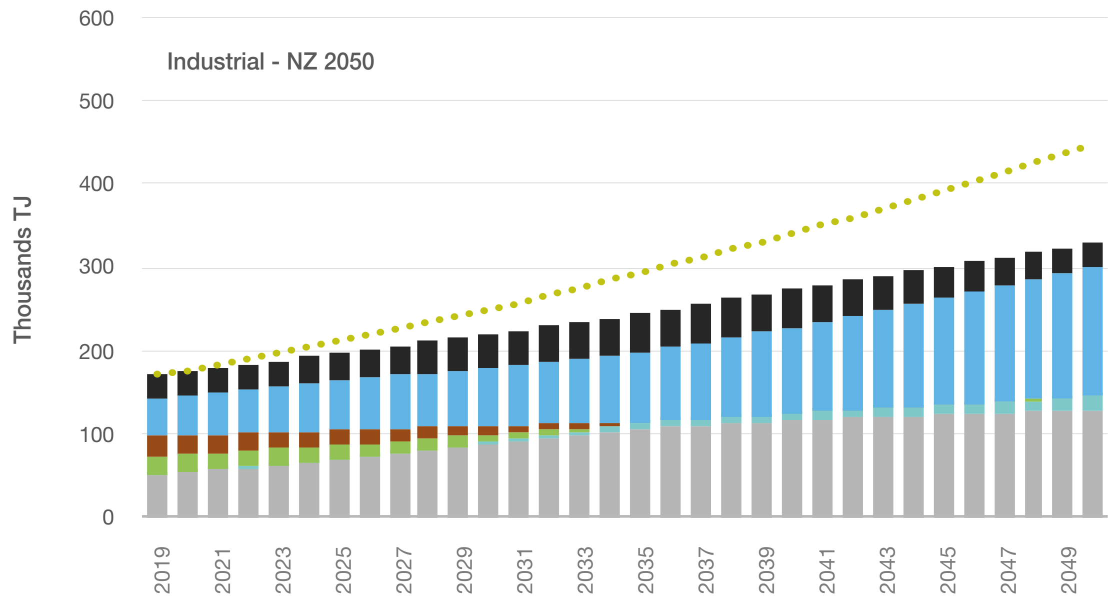
Source: Own preparation. **Note:** The renewables category refers to solar thermal energy.

Results

Even though an increase of over 300% in the GDP of the sector is projected, the demand for final energy in the BAU scenario will grow by 228% due to fuel substitution and energy efficiency measures. In this scenario, electrification of the final demand goes from 26% to 32%.

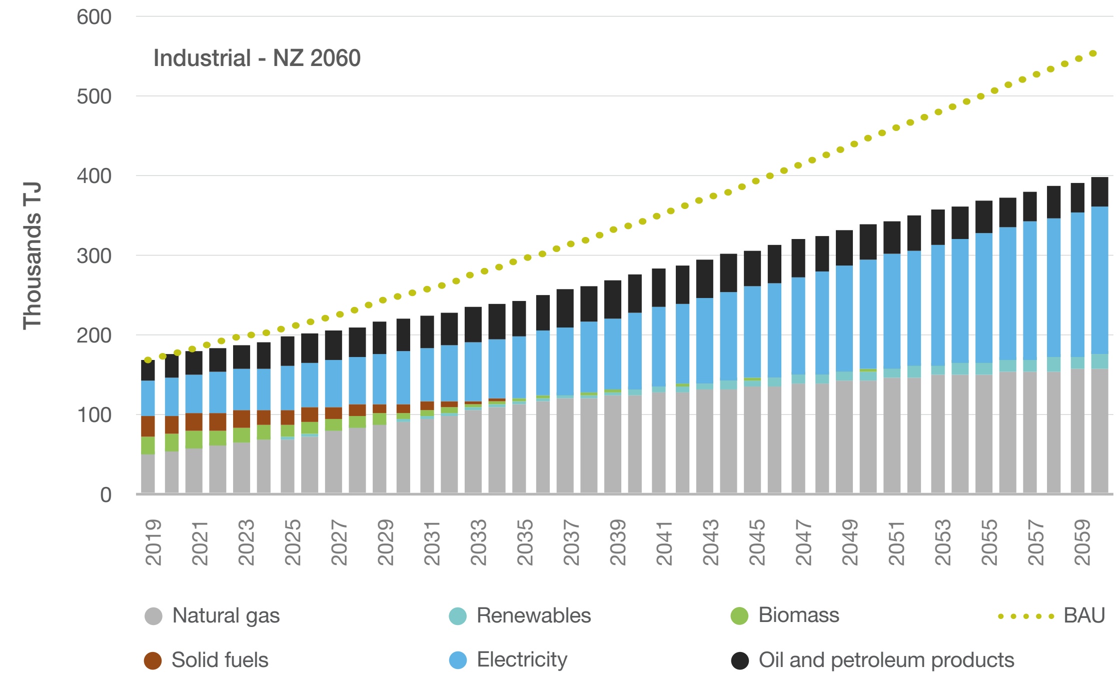
Graphic 48 A Industrial sector: final consumption by fuel and by scenario (10^3 TJ)





Source: Own preparation. **Note:** The renewables category refers to solar thermal energy..

Graphic 48 B Industrial sector: final consumption by fuel and by scenario (10^3 TJ)

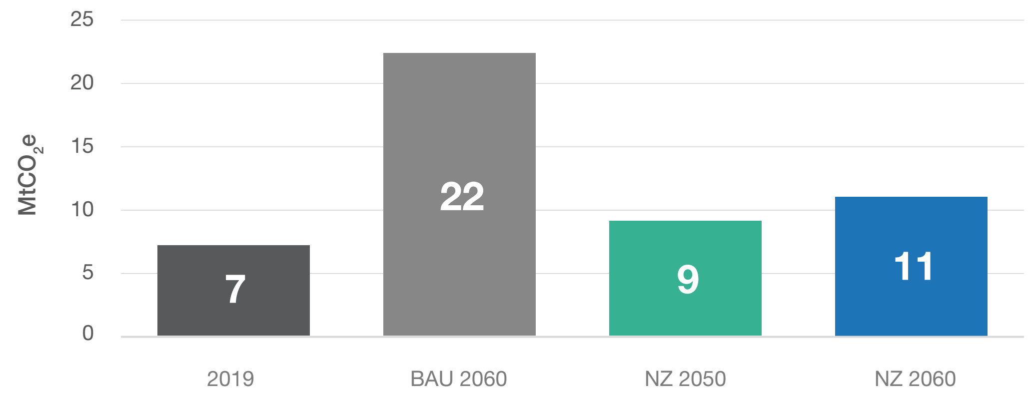


Source: Own preparation. **Note:** The renewables category refers to solar thermal energy..

For the NZ scenarios, coal and biomass are completely substituted whereas electrification grows from 26% to 47%, and natural gas also grows in line with historical trends.

Graphic 49

Industrial sector: direct emissions by scenario, $MtCO_2e$



Source: Own preparation.

CO_2e emissions grow in the three scenarios; the BAU scenario records a growth of +210% whereas the NZ 2050 and NZ 2060 scenarios show 26% and 53%, respectively, a much slower pace than that of the GDP.

The energy transition measures required to limit GHG emissions in the industrial sector relate to existing technologies worldwide but that are not always very mature. As years go by, it will be necessary to adapt the industrial processes with the best technological option available and, in turn, rethink the processes in a comprehensive manner.

Transportation sector

In Peru, the transportation sector is the maximum energy consumer (42% in 2019) and greenhouse gas emitter. It mainly consumes liquid fuels (diesel, gasoline, etc.). Even though electric vehicle sales have increased worldwide in recent years, these vehicles account for a very small portion in Peru. Road transportation accounted for 94% of total final consumption in 2019, led by road freight transportation (51%).

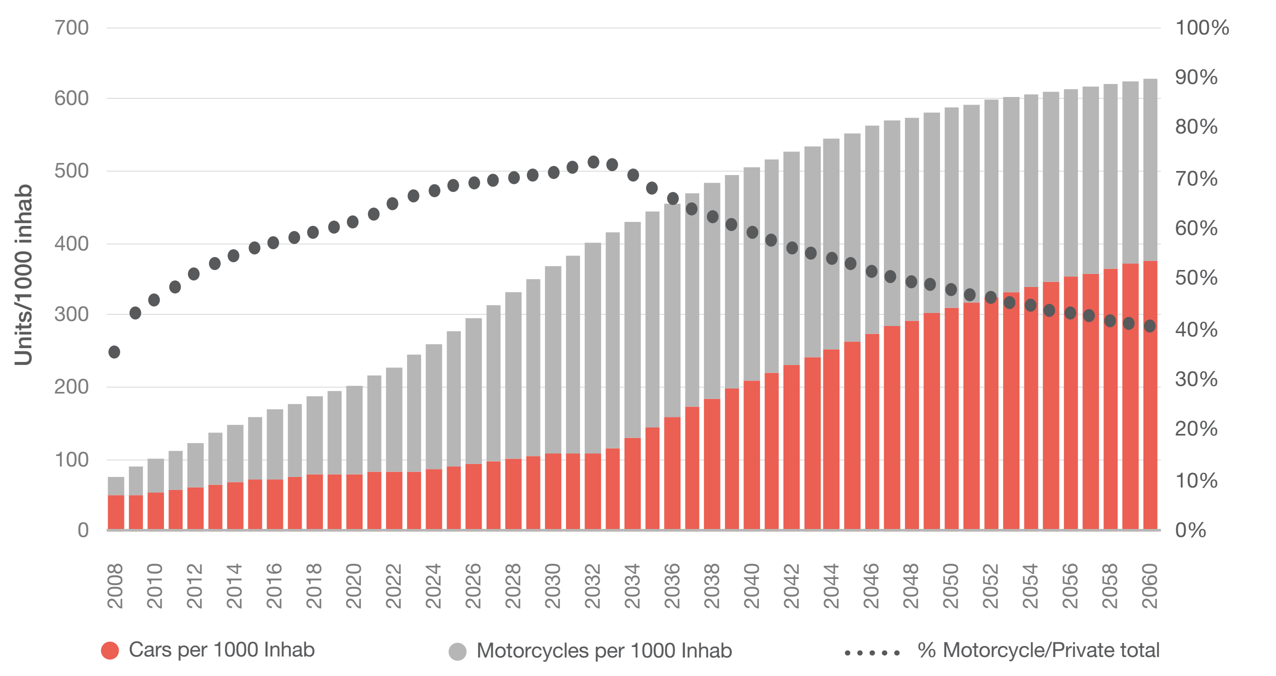
Road passenger transportation

Energy consumption by road transportation depends on the evolution of the number of vehicles. A **significant increase in motorization** is expected in all the scenarios, in line with the growth in the standard of living and the recent trend in Peru. This increase follows the trend in the Peruvian market of an increase in the number of motorcycles per 1,000 inhabitants that was observed in the last decade. From a certain level in GDP per capita on, the increase in motorization starts focusing on cars[30]. 627 vehicles per 1,000 inhabitants are projected in 2060, 40% of which are motorcycles and 60% cars.

30 Law, Hamid & Goh (2015), *The motorcycle to passenger car ownership ratio and economic growth: A cross-country analysis*.

Graphic 50

Number of private vehicles per 1,000 inhabitants and share of motorcyles (%)



Source: Own preparation.

In this motorization context, measures will be required to promote the energy transition in order to limit the increase in GHG emissions. One of the main measures to contemplate is the **electrification** of the vehicle fleet, which reduces emissions and total consumption (a reduction of 75% to 80% in consumption per km compared to a standard vehicle). The use of hybrid vehicles also allows for a significant reduction in unitary energy consumption. In the case of cars, it is estimated that their share will be 30% electric and 20% hybrid in the BAU scenario by 2060. Instead, in the NZ scenarios, an 80% share of electric and 20% of hybrid is projected at the end of the period. In addition, the electrification of the motorcycle and public bus fleet is envisaged until 100% of the fleet is reached in both scenarios within the planning horizon (see *Just Energy Transition / Projection Assumptions* report).

In line with historical observations, the average efficiency of the vehicle fleet is expected to improve due to technological enhancements and/or the reduction in vehicle weight.

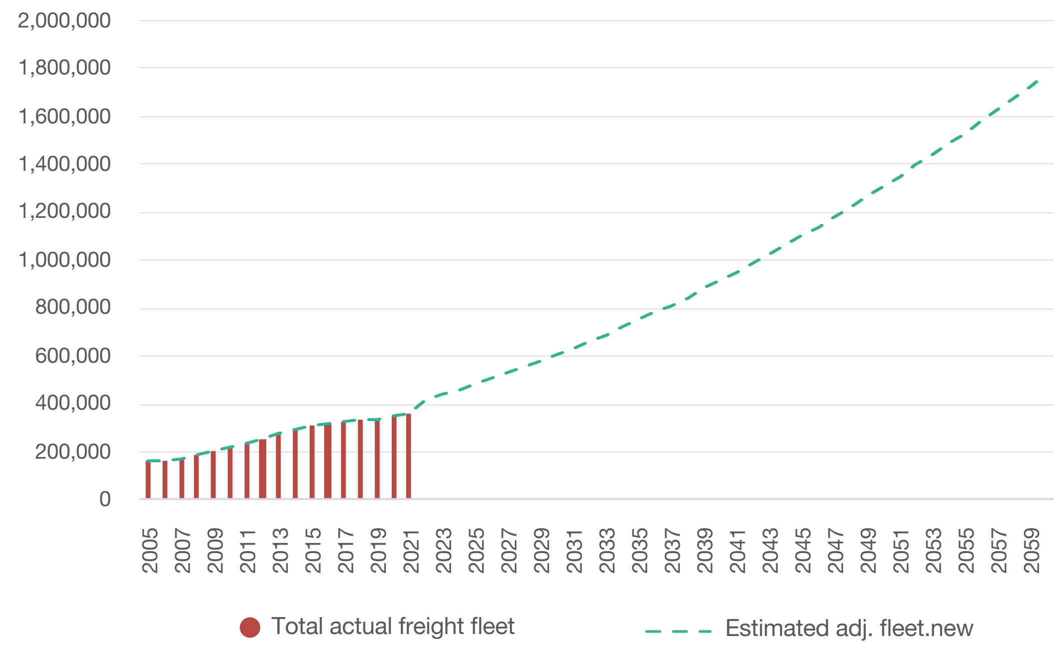
Finally, a decrease in the average distances traveled by vehicle (km/vehicle) is envisaged as a result of the **digitalization** of society (remote work, etc.) and greater penetration of **public transportation** systems.

Road freight transportation

Road freight transportation grows with economic activity (GDP), taking into account the historical elasticity of income. In this context, sustained growth in the number of freight vehicles is expected in the period (4.1% annual average), both for trucks (64% of the total) and for truck tractors.

Graphic 51

Total number of freight vehicles



Source: Own preparation.

In order to limit GHG emissions, it will be necessary to promote energy transition fuels depending on the time horizon considered: compressed natural gas (CNG), liquefied natural gas (LNG), electricity (available now) and hydrogen derivatives (as from 2040). It is assumed that natural gas (CNG, LNG) will play an important role in the period 2030-2040. Moreover, the energy transition must be accompanied by an **enhancement in vehicle performance, logistics enhancements, and a shift to railway transportation**.

It has been assumed that, in the BAU scenario and for 2060, 10% of the truck fleet will be electric, 40% will run on CNG, 4% on LPG, and the rest will continue on diesel. As to truck tractors, 50% of the fleet is expected to use LNG and 50% diesel. In the NZ scenarios, more transition efforts are required, with 80% electric trucks and 60% electric truck tractors in the long term. Electrification appears as a relevant alternative for trucks and truck tractors, but a smaller electrical penetration is expected for truck tractors, as technological solutions to transport very heavy loads are still being developed and electrification is not always a solution. Hydrogen cells may also play an important role in this segment in the long term. Natural gas allows the transition to start in both segments.

Air, naval, and railway transportation

These sectors are more difficult to transform (in particular, the air and maritime/river subsectors are not electrifiable). Some of the energy transition options available are synthetic fuels and ammonia (H_2 derivatives), contemplated in the NZ scenarios.

Results

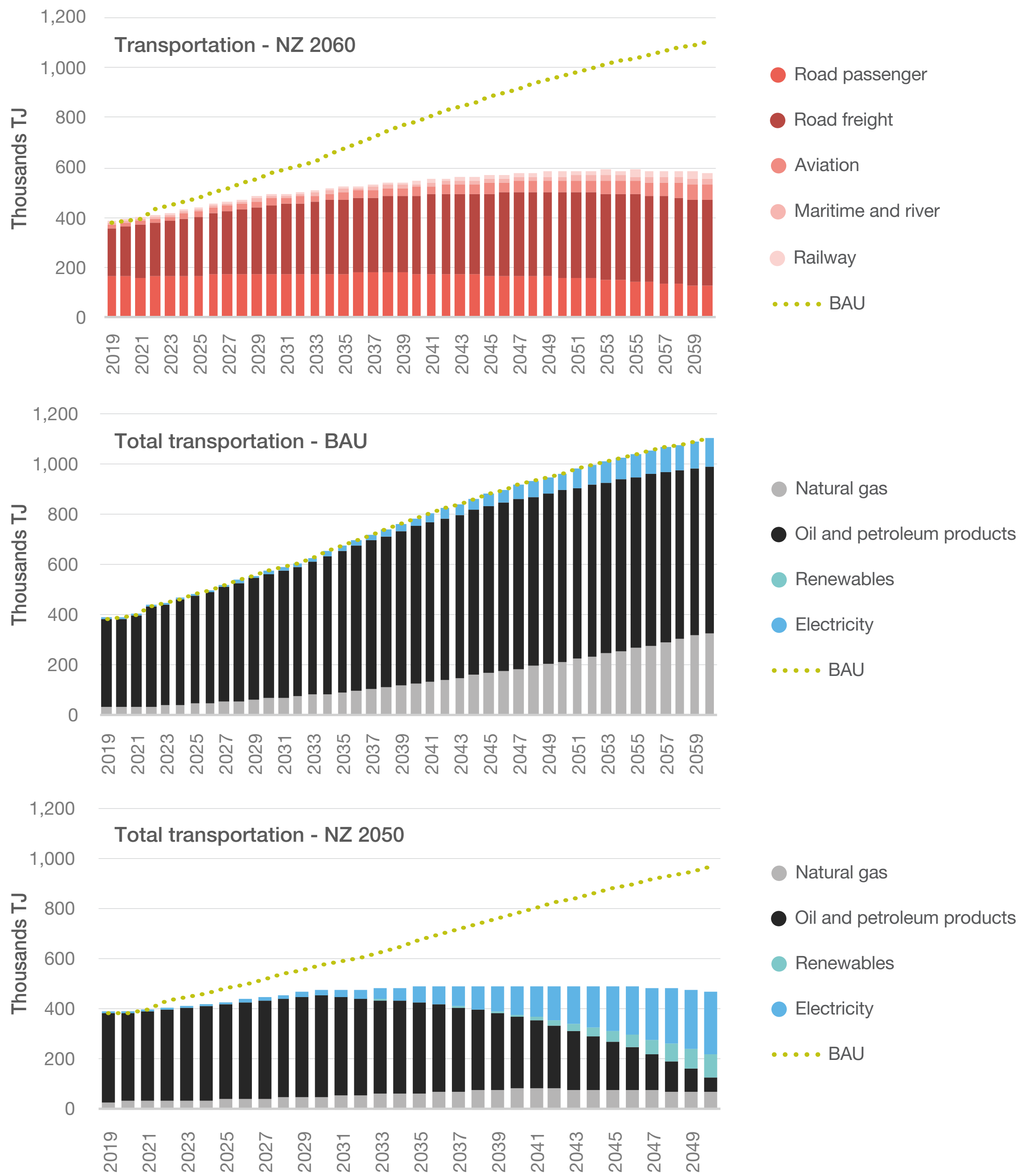
In the BAU scenario, energy consumption in the transportation sector grows by almost 200%, driven by the freight sector. The consumption of oil and petroleum

products grows by 89%, electricity grows considerably in the private and public passenger sector, whereas natural gas becomes relevant in the freight sector. .

Graphic 52 A Transportation: final consumption by type/fuel and by scenario (10^3 TJ)

Source: Own preparation. **Note:** The renewables category refers to hydrogen derivatives.

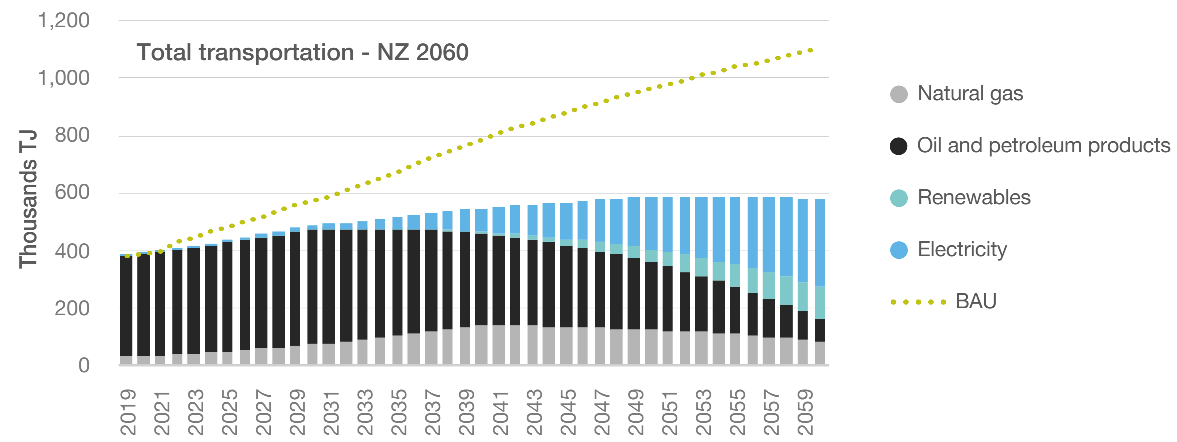
Graphic 52 B ▶ Transportation: final consumption by type/fuel and by scenario (10³ TJ)



Source: Own preparation. **Note:** The renewables category refers to hydrogen derivatives.

Transition scenarios

Graphic 52 C ▶ Transportation: final consumption by type/fuel and by scenario (10³ TJ)

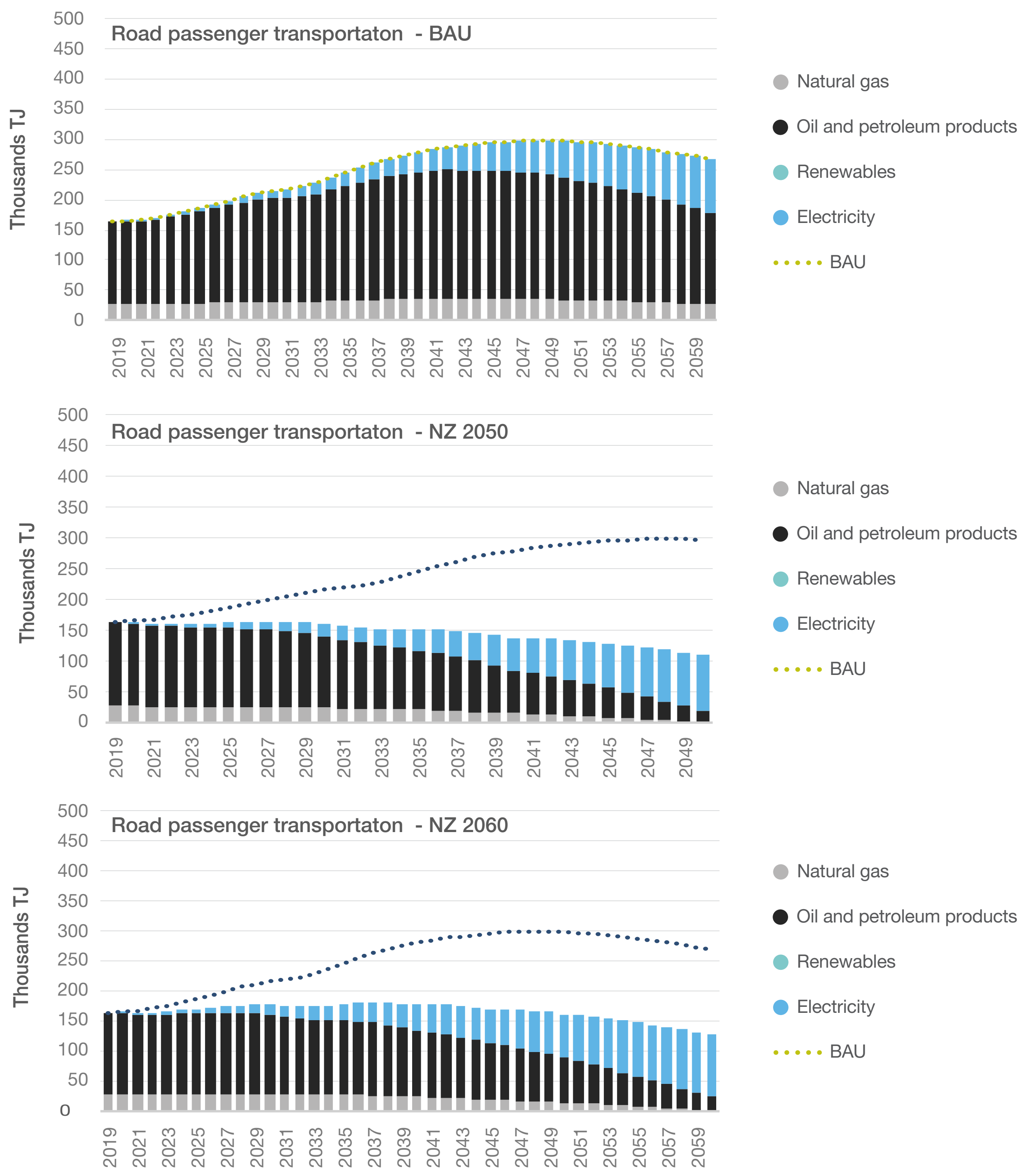


Source: Own preparation. **Note:** The renewables category refers to hydrogen derivatives.

In the analyzed period, energy demand in the transportation sector grows (23% in the NZ 2050 scenario and 53% in the NZ 2060 scenario) due to the measures to promote electric transportation and synthetic fuels. In the passenger sector, electric penetration increases strongly, whereas the rest use gasoline in hybrid motors. As to freight transportation, electrification appears as the main alternative for trucks and truck tractors; hydrogen cells play a more limited role. Bearing in mind these considerations, the passenger sector reduces its energy consumption considerably whereas the freight transportation sector grows slightly. The NZ 2060 scenario is very similar to the one mentioned above, with a slower implementation of the measures.

Graphic 53 A

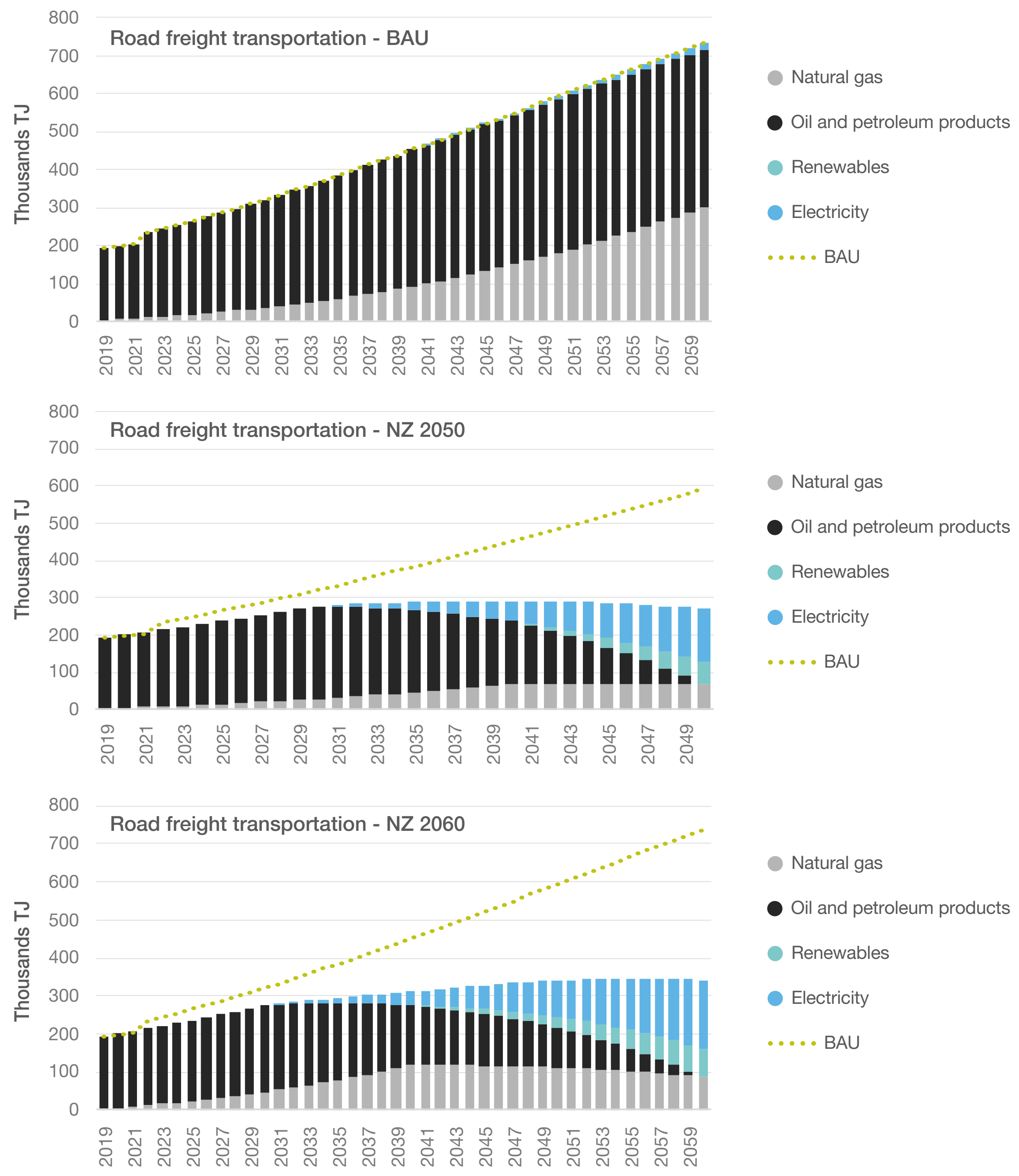
Final consumption of road passenger and freight transportation, by fuel and by scenario (10^3 TJ)



Source: Own preparation. Note: The renewables category refers to hydrogen derivatives.

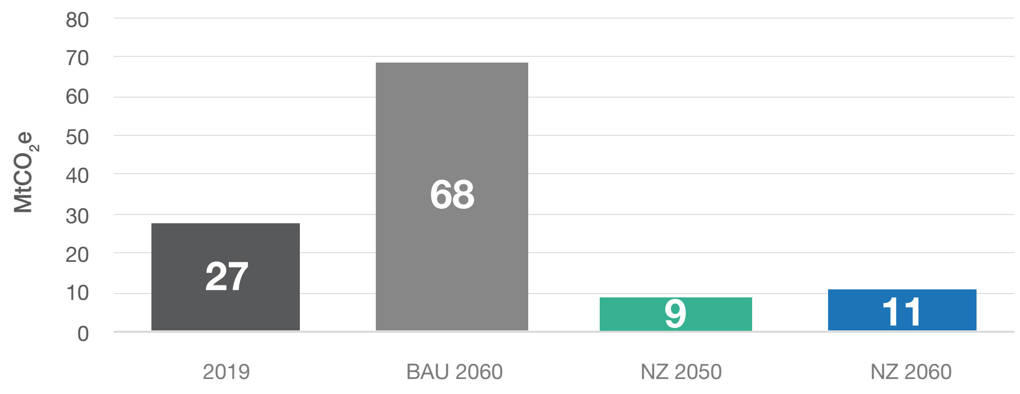
Graphic 53 B

Final consumption of road passenger and freight transportation, by fuel and by scenario (10^3 TJ)



Source: Own preparation. Note: The renewables category refers to hydrogen derivatives.

Graphic 54 Transportation sector: direct emissions by scenario ($MtCO_2e$)



Source: Own preparation.

CO_2e emissions grow in the BAU scenario (+150%) but at a slower pace than that of the vehicle fleet. On the other hand, emissions fall by over two thirds in the NZ scenarios in the long term, as a result of fuel substitution (mainly electrification), energy efficiency, and measures to change behavior.

The energy transition measures required to limit GHG emissions in the transportation sector relate to mature technologies for the light vehicle segment and developing ones for the other segments. Substantial changes are expected in all scenarios, given the strong motorization associated with economic growth.

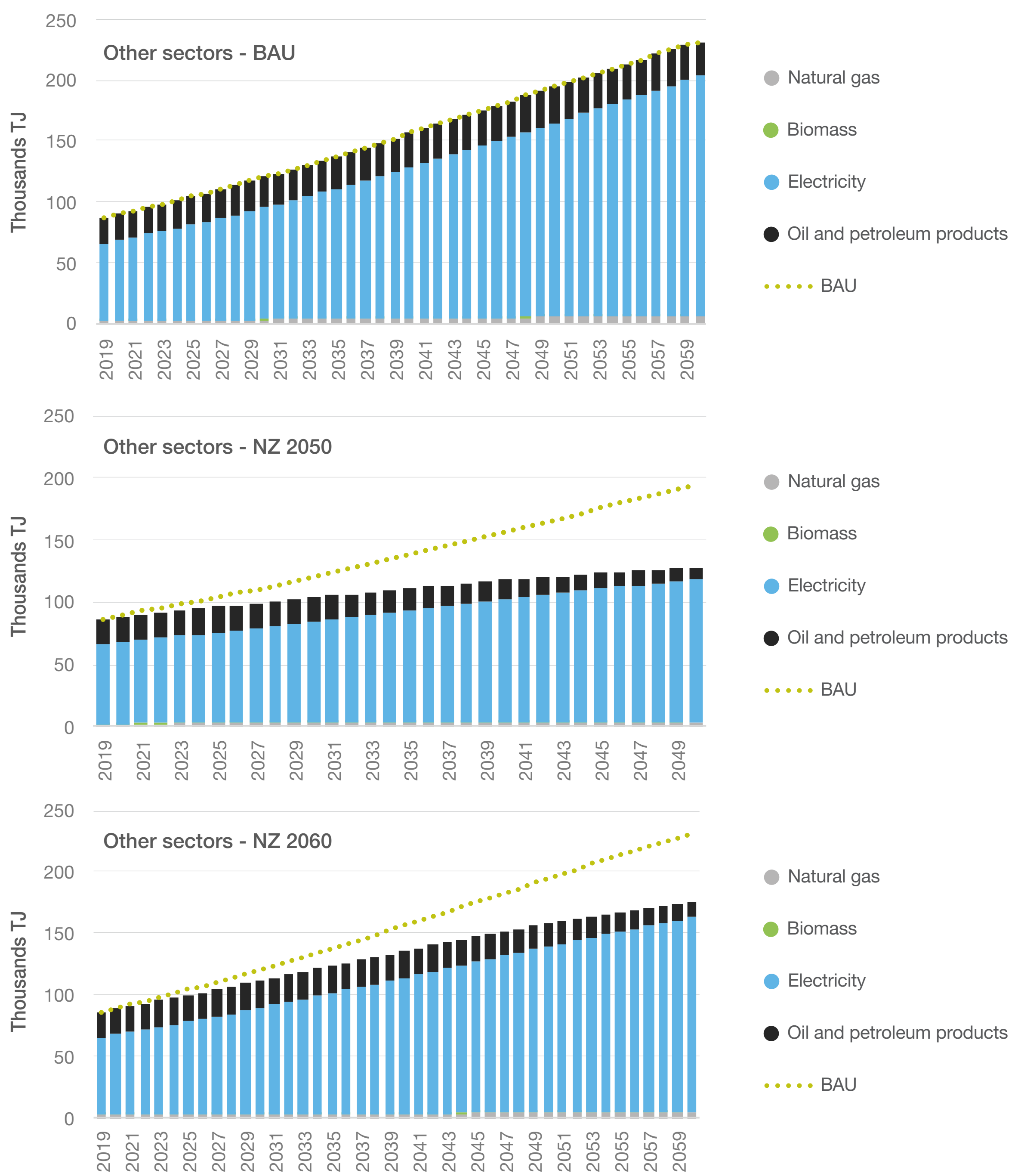
Agricultural, fishing, mining, and construction sector

The agricultural, fishing, mining, and construction sector, along with the commercial, services, and public sector, are the sectors with the lowest energy consumption. The electrification of the sector is high (74% in 2019). When analyzing the demand by subsector, we can see the importance of the mining sector, which accounts for 88.6% of the total in Peru, whereas the agricultural sector shows 7.6%, and fishing 3.8 %[31]. The mining sector has high potential to electrify uses related to motive force or mining trucks, among other things, whereas strong electrification of agricultural machinery is expected in the long term, in line with the trends observed in this subsector. There is also potential to increase the energy efficiency of the equipment in both subsectors.

In the BAU scenario, the demand of this sector grows by around 2.4% annually (cumulative 168% in the period), which maintains the current fuel share. An enhancement of the sector's energy intensity is observed (GDP growth is higher than that of demand, annual 3.6% versus annual 2.4%).

31 No specific information on the construction sector is available.

Graphic 55 Results of the agricultural, fishing, mining, and construction sector, by scenario (10^3 TJ)

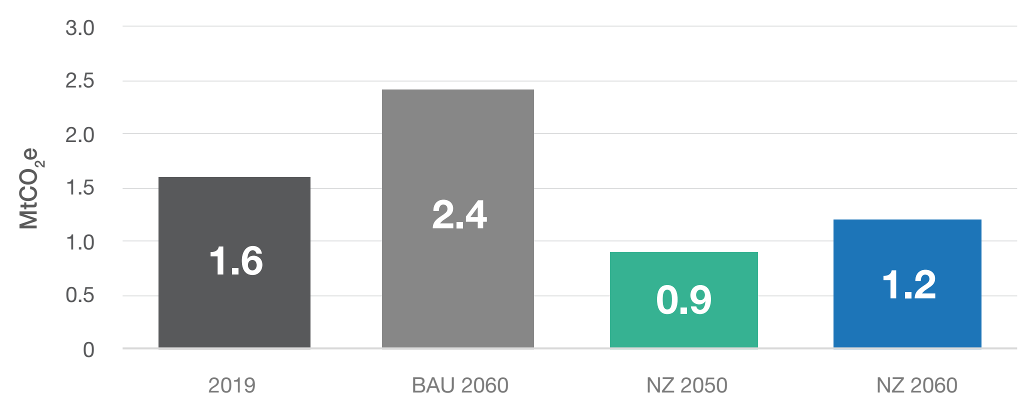


Source: Own preparation.

Transition scenarios

In the NZ scenarios, almost total electrification of the sector is achieved; oil and petroleum products are the drivers of the rest. Consumption remains relatively constant in the analyzed period due to the combined effect of greater energy efficiency and the savings from the expected electrification of some uses.

Graphic 56 Agricultural, fishing, mining, and construction sector: direct emissions by scenario ($MtCO_2e$)



Source: Own preparation.

CO_2e emissions grow in the BAU scenario (+50%) at a slower pace than that of the GDP. On the other hand, emissions fall by between 25% and 44% in the NZ scenarios in the long term, thanks to the electrification of the sector and energy efficiency efforts.

The energy transition measures required to limit GHG emissions in the sector relate to technologies that are expected to have matured worldwide in the next few years, such as the use of electric agricultural machinery and electric mining trucks.

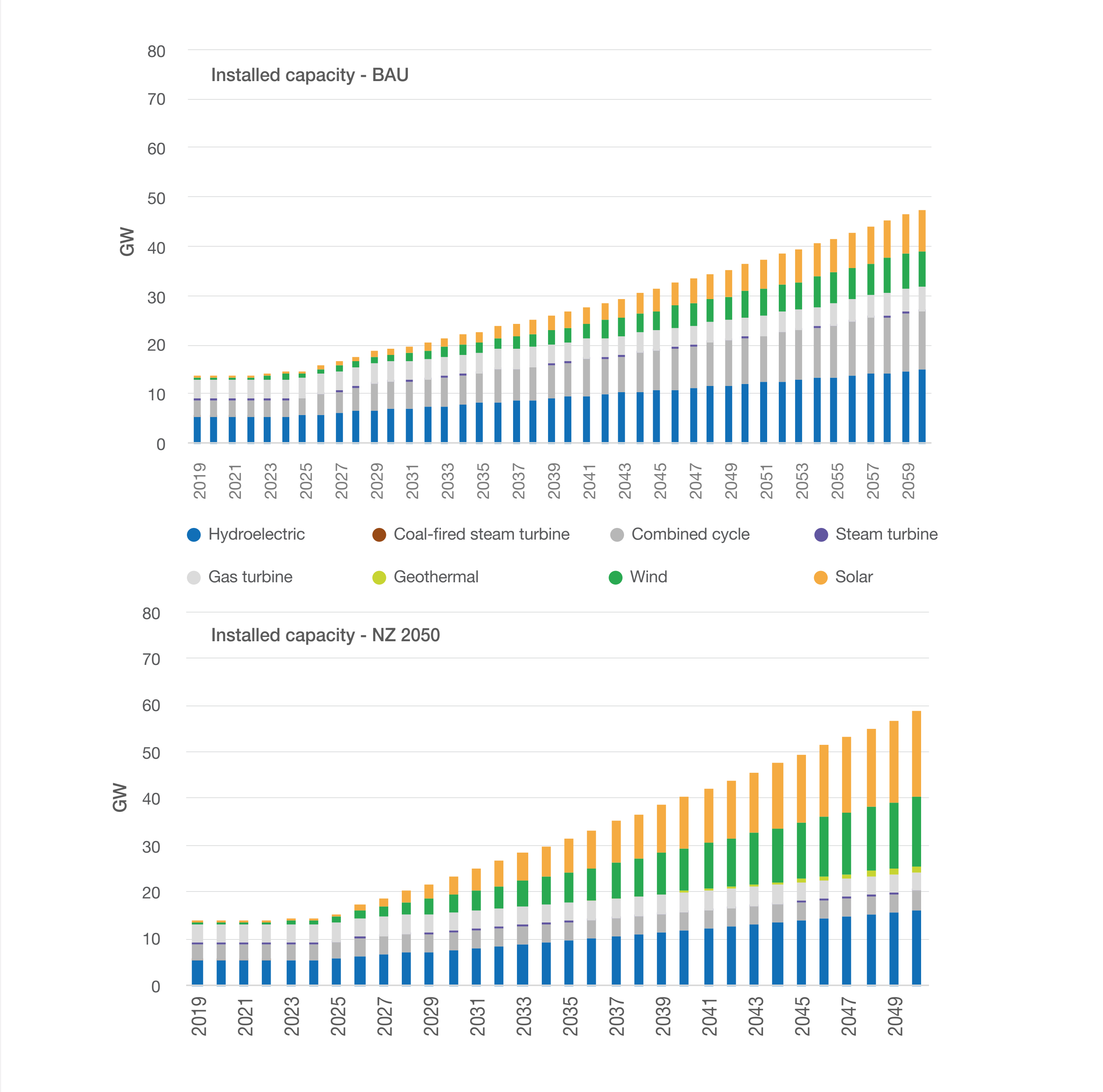
Power sector

Peru starts with a power generation mix with a large share of hydroelectricity and natural gas. It has abundant natural resources and great hydroelectric potential (70 GW) as well as onshore wind (20 GW), solar (25 GW), and geothermal (3 GW) potential, which is favorable to develop a low-emission generation fleet. It also has great potential for offshore wind projects and abundant gas reserves at competitive prices (Camisea). In the last decade, Peru commissioned a large number of natural gas-based power plants, and very recently it has experienced greater dynamisms in developing renewable projects (wind and solar). It is expected that these projects will continue in the future in a context of lower investment costs (CAPEX) for these technologies.

In all the scenarios presented, an increase in solar, wind, and hydro capacity is expected. A much higher growth in the generation fleet than the one observed in the last 20 years is required. In the BAU scenario, the additional renewable capacity to be installed is 24 GW, 8 GW of which is solar and 7 GW wind. In the NZ scenarios, even more renewable capacity needs to be installed to cover the greater power demand and ensure a significant reduction in GHG emissions. In the NZ 2050 scenario, the addition of 45 GW of renewable energy is expected, 18 GW of which will be solar; 15 GW, wind and 11 GW, hydro. In the NZ 2060 scenario, the installation of 55 additional GW of renewable energy is required, 22 GW of which is solar; 18 GW, wind; and 14 GW, hydro.

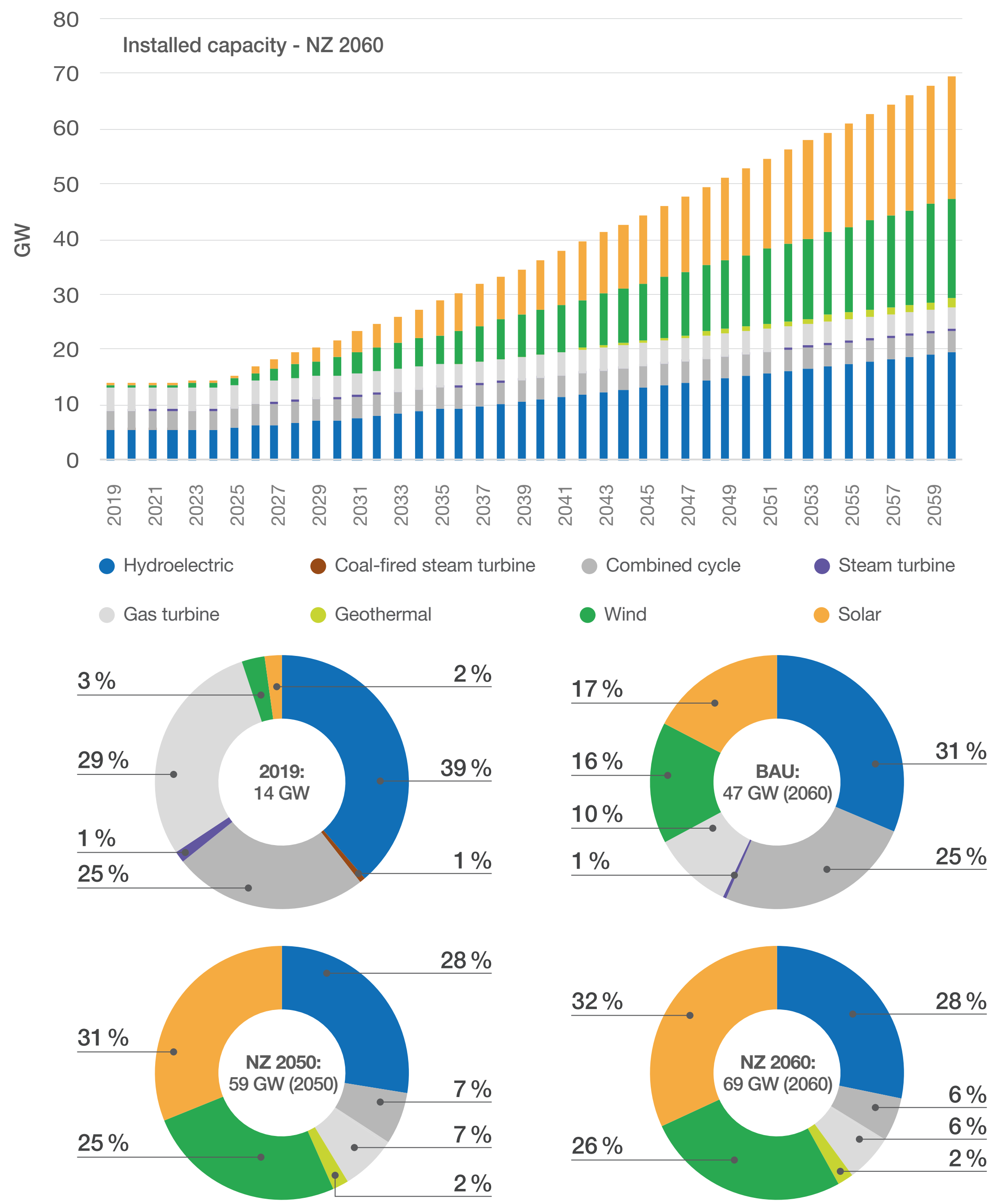
In all the scenarios, the installation of new thermal plants or the preservation of the existing ones is also required, as they play a backup role, particularly in dry hydrology situations, as well as batteries and smart grids, which participate in a better integration of renewable energy in the grid.

Graphic 57 A Projection of installed capacity by source and by scenario (GW)



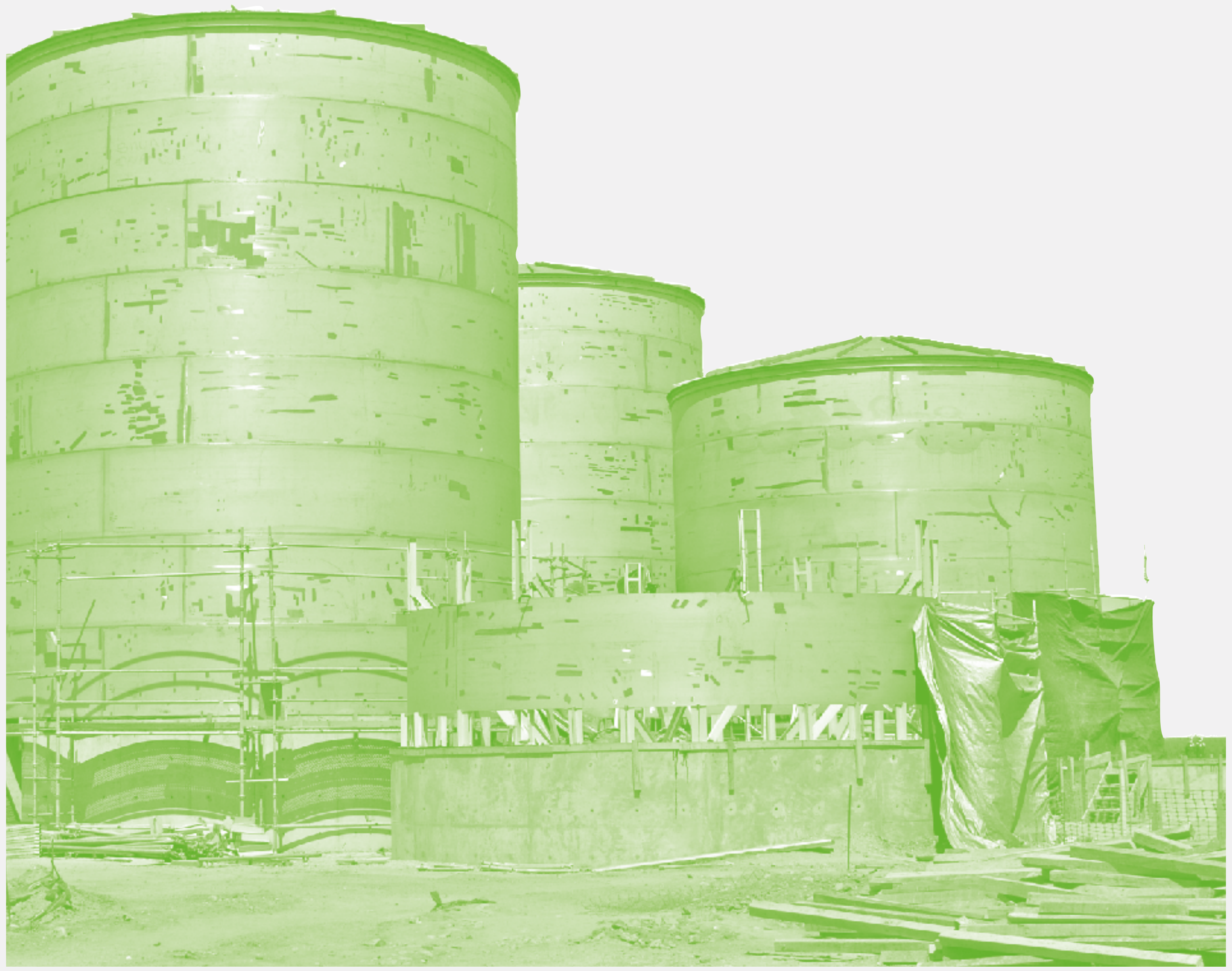
Source: Own preparation. **Note:** No isolated systems are included.

Graphic 57 B Projection of installed capacity by source and by scenario (GW)

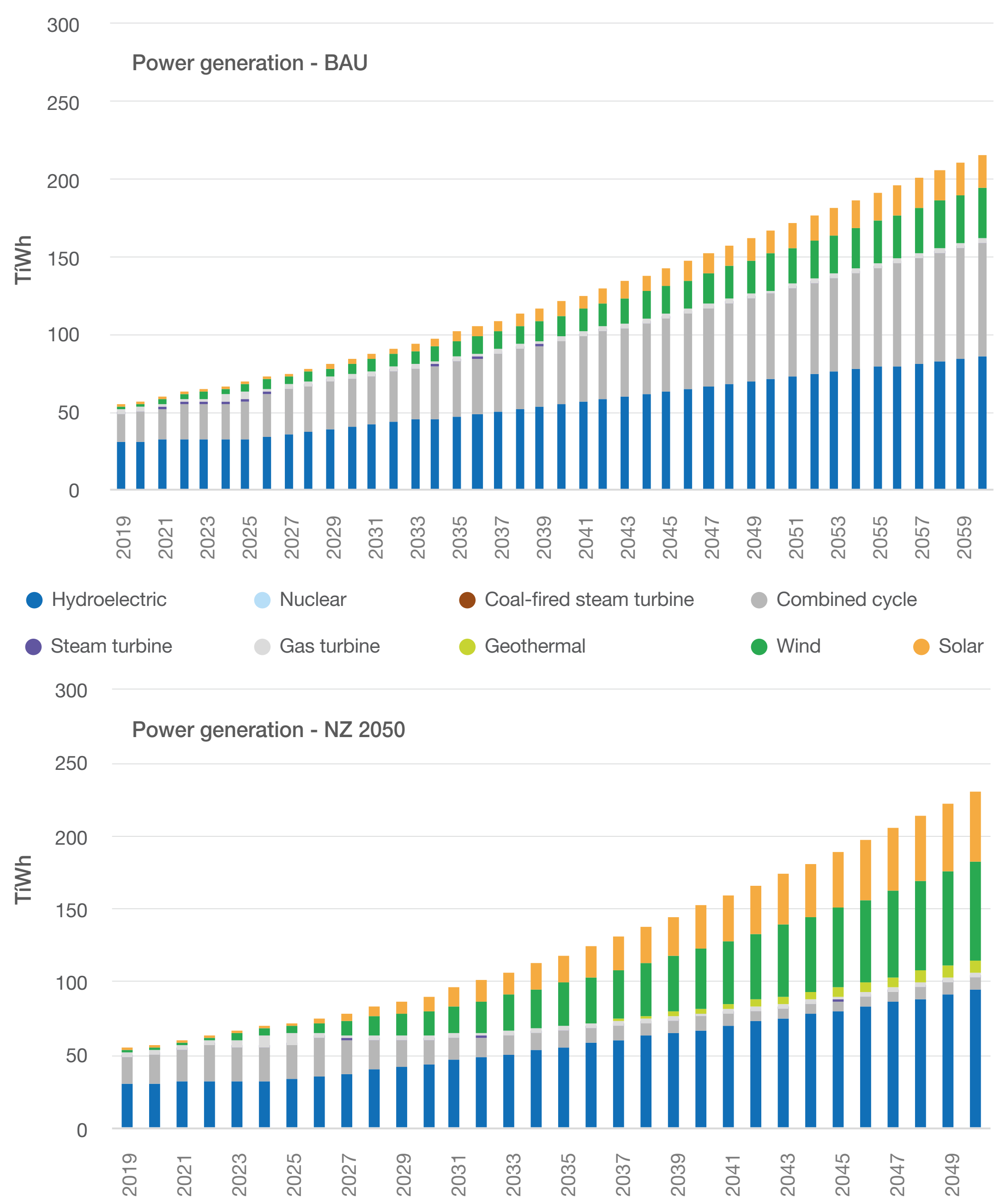


Source: Own preparation. **Note:** No isolated systems are included.

In all the scenarios, the power generation matrix becomes more renewable, with over 65% of the generation free from emissions in the BAU scenario and over 90% in the NZ scenarios (see Graphic 58). Hydroelectric production continues playing a major role in all the scenarios, although lower than its current importance.



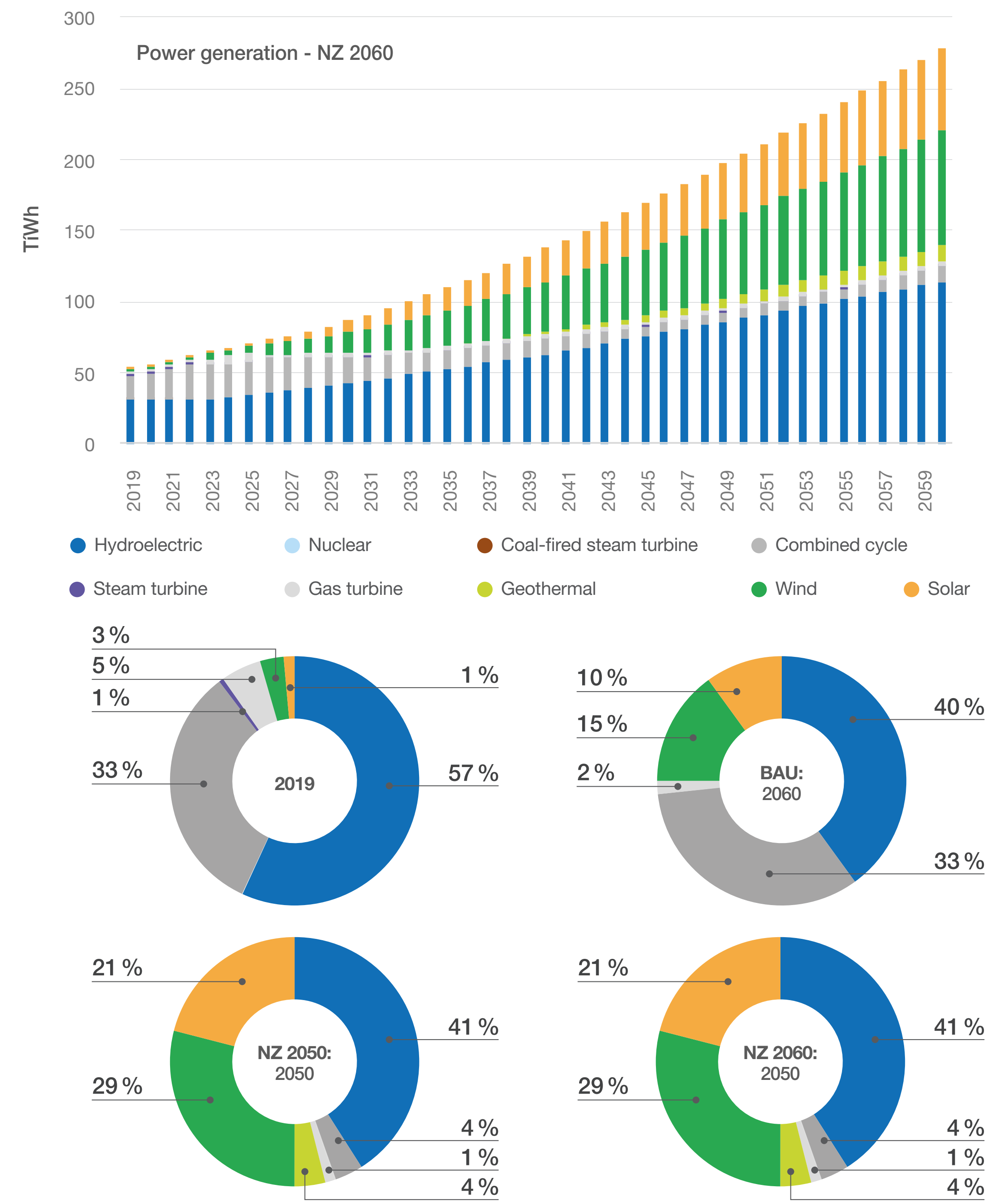
Graphic 58 A ▶ Projection of power generation by source and by scenario (TWh)



Source: Own preparation. **Note:** No isolated systems are included.

Transition scenarios

Graphic 58 B ▶ Projection of power generation by source and by scenario (TWh)



Source: Own preparation. **Note:** No isolated systems are included.

3. Energy transition financing

Investment related to each scenario is presented in this section as a result of all the energy transition measures described above.

The main items requiring investment are shown below, including a brief description of the assumptions used to derive the amounts presented in the following sections:

1. power generation (and the need for additional grids as well as flexibility measures);
2. electrification of the road transportation sector (investment in electric vehicles and charging stations);
3. energy efficiency measures and electrification of subsectors and end uses for the other sectors as well as fuel substitution.

.

Total investment

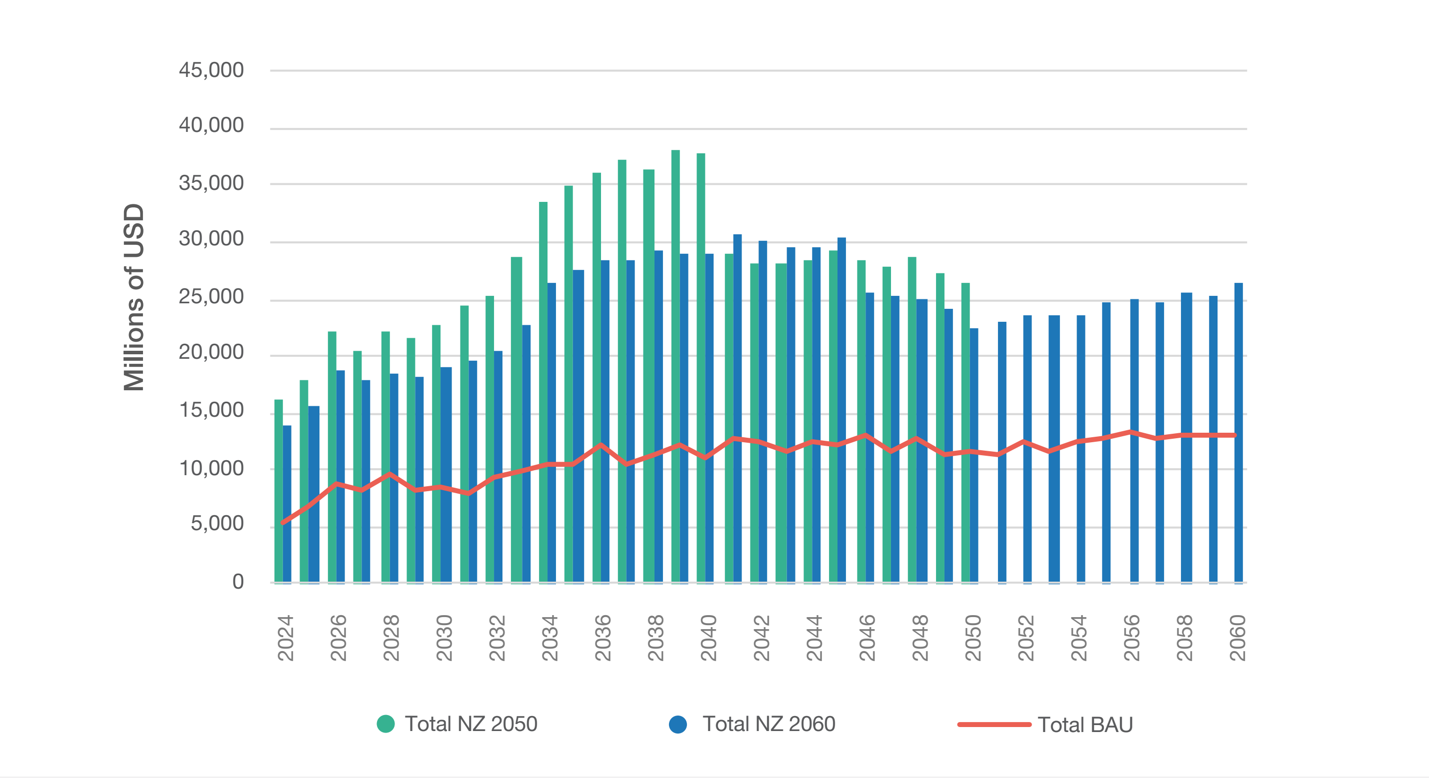
Investment is calculated on an annual basis and the total investment amount is applied as of the first year in which it is possible to reduce CO_2 emissions. This is a simplification of the model, as large investment must take place in advance, from one to five years before, depending on construction times or the

Transition scenarios

implementation of the investment considered (hydro plants, for example, are characterized by a construction period of several years).

Graphics 59 and 60 show the estimated total annual investment by scenario, in millions of USD and as a percentage of the GDP, according to the guidelines and assumptions described in "Investment", chapter "Methodological section and assumptions" in the *Just Energy Transition / Projection assumptions* report.

Graphic 59 Estimated annual investment (millions of USD)

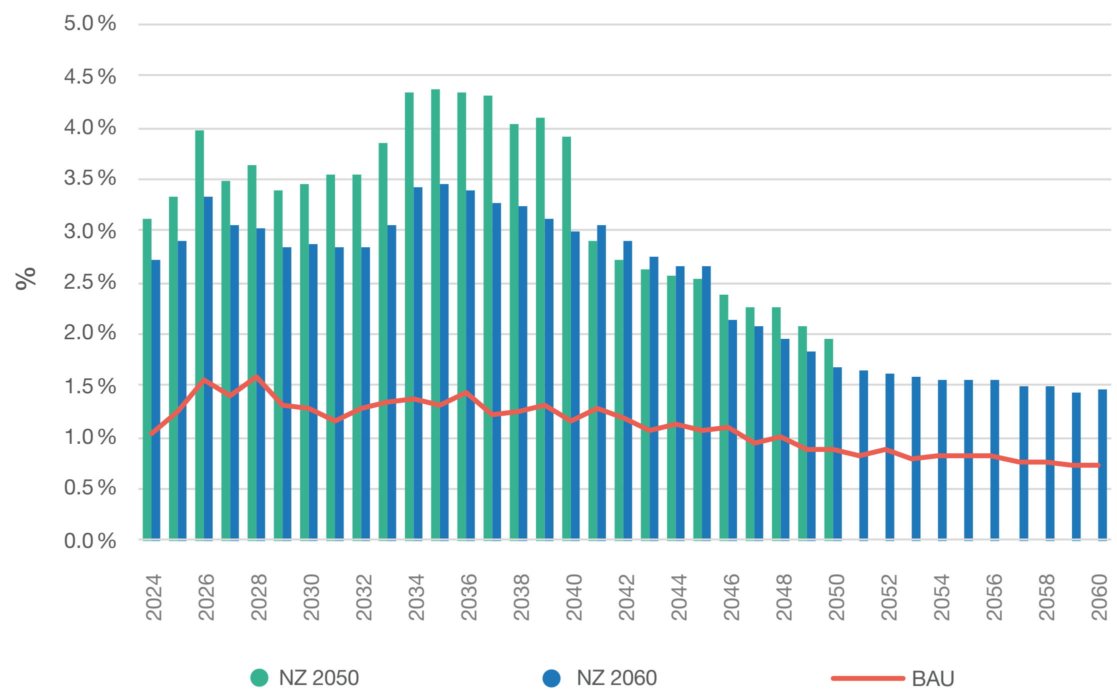


Source: Own preparation.

The cumulative investment in the period was about USD 409,000 million in the BAU scenario, USD 908,000 million in the NZ 2050 scenario and USD 901,000 million in the NZ 2060 scenario.

By year, investment shows a growing trend until 2040 or 2045 in the NZ scenarios. From then on, decreasing or variable investment is observed, which reflects the fall in the unitary cost of some of the transition technologies in the long term, particularly, electric vehicles and the vehicle fleet replacement speed, which varies depending on the scenario. In the case of the BAU scenario, annual investment with a slightly upward trend can be observed in all the period. The maximum annual investment in the BAU scenario is approximately USD 13,000 million, USD 38,000 million in the NZ 2050 scenario, and around USD 31,000 million in the NZ 2060 scenario, which implies doubling or trebling the annual investment compared to the BAU scenario. As from 2051, investment in the NZ 2050 scenario is lower than in previous years and similar to the BAU scenario.

Graphic 60 Total estimated annual investment in % of GDP



Source: Own preparation.

Transition scenarios

The investment effort, measured in GDP percentage, is close to 1.5% in the period 2026-2035 in the BAU scenario; 4.3% in the period 2034-2037 in the NZ 2050 scenario; and 3.4% in the same period in the NZ 2060 scenario.

Investment by type is presented in the following sections.

Power sector

Investment in the power sector includes:

- investment in new power generation plants, in line with the generation expansion presented in the "Power section" subsection, "Results and assumptions by sector" section, pursuant to the CAPEX prices projected by the National Renewable Energy Institute (NREL) to start up new facilities[32];
- investment in infrastructure and flexibility, including the concepts of smart grids, batteries, and modernization of old hydro plants, estimated at an additional 15%[33] to investment in power generation. This investment is key to facilitate the integration of intermittent power generation in the electric dispatch;
- investment in transmission and distribution grids, which accompanies the very significant growth in power demand as a result of the projected economic growth and the electrification of end uses, based on a 16% share of transmission and 44% of distribution[34].

It is important to point out that, even though the addition of new power generation capacity grows in the long term, the unitary costs of the renewable technologies

32 Table 9, *Just Energy Transition / Projection Assumptions*

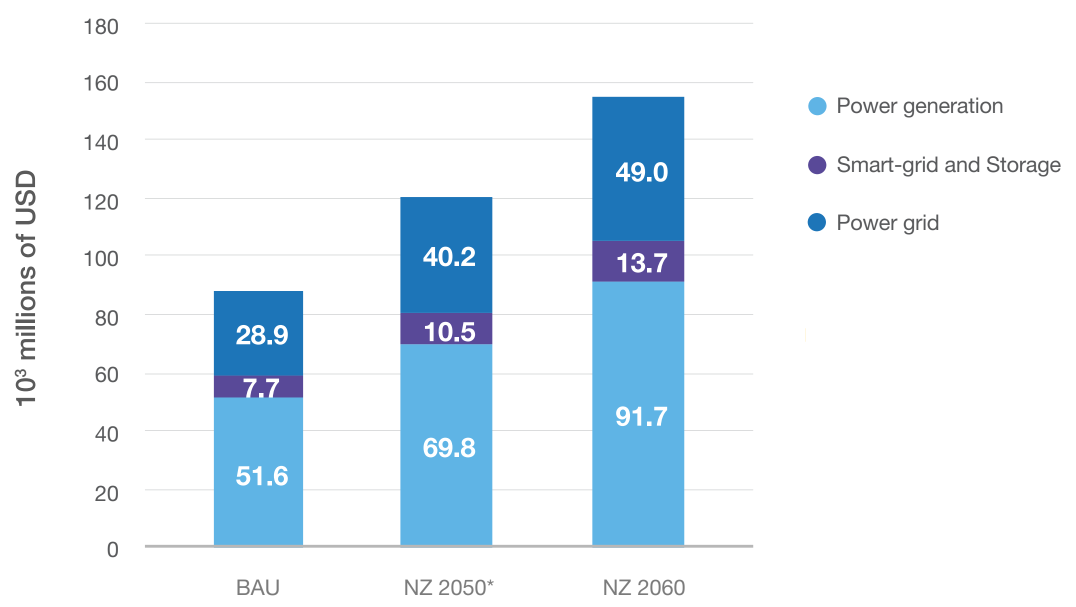
33 This generic amount is in line with the global investment amounts estimated by the International Renewable Energy Agency (IRENA) in its report *World energy transitions outlook 2023: 1.5 °C pathway*.

34 See again the *Just Energy Transition / Projection Assumptions* report.

are expected to fall gradually over time as a result of the technological enhancements and the returns to scale originating in the sector's growth.

Cumulative investment in the transition period is presented below for each scenario.

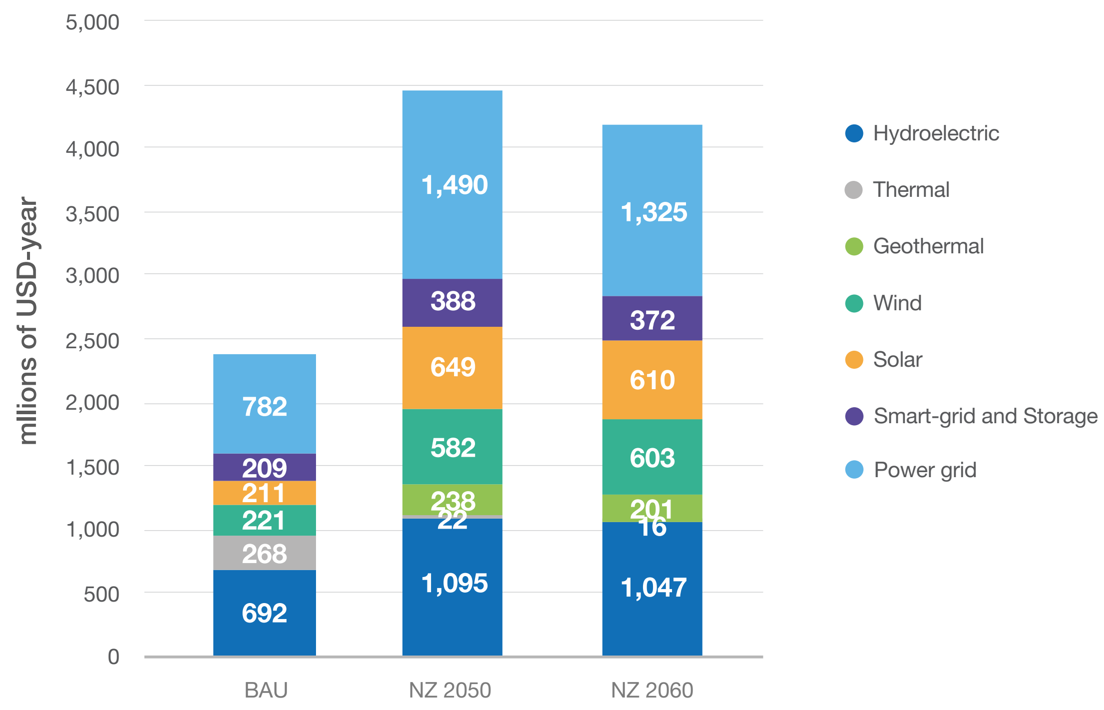
Graphic 61 Power sector: cumulative investment in the transition period (billions of USD)



Source: Own preparation. *Investment in the NZ 2050 scenario refers to the period 2024-2050 whereas it refers to the period 2024-2060 in the other scenarios.

Cumulative investment related to the power sector is approximately USD 88 billion in the period 2024-2060 for the BAU scenario; USD 120 billion in the period 2024-2050 for the NZ 2050 scenario; and USD 154 billion in the period 2024-2060 for the NZ 2060 scenario. Investment related to power generation, smart grids, and storage adds up to around two thirds of this, whereas investment in the power grid is about one third.

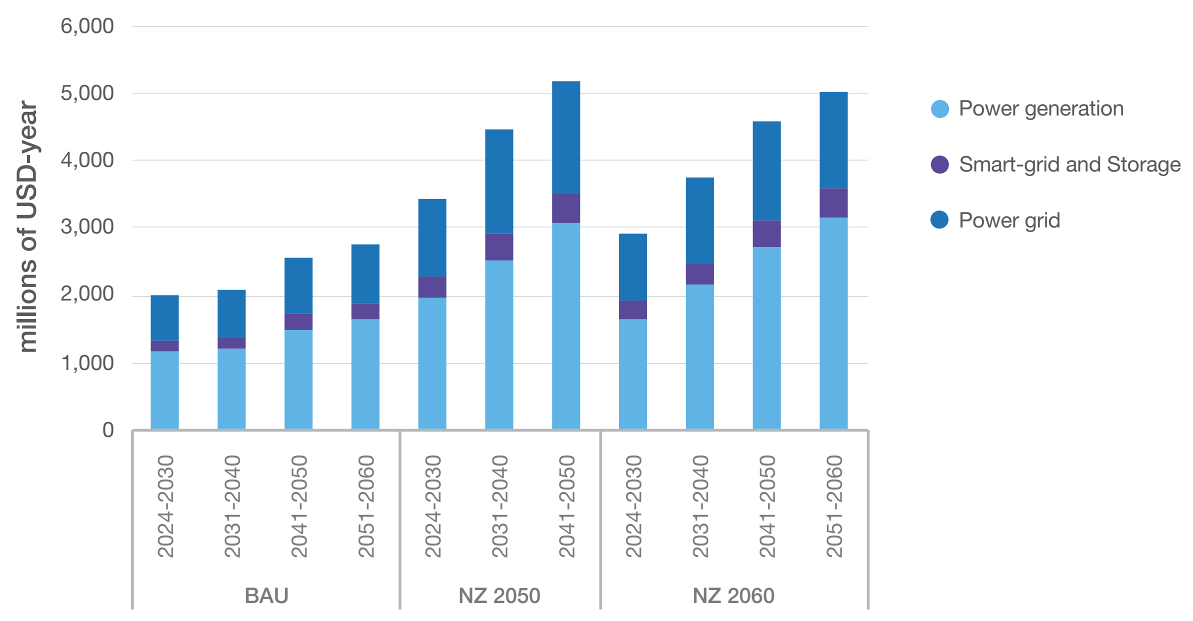
Graphic 62 Power sector: average annual investment by type (millions of USD)



Source: Own preparation.

By year (average value), the required investment is higher in the NZ 2050 scenario with USD 4,463 million. The NZ 2060 scenario follows with USD 4,174 million and, finally, the BAU scenario with USD 2,384 million. By technology, the investment in power generation with the largest participation is in hydro, solar, and wind. Even though the cumulative hydro capacity to be installed is lower than the wind or solar capacity, the unitary CAPEX of the former is two to four times higher, depending on the year considered.

Graphic 63 Power sector: annual investment by period (millions of USD-year)



Source: Own preparation.

By time interval, the need for investment grows over time. This need for investment occurs in a context of demand growth as a result of strong economic development and the electrification of end uses.

End uses

From the point of view of investment related to energy end uses, it is possible to mention the following:

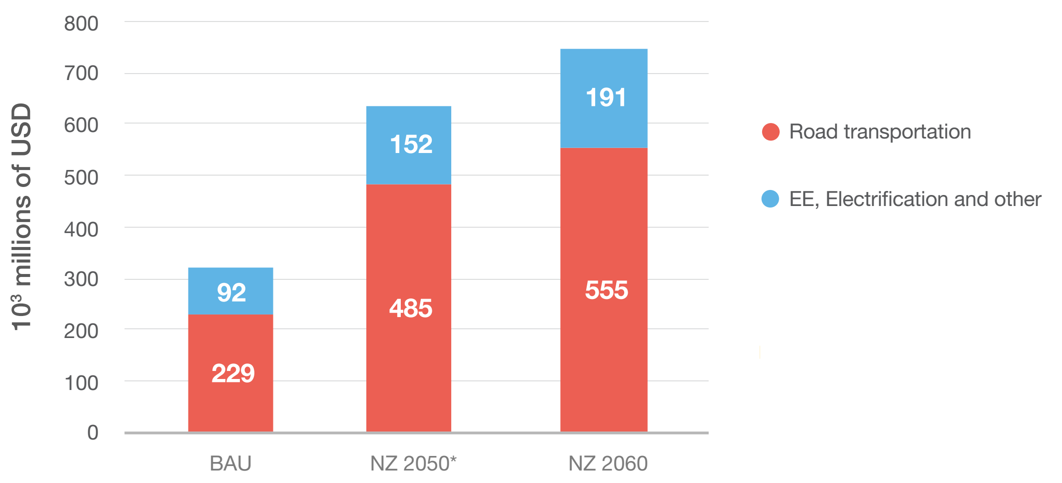
- the road transportation sector, in which the total investment[35] in electric vehicles (EV) and hybrid vehicles (VH) is estimated on the basis of the unitary CAPEX projected by IRENA, and the number of new vehicles, as well as the charging stations, based on a calculation of the number of stations required and a unitary cost;
- energy efficiency measures, electrification, use of alternative fuels (hydrogen and its derivatives, among others), and behavior changes with an impact on the end use sectors, except for road transportation and the carbon capture, use, and storage technology (CCUS). A proxy[36] was considered by final consumer sector, equal to a unitary CAPEX expressed in USD/ton of avoided emissions, times the savings in emissions in each sector.

Graphic 64 presents cumulative investment in the transition period for each scenario.

35 This investment does not consider the necessary replacement of EVs at the end of their useful life or the anticipated replacement of batteries.

36 This equivalent CAPEX by sector was estimated based on a study conducted by the Climate Change Committee (CCC).

Graphic 64 End uses: cumulative investment in the transition period (billions of USD)

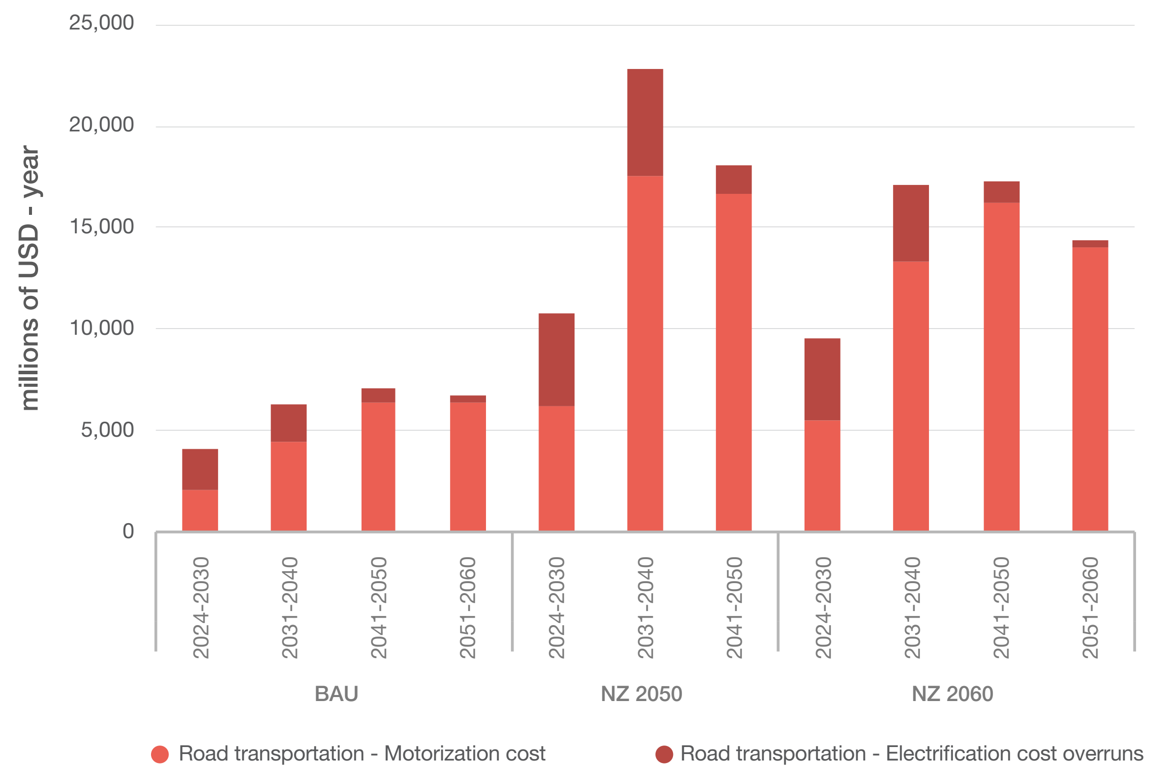


Source: Own preparation. *Investment in the NZ 2050 scenario refers to the period 2024-2050, whereas it refers to the period 2024-2060 in the rest of the scenarios.

Cumulative investment related to end uses is approximately USD 321 billion in the period 2024-2060 for the BAU scenario; USD 637 billion in the period 2024-2050 for the NZ 2050 scenario; and USD 746 billion for the period 2024-2060 in the NZ 2060 scenario. Investment related to road transportation amounts to approximately 70% to 80% of this investment in the three scenarios if total investment related to EVs and HVs required for this segment is contemplated. If only the cost overruns related to this investment (calculated in a simplified way as the difference in cost between buying EV, HV and investing in charging stations, and buying a vehicle that runs on fossil fuel) are considered, road transportation adds up to less than half of the investment related to end uses (see Graphics 65 and 66, purple segment referring to electrification cost overruns).

Graphic 65 illustrates the difference between both concepts for road transportation.

Graphic 65 Road transportation: annual investment by period (millions of USD-year)



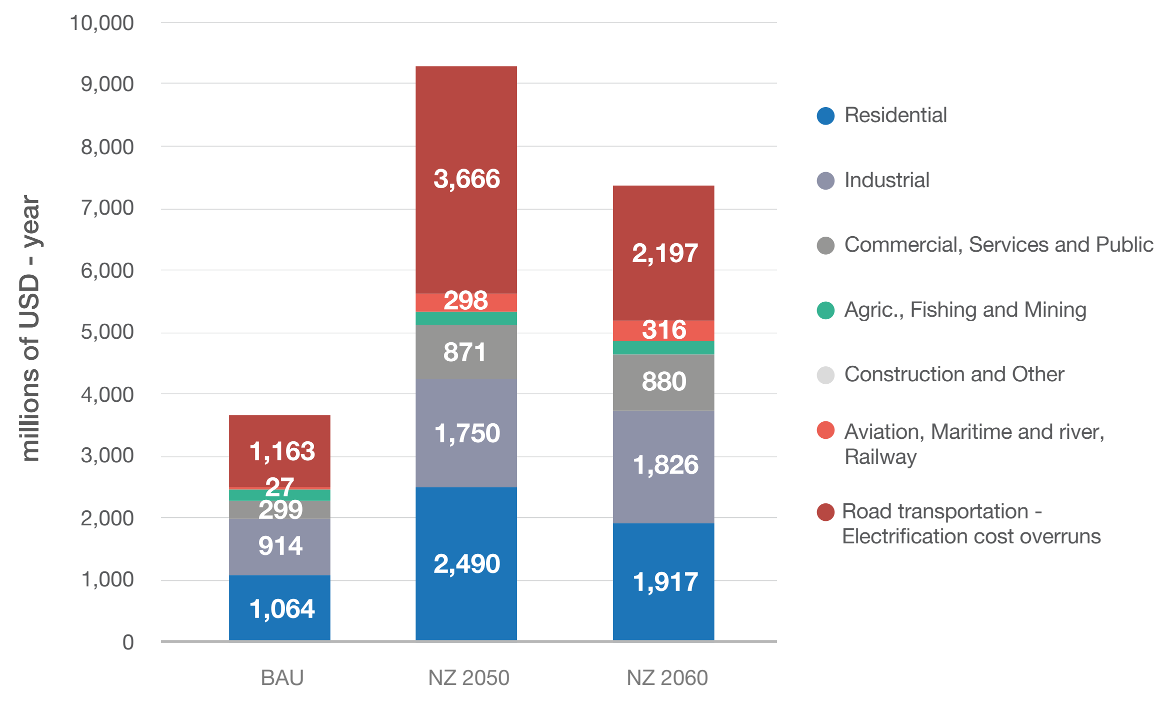
Source: Own preparation.

It should be mentioned that all the analyzed scenarios present a future reduction in the cost of electric vehicles of about 60% in the period. In addition, the scenarios contemplate an increase in motorization, evidenced through the possession of vehicles per 1,000 inhabitants, as indicated in the assumptions by sector. The need for investment includes two major effects: greater access to mobility and mobility electrification. The latter represents lower cost overruns in the long term due to the competitiveness of EVs against vehicles running on fossil fuels in almost all the vehicle segments.

It is important to remember that an increase in the possession of cars and a reduction in their annual unitary use were estimated for private passenger transportation. Other schemes may also exist, such as shared autonomous vehicles, which could partially reduce the total number of vehicles and their associated investment.

Graphic 66 presents investment by type, without considering the cost of motorization of EVs and HVs.

Graphic 66 End uses: average annual investment by type (millions of USD)



Source: Own preparation. This graphic does not consider the cost of motorization of EVs and HVs.

By year (average value), the investment required is higher in the NZ 2050 scenario, since the transformation of the sector must be achieved fast. By technology, the investment with more participation is that of the road transportation sector, followed by the residential, industrial, and commercial sectors.

4. Main transition indicators

Table 12 presents some of the indicators of the just energy transition.

These indicators illustrate the increase in the penetration of renewable energy in final consumption and power generation, energy intensity enhancements in the sector, the use of energy per capita, and the penetration of electric mobility, among other aspects related to the just energy transition.

Table 12 Indicators by time horizon and scenario

Número	Indicadores potenciales	Unidad	2019	BAU 2060	NZ 2050	NZ 2060
E-2.1	Share of renewable energy in total final energy consumption	%	27%	23%	69%	69%
	Share of renewable energy in power generation	%	62%	65%	95%	95%
E-2.1bis	Installed renewable energy generation capacity	GW	6.0	30.3	50.7	61.3
E-2.2	Energy intensity measured on the basis of primary energy and GDP	TJ/ MUSD PPP 2017	2.6	1.3	0.9	0.8
E-2.3	Efficiency of energy conversion	%	36%	50%	50%	50%
	Efficiency of energy distribution	%	87%	87%	87%	87%
E-2.4	Energy efficiency by sector (industrial)	TJ/ MUSD PPP 2017	2.9	2.2	1.8	1.6
	(Agricultural, fishing, and mining)		1.2	0.7	0.5	0.6
	(Services and commercial)		0.3	0.2	0.1	0.1
	(Transportation)		1.0	0.6	0.3	0.3
E-2.5	Energy intensity of the residential sector	TJ/ 1,000 inhabitants	4.9	7.2	4.6	4.5
E-2.6	Penetration of electricity in the transportation sector	%	0.1%	10%	54%	53%
E-2.7	Penetration of natural gas in the transportation sector	%	15%	30%	15%	15%
	Penetration of hydrogen in the transportation sector	%	0%	0%	19%	19%
S-1.4	Energy use per capita	TJ/1,000 inhabitants	27.0	55.8	29.4	34.5
A-1.1	GHG emissions per year, energy*	$MtCO_2e$	54	147	28	33

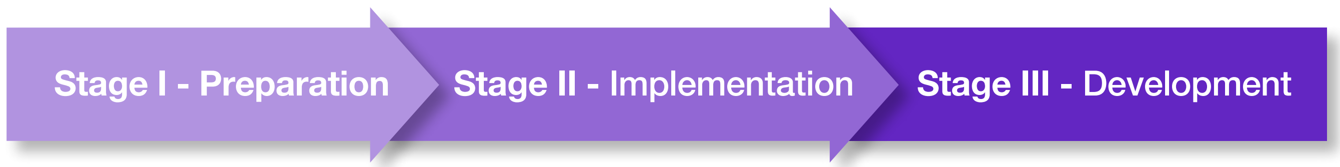
Source: Own preparation. *Fugitive emissions are not included.

1. The environment for the transition

Projections

When analyzing the results of the projections of the energy matrix in Peru in the long-term NZ scenarios, we observe more consumption electrification, a reduction in the demand for liquid fuels (refined hydrocarbons), and a slight decrease in natural gas consumption, with a change in the composition of its demand. In turn, we can divide the projection into three stages: the preparation stage between 2020 and 2030, the implementation stage with strong investment between 2030 and 2040, and the development stage as from 2040.

Graphic 67 Roadmap: stages



STAGE I – Preparation (between 2020 and 2030). Investment levels are still low due to the following:

- the relative inertia of the first years of the period (particularly for power generation and energy infrastructure, projects may take several years before being commissioned);
- it is expected that electric vehicles and batteries for power generation will not be as massive and competitive as in the following decades.

In this period, we can point out investment in energy efficiency, renewable generation (in particular, solar and wind) and its associated transmission grid and, in the case of Peru, total phase-out of highly polluting technologies (coal and fuel oil) and their replacement with electricity or natural gas. Peru is an importer of coal, oil, and petroleum products; in addition, it has a liquefaction plant locally that allows it to advance with the country's gasification. In this period, investment in natural gas infrastructure is required.

STAGE II - Implementation (between 2030 and 2040). It is assumed that the technologies for the use of renewable sources are massive, available, and have high demand. The CAPEX of the energy transition technologies (in particular, electric vehicles, power generation, and batteries) continue their downward trend, which allows for their massive development. In this decade, the introduction of clean technologies and the enhancement of energy efficiency in the energy sector's value chains gain speed, investment in natural gas is maintained, and the supply of hydrogen-based technologies starts.

STAGE III - Development (as from 2040). Clean technologies are already mature and massive; therefore, their prices are competitive and the cost of the transition is more related to accelerating the phase-out of the technologies with higher CO_2 emissions. Investment in the sectors responsible for CO_2e emissions stops, for example, in natural gas, and this marginally gives way to the technologies that replace it, such as hydrogen and CCUS.

Implications for public policies

Peru is classified in the 84th position in the human development index ranking, with a value of 0.762 (high indicator)[37]. Moreover, it is not a country in Annex I to the Paris Agreement. Therefore, its policies must focus on those that allow it to meet its emission reduction targets and the need for its economy to grow in order to reach the maximum emissions in the shortest possible time; it is likely to meet the net zero emissions target after 2050.

Stage I – Preparation

In preparation stage I, Peru's policies must focus on the following points.

1. **Public policies.** Peru is developing its National Strategy on Climate Change 2050 (MINM, 2023). This process is led by the Ministry of Environment (MINAM) and is supplemented with documents such as *Costos y Beneficios de la carbono-neutralidad en Peru* (Jairo Quirós-Tortós, 2021). These policies should be aligned and updated to comply with the nationally determined contribution for 2030. In addition, these policies must be developed, published, and communicated to the population.

2. **Access.** Reach full electricity coverage of the electricity services in order to displace and substitute firewood (and other inefficient fuels with high CO_2 emissions) in the residential sector.

   Peru has implemented several programs to increase access through the National Rural Electrification Plan (PNER) prepared by the MINEM (MINEM, 2020) in order to reach 95% coverage of rural households, as well as different programs financed by the FISE such as Bonogas and *Electricidad al Toque*.

3. **Energy efficiency.** Promote energy efficiency in all the segments of the economy (residential, industrial, commercial, transportation, agricultural, public sector, etc.) in order to reduce energy consumption.

   Peru has energy efficiency policies and programs, as indicated in the diagnosis; therefore, actions must focus on promoting equipment and car replacement and scrappage programs in order to retire cars and equipment that are 20 years old[38], with low efficiency and high pollution levels. These programs should promote the enhancement of constructive aspects in existing houses by replacing windows and other equipment.

   The development of programs to facilitate investment in energy efficiency that, in many sectors, imply adopting mature technologies is a policy that can be rapidly applied to implement the just energy transition in Peru.

4. **Renewables.** LGas competitiveness and electrical over supply in the last few years have delayed the incorporation of renewable energy in the matrix. Price reductions are expected to permit greater penetration in the short and medium term.

5. **Subsidies and prices.** In order to be effective, energy efficiency policies require redesigning price schemes and focusing subsidies on people with unfulfilled energy needs so that the prices can reflect their costs and encourage the adoption of efficient technologies. In some cases, this will imply subsidizing demand and not supply.

   The price stabilization scheme must be eliminated so that the stability of LNG and CNG prices and of electricity prices in Peru may generate the incentive to change, especially in the production sectors.

37 The UNDP establishes four categories: low (less than 0.55), medium (between 0.55 and 0.70), high (between 0.70 and 0.80), and very high (over 0.80).

38 COFIGAS program, which has promoted the introduction of CNG, must focus its efforts on freight transportation and enable the expansion of the use of LNG.

Roadmap of a just energy transition - Recommendations

The subsidy system financed by the FISE and FOSE in Peru must be revised while schemes associated with carbon taxes are developed in order to improve price signals.

6. **Regulations.** Promote fiscal and financial incentives to foster investment in renewable energy and energy efficiency.

   Promote banking regulations to incentivize loans associated with energy transition (renewable sources and transition fuels).

   Within the fiscal incentives, taxes on carbon should relate to the international prices of carbon credits so that they adequately reflect the mitigation cost[39].

   Develop regulations to foster policies related to hydrogen and CCUS in order to reduce uncertainty in these businesses and allow for their development in the long term.

7. **Transition fuels.** The consolidation of gas supply and its transportation systems must take place in this period, guaranteeing that the projects that are developed can be depreciated with no cost overruns.

8. **Reconversions.** Peru is an oil and coal importer, a producer and exporter of natural gas, and a minor producer of oil in the north. Reconverting assets related to oil and coal imports and the oil producing regions is not the focus of reconversion in this period.

   Generation plants running on fuel oil should be phased out and replaced. The focus should be placed on those areas that are not connected and use this type of fuel.

   Efforts must be focused on a project that is under development in Peru: the transformation of its freight transportation to LNG and CNG.

39 It is important to mention that price signals should be constant over time in order to be effective; therefore, developing levelized mitigation costs could be another alternative.

   This opportunity must be analyzed in the life cycle of all the value chain, since transportation fueled by LNG and diesel do not differ in terms of emissions; however, in Peru, the former does not accumulate a long chain of supply.

9. **Smart grids.** Modernize energy infrastructure by promoting investment in smart grids and energy storage systems to facilitate the integration of renewable energy and enhance supply reliability. The costs of introducing smart grids for lower consumptions must be analyzed and promoted as part of the agenda to facilitate energy efficiency.

10. **Transportation.** Promote clean energy in transportation, including electric vehicles and their associated charging infrastructure, and foster vehicles running on natural gas (CNG and LNG) as transition fuel. Electric vehicles have an advantage that is not a minor one and is the reduction of polluting emissions to improve the quality of air, particularly in large cities[40].

    Policies to introduce electric railways also constitute a mechanism to accelerate energy transition and replace freight transportation running on liquid fuels. Therefore, studies, layout-related expropriations, and tenders to develop these projects should be promoted.

    In Peru, the energy transition will extend between ten and twenty years after 2050; therefore, gas technologies will have time to be depreciated.

11. **Markets.** Develop secondary markets in the power sector, focusing on electricity trading and its financial derivatives (futures, swaps, options, etc.) to allow the residential and commercial segments to select the energy sources they want to acquire and allow the industrial sectors to calculate their prices in the very long term.

12. **Education.** Promote education policies on the energy transition to develop habits regarding energy consumption in the population. During this stage, the energy transition should be included at all education levels and in awareness campaigns addressed to society.

40 According to the WHO, Lima is the second most polluted city in Latin America.

Stage II - Implementation

In the second stage there will be more investment.

1. **Public policies.** Develop the transition plans to NZ detailed in the planning horizon that is finally defined.

2. **Energy efficiency.** Promote energy efficiency in all segments of the economy (residential, industrial, commercial, transportation, agricultural, public sector, etc.) in order to reduce energy consumption. The alignment of prices, subsidies, banking regulations to foster the energy transition and the introduction of carbon taxes should be drivers of this investment.

   Promote equipment and car replacement and scrappage programs, focusing on vehicles (trucks and cars), given the expected advance in EV development and prices. These programs must promote electric vehicles and trucks running on LNG and CNG in order to use the competitive advantage of this fuel in Peru.

3. **Subsidies and prices.** In this period, the FISE must continue functioning in all access aspects and must be used to finance reconversion and energy efficiency mechanisms.

   Subsidies for people with unfulfilled energy needs should be maintained and prices must be designed to internalize environmental and remediation costs.

4. **Regulations.** Foster tariff schemes that envisage investment in mitigation and adaptation to climate change.

   Promote restrictive regulations for the vehicle fleet in order to incentivize the replacement of units with high CO_2 emissions.

   Within the fiscal incentives, it should be established that taxes on carbon should relate to remediation and adaptation costs.

   Develop regulations to promote hydrogen and CCUS-based policies in order to reduce the uncertainty in these businesses.

5. **Social aspects.** Propose socio-environmental agreement schemes to make the development of hydrogen projects and CCUS technologies viable.

6. **Transition fuels.** Maintain investment in the gas sector and promote CNG and LNG in transportation as a mechanism to ensure the phase-out of part of the hydrocarbon value chain in the last stage.

7. **Reconversions.** Study and initiate the financing schemes of the policies defined to reconvert regional economies.

8. **Smart grids.** Consolidate the energy infrastructure by promoting investment in smart grids and energy storage systems to facilitate the integration of renewable energy and enhance supply reliability.

   The introduction of smart metering systems seeks to provide more adequate price signals to energy consumption.

   In addition, data transmission schemes should be envisaged to be able to create a safe data administration scheme of the centralized transmission and distribution grid (including cybersecurity aspects) without neglecting distributed generation.

9. **Transportation.** Foster clean technologies in transportation, including the promotion of freight vehicles running on LNG as transition fuel and electric vehicles and their associated charging infrastructure.

   Implement electric railway transportation to transport cargo and passengers.

10. **New technologies.** Development of concessional financial instruments to implement hydrogen and CCUS technology projects[41].

41 Several pilot projects are being proposed to finance hydrogen and CCUS; however, these mechanisms seek to allow an increase in the amount of funds through the development of these technologies. Here, what is proposed is financing technologies that have already been developed.

Stage III – Development

In the third stage, efforts are concentrated on few objectives.

1. **Energy efficiency.** Promote energy efficiency in all the segments of the economy (residential, industrial, commercial, transportation, agricultural, public sector, etc.) in order to reduce energy consumption. The alignment of prices, subsidies, banking regulations that promote energy transition, and taxes on carbon should foster this investment.

   Promote replacement and scrappage programs for equipment and cars, focusing on all the equipment using liquid fuels. Start programs to shift freight transportation to electricity and hydrogen, depending on the technology available.

2. **Subsidies and prices.** Maintain subsidies for people with unfulfilled energy needs.
3. **Regulations.** Within the fiscal incentives, carbon taxes should have highly prohibitive effects so that they incentivize scrappage and the replacement of such equipment.
4. **Reconversions.** Financially assist those regions affected by the phase-out of oil extraction assets.
5. **Transportation.** Promote clean technologies in transportation, hydrogen, and electricity, and their associated charging infrastructure.

   Implement transportation by electric railway, and electric or hydrogen-based freight and passenger transportation.

6. **New technologies.** Promote the massive adoption of the new technologies.

2. The roadmap

In order to develop the roadmap, three stages were proposed. In the first stage, there are two phases, one for debate and another for development, where the public policies to be developed and the segments that require concessional financing or support are defined. Table 13 shows the policies by topic and the expected action.

The debate phase is focused on conceptualizing with the countries the implications of the just energy transition between 2024 and 2025. This transition raises the need to combine economic plans that allow high growth rates and an enhancement of the population’s quality of life through public policies that focus on reducing energy needs.

Moreover, the just energy transition must also discuss the financing of the transition measures in line with the content of Article 7 of the Paris Agreement.

Table 13 Roadmap to be promoted from CAF

Policy	Between 2024 and 2025	Between 2026 and 2030	Between 2031 and 2040	As from 2040
Public policies	- Integrate the concepts of JET in the transition plans.	- Issue the first plans for the JET integrating clear decarbonization targets in the long term.	- Adjust JET plans to the deadlines to meet decent standard of living goals.	
Access	- Extend the PNER to maximum coverage. - Maintain the FISE schemes to promote the connection to the power and natural gas system.			
Energy efficiency	- Design, finance and implement replacement policies for home appliances (refrigerators, air conditioning, freezers, etc.). - Implement stronger policies to promote natural gas in transportation and seek financing to replace old commercial vehicles with very low efficiency with LNG and CNG equipment. - Promote studies for business reconversion.		- Continue the replacement policies, including all types of home appliances. - Promote plans to replace commercial and private vehicles with low efficiency with vehicles running on LNG or CNG in the case of the former, and start introducing electric vehicles in the residential sector.	- Continue the replacement policies, including all types of home appliances. - Promote plans to replace freight vehicles with low efficiency with electric or hydrogen-based vehicles. - Massively introduce electric vehicles in the residential sector.
Energy subsidies	- Analyze the subsidy system, its legal and economic considerations, and propose enhancements so that they do not modify price signals. - Reduce the State's contribution. - Propose enhancements of the FOSE scheme.	- Modify the regulations that support subsidies. - Implement new subsidy mechanisms.	- Focus subsidies on inhabitants with unfulfilled energy needs.	
Fuel prices	- Eliminate the liquid fuel price mitigation system to reinforce the vehicle reconversion process.	- Modify the regulations by introducing a price mechanism that gradually reflects market prices. - Modify the regulations by introducing modifications in the subsidy system.	- Increasingly internalize remediation costs in fuel prices, either through taxes on emissions or emission trading certificates.	
Utility tariffs	- Propose the necessary regulations that permit decoupled tariffs to remunerate companies.	- Establish decoupled tariffs.	- Internalize investment in mitigation and adaptation in the tariffs.	
Regulations	- Strengthen fiscal and financial incentive policies that promote investment in renewable energy and energy efficiency. - Promote banking regulations that incentivize loans associated with energy transition (renewable sources and transition fuels).		- Promote regulations that favor electric, hybrid, or natural gas-based vehicles in order to incentivize the replacement of highly polluting units. - Within the fiscal incentives, carbon taxes should relate to remediation and adaptation costs. - Develop regulations to foster policies related to hydrogen and CCUS in order to reduce uncertainty in these businesses.	- Within the fiscal incentives, carbon taxes should have prohibitive effects so that they incentivize the scrappage and replacement of this equipment.
Socio-environmental aspects for project development			- Propose socio-environmental agreement schemes to make the development of hydrogen and CCUS projects viable.	
Transition fuels	- Allow banking regulations to finance the gas sector.	- Maintain investment in the gas sector and promote LNG and CNG in transportation as a mechanism to ensure the phase-out of part of the hydrocarbon value chain in the last stage.		

Policy	Between 2024 and 2025	Between 2026 and 2030	Between 2031 and 2040	As from 2040
Reconversions	- Promote the reconversion of freight transportation fleets to electric trains and vehicles running on LNG and CNG.	- Start studies on the impact on communities related to extractive industries. - Develop strategic plans to reconvert regional economies associated with extractive industries to ensure the JET.	- Implement strategic plans to reconvert regional economies associated with extractive industries to ensure the JET.	- Establish strategies to mitigate the impact of the JET on the sectors that could not achieve their reconversion.
Phase-out of fuel oil-fired plants		- Establish regulations to phase out coal and fuel oil-fired plants that remain operational.		
Development of smart grids (AMI)	- Analyze the mechanisms to integrate smart grids and international financing to allow for a better administration of the system as a whole.	- Introduce smart metering.		
Integration of renewable energy and storage systems	- Develop detailed certification, operation, and remuneration rules for storage services.	- Include storage systems in the planning to expand generation, transmission, and distribution in the sector in order to integrate large amounts of renewable energy.		
Operation of the transmission and distribution grids in a coordinated manner		- Develop integrated operation mechanisms between distributors and transporters.		
Development of secondary electricity markets		- Deregulate commercial and residential commercialization to introduce consumer decisions based not only on prices but also on the type of energy produced. - Introduce derivative markets for all energy segments.		

Works cited

Engrinter, Mercados Energéticos Consultores, Datum. (2016). *Balance Nacional de Energía Útil.*

EUROSTAT. (2021). Obtained from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households

IEA. (2021). *Net Zero by 2050, A Roadmap for the Global Energy Sector.*

IEA. (2022). *Energy Efficiency 2022.*

International Transport Forum, IDB. (2022). Obtained from https://publications.iadb.org/publications/english/viewer/Decarbonising-Transport-in-Latin-American-Cities-Assessing-Scenarios.pdf

Jairo Quirós-Tortós, et al. (2021). *Costos y beneficios de la carbono neutralidad en Perú.* Washington D. C.: BID.

Law, H. &. (2015). *The motorcycle to passenger car ownership ratio and economic growth: A cross-country analysis.*

MINAM. (2023). *Estrategia Nacional de Cambio Climatico 2050*. Obtenido de www.gob.pe: https://www.gob.pe/institucion/minam/campa%C3%B1as/3453-estrategia-nacional-ante-el-cambio-climatico-al-2050

MINEM. (2020). *Plan Nacional de Electrificación Rural.* Lima: MINEM.

DEVELOPMENT BANK
OF LATIN AMERICA
AND THE CARIBBEAN