EU-LAC Foundation, Consejo Latinoamericano de Ciencias Sociales (CLACSO)

Spotlight on inequality: Is energy a manifestation of inequality between and within Latin America and Europe?

Autors:
María María Ibáñez Martin
Federico Nastasi
Yormy Eliana Melo Poveda

EU-LAC Foundation
Fundación EU-LAC

CLACSO
Consejo Latinoamericano de Ciencias Sociales

EU-LAC Foundation, Consejo Latinoamericano de Ciencias Sociales (CLACSO)

Spotlight on inequality: Is energy a manifestation of inequality between and within Latin America and Europe?

Authors:
María María Ibáñez Martin, Universidad Nacional del Sur e Instituto de Investigaciones Económicas y Sociales del Sur (CONICET) – Argentina

Federico Nastasi, Centro Studi di Politica Internazionale – Italia

Yormy Eliana Melo Poveda, Grupo de Energía y Regulación (GENER) de la Universidad Federal Fluminense – Brasil

EU-LAC Foundation
Fundación EU-LAC

CLACSO
Consejo Latinoamericano de Ciencias Sociales

EU-LAC FOUNDATION, 2025
ABC-Straße 2
20354 Hamburg
Germany
eulacfoundation.org

PUBLISHED BY:
EU-LAC Foundation
GRAPHIC DESIGN: Carlos Gómez
ISBN: 978-3-949142-42-0
DOI: 10.12858/0625en

This edition was produced by the EU-LAC Foundation. The organisation is funded by its members and, particularly for this initiative, by the European Union and the Federal Republic of Germany. The concepts expressed in the presentations compiled in this edition are solely the responsibility of the authors and cannot be considered as the viewpoint of the EU-LAC Foundation, its Member States, or the European Union.

Federal Foreign Office

Acknowledgements and presentation of research proyect

This study is a hybrid between a public policy report and an academic article. This crossover nature responds to its origin: it was born in the framework of the EU-LAC Foundation and CLACSO's call for a comparative study on inequality between Europe and Latin America and the Caribbean, with the aim of generating results applicable to policy practice. The authors, researchers from the academic world, used their toolbox of scientific research, while at the same time seeking to use language accessible to a wider audience than the strictly academic. The text therefore deliberately straddles the boundary between broad accessibility and methodological rigour.

The authors would like to express their sincere thanks to the EU-LAC Foundation and CLACSO for the institutional support and resources provided for this study. They are also grateful for the valuable opportunity to develop a research project that has brought together the three authors, from three different countries and two different regions, in a collaborative experience that has been both professionally and personally enriching. This is an example of the relevance of continuing inter-regional cooperation mechanisms between international organisations, public and private institutions and the academic sector that promote joint exercises to develop new capacities and exchange knowledge. We would like to give special thanks to Anna Barrera, María Josefina Torres Jiménez and Teresa Arteaga for their constant support and valuable contributions during the process of elaborating this research.

Our thanks are also extended to those who participated in the webinar on 28 March 2025: Valentina Leiva, Sofia-Natalia Boemi, Marina Gil, Irene González Pijuan, Cecilia Fernández, Federico Dubois, Carina Guzowski, Angela Livino, Willington Ortiz, Luis Ordóñez, Carolin Oppenrieder, Giorgos Koukoufikis, Nora Estela Fernandez Mora, Oscar Ugarteche, Esteban Serrani, Anahí Urquiza, Irene Miguelsanz Villanueva and Viktoria Noka. Their comments and criticisms have been instrumental in shaping the final form of this research.

The authors assume full responsibility for any errors or omissions that may be found in this work.

Finally, it is worth noting that this research identified the need for future analyses for the implementation of public policies in Latin America and the Caribbean and in Europe so that each State has a diagnosis of the problem as a basis and can focus its interventions on the most affected groups and implement them more efficiently, considering the causes and socio-economic characteristics that determine energy inequality. Given that on this occasion the object of study was limited to two countries in LAC and two in Europe, it is considered relevant to carry out similar studies involving other countries that were affected by the global macro-events of the 2020-2022 triennium in these two regions.

INDEX

Executive summary

Between 2020 and 2022, an unprecedented global energy crisis exposed and deepened existing inequalities in energy access and use. This study analyses how energy inequality, understood as a set of energy deprivations of varying severity, manifests itself in Latin America and Europe, comparing cases from Germany, Argentina, Colombia and Spain, with a quantitative and econometric approach focusing on households. It adopts a perspective that understands energy as a social right essential to well-being, and not just as an economic input.

Relevance

Households do not demand energy per se, but energy services that influence well-being, as energy permeates every daily action of contemporary life. Energy inequality is not limited to physical access to energy, but encompasses the quality, affordability and quantity needed to meet energy services. In contexts marked by economic, climatic and geopolitical crises, energy gaps aggravate social exclusion and limit individual and collective capacities.

Main results of the study

- Energy inequality is a significant phenomenon in both Europe and Latin America, although its forms of manifestation differ substantially between the two regions. On the one hand, in Argentina and Colombia more than 50% of households suffer from at least one energy deprivation (54% and 51% respectively), while in Germany and Spain the number of households affected does not exceed 40%. On the other hand, in the two European countries analysed, more households live with the juxtaposition of the three deprivations (close to 4% of households in both countries, compared to 1.35% in Colombia and 2.51% in Argentina).

- The causes of energy inequality vary both between and within regions, and also depend on the type of deprivation considered. Energy indigence shows considerable variability between countries, reflecting the interaction between national structural factors, energy policies and local socio-economic conditions. In terms of energy poverty, Europe has higher levels than Latin America, a difference attributable to the high cost of energy, dependence on energy imports and the reduction of subsidies in several European countries. In contrast, energy vulnerability is more acute in Latin America, which is consistent with the deeper levels of structural poverty and social exclusion in the region. A common element between the two regions is the high incidence of energy vulnerability as an isolated deprivation, i.e. not necessarily combined with energy poverty or destitution.

- In Latin America, Argentina shows greater severity in its indicators, with patterns similar to those observed in the Colombian Caribbean, suggesting the existence of common territorial and socio-economic factors in contexts of high vulnerability.

- In Europe, energy poverty - the only dimension measured homogeneously in Spain and Germany - affects Spain to a larger extent, which is related to structural conditions that hinder equitable access to energy services in lower-income contexts.

- Individual factors affecting energy inequality include household size, education level, employment status of the head of household and housing conditions, all with statistically significant effects. Gender also plays an important role, with a trend towards feminisation of energy poverty, observed both in the leadership of deprived households and in unequal participation in the household dynamics of energy access and use.

- Likewise, in the countries where it was possible to measure - Spain and Colombia - it was found that ethnic or racial origin significantly influences the risk of energy inequality, evidencing its structural and intersectional dimension.

- There are social inequalities that promote energy inequality, but they are not necessarily overlapping phenomena.

- Energy inequality, more specifically energy poverty, is not necessarily a mirror image of income poverty. A non-negligible proportion of households - 50% in Colombia - are affected by energy poverty without being exposed to significant material and monetary deprivation. This finding reinforces the complexity of the phenomenon and the need for differentiated approaches that consider national specificities and the multiple dimensions of energy inequality.

- Measuring energy inequality with a focus on traditional monetary poverty indicators, such as the 10% of income threshold, can hide phenomena behind energy poverty - i.e. households that do not exceed conventional thresholds but suffer real energy deprivation due to low levels of forced or limited consumption.

Key public policy implications

- **Recognise energy inequality as a multidimensional phenomenon:** policies must move beyond a narrow focus on energy poverty based on wasteful spending, and incorporate other forms of energy deprivation and exclusion.

- **Develop and incorporate official statistics on energy inequality:** there is an urgent need to incorporate multidimensional indicators into official statistics to guide fairer interventions.

- **Remove the policy focus away from the energy poverty and overspending dimension:** energy deprivation is of varying intensity and the conditions that promote it are different. Alleviating energy deprivation requires a multi-scalar and multi-dimensional approach.

- **Incorporate an intersectional approach in energy planning:** gender, age, education, and ethnicity must be explicitly integrated into energy policy design.

- **Design policies that are sensitive to the territorial and socio-economic context:** there are no universal solutions. Responses must be tailored to national and local realities. This is even more relevant in less developed economies, where the import of measures from developed contexts has proven in other contexts to be the initial seed of policy failure.

- **Focus energy subsidies on a broad perspective:** reformulate the segmentation of energy subsidies according to the type and level of energy deprivation, and not just the economic level of households. In this respect, it is important that the criteria are tested, easy to apply and monitor, and relevant to the national context. These aspects reduce exclusion and inclusion errors.

- **Expand access to basic infrastructure:** In Latin America, policies should prioritise the extension of electricity and gas networks, particularly in rural or marginal areas, and encourage the financing of housing improvements and access to equipment.

- **Territorialise policies:** in both Europe and Latin America, energy inequalities have strong territorial roots. The inclusion of geographical criteria can improve the targeting and effectiveness of public policies.

- **Promote bilateral and multilateral cooperation initiatives** with the aim of disseminating good practices, tools and knowledge in support of national government initiatives to address energy inequality.

Conclusion

Energy inequality is a manifestation of structural gaps in our societies. Implementing policies to reduce energy inequality requires a comprehensive approach that combines three elements: intensity (adapting to different types of deprivation), territorial approach (given contextual differences) and targeting (targeting particularly vulnerable social groups). While there are clear interrelationships between income poverty and energy inequality, they are not fully overlapping phenomena. If public policies - short, medium and long term - are not adopted with an intersectional, territorial and multidimensional approach, the energy transition risks deepening exclusion. This study offers tools to design fairer and more effective policies that integrate energy, equity and social rights.

List of figures and tables

Figures

Tables

Glossary of acronyms

IEA International Energy Agency
LAC Latin America and the Caribbean
IDB Inter-American Development Bank
BMBF Federal Ministry of Education and Research of Germany
BMEL Federal Ministry of Food and Agriculture of Germany
BMF Federal Ministry of Finance of Germany
BMU Federal Ministry for Environment, Nature Conservation and Nuclear Safety of Germany
BMVI Federal Ministry of Transport and Digital Infrastructure of Germany
BMWi Federal Ministry for Economic Affairs and Energy of Germany
CAMMESA Compañía Administradora del Mercado Mayorista Eléctrico de Argentina (Argentinean Wholesale Electricity Market Administrator)
Cammesa Compañía Administradora del Mercado Mayorista Eléctrico S.A.
ECLAC Economic Commission for Latin America and the Caribbean
CNEA Comisión Nacional de Energía Atómica de Argentina (National Atomic Energy Commission of Argentina)
CNO Colombian National Operating Council
CREG Comisión Reguladora de Energía y Gas de Colombia (Colombian Energy and Gas Regulatory Commission)

DANE National Administrative Department of Statistics
DIW German Institute for Economic Research
ECOICOP European Classification of Individual Consumption by Purpose
LCS Quality of Life Survey
USA United States
ENARGAS Ente Nacional Regulador del Gas (National Gas Regulatory Entity) of Argentina
ENGHo National Household Expenditure Survey
ENRE Ente Nacional Regulador de la Electricidad de Argentina (National Electricity Regulatory Entity of Argentina)
ENUT National Time Use Survey
HBS Household Budget Survey
EPH Permanent Household Survey
EPOV European Observatory on Energy Poverty
LPG Liquefied Petroleum Gas
IMPE multidimensional energy poverty index
INDEC National Institute of Censuses and Statistics of Spain
CPI Consumer Price Index
IPSE Instituto de Planeación y Promoción de Soluciones Energéticas para Zonas No Interconectadas de Colombia (Institute for Planning and Promotion of Energy Solutions for Non-Interconnected Areas of Colombia)
MEM Wholesale Electricity Market in Argentina
MINENERGY Ministry of Mines and Energy of Colombia
MMUVRA Urban Master Housing Sample of Argentina
OECD Organisation for Economic Co-operation and Development
OLADE Latin American Energy Organisation
WHO World Health Organisation
TES Total Energy Supply
GDP Gross Domestic Product
UNDP United Nations Development Programme
SOEP German Socio-Economic Panel
SSPD Superintendencia de Servicios Públicos Domiciliarios de Colombia (Superintendency of Public Utilities of Colombia)
EU European Union
UPME Colombian Mining and Energy Planning Unit
XM Market Operator of Colombia
YPF Yacimientos Petrolíferos Fiscales of Argentina

1. INTRODUCTION

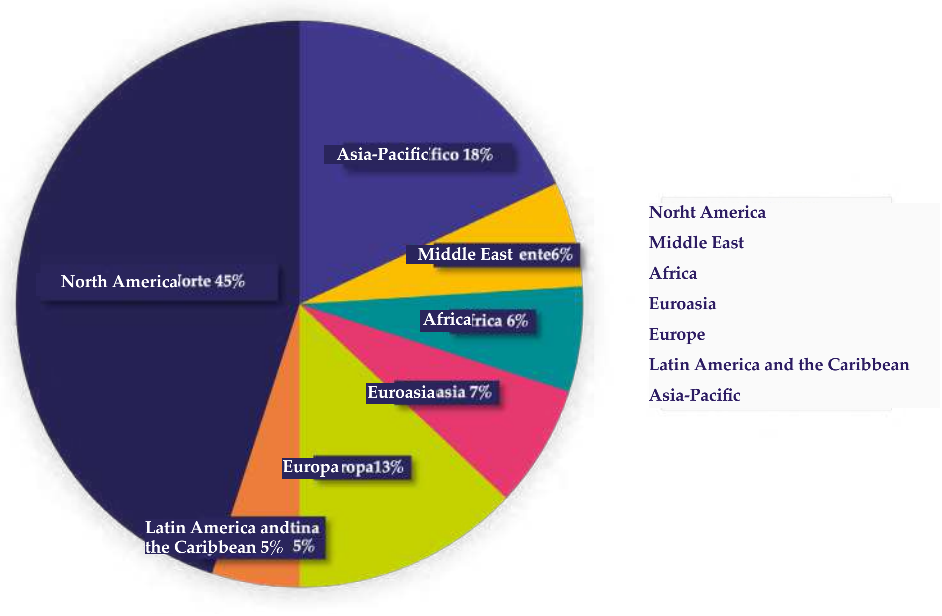
2020-2022: the terrible energy triennium

Between 2020 and 2022, the world went through an energy crisis characterised by an increase in energy prices, in a context of a generalised rise in the prices of goods and services. Millions of households had difficulty accessing lighting, heating, food refrigeration, and energy to ensure a decent standard of living and health (Carfora et al., 2022).

The three-year period saw the COVID-19 outbreak (2020), a brief period of post-pandemic recovery during the second half of 2021, interrupted by Russia's invasion of Ukraine in February 2022 (Burguillo et al. 2025). The period was characterised by geopolitical tensions, such as the oil price war between Saudi Arabia and Russia, the blockade of Chinese imports of Australian coal and Western sanctions on the Russian energy sector. The energy crisis in some countries was aggravated by the consequences of climate change, such as droughts that have undermined hydropower production in Brazil, China and the United States (US), and energy production processes in Europe.

The crisis has hit the global energy market, whose main suppliers are China (25% of supply), followed by the US (15%), India (7%), and Russia (6%). At the regional level, in 2022, the Asia-Pacific region led the global primary energy supply (Figure 1) with 45% of the total, followed by North America with 18%, and Europe with 13% of the total. Latin America and the Caribbean made the smallest contribution in terms of primary energy supply.

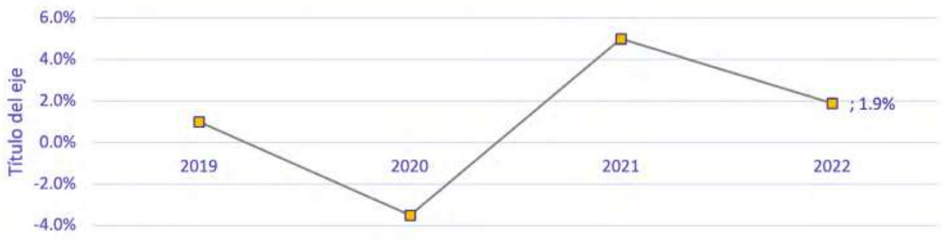
Figure 1. Total primary energy supply by region, in percentages of exajoules 2022.



Source: Prepared by author based on IEA (2023a)

In the harshest phase of the pandemic, in 2020, with restrictions imposed by governments to deal with COVID-19, with millions of people confined to their homes, with economic activities halted or severely affected, and with global supply chains disrupted, global energy demand was reduced by 4% between 2019 and 2020, as shown in Figure 2. In 2020, global oil demand plummeted by almost 9% compared to 2019, crude oil prices fell by around 30%. For the first time in history, crude oil in the US reached negative prices (30 April 2020).

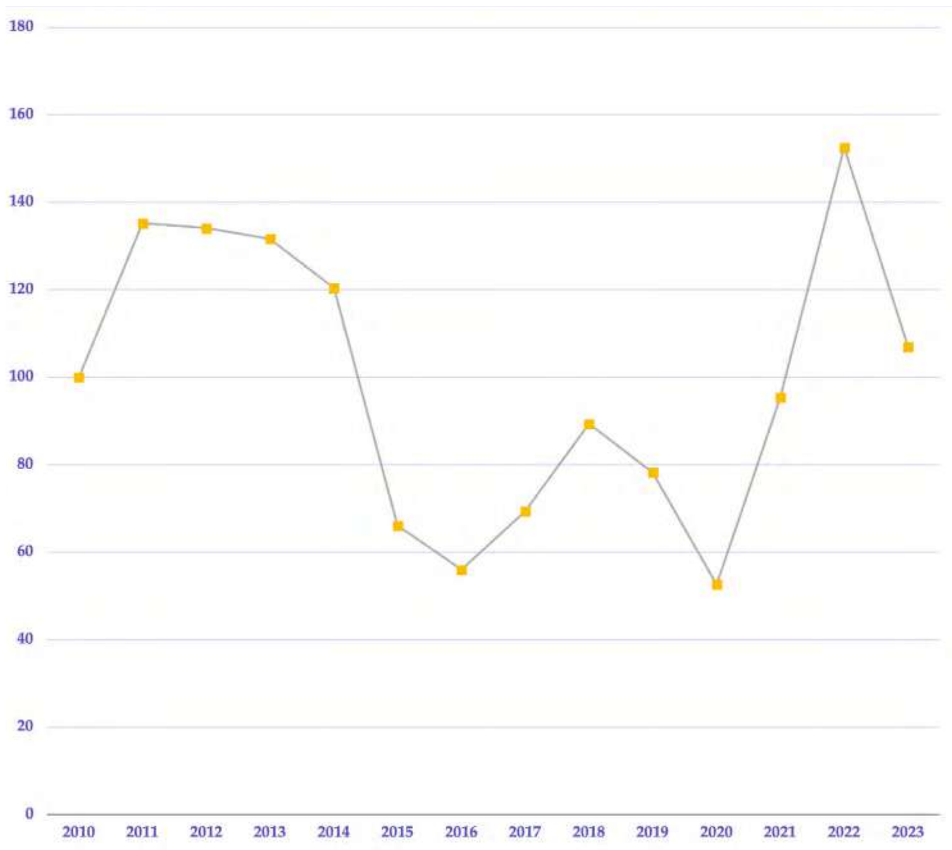
Figure 2. Year-on-year change in primary energy consumption, substitution method



Source: Prepared by the authors based on data from the Energy Institute (2024)

By 2021, as containment restrictions eased worldwide and vaccination programmes unfolded their effects, energy demand increased above pre-pandemic levels. The increase in demand was met by an unusually low supply that was barely covered by available resources, constrained by the legacy of limited investment in the oil and gas sector and unfavourable weather conditions. Energy prices increased to unprecedented levels in the course of 2021, before rising further in 2022, as shown in Figure 3. Russia's invasion of Ukraine and the ensuing sanctions adopted by Western governments in an attempt to hinder Moscow's energy exports aggravated the energy crisis (Sun et al. 2024), with an increase in energy prices not seen since the 1970s, according to the Organisation for Economic Co-operation and Development (OECD). Between 2020 and 2022, gas prices in the US more than doubled while in Europe they increased tenfold.

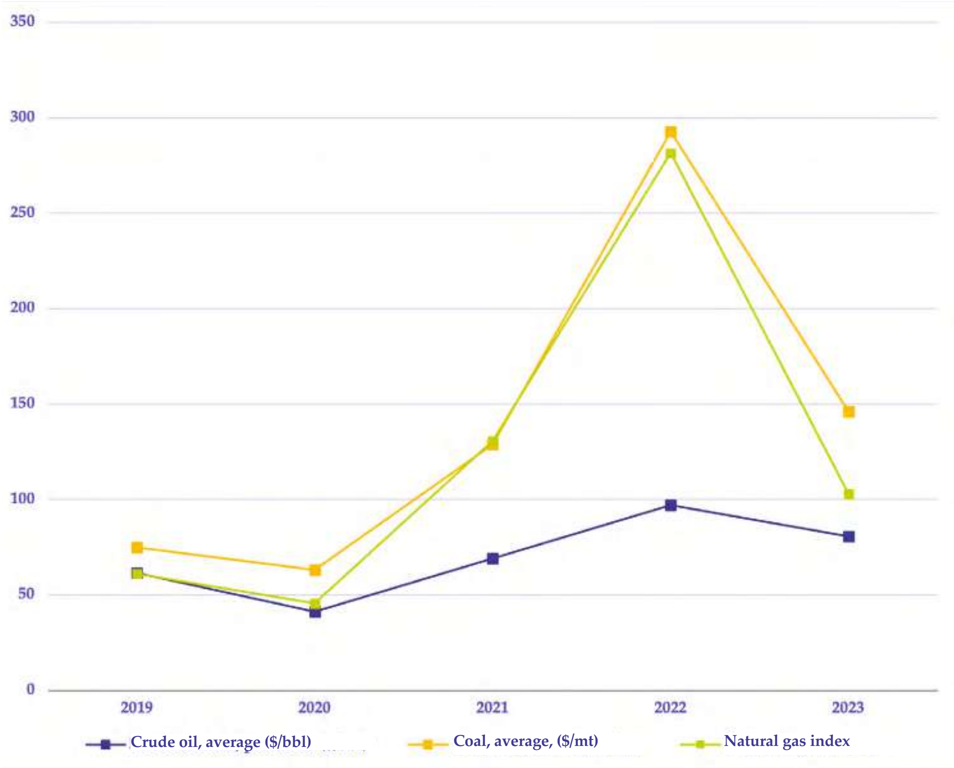
Figure 3. Energy price index, 2010-2023



Source: drawn up by the authors based on World Bank data (2025).
annual indices, 2010=100, 1960 to date, real 2010 US dollars

This upward trajectory, especially of oil, coal, and natural gas prices, as shown in Figure 4, has exerted significant inflationary pressures on countries around the world and has significantly affected global energy trade. On the eve of the invasion of Ukraine, Russia was by far the world's largest exporter of oil and natural gas to global markets (IEA, 2023). Europe, which bought around 50 per cent of Russia's oil exports and more than 60 per cent of its gas exports, was one of the hardest hit energy markets.

Figure 4. World crude oil, coal, and natural gas prices, 2015-2023



Source: Prepared by the authors based on data from the World Bank (2025).
annual indices, 2010=100, 1960 to date, real 2010 US dollars

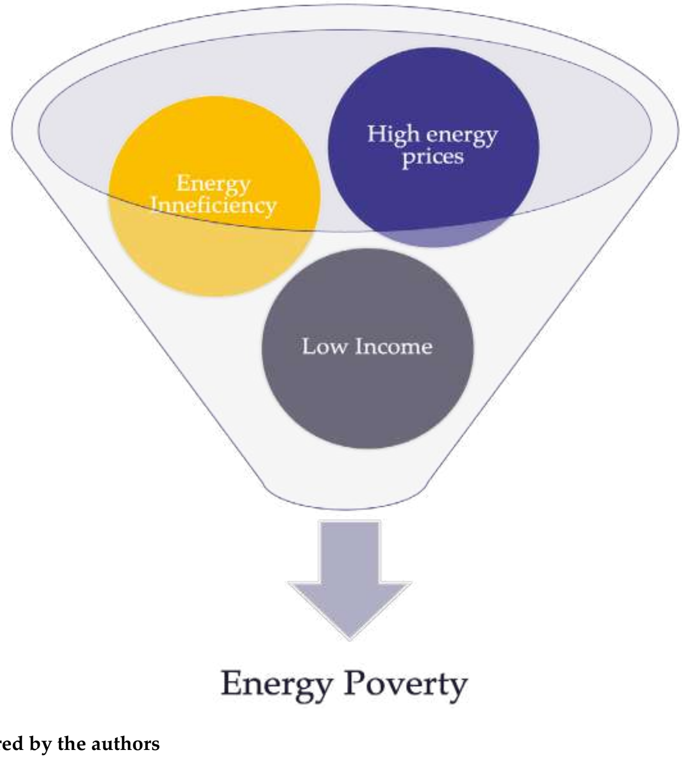
In the Latin American and Caribbean (LAC) energy market, the effects of the Russian invasion were indirect, although the conflict contributed to higher prices and disruptions in energy supply chains in the region. Higher energy prices benefited net energy-exporting countries — such as the Andean countries — andhurt the incomes of some energy importers, in particular, Central American and Caribbean countries (UNDP, 2022).

The social effects of the terrible triennium

The central question of the present study[1] can be summarised as follows: Is energy a dimension of new inequalities? In response, a micro-perspective analysis is carried out on how access to energy services can be a new form of manifestation of inequality in households in two European and two Latin American countries: Germany, Argentina, Colombia, and Spain.

Despite the household approach, it is inevitable to analyse how the macro-events of the 2020-2022 triennium, interacting with the three main elements of energy poverty — low-income, high-energy prices and energy inefficiency (Figure 5) — carved the inequality crack around the satisfaction of energy services.

Figure 5. Three main elements of energy poverty

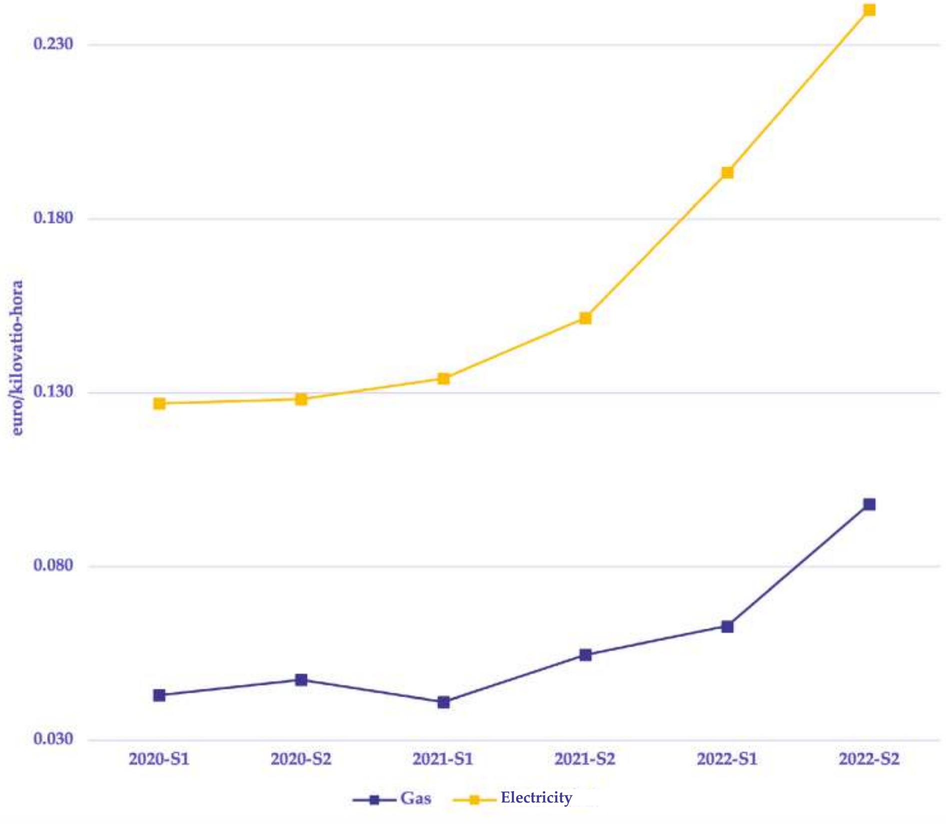


Source: Prepared by the authors

1 This study is a hybrid between a public policy report and an academic article. This cross-cutting nature responds to its origin: it was born in the framework of the EU-LAC Foundation and CLACSO's call for a comparative study on inequality between Europe and Latin America and the Caribbean, with the aim of generating results applicable to political practice. The authors, researchers from academia, used their toolbox of scientific research, while trying to use language accessible to a wider audience than the strictly academic one. Thus, the text deliberately treads a borderline between broad accessibility and methodological rigour.

In particular, the COVID-19 pandemic generated new energy inequalities, mostly affecting oil- and gas-dependent countries (such as some in Latin America and the Caribbean) and those less developed (Escribano and Lazaro, 2020), but it also led to an increase in electricity consumption and a change in household consumption habits (Aguirre Padilla, Alvarado Espejo and Ponce, 2023). Due to recommendations to spend more time indoors, demand for residential energy consumption increased, in a context of job losses and rising costs of energy services, as shown in Figures 4, 6, and 7[2].

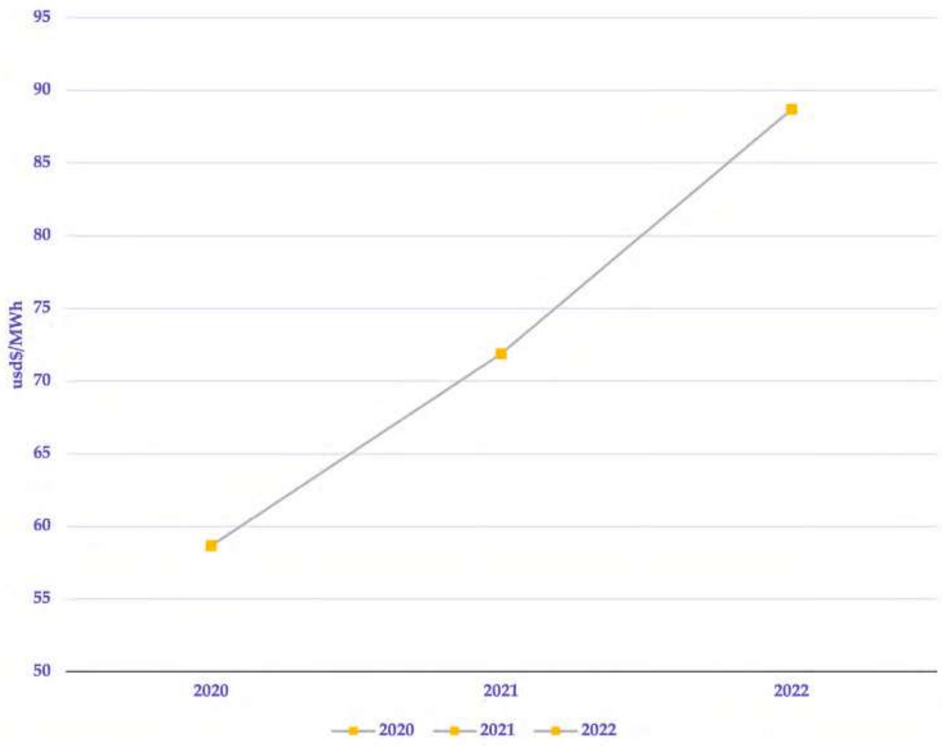
Figure 6. Electricity and gas prices for EU household consumers, half-yearly data 2020-2022



Source: Prepared by the authors with Eurostat data

2 It was not possible to find a homogeneous series of energy commodity prices for the LAC region and Colombia for the 2020-2022 period.

Figure 7. Energy prices in Argentina, 2020-2022, total monomics[3]



Source: Prepared by the authors with CAMMESA data

In that period, new forms of energy inequality emerged, for example, between those who could or could not charge technological devices to continue with work or school or to stay connected to friends and family, and thus avoid social exclusion. Another form of inequality was evident in the physical quality of households, between those living in energy-efficient homes and those who did not live in such conditions (Bahmanyar et al. 2020; Bienvenido-Huertas, 2021).

The traditional rural-urban divide, in the pandemic era, was compounded by another difference related to access to energy services. In terms of access to energy during confinement, there is little comparison possible between the experiences of, say, Colombian Caribbean villages or Bogotá.

3 Total monomics: Weighted average price (in relation to prices and monthly demand) of energy per MWh demanded (monomic). The monthly prices are obtained from the different charges payable for energy, power, transport and services related to the activity of energy generation and transport.

The *terrible triennium* has marked changes not only in the poorest corners of the world, but also in prosperous Europe. Even in its most affluent regions: in the winter of 2022, Germany saw an increase in the practice of cutting down trees to procure firewood for energy use, as an alternative to buying firewood whose prices were rising[4].

In LAC, 58 million families use firewood for cooking, a polluting source of energy that generates deforestation, contributes to global warming, harms the health of those who use it, mainly women and children, and implies more work due to the time spent collecting and preparing food with this fuel.

In LAC, one of the most unequal regions in the world, with high levels of poverty and reduced capacity of the state to solve structural problems, access and/or capacity to consume energy deepened the fracture between social groups. In this region, energy poverty interacts with other deprivations that amplify its various impacts. For example, the poorest 20% spend significantly more on energy services than the richest 20%, yet only the richest fifth of the population achieves thermal comfort and coverage of their energy requirements (ECLAC, 2022). It was in this context that, in 2022, in countries such as Haiti, Peru, Panama and Ecuador, people protested against energy inflation. In June 2022, annual energy inflation in LAC was 18.4% (as compared to June 2021), a doubling of the general inflation statistic (OLADE, 2024). In the same year, in Europe, 41 million people (9.3% of the population) were unable to adequately heat their homes and 7% of the EU population were in arrears with their utility bills (European Union, 2023). In both regions, the consequences of climate change — such as increased extreme weather events and droughts — endangered energy security and particularly the supply of renewable energy.

Based on this evidence, the study seeks to understand how energy inequality manifests itself in Latin America and Europe, what differences exist between the two regions and who is most affected by it.

Energy, in the theoretical framework adopted in this study, is not simply a tradable production good, but it is considered a social good, as it enables the satisfaction of basic needs, increasing the level of well-being of the population, and it is essential for the processes of development and social inclusion (Guzowski, 2016). In addition, it is a critical input to any social economic system and central to sustainable development (UN-ENERGY, 2007). From this perspective, people do not demand energy per se, but energy services. Energy services are those functions performed using energy that are means to obtain or facilitate final services or desired states, such as heating, cooking, lighting, cooling, etc. (Day, Walker and Simcock, 2016; Fell 2017). Consequently, the degree of coverage, quality, and cost of energy services are ultimately determinants of human well-being.

4 Information retrieved from: https://www.srf.ch/play/tv/srf-news-videos/video/selber-holz-zu-faellen-boomt-in deutschland?urn=urn:srf:video:7e427a79-be61-4e8a-b812-8b106c55cfa3

Based on this concept, and within the framework of the *terrible energy triennium* 2020-2022, we will investigate the existence of patterns among the groups that are affected by energy inequality, understood as the set of energy deprivations of different intensity, and socio-economic characteristics that increase the probabilities of suffering from this situation.

2. THEORETICAL FRAMEWORK

2.1. Domestic energy services: responding to residential energy demand

Energy is not an end in itself but an instrumental and social good, serving human needs that vary in time and territory (Bouzarovski and Petrova, 2015a). These needs are conditioned by the social practices in which energy use occurs (Bouzarovski, 2018) and include elements that allow for a minimum standard of living that reflects contemporary norms (Walker, et al., 2016). However, energy use practices change over time: one can think of the growing demand for the use of information technologies, such as artificial intelligence, among other requirements that were unthinkable decades ago.

Energy services are the response to energy demands, or needs. Final energy demand in the residential sector is reflected in five types of energy services (Sovacool, 2011):

I. services for thermal comfort, space heating or cooling
II. hot water services
III. services to cook food
IV. lighting services
V. services provided by household appliances (including entertainment/educational services, communication services, food refrigeration services, and laundry services, among others).

Table 1 contains the most relevant types of household energy services, their definition and manifestation of energy deprivation according to geographical location. Failure to meet these energy demands implies the deprivation of one or more of the energy services in a household, and results in what is known as energy deprivation or lack.

Table 1. Definition of residential energy services

Residential energy service	Definition	Relevance or manifestation of the deprivation of service
Lighting	Service that allows the illumination of internal spaces	On the one hand, service deprivation is related to the absence of infrastructure, particularly in Africa, some Asian countries, and other developing countries. On the other hand, it is related to households' ability to pay, which is the case in European and Latin American countries.

Cooking	Service that provides heat for the stove and allows food to be cooked.	Energy deprivation in this service occurs when families depend on unclean fuels (firewood or charcoal), which pollute the internal and external environments of the residence. It is prevalent in developing countries in Asia and sub-Saharan Africa regions (IEA, 2017). In some Latin American countries, wood or charcoal is also used and combined with modern fuels, as a way to support energy expenditure (Heltberg, 2004).
Space cooling	This is a service that allows the cooling of internal spaces for thermal comfort in the event of high temperatures.	The relevance of this service is associated with regions with very high temperatures or very hot summers. It is a poorly studied problem in developing countries. Urban areas are the most affected.
Space heating	It is a service that allows domestic heating until adequate temperatures are reached to achieve thermal comfort.	It occurs mainly in regions with low temperatures or in developed countries. It is also a problem for developing countries with very cold seasons.
Domestic water heating	This is a service that allows the heating of water for bathing.	It is one of the energy deprivations that occur in low- and medium-temperature countries.
Other services: Refrigeration, household appliances, information, and communication technologies.	These are services enabling the refrigeration and preservation of food, the use of information and communication technologies and, in general, of electronic devices.	Deprivation of these services can be found all over the world, but its determinants are diverse. The most influential are linked to economic, cultural, and social factors. The level of development of countries and technological dependence explain in many cases the deprivation in this type of services.

Source: Prepared by the authors based on Bouzarovski and Petrova, 2015a and Fell, 2017.

The demand for energy services varies between households, depending on the topographical, climatic, and social conditions in which they are located. For example, Colombia — with its great variety of climates due to its location in the intertropical zone and its topography — has territories that are permanently at a temperature of around 30°C — on the coasts and plains — and 0°C in the high mountains. In Argentina there are bioclimatic zones with considerable temperature differences: the average annual temperatures in the Argentinean Patagonia are 6.8°C, while in the northern provinces of the country they are around 25°C. This variety of climates in different geographical areas determines the energy needs and thus the demand for services for thermal comfort, space heating or cooling. The same is true, albeit to a lesser extent, for the European countries covered in this paper (as can be seen in the country descriptions section).

For the satisfaction of energy services, it is essential to analyse the source of energy used by households, the way in which they access it, the affordability, and the conditions of the household. Thus, the use of various energy sources depends on the socio-economic, territorial, climatic, and infrastructural characteristics of the dwelling, which influence the identification of energy needs, and the amount of energy required to satisfy them. In the different regions of the world, in addition to the above-mentioned factors, cultural aspects, energy geopolitics, government policy and energy market regulation are also determinants of household energy use and consumption (World Bank, 2003; Heltberg, 2004; Melo, 2022).

2.2. Energy inequality: a manifestation of deprivation of different intensity

2.2.1 Energy as a social right

Energy is a social good that satisfies basic needs, increases the level of well-being of the population, and it is essential for development and social inclusion processes (Ibáñez Martín et. al, 2022).

Access to energy is part of the social ingredients that guarantee individual freedom, human development, and full citizenship. According to the rights-based approach adopted in this study, equal and universal access to energy contributes to integral citizenship[4]. From this more systematic perspective, energy can be reconceptualised, leaving aside its productive and tradable character, as a basic good for full human development and as a strategic and geopolitical good, which affects the dependence of societies, environmental sustainability, and the quality of life of the global population (Arenas Pinilla et. al., 2019).

Thus, if one accepts the idea that every human being is entitled to a minimum of economic well-being and security, the existence of energy inequality is a threat to integral citizenship. Therefore, deprivations in the energy dimension are explanatory factors for situations of inequality, vulnerability, and exclusion (Ibáñez Martín, Guzowski and Maidana, 2019). In order to guarantee these minimum levels of social rights, several countries around the world have adopted public policies against energy poverty.

2.2.2 Inequality: Are there inequalities regarding energy?

What are we talking about when we mention inequality?

Inequality is not a new phenomenon but has been present since the origin of modern society. Despite its long existence, inequality does not have an unambiguous definition,

5 Citizenship is a status of belonging to a community that is granted to all its members and that enables equal rights and obligations for each of them. Unlike in the Middle Ages, these rights are provided on an egalitarian basis, and therefore not linked to social class. The consequence is that, amidst the class inequalities associated with capitalism, citizenship introduces a principle of equality, embodied in certain universal minimums that expand over time. These minimums are the constituent elements of citizenship: civil, political, and social components (Millán Valenzuela, 2023).

and there is still debate in various quarters about its meaning, scope, and consequences. In the academic environment, Sen's (1979) work, in which he asks the question "Equality in what?, is considered a pioneer precedent in the topic.

Inequality arises from an asymmetrical distribution of resources, opportunities, and power among different groups within a society. There is inequality in terms of income, education, access to basic services, health, and political participation. And inequality is also generated by individual capabilities to achieve a decent standard of living (Sen, 1992). From this perspective, structural inequalities limit people's fundamental freedoms, perpetuating cycles of poverty and social exclusion. Wilkinson and Pickett (2009) note that societies with higher levels of inequality tend to experience worse outcomes in terms of collective well-being, including higher rates of crime, mental health problems, and lower social cohesion. Inequality therefore affects not only individuals, but also economic development and the stability of social institutions, making it a central challenge for states.

Taking a multidimensional view, inequality can be classified as either vertical or horizontal. The first is generated by unequal access to tangible and intangible resources by people, regardless of where they live or the social group to which they belong. In contrast, horizontal inequality is a consequence of race, gender, age, origin, and other factors. Both dimensions often reinforce each other and can perpetuate and recreate vicious cycles of social disadvantage (OAS, 2014).

The dimensions in which inequality materialises are multiple and changing, depending on space and time, although historical, economic, and cultural factors contribute to the perpetuation of social inequality (Reygadas, 2008). Some dimensions, which could be called classic, find consensus in the various studies that address the issue, such as education, income, and work. In turn, depending on the approach, a series of aspects are added that consider infrastructure, access to information technologies, territoriality, the environment, energy, transport, crime, insecurity, among others.

What role does energy play in the phenomenon of inequality?

Because of the central role of energy in human life and in determining the level of well-being, energy deficiencies are a manifestation of **energy inequality**. This phenomenon refers to disparities in energy use and can be measured within a country and/or region or between groups of countries/regions (Dubois and Meier, 2016; Bianco, Proskuryakova and Starodubtseva, 2021).

Energy inequality can be understood as the inequitable distribution of benefits and burdens associated with energy systems, ranging from access to resources to exposure to the negative impacts of their exploitation (Heffron and McCauley, 2017). This perspective underlines the need for a more inclusive and equitable approach to energy transitions.

A key aspect of energy inequality is that it is not only limited to access, but also includes factors such as affordability, quality of supply, and sustainability of energy resources [2].[6] It is considered a social pathology, as it perpetuates socio-economic vulnerability, particularly in developing countries and among marginalised communities (Sovacool et al. 2014). These communities often rely on less efficient and more polluting energy sources, which not only limits their development, but also exacerbates public health, and environmental problems. Energy inequality thus amplifies other forms of social inequality, creating a vicious circle that is difficult to break.

Energy inequality thus encompasses two central aspects: energy deprivation and the unequal distribution of energy as a social good. In addition, it is a multidimensional phenomenon, which encompasses but goes beyond the lack of access to clean energy sources.

A recurring question in the debate on energy inequality is whether it is really distinct from the concept of energy poverty. The latter has gained prominence in both academic research and the policy arena, and it is defined as the situation where households are unable to meet their basic energy needs to achieve decent living conditions (Bouzarovski & Petrova, 2015). It is precisely this definition that marks the starting point for establishing the difference with energy inequality. While energy poverty focuses on absolute deprivation, it tends to make invisible the relative inequalities in energy access and use between different social groups, territories, and types of households.

In this context, authors such as Middlemiss et al. (2019) and Simcock et al. (2021) propose adopting a perspective that considers energy inequality, understood not only as extreme deprivation, but also as systematic differences in access, use, quality, and affordability of energy services according to social, economic, territorial and cultural factors. This notion makes it possible to address how, even in scenarios where energy poverty has been reduced, inequalities in energy-related living conditions persist and are reproduced, affecting dimensions such as health, well-being, educational performance or the environmental quality of housing (Walker et al., 2016).

Working specifically on energy inequality is fundamental, as it allows us to identify gradients and patterns of distribution of energy resources beyond the deprivation threshold, highlighting the unequal position occupied by certain groups or territories within the socio-energy structure (Bouzarovski, 2018). Furthermore, this approach facilitates the analysis of the distributional — progressive or regressive — effects of energy policies, showing how they impact in a differentiated manner according to the socio-economic and territorial position of households (Simcock et al., 2021).

Incorporating energy inequality as an analytical category therefore broadens the diagnosis of energy inequities, overcomes binary approaches of inclusion/exclusion and supports the design of more equitable and contextualised interventions.

---

5 According to the International Energy Agency, energy resources are sources of energy available in nature that can be converted into useful energy to meet human needs.

Energy deprivation and its manifestations

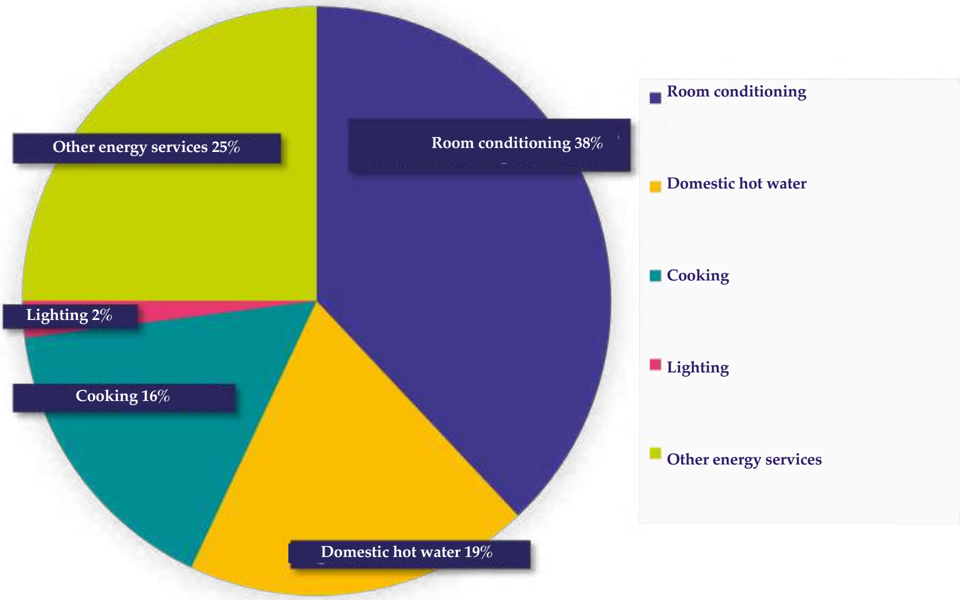
Energy deprivation can be typified by its intensity and the dimensions it affects. The different types of deprivation are components of the energy inequality phenomenon (Figure 8). In the framework of this work, manifestations of energy deprivation are considered (in increasing order of severity): vulnerability, poverty and indigence.

Figure 8. Different manifestations of energy deprivation: components of energy inequality

Source: Prepared by the authors

The different energy deprivations represent how households meet essential energy services. According to the Energy Efficiency Programme funded by the European Union and Fundación Bariloche (Fundación Bariloche, 2021), the main residential consumptions are those associated with thermal conditioning (heating and air conditioning), domestic hot water, cooking, and lighting (Figure 9).

Figure 9. Relevance of energy services in residential consumption



Source: Prepared by the authors based on Secretaría de Energía de Argentina (2020) and Energy Efficiency Programme financed by the European Union

Energy indigence, also known as **extreme energy poverty**, refers to the inability of households to access minimum energy services to meet basic needs, such as lighting, cooking or heating, obtaining domestic hot water (Bouzarovski & Petrova, 2015b). Mostly, it is associated with the lack of access to clean sources of energy to satisfy these needs. In this sense, this problem can be understood as a one-dimensional phenomenon that refers to the source that households use to satisfy the basic energy services of cooking, heating, and domestic hot water.

Energy indigence is particularly relevant in developing countries, where the combination of low incomes, poor infrastructure, and inefficient energy systems severely restricts access to modern and affordable energy sources (Sovacool, 2012). In these regions, millions of people rely on traditional energy sources, such as biomass, which are inefficient and pose significant health risks due to indoor air pollution. This pathology is not only a reflection of material poverty, but also of structural inequalities in global energy systems. According to Pachauri et al. (2013), more than 80% of people without access to electricity live in rural areas of Asia and sub-Saharan Africa, regions marked by high levels of widespread poverty.

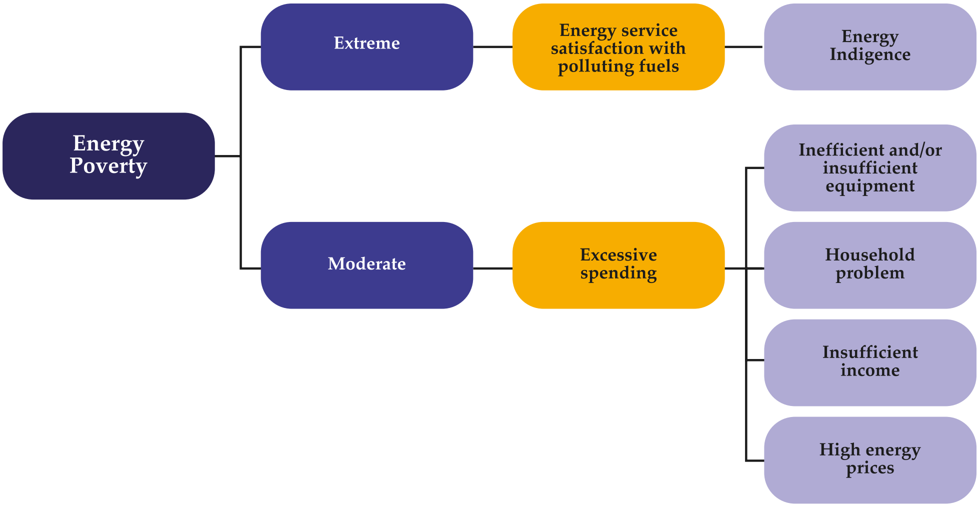
In Latin America and the Caribbean, energy indigence represents a persistent challenge, particularly in rural areas and in poverty belts in urban areas (Tornarolli and Puig, 2023). Although the region has made significant progress in electrification over the last decades, important gaps in access and quality of energy services persist. According to the World Bank (2021), approximately 16 million people in LAC lack access to electricity, while millions more rely on traditional energy sources, such as firewood or charcoal, for cooking, with negative impacts on health and the environment. This phenomenon is especially prevalent in countries with high levels of social inequality, such as Guatemala, Honduras, and Haiti, where extreme energy poverty disproportionately affects women and indigenous communities (Alonso et al., 2020). Energy indigence in LAC is deeply influenced by economic and structural factors, including high energy costs, dependence on fossil fuels, and inequalities in the distribution of energy resources (Rojas et al., 2019; Ibáñez Martín, Zabaloy and Guzowski, 2022). These barriers limit sustainable development and amplify other forms of social exclusion.

Energy poverty encompasses households with inadequate levels of energy services, due to a combination of high energy expenditure, low income, inefficient buildings and appliances, and household-specific energy needs (European energy poverty Observatory, EPOV). It differs from energy indigence in its multidimensional character, going beyond the form of access or energy source used (Figure 8).

In other words, energy poverty can be caused by "dissatisfaction of energy services essential for human life, induced by a lack of access, quantity and quality not only of energy but also of equipment caused by various factors, for example socio-economic (insufficient income level, education, etc.), geographic (disconnection from the grid), building (type of construction, insulation in openings, etc.) and cultural factors (such as preferences for certain energy sources, etc.), which ultimately have an impact on the level of well-being of household members" (Ibáñez Martín, Zabaloy and Guzowski, 2019).

In Europe, the European Observatory on Energy Poverty (EPOV) underlines that energy poverty is closely linked to three main factors: low-income, high-energy prices, and inefficient housing. These three factors constitute the "energy poverty triangle", although they are not the only explanatory aspects of the phenomenon. As a result, millions of European households face difficulties in maintaining an adequate temperature in their homes, especially during the winter, which can lead to health problems such as respiratory and cardiovascular diseases (EPOV, n.d.). This phenomenon is exacerbated in regions with extreme climates and liberalised energy markets, where the most vulnerable households bear a disproportionate burden in terms of energy costs (Ibáñez Martín, 2020).

Figure 10. Relationship between energy poverty and energy indigence



Source: Prepared by the authors

In LAC, energy poverty assumes particular characteristics, due to structural inequalities and dependence on traditional energy sources, such as firewood and coal, especially in rural areas. Latin American energy poverty is not only reflected in the lack of access to electricity, but also in the use of inefficient technologies that affect health and the environment (Ibáñez Martín, 2020). In contrast to Europe, where energy poverty is more related to affordability and efficiency, in LAC the main challenge lies in ensuring universal access to modern and sustainable energy services (Lampis, et. al, 2023).

Energy poverty is part of the broader phenomenon of energy inequality, as both concepts describe dimensions of exclusion in access to energy. While the former usually focuses on people's inability to access basic energy services (Bouzarovski & Petrova, 2015), the latter covers a broader spectrum, including disparities in participation in and benefits from energy policies. For example, those in positions of power tend to benefit most from transitions to renewable energy sources, while the costs tend to fall on the most disadvantaged groups (Jenkins et al., 2016). Addressing energy inequality requires comprehensive policies that not only expand energy access in quantity and quality, but also ensure distributive justice and recognition of the needs of the most vulnerable groups.

However, a common questioning of the concept of energy poverty revolves around two central questions: Isn't energy poverty simply a manifestation of income poverty? Is there an overlap between financially poor households and those in energy poverty? The answer to both questions is undoubtedly negative. Although they are related phenomena, they are distinct and understanding this difference is essential for the design of more effective public policies. While monetary poverty refers to insufficient income to meet a basic set of needs, energy poverty refers specifically to a household's inability to access adequate energy services to ensure decent living conditions (Bouzarovski and Petrova, 2015).

Energy poverty is not merely a consequence of a lack of income. While there is a correlation, multiple studies point out that factors such as inefficient housing, high energy costs and the particular needs of certain groups — such as the elderly or those with health problems — also play a role (Thomson, Snell and Bouzarovski, 2017). Thus, even households that are not considered poor in monetary terms may experience energy poverty if, for example, they live in poorly insulated dwellings or face disproportionately high energy tariffs. Empirical evidence supports the idea that energy poverty is a multidimensional phenomenon that cannot be explained by income alone (Ibañez Martín, Zabaloy and Guzowski, 2019). According to Boardman (1991), a household can be considered in energy poverty if it has to spend more than 10% of its income on maintaining adequate heating, a threshold that can be exceeded either due to low-income, high-energy inefficiency or extreme weather conditions.

Working on the concept of energy poverty in a specific way is crucial in order to make visible structural problems that would be hidden in an analysis focused exclusively on monetary poverty. As Middlemiss and Gillard (2015) argue, tackling energy poverty involves not only raising incomes, but also improving the quality of the housing stock, reforming energy markets, and promoting sustainable consumption practices.

Finally, the phenomenon of **energy vulnerability** (the least severe manifestation) reaches those households that, although they do not suffer from the most severe energy deprivation, are exposed to the risk of suffering from it due to their environmental conditions, where territory plays a central role (Desvallées, 2021). This concept broadens the understanding of energy inequality, focusing on the conditions of those households that are on the edge of energy poverty and the factors that may increase the likelihood of crossing that edge and falling into energy poverty. The factors that place a household in a condition of energy vulnerability are structural, socio-economic — such as low income, housing inefficiency, and reliance on inadequate energy systems (Middlemiss & Gillard, 2015) — or energy risks, such as economic crises, fluctuations in energy prices, extreme weather events.

In Europe, energy vulnerability has been analysed mainly in the context of the liberalisation of energy markets, which has led to disparities in access to affordable tariffs and exposed poorer consumers to volatile prices (Thomson et al., 2017). In addition, the energy crisis of the terrible 2020-2022 triennium has shown how vulnerable households disproportionately bear the negative effects of these dynamics. Energy vulnerability for some European population groups is being characterised as a persistent condition, usually lasting several years, indicative of a chronic inability to meet basic energy needs, rather than a transitory difficulty (Ozdemir, E. and Koukoufikis, G., 2024).

In LAC, this pathology is mostly linked to energy inequality and historical challenges in access to basic services. Countries in the region face a triple burden: uneven energy infrastructure, high rates of economic informality, and insufficient public policies to protect vulnerable households (Islar et al., 2017). These conditions increase the exposure of the poorest sectors to costly or polluting energy sources, perpetuating cycles of social exclusion. The relationship between energy vulnerability and energy inequality is particularly evident in contexts where energy policies fail to meet the needs of marginalised communities, leaving many without access to sustainable solutions (Rosa, Aguiar and Aguirre, 2021). Addressing this issue involves not only ensuring equitable access to energy, but also strengthening household resilience to energy and climate risks.

Thus, energy indigence is the most severe deprivation, followed by energy poverty and then vulnerability (Figure 8).

Summary

Energy inequality is closely linked to household conditions, but also to environmental conditions, and the availability of resources in countries. These environmental conditions are directly defined by the institutional context, regulatory policies, and legal framework that promote the sustainability of an energy system over time: technological conditions, resources and practices, which are subject to changes in government action, while taking into account the international context (Recalde, Bouille & Girardin, 2015).

The variety of conditions that determine energy inequality translates into different forms of the same phenomenon in different countries and regions of the world.

In the approach adopted in this study, energy is considered as a social good, and not only as a productive input and tradable good, because it satisfies basic needs, increases the level of well-being of the population, and it is essential for the processes of development and social inclusion (Ibáñez Martín et. al, 2022).

Public policies to guarantee energy as a social right must have a comprehensive approach that not only expands access to energy in quantity and quality, but also guarantees distributive justice and recognition of the needs of the most vulnerable groups.

Universal and equal access to energy, in quantity and quality, has a key role to play in eradicating poverty, and addressing and understanding the phenomena of inequality and energy poverty can provide great opportunities in this regard.

2.3. The relevance of energy inequality in today's world. Who is most affected?

Energy deprivation (in its various manifestations: indigence, poverty, vulnerability) has an unequal impact on different population groups. Households and individuals are affected differently, depending on the territory they live in.

In both Latin America and Europe, energy inequality disproportionately affects vulnerable groups, although the causes and manifestations have different expressions. While in Latin

America the lack of infrastructure and dependence on traditional energy sources are key factors, in Europe high energy costs and energy efficiency of housing play a more significant role. Energy thus becomes a determinant of new inequalities.

Who are the most affected in Latin America and the Caribbean?

Latin America is the most unequal region in the world, and the energy dimension is no exception (González and Ibáñez Martín, 2023). Each country in the region has its particularities, however, it is possible to identify characteristics — such as gender, access to health, level of education, employment status — that differentiate groups that are more affected by energy deprivation than others.

A common variable to understand energy inequality across the region is gender (ECLAC, 2021), households headed by women or with a higher proportion of women suffer more severe energy poverty.

However, when looking at each country, the gender effect is not homogeneous. In Brazil and Peru, female-headed households are those most likely to suffer from severe energy poverty, while for Colombia and Uruguay, the relationship changes, with male-headed households being the most susceptible (Soares et al., 2023). In the case of Argentina, no gender effect is found when analysing energy poverty, but a disadvantage is found in female-headed households in the case of energy indigence (Ibáñez Martín, Zabaloy and Guzowki, 2022; Ibáñez Martín, Poggiese and Martínez, 2025).

The health dimension is another characteristic that makes it possible to identify vulnerable groups in terms of energy. Households lacking health coverage are more affected by energy poverty and indigence (Ibáñez Martin, Melo Poveda and Zabaloy, 2021). The same is true for the other dimension that is assessed when considering human capital: education. Energy poverty is most severe in households with lower educational backgrounds and whose main breadwinners have deficiencies in their educational trajectory (Soares et al. 2023; Lampis et al. 2023; Ibáñez Martín, Zabaloy and Guzowski 2022; Ibáñez Martin, Melo Poveda and Zabaloy 2021).

Somewhat surprising is the relationship that the employment status of the head of household has with severe energy poverty. Households with employed heads are more likely to experience acute energy deprivation (Soares et al. 2023). When drilling down into occupational categories, informality and job instability appear to have a positive relationship with household energy deficiencies (Durán and Condorí, 2016; Garcia Ochoa and Graizbord, 2016; Maidana, Torrontegui and Villoldo, 2020; Viñuela et al, 2022)

The rurality and indigenous origin of the populations is another factor of energy inequality. According to ECLAC (2021), the biggest problem is access to clean and quality energy sources, with a strong presence of energy indigence in both types of population. Soares et. al (2023) find that a household whose head is of African-American or Brown descent is more likely to suffer from acute energy deprivation, depending on the country, the chances may even double. The migrant status of the main breadwinner has also been analysed as a driver of inequalities around energy deprivation; however, no robust result is found for different countries in the region (UNDP, 2018).

Who are the most affected in European countries?

In the EU, energy deprivation is mostly associated with excessive energy expenditure by households. According to data from the European Commission's Energy Poverty Hub (2020), in 2020, 15.1% of households in the region had energy expenditure relative to income more than double the national average. High energy prices and the effects of the terrible triennium have hit European households hard, which had already been hit hard by the liberalisation of energy markets in previous years. As expected, lower-income households with unstable employment are the most affected by energy deprivation (UNDP, 2018). In this line, the Confederation of Consumers and Users of Spain (2023) highlights that families with the lowest incomes spend almost 9% of their total expenditure on energy, compared to an average of 6% for EU families. This disproportionate expenditure, just below the 10% overspending threshold, affects the ability of these households to meet other basic needs, exacerbating their socio-economic vulnerability.

One of the factors characterising energy-poor households in European countries is the lack of employment of the household heads. This is closely related to migrant status, as language and cultural barriers can limit not only labour market insertion, but also access to energy assistance programmes, increasing their risk of living in energy poverty (Fernández, Lezcano, and González, 2023).

According to La Caixa Foundation (2016), single-parent households and households with a high proportion of children are more likely to experience energy deprivation. This situation is exacerbated if the sole breadwinner is a woman and is widowed or divorced. The same study found that the migrant status of the person in charge of the household favours the appearance of energy poverty and that it becomes more severe if the origin is from countries outside the European continent.

In the context of energy poverty understood as excessive energy expenditure, the condition of the household envelope[7] and building conditions become central to understanding who is most affected by this phenomenon. The report by the Naturgy Foundation and the Chair of Energy Sustainability of the Institute of Economics of the University of Barcelona (2020), highlights that homes with low energy efficiency and problems in their roofs, walls and openings are more likely to spend more of their income on energy costs. In addition, the problem of energy under-spending, known as hidden energy poverty, is more frequent in these dwellings[8]. The same study finds another dimension that shows heterogeneous effects: household size. Larger

7 The envelope of a house consists of all building elements that are in contact with the outside.

8 Hidden energy poverty occurs when households consume less energy than expected, which can be difficult to detect. This can occur when households limit their energy consumption to avoid disconnections or financial strain (Karpinska and Śmiech, 2020).

households headed by older people are more likely to suffer from energy deprivation than smaller households with younger leaders.

Thus, in Europe, household composition, the characteristics of the main breadwinner (gender, employment, nationality) and housing conditions seem to explain more strongly the generation of energy deprivation of households.

How important is gender in understanding energy poverty?

Lack of access to modern household energy, electricity and natural or bottled gas for cooking mainly affects women and girls, due to inequalities in social position and gender roles in traditional societies (O'Dell & Wharton, 2014; Moniruzzaman and Day; 2020; Robinson, 2019; Acheampong et al., 2024). This form of inequality is due to the traditional view that assigns a reproductive role to women, of carrying out domestic work, caring for and educating children, maintaining the home and family relations (OLADE, 2013).

According to the Inter-American Development Bank (IDB, 2018), energy and gender mainstreaming is closely associated with domestic work, although this is a temporary and stereotypical problem, it is a reality in many regions, especially in LAC. For example, without access to clean and efficient energy sources, women are the most affected in a household, due to the fact that they are the most affected: (i) they have to cook more and for longer as they may not have a fridge to preserve food; (ii) they will be more exposed to indoor air pollution, as they will have to use charcoal for cooking; (iii) if there is a lack of water and energy for pumping, they have to go out to fetch it; and (iv) if there is a lack of energy, it is often the women who have to look for alternatives for the upkeep of the house. In other words, in general, women are more impacted by the scarcity of clean energy options.

In many developing countries, where households do not have access to modern energy, the use of traditional biomass, wood or charcoal, for cooking and other household energy demands is common. Often it is women and girls who are responsible for searching and collecting the biomass, a time-consuming task that could be used for other activities. The International Energy Agency (2018) estimated that women in developing countries spend on average 1.4 hours a day collecting firewood for cooking and 4 hours cooking with firewood (cooking with firewood takes longer than with modern energy sources). In addition, firewood collection exposes women and girls to the risk of injury due to heavy loads, exertion and, in some cases, sexual violence (Parikh, 2011; Bizzarri et al., 2009). The use of traditional biomass for cooking affects the health of women, and their children, as smoke inhalation increases the risk of respiratory and heart disease and cancer (World Health Organization, WHO, 2016).

In Europe, gender inequality and its relation to energy is associated with affordability. According to Clandy and Feenstra (2019) and Clancy et al. (2017), households in Denmark and Germany pay the highest prices per kilowatt hour, with women being the most affected because of their higher risk of living in poverty, the income gaps between men and women, and the higher proportion of single-parent households with responsibility for children. High taxes in Denmark and Germany, 67% and 54% respectively, explain part of the high energy prices in the two countries.

Other determinants of a woman's increased risk of being in energy poverty include life expectancy. Women tend to live, on average, longer than men, so they are left living alone in old age and risk spending more time in energy poverty. The biological/psychological perspective is also considered to be a determining factor, as women are more sensitive to ambient temperature than men, with younger and older women being more vulnerable. In part, this is due to physiological reasons related to the way the body cools and, in the case of older people, to lack of mobility and behaviour (reduced food intake) (Clancy et al., 2017).

A technical study on energy poverty in the neighbourhoods of the city of Madrid identified a strong feminisation of energy poverty (Sanz, et al., 2017). The results showed that while 23% of households are at risk of energy poverty, 32% of female-headed households can be considered energy poor. Within the group of female-headed households, the energy poverty rate of single-parent households is 51% and older women (65+) have an energy poverty rate of 45%. The study showed that female-headed households were disproportionately affected by high energy prices.

According to the literature, women are observed to be more vulnerable in terms of energy due to the unequal division of time-consuming and unpaid household chores, care and gender roles such as ensuring food security, exposure to physical and mental health impacts, and lack of social protection over the life course (Robinson, 2019). Thus, energy poverty and its relationship to gender are often analysed in terms of worsening health, time loss and drudgery (Moniruzzaman and Day, 2020).

In both rural and urban areas, women tend to be the main users of household energy, either because of their responsibility for doing different productive tasks (food production or trade initiatives) or because of their unpaid domestic work for the reproduction of their families.

Summary: relevant dimensions

As can be seen, the evidence shows that energy deprivation has an erratic behaviour that strongly depends on the characteristics of the households, their leaders, and the space in which they are located.

Certain dimensions, such as gender, number of members, income level, and educational level of the household seem to show a consistent effect on energy poverty in Latin America and the Caribbean and Europe. Female-headed households, large households, households that are cash poor or at risk of being cash poor, and those with low levels of education are more affected by energy deprivation than households with other characteristics.

However, when analysing the dimensions for each of the countries that make up these regions, the heterogeneities are irremediable. The effects of the gender of the household head are not as clear among LAC countries, and the same is true for the employment status in European countries. Thus, assessing the behaviour of the dimensions at the regional but also at the national level becomes necessary when making policy recommendations aimed at alleviating energy inequality.

3. CASE STUDY

3.1. Germany, Argentina, Colombia, and Spain. Why?

One of the main axis of the study is to carry out a comparative analysis of energy deprivation at two levels: between Europe and Latin America and the Caribbean on the one hand, and within each of these regions on the other. This dual comparative perspective imposes important limits on the empirical scope of the research.

To compare across regions, it is necessary to include at least one LAC and one EU country. Furthermore, to observe similarities and contrasts within each region, it is necessary to analyse at least two countries per region.

Given that energy deprivation is influenced by a wide variety of factors (Lampis et al., 2022; Ibáñez Martín, Guzowski and Zabaloy, 2022), the selection of countries should consider elements such as the type of energy sources available, the country's commercial role in energy, socio-economic conditions, and climatic diversity, among other relevant aspects.
The centre of the study is microeconomic, focusing on the population groups that suffer most from energy deprivation. Therefore, selected countries should have databases that simultaneously include information on household socio-economic conditions, access to energy sources and coverage of basic energy services, income, geographic location, energy expenditures, and employment status, among other factors.

These information requirements reduce the number of micro-databases suitable for analysis. Consequently, it was decided to work with the cases of Germany, Argentina, Colombia and Spain. Together, these four countries account for approximately 230 million people, equivalent to 20 per cent of the total population of both regions, and present extremely valuable profiles for the study.

In particular, Colombia was included due to its demographic weight (52 million inhabitants, 7.9% of the LAC population), its relevance as an energy producing country (it represents 10% of total regional production and 5.3% of final consumption in LAC according to OLADE data (2023)) and its marked socio-economic and climatic heterogeneity. It is a country with high levels of wealth concentration, notorious urban-rural inequalities, and a history of social conflicts that hinder access to electricity in rural areas. To this day, there are still households without this service. In addition, the country's climatic diversity conditions energy needs and determines specific consumption patterns.

Analysing this country also allows for an approach to the Colombian Caribbean region, which helps to incorporate a Caribbean perspective to the study, especially considering that there are no open and updated databases available for Caribbean countries after the pandemic.

For its part, Argentina also offers relevant conditions for analysis. It is a country with a wide bioclimatic diversity, which implies differentiated energy demands. It also has one of the most significant energy subsidy regimes in the region: on average, the population paid only 5% of the cost of the energy consumed (Poggiese and Ibáñez Martín, 2024). This situation has led to intensive energy use and limited the effectiveness of energy efficiency policies. In addition, Argentina — which accounts for 7.5% of LAC's total energy production and 8.4% of consumption (OLADE, 2023) — is in the process of redefining its role in the international energy market thanks to its abundant fossil fuel reserves, such as the Vaca Muerta field, which could turn it into a net exporter. With a population of 45.5 million (6.9% of LAC), it is also one of the largest countries in the region.

For the European Union, Germany was selected as the strongest economy and the most populous country in the region: it is home to 18% of the population, generates 14.9% of the EU's energy production and accounts for 21.9% of the EU's final energy consumption (European Commission, 2023). It is interesting to analyse how energy poverty manifests itself in a country with high economic resources and strong institutions. Energy poverty has increased in recent years, especially during the recent crisis period. In addition, Germany has been pursuing ambitious policies for the transition to renewable energy sources for the past two decades. However, the war in Ukraine and its geopolitical repercussions have had a strong impact on its energy market and have put a strain on plans for decarbonisation and nuclear phase-out.

Finally, Spain was included because it represents the climatic diversity of the European continent, providing a complementary view to the German case by comparing a Mediterranean with a continental country. In terms of representativeness, Spain accounts for 10% of the population, 6.7% of EU energy production and 8.1% of EU final energy consumption (European Commission, 2023). In addition, there has been the steepest increase in energy poverty in recent years, from 7.5% in 2019 to 17.1% in 2022, coinciding with the major energy price crisis in Europe. The Spanish case allows us to analyse the impact of public policies aimed at mitigating this phenomenon, such as electricity social vouchers, non-disconnection guarantees and the National Plan for the Eradication of Energy Poverty. On the other hand, Spain, unlike Germany, shares historical, cultural and linguistic links with Latin America and the Caribbean, which makes it a particularly useful point of reference for comparative study.

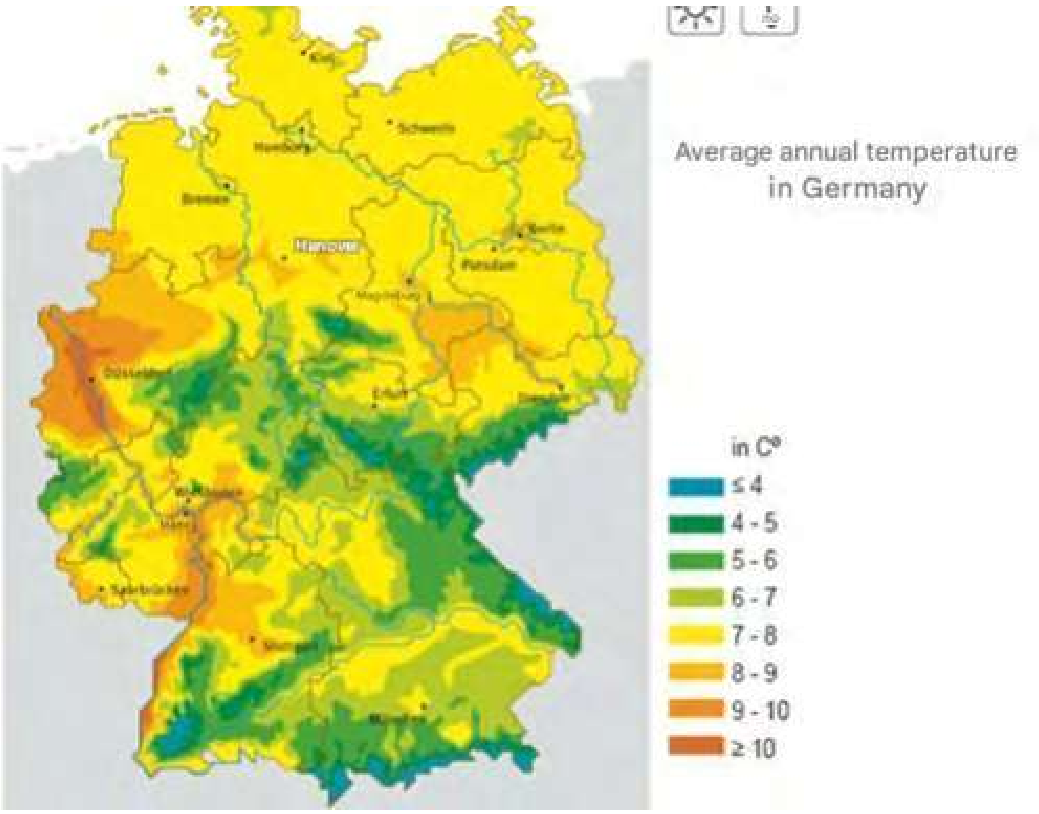
3.2. Germany — brief contextualisation

Relevant economic, social and geographical indicators:

Germany, with 83.2 million inhabitants, is the most populous country in Europe. Its economy is the largest in the European Union and accounts for a quarter (24%) of its total GDP (Eurostat, 2025). Electricity access coverage is complete and uniform, being 100% at both urban and rural levels (World Bank, 2022).

There are three main climatic regions: (i) the north, with a maritime climate, characterised by mild winters and cool summers with high levels of precipitation; (ii) the centre, with its continental climate, hot summers, cold winters and lower levels of precipitation compared to the north; (iii) in the south there is an alpine climate, with colder temperatures, heavy snowfall in winter, and milder summers.

Figure 11. Average temperatures in Germany



Source: Map School (2025).

Energy matrix:

In the 1990s, after the unification of the two Germanys, the country adopted substantial reforms in the energy sector that transformed its energy matrix. Thus, there was a shift from a predominance of coal and oil to a more diversified system. Since 2010, the energy policy known as Energiewende (literally “energy turnaround”) has been implemented, which is based on the transition to clean energy sources and the elimination of nuclear power generation.

Despite the implementation of the Energiewende, crude oil is today Germany's main source of energy, accounting for 33% of the Total Energy Supply (TES). Domestic production of this fuel is rather limited; most of the oil and its derivatives are imported, transported from the port of Rotterdam in the Netherlands.

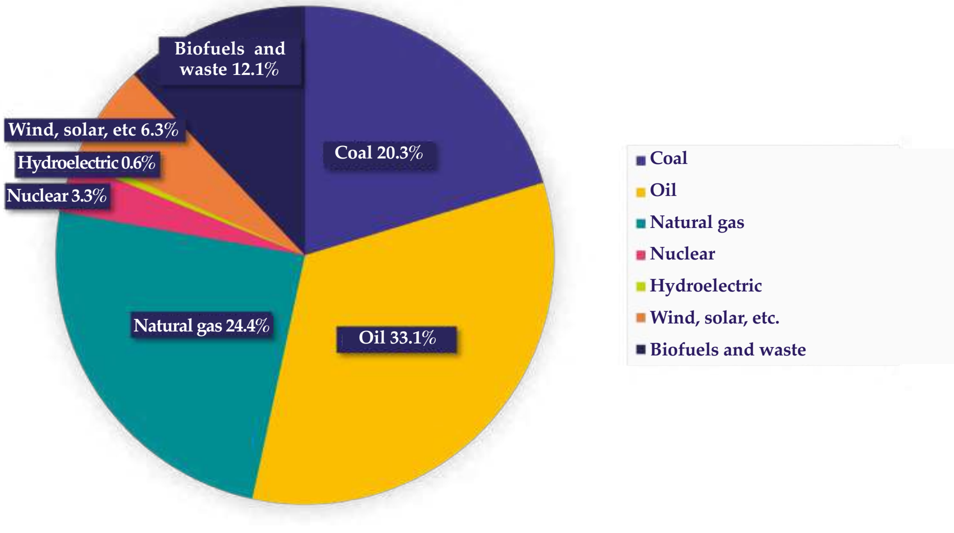
Natural gas represents 24.4% of the TES and is the second source of the national energy matrix. German natural gas supplies are significant, but domestic production has declined over the last decade and Berlin has had to increase its reliance on imports, most of which come from Russia (particularly before the invasion of Ukraine) and the Netherlands. In the context of the reduction of European gas production, Germany is looking for alternative sources of long-term security of supply, such as liquefied natural gas (LNG).

Coal is the third largest energy source in the TES, accounting for 20.3%, and the second largest energy source of national production, with 29.8%. Coal mining has been a mainstay of the German economy for the last century, in particular Germany's post-war industrial boom was largely due to hard coal from North Rhine-Westphalia and Saarland. The activity remains a dominant industry in several German states, sourced from deposits in the Ruhr, Saar, Aachen and Ibbenbüren, although extraction is costly and often subsidised. Production has been significantly reduced over time and the aim of the Energiewende plan is to phase it out completely by 2038.

Nuclear generation, introduced in the 1970s, accounts for only 3.3% of TES. The plants are located in western Germany, on the coast or on rivers far from the coal mines, while the plants in the east, built on the Soviet model (such as Chernobyl), were shut down for safety reasons. In 2002, the government passed a law stipulating the end of the nuclear power industry by 2022, although in 2010 — arguing that nuclear power plants would be needed until renewable energy technologies became sufficiently productive — it extended the deadline to the 2030s. Today, a public debate on the complete shutdown of the nuclear sector has been reopened, mainly driven by Germany's energy dependence in case of shutting down its plants and by the high energy costs in the framework of the new energy geopolitics resulting from the Ukraine-Russia war.

Renewable energy sources (biomass, wind, solar, and hydro) are advancing rapidly, accounting for 18.9% of TES and 54.1% of national energy production in 2022 (6.8% and 19.5% if biomass is excluded). Final consumption of modern renewables — which exclude biomass — has grown by 376% between 2000 and 2021.

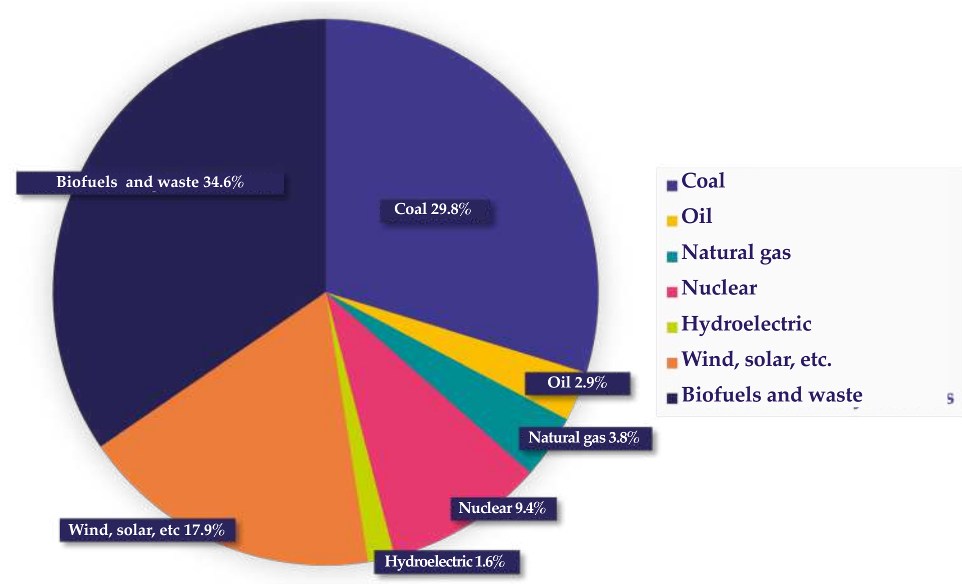
Figure 12. Total Energy Supply (TES) — Germany, 2022



Source: Prepared by the authors with data from IEA (2025a)

Germany was a leader in the development of rooftop solar PV and biogas energy; in recent years growth has been dominated by wind energy. Bioenergy, which includes both modern and traditional bioenergy, and waste represent the largest share of national production (Figure 13) with 34.6%, half of which is used for heat and power generation and the other half for final consumption.

Figure 13. National energy production — Germany, 2022



Source: Prepared by the authors with data from IEA (2025a)

Energy trade balance

The country is substantially dependent on global markets for its energy consumption: in 2023, approximately 70% of the TES was supplied by imports from various sources.

Figure 14. Germany's energy trade balance, 2000-2023

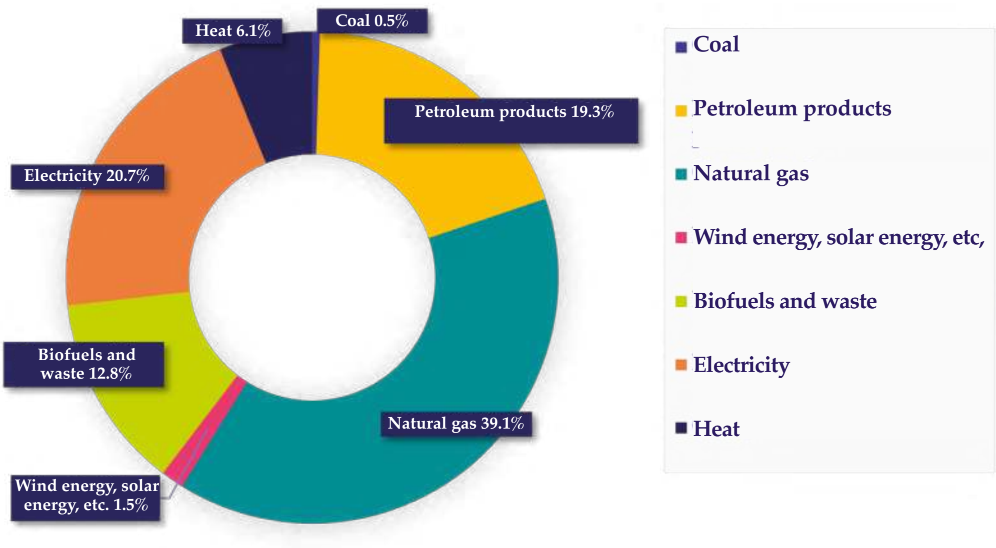
Source: Prepared by the authors with data from IEA (2025a)

Germany was among the European countries most dependent on oil and natural gas imports from Russia, also thanks to important transport infrastructure such as pipelines, including the famous North Stream2, which was completed in 2021 and did not come into operation as a result of the Russian invasion of Ukraine. Due to the impact of the war on trade and infrastructure, imports from Russia declined substantially. In 2021, 28.9% of imported crude oil came from Russia, in 2023 this value dropped to 0.1% (Observatory of Economic Complexity, OEC, 2023). Over that time, the suppliers have diversified, and today the main players are: Libya, the US, and Norway. Dependence on Russia also revolved around natural gas: until January 2022, 34% of imported natural gas was of Russian origin. Towards the end of that year, Russian imports were completely replaced by Norwegian and Dutch suppliers (Clean Energy, 2024).

How is energy consumed at the residential level?

The residential sector accounts for approximately 27% of total energy consumption, with gas being the energy source most used by this sector, followed by electricity and petroleum products.

Figure 15. Residential final consumption by source type, Germany, 2022

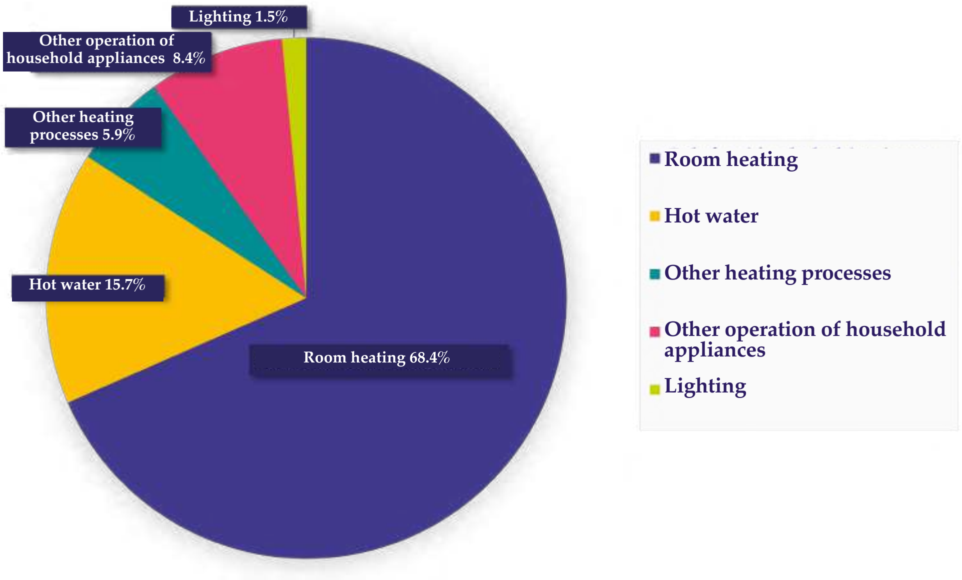


Source: Prepared by the authors with data from IEA (2025a)

Over the last 20 years, the energy intensity of the residential sector has been reduced by almost one third, -27% between 2000-2021, thus showing an increase in energy consumption efficiency.

68% of energy is consumed to satisfy energy services for heating and hot water (Statistisches Bundesamt, Destatis, 2025).

Figure 16. Residential energy consumption by type of use, Germany, 2022



Source: Prepared by the authors with data from Federal Statistical Office of Germany (2025)

Energy poverty situation

Germany has no official statistics on energy poverty and no official position on the definition of the problem.

Using the 10% indicator, which characterises a household as energy poor if it spends more than 10% of its total income on paying for the energy it consumes, it is found that by 2022, 10.4% of low-income households were energy poor. In 2018, this value was around 8%. However, energy poverty is not a phenomenon exclusive to low-income households in Germany. In contrast, in 2022, 16.8% of lower-middle-income households had excessive energy expenditure. An increase was noticed compared to 2018, which recorded 12% of households in this situation.

In 2022, 6.7% of German households reported not being able to adequately heat their homes for financial reasons, a threefold increase compared to 2018 (Eurostat, 2025). Another indicator of energy poverty is represented by the lack of electricity connection (Social Watt, 2023): 234.926 in 2021 (0.45% of households).

Public policies against energy poverty

In the absence of a precise definition of energy poverty, there are no specific funds or policies to combat energy poverty at the federal level. Public policies to counter the phenomenon fall under the comprehensive approach to alleviate poverty. The federal government considers basic energy needs to be part of the minimum subsistence level, part of the guaranteed rights of all citizens. This subsistence minimum is focused on covering the basic material needs for food, hygiene and other necessities, as well as for participation in the social, cultural, and political life of the country. Under this framework, energy costs are part of this vital subsistence level and would therefore be covered through guaranteed minimum income programmes. Among the policies that have an impact on the energy consumed by households, the following can be mentioned:

- The housing allowance, active since 2009, is one of the most important measures to reach the minimum subsistence level, benefiting households entitled to the living wage (Wohngeld/Hartz 4; about 500,000 households in 2019). The determination of the amount of the housing allowance includes the costs of heating the dwelling and a fixed payment for electricity.

- Households that are entitled to social or unemployment benefits can receive support, in the form of interest-free loans, from their social or employment centre if they are unable to pay their electricity bills.

- Electricity and/or gas supply cuts are regulated by law and controlled by the Ministry of Economics and Energy (BMWi) and the Federal Network Agency (Bundesnetzagentur — BnetzA). During the coronavirus period, many energy suppliers voluntarily suspended outages, which significantly reduced the number of outages.

In the context of the 2022 energy crisis, the German government took several measures to contain rising energy costs and launched a campaign to urge citizens to save energy. Universal aid was applied to all citizens and vulnerable groups were targeted. However, targeted policies were not specific to energy. The main measures included the following:

Main measures targeting vulnerable groups

- Heating allowance (June 2022): one-off automatic payment to eligible households/ individuals at the time of issuing annual heating bills or supplementary (summer) bills. It is estimated to benefit a total of 2.1 million people (2.5% of the population), with total funding calculated at 380 million euros

- Additional support for housing allowance recipients, with the amount depending on the size of the household (270 euros for single persons, 350 euros for two persons and then 70 euros for each additional person in the household) reaching a total of 710,000 households.

Universal measures

- Abolition of the EEG-tax on electricity (as of July 2022, permanently): the EEG-tax (the "green electricity tax" in force since 2000) was completely abolished as of July 2022. For an average electricity consumption of 3,500 kWh/year, this represents a bill saving of €227.5/year.

- Fixed energy price tariff (September 2022): single fixed energy price tariff of 300 euros for employees, self-employed persons and traders.

- Gas tax reduction (October 2022 — March 2024): the gas sales tax was temporarily reduced from 19% to 7% to compensate for the new gas surcharge.

- Emergency aid for households and businesses (December 2022): households with gas heating or district heating did not have to pay the advance or payment on account due in December 2022.

- "Price freeze" for electricity, gas and district heating (March 2023-April 2024, retroactive to January-February 2023): a price cap is applied to 80% of planned or historical consumption by 2023 (limit to encourage energy savings).

- Economic Stabilisation Fund (1.8 billion euros, in 2023) to provide financial support to households with heating systems fuelled by oil, LPG or pellets.

- Extension of the exemption agreement to all households (2023): households with basic electricity service are now entitled to pay energy bills in instalments without interest, avoiding power cuts. This possibility is extended to all households during the price brake period for both electricity and gas bills.

- No increase in electricity transmission tariffs (2023): the federal budget will be used to cover the increase in electricity transmission costs in 2023.

- Additional funding to replace heating systems with heat pumps or renewable energy systems.

Energy market regulatory institutions

The German energy system is regulated by both the federal government and the Länder (the Länder, the territorial entities into which the country is divided), with the former responsible for legislation and the latter participating through the Bundesrat (IEA, 2018).

The Federal Ministry of Economics and Energy (BMWi) leads energy policy, ensuring industrial competitiveness and promoting renewable energies. Other ministries with specific roles include:

- BMU — Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety): environmental policies and climate change.
- BMVI — Bundesministerium für Verkehr und digitale Infrastruktur (Federal Ministry of Transport and Digital Infrastructure): energy transition in the transport sector.
- BMEL — Bundesministerium für Ernährung und Landwirtschaft (Federal Ministry of Food and Agriculture): bioenergy and biomass.
- BMBF — Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research): energy research.
- BMF — Bundesministerium der Finanzen (Federal Ministry of Finance): energy taxation and budget management.

At the regulatory level, the Bundesnetzagentur (Federal Network Agency) is responsible for overseeing the liberalisation of energy markets and the operation of the electricity grid. The Monopolkommission (Monopoly Commission) ensures that competition in the sector is maintained. The electricity distribution and marketing system is of a mixed nature, with a predominance of the private sector, but with a significant presence of public companies, especially the Stadtwerke (municipalities).

3.3. Argentina — brief contextualisation

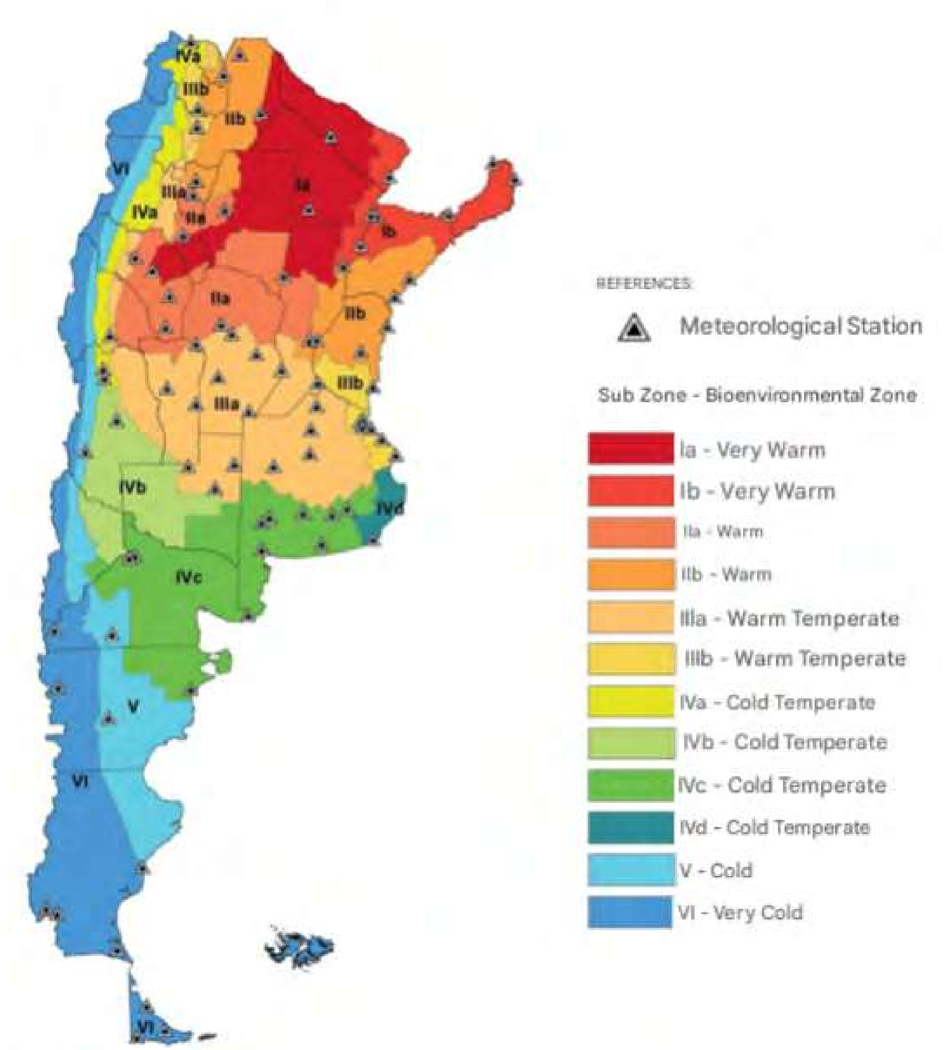
Relevant economic, social and geographical indicators:

Argentina has 45,892,285 inhabitants, the fifth largest population in Latin America and the Caribbean. With a GDP of USD 629 billion, equivalent to 10% of regional GDP, it is the third largest economy in the region.

Argentina is among the first Latin American countries to achieve universal access to electricity, with a successful rural electricity markets programme that accelerated the connection of remote last-mile users to the grid in recent years (IEA, 2024). Electricity access coverage is total and uniform, 100% at urban and rural levels (World Bank, 2022).

It has a large territorial extension — it is three times larger than Germany and Spain combined — in latitude it extends between 22° and 55° S, covering a great climatic diversity (Figure 17).

Figure 17. Bio-environmental zones of Argentina



Source: Argentine Energy Secretariat (2025)

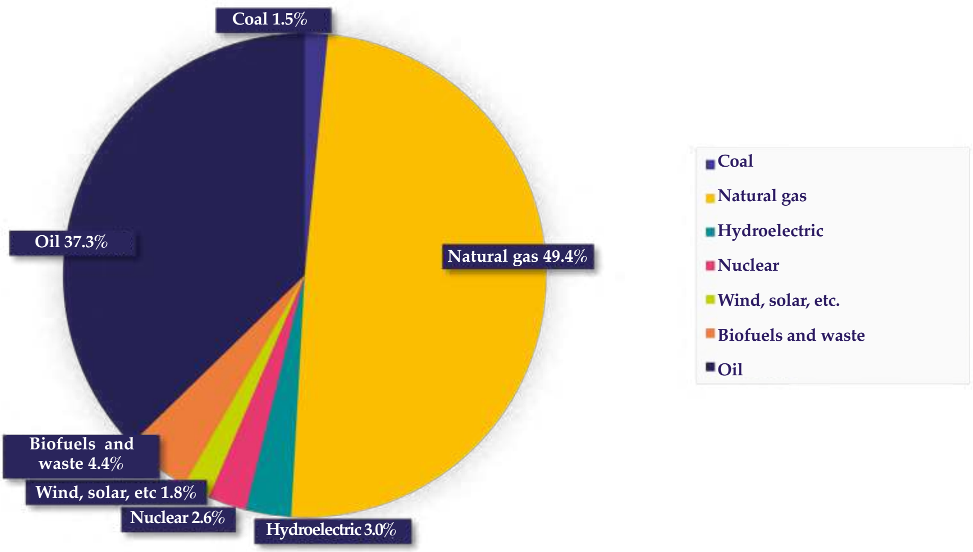
The country ranges from the tropical climates of the Chaco, Tucumán-Orananense and Misiones ecoregions to the cold climates of the south (National Geographic Institute, 2025). Its cone shape, tapering between the Atlantic and Pacific oceans, means that many areas have a mainly oceanic climate. In the west, it is crossed by the Andes mountain range, which is also a major climatic factor.

Energy matrix

The country has an abundance of energy resources, such as oil and gas, and it is the largest producer in LAC. The deposits of these polluting fuels are found mainly in the Northwest and Patagonia.

In terms of domestic energy generation, Argentina relies on natural gas (45%), oil (41%), hydroelectric power (3%), nuclear power (2.5%, it is one of the main producers of nuclear energy in Latin America), and geothermal, wind and solar power (1.8%). A range of public policies have driven utility-scale projects in variable renewable energies, taking advantage of its rich solar and wind resources. Argentina's TES (Figure 18) is dominated by natural gas and oil, accounting for almost 88%, bioenergy, hydropower and nuclear power.

Figure 18. Total Energy Supply (TES) in Argentina -2022

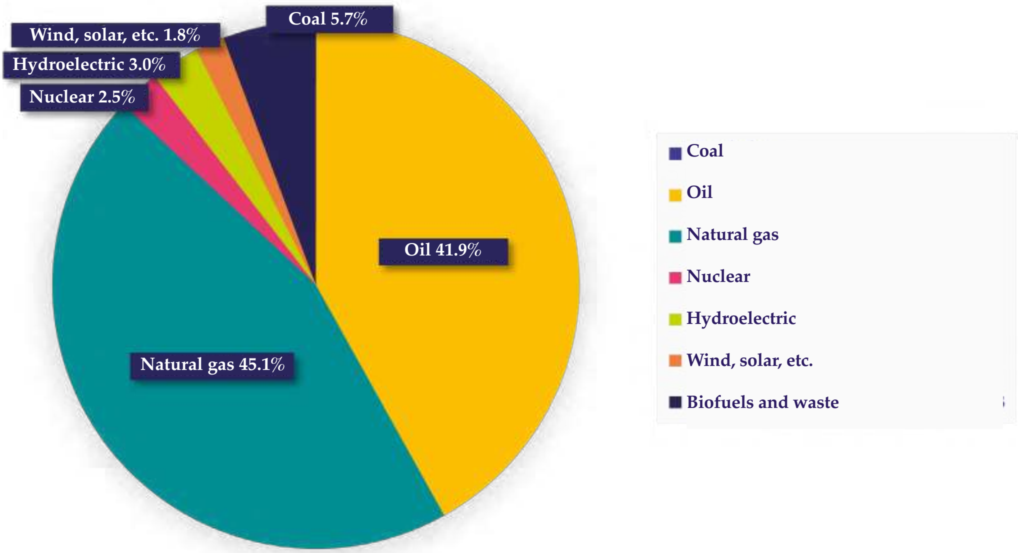


Source: Prepared by the authors with data from IEA (2025b)

By the end of the 20th century, the country was self-sufficient in fossil fuels and hydroelectric generation and had become an oil exporter. Prior to the exploitation of the gas fields in the 1980s, Argentina imported gas from Bolivia. The most important coal deposits are in the south of the country, located in Patagonia. Until 2000, some of the coal used was mined there, but this activity has ceased; Argentina's needs are now met by imports, although coal accounts for only 0.1% of TES.

Nuclear energy in Argentina is preponderant as base energy, ranging between 5% and 9% as a source of electricity generation. In 2024, the government announced a new Nuclear Plan that focuses on increasing the share of this source in the matrix and on the generation and development of small modular reactors.

Figure 19. National energy production, Argentina -2022



Source: Prepared by the authors with data from IEA (2025b)

Trade balance

Between 2010 and 2024, Argentina imported more energy inputs than it sold. In 2024, a surplus was recorded in the energy trade balance. The main origins of imports are Brazil, Uruguay, Paraguay, Bolivia, and Chile. Chile is the main destination for Argentina's energy exports.

In 2022, the year of analysis of this study, Argentina had an energy balance deficit (Figure 20).

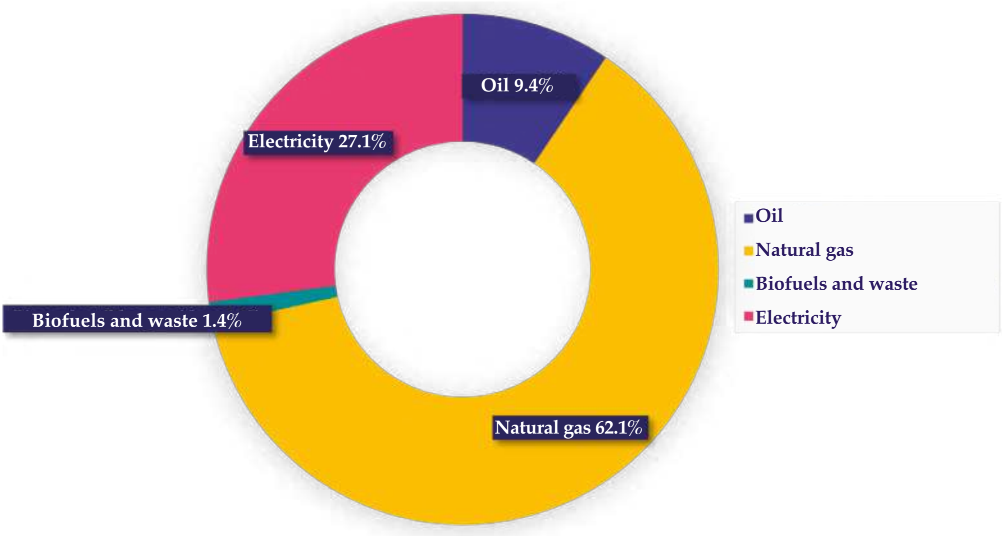
Figure 20. Trade balance of energy products, Argentina, 2000-2022

Source: Prepared by the authors with data from IEA (2025b)

How is energy consumed at the residential level?

Residential sector consumption accounts for 26% of total energy consumption and its main source of supply is gas (62%), followed by electricity use.

Figure 21. Residential sector energy consumption by type of source, Argentina



Source: Prepared by the authors with data from IEA (2025b)

Energy intensity has increased by 44% between 2005 and 2012 (latest available year for this variable), indicating an increase in consumption without an improvement in energy efficiency. 35% of energy is used for heating, 14% for domestic hot water and 13% for running refrigerators/fridges (Ministerio de Economía de la Nación Argentina, 2016).

State of energy poverty

Argentina has no official statistics on energy poverty. In 2020, the Energy Secretariat, in agreement with ECLAC and the Chilean Energy Poverty Network, studied the information needs and design of indicators for the country, however, there is still no published information.

Energy poverty in the pre-COVID-19 era was estimated at 17% by Lampis et al. (2022). However, the exit from the terrible triennium was accompanied by major changes in Argentina's energy tariffs. In 2021, the "Cold Zone Law" [9], was extended, which implies a 30-50% reduction in mains and bottled gas in the coldest areas of the country. Additionally, in 2022, Argentina moved from having a universal energy subsidy to a scheme of targeted subsidies based on the socio-economic level of households. According to some estimates, these changes increase energy poverty to values close to 30% (Poggiese and Ibáñez Martin, 2024; Poggiese, Ibáñez Martin and Martínez, 2024).

Prior to the changes mentioned above, households in Argentina covered on average 6% of the cost of mains gas and 15% of the cost of the electricity they consumed. The remainder was financed through various subsidies. The relevance of energy subsidies reached 4% of national GDP in 2021. Naturally, since energy price is one of the three main elements of energy poverty, this scheme kept Argentina with low energy poverty values.

In 2023, together with the change of the national government (to a liberal one), a process of eliminating energy subsidies and updating tariffs began. By early 2025, as a result of this process, households cover, on average, 49% of the cost of the electricity they consume and 53% of the cost of natural gas (IIEP, 2025).

In addition, several studies find that the incidence of energy deprivation affects the population unequally, with the most socially vulnerable groups being at a disadvantage (Ibáñez Martín, Guzowski and Zabaloy, 2022; Lampis, et. al, 2022; Ibáñez Martin, Melo Poveda and Zabaloy, 2022; Ibáñez Martin, et. al, 2022; Reyes Pontet, Ibáñez Martin and Zabaloy, 2022; Reyes Pontet, Ibáñez Martin and London, 2020).

Public policies against energy poverty

- Energy Subsidy Segmentation Regime: By Decree No. 332 of 16 June 2022, the National Government established a subsidy segmentation regime for residential electricity and

8 For more details on this law, please see: Pontet, M. D. R., Martín, M. M. I., & Zabaloy, M. F. (2022). Argentina's Cold Zone Law and vulnerable sectors: first reflections for Bahía Blanca. Estudios Socioterritoriales, 32, 11-11.

natural gas users. This scheme classifies users into different levels according to their economic capacity, with the aim of targeting subsidies to the most vulnerable sectors and gradually reducing state assistance to higher income sectors.

- Update of electricity tariffs: In 2022, the Ente Nacional Regulador de la Electricidad (ENRE) held public hearings to discuss the adjustment of electricity distribution tariffs. These updates aim to reflect the real costs of service provision and ensure its sustainability, taking into account post-pandemic economic variations.

- Energy subsidy reduction policy: In line with the objectives of fiscal sustainability, the National Government implemented measures to reduce energy subsidies as of December 2023, seeking to balance public accounts and promote more efficient energy use. These actions include the review and restructuring of the subsidies granted, with a focus on efficiency and equity.

- Extension of the Cold Zone Regime: Law No. 27,637, passed in July 2021, extended the benefit of tariff reductions for natural gas services to new regions of the country. This extension allows more residential users to access discounts of 30% to 50% on their gas bills, depending on their geographic location and socio-economic conditions. The measure aims to alleviate the cost of service in areas with low temperatures, recognising the higher energy demand for heating.

Institutions

Argentina's energy market operates under a mixed scheme, where public and private actors coexist in the generation, transmission and distribution of energy. The electricity sector is regulated by the Ministry of Energy and the Ente Nacional Regulador de la Electricidad (ENRE), while natural gas is supervised by the Ente Nacional Regulador del Gas (ENARGAS). In addition, the system is organised in a wholesale market (MEM), where generators sell energy to distributors and large consumers under regulated prices and forward contracts.

In terms of regulation, the Argentine state intervenes through subsidies to keep tariffs affordable, especially for vulnerable sectors. However, price distortions have created challenges for system sustainability and infrastructure investment. Generation is in the hands of private and state-owned companies, such as YPF Luz and CAMMESA (Compañía Administradora del Mercado Mayorista Eléctrico), which coordinates the operation of the system. Distribution is divided into regional concessions.

The main institutions that intervene and regulate the Argentine energy market can be summarised as follows:

- Ministry of Economy - Secretariat of Energy. It is the governing body for national energy policy. It designs and implements strategies related to hydrocarbons, electricity and renewable energies.

- Ente Nacional Regulador de la Electricidad (ENRE). It regulates the public electricity distribution and transmission service, supervising concessionary companies and protecting users' rights.

- Ente Nacional Regulador del Gas (ENARGAS). It oversees the distribution, transport and storage of natural gas. It also regulates the liquefied gas market. Regulador del Gas (ENARGAS) Supervisa la distribución, transporte y almacenamiento de gas natural. También regula el mercado del gas licuado.

- National Atomic Energy Commission (CNEA). It develops nuclear policies, promotes research in atomic energy and encourages the generation of nuclear energy.

- Cammesa (Compañía Administradora del Mercado Mayorista Eléctrico S.A.). It manages the Wholesale Electricity Market (MEM), planning the operation of the national electricity system and settling costs between market agents.

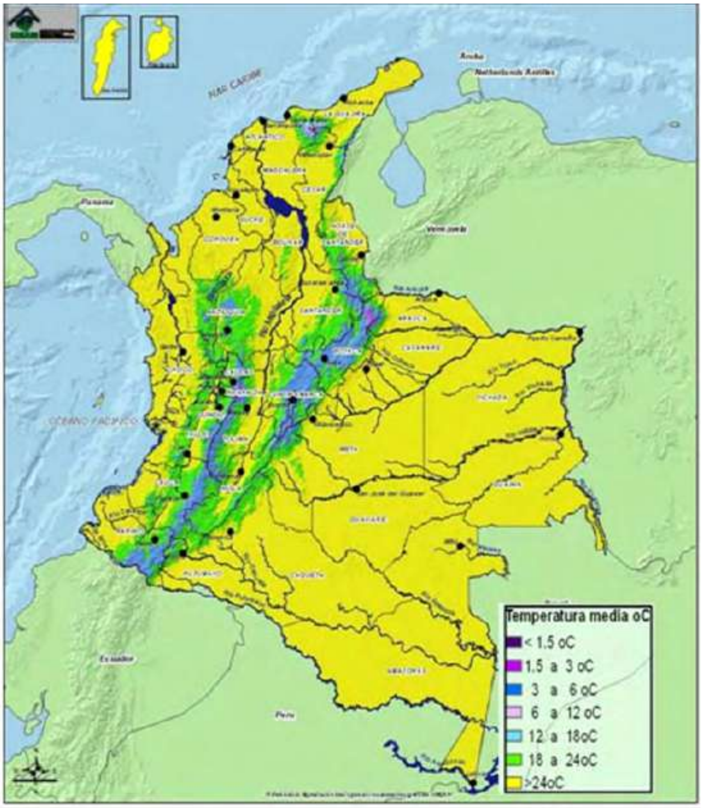
3.4. Colombia — brief contextualisation

Relevant economic, social and geographical indicators:

Colombia is the third most populous country in Latin America and the fourth in terms of GDP. However, it stands out for its high inequality, reflected in a Gini coefficient of 51.5, one of the highest in the region. Approximately one third of the population lives below the poverty line, and more than half of the population works in the informal sector. In addition, there is a marked socio-economic divide separating urban areas — one fifth of the national population resides in the capital, Bogotá — from rural areas, where many public development policies are concentrated. In terms of access to electricity, 94.93% of the national population has access to this service (UPME, 2023). However, access to electricity is still very unequal: while the Andean zone has high coverage rates, the periphery of the country — Orinoco-Amazon and the Pacific — has low coverage.

In environmental terms, Colombia stands out as one of the most megadiverse countries on the planet, with a high biodiversity index (Ministry of the Environment, 2025). This biological richness is due to its unique geographical location: situated in the far north of South America, between the Amazon and Panama, it is the only country on the continent with coasts on both oceans. In addition, the country is crossed by the Andean mountain range and the equator crosses its territory, which eliminates the existence of marked seasons and thus avoids climatic extremes. Colombia has five bioclimatic zones — paramos, tropical desert, tropical savannah, tropical mountain and tropical rainforest — that form a mosaic of climates and microclimates. These range from high temperatures, 30°C on the coasts and plains, to cold conditions, with values below 0°C in the peaks of the Andes Mountains and the Sierra Nevada de Santa Marta.

Figure 22. Spatial distribution of mean temperature (°C) - Colombia, 1971-2000



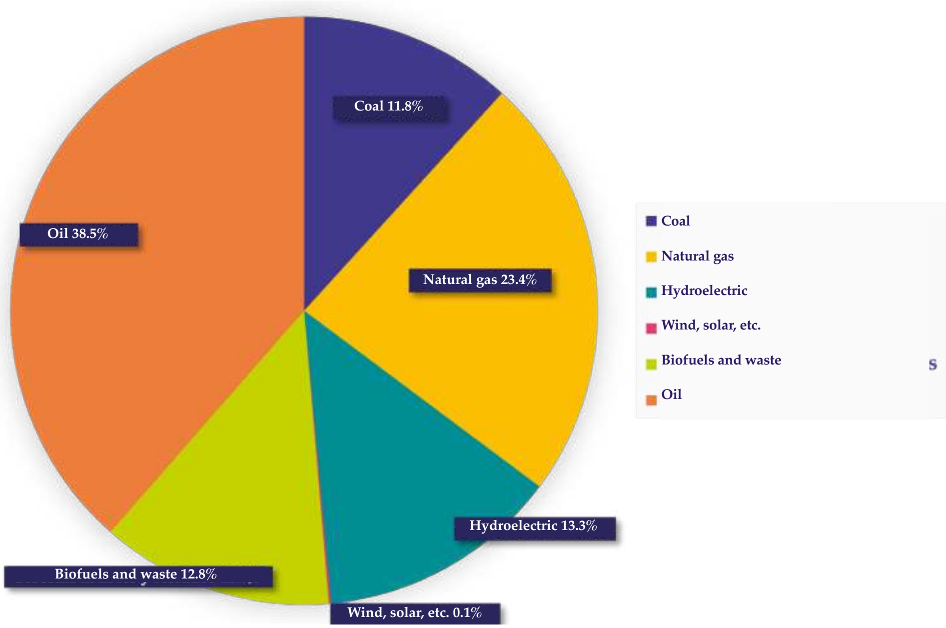
Source: Guzmán, Ruiz and Cadena (2014).

Energy matrix

Colombia has a large number of non-renewable fuels, such as oil and coal (with its La Guajira coal deposits, the largest in all of northern South America). The latter accounts for 36.2% of national energy production.

Oil reserves, historically exploited in the Magdalena and Catatumbo river valleys, expanded towards the end of the 20th century with the opening of new deposits in the Llanos and the Amazon. Between 2008 and 2015, oil production has shown a cumulative growth of 88%, reaching production of one million barrels in 2015. Today, oil is the number one export product and the main source of tax revenues. Despite the fall in oil prices during the pandemic, the country recovered, recording GDP growth of 7.3% in 2022. In 2022, liquid petroleum fuels (diesel and gasoline) accounted for about 40% of energy supply, while natural gas and coal contributed about 9.7% and 36.2%, respectively.

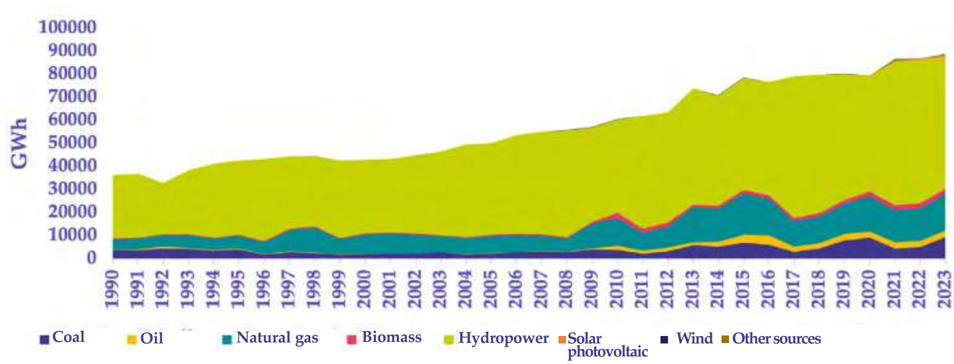
Figure 23. Total Energy Supply, Colombia, 2022



Source: Prepared by the authors with data from IEA (2025c)

With the largest hydropower potential in the region after Brazil, hydroelectric plants supply about three quarters of the country's electricity, while weighing in at 5.1% of national energy production. However, droughts have caused concerns and challenges in service delivery, prompting the construction of complementary thermoelectric plants, which mainly use natural gas and coal and account for about30% of installed capacity.

Figure 24. Electricity generation by type of source — Colombia 1990-2023



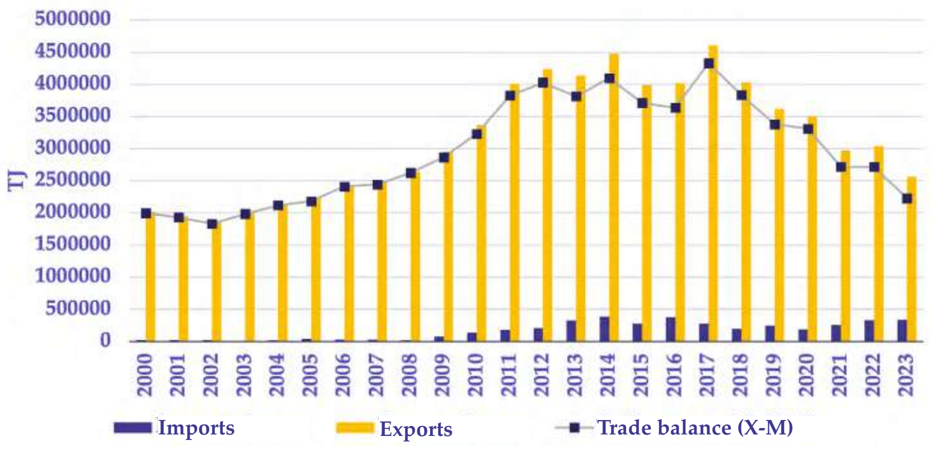
Source: Prepared by the authors with data from IEA (2023).

However, significant challenges remain to increase the share of renewables in national production. According to IEA data, in 2022 only 5.3 % of the total national energy production was generated from renewable sources such as hydro, solar, geothermal and wind. In 2022, in the electricity sub-sector, renewables were the main sources of generation, contributing 74.9% of the total. Although Colombia has adopted public policies for energy transition since the mid-1990s, it was from 2015 — following the energy crisis caused by droughts resulting from the El Niño phenomenon, which reduced hydroelectric capacity — that the government intensified its efforts to promote the use of non-conventional renewable energy sources. In this context, the National Development Plan (NDP) 2022-2026 set targets on renewable energy, energy communities and the promotion of green and white hydrogen and offshore wind sources. Under the guidelines of this Plan, the state-owned oil company Ecopetrol is positioned as a key player in the transformation towards a low-carbon economy, also promoting the development of research, science, and technology in the field of clean energy.

Balance of trade

Colombia is positioned as a net exporter of oil and coal, being the second largest energy exporter in Latin America. In 2021, the country sent 59% of its energy production abroad. Earnings from the production and export of oil, gas and coal remain an essential component of national GDP. Over the last decade, the oil sector has accounted for, on average, about 2% of GDP and has contributed 13% of total government revenues through taxes, dividends and royalties. Additionally, in the five-year period from 2016 to 2020, coal accounted, on average, for 16% of exports.

Figure 25. Trade balance of energy products, Colombia, 2000-2022



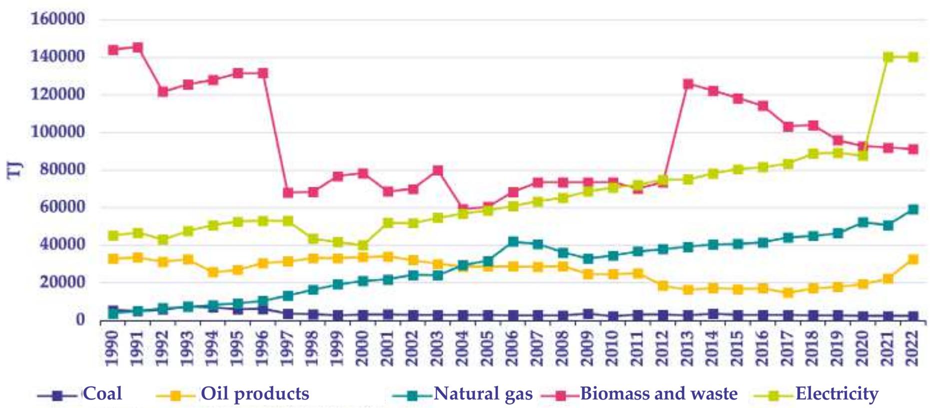
Source: Prepared by the authors with data from IEA (2025c)

How is energy consumed at the residential level?

The residential sector accounts for 26% of total energy consumption (IEA, 2022). Within this segment, electricity is the main source of energy used by Colombian households in 2022, accounting for 43.1%, followed by biomass and waste with a share of 28% and natural gas, which registered 18.1%. Electricity use in Colombia is primarily determined for refrigeration processes, in equipment such as refrigerators and air conditioning systems, which consume 48% of final energy, followed by television and lighting with 15% and 14% respectively (UPME, 2019). The data also show the importance of natural gas and biomass in domestic consumption, which is understandable given that cooking is an essential activity in the daily life of a Colombian household.

Despite energy policies to reduce the use of traditional fuels in Colombia, 9.7% of households still use these sources for cooking. This scenario is more common in rural areas.

Figure 26. Total residential final consumption, 1990-2022, Colombia



Source: Prepared by the authors with data from IEA (2023).

State of energy poverty

According to Promigas' multidimensional energy poverty index (IMPE), in 2023 in Colombia, 16.1% of the population — corresponding to 8.4 million people — will be in a situation of energy poverty, a situation that is worse in rural areas and in the Caribbean region (where 44% of the energy poor live) (Inclusión SAS and Promigas, 2024). Furthermore, the Colombian Ministry of Mines and Energy (MME, 2024) estimated that 22% of households suffer from this problem. The MME relied on an index composed of several dimensions to measure multidimensional energy poverty in Colombia.

Public policies against energy poverty

Electricity coverage in Colombia, on the one hand, has been based on programmes that seek to financially support access to this service for the country's rural and most vulnerable population. On the other hand, the electricity service was also boosted by the adoption of subsidies through Law 142 of 1994, which deals with the legal framework for residential public utilities. This subsidy is a benefit in which users located in upper middle- and upper-class neighbourhoods pay an additional contribution to the tariff to subsidise the lower and middle class population. In Colombia, residential properties are classified into a socio-economic level known as "stratum", where those classified as strata 1, 2 and 3 receive subsidies, while strata 5 and 6 pay cost overruns. Stratum 4 does not receive subsidies or pay cost overruns. Furthermore, the benefit depends on the energy consumption and the height above sea level at which the municipality is located.

The main policies that promoted the penetration of natural gas were implemented at the end of the 20th century, such as the Natural Gas Massification Plan, which consisted of financial support for the development of service infrastructure in the country for the installation and connection of piped gas to lower-income families.

As a policy for the substitution of traditional energy sources with LPG, in 2013 the Colombian Ministry of Mines and Energy adopted a subsidy programme targeting families in three departments in the south of the country. The programme is funded by the national government and the benefit is transferred through the LPG distributor. Despite the relevance of LPG in the residential sector, its use has declined over the last two decades due to the massification of piped gas, the lower relative price of natural gas, and financial support funds for infrastructure and service connection. These factors have contributed to the partial substitution of LPG with piped gas in Colombia's large urban centres.

Colombia does not have an official definition of energy poverty established by the national government, although recent efforts have been made to highlight the issue through its measurement by the National Administrative Department of Statistics (DANE).

Institutions

Colombia's 1991 Constitution established that public services could be provided by the state directly or indirectly, by organised communities or by private companies, and the system has expanded with public and private investment. The state retained control and regulation and oversight of the services because, in general, they are natural monopolies.

The major reform of the sector was based on Law 142 of 1994, which focused on residential public utilities such as water, aqueduct, sewerage, electricity and gas. Law 143 of 1994 defined the electricity regime in Colombia.

The national government, through different entities and bodies, has the role of supervising the electricity market, thus electricity supply is considered an essential right according to the Constitution. The electricity sector in Colombia is made up of entities with management and planning functions, the main institutions are:

- The Ministry of Mines and Energy (MINENERGÍA), the Institute for Planning and Promotion of Energy Solutions for Non-Interconnected Zones (IPSE), and the Mining and Energy Planning Unit (UPME).

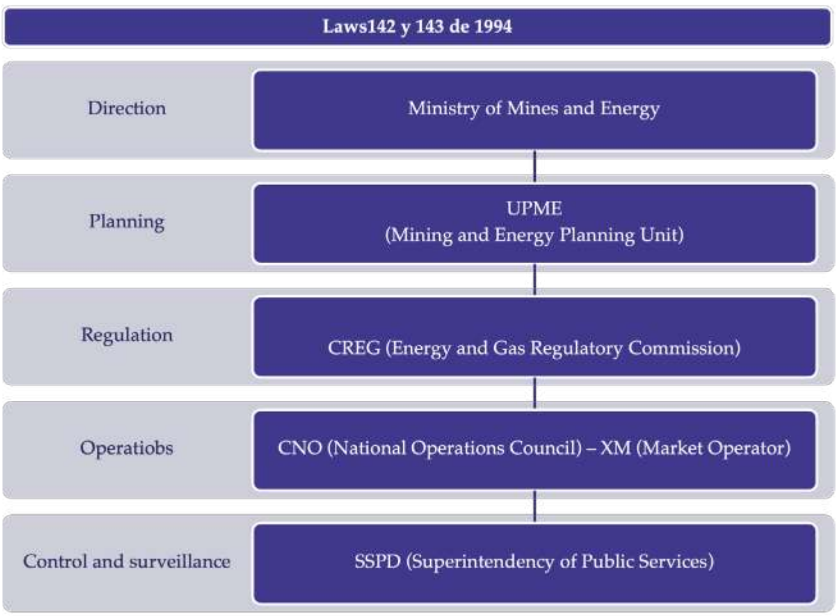
- The Energy and Gas Regulatory Commission (CREG) with regulatory functions

- The Superintendencia de Servicios Públicos Domiciliarios (SSPD) with oversight and control functions

- The National Operating Council (CNO is the Spanish acronym) and the Market Operator (XM is the Spanish acronym), for system operators

- Laws 142 and 143 of 1994 laid the foundations for the reform that was adopted in the Colombian electricity sector in the mid-1990s and constitute the main legal regulatory framework that currently governs the sector. These laws define the separation of activities necessary for the provision of the electricity service (generation, transmission, distribution, and commercialisation), the institutional structure of the electricity sector and the regulation of electricity transmission and distribution activities, among other aspects.

Figure 27. Role of the institutions in the electricity sector in Colombia



Source: Prepared by the authors based on information from UPME (2025)

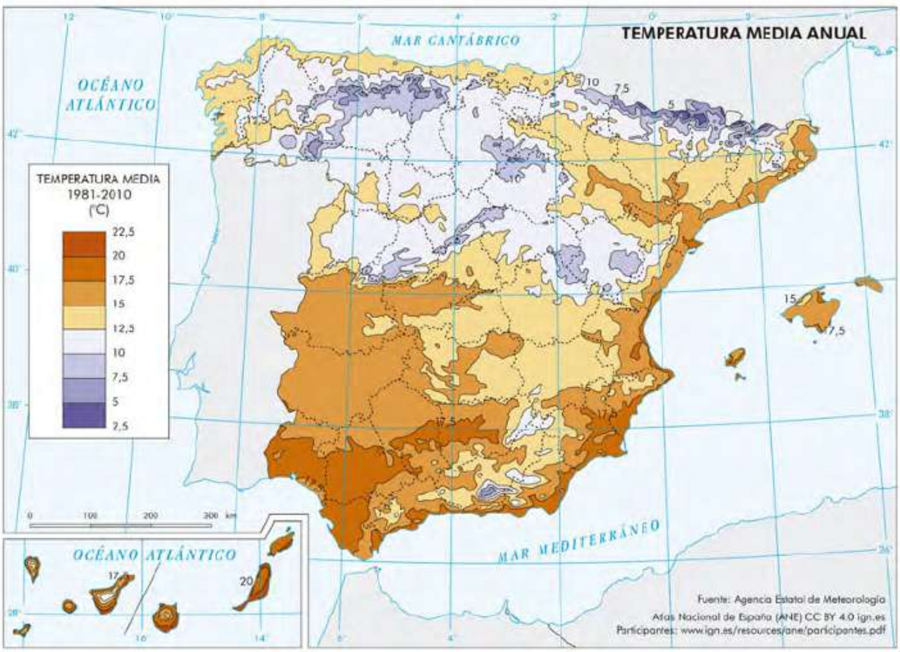
3.5. Spain — Brief contextualisation

Relevant economic, social and geographical indicators:

Spain, with 48.3 million inhabitants, is the fourth most populous country in Europe, the fourth largest in terms of GDP and the fourth largest energy consumer. Electricity access coverage is 100%, both urban and rural (World Bank, 2022).

Annual average temperatures in the country vary between 0°C and 22°C. The lowest temperatures are recorded in the Pyrenees, the Cantabrian Mountains, Sierra Nevada, while the highest are found in the extreme south, particularly on the coasts of the eastern Canary Islands. In winter, the climate is cold in the interior of the northern half of the peninsula, with temperatures not exceeding 6°C, while in the south it is milder, with average temperatures twice as high. During the summer, the north of the Iberian Peninsula enjoys moderate temperatures, below 18°C. However, as one moves southwards, the values increase progressively: in the Northern Meseta they rise by about two degrees, in the Southern Meseta and the Ebro valley by four, and in Andalusia the increase reaches eight degrees, which results in very hot summers, with average temperatures in July exceeding 26°C.

Figure 28. Average annual temperature, 1981-2000, Spain

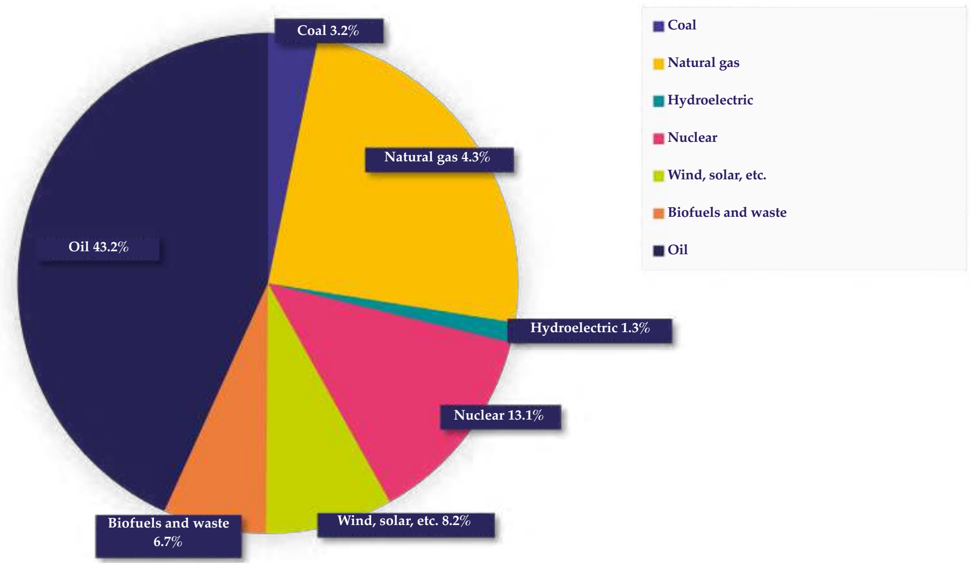


Source: National Geographic Institute of Spain (2024)

Energy matrix:

Spain, until the 20th century, was a coal-producing country, with mines in the Cantabrian Mountains, the eastern Iberian Mountains and the Sierra Morena. The closure of this sector in 2019 — the result of a long-term national policy agreed with the European Union — the absence of oil and the limited potential of natural gas fields, have turned the country into a net importer of fossil fuels. In 2022 they accounted for almost 68% of Spanish TES.

Figure 29. Total Energy Supply (TES), 2022, Spain



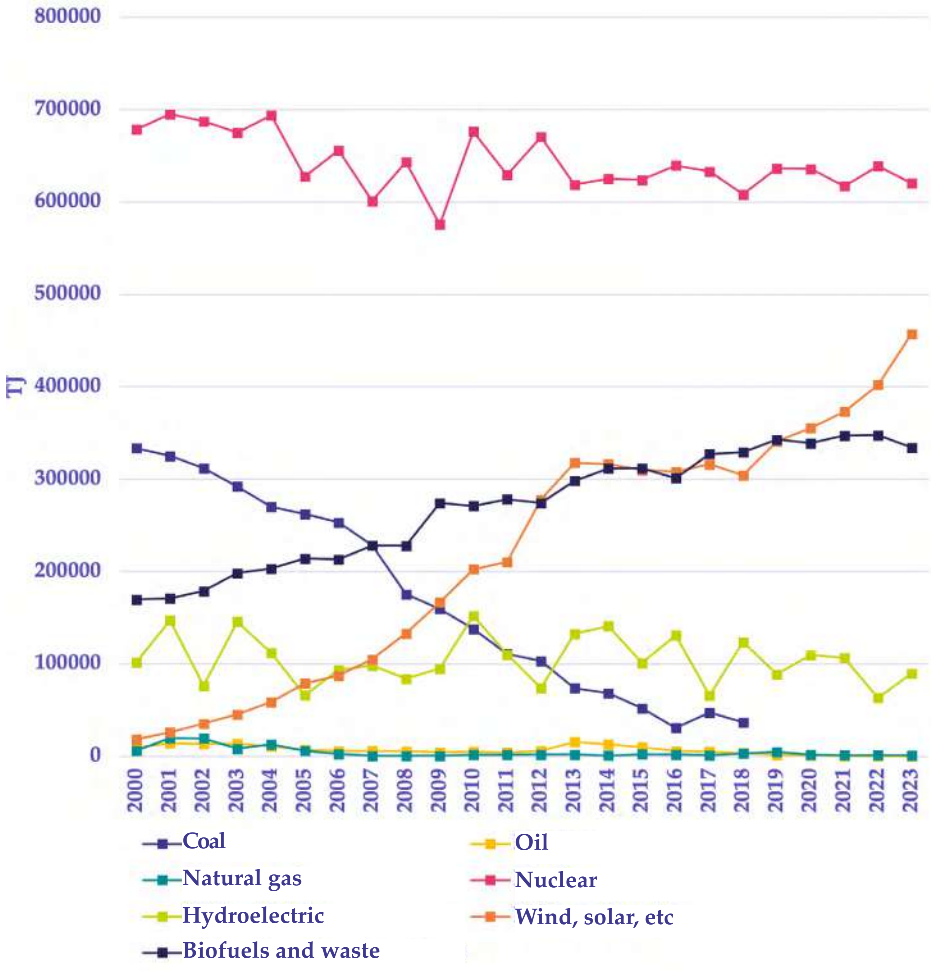
Source: Prepared by the authors with data from IEA (2025d)

Just under a quarter of TES was produced domestically in 2023; 77.1% of TES was imported. Thermal power plants receiving imported oil supply about half of Spain's electricity needs. To address its energy shortage, the Spanish government adopted an ambitious nuclear energy programme in the 1960s that led to the construction of 10 nuclear power plants. Since the early 1990s, the government tried to advance the penetration of renewable energy sources by closing three nuclear power plants. The seven operational nuclear power plants generate one fifth of the TES.

In this process in 2007, solar thermal power plants were opened near Seville and wind farms were opened across the country, generating a third of the country's energy. Renewable energy production increased by 141% between 2000 and 2023 to cover more than half of the national energy production in 2023 (58.6%, produced by renewables and waste). The country also relies heavily on hydropower, provided mainly by its northern rivers, which produce 5.6 per cent of its electricity.

Total domestic energy production did not change significantly between 2010 and 2023, but its composition did change, with a significant reduction in the share of coal, offset by an increase in renewables.

Figure 30. National energy production by type of source, 2000-2023, Spain

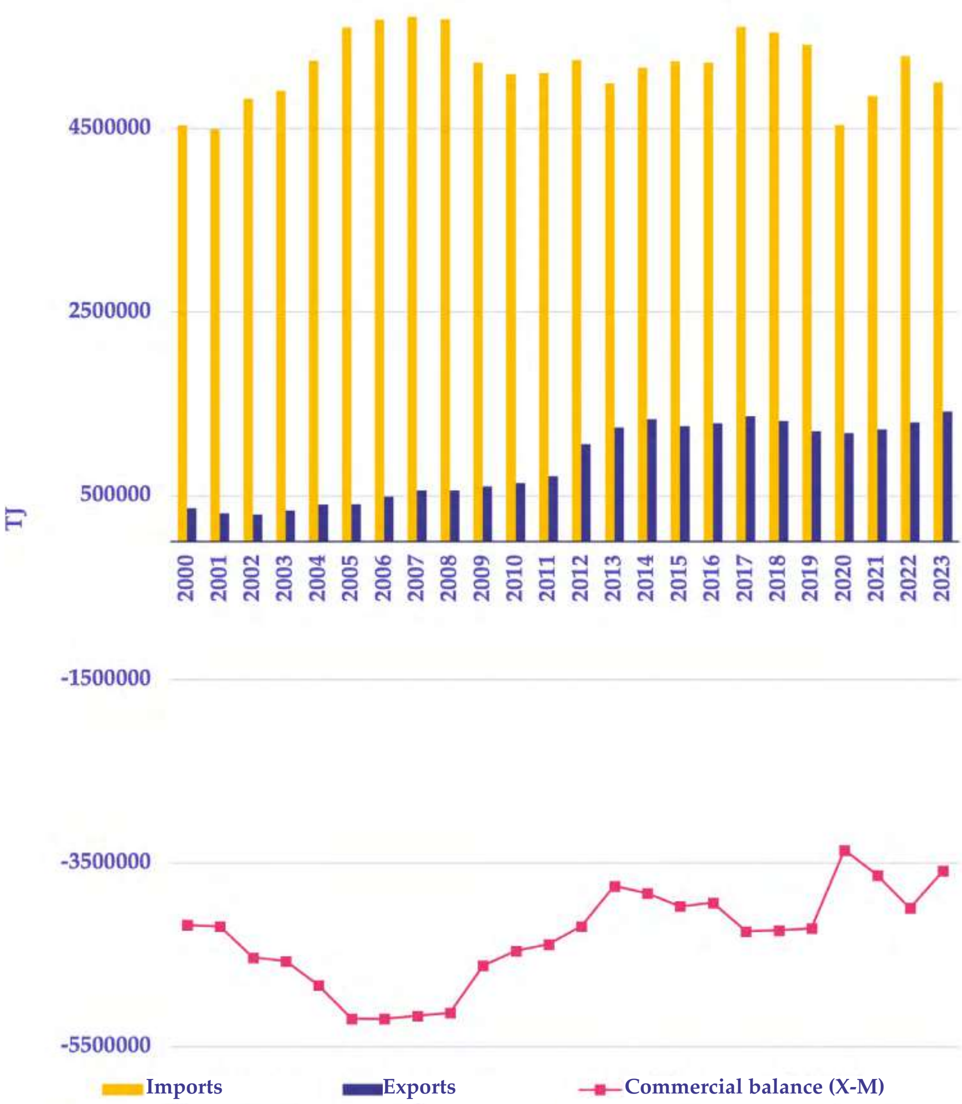


Source: Prepared by the authors with data from IEA (2025d)

Energy trade balance

The country is a net energy importer, 77% of the energy consumed is imported (IEA, 2023). The most relevant energy imports are fossil fuels, as shown in Table 2. Spain, like all European countries, had to redirect its natural gas imports after the outbreak of the war in Ukraine. In line with the reduction of gas purchases from Moscow, the weight of imports from other countries, in particular Algeria, has been increasing.

Figure 31. Trade balance of energy products, Spain, 2000-2023



Source: Prepared by the authors with data from IEA (2025d)

The government aims to reduce energy import dependence from 73% in 2017 to 61% in 2030, based on energy efficiency measures and a reduction in oil consumption. It is estimated that this change will result in savings in fossil fuel imports of 13.3 billion euros by 2030.

Table 2. Spain's imports of energy products

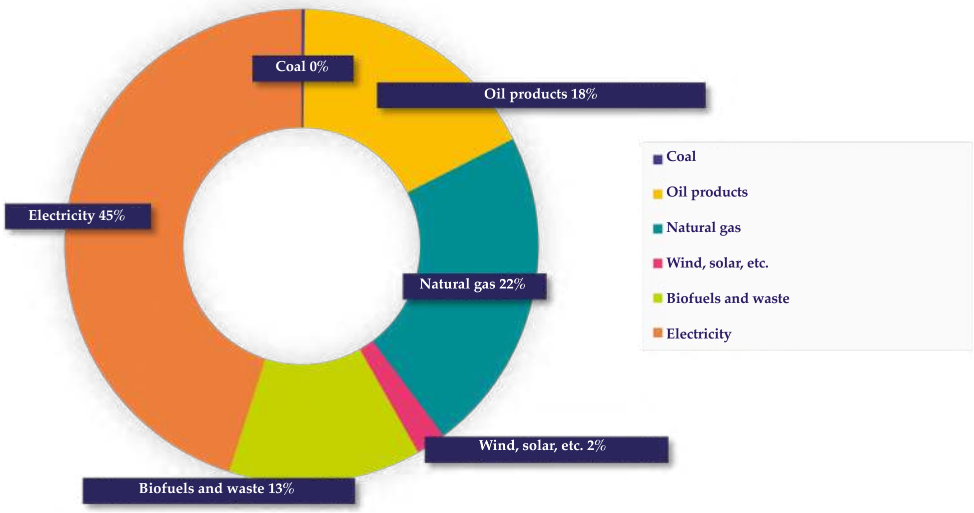
Type of products	Countries of origin (first 3, % of total imported product)	Value
Crude oil	USA, 16.4%; Mexico, 10.5%; Nigeria, 10.2%	$35.7 billion; 7.94% of total imports
Petroleum gas	Algeria, 30.4%; USA, 24.4%; Russia 15.7%	$15.8 billion; 3,5% of total imports
Refined oil	Italy, 18.2%; Netherlands, 10%; India, 9.3%	$10.5 billion; 2.3% of total imports

Source: Prepared by the authors based on data from OEC trade, 2023

How is energy consumed at the residential level?

The residential sector accounts for about 17% of total energy consumption, of which about 40% corresponds to energy consumption associated with household heating. The residential sector is responsible for about 12-15% of total greenhouse gas emissions, with a much lower share than the rest of Europe (del Barrio Partner, L., Olivera, C., 2023).

Figure 32. Residential sector energy consumption by type of source, 2022, Spain



Source: Prepared by the authors with data from IEA (2025d)

State of energy poverty

The energy poverty rate (EP, measured as the percentage of households that cannot keep their homes adequately warm) in Spain is one of the highest in Europe and is one of the fastest growing among European countries (Burguillo et al., 2025). According to Eurostat (2025), EP in the country has risen from 7.5% in 2019 to 17.1% in 2022, the year of the great energy price crisis in Europe. In 2022, Spain ranked fifth by EP in the EU, after Bulgaria (22.5 %), Cyprus (19.2 %), Greece (18.7 %), Lithuania and Portugal (17.5 % for both countries). It is the EU member state that has experienced the steepest increase in EP in recent years.

Public policies against energy poverty

In 2022, the Spanish government adopted a comprehensive set of measures to mitigate the impact of the crisis on vulnerable consumers (Llopis and Baute, 2023; Ministry for Ecological Transition, 2019). The main policy interventions were:

- Electricity social bonus: Their income limits were increased and a new category of beneficiaries — "Energy Justice" — was introduced with a 40% discount on electricity bills (Royal Decree-Law 18/2022). In addition, the discount applied to the electricity price — up to a maximum consumption — was increased twice from 25% and 40% to 65% and 80%, respectively for vulnerable and severe vulnerable consumers.

- Thermal social bonus: The average amount of this heating subsidy for vulnerable consumers increased by 246% compared to 2021.

- Disconnection guarantees: The government implemented a ban on disconnection of vulnerable consumers until the end of 2022 (then extended this until December 2023).

In addition, a comprehensive set of measures was adopted to mitigate the impact of the crisis on small consumers. The main ones can be summarised as follows:

- Value Added Tax (VAT) rebate [10] on electricity consumed by households.

- Suspension of the 7% tax on electricity generation (in force from the end of June 2021 - RDL 12/2021).

- The Iberian Derogation or gas cap in the wholesale electricity market (González Salas Mosquera et al., 2022), in force since June 2022. This adjustment mechanism was accompanied by a fund to compensate electricity companies for the difference between the regulated price and the market price of gas, in order to reduce their costs and avoid passing it on to consumers.

---

10 Reduction of VAT on electricity bills from 21% to 10% (from the end of June 2021 — RDL 12/2021), subsequently reduced to 5% from 1 July 2022 (RDL 11/2022), for households with less than 10 kW of contracted power. Reduction of VAT on natural gas from 21% to 5% from October 2022.

- Promotion of energy efficiency and self-consumption initiatives, such as subsidies for the installation of solar panels, smart meters and LED lighting.

- Public awareness campaigns to encourage consumers to reduce their electricity consumption, especially during peak hours, and to switch to more efficient appliances and tariffs.

All these measures fall under the framework of the National Strategy against energy poverty 2019-2024, drafted by the Ministry for Ecological Transition, submitted for public consultation and approved by the Council of Ministers on 5 April 2019.

The National Strategy establishes, for the first time, a definition of the situation of energy poverty and vulnerable consumers, makes a diagnosis of the situation in Spain, determines lines of action, and sets targets for reducing this social problem that affects more than 3.5 million people in the country.

The electricity distribution system is mostly public in terms of transmission infrastructure (high voltage), while distribution/commercialisation is private. The company Red Eléctrica de España (with a majority public shareholding) is responsible for the transmission and distribution grid. On the distribution side, there are a number of licensed distribution companies, some of them private, while regulation and supervision is carried out by public bodies.

Which institutions and bodies regulate the Spanish energy market?

- The Ministry for Ecological Transition and the Demographic Challenge leads the formulation of energy policy and governs basic energy competences at the national level (while the autonomous communities are responsible for areas such as the authorisation of certain power plants and energy grids) (IEA, 2021). The Ministry, among other competences, is responsible for legislation regulating the tariff structure, prices of energy products, energy and mining regulations, energy saving legislation, promotion of renewable energies, and legislation on measures to guarantee energy supply.

In turn, this body has under its direction some key institutions in the energy field:

  - Secretariat of State for Energy

  - Fair Transition Institute, which oversees the economic transition of regions where coal mines and coal-fired power plants are being closed

  - Institute for Energy Diversification and Saving, which oversees research programmes on electrification, mobility, energy efficiency and renewable energies, among others.

- Comisión Nacional de los Mercados y la Competencia (CNMC is the Spanish acronym) (National Commission of Markets and Competition) is an independent regulatory body under the direction of the Congress of Deputies. In the field of energy, among other competences, it is responsible for the supervision and control of the proper functioning of energy markets and the calculation of network access tariffs on the basis of transmission and distribution costs.

4. METHODOLOGY AND DATABASES: DESCRIPTION, STRENGTHS AND WEAKNESSES

4.1. Germany

To analyse the determinants as well as the dynamics of energy poverty in Germany, this research is based on the German Socio-Economic Panel (SOEP) dataset. SOEP is a nationally representative household survey conducted annually since 1984 by the German Institute for Economic Research (DIW), whose target population is the population residing on German territory.

SOEP focuses on the analysis of quality of life with objective and subjective indicators of well-being. Among the central topics contained in SOEP that are of interest for this study are household and population demographics, education and skills, occupation and employment, income, housing characteristics, and expenditure on household energy services.

The SOEP survey employs a stratified, multi-stage sampling design, with a probabilistic selection of households and individuals within households. The sample includes approximately 30,000 individuals in more than 15,000 households, ensuring a representative coverage of the German population. Given its longitudinal nature, the survey follows the same individuals and households over time, incorporating new cohorts to maintain representativeness and capture socio-demographic dynamics. Particularly in 2022, the year of analysis of this research, the sample size was 19,876 households with approximately 19.92% of missing data for the energy poverty variables, because no electricity and heating expenditure data were recorded for those households, and energy indigence due to non-response in one of the variables used for its construction, as detailed in section 4.

SOEP's interview methodology is based on a set of pre-tested questionnaires for households and individuals. Information is collected through annual interviews conducted through face-to-face, self-administered surveys of all members of a given household aged 12 and over. In addition, the head of household is asked to answer a household-related questionnaire, which includes information on housing, housing costs and different sources of income.

SOEP also has a distinct file structure, organising information into different datasets:

- Individual and household data: Income, employment, education, health, housing conditions, and family dynamics.

- Specific thematic modules: Social mobility, subjective well-being, discrimination, social networks, and political attitudes.

- Additional information: Regional level information, retrospective biographies, and specialised surveys on specific groups (such as immigrants or older adults).

One of the advantages of the SOEP survey is its harmonisation with surveys in other countries. For example, SOEP mimics the data structure of the European Union Statistics on Income and Living Conditions (EU SILC). Another advantage is the extension of sub-samples on specific groups, which has given better representativeness to minority population groups, and the possibility to analyse relevant issues longitudinally.

Among its limitations, SOEP suffers from the typical longitudinal survey problem of sample attrition. The existence of under-represented minority groups, even with the incorporation of sub-samples, is another strong limitation.

Also, there are variables with different collection periodicity that may compromise the analyses. Finally, the variable on "monthly costs of gas not used for heating" was not included in the survey for this period, as according to SOEP (2022), this variable was only collected in 2014. However, none of these limitations significantly affects the proposed study, since it is a cross-sectional analysis and the variables of interest have the same periodicity.

4.2. Argentina

As mentioned in section 3.a of this study, the data requirements to carry out the proposed analysis are not negligible. The information base that meets the requirements, although not without limitations, is the National Household Expenditure Survey (ENGHo is the Spanish acronym). It is carried out by INDEC, with a variable frequency. The first edition was held in 1985-1986, followed by the 1996-1997, 2004-2005, 2012-2013 and 2017-2018 editions. The ENGHo is a survey conducted in urban centres with a population of 2,000 inhabitants or more. It is a comprehensive source of information, providing insight into the living conditions of urban households, especially in terms of access to goods and services, and income. The information collected is used, among other things, to adjust the weights in the calculation of the Consumer Price Index, the structure of the basic basket of goods, to estimate national accounts, and to contribute to the design of public policies.

This study works with the 2017-2018 edition of the ENGHo because it is the last one carried out in the country and incorporates a Special Energy Module, thanks to a technical cooperation agreement between the Secretariat of Energy and INDEC in 2017. This special module aimed to extend and update the equipment section of the ENGHO 2012-2013 and adds, in addition to ownership, questions on equipment usage, age of equipment, energy efficiency label if applicable and other questions linked to energy use. The aforementioned differential of ENGHo 2017-2018 makes it a fundamental input for the development of energy policies aimed at the residential sector.

The 2017-2018 edition surveyed 45,000 households in Argentina, following a probability sample that ensures representativeness at national, regional and provincial levels. Applying the expansion factors, this edition reaches 13.3 million households in Argentina's urban areas.

In order to reduce the costs of large-scale surveys, INDEC uses a master sample scheme. In other words, it uses a single probability sample, known as the Master Urban Sample of Dwellings of the Argentine Republic (MMUVRA is the Spanish acronym), which is characterised by keeping the area units that make it up and its associated probability structure fixed. The sampling process of the ENGHo 2017-2018 is defined by three stages, which guarantee the desired representativeness.

The unit of analysis of the ENGHo is households; however, with the aim of surveying their socio-economic and demographic conditions, information is collected at the housing and individual level. The survey consists of 5 questionnaires: household characteristics, daily expenses, miscellaneous expenses, personal expenses, income. These questionnaires result in 6 different databases: households, persons, equipment, expenditure, items and habits. Given the information requirements of this work, all databases, with the exception of the habit database, had to be spliced.

One of the benefits of using the 2017-2018 ENGHo is that given the relevance of the energy issue in this edition, the omitted responses in the variables of interest represent 0.17% of the total base. On the other hand, the detail in terms of equipment for the satisfaction of energy services, energy consumption habits and energy expenditure, has no other similar precedent at the national level. One of the weaknesses of the survey is in terms of consumption; in fact, several authors mention the anomalous and inconsistent behaviour of consumption variables in terms of quantities (Poggiese and Ibáñez Martín, 2024). Another weakness is that there is neither an update nor a new survey in the post-pandemic era.

The two weaknesses mentioned are relevant in terms of this work in two senses: on the one hand, the work is focused on energy inequalities after the COVID-19 pandemic (in fact, the other countries are analysed with databases from 2022); on the other hand, the weakness in the survey of energy consumption makes it impossible to calculate the updated energy expenditure of Argentine households.

To overcome both difficulties, in this paper we proceeded to estimate household energy consumption (in quantities) following the methodology proposed by Dubois, Zabaloy and Ibáñez Martín (2023) and then update household energy expenditure by applying the tariff tables for natural gas, electricity and bottled gas prices to the year 2022, following the proposal of Poggiese and Ibáñez Martin (2024). The procedure involves the following steps:

1. Adjust the declared energy consumption according to the characteristics of the household: building conditions, location, number of members and declared equipment.

2. Once the adjusted energy consumption, in quantities consumed, has been achieved, the tariffs updated to 2022 are applied. The tariff charts currently in force in each of the 24 provinces (23 provinces and the Federal Capital) of Argentina were used.

3. The calculated energy cost is imputed with the tax components according to each jurisdiction's regime.

4. Depending on the characteristics of the household (vulnerability status and income), the subsidies applicable to 2022 are imputed[11].

5. The consolidated energy expenditure by energy source is obtained for each household in the sample.

This procedure makes it possible to work for the Argentinean case with energy expenditure estimates updated to the year of interest, 2022. The modelling of consumption, using the procedure described above, is not without its criticisms and weaknesses. However, it is a robust strategy used in specialised literature that allows working with the four selected countries at the same point in time. The robustness of this estimate was tested on the basis of other economic variables linked to energy consumption, such as Gross Domestic Product per capita and household income per capita by income decile. The modelling for these variables shows an evolution congruent with the evolution of the estimated energy consumption at household level, calculated by income decile.

4.3. Colombia

The source of information selected for the study is the Quality-of-Life Survey (LCS is the Spanish acronym) 2022, produced by the National Administrative Department of Statistics (DANE). This survey aims to analyse and compare the socio-economic conditions of Colombian households.

The LCS collects information on different aspects and dimensions of household well-being. Specifically, it looks at the characteristics of the dwellings and their surroundings, the living conditions of the households and the demographic and socio-economic characteristics of the people who make up the households.

With respect to households, the LCS covers aspects of interest for this research such as the quality of public, private or communal services; tenure of housing and assets; perceptions of living conditions, poverty and security; and household expenditures.

11 It is worth noting that in 2021 Argentina implemented the extension of the Cold Zone Law, which is included in the calculations. On the contrary, since the implementation of tariff segmentation was launched in September 2022, the subsidy calculations were made on the basis of the tariff tables in force prior to the implementation of tariff segmentation. This implies that energy expenditures are calculated under the universal energy subsidy scheme, in force in the country until 2022.

The unit of analysis of the LCS is dwellings, households and persons, although in this study the object of analysis is households. Thus, the Household Data module was initially taken and spliced with the surveys containing household information, where only information referring to the main household of a dwelling was considered. The splicing between these LCS modules meant the exclusion of 0.51% observations, given the existence of dwellings with multiple cohabiting households.

Additionally, in order to carry out the socio-economic characterisation of the household, it was necessary to splice the module at the individual level (persons) and only the socio-demographic characteristics of the head of household were considered. There are approximately 87,878 households in the data sample, which when expanded represents 17,413,863 households in Colombia. It is worth noting that for the energy poverty indicators there are approximately 3.03% of missing data in relation to the total sample due to households that did not report an energy expense because it was included in the rental value.

The sample design for the LCS is probabilistic, multistage, stratified and clustered. LCS coverage is national and can be disaggregated by department and by nine regions of the country (Bogotá, Antioquia, Valle del Cauca, Caribbean, Eastern, Central, Pacific, Orinoco-Amazon, San Andrés).

One of the advantages of using the LCS is that it allows obtaining recent and updated information on socio-economic conditions at household, household and individual levels and on the budget spent for the satisfaction of essential services, which is a key instrument for the definition of national and targeted energy policies.

Given that the main objective of the LCS is not to survey household expenditure, this could be a weakness in the choice of this database. In the same vein, there is no specific variable on exclusive expenditure on piped gas (LPG) for cooking. This is not a minor constraint, considering that this is one of the energy sources most used by low-income families or in areas where there is no piped gas network. However, the survey includes the question on expenditure on natural gas consumption for cooking and a strength of the LCS is that it asks the respondent to confirm the value paid for these two energy sources, electricity and gas for domestic use.

4.4. Spain

In the case of Spain, the Household Budget Survey (Encuesta de Presupuestos Familiares, HBS), carried out by the Spanish National Statistics Institute since 1958, is used. The main purpose of the HBS is to collect information on the nature and destination of Spanish households, as well as various characteristics of living conditions.

With the methodological change implemented in 2006, the periodicity of the HBS changed from quarterly (imposed since 1997) to annual. The version implemented since 2006 incorporates several improvements, the most relevant of which is the increase of the sample to 24,000 dwellings. In addition, with the change, the following priority objectives were established:

- Obtain information on annual household expenditure on certain priority items, with national and Autonomous Community level representation.

- Obtain the year-on-year comparison of aggregate consumption expenditure, for the country and the Autonomous Communities.

- Estimate the consumption in physical quantities of selected foodstuffs and energy sources for the country as a whole.

As can be seen, the energy issue is a priority in the survey carried out by the INE. This translates into an almost total completeness in the answers concerning expenditure, consumption and demand for energy sources (only 0.1% of answers in variables relevant to this work are omitted for the year 2022).

The HBS follows a methodology based on a stratified, multi-stage probability sample design, with random selection of dwellings in each primary sampling unit. The annual sample is made up of approximately 24,000 households, guaranteeing the representativeness of the different socio-demographic and territorial groups. To ensure that the data are representative of the Spanish population, weights and weighting factors are applied to adjust the sample to the socio-demographic and territorial characteristics of the country. Applying these factors, the 2022 edition reaches 18.9 million households in Spain.

The scope of the survey covers the entire Spanish territory, including both urban and rural areas. Data collection is carried out through direct interviews and household self-administered expenditure diaries, supplemented by additional information obtained from administrative sources.

In terms of expenditure classification, the HBS uses the ECOICOP (European Classification of Individual Consumption by Purpose) nomenclature, an international standard that allows for homogeneous comparison of consumption across EU countries. ECOICOP categorises household expenditure into different groupings, facilitating studies on consumption structure, demand elasticities and inequalities in access to essential goods and services. Data derived from the HBS are widely used in studies on income distribution, poverty and welfare, as well as in the construction of macroeconomic indicators, including the measurement of the Consumer Price Index (CPI) and the estimation of aggregate demand in economic policy models.

The HBS is published in several databases organised in Excel files, each designed to provide specific information on household expenditure. In general terms, the HBS is structured in three main blocks of data: microdata, results tables and time series. The micro-data contain disaggregated information at household and individual level, allowing for detailed analyses of individual expenditure, socio-demographic and economic characteristics of households. These files include variables on income, household composition and housing characteristics, as well as the amounts spent in each consumption category. For this work it was necessary to splice the three bases that complete the information of the HBS 2022.

Finally, like any respondent-declaration survey, the HBS may be affected by recall bias (under-reporting of certain expenditures), non-response rates in some segments of the population, inaccuracies in the method of collecting certain expenditures, such as those made in cash versus those recorded electronically.

4.5. Methodology

4.5.1. Variables

The empirical work aims to explore energy inequality among households in Germany, Argentina, Colombia and Spain.

As mentioned in the theoretical section, section 2 of this report, energy inequality encompasses energy deprivation at different levels of severity. The study will focus on the analysis of energy indigence, poverty and vulnerability, which are the dependent variables of the logistic estimations that follow.

Table 3 summarises the empirical definition of each of the concepts. It should be clarified that these definitions were adapted to the comparative objective of this study, so that the construction of the variables not only attempts to capture the phenomenon, but to construct it in a similar way in the four economies under study.

Table 3. Dependent variables: energy deprivation

Dependent variable energy deprivation	Description
Energy indigence	Dichotomous variable whose value is 1 if essential energy services (cooking, heating, domestic hot water, depending on the country) are met in the household with solid or unclean liquid fuels. For Germany, due to the availability of information in SOEP, this energy deprivation was represented as: Dichotomous variable whose value is 1 if the household has no thermal insulation and is at risk of monetary poverty after paying energy costs (High Cost-Low Income).

Energy poverty	Dichotomous variable whose value is 1 if the household is considered energy poor, due to excessive energy expenditure, and zero otherwise. This deprivation is measured through two indicators: *Energy poverty 1: ratio 10%* whose value is 1 if the household spends more than 10% of its total monthly income on energy payments and zero otherwise *Energy poverty 2: 2M* whose value is 1 if the household has an energy expenditure relative to income of more than twice the national median and 0 otherwise.
Energy vulnerability	Dichotomous variable whose value is equal to 1 if the household is at risk of monetary poverty, precarious material in the dwelling or deficient equipment. For the case of Germany, due to the availability of information in SOEP, this variable is defined as: Dichotomous variable whose value is equal to 1 if the household is at risk of monetary poverty or considers the size of the dwelling to be small. The operational definition of these variables can be found in Table 4.

Source: prepared by the authors based on section 2b

It is important to note that, although in the case of Germany the construction of energy deprivation has certain particularities that could lead to deviations from the other countries included in the analysis, care has been taken to maintain the criterion of severity as a guiding principle, which allows the comparative validity of the study to be preserved.

The indicators used in this research were selected based on the evidence available in the specialised literature and the accessibility of data in the countries analysed, with the aim of capturing energy differences and inequalities between European and Latin American countries. Traditionally, the literature has grouped energy deprivation indicators into three main approaches: i) expenditure-based metrics; ii) consensus metrics (Rademakers et al., 2016); and iii) metrics focused on access to energy services (Guzowski et al., 2021)[12].

Given the availability of survey data in the four countries included in the study, the analysis focused mainly on indicators based on expenditure and access to modern energy sources.

Energy poverty was defined using two expenditure indicators widely used in the literature: the Ten Percent Rule (TPR) and the 2M indicator. The aim of using both is to capture the size of overspending from both an absolute and a relative perspective. The TPR considers a household to be in energy poverty if it spends more than 10% of its income on basic energy needs. Although

12 Expenditure metrics define energy poverty in terms of the proportion of household income spent on energy consumption. Consensual metrics, on the other hand, identify households that report difficulties in meeting their basic energy needs, reflecting a subjective perception of deprivation (Rademakers et al., 2016). Finally, metrics focusing on energy services refer to effective access to modern household energy sources — such as electricity, natural gas or LPG — beyond the level of energy expenditure (Guzowski et al., 2021).

it is a simple and straightforward measure, it has been criticised. In contrast, the 2M indicator states that a household is in energy poverty if its energy expenditure is more than twice the median expenditure and, at the same time, its equivalent income is below the median. This metric introduces a more contextualised and relative view of energy deprivation. Several studies highlight the advantages of the 2M indicator over the TPR, despite its less widespread use (Ibáñez Martín et al., 2024; Opatrný, 2023; Tirado Herrero and Jiménez Meneses, 2020; Gouveia, Palma and Simoes, 2019; Thomson, Bouzarovski and Snell, 2017):

- It avoids false positives: Unlike the TPR, the 2M reduces the possibility of identifying high-income households that simply have high energy consumption due to housing choice or size as energy poor.

- It incorporates a relative perspective: As it is based on median income and expenditure, the 2M is better adjusted to local economic conditions, unlike the fixed 10% threshold, which is less sensitive to regional or conjunctural contexts.

- It is more robust to extreme data: The TPR may overestimate energy poverty in cases of extremely low income, while the 2M, by considering full distributions, mitigates this effect.

- Better identification of real exclusion: The 2M allows for a more accurate identification of households that are truly unable to access adequate energy services for structural reasons, rather than due to voluntary consumption decisions.

The empirical definition of the problem of energy vulnerability aims to identify those factors that place households at a higher risk of suffering more severe energy deprivation, taking as a reference the ideas of Middlemiss and Gillard (2015), in which "the concept of energy vulnerability refers to the predisposition of certain households or communities to experience energy poverty due to structural and socio-economic factors, such as low income, housing inefficiency, and dependence on inadequate energy systems."

For the construction of the variables detailed in Table 3, it is necessary to determine intermediate variables that feed into or form part of the energy deprivation variables under study. These variables are:

- Total monthly household income: It is obtained by adding up the individual income of all household members and includes amounts not attributable to a particular household member during a month.

- Household monthly expenditure on electricity/mains gas/packed gas/solid fuels: this is the value of expenditure on each of the sources reported by the household in the survey.

- Total monthly household energy expenditure: this is the sum of expenditures on all energy sources demanded by the household during a month.

Additionally, one of the research questions guiding this research is: Are there national and regional patterns among groups that are affected by energy deprivation of varying intensity? In order to provide an answer, it is necessary to identify relevant characteristics of the households and populations under study, which constitute the set of control variables in the logistic estimations and allow characterising the different energy deprivations. Table 4 describes the construction of each descriptive variable.

Table 4. Control variables: descriptive variables

Variable	Description
Gender PSH	Dichotomous variable taking value 1 if the main breadwinner is female and 0 otherwise.
Single-parent household	Dichotomous variable taking value 1 if it is a cohabiting household consisting of only one adult and at least one child and zero otherwise. That is, the PSH does not report spouse/cohabitant.
Feminisation of the household	Continuous variable taking a value from 0 to 1, constructed as the ratio between: number of women/ number of household members
Migrant PSH	Dichotomous variable taking value 1 if the PSH was born in a country other than the country of the survey and zero otherwise.
Age PSH	Categorical variable indicating the age of the PSH.
Race PSH	Dichotomous variable that takes the value of 1 if the HRH is Afro-descendant or indigenous and 0 otherwise, only for the case of Colombia.
Unemployment PSH	Dichotomous variable taking value 1 if the PSH is unemployed (unemployed, but actively looking for a job in the last week) and zero otherwise.
Low household educational climate	A household is considered to have a low educational climate if the main breadwinner has gone through the education system, but has not completed the first level of education. When incorporating the variables medium and high household educational climate, the base category is low educational climate.
Average household educational climate	Dichotomous variable taking value 1 if the PSH has completed at least secondary level of education.
High household educational climate	Dichotomous variable taking value 1 if the PSH has attended or completed university, technical or tertiary higher education.
Risk of monetary poverty	Dichotomous variable that takes the value of one if the household's disposable income is less than 60% of the national median income. It has a value of 0 otherwise.
Household size	Categorical variable that captures the total number of members permanently living in the household.
Household deficient in equipment	Dichotomous variable that has a value of 1 if the household lacks equipment to adequately satisfy at least one of the essential energy services in each country. • Argentina: heating, cooking, cooling of food and domestic hot water. • Spain Heating, cooking and cooling of food. • Colombia Cooking, food refrigeration and service provided by the washing machine.

Housing with problems	Dichotomous variable that has a value of 1 if the dwelling has problems in its building structure (roofs, floors, walls) and zero otherwise. This variable is constructed on the basis of the existence of deficit materials. For Germany, this variable takes a value of 1 if the size of the dwelling is considered to be small

Source: Prepared by the authors

Some of the control variables considered capture the three main elements of energy poverty (Figure 5). In particular: energy inefficiency is captured by "Household under-equipped" and "Housing with problems;" Low income is captured by "At risk of monetary poverty." High energy prices are indirectly captured by the two overspending indicators (10% and 2M).

4.5.2. Logistic regression

In order to answer the research questions, an econometric analysis using a logistic regression model(logit) was chosen. The main purpose of this type of model is to estimate the probability of a certain event occurring as a function of certain explanatory variables (Liao, 1994). Its use is particularly appropriate when dealing with situations characterised by categorical variables that do not comply with the continuity assumption (Gujarati and Porter, 2009; Williams, 2006).

In this study, the logit model allows us to examine the factors associated with the likelihood of experiencing energy deprivation of varying intensity, considering multiple household characteristics simultaneously. This makes it possible to identify the specific contribution of each factor, under equal conditions with respect to the others, and in comparison, with a reference category. As explained by Pindyck and Rubinfeld (1998), the impact of each individual variable depends both on its initial value and on the value adopted by the other variables included in the model.

The model can be expressed from the following functional form in Equation1:

$$logit(p_i) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \ldots + \beta_k X_{k,i} \qquad (1)$$

Where the parameters accompanying the explanatory variables are estimated via maximum likelihood and p_i is the probability that the event under interest happens.

The dependent variable, Y, corresponds to energy deprivation in its three levels of intensity. Among the explanatory factors considered are those indicated in Table 4, such as gender and race of the PSHs, single-parent household structure, lack of adequate equipment, among others. Explanatory variables may be dichotomous (e.g. "single-parent household", whose value is 1 if the household is a single-parent household, and 0 otherwise) or, in some cases, continuous (such as the age of the household head or the size of the household).

The coefficients obtained from the model allow us to determine, for example, whether the probability of a household being energy deprived is positively or negatively influenced by factors such as female headship, low income or low educational capital in the household. Given the objective of the study, the regressors of greatest interest are those related to the socio-economic level of the household and the physical conditions of the dwelling. However, other variables are also included in order to control possible statistical biases that could affect the dependent variable (Wooldridge, 2010).

4.5.3 Profiles

A common practice in the context of logistic estimation is the construction of profiles. This technique is used to facilitate the interpretation of results and to verify their validity within the framework of logistic models (Formichella and Kruger, 2019).

In general terms, profiles represent specific combinations of explanatory variables that allow estimating the probability of a given event occurring under different scenarios (Agresti, 2013; Hosmer, Lemeshow & Sturdivant, 2013). In this study, for example, it may be relevant to estimate the likelihood of a household experiencing energy indigence if it is female headed, has many members and is economically vulnerable. In this case, the logistic model would be estimated specifically for that type of household, in order to assess whether the combination of these conditions is significant in explaining the presence of energy indigence.

The use of profiles requires, as a first step, identifying those that are representative of the problem in question. For this, it is essential to have descriptive statistics relating to the phenomenon under study, as well as a preliminary estimation of comprehensive logistic models that include all relevant explanatory variables (Menard, 2002). This stage makes it possible to detect combinations of values that form characteristic profiles within the analysed universe. Screening can be supported by indicators such as measures of central tendency, percentiles or extreme cases that reflect different degrees of risk or exposure (Train, 2009).

Once the representative profiles have been defined, the adjusted logistic model is estimated for each one, with the aim of calculating the probability of occurrence of the event in question. This analysis allows us to observe how these probabilities vary according to the characteristics that make up each profile (Ibáñez Martin and Martínez, 2022).

Finally, comparing the adjusted results of the logistic models between the different profiles is key to understanding the weight of the explanatory variables in the occurrence of the phenomenon analysed, which in this case refers to the different types of energy deprivation (Agresti, 2013).

Following what is usually found in empirical work using this econometric strategy (Formichella and Kruger, 2019), this study works with two extreme profiles: households that are deprived in all dimensions that are statistically significant versus households that are not deprived in any of them. Thus, for example, if for Argentina the variables of gender, age and precarious housing are statistically significant in explaining greater chances of suffering from energy indigence, we work with a profile called “more deprived household”, which will be the one whose leader is a woman, who is older than the average age of the other heads of energy-poor households and who lives in a dwelling with construction problems. In turn, the probability of a household being in energy indigence is calculated as a “less deprived” household where the head is male, is younger than average in age and does not suffer from structural housing deprivation.

In addition, it also assesses the sensitivity of each of the variables in order to identify to which dimension the occurrence of energy deprivation under assessment is most sensitive. This strategy is pursued for the 4 economies under analysis and the three energy deprivations studied.

It is worth mentioning that the analysis of the estimates and profiles will be carried out separately for each country, given that energy inequalities are constructed from the interaction of multiple variables, social, economic and demographic, which combine in different ways and can aggravate energy deprivation according to each context (Heltberg, 2004; Ibáñez Martin, Melo Poveda and Zabaloy, 2021; Soares, et al., 2023). The results are then compared within and across regions.

5. EMPIRICAL ANALYSIS

5.1. Descriptive statistics for the countries analysed

Table 5 presents the descriptive statistics of the control/explanatory variables considered in this study. As can be seen, there are significant differences between the four economies analysed as well as between the two regions under study.

In particular, the data show that Germany has a higher proportion of single-parent and female-headed households compared to the other countries, although the proportion of female household members is lower in German households. In terms of household size, there are no significant differences between countries.

In relation to the migration dimension, Spain exhibits a higher presence of migrant leaders, and the average age of the main breadwinner (PSH) is higher than in Latin American and Caribbean (LAC) countries. The PSH disengagement affects European households to a greater extent, with the case of Spain in 2022 standing out in particular.

Regional differences are less marked in terms of educational attainment. In Europe, it is more common for the household leader to have attained a higher level of education (an indicator of a high educational climate) compared to LAC. The distribution by educational level of the PSH is more diverse in European households, while in Latin America a more balanced distribution between the three levels predominates. However, there is a higher incidence of low educational climate in Argentina and medium level in Colombia.

In terms of material conditions, poor equipment affects about two thirds of households in Spain and Argentina and is less common in Colombia. On the other hand, the lack of adequate housing affects less than 20% of households in all four countries, with no significant differences.

Finally, residential electricity coverage is high in Argentina, Colombia and Spain. The main regional difference is in access to the natural gas network: Argentina leads with the highest coverage, followed by Spain and, in last place, Colombia, where at least half of the households lack this service. Although the German database (SOEP) does not include this variable, IEA data indicate that approximately 50% of households in Germany use natural gas as their main heating source.

Table 5. Descriptive statistics for control variables by country

Variables	Germany	Argentina	Colombia	Spain
Gender PSH				
Woman	53.73%	41.10%	44.23%	33.53%
Man	46.27%	58.90%	55.77%	66.47%
Single-parent household	56.24%	33.40%	44.37%	10.4%
Feminisation of the household	41.94%	52.11%	50.58%	51.46%
Migrant PSH	No information	No information	3.96%	12.88%
PSH age (average)	53.91	48.43	48.42	55.61
Race PSH	No information	No information	12%	No information
Unemployment PSH	3.87%	3.08%	3.11%	11.16%
Household size (average)	1.99	3.41	2.95	2.81
Home Educational Climate				
Low	2.42%	39.50%	32.72%	15.59%
Medium	55.69%	32.98%	39.67%	46.21%
High	32.42%	27.52%	27.61%	38.19%
Risk of monetary poverty	25.35%	40.83%	20.29%	29.31%
Household deficient in equipment	NA	66.28%	39.51%	61.6%
Housing with problems	14.82%	16.62%	12.07%	16.05%
Access to electricity	NA	99.93%	98.58%	99.67%
Access to natural gas	NA	62.82%	31.47%	51.61%

Source: prepared by the authors based on SOEP, ENGHo, LCS and HBS.

Table 6 shows the incidence of energy deprivation according to different levels of intensity. At first glance, no significant differences between regions are evident, indicating that no area is clearly more affected by energy inequality than another. However, deprivation manifests itself unevenly both between and within regions.

The most extreme form of this deprivation, energy indigence, hits Latin American households hardest, especially those in Argentina. This situation cannot be directly compared with the case of Germany, as the SOEP database does not include information on the energy sources used. In the German context, energy indigence is defined as the lack of thermal insulation and the condition of being at risk of monetary poverty after paying energy costs, following the criteria of the *High Cost-Low Income indicator.*

Table 6. Energy deprivation of varying intensity by country

Energy deprivation	Germany	Argentina	Colombia	Spain
Energy indigence	5,50%	15,96%	9,02%	11,51%
Energy poverty				
Energy poverty 1: 10%	22,13%	17,18%	21,04%	26,29%
Energy poverty 2: 2M	18,42%	29,47%	19,75%	31,15%
Energy vulnerability	36,40%	68,14%	48,01%	23,53%

Source: prepared by the authors based on SOEP, ENGHo, LCS and HBS.

Energy poverty, understood as excessive energy expenditure, shows a marked sensitivity according to the indicator used for its measurement in all the countries analysed, although its severity is particularly notable in Argentina. When applying the first indicator (the 10% ratio), energy poverty seems to affect European households more intensely, exceeding 20% of households in both Germany and Spain. This result is consistent with the strong weight of energy subsidies in Latin America, which significantly reduce the costs that consumers must assume with respect to the energy they consume.

The second indicator (2M) shows a different pattern to the 10%, with a higher incidence of energy poverty in Argentina and Spain, where approximately 30% of households are affected. In the Argentinean case, using the 2M indicator implies an increase of 12% over the first indicator, which could reflect the existence of significant hidden energy poverty.

Energy vulnerability, on the other hand, exhibits the most heterogeneous behaviour among the economies analysed. In Germany, this form of deprivation reaches about 36.40% of households, largely due to the perception of household size being inadequate according to the family or the risk of monetary poverty. It is relevant to note that energy vulnerability affects at least half of the households in the two Latin American countries studied.

The analysis of the descriptive statistics presented in Table 6 shows that:

- Energy deprivation, at different levels of intensity, affects a significant proportion of the population in all the countries analysed.
- Contrary to what might be assumed, these deprivations are not concentrated exclusively in the least developed countries.
- Within each region, the problems vary in intensity, and there is no clearly more severe energy inequality in a specific economy. In contrast, the incidence of different forms of energy deprivation varies between countries depending on the indicator considered.

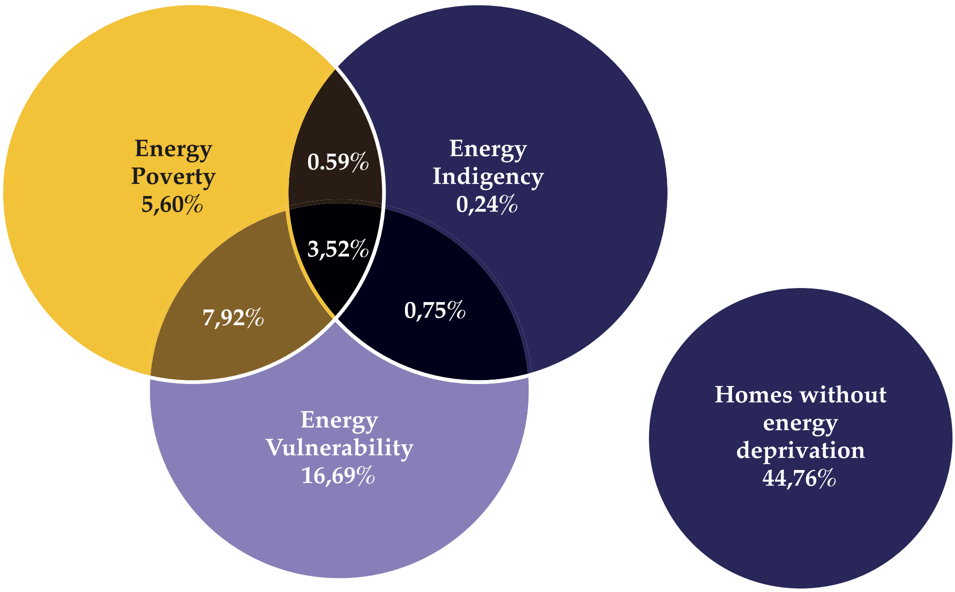
5.2. Results by country

5.2.1. Germany

In 2022, 35.31% of German households suffered from some form of energy deprivation, i.e. around 14 million out of the 39,809,277 households analysed in the expanded sample.

Figure 33 shows that 0.24% of households suffer from energy indigence only, 5.60% from energy poverty only and 16.69% from vulnerability only. The transposition of the three problems reaches a level of 3.52% of German households, so it could be said that, in these households, the intensity of energy inequality is more profound than in other households that only suffer from one or two of them. It should be noted that the energy poverty and indigence indicators have approximately 16.69% of observations with missing data in relation to the total size of the expanded database. Details on the casuistry and treatment of these observations with missing data can be found in the methodological annex.

Figure 33. Incidence of energy inequality in Germany by deprivation and co-occurrence



Source: prepared by the authors based on SOEP

More than 70% of German households facing energy poverty are often single-parent households. Moreover, they are mostly composed of and headed by women, and with a relatively high average age compared to the other groups analysed.

Households in energy poverty are distinguished by a higher percentage of unemployed people (between 9.13% and 9.94%), relative to the other dimensions of energy inequality. This trend can largely be attributed to the fact that those who are unemployed have low or no monthly income and, in addition, spend more time at home, which increases both energy consumption and expenditure. It can also be seen that larger households and households with a low level of education are in a situation of energy vulnerability when compared with the percentages for other problems.

Table 7. Incidence of each energy deprivation — characterisation in Germany

Variables	Energy Indigency	Energy Poverty 1	Energy Poverty 2	Energy Vulnerability
Gender PSH	63,88%	60,21%	59,65%	59,32%
Single-parent household	79,27%	70,32%	72,33%	75,31%
Feminisation of the household	55,5%	51,35%	51,38%	49,03%
PSH age	60,43	59,52	59,65	52,39
Unemployment PSH	6,57%	9,13%	9,94%	8,14%
Low household educational climate	2,70%	2,84%	3,03%	3,84%
Medium home educational climate	73,20%	68,70%	68,67%	62,78%
High household educational climate	13,99%	20,03%	19,97%	24,62%
Risk of monetary poverty	79,13%	61,20%	64,78%	69,65%
Household size	1,44	1,62	1,59	1,72
Household deficient in equipment	ND	ND	ND	ND
Deficit housing	13,97%	12,10%	11,57%	40,71%

Source: prepared by the authors based on SOEP

Table 8 presents the estimated coefficients of the logistic model applied to the four dependent variables considered in this study for the case of Germany.

During the period analysed, energy indigence is positively associated with the presence of poor housing quality conditions, as well as with households whose head of household is unemployed. The age of the household head also shows a positive and statistically significant relationship: as age increases, the probability of experiencing energy indigence increases. This result is consistent with expected results, given that retired people tend to have lower incomes and, at the same time, face higher energy needs, especially in winter, due to factors such as lower thermoregulation capacity, reduced blood circulation and more time spent indoors. Conversely, higher educational attainment and larger household size reduce the likelihood of being in energy indigence.

In relation to the energy poverty indicators, unemployment is confirmed as a statistically significant factor at a 99% confidence level, an expected result given that lack of employment reduces or eliminates disposable income, thus hindering access to basic energy services. Single-parent households also appear to be particularly vulnerable to this problem, both because of their limited economic resources and the greater financial burden of supporting the household. The age of the head of household has a positive relationship with energy poverty: the older the household is, the more likely it is to be in energy poverty, according to both indicators used. Indeed, as argued by Chard and Walker (2016), older people living in their own homes and on low incomes may struggle to pay their energy bills, as well as suffer more severely from the health consequences of living in cold housing. In contrast, household size and higher educational attainment are associated with a lower probability of energy poverty, both under the 10% expenditure criterion and the 2M indicator, which is in line with the results of Drescher and Janzen (2021). The fact that a woman is the head of household increases the probability of falling into energy poverty when the indicator of 10% of income spent on energy is applied, although this factor is not significant in the case of indicator 2M.

Substandard housing is also identified as a factor that increases the likelihood of being in energy poverty, especially according to the first indicator used. This occurrence is not present in the 2M energy poverty indicator, so it may be more sensitive than the 10% energy poverty indicator when considering the energy costs that a German household would actually incur. In relation to energy vulnerability, the results indicate that this condition is mainly associated with households headed by unemployed, older and less educated heads of household, as well as single-parent households, smaller households and households with more female family members. Age has a negative relationship with energy vulnerability.

Table 8. Logistic model results for energy deprivation — Germany

Variables	Energy Indigency	Energy Poverty 1	Energy Poverty 2	Energy Vulnerability
N=Obs	36.786.537	32.798.620	32.798.620	38.624.905
Constant	-3,489*** (0,407)	-2,122*** (0,2113)	-2,403*** (0,22)	2,729*** (0,204)
Gender PSH	0,353 (0,253)	0,2032* (0,107)	0,130 (0,117)	-0,096 (0,109)
Single-parent household	0,677*** (0,159)	0,525*** (0,088)	0,630*** (0,095)	0,880*** (0,105)
Feminisation of the household	-0,1638 (0,317)	-0,029 (0,152)	-0,110 (0,164)	0,458** (0,201)
PSH age	0,017*** (0,003)	0,019*** (0,002)	0,018*** (0,002)	-0,007*** (0,002)
Unemployment PSH	0,597** (0,237)	1,447*** (0,147)	1,497*** (0,148)	1,474*** (0,336)
Medium home educational climate	-0,096 (0,173)	-0,125 (0,100)	-0,145 (0,107)	-0,099 (0,115)
High household educational climate	-1,091*** (0,223)	-0,828*** (0,114)	-0,809*** (0,1242)	-0,298*** (0,112)
Household size	-0,405*** (0,110)	-0,227*** (0,045)	-0,2143*** (0,050)	-0,233*** (0,033)
Deficit housing	0,317* (0,169)	-0,001* (0,105)	-0,087 (0,113)	NA

Source: prepared by the authors elaboration based on SOEP
***, **, ***, variables statistically significant at 10%, 5%, 1% respectively. Standard deviations in brackets.**

Looking at the profiles of extreme households — i.e. those with all deprivations at the same time — and comparing them to households with no deprivation, significant gaps in the probabilities of occurrence of energy deprivation are found.

- The probability of indigence in a household with deprivation in all dimensions is 17% and is reduced to 3% if the household has no problems in any of the variables. The variables with the greatest impact on this gap are: single-parent household and main breadwinner outside the labour market.

- Regarding the likelihood of experiencing energy poverty, it is 53% for a household deprived in all relevant variables while only 7% for those not deprived. The dimensions that most affect the likelihood of a German household being in energy poverty are associated with gender, employment status and educational level of the head of household.

- Energy vulnerability has a probability of occurrence of 68% in households with a more deprived profile and 18% in those with no deprivation in the relevant dimensions. In this case, the proportion of women in the household, the educational level of the main breadwinner and the number of people living in the dwelling are the variables with the greatest sensitivity to the probabilities of occurrence of this problem.

A summary of the results obtained from the assessment of extreme profiles can be found in Table 9 below:

Table 9. Probability analysis in extreme cases per problem area — Germany

Energy Deprivation	Profile with all deprivations	Profile without deprivations	Variables with the greatest impact/sensitivity
Energy Indigency	17%	3%	Single-parent household Unemployment PSH
Energy Poverty	53%	7%	Gender PSH Unemployment PSH High household educational climate
Energy Vulnerability	68%	18%	Feminisation ratio Household size High household educational climate

Source: prepared by the authors based on SOEP 2022.

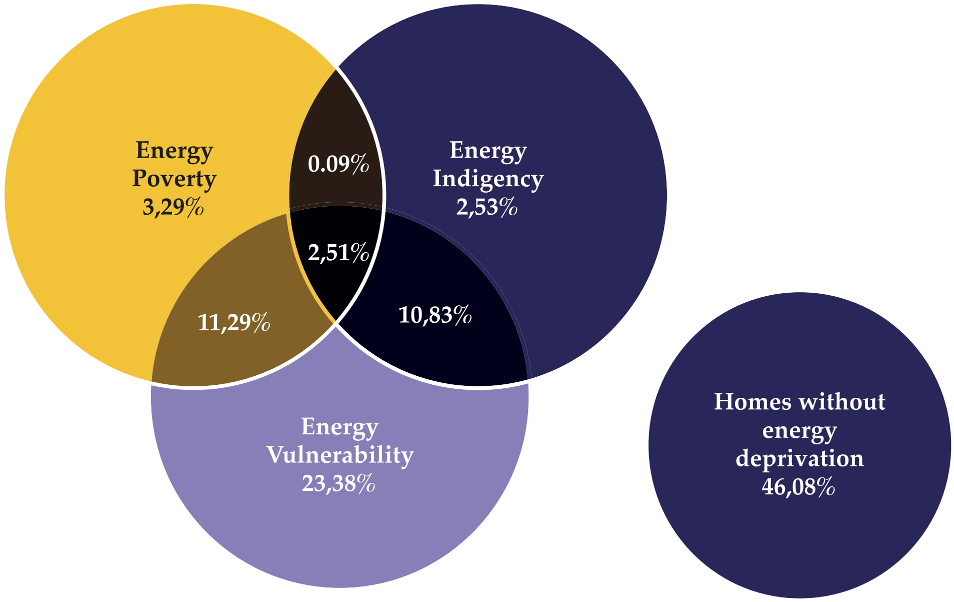
In conclusion, it can be noted that during 2022 in Germany, energy indigence, poverty and vulnerability jointly manifest themselves as expressions of inequality, particularly in families outside the labour market. These phenomena tend to be concentrated in small and single-parent households, which face difficulties in meeting their basic energy needs. It should be mentioned that while this energy poverty condition occurred in one family in 2022, it may be a temporary consequence.

5.2.2. Argentina

Argentina is deeply affected by energy inequality: 54% of the country's households suffer from some dimension of the problem.

The incidence of energy inequality is not even across households in Argentina, with different intensities and overlapping issues. As can be seen in Figure 34, 2.53% of households suffer from energy indigence only, 3.29% from energy poverty only and 23.38% from vulnerability only. The remaining 24.8% have at least two simultaneous energy deprivations.

Figure 34. Incidence of energy inequality in Argentina by deprivation and simultaneity



Source: prepared by the authors based on ENGHo

According to the data presented in Table 6, in 2022, energy vulnerability reached almost 68% of households in Argentina. At the same time, one third were in energy poverty (by indicator 2M), while 15% of households cooked and heated with traditional fuels, which places them in a condition of energy indigence.

A particularly relevant aspect of the Argentinean case is the high sensitivity of energy poverty to the indicator used to measure it. As previously mentioned, if the 10% income criterion is applied to energy expenditure, 17% of households are considered to be in energy poverty. However, this percentage rises to 29.5% if the so-called 2M indicator is used. This contrast suggests that there is a significant number of households that do not have access to adequate energy services due to lack of financial resources, rather than consumption decisions. This behaviour is linked to what is known as hidden energy poverty.

Table 10 also details the characteristics of households affected by these deprivations. More than 60% of energy-indigent households are single-parent and mostly headed by women. The average age of the main breadwinner is considerably higher than in households with other forms of energy deprivation. In addition, these households tend to face higher levels of unemployment, low levels of education and severe material deprivation in their homes. In fact, they are more numerous than households considered energy poor or vulnerable.

The profile of energy-poor households varies significantly depending on the indicator used. Under the definition of "energy poverty 1" (10% ratio), households with a high female presence, young family leaders, low educational level, high risk of monetary poverty, structural housing problems and an average household size of four members predominate. On the other hand, if the definition of "energy poverty 2" (indicator 2M) is adopted, households have better education levels, lower risk of monetary poverty, older heads of household, fewer members and less housing deprivation.

In summary, households identified as energy poor by the 2M indicator show a less unfavourable socio-economic profile than those defined by the 10% criterion. This distinction is key to understanding the difference between income poverty and energy poverty, and highlights that there is not a complete overlap between the groups affected by the two conditions.

Table 10. Incidence of each energy deprivation — characterisation in Argentina

Variables	Energy indigence	Energy poverty 1	Energy poverty 2	Energy vulnerability
Gender PSH	64,89%	48,75%	37,55%	42,14%
Single-parent household	62,06%	46,07%	25,76%	37,26%
Feminisation of the household	50,02%	54,53%	52,38%	52,67%
PSH age	56,24	29,17	41,6	33,73
Unemployment PSH	13,48%	6,63%	2,69%	3,12%
Low household educational climate	62,40%	53,91%	33,65%	41,13%

Medium home educational climate	26,47%	32,85%	36,98%	33,7%
High household educational climate	11,13%	13,24%	29,37%	25,3%
Risk of monetary poverty	59,7%	81,52%	25,75%	46,76%
Household size	5,11	4,28	3,11	3,42
Household deficient in equipment	91,25%	89,64%	88,51%	96,13%
Deficit housing	38,06%	25,05%	12,55%	19,38%

Source: prepared by the authors based on ENGHo

As can be seen in the table above, households facing situations of energy vulnerability are characterised — as was to be expected given the construction of the variable — by deficiencies related to the equipment and structural conditions of the dwellings they inhabit. In terms of the other socio-economic variables, these households do not show more severe levels of multidimensional deprivation than those affected by other forms of energy poverty. This is further evidence that energy inequality does not necessarily overlap with income poverty or other forms of material deprivation.

The results of the logistic model estimations for the Argentinean case are presented in Table 11 below. According to these results, households with a higher proportion of female members are more likely to use traditional fuels for basic energy needs. In addition, being part of a large family and living in dwellings built with precarious materials significantly increases the likelihood of being in energy indigence.

Conversely, when the head of household has a higher level of education, the likelihood of the household being in this condition decreases. Among all the factors considered, housing deficiencies are consolidated as the main determinant of energy indigence, a result that coincides with the findings of Ibañez Martin, Melo and Zabaloy (2022).

Table 11. Results of the logistic model for energy deprivation — Argentina

Variables	Energy Indigency	Energy Poverty 1	Energy Poverty 2	Energy Vulnerability
N=Obs	17.780.210	16.486.964	16.041.788	17.268.971
Constant	-2,406 (0,166)	-1,485 (0,185)	-2,961 (0,187)	3,723 (0,175)

Gender PSH	0,029 (0,069)	0,163* (0,076)	0,010 (0,075)	-0,389*** (0,115)
Single-parent household	0,045 (0,067)	0,300*** (0,070)	0,591*** (0,078)	0,733 (1,246)
Feminisation of the household	0,003*** (0,001)	0,003*** (0,001)	0,006*** (0,002)	0,001 (0,022)
PSH age	0,002* (0,001)	-0,005** (0,002)	-0,009** (0,002)	0,030 (0,003)
Unemployment PSH	-0,063 (0,142)	0,760*** (0,124)	0,067 (0,178)	0,619 (0,411)
Medium home educational climate	-0,321*** (0,065)	-0,374*** (0,068)	-0,349** (0,072)	-0,395*** (0,121)
High household educational climate	-0,465*** (0,082)	-1.057*** (0,093)	-0,371*** (0,081)	-0,743*** (0,131)
Risk of monetary poverty	0,546*** (0,060)	NA	NA	NA
Household size	0,145*** (0,015)	0,058*** (0,017)	0,188*** (0,016)	-0,114* (0,029)
Household deficient in equipment	0,094 (0,091)	0,232** (0,107)	0,172* (0,103)	NA
Deficit Housing	0,897** (0,063)	0,347*** (0,075)	0,402*** (0,094)	NA
Access to eletricity	NA	NA	NA	-0,111** (0,013)
Access to natural gas	NA	NA	NA	-0,581** (0,125)

Source: prepared by the authors elaboration based on SOEP
***, **, ***, variables statistically significant at 10%, 5%, 1% respectively. Standard deviations in brackets.**

Energy poverty at the household level seems to be influenced by most of the explanatory variables included in the logistic model. Larger households, with poorly equipped and structurally poor housing, with low educated or unemployed heads of household, headed by young people, single-parent households and with a higher proportion of female members, are more exposed to this problem.

Statistical significances remain relatively consistent under both definitions of energy poverty, with the exception of the variables related to unemployment and gender, which are significant only in the case of the indicator based on the 10% ratio. In this sense, female-headed households seem to be particularly exposed to excessive energy expenditure, which is consistent with the findings of Castelao Caruana and Méndez (2019).

In contrast, energy vulnerability is presented as a problem that is less associated with other forms of deprivation. In fact, households with a larger number of members, with access to both gas and electricity, and headed by women, are less likely to be in a situation of energy vulnerability. These results are revealing for two reasons: on the one hand, female household leadership has a protective effect in this case — the opposite of energy poverty; on the other hand, larger households seem to be better prepared to cope with changes in the environment. This could reflect more effective coping strategies linked to women's role in household management and in meeting basic energy needs such as cooking, which is in line with the findings of Arevalo and Paz (2016).

To conclude the econometric analysis on Argentina, we examine how the probabilities of a household suffering from some of the energy deprivations change by constructing extreme profiles.

- A household that has all the deprivations in variables/dimensions that were found to be significant in explaining energy indigence has a 27% chance of suffering this deprivation, while having no deprivations in other relevant dimensions reduces the chances to 7%. The likelihood of falling into energy indigence is more sensitive to larger households and to heads with an average educational background.

- In terms of the likelihood of experiencing energy poverty, the profile of a household with all deprivations in relevant dimensions has a probability of 48%, while a household that is not deprived in any of them has a probability of 4%. The variables that have the greatest impact are the gender of PSHs, the feminisation ratio and the presence of poor equipment in the household.

- Energy vulnerability has a probability of occurrence of 27% in households with a more deprived profile and 9% in those with no deprivation in the relevant dimensions. In this case, the high educational climate of the PSH is the variable with the greatest sensitivity to the probability of occurrence of this problem.

A summary of the results obtained from the assessment of extreme profiles can be found in Table 12 below:

Table 12. Probability analysis of extreme cases by issue — Argentina

Energy depriva-on	Profile with all deprivations	Profile without deprivation	Variables with most impact/sensitivity
Energy indigence	27%	7%	Household size Average educational climate
Energy poverty	48%	4%	Gender of PSH Feminisation rate Poor equipment
Energy vulnerability	27%	9%	High educational climate

Source: prepared by the authors based on ENGHo for 2017-2018.

In general terms, an integrated analysis of the determinants shows that in Argentina, energy inequality — understood as a set of deprivations of different intensity — is mainly determined by the educational level of the household, the size of the family and the construction quality of the dwelling. Consequently, large households, with leaders who have few years of educational experience and who live in poor housing conditions, are the most vulnerable to experiencing varying degrees of energy deprivation.

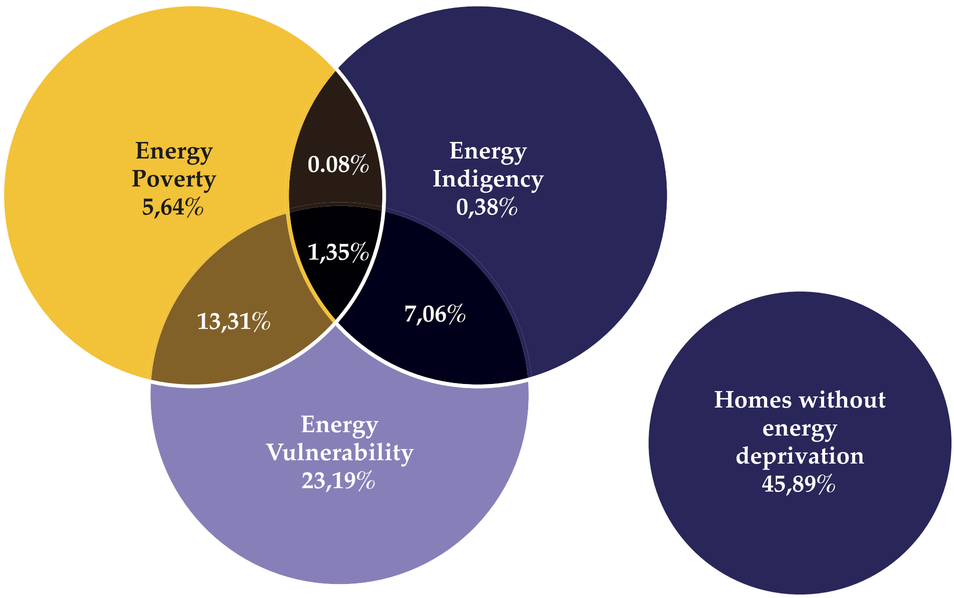
5.2.3. Colombia

More than half, 51.01%, of Colombian households suffer from one of the three dimensions of energy inequality, either simultaneously or exclusively. 1.35% of the families suffer from these three problems and 13.31% suffer from both vulnerability and energy poverty. However, there are families that are not in a situation of indigence or poverty, but they do present exclusive energy vulnerability in a proportion of 23.19%.

Poverty and indigence are the phenomena with the lowest proportion of overlap. This may occur because households that have access to traditional energy sources (firewood or charcoal) are not captured as being in energy poverty because they have already met their needs with affordable energy resources found in the environment and, consequently, do not incur excessive energy costs.

It is worth clarifying that these proportions are presented in relation to the population of the expanded database and that in the case of the energy poverty indicator there is a proportion of 3.10% of missing data in relation to the total number of households in the database analysed. More details on the treatment of the missing data can be found in the methodological annex.

Figure 35. Incidence of energy inequality in Colombia by deprivation and simultaneity



Source: Prepared by the authors based on LCS

Table 13 presents the relationship of households in energy indigence, poverty and vulnerability with the main economic, social and demographic characteristics of the head of household at the national level.

Households in energy indigence are generally characterised by poorly equipped dwellings and a lack of basic appliances for energy service fulfilment. Moreover, these households tend to be, on average, more numerous than those affected by the other forms of energy deprivation analysed. Some 71.04% of households in this situation have a low level of education, while 30.74% belong to Afro-descendant or ethnic communities, which reflects a structural dimension of inequality that permeates this problem.

For households in energy poverty — under both definitions — there is a greater feminisation of the household, and a higher proportion of female-headed households compared to those observed in energy indigence and vulnerability. This aspect is especially relevant in contexts such as Colombia and other Latin American countries, where women face higher levels of structural vulnerability due to their limited access to education, lower rates of labour market insertion and persistent wage gaps (UN WOMEN, 2018).

Although the two energy poverty indicators do not differ substantially in terms of socio-economic profile, there are some variations. For example, indicator 2M shows a higher incidence of households with low educational attainment and racial/ethnic background. In geographical terms, energy poverty in Colombia is mainly concentrated in peripheral departments and to a lesser extent, although with relevant incidence, in departments of the Colombian Caribbean. These areas have a high presence of indigenous and Afro-descendant communities, which are characterised by lower incomes than the national average (DANE, 2023).

Energy vulnerability, on the other hand, has a distinctive profile: it is particularly associated with immigrant heads of household and with low educational attainment. This limited educational status translates into lower labour income, since, as argued by Franco (2008), investment in human capital determines people's knowledge and skills and is also reflected in their productivity and labour returns. In addition, income can also be a determining factor in the capacity to invest in housing improvements and in the acquisition of durable goods such as a cooker, refrigerator or washing machine, which are essential to ensure a decent standard of living. This situation is aggravated in the case of migrants, who may face additional barriers related to economic and social integration in Colombia.

Table 13. Incidence of each energy deprivation — characterisation in Colombia

Variables	Energy Indigency	Energy Poverty 1	Energy Poverty 2	Energy Vulnerability
Gender PSH	33,55%	50,81%	51,07%	45,16%
Single-parent household	36,67%	49,93%	50,14%	50,03%
Feminisation of the household	45,35%	53,2%	53,3%	48,38%
PSH migrant	1,36%	3,53%	3,48%	5,73%
PSH age	48,45	50,81	50,87	47,66
PSH race	30,74%	16,92%	17,10%	17,80%
Unemployment PSH	1,19%	4,99%	5,13%	4,49%
Low household educational climate	71,04%	44,76%	45,11%	45,81%
Medium home educational climate	26,60%	41,08%	40,93%	40,89%
High household educational climate	2,36%	14,16%	13,96%	13,30%
Risk of monetary poverty	45,74%	49,46%	51,57%	42,25%
Household size	3,20	2,77	2,76	2,83

Household deficient in equipment	90,52%	52,51%	52,76%	82,29%
Deficit housing	58,80%	15,74%	15,87%	15,13%
Access to electricity	87,26%	99,55%	99,53%	97,04%
Access to natural gas	0,30%	50,36%	50,12%	49,94%

Source: prepared by the authors based on ECV

Table 14 presents the proportions of households in Colombia that are in a situation of energy indigence, poverty and vulnerability, both at the national level and in the Caribbean region. At the national level, 48.03% of households are classified as vulnerable, i.e. at risk of monetary poverty, precarious housing conditions or insufficient equipment. In terms of energy poverty, 21.04% and 19.75% of Colombian households were identified as being in this condition according to indicators 1 and 2, respectively. This suggests that a significant proportion of households spend a high proportion of their income on energy consumption, whether in electricity, natural gas or other sources used mainly for cooking. It should be noted that the 2M energy poverty indicator identifies households in this situation as those whose energy expenditure in relation to their income is more than double the national median (5.21%). In this sense, the threshold in these two indicators of energy poverty is very similar, one of the advantages of this indicator being that it considers the characteristics and profiles of energy consumption and expenditure of Colombian households. Energy indigence affects 9% of households in the country.

The table also includes the breakdown of these variables for the Caribbean region, which comprises the departments of Atlántico, Bolívar, Cesar, Córdoba, La Guajira, Magdalena and Sucre. In this area, energy vulnerability, poverty and indigence rates exceed national averages. This result is consistent with the regional context, where Caribbean households historically face higher electricity tariffs than those in the interior of the country. For example, in 2022, the average unit tariff for electricity service for a middle-class family (defined as stratum 4, according to the socio-economic stratification adopted by Colombia) charged by Afinia in the Caribbean region was USD 0,174[13] per kilowatt-hour (USD/kWh). In contrast, the average tariff charged by ENEL Colombia, the operator in Bogotá and Cundinamarca, was 0.160 USD/kWh for the same stratum. On average, the price of Afinia's electricity service in the Caribbean was 8.26% higher than that paid by users in the capital, with even greater differences in certain months of the year (Superintendencia de Servicios Públicos Domiciliarios (SSPD is the Spanish acronym), 2022).

13 The conversion was made based on the 2022 average market representative rate of Colombian pesos per dollar (COP/USD), which was COP 4,255.44/USD.

Table 14. Energy deprivation of varying intensity in Colombia and the Caribbean region

Energy deprivation	Colombia	Caribbean
Energy indigence	9,02%	16,92%
Energy poverty		
Energy poverty 1: 10%	21,04%	28,66%
Energy poverty 2: 2M	19,75%	27,09%
Energy vulnerability	48,01%	59,47%

Source: prepared by the authors based on LCS

Table 15 presents the estimated coefficients of the logistic model, in which the dependent variables correspond to energy indigence, the two energy poverty indicators and energy vulnerability in Colombia.

In terms of energy indigence, deficiencies in household equipment, precarious housing conditions and the risk of monetary poverty are identified as the main determinants. These variables are statistically significant and have a positive relationship with the probability of indigence, which is consistent with previous descriptive findings: the greater the accumulation of monetary and multidimensional deprivation, the greater the probability that a household is in energy indigence. In contrast, a higher level of education of the household head is negatively and significantly associated with the probability of energy indigence, suggesting that education acts as a protective factor against this condition. Unemployment and feminisation of the household were also found to reduce the likelihood of being energy indigent. That is, male headship is more susceptible to severe energy deprivation, which is in line with the findings of Soares et al. (2023).

Regarding energy poverty, measured by the 10% indicator, the results show a higher probability of occurrence in households headed by unemployed people, women, members of ethnic or Afro-descendant communities, older people and in poorly equipped dwellings. These findings are consistent with economic logic: the absence of employment reduces disposable income, which increases the proportion spent on energy expenditure. Moreover, women in Colombia, as in the rest of Latin America, tend to earn lower wages than men (DANE, 2020). Similarly, structural inequalities affecting ethnic populations explain their greater exposure to energy poverty, given their lower insertion in the formal labour market and living conditions below the national average. The lack of adequate household equipment is also a significant variable, reflecting the fact that some households lack even basic household appliances to meet their daily energy needs. These relationships are also verified when using the second energy poverty indicator (2M).

In relation to energy vulnerability, the model shows that households headed by immigrants, indigenous or Afro-descendant people, as well as those in a situation of unemployment, are more likely to be in this condition. This result shows that certain population groups, such as migrants, face additional structural barriers to access basic services such as energy, adequate housing and formal employment. Similarly, the fact that racial groups determine energy vulnerability may be related to differences in income between the two population groups (racial and non-racial), although other studies also link it to the innate structure that causes categorisation and discrimination within a social structure (Lin and Adu, 2023).

It is also observed that access to modern household energy sources, such as electricity and natural gas, significantly reduces the likelihood of a household being in a situation of energy vulnerability. A particularly illustrative fact is that 99.88% of households without access to electricity are in this situation, which confirms that the lack of access to modern energy prevents them from meeting basic energy needs through the use of household equipment. These devices are essential for human development, as they help to optimise time spent on household chores and improve living conditions.

On the other hand, factors such as feminisation of the household, age of the head of household and larger household size are associated wit

Table 15. Results of the logistic model for energy deprivation — Colombia

Variables	Energy indigence	Energy poverty 1	Energy poverty 2	Energy vulnerability
N=Obs	17.413.863	16.874.165	16.874.165	17.413.863
Constant	-3,261*** (0,097)	-1,489*** (0,084)	-1,565*** (0,086)	-8,257*** (0,392)
Gender PSH	-0,273*** (0,042)	0,321*** (0,040)	0,327*** (0,041)	0,217*** (0,041)
Single-parent household	-0,451*** (0,040)	-0,057 (0,037)	-0,057 (0,038)	0,430*** (0,038)
Feminisation of the household	-0,150** (0,066)	0,308*** (0,059)	0,315*** (0,060)	-0,483*** (0,062)
PSH migrant	-1,181*** (0,109)	-0,021 (0,098)	-0,037 (0,101)	1,344*** (0,106)
PSH age	-0,008*** (0,001)	0,006*** (0,000)	0,005*** (0,001)	-0,020*** (0,001)
PSH race	0,332*** (0,037)	0,431*** (0,038)	0,436*** (0,039)	0,717*** (0,046)

Unemployment PSH	-1,292*** (0,127)	0,884*** (0,089)	0,912*** (0,090)	1,214*** (0,105)
Medium home educational climate	-1,000*** (0,038)	-0,215 (0,035)	-0,224*** (0,036)	-0,896*** (0,037)
High household educational climate	-2,133*** (0,081)	-1,00*** (0,050)	-1,015*** (0,051)	-2,05*** (0,048)
Risk of monetary poverty	0,647*** (0,036)	NA	NA	NA
Household size	0,096*** (0,011)	-0,129*** (0,011)	-0,131*** (0,011)	-0,164*** (0,011)
Household deficient in equipment	2,025*** (0,046)	0,435*** (0,033)	0,433*** (0,033)	NA
Deficit Housing	1,797*** (0,034)	-0,0519 (0,035)	-0,047 (0,035)	NA
Access to electricity	NA	NA	NA	-5,215*** (0,384)
Access to natural gas	NA	NA	NA	-1,364*** (0,032)

Source: prepared by the authors elaboration based on ECV
***, **, ***, variables statistically significant at 10%, 5%, 1% respectively. Standard deviations in brackets.**

The probabilities of occurrence of each deprivation are now analysed. As in the other countries, the analysis uses profiles of households with extreme deprivation (all deprivations at the same time) and compares them with those with none. For Colombian households it is found that:

- The probability of indigence in a household with deprivation in all dimensions is 76% and is reduced to 19% if the household has no problems in any of the variables. The dimensions with the greatest impact on this change are: the gender and race of the main breadwinner, and also the number of household members.

- The probability of experiencing energy poverty is 63% for a household deprived in all relevant variables, while it is only 12% for those not deprived. The dimensions that most affect the likelihood of a Colombian household being in energy poverty are associated with the gender and employment status of the head of household as well as the ratio of women to men in the household.

- Energy vulnerability has a probability of occurrence of 51% in households with a more deprived profile and 14% in those with no deprivation in the relevant dimensions. In this case, the gender and race of the main breadwinner and access to natural gas are the variables with the highest sensitivity to the likelihood of occurrence of this problem.

A summary of the results obtained from the assessment of extreme profiles can be found in Table 16 below:

Table 16. Probability analysis of extreme cases by issue — Colombia

Energy Deprivation	Profile with all deprivations	Profile without deprivations	Variables with the greatest impact/sensitivity
Energy Indigency	76%	19%	Gender PSH PSH Race Household size
Energy Poverty	63%	12%	Unemployment PSH Feminisation ratio High household educational climate
Energy Vulnerability	51%	14%	Gender PSH PSH Race Access to natural gas

Source: prepared by the authors based on ECV 2022.

In summary, unemployment and ethnicity of the head of household are significant variables in explaining energy poverty and vulnerability at the national level in Colombia. In the specific case of energy indigence, the main determinants are precarious housing conditions, lack of basic equipment and the risk of monetary poverty. It follows that material and economic deprivation are key factors that explain the likelihood of a household resorting to the use of traditional sources such as wood or charcoal for cooking, water heating or space heating.

Table 17 presents the estimated results for the Colombian Caribbean. Similar to what is observed at the national level, in this region energy indigence is associated with lack of equipment, poor housing conditions, risk of monetary poverty, ethnicity of the household head and household size. However, some factors exert a protective effect: medium and high levels of education, the feminisation of the household, and the fact that women or immigrants head the household and are in search of work reduce the probability of being in a situation of energy indigence.

Energy poverty is positively related to female-headed households, feminisation of the household, single-parent structures, age of the head of household, unemployment and lack of household equipment. In contrast, high level of education, ethnicity, precarious housing and household size show a negative relationship. While these results differ from the findings at the national level, it could be explained by the particularities of climate and consumption in the Caribbean: the frequent use of fans and air conditioners to ensure thermal comfort tends to increase energy consumption across the population, regardless of income level or race, so that energy expenditures can represent a significant burden in relation to disposable income. On the other hand, it is also possible that there is a phenomenon of hidden energy poverty in the population groups belonging to an ethnic community because they looked for other alternatives to reduce energy expenditure and, therefore, it has not been identified that these groups explain energy poverty in the Colombian Caribbean. However, a rigorous study on the relationship between race and energy poverty in the Colombian Caribbean is needed to verify this assertion.

With regard to energy vulnerability in the Caribbean, unemployment, female headship, migrant status, belonging to ethnic or Afro-descendant communities and single parenthood are identified as determining factors. On the other hand, variables such as the feminisation of the household, the age of the head of household, a medium or high level of education and a larger household size are associated with a lower probability of suffering this form of deprivation.

Table 17. Results of the logistic model for energy deprivation in the Colombian Caribbean region

Variables	Energy Indigency	Energy Poverty 1	Energy Poverty 2	Energy Vulnerability
N=Obs	3.436.669	3.345.561	3.345.561	3.343.669
Constant	-3,2841*** (0,180)	-1,217*** (0,129)	-1,264*** (0,130)	3,933*** (0,140)
Gender PSH	-0,317*** (0,071)	0,172*** (0,052)	0,174*** (0,055)	0,104* (0,058)
Single-parent household	-0,361*** (0,068)	0,021 (0,052)	0,040 (0,053)	0,514*** (0,057)
Feminisation of the household	-0,165 (0,122)	0,689*** (0,091)	0,697*** (0,092)	-0,408*** (0,100)
PSH migrant	-0,508*** (0,169)	-0,109 (0,138)	-0,097 (0,142)	0,851*** (0,157)
PSH age	-0,010*** (0,002)	0,011*** (0,001)	0,010*** (0,001)	-0,021*** (0,001)
PSH race	0,683*** (0,061)	-0,152*** (0,056)	-0,133** (0,058)	0,246*** (0,069)
Unemployment PSH	-1,032*** (0,212)	0,622*** (0,127)	0,6712*** (0,1283)	0,963*** (0,147)

Medium home educational climate	-0,875*** (0,069)	0,002 (0,054)	-0,00374 (0,054)	-0,914*** (0,060)
High household educational climate	-1,699*** (0,129)	-0,499*** (0,072)	-0,509*** (0,073)	-2,095*** (0,073)
Risk of monetary poverty	0,534*** (0,064)	NA	NA	NA
Household size	0,065*** (0,019)	-0,1334*** (0,014)	-0,140*** (0,0147)	-0,146*** (0,015)
Household deficient in equipment	2,257*** (0,097)	-0,004 (0,050)	-0,014 (0,050)	NA
Deficit housing	2,210*** (0,057)	-0,613*** (0,058)	-0,601* (0,059)	NA
Access to electricity	NA	NA	NA	NA
Access to natural gas	NA	NA	NA	-1,687*** (0,140)

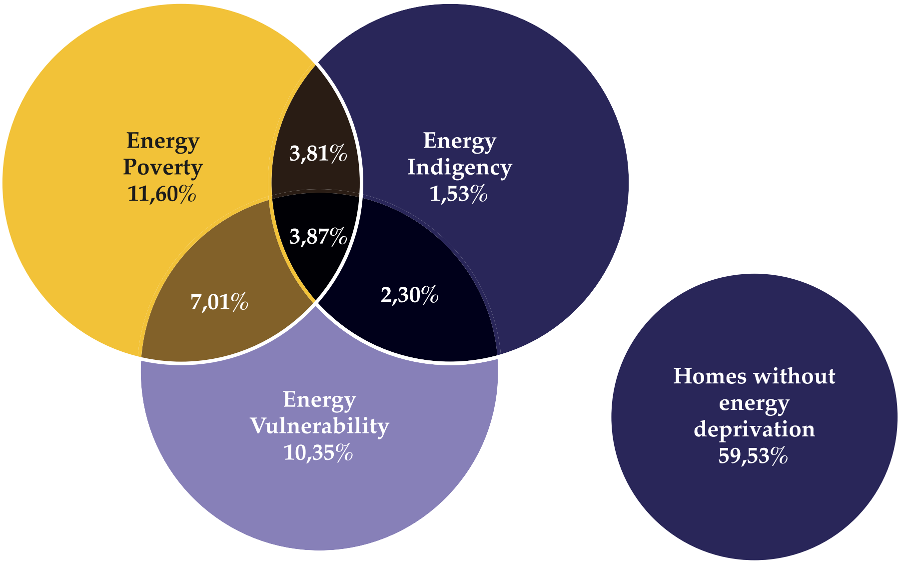
Source: prepared by the authors based on ECV 2022.

Finally, it is worth noting that similar to what was found at the national level, in the Colombian Caribbean the main determinants of energy indigence are precarious housing conditions, lack of basic equipment and the risk of monetary poverty. Divergence was found in energy poverty in relation to the explanatory variable race because at the national level the coefficient is positive, while in the Caribbean the opposite sign was identified. They converge at both national and regional levels in that energy poverty is more likely to occur in households headed by unemployed people, women, older people and those with poor household equipment. Unemployment, race and immigrant status of the household head, as well as female headship and single-parent households were significant variables with a positive sign that explain energy vulnerability at the two geographical levels studied. Households in a situation of energy vulnerability should be considered in the design and targeting of energy policies in order to reduce the energy inequality gap.

5.2.4. Spain

In 2022, energy inequality in Spain affected two-fifths of households, reaching 40.47%. 1.53% of households suffer from energy indigence only, 11.6% from energy poverty only and 10.35% from vulnerability only. The remaining 17% have at least two simultaneous energy deprivations.

Figure 36. Incidence of energy inequality in Spain by deprivation and simultaneity



Source: prepared by the authors based on EPF

Table 18 presents the characteristics of Spanish households affected by energy deprivation of different intensity. If we look at the last column, corresponding to the least severe form of the problem — energy vulnerability — we see that it mainly affects households with low and medium levels of education, a greater presence of women as heads of household, a significant incidence of unemployment in the main breadwinner of the family, as well as housing, equipment and monetary deprivation.

Unlike in the other countries in the sample, in Spain households in a situation of energy indigence also face multidimensional deprivations, although the most relevant ones are associated with an average educational background, unemployment of the head of household and a high risk of monetary poverty.

With regard to energy poverty, the profiles of affected households show a relative homogeneity between the two definitions used. However, relevant differences are identified: households classified as energy poor according to the 10% criterion face greater deficiencies in the equipment and construction quality of their dwellings compared to those defined by the 2M indicator.

Among the countries analysed, Spain stands out for having the most homogeneous profiles among energy indigent, poor and vulnerable households. Moreover, a distinctive feature is that energy inequality — understood as the aggregate of the three forms of deprivation — tends to be concentrated in two-parent and male-headed households.

Table 18. Incidence of each energy deprivation — characterisation in Spain

Variables	Energy Indigency	Energy Poverty 1	Energy Poverty 2	Energy Vulnerability
Gender PSH	28,59%	31,20%	31,83%	40,16%
Single-parent household	2,67%	3,85%	3,44%	5,09%
Feminisation of the household	51,54%	53,85%	51,07%	54,49%
PSH migrant	5,46%	10,22%	16,46%	15,56%
PSH age	59,69	56,79	55,71	58,59
Unemployment PSH	44,57%	36,94%	35,92%	52,99%
Low household educational climate	17,50%	13,89%	13,44%	26,18%
Medium home educational climate	47,40%	45,75%	43,69%	53,00%
High household educational climate	35,09%	40,46%	42,87%	2,82%
Risk of monetary poverty	28,48%	25,24%	23,67%	57,68%
Household size	2,48	2,82	3,09	2,07
Household deficient in equipment	10,55%	61,92%	34,74%	89,6%
Deficit housing	26,87%	63,67%	32,29%	76,48%

Source: prepared by the authors based on EPF

Table 19 presents the results of the logistic model applied to the case of Spain. Energy indigence is more likely in households where the main breadwinner is a migrant, older and in households with a higher number of members than the national average (2.5 persons in 2022). Also, households at risk of monetary poverty and those living in dwellings with precarious structural conditions are more likely to face this form of energy deprivation. In contrast, having heads of household with medium or high levels of education significantly reduces the likelihood of using traditional fuels within the household.

The results on energy poverty provide striking elements. For example, the migrant status of the main breadwinner appears to decrease the likelihood of the household incurring excessive energy expenditure. This finding has also been pointed out by Antón and Medrano (2024) and by the European Commission (2025), who stress that the lower energy consumption of migrant populations in Europe does not necessarily respond to greater efficiency or environmental awareness, but to situations of need and vulnerability.

Another interesting result is that higher educational climates seem to be associated with a higher risk of energy poverty in Spain, which contrasts with what has been observed in other countries. This pattern has also been reported by Jové-Llopis and Segarra-Blasco (2022) for Spain, by Heindl and Schüßler (2019) in Germany and by Thomson, Snell and Bouzarovski (2017) in a study of 32 European countries. In addition, household size is confirmed as a relevant factor: large households tend to spend a higher proportion of their income on energy services.

The results also show some heterogeneity according to the indicator used to measure energy poverty. In the case of the 10% threshold, female-headed and older households are more likely to fall into this situation. However, when applying the 2M indicator, these same characteristics appear to reduce risk. On the other hand, housing deprivation and the two-parent household structure are significant in explaining higher energy expenditure under indicator 2M, but not when the 10% criterion is used.

In terms of energy vulnerability, the determinants show signs and significance in line with expectations. The likelihood of facing this form of deprivation increases in households headed by women or migrants, with unemployed heads of household, low educational level, a single responsible adult, lack of access to electricity and natural gas, and with a larger number of members.

Table 19. Results of the logistic model for energy deprivation — Spain

Variables	Energy indigence	Energy poverty 1	Energy poverty 2	Energy vulnerability
N= Obs	17.332. 088	17.026.798	17.109.267	16.985.746
Constant	-3,804 (2,024)	-0,794** (0,167)	-0.510*** (0,167)	3.748*** (0,171)
Gender PSH	-0,122 (0,078)	0,275*** (0,062)	-0,007** (0,006)	0,395*** (0,064)
Single-parent household	-0,096 (0,145)	0,007 (0,115)	-0,355*** (0,0117)	0,791*** (0,101)
Feminisation of the household	-0,001 (0,003)	0,0008 (0,0009)	0,011 (0,017)	-0,001* (0,000)
PSH migrant	0.918*** (0,125)	-0,662*** (0,073)	-0,458*** (0,072)	0,595*** (0,082)
PSH age	0,029*** (0,002)	0,026*** (0,002)	-0,008** (0,002)	-0,026 (0,865)
PSH Unemployment	-0,195* (0,078)	-0,685*** (0,053)	-0,127* (0,062)	0,790* (0,063)

Medium home educational climate	-0,245*** (0,076)	0,290*** (0,064)	0,000 (0,069)	-1,034*** (0,065)
High household educational climate	-0,262*** (0,090)	0,495*** (0,071)	0,263*** (0,074)	-2,377*** (0,072)
Risk of monetary poverty	0,384*** (0,065)	NA	NA	NA
Household size	0,1060** (0,023)	0,161*** (0,023)	0,136*** (0,018)	0,496*** (0,022)
Household deficient in equipment	-0,189 (0,342)	-0,137 (0,269)	-0,128 0,275	NA
Deficit housing	1,298*** (0,056)	0,080 (0,054)	0,255*** (0,056)	NA
Access to electricity	NA	NA	NA	-0,313*** (0,062)
Access to natural gas	NA	NA	NA	-0,641** (0,060)

Source: prepared by the authors based on EPF 2022.
***, **, ***, statistically significant variables at 10%, 5%, 1% respectively. Standard deviations in brackets.**

In this last section, we analyse how the probabilities of a household suffering from some of the energy deprivations analysed change based on the construction of extreme profiles.

- The probability of indigence in a household with deprivation in all dimensions is 38% and is reduced to 8% if the household has no problems in any of the variables. The probabilities of occurrence of energy indigence are shown to be sensitive to the migrant origin of the main breadwinner, to above-average household size and to the risk of monetary poverty. .

- With regard to the likelihood of experiencing energy poverty, the profile of a household with all deprivations together in relevant dimensions has a probability of 63% while the household with no deprivations has a chance of 15%. The dimensions that most affect the likelihood of a Spanish household being in energy poverty in 2022 are associated with the gender and age of the main breadwinner. .

- Energy vulnerability has a probability of occurrence of 77% in households with a more deprived profile and 13% in those with no deprivation in the relevant dimensions. In this case, access to electricity, the educational climate of the household and the gender of the main breadwinner are the variables with the highest sensitivity to the probability of occurrence of this problem.

A summary of the results obtained from the assessment of extreme profiles can be found in Table 20 below:

Table 20. Probability analysis of extreme cases by issue — Spain

Energy Deprivation	Profile with all deprivations	Profile without deprivations	Variables with the greatest impact/sensitivity
Energy Indigency	38%	8%	Household size PSH migrant
Energy Poverty	63%	15%	Gender PSH PSH Age
Energy Vulnerability	77%	13%	Gender PSH Access to electricity High and medium household educational climate

Source: prepared by the authors based on EPF 2022.

In summary, the logistic models estimated for the Spanish case show a marked heterogeneity in the determinants of each type of energy deprivation. Energy indigence and poverty are closely related to conditions of material and social deprivation, while energy poverty as measured by overspending may also affect households that are relatively better off in socio-economic terms.

5.3. Results by region

5.3.1. Latin America and the Caribbean

El análisis comparativo de la desigualdad energética en América Latina y el Caribe The comparative analysis of energy inequality in Latin America and the Caribbean shows that the phenomenon is more severe in Argentina than in Colombia. In particular, the incidences recorded in Argentina present characteristics closer to those observed in the Colombian Caribbean, suggesting common territorial and socio-economic patterns in contexts of high energy vulnerability (Urquiza et al., 2021).

Among the different manifestations analysed, energy vulnerability emerges as the most critical dimension, highlighting its relevance for the design of energy and social policies that integrate equity and sustainability criteria (Bouzarovski & Petrova, 2015; Middlemiss & Gillard, 2015). The results also indicate that Argentina is more sensitive to how energy poverty is measured, with a high incidence of what the literature refers to as hidden energy poverty, that is, households that do not exceed conventional thresholds but suffer real energy deprivation due to low levels of forced or limited consumption (Simcock, Walker, & Day, 2016; Thomson, Bouzarovski, & Snell, 2017). This phenomenon is related to the income structure and the influence of energy subsidies on the configuration of deprivation thresholds (Tirado Herrero & Jiménez Meneses, 2016; Bouzarovski, Petrova, & Tirado Herrero, 2014). Although the data suggest that this phenomenon is more severe in Argentina than in Colombia, specific empirical studies would be necessary to confirm this hypothesis.

Both countries have structurally high levels of energy inequality: it affects 53.92% of households in Argentina and 51.01% in Colombia, confirming the persistence of patterns of exclusion in energy access, use and affordability in the region (Urquiza et al., 2021; Baptista, 2019). Among the socio-economic determinants, the educational level of the head of household appears as a key factor: a higher educational background is associated, in both countries, with a lower probability of experiencing energy deprivation, in line with the findings of Thomson et al. (2017) and Gouveia, Palma and Simões (2019).

However, there are significant differences between the two contexts. In Argentina, household size is positively related to energy inequality, while in Colombia the relationship is inverse. In the Colombian case, moreover, variables such as race and the employment status of the main breadwinner acquire greater explanatory relevance, in line with studies that highlight the intersectional dimension of energy poverty (Baptista, 2019; Robinson, Bouzarovski, & Lindley, 2021).

As for female leadership, the results do not show a univocal relationship: its effect varies according to the specific dimension of energy deprivation and the country analysed. For example, in Colombia female headship reduces the probability of energy indigence, while in Argentina there is no significant effect. In contrast, in both countries, female-headed households tend to be more likely to experience energy poverty, although in Argentina the presence of women seems to reduce the risk of energy vulnerability, a trend that is reversed in Colombia (Simcock, Petrova, & Bouzarovski, 2021; Clancy et al., 2017).

With regard to the explanatory factors according to the type of energy deprivation, differentiated patterns are identified:

- Energy indigence: the main determinants are the educational climate of the household, the risk of monetary poverty and precarious housing. In Argentina, female leadership and household size increase the probability of energy indigence, while in Colombia they tend to reduce it (Urquiza et al., 2021; Bouzarovski et al., 2014).

- Energy poverty: in both countries, variables such as household equipment, gender of the head of household, feminisation ratio and unemployment are significant. However, housing precariousness has a more marked effect in Argentina (Thomson, Bouzarovski, & Snell, 2017).

- Energy vulnerability: Gender has opposite effects depending on the country. In Argentina, the presence of female dependents reduces the likelihood of vulnerability, while in Colombia it increases it. In both contexts, access to adequate energy services acts as a protective factor (Urquiza et al., 2021; Middlemiss et al., 2019)..

Finally, the analysis shows a partial decoupling between monetary poverty and energy deprivation. In Colombia, approximately 50% of energy-deprived households are not in monetary poverty, which supports the evidence on the multidimensionality of the phenomenon. In Argentina, this decoupling is less pronounced, especially with regard to excessive energy expenditure, where affected households tend to coincide with those in low-income situations (Baptista, 2019).

Taken together, these results confirm the complexity of the phenomenon of energy poverty and inequality in Latin America, and reinforce the need for differentiated approaches that consider both national specificities and the multiple dimensions of energy deprivation.

5.3.2. Europe

The analysis of energy inequality in Europe reveals that, in terms of energy poverty — the only dimension measured homogeneously between Spain and Germany — the incidence is significantly higher in Spain. This result coincides with studies that point to the persistence of structural conditions that hinder equitable access to energy services in lower average income contexts, such as the Spanish case (Sánchez-Guevara, Gómez-Acebo, & González, 2020).

Other dimensions of energy deprivation have been constructed with some methodological variation, mainly due to the differential availability of information in the German case. Despite these limitations, the analysis suggests that energy indigence — understood as the most extreme form of deprivation — is more severe in Spain, while energy vulnerability stands out in Germany, although in the latter country the measurement does not incorporate the household equipment dimension, which could underestimate its real incidence (Bouzarovski, Petrova, & Tirado Herrero, 2014; Robinson, Bouzarovski, & Lindley, 2021).

In relation to the energy expenditure indicators, it is observed that in Spain the incidence of the relative threshold 2M (high energy expenditure combined with low income) exceeds that of the absolute indicator of 10% of income, while in Germany the opposite is true. This pattern, also observed in Latin American contexts such as Argentina and Colombia, has been interpreted as indicative of a greater presence of hidden energy poverty — i.e. households that consume little energy not because of lack of need, but because of economic constraints — in lower middle-income countries (Simcock, Walker, & Day, 2016; Thomson, Bouzarovski, & Snell, 2017). This finding is consistent with the income differences between the two populations and with the limitations of traditional indicators in capturing restricted consumption situations.

When disaggregating the determinants of different energy deprivations, specific patterns are identified according to the national context:

- Energy indigence: in both Spain and Germany, the precariousness of housing, the educational climate of the household and the age of the head of household are significant variables, in line with the findings of Gouveia, Palma and Simões (2019) and

Tirado Herrero and Jiménez Meneses (2016). However, household size increases the probability of indigence in Spain but reduces it in Germany. Moreover, unemployment appears as a factor that reduces indigence in the Spanish context but increases it in the German context, which may be linked to differences in social protection systems and energy subsidies (Bouzarovski & Thomson, 2020). It should be noted that in Germany, by methodological construction, the monetary poverty risk variable was not incorporated into the logistic model, as it is already part of the definition of energy indigence (Walker, Simcock, & Day, 2016). In Spain, on the other hand, this dimension is statistically significant.

- Energy poverty: variables such as gender, education level, unemployment, single-parent structure and age are revealed as determining factors in both countries. As documented by Clancy, Daskalova, Feenstra and Franceschelli (2017), household size increases the risk of energy poverty in Spain, while it reduces it in Germany. Age tends to increase the likelihood of energy poverty in both contexts, a phenomenon that may be related to longer household tenure, fixed income or lower investments in energy efficiency in older households (Boardman, 2010).

- Energy vulnerability: in this dimension, single-parent households, educational climate and unemployment status emerge as significant variables. Household size increases vulnerability in Spain, while in Germany it operates as a protective factor. In the opposite direction, the ratio of feminisation of the household acts, which reduces vulnerability in Spain but increases it in Germany. Likewise, the gender of the main breadwinner is significant and positive in the Spanish context, but loses significance in Germany, in line with studies on gender, employment and unequal access to energy (Simcock, Petrova, & Bouzarovski, 2021).

A particular finding in the Spanish case is the influence of PSH migration, which is statistically significant in all three dimensions of energy deprivation: it increases energy indigence and vulnerability, but reduces energy poverty. This apparent paradox may be due to forced consumption patterns, support networks or differences in the perception of energy needs in migrant households (Baptista, 2019; Robinson et al., 2021).

In general terms of energy inequality, variables such as household size, educational level and single parenthood are consolidated as relevant determinants in both countries. However, the gender of the PSH has a higher explanatory impact in Spain, while in Germany its relevance is limited to the energy poverty dimension. These results reflect profound structural differences and socio-economic specificities between the two European countries, highlighting the need for differentiated policies, sensitive to the national context, to address energy poverty and inequality effectively and equitably (Bouzarovski & Thomson, 2020; Sánchez-Guevara et al., 2020).

5.4. Comparison of results between Latin America and the Caribbean and Europe

The comparative analysis confirms that energy inequality is a relevant phenomenon in both Europe and Latin America, although its specific manifestations vary considerably between regions. Breaking down inequality into the three dimensions of deprivation analysed — energy indigence, energy poverty and energy vulnerability — does not identify one region systematically more affected than another; differences appear heterogeneously according to the deprivation considered, in line with multidimensional approaches to energy poverty (Bouzarovski & Petrova, 2015).

However, when analysing the total number of households exposed to single or simultaneous energy deprivation, a regional pattern is found. In Argentina and Colombia more than 50% of households suffer from at least one energy deprivation (54% and 51% respectively), while in Germany and Spain the number of households affected does not exceed 40%. Thus, more Latin American households are affected by energy inequality than those that are not deprived, while the relationship is the other way around in European countries. One aspect of regional difference, based on the cases analysed, is that in Europe more households live with all three deprivations simultaneously (close to 4% of households in both countries, compared to 1.35% in Colombia and 2.51% in Argentina).

In particular, energy indigence exhibits high variability across countries in both regions, reflecting the interaction between national structural conditions, energy policies and local socio-economic characteristics (Walker, Simcock, & Day, 2016). On the other hand, energy poverty affects Europe more than Latin America. This difference can be explained by multiple factors, including high energy prices in Europe, dependence on external sources of supply and the withdrawal or limitation of energy subsidies in several European countries (Sánchez-Guevara, Gómez-Acebo, & González, 2020; Thomson, Bouzarovski, & Snell, 2017).

In contrast, energy vulnerability manifests itself more acutely in Latin America, an expected result given the context of deeper structural poverty that characterises much of the region, where populations are exposed to multiple and simultaneous forms of exclusion, including energy exclusion (Urquiza et al., 2021). A homogeneous aspect between regions is the relevance of vulnerability as simple deprivation among households, i.e. this problem alone (without considering households that suffer from it in combination with energy poverty and/or indigence) is the highest.

Regarding individual determinants, the analysis confirms that variables such as household size, educational level, unemployment status of the head of household, and housing conditions have significant effects on the probability of experiencing energy deprivation, findings consistent with those reported by Gouveia et al. (2019). Furthermore, in the two countries where it was possible to measure it — Spain and Colombia — it was observed that ethnic or racial origin significantly influences the risk of suffering energy inequality, reinforcing the idea that this problem has a strong structural and intersectional dimension (Robinson et al., 2021).

Gender also emerges as a relevant factor, although its influence is heterogeneous: a trend towards feminisation of energy poverty is identified, both in terms of leadership of deprived households and in relation to unequal participation in household dynamics of energy access and use (Clancy et al., 2017).

Finally, the risk of monetary poverty emerges as a key determinant of energy indigence in all the countries where it was possible to analyse it — Argentina, Spain and Colombia — corroborating the close link between income poverty and the most extreme energy deprivation (Boardman, 2010). In the case of Germany, where the risk of monetary poverty is part of the very construction of the dependent variable of energy indigence, it is not possible to identify this effect independently.

These results underline the need for energy policies that recognise the specificities of each national context and the multiple dimensions — economic, social and territorial — that shape energy inequality on a global scale.

6. POLICY RECOMMENDATIONS

Understanding the intensity and drivers of energy inequality in Latin America and Europe is one of the main objectives of this report. The previous sections were implemented to that end.

Studying the problem from a multidimensional perspective, going beyond issues related to energy access and cost, allows for a systemic approach and provides essential results for policy programming aimed at mitigating and alleviating energy inequality. The results detailed in the previous section, because of the form of exposure and their level of detail, provide relevant information for general, region-specific and also country-specific policy recommendations.

General policy recommendations

- **Tackle energy inequality, not just energy poverty, with policies.** Energy inequality understood as the phenomenon that combines deprivations of different gradients is relevant in both regions (and countries analysed). Implementing policies that focus on overspending alone (energy poverty) significantly reduces the scope, leaving unaddressed other forms of energy deprivation that have serious consequences on the well-being of the population.

- **Recognise the multidimensionality of energy inequality.** In this sense, policies that only focus on the cost of energy (e.g. energy subsidies or economic support programmes) are insufficient to address the root of the problem. The results show that multiple factors condition energy inequality (household size, educational level, housing quality, feminisation of the household and employment of the main breadwinner), irrespective of the country / region analysed.

- **Segmenting energy policies by considering criteria that go beyond the economic dimension.** The multiple dimensions that explain energy inequality show that income is a relevant variable, but not the only one. In addition, the relationship between income and energy deprivation is more visible in energy indigence, but not in less severe deprivation. These aspects justify social and energy policies that contemplate segmentation criteria that go beyond household income, in order to avoid exclusion errors.

- **Targeting policies according to risk profiles.** According to the results, the variables that promote different energy deprivation are diverse depending on the region and country analysed. Thinking in terms of a representative profile for policy implementation implies simplifying a phenomenon that is extremely complex and multidimensional. However, there are patterns: single-parent households, female-headed, with older or unemployed heads of household, and with low educational attainment, should be prioritised in the allocation of subsidies or energy efficiency programmes.

- **Design policies that are sensitive to gender and the feminisation of the household.** While the effect of female leadership and the proportion of women in a household is heterogeneous across countries and energy deprivation (indigence, poverty and vulnerability), there is a notable tendency for households affected by energy poverty and indigence to be headed by a woman and/or to have more women than men among household members. Given this aspect, and also the relevance of substandard housing as an explanatory variable, it is key to integrate a gender perspective both in the distribution of resources and in the formulation of technological and housing solutions.

- **Reformulate eligibility criteria for subsidies with a view to reducing exclusion errors.** The use of single indicators (such as ranking by the 10% ratio) can obscure hidden forms of energy inequality. It is advisable to apply combined and context-sensitive criteria. The establishment of criteria should address the variables that are significant within each issue and be implemented with low control costs. Defining unclear/strict criteria could lead to inclusion errors that increase the cost of funding and promote regressive outcomes, such as those found by Poggiese and Ibañez Martin (2024) in the case of Argentina.

- **Promotion of bilateral and multilateral cooperation initiatives** with the aim of disseminating good practices, tools and knowledge in support of national government initiatives to address energy inequality.

Regional policy recommendations

The following recommendations are based on the analysis and results of two specific cases per region. Although this could be considered small, the selection of countries (justified in detail in section 3.1 of this report) pursued the objective of analysing economies that were representative of the region, taking into account economic, demographic and also energy aspects.

Latin America and the Caribbean

- **Expand access to distribution networks.** Energy indigence, poverty, and vulnerability affect more than 50% of households in the countries analysed. Lack of access to electricity and natural gas networks emerges as a dimension of energy inequality, more specifically of indigence and vulnerability. In addition, the lack of access to these networks can also be associated with excessive expenditures, because those households that are not connected to the distribution networks use more expensive sources (organic material and bottled gas) and also do not benefit from subsidies related to energy access and consumption. Finally, it is important to explore the coordination possibilities among different levels of the public sector and the private sector to allow access of energy network expansion programmes to populations in isolated areas.

- **Promote programmes to improve the quality of housing and equipment.** The quality of buildings and the lack of equipment to meet essential energy needs are aspects that increase the chances that a household in LAC suffers from energy poverty, i.e. spends an excessive proportion of income to pay for the energy it consumes. Programmes and investments in infrastructure, housing improvement programmes, promotion of credits and micro-credits for the purchase of equipment can be social policy alternatives that have an impact on energy inequalities.

- **Promote credit and financing programmes in vulnerable populations to guarantee access to networks, equipment and improvement of the home envelope.** In line with the previous recommendation, lack of access to equipment and distribution networks such as substandard housing is a characteristic of vulnerable populations in LAC. These deprivations are combined with a severe constraint on financial inclusion (Carballo, 2020; Azar, Lara and Mejía, 2018). Alleviating the restriction of access to targeted finance to reduce these material and energy deprivations would, according to our results, have an impact on deprivations of energy indigence, vulnerability and poverty in LAC households. An alternative to this may be the work coordinated between national governments and international organisations such as the Inter-American Development Bank through programmes such as FINLAC, a comprehensive initiative to promote financial inclusion in Latin America and the Caribbean that aims to ensure that the most vulnerable people can access the financial services they need.

- **Strengthen education and training programmes for women and youth:** The educational climate of the household is key to alleviating energy deprivation, as is female leadership and the age of the main breadwinner. Combine these three dimensions and target educational and assistance programmes that promote the advancement of educational trajectories in these vulnerable groups.

- **Implement energy efficiency and energy education programmes.** The problem of energy poverty and energy vulnerability is associated with populations with multiple material and economic deprivations, however, as expected, the socio-economic profile is more advantageous than in the group of households that face energy indigence. Programmes for reasonable and efficient energy use in vulnerable or energy-poor households could have a significant effect in reducing these problems.

- **Include ethnic and migrant populations as priority groups.** In Colombia, these communities face greater structural barriers and have a high incidence of energy deprivation. In Argentina these dimensions could not be incorporated into the empirical analysis.

Europe

- **Implement/prioritise energy efficiency schemes and thermal assistance for single-parent and elderly households.** These groups were vulnerable to energy deprivation of varying intensity, but mostly in the case of energy vulnerability.

- **Consider migrant profiles within the priority groups in energy and social policies.** In Spain, migrant-headed households have a high incidence of vulnerability and energy indigence. Social integration should include the energy dimension.

- **Assess subsidies and tariff adjustments considering the socio-economic profile of the household.** Given that energy poverty also affects households with medium and high levels of education, policies must go beyond purely economic criteria.

- **Promote employment policies households of middle socio-economic status.** Energy vulnerability reaches households with an intermediate socio-economic profile, where severe material deprivation is less pronounced than other energy deprivations. Energy-vulnerable households are mostly affected by PSH unemployment and housing/equipment problems.

- **Programming policies on energy vulnerability**. The problem affects a considerable proportion of households, putting them at risk to any changes that affect the energy sector and the ability to pay (this happened during the terrible triennium). Addressing households affected by this deprivation is a preventive measure for more severe energy problems, which require greater resources to be able to manage them.

Country-level recommendations

Germany

- Prioritise single-parent and elderly households in energy rehabilitation and consumption subsidy programmes.

- Promote information campaigns on energy efficiency targeting women and the elderly.

- Include the concept of "energy vulnerability" in the design of public policies, beyond monetary poverty.

Argentina

- Expand housing improvement schemes and access to equipment to meet basic energy services.

- Update energy subsidies with criteria that incorporate hidden deprivations (e.g. low non-voluntary consumption) and criteria that reduce the regressivity of the current scheme.

- Implement educational and technical training programmes in vulnerable communities to promote efficient energy use.

- Increase the coverage of distribution networks throughout the country, mainly for natural gas.

Colombia

- Reduce regional gaps in electricity tariffs, in particular in the Caribbean, through targeted subsidies or regulatory review.

- Develop natural gas access programmes in areas with high dependence on traditional fuels.

- Design inclusive policies that consider the ethnic and migrant status of the head of household as structural factors of energy inequality.

- Apply geographical criteria to target energy inclusion policies.

Spain

- Strengthen energy payment subsidies for households headed by women, migrants and the unemployed, adjusting the criteria according to household composition and age.

- Integrate housing energy rehabilitation measures in dense urban areas with a focus on households at risk of monetary poverty.

- Promote policies that link energy efficiency and employment, through training and subsidies for green jobs in vulnerable sectors.

7. CONCLUSIONS

This comparative study provides a perspective on the multiple dimensions of energy inequality, approached as a concrete manifestation of energy deprivation of varying intensity. Based on the approach adopted, energy is conceived not only as a productive input or a tradable good, but also as a fundamental social good for well-being, inclusion and the full exercise of citizenship. Unequal access to energy services thus appears to be a critical expression of the structural inequalities that span both Latin America and Europe.

The *terrible triennium*, from 2020 to 2022, — characterised by the COVID-19 pandemic, the energy price crisis and geopolitical tensions — created a particularly adverse scenario that highlighted the fragility of global energy systems. During this period, millions of households faced difficulties in accessing essential energy services. This global crisis exacerbated existing inequalities and created new gaps between those who were able to sustain access to energy for lighting, heating, connectivity or cooling, and those who were excluded, deepening the energy divide.

Inequality is expressed in the unequal distribution of resources, opportunities, and power among different social sectors. This is manifested in multiple dimensions such as income, education, health, access to essential services, and political participation. In this framework, energy takes on a central role: energy deprivation is a concrete form of inequality, given its direct impact on human well-being. So-called energy inequality encompasses disparities in access, use and quality of energy services, both within countries and among regions or social groups.

It is important to underline that this form of inequality is not just about lack of access, but includes aspects such as affordability, stability of supply, and sustainability of the energy system. Addressing it requires an approach that recognises not only extreme deprivation, but also the structural and persistent inequalities that affect diverse social groups differently according to their location, income, gender, or cultural identity. Even if progress is made in reducing energy poverty, many of these energy inequalities continue to be reproduced, conditioning key aspects of daily life such as health, housing comfort, educational performance, or general well-being.

To approach this conception and in the empirical analysis, a framework was constructed based on three indicators that classify energy deprivation in decreasing order of severity and together attempt to operationalise the concept of energy inequality: energy poverty, energy indigence and energy vulnerability. These dimensions are not mutually exclusive, but represent different levels of deprivation and risk that may (or may not) be combined. Energy indigence refers to the impossibility of satisfying essential energy services such as cooking, heating water, lighting, etc., and is often associated with the use of traditional and polluting sources such as firewood. Energy poverty, on the other hand, is a multidimensional manifestation that is expressed in terms of excessive energy expenditure (ratio of energy expenditure to household income). Finally, energy vulnerability describes situations of risk: households that, due to their location, building characteristics or socio-demographic composition, are exposed to more severe energy deprivation.

The empirical analysis carried out for Argentina, Colombia, Germany, and Spain shows that energy inequality is not evenly distributed. In Europe, the problem is strongly linked to excessive spending on energy relative to disposable income, as well as to housing efficiency and the design of energy markets. In Latin America, access deprivation, use of polluting sources, and urban-rural gaps predominate. Despite these differences, in both regions the most affected groups are female-headed households (although the influence of gender is heterogeneous), the elderly, and large families. One of the key findings of the study is that energy deprivation cannot be explained by monetary poverty alone. Although there is a correlation, multiple structural factors — such as the type of energy source used, the building quality of the dwelling, climatic conditions and socio-demographic profiles — influence the occurrence of energy deprivation. Thus, not all low-income households suffer from some dimension of energy deprivation, nor are all households experiencing energy deprivation monetarily poor. This dissociation is fundamental to avoid reductionist approaches and to promote more precise public policies, with a comprehensive approach to the effects that energy shortages can have on populations with different profiles.

In empirical terms, the study reveals that energy inequality affects more than 50% of households in Argentina and Colombia, while in Germany and Spain the percentage is less than 40%. However, in European countries the proportion of households facing all three forms of deprivation simultaneously is higher (about 4%), compared to lower values in the Latin American countries analysed. This difference suggests that, although Latin America has a greater extent of deprivation, in Europe the intensity of deprivation may be more severe in certain cases.

With regard to the distribution of the three dimensions of energy deprivation, there is a high variability in indigence across countries, reflecting the interaction between public policies, energy infrastructure and local social characteristics. Energy poverty, on the other hand, is more prevalent in Europe, which can be explained by price increases, market liberalisation and the withdrawal of subsidies. Energy vulnerability is more acute in Latin America, due to more persistent structural conditions of poverty, coupled with exposure to multiple forms of social exclusion.

At the micro level, the analysis confirms that variables such as household size, the educational level of the head of household, unemployment, and the building characteristics of the dwelling are critical factors that determine the probability of experiencing energy deprivation. In the cases of Spain and Colombia, a significant correlation between ethnicity and energy inequality was also identified, reinforcing the intersectional nature of the phenomenon. Gender emerges as another important determinant, although its effect is not homogeneous across the countries analysed.

The risk of monetary poverty, on the other hand, is a clear predictor of energy indigence, especially in Argentina, Colombia and Spain. However, this does not imply that income level is the sole or main explanatory factor for the most severe energy deprivation. In fact, the results highlight the need for specific policies for each of the three dimensions of energy deprivation, with interventions that combine distributional, territorial and social justice approaches.

In short, energy inequality is a complex, cross-cutting phenomenon, deeply rooted in the social and economic structures of both regions. Overcoming energy deprivation and reducing the gaps in access to energy services cannot be approached solely from a logic of coverage or subsidies, but requires a profound transformation of regulatory frameworks, institutional design and the rights-based approach to energy. Recognising access (in quantity and quality) to energy as a social right and not as a tradable good is the first step towards building fairer, more sustainable and inclusive energy systems.

8. REFERENCES

Acheampong, A.O; Osei, E; Amankwaa, A.; Dzator, J. (2024). Energy poverty and gender equality in education: Unpacking the transmission channels. Technological Forecasting & Social Change 202 (2024).

Agresti, A. (2013). Categorical data analysis (3rd ed.). Wiley.

Aguirre Padilla, N. I., Alvarado Espejo, J. M., & Ponce, P. (2023). Incidence of COVID-19, social norms, and environmental awareness on the saving of electrical energy in homes in Loja. Revista Economía y Política, (38), 92-118.

Alonso, C., Buendía, F., & Montoya, C. (2020). Energy poverty and health in Latin America: Challenges and solutions. Energy Policy, 144, 111561.

Antón, L., & Medrano, A. (2024). Evaluating the energy poverty in the EU countries. Energy Economics, 126, 107728. https://doi.org/10.1016/j.eneco.2024.107728

Arenas Pinilla, E. M., Barrella, R., Burzaco Samper, M., Cabrera, P. J., Centeno Hernáez, E., Escribano Alonso, M. E., ... & Sanz Bayón, P. (2019). La pobreza energética en España. Informe XXIX, 308 p. Available in: https://repositorio.comillas.edu/xmlui/bitstream/handle/11531/56293/IIT-19-120A.pdf?sequence=1

Arévalo, M. A., & Paz, J. (2016). Privaciones múltiples en la Argentina: diferencias entre hogares con jefatura masculina y hogares con jefatura femenina. Comisión Económica para América Latina y el Caribe (CEPAL). Available in: https://repositorio.cepal.org/handle/11362/40820

Azar, K., Lara, E., & Mejía, D. (2018). Inclusión financiera de las mujeres en América Latina: Situación actual y recomendaciones de política. CAF – Banco de Desarrollo de América Latina. Available in: https://scioteca.caf.com/handle/123456789/1162

Bahmanyar, A., Estebsari, A., & Ernst, D. (2020). The impact of different COVID-19 containment measures on electricity consumption in Europe. Energy Research & Social Science, 68, 101683.

Baptista, I. (2019). Energy justice and the poor: Lessons from utility disconnections in the United States. Energy Research & Social Science, 56, 101207. https://doi.org/10.1016/j.erss.2019.05.007

Bianco, V., Proskuryakova, L., & Starodubtseva, A. (2021). Energy inequality in the eurasian Economic union. Renewable and Sustainable Energy Reviews, 146, 111155.

Bienvenido-Huertas, D. (2021). Do unemployment benefits and economic aids to pay electricity bills remove the energy poverty risk of Spanish family units during lockdown? A study of COVID-19-induced lockdown. Energy Policy, 150, 112117. Available in: https://doi.org/10.1016/j.enpol.2020.112117

Bizzarri, M, Bellamy, C, Patrick, E, Roth, C, 2009. Safe Access to Firewood and Alternative Energy in Uganda: An Appraisal Report. World Food Programme. Available in: https://data2.unhcr.org/en/documents/download/64174

Boardman, B. (2010). Fixing Fuel Poverty: Challenges and Solutions. Earthscan.

Bouzarovski, S. (2018). Energy Poverty. Cham: Palgrave Macmillan. Available in: https://link.springer.com/content/pdf/10.1007%2F978-3-319-69299-9.pdf

Bouzarovski, S., Petrova, S., & Tirado Herrero, S. (2014). From fuel poverty to energy vulnerability: The importance of services and needs. Energy Policy, 68, 1–11. Available in: https://doi.org/10.1016/j.enpol.2014.01.004

Bouzarovski, S., & Petrova, S. (2015b). A global perspective on energy poverty and urban development. International Journal of Urban and Regional Research, 39(6), 1088-1109.

Bouzarovski, S., & Petrova, S. (2015a). A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. Energy Research & Social Science, 10, 31-40.

Bouzarovski, S., & Thomson, H. (2020). Alleviating energy poverty in Europe: Front-runners and laggards. Energy Research & Social Science, 66, 101485. Available in https://doi.org/10.1016/j.erss.2020.101485

Burguillo, M., del Río, P., & Juez-Martel, P. (2025). How have the COVID pandemic and the war in Ukraine affected energy poverty? Applied Energy, 377, 124690.

Calvo, R., Álamos, N., Billi, M., Urquiza, A., & Contreras Lisperguer, R. (2021). Desarrollo de indicadores de pobreza energética en América Latina y el Caribe. Serie Recursos Naturales y Desarrollo, N 207. Santiago. Available in: https://repositorio. cepal. org/bitstream/handle/11362/47216/4/S2100433_es. pdf.

Campí, M. T. C., Llopis, E. J., & Baute, E. T. (2020). Pobreza energética en Europa: un análisis comparativo: ¿qué hacen los países europeos para afrontar la pobreza energética? Fundación Naturgy. Available in: https://www.fundacionnaturgy.org/publicacion/demanda-de-calor-en-los-hogares-una-transicion-energetica-eficiente/

Carballo, I. E. (2020). Inclusión financiera en poblaciones vulnerables de Argentina: Un diagnóstico multidimensional en base al estudio empírico del Barrio Padre Carlos

Múgica [Tesis de maestría, Universidad Nacional de San Martín – CONICET]. Repositorio Institucional CONICET. Available in: https://ri.conicet.gov.ar/handle/11336/160441

Carfora, A., Scandurra, G., & Thomas, A. (2022). Forecasting the COVID-19 effects on energy poverty across EU member states. Energy policy, 161, 112597.

Castelao Caruana, M. E., & Méndez, F. M. (2019). La pobreza energética desde una perspectiva de género en los hogares urbanos de Argentina. SaberEs, 11(2), 133-151.

Chard, R. and Walker, G. (2016) Living with fuel poverty in older age: Coping strategies and their problematic implications. Energy Research & Social Science 18: 62–70. Available in: https://doi.org/10.1016/j.erss.2016.03.004

Clancy, J; Daskalova, V.; Feenstra, M.; Franceschelli, N.; Sanz, M. (2017). Gender perspective on access to energy in the EU. Available in: https://www.europarl.europa.eu/RegData/etudes/STUD/2017/596816/IPOL_STU(2017)596816_EN.pdf

Clancy, J.; Feenstra, M. (2019). Women, Gender Equality and the Energy Transition in the EU.

Clean Energy Wire. (2024). Germany 's dependence on imported fossil fuels. Clean Energy Wire. Available in: https://www.cleanenergywire.org/factsheets/germanys-dependence-imported-fossil-fuel

Compañía Administradora del Mercado Mayorista Eléctrico Sociedad Anónima (CAMMESA). (2023). Estadísticas anuales 2005 – 2023. Available in: https://cammesaweb.cammesa.com/informe-anual/

Confederación de Consumidores y Usuarios (CECU). (2023). Informe sobre pobreza energética en Europa. Available in: https://cecu.es/wp-content/uploads/2023/04/Informe-Pobreza-energetica-1_compressed.pdf

DANE. (2020). Brecha salarial de género en Colombia. Departamento Administrativo Nacional de Estadísticas.

DANE. (2023). Mercado laboral de los grupos étnico raciales: En Colombia antes y después de los confinamientos por el Covid-19. Departamento Administrativo Nacional de Estadísticas. Nota estadística no. 2 de 2023.

Day, R., Walker, G., & Simcock, N. (2016). Conceptualizing energy use and energy poverty using a capabilities framework. Energy Policy, 93, 255-264.

del Barrio Partner, L., Olivera, C. (2023). Demanda de calor en los hogares: una transición energética eficiente. Fundación Naturgy. Available in: https://www.fundacionnaturgy.org/publicacion/demanda-de-calor-en-los-hogares-una-transicion-energetica-eficiente/

Desvallées, L. (2021). Identificación, localización y caracterización de la vulnerabilidad energética a nivel de sección censal en el municipio de Barcelona. Scripta Nova. Revista Electronica de Geographia y Ciencias Sociales, 25(1), 239-263.

Drescher, K. & Janzen B. Determinants, persistence, and dynamics of energy poverty: An empirical assessment using German household survey data. Energy Economics, Volume 102, October 2021, 105433. Available in: https://doi.org/10.1016/j.eneco.2021.105433

Dubois, U., & Meier, H. (2016). Energy affordability and energy inequality in Europe: Implications for policy making. Energy Research & Social Science, 18, 21-35. Available in: https://doi.org/10.1016/j. erss.2016.04.015

Durán, R. J., & Condori, M. A. (2016). Índice multidimensional de pobreza energética para Argentina: su definición, evaluación y resultados al nivel de departamentos para el año 2010. Avances en energías renovables y medio ambiente, 20.

Encuesta Nacional de Calidad de Vida (ECV). (2022). Departamento Administrativo Nacional de Estadísticas. Available in: https://www.dane.gov.co/index.php/estadisticas-por-tema/salud/calidad-de-vida-ecv/encuesta-nacional-de-calidad-de-vida-ecv-2022

Economic Commission for Latin America and the Caribbean (ECLAC). (2021). Estudio sobre condiciones de acceso desigual a servicios energéticos de calidad en América Latina y el Caribe. Available at: https://repositorio.cepal.org.

European Commission. (2020). Energy poverty and vulnerable consumers in the energy sector across the EU: Analysis of policies and measures. Publications Office of the European Union. Available at: https://energy.ec.europa.eu/publications/energy-poverty-and-vulnerable-consumers-energy-sector-across-eu-analysis-policies-and-measures_en

European Commission. (2020). EPAH Indicators. Energy Poverty Advisory Hub. Available in: https://energy-poverty.ec.europa.eu/epah-indicators

European Commission (2023). General Directorate for Energy. (2023). EU energy in figures: statistical pocketbook 2023. Publications Office of the European Union. Available in: https://data.europa.eu/doi/10.2833/502436.

European Energy Poverty Observatory. European Energy Poverty Observatory (EPOV), n.d., "Energy Poverty." https://energy-poverty.ec.europa.eu.

European Union. (2023). Regulation (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast). EUR-Lex.Recuperado el [27/02/2025], de https://eur-lex.europa.eu/resource.html?uri=cellar:31c5ee91-888f-11ee-99ba-01aa75ed71a1.0019.02/DOC_1&format=PDF

Eurostat. (2025). Data Browser. Available in: https://ec.europa.eu/eurostat/databrowser/view/ilc_lvhe07/default/table?lang=en

Fell, M. (2017). Energy services: A conceptual review. Energy Research & Social Science (27), 129-140.

Fernández, K., Lezcano, L., & González, A. (2023). Medición de la pobreza energética con enfoque multidimensional: revisión sistemática de la literatura. Revista INVI, 38(109), 172-208.

Formichella, M. M., & Krüger, N. S. (2019). Diferencias Inter e Intra–Provinciales en el Logro de Aprendizajes Básicos en Matemáticas. LIV Reunión Anual Asociación Argentina de Economía Política.

Franco, C. (2008). Educación y pobreza en Colombia: un enfoque institucional. Universidad de los Andes.

Fundación "la Caixa". (2016). Radiografía de la pobreza energética en Europa. Observatorio Social de la Caixa. Available in: https://elobservatoriosocial.fundacionlacaixa.org/es/-/radiografia-de-la-pobreza-energetica

Fundación Bariloche. (2021). El rol de la eficiencia energética en la reducción de la pobreza energética. Portal de Eficiencia Energética. Available in: https://eficienciaenergetica.net.ar/novedades_detalle.php?id=80

García-Ochoa, R., & Graizbord, B. (2016). Caracterización espacial de la pobreza energética en México. Un análisis a escala subnacional. Economía, sociedad y territorio, 16(51), 289-337.

González, F. A. I., & Ibáñez Martín, M. M. (2023). Seis décadas de pobreza energética: ¿Reduciendo las disparidades en América Latina y el Caribe? Revista INVI, 38(109), 71-99.

Gouveia, J. P., Palma, P., & Simões, S. G. (2019). Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports, 5, 187–201. https://doi.org/10.1016/j.egyr.2018.07.006

Gouveia, J. P., Palma, P., & Simoes, S. G. (2019). Energy poverty indicators: Inconsistencies, implications and where next? Energy and Buildings, 198, 21–29. Available in: https://doi.org/10.1016/j.enbuild.2019.05.019

Gujarati, D., & Porter, D. (2009). Essentials of econometrics 4e. McGraw Hill.

Guzmán, D., Ruiz, J., & Cadena, M. (2014). Grupo de Modelamiento de Tiempo, Clima y Escenarios de Cambio Climático. Subdirección de Meteorología. IDEAM.

Guzowski, C. (2016): "Los nuevos desafíos de las políticas públicas aplicadas al sistema energético ambiental argentino". En Los desafíos de la política energética en Argentina. Panorama y propuestas, C. Guzowski, M. Ibáñez Martín y M. Rojas (Coord.). Buenos Aires, Dunken, 159-171.

Guzowski, C., Ibañez, M. Zabaloy. (2021). Pobreza Energética: Conceptualización y su Vínculo con la Exclusión. Breve Revisión para América Latina. Ambienta y Sociedad, Vol. 24, São Paulo. http://dx.doi.org/10.1590/1809-4422asoc20200027r2vu2021L2DE

Hand, D. J., & Henley, W. E. (1997). Statistical classification methods in consumer credit scoring: A review. Journal of the Royal Statistical Society: Series A (Statistics in Society), 160(3), 523-541.

Heffron, R. J., & McCauley, D. (2017). The concept of energy justice across disciplines. Energy Policy, 105, 658-667.

Heindl, P., & Schüßler, R. (2019). A deprivation-based assessment of energy poverty: Conceptual problems and application to Germany. Energy Economics, 80, 125–133. Available in: https://doi.org/10.1016/j.eneco.2019.01.010

Heltberg, R. (2004). Fuel switching: evidence from eight developing countries. Energy Economics, 26, 869-887.

Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). Applied logistic regression (3rd ed.). Wiley.

Ibáñez Martin, M. M., & Martínez, C. K. (2022). Endeudamiento y vulnerabilidad financiera: factores asociados. Un caso de estudio. Apuntes de Economía y Sociedad, 3(1), 57-68.

Ibáñez Martín, M. M., Zabaloy, M. F., & Dubois, F. (2023). How Do We Measure Energy Poverty? The Limitations of Energy Expenditure as an Indicator. In Living with Energy Poverty (pp. 29-40). Routledge.

Ibáñez Martín, M. M., Zabaloy, M. F., Reyes Pontet, M. D., Chaz Sardi, M. C., & González, F. A. I. (2022). ¿Cómo aliviar la pobreza energética a partir de energías renovables?

Diseño de un ensayo aleatorio en barrios vulnerables. Revista Latinoamericana de Metodología de las Ciencias Sociales, 12(1).

Ibáñez Martín, M., Guzowski, C., & Maidana, F. (2020). Pobreza energética y exclusión en Argentina: mercados rurales dispersos y el programa PERMER. Revista Reflexiones, 99(1), 40-71.

Ibáñez Martín, M., Zabaloy, M. F., & Guzowski, C. (2022). Privación y pobreza energética: cocción limpia en Argentina. SaberEs, 14(1), 53-84.

Ibáñez Martín, M., Zabaloy, M.F. y Guzowski, C. (2019). Una Primera Exploración de la Situación de Pobreza Energética en Argentina: ¿Es la Pobreza Energética un Fenómeno Independiente de las Privaciones Multidimensionales? LIV Reunión Anual de la Asociación Argentina de Economía Política. Bahía Blanca, noviembre de 2019. Available in: https://aaep.org.ar/anales/works/works2019/iban%CC%83ez.pdf

Ibáñez Martín, M.M., Melo Poveda, E. y Zabaloy, M.F. (2021) "Analyzing energy deprivation for cooking in Argentina and Brazil". Revista Iberoamericana de Estudios de Desarrollo. Available in: https://doi.org/10.26754/ojs_ried/ijds.603

Ibáñez Martin, M.M., Poggiese, M. y Martínez (2025). Energy poverty and tariff segmentation in Argentina: distributive incidence and the gender effect. En Benites Lazaro, Neiva y Serrani (Eds.) Energy Poverty, Justice and Gender. Springer Book.

Inter-American Development Bank (IDB)(2018). Género y Energía: un tema de todos. Inter/American Development Bank

International Energy Agency (IEA) (2018). Tracking gender and the clean energy transition. Available in: https://www.iea.org/articles/tracking-gender-and-the-clean-energy-transition

International Energy Agency (IEA) (2017). Energy Access Outlook. Paris: WEO e STO.

International Energy Agency (IEA) (2021). Spain 2021: Energy policy review. IEA. https://iea.blob.core.windows.net/assets/2f405ae0-4617-4e16-884c-7956d1945f64/Spain2021.pdf fecha de acceso 27 de febrero 2025

International Energy Agency (IEA) (2023). Where things stand in the global energy crisis one year on, IEA, Paris. https://www.iea.org/commentaries/where-things-stand-in-the-global-energy-crisis-one-year-on,

International Energy Agency (IEA) (2023a). Energy Statistics Data Browser. https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=WORLD&fuel=Energy%20supply&indicator=TESbySource

International Energy Agency (IEA) (2023). Energy Statistics Data Browser. https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=COLOMBIA&fuel=Energy%20consumption&indicator=ResidentialBySource

International Energy Agency (IEA) (2025a). Energy mix de Alemania. Available in: https://www.iea.org/countries/germany/energy-mix

International Energy Agency (IEA) (2025b). Energy mix de Argentina. Available in: https://www.iea.org/countries/argentina/energy-mix

International Energy Agency (IEA) (2025c). Energy mix de Colombia. Available in: https://www.iea.org/countries/colombia

International Energy Agency (IEA) (2025d). Energy mix de España. Available in: https://www.iea.org/countries/spain

Inclusión SAS & Promigas (2024). El camino recorrido: Pobreza energética en Colombia 2022-2023. Análisis del. Índice Multidimensional de Pobreza. Energética (IMPE). Bogotá D.C. Consultado el 27 de febrero https://fundacionpromigas-offloadmedia.s3.amazonaws.com/wp-content/uploads/2025/01/27090744/Informe_IMPE-2024-VF-web.pdf

INDEC (2020). Factores de expansión, estimación y cálculo de los errores de muestreo de la Encuesta Nacional de Gasto de los Hogares edición 2017-2018. https://www.indec.gob.ar/ftp/cuadros/menusuperior/engho/engho2017_18_nota_tecnica_4.pdf

INDEC (2020). Manual de uso de la base de datos usuario de la Encuesta Nacional de Gasto de los Hogares edición 2017-2018. https://www.indec.gob.ar/ftp/cuadros/menusuperior/engho/engho2017_18_manual_uso_bases.pdf

INDEC (2020). Metodología de Imputación de la Encuesta Nacional de Gasto de los Hogares edición 2017-2018. https://www.indec.gob.ar/ftp/cuadros/menusuperior/engho/engho2017_18_nota_tecnica_5.pdf

Instituto Interdisciplinario de Economía Política (IIEP). (2025). Reporte de tarifas y subsidios #22. Recuperado de https://iiep.economicas.uba.ar/wp-content/uploads/2025/01/INFORME-TARIFAS-Y-SUBSIDIOS-ENERO-2025.pdf

Instituto Geográfico Nacional (IGN). (2025). Atlas climático digital de la República Argentina. Instituto Geográfico Nacional de Argentina. Recuperado el [27/02/2025], de https://ide.ign.gob.ar/portal/apps/MapJournal/index.html?appid=b58d8b8841ef472e962317cac879e87f

Instituto Geográfico Nacional de España (2024). Atlas Nacional de España. https://atlasnacional.ign.es/wane/Clima

Instituto Nacional de Estadística y Censos (INDEC). (2019). Encuesta Nacional de Gastos de los Hogares 2017-2018: Informe de gastos. Recuperado de https://www.indec.gob.ar/ftp/cuadros/sociedad/engho_2017_2018_informe_gastos.pdf

Instituto de Energía. (2024). Annual change in primary energy consumption. Energy Institute - Statistical Review of World Energy (2024).

Instituto Nacional de Estadística. (2022). Encuesta de Presupuestos Familiares 2022. Recuperado de https://www.ine.es/prensa/epf_2022.pdf

Islar, M., Brogaard, S., & Lemberg-Pedersen, M. (2017). Feasible and just? Navigating imaginaries in the transition to low-carbon energy in Europe. Energy Research & Social Science, 25, 25-34.

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. Energy Research & Social Science, 11, 174-182.

Jové-Llopis, E., & Segarra-Blasco, A. (2022). Determinants of energy poverty: Trends in Spain in Karpinska, L., & Śmiech, S. (2020). Invisible energy poverty? Analyzing housing costs in Central and Eastern Europe. Energy Research & Social Science, 70, 101670.

Lampis, A., Ibáñez Martín, M. M., Zabaloy, M. F., Soares, R. S., Guzowski, C., Mandai, S. S., ... & Bermann, C. (2022). Energy transition or energy diversification? Critical thoughts from Argentina and Brazil. Energy Policy, 171, 113246.

Latin American Energy Organisation (OLADE). (n.d.). Inflación energética mensual en ALC. OLADE. Retrieved [27/02/2024], from https://www.olade.org/noticias/inflacion-energetica-mensual-en-alc/https://www.olade.org/noticias/inflacion-energetica-mensual-en-alc/

Latin American Energy Organisation (OLADE). (2013). Latin American Energy Organisation. Estrategia de equidad de género de la secretaría permanente de OLADE. Available in: https://www.olade.org/wp-content/uploads/2021/03/ESTRATEGIA-EQUIDAD-GENERO-OLADEdic20131.pdf

Latin American Energy Organisation (OLADE). Panorama energético de América Latina y el Caribe 2023. Retrieved [17/04/2024], from https://www.olade.org/publicaciones/panorama-energetico-de-america-latina-y-el-caribe-2023/

Liao, T. F. (1994). Interpreting probability models: Logit, probit, and other generalized linear models (No. 101). Sage.

Llopis, E. J., & Baute, E. M. T. (2023). Pobresa energètica:: mesurament i polítiques per combatre-la. Nota d'Economia, (107), 166-178.

Maidana, M. F., Torrontegui, M., & Villoldo, F. (2020). Energía Y Pobreza: Una Aproximación Al Trabajo De Extensión Universitaria en Villa del Mar. En Energía, innovación y ambiente para una transición energética sustentable: retos y perspectivas coordinación general de Carina Guzowski; María Ibáñez Martín; María Florencia Zabaloy. - 1a ed. - Bahía Blanca: Editorial de la Universidad Nacional del Sur. Ediuns, 2020. Available in: https://www.researchgate.net/profile/Silvia-London/publication/346631968_Analisis_de_la_situacion_de_los_barrios_vulnerables_de_bahia_blanca_las_desventajas_medioambientales_como_contribucion_a_las_trampas_de_pobreza/links/5fca71db92851c00f84d591e/Analisis-de-la-situacion-de-los-barrios-vulnerables-de-bahia-blanca-las-desventajas-medioambientales-como-contribucion-a-las-trampas-de-pobreza.pdf#page=95

Map school. (2025). Map of Germany, description of features Available at: https://escuelademapas.com/mapa-de-alemania-descripcion-de-caracteristicas/

Melo, Y. (2022) As dimensões da pobreza energética no Brasil. Tesis (Doctorado en Economía), Universidad Federal Fluminense, Niterói, Brasil, 2022. Available in: https://bdtd.ibict.br/vufind/Record/UFF-2_16255e4a5a0185de3139a6e342fda484

Menard, S. (2002). Applied logistic regression analysis (2nd ed.). SAGE

Middlemiss, L., & Gillard, R. (2015). Fuel poverty from the bottom-up: Characterising household energy vulnerability through the lived experience of the fuel poor. Energy Research & Social Science, 6, 146–154. https://doi.org/10.1016/j.erss.2015.02.001

Middlemiss, L., Ambrosio-Albalá, P., Emmel, N., Gillard, R., Gilbertson, J., Hargreaves, T., Mullen, C., & Tod, A. (2019). Energy poverty and social relations: Dimensions of resilience amongst vulnerable households. Energy Research & Social Science, 18, 86–94. https://doi.org/10.1016/j.erss.2016.06.013

Millán Valenzuela, H. (2023). The Concept of Development: Heuristic Turns. From Economic Growth to The Rights Approach. Sociedad y Economía, (49), e10712213. https://doi.org/10.25100/sye.v0i49.12213

Mining and Energy Planning Unit (UPME). (2025). Estructura del sector. Available at: https://www1.upme.gov.co/simco/Paginas/Estructura-del-Sector.aspx

Mining and Energy Planning Unit (UPME). (2019). Primer balance de Energía Útil para Colombia y Cuantificación de las pérdidas energéticas relacionadas y la brecha de eficiencia energética. https://www1.upme.gov.co/DemandayEficiencia/Documents/Balance_energia_util/BEU-Residencial.pdf

Mining and Energy Planning Unit (UPME). (2023). Plan Indicativo de Expansión de Cobertura de Energía Eléctrica - PIEC 2019-2023. Mining and Energy Planning Unit. Available at: https://www1.upme.gov.co/siel/Pages/Plan-indicativo-expansion-cobertura-EE-PIEC.aspx

Ministry of Economy of Argentina. (2016). Mayores consumos en el hogar. Government of Argentina. Retrieved [27/02/2025], from https://www.argentina.gob.ar/energia/uso-responsable/mayores-consumos-hogar

Ministry of Energy (2020). Balance Nacional de Energía Útil Residencial. Available in: https://www.argentina.gob.ar/produccion/energia/eficiencia-energetica/balancenacional-de-energia-util/balance-nacional-de-energia-util-residencia

Ministry of the Environment. (2025). https://archivo.minambiente.gov.co/index.php/noticias-minambiente/3196-colombia-celebra-su-biodiversidad

Ministry of Mines and Energy. (2024). Informe sobre Pobreza Energética Multidimensional en Colombia 2022-2023

Ministry for Ecological Transition (2019). Estrategia Nacional Contra la Pobreza Energética 2019-2024. Available at: https://www.miteco.gob.es/es/ministerio/planesestrategias/estrategia-pobrezaenergetica/estrategianacionalcontralapobrezaenergetica_tcm30502982.pdfMoniruzzaman,

M., & Day, R. (2020). Gendered energy poverty and energy justice in rural Bangladesh. Energy Policy, 144, 111554.

O'Dell, K., Peters, S., & Wharton, K. (2014). Women, Energy, and Economic Empowerment. Deloitte University Press.

Observatory of Economic Complexity. (2022). Germany (DEU) Exports, Imports, and Trade Partners. OEC. Available in: https://oec.world/en/profile/country/deu?flowLineplot=importOption&timeLinePlot=yearOption&yearlyTradeFlowSelector=flow1&depthSelector1=HS2Depth&yearSelector1=2022 (Accessed on 27 February 2025)

Organisation of American States (OAS). (2014). Desigualdad e inclusión social en las Américas: elementos clave, tendencias recientes y caminos hacia el futuro. In Organization of American States, 14 essays, Second Edition

Opatrný, V. (2023). Bridging the Gap: A Novel 2M/LIHC Hybrid Indicator. Florence School of Regulation. Recuperado de https://fsr.eui.eu/wp-content/uploads/2024/12/Opatrny_Energy_poverty_presentation.pdf

Ozdemir, E., & Koukoufikis, G. (2024). The persistence of energy poverty in the EU. Publications Office of the European Union, Luxembourg. Recuperado el [18/04/2024], de https://publications.jrc.ec.europa.eu/repository/handle/JRC138409

Pachauri, S., van Ruijven, B. J., Nagai, Y., Riahi, K., van Vuuren, D. P., Brew-Hammond, A., Nakicenovic, N. (2013). Pathways to achieve universal household access to modern energy by 2030. Environmental Research Letters, 8(2), 024015.

Parikh, J. (2011). Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India. Energy Policy, 39(12), 7587-7594.

Pindyck, S., & Rubinfeld, L. (1998). Economentric models and economic forecasts.

Rademaekers, K. et al. Selecting Indicators to Measure Energy Poverty. Rotterdam, 2016.

Recalde, M. Y.; Bouille, D. H. y Girardin, L. O. (2015). Limitaciones para el desarrollo de energías renovables en Argentina. Problemas del desarrollo, ILVI (183), 89-115. Recuperado el 25 de junio de 2023 de https://www.scielo.org.mx/pdf/prode/v46n183/ 0301-7036-prode-46-183-00089.pdf

Reygadas, L. (2008). La apropiación: destejiendo las redes de la desigualdad. Buenos Aires: Anthropos.

Robinson, C. (2019). Energy poverty and gender in England: A spatial perspective. Geoforum 104 (2019) 222–23.

Robinson, C., Bouzarovski, S., & Lindley, S. (2021). 'Under the radar': The importance of understanding household energy practices for tackling energy poverty. Energy Research & Social Science, 72, 101859. Available in: https://doi.org/10.1016/j.erss.2020.101859

Rojas, A., Zambrano, A., & Gómez, L. (2019). Energy vulnerability in Latin America: Inequalities and opportunities. Energy Research & Social Science, 57, 101256.

Romero Mora, J. C., Barrella, R., & Centeno Hernáez, E. (2024). Informe de Indicadores de Pobreza Energética en España 2023. Universidad Pontificia Comillas. Available in http://hdl.handle.net/11531/95198Repositorio Comillas+3Repositorio

Rosa, M., Aguiar, B. V., & Aguirre, A. V. (2021). Análisis crítico de lacontribución de la Agenda 2030 a la identificación de la vulnerabilidad energética. Libro de actas XVII Jornadas de Economía Crítica:'Emergencias, Transiciones y Desigualdades Socioeconómicas'. 4 y 5 de febrero de 2021 Universidade de Santiago de Compostela, 36.

Sánchez-Guevara, C., Gómez-Acebo, I., & González, M. (2020). Fuel poverty in Spanish housing stock: Temporal evolution and geographical distribution. Energy Policy, 140, 111418. Available in: https://doi.org/10.1016/j.enpol.2020.111418

Sanz, A., Gómez, G., Sánchez, C., Nuñez, M. (2016). Estudio técnico sobre pobreza energética en la ciudad de Madrid, ciudad de Madrid, España.

Sen, A. (1979). ¿Igualdad de qué? Libertad, igualdad y derecho, las conferencias Tanner sobre filosofía moral, pp. 133-156.

Sen, A. (1992). Inequality Reexamined. Harvard University Press.

Simcock, N., Petrova, S., & Bouzarovski, S. (2021). Energy poverty and social relations: Dimensions of resilience amongst vulnerable households. Energy Research & Social Science, 18, 86–94. https://doi.org/10.1016/j.erss.2016.06.013

Simcock, N., Walker, G., & Day, R. (2016). Fuel poverty in the UK: Beyond heating? People, Place and Policy, 10(1), 25–41. https://doi.org/10.3351/ppp.0010.0001.0004

Soares, R. S., Weiss, M., Lampis, A., Bermann, C., & Hallack, M. (2023). Pobreza energética en los hogares y su relación con otras vulnerabilidades en América Latina. El caso de Argentina, Brasil, Colombia, Perú y Uruguay. Banco Interamericano de Desarrollo (BID).

SocialWatt. (2023). Connecting Obligated Parties to Adopt Innovative Schemes towards Energy Poverty Alleviation. Informe final del proyecto Horizon 2020 (ID 845905). Comisión Europea. Available in: https://socialwatt.eu/sites/default/files/2023-07/SocialWatt_D4.7_PolicyBriefs.pdf

SocialWatt. (2020). Energy poverty alleviation. Country factsheet: Germany. Final publishable report D4.6. https://socialwatt.eu/sites/default/files/socialwatt_tools/D4.6%20Policy%20fact%20sheets_final.pdfEscribano, G., & Lázaro, L. (2020). Energía, clima y coronavirus. Real Instituto Elcano, 27. Available in: https://www.realinstitutoelcano.org/analisis/energia-clima-y-coronavirus/

Socio-Economic Panel (SOEP), version 39, data for years 1984-2022 (SOEP-Core v39, EU Edition). 2024. DOI:10.5684/soep.core.v39eu

Sovacool, B. K. (2011). Conceptualizing urban household energy use: climbing the "Energy Services Ladder". Energy Policy, 39, 1659-1668.

Sovacool, B. K. (2012). The political economy of energy poverty: A review of key challenges. Energy for Sustainable Development, 16(3), 272-282.

Sovacool, B. K., Burke, M., Baker, L., Kotikalapudi, C. K., & Wlokas, H. (2017). Energy and development: Three big questions. Energy Research & Social Science, 40, 1-3.

Statistisches Bundesamt (Destatis). (2025). Private households – Environmental Economic Accounting. Destatis. Recuperado el [27/02/2025], de https://www.destatis.de/EN/Themes/Society-Environment/Environment/Environmental-Economic-Accounting/private-households/_node.html#475118

Sun, M., Cao, X., Liu, X., Cao, T., & Zhu, Q. (2024). The Russia-Ukraine conflict, soaring international energy prices, and implications for global economic policies. Heliyon, 10(16).

Superintendencia de Servicios Públicos Domiciliarios (SSPD). (2022). Available in: https://www.superservicios.gov.co/sites/default/files/2022-12/informacion_tarifaria_de_energia_-_principales_comercializadores_integrados_al_operador_de_red_DICIEMBRE_2022.xlsm

Thomson, H., Bouzarovski, S., & Snell, C. (2017). Energy poverty in the European Union: a review of the evidence. Energy Policy, 52, 137–151. Available in: https://doi.org/10.1016/j.enpol.2012.09.045

Thomson, H., Bouzarovski, S., & Snell, C. (2017). Rethinking the measurement of energy poverty in Europe: A critical analysis of indicators and data. Indoor and Built Environment, 26(7), 879–901. Available in: https://doi.org/10.1177/1420326X17699260

Thomson, H., Snell, C., & Bouzarovski, S. (2017). Health, well-being and energy poverty in Europe: A comparative study of 32 European countries. International Journal of Environmental Research and Public Health, 14(6), 584 .Available in: https://doi.org/10.3390/ijerph14060584

Tirado Herrero, S., & Jiménez Meneses, L. (2016). Energy poverty, crisis and austerity in Spain. People, Place and Policy, 10(1), 42–56.Available in: https://doi.org/10.3351/ppp.0010.0001.0005

Tirado Herrero, S., & Jiménez Meneses, L. (2020). Midiendo la pobreza energética. Una revisión de indicadores. Revista INVI, 35(99), 147–177. Available in: https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-83582020000100147

Tornarolli, L. & Puig, J. (2023). Acceso y consumo de energía residencial en América Latina y el Caribe. Caracas: CAF. Available in https://scioteca.caf.com/handle/123456789/2253

Train, K. (2009). Discrete choice methods with simulation (2nd ed.). Cambridge University Press UN-Energy. (2007). Sustainable Bioenergy: A Framework for Decision Makers. Recuperado de https://www.cepal.org/en/publications/2856-sustainable-bioenergy-framework-decision-makers

UN WOMEN. (2018). Hacer las promesas realidad: La igualdad de género en la Agenda 2030 para el Desarrollo Sostenible. Available in: https://www.unwomen.org/es/digital-library/publications/2018/2/gender-equality-in-the-2030-agenda-for-sustainable-development-2018

Urquiza, A., Billi, M., Amigo, C., & Oscullo, D. (2021). Multidimensional energy poverty in Chile: Evidence and policy implications. Energy Policy, 152, 112236. https://doi.org/10.1016/j.enpol.2021.112236

Viñuela, J., Chévez, P. J., Martini, I., & San Juan, G. A. (2022). Análisis y caracterización de hogares en pobreza energética, a partir de la Encuesta Nacional de Gastos de los Hogares. Avances en Energía Renovables y Medio Ambiente, 26.

Walker, G., Simcock, N., & Day, R. (2016). Necessary energy uses and a minimum standard of living: Energy justice or escalating expectations? Energy Research & Social Science, 18, 129–138. https://doi.org/10.1016/j.erss.2016.03.017

Wilkinson, R., & Pickett, K. (2009). The Spirit Level: Why More Equal Societies Almost Always Do Better. Allen Lane.

Williams, R. (2006, July). Interpreting and using heterogeneous choice & generalized ordered logit models. In North American Stata Users' Group Meeting, Boston.

Wooldridge, J. M. (2010). Econometric analysis of cross section and panel data. MIT press.

World Bank. (2022). Access to electricity (% of population) - Latin America & Caribbean.

World Bank. (2025). Commodity Markets. Available in: https://www.worldbank.org/en/research/commodity-markets

World Bank. (2003). Household Fuel Use and Fuel Switching in Guatemala. Washington, DC: ESMAP Technical Paper no. 036-03. Available in: https://openknowledge.worldbank.org/handle/10986/19643

World Health Organisation (WHO). (2016). Burning opportunity: clean household energy for health, sustainable development, and wellbeing of women and children. World Health Organization. https://www.who.int/publications/i/item/9789241565233

9. ANNEXES

ANNEX A. Methodological procedure

This annex expands on some aspects of the methodological strategydetailed in section 4 and is divided as follows: A.1) Definition of the dependent variables analysed; A.2) Control variables used for the econometricestimations for each country; A.3) Treatment of missing data in the four databases.

A.1 Definition of dependent variables analysed in each country

Energy indigence

Germany	It has a value of 1 if the household has no thermal insulation and the household is at risk of monetary poverty after paying energy costs, following the criteria of the *High cost-low income*indicator.
Argentina	Dichotomous variable with a value of 1 if essential energy services (cooking, heating, domestic hot water) are met in the household with solid or unclean liquid fuels.
Colombia	Dichotomous variable with a value of 1 if the household satisfies the energy service for cooking food mainly through charcoal, firewood, wood, charcoal or waste material.
Spain	Dichotomous variable with a value of 1 if essential energy services (cooking, heating, domestic hot water) are met in the household with solid or unclean liquid fuels.

Energy poverty according to the 10% ratio

Germany	It has a value of 1 if the household spends more than 10% of its total monthly income on energy, electricity and heating energy payments, and zero otherwise
Argentina	It has a value of 1 if the household spends more than 10% of its total monthly income on energy payments, all sources considered, and zero otherwise
Colombia	It has a value of 1 if the household spends more than 10% of its total monthly income on energy, electricity and natural gas or LPG, and zero otherwise
Spain	It has a value of 1 if the household spends more than 10% of its total monthly income on energy payments, all sources considered, and zero otherwise

Energy poverty according to the 2M indicator

Germany	Whose value is 1 if the household has an energy expenditure relative to income of more than twice the national median and 0 otherwise. National median expenditure to income ratio: 5.38%
Argentina	Whose value is 1 if the household has an energy expenditure relative to income of more than twice the national median and 0 otherwise. National median expenditure to income ratio: 6.71%

Colombia	Whose value is 1 if the household has an energy expenditure relative to income of more than twice the national median and 0 otherwise. National median expenditure to income ratio: 5.21%
Spain	Whose value is 1 if the household has an energy expenditure relative to income of more than twice the national median and 0 otherwise. National median expenditure to income ratio: 5.48%

Energy vulnerability

Germany	Dichotomous variable that has a value equal to 1 if the household is at risk of monetary poverty or considers the size of the dwelling to be small.
Argentina	Dichotomous variable whose value is equal to 1 if the household is at risk of monetary poverty, precarious material in the dwelling or deficient equipment. Precarious material in housing: On floors, walls or ceilings. Deficiency in equipment: heating, cooking, food refrigeration and hot water supply.
Colombia	Dichotomous variable whose value is equal to 1 if the household is at risk of monetary poverty, precarious material in the dwelling or deficient equipment. Precarious material in housing: Floors, walls or ceilings Deficiency in equipment: Cooking, food refrigeration and service provided by the washing machine.
Spain	Dichotomous variable that has a value equal to 1 if the household is at risk of monetary poverty, poor housing or poor facilities. Precarious housing: precarious house, type of house and located in a precarious area Deficiency in equipment: Heating, cooking and cooling of food.

A.2 Control variables used for econometric estimations for each country

Germany

Particularly in the case of Germany, the control variables differ from the other countries mainly in 2 aspects: i) the non-inclusion of the equipment deficit variable due to data unavailability; ii) the construction of the housing deficit variable, which has a value of 1 if it considers the size of the dwelling to be small. This construction was chosen as a proxy in accordance with the availability of SOEP survey data. The following is a detail of the equations estimated for each problem analysed:

$$logit(p_{iAle-ie}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 tamaño\ hogar_i + \beta_9 déficit\ vivienda_i \quad (2)$$

$$logit(p_{iAle-pe10}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 tamaño\ hogar_i + \beta_9 déficit\ vivienda_i \quad (3)$$

$$logit(p_{iAle-pe2m}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 tamaño\ hogar_i + \beta_9 déficit\ vivienda_i \quad (4)$$

$$logit(p_{iAle-ve}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 tamaño\ hogar_i \quad (5)$$

Argentina

The independent variables used to explain each problem are shown below:

$$logit(p_{iArg-ie}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 riesgo\ de\ pobreza\ monetaria_i + \beta_9 tamaño\ hogar_i + \beta_{10} deficiencia\ equipamiento_i + \beta_{11} déficit\ vivienda_i \quad (6)$$

$$logit(p_{iArg-pe10}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 tamaño\ hogar_i + \beta_9 deficiencia\ equipamiento_i + \beta_{10} déficit\ vivienda_i \quad (7)$$

$$logit(p_{iArg-pe2M}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 tamaño\ hogar_i + \beta_9 deficiencia\ equipamiento_i + \beta_{10} déficit\ vivienda_i \quad (8)$$

$$logit(p_{iArg-ve}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 tamaño\ hogar_i + \beta_9 acceso\ electricidad_i + \beta_{10} acceso\ gas\ natural_i \quad (9)$$

Colombia

In the case of Colombia and the Caribbean region, race was included as an explanatory variable due to its ethnic diversity, which includes indigenous or Afro-Colombian communities and migrant heads of household. Below are the equations:

$$logit(p_{iCol-ie}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 migrante_i + \beta_5 edad_i + \beta_6 raza_i + \beta_7 desocupación_i + \beta_8 educ\ media_i + \beta_9 educ\ alta_i + \beta_{10} riesgo\ de\ pobreza\ monetaria_i + \beta_{11} tamaño\ hogar_i + \beta_{12} deficiencia\ equipamiento_i + \beta_{13} déficit\ vivienda_i \quad (10)$$

$$logit(p_{iCol-pe10}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 migrante_i + \beta_5 edad_i + +\beta_6 raza_i + \beta_7 desocupación_i + \beta_8 educ\ media_i + \beta_9 educ\ alta_i + \beta_{10} tamaño\ hogar_i + \beta_{11} deficiencia\ equipamiento_i + \beta_{12} déficit\ vivienda_i \quad (11)$$

$$logit(p_{iCol-pe2M}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 migrante_i + \beta_5 edad_i + +\beta_6 raza_i + \beta_7 desocupación_i + \beta_8 educ\ media_i + \beta_9 educ\ alta_i + \beta_{10} tamaño\ hogar_i + \beta_{11} deficiencia\ equipamiento_i + \beta_{12} déficit\ vivienda_i \quad (12)$$

$$logit(p_{iCol-ve}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 migrante_i + \beta_5 edad_i + +\beta_6 raza_i + \beta_7 desocupación_i + \beta_8 educ\ media_i + \beta_9 educ\ alta_i + \beta_{10} tamaño\ hogar_i + \beta_{11} acceso\ electricidad_i + \beta_{12} acceso\ a\ gas_i \quad (13)$$

Spain

One difference in the explanatory variables studied in Spain is the incorporation of the migrant status of the head of household. Below are the equations:

$$logit(p_{iEsp-ie}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 edad_i + \beta_5 desocupación_i + \beta_6 educ\ media_i + \beta_7 educ\ alta_i + \beta_8 riesgo\ de\ pobreza\ monetaria_i + \beta_9 tamaño\ hogar_i + \beta_{10} deficiencia\ equipamiento_i + \beta_{11} déficit\ vivienda_i \quad (14)$$

$$logit(p_{iEsp-pe10}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 migrante_i + \beta_5 edad_i + \beta_6 desocupación_i + \beta_7 educ\ media_i + \beta_8 educ\ alta_i + \beta_9 tamaño\ hogar_i + \beta_{10} deficiencia\ equipamiento_i + \beta_{11} déficit\ vivienda_i \quad (15)$$

$$logit(p_{iEsp-pe2m}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 migrante_i + \beta_5 edad_i + \beta_6 desocupación_i + \beta_7 educ\ media_i + \beta_8 educ\ alta_i + \beta_9 tamaño\ hogar_i + \beta_{10} deficiencia\ equipamiento_i + \beta_{11} déficit\ vivienda_i \quad (16)$$

$$logit(p_{iEsp-ve}) = In\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 género_i + \beta_2 hogar\ monoparental_i + \beta_3 feminización\ hogar_i + \beta_4 migrante_i + \beta_5 edad_i + \beta_6 desocupación_i + \beta_7 educ\ media_i + \beta_8 educ\ alta_i + \beta_9 tamaño\ hogar_i + \beta_{10} acceso\ electricidad_i + \beta_{11} acceso\ gas\ natural_i \quad (17)$$

The explanatory variables access to electricity and access to natural gas were linked in the energy vulnerability model for all countries except Germany due to the absence of the variable in the survey. These variables were not considered as explanatory variables for energy indigence or energy poverty metrics to avoid endogeneity and, therefore, affecting the accuracy of the results.

A.3 Processing of missing data

The strategy for the treatment of missing data (missing data) was considered based on the number of missing data and whether they affect only some dependent or explanatory variables. In general, the criterion was to retain dependent or independent variables with missing data because their percentage was not representative of the total survey sample and not to eliminate them in order not to lose observations.

In the German survey, SOEP, an approximate 19.92% proportion of missing data was found, mainly in the energy poverty metrics to measure the ratio of expenditures exceeding 10% of income to 2M, as no response was found on electricity or home heating expenditures. There is also a non-significant proportion of missing data on explanatory variables. The sample size was 19,876 households, which when expanded represented 39,809,277 households in Germany.

Argentina is the country with the lowest number of missing data, at 0.17% of the total base, related to the omission of responses in the variables of interest. Similarly for Spain, where the percentage of omitted responses in 2022 for the relevant variables in this paper was 0.1%.

EU-LAC