In partnership with National Council for Scientific and Technological Research Argentina (INCIHUSA CONICET), University: Faculty of Architecture, Urbanism and Design. University of Mendoza

Master of Science Program in
Territorial, Urban, Environmental and Landscape Planning

Master's Thesis

Establishing Top-Down Urban Energy Models in Different Sectors of Mendoza (AR):

Statistical Models Approach at the Urban Scale for Residential, Industrial, and Commercial/Services Sectors according to Space Heating & Domestic Hot Water

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Abstract:

Urban energy consumption emerges as a global concern, with buildings playing a pivotal role. This thesis investigates the unique context of Mendoza, Argentina, aiming to harness the transformative potential of Building Energy Modeling (BEM) tools. The primary objective is to evaluate and optimize energy utilization at an urban scale, specifically focusing on statistical models tailored for home hot water and space heating systems. At the core of this investigation is a data-driven approach, utilizing a comprehensive dataset with building attributes, climatic information, and detailed energy consumption records. This dataset forms the foundation for constructing 51 predictive models for three different sectors, dynamically bridging the architectural, behavioral, and climatic facets of energy consumption, uniquely tailored for residential, industrial, and commercial/services sectors.

These models serve as a holistic urban energy portrait, providing nuanced insights into the diverse energy dynamics of Mendoza. In this work, various variables are considered. Obtaining different variables for buildings throughout designated districts and identifying homogenous areas based on the similarity of these variables are crucial to model construction. These factors hold utmost significance due to their close ties to natural gas use. Consequently, efforts were made to identify homogenous areas based on building characteristics through k-means clustering. Importantly, this investigation considered different sectors such as residential, commercial, and services, recognizing the diverse energy needs and patterns within each sector.

Moreover, the computation of actual energy consumption occurred at a district level, lacking detailed information regarding individual buildings. To address this, employing top-down modeling techniques becomes imperative. Simultaneously, recognizing the impact of altitude and climate variations on gas consumption, we undertook the normalization of real gas consumption concerning altitude to enhance the robustness of our analysis. This approach aims to refine and augment our understanding of energy consumption patterns, laying the groundwork for a more nuanced and accurate portrayal of the intricate interplay between gas consumption and diverse environmental factors. For investigating the relationship between two quantitative variables, correlation and linear regression were employed. Correlation was used to understand which independent variable has a connection with the dependent variable. After the modeling procedure is complete, the created model and real consumption statistics provided by energy providers are rigorously compared. This comparison exercise serves two other purposes: first, to validate the model's accuracy, and second, to use validation for expanding our models to different years.

Moving beyond technical prowess, the thesis delves into broader implications, shedding light on the transformative potential of implementing energy-efficient strategies while recognizing the priority of investment districts. The study goes beyond traditional modeling approaches by extracting latent knowledge from Mendoza's census records. By elegantly weaving this historical tapestry into the contemporary timeline of natural gas (NG) consumption, the research creates a multifaceted model that transcends traditional limitations. The focus extends to residential, commercial, and service sectors within urban areas, addressing the unique challenges and opportunities each sector presents. The outcomes of this study offer practical insights for Mendoza's urban planners, legislators, and building designers. Through data-driven strategies, the thesis aims to enhance energy efficiency within the urban building stock, providing tailored solutions for the distinct characteristics of each sector. Furthermore, the crafted methodology serves as a guiding beacon for future projects, not only in Argentina but also in other locales with unique climatic and architectural characteristics.

In summation, this thesis significantly contributes to the ongoing discourse surrounding sustainable urban development. It exemplifies the potential for bridging the divide between theoretical modeling and practical implementation, all while honoring the distinctive essence of Mendoza's urban environment. The research illuminates a path toward a future where urban energy use becomes a harmonious, data-driven orchestration, contributing to a more sustainable, resilient, and efficient urban existence.

Acknowledgment

We extend our sincere and heartfelt appreciation to our esteemed supervisors, Professor Gugliemina Mutani and Professor Mariela Arboit. Their unwavering commitment to our academic and research pursuits has been truly exceptional. The invaluable guidance they provided, coupled with their scholarly insights, played a pivotal role in shaping the trajectory of our research. Their mentorship has not only enriched our academic experience but has also been a source of inspiration for our future endeavors.

A special note of gratitude goes to the vibrant and supportive academic community at Politecnico di Torino. The university provided a nurturing environment that fostered intellectual growth and offered essential resources pivotal for the successful completion of our thesis. The collaborative spirit and diverse perspectives within the academic community enhanced the depth and breadth of our research, contributing to a more comprehensive understanding of our chosen field.

Finally, we extend our deepest thanks to our families for their unwavering support, constant encouragement, and understanding throughout the demanding phases of our academic pursuits. Their steadfast belief in our abilities and the sacrifices they made on our behalf have been our pillars of strength. Their role in our academic journey is immeasurable, and we are profoundly grateful for the love and support they have showered upon us.

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1. Introduction

Energy planning is a crucial element in achieving sustainable development and reducing greenhouse gas emissions. The rapidly increasing global population and urbanization have led to a significant increase in energy consumption and its consequences like increasing the earth's temperature and climate change. Consequently, increasing energy efficiency, conserving energy, and utilizing renewable energy sources are essential in urban areas. Finding energy models and consumption patterns in urban settings is the initial step toward achieving this goal. This not only serves to pinpoint crucial system issues but also proves pivotal in forecasting future energy consumption trends. In this thesis, we aim to advance energy planning at a city scale by constructing an energy model in different sectors and comparing it with the actual amount of energy consumption for Mendoza, Argentina.

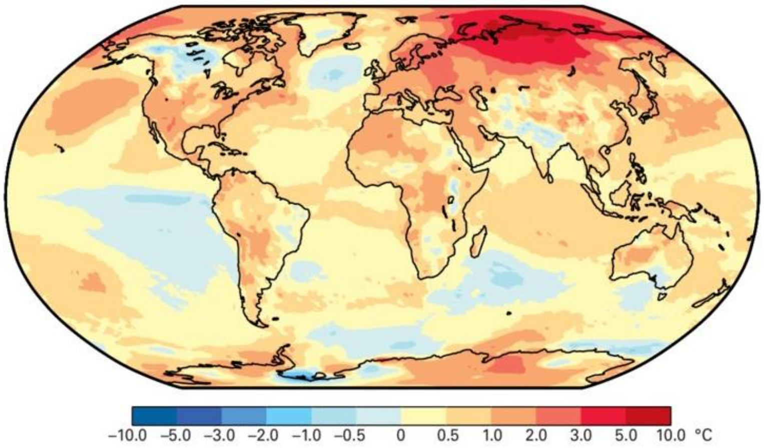


Figure 1: shows temperature anomalies from the ERA5 reanalysis for 2020 in comparison to the long-term average for the years 1981–2010. Source: European Centre for Medium-Range Weather Forecasts (ECMWF), Copernicus Climate Change Service

Recently, the creation of new, livable, energy-efficient, and environmentally sustainable metropolitan areas has made urban development a viable means of combating climate change (Dogan and Reinhart 2017). Globally, cities have started establishing goals for reducing their greenhouse gas (GHG) emissions to prevent negative environmental effects and address climate change (Sokol et al. 2017). Urban sustainability and climate change are significantly impacted by building energy use, and these effects are more noticeable in densely populated areas. 75% of greenhouse gas emissions come from cities, with the building and transportation industries accounting for the majority of these emissions (UNEP 2018). Planning for energy should always consider the results of economic and demographic expansion. To determine and justify energy policies and measures in decision-making, as well as the relationship between scientific knowledge and practical knowledge, predictive energy models can make special contributions, and by utilizing them, urban planners can make short-term to long-term analyses of the urban system, considering different scenarios. In this project, we explain predictive energy models to calculate the energy consumption of space heating in the residential - industrial - commercial, and services sectors according to the different characteristics of the buildings. With the help of these models and comparing them with the actual amount of energy consumption, suitable conditions are provided for us to discover priority areas for intervention.

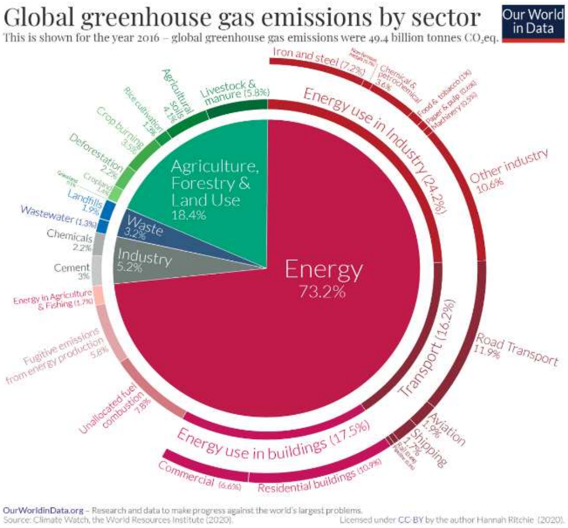


Figure 2: Global emissions of greenhouse gases by sector in 2016. (Source: World Resources Institute 2020, Climate Watch)

1.1 Background of energy planning

Planning for energy might entail many different things. However, one common definition of the term is the process of developing long-term policies to help guide the future of a local, national, regional, or even global energy system. Energy planning is often done within governmental organizations, but it can also be done by large energy companies such as electric utilities or oil and gas producers. During the energy planning process, a variety of stakeholders, including those from governmental organizations, regional utilities, the academic community, and other interest groups, may offer their opinions. Integrated methods are widely used in energy planning, considering the availability of energy supplies as well as the role that energy efficiency plays in reducing demand. Population growth should always be considered in energy planning.

The framework for laws in the energy sector (affecting, for example, the types of power plants that might be built or the costs for fuels) has historically been heavily influenced by energy planning. However, a number of countries have liberalized their energy markets in the last 20 years, which has diminished the significance of energy planning and increased the number of decisions that are determined by the market. There is little evidence that this has led to lower consumer energy prices, but there is some evidence that it has increased competition in the energy sector. In some cases, deregulation has really led to enormous concentrations of "market power," with big, incredibly successful companies holding a substantial amount of sway over pricing.

This tendency currently appears to be changing as worries about the environmental effects of energy use and production increase. This is especially true given the threat posed by global climate change, which is mostly brought on by greenhouse gas emissions from the world's energy systems. Planning for sustainable energy is especially suitable for communities that seek to improve their local energy security while implementing best practices in their planning procedures. (Advanced Renewable Energy Systems, Book 2014)

1.2 The Energy Conundrum in Buildings: A Call for Sustainable Solutions

Buildings are omnipresent in today's world, forming our skylines and acting as the foundation of our neighborhoods (Pérez-Lombard et al., 2008). Beneath their exterior of grandeur and utility, however, is a stark reality: buildings consume a lot of energy. According to Economidou et al. (2020), buildings account for a staggering 30% of global energy use and 40% of energy-related CO2 emissions. Buildings are naturally energy-intensive due to a variety of factors, such as their age, size, climate, and occupant behavior (Menezes et al., 2014).

Consequently, buildings have a significant impact on energy use and GHG emissions. Buildings' constant energy demands present a significant obstacle to global efforts to achieve sustainability (Santos et al., 2023). Building energy consumption is expected to rise by 30% by 2040 as urbanization and global population growth pick up speed, worsening the built environment's already negative environmental effects (Sorrel, Dimitropoulos, & Ballinger, 2023).

According to that, designers, architects, and urban planners are now giving top priority to a building's energy efficiency. The way forward is to take a holistic approach that includes adopting green building practices, upgrading to more energy-efficient buildings, and changing behavior (Cengel & Turner, 2015; Haggerty et al., 2020; Moudon, 2022).

At the heart of addressing the energy crisis lies a fundamental shift towards energy-efficient upgrades (Pérez-Lombard et al., 2008). This entails retrofitting existing buildings with energy-saving technologies, such as high-efficiency lighting systems, improved insulation, and smart thermostats (Menezes et al., 2014). These upgrades have the potential to significantly reduce energy consumption, leading to substantial cost savings and environmental benefits (Santos et al., 2023).

In addition to technology improvements, building occupant behavior modifications are critical to reducing energy use (Economidou et al., 2020). When combined, these easy yet efficient habits—like turning off lights and appliances when not in use, utilizing natural light whenever possible, and responsibly adjusting thermostat settings—can result in large energy savings (Sorrel, Dimitropoulos, & Ballinger, 2023).

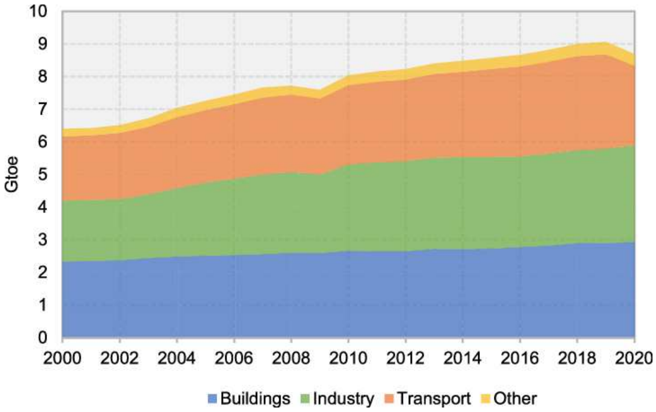


Figure 3 : Total energy consumed worldwide by sector. Based on information from the IEA (IEA, 2021e,d,b)

1.3 The importance of paying attention to energy planning in Argentina

Argentina boasts one of the biggest economies in Latin America, abundant natural resources such as gas and lithium reserves, incredibly fertile land, and significant potential for renewable energy. It is a major food producer with sizable livestock and agricultural sectors. Furthermore, Argentina offers promising prospects in select manufacturing subsectors and cutting-edge services in high-tech industries. However, the nation's development has been hampered by the historical volatility of economic growth and the accumulation of institutional barriers, and urban poverty is still very high. (Source: World Bank (2021)) Argentina's Second Biennial Update Report to the UNFCCC (2022): This report states that Argentina's GHG emissions increased from 413 MtCO2e in 2017 to 420 MtCO2e in 2019. The report also projects that emissions will continue to increase in the coming years, reaching around 460 MtCO2e in 2030. This is higher than the country's NDC target of 430 MtCO2e.the Climate Action Tracker (2023) which is an independent organization that assesses the climate action plans of countries around the world. Their most recent assessment of Argentina found that the country's NDC is not consistent with the Paris Agreement's temperature limit. Additionally, they discovered that Argentina's policies lack the ambition necessary to meet its NDC target. Argentina is among the few nations that has raised its Nationally Determined Contributions (NDC) targets, enhancing the substance and alignment of domestic policies. However, the NDC is not in line with the temperature limit set forth in the Paris Agreement, implying a warming of approximately 3°C to 4°C.2. Particularly when it comes to fossil fuels, agriculture, and transportation, Argentina's sectoral policies still don't quite match the temperature limit, but the country is making some headway in the renewable energy space.

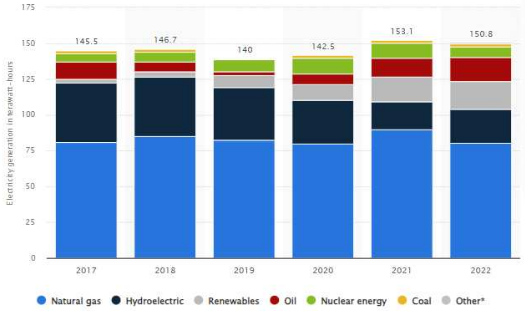


Figure 4:shows the amount of electricity generated in Argentina by fuel type (in terawatt-hours) between 2017 and 2022 (source: enerdata2022)

1.4 The purpose and method of research

Mitigating the Effects of Urbanization and Energy Consumption: A Systematic Approach to Urban Heating Needs Experts and stakeholders need to work together to mitigate the negative effects and promote sustainable development as human activities become more intense and urbanization picks up speed. Population growth-driven urbanization has inescapable effects that must be taken into consideration in the effort to create a prosperous and healthy society. The overall outdoor environment, indoor air quality, and thermal comfort are just a few of the parameters that need to stay within minimum acceptable ranges due to rising living standards.

This study suggests a systematic method to calculate the energy requirements for urban heating to allay these worries. The main goal of the project is to identify important environmental and social factors that have a significant impact on energy consumption to develop a predictive energy model. We can maximize energy use, lessen our impact on the environment, and improve the quality of life for city dwellers by being aware of these factors.

This novel approach aims to provide insights into critical areas, which are then used to create locally relevant short- and long-term solutions. This approach is effectively synthesized through the use of Geographic Information Systems (GIS) and statistical models. The central-western region of Argentina, namely the Mendoza metropolitan area, has been chosen as the subject of this investigation's case study. Notably, the primary energy source used for consumption in this region is natural gas. The informational foundation for this study is provided by the three hierarchical tiers of census sections, districts, and specific buildings within each census section. Since district-level energy usage data are readily available, a top-down approach is used to facilitate the development of a micro-scale model that incorporates census sections. The first stages make use of the Mendoza census database, which is laboriously imported into GIS to display a consistent distribution of data. It also facilitates the computation of pertinent building and urban metrics, readying them for subsequent modeling evaluations.

An essential component of building the model is estimating the heating volumes of buildings in each of the designated districts. Because of their strong connections to the use of natural gas, these factors are extremely important. Following the modeling process, an extensive comparison is made between the generated model and the actual consumption data that energy providers have provided. This comparison exercise has two functions: it verifies the accuracy of the model and calibrates it to reduce discrepancies and correct errors.

The real-world implementation of this approach could help urban planners and designers comprehend the precise location and gravity of energy-related challenges in the contemporary urban environment. They are now more capable of implementing proactive, focused solutions that will boost thermal comfort, reduce adverse environmental effects, improve energy efficiency, and—above all—achieve substantial energy savings for urban areas. This comprehensive approach is a component of the research's endeavor to establish the foundation for a more resilient and sustainable urban future, where energy consumption is in balance with social and environmental considerations.

1.5 Research Structure

The 7 chapters that make up this research contribute to a thorough knowledge of the energy dynamics in Mendoza's (AR) urban setting

Chapter 1: Introduction: The opening chapter introduces the research by exploring the significant role of energy in daily human life, with a specific emphasis on the building sector. It addresses environmental concerns arising from energy production and proposes actions for mitigation. The chapter outlines the project's objectives and provides an overview of the document's structure.

Chapter 2: Literature Review: To build a solid foundation for the study goals, a thorough analysis of important issues is conducted in the second chapter. The discussion opens with an examination of climate change, recognizing it as an urgent worldwide concern. After analyzing its three aspects and many techniques, sustainable development appears as a strategic solution to the issues provided by climate change. The story then turns to the critical relevance of energy-related concerns and the need for savings in the current context, exploring the environmental and energy crises and offering remedies. When examining energy use and researching ways to increase energy efficiency via decarbonization, energy analysis plays a crucial role. Broadening the focus, the conversation proceeds to outline the complex relationship between buildings and the city, investigating the effects of urban design and climatic variables on energy flow. The chapter concludes with a study of urban energy dynamics via the prism of urban scale energy models (USEMs). This includes global energy models, modeling techniques, statistical techniques, and relevant tools to fully comprehend the intricate interactions among variables influencing energy consumption at the urban scale.

Chapter 3: Methodological Procedure: This crucial chapter provides the methodological framework by carefully outlining the strategic framework that is used to achieve the predetermined study goals. First, the section provides a clear explanation of the study goal, which is to produce building energy models (BEMs). The next subsections explore the whole data-gathering process, covering several different aspects including the Buildings GEO DATABASE, Census Database, Urban Morphology Factors, Climatic and Geographical Characteristics, and Annual Gas Energy Consumption Data. Together, these datasets serve as the basis for the energy modeling method that follows. Model development and the integration of data from building and census scales down to the district level are the main foci of this technique. The statistical methods and analyses used, such as regression analysis and variable correlation in energy use, are also covered in this chapter. A thorough flowchart is presented to provide a visual depiction of the methodological flow. It summarizes the sequential procedures that are done to arrive at an informative and comprehensive energy model. The chapter aims to ensure the robustness and reliability of the resulting findings by providing clarity and transparency in the research technique through the use of this structured methodological framework.

Chapter 4: Case Study: As part of the case study's comprehensive analysis, this section closely looks at key components that have a big impact on Mendoza's energy dynamics. The weather takes center stage, with sections devoted to the effects of temperature, humidity, and sun addressing how weather stations and altitude affect energy patterns. A parallel study is conducted on the unique attributes of buildings, including important variables like building height, area and volume, orientation, surface-to-volume ratio, typology, building density, and building cover ratio. The focus shifts to the quality of the materials used in construction, which is further enhanced by information on the characteristics of the building population. A comprehensive knowledge of patterns of energy usage is achieved by closely examining homogeneous buildings and district features. The chapter ends with a thorough analysis of natural gas energy consumption, offering a thorough understanding of the quantitative factors supporting the energy dynamics of the metropolis. This chapter aims to clarify the complex links among building attributes, climate, and energy usage through this thorough investigation, setting the stage for the interpretive phase that follows.

Chapter 5: Research Outcomes and Analysis: The study project is anchored by this crucial chapter, which presents a thorough presentation of the results and analysis, including regression models for the various industries of residential, industrial, and commercial/services. The chapter offers a comprehensive overview of distribution patterns across several measured parameters through an amalgamation of important data, maps, and statistical models. The results are carefully explained via the use of tables, charts, and graphs, providing a comprehensive understanding of the building geometry, typology, social aspects, altitude ranges, and thermal energy use within each sector. The story deftly navigates through a sophisticated study to reveal how these elements interact to shape the city's energy environment in the residential, commercial/services, and industrial sectors. This results in the most energy-intensive parts of each sector being identified and illustrated, offering an industry-specific perspective on urban energy dynamics. The goal of this synthesis of quantitative and sector-specific qualitative assessments is to provide deep insights into Mendoza's energy dynamics, laying the groundwork for strategic urban energy planning that is adapted to the particulars of each sector.

Chapter 6: Discussion: In addition to summarizing the results of Chapter 5, this last chapter explores important facets of the reliability and relevance of the study findings. To guarantee the models' dependability and preparation for wider use, the study is extended to several years in the discussion of model validation. The chapter strengthens the research's practical value by examining the models' performance over a range of temporal circumstances. This allows the research to be adjusted for future years and maintains its relevance even after the initial study period. Moreover, the story shifts to a critical analysis of district-level energy policy and intervention goals, clarifying conclusions drawn from the models acquired. The chapter offers practical suggestions for urban energy planning and policy execution, going beyond statistical analysis. By identifying critical variables that have a substantial impact on the produced models, the discussion seeks to educate stakeholders and policymakers about important elements that require consideration and action. By using a comprehensive approach, the research is certain to have both academic and practical ramifications, influencing sustainable energy policy in the areas under study. The chapter ends with a discussion of directions for future study, laying the groundwork for more investigation and improvement in the ever-evolving subject of urban energy planning.

Chapter 7: Conclusion

The research has developed data-driven approaches to improve energy efficiency in Mendoza. it has identified the need for more detailed building-level data, continuous monitoring, and integration of renewable energy sources. and it has used scenario analysis to explore possible paths for urban growth.

2. Literature Review

This chapter explores the corpus of literature that explores the complexities of energy modeling and planning, with an emphasis on the applications, approaches, and ramifications in the context of cities. This literature review attempts to highlight the complexity of energy planning and the usefulness of energy models as instruments for well-informed decision-making and sustainable urban transformation through a critical analysis of relevant studies and research. By comprehensively assessing the existing knowledge landscape, this section sets the stage for a deeper exploration of the energy planning and modeling practices pertinent to the metropolitan area of Mendoza, Argentina.

2.1 climate change: A pressing global issue

Long-term changes in temperature and weather patterns are referred to as climate change. Although these changes can happen naturally as a result of things like solar activity or volcanic eruptions, since the 1800s, human action has been the main cause of climate change. The primary culprit is the widespread use of fossil fuels including gas, oil, and coal (NASA, 2023). Fossil fuel combustion releases greenhouse gases, mostly carbon dioxide and methane, which envelop the Earth like a blanket, trapping the heat from the sun and raising global temperatures (EPA, 2023). These emissions are produced by routine activities like heating a building with coal or operating a car that runs on gasoline. Furthermore, deforestation and land clearance emit carbon dioxide, but major industries like oil and gas and agriculture

The effects of climate change are extensive and becoming more noticeable; they have an impact on many different industries and facets of daily life. The average long-term changes over the whole Earth are referred to as global climate change, and they show themselves as:

- Rising sea levels threaten coastal communities and ecosystems (NOAA, 2023).
- Shrinking mountain glaciers, reducing water resources, and affecting ecosystems dependent on meltwater (EEA, 2020).
- Accelerated ice melting in Greenland, Antarctica, and the Arctic, contributes to sea-level rise and disrupting ocean currents (WMO, 2021).
- Shifts in the timing of plant and flower blooming, altering ecosystems and impacting agriculture (IPCC, 2021).

Even before the emergence of humanity, the Earth's climate has changed constantly over time. Nonetheless, the amount of change that has been witnessed recently is incredibly quick, with average global temperatures rising at a never-before-seen rate during the last 150 years (NASA, 2023).Global cooperation is needed to cut greenhouse gas emissions and switch to renewable energy sources to combat climate change. Collaboration and international cooperation are crucial to reducing the effects of climate change and preparing for the changes that are currently occurring. Not only is combating climate change necessary for the environment, but it is also a critical first step in securing a sustainable future for future generations.

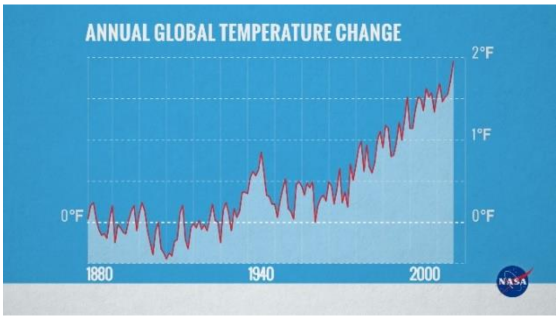
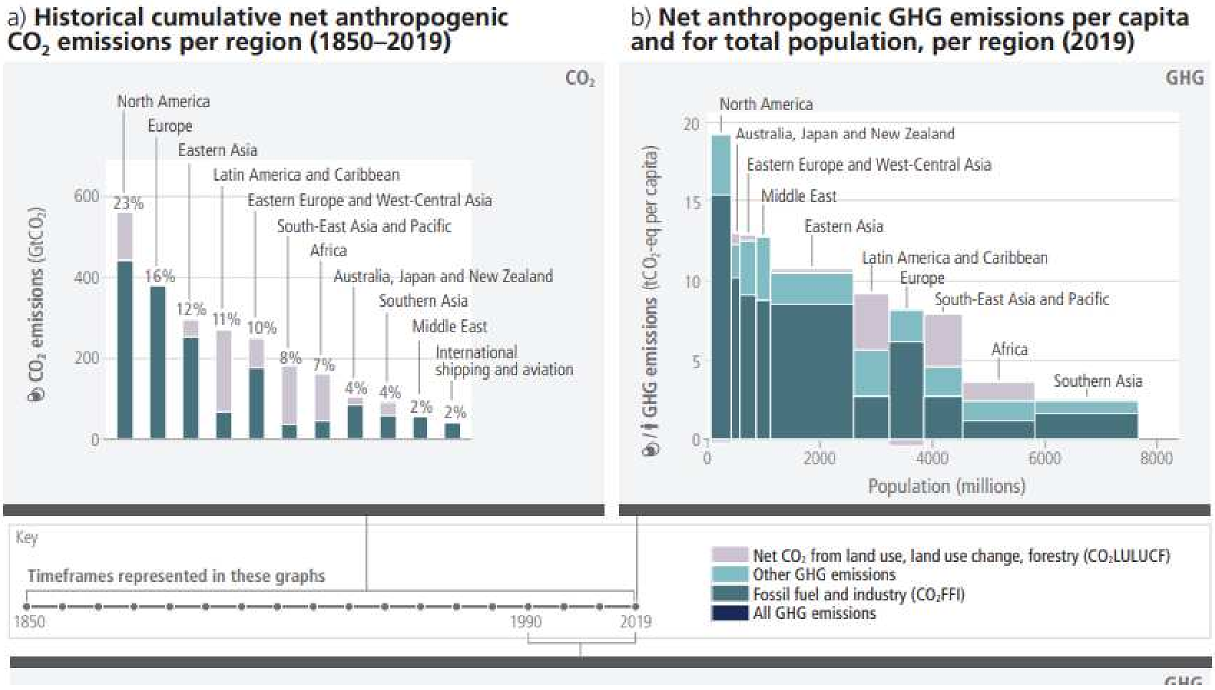
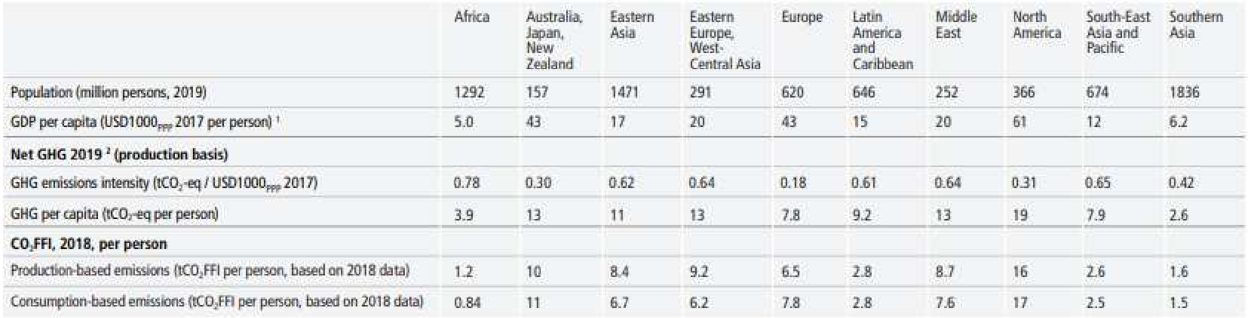


Figure 5 : Global temperature change throughout time plotted against the average yearly global temperature between 1880 and 1899. NASA's Goddard Space Flight Center is credited.

The Earth is warming more quickly in some places than others (NASA, 2023). However, throughout the previous 100 years, the average worldwide air temperature at the Earth's surface has increased by roughly 2 degrees Fahrenheit (EPA, 2023). According to the IPCC (2021), the last five years have been the warmest in centuries. Many people, including scientists, are concerned about this warming. As Earth's climate continues to warm, the intensity and amount of rainfall during storms such as hurricanes are expected to increase. Droughts and heat waves are also expected to become more intense as the climate warms (EPA, 2023). Human activities — such as burning fuel to power factories, cars, and buses — are changing the natural greenhouse (IPCC, 2021). These changes cause the atmosphere to trap more heat than it used to, leading to a warmer Earth (NASA, 2023; EPA, 2023; IPCC, 2021).





	Africa	Australia, Japan, New Zealand	Eastern Asia	Eastern Europe, West-Central Asia	Europe	Latin America and Caribbean	Middle East	North America	South-East Asia and Pacific	Southern Asia
Population (million persons, 2019)	1292	157	1471	291	620	646	252	366	674	1836
GDP per capita (USD1000$_{PPP}$ 2017 per person) [1]	5.0	43	17	20	43	15	20	61	12	6.2
Net GHG 2019 [2] (production basis)										
GHG emissions intensity (tCO$_2$-eq / USD1000$_{PPP}$ 2017)	0.78	0.30	0.62	0.64	0.18	0.61	0.64	0.31	0.65	0.42
GHG per capita (tCO$_2$-eq per person)	3.9	13	11	13	7.8	9.2	13	19	7.9	2.6
CO_2FFI, 2018, per person										
Production-based emissions (tCO$_2$FFI per person, based on 2018 data)	1.2	10	8.4	9.2	6.5	2.8	8.7	16	2.6	1.6
Consumption-based emissions (tCO$_2$FFI per person, based on 2018 data)	0.84	11	6.7	6.2	7.8	2.8	7.6	17	2.5	1.5

Figure 6:Regional accounting for production vs consumption in 2019 and 2018The Climate Change Synthesis Report for 2023

- 2019 GDP per capita on a purchasing power level based on USD 2017 currency.
- CO2FFI, CO2LULUCF, and other greenhouse gases are included; international aviation and shipping are not included.
- The regional groupings used in this figure are for statistical
- purposes only and are described in WGIII Annex II, Part I

2.2 Sustainable development: response to global issue

Sustainable development is the philosophy that advocates meeting present demands without compromising the ability of future generations to meet their own (Brundtland, 1987). According to Sachs (2015), it addresses a wide variety of subjects, including social justice, environmental protection, and economic growth. Sustainable development is a concept that has gained popularity recently as the world strives to solve concerns including poverty, resource depletion, and climate change (United Nations, 2015).

The concept of sustainable development emerged in the 1970s as concerns over the effects of human activities on the environment grew (Meadows et al., 1972). A 1972 document titled "The Limits to Growth" by the Club of Rome warned that the environment would collapse if current patterns continued (Meadows et al., 1972). This paper has contributed to the worldwide conversation on the necessity of sustainable development. The United Nations convened the inaugural Earth Summit in 1972, which was held in Stockholm, Sweden (United Nations, 1972). At this momentous summit, heads of state, scientists, and policymakers convened to discuss environmental issues and promote sustainable development (United Nations, 1972). The United Nations Environment Programmed (UNEP), which was founded as a result of the conference, has been instrumental in advancing sustainable development globally (UNEP, n.d.).

Growing awareness of the connections between environmental, economic, and social challenges emerged in the 1980s (IUCN, 1980; WCED, 1987). A roadmap for sustainable development was released in the 1980 World Conservation Strategy by the International Union for Conservation of Nature (IUCN) (IUCN, 1980). The idea of sustainable development gained popularity and a worldwide commitment to its realization was called for in the 1983 study "Our Common Future," commonly known as the Brundtland study, released by the World Commission on Environment and Development (WCED) (WCED, 1987).To evaluate the scientific underpinnings of climate change, the Intergovernmental Panel on Climate Change (IPCC) was founded in 1987 (IPCC, n.d.). The IPCC has played a critical role in providing policymakers with the information they need to make informed decisions about climate change (IPCC, n.d.).

The second Earth Summit was called by the UN in Rio de Janeiro, Brazil, in 1992 (UNCSD, 1992). Known by several names, the Rio Earth Summit brought together more than a hundred heads of state and produced a number of significant accords, such as the Convention on Biological Diversity (UNCED, 1992) and the agenda 21 action plan for sustainable development. The UN's Framework Convention on Climate Change (UNFCCC) convened its third Conference of the Parties (COP3) in Kyoto, Japan in 1997 (UNFCCC, 1997). The Kyoto Protocol, which established mandatory goals for wealthy nations to cut their greenhouse gas emissions, was enacted during this meeting (UNFCCC, 1997).In 1998, the fourth Conference of the Parties (COP4) to the UNFCCC was held in Buenos Aires, Argentina (UNFCCC, 1998). At this conference, parties to the UNFCCC adopted the Buenos Aires Plan of Action, which set out a framework for implementing the Kyoto Protocol (UNFCCC, 1998).

The Hague, Netherlands hosted the sixth Conference of the Parties (COP6) to the UNFCCC in 2000 (UNFCCC, 2000). The Bonn Guidelines on Reporting Criteria for Greenhouse Gas Inventories, which offer recommendations on how nations should measure and report their greenhouse gas emissions, were approved by UNFCCC parties during this meeting (UNFCCC, 2000). The Fourth

Assessment Report of the IPCC was published in 2007 and found that, since the mid-1900s, human activity has been the primary cause of the warming that has been seen (IPCC, 2007). The IPCC (2007) said that this study contributed to the growing agreement on the urgent need to address climate change. In 2015, the United Nations adopted Agenda 2030, a set of 17 Sustainable Development Goals (SDGs) that aim to achieve a better and more sustainable future for all (United Nations, 2015). The SDGs address a wide range of issues, including poverty, hunger, inequality, climate change, and environmental protection (United Nations, 2015).

2.2.1 Three Dimensions of Sustainable Development

Sustainability, as was previously said, encompasses not only the environment but also society and the economy. Despite frequently being at the center of current conversations, ecological concerns are inextricably related to economic and social challenges and cannot be seen in isolation. For instance, droughts in one nation may result in refugee flows, which in turn may cause social unrest in other nations. To achieve sustainable growth, the social dimension must be included, much as Raworth's Doughnut Economy model includes. Ecological issues also directly affect the economy at the same time. For example, if the sea level rises by 5 m, many cities with millions of inhabitants will be affected by floods, which will lead to huge economic costs. The three dimensions of sustainability must accordingly be understood as a system, whereby interrelationships must be considered to make efficient decisions (Raworth, 2017).

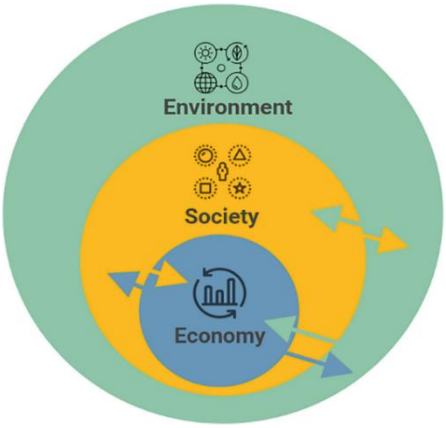


Figure 7: Springer Briefs in Business, the source, illustrates the three elements of sustainable

2.2.2 Three Approaches to Sustainable Systems:

The three main strategies for making any resource-based system more sustainable are (a) efficiency, (b) consistency, and (c) sufficiency. These strategies apply to both organizational sustainability and sustainable development. The goal of all these strategies is to use less resources. While none of these strategies can completely eliminate negative influence on the environment, when used in concert, they can greatly increase a system's resource-related sustainability (Scholz & Heyen, 2016).

Figure 8 : The three approaches to sustainability

2-2-2-1 Efficiency

Of the three techniques, efficiency is perhaps the most well-known and, hence, the most logical. Electrical equipment is one example of this that is frequently observed. It gauges the amount of work and changes required to change a source material into its desired condition. Low efficiency means that a lot of work and/or raw materials must be used to produce the necessary amount of the finished product, meaning that there will be a lot of input and little output. Consequently, as materials and labor are typically the primary cost drivers, low-efficiency systems typically result in higher production costs (Scholz & Heyen, 2016).

Figure 9: Energy efficiency ratings are used to compare different devices, buildings, vehicles, etc. (source: www.europarl.europa.eu)

2-2-2-2 Consistency

Consistency methods strive to either employ endless, renewable resources or keep resources in a condition where they may be converted into something valuable, in contrast to efficiency techniques that concentrate on lowering resource usage. For example, there is no depletion of resources like as wind, sunshine, and waves, therefore using these almost infinite resources more does not have a detrimental effect on resource availability. To attain 100% consistency, these resources must be converted into energy using instruments like solar panels and wind farms, which must also be obtained from renewable resources. In practice, consistency is often an approximation of its ideal state, seeking to optimize the availability and efficient usage of renewable resources (Scholz & Heyen, 2016)

2-2-2-3 Sufficiency

Unlike efficiency and consistency techniques, which concentrate on the production and usage of resources, respectively, sufficiency strategies target patterns of consumption to lower the demand for resources and, as a result, the extraction of those resources. Sufficiency comes in three main forms:(Scholz & Heyen, 2016)

- Reduction: The most straightforward and apparent form of sufficiency, reduction aims to quantitatively reduce resource usage by lowering demand.
- Adaptation: Closely linked to the efficiency approach discussed earlier, adaptation focuses on supplying resources only where there is genuine demand and a guarantee of their utilization.
- Substitution: Substitution seeks to reduce resource consumption but only in a specific aspect.

2.2.3 Policy Action and SDGs

The effects of human-caused environmental pollution, such as burning rivers, smog, mountains of trash, poisoned soil, and the extinction of entire species, became more obvious in the latter half of the 20th century. Because of globalization, environmental preservation gained political attention and became more linked to the issue of inequality between the so-called global north and global south (Sustainable Business, n.d.).

Aware of these serious issues, scientists, policymakers, and concerned citizens began looking for new insights and solutions. This search process and the growing realization that we need to change quickly to maintain our standard of living have made global sustainable development more important during the last several decades (Sustainable Business, n.d.).

The first step toward global action coordination was the signing of the Climate Change Convention (UNFCCC) in Rio in 1992. For the first time, climate change and biodiversity loss were expressly debated at the highest levels of government, and widespread media coverage introduced sustainable development to a large section of the world's population. The wealthier countries promised to reduce emissions and support poorer countries, for example through project finance, in their efforts to reduce greenhouse gas emissions and prepare for climate change (United Nations, 1992).

The Paris Agreement was adopted in December of 2015. It was the first global climate agreement that mandated action from all nations, according to their commitments and capacities, to reduce emissions and prepare for climate change. The fundamental goal of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping the global temperature rise this century well below 2 °C over pre-industrial levels and continuing efforts to restrict the temperature rise further to 1.5 °C (United Nations, 2015).

Following the Climate Change Convention for over twenty years and over a dozen sustainability-related UN conferences, the UN General Assembly overwhelmingly adopted Agenda 2030, which expands on Agenda 21's provisions and is centered around the seventeen Sustainable Development Goals (SDGs). "The road map to attain a better, more sustainable future for everybody" is contained in these objectives. According to the UN Sustainable Development Platform, "They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace, and justice." The aim of these seventeen interconnected development goals about the environment, economy, and society is to guarantee the welfare of the planet's present and future inhabitants while safeguarding and conserving the natural foundation of life. The 17 SDGs are specified by 169 sub-goals, whose implementation is based on 232 indicators, and should be achieved globally and by all member states by 2030. The agenda 2030 was adopted by all 193 UN member states (UN Sustainable Development Platform).

Figure 10 :The 17 sustainable development goals of the agenda 2030 (source: www.un.org)

2.3 importance of energy issues and savings

Global energy demand is rising as a result of population growth. Research indicates that a substantial amount of the energy used by governments globally comes from fossil fuels (IEA, 2022). Nevertheless, the amount of readily available fossil fuels is limited. Furthermore, research has shown that these fuels have detrimental effects on the ecosystem. Overuse of fossil fuels has been connected to droughts, recurrent floods, biodiversity loss, and climate change. A sensible and workable approach is to switch from fossil fuels to renewable energy sources (REN21, 2022). One of the most important measures of a country's economic development is its energy industry. This trend has been driven by the use of fossil fuels, which are the main cause of emissions that contribute to climate change. (IEA, 2022) In response to the 1973 oil crisis and subsequent oil price spike, developed nations adopted new strategies to ensure energy security. Since then, renewable energy has played a prominent role in their energy policies, with substantial investments in alternative energy sources such as wind, solar, and geothermal power (Rogelj et al., 2019).

2.3.1 Environmental and energy crises in today's world

Since energy cannot be produced, transported, or used without having a substantial negative impact on the environment, energy and environmental concerns are inextricably linked (Edenhofer et al., 2014). Several environmental issues are closely related to the production and consumption of energy, including air pollution, thermal pollution, water pollution, and solid waste disposal. The burning of fossil fuels releases air pollutants into the atmosphere, which is the main cause of air pollution in cities (WHO, 2021).

The fear that the world's demands on the limited natural resources needed to power modern civilization are decreasing while demand rises is known as the "energy crisis." Because natural resources are limited, it may take tens of thousands of years for them to recover. Governments and concerned individuals are working together to reduce the irresponsible depletion of natural resources through increased conservation and prioritize the use of renewable resources (Hall & Kytölä, 2020).

2.3.1.1 Various Causes of the Global Energy Crisis

The energy problem is complicated, with many underlying causes. Nonetheless, excessive consumption, population growth, and underutilization of renewable energy sources rank as the top three contributing factors (IEA, 2022; REN21, 2023).

1. **Overconsumption:** The amount of energy we now use is unsustainable and puts excessive pressure on natural resources such as water, oxygen, and fossil fuels. Numerous variables, such as population growth, technology improvements, and cultural standards, contribute to this excessive consumption (Wackernagel et al., 2020).
2. **Overpopulation:** The demand for energy and other resources rises in tandem with the world's population growth (UN DESA, 2022). This increased demand puts additional pressure on already strained ecosystems and contributes to environmental degradation (Pimentel et al., 1994).
3. **Underutilization of Renewable Energy Resources:** A potential remedy for the energy issue is the use of renewable energy sources including solar, wind, and geothermal power. But in many nations, these sources are still underused, and fossil fuels continue to dominate the energy mix (IEA, 2022).
4. **Wastage of Energy:** Energy waste is a major contributing factor to the energy problem in addition to the aforementioned basic factors. The majority of people throughout the world are unaware of how important energy conservation is. (World Bank, 2022). It is only limited to books, the internet, newspaper ads, lip service, and seminars. Unless we give it a serious thought, things are not going to change anytime soon

2.3.1.2 Various Effects of the Global Energy Crisis

There are several negative effects of the growing reliance on conventional energy sources, especially fossil fuels, on the environment and the economy (IPCC, 2021).

1. **Environmental Consequences:** Energy is produced by the burning of nonrenewable fossil fuels. This affects the ecology in addition to the world's supply of fossil fuels. Fossil fuel combustion generates greenhouse gases, mostly carbon dioxide, which trap heat in the atmosphere of the Earth and cause global warming. Rising sea levels, harsh weather, and ecological disturbances are only a few of the major environmental effects of this phenomenon (IPCC, 2022).
2. **Increasing Fuel Resource Prices:** The price of fossil fuels will eventually rise because demand for them exceeds supply. The limited quantity of these resources—whose depletion quickens with rising consumption—is what causes this scarcity. The price increases that follow have a significant impact on consumer spending, transportation, and industry (World Bank, 2023).

2.3.2 Solutions to the Problem of Global Energy Crisis

Many of the possible solutions are already in place today, but they have not been widely adopted.

2.3.2.1 Utilizing Renewable Resources: Powering a Sustainable Future

There is a growing demand for clean and sustainable energy sources as the globe transitions to a low-carbon economy. In addition to the environment, everything that depends on it is threatened by climate change, including food and water security, economic stability, and the health of people and animals. Renewable energy has emerged as a vital weapon in the battle against this worldwide issue and is starting to revolutionize our energy infrastructure.

After using fossil fuels as the main source of energy for more than a century, the world urgently has to move away from them. Fossil fuel combustion generates greenhouse gases, mostly carbon dioxide, that are linked to climate change and global warming. In addition, fossil fuels are a finite resource, and their depletion is causing environmental damage and economic instability (REN21, 2023). Renewable energy sources, such as solar, wind, geothermal, and hydropower, offer a viable solution to the global energy crisis. These sources are abundant, sustainable, and environmentally friendly. They do not emit greenhouse gases, and they can be replenished naturally

- Solar energy is produced by using the sun's copious beams. Photovoltaic (PV) panels are a clean and effective power source because they directly transform sunshine into energy. Whole cities may be powered by solar energy, as well as companies. (UNEP, 2023)
- The kinetic energy of flowing air is converted into wind energy. Electricity is produced by wind turbines, which are large towers with rotating blades. One flexible and scalable renewable energy source is wind power (IEA, 2022).
- The heat that exists inside the Earth provides geothermal energy. This heat is captured by geothermal power plants, which use it to create energy and supply heating and cooling. A dependable and long-lasting renewable energy source is geothermal energy (US Department of Energy, 2023).
- Hydropower harnesses the energy of moving water. Dams and turbines are used to convert the energy of flowing water into electricity. Hydropower is a mature and proven renewable energy source (IRENA, 2023).

Governments, businesses, and individuals must work together to make the switch to renewable energy. Renewable energy mandates, tax incentives, and subsidies are some of the ways that governments may encourage the use of renewable energy. Renewable energy technology, such wind turbines, geothermal power plants, and solar farms, are accessible to industries for investment. Installing solar panels or moving to a green energy supplier are two examples of how individuals may implement renewable energy solutions for their homes and businesses. (REN21, 2023)

2.3.2.2 Energy Analysis: Unveiling Hidden Savings Opportunities

To effectively handle the global energy crisis, energy analysis is essential in determining and putting into practice energy-saving strategies (IEA, 2021). Energy analysts can identify inefficiencies and waste by closely examining patterns of energy usage in both residential and commercial settings (World Bank, 2023). When carried out by trained experts, energy audits offer a thorough evaluation of energy use and point out areas where energy is being squandered or lost (US Department of

Energy, 2023). Numerous elements are taken into account in these audits, including industrial processes, appliances, lights, heating and cooling systems, and IEA, 2022).

Energy analysts can suggest a variety of energy-saving measures, including replacing outdated appliances with more energy-efficient models, implementing weatherization and insulation measures, adopting smart thermostat technologies, and streamlining industrial processes, based on the results of energy audits (World Bank, 2023). Both homes and businesses may save a significant amount of money by implementing energy-saving measures (IEA, 2022). Additionally, these actions help to mitigate climate change, lower greenhouse gas emissions, and preserve valuable natural resources (IPCC, 2021).

2.3.2.3 Energy Analysis: Enhancing Efficiency for a Sustainable Future

Energy analysis involves more than just finding ways to save energy; it also includes improving energy efficiency in general (US Department of Energy, 2023). We can address the global energy issue and lessen our collective energy footprint by optimizing energy consumption across many industries. Energy efficiency methods cover a broad spectrum of tactics, ranging from basic behavioral modifications to advanced technical innovations. Energy usage in homes and offices may be greatly decreased by turning off lights when not in use, utilizing energy-efficient equipment, and implementing sustainable practices (IEA, 2022).

Energy-efficient technology adoption, waste heat recovery, and process optimization are ways to increase energy efficiency in industrial settings. One way to reduce energy losses is by utilizing combined heat and power (CHP) systems, which may produce heat and electricity concurrently. The application of laws and regulations by governments can significantly contribute to the promotion of energy efficiency. The adoption of energy-efficient methods and goods can be encouraged by energy efficiency regulations for buildings and appliances. Furthermore, governments can offer monetary rewards and assistance for improving energy efficiency. We can all cut expenses, minimize energy use, and help create a more sustainable future by adopting energy analysis and energy-efficient practices (IEA, 2022).

2.4 Energy analysis of buildings

The foundation of contemporary civilization, buildings demand a substantial amount of energy during every stage of their existence, from construction to destruction (International Energy Agency [IEA], 2022). To achieve sustainable development and lower greenhouse gas emissions, it is essential to comprehend and optimize building energy use. Structures for usage as offices, businesses, and residences are constructed all around the world. They contribute significantly to the socioeconomic development of a nation and use a large portion of the available energy and natural resources. Buildings are thought to comprise 40–50% of the source of greenhouse gas emissions and contribute significantly to global energy consumption, accounting for an estimated 30–40% of all primary energy utilized (IEA, 2022). This energy consumption is primarily attributed to the operation of buildings, including heating, cooling, lighting, and appliances (IPCC, 2021).

Thus, the building construction industry depends on attaining sustainable growth in society. The concept of sustainable development highlights the need to strike a balance between social responsibility, environmental preservation, and economic growth (World Business Council for Sustainable Development [WBCSD], 2022). To achieve sustainability, it is imperative to use a multidisciplinary approach that addresses issues such as energy saving, improved resource utilization, including water, material reuse and recycling, and emissions management. Building life cycle energy analysis is more important for establishing strategies to control emissions and lower the primary energy consumption of the structures.

According to the American Society of Heating, Refrigeration, and Air-Conditioning Engineers [ASHRAE], 2019: "Building energy analysis focuses specifically on the energy consumption within a building, examining energy usage patterns and identifying areas for improvement." Either the entire building or specific rooms inside the structure might be the subject of this examination (ASHRAE, 2019). Compared to building energy analysis, performance analysis is more comprehensive, including not just energy use but also other factors that affect a building's total performance (Association of Energy Engineers [AEE], 2022). This includes factors such as ventilation, thermal comfort, indoor air quality, and daylighting (AEE, 2022). Energy analysis plays a critical role in achieving sustainable building practices and reducing the environmental impact of the building sector. By understanding energy consumption patterns and implementing energy-efficient measures, we can optimize building performance and contribute to a more sustainable future.

2.4.1 Residential Energy Consumption analysis

Understanding and enhancing the energy efficiency of dwellings in the residential sector requires the use of energy analysis. To minimize energy usage, utility costs, and environmental effects, it entails evaluating and optimizing the energy use of residential structures. According to the International Energy Agency (IEA), in 2022, residential energy consumption constituted 27% of all greenhouse gas (GHG) emissions in the energy sector and 30% of global energy use.

About 22% of the world's energy consumption in 2019 came from residential use in a few IEA member nations. To effectively save energy and promote sustainable behaviors, it is important to comprehend the patterns of home energy usage (World Resources Institute, 2023). A household's total energy demand is influenced by a variety of end uses that are included in residential energy consumption. According to the International Energy Agency (2019), the main end users are:

- **Space heating**: Maintaining comfortable indoor temperatures during cold seasons is a significant energy consumer, accounting for an average of 43% of residential energy consumption in the selected IEA countries (International Energy Agency, 2022).
- **Water heating**: Heating water for domestic purposes, such as bathing, washing, and cooking, represents approximately 19% of residential energy consumption (International Energy Agency, 2021a).
- **Cooking:** Cooking appliances, including stoves, ovens, and microwaves, consume an average of 11% of residential energy (International Energy Agency, 2021b).
- **Appliances**: Various household appliances, such as refrigerators, televisions, and lighting, collectively account for approximately 17% of residential energy consumption (International Energy Agency, 2021c).
- **Other:** Other end uses, such as air conditioning, pool heating, and landscaping, contribute the remaining 10% of residential energy consumption (International Energy Agency, 2021d).

The share of residential energy consumption by end use varies across the selected IEA countries, reflecting differences in climate, building practices, and lifestyle preferences. For instance, countries with colder climates tend to have a higher share of energy consumption dedicated to space heating

(International Energy Agency, 2022), while those with warmer climates may have a higher share of air conditioning (International Energy Agency, 2021d).

Understanding the breakdown of residential energy consumption by end-use provides valuable insights for targeted energy conservation efforts. By focusing on the end uses with the highest energy consumption, policymakers and individuals can implement effective measures to reduce energy demand and promote sustainable practices (World Resources Institute, 2023).

Figure 11 : Shares of residential energy consumption by end use in selected IEA countries, 2019. (Source: IEA)

2.4.2 Industrial Energy Consumption analysis

Analyzing and optimizing energy usage in the industrial sector is essential for improving energy efficiency and lowering environmental impact, much like it is for household energy consumption. By 2021, industrial energy usage accounted for a sizable share of the world's energy consumption and was a major contributor to both total energy demand and greenhouse gas emissions. According to the International Energy Agency (IEA, 2022), industrial activities constitute a significant portion of global energy usage, highlighting the necessity of a thorough examination of the patterns of energy use in this industry. In 2023, industrial energy usage will make up around 23% of the world's energy consumption and 28% of greenhouse gas emissions (International Energy Agency, 2023).

The use of energy in the industrial sector is complex and involves several activities and processes. The industrial sector's energy consumption breakdown usually consists of important elements like:

- **Manufacturing Procedures:** Energy-intensive manufacturing procedures are a common feature of industrial facilities, and the energy requirements of these procedures are greatly increased by the use of machinery, equipment, and production lines.
- **Heating and Cooling:** One of the most important aspects of energy consumption in this industry is the maintenance of specified temperatures for industrial operations, whether they include heating or cooling. Among the industrial sector's biggest energy users are manufacturing processes like those used in the manufacture of steel, chemicals, and paper.
- **Building activities:** Industrial processes frequently need the heavy usage of electrical equipment and lighting systems, which raises the energy demand overall.
- **Transportation:** Including the movement of workers, completed items, raw materials, logistics, and transportation in the industrial sector account for a significant amount of energy consumption.
- **further end applications:** Waste management, cooling, and water heating are further end uses.

varied industrial sectors have varied end-use energy consumption. For instance, in 2023, the building operations sector consumed 25% of industrial energy, but the manufacturing sector consumed 61% (International Energy Agency, 2023). To develop focused methods to increase energy efficiency and lessen environmental effects, it is crucial to comprehend the subtleties of industrial energy usage. Through the identification of significant drivers of energy consumption in industrial processes, stakeholders may take appropriate action to improve efficiency, integrate renewable energy sources, and harmonize with sustainability objectives.

2-4-3 Commercial and services Energy Consumption analysis

With 15% of the world's energy consumption coming from commercial and service sectors in 2023, they represent another major contributor to the global energy demand. 19% of global greenhouse gas emissions in 2023 came from the business and services sector, which is also largely to blame for the emissions (International Energy Agency, 2023). A significant portion of the energy used overall is accounted for by the commercial and services sector, which includes a variety of industries like retail, hotel, healthcare, and office operations. When developing methods to encourage sustainability and lessen environmental impact, it is essential to analyze the energy consumption in this industry.

Commercial and services energy consumption is diverse, encompassing a wide range of end uses, including:

- Building operations: Energy is used by HVAC systems, lights, appliances, and equipment in commercial and service buildings, including offices, retail establishments, and hotels.
- Electronic Equipment: A large portion of the energy consumption is attributed to the use of different electronic equipment in offices and commercial buildings, such as computers, servers, and communication systems.
- Transportation: A major energy user in business and service facilities is the movement of personnel and commodities inside and between them.
- Other end uses: Other end uses include waste management, irrigation, and landscaping.

Within the business and services sector, there are variations in energy consumption by end-use. For instance, according to the International Energy Agency (2023), the retail trade sector consumed 28% of the energy used for commercial and services, while the hotel sector consumed 14%. (International Energy Agency, 2023).

The identification of potential for efficiency improvements, the adoption of renewable energy sources, and the implementation of sustainable practices are made possible by the analysis of energy consumption patterns in the commercial and services sector. The objective of this chapter is to furnish a thorough comprehension of the distinct energy dynamics present in this industry, so aiding policymakers and enterprises in making well-informed decisions.

2.4.4 Analysis Building Energy Efficiency with DE carbonization

Examining the sources of direct CO2 emissions in detail is necessary before delving into the topics of building energy efficiency and DE carbonization. These emissions account for a significant amount of the built environment's total carbon footprint and are mostly produced by appliances, cooking, water heating, and space heating (IEA, 2021). It is critical to comprehend the nuances of these emission sources to develop solutions that effectively reduce the environmental impact of buildings.

The primary source of CO2 emissions, space heating, is mostly caused by the energy usage of systems that keep interior spaces warm, especially in colder climates. Significant emissions result from this reliance on energy-intensive heating systems, which are frequently fuelled by fossil fuels. The second-highest contributor, water heating, is the process of heating water for home use, including cooking, washing, and bathing (IEA, 2022). CO2 emissions are largely caused by the energy requirements of water heating operations, especially those employing inefficient appliances. Microwaves, stoves, and ovens are examples of cooking appliances that significantly contribute to CO2 emissions. The type of cooking appliances used and how often they are used have a direct influence on how much energy is used during cooking activities (IEA, 2023). If not utilized efficiently, traditional appliances—which are frequently fueled by gas or electricity—can result in significant emissions.

structure analysis is essential for pinpointing the precise locations and activities inside a structure that have the most impact on reducing these emissions and creating a more sustainable built environment. Building analysts can identify the hotspots of CO2 emissions by using comprehensive energy audits, carried out by certified specialists, which give a full picture of energy usage trends (US Department of Energy [DOE], 2023). Advanced energy modeling methods that use computer simulations expand on this knowledge by forecasting energy use about several variables, including building layout, occupancy trends, and weather (DOE, 2023). This fine-grained knowledge, which comes from painstaking research and modeling, is essential for carrying out focused interventions and efficiency improvements meant to lower the building's carbon footprint. There are several ways to drastically cut down on the amount of energy used for space heating, water heating, cooking, and appliance usage, including installing energy-efficient appliances, improving HVAC systems, updating insulation, and switching to renewable energy sources (IEA, 2022).

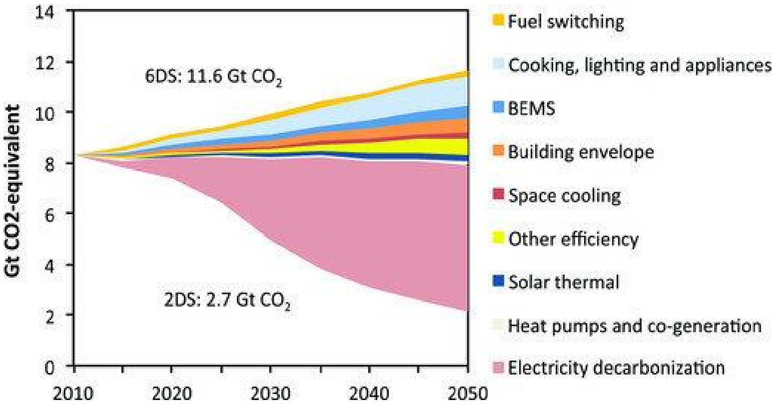


Figure 12 : Based on updated data from IEA [2013], shows the contribution of CO2 emissions of particular technologies to IEA 2 DS and 6 DS. CO2 is carbon dioxide; DS is degree scenario; IEA is the International Energy Agency.

2.5 Energy analysis of environment- Nexus Between Buildings and Urban

Building energy use and the surrounding urban environment are closely intertwined. Creating and putting into practice sustainable methods in the built environment requires a thorough grasp of the variables that affect a building's energy use. The constructed surroundings, which include structures, facilities, and the areas in between, are crucial in determining our habits of energy use. Particularly, buildings are major energy users, making up a sizeable amount of the world's energy consumption. Developing sustainable methods that encourage energy efficiency and lessen the built environment's negative environmental effects requires a thorough understanding of the complex interactions between buildings and the surrounding urban environment.

2.5.1 Urban Structure

The urban environment in which buildings are located has a significant impact on their energy usage in addition to their internal features. The location, direction, density, and closeness to natural elements are some of the major variables that influence how much energy a structure uses. It is essential to comprehend these complex interactions between buildings and their urban surroundings in order to develop energy-efficient techniques that work. These tactics are based on energy analysis, which includes a thorough evaluation of a building's energy use trends and pinpointing opportunities for improvement. By reducing the need for vehicles and boosting walking and cycling, sustainable urban design principles—like those that support compact urban forms, mixed-use development, and easily accessible public transit—can dramatically cut energy usage. The built environment may be further decarbonized by incorporating renewable energy sources, such as solar and wind power, into the urban fabric.

In summary, buildings' energy usage is a result of their interactions with the surrounding urban environment rather than an isolated occurrence. We may work toward creating a constructed environment that is more ecologically sustainable and energy-efficient for coming generations by comprehending and resolving these intricate linkages.

2.5.1.1 Geography Situation

A building's energy requirements are significantly influenced by its location (Coley, 2012). Buildings in colder areas usually use more energy for heating, and buildings in warmer climates could need to use more energy for cooling. Furthermore, the surrounding area's geography may have an impact on energy usage. Structures in valleys or encircled by mountains frequently endure more drastic temperature swings and stronger winds, which can have an impact on their heating and cooling requirements. For example, the build-up of cold air in valleys can result in lower temperatures for structures there, raising the need for heating. Buildings that are encircled by mountains may also see increased wind speeds, which can lead to increased heat loss through building envelopes and an increase in the need for heating. (Khatib & Mahdavi, 2012)

2.5.1.2 Altitude-Related Sea level

A building's energy usage might be positively or negatively impacted by its proximity to the water. By stabilizing temperatures, the sea's moderating impact can lessen the demand for heating and cooling equipment. Coastal regions, however, are frequently subject to strong winds, which can raise the energy requirements of ventilation systems and enhance heat loss via building envelopes (Cui et al., 2016).

Architects and engineers consider a variety of design solutions to minimize the adverse impacts of strong winds and maximize the advantages of temperature moderation. To reduce heat loss from wind infiltration, buildings in coastal locations can use wind-resistant construction techniques such as reinforced walls, high-quality windows and doors, and appropriate sealing around openings. Furthermore, wind pressure control techniques may be included in ventilation system design to maximize efficiency and minimize energy usage.

2.5.1.3 Urban Density

The quantity of people or structures in a particular area is known as urban density, and it has a big impact on energy use. Densely populated metropolitan regions can gain from economies of scale by implementing district energy networks or shared HVAC systems, which can raise total energy efficiency. However, microclimates that trap heat can also be produced by dense urban areas, raising the energy requirements for cooling (Shafer et al., 2012).

2.5.1.4 Orientation

One important aspect of energy efficiency in a structure is its orientation, or its placement in the path of the sun (Akbari & Taha, 2001). Structures designed to decrease summer solar exposure and promote winter solar gain can save a substantial amount of energy used for heating and cooling. An further benefit of proper orientation is that it may maximize daylighting and natural ventilation, minimizing the need for mechanical systems and artificial lighting.

2.5.2 Climate Factors

Climate analysis is essential for designing buildings that are both sustainable and energy-efficient. Temperature, wind, and sun irradiation are examples of climate variables that directly affect how much energy a structure uses. Energy-efficient buildings must be designed and operated with an understanding of these variables (Coley, 2012). It is an indispensable instrument for setting critical limits and providing critical direction. Numerous variables are included in this research, with the most important ones being temperature differences between interior and outdoor spaces, degree days of heating and cooling, wind patterns, including direction and velocity, and sun irradiation. Every one of these elements is carefully evaluated and customized for the specific geographic area in which the building project is located.

2.5.2.1 Temperature Considerations

The method used to measure air temperature determines how hot or cold the air is. Both incoming and outgoing energy control or observe how the earth's air temperature operates. It is observed that during the day, the air temperature tends to rise in proportion to the excess energy lost from the earth's surface. Similar to this, the air temperature tends to drop at night in proportion to the energy absorbed by the surface of the planet. An example can assist in clarifying this: an increase in temperature occurs when gas molecules move quickly, and a decrease in air gas molecules results in a corresponding drop in air temperature.

Extremes in temperature, both hot and cold, put a lot of strain on the energy systems of buildings. Cooling systems in warmer areas must offset the impacts of high ambient temperatures, while heating systems in colder locations must work more to maintain appropriate inside temperatures. Designing successful energy-efficient systems requires analyzing temperature data and degree days, a measurement of the heating or cooling demand during a certain period (Khatib & Mahdavi, 2012).

2.5.2.2 wind analysis

Wind analysis is the examination of wind patterns and their effects on surrounding landscapes, structures, and the surrounding region in the context of architectural planning and environmental assessment. It comprises obtaining and analyzing data on the wind's properties, such as direction, turbulence, and velocity. Wind analysis is necessary for many different jobs, including environmental impact assessments, renewable energy projects, city planning, and architectural design. The wind has several major effects on how much energy a structure uses. Strong winds can cause building envelopes to lose more heat, increasing the need for heating. In contrast, wind energy may also be used to generate renewable energy, which lessens the need for fossil fuels (Gago et al., 2012). Buildings that are designed to be sustainable must take wind patterns and their potential for energy generation into account.

2.5.2.3 Degree Days

Degree days are useful statistics in energy management and climate analysis that help to identify and quantify a building's heating and cooling needs dependent on outside temperatures. They provide light on the degree and length of temperature fluctuations from a selected reference or baseline temperature, which is normally 65°F (18.3°C) in the US and some other nations. Heating degree days (HDD) and cooling degree days (CDD) are the two categories of degree days.

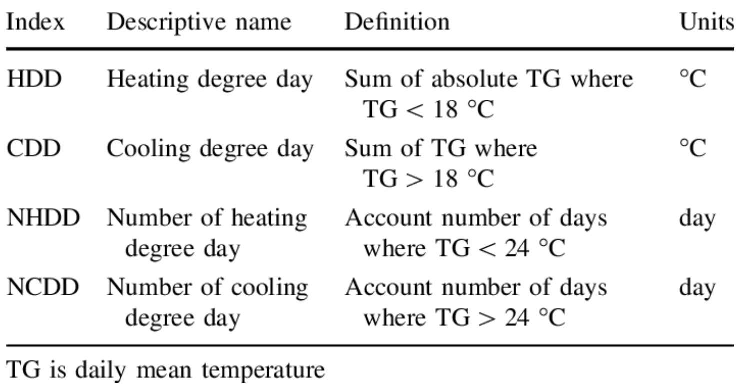
Heating Degree Days (HDD): The number of degrees a location's average temperature falls below a base temperature—say, 18°C (64°F)—is known as a heating degree day, while the number of degrees above a base temperature is known as a cooling degree day. By calculating the energy usage of heating and cooling systems, degree days help engineers and architects create climate-specific, energy-efficient building designs.

Calculation: HDD For each day when the average temperature falls below the baseline—typically 65°F or 18.3°C—HDD is computed by deducting the daily average temperature from the baseline. A favorable outcome adds to the total number of heating degree days for that time frame.

$$DD = \sum_{j=ngr} (t_{i,j} - t_{e,j})$$

Use: In colder areas, HDD is mostly used to calculate how much energy is required for space heating throughout the heating season. The severity and coldness of the winter weather are correlated with the HDD rating.

Table 1 : table of units and definitions for four-degree day indices



Index	Descriptive name	Definition	Units
HDD	Heating degree day	Sum of absolute TG where TG < 18 °C	°C
CDD	Cooling degree day	Sum of TG where TG > 18 °C	°C
NHDD	Number of heating degree day	Account number of days where TG < 24 °C	day
NCDD	Number of cooling degree day	Account number of days where TG > 24 °C	day

TG is daily mean temperature

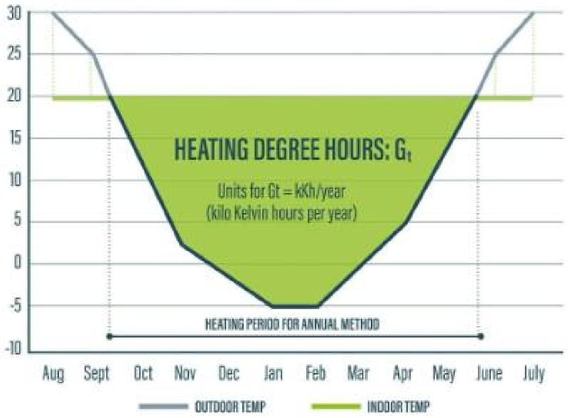


Figure 13 : HDD (heating degree day)

2.6 Urban Energy Dynamics with Urban Scale Energy Models (USEMs)

Effective energy management solutions are becoming more and more important as cities grow and energy needs rise. To tackle this issue, Urban Scale Energy Models (USEMs) become more effective instruments, offering a thorough comprehension of patterns of energy use in urban settings (Mutani & Todeschi, 2021). A collection of computer programs known as USEMs are used to model energy use at the municipal or district level. These models take into account several variables that affect the dynamics of urban energy, such as:

- **Building Characteristics**: Building typology, geometry, energy efficiency of heating and cooling systems, and occupancy patterns significantly impact energy consumption (Sartori & Hestnes, 2007).
- **Urban Context:** The built-up environment, including street layout, vegetation, and proximity to natural elements, influences energy demands through factors like solar radiation, wind patterns, and heat island effects (Akbari & Taha, 2001).
- **Social Characteristics:** Occupant behavior, building usage patterns, and socio-economic factors play a role in shaping energy consumption patterns (Lo et al., 2014).

To sum up, Urban Scale Energy Models (USEMs) are essential resources for comprehending, maximizing, and controlling urban energy use. USEMs enable communities to move toward a more sustainable and energy-efficient future by giving a complete picture of energy use trends and pinpointing opportunities for action (Ryberg et al., 2016).

2.6.1 Global Energy Models

Since 1993, the International Energy Agency (IEA) has produced medium- to long-term energy projections using a sophisticated range of cutting-edge modeling tools. First, a large-scale simulation model called the World Energy Model (WEM) was developed to simulate how energy markets function. Ten years later, the highly technological, bottom-up Energy Technology Perspectives (ETP) model was developed to be used with the WEM. In 2021, the IEA devised a novel hybrid modeling approach, emphasizing the benefits of both models to produce the first comprehensive examination of the transition to an energy system with net zero CO2 emissions by 2050. (Source: IEA)

2.6.2 Energy Modeling Approaches: Top-down, Bottom-up, and Hybrid Strategies

Energy modeling becomes a vital tool for comprehending, optimizing, and regulating patterns of energy consumption as cities struggle with the increasing energy needs of urbanization and the necessity for sustainable practices (Mutani & Todeschi, 2021). Among the many different energy modeling techniques, top-down, bottom-up, and hybrid tactics are separate approaches that each have their own benefits and meet certain needs (Giamalidis et al., 2013). Generally, USEMs use three main strategies:

- **Top-down approaches**: These models aggregate energy consumption data at the city level, providing an overall picture of energy usage (Giamalidis et al., 2013).
- **Bottom-up approaches**: These models disaggregate energy consumption at the individual building level, offering a detailed understanding of energy usage patterns across different building types and locations (Khatib & Mahdavi, 2012).
- **Hybrid approaches:** These models combine top-down and bottom-up methods, providing both a broad overview and a detailed assessment of energy consumption (Sorknæs & Krarup, 2014).

2.6.2.1 Top-Down modeling approaches

Top-down methods begin with a thorough summary of energy use at the local or regional level and then progressively delve into more specific information. Top-down models treat a collection of buildings as a single, collective energy entity, estimating at the sectoral level without taking into account the unique energy requirements of every particular structure. This method uses aggregated data from several sources—such as land-use surveys, utility companies, and census records—to provide a comprehensive picture of trends in energy consumption (Akbari & Taha, 2001). This strategy is beneficial since it focuses mostly on aggregated socio-demographic and market-economic characteristics and requires less specific data. It's not always required to have detailed energy usage statistics or in-depth information on building technologies. Additionally, top-down models occasionally integrate physical parameters such as meteorological and climatic data. Top-down techniques are easy to use since they rely on easily accessible aggregated data, which makes them ideal for preliminary evaluations and trend research. These methods enable the identification of locations with high energy usage and the possibility for action by offering insightful information about general patterns of energy consumption (Khatib & Mahdavi, 2012).

2.6.2.2 Bottom-up modeling approaches

In contrast to their top-down competitors, bottom-up techniques carefully analyze energy use at the building level. With this approach, building energy consumption may be modeled for specific uses, and data can be aggregated at several levels, such as national, regional, or urban ones. Using this method, granular energy models are created for every building by painstakingly compiling information on geometry, materials, occupancy patterns, and energy systems (Sartori & Hestnes, 2007). Bottom-up techniques are quite accurate in collecting the distinct energy profiles of specific buildings because of their thorough nature. Because of this granularity, it is possible to identify particular energy-saving possibilities that are customized to the features and consumption patterns of each building (Mutani & Todeschi, 2021).

Bottom-up models fall into two categories: statistical and physics-based methods.

- **Statistical Methods**: These methods share some similarities with top-down approaches, using socioeconomic factors. However, they predominantly rely on disaggregated and detailed data regarding the energy usage of individual buildings. Historical data, often long-term, plays a crucial role in these models.
- **Physics-Based Methods**: Physics-based models simulate energy consumption by considering the physical attributes of individual buildings. This includes building geometry, non-geometric features like heating, ventilation, and air conditioning (HVAC) systems, usage patterns, and building envelope characteristics. Additionally, these models factor in user characteristics.

2.6.2.3 Hybrid modeling approaches

Hybrid approaches seek to reconcile the strengths of top-down and bottom-up approaches, leveraging the broad insights of the former and the granular accuracy of the latter. These approaches typically employ top-down models to estimate energy consumption for buildings lacking detailed data, while utilizing bottom-up models for buildings with comprehensive data sets (Ryberg et al., 2016).

Hybrid techniques provide a more comprehensive knowledge of energy usage patterns by integrating the benefits of both approaches, striking a balance between granular-level accuracy and broader insights. When comprehensive data is provided for a subset of buildings within a wider urban region, this synergistic technique is very effective (Mutani & Todeschi, 2021).

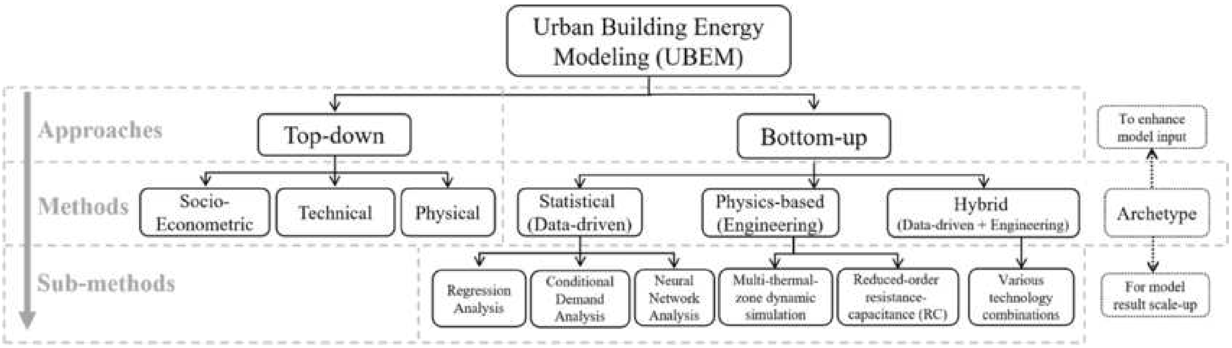


Figure 14 : The hierarchy of urban building energy modeling techniques is shown. Urban building energy modeling (UBEM): a comprehensive evaluation of prospects and difficulties (Kong, D., Cheshmehzangi &., 2023)

2.6.3 Statistical methods:

A study's planning, design, data collection, analysis, relevant interpretations, and publication of research findings are all statistical approaches. Dead data is given life by the statistical analysis, which interprets the meaningless numbers. Only when appropriate statistical tests are applied will the findings and conclusions be accurate. (source: Research and data analysis using basic statistical methods)

Different approaches in statistical method analysis can be categorized and counted in different ways. However, multiple linear regression analysis is the specific technique used in this case study. Variables in the context of linear regression analysis may be roughly categorized into two groups: independent variables, which include various energy-related aspects, and dependent variables, which in this case correspond to energy consumption. This study uses multiple linear regression analysis to try to extract useful information. The results produced by this technique will provide insightful knowledge about the variables or input data that have the biggest effects on energy usage. Importantly, this analysis provides insights across different scales and showcases a smaller deviation when compared to real-world data. In essence, employing multiple linear regression allows for a comprehensive understanding of the factors shaping energy consumption patterns. (source: Mutani G., Fontana R., & Barreto A. (2019). Statistical GIS-based analysis of energy consumption for residential buildings in Turin (IT), IEEE International Conference and Workshop in Óbuda on Electrical and Power Engineering, Budapest, Hungary)

2.6.4 tools of Statistical models of energy:

In the subject of energy analysis, statistical models use a variety of instruments and methods for data processing and interpretation. These resources support the decision-making and forecasting processes used by researchers and analysts in the areas of energy production, efficiency, and consumption. The following are some typical instruments utilized in energy analysis statistical models:

- **Regression Analysis**: Energy analysis makes extensive use of regression models, including multiple linear, nonlinear, and linear regression. They aid in comprehending how diverse variables, including energy usage and its affecting components, relate to one another.
- **Time Series Analysis**: To study data points that have been gathered or recorded over time, time series models are utilized. This is especially helpful for comprehending long-term trends, seasonal fluctuations, and patterns of energy usage.
- **Data Mining Techniques**: Large datasets may be mined for hidden patterns and connections using techniques like clustering, decision trees, and neural networks. These methods can aid in streamlining energy-related procedures and offer insightful information on patterns of energy consumption.
- **Monte Carlo Simulation**: A statistical method called Monte Carlo simulation is used to simulate the likelihood of various outcomes in a process that is difficult to forecast because of random variable intervention. It may be used to evaluate the risks and uncertainties associated with investments and initiatives pertaining to energy.
- **Optimization Models:** To identify the optimum answer for energy-related problems, such as maximizing energy production, distribution, and consumption to reduce costs or improve efficiency, optimization techniques, such as linear and nonlinear programming, are applied.
- **GIS (Geographic Information Systems):** Spatial data on energy supplies, distribution networks, and patterns of energy usage are analyzed using GIS technologies. GIS technology makes it possible to see and analyze geographic data, which offers insightful information for energy planning and decision-making.
- **Econometric Models:** Econometric models are used to forecast and evaluate energy-related variables by combining statistical techniques with economic theory. Understanding how economic variables affect energy demand, price, and consumption patterns is made easier with the help of these models.
- **Stochastic Models:** Unpredictability and randomness are included in energy analysis using stochastic models. These models aid in risk assessment and decision-making by evaluating the probabilistic behavior of energy systems under various uncertain circumstances.
- **Machine Learning Algorithms:** Energy analysis is using more and more machine learning approaches, such support vector machines, random forests, and deep learning. These algorithms are utilized for tasks like demand forecasting, anomaly detection, and energy efficiency optimization because they can handle intricate patterns in huge datasets.

3. Methodology:

3.1 Research Objective (Establishing Energy Models)

The goal of the research was to create an energy model for assessing gas usage in Argentinean structures, as was stated in earlier chapters. In particular, the goal of this study's research is to create an energy model that can precisely forecast and assess the amount of gas used in buildings in different parts of Argentina. It is imperative to look into the use of gas in buildings in Argentina because this can include things like how much energy buildings contribute to the country's overall energy consumption, whether energy efficiency measures are necessary, or how using gas can affect the environment. Creating a top-down energy model to analyze gas use in Mendoza, Argentina's buildings is the first stage in our process. The top-down approach is a statistical method that allows the average consumption of buildings to be determined by starting with city-scale consumption data or similar. When examining energy use at a regional level or when comprehensive building-level data is unavailable, this method is especially helpful. The district-level data on energy use was given by the local firm that supplies gas. after clustering homogenous districts for different sectors, numerous linear regression models are used to determine natural gas usage, and the results are calibrated using actual data. The methodology starts by examining statistics on gas usage and grouping different parts of the city into several homogenous energy classes (residential 5 groups, industrial 4 groups, and commercial and services 3 cluster groups) according to their form factor, typology, density of inhabitants, and material quality. This allows the researcher to calculate the gas consumption on each level of a building and assign it to the appropriate energy class.

A bottom-up technique was used to compare the estimated consumption at the district scale with the actual consumption data supplied by the Mendoza Network Gas Distribution Company in other years to verify the correctness of the model. With this method, specific building-level gas usage data is analyzed in depth before being scaled up to the district level. With the use of this top-down and bottom-up methodology, the research can determine the average gas consumption in each census tract with accuracy, allowing for the identification of patterns and trends in the city's gas use. Policymakers and building managers may find this information helpful in creating energy-efficient plans and lowering gas usage in buildings, which will ultimately result in financial savings and a smaller environmental effect.

3.2 Data Collection:

To create precise and trustworthy energy models for assessing building gas use, data collecting is essential. A thorough approach to gathering data should include a variety of sources, such as tenant surveys, energy providers, and government databases. These resources offer insightful information about the features of buildings, patterns of energy use, and environmental elements that affect gas use.

Energy suppliers give comprehensive statistics on gas use at the building or regional levels, making them a valuable source of information. By using this data, baseline consumption patterns may be established, energy-intensive buildings can be identified, and the effects of different factors on gas usage can be evaluated. Furthermore, detailed information on building usage patterns, occupancy schedules, and tenant behavior may be obtained through occupant surveys. These factors can have a big impact on gas consumption.

A crucial phase in gathering data is specifying the precise information needed for the energy model. This entails figuring out and compiling information on gas utilization as well as building attributes (such as age, size, and kind of use), climatic data (such as temperature and humidity), occupancy patterns (such as the number of inhabitants and their behavior patterns), and any other pertinent elements that could influence gas usage. The thoroughness of the data gathering guarantees that the energy model precisely represents the subtleties of gas consumption patterns and makes it easier to make well-informed decisions for energy management. These variables may be created throughout the work process or simply taken from a database.

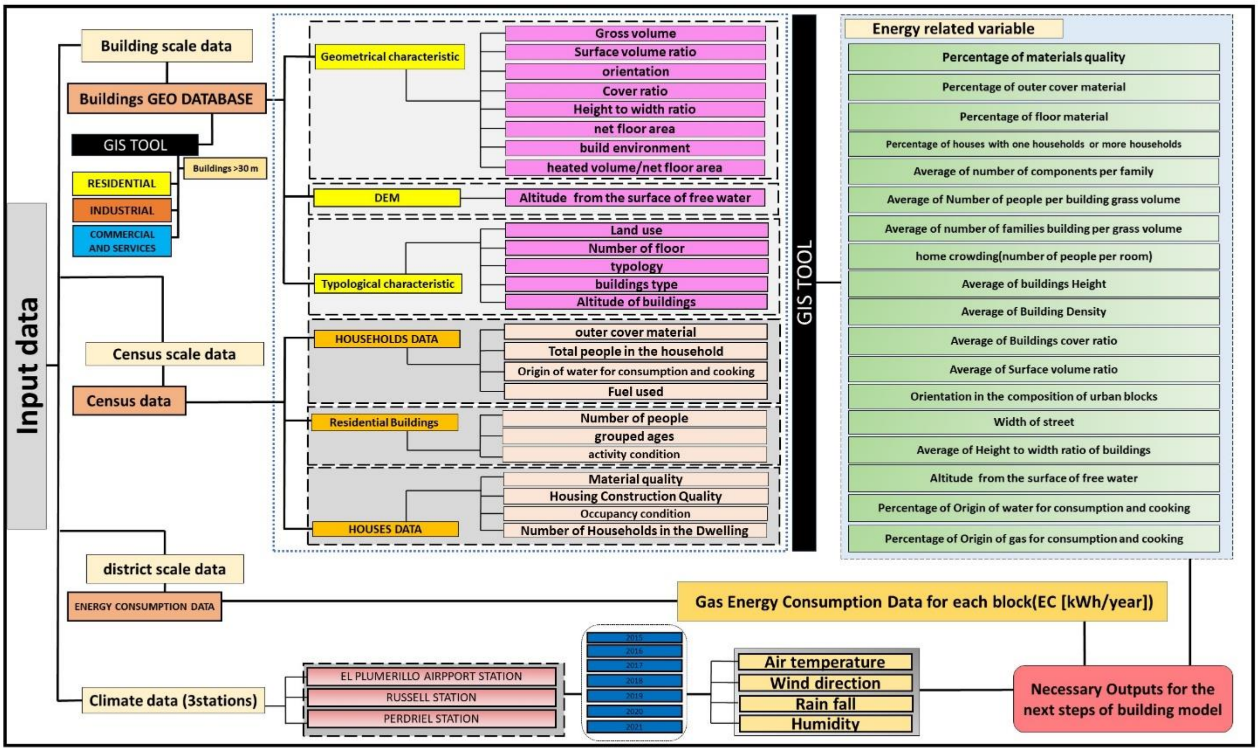


Figure 15 : Classification & Types of Input Data and Energy Related Variables (By Authors)

3.2.1 Buildings GEO DATABASE

Building-scale data is essential for creating precise and intelligent energy models, which are then used to accurately assess and optimize energy consumption in the top-down model. The energy model may provide important insights into the energy dynamics of buildings by utilizing building-scale data. This opens the door for well-informed decision-making to increase occupant comfort, lower environmental impact, and improve energy efficiency in urban structures. Geographic Information System (GIS) data is the initial type of data we have for this use. Building geodatabases are essential for obtaining detailed information about buildings since they combine a multitude of spatial and attribute data.

The GIS database was updated in 2017 and includes geographic and geometric data on Mendoza City which was acquired in 2010. Furthermore, the data about the city area that was acquired in 2017 indicates that Mendoza City's geographical area has expanded. As a result, it can be inferred that the data from that year about the city area and the political divisions of the city's six departments has altered. We will have access to information in this database category ranging from tiny to huge size. This database's smallest divisional unit is connected to buildings, which include raw information as well as geometric and topographical data. The most comprehensive category pertains to political division data for six distinct departments, providing valuable insights for comparing and evaluating the ultimate outcomes. The district scale information, which is used to link the census data with GIS data, is also available for the final analysis in the interim. We have also utilized the DEM data, which is used to ascertain the city's shape and height, in addition to this category. This cadastral data has a scale of 10x10 meters.

The GIS data we employ for our analysis falls into three distinct categories: geometrical characteristics, typological characteristics, and digital elevation models (DEMs).

- Geometrical parameters provide intricate details about a building's shape, size, orientation, and arrangement within its urban context. This information is crucial for understanding the building's interaction with the surrounding microclimate and its potential energy performance.
- Typological data complements the geometrical data by revealing insights into land use and building types. This information helps to contextualize the building's energy consumption patterns within the broader urban landscape.
- Finally, DEMs, with a resolution of 10 meters by 10 meters, furnish elevation data relative to sea level. This information is essential for understanding the impact of topography on building energy consumption. Variations in elevation can influence factors such as wind exposure, solar radiation patterns, and microclimate conditions, all of which can affect a building's energy usage.

It is important to emphasize that our analysis focuses exclusively on residential buildings above 30 meters in area as they can be considered as garage and not residential buildings

3.2.1.1 Geometrical characteristics of the buildings

The size, form, orientation, and layout of a structure are all explained by its geometric factors. Design-wise, building geometry is an important factor to consider. The load needed for heating and cooling is impacted by changes in solar gains, infiltration, heat gains, and losses. The quantity of windows and accessible wall space is often correlated with the quantity of heating and cooling loads. The characteristics of a structure have a big impact on how much energy it needs. Thus, a fundamental step in energy modeling is determining and producing the geometric characteristics associated with structures. In the context of the Mendoza case study, the following variables have been computed using the GIS tool field calculator.

- **Building area**
- **Building perimeter**

- **Buildings Height**: To calculate building height, information must be taken out of the local database. Specifically, information about the number of stories in each structure must be taken out of the relevant shape files. It's also important to remember that a single floor's average height in Mendoza is set at three units. These two factors are multiplied to determine the overall building height. Essentially, this procedure guarantees a precise portrayal of the vertical dimensions of buildings within the Mendoza region, considering both the number of floors and the average height of each story.

$$\boxed{H\ \text{Building} = N\ \text{floors} \times 3}$$

- **Buildings Footprint Area:** The area of external envelope of buildings on the ground floor, calculated by area function in GIS.

- **Building orientation**: The way a structure faces the sun and the direction of the predominant winds may significantly affect how much energy it uses. A well-designed building may optimize natural light and ventilation, negating the need for artificial lighting and mechanical ventilation. Control interior temperature by absorbing and releasing heat gradually.
- **Buildings Volume:** Building volume is determined by a simple but important calculation. This is accomplished by increasing each building's footprint area—which is derived from the local database and shapefiles—by its matching height. The building's total volume is calculated by multiplying the footprint area by the building's height, which indicates the horizontal space the structure occupies at its base. Taking into consideration both the horizontal and vertical dimensions of any building, this calculation approach offers a thorough comprehension of its spatial size. As a result, the resulting volume is an important parameter for describing and evaluating the built environment in the region under study.

$$V = A_{\text{footprint}} \times H_{\text{buildings}}$$

- **Gross Heated:** Taking into consideration Mendoza's particular features, the Gross Heated size is computed using a straightforward method that multiplies the footprint size of each structure by the matching number of floors. Here, the number of stores indicates the vertical dimension and the footprint size indicates the amount of horizontal space a structure occupies at its base. The Gross Heated Area is calculated by multiplying these two factors. This measure provides a comprehensive evaluation of the total area included inside the building structure, accounting for both the horizontal and vertical extension as indicated by the number of stories. As a result, our analysis offers crucial new insights into the overall spatial use and energy dynamics of the Mendoza region's structures.

$$A_{\text{Gross}} = A_{\text{footprint}} \times N_{\text{floors}}$$

- **Heat Loss Surface:** The Heat Loss Surface, a critical parameter in assessing the energy dynamics of buildings, is defined as the aggregated area of surfaces that directly interface with the outdoor environment. The calculation of this parameter employs a general formula, as outlined below:

$$\text{Heat Loss Surface} = \sum_{i=1}^{n} A_i$$

$$S_{\text{loss}} = (A_{\text{footprint}} \times 2) + (\text{Perimeter} \times H_{\text{building}})$$

Where Ai represents the area of each surface in direct contact with the outdoor environment, and n denotes the total number of such surfaces for a given building. This comprehensive formula encapsulates the summation of all relevant surface areas, providing a consolidated measure of the building's heat-exposed surfaces. In essence, the Heat Loss Surface parameter offers a valuable quantitative insight into the potential avenues for heat dissipation and contributes significantly to the broader evaluation of the building's thermal characteristics.

- **Surface to Volume Ratio:** A metric called the Surface to Volume Ratio (S/V) is used to evaluate how compact a building is; a smaller S/V value corresponds to a more compact construction. This ratio may be calculated using the following formula, which is defined as the Heat Loss Surface divided by the building's total volume.

$$\text{Surface to volume Ratio} = \text{Heat loss surface} / \text{Building Volume}$$

The overall space contained within the structure is known as the structure Volume, and the aggregated area of surfaces in direct contact with the outside environment is represented by the Heat Loss Surface in this calculation. About its interior volume, the resultant ratio offers a quantitative indicator of how well a structure is built to minimize heat-exposed surfaces. A building that has a lower Surface to Volume Ratio is more compact and thermally efficient, which can have an impact on thermal performance and energy saving.

In actuality, certain surfaces are shared by buildings in an urban setting. Consequently, there will be certain areas where at least one building and the other overlap. As a result, the heat loss surface computation must remove these overlaps.

Real Surface to volume Ratio = Real Heat loss surface / Building Volume

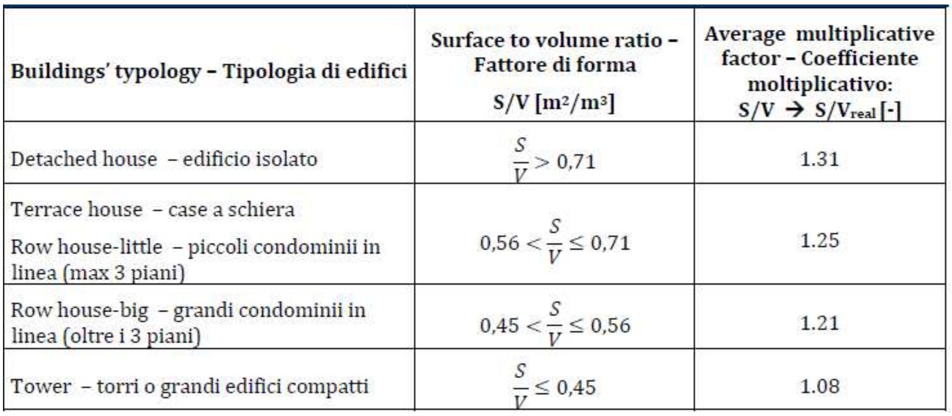
3.2.1.2 Typological Characteristics of the Buildings

After all buildings' Surface Volume (S/V) values were calculated, the results were divided into four different ranges. The residential building typologies are categorized using these defined ranges as the foundation. As part of the categorization process, each building is given a typology based on which S/V range it corresponds to. Buildings can be categorized in this way to facilitate the identification and differentiation of various residential typologies, each distinguished by its own compactness or spatial efficiency. Urban planning, energy-efficiency tactics, and architectural concerns may all benefit from the systematic study and characterization of the variety of building designs found in the examined region that this categorization technique gives.

To ascertain the heated surface and volume, dispersion surface, and overall compactness of residential, industrial, commercial, and service structures, certain geometric properties are ascertained. The section then goes on to present these variables. The building's base area multiplied by the number of stories, including wall size, yields the gross heated area. Next, the volume and surface area are allotted to the parcel together with the total gross heated area per built-up area. To account for an effective heated surface, the gross heated area formula is modified for a several housing typologies in the Mendoza case study.

The building's volume divided by the average floor height of three meters, multiplied by the number of stories, yields the gross heated volume. The dispersion surface is defined as the total of the base area, covering area, and vertical surfaces that are in contact with the outside world or unheated rooms. In insulated structures, this surface is just the total of these zones. Because of the lowered height between the two buildings, the common area of the walls for both buildings is eliminated for neighboring constructions, which is noted in the room on the shared side. The form factor is a synthesis parameter that quantifies the building's compactness by illustrating the link between the heated gross volume and the dispersion surface. By dividing the actual dispersion surface by the volume, one may get the form factor. From an energy perspective, a low form factor value is favorable since it corresponds to a smaller dispersing surface (i.e., less dispersion) for the same volume.

Table 2 : building typology and surface to volume ratio (Professor Mutani's class booklet. Exercise 4)



Buildings' typology – Tipologia di edifici	**Surface to volume ratio – Fattore di forma S/V [m²/m³]**	**Average multiplicative factor – Coefficiente moltiplicativo: S/V → S/V_{real} [-]**
Detached house – edificio isolato	$\frac{S}{V} > 0{,}71$	1.31
Terrace house – case a schiera Row house-little – piccoli condominii in linea (max 3 piani)	$0{,}56 < \frac{S}{V} \leq 0{,}71$	1.25
Row house-big – grandi condominii in linea (oltre i 3 piani)	$0{,}45 < \frac{S}{V} \leq 0{,}56$	1.21
Tower – torri o grandi edifici compatti	$\frac{S}{V} \leq 0{,}45$	1.08

3.2.1.3 DEM (Digital elevation model) and Altitude

Crucial elevation data concerning sea level are provided by digital elevation models (DEMs), which have a resolution of 10 meters by 10 meters. Understanding the complex interactions between topography and building energy consumption requires knowledge of this kind. Elevation variations may have a large impact on variables including wind exposure, solar radiation patterns, and microclimate conditions. These factors can all have a substantial impact on how much energy a structure uses.

We employed a raster file of a digital terrain model (DTM) that we downloaded from a local database to precisely record the elevation data for every district. After importing the DTM raster into the GIS program, individual points were extracted from the raster using the "raster pixel to points" function. We calculated the height of each district, enabling a precise evaluation of elevation disparities, by choosing the produced locations within each district and averaging their elevation values.

Because altitude fluctuations are common in Mendoza, it's important to take the associated temperature differences into account. To rectify this, we computed heating degree days (HDD) and altitude increases to normalize the energy consumption data. Through this technique, we were able to more accurately assess the variations in energy data while accounting for the combined effects of temperature and altitude.

3.2.2. Census Database

To fully comprehend Mendoza, Argentina's energy consumption trends, it is essential to examine the underlying socioeconomic and housing features of the city's populace. In light of this, the 2010 census data offers priceless insights on the characteristics of households, housing conditions, and demography that influence patterns of energy use in metropolitan areas.

1. The population data

   The census data reveals Mendoza's population to be dynamic and diversified, with a broad range of household compositions and socioeconomic origins. An extensive summary of Mendoza, Argentina's population, households, and dwellings as of 2010 can be found in the census statistics. This information is crucial for comprehending the patterns of energy usage in the city as it can be used to spot trends in dwelling types, household sizes, and population density. Additionally, the demographic data provides information on nationality, work status, age groups, gender distribution, and household dynamics. These traits offer important hints regarding the preferences and patterns of energy use of various demographic groupings.

- Gender
- Age groups
- Household relationships
- Nationality
- Educational background
- Employment situation

2. The household data

   The census data explores the nuances of household arrangements and living situations, going beyond the demographic domain. The number of families living in each property, the types of building materials used, the number of rooms, the degree of home congestion, and the size of the families all provide insight into the variables that affect how much energy is used in homes. These variables might include everything from how different-sized households utilize their appliances to the characteristics of various building materials' thermal insulation.

   - Number of families
   - Building’s material types
   - Number of rooms
   - Home crowding
   - Number of people in families

3. The dwellings database consists of:

   The housing kinds, occupancy rates, building and material quality, and relationship to service quality are all included in the dwellings statistics. With the use of this data, one can comprehend the many kinds of buildings that are available in the city, how their energy efficiency may differ, and how service accessibility may impact energy usage.

   - Types of housing
   - Occupancy situation of houses
   - Materials quality
   - Construction quality
   - Connection to service quality

3.2.3 Urban Morphology Factors

A number of factors were computed to get a deeper understanding of Mendoza's urban environment and to explore new variables related to energy dynamics. When examining the morphological features of the urban environment, these measurements are essential.

- **Building Coverage Ratio (BCR):** The Building Coverage Ratio is determined by the ratio between the built surface area (plan) and the surface area of the census section (m²/m²). Mathematically, it is expressed as:

  $$BCR = \frac{\sum A_{\text{building}}}{A_{\text{census}}}$$

  This ratio provides insights into the extent of land covered by buildings within a given census section, aiding in the assessment of the urban landscape.

- **Building Density (BD):** Building Density is defined as the ratio of the total volumes of buildings within a census section divided by the relevant surface area of that section. Mathematically, it is expressed as:

  $$BD = \frac{\sum V_{\text{building}}}{A_{\text{census}}}$$

  A higher building density value indicates a denser built environment, offering valuable information about the spatial organization and intensity of development in the area.
- **Permeability** in urban structures is also an important concept that affects energy efficiency, and the overall livability of cities.
- **Orientation in the composition of urban blocks**: The placement of buildings inside city blocks and the interaction between this arrangement and the surrounding urban setting are referred to as orientation in the composition of urban blocks. The microclimate, energy use, and general livability of a city may all be significantly impacted by the orientation of its urban blocks.
  Urban blocks should be oriented to maximize shade and decrease exposure to direct sunlight in hot, sunny areas. Blocks can be oriented east-west, and small streets can run north-south to accomplish this. This promotes passive cooling and lessens the demand for air conditioning by enabling buildings to shadow one another during the warmest portion of the day.
  Urban blocks should be oriented to optimize their exposure to sunlight in cold areas. Blocks can be oriented north-south and large roadways can run east-west to accomplish this. By allowing structures to receive sunlight during the coldest part of the day, passive heating is encouraged and the need for heating is decreased.
- **Family Density:** By adding together the entire area and building volumes inside each section, the population or family density for each census section may be determined. The total area or volume figures are divided by the sum of the building's square meters (m2) or cubic meters (m3) at the census scale in this straightforward computation. The resultant quotient provides a quantifiable measure of the concentration of families or individuals within a given geographic region at the census section level, offering crucial insights into patterns of density and geographic dispersion. This approach facilitates the rigorous assessment of the link between constructed structures and demography, which aids in urban planning, resource allocation, and the development of targeted community projects.

3.2.4 Climatic and geographical characteristics

Because of increased average temperatures and wind speeds brought on by climate change, energy consumption will be impacted. The environment is greatly impacted by our energy production and usage, while the reverse is becoming increasingly true. Both our energy needs and our ability to generate energy can be altered by climate change. Hydropower is affected by changes in the water cycle, for example; higher temperatures raise the energy needed for cooling in the summer and decrease it for heating in the winter.

The energy model was developed with the climatic data in mind, particularly for determining the heating and cooling demands for each structure. Based on the energy model, these loads were then utilized to calculate each building's gas consumption. Given the local temperature and weather patterns, the energy model's use of climatic data guarantees that the anticipated gas consumption is indicative of each building's real gas consumption.

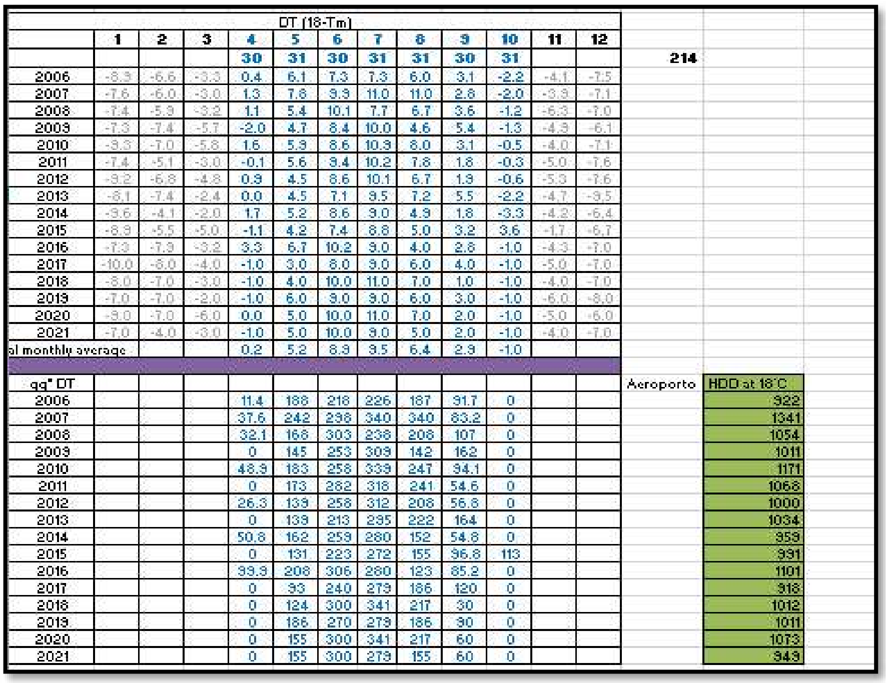
According to the analysis overall in our case study, we considered 3 stations (El Plumerillo, Russel, and Perdriel) which are the nearest stations to Mendoza In addition the weather for each of Mendoza's departments corresponds to one of these stations that has The highest amount of similarity between their altitude. The altitude of El Plumerillo station is 703 m a.s.l , Russel station is 850 m a.s.l and perdriel station is 960 m a.s.l .

3.2.4.1 Heating Degree days

The temperature of the outside air has an impact on how much energy buildings use for heating and cooling to maintain thermal comfort. However, a building's consumption might vary greatly depending on the season and altitude. Degree days are used to standardize and make comparable energy statistics. The amount of energy required to heat or cool an environment about a reference temperature is measured in degree days. A couple of regularly used measures are "HDD" (Heating Degree Days) and "CDD" (Cooling Degree Days) for assessing building energy consumption trends. The terms "Integration Method" and "Approximation Method" refer to the two different approaches used to calculate HDD/CDD. The choice between these 2 for calculating HDD/CDD depends on the type of temperature data available from weather stations. By using hourly temperature data, the "Integration Method" offers a more accurate and detailed analysis of trends in energy utilization. On the other hand, the "Approximation Method" provides a less complex and data-intensive method by utilizing daily records of the highest and lowest temperatures. In both cases, the number of days in a given time frame is multiplied by the difference in temperature between the outside air temperature and the base temperature. The base temperature, which is normally set at 18°C during Mendoza, Argentina's winters, indicates the point below which heating is necessary. Winter in the Mendoza metropolitan region starts on April 1st and lasts through the end of October. Local weather stations provide the data on the outside air temperature.

DD = S Days of winter/summer period x ((T base (18°C))– T external)

The integration method is preferred when hourly temperature data is readily available, as it provides more detailed insights into energy consumption patterns. However, the approximation method offers a simpler and less data-intensive alternative when hourly data is limited or unavailable.



	DT (18-Tm)													
	1	2	3	4	5	6	7	8	9	10	11	12		
				30	31	30	31	31	30	31			214	
2006	-8.3	-6.6	-3.3	0.4	6.1	7.3	7.3	6.0	3.1	-2.2	-4.1	-7.5		
2007	-7.6	-6.0	-3.0	1.3	7.8	9.9	11.0	11.0	2.8	-2.0	-3.9	-7.1		
2008	-7.4	-5.9	-3.2	1.1	5.4	10.1	7.7	6.7	3.6	-1.2	-6.3	-7.0		
2009	-7.3	-7.4	-5.7	-2.0	4.7	8.4	10.0	4.6	5.4	-1.3	-4.9	-6.1		
2010	-9.3	-7.0	-5.8	1.6	5.9	8.6	10.9	8.0	3.1	-0.5	-4.0	-7.1		
2011	-7.4	-5.1	-3.0	-0.1	5.6	9.4	10.2	7.8	1.8	-0.3	-5.0	-7.6		
2012	-9.2	-6.8	-4.8	0.9	4.5	8.6	10.1	6.7	1.9	-0.6	-5.3	-7.6		
2013	-6.1	-7.4	-2.4	0.0	4.5	7.1	9.5	7.2	5.5	-2.2	-4.7	-9.5		
2014	-9.6	-4.1	-2.0	1.7	5.2	8.6	9.0	4.9	1.8	-3.3	-4.2	-6.4		
2015	-8.9	-5.5	-5.0	-1.1	4.2	7.4	8.8	5.0	3.2	3.6	-1.7	-6.7		
2016	-7.3	-7.9	-3.2	3.3	6.7	10.2	9.0	4.0	2.8	-1.0	-4.3	-7.0		
2017	-10.0	-8.0	-4.0	-1.0	3.0	8.0	9.0	6.0	4.0	-1.0	-5.0	-7.0		
2018	-8.0	-7.0	-3.0	-1.0	4.0	10.0	11.0	7.0	1.0	-1.0	-4.0	-7.0		
2019	-7.0	-7.0	-2.0	-1.0	6.0	9.0	9.0	6.0	3.0	-1.0	-6.0	-8.0		
2020	-9.0	-7.0	-6.0	0.0	5.0	10.0	11.0	7.0	2.0	-1.0	-5.0	-6.0		
2021	-7.0	-4.0	-3.0	-1.0	5.0	10.0	9.0	5.0	2.0	-1.0	-4.0	-7.0		
al monthly average				0.2	5.2	8.9	9.5	6.4	2.9	-1.0				
qq° DT													Aeroporto	HDD at 18°C
2006				11.4	188	218	226	187	91.7	0				922
2007				37.6	242	298	340	340	83.2	0				1341
2008				32.1	168	303	238	208	107	0				1054
2009				0	145	253	309	142	162	0				1011
2010				48.9	183	258	339	247	94.1	0				1171
2011				0	173	282	318	241	54.6	0				1068
2012				26.3	139	258	312	208	56.8	0				1000
2013				0	139	213	295	222	164	0				1034
2014				50.8	162	259	280	152	54.8	0				959
2015				0	131	223	272	155	96.8	113				991
2016				99.9	208	306	280	123	85.2	0				1101
2017				0	93	240	279	186	120	0				918
2018				0	124	300	341	217	30	0				1012
2019				0	186	270	279	186	90	0				1011
2020				0	155	300	341	217	60	0				1073
2021				0	155	300	279	155	60	0				949

Figure 16 : Sample of HDD Calculation for Years 2006-2021 (Authors)

3.2.4.2 Altitude difference & Normalization

The temperature of the outside air has an impact on how much energy buildings use for heating and cooling to maintain thermal comfort. However, a building's consumption might vary greatly depending on the season and altitude. Degree days are used to standardize and make comparable energy statistics.

But given that Mendoza's districts range in height from 650 to 930 meters, it's crucial to take altitude-related variations in temperature and consumption into account. The digital terrain model (DTM) raster file, which is supplied by the local database, is where these values were obtained. To find the altitude of each district independently, the DTM raster is first put into GIS. Next, using the "raster pixel to points" tool, the produced points inside each district are selected, and their average is calculated.

Consequently, the degree days are computed using the district's average altitude to precisely assess energy usage. This computation is predicated on the UNI 10349 standard, which offers a technique to compute a location's temperature using a reference station situated on the same slope while accounting for altitude variation. Mendoza's locations differ in altitude; therefore these temperature changes must be taken into account. To comprehend these disparities, it is crucial to standardize energy consumption data by taking altitude increments into account and executing HDD computations. This approach makes it easier to assess disparities in data about energy more precisely. To equalize energy consumption concerning variations in altitude, the temperature must first be adjusted. The UNI 10349 standard is used as the baseline for this calculation. A formula that makes use of data from a designated reference meteorological station is used to determine the normalized temperature. For accurate results, the height of the chosen reference weather station and a base temperature must be included. The following is a representation of the normalizing formula:

$$\boxed{d\ {}^{\circ}C\ /M = (HDD1 - HDD2)/\ (Z1 - Z2).}$$

When determining degree days for a district, the temperature differential is determined by comparing the degree days of the two meteorological stations under consideration, and the altitude difference is determined by measuring the height difference between them. Consequently, the following formula is used to get the parameter "d": it is the ratio of the degree day difference to the altitude difference of the meteorological stations.

$$\boxed{T = Tref - (Z - Zref) \times d.}$$

To get precise degree day values for the district, this procedure is done for each of the three weather stations for which data is available.

Since HDD (Heating Degree Days) is a variable derived from temperature ranges, there is an alternative remedy for this particular situation. Alternatively, HDD can be normalized by calculating it based on the average altitude that is specific to each area. Interestingly, Mendoza's reference temperature (Tbase) for HDD calculations is set at 18 °C. This change makes it possible to examine the relationships between altitude, temperature, and energy use in many Mendoza districts in more detail.

$$\boxed{(18 - T) \times days = HDD\ (18 - T) \times days = \{18 - [Tref - (Z - Zref) \times d]\ \} \times days}$$

$$\boxed{HDD = HDDref + (Z - Zref) \times d \times days}$$

Finally, by having normalized HDD we are able to calculate the normalization of energy consumption data. The weather station "Russel" is chosen as the reference with altitude of 850 m a.s.l. & HDD of *1382.3* for 2017.

$$\frac{Energy\ Consumption}{Energy\ Consumption\ \mathbf{norm}} = \frac{HDD}{HDD\ Russel}$$

$$Energy\ Consumption\ \mathbf{norm}\ = \frac{Energy\ Cosumption\ \times HDD\ Russel}{HDD}$$

3.2.5 Annual GAS Energy Consumption Data

Gas consumption statistics is the quantity of natural gas used by a building or collection of buildings for hot water generation and/or heating. Gas meters installed on the building's gas supply line can be used to collect this data. They can measure the amount of energy used in megajoules (MJ) or the volume of gas consumed in cubic meters (m3).

Finding the gas's calorific value—the amount of energy released during combustion—is the first step in assessing gas consumption in terms of energy. This value, which is often provided by the gas supplier, is stated in British thermal units per cubic foot (BTU/ft3) or megajoules per cubic meter (MJ/m3).

Using the following formula, we can determine the energy consumption in megajoules or kilowatt-hours (kWh) if we know the gas consumption statistics and the gas's calorific value:

Energy consumption = Gas consumption x Calorific value

The energy consumption will be measured in megajoules if the calorific value is measured in megajoules per cubic meter and the gas consumption data is measured in cubic meters. The conversion factor of 3.6 must be divided to convert it to kilowatt-hours:

Energy consumption in kWh = Energy consumption in MJ / 3.6

To compare the energy performance of various buildings or to track energy consumption over time, we may also compute the energy consumption per unit of floor area or per unit of degree days.

Local gas distribution firms are the source of this type of information. These consumption figures correspond to the size of each district. Regretfully, we are unable to obtain information on the gas usage of individual buildings. This data may be used to compare the produced data with the real data and determine how accurate and precise the model is. Only the quantity of gas consumed for residential space heating between 2010 and 2021 Covering was considered in this analysis. Every year, the yearly statistics on energy use are given in kilowatt-hours (kWh). To improve our understanding of energy efficiency, different scenarios have been developed. In the first case, it is the real amount of consumption according to kWh, and in the second one is a normalization method is applied to the kWh data to account for altitude variations. The goal of this normalization is to show how temperature variations affect energy use.

Additionally, four additional outputs for the original kWh data and the normalized kWh data are generated for each scenario. The energy consumption normalized per square meter is shown by the first and second supplementary outputs, kWh/m2 and kWh/m3, respectively. Taking into account size variances, this statistic offers insights into the energy efficiency of buildings and spaces. Two other outputs that assess energy use on a per-family and population basis are kWh/family and kWh/inh.

This viewpoint allows for a more focused comprehension of energy use in units. The examination of these possibilities and the production of these extra results make the analysis more complex and situation-specific. It enables a thorough evaluation of energy-saving elements, taking altitude effects into account and providing information on the relative energy consumption efficiency of buildings and populations. The aforementioned scenarios and their corresponding results enhance our comprehension of the complex dynamics influencing the patterns of energy use within the researched area.

Table 3 : Different converted and normalized energy consumption scenarios for better analysis

GAS energy consumption	kWh	kWh [normalized by altitude]
	kWh /m2	kWh[normalized] /m2
	kWh /m3	kWh[normalized] /m3
	kWh/inh `	kWh[normalized] / inh
	kWh/ family	kWh[normalized] / family

3.3 Energy Modeling Approach

Using an efficient energy modeling technique is essential when researching gas consumption in buildings. Either software tools or a basic analytical model can be used for this. Conversely, less data is needed for simplified analytical models, which are easier to understand. They can offer insightful information about potential energy savings and help make rapid evaluations of the building's energy efficiency. Nevertheless, they lack the accuracy of software tools and make it impossible to conduct a thorough examination of the energy performance of the structure.

Using a mix of software tools and simplified analytical models might be acceptable for our purpose. For instance, you may use Excel to make charts and graphs and GIS software to analyze and visualize the data you have gathered. After that, you may rapidly evaluate a building's energy performance and pinpoint areas for enhancement using a condensed analytical model. Lastly, you might run through energy calculations on certain buildings using a program like Energy Plus.

It is crucial to provide evidence for the selected method's applicability in the analysis of building gas consumption. Consider elements like the building's complexity, the volume of accessible input data, and the necessity of the analysis's precision and depth. In the end, the method of choice should offer trustworthy and useful information on how energy-efficient buildings are and where energy may be saved. The energy modeling technique that was selected should be supported by evidence that it is appropriate for examining gas usage in buildings.

3.3.1 Model Development

The urban variables and indicators play a crucial role in the Model Development stage because they facilitate the spatial and socioeconomic reconstruction of the urban setting. These variables and indicators, which may be computed using building and census data, can offer crucial insights into the features of a particular region or segment. One example of a calculated variable is the prevailing typology, which takes into account the proportion of apartment buildings vs single-family dwellings in a certain location. This makes it possible to determine the prevailing typology—such as single-family houses or condominiums—for that particular neighborhood.

Another statistic that may be computed is the proportion of gas-distributed residences that are heated. This implies a direct proportion between the number of families and the number of homes and is based on the number of families connected to the gas network.

Another important statistic is the gas-heated area, which is computed by multiplying the section's occupied residential area by the proportion of gas-heated residences. Lastly, the ratio of the total number of homes to the total area distributed across the network that is heated by gas may be used to determine the gas housing density. These variables and indicators offer useful information for the investigation of gas consumption in buildings and may be used to guide the energy modeling technique.

The focus is on creating a model that illustrates the patterns of energy consumption of buildings in an urban environment by incorporating the factors and indicators that were previously discussed. The interdependence of the variables should be reflected in the model, which should also produce reliable results for analysis and judgment. Choosing appropriate methods and software for analysis is a step in the model-building process.

Once the method and software tools have been selected, the variables and indicators may be added to the model. By taking the average of the values of the structures or other components in the region under study, the spatial variables may be computed.

There are many phases involved in using the model to estimate Mendoza's particular energy consumption:

1. Data Collection: Gather data from various sources, including census data, energy consumption data, natural gas usage data, and information on housing characteristics. Ensure that the data is accurate, relevant, and representative of the different departments and localities within Mendoza.
2. Data Processing: Clean and preprocess the collected data to ensure consistency and uniformity. Standardize units and formats to facilitate analysis and comparison.
3. Spatial Analysis: Utilize Geographic Information System (GIS) tools to map the data and visualize energy consumption patterns across different regions of Mendoza. This spatial analysis helps identify areas with higher or lower energy consumption and potential factors influencing these variations.
4. Model Calibration: Calibrate the model using historical data to establish the relationship between energy consumption, housing characteristics, and other relevant factors. Fine-tune the model parameters to improve its accuracy in predicting specific energy consumption.

3.3.2 Data Synthesis from building and Census scale to District level

At the district level, data integration is the act of bringing together and organizing disparate datasets and data from different sources inside a certain administrative territory or district. This all-encompassing strategy is essential for producing a cohesive and coherent dataset that enables a full comprehension of the dynamics inside the area.

To fully comprehend the characteristics of each department or district, all previously computed or collected data was combined, combined with natural gas energy consumption data, and rigorously analyzed to determine the energy-related variables that had the greatest influence. Since most of the data was available at the census scale, whereas energy consumption data was at the district level, data from all census sections within each district was consolidated to ensure consistency and balance across all variables.

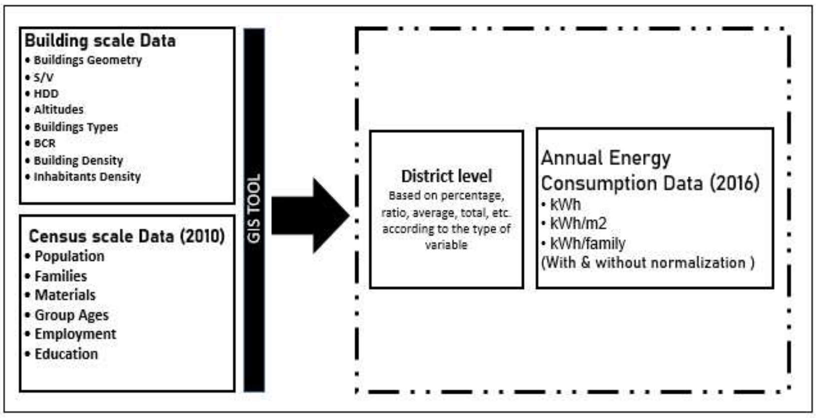


Figure 17 :Data Synthesis from building and Census scale to District level (By Authors)

3.4 statically tools and analysis

Clustering: Using the data mining process of clustering, data points are grouped into clusters according to how similar they are. Numerous applications, including as regression analysis and correlation, might benefit from this grouping procedure. Clustering may greatly improve the accuracy and interpretability of correlation and regression findings by locating homogeneous districts within a dataset.

Correlation and linear regression are the methods most frequently employed to look into the relationship between two quantitative variables. Regression expresses the relationship as an equation, whereas correlation measures the strength of the linear link between two variables. (Source: Online publication, November 5, 2003, Statistics Review 7: Correlation and regression.)

A sensitivity analysis has been conducted due to the large number of input variables and the inherent ambiguity around which ones have a substantial impact on energy usage. By identifying the most relevant factors from the large dataset, this analytical method seeks to illuminate their possible influence on patterns of energy usage.

Analysis fulfills two functions. First, it tackles the difficulty of locating important variables amidst a plethora of inputs, assisting in the ranking of elements that have a major impact on variations in energy usage. Second, the link between the input variables and the desired data is explored in depth by this study. In particular, it explores the complex relationship that exists between key energy-related factors and statistics on energy usage. To improve our comprehension of the intricate interactions between numerous variables and their effects on energy usage, this study aims to reveal the subtleties of how various factors affect energy consumption. This approach facilitates a more informed and targeted exploration of the key determinants shaping energy consumption patterns in the studied context.

3.4.1 clustering district for finding the homogeneous area

Determining homogenous districts with common characteristics and examining spatial patterns are essential in urban studies to comprehend the complexity of diverse urban environments. In this regard, clustering analysis, a method that facilitates the grouping of similar objects according to preset criteria, is a helpful tool. This study uses clustering, namely the Excel version of the K-means method, as a preliminary step to find patterns in Mendoza's building inventory.

Two statistical methods that are frequently used to comprehend connections between data are correlation and regression analysis. Before conducting correlation and regression analyses, the process of clustering districts to identify homogeneous districts improves the precision and applicability of the analyses that follow. Clustering reduces the effect of heterogeneity within the dataset by assembling regions with comparable features, resulting in a more complex understanding of the relationships between variables. The existence of noise and outliers in the data may impair the efficacy of these studies. To overcome these obstacles, clustering is essential since it:

- Reducing Noise: Outliers can skew the findings of regression and correlation studies, therefore clustering aids in locating and removing them. Clustering guarantees that the study is concentrated on the underlying patterns and relationships within the data by eliminating these excessive values.
- Finding homogeneous Subgroups: By identifying homogeneous subgroups in the data, clustering algorithms enable more focused regression and correlation analysis. Researchers can obtain deeper insights into the correlations between variables inside particular clusters by concentrating on them, which can produce more accurate and significant results. More than that, by revealing underlying patterns and associations that might not be immediately obvious, clustering helps the researcher maximize data exploration. This facilitates the development of more specialized research questions and hypotheses, guaranteeing that correlation and regression studies that follow are carried out with a thorough comprehension of the underlying urban structure.

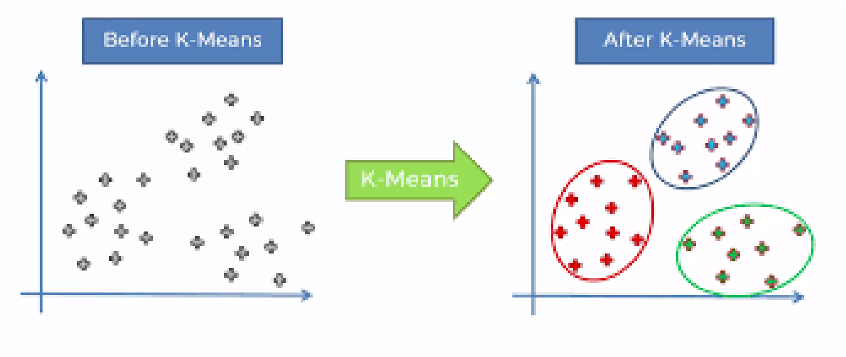
Clustering is important because it helps find geographically coherent groupings, which gives researchers information about the underlying dynamics and structure of a certain area. It is very important to divide the urban environment into homogeneous areas to prepare for the next correlation and regression studies. In the setting of Mendoza, where a variety of commercial, industrial, and architectural structures contribute to the complex urban fabric, this becomes more important.

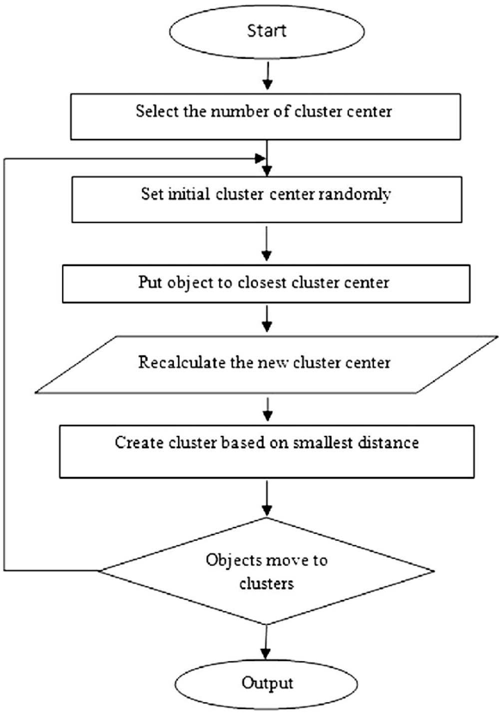
K-means clustering is one of the most popular and well-researched clustering methods. Using Euclidean calculus, successively assigning data points to the cluster with the closest mean divides the data into a predetermined number of clusters (k). K-means clustering has several benefits, such as:

- Simplicity: K-means clustering is a popular option for many data analysis applications since it is very simple to learn and execute.
- Efficiency: K-means clustering techniques work well with big datasets because of their computational efficiency.
- Interpretability: Depending on the properties of the data points inside each cluster, the resultant clusters are frequently interpretable and capable of meaningful labeling.

Notwithstanding its benefits, k-means clustering has many drawbacks, including the assumption of spherical clusters and sensitivity to the initial cluster centroids. There are several ways to find homogeneous groups in data using clustering techniques including density-based clustering and hierarchical clustering.

Figure 18 : Data clustering-means clustering algorithm (Younus et al. (2019))





3.4.2 Correlations of Variables in Energy Consumption

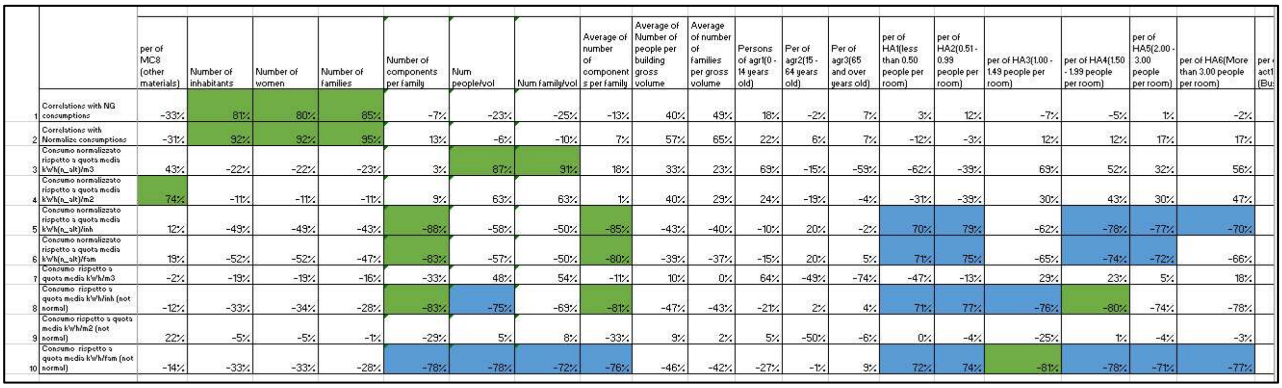
Correlation analysis is used in the Mendoza case study to look at the relationships between different factors and energy use. By examining the degree and direction of the association between two sets of data, this statistical tool gives crucial insights into the probable correlations between changes in one variable and changes in another. A more in-depth comprehension of the factors influencing energy consumption patterns is made possible by analyzing correlations within the dataset within the framework of the Mendoza case study.

Several energy-related variables are included in the correlation analysis, including building characteristics, environmental factors, and demographic data. Correlation coefficients, which measure the strength and direction of correlations (positive or negative) and identify which factors may have a substantial impact on energy use, are used to display patterns.

To achieve greater precision and accuracy in our correlation analysis, we performed the correlation 10 times, each time considering a different measure of energy consumption. This allowed us to identify the variables that exhibited the strongest correlations across different energy consumption levels.

Correlations of Annual Energy Consumption	**kWh**	This analysis provided a holistic view of energy usage across the entire sample population, offering insights into overall energy demand patterns.
Correlations of Normalized Energy Consumption from Average Altitude of each districts	**kWh(n_alt)**	By normalizing energy consumption data to average altitude, we sought to account for the potential impact of altitude on energy consumption patterns. This approach allowed us to identify the variables that were most strongly correlated with energy consumption, independent of altitude differences between districts.
Correlations of Normalized Energy Consumption from Average Volume of each districts	**kWh/m³** **kWh(n_alt)/m³**	This analysis controlled for the impact of building size and occupancy on energy consumption by normalizing data to average volume. This allowed us to isolate the influence of other factors, such as household characteristics and energy-efficient practices.
Correlations of Normalized Energy Consumption from Average Area of each districts	**kWh/m²** **kWh(n_alt)/m²**	By normalizing energy consumption data to average area, we sought to account for the influence of building floor space on energy consumption. This analysis allowed us to identify variables that were more strongly correlated with energy use in denser or more expansive districts.
Correlations of Normalized Energy Consumption from Average Inhabitants of each districts	**kWh/inh** **kWh(n_alt)/inh**	This analysis focused on the relationship between energy consumption and population density, normalizing data to the average number of inhabitants per district. This allowed us to identify variables that were more strongly correlated with energy use in districts with higher or lower population densities.
Correlations of Normalized Energy Consumption to Average Households of each districts	**kWh/family** **kWh(n_alt)/family**	This analysis focused on the relationship between energy consumption and household size, normalizing data to the average number of households per district. This allowed us to identify variables that were more strongly correlated with energy use in districts with larger or smaller households.

Table 4 : correlation of variables according to different kind of normalize energy consumption



		per of MC8 (other materials)	Number of inhabitants	Number of women	Number of families	Number of components per family	Num people/vol	Num family/vol	Average of number of components per family	Average of Number of people per building gross volume	Average of number of families per gross volume	Persons of agr1(0 - 14 years old)	Per of agr2(15 - 64 years old)	Per of agr3(65 and over years old)	per of HA1(less than 0.50 people per room)	per of HA2(0.51 - 0.99 people per room)	per of HA3(1.00 - 1.49 people per room)	per of HA4(1.50 - 1.99 people per room)	per of HA5(2.00 - 3.00 people per room)	per of HA6(More than 3.00 people per room)	per act1 (Bu
1	Correlations with NG consumptions	-33%	81%	80%	85%	-7%	-23%	-25%	-13%	40%	49%	18%	-2%	7%	3%	12%	-7%	-5%	1%	-2%	
2	Correlations with Normalize consumptions	-31%	92%	92%	95%	13%	-6%	-10%	7%	57%	65%	22%	6%	7%	-12%	-3%	12%	12%	17%	17%	
3	Consumo normalizzato rispetto a quota media kWh(n_alt)/m3	43%	-22%	-22%	-23%	3%	87%	91%	18%	33%	23%	69%	-15%	-59%	-62%	-39%	69%	52%	32%	56%	
4	Consumo normalizzato rispetto a quota media kWh(n_alt)/m2	74%	-11%	-11%	-11%	9%	63%	63%	1%	40%	29%	24%	-19%	-4%	-31%	-39%	30%	43%	30%	47%	
5	Consumo normalizzato rispetto a quota media kWh(n_alt)/inh	12%	-49%	-49%	-43%	-88%	-58%	-50%	-85%	-43%	-40%	-10%	20%	-2%	70%	79%	-62%	-78%	-77%	-70%	
6	Consumo normalizzato rispetto a quota media kWh(n_alt)/fam	19%	-52%	-52%	-47%	-83%	-57%	-50%	-80%	-39%	-37%	-15%	20%	5%	71%	75%	-65%	-74%	-72%	-66%	
7	Consumo rispetto a quota media kWh/m3	-2%	-19%	-19%	-16%	-33%	48%	54%	-11%	10%	0%	64%	-49%	-74%	-47%	-13%	29%	23%	5%	18%	
8	Consumo rispetto a quota media kWh/inh (not normal)	-12%	-33%	-34%	-28%	-83%	-75%	-69%	-81%	-47%	-43%	-21%	2%	4%	71%	77%	-76%	-80%	-74%	-78%	
9	Consumo rispetto a quota media kWh/m2 (not normal)	22%	-5%	-5%	-1%	-29%	5%	8%	-33%	9%	2%	5%	-50%	-6%	0%	-4%	-25%	1%	-4%	-3%	
10	Consumo rispetto a quota media kWh/fam (not normal)	-14%	-33%	-33%	-28%	-78%	-78%	-72%	-76%	-46%	-42%	-27%	-1%	9%	72%	74%	-81%	-78%	-71%	-77%	

Table 5 : Sample of correlation analysis results (Authors)

For this analysis the correlation above +%80 or below -%80 were considered good & significant for further steps.

3.4.3 Regression Analysis:

In Excel, regression analysis is a statistical tool that helps us understand the relationship between one variable (dependent) and one or more explanatory variables (independent). It estimates the average change in the dependent variable that is associated with a one-unit change in an independent variable.

Therefore, in regression analysis, there are two types of data:

1. Dependent variables
2. Independent variables

The dependent variable is the variable that we are trying to predict, and the independent variables are the variables that we think might be influencing the dependent variable.

in addition, there are two main types of regression in Excel: **linear regression and multiple regression**.

Linear regression is used when there is a linear relationship between the dependent and independent variables. This means that the change in the dependent variable is proportional to the change in the independent variable.

Multiple regression is a type of regression analysis that can be used to analyze the relationship between a dependent variable and multiple independent variables. in fact, when there is more than one independent variable. This means that we can measure the effect of multiple factors on the dependent variable. also, this allows users to identify the independent variable with the strongest impact on the dependent variable.

Regression analysis in Excel can be used to:

- Identify the strength and direction of the relationship between variables: The correlation coefficient (r) indicates the strength and direction of the relationship between a dependent variable and an independent variable. A correlation coefficient of 1 indicates a perfect positive correlation, while a correlation coefficient of -1 indicates a perfect negative correlation. Correlation coefficients closer to 0 indicate weaker relationships between variables.
- Estimate the value of the dependent variable given the value of the independent variable: The regression equation can be used to estimate the value of the dependent variable for a given value of the independent variable.
- Predict future values: Regression analysis can be used to predict future values of the dependent variable based on historical data.

3.4.3.1 Multiple Linear Regression Analysis

We could estimate the relationship between a quantitative dependent variable and two or more independent variables using a straight line. Multiple regression analysis allows for the assessment of the strength of the relationship between an outcome (the dependent variable) and several predictor variables as well as the importance of each of the predictors to the relationship, often with the effect of other predictors statistically eliminated.

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_p x_{ip} + \epsilon$$

where, for $i = n$ observations:

$y_i =$ dependent variable

$x_i =$ expanatory variables

$\beta_0 =$ y-intercept (constant term)

$\beta_p =$ slope coefficients for each explanatory variable

$\epsilon =$ the model's error term (also known as the residuals)

Formula and Calculation of Multiple Linear Regression:

We evaluate the relative contribution of variances in the chosen energy-related variables to variations in energy use using multiple linear regression. With the use of this statistical technique, a predictive equation can be created, allowing energy consumption to be estimated using the significant factors. We may make important predictions that will help the Mendoza area with resource allocation, policy choices, and energy planning by knowing the weights and contributions of each variable in the regression model.

With this regression analysis, which is customized for the case study, significant insights may be extracted and a quantitative basis for forecasting Mendoza's energy consumption patterns can be established. Consequently, the goal is to identify trends and create a prediction model that may provide information about the variables affecting Mendoza's energy usage.

Before doing multiple linear regression analysis in the Mendoza case study, as previously mentioned, all relevant data had to be integrated into a standard scale and matched the scale of the energy consumption data. This alignment makes sure that all of the different variables are consistent and uniform, which makes a thorough regression analysis easier.

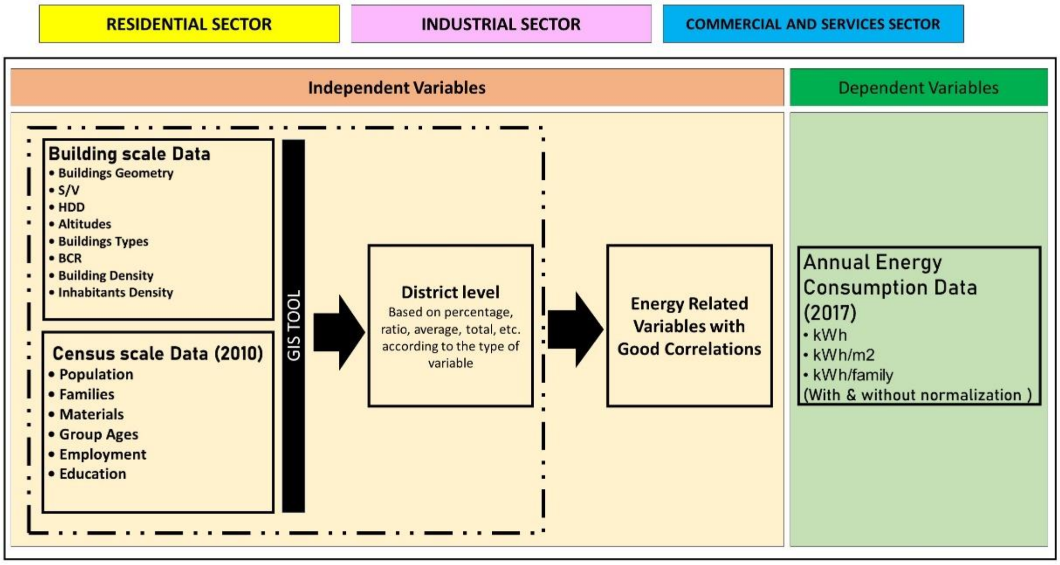


Figure 19 : Scheme of regression analysis between variables (Authors)

3.4.3.2 Regression Analysis Significance Test

Several factors need to be controlled after doing multiple linear regression analyses to assess the relevance of the findings. To ascertain if there is a statistically significant link between the dependent and independent variables, a regression analysis significance test is utilized. This indicates that there is no hope behind the connection. In actuality, the regression must demonstrate that the input data has a significant and robust impact on energy usage in order to create a flawless or highly dependable model.

R Square Value (R2): The R-squared number, sometimes referred to as the coefficient of determination in regression analysis, is a statistical indicator of how well the regression line fits the data points. It shows the percentage of the dependent variable's variation that the independent variable accounts for. The range of R-squared values is 0 to 1, where:

- R-squared = 0 indicates that the regression line does not fit the data at all and the independent variable does not explain any of the variance in the dependent variable.
- R-squared = 1 indicates that the regression line perfectly fits the data and the independent variable explains all of the variance in the dependent variable.

In this project the R square values greater than 80% are considered significant.

R2 > 80%

Significance-F (F-tests) are employed to evaluate the regression equation's general relevance. The F-test contrasts the variance that the regression equation explains overall with the variance of the dependent variable. A statistically significant regression equation may be determined by comparing the F-statistic to the critical value.

Significance-F < 0.05

p-value: The purpose of the test is to see how closely all coefficient values approach zero. Values that are much larger than zero demonstrate that they have no bearing on the dependent variable. A p-value greater than 5% would thus not be desirable.

p-value < 0.05

3.4.3.3 Validation of The Model

The average absolute difference between the values that were predicted and those that were observed is measured by the Mean Absolute Error (MAE), commonly referred to as the L1 norm in regression analysis. By calculating the average error over all data points, it offers a means of evaluating the overall accuracy of a regression model.

Following model development, "Distribudora de Gas Cuyana," the local provider, provides real consumption data, which is used to evaluate the output data. There will always be some mistakes because the model simply provides a prediction of the data that will be produced.

The regression chart's trend line and projected points differ from one another, making these inaccuracies visible.

However, these errors can also be calculated through a formula that is called "Mean Absolute Error Percentage". With this calculation, the percentage of error is identified through subtracting the predicted value from real data and then dividing it by the real data.

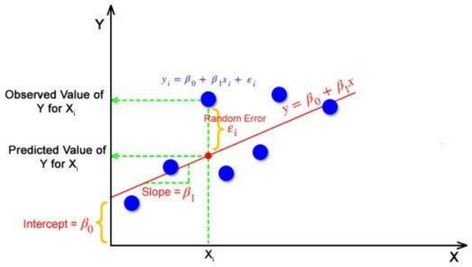


Figure 20 : Errors between variables in linear regression chart (source: Analytics Vidhya)

$$\boxed{\text{MAPE} = \frac{|\,\textit{The Real Data} - \textit{The Predicted Data}\,|}{\textit{The Real Data}} \times 100}$$

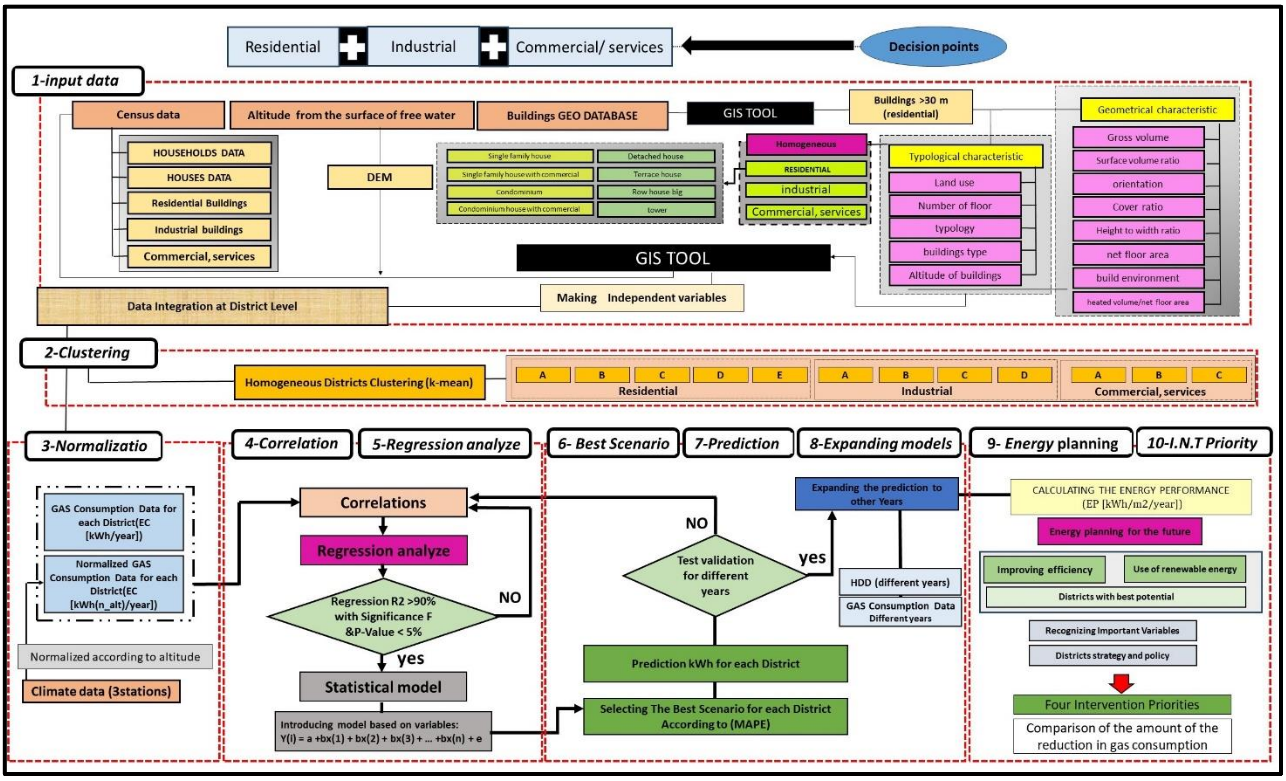
High Errors & Specific Modelling

Since the maximum error percentage is often 15 or 20 (for large regions), data with larger errors may be regarded as outliers and removed from the main model in order to create a new regression analysis model that is particular to that data set. Thus, we would want special models for outliers who have significant errors and the similar features.

3.5. Flowchart of Methodology

Below you can see all the procedure in methodology chapter with a flowchart for better understanding of different steps and details.

Figure 21 : Flowchart of The Methodology (Authors)



4 case study: MENDOZA, ARGENTINA

Introduce Mendoza as the special setting for the case study first. We will discuss some background information on the city, such as its location, climate, and any relevant energy-related issues or objectives.

4.1 Geographical Location

Mendoza, in western Argentina, is an intriguing case study for studying urban energy planning. The Mendoza Province's vibrant capital is situated at around -32.86" S latitude and -63.85" W longitude. The province of Mendoza extends eastward from the Andes Mountains' lofty peaks, which form its boundary with Chile. Much of its land area is made up of piedmont, foothills, and semiarid and dry sub-Andean mountains. The highest peak in the Andes in the Western Hemisphere, Mount Aconcagua, rising to a height of 22,831 feet (6,959 meters), is situated close to the Chilean border in the northwest. The districts in the north, close to the foot of the cordillera, are home to the majority of the province's population. Here, the Mendoza River in particular supplies water for agriculture. Except for the Grande River in the southwest, all rivers fall into the vast saline basins that stretch over the sandy plains to the east. The area around San Rafael has seen an improvement in agricultural output as a result of dams built on the Atuel and Diamante rivers in the foothills of central Mendoza province.Figure 20 - Mendoza Province & Gran Metropolitan Area Locations (source :Todo Argentina & Social Mendoza Atlas Maps)

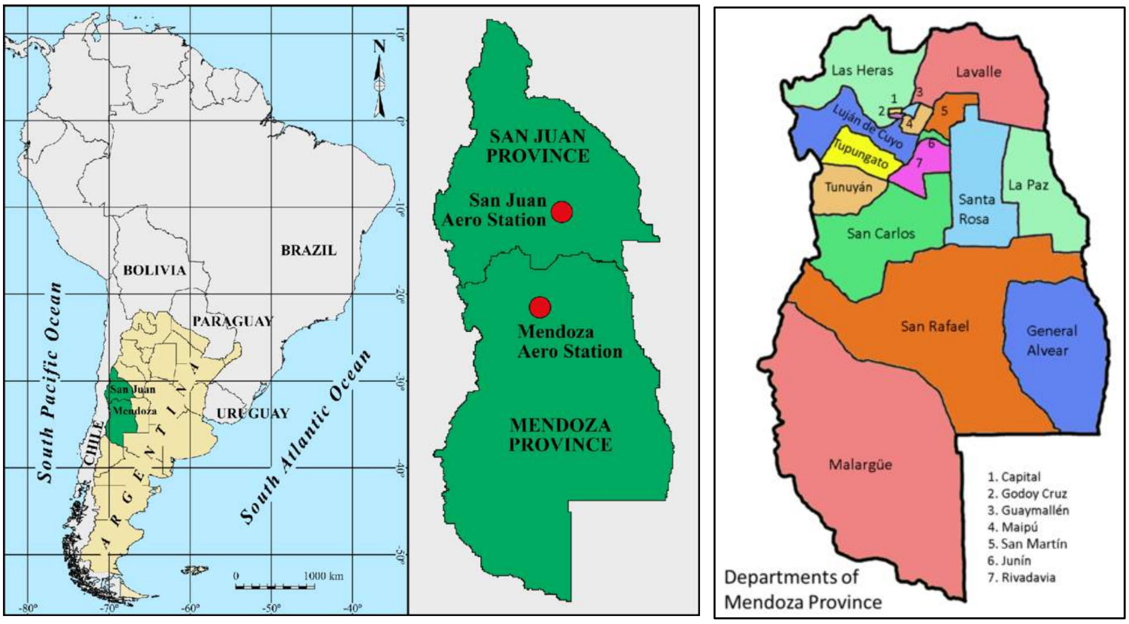


Figure 22 : The geographical location of Argentina and the city of Mendoza

4.2. Departments & Districts

Six main departments make up the vast metropolitan agglomeration known as the Gran Mendoza region, which is located in west-central Argentina. Its multi-layered administrative structure, which includes districts, departments, and census divisions, makes it possible to analyze energy consumption trends and the sociodemographic variables that affect them in great detail.

Located in the "Capital" department, the provincial capital of Mendoza is the center of the agglomeration. Six departments make up this city: Capital, Guaymallen, Las Heras, Godoy Cruz, Maipu, and Lujan. Each of these departments has unique requirements and attributes that set them apart from one another. Meanwhile, the stark contrast in construction and population density, together with their altitude disparities, is one of the most significant variances.

Characteristics of the 6 Departments

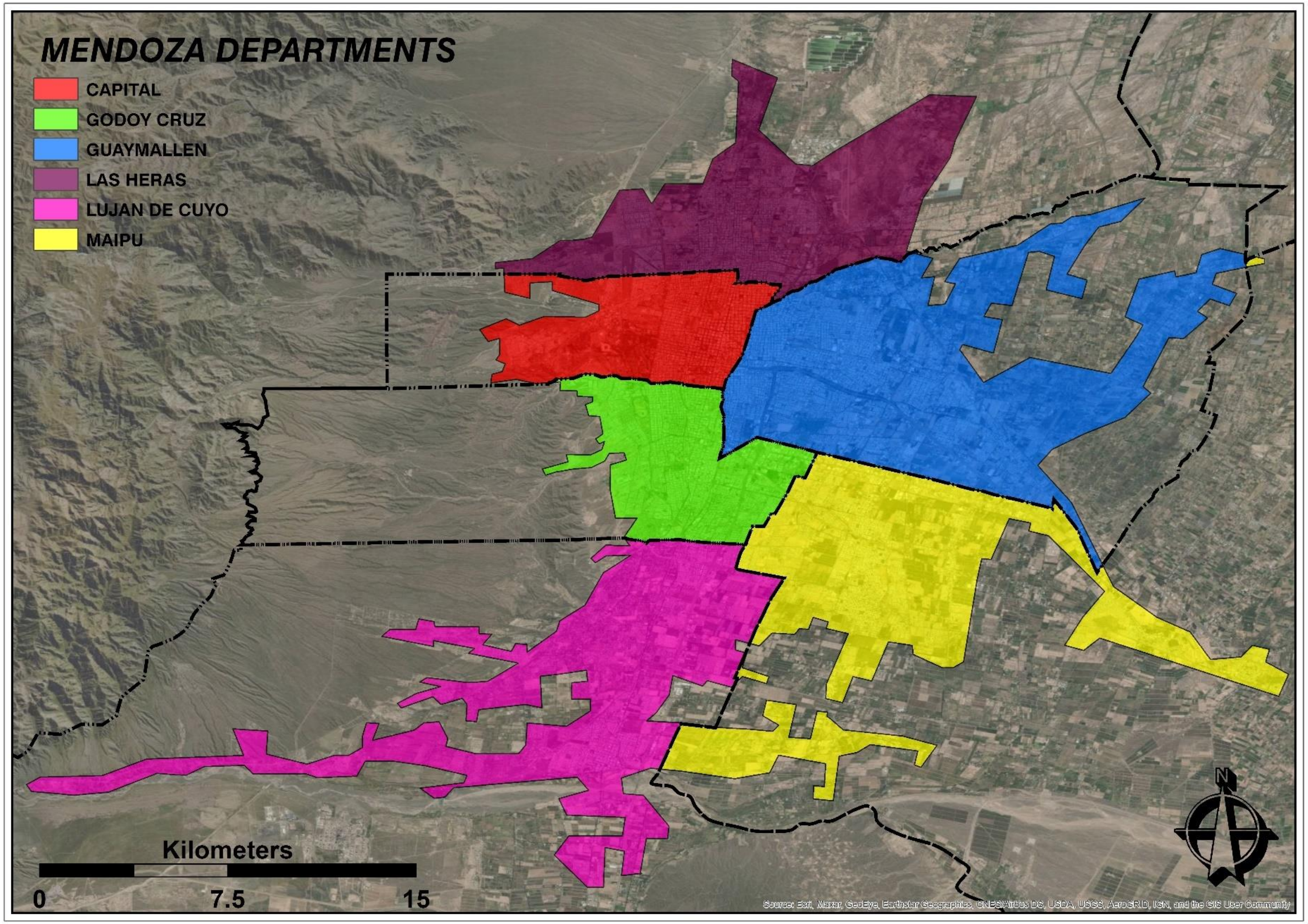
Maipú	Luján	Las Heras	Guaymallen	Godoy Cruz	capital	MENDOZA			
12	14	14	20	5	12	77	Number of districts		Political divisions
144	109	209	294	244	203	1203	Number of sections		
71308	53874	99847	156916	125890	85968	593803	Number of buildings		
7727.432	6621.116	5973.299	9005.987	3416.86	3248.435997	35993.13	Area per hectare	Area in an urban Territory	
21.50%	18.50%	16.50%	9%	9.50%	25%	100%	Share of the total		
161405	102874	214614	287940	214258	135525	1116616	Number of people		Demographic information
14.45	9.21	19.22	25.78	19.18	12.13	100	Share of the total		
26.44	25.98	26.84	24.68	22.99	18.5	24.23	0-14 year		
64.66	65.06	63.97	64.81	64.82	66.71	65	14_64 year		
8.89	8.95	9.18	10.49	12.17	14.77	10.74	over 64 year		
48.24 %	34.05 %	70.03 %	62.31 %	70.88 %	70.58 %	59.34 %	population density		
30.41 %	28.34 %	40.43 %	45.95 %	52.06 %	73.9 %	44.47 %	Building density		Building information
29.28 %	26.48 %	38.78 %	42.66 %	47.17 %	50.75 %	39.37 %	buildings average of cover ratio		
3.11 m	3.19 m	3.11 m	3.25 m	3.32 m	4.36 m	3.39 m	average buildings height		
358.81	381.26	320.74	360.69	349.79	457.06	371.39	buildings average of heat loss surface		
195.75	210.83	161.3	204.26	199.67	617.37	264.86	buildings average heated gross volume		
1.37	1.35	1.38	1.33	1.33	1.2	1.32	buildings average of real s/v		
51.55	59.86	57.16	65.27	68.16	77.22	63.2	QM 1	quality of material	
37.37	31.51	32.05	25.67	26.88	17.86	28.55	QM 2		
3.96	3.62	3.06	2.34	1.8	1.66	2.74	QM 3		
7.09	4.49	7.71	7.72	3.14	3.24	5.56	QM 4		

Table 6 : Characteristics of the 6 departments (Authors)

There is a system of discrete districts inside each of these departments. The districts display a range of attributes, such as dimensions, population density, types of buildings, elevation, and more aspects. The availability of district-level energy consumption data is noteworthy as it offers a significant basis for studying and scaling patterns of energy usage over the whole metropolitan agglomeration.

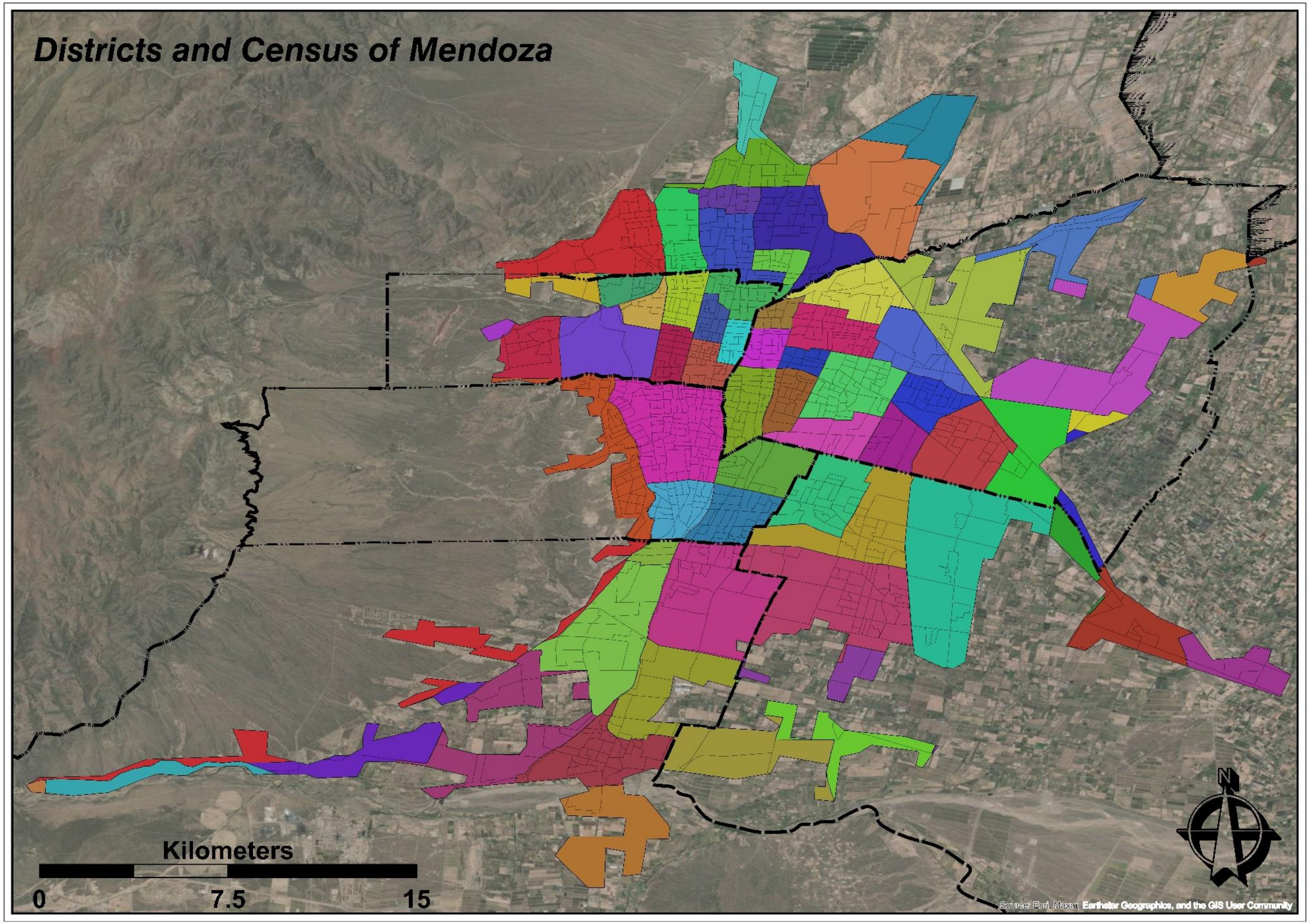
Moreover, census parts are created inside each district. These sections function as archives for vital information about the city's housing stock, building materials, and other pertinent factors. The Census database offers a thorough analysis of the socioeconomic structure of the city and was created by CONICET Incihusa using 2010 as the reference year.

Figure 23 ; 6 departments of Mendoza (Authors)



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 24 : Districts and Census of Mendoza (Authors)



4.3. The Population

Mendoza's population is rising faster than the national average, at a rate of 1.2% each year, according to the Instituto Nacional de Estadística y Censos (INDEC). With 80% of the people residing in urban areas, the province's population is likewise getting more and more urbanized. This is because more than half of the province's population lives in the Gran Mendoza Metropolitan Area, which is expanding (Gobierno de Mendoza 2023).

Gran Mendoza is one of Argentina's most populous areas and its fourth most populated area with over 937,154 residents in 2010, 10% higher than the 848,660 residents recorded in 2001. Guaymallen and Godoy Cruz are the two departments in Gran Mendoza with the highest population. Both are fairly large territories that surround the Capital department, with Godoy Cruz on the southern boundary and Guaymallen on the eastern side. The distribution of population concentration in each department is displayed in table 7. The level of education among the people in the province is likewise rising. In 2010, 12.1 years of schooling was the average education level, and 99% of people were literate. Due to the province's robust economy and investments in education, this figure is greater than the national average (UNESCO Institute for Statistics, 2023).

It is important to note that the census database was accessible for the reference year of 2010 at the time this research was conducted which was updated in 2017. As a result, subsequent studies that use updated demographic data may produce more accurate outcomes.

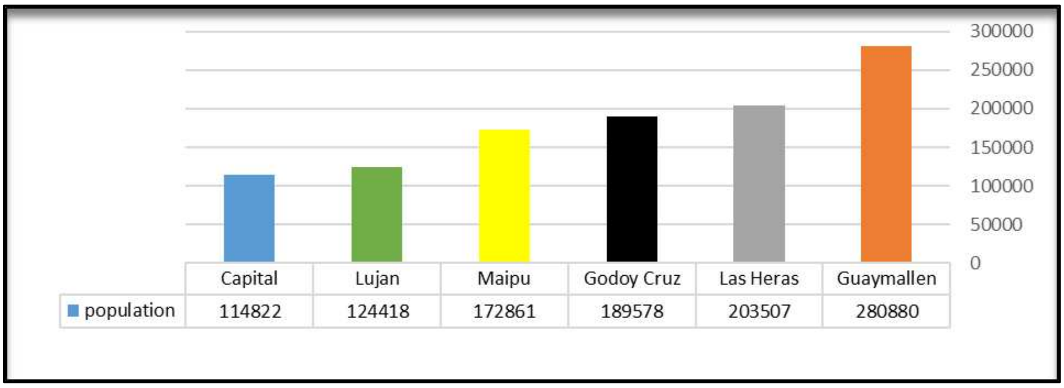


Table 7 : papulation of 6 departments (Authors)

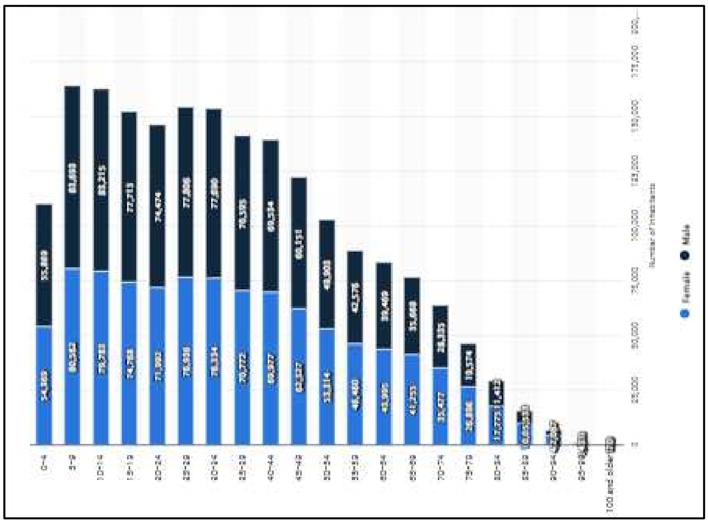


Figure 25 : Population of Mendoza as of January 2023, by group age and gender ((UNESCO Institute for Statistics 2023), statista.com)

Figure 26 : Population Density of Mendoza (Authors)

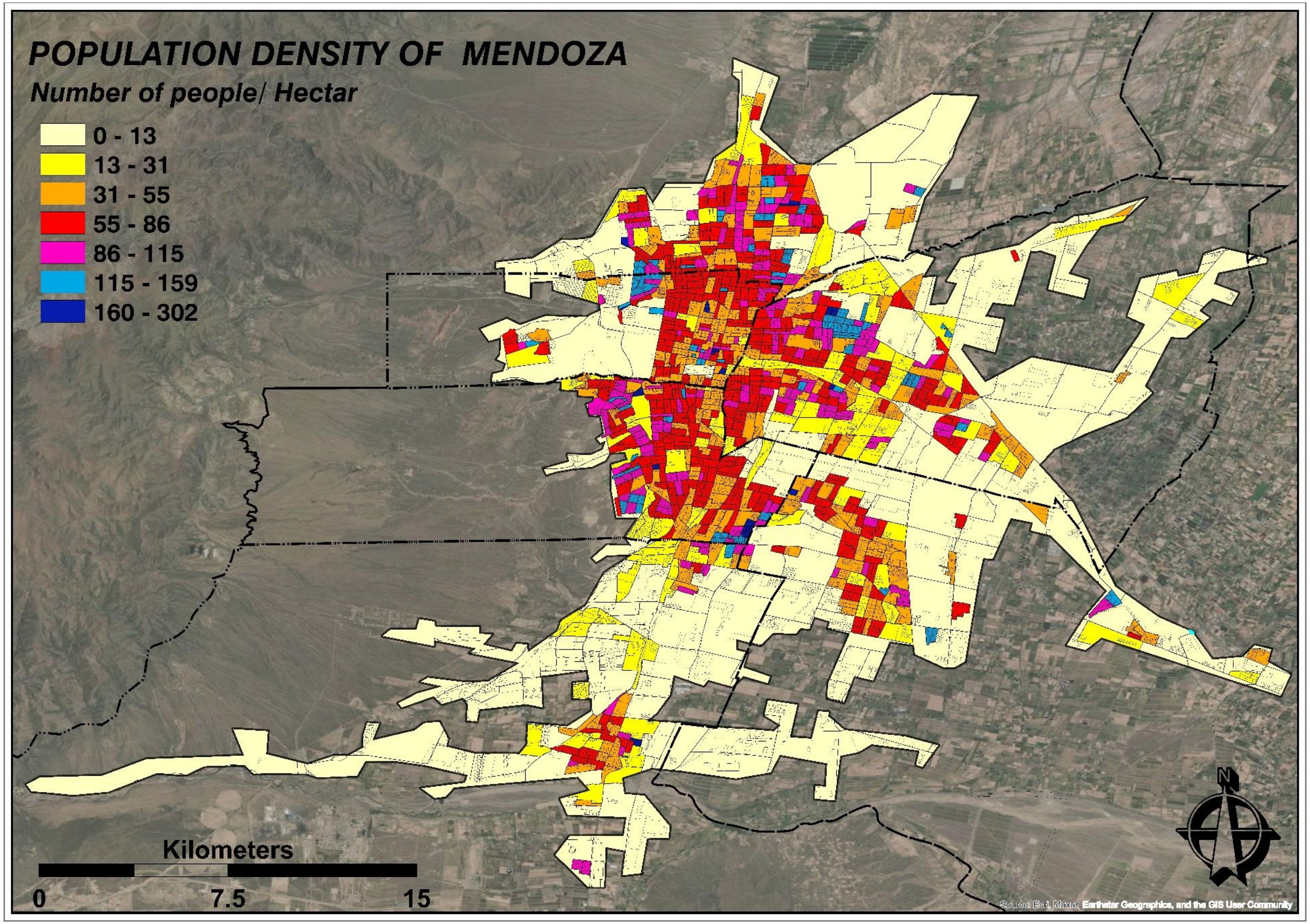
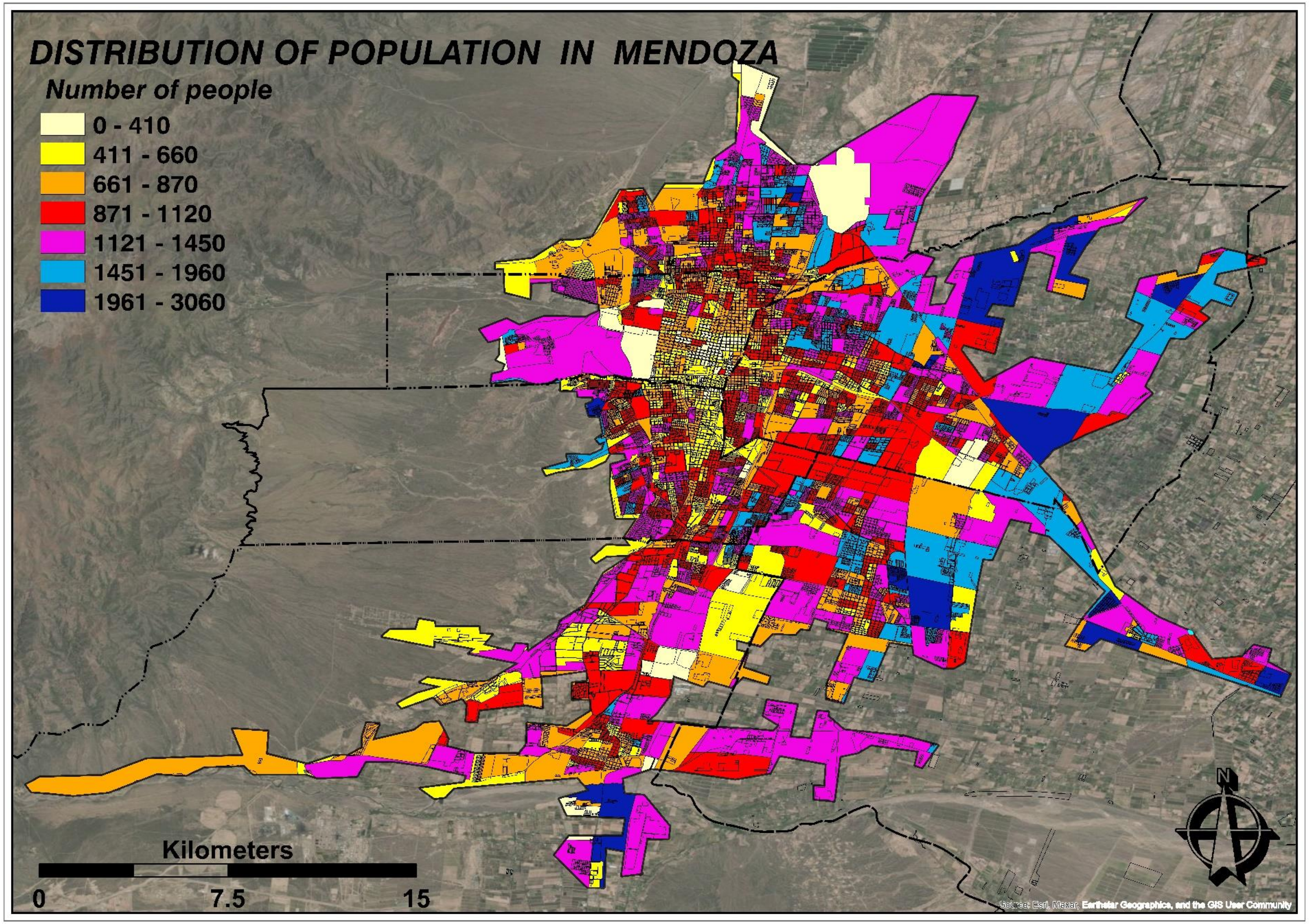


Figure 27 : Distribution of population in Mendoza (Authors)



4.4 Climatic Conditions

Our ability to generate energy and our need for energy may both be affected by the climate. For instance, raises the energy needed for summer cooling while reducing the requirement for winter heating. The energy model was developed with the climatic data in mind, particularly for determining the heating and cooling demands for each structure. Based on the energy model, these loads were then utilized to calculate each building's gas consumption. Given the local temperature and weather patterns, the energy model's use of climatic data guarantees that the anticipated gas consumption is indicative of each building's real gas consumption.

Mendoza has an altitude-dependent, arid subtropical climate with hot, humid summers and dry, moderate winters that can turn chilly at night. Though they are rarely heavy, summertime showers frequently take the shape of thunderstorms. However, even in the summer, there may be sudden cold air bursts from the south, sometimes accompanied by a thunderstorm, which can significantly reduce the temperature for two or three days. It can become rather cold at night even in the middle of summer. The majority of the precipitation falls during the winter months, with the total annual precipitation averaging only 200 mm (8 in). Since winter is dry, snow in Mendoza is rare, however, it can occur from time to time, such as in July 2000, 2007, and 2010 On the other hand, night frosts are quite frequent. (Source: climatestotravel)

4.4.1 Weather Stations and Altitude Influence

To use and analyze the climate data, one should refer to the meteorological stations located across the provinces. To track and record weather information in Gran Mendoza, meteorological stations are necessary. These stations gather data that is useful for forecasting and comprehending regional climate trends, including temperature, humidity, wind speed, and precipitation levels.

According to the analysis overall in our case study, we considered 3 stations **(El Plumerillo, Russel, and Perdriel)** which are the nearest stations to Mendoza in addition the weather for each of Mendoza departments corresponds to one of these stations that has the highest amount of similarity between their altitude. The altitude of El Plumerillo station is 703 m a.s.l , Russel station is 850 m a.s.l and perdriel station is 960 m a.s.l. These stations were chosen for their vicinity of Mendoza, ensuring that the meteorological data acquired from them was relevant to the region under investigation.

Determining local weather patterns requires an understanding of how height affects temperature, air pressure, and other meteorological components. By linking each department to the weather station with the highest degree of altitude similarity, we hope to capture the most accurate meteorological conditions for each specific site. For one of Mendoza's departments, the El Plumerillo weather station, which is situated 703 meters above sea level (m a.s.l.), provides essential meteorological data. The meteorological data from El Plumerillo station, whose elevation is almost the same as that of the department being studied, sheds light on the unusual atmospheric circumstances that were noted there. Similarly, another Mendoza department correlates to the Russel weather station, which is situated at a height of 850 meters above sea level. Finally, the Perdriel weather station, located at an elevation of 960 meters above sea level, corresponds to yet another Mendoza department. The altitude similarity between Russel station and the department lets us more effectively examine and comprehend the weather patterns particular to that location.

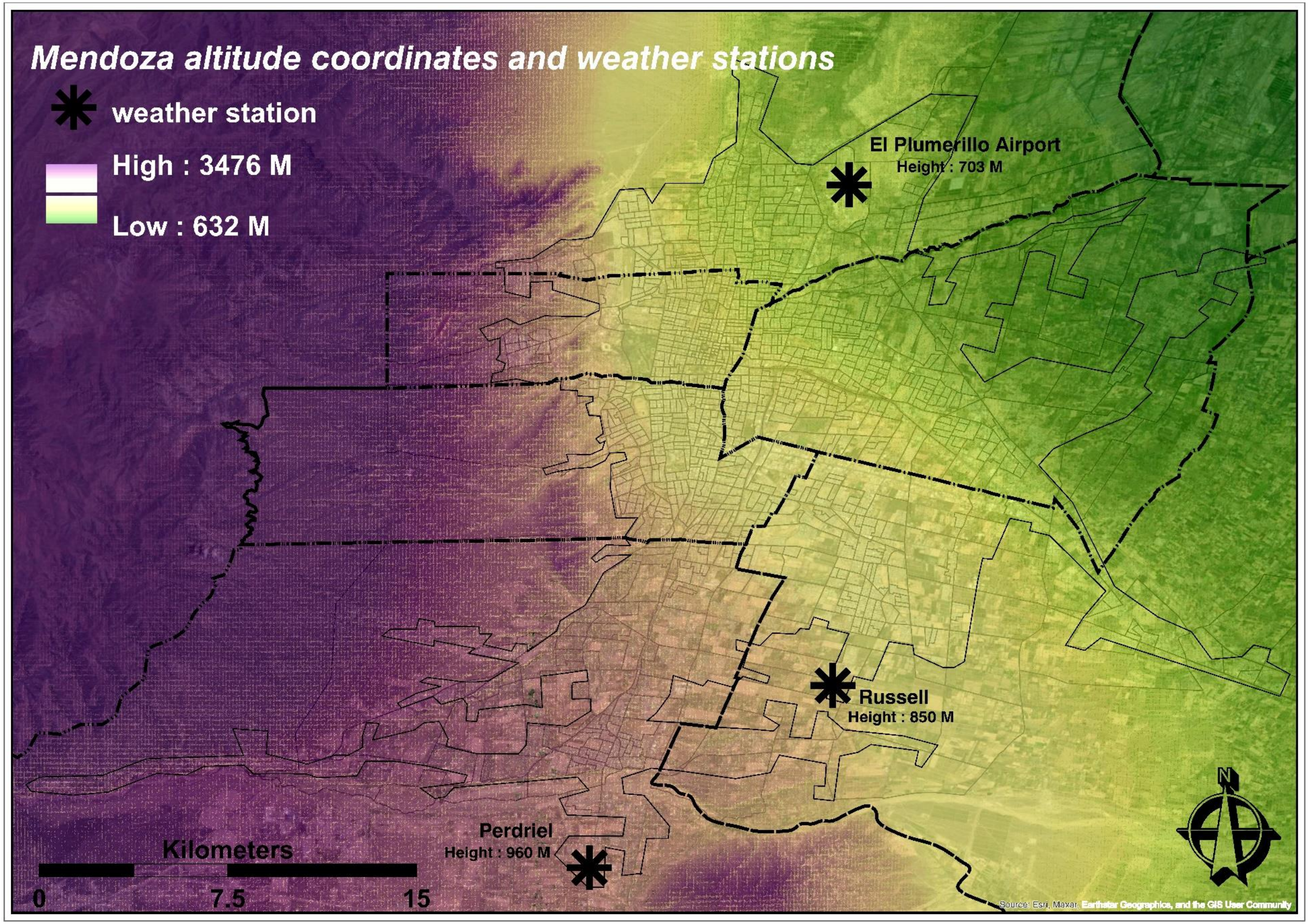
There is a range of up to 257 meters when the height differences between the weather stations and the departments that are affiliated with them are considered. This altitude shift may have a significant effect on patterns of temperature and heating needs. increased elevations frequently experience cooler temperatures, which might lead to increased energy requirements for room heating. By correcting for temperature variations and taking into consideration altitude variations between weather stations, we can more accurately estimate the amount of energy used for space heating in each department. This approach ensures that the calculations accurately reflect the distinct meteorological conditions of each department by accounting for altitude-related temperature variations that are recorded by the weather stations. A more precise assessment of energy use for space heating is possible when altitude variations across departments and the weather stations that correlate with them are taken into consideration. By taking into consideration the effect of height on temperature changes, we can obtain a more precise assessment of the heating demands within each department and provide informed recommendations for energy planning at the urban scale in Mendoza.

The table below shows the air temperatures recorded by the 3 weather stations and the HDDs at 18°C (thermal comfort limit of Mendoza)for the reference year 2017. it is clear that, there is an altitude difference of up to 257 m.

	Altitude(m a.s.l.)	**Tmean (°C)**	**Tmax (°C)**	**Tmin (°C)**	**HDD at 18°C in 2017**
El Plumerillo	703	17.48	27.41	8.98	1093
Russel	850	16.3	26.7	8	1382
perdriel	960	13.41	23.9	2.5	2000

Table 8 : Air temperatures registered by the weather stations in Mendoza in the reference year 2017(Authors)

Figure 28 : altitude coordinates and Weather stations in the metropolitan city of Gran Mendoza



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

4.4.2 Rainfall

To show variation within the months and not just the monthly totals, we show the rainfall accumulated over a sliding 31-day period centered around each day of the year. Mendoza experiences some seasonal variation in monthly rainfall.

- The rainy period of the year lasts for 5.7 months, from October 26 to April 15, with a sliding 31-day rainfall of at least 0.5 inches. The month with the most rain in Mendoza is February, with an average rainfall of 1.4 inches.
- The rainless period of the year lasts for 6.3 months, from April 15 to October 26. The month with the least rain in Mendoza is July, with an average rainfall of 0.2 inches.

Days of	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	1.2″	1.4″	1.0″	0.5″	0.3″	0.3″	0.2″	0.3″	0.4″	0.5″	0.6″	0.8″
Days of Rain	6.2d	5.5d	4.2d	2.2d	1.9d	1.4d	1.4d	1.5d	1.9d	2.2d	3.1d	4.3d

Figure 29 : Average Monthly Rainfall in Mendoza (Source: weatherspark)

The average rainfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average snowfall.

4.4.3 Sun

The length of the day in Mendoza varies significantly over the course of the year. In 2023, the shortest day is June 21, with 9 hours, 59 minutes of daylight; the longest day is December 22, with 14 hours, 20 minutes of daylight.

Hours of	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daylight	14.0h	13.2h	12.2h	11.2h	10.4h	10.0h	10.2h	11.0h	11.9h	12.9h	13.8h	14.3h

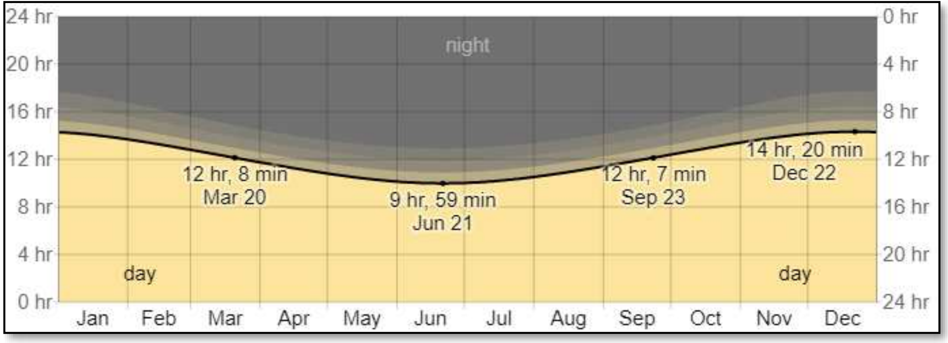


Figure 30 : Hours of Daylight and Twilight in Mendoza (Source: weather spark)

4.4.3.1 Solar Energy

This section discusses the total daily incident shortwave solar energy reaching the surface of the ground over a wide area, taking full account of seasonal variations in the length of the day, the elevation of the Sun above the horizon, and absorption by clouds and other atmospheric constituents. Shortwave radiation includes visible light and ultraviolet radiation. The average daily incident shortwave solar energy experiences extreme seasonal variation over the course of the year. The brighter period of the year lasts for 3.6 months, from October 24 to February 11, with an average daily incident shortwave energy per square meter above 7.6 kWh. The brightest month of the year in Mendoza is December, with an average of 8.6 kWh. The darker period of the year lasts for 3.3 months, from May 2 to August 11, with an average daily incident shortwave energy per square meter below 4.2 kWh. The darkest month of the year in Mendoza is June, with an average of 3.1 kWh.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar Energy (kWh)	8.2	7.5	6.3	4.9	3.7	3.1	3.5	4.5	5.8	7.3	8.4	8.6

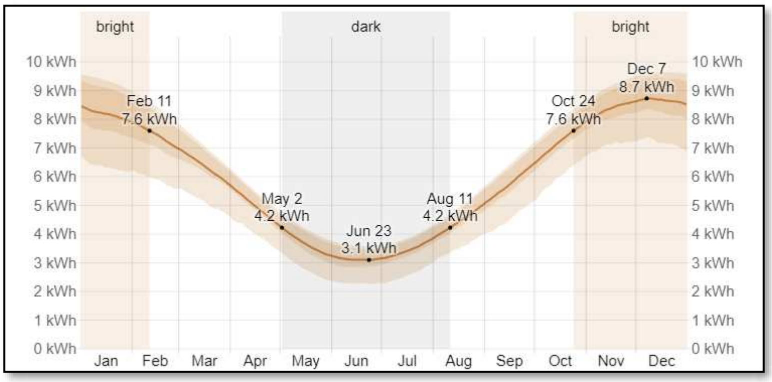


Figure 31 : Average Daily Incident Shortwave Solar Energy in Mendoza

4.4.4 Humidity

We base the humidity comfort level on the dew point, as it determines whether perspiration will evaporate from the skin, thereby cooling the body. Lower dew points feel drier and higher dew points feel more humid. Unlike temperature, which typically varies significantly between night and day, dew point tends to change more slowly, so while the temperature may drop at night, a muggy day is typically followed by a muggy night. The perceived humidity level in Mendoza, as measured by the percentage of time in which the humidity comfort level is muggy, oppressive, or miserable, does not vary significantly over the course of the year, staying within 3% of 3% throughout.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Muggy days	1.2d	1.3d	0.9d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.5d

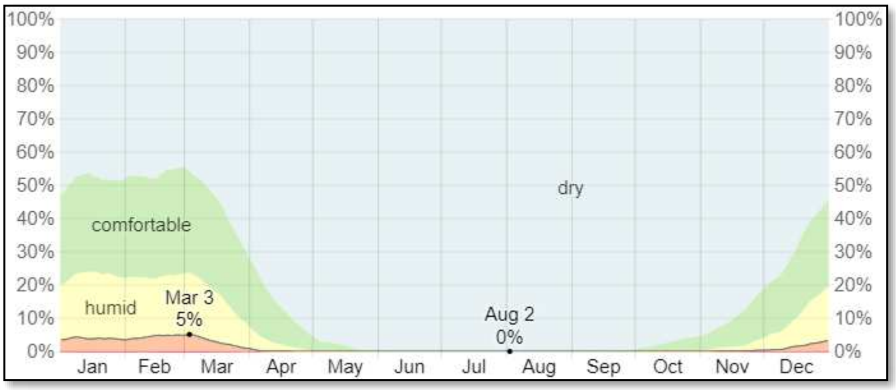
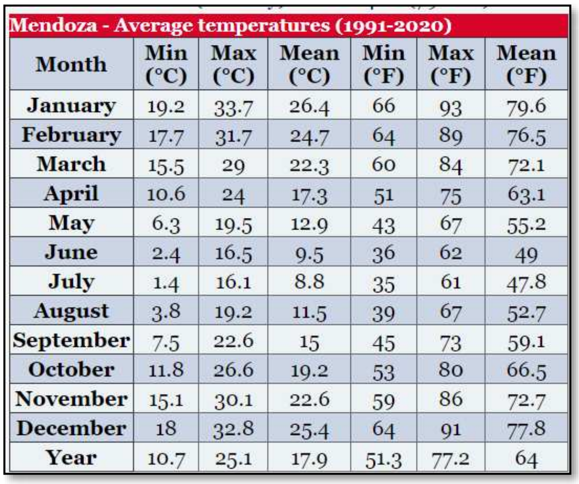


Figure 32 : Humidity Comfort Levels in Mendoza (Source: weatherspark)

4.4.5 Temperature

Mendoza's climate is characterized as arid (Köppen climate classification BWk); with continental characteristics. Most precipitation in Mendoza falls in the summer months (November–March). Summers are hot and humid where mean temperatures exceed 25 °C. Average temperatures for January (summer) are 32 °C during daytime, and 18.4 °C at night. Winters are cold and dry with mean temperatures below 8 °C. Night-time temperatures can occasionally fall below freezing during the winter. Because winters are dry with little precipitation, snowfall is uncommon, occurring once per year. In July (winter) the average temperatures are 14.7 °C and 2.4 °C, day and night respectively. Mendoza's annual rainfall is only 223.2 mm, so extensive farming is made possible by irrigation from major rivers. The highest temperature recorded was 44.4 °C on January 30, 2003, while the lowest temperature recorded was −7.8 °C on July 10, 1976.



Mendoza - Average temperatures (1991-2020)

Month	Min (°C)	Max (°C)	Mean (°C)	Min (°F)	Max (°F)	Mean (°F)
January	19.2	33.7	26.4	66	93	79.6
February	17.7	31.7	24.7	64	89	76.5
March	15.5	29	22.3	60	84	72.1
April	10.6	24	17.3	51	75	63.1
May	6.3	19.5	12.9	43	67	55.2
June	2.4	16.5	9.5	36	62	49
July	1.4	16.1	8.8	35	61	47.8
August	3.8	19.2	11.5	39	67	52.7
September	7.5	22.6	15	45	73	59.1
October	11.8	26.6	19.2	53	80	66.5
November	15.1	30.1	22.6	59	86	72.7
December	18	32.8	25.4	64	91	77.8
Year	10.7	25.1	17.9	51.3	77.2	64

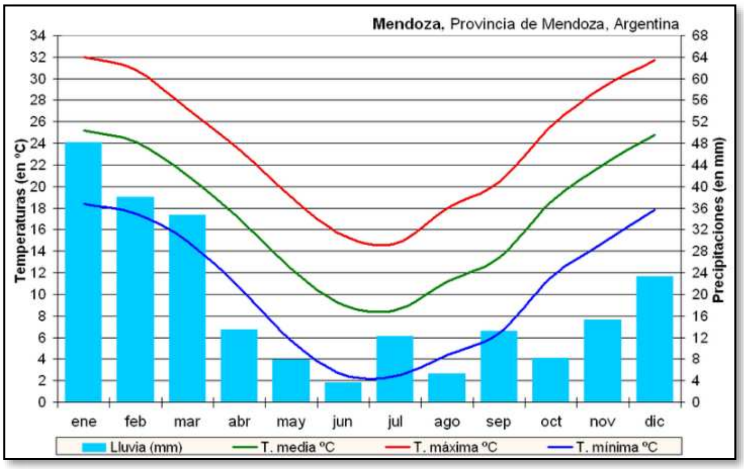


Table 9 : Climatogram of Mendoza in 30 years _1991/2020. (Source: climatestotravel)

Figure 33 : Max, Min and average temperatures of Mendoza. (Source: climatestotravel)

As mentioned above the meteorological stations have a key role in understanding microclimatic data. For this research 3 weather stations are considered to use their Temperature & thermal comfort data in the calculation of HDD & altitude normalization of NG consumption. Furthermore, based on the database provided by CONICET Incihusa the thermal comfort limit of Mendoza is considered as 18 degrees C. In Figure 9, the temperature changes during the reference year of 2016 are shown in a chart with the specification of months & three chosen weather stations' registered data, which demonstrate the winter period of the city & need for heating consumption regarding months that are below the thermal comfort line.   The table below shows the air temperatures recorded by the 3 weather stations and the HDDs at 18°C for the reference year 2017. it is clear that , there is an altitude difference of up to 257 m.

	Altitude m a.s.l.	Tmean (°C)	Tmax (°C)	Tmin (°C)	HDD at 18°C in 2017
El Plumerillo	703	17.48	27.41	8.98	1093
Russel	850	16.3	26.7	8	1382
perdriel	960	13.41	23.9	2.5	2000

Table 10 :   Air temperatures registered by the weather stations in Mendoza in the reference year 2017(Authors)

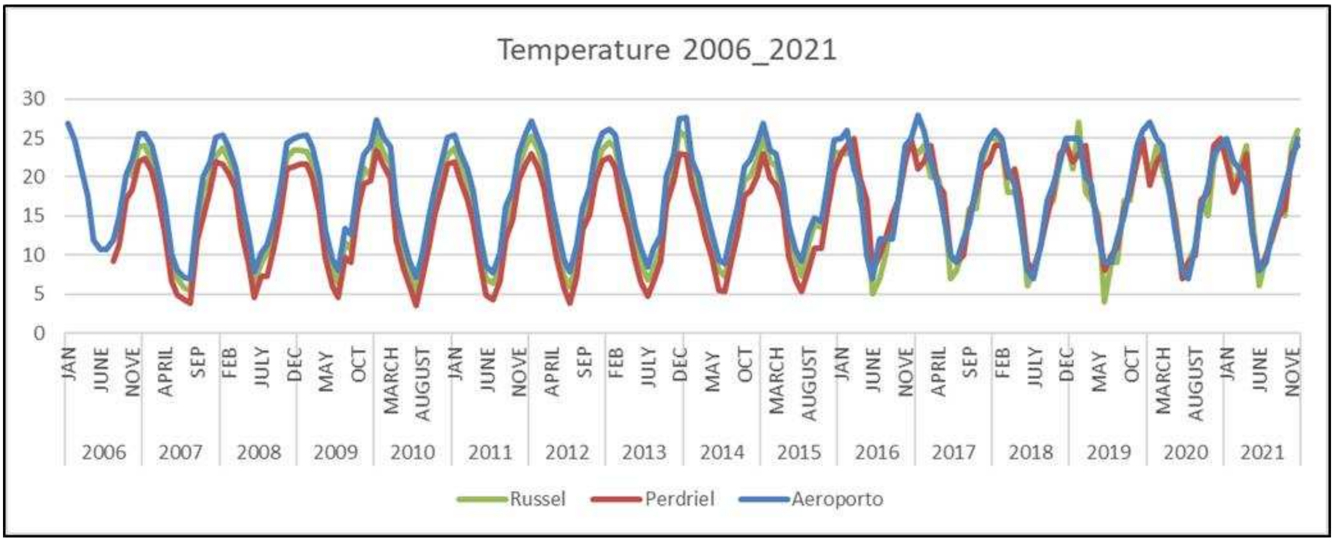


Figure 34 : Air temperatures registered by the weather stations in Mendoza 2006-2021(Authors)

T, °C	**alt**	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEP	OCT	NOVE	DEC
Aeroporto	703	26.12	24.37	21.59	17.32	12.47	9.09	8.44	11.40	14.83	19.01	22.41	25.03
Perdriel	960	22.36	21.03	18.99	15.23	10.54	6.14	5.97	8.51	12.44	15.83	19.88	22.23
Russel	850	23.79	22.95	19.93	16.90	12.33	6.99	7.39	10.09	14.21	16.65	21.21	23.71

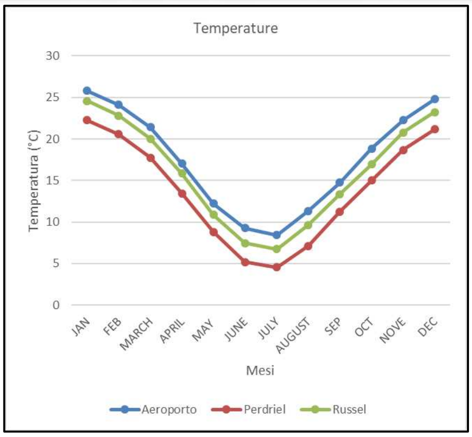


Figure 35 : average Air temperatures registered by the weather stations in Mendoza 2006-2021(Authors)

	alt	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	avarage
Aeroporto	703	1340.5	1054.389	1011.278	1170.778	1067.778	1000.222	1033.638	958.9444	990.7778	1101.395	918	1012	1011	1073	949	1046
Perdriel	960	2043.5	1781.8	1703.3	1925.2	1855.7	1785.5	1816.8	1629	1780.8	1734.8	1654.6	918	949	1011	1041	1575
Russel	850	1621.2	1390.7	1293.9	1540.2	1434.1	1390.3	1404.5	1275.6	1248.5	1456.1	1010	1040	1222	1012	1009	1290
average	837.67	1668.4	1408.963	1336.159	1545.393	1452.526	1392.007	1418.313	1287.848	1340.026	1430.765	1194.2	990	1060.667	1032	999.66667	

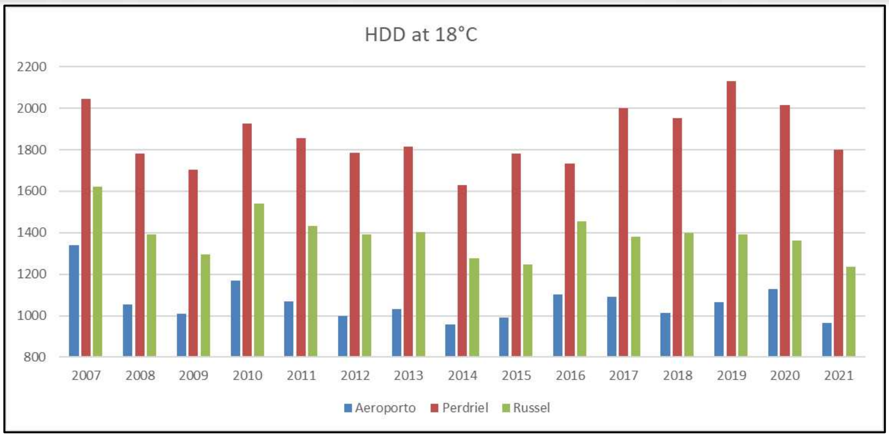


Figure 36 : HDD at 18c registered by the weather stations in Mendoza 2006-2021(Authors)

4.5 Characteristics of Residential, Industrial, Commercial and Services buildings

Based on the first investigation of Mendoza's building stock, this study includes an extensive analysis of data from the national census of 2010 and the updated GIS database of 2017. This aggregated dataset offers a comprehensive overview of the changing built environment of the city, with a primary focus on the metropolitan area, which comprises Godoy Cruz, the capital city, as well as portions of Guaymallen, Las Heras, Lujan de Cuyo, and Maipù. Seen as extensions of the city, these other departments make a substantial contribution to the total municipal divisions that form Mendoza's urban landscape.

The city's architectural stock is shown as a varied tapestry of commercial, industrial, and residential buildings, all of which are essential to the social cohesion and economics of the area. Building distribution and features are complex, and a thorough understanding of them is essential for infrastructure development, energy planning, and sustainable growth.

We produced the following visuals to better highlight the spatial dispersion of Mendoza's building stock:

- Residential Buildings: The prevalence of detached houses in Las Heras, Luján, and Maipú is evident, while apartments are more concentrated in the capital city and other municipalities.
- Industrial Buildings: Heavy industries are primarily located in Godoy Cruz, Maipú, and Guaymalan, while lighter industries are dispersed across the metropolitan area.
- Commercial and Services: The city center stands out as the commercial and service hub, with some larger establishments extending into the suburbs.

Residential Buildings: When we look at the residential sector, we find that there are 338,977 single-family and multi-family homes in the city. These homes are mostly standalone detached residences with distinct land parcels that belong to their own owners. The most common type of residential building is the independent detached home, especially in the departments of Las Heras, Luján, and Maipú. In the meantime, the other three municipalities are dominated by apartments, with the capital city enjoying a about 50% apartment occupancy rate. This distribution highlights the heterogeneous housing stock, impacting lifestyle choices as well as urban development.

Industrial Buildings Taking an even broader view, Mendoza's economic strength is derived from 2,516 businesses in the industrial sector. These structures are essential for a variety of industrial and manufacturing processes. The distribution of heavy industries, including food processing and metallurgy, is strategically located in the outer districts of Godoy Cruz, Maipú, and Guaymallen. This is explained by the fact that they need bigger areas and specialized infrastructure. Lighter industries, such as those that produce textiles and furnishings, are, on the other hand, distributed across the metropolitan region and frequently border residential areas. Interestingly, vineyards add a great deal to Mendoza's industrial environment and greatly boost the area's economic vibrancy.

Commercial and Services Buildings: The 14,496 buildings that makeup Mendoza's business and services sectors are crucial to the city's economic health. Small and big commercial structures, service buildings, health service buildings, education service buildings, and public service buildings are all included in this broad category. The concentration of these buildings in the city center (district capital), which serves as the hub for commerce and vital services and forms the core of the urban economy, is indicative of the typical urban plan.

The city center is just one aspect of the urban dynamics; the suburbs are characterized by the tasteful expansion of massive commercial and service buildings. The many commercial and service sectors of Mendoza are brought into focus by this complex geographical distribution, which also demonstrates the substantial contribution that suburban regions make to the general operation of the region. These places, meeting the demands of an expanding populace, are essential to the economic expansion of the area.

A broad variety of institutions, including as high-end retail stores, office skyscrapers housing multinational corporations, and lively eateries and bars serving a variety of cuisines, define Mendoza's commercial and services scene. The city's economic and tourist attraction is further enhanced by the increasing number of hotels and hostels that it is home to, which cater to both local and foreign guests.

4.5.1 Building Area and Volume in Mendoza:

Area and volume considerations include Mendoza's varied architectural environment, which includes commercial, industrial, and service buildings in addition to residential buildings. The region's buildings differ greatly in terms of volume and scale because of several variables including topography, population congestion, and popular architectural styles. The variety and dynamic nature of Mendoza's building stock reflects the social and economic makeup of the city. Understanding the area and volume of Mendoza's residential, commercial, industrial, and service structures together offers a comprehensive perspective on the architectural dynamics of the area. This all-encompassing viewpoint is essential for infrastructure development, urban planning, and attaining sustainable growth that balances the many requirements of Mendoza's communities.

Residential Buildings: Mendoza has a diverse range of housing patterns and architectural styles, from single-family homes to multi-story apartment buildings and condos. In the urban environment, residential buildings are frequently built compactly to maximize available space. Smaller unit sizes, more stories, and higher building densities follow, all of which are indicative of the requirement for effective use of available space in urban settings. On the other hand, suburban and rural locations include larger lots and more roomy single-family homes, representing an alternative style of home architecture that complements the peace and quiet of these places.

Industrial Buildings: Simultaneously, the urban fabric as a whole benefit from the industrial environment. Mendoza boasts a broad range of industrial structures that meet different manufacturing and production demands. These structures' sizes and volumes are determined by the industry they belong to as well as the unique geographical pattern of their distribution. The particular industry that an industrial building serves has an impact on its volume and size as well. Larger quantities may be found at heavy industrial facilities on the periphery, including those in Godoy Cruz, Maipú, and Guaymallen, to accommodate specialized machinery and manufacturing processes. Concurrently, lighter industrial structures scattered around the city may take on a more condensed form, reflecting the need for efficiency and closeness to residential areas.

Commercial and Service Buildings: Commercial and service buildings, pivotal to Mendoza's economic vitality, add another layer of diversity to the cityscape. Commercial and service buildings differ in size and capacity based on the kind of company, the number of inhabitants, and the facilities that are sought. Compared to office skyscrapers or hotels, retail outlets usually demand smaller footprints and lower ceilings. Bigger retail and service structures, such as conference halls or shopping malls, may feature many stories, large outdoor areas, and spacious floor plans. To maximize the use of vertical space, multi-story commercial complexes and service buildings are frequently constructed in the city center (district capital). These buildings serve the densely populated areas by acting as a major center for trade and basic services. On the other side, larger commercial structures may be found in suburban regions, meeting the demands of an expanding population and boosting the local economy.

4.5.2Height of the building

The analysis's conclusions supported the previously cited facts on the number of independent houses. The single-story buildings make up around 89% of the total buildings, suggesting a strong correlation with detached or terraced single-family homes. Ten percent of the buildings are two to five stories high, fewer than one percent are higher than six stories, and there are very few tower structures that are higher than ten stories.

4.5.3 Orientation

A building's orientation is determined by which way its primary façade faces. The quantity of sunlight that enters a structure is greatly affected by its direction. Compared to buildings facing south, those facing north receive more direct sunshine.

The year-round weather in Mendoza is pleasant and bright with plenty of sunshine. In order to maximize the quantity of natural light that enters the building, the majority of structures in Mendoza are facing north. This improves living conditions and lowers the need for artificial illumination, both of which increase energy efficiency

Figure 37 : Distribution of 3 gas consumption sectors in the metropolitan city of Gran Mendoza

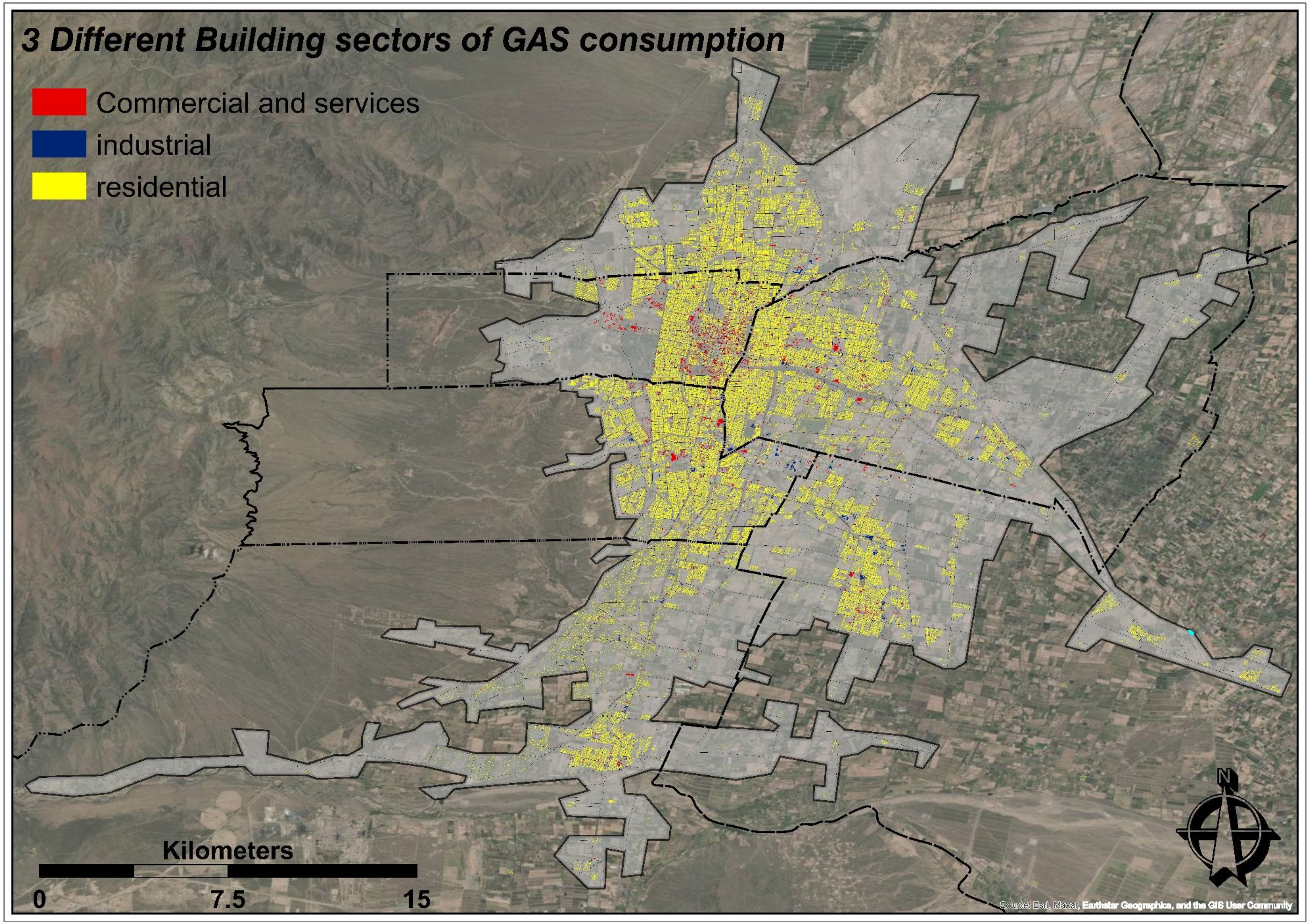


Figure 38 : Height of Buildings in the metropolitan city of Gran Mendoza

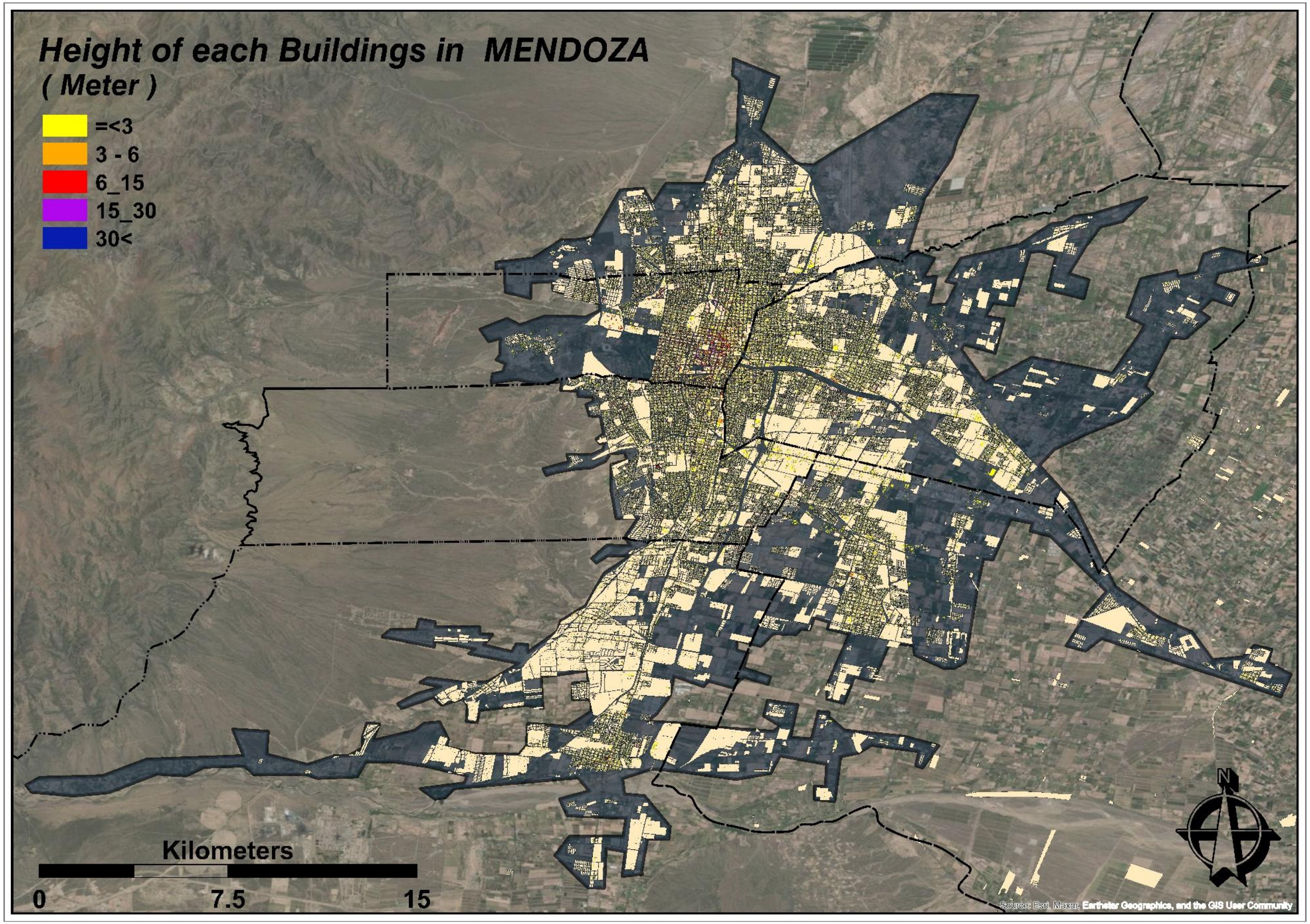


Table 11 : Residential First group Characteristics of building (Physically) registered in Districts (Authors)

	DISTRITOS	NUMBER OF CENSUS	District area(m2)	Footprint area of buildings (sum)(m2)	heated gross area	MEAN OF Altitude	MEAN Height (M)	MEAN ANGLE	SUM of buildings volume m3	SUM of buildings floor surface m2	SUM of buildings heat loss surface m2
CAPITAL	Cuarta Sección	27	3190921.6	853195.2825	853195.3	758.55	4.06	-37.97	3098082.58	1032694.19	3078486.56
	Décima Sección	3	593340.206	153956.9964	153957.0	913.36	3.97	14.17	563797.73	187932.58	559172.99
	Décimo Primera Sección	6	11031463.32	22206.05319	22206.1	982.28	3.05	53.62	67214.92	22404.97	85556.62
	Octava Sección	11	2140848.744	262750.1671	262750.2	836.90	3.77	-8.22	867198.10	289066.03	973588.45
	Primera Sección	17	1634170.626	316596.4346	633192.9	780.39	7.14	-46.12	1978699.44	659566.48	1426285.78
	Quinta Sección	24	2440912.231	727413.0841	727413.1	813.14	4.46	-27.37	3307014.49	1102338.16	3041225.53
	Segunda Sección	33	2339614.262	569615.1081	1139230.2	794.40	8.52	-40.35	3912077.35	1304025.78	2873715.07
	Séptima Sección	7	4426460.669	90257.30062	90257.3	822.79	4.63	-58.91	354582.10	118194.03	331798.24
	Sexta Sección	24	2718794.52	747804.6733	747804.7	789.92	3.62	-3.19	2663088.10	887696.03	2775223.85
	Tercera Sección	17	1501605.202	391594.1421	783188.3	776.15	6.71	-34.92	2274800.16	758266.72	1675536.61
GODOY CRUZ	Ciudad (GC)	106	12261488.51	2672227.391	2672227.4	842.55	3.58	-0.39	9297680.60	3099226.87	9703452.87
	Gobernador Benegas	26	3990614.879	819258.4998	819258.5	877.51	3.33	-4.28	2680376.28	893458.76	2903657.06
	Las Tortugas	33	4869247.254	757291.2074	757291.2	859.16	3.30	-34.28	2483939.69	827979.90	2779631.91
	Presidente Sarmiento	40	7737231.03	647782.5001	647782.5	902.16	3.15	0.71	2034921.62	678307.21	2387884.91
	San Francisco del Monte -GC	13	4069493.942	182766.6762	182766.7	834.74	3.12	-13.72	1225747.62	408582.54	1357498.53
GUAYMALLEN	Belgrano	34	4592690.362	873828.4727	873828.5	735.22	3.14	-37.20	2734136.77	911378.92	3096819.63
	Bermejo	14	5489069.834	294218.9717	294219.0	723.69	3.09	-18.24	908303.24	302767.75	1047503.76
	Buena Nueva	11	5676876.292	248747.61	248747.6	725.24	3.22	-30.43	779813.16	259937.72	871970.22
	Capilla del Rosario	19	3577864.482	474229.855	474229.9	736.28	3.10	-12.89	1466408.48	488802.83	1677639.75
	Colonia Segovia	4	4400033.205	20438.19262	20438.2	676.01	3.03	-27.65	102486.46	34162.15	109457.23
	Dorrego	35	4723783.969	1123728.241	1123728.2	796.32	3.39	-18.40	3721822.13	1240607.38	3978952.15
	El Sauce	8	12624720.1	69336.1956	69336.2	704.64	3.07	-14.89	209066.76	69688.92	262003.07
	Jesús Nazareno	7	3679936.972	155573.3651	155573.4	771.63	3.15	-33.15	485174.35	161724.78	555532.55
	Kilómetro 11	5	8109557.178	123037.5025	123037.5	725.40	3.15	-26.80	382561.65	127520.55	413804.96
	La Primavera (Gy)	1	1156534.144	1537.600856	1537.6	725.00	3.00	52.68	4612.80	1537.60	4963.20
	Las Cañas	17	2917478.651	395205.2782	395205.3	779.71	3.33	-39.29	1312460.86	437486.95	1437611.89
	Los Corralitos	3	9418720.097	26237.32598	26237.3	680.46	3.04	-25.70	79340.31	26446.77	86131.68
	Nueva Ciudad	9	1530762.996	325786.1584	325786.2	757.08	3.24	-16.37	1040069.32	346689.77	1114966.42
	Pedro Molina	11	1563809.049	387546.7904	387546.8	748.55	3.20	-11.56	1223643.58	407881.19	1331759.78
	Rodeo de La Cruz	20	7766457.995	498762.2264	498762.2	737.41	3.07	-20.11	1528535.21	509511.74	1731982.29
	San Francisco del Monte (Gy	8	5339915.93	396158.9356	396158.9	785.74	3.22	-40.93	584891.51	194963.84	659865.26
	San José (Gy)	16	2142001.273	552351.0132	552351.0	761.18	3.39	-32.56	1840828.95	613609.65	1918470.64
	Villa Nueva	41	6250655.425	1061196.24	1061196.2	758.90	4.11	-24.15	3731965.81	1243988.60	3881977.53
LAS HERAS	Capdevila	3	2969905.671	57186.92146	57186.9	730.25	3.01	-9.02	172049.65	57349.88	202044.75
	Ciudad (LH)	39	5034736.758	1088031.657	1088031.7	749.44	3.26	-24.24	3525076.55	1175025.52	3845242.64
	El Algarrobal	8	19694890.55	127084.6251	127084.6	716.68	3.02	-1.97	384412.93	128137.64	436743.12
	El Challao	29	15457078.16	488475.4751	488475.5	836.76	3.13	24.51	1514132.30	504710.77	1788158.36
	El Plumerillo	32	8640670.344	686969.4831	686969.5	733.10	3.07	-4.50	2101138.62	700379.54	2442348.51
	El Resguardo	17	4692401.07	278166.0637	278166.1	733.36	3.01	-29.61	838359.65	279453.22	1034828.02
	El Zapallar	14	1852326.194	329323.7068	329323.7	739.64	3.15	-27.63	1033439.07	344479.69	1185516.19
	La Cieneguita	17	4699518.844	359804.5646	359804.6	774.04	3.18	17.24	1149380.56	383126.85	1288712.38
	Panquegua	14	1762187.374	275078.0157	275078.0	742.83	3.09	-24.34	845868.49	281956.16	979859.66
LUJAN DE CUYO	Carrodilla	23	13863507.62	527725.5112	527725.5	895.20	3.15	-35.14	1639533.02	546511.01	1883558.71
	Chacras de Coria	15	14433682.67	670718.915	670718.9	956.57	3.33	-15.52	2177064.91	725688.30	2265043.42
	Ciudad (L)	28	7735477.93	721346.3666	721346.4	977.52	3.27	-33.99	2399973.37	799991.12	2528709.87
	La Puntilla	3	1215408.591	153284.9924	153285.0	909.89	3.30	-18.80	501639.83	167213.28	524676.97
	Las Compuertas	1	3894619.288	23965.75528	23965.8	1069.59	3.08	-38.05	72851.13	24283.71	78557.13
	Mayor Drummond	10	9558583.45	237387.9824	237388.0	958.10	3.12	-38.64	743909.41	247969.80	811990.72
	Perdriel	1	832838.3806	9855.157647	9855.2	982.83	3.00	-28.45	29565.47	9855.16	35278.98
	Vistalba	10	11745352.38	247165.2577	247165.3	1012.55	3.16	-24.82	772541.01	257513.67	826906.26
MAIPU	Coquimbito	14	19604249.37	270596.5062	270596.5	790.32	3.04	-30.67	819488.80	273162.93	950714.46
	Cruz de Piedra	3	4519057.845	24107.49224	24107.5	866.06	3.11	-39.28	72900.55	24300.18	80988.90
	Fray Luis Beltrán	5	3269915.754	103684.8591	103684.9	714.42	3.04	-16.51	315227.71	105075.90	360111.37
	General Gutierrez	18	7452652.861	585730.7987	585730.8	818.15	3.12	-23.88	1811261.22	603753.74	1999369.88
	General Ortega	1	2191557.927	1695.143717	1695.1	728.38	3.14	-12.86	5314.34	1771.45	5875.52
	Lunlunta	2	4894807.3	8788.911995	8788.9	933.21	3.15	-24.33	28048.00	9349.33	30801.65
	Luzuriaga	21	8595136.259	563527.6105	563527.6	819.47	3.17	-15.45	1767824.83	589274.94	2009214.44
	Maipú	44	16381214.53	1172124.781	1172124.8	840.19	3.14	-23.67	3663963.00	1221321.00	4109836.50
	Rodeo del Medio	7	5994006.266	158343.9143	158343.9	740.18	3.09	-31.19	485129.48	161709.83	549610.07
	Russel	3	2764258.455	8305.059443	8305.1	862.72	3.17	-10.03	25781.71	8593.90	28378.99

Table 12 : Industrial First group Characteristics of building (Physically) registered in Districts (Authors)

	DISTRITOS	NUMBER OF CENSUS	Footprint area of buildings (sum)	sum of buildings area floor m	SUM of buildings volume m3	SUM of buildings premiters m2	SUM of buildings floor surface m2	SUM of heavy industrial buildings volume m3	sum of heavy industrial buildings area floor m2	SUM of light industrial buildings volume m3	sum of light industrial area floor m2	MEAN Height (M)	MEAN ANGLE
CAPITAL	Cuarta Sección	27	6513.969832	8397.5	25192.64294	2297.186911	22224.01349	1307.400028	435.79	23884.9	7961.71	3.833549784	-20.47813
	Primera Sección	17	1748.750171	1748.76	5246.250514	535.0080032	5102.524352	148	49.34	5098.2999	1699.42	3	-47.57295
	Quinta Sección	24	1489.601543	1700.36	5101.048841	596.4960592	5028.777867	1594.100006	531.35	3506.90005	1169.01	3.125	-47.58534
	Segunda Sección	33	451.4299917	543.32	1629.950686	241.9315162	1745.709154	1629.800011	543.32	0	0	3.5	-62.3376
	Sexta Sección	24	385.4717695	385.49	1156.415309	194.9655109	1355.840072	560.8000107	186.92	595.699982	198.57	3	-10.12183
	Tercera Sección	17	1732.648273	1734.76	5204.199965	606.464774	5302.040263	1237.50001	412.49	3966.69994	1322.27	3.1	-11.2351
GODOY CRUZ	Ciudad (GC)	106	33617.71905	45378.39	136132.394	6622.891439	93402.75555	26740.40009	8913.37	42622.7002	36465.02	3.718520408	-6.014985
	Gobernador Benegas	26	4073.371967	4142.58	12427.78637	1310.536812	12186.63218	3315.19993	1105.09	9112.39986	3037.49	3.035294118	18.809911
	Las Tortugas	33	7815.739514	10741.07	32223.17451	2701.096354	26029.98251	2258.200022	752.67	29965.3003	9988.4	3.364090909	-30.49846
	Presidente Sarmiento	40	17397.10128	18849.61	56548.97416	5266.619262	52373.3763	0	0	56549.0001	18849.61	3.277777778	13.550731
	San Francisco del Monte -GC	13	2075.755255	2147.87	6443.585243	393.2894693	5439.369431	0	0	6443.60022	2147.87	3.5	-63.20959
GUAYMALLEN	Belgrano	34	3387.880655	3582.34	10747.00117	866.9254083	9674.137311	1663.699993	554.55	9083.30003	3027.79	3.45	-55.45859
	Bermejo	14	5196.212093	5696.37	17088.9873	2028.345514	16983.12849	0	0	17089.3	5696.37	3.205	-27.84273
	Buena Nueva	11	19739.45182	20310.38	60931.20501	3837.434401	51622.46762	15852.60019	5284.27	45078.3005	15026.11	3.284415584	-37.81142
	Capilla del Rosario	19	9579.585849	10158.07	30474.09134	2491.8464	27264.10642	3202.59993	1067.51	27271.4995	9090.56	3.24375	-12.34072
	Dorrego	35	19886.94538	29284.72	62761.04555	5871.003063	54977.17354	2858.400003	952.75	45348.8001	28331.97	3.053321678	-12.15534
	Jesús Nazareno	7	2902.273794	3734.32	11202.89362	888.6542032	8960.033201	1938.999981	646.33	9263.99999	3087.99	3.230769231	-29.92083
	Kilómetro 11	5	5250.332003	5277.04	15831.18998	1484.212571	15017.39517	0	0	15831.4	5277.04	3.055555556	-50.76225
	Las Cañas	17	9364.989144	11295.37	33886.04771	2535.191669	28600.28783	4843.099976	1614.34	29042.9998	9681.03	3.630769231	-6.217572
	Nueva Ciudad	9	9353.732342	9602.74	28808.35479	2353.12745	26039.38192	2021.499985	673.84	26787.0999	8928.9	3.3	10.967166
	Pedro Molina	11	3643.640773	3896.03	11688.0552	1268.401254	11532.93651	931.3999939	310.45	10756.5999	3585.58	3.377142857	-40.0884
	Rodeo de La Cruz	20	27122.7554	27122.78	81368.26619	6058.55994	72421.19061	0	0	81368.3992	27122.78	3	-33.27837
	San Francisco del Monte (Gy	8	69201.96618	74107.88	222323.7568	13526.65198	183033.7879	13445.29986	4481.72	160149.9	69626.16	3.259118037	-38.63276
	San José (Gy)	16	17931.05485	19807.14	59421.46242	4106.365875	50076.24153	5453.600067	1817.85	41372.3999	17989.29	3.328571429	-0.063193
	Villa Nueva	41	27743.94376	28256.57	84769.72639	7069.113917	77614.14099	13195.49983	4398.53	71574.3001	23858.04	3.187609492	-27.2585
LAS HERAS	Ciudad (LH)	39	5298.662097	5328.12	15984.33794	1418.578196	14927.26822	2627.499985	875.81	13356.8998	4452.31	3.068181818	-33.18505
	El Plumerillo	32	14749.58627	15238.04	45714.02144	3469.977977	40563.71133	4671.59994	1557.22	30946.6997	13680.82	3.425925926	-7.412211
	El Resguardo	17	826.5253587	826.53	2479.576076	294.7450242	2537.28579	0	0	2479.49998	826.53	3	-73.16349
	El Zapallar	14	22754.88566	22754.94	68264.65697	4228.390838	58194.94383	0	0	58170.0996	22754.94	3	6.503209
	La Cieneguita	17	5548.927489	5548.92	16646.78247	1471.384856	15512.00955	0	0	16647.0001	5548.92	3	-7.295999
LUJAN DE CUYO	Carrodilla	23	21042.43726	26470.14	73443.42248	7047.550611	66187.08275	5742.800087	3902.98	67701.5996	22567.16	3.440768982	-37.83714
	Chacras de Coria	15	20383.72007	22374.38	67123.26759	5777.033637	59409.97297	0	0	67123.1998	22374.38	3.168344156	-5.323635
	Ciudad (L)	28	9481.243212	10142.71	30427.61443	2916.353764	28236.89051	0	0	30428.0999	10142.71	3.231617647	-14.68536
	Mayor Drummond	10	20114.30463	20953.73	62861.30633	4306.876803	53862.9879	481.8000031	160.58	51441.4002	20793.15	3.115546218	-38.5184
MAIPU	Coquimbito	14	7576.480799	7576.47	22729.4424	1911.872938	20888.58041	0	0	22729.4997	7576.47	3	-71.53163
	Cruz de Piedra	3	453.9045049	453.91	1361.713515	152.945845	1366.646545	0	0	1361.69998	453.91	3	-76.82707
	General Gutierrez	18	64978.97573	71989.93	215969.8785	15407.19565	181530.8638	7453.500065	2484.48	208516.201	69505.45	3.385874079	-13.92586
	Luzuriaga	21	42331.6882	46835.27	134262.4553	9013.935152	113035.4141	9790.499928	3263.54	100928	43571.73	3.295454545	21.27972
	Maipú	44	40550.06275	47533.16	142599.497	11249.00772	120497.6166	1972.700056	657.55	140626.5	46875.61	3.264271786	-12.382
	Rodeo del Medio	7	570.2842749	570.28	1710.852825	232.6393372	1838.486562	0	0	1710.8	570.28	3	-49.41268

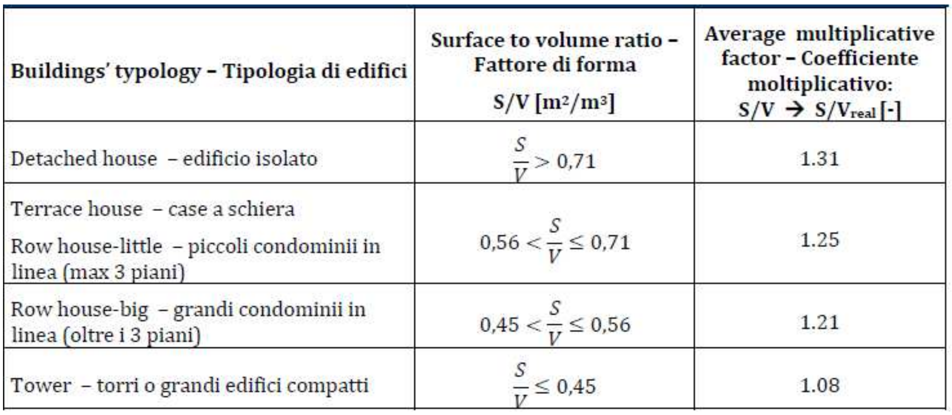
Table 13 : Commercial and services First group Characteristics of building (Physically) registered in Districts (Authors)

	DISTRITOS	Footprint area of buildings (sum)	sum of buildings area floor m2	SUM of buildings volume m3	SUM of buildings premiters m2	SUM of buildings floor surface m2	SUM of commercial buildings volume m3	sum of commercial buildings area floor m2	SUM of servises buildings volume m3	sum of servises buildings area floor m2	SUM of health_servises buildings volume m3	sum of health_servises buildings area floor m2	SUM of education_servises buildings volume m3	sum of education_servises area floor m2	SUM of public_servises buildings volume m3	sum of public_servises area floor m2	MEAN ANGLE	MEAN Height (M)
CAPITAL	Cuarta Sección	82051.87	98492.21	295476.50	27801.92	266977.49	220438.10	73479.44	75038.00	25012.77	37967.10	12655.74	19674.30	6558.15	17396.60	5798.88	-40.79	3.63
	Décimo Primera Sección	6151.13	6151.11	18453.38	1427.39	16584.43	1886.90	628.97	16566.40	5522.14	13499.30	4499.77	0.00	0.00	3067.10	1022.37	36.19	3.00
	Primera Sección	98219.59	156727.05	469801.29	34602.58	368317.15	350311.40	128212.08	85545.50	28514.97	16570.10	5523.35	11964.30	3988.00	57011.10	19003.62	-50.78	4.76
	Quinta Sección	71170.06	124919.32	374075.49	25836.23	271374.05	122215.30	47688.53	195904.40	77230.79	135736.10	57174.63	8165.00	2721.67	52003.30	17334.49	-21.74	4.39
	Segunda Sección	190485.38	379722.05	1139166.61	66741.68	812637.80	701018.60	261626.38	256421.40	118095.67	96300.30	54750.38	36101.20	12033.71	124019.90	51311.58	-42.35	5.50
	Sexta Sección	72102.41	84376.30	253128.88	19774.67	204844.23	125347.60	59516.81	56192.40	24859.49	19435.40	6478.41	15434.30	11273.47	21322.70	7107.61	-0.99	3.54
	Tercera Sección	137063.49	239246.15	716652.45	44520.13	501911.77	399559.20	170667.97	168059.60	68578.18	78376.10	35165.92	44453.90	18335.82	45229.60	15076.44	-34.98	5.28
GODOY CRUZ	Ciudad (GC)	319675.73	395002.98	1184627.94	86548.87	888216.24	488309.40	219797.52	364648.90	175205.46	99583.70	37783.10	102540.00	39350.53	162525.20	98071.83	0.06	3.63
	Gobernador Benegas	25629.16	27513.82	82541.34	7364.82	75841.36	49513.80	20161.97	22055.50	7351.85	15061.60	5020.59	0.00	0.00	6993.90	2331.26	13.25	3.34
	Las Tortugas	32418.30	39009.56	112950.60	10586.34	101406.96	57670.80	19223.53	55280.10	19786.03	27102.30	9034.15	3536.40	2538.13	24641.40	8213.75	-41.17	3.68
	Presidente Sarmiento	31783.98	33993.67	101981.32	10856.04	98147.85	41419.20	13806.55	60561.40	20187.12	22422.90	7474.23	900.90	300.31	37237.60	12412.58	-9.55	3.22
	San Francisco del Monte -GC	14357.96	14668.09	44004.34	3483.01	39567.85	11938.00	7422.01	21738.30	7246.08	7327.00	2442.35	0.00	0.00	14411.30	4803.73	-28.70	3.07
GUAYMALLEN	Belgrano	89765.73	94818.40	284455.28	23382.92	257421.12	123187.60	65759.05	87178.50	29059.35	13100.70	4366.86	0.00	0.00	74077.80	24692.49	-34.08	3.53
	Bermejo	31878.78	33761.29	101283.66	8460.41	91535.85	62933.70	24977.54	26351.30	8783.75	9850.10	3283.37	0.00	0.00	16501.20	5500.38	-23.53	3.24
	Buena Nueva	9540.60	10555.25	47232.04	2458.95	31383.05	24246.50	8082.28	7418.90	2472.97	4092.50	1364.18	0.00	0.00	3326.40	1108.79	-36.79	4.64
	Capilla del Rosario	11407.35	12260.67	36781.94	3476.20	34184.41	31674.70	10558.15	5107.50	1702.52	0.00	0.00	0.00	0.00	5107.50	1702.52	-2.36	3.13
	Colonia Segovia	519.97	519.96	1559.91	256.47	1809.34	0.00	0.00	1559.90	519.96	0.00	0.00	0.00	0.00	1559.90	519.96	-42.21	3.00
	Dorrego	61501.88	76780.93	230343.14	22247.01	207143.77	166792.20	55597.80	63549.50	21183.13	30702.10	10234.03	4166.80	1388.95	28680.60	9560.15	-9.88	3.51
	El Sauce	2338.07	2908.74	8726.30	786.28	7446.53	6723.20	2241.05	2003.30	667.69	0.00	0.00	0.00	0.00	2003.30	667.69	33.48	3.75
	Jesús Nazareno	12195.95	13990.07	41970.07	4103.02	38493.54	35509.80	11836.70	6460.10	2153.37	0.00	0.00	0.00	0.00	6460.10	2153.37	-55.55	3.49
	Kilómetro 11	15518.89	16364.15	49092.50	4766.38	46547.52	19824.60	6608.12	29268.10	9756.03	0.00	0.00	0.00	0.00	29268.10	9756.03	-44.22	3.29
	Las Cañas	14063.86	18485.37	55455.77	4880.84	46101.34	17552.20	5850.70	22860.00	12634.67	7969.80	7671.22	0.00	0.00	14890.20	4963.45	-36.79	3.28
	Los Corralitos	1933.07	2056.57	6169.75	664.95	6011.60	2614.30	871.42	3555.60	1185.15	3555.60	1185.15	0.00	0.00	0.00	0.00	-56.07	3.27
	Nueva Ciudad	41387.99	58132.84	174398.64	11646.61	131919.84	78329.30	26109.62	61307.00	32023.22	6832.60	2277.55	53352.30	29371.65	1122.10	374.02	-23.93	3.66
	Pedro Molina	20428.33	23364.93	70094.89	7217.05	65949.02	53842.00	17947.17	16253.10	5417.76	4321.20	1440.40	1923.40	641.14	10008.50	3336.22	-25.99	3.73
	Rodeo de La Cruz	34261.72	40955.57	122065.60	10234.23	105063.59	87909.20	32756.18	24598.20	8199.39	19236.00	6411.97	1446.80	482.29	3915.40	1305.13	-27.74	3.50
	San Francisco del Monte (Gy	71439.64	91430.29	247835.83	17727.48	205647.91	192314.00	83930.75	22498.60	7499.54	12563.20	4187.73	628.70	209.55	9306.70	3102.26	-32.10	3.62
	San José (Gy)	76740.40	100771.97	302316.11	27385.83	260730.86	194349.30	75523.57	75745.90	25248.40	31919.00	10639.55	25500.60	8500.21	18326.30	6108.64	-35.96	3.82
	Villa Nueva	118266.97	159851.76	479555.17	29218.28	350820.05	237981.10	124467.18	106153.60	35384.58	49301.60	16433.92	1307.50	435.82	55544.50	18514.84	-28.12	3.64
LAS HERAS	Capdevila	688.97	688.95	2066.90	291.33	2251.92	487.50	162.50	1579.30	526.45	1312.00	437.35	0.00	0.00	267.30	89.10	-17.00	3.00
	Ciudad (LH)	53903.85	61135.40	182974.33	18974.92	170110.87	123562.60	41331.13	59413.20	19804.27	30473.80	10157.85	3450.80	1150.28	25488.60	8496.14	-27.84	3.37
	El Algarrobal	11618.68	11976.23	35928.65	3636.08	34584.74	12067.00	4022.44	23861.10	7953.79	11577.00	3859.02	5067.80	1689.35	7216.30	2405.42	-4.05	3.12
	El Challao	13605.21	14857.31	44571.99	5157.15	43613.61	15100.10	5033.46	29471.60	9823.85	22068.50	7356.21	0.00	0.00	7403.10	2467.64	9.13	3.12
	El Plumerillo	40586.14	43146.58	129439.84	11368.16	103231.14	71434.00	30969.25	36531.90	12177.33	21005.00	7001.74	1648.20	549.41	13878.70	4626.18	-22.21	3.18
	El Resguardo	9755.32	10733.98	32201.96	3177.94	30011.72	9689.80	3229.86	22512.50	7504.12	17780.30	5926.74	257.70	85.93	4474.50	1491.45	-41.86	3.14
	El Zapallar	19364.72	20918.34	62755.10	4491.86	53318.13	36175.10	15996.59	14765.50	4921.75	8636.00	2878.61	468.30	156.09	5661.20	1887.05	-35.06	3.10
	La Cieneguita	1078.01	1173.53	3520.62	544.24	3991.65	2556.70	852.20	964.00	321.33	810.90	270.30	0.00	0.00	153.10	51.03	67.78	3.15
	Panquegua	4817.11	5189.26	15567.75	2202.15	16716.65	8816.00	2938.66	6751.80	2250.60	2662.00	887.37	0.00	0.00	4089.80	1363.23	14.52	3.24
LUJAN DE CUYO	Carrodilla	30472.87	32472.51	97417.38	9580.30	91895.53	63989.60	21330.01	33427.80	11142.50	16528.30	5509.54	1202.10	400.70	15697.40	5232.26	-38.87	3.15
	Chacras de Coria	28569.46	30700.31	92101.00	6474.63	78691.90	29031.40	9677.01	24941.60	21023.30	12459.00	4153.01	0.00	0.00	12482.60	16870.29	-14.91	3.34
	Ciudad (L)	54207.75	66284.76	183174.28	16650.69	166053.50	133460.80	49713.47	49714.20	16571.29	24223.00	8074.21	5393.60	1797.84	20097.60	6699.24	-28.42	3.50
	La Puntilla	4345.74	4345.72	13037.22	1287.57	12554.19	2448.00	816.00	10589.10	3529.72	3803.50	1267.84	0.00	0.00	6785.60	2261.88	3.98	3.00
	Las Compuertas	877.42	877.42	2632.26	117.10	2106.14	2632.30	877.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-80.07	3.00
	Mayor Drummond	14198.00	16871.69	50615.06	4374.79	43978.70	32724.80	10908.42	17889.80	5963.27	15102.50	5034.20	0.00	0.00	2787.30	929.07	-39.55	3.43
	Vistalba	4900.60	5512.03	16536.05	1376.07	15145.69	15931.60	5310.55	604.40	201.48	0.00	0.00	0.00	0.00	604.40	201.48	-17.48	3.84
MAIPU	Coquimbito	8084.47	8612.00	25835.93	2868.38	25330.06	8094.70	2698.25	17741.20	5913.75	10525.80	3508.60	335.30	111.76	6880.10	2293.39	-41.33	3.39
	Cruz de Piedra	1035.85	1035.84	3107.54	307.07	2992.91	550.40	183.47	2557.20	852.37	0.00	0.00	0.00	0.00	2557.20	852.37	-76.70	3.00
	Fray Luis Beltrán	5016.51	5567.98	16703.98	1653.04	15421.12	5837.50	1945.84	10866.30	3622.14	5923.00	1974.32	4943.30	1647.82	0.00	0.00	-32.35	3.20
	General Gutierrez	22610.25	24626.57	73879.92	8058.03	72072.08	54560.50	18186.80	19319.30	6439.77	11450.80	3816.89	928.40	309.46	6940.10	2313.42	-15.64	3.40
	Lunlunta	186.85	186.85	560.55	79.84	613.23	560.50	186.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	3.00
	Luzuriaga	44622.04	46432.93	139298.77	11358.23	125856.90	131888.50	43962.89	7410.30	2470.04	7359.00	2452.93	0.00	0.00	51.30	17.11	-3.49	3.48
	Maipú	99970.16	140784.30	422353.33	31342.73	316389.28	148219.70	49406.29	214746.80	91378.01	86221.30	28740.27	33554.80	11184.90	94970.70	51452.84	-26.18	3.59
	Rodeo del Medio	4230.67	5123.09	15369.25	1576.17	14099.03	14470.10	4823.40	899.00	299.69	294.90	98.31	604.10	201.38	0.00	0.00	-46.87	3.98

4.5.4 Surface-to-Volume Ratio

Utilizing GIS to determine the surface-to-volume ratios (S/V) of each structure in Mendoza, an intriguing hypothesis may be formulated at the census scale to pinpoint residential characteristics. The way S/V ranges are classified at the building-by-building level serves as the foundation for this idea. Once these ranges are established, the next step is to find the combined average S/V value for each census region. Stated differently, this process comprises grouping buildings according to their S/V ranges and then categorizing them based on certain residential qualities. After that, an average ratio is determined for every census zone by adding together all of these distinct S/V values. This aggregated average S/V serves as a representative statistic for comprehending residential attributes and offers significant insights into the spatial patterns of residential characteristics within a certain geographic area.

The results show that the central region has the largest share of condominiums, whereas other locations have a mix of or mostly detached residences.



Buildings' typology – Tipologia di edifici	**Surface to volume ratio – Fattore di forma S/V [m²/m³]**	**Average multiplicative factor – Coefficiente moltiplicativo: S/V → S/V$_{real}$ [-]**
Detached house – edificio isolato	$\frac{S}{V} > 0{,}71$	1.31
Terrace house – case a schiera Row house-little – piccoli condominii in linea (max 3 piani)	$0{,}56 < \frac{S}{V} \leq 0{,}71$	1.25
Row house-big – grandi condominii in linea (oltre i 3 piani)	$0{,}45 < \frac{S}{V} \leq 0{,}56$	1.21
Tower – torri o grandi edifici compatti	$\frac{S}{V} \leq 0{,}45$	1.08

Table 14 : table of building typology and surface to volume ratio (Professor Mutani's class booklet. Exercise 4)

4.5.5 Typology

The analysis determined the percentage of heated volume for each form of a structure and found recurring construction types. Among the residential building types are condominiums and single-family residences, some of which have ground-level business space.

Nonetheless, the Mendoza building typologies are as follows, based on the examination of data from the census and geodatabase:

- **Single-family homes**: Usually including one or two stories, these are detached dwellings. Frequently, gardens and yards encircle them.
- **Multi-family homes**: These are structures made up of apartments that usually have three stories or more. They are frequently seen in the city's center.
- **Commercial buildings**: These structures house businesses like restaurants, stores, and offices. They are frequently found in crowded business areas.
- **industrial buildings**: structures used for industry, separated into light and heavy industries
- **services buildings**: These structures refer to services buildings, housing municipal offices, and educational facilities, among other things. They are frequently seen in the city's center.

The homogeneity of the building stock is a key area of inquiry, especially with regard to blockhouses and building status. Based on their typology, the buildings are separated into two categories:

detached homes and condominiums. Based on the proportion of actual residential space to commercial space within the building, the condominiums are further divided into "Entirely residential" and "Mixed" categories. Data was taken from the census department in order to standardize the categories.

There is diversity in Mendoza's building typologies. We employ building density to more clearly distinguish between these various building styles and to pinpoint locations with more uniformity. The number of buildings per unit area is known as building density. High-density regions are defined as those where the density is greater than 60%, while low-density areas are defined as those where the density is less than 60%. The distribution of buildings in Mendoza may be better understood and regions that are likely to share similar features can be found by using building density to locate areas with more homogeneity.

Most regions are dominated by detached houses, which are further classified into three sub-groups depending on location and distribution: central, peripheral, and rural. The center portions are higher in density and 2 other areas are a mix of high and less than 60% density.

4.5.6 building density

Lower energy use is generally correlated with increased building densities. This is due to the fact that buildings in denser locations often have smaller surface-to-volume ratios and are more compact. This can lessen the requirement for heating and cooling because they lose less heat or absorb less heat from the surroundings. Furthermore, residences in denser locations are frequently situated nearer to services like dining options, retail establishments, and public transit, which might lessen the need for inhabitants to drive and consume more energy.

Building density has been shown to be a reliable indicator of building type. In Mendoza, single-family homes are more common in low-density neighborhoods while multi-family homes are more common in high-density neighborhoods. It is commonly known that the core portions of the map have a significantly higher density than the periphery areas.

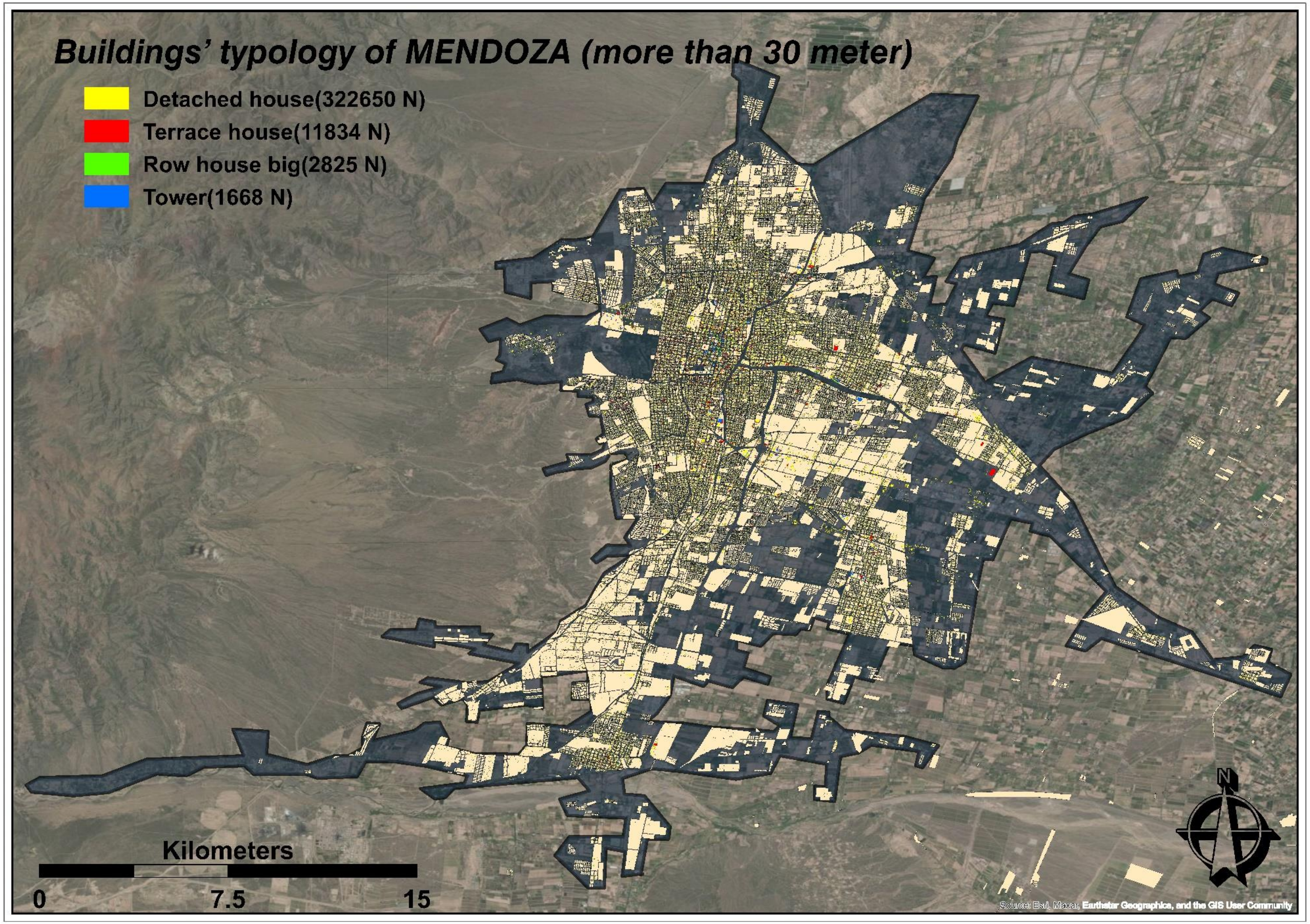
4.5.7 Building Cover Ratio

The ratio of a building's built-up area to the plot's overall area is known as the cover ratio. This ratio can have an impact on the surrounding environment's temperature and is crucial in regulating how much sunlight reaches the earth.

The cover ratio is comparatively high in Mendoza. This is because developers are motivated to build as much as possible on each piece of land due to the city's warm and sunny atmosphere. Nevertheless, a high cover ratio can also result in several environmental issues, such as an increased heat island effect: When metropolitan areas are noticeably warmer than the nearby rural regions, a phenomenon known as the heat island effect takes place. The heat island effect can be exacerbated by a high cover ratio, which makes it more difficult for cities to cool off at night.

The cover ratio of buildings in Mendoza varies according to local zoning laws. Still, Mendoza has a rather high building cover ratio overall. This suggests that built-up structures occupy a significant amount of the city's land area, leaving less room for open spaces and greenery.

Figure 39 : building typology of Mendoza (more than 30 meter) (Authors)



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Figure 40 : Residential building types normalized with building density in Mendoza (more than 30 meter) (Authors)

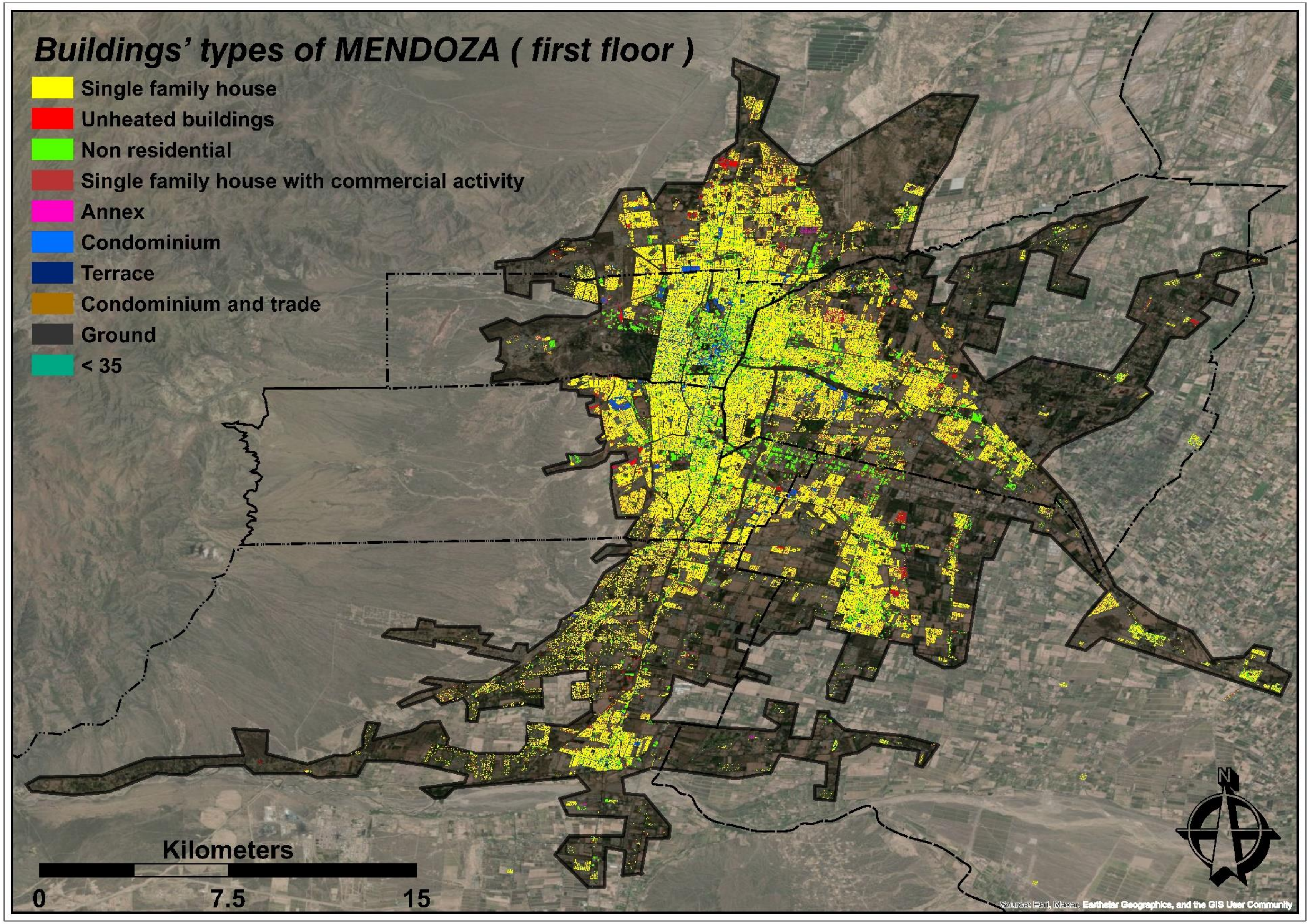


Figure 41 : building density in Mendoza (more than 30 meter)(Authors)

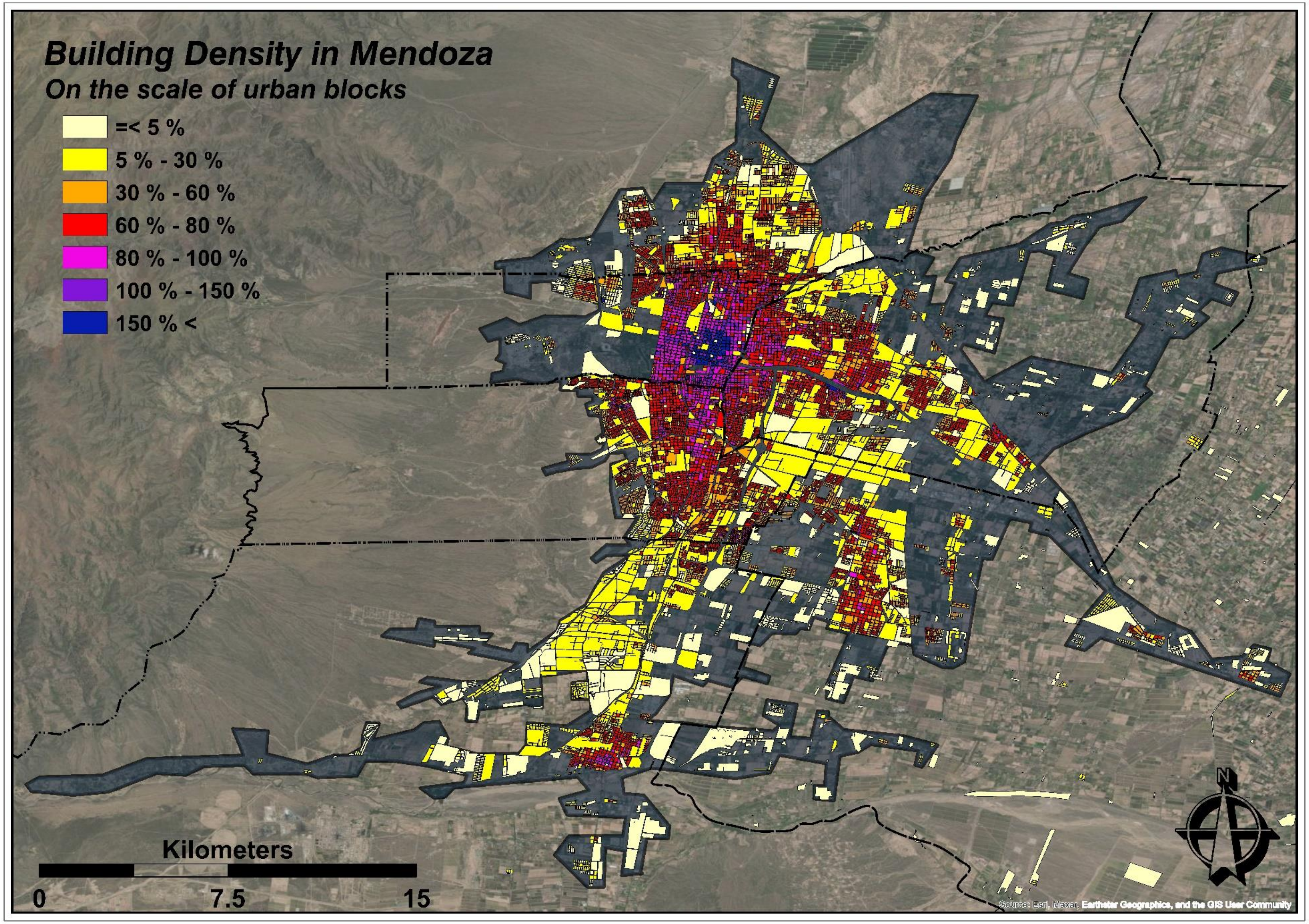


Figure 42 : building cover ratio (more than 30 meter) (Authors)

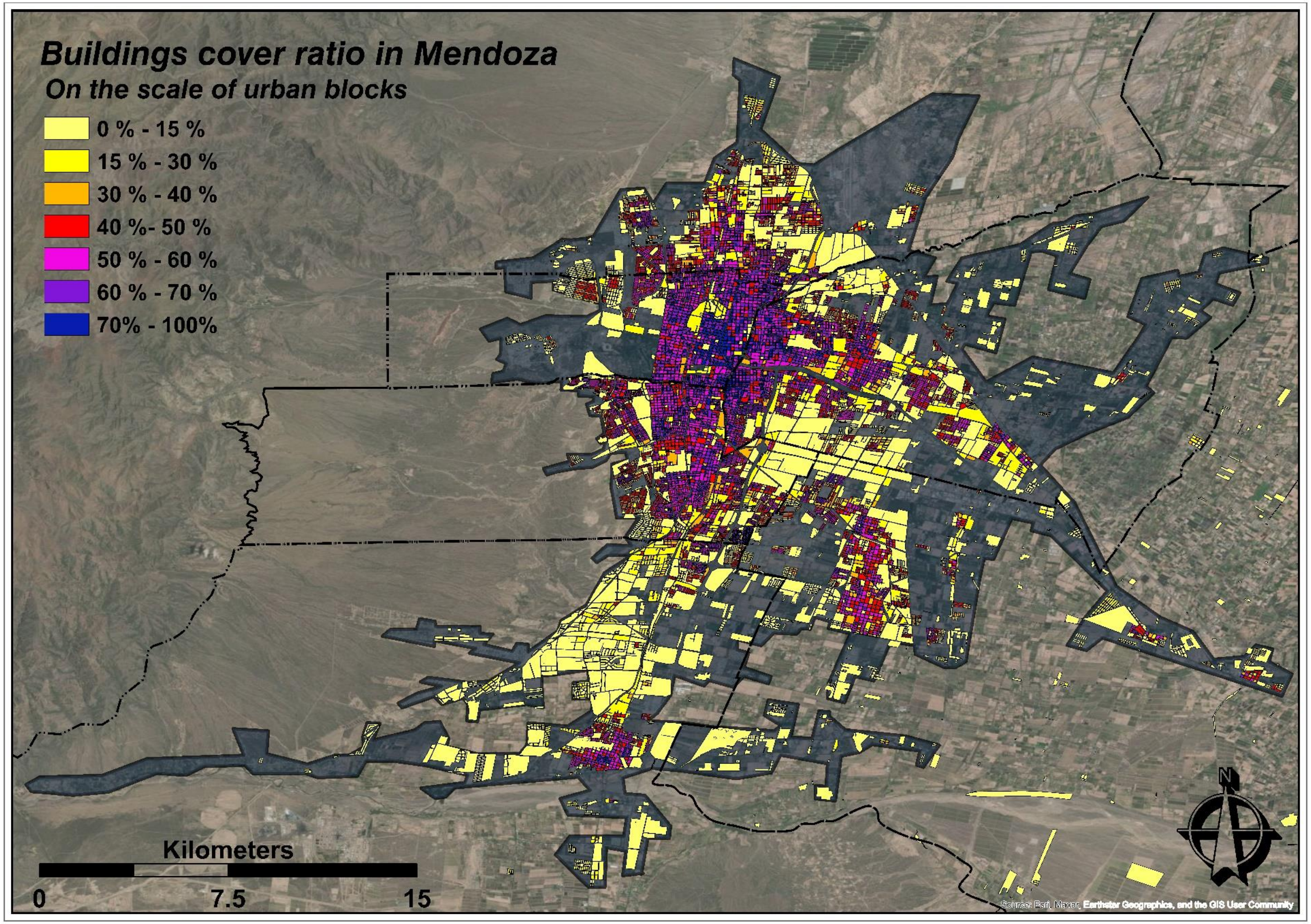


Table 15 : Second group of building Characteristics (typology) registered in Districts (Authors)

	DISTRITOS	Percentage of INSOLATED BUILDINGS	Percentage of NO INSOLATED BUILDINGS	Volume Percentage of Detached house	Volume Percentage of Terrace house	Volume Percentage of Row house big	Volume Percentage of Tower	MEAN of Buildings cover ratio (%)	Average of surface-to-volume ratio
CAPITAL	Cuarta Sección	9.52	90.48	82.16	9.48	2.36	5.99	37.69	1.23
	Décima Sección	50.69	49.31	80.83	17.91	1.26	0.00	22.47	1.27
	Décimo Primera Sección	49.35	50.65	98.48	0.00	0.00	1.52	21.65	1.51
	Octava Sección	26.22	73.78	87.70	8.76	3.44	0.10	25.69	1.37
	Primera Sección	22.59	77.41	40.35	26.43	10.60	22.62	31.03	1.02
	Quinta Sección	5.41	94.59	73.73	18.51	3.08	4.68	31.01	1.21
	Segunda Sección	2.05	97.95	41.39	26.70	11.87	20.03	32.02	0.95
	Séptima Sección	29.71	70.29	64.48	17.86	16.61	1.05	14.27	1.22
	Sexta Sección	8.70	91.30	89.29	9.91	0.76	0.03	36.05	1.29
	Tercera Sección	2.18	97.82	42.98	27.65	10.75	18.62	35.94	0.98
GODOY CRUZ	Ciudad (GC)	12.16	87.84	86.67	9.88	2.01	1.43	33.73	1.30
	Gobernador Benegas	12.13	87.87	95.11	4.43	0.35	0.11	34.80	1.33
	Las Tortugas	13.92	86.08	94.91	4.61	0.44	0.05	34.04	1.36
	Presidente Sarmiento	13.40	86.60	96.38	3.01	0.61	0.00	28.89	1.40
	San Francisco del Monte -GC	13.75	86.25	97.69	2.31	0.00	0.00	33.21	1.34
GUAYMALLEN	Belgrano	19.23	80.77	96.60	2.53	0.87	0.00	34.35	1.40
	Bermejo	23.08	76.92	98.98	0.98	0.04	0.00	24.01	1.42
	Buena Nueva	23.09	76.91	98.67	1.33	0.00	0.00	27.61	1.42
	Capilla del Rosario	16.36	83.64	98.12	1.86	0.02	0.00	31.79	1.39
	Colonia Segovia	61.12	38.88	100.00	0.00	0.00	0.00	12.44	1.46
	Dorrego	7.94	92.06	92.46	5.83	0.70	1.02	38.96	1.29
	El Sauce	44.02	55.98	98.77	1.23	0.00	0.00	17.65	1.51
	Jesús Nazareno	36.02	63.98	99.25	0.75	0.00	0.00	23.57	1.43
	Kilómetro 11	32.03	67.97	97.46	2.14	0.22	0.19	22.13	1.40
	La Primavera (Gy)	53.64	46.36	100.00	0.00	0.00	0.00	18.38	1.45
	Las Cañas	17.33	82.67	92.53	5.13	0.19	2.16	31.04	1.36
	Los Corralitos	64.47	35.53	99.90	0.10	0.00	0.00	20.59	1.40
	Nueva Ciudad	7.94	92.06	96.54	3.20	0.26	0.00	36.38	1.30
	Pedro Molina	11.58	88.42	96.52	3.20	0.29	0.00	37.60	1.33
	Rodeo de La Cruz	20.41	79.59	98.52	1.24	0.23	0.01	27.66	1.40
	San Francisco del Monte (Gy	30.95	69.05	98.55	1.45	0.00	0.00	24.42	1.41
	San José (Gy)	5.78	94.22	90.53	7.66	1.62	0.19	37.76	1.27
	Villa Nueva	14.04	85.96	81.76	12.18	4.92	1.14	30.49	1.28
LAS HERAS	Capdevila	35.60	64.40	99.81	0.19	0.00	0.00	20.80	1.50
	Ciudad (LH)	15.08	84.92	93.54	5.54	0.77	0.16	33.58	1.36
	El Algarrobal	38.65	61.35	97.04	2.96	0.00	0.00	20.58	1.46
	El Challao	25.75	74.25	98.25	1.60	0.16	0.00	27.46	1.42
	El Plumerillo	24.95	75.05	99.09	0.89	0.01	0.00	26.94	1.45
	El Resguardo	23.43	76.57	99.58	0.42	0.00	0.00	20.43	1.48
	El Zapallar	14.41	85.59	95.96	3.98	0.06	0.00	33.77	1.37
	La Cieneguita	24.08	75.92	95.60	4.30	0.10	0.00	30.42	1.39
	Panquegua	24.26	75.74	99.18	0.82	0.00	0.00	29.84	1.43
LUJAN DE CUYO	Carrodilla	24.12	75.88	97.86	2.14	0.00	0.00	28.03	1.40
	Chacras de Coria	50.45	49.55	93.76	6.21	0.01	0.02	12.78	1.38
	Ciudad (L)	19.69	80.31	92.13	6.11	1.64	0.12	30.54	1.35
	La Puntilla	36.54	63.46	94.23	5.51	0.00	0.26	16.80	1.38
	Las Compuertas	84.57	15.43	98.91	1.09	0.00	0.00	10.08	1.49
	Mayor Drummond	30.13	69.87	96.28	2.72	0.14	0.86	23.49	1.40
	Perdriel	20.06	79.94	100.00	0.00	0.00	0.00	25.35	1.46
	Vistalba	73.47	26.53	97.94	2.06	0.00	0.00	14.94	1.45
MAIPU	Coquimbito	34.55	65.45	99.82	0.18	0.00	0.00	21.32	1.45
	Cruz de Piedra	46.56	53.44	99.25	0.75	0.00	0.00	19.12	1.44
	Fray Luis Beltrán	31.87	68.13	99.66	0.34	0.00	0.00	24.54	1.45
	General Gutierrez	20.30	79.70	98.22	1.69	0.09	0.00	28.37	1.38
	General Ortega	89.54	10.46	100.00	0.00	0.00	0.00	27.30	1.48
	Lunlunta	61.30	38.70	90.61	9.39	0.00	0.00	11.71	1.44
	Luzuriaga	16.23	83.77	94.33	4.41	1.26	0.00	28.97	1.37
	Maipú	20.39	79.61	97.46	2.18	0.35	0.01	27.79	1.37
	Rodeo del Medio	36.00	64.00	97.51	2.49	0.00	0.00	24.66	1.45
	Russel	60.35	39.65	100.00	0.00	0.00	0.00	18.89	1.46

4.5.8 quality of material

Considerable information on the overall standard of Mendoza's buildings at the section level may be gained by analyzing data from the INDEC national census. The census data allows for an assessment of the solidity, resistance, thermal insulation capacity, and finishing of building components such as flooring and roofs by classifying dwellings into four groups based on the grade of materials used. Determining how Mendoza's building quality is distributed throughout its many neighborhoods might help with decisions about housing and urban development. It can assist in determining which areas need to be funded for infrastructure improvements, repairs, or redevelopment projects to encourage sustainable urban growth and enhance the quality of life for locals. The census data gives a thorough picture of the general quality and condition of conservation of Mendoza's residential structures, even though it does not provide precise information on the building's construction time or the materials that were utilized in each one. To meet the housing requirements and enhance the urban environment in the area, it provides a useful foundation for future study and focused actions.QM1, resistant and solid materials and has an internal coating;

- QM2, resistant and solid materials but without internal coating or low quality of the floor
- QM3, low-quality roof, and floor materials
- QM4, very low-quality materials

Mendoza grades the quality of buildings based on the floor and roof materials, which are listed in a chart from best (group 1) to worst (group 8). Group 1 constructions have greater solidity, resistance, thermal insulation capacity, and finishing because the best floor and roof materials are chosen. In addition to ensuring structural integrity, these premium materials contribute to energy efficiency by preserving comfortable interior temperatures and lowering the need for heating and cooling. The lowest-quality roof and floor materials, which may have limitations in terms of lifetime, insulation, and finishing, are what set Group 8 buildings apart. These structures may need more regular maintenance and may lack adequate thermal and acoustic insulation, thus resulting in less pleasant living conditions for tenants.

- MC1 (Asphaltic cover or membrane)
- MC2 (Tile or slab (without cover))
- MC3 (Slate or tile)
- MC4 (Sheet metal (without cover))
- MC5 (Fiber cement or plastic sheet)
- MC6 (cardboard sheet)
- MC7 (Cane, palm, board or straw with or without mud)
- MC8 (other materials)

In addition to this, the data gathered on the outside covering of buildings is also shown by being divided into four categories. The materials-based classification scheme offers academics, policymakers, and urban planners' important information on the general performance and quality of Mendoza's building structures. It is a useful tool for pinpointing areas that could need focused interventions or modifications in order to enhance the stock of buildings and encourage better living conditions within the community.

- MP1 (Ceramic, tile, mosaic, marble, wood or carpet)
- MP2 (Fixed cement or brick)
- MP3 (loose earth or brick)
- MP4 (other materials)

Table 16 : Residential¬ _ industrial _commercial and services Third group of building Characteristics (Material) registered in Districts (Authors)from census data

	DISTRITOS	per of QM1	per of QM2	per of QM3	per of QM4	per of MP1	per of MP2	per of MP3	per of MP4	per of MC1	per of MC2	per of MC3	per of MC4	per of MC5	per of MC6	per of MC7	per of MC8
CAPITAL	Cuarta Sección	81.65	14.43	1.21	2.71	97.94	1.55	0.16	0.35	61.53	19.46	10.57	4.65	0.45	0.09	2.55	0.71
	Décima Sección	82.81	16.00	0.88	0.31	98.48	0.71	0.20	0.61	21.12	2.72	72.45	3.01	0.10	0.00	0.20	0.39
	Décimo Primera Sección	30.45	45.10	7.49	16.95	59.66	32.57	7.39	0.38	70.20	3.60	0.65	8.51	2.24	1.35	7.78	5.67
	Octava Sección	56.58	35.62	2.63	5.17	81.70	14.89	2.09	1.33	69.35	16.80	3.87	2.89	0.45	0.11	4.65	1.89
	Primera Sección	83.43	15.52	0.74	0.31	95.12	1.60	0.04	3.23	49.34	40.38	3.75	5.27	0.17	0.02	0.29	0.77
	Quinta Sección	88.98	9.76	0.52	0.74	99.11	0.62	0.03	0.24	47.12	28.00	18.44	4.83	0.32	0.02	0.67	0.59
	Segunda Sección	87.64	11.46	0.59	0.31	97.65	0.95	0.01	1.40	41.16	48.61	6.22	1.89	0.19	0.03	0.24	1.66
	Séptima Sección	45.13	11.01	14.60	0.69	67.00	4.26	0.06	0.11	29.56	17.39	8.90	14.63	0.17	0.00	0.77	0.00
	Sexta Sección	80.69	16.94	1.05	1.33	98.10	1.08	0.22	0.60	53.55	17.33	23.37	3.65	0.50	0.01	1.12	0.47
	Tercera Sección	83.52	14.64	1.47	0.37	98.02	0.85	0.11	1.03	52.02	38.04	3.92	4.68	0.56	0.07	0.37	0.34
GODOY CRUZ	Ciudad (GC)	75.13	20.56	1.61	2.71	95.04	4.25	0.27	0.44	62.60	17.10	11.42	4.89	0.48	0.06	2.52	0.92
	Gobernador Benegas	75.14	21.98	0.93	1.96	97.37	2.20	0.09	0.33	65.15	11.67	17.36	3.16	0.11	0.01	1.93	0.61
	Las Tortugas	62.10	34.48	1.62	1.81	88.08	11.21	0.22	0.49	65.38	20.46	7.81	3.44	0.47	0.01	1.70	0.74
	Presidente Sarmiento	56.00	35.05	2.87	6.08	81.03	14.85	2.11	2.01	57.23	15.79	13.99	5.26	0.75	0.20	4.36	2.42
	San Francisco del Monte -GC	68.24	28.55	2.24	0.97	94.60	3.77	0.07	1.56	64.13	17.35	13.11	3.15	0.53	0.00	1.02	0.72
GUAYMALLEN	Belgrano	55.70	30.97	2.73	10.61	81.48	15.92	2.03	0.57	59.39	22.40	2.61	3.63	0.72	0.20	8.83	2.22
	Bermejo	53.77	37.06	3.39	5.79	79.34	18.57	1.75	0.34	66.95	10.30	8.21	6.29	1.15	0.20	5.02	1.87
	Buena Nueva	49.95	33.50	3.00	13.55	79.20	17.95	2.51	0.33	58.17	10.06	7.84	9.03	1.19	0.43	11.82	1.45
	Capilla del Rosario	71.91	25.00	1.51	1.58	92.44	6.21	0.11	1.24	58.34	20.79	15.40	3.16	0.36	0.08	1.39	0.48
	Colonia Segovia	24.75	53.95	4.44	16.86	62.75	32.48	4.35	0.42	61.82	4.15	8.91	6.81	0.86	0.28	13.39	3.78
	Dorrego	80.75	15.10	0.93	3.22	97.70	1.70	0.23	0.36	64.78	13.06	15.43	2.56	0.40	0.05	3.14	0.58
	El Sauce	41.65	44.62	5.73	8.00	73.83	23.83	2.10	0.24	48.78	12.73	21.44	6.80	1.82	0.13	7.00	1.31
	Jesús Nazareno	52.15	35.23	5.32	7.30	78.56	18.98	2.19	0.27	56.11	10.60	7.84	16.78	1.42	0.51	5.65	1.09
	Kilómetro 11	50.42	35.17	3.86	10.55	76.57	20.08	2.92	0.43	62.28	10.40	8.68	6.81	1.18	0.37	9.11	1.18
	La Primavera (Gy)	36.36	42.56	7.02	14.05	62.99	34.65	1.97	0.39	59.84	4.72	5.91	14.96	1.97	0.39	11.81	0.39
	Las Cañas	75.28	20.66	1.32	2.74	94.14	5.30	0.25	0.31	65.49	12.38	15.64	2.99	0.46	0.10	2.38	0.56
	Los Corralitos	51.39	30.71	7.80	10.11	76.20	21.54	1.75	0.51	54.64	5.92	7.86	19.48	1.96	0.31	8.59	1.23
	Nueva Ciudad	75.29	18.16	1.49	5.06	96.08	3.53	0.23	0.15	70.26	12.45	7.85	3.57	0.37	0.24	4.93	0.34
	Pedro Molina	72.35	19.77	1.82	6.06	94.02	5.22	0.63	0.13	70.56	13.28	5.03	4.28	0.45	0.05	5.58	0.77
	Rodeo de La Cruz	50.74	36.36	2.25	10.64	80.57	17.04	1.68	0.71	64.63	14.73	5.43	3.26	0.67	0.14	9.41	1.73
	San Francisco del Monte (Gy	63.00	32.80	2.12	2.09	91.16	8.21	0.43	0.20	49.01	12.94	28.31	7.04	0.28	0.00	1.91	0.50
	San José (Gy)	81.38	12.69	1.44	4.49	97.94	1.88	0.13	0.05	68.99	12.30	7.67	5.20	0.67	0.14	4.19	0.86
	Villa Nueva	79.31	17.87	0.86	1.96	97.05	2.35	0.15	0.45	62.12	17.80	14.95	2.41	0.30	0.05	1.78	0.58
LAS HERAS	Capdevila	43.41	40.77	2.96	12.86	76.78	16.94	6.29	0.00	73.49	8.91	0.75	3.12	2.69	0.55	7.84	2.64
	Ciudad (LH)	68.68	23.51	1.91	5.90	95.01	4.15	0.52	0.32	66.68	15.78	6.49	3.81	0.72	0.12	5.56	0.84
	El Algarrobal	32.12	42.06	4.12	21.70	71.65	21.79	6.15	0.41	65.24	5.98	1.38	2.69	2.16	0.40	18.32	3.84
	El Challao	59.21	33.53	3.98	3.27	85.20	12.56	0.78	1.45	61.57	14.83	12.85	6.62	0.63	0.08	2.24	1.19
	El Plumerillo	46.68	40.98	4.04	8.31	82.61	13.24	2.48	1.66	69.70	12.94	2.48	4.86	1.08	0.29	6.79	1.87
	El Resguardo	39.58	45.12	5.96	9.35	76.34	19.73	3.73	0.19	62.92	11.79	2.62	11.44	1.27	0.53	7.18	2.25
	El Zapallar	70.53	24.43	1.99	3.06	96.00	2.57	0.11	1.32	57.79	18.40	17.64	2.18	0.10	0.07	3.10	0.71
	La Cieneguita	70.55	25.59	1.61	2.25	93.40	5.38	0.33	0.89	49.19	17.79	26.85	3.14	0.30	0.06	1.93	0.75
	Panquegua	52.50	35.92	2.58	9.00	86.54	12.07	1.18	0.22	67.83	13.76	3.42	4.12	0.79	0.16	7.89	2.02
LUJAN DE CUYO	Carrodilla	59.31	36.71	2.91	1.07	90.91	8.05	0.13	0.90	57.32	11.64	23.06	6.05	0.36	0.00	0.99	0.57
	Chacras de Coria	67.91	27.27	2.19	2.63	89.98	9.04	0.60	0.39	41.01	5.62	40.62	8.83	0.72	0.30	1.72	1.18
	Ciudad (L)	65.23	25.70	2.67	6.40	88.83	9.56	1.00	0.62	64.09	13.36	9.30	5.81	0.66	0.26	5.73	0.78
	La Puntilla	69.16	25.53	3.28	2.02	95.19	4.55	0.00	0.25	48.54	4.37	37.63	5.57	0.89	0.12	1.89	0.99
	Las Compuertas	56.48	34.26	4.17	5.09	76.23	22.54	0.00	1.23	56.56	4.10	13.11	19.67	2.05	0.82	2.87	0.82
	Mayor Drummond	51.79	27.99	5.27	4.95	78.00	11.55	0.25	0.20	51.88	6.67	12.41	12.43	0.80	0.12	4.88	0.81
	Perdriel	21.28	47.14	7.09	24.49	46.28	44.16	8.70	0.85	32.91	3.18	30.79	7.01	2.97	1.06	16.14	5.94
	Vistalba	60.59	32.67	3.20	3.54	86.72	12.24	0.58	0.47	43.43	4.70	34.13	12.27	0.70	0.20	3.34	1.22
MAIPU	Coquimbito	40.42	44.85	6.01	8.71	75.52	22.15	1.74	0.59	58.58	10.08	8.50	11.44	2.00	0.25	7.36	1.80
	Cruz de Piedra	38.84	41.52	5.95	13.69	68.85	27.76	2.58	0.81	57.85	5.23	10.56	9.05	2.45	0.35	12.44	2.08
	Fray Luis Beltrán	51.82	36.57	4.52	7.10	84.20	14.49	0.99	0.32	51.68	6.65	22.91	9.26	0.90	0.37	5.60	2.63
	General Gutierrez	55.51	32.23	3.97	8.29	87.17	11.57	1.08	0.18	65.08	9.39	6.60	9.25	0.80	0.27	7.26	1.35
	General Ortega	31.26	52.18	6.44	10.11	57.60	38.97	2.78	0.64	60.17	12.63	6.64	9.42	0.64	0.64	7.71	2.14
	Lunlunta	34.60	49.79	10.26	5.36	69.08	28.38	1.79	0.75	56.95	4.66	7.84	23.52	1.52	0.00	4.50	1.02
	Luzuriaga	66.42	28.30	2.45	2.82	92.24	4.81	0.33	2.63	58.66	13.04	14.96	9.47	0.33	0.10	2.38	1.05
	Maipú	58.93	34.24	2.31	4.51	89.17	9.34	0.85	0.65	61.73	10.79	16.63	5.76	0.41	0.16	3.84	0.67
	Rodeo del Medio	45.12	36.83	5.07	12.97	66.62	28.94	2.67	1.78	63.13	8.97	5.27	8.34	1.15	0.22	10.19	2.72
	Russel	48.52	33.93	5.21	12.34	73.52	22.71	3.41	0.36	64.03	6.80	5.50	9.66	1.78	0.40	10.55	1.28

4.5.9 Building Population Characteristics

The census data, a wealth of information, provides a complete picture of the people, homes, and dwellings in the city in 2010. This data is extremely valuable for comprehending patterns of energy use since it makes trends in home type, household size, and population density easier to identify. A tapestry of traits, including gender distribution, age groupings, household relationships, nationality, educational achievement, and job status, is revealed by the census data's demographic dimension. These characteristics offer insightful information about the preferences and patterns of energy use of various demographic groupings.

- **Number of inhabitants:** This metric provides a comprehensive overview of the total population residing in Mendoza. It serves as a baseline for understanding the overall size and dynamics of the city's population.
- **Number of women:** The proportion of women in the population reflects the gender balance in the city. This information can be used to analyze gender-specific trends in energy consumption, such as appliance usage patterns and heating and cooling preferences.
- **Number of families**: This indicator reflects the household structure of the population. It can be used to analyze the distribution of household sizes and the impact of household size on energy consumption.
- **Number of components per family:** This measure provides insights into the average size of families in Mendoza. It can be used to assess the correlation between family size and energy consumption patterns.
- **Num people/vol:** This metric represents the average number of people per unit of building volume. It indicates the density of occupancy in dwellings. This information can be used to analyze the impact of occupancy density on energy consumption patterns.
- **Num family/vol:** This measure represents the average number of families per unit of building volume. It indicates the distribution of families across different dwelling sizes. This information can be used to analyze how family size and dwelling size influence energy consumption.
- **Average of number of components per family:** This measure represents the average number of individuals residing in a family. It provides a more refined understanding of family size compared to the simple count of family members.
- **Average of Number of people per building gross volume**: This metric represents the average number of people occupying a given dwelling size. It indicates the typical occupancy of different dwelling units. This information can be used to analyze how dwelling size and occupancy patterns affect energy consumption.
- **Average of number of families per gross volume:** This measure represents the average number of families residing in a dwelling of a given size. It provides insights into the distribution of families across different dwelling types. This information can be used to analyze the impact of dwelling type and family size on energy consumption.
- **Persons of agr1(0 - 14 years old)**: This metric represents the proportion of children under the age of 14 in the population. It indicates the dependency ratio, which is the ratio of non-working individuals to working individuals. This information can be used to analyze how the age structure of the population affects energy consumption patterns.
- **Per of agr2(15 - 64 years old):** This metric represents the proportion of people between the ages of 15 and 64 in the population. This group forms the backbone of the labor force and is a significant factor in energy consumption patterns.
- **Per of agr3(65 and over years old):** This metric represents the proportion of people aged 65 and over in the population. This group is generally less energy-intensive due to their lifestyle and smaller living spaces.
- **per of act1 (Busy):** This metric represents the proportion of people who are actively employed. This group drives the economy and contributes to energy consumption related to transportation and other activities.
- **per of act2(Not busy):** This metric represents the proportion of people who are not actively employed or in school. This group includes retirees, students, and stay-at-home individuals, who typically have lower energy consumption patterns.
- **per of act3 (Inactive):** This metric represents the proportion of people who are either unemployed or unable to work due to disability or other reasons. This group generally has lower energy consumption patterns.

Table 17 : Fourth group of buildings Characteristics (population) registered in Districts (Authors) according to census data

	DISTRITOS	Number of inhabitants	Number of women	Number of families	Number of components per family	Num people/vol	Num family/vol	Average of number of components per family	Average of Number of people per building gross volume	Average of number of families per gross volume	Persons of agr1(0 - 14 years old)	Per of agr2(15 - 64 years old)	Per of agr3(65 and over years old)	per of act1 (Busy)	per of act2(Not busy)	per of act3 (Inactive)
CAPITAL	Cuarta Sección	20668	11037	8355.00	2.47	0.007	0.0027	2.50	3.96	1.65	17.49	66.23	16.29	62.97	4.27	32.76
	Décima Sección	1817	954	613.00	2.96	0.003	0.0011	3.00	5.57	1.85	21.68	70.67	7.64	61.59	2.44	35.97
	Décimo Primera Sección	8470	4261	2121.00	3.99	0.126	0.0316	4.22	278.07	66.38	32.01	63.36	4.62	62.34	5.52	32.14
	Octava Sección	12535	6429	3043.00	4.12	0.014	0.0035	4.27	3.43	0.94	26.82	64.05	9.13	58.62	6.69	34.69
	Primera Sección	9464	5292	5005.00	1.89	0.005	0.0025	1.88	5.94	3.33	12.86	69.34	17.81	65.59	3.74	30.67
	Quinta Sección	14188	7645	7208.00	1.97	0.004	0.0022	2.00	1.60	0.81	12.33	68.41	19.26	63.88	2.73	33.39
	Segunda Sección	14013	8023	10874.00	1.29	0.004	0.0028	1.34	2.54	2.28	10.41	69.44	20.16	63.00	3.17	33.83
	Séptima Sección	4658	1764	1125.00	4.14	0.013	0.0032	3.46	8.90	3.54	14.15	75.91	9.94	50.05	2.82	18.56
	Sexta Sección	17502	9427	7208.00	2.43	0.007	0.0027	2.44	2.14	0.92	15.67	66.46	17.88	61.70	3.58	34.72
	Tercera Sección	7770	4180	4933.00	1.58	0.003	0.0022	1.57	5.45	4.60	10.89	69.81	19.30	66.26	4.26	29.48
GODOY CRUZ	Ciudad (GC)	79051	42047	28976.00	2.73	0.009	0.0031	2.77	3.12	1.13	20.12	65.15	14.73	62.20	4.64	33.16
	Gobernador Benegas	22433	11835	7386.00	3.04	0.008	0.0028	3.05	2.86	0.92	18.25	65.90	15.85	61.07	4.09	34.84
	Las Tortugas	36007	18736	9374.00	3.84	0.014	0.0038	3.90	5.42	1.33	25.22	64.52	10.26	59.72	5.52	34.77
	Presidente Sarmiento	42375	21912	10526.00	4.03	0.021	0.0052	4.04	20.12	5.49	26.04	64.34	9.62	59.03	6.06	34.92
	San Francisco del Monte -GC	9084	4580	2604.00	3.49	0.007	0.0021	3.38	3.39	0.99	19.33	64.32	16.35	60.03	3.96	36.01
GUAYMALLEN	Belgrano	41835	21412	9964.00	4.20	0.015	0.0036	4.26	8.79	2.11	27.82	63.23	8.95	60.33	5.39	34.28
	Bermejo	16286	8228	4045.00	4.03	0.018	0.0045	4.05	3.65	0.86	28.96	64.23	6.81	60.52	4.46	35.02
	Buena Nueva	13668	7051	3431.00	3.98	0.018	0.0044	3.97	4.79	1.17	29.16	64.03	6.81	61.67	5.20	33.14
	Capilla del Rosario	18284	9597	5391.00	3.39	0.012	0.0037	3.44	5.41	1.90	22.76	65.42	11.81	60.91	4.79	34.30
	Colonia Segovia	4791	2339	1258.00	3.81	0.047	0.0123	3.76	32.11	9.35	30.87	61.91	7.21	64.30	2.71	32.99
	Dorrego	29463	15703	10644.00	2.77	0.008	0.0029	2.75	2.53	0.93	18.84	66.18	14.99	62.68	4.05	33.28
	El Sauce	10769	5368	2676.00	4.02	0.052	0.0128	4.00	150.55	45.00	28.50	65.92	5.58	61.92	5.49	32.59
	Jesús Nazareno	7979	4040	2099.00	3.80	0.016	0.0043	3.78	6.57	1.82	27.74	65.98	6.28	63.17	4.35	32.48
	Kilómetro 11	6559	3313	1867.00	3.51	0.017	0.0049	3.49	11.92	3.41	26.96	64.73	8.30	62.25	3.67	34.08
	La Primavera (Gy)	949	450	281.00	3.38	0.206	0.0609	3.38	54.96	16.27	25.71	66.28	8.01	67.09	1.82	31.09
	Las Cañas	14650	7683	4708.00	3.11	0.011	0.0036	3.11	4.87	1.62	22.32	67.83	9.85	63.68	4.16	32.16
	Los Corralitos	3532	1788	1020.00	3.46	0.045	0.0129	3.43	35.98	10.19	26.01	64.28	9.71	58.76	4.82	36.41
	Nueva Ciudad	8438	4477	2767.00	3.05	0.008	0.0027	3.05	2.92	0.98	22.78	64.21	13.01	61.11	5.60	33.29
	Pedro Molina	10992	5742	3432.00	3.20	0.009	0.0028	3.21	2.36	0.74	22.12	65.45	12.42	60.46	4.77	34.77
	Rodeo de La Cruz	20106	10329	5168.00	3.89	0.013	0.0034	3.92	4.27	1.09	26.80	63.30	9.90	59.51	5.51	34.98
	San Francisco del Monte (Gy	10927	5733	3346.00	3.27	0.019	0.0057	3.50	7.77	2.23	29.61	65.15	5.24	66.10	5.03	28.86
	San José (Gy)	12095	6400	4236.00	2.86	0.007	0.0023	2.90	2.62	0.92	18.73	65.56	15.71	61.44	4.40	34.16
	Villa Nueva	33737	17887	11514.00	2.93	0.009	0.0031	2.94	5.11	1.98	19.79	65.78	14.44	60.65	4.56	34.79
LAS HERAS	Capdevila	3397	1678	806.00	4.21	0.020	0.0047	4.21	4.64	1.11	32.64	60.64	6.72	58.01	6.12	35.86
	Ciudad (LH)	35590	18643	11506.00	3.09	0.010	0.0033	3.12	2.82	0.89	23.17	64.25	12.58	60.46	5.66	33.88
	El Algarrobal	10035	5011	2367.00	4.24	0.026	0.0062	4.30	12.23	2.92	31.72	61.11	7.17	59.44	4.74	35.81
	El Challao	28145	14520	7968.00	3.53	0.019	0.0053	3.60	21.94	5.69	26.46	64.58	8.95	61.84	4.87	33.29
	El Plumerillo	40123	20479	9771.00	4.11	0.019	0.0047	4.11	11.69	2.72	29.30	62.47	8.23	58.24	5.77	35.98
	El Resguardo	23595	12065	5137.00	4.59	0.028	0.0061	4.67	7.97	1.74	31.77	62.69	5.55	58.87	6.20	34.93
	El Zapallar	12068	6354	3781.00	3.19	0.012	0.0037	3.27	3.47	1.19	21.42	65.57	13.01	59.77	5.23	35.00
	La Cieneguita	15544	8095	4698.00	3.31	0.014	0.0041	3.31	5.63	1.61	23.71	67.88	8.41	63.00	4.63	32.37
	Panquegua	13552	7022	3432.00	3.95	0.016	0.0041	3.94	4.00	1.01	26.64	64.60	8.75	60.03	5.47	34.51
LUJAN DE CUYO	Carrodilla	21916	11366	6767.00	3.24	0.013	0.0041	3.20	2.88	0.94	25.60	65.64	8.76	62.69	4.81	32.50
	Chacras de Coria	13441	6856	4654.00	2.89	0.006	0.0021	2.90	3.21	1.07	26.31	64.95	8.74	66.32	2.55	31.12
	Ciudad (L)	24385	12753	7550.00	3.23	0.010	0.0031	3.28	7.69	2.04	22.61	65.09	12.30	58.63	4.43	36.95
	La Puntilla	2800	1446	871.00	3.21	0.006	0.0017	3.21	2.20	0.69	19.80	68.57	11.63	62.61	2.60	34.78
	Las Compuertas	827	422	382.00	2.16	0.011	0.0052	2.16	2.05	0.94	26.72	62.64	10.64	59.57	4.09	36.33
	Mayor Drummond	9300	4736	2774.00	3.35	0.013	0.0037	3.45	4.54	1.29	23.81	57.75	8.44	53.64	3.80	32.56
	Perdriel	2093	1053	631.00	3.32	0.071	0.0213	3.32	21.52	6.49	38.51	58.34	3.15	55.12	4.97	39.91
	Vistalba	8833	4494	2897.00	3.05	0.011	0.0037	3.22	4.58	1.28	27.23	66.87	5.90	66.01	3.78	30.21
MAIPU	Coquimbito	19515	9895	4923.00	3.96	0.024	0.0060	3.91	13.08	3.55	27.37	64.15	8.48	58.27	5.28	36.45
	Cruz de Piedra	3845	1900	1067.00	3.60	0.053	0.0146	3.60	19.34	5.36	27.82	63.81	8.37	57.83	4.90	37.27
	Fray Luis Beltrán	6319	3276	1861.00	3.40	0.020	0.0059	3.37	13.23	3.78	25.92	64.14	9.94	58.24	4.27	37.49
	General Gutierrez	21077	10835	5746.00	3.67	0.012	0.0032	3.66	4.99	1.31	25.31	63.64	11.05	58.00	4.87	37.13
	General Ortega	1790	879	464.00	3.86	0.337	0.0873	3.86	98.91	25.64	31.84	61.73	6.42	62.57	4.58	32.85
	Lunlunta	2280	1107	708.00	3.22	0.081	0.0252	3.19	46.60	14.77	26.64	66.35	7.01	58.68	4.11	37.21
	Luzuriaga	22549	11703	6570.00	3.43	0.013	0.0037	3.43	3.69	1.07	22.63	67.50	9.87	62.36	4.47	33.17
	Maipú	44449	22952	12618.00	3.52	0.012	0.0034	3.52	21.58	7.90	24.07	65.27	10.67	59.79	5.01	35.20
	Rodeo del Medio	11875	5966	3063.00	3.88	0.024	0.0063	3.84	5.04	1.27	28.33	63.42	8.25	57.44	4.71	37.85
	Russel	3585	1816	971.00	3.69	0.139	0.0377	3.65	46.72	12.45	25.69	65.03	9.28	54.71	3.73	41.56

4.6 Homogeneous building and district

Comprehending the complexities of heterogeneous urban environments requires investigating spatial patterns and locating similar places. Urban landscapes may be more easily understood by using clustering analysis, a technique that makes it easier to group related objects based on predefined criteria. The K-means technique in Excel is used in this study to find trends in Mendoza's building inventory.

To provide readers with a thorough knowledge of Mendoza's complex urban environment, this part focuses on using clustering analysis to analyze residential, commercial, and industrial structures. Finding significant patterns within each type of building and analyzing the complex structure of the city are the main objectives. Three iterations of the clustering procedure were carried out, with each iteration customized to the unique factors pertinent to the attributes of the individual districts. The analytical engine, the K-means algorithm, identified homogenous areas within the city's commercial, industrial, and residential building sectors. The technique, conclusions, and possible uses of this clustering strategy are explained in this section. Finding homogenous clusters for every kind of building provides important information on the diversity of Mendoza's urban environment. These clusters give a detailed knowledge of the interactions between variables within particular types of districts, laying the groundwork for further analysis such as regression and correlation studies. The understanding that the popularity and distribution of different building types are critical factors in determining changes in energy use is essential to this investigation. Building size, design, and construction material choices all have a big impact on energy use. As a result, Mendoza's energy planning and optimization initiatives benefit greatly from the insights provided by this building stock study, which allows for a focused strategy to meet the distinct energy needs of various building types throughout the province. To partition the building stock of the city, the well-known K-means clustering technique is used. By assigning data points to clusters with the closest mean, this iterative process makes sure that each cluster reflects a unique collection of buildings that have common traits. Three distinct clustering studies were carried out, with a particular emphasis on one of the three main categories of buildings: residential, commercial/services, and industrial. During the clustering process, specific variables were carefully chosen for each type of building, taking into account factors like the building cover ratio, surface-to-volume ratio, population and building density, and different ratios of volume to family and inhabitant. These variables were selected to illuminate significant patterns within the data, take into account their applicability to the particular attributes of each form of building.

Residential Building Cluster: Several factors were taken into consideration while clustering residential structures, such as surface-to-volume ratios, building cover ratios, population density, building density, and different ratios of volume to family and occupant. Using the Euclidean distance in conjunction with the K-means method, the research revealed five homogenous clusters around the city. Every cluster is a collection of districts with comparable residential building characteristics. Mendoza's study of the building stock reveals an interesting trend in the main types of residential buildings. It is evident that detached houses, which are characterized by their individual entrances and isolated structures, predominate over other building styles in the area. This data highlights the preference for single-family homes among Mendoza residents. Detached houses make up the majority of the residential landscape; they are divided into three subgroups based on their geographic distribution: central, peripheral, and rural. The departments with the largest concentration of detached homes are Las Heras, Luján, and Maip. The entirety of Mendoza's housing stock is composed largely of these three departments. The capital city's remaining three municipalities have a higher percentage of apartments than detached homes. Although the precise ratio varies, there are some locations where apartment complexes are more common. In the capital city, the percentage of apartments is over 50%, indicating a more balanced distribution of households with attached and detached homes. The material quality uniformity seen in central locations is an important factor for energy categorization. However, blocks with more than 80% high-quality material buildings are grouped individually to further enhance this category. There might be several reasons for this variation in Mendoza's housing types, such as population density, urban planning techniques, and demographic preferences. There may be more detached homes in the departments of Las Heras, Luján, and Maip as a result of increased suburban expansion and land availability. On the other hand, the capital city and the neighboring municipalities may have seen a higher level of urbanization, which would have increased the need for apartment buildings to house people in constrained areas. Detached homes are more common in peripheral areas; high-density and low-density areas are distinguished by the building coverage ratio (BCR). For the latter, which are further classified according to altitude range, the height turns into a distinguishing feature. Single-family rural homes, on the other hand, make up a separate category.

Industrial Building Clustering: Using an approach similar to that of residential buildings but customized for the particular issues of industrial areas, the clustering analysis of buildings was conducted. A wide range of factors were carefully considered, such as the standard of industrial materials, floor area ratio, closeness to transit centers, and industrial density. Using the K-means algorithm, this analytically sound method revealed four separate homogenous clusters that each highlighted unique patterns related to industrial operations. These clusters provide useful insights into the distinguishing features of industrial zones within Mendoza's heterogeneous terrain, in addition to improving our understanding of the geographical distribution.

Commercial and Services Clustering: The quality of commercial structures, floor area ratio, closeness to city centers, and variety of services offered were among the important criteria covered by the clustering analysis in the analysis of commercial and service buildings. Using the K-means algorithm, this analytical method identified three homogenous clusters, revealing distinctive characteristics of the city's commercial and service sectors. These groups depicted regions with a high density of retail businesses, office buildings, and lodging facilities, offering a thorough grasp of the complex dynamics prevalent in Mendoza's business and service environment. Most of the empty homes are used for office, research, or commercial purposes, according to a survey of them. A third component, which is located in the Capital and other departments, is undefined, while the other half is up for grabs or rent. The distribution of empty homes for a variety of functions points to a dynamic real estate market with shifting consumer desires for different kinds of assets. Mendoza's growth rate distribution indicates that Guaymallen and Las Heras are the fastest-growing departments, with Luján following closely behind. There are more newly constructed and for sale homes in these departments. Vacation houses make up a comparatively small fraction of the population overall, with the Capital department and Luján municipality having the largest numbers.

Table 18 : Residential- Industrial – Commercial and Services Homogeneous Clusters Districts

RESIDENSIAL CLUSTER CLASS

RESIDENSIAL CLUSTER A	RESIDENSIAL CLUSTER B	RESIDENSIAL CLUSTER C	RESIDENSIAL CLUSTER D	RESIDENSIAL CLUSTER E
Ciudad (GC)	Capilla del Rosario	Carrodilla	Belgrano	Décimo Primera Sección
Cuarta Sección	Ciudad (L)	Chacras de Coria	Bermejo	El Sauce
Primera Sección	Ciudad (LH)	El Challao	Buena Nueva	Los Corralitos
Quinta Sección	Dorrego	Fray Luis Beltrán	Capdevila	Lunlunta
Segunda Sección	El Zapallar	General Gutierrez	Colonia Segovia	Presidente Sarmiento
Sexta Sección	Gobernador Benegas	La Cieneguita	Coquimbito	Vistalba
Tercera Sección	Las Cañas	La Puntilla	Cruz de Piedra	General Ortega
Villa Nueva	Las Tortugas	Maipú	El Algarrobal	La Primavera (Gy)
	Luzuriaga	Mayor Drummond	El Plumerillo	Perdriel
	Pedro Molina	San Francisco del Monte (Gy	El Resguardo	
	San Francisco del Monte -GC		Jesús Nazareno	
	San José (Gy)		Kilómetro 11	
			Las Compuertas	
			Panquegua	
			Rodeo de La Cruz	
			Rodeo del Medio	
			Russel	

INDUSTRIAL CLUSTER CLASS

INDUSTRIAL CLUSTER A	INDUSTRIAL CLUSTER B	INDUSTRIAL CLUSTER C	INDUSTRIAL CLUSTER D
Coquimbito	Belgrano	Buena Nueva	Capilla del Rosario
Cruz de Piedra	Bermejo	Carrodilla	Chacras de Coria
El Resguardo	Ciudad (LH)	Ciudad (GC)	Ciudad (L)
Kilómetro 11	General Gutierrez	Cuarta Sección	Jesús Nazareno
Las Tortugas	Gobernador Benegas	Dorrego	La Cieneguita
Luzuriaga	Pedro Molina	El Plumerillo	Mayor Drummond
Rodeo de La Cruz	Primera Sección	El Zapallar	Nueva Ciudad
San Francisco del Monte –(GC)	Quinta Sección	Las Cañas	San Francisco del Monte (Gy)
	Rodeo del Medio	Maipú	San José (Gy)
	Tercera Sección	Presidente Sarmiento	
	Villa Nueva	Segunda Sección	
		Sexta Sección	

COMMERCIAL AND SERVICES CLUSTER CLASS

COMMERCIAL AND SERVICES CLUSTER A	COMMERCIAL AND SERVICES CLUSTER B	COMMERCIAL AND SERVICES CLUSTER C
Belgrano	Bermejo	Colonia Segovia
Buena Nueva	Capdevila	Coquimbito
Ciudad (GC)	Capilla del Rosario	Cruz de Piedra
Cuarta Sección	Carrodilla	El Resguardo
Décimo Primera Sección	Chacras de Coria	El Sauce
El Zapallar	Ciudad (L)	Fray Luis Beltrán
Kilómetro 11	Ciudad (LH)	La Cieneguita
La Puntilla	Dorrego	Las Compuertas
Luzuriaga	El Algarrobal	Los Corralitos
Maipú	El Challao	Lunlunta
Pedro Molina	El Plumerillo	Rodeo del Medio
Presidente Sarmiento	General Gutierrez	San Francisco del Monte -GC
Rodeo de La Cruz	Gobernador Benegas	Vistalba
San Francisco del Monte (Gy)	Jesús Nazareno	
San José (Gy)	Las Cañas	
Segunda Sección	Las Tortugas	
Tercera Sección	Mayor Drummond	
Villa Nueva	Nueva Ciudad	
	Panquegua	
	Primera Sección	
	Quinta Sección	
	Sexta Sección	

Figure 43 : MAIN CHARACTERISTICS OF RESIDENTIAL CLUSTER CLASSES

	Footprint area of buildings (sum)	SUM of buildings volume m3	Volume Percentage of Detached house	Volume Percentage of Terrace house	Volume Percentage of Row house big	Volume Percentage of Tower	Area Percentage of INSOLATED BUILDINGS	Area Percentage of NO INSOLATED BUILDINGS	MEAN Height (M)	MEAN ANGLE	percentage MCAL1	percentage MCAL2	percentage MCAL3	percentage MCAL4	MEAN of Buildings cover ratio (%)	Average of surface-to-volume ratio	Number of inhabitants	Number of components per family	Num people/vol	Average of Number of people per building gross volume	Average of number of families per gross volume	Persons of agr1(0 - 14 years old)	Per of agr2(15 - 64 years old)	Per of agr3(65 and over years old)
A	7339642.36	30263408.53	67.29	17.59	5.80	9.32	9.58	90.42	5.27	-26.81	82.54	15.15	1.00	1.31	33.49	1.16	196393.00	2.16	0.01	3.73	2.09	14.94	67.58	17.48
B	7394606.90	24681541.40	94.49	4.59	0.61	0.32	13.68	86.32	3.25	-22.36	71.50	23.35	1.73	3.42	33.84	1.34	247600.00	3.22	0.01	3.93	1.21	21.45	65.63	12.92
C	4695096.81	14101003.46	96.99	2.81	0.09	0.11	29.46	70.54	3.17	-17.13	60.72	31.25	3.22	3.82	24.41	1.40	173918.00	3.34	0.01	8.80	2.65	25.06	64.76	9.18
D	4124410.18	12738991.85	98.80	1.10	0.08	0.01	36.70	63.30	3.09	-24.25	45.95	38.73	4.18	11.14	22.61	1.44	241573.00	3.86	0.03	11.70	3.11	28.61	63.41	7.98
E	1034604.15	3230625.24	98.01	1.75	0.07	0.17	52.14	47.86	3.08	-2.67	40.40	42.20	6.43	10.96	20.72	1.46	81091.00	3.59	0.11	79.03	21.28	29.17	64.16	6.67

Figure 44 : MAIN CHARACTERISTICS OF INDUSTRIAL CLUSTER CLASSES

	Footprint area of buildings (sum)	sum of buildings area floor m	SUM of buildings volume m3	SUM of buildings premiters m2	SUM of buildings floor surface m2	SUM of heavy industrial buildings volume m3	sum of heavy industrial buildings area floor m2	SUM of light industrial buildings volume m3	sum of light industrial area floor m2	MEAN ANGLE	MEAN Height (M)	percentage MCAL1	percentage MCAL2	percentage MCAL3	percentage MCAL4	Average of surface-to-volume ratio	MEAN of Buildings cover ratio (%)	Number of inhabitants	Number of families	Number of components per family	Num family/vol	Num people/vol	per of act1 (Busy)2	per of act2(Not busy)3	per of act3 (Inactive)4
A	93453	100981	296699	22011	256736	12049	4016	261107	96965	-47.25	3.15	49.04	38.10	4.04	8.83	1.34	22.35	29849	8219	3.71	0.10	0.39	59.60	4.73	35.67
B	119864	128646	385938	31340	341721	32166	10722	353772	117924	-30.43	3.18	71.75	21.57	1.93	4.74	1.30	32.36	61416	18614	3.24	0.14	0.45	61.65	4.31	34.04
C	206454	246441	708260	52862	591745	66180	24049	540567	222393	-16.06	3.37	67.92	25.91	1.93	4.24	1.38	30.82	79245	23856	3.38	0.15	0.44	62.42	4.64	32.94

Figure 45 : MAIN CHARACTERISTICS OF COMMERCIAL AND SERVICES CLUSTER CLASSES

	Footprint area of buildings (sum)	sum of buildings area floor m2	SUM of buildings volume m3	SUM of buildings premiters m2	SUM of buildings floor surface m2	SUM of commercial buildings volume m3	sum of commercial buildings area floor m2	SUM of servises buildings volume m3	sum of servises buildings area floor m2	MEAN ANGLE	MEAN Height (M)	percentage MCAL1	percentage MCAL2	percentage MCAL3	percentage MCAL4	Average of surface-to-volume ratio	MEAN of Buildings cover ratio (%)	Number of inhabitants	Number of families	Num family/vol	Num people/vol	per of act1 (Busy)2	per of act2(Not busy)3	per of act3 (Inactive)4
A	1371477	1903202	5696450	408768	4416157	3105017	1265263	1557922	637939	-23.18	3.73	67.51	25.19	2.13	5.17	1.31	30.09	308409	94708	0.03	0.10	61.70	4.64	33.67
B	747254	953907	2840468	239747	2394363	1643085	604007	903515	349900	-19.92	3.45	64.78	27.04	2.45	5.22	1.38	29.38	297544	87873	0.06	0.21	60.80	4.46	34.23
C	54315	58976	176928	16891	164547	81599	30642	85002	28334	-27.86	3.29	50.30	39.35	3.95	6.41	1.33	20.58	54353	14469	0.15	0.56	60.45	4.68	34.88

Figure 46 : RESIDENTIAL HOMOGENEOUS DISTRICTS CLUSTER

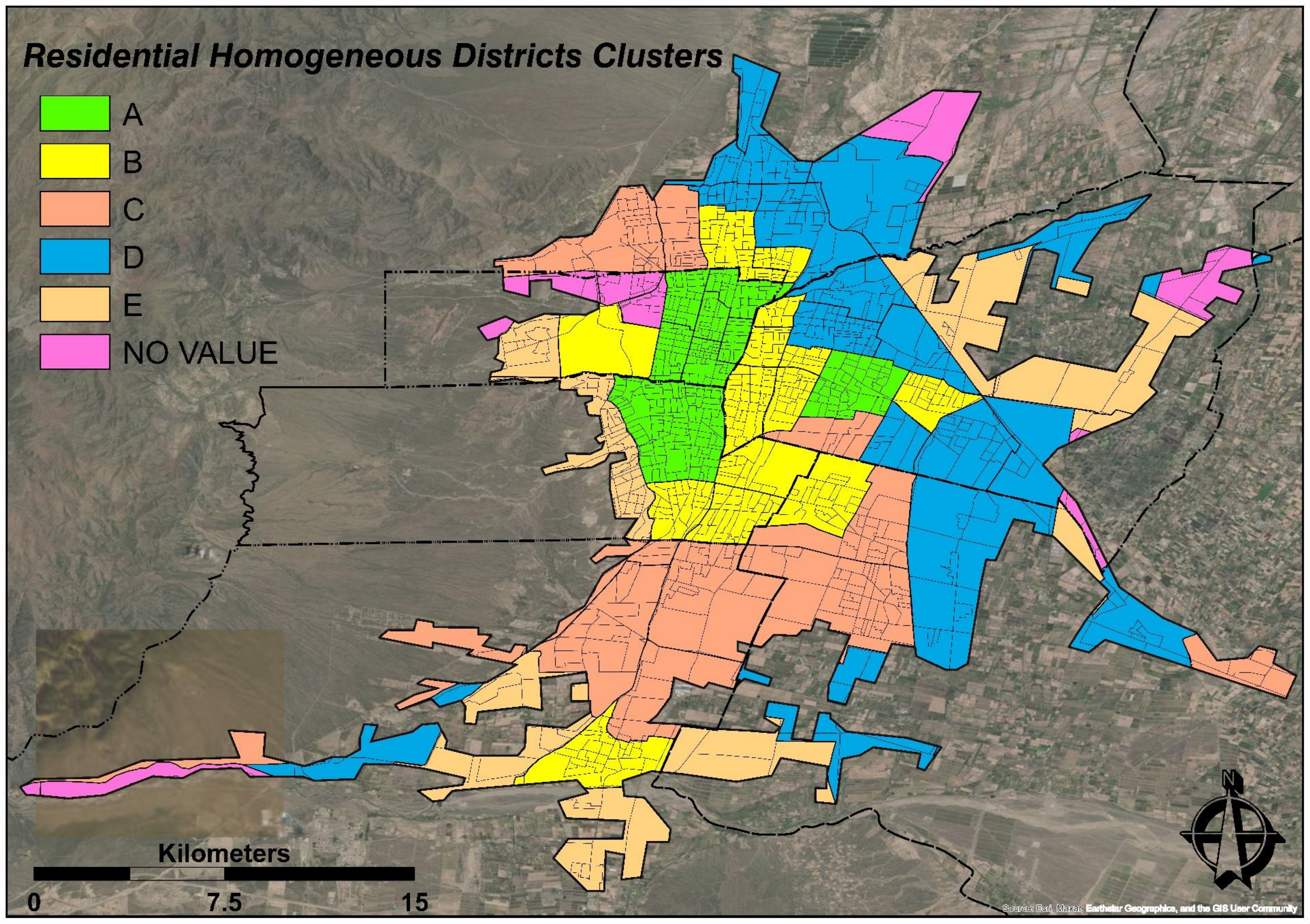


Figure 47 : INDUSTRIAL HOMOGENEOUS DISTRICTS CLUSTER

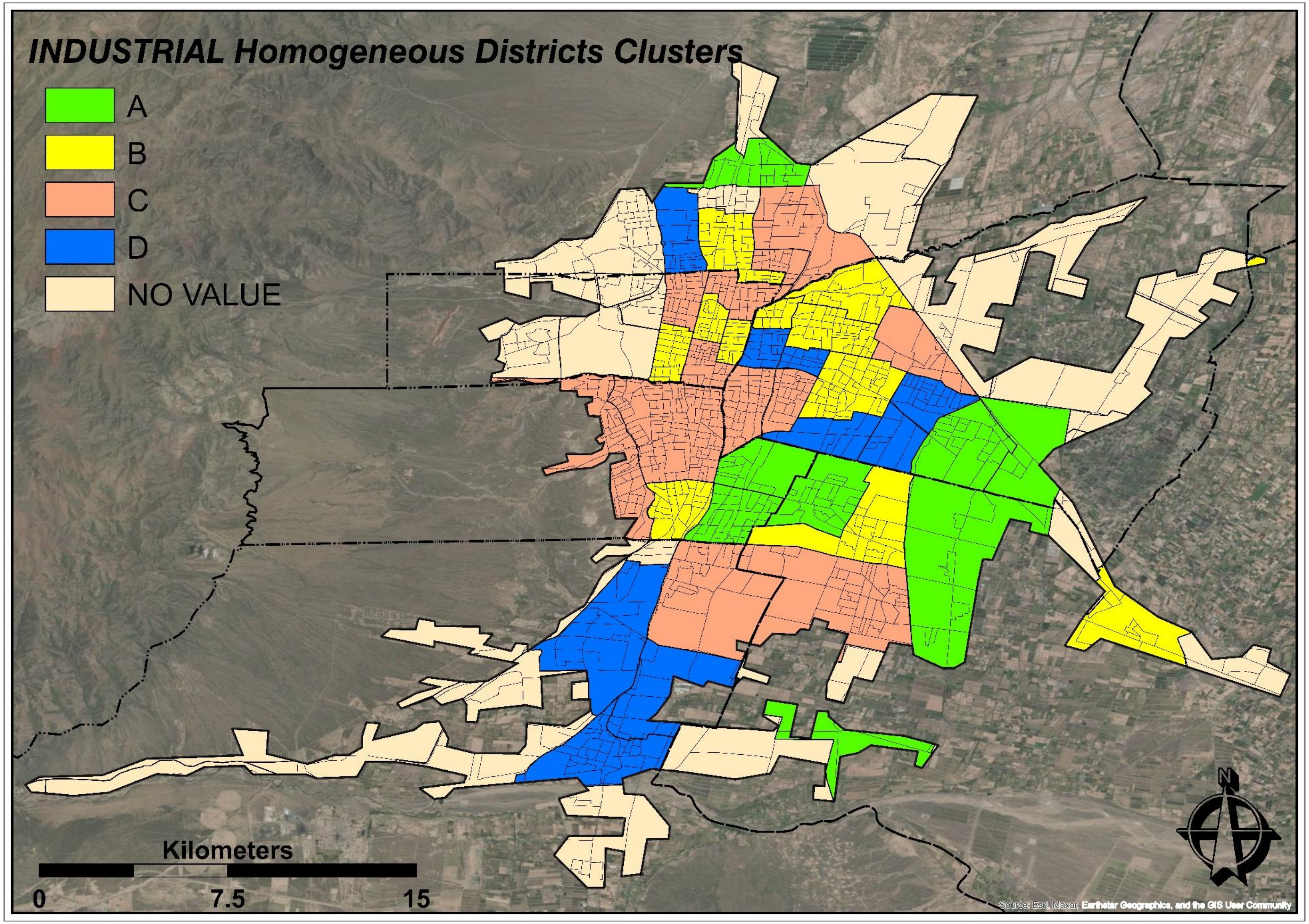
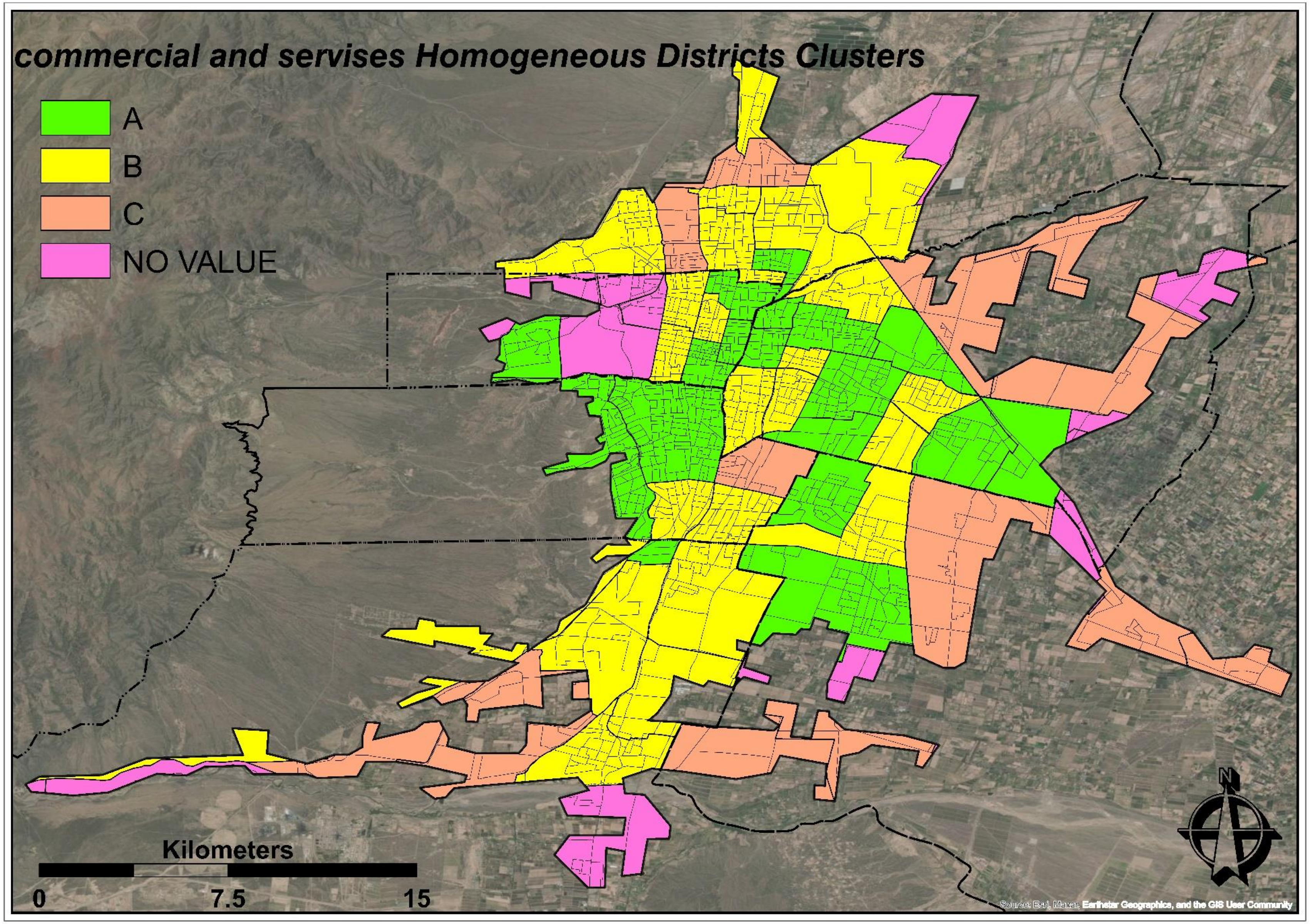


Figure 48 : COMMERCIAL AND SERVICES HOMOGENEOUS DISTRICTS CLUSTER



4.7 ENERGY CONSUMPTION OF NATURAL GAS

Natural gas is the main energy source that Mendoza, Argentina depends on for several different applications, including power generation, commercial, industrial, and residential. The importance of natural gas energy consumption in Mendoza is still fundamental to the region's energy landscape, even though the specifics may differ and may have changed over time.

The demand for natural gas is increased by the region's colder winters, especially in residential and commercial buildings where it is widely used for heating. Natural gas is essential for cooking, water heating, and space heating in household settings. Likewise, for comparable heating needs, establishments such as eateries, lodging facilities, and motels significantly depend on natural gas in the commercial sector. Natural gas is essential to Mendoza's industrial sector in addition to its use in home and commercial settings. Natural gas is used extensively in Mendoza's industrial environment, where it is the main energy source for process heating and a feedstock for several different production processes, such as the synthesis of chemicals, fertilizers, and metals. Its flexibility also extends to process heating, where it is used to achieve desired temperatures and conditions in a variety of manufacturing processes. The intelligent use of natural gas in industrial applications greatly lowers operating costs and improves production efficiency.

Moreover, natural gas plays a crucial part in Mendoza's energy generation industry. A large amount of the electricity produced in the area comes from gas-fired power facilities. This contributes to a varied and resilient energy mix by offering a dependable and flexible energy source that works well with other renewable energy sources. It is important to acknowledge that particulars of Mendoza's natural gas consumption may have changed over time, and current information would be crucial in furnishing a thorough and precise depiction of the state of the energy sector now. Mendoza's many industries have complex energy demands, which is why natural gas use optimization and ongoing exploration are so important.

The Ecogas company supplies natural gas to the Mendoza metropolitan area. Distribuidora de Gas Cuyana, which operates in the provinces of Mendoza, San Luis, and San Juan, is the party responsible for managing gas distribution in the network. With a calorific value of 9300 kcal per m3, the amount of natural gas used throughout the network is expressed in cubic meters (m3). Natural gas is mostly used in power plants, where it is burned to produce electricity. Consequently, the home sector receives around half of the natural gas that is meant for power plants. It is used in homes for cooking, heating, and producing hot water. Along with the business, services, and transportation sectors, home consumption has been trending upward. Nonetheless, the transportation industry is experiencing a decline in the need for compressed natural gas. Natural gas consumption in the industrial sector varies according to the usage of the gas in power plants and other industrial activities.

Growth in the population, changes in consumer behavior, and economic development are probably the main causes of the trend of rising natural gas use in the transportation, commercial, residential, and service sectors. The need for commercial buildings, public transit, public heating, and other services rises with urbanization and economic activity. On the other side, the use of alternative fuels or more energy-efficient transportation technology may have an impact on the decline in the demand for compressed natural gas in the transportation sector. Furthermore, modifications to energy-intensive manufacturing processes, shifts in industrial output, or energy-efficiency initiatives might all be contributing factors to the industry's erratic usage.

Overall, Mendoza's gas consumption patterns have evolved throughout time due to a variety of reasons, including population growth, economic activity, climatic shifts, and advancements in energy-saving technologies. When developing tailored energy management and sustainability strategies for the region, energy planners and policymakers may find valuable information from these variations in gas consumption. Possible correlations between changes in gas use and the implementation of energy-saving measures can be found using correlation analysis. To determine whether there is a meaningful connection between the implementation of energy-saving measures and the noted drops in gas consumption, statistical data must be examined.

The total amount of energy saved by energy efficiency measures may also be influenced by variables other than direct decreases in gas consumption. We attempted to use correlation in the next phases, thus we went into much more detail than we did in this one. A thorough analysis of the energy consumption units in each Mendoza sector across a range of years is shown in the table and graph below. The simplicity of comparison and trend detection in energy consumption patterns is made possible by this information. We have chosen 2017 as the reference year to guarantee the precision of our computations for the general audience. This choice corresponds with the year when the administrative changes made by the city were last reflected in our GIS data. Therefore, the data that is most comparable to the contemporary cityscape comes from 2017.

Figure 49 : Gas consumption Trent in different sectors of Mendoza kWh (2010-2021) (Authors)

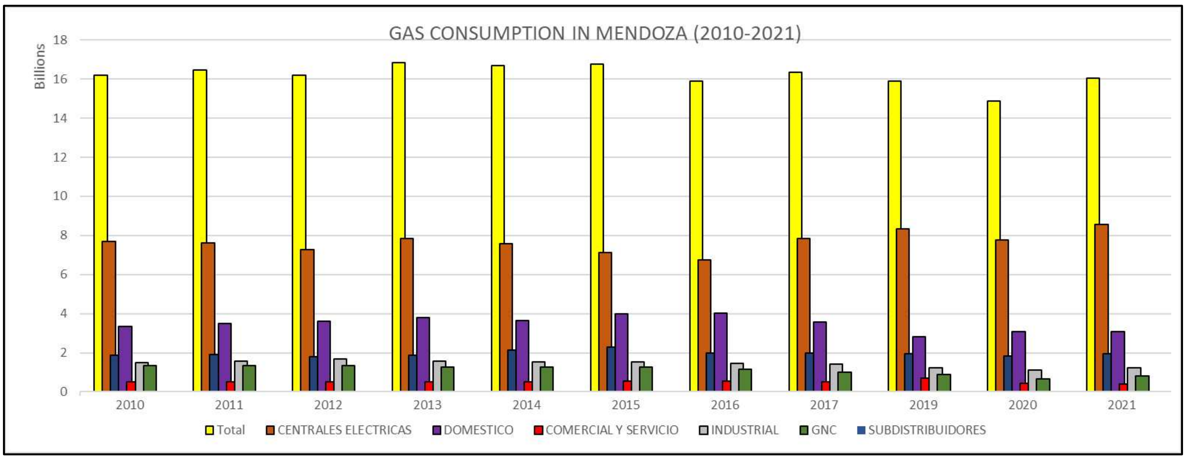
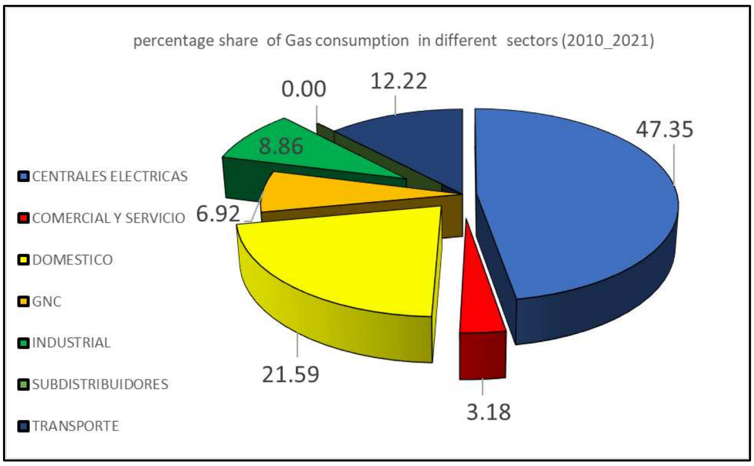
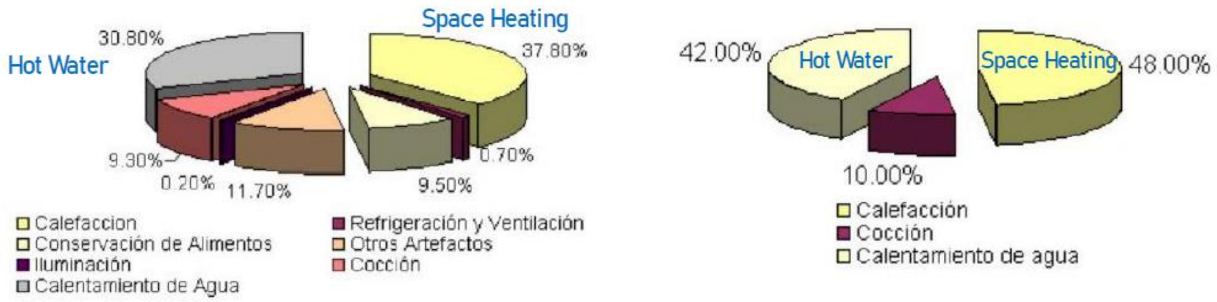


Figure 50 : percentage share of Gas consumption in different sectors (2010_2021) (Authors)



Regarding the home building industry, it is important to note that of the total energy utilized in the urban domestic building industry, 37.8% goes toward heating and 30.8% goes toward water heating. Gas usage in each department and district of Mendoza has been estimated for the years 2010 to 2021 based on the data gathered and examined. The information sheds light on the trends and patterns of gas usage during the last ten years in the province's various areas. The three main applications of distributed gas are cooking (10%), water heating (42%), and heating (48%). Ninety percent of the overall consumption is explained by the two applications of water heating and heating.

Figure 51 : The energy consumption of buildings by end-use (Arboil, Mesa, Fernandez, & de Rosa, 2008)



4.7.1 Main database (Gas consumption from M3 to kWh)

This all-inclusive model that pulls information from several sources gives the study of natural gas use in the Mendoza metropolitan region a more precise and in-depth look. The model gives important insights into the patterns of energy use in the residential, commercial, industrial, and transportation sectors by dividing the data into distinct districts and usage categories.

The emphasis on kilowatt-hours of gas use is a helpful signal for assessing the energy needs of households. This information may be used to pinpoint areas with excessive energy use, identify potential energy-saving opportunities, and develop customized building energy efficiency programs.

1 cubic meter (m^3) of gas with a calorific value of 9300 kcal is equivalent to 10.81 kilowatt-hours (kWh)

1 cubic meter (m^3) *10.81 = kWh

In addition to selecting 2017 as the reference year, we further refined our analysis by normalizing gas consumption based on various variables. This normalization process enables us to compare energy consumption patterns across different households and neighborhoods while accounting for factors such as household size, dwelling size, and occupancy.

- Consumption not normalized and normalized with respect to average share kWh and kWh(n_alt)
- Consumption not normalized and normalized with respect to average share kWh/m3 and kWh(n_alt)/m3
- Consumption not normalized and normalized with respect to average share kWh/m2 and kWh(n_alt)/m2
- Consumption not normalized and normalized with respect to average share kWh/ inh and kWh(n_alt)/inh
- Consumption not normalized and normalized with respect to average share kWh /family and kWh(n_alt)/family

Table 19 : Normalized GAS energy consumption 2017 FOR residential sector (Authors)

			NORMALIZED BY ALTITUDE					NOT NORMALIZED			
RESIDENSIAL	**DISTRITOS**	**DOMESTICO 2017 kWh22**	**Consumo normalizzato rispetto a quota media kWh(n_alt)**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/m3**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/m 2**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/inh**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/fam**	**Consumo rispetto a quota media kWh/m3**	**Consumo rispetto a quota media kWh/m2 (not normal)**	**Consumo rispetto a quota media kWh/inh (not normal)**	**Consumo rispetto a quota media kWh/fam (not normal)**
A	**Ciudad (GC)**	289472748.8	295405704.1	31.8	110.5	3736.9	10194.8	31.1	108.3	3661.8	9990.1
	Cuarta Sección	76575004.8	101644865.9	32.8	119.1	4918.0	12165.8	24.7	89.8	3705.0	9165.2
	Primera Sección	36589494.6	45047157.1	22.8	71.1	4759.8	9000.4	18.5	57.8	3866.2	7310.6
	Quinta Sección	93341759.6	103644406.3	31.3	142.5	7305.1	14379.1	28.2	128.3	6578.9	12949.7
	Segunda Sección	73634135.2	86624809.2	22.1	76.0	6181.7	7966.2	18.8	64.6	5254.7	6771.6
	Sexta Sección	147501293.4	176024125.6	66.1	235.4	10057.4	24420.7	55.4	197.2	8427.7	20463.6
	Tercera Sección	29806296.8	37219596.1	16.4	47.5	4790.2	7545.0	13.1	38.1	3836.1	6042.2
	Villa Nueva	142047865.5	188319118.4	50.5	177.5	5582.0	16355.7	38.1	133.9	4210.4	12337.0
B	**Capilla del Rosario**	64912230.9	93630718.8	63.9	197.4	5120.9	17368.0	44.3	136.9	3550.2	12040.9
	Ciudad (L)	100635145.3	74881300.5	31.2	103.8	3070.8	9918.1	41.9	139.5	4126.9	13329.2
	Ciudad (LH)	109946479.8	150866710.7	42.8	138.7	4239.0	13112.0	31.2	101.1	3089.3	9555.6
	Dorrego	111786654.7	130712546.2	35.1	116.3	4436.5	12280.4	30.0	99.5	3794.1	10502.3
	El Zapallar	38769311.7	55200992.9	53.4	167.6	4574.2	14599.6	37.5	117.7	3212.6	10253.7
	Gobernador Benegas	122122913.6	113686746.1	42.4	138.8	5067.8	15392.2	45.6	149.1	5443.9	16534.4
	Las Cañas	68334682.2	84321294.4	64.2	213.4	5755.7	17910.2	52.1	172.9	4664.5	14514.6
	Las Tortugas	112328119.7	109619409.2	44.1	144.8	3044.4	11694.0	45.2	148.3	3119.6	11982.9
	Luzuriaga	88096839.2	96000849.8	54.3	170.4	4257.4	14612.0	49.8	156.3	3906.9	13409.0
	Pedro Molina	32555411.5	44819610.9	36.6	115.6	4077.5	13059.3	26.6	84.0	2961.7	9485.8
	San Francisco del Monte -GC	38370413.2	40017695.8	32.6	219.0	4405.3	15367.8	31.3	209.9	4224.0	14735.2
	San José (Gy)	44086115.5	57974204.3	31.5	105.0	4793.2	13686.1	23.9	79.8	3645.0	10407.5
C	**Carrodilla**	114571987.1	102122582.0	62.3	193.5	4659.7	15091.3	69.9	217.1	5227.8	16931.0
	Chacras de Coria	157122154.4	122042615.5	56.1	182.0	9079.9	26223.2	72.2	234.3	11689.8	33760.7
	El Challao	116382836.7	120692656.0	79.7	247.1	4288.2	15147.2	76.9	238.3	4135.1	14606.3
	Fray Luis Beltrán	21725396.7	34249389.4	108.6	330.3	5420.1	18403.8	68.9	209.5	3438.1	11674.0
	General Gutierrez	74242818.5	81219866.1	44.8	138.7	3853.5	14135.0	41.0	126.8	3522.5	12920.8
	La Cieneguita	57143444.3	71866391.8	62.5	199.7	4623.4	15297.2	49.7	158.8	3676.2	12163.4
	La Puntilla	22598752.4	19456056.1	38.8	126.9	6948.6	22337.6	45.0	147.4	8071.0	25945.8
	Maipú	182341288.1	187295082.6	51.1	159.8	4213.7	14843.5	49.8	155.6	4102.3	14450.9
	Mayor Drummond	59200645.5	45836672.0	61.6	193.1	4928.7	16523.7	79.6	249.4	6365.7	21341.3
	San Francisco del Monte (Gy	47937573.4	57987423.7	99.1	146.4	5306.8	17330.4	82.0	121.0	4387.1	14326.8
D	**Belgrano**	81388806.9	117881097.1	43.1	134.9	2817.8	11830.7	29.8	93.1	1945.5	8168.3
	Bermejo	41308214.8	62652734.8	69.0	212.9	3847.0	15488.9	45.5	140.4	2536.4	10212.2
	Buena Nueva	33643154.6	50705647.7	65.0	203.8	3709.8	14778.7	43.1	135.3	2461.5	9805.6
	Capdevila	4923772.6	7272633.2	42.3	127.2	2140.9	9023.1	28.6	86.1	1449.4	6108.9
	Colonia Segovia	9954075.8	18755560.4	183.0	917.7	3914.7	14909.0	97.1	487.0	2077.7	7912.6
	Coquimbito	49816036.5	59372791.9	72.5	219.4	3042.4	12060.3	60.8	184.1	2552.7	10119.0
	Cruz de Piedra	11873516.8	11380613.5	156.1	472.1	2959.8	10666.0	162.9	492.5	3088.0	11127.9
	El Algarrobal	16769341.7	26185293.7	68.1	206.0	2609.4	11062.7	43.6	132.0	1671.1	7084.6
	El Plumerillo	79541229.2	116170068.0	55.3	169.1	2895.3	11889.3	37.9	115.8	1982.4	8140.5
	El Resguardo	40093634.4	58496202.9	69.8	210.3	2479.2	11387.2	47.8	144.1	1699.2	7804.9
	Jesús Nazareno	23701517.4	30054405.8	61.9	193.2	3766.7	14318.4	48.9	152.3	2970.5	11291.8
	Kilómetro 11	23131012.7	34839376.9	91.1	283.2	5311.7	18660.6	60.5	188.0	3526.6	12389.4
	Las Compuertas	6164795.7	3871709.9	53.1	161.6	4681.6	10135.4	84.6	257.2	7454.4	16138.2
	Panquegua	30302498.8	42622199.6	50.4	154.9	3145.1	12419.1	35.8	110.2	2236.0	8829.4
	Rodeo de La Cruz	50928227.8	73139642.8	47.8	146.6	3637.7	14152.4	33.3	102.1	2533.0	9854.5
	Rodeo del Medio	31996691.0	45462239.8	93.7	287.1	3828.4	14842.4	66.0	202.1	2694.5	10446.2
	Russel	12516047.7	12100781.4	469.4	1457.0	3375.4	12462.2	485.5	1507.0	3491.2	12889.9
E	**Décimo Primera Sección**	16561446.8	12206536.1	181.6	549.7	1441.1	5755.1	246.4	745.8	1955.3	7808.3
	El Sauce	29269814.3	48145630.0	230.3	694.4	4470.8	17991.6	140.0	422.1	2718.0	10937.9
	Los Corralitos	23689107.6	43647382.0	550.1	1663.6	12357.7	42791.6	298.6	902.9	6707.0	23224.6
	Lunlunta	17946621.3	14657059.6	522.6	1667.7	6428.5	20702.1	639.9	2042.0	7871.3	25348.3
	Presidente Sarmiento	105988249.6	92917508.5	45.7	143.4	2192.7	8827.4	52.1	163.6	2501.2	10069.2
	Vistalba	73238195.7	50915839.0	65.9	206.0	5764.3	17575.4	94.8	296.3	8291.4	25280.7
	General Ortega	1825988.2	2717344.4	511.3	1603.0	1518.1	5856.3	343.6	1077.2	1020.1	3935.3
	La Primavera (Gy)	4966878.5	7493144.9	1624.4	4873.3	7895.8	26666.0	1076.8	3230.3	5233.8	17675.7
	Perdriel	55072036.2	40545770.7	1371.4	4114.2	19372.1	64256.4	1862.7	5588.1	26312.5	87277.4

Table 20 : Normalized GAS energy consumption 2017 FOR industrial sector(Authors)

				NORMALIZED BY ALTITUDE				NOT NORMALIZED			
	DISTRITOS	**INDUSTRIAL Consum kWh 2017**	**INDUSTRIAL (normRussel) kWh 2017**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/m3**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/m2**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/inh**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/fam**	**Consumo rispetto a quota media kWh/m3**	**Consumo rispetto a quota media kWh/m2 (not normal)**	**Consumo rispetto a quota media kWh/inh (not normal)**	**Consumo rispetto a quota media kWh/fam (not normal)**
A	**Coquimbito**	**25231901.0**	**30072412.7**	**1323.1**	**3969.2**	**8555.5**	**31489.4**	**1110.1**	**3330.3**	**7178.4**	**26420.8**
	Cruz de Piedra	**18476042.8**	**17709050.0**	**13005.0**	**39014.9**	**13889.5**	**49744.5**	**13568.2**	**40704.7**	**14491.0**	**51899.0**
	El Resguardo	**14861483.9**	**21682753.2**	**8744.5**	**26233.6**	**6620.7**	**28269.6**	**5993.6**	**17980.7**	**4537.9**	**19376.1**
	Kilómetro 11	**31338406.3**	**47201156.4**	**2981.5**	**8990.1**	**23103.8**	**81521.9**	**1979.5**	**5968.8**	**15339.4**	**54125.1**
	Las Tortugas	**35424453.3**	**34570218.5**	**1072.8**	**4423.2**	**3575.0**	**12413.0**	**1099.3**	**4532.5**	**3663.3**	**12719.7**
	Luzuriaga	**188839033.4**	**205781590.5**	**1532.7**	**4861.2**	**44102.4**	**157085.2**	**1406.5**	**4460.9**	**40471.3**	**144151.9**
	Rodeo de La Cruz	**416842067.1**	**598640110.3**	**7357.2**	**22071.5**	**143181.1**	**516069.1**	**5122.9**	**15368.7**	**99699.1**	**359346.6**
	San Francisco del Monte -GC	**16492213.0**	**17200241.3**	**2669.4**	**8286.3**	**14052.5**	**56026.8**	**2559.5**	**7945.2**	**13474.0**	**53720.6**
B	**Belgrano**	**1771785.1**	**2566200.1**	**238.8**	**757.5**	**373.6**	**1378.2**	**164.9**	**523.0**	**258.0**	**951.5**
	Bermejo	**6347026.6**	**9626622.2**	**563.3**	**1852.6**	**3004.6**	**10672.5**	**371.4**	**1221.5**	**1981.0**	**7036.6**
	Ciudad (LH)	**2172961.7**	**2981701.5**	**186.5**	**562.7**	**277.0**	**916.6**	**135.9**	**410.1**	**201.8**	**668.0**
	General Gutierrez	**111115851.1**	**121558081.0**	**562.8**	**1870.7**	**12317.2**	**42295.8**	**514.5**	**1710.0**	**11259.1**	**38662.4**
	Gobernador Benegas	**1450196.4**	**1350017.8**	**108.6**	**331.4**	**280.8**	**886.4**	**116.7**	**356.0**	**301.7**	**952.2**
	Pedro Molina	**4197270.6**	**5778456.7**	**494.4**	**1585.9**	**1158.5**	**3809.1**	**359.1**	**1151.9**	**841.5**	**2766.8**
	Primera Sección	**1751790.4**	**2156716.8**	**411.1**	**1233.3**	**1259.0**	**3407.1**	**333.9**	**1001.7**	**1022.6**	**2767.4**
	Quinta Sección	**742153.3**	**824068.9**	**161.5**	**553.2**	**211.0**	**573.5**	**145.5**	**498.2**	**190.1**	**516.5**
	Rodeo del Medio	**647167.7**	**919523.0**	**537.5**	**1612.4**	**631.5**	**2133.5**	**378.3**	**1134.8**	**444.5**	**1501.5**
	Tercera Sección	**617040.6**	**770508.4**	**148.1**	**444.7**	**278.7**	**860.9**	**118.6**	**356.1**	**223.2**	**689.4**
	Villa Nueva	**21232396.5**	**28148724.3**	**332.1**	**1014.6**	**2541.6**	**8563.7**	**250.5**	**765.3**	**1917.1**	**6459.5**
C	**Buena Nueva**	**3939849.6**	**5937987.3**	**97.5**	**300.8**	**827.0**	**3170.3**	**64.7**	**199.6**	**548.7**	**2103.5**
	Carrodilla	**3453145.2**	**3077926.1**	**41.9**	**146.3**	**668.1**	**2373.1**	**47.0**	**164.1**	**749.5**	**2662.4**
	Ciudad (GC)	**11424611.8**	**11658767.6**	**85.6**	**346.8**	**743.9**	**2267.8**	**83.9**	**339.8**	**729.0**	**2222.3**
	Cuarta Sección	**1969117.5**	**2613786.1**	**103.8**	**401.3**	**291.6**	**842.1**	**78.2**	**302.3**	**219.7**	**634.4**
	Dorrego	**2241728.8**	**2621261.8**	**41.8**	**131.8**	**342.8**	**1054.8**	**35.7**	**112.7**	**293.2**	**902.1**
	El Plumerillo	**2428471.9**	**3546786.4**	**77.6**	**240.5**	**315.1**	**1223.5**	**53.1**	**164.6**	**215.7**	**837.7**
	El Zapallar	**4673619.8**	**6654450.2**	**97.5**	**292.4**	**9843.9**	**35585.3**	**68.5**	**205.4**	**6913.6**	**24992.6**
	Las Cañas	**1296741.5**	**1600108.8**	**47.2**	**170.9**	**390.3**	**1231.8**	**38.3**	**138.5**	**316.3**	**998.3**
	Maipú	**5612182.9**	**5764653.1**	**40.4**	**142.2**	**481.4**	**1804.8**	**39.4**	**138.4**	**468.6**	**1757.1**
	Presidente Sarmiento	**2168256.2**	**1900861.3**	**33.6**	**109.3**	**1121.5**	**4740.3**	**38.3**	**124.6**	**1279.2**	**5407.1**
	Segunda Sección	**81356.9**	**95710.1**	**58.7**	**212.0**	**35.9**	**95.9**	**49.9**	**180.2**	**30.5**	**81.5**
	Sexta Sección	**333183.9**	**397612.8**	**343.8**	**1031.5**	**141.8**	**406.6**	**288.1**	**864.4**	**118.8**	**340.7**
D	**Capilla del Rosario**	**200088.9**	**288612.3**	**9.5**	**30.1**	**71.2**	**262.6**	**6.6**	**20.9**	**49.3**	**182.1**
	Chacras de Coria	**207260.7**	**160987.1**	**2.4**	**7.9**	**17.4**	**61.5**	**3.1**	**10.2**	**22.5**	**79.2**
	Ciudad (L)	**633940.3**	**471706.7**	**15.5**	**49.8**	**141.8**	**483.8**	**20.8**	**66.9**	**190.6**	**650.2**
	Jesús Nazareno	**90536.7**	**114803.9**	**10.2**	**39.6**	**37.1**	**144.2**	**8.1**	**31.2**	**29.3**	**113.7**
	La Cieneguita	**311147.9**	**391314.8**	**23.5**	**70.5**	**512.9**	**1811.6**	**18.7**	**56.1**	**407.8**	**1440.5**
	Mayor Drummond	**193033.5**	**149458.1**	**2.4**	**7.4**	**22.9**	**86.2**	**3.1**	**9.6**	**29.6**	**111.4**
	Nueva Ciudad	**2290.5**	**3056.5**	**0.1**	**0.3**	**0.6**	**2.1**	**0.1**	**0.2**	**0.4**	**1.6**
	San Francisco del Monte (Gy	**2520610.8**	**3049043.1**	**13.7**	**44.1**	**966.1**	**3339.6**	**11.3**	**36.4**	**798.7**	**2760.8**
	San José (Gy)	**841727.8**	**1106890.4**	**18.6**	**61.7**	**213.3**	**679.1**	**14.2**	**46.9**	**162.2**	**516.4**

Table 21 : Normalized GAS energy consumption 2017 FOR commercial and services sector(Authors)

	DISTRITOS	**COMERCIAL Y SERVICIO kWh 20172**	**COMERCIAL Y SERVICIO (norm) kWh 2017**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/m3**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/m2**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/inh**	**Consumo normalizzato rispetto a quota media kWh(n_alt)/fam**	**Consumo rispetto a quota media kWh/m3**	**Consumo rispetto a quota media kWh/m2 (not normal)**	**Consumo rispetto a quota media kWh/inh (not normal)**	**Consumo rispetto a quota media kWh/fam (not normal)**
A	Belgrano	5495980.6	7960212.8	28.0	88.7	241.4	899.5	19.3	61.2	166.7	621.0
	Buena Nueva	1635231.6	2464557.2	52.2	258.3	383.8	1439.6	34.6	171.4	254.6	955.2
	Ciudad (GC)	45272770.2	46200668.7	39.0	144.5	654.7	1992.6	38.2	141.6	641.5	1952.6
	Cuarta Sección	11437742.0	15182339.9	51.4	185.0	797.8	2315.1	38.7	139.4	601.0	1744.1
	Décimo Primera Sección	885226.6	652452.1	35.4	106.1	200.1	775.8	48.0	143.9	271.5	1052.6
	El Zapallar	1360025.4	1936448.0	30.9	100.0	208.7	721.2	21.7	70.2	146.6	506.5
	Kilómetro 11	913949.4	1376568.7	28.0	88.7	312.1	1099.5	18.6	58.9	207.2	730.0
	La Puntilla	425867.2	366644.0	28.1	84.4	130.9	453.8	32.7	98.0	152.1	527.1
	Luzuriaga	3597562.2	3920333.9	28.1	87.9	307.2	1074.4	25.8	80.6	281.9	985.9
	Maipú	20369549.3	20922943.2	49.5	209.3	707.4	2501.8	48.2	203.8	688.6	2435.7
	Pedro Molina	2632724.7	3624518.7	51.7	177.4	329.7	1100.7	37.6	128.9	239.5	799.5
	Presidente Sarmiento	4571909.8	4008090.3	39.3	126.1	201.5	752.6	44.8	143.8	229.8	858.4
	Rodeo de La Cruz	5768407.0	8284192.2	67.9	241.8	513.6	1867.1	47.3	168.4	357.6	1300.1
	San Francisco del Monte (Gy	2262072.2	2736303.2	11.0	38.3	300.7	993.2	9.1	31.7	248.6	821.1
	San José (Gy)	11286256.7	14841674.0	49.1	193.4	1227.1	3830.1	37.3	147.1	933.1	2912.6
	Segunda Sección	44974433.3	52908908.2	46.4	277.8	3979.3	9672.6	39.5	236.1	3382.6	8222.0
	Tercera Sección	31518554.3	39357719.2	54.9	287.1	5065.3	13220.6	44.0	230.0	4056.4	10587.
	Villa Nueva	20513656.9	27195859.5	56.7	230.0	969.8	3136.4	42.8	173.5	731.5	2365.8
B	Bermejo	5649220.9	8568250.7	84.6	268.8	868.1	3438.3	55.8	177.2	572.4	2266.9
	Capdevila	315912.0	466616.2	225.8	677.3	177.6	708.1	152.8	458.5	120.3	479.4
	Capilla del Rosario	2463865.6	3553929.7	96.6	311.5	393.1	1349.8	67.0	216.0	272.6	935.8
	Carrodilla	7064412.9	6296793.0	64.6	206.6	454.8	1663.2	72.5	231.8	510.2	1865.9
	Chacras de Coria	10342299.6	8033248.4	87.2	281.2	867.4	3049.8	112.3	362.0	1116.8	3926.5
	Ciudad (L)	13063275.3	9720213.0	53.1	179.3	614.7	2044.6	71.3	241.0	826.2	2747.8
	Ciudad (LH)	9366521.1	12852582.8	70.2	238.4	375.1	1267.0	51.2	173.8	273.3	923.4
	Dorrego	12096211.7	14144144.8	61.4	230.0	566.6	1735.9	52.5	196.7	484.6	1484.6
	El Algarrobal	3172453.7	4953780.2	137.9	426.4	818.5	3165.4	88.3	273.0	524.2	2027.1
	El Challao	4509682.4	4676682.2	104.9	343.7	348.5	1279.9	101.2	331.5	336.1	1234.2
	El Plumerillo	13136045.6	19185211.6	148.2	472.7	783.0	3074.6	101.5	323.7	536.1	2105.1
	General Gutierrez	5508217.8	6025858.4	81.6	266.5	342.3	1210.7	74.6	243.6	312.9	1106.7
	Gobernador Benegas	8225984.6	7657739.2	92.8	298.8	521.8	1651.8	99.7	321.0	560.5	1774.4
	Jesús Nazareno	2669094.6	3384511.3	80.6	277.5	978.2	3790.0	63.6	218.9	771.4	2988.9
	Las Cañas	5479626.5	6761562.1	121.9	480.8	603.4	2014.8	98.8	389.6	489.0	1632.8
	Las Tortugas	7901871.6	7711323.8	68.3	237.9	290.5	1071.0	70.0	243.7	297.7	1097.5
	Mayor Drummond	4372395.0	3385369.1	66.9	238.4	429.3	1581.2	86.4	308.0	554.5	2042.2
	Nueva Ciudad	9584663.7	12789983.4	73.3	309.0	1651.0	5546.4	55.0	231.6	1237.2	4156.4
	Panquegua	2338564.9	3289325.5	211.3	682.8	435.3	1666.3	150.2	485.5	309.5	1184.7
	Primera Sección	26805343.2	33001398.9	70.2	336.0	4214.2	11690.2	57.1	272.9	3423.0	9495.3
	Quinta Sección	36411752.7	40430719.4	108.1	568.1	2919.6	7653.0	97.3	511.6	2629.4	6892.2
	Sexta Sección	35667347.1	42564464.7	168.2	590.3	2741.3	7634.9	140.9	494.7	2297.1	6397.7
C	Colonia Segovia	1933216.2	3642583.6	2335.1	7005.4	1351.6	5256.3	1239.3	3717.9	717.3	2789.6
	Coquimbito	5140888.7	6127121.6	237.2	757.9	423.2	1582.8	199.0	635.9	355.1	1328.1
	Cruz de Piedra	1769685.1	1696220.5	545.8	1637.5	695.5	2498.1	569.5	1708.4	725.6	2606.3
	El Resguardo	9324870.5	13604890.8	422.5	1394.6	1354.9	5728.4	289.6	955.9	928.7	3926.3
	El Sauce	3802423.7	6254569.3	716.7	2675.1	2107.3	8809.3	435.7	1626.3	1281.1	5355.5
	Fray Luis Beltrán	4539792.1	7156836.3	428.5	1426.7	1834.1	6418.7	271.8	905.0	1163.5	4071.6
	La Cieneguita	1616404.1	2032868.8	577.4	1885.8	748.5	2374.8	459.1	1499.4	595.1	1888.3
	Las Compuertas	480940.5	302047.6	114.7	344.2	365.2	1237.9	182.7	548.1	581.5	1971.1
	Los Corralitos	1602201.3	2952069.6	478.5	1527.1	4723.3	15957.1	259.7	828.8	2563.5	8660.5
	Lunlunta	1042474.0	851391.7	1518.8	4556.5	925.4	3287.2	1859.7	5579.2	1133.1	4025.0
	Rodeo del Medio	5219778.3	7416479.8	482.6	1753.0	2572.5	8694.6	339.6	1233.8	1810.5	6119.3
	San Francisco del Monte -GC	8148176.8	8497986.7	193.1	591.9	1065.0	4054.4	185.2	567.5	1021.2	3887.5
	Vistalba	8644440.2	6009691.0	363.4	1226.3	3196.6	11275.2	522.8	1764.0	4598.1	16218.

5. ANALYSIS AND RESULTS:

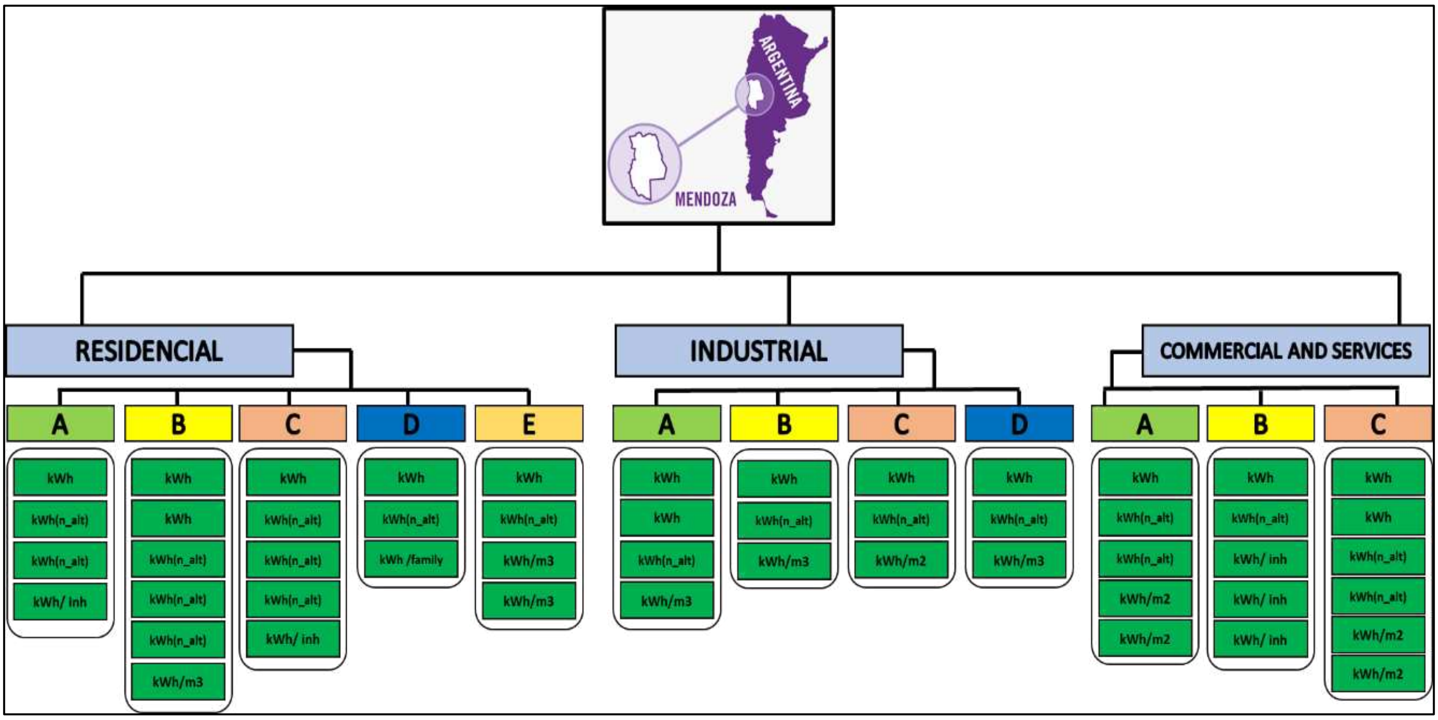
Here, we attempt to clarify the particular results that we obtained from our study and provide a thorough analysis of them. Meanwhile, we carefully arrange the necessary resources for our research using regression techniques and correlation analysis to build energy models. The assessment of energy consumption levels is made possible by these energy models, which function as prediction tools. We can take on the vital duty of energy planning for the city of Mendoza by utilizing these models. The findings in this thesis's "Analysis and Results" chapter not only make it easier to examine Mendoza's urban energy environment in detail but also provide the groundwork for later phases of energy planning. Our results open the door for future energy planning initiatives by highlighting the potential for energy reductions and the use of renewable resources. The insights gathered from this chapter contribute to the increase of system efficiency depending on many variables, directing the city toward a more sustainable and resource-efficient energy future.

5.1 Statistical Models

After assembling all the necessary components, we started putting our models into practice. We used a clustering technique, as previously mentioned, to group districts according to homogenous features. This led to the creation of three commercial and services clusters, four industrial clusters, and five residential clusters. Several characteristics were common to these districts: low building coverage ratios, low construction densities, significant separations from the city center, high elevations, and large district sizes. More importantly, this intentional segmentation greatly increased the models' precision and accuracy while also addressing issues related to large error percentages. To achieve even more precision, we also normalized the gas consumption data based on altitude. This resulted in ten different types of gas consumption, both normalized and not, taking into account factors like altitude, area (m2), volume (m3), population, and family size. We next used correlation analysis to find the most correlated form of energy for further refining by comparing these ten energy types with the data unique to each cluster. Based on the normalized energy data, various scenarios were created for each kind that was found and for each cluster. By using a rigorous approach, we were able to evaluate and investigate any differences in energy consumption between various situations, which helped us to improve our models and give a more accurate and nuanced picture of the energy dynamics inside each cluster.

A crucial factor in choosing different models is the correlation between data points and the kinds of energy they are associated with. This important factor directs our strategy, leading us to give priority to building models with strong and high correlations. We set the stage for building models that accurately represent the complex relationships discovered in the data by starting with the strongest correlations. By ensuring that our models are based on the most significant and useful variables, this methodical approach improves the accuracy and dependability of our models in representing the intricate dynamics of the system we are studying.

Figure 52 : accepted Scenarios of Models for different sectors and according to best correlation between different types of energy and variables



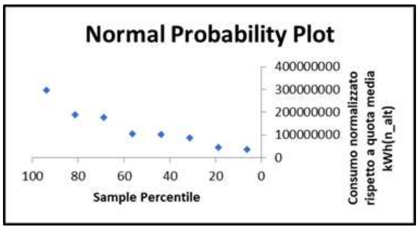
5.1.1 residential Statistical Models

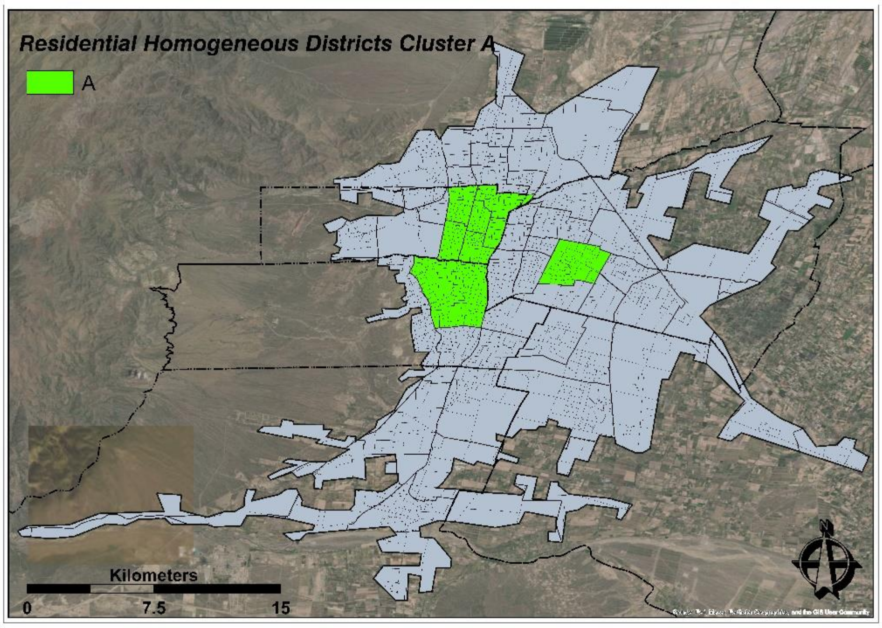
Statistical models designed exclusively for the residential sector are presented in this section. It includes separate regression models for every one of the residential clusters that were found, which are referred to as Clusters A through E.

5.1.1.1. Residential Regression Models for Cluster A

In-depth, this section explores the residential regression models developed for Cluster A. The models shed light on the patterns of energy use in this particular household cluster.

RESIDENSIAL CLUSTER A
Ciudad (GC)
Cuarta Sección
Primera Sección
Quinta Sección
Segunda Sección
Sexta Sección
Tercera Sección
Villa Nueva

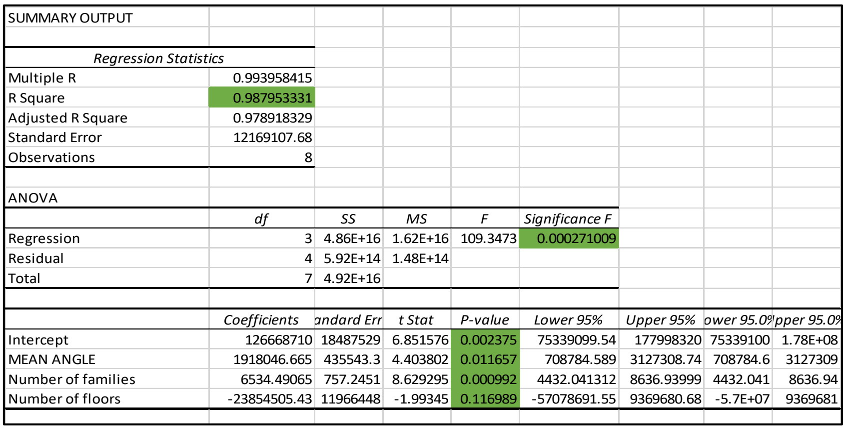




Scenario 1: RESIDENCIAL CLUSTER A (KWH)

y = 0.988x + 1E+06

X = (126668710) + (1918046.66 * MEAN ANGLE)+ (6534.49 * Number of families) + (-23854505.43 * Number of floors)



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.993958415
R Square	0.987953331
Adjusted R Square	0.978918329
Standard Error	12169107.68
Observations	8

ANOVA

	df	SS	MS	F	Significance F
Regression	3	4.86E+16	1.62E+16	109.3473	0.000271009
Residual	4	5.92E+14	1.48E+14		
Total	7	4.92E+16			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	126668710	18487529	6.851576	0.002375	75339099.54	177998320	75339100	1.78E+08
MEAN ANGLE	1918046.665	435543.3	4.403802	0.011657	708784.589	3127308.74	708784.6	3127309
Number of families	6534.49065	757.2451	8.629295	0.000992	4432.041312	8636.93999	4432.041	8636.94
Number of floors	-23854505.43	11966448	-1.99345	0.116989	-57078691.55	9369680.68	-5.7E+07	9369681

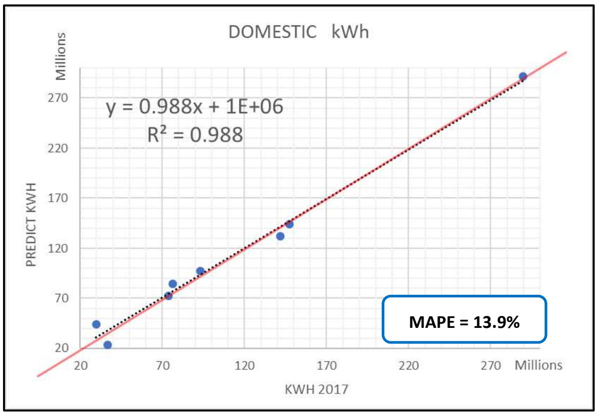


Figure 53 : The Multiple Regression Result of Scenario 1 - RESIDENCIAL CLUSTER A (KWH) (By Authors)

Scenario 2: RESIDENCIAL CLUSTER A 1- kWh{n-alt}

y = 0.9993x + 350703

X= (956936967.84) + (1671088.754 *MEAN ANGLE) + (1978.87* Number of inhabitants) + (-13139645.07 * per of act1 (Busy))

Regression Statistics	
Multiple R	0.998467056
R Square	0.996936462
Adjusted R Square	0.994638809
Standard Error	6315576.025
Observations	8

ANOVA					
	df	*SS*	*MS*	*F*	*gnificance F*
Regression	3	5.19E+16	1.73E+16	433.8933477	1.76E-05
Residual	4	1.6E+14	3.99E+13		
Total	7	5.21E+16			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	956936967.8	99053143	9.660844	0.000642228	6.82E+08	1.23E+09	6.82E+08	1.23E+09
MEAN ANGLE232	1671088.754	211710.4	7.893276	0.001393233	1083286	2258891	1083286	2258891
Number of inhabitants	1978.870386	142.5876	13.87828	0.000156287	1582.984	2374.757	1582.984	2374.757
per of act1 (Busy)4	-13139645.08	1585997	-8.28478	0.001158722	-1.8E+07	-8736210	-1.8E+07	-8736210

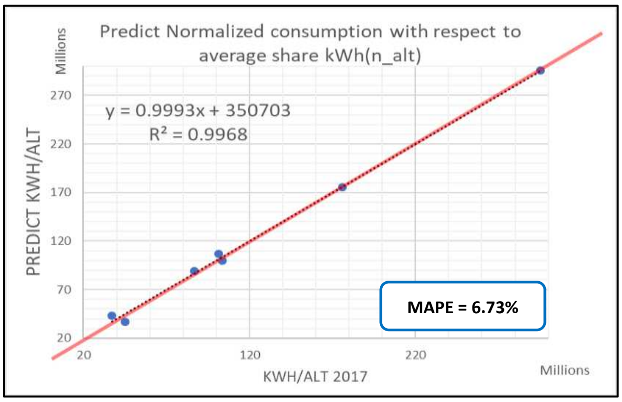


Figure 54 : The Multiple Regression Result of Scenario 2 - RESIDENCIAL CLUSTER A 1-kWh{n-alt} (By Authors)

Scenario 3: RESIDENCIAL CLUSTER A 2-kWh{n-alt}

y = 0.9974x + 332477

X= (961181111.31) + (1765171.46*MEAN ANGLE) + (1629.20* Number of inhabitants) + (-13195039.15 *per of act1 (Busy)) +(6260641.05 * per of MP2 (Fixed cement or brick))

Regression Statistics	
Multiple R	0.998713
R Square	0.997427
Adjusted R Square	0.993997
Standard Error	6682682
Observations	8

ANOVA					
	df	*SS*	*MS*	*F*	*gnificance F*
Regression	4	5.19E+16	1.3E+16	290.792	0.000326
Residual	3	1.34E+14	4.47E+13		
Total	7	5.21E+16			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	9.61E+08	1.05E+08	9.157528	0.002753	6.27E+08	1.3E+09	6.27E+08	1.3E+09
MEAN ANGLE232	1765171	256206.8	6.889635	0.006265	949807.1	2580536	949807.1	2580536
Number of inhabita	1629.206	486.0971	3.351605	0.044006	82.22772	3176.183	82.22772	3176.183
per of act1 (Busy)4	-1.3E+07	1679783	-7.85521	0.004298	-1.9E+07	-7849221	-1.9E+07	-7849221
per of MP2 (Fixed c	6260641	8273573	0.756703	0.50423	-2E+07	32590844	-2E+07	32590844

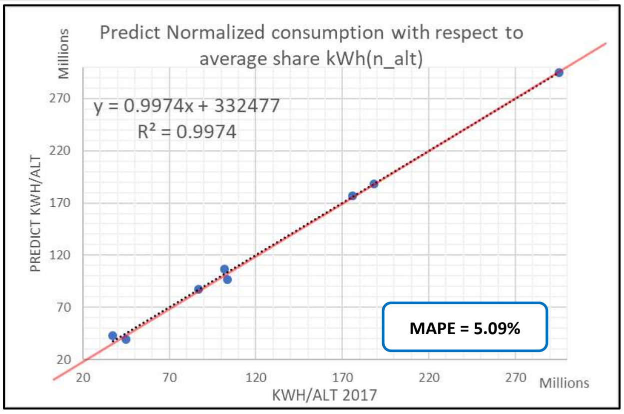


Figure 55 : The Multiple Regression Result of Scenario 3 - RESIDENCIAL CLUSTER A 2-kWh{n-alt} (By Authors)

Scenario 4: RESIDENCIAL CLUSTER A kWh/inh

y = 0.9928x - 44.883

X= (-3938.16) + (3872.08* Number of floors) + (370.88* per of MC3 (Slate or tile)) +(-353.44* Average of number of families per gross volume))

Regression Statistics	
Multiple R	0.985043
R Square	0.97031
Adjusted R Square	0.948042
Standard Error	394.9209
Observations	8

ANOVA					
	df	*SS*	*MS*	*F*	*gnificance F*
Regression	3	20388014	6796005	43.57459	0.001636
Residual	4	623850.2	155962.5		
Total	7	21011864			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-3938.17	1104.192	-3.56656	0.023448	-7003.89	-872.438	-7003.89	-872.438
Number of floors	3872.081	579.0404	6.687066	0.002601	2264.407	5479.755	2264.407	5479.755
per of MC3 (Slate or tile)	370.8851	40.21787	9.221899	0.000768	259.2224	482.5478	259.2224	482.5478
Average of number of families	-353.448	224.2205	-1.57634	0.190076	-975.984	269.0882	-975.984	269.0882

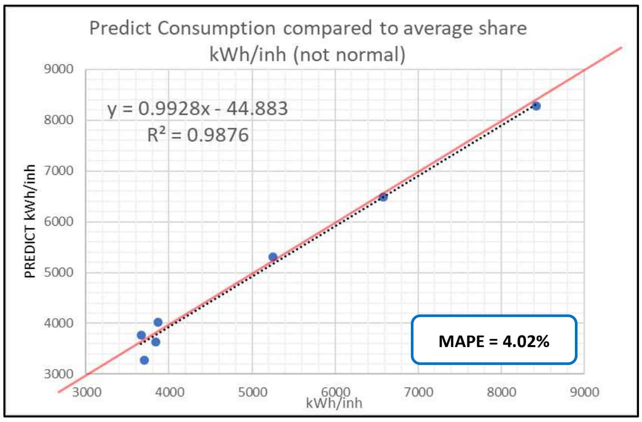
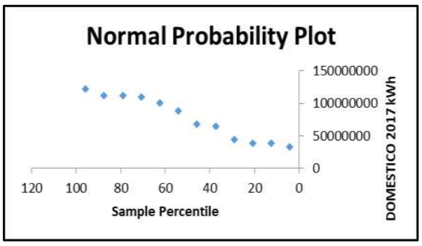


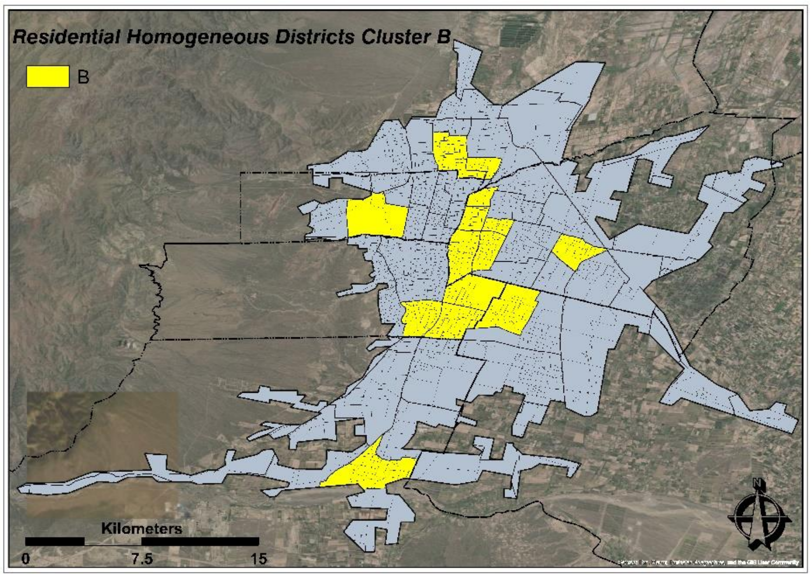
Figure 56 : The Multiple Regression Result of Scenario 4 - RESIDENCIAL CLUSTER A kWh/inh (By Authors)

5.1.1.2. Residential Regression Models for Cluster B

In a similar vein, this subsection describes the special residential regression models created for Cluster B, illuminating patterns and traits related to this cluster's energy use.

RESIDENSIAL CLUSTER B
Capilla del Rosario
Ciudad (L)
Ciudad (LH)
Dorrego
El Zapallar
Gobernador Benegas
Las Cañas
Las Tortugas
Luzuriaga
Pedro Molina
San Francisco del Monte -GC
San José (Gy)





Scenario 5: RESIDENCIAL CLUSTER B 1-kWh (B) (not normal)

y = 0.9736x + 2E+06

X= (-163635336.01) + (112.16* Footprint area of buildings (sum))+ (254361.99 * MEAN OF Altitude) +(-12438921.79* percentage MCAL3)+ (-227.96* SUM of buildings volume m3) + (203.66* SUM of buildings heat loss surface m2)

Regression Statistics	
Multiple R	0.986706
R Square	0.973589
Adjusted R Square	0.951581
Standard Error	7414686
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	5	1.22E+16	2.43E+15	44.23639	0.000117
Residual	6	3.3E+14	5.5E+13		
Total	11	1.25E+16			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-1.6E+08	27231969	-6.00894	0.000957	-2.3E+08	-9.7E+07	-2.3E+08	-9.7E+07
Footprint area of buildings (	112.161	41.48482	2.703665	0.035403	10.65134	213.6708	10.65134	213.6708
MEAN OF Altitude	254362	38108.53	6.674673	0.000548	161113.8	347610.2	161113.8	347610.2
percentage MCAL3	-1.2E+07	4837142	-2.57154	0.042247	-2.4E+07	-602863	-2.4E+07	-602863
SUM of buildings volume m3	-227.966	44.55251	-5.11678	0.002185	-336.982	-118.949	-336.982	-118.949
SUM of buildings heat loss s	203.6645	41.62938	4.892327	0.002732	101.8011	305.5279	101.8011	305.5279

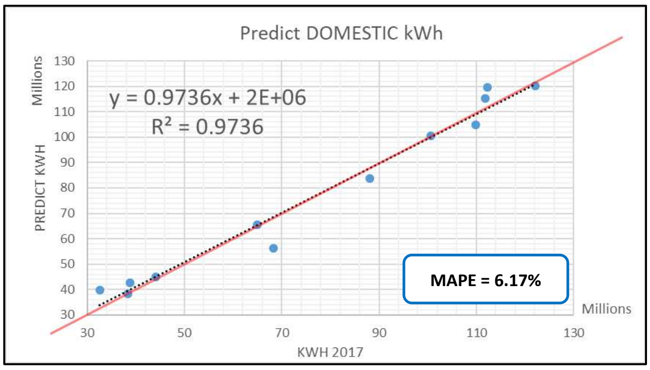


Figure 58 : The Multiple Regression Result of Scenario 5 - RESIDENCIAL CLUSTER B 1-kWh (By Authors)

Scenario 6: RESIDENCIAL CLUSTER B 2- kWh (B) (not normal)

y = 0.9445x + 4E+06

X= (-155586751.36) + (119.72* Footprint area of buildings (sum)) + (211367.85* MEAN OF Altitude) +(-203.56* SUM of buildings volume m3)+ (181.49* SUM of buildings heat loss surface m2)

Regression Statistics	
Multiple R	0.971844
R Square	0.944481
Adjusted R Square	0.912756
Standard Error	9952912
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	4	1.18E+16	2.95E+15	29.77093	0.000174
Residual	7	6.93E+14	9.91E+13		
Total	11	1.25E+16			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-1.6E+08	36311891	-4.28473	0.003634	-2.4E+08	-7E+07	-2.4E+08	-7E+07
Footprint area of buildings (s	119.7193	55.54614	2.155313	0.068077	-11.6264	251.0651	-11.6264	251.0651
MEAN OF Altitude	211367.9	45968.06	4.598146	0.00249	102670.7	320065.1	102670.7	320065.1
SUM of buildings volume m3	-203.565	58.43182	-3.4838	0.010214	-341.734	-65.3955	-341.734	-65.3955
SUM of buildings heat loss su	181.4975	54.669	3.319934	0.012766	52.22583	310.7691	52.22583	310.7691

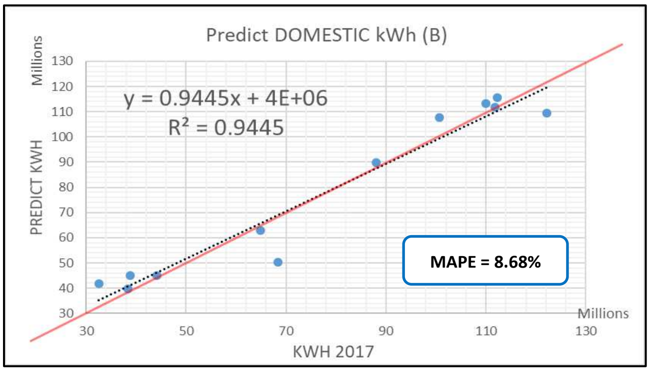
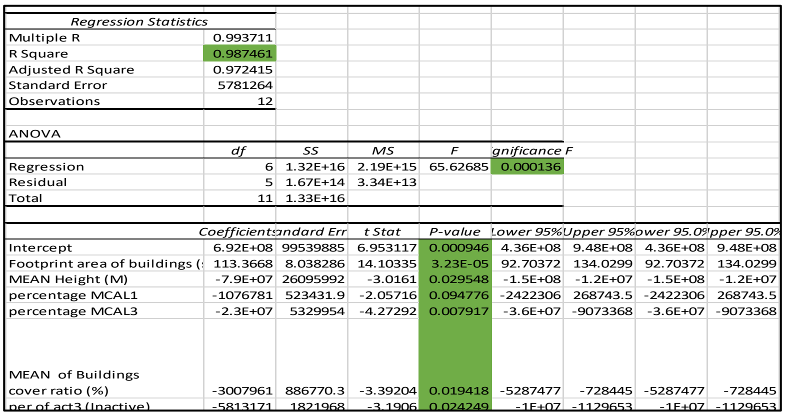


Figure 57 : - The Multiple Regression Result of Scenario 6 - RESIDENCIAL CLUSTER B 2-kWh (By Authors)

Scenario 7: RESIDENCIAL CLUSTER B 1-kWh{n-alt}

y = 0.9875x + 1E+06

X= (692112459.46) + (113.37* Footprint area of buildings (sum)) + (-78708212.60* MEAN Height (M)) +(-1076781.05* percentage MCAL1) + (-22774450.32* percentage MCAL3) + (-3007961.13* MEAN of Buildings cover ratio (%)) +(-5813171.44* per of act3 (Inactive))



Regression Statistics	
Multiple R	0.993711
R Square	0.987461
Adjusted R Square	0.972415
Standard Error	5781264
Observations	12

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	1.32E+16	2.19E+15	65.62685	0.000136
Residual	5	1.67E+14	3.34E+13		
Total	11	1.33E+16			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	6.92E+08	99539885	6.953117	0.000946	4.36E+08	9.48E+08	4.36E+08	9.48E+08
Footprint area of buildings (	113.3668	8.038286	14.10335	3.23E-05	92.70372	134.0299	92.70372	134.0299
MEAN Height (M)	-7.9E+07	26095992	-3.0161	0.029548	-1.5E+08	-1.2E+07	-1.5E+08	-1.2E+07
percentage MCAL1	-1076781	523431.9	-2.05716	0.094776	-2422306	268743.5	-2422306	268743.5
percentage MCAL3	-2.3E+07	5329954	-4.27292	0.007917	-3.6E+07	-9073368	-3.6E+07	-9073368
MEAN of Buildings cover ratio (%)	-3007961	886770.3	-3.39204	0.019418	-5287477	-728445	-5287477	-728445
per of act3 (Inactive)	-5813171	1821968	-3.1906	0.024249	-1E+07	-1129653	-1E+07	-1129653

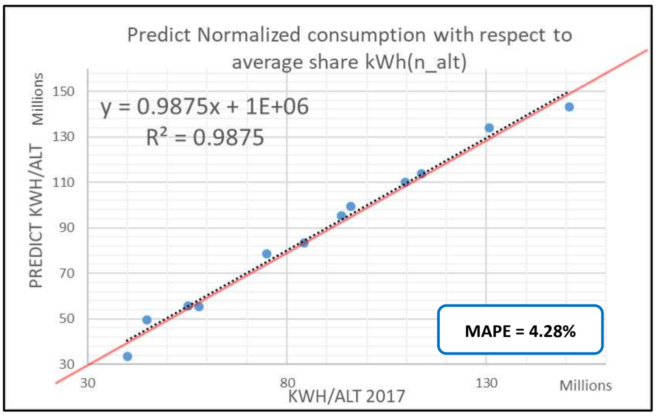
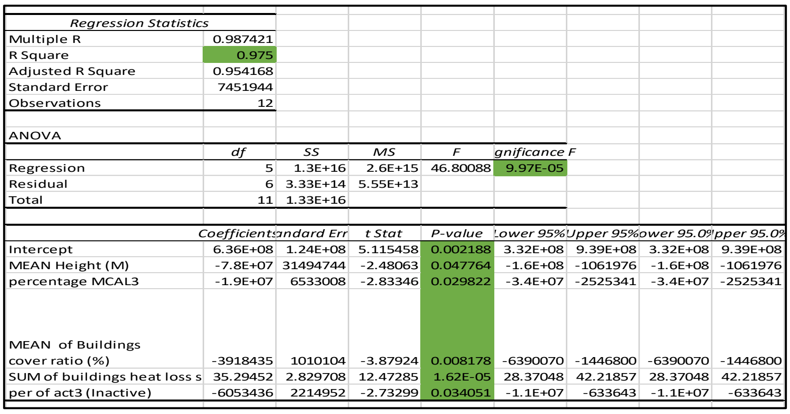


Figure 59 : The Multiple Regression Result of Scenario 7 - RESIDENCIAL CLUSTER B 1-kWh{n-alt} (By Authors)

Scenario 8: RESIDENCIAL CLUSTER B 2-kWh{n-alt}

y = 0.975x + 2E+06

X= (635502620.27) + (-78126838.20* MEAN Height (M)) + (-18511035.46* percentage MCAL3) +(-3918435.31* MEAN of Buildings cover ratio (%))+ (35.29* SUM of buildings heat loss surface m2) + (-6053435.96 * per of act3 (Inactive))



Regression Statistics	
Multiple R	0.987421
R Square	0.975
Adjusted R Square	0.954168
Standard Error	7451944
Observations	12

ANOVA

	df	SS	MS	F	gnificance F
Regression	5	1.3E+16	2.6E+15	46.80088	9.97E-05
Residual	6	3.33E+14	5.55E+13		
Total	11	1.33E+16			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	6.36E+08	1.24E+08	5.115458	0.002188	3.32E+08	9.39E+08	3.32E+08	9.39E+08
MEAN Height (M)	-7.8E+07	31494744	-2.48063	0.047764	-1.6E+08	-1061976	-1.6E+08	-1061976
percentage MCAL3	-1.9E+07	6533008	-2.83346	0.029822	-3.4E+07	-2525341	-3.4E+07	-2525341
MEAN of Buildings cover ratio (%)	-3918435	1010104	-3.87924	0.008178	-6390070	-1446800	-6390070	-1446800
SUM of buildings heat loss s	35.29452	2.829708	12.47285	1.62E-05	28.37048	42.21857	28.37048	42.21857
per of act3 (Inactive)	-6053436	2214952	-2.73299	0.034051	-1.1E+07	-633643	-1.1E+07	-633643

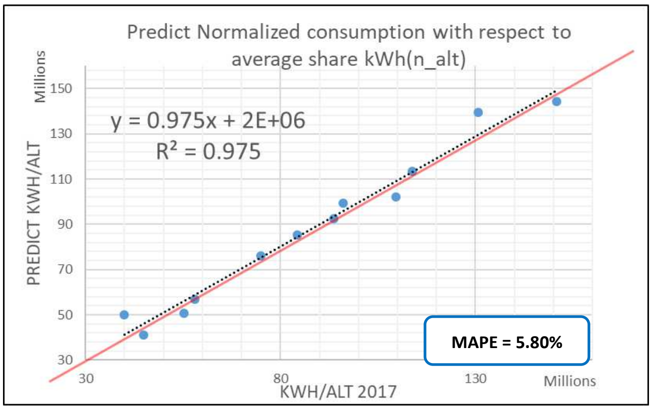
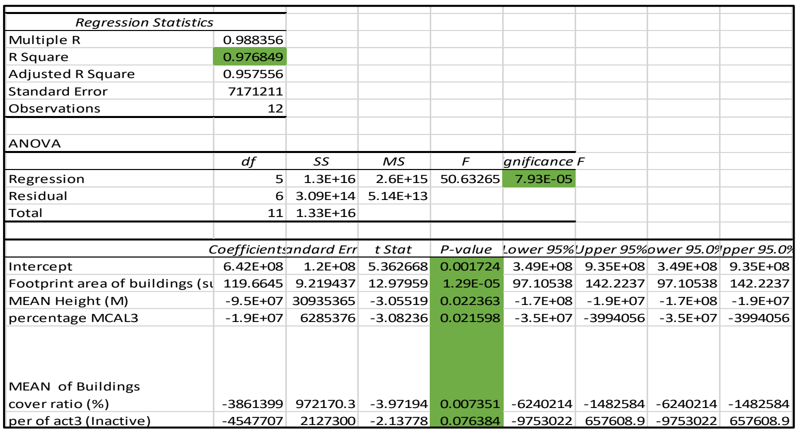


Figure 60 : The Multiple Regression Result of Scenario 8 - RESIDENCIAL CLUSTER B 2-kWh{n-alt} (By Authors)

Scenario 9: RESIDENCIAL CLUSTER B 3-kWh{n-alt}

y = 0.9768x + 2E+06

X= (642014282.99) + (119.66* Footprint area of buildings (sum)) +(-94513329.94* MEAN Height (M)) +(-19373817.13* percentage MCAL3)+ (-3861399.26* MEAN of Buildings cover ratio (%)) + (-4547706.64 * per of act3 (Inactive))



Regression Statistics	
Multiple R	0.988356
R Square	0.976849
Adjusted R Square	0.957556
Standard Error	7171211
Observations	12

ANOVA

	df	SS	MS	F	gnificance F
Regression	5	1.3E+16	2.6E+15	50.63265	7.93E-05
Residual	6	3.09E+14	5.14E+13		
Total	11	1.33E+16			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	6.42E+08	1.2E+08	5.362668	0.001724	3.49E+08	9.35E+08	3.49E+08	9.35E+08
Footprint area of buildings (su	119.6645	9.219437	12.97959	1.29E-05	97.10538	142.2237	97.10538	142.2237
MEAN Height (M)	-9.5E+07	30935365	-3.05519	0.022363	-1.7E+08	-1.9E+07	-1.7E+08	-1.9E+07
percentage MCAL3	-1.9E+07	6285376	-3.08236	0.021598	-3.5E+07	-3994056	-3.5E+07	-3994056
MEAN of Buildings cover ratio (%)	-3861399	972170.3	-3.97194	0.007351	-6240214	-1482584	-6240214	-1482584
per of act3 (Inactive)	-4547707	2127300	-2.13778	0.076384	-9753022	657608.9	-9753022	657608.9

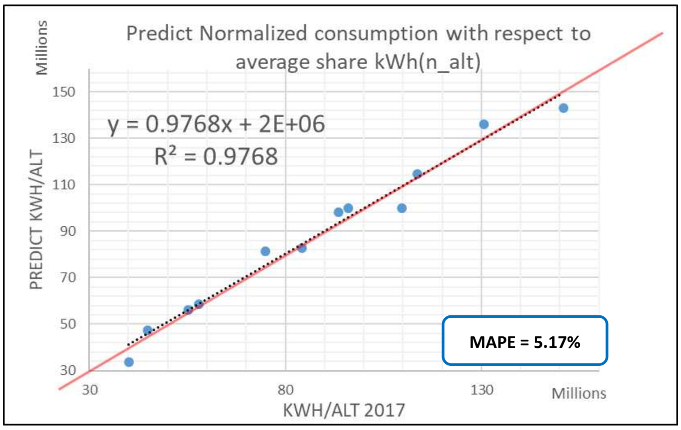
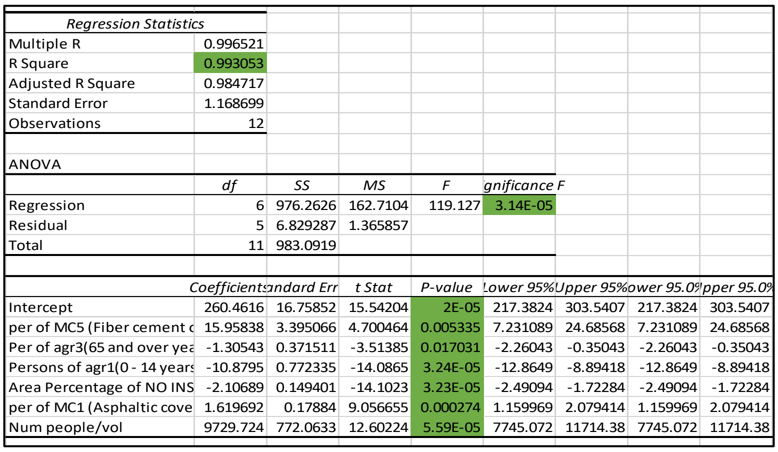


Figure 61 : The Multiple Regression Result of Scenario 9 - RESIDENCIAL CLUSTER B 3-kWh{n-alt} (By Authors)

Scenario 10: RESIDENCIAL CLUSTER B kWh/m3

y = 0.9931x + 0.266

X= (260.461551699276) + (15.958383910519* per of MC5 (Fiber cement or plastic sheet)) + (-1.30543291443097* Per of agr3(65 and over years old)) +(-10.8795279593911* Persons of agr1(0 - 14 years old) + (-2.10688986965799* Area Percentage of NO INSOLATED BUILDINGS) + (1.61969172892607* per of MC1 (Asphaltic cover or membrane)) +(-9729.7237040507*Num people/vol)



Regression Statistics	
Multiple R	0.996521
R Square	0.993053
Adjusted R Square	0.984717
Standard Error	1.168699
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	6	976.2626	162.7104	119.127	3.14E-05
Residual	5	6.829287	1.365857		
Total	11	983.0919			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	260.4616	16.75852	15.54204	2E-05	217.3824	303.5407	217.3824	303.5407
per of MC5 (Fiber cement c	15.95838	3.395066	4.700464	0.005335	7.231089	24.68568	7.231089	24.68568
Per of agr3(65 and over yea	-1.30543	0.371511	-3.51385	0.017031	-2.26043	-0.35043	-2.26043	-0.35043
Persons of agr1(0 - 14 years	-10.8795	0.772335	-14.0865	3.24E-05	-12.8649	-8.89418	-12.8649	-8.89418
Area Percentage of NO INS	-2.10689	0.149401	-14.1023	3.23E-05	-2.49094	-1.72284	-2.49094	-1.72284
per of MC1 (Asphaltic cove	1.619692	0.17884	9.056655	0.000274	1.159969	2.079414	1.159969	2.079414
Num people/vol	9729.724	772.0633	12.60224	5.59E-05	7745.072	11714.38	7745.072	11714.38

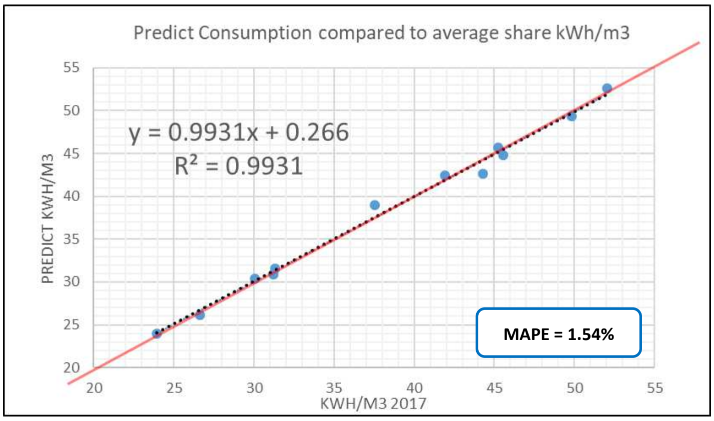
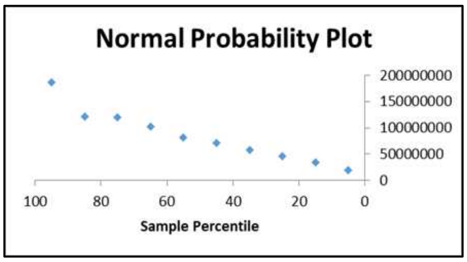


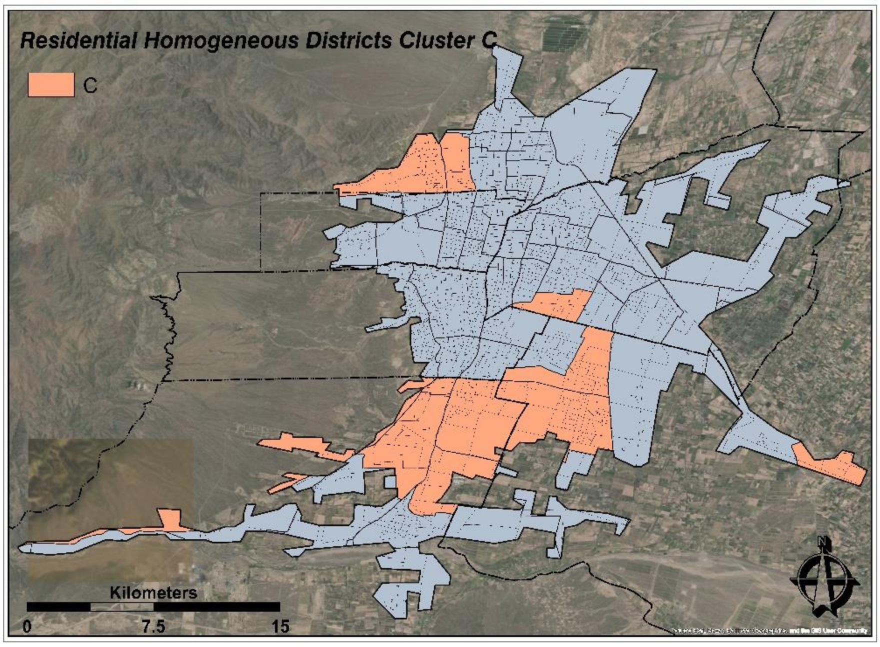
Figure 62 : The Multiple Regression Result of Scenario 10 - RESIDENCIAL CLUSTER B kWh/M3 (By Authors)

5.1.1.3. Residential Regression Models for Cluster C

Focusing on Cluster C, this part unveils the residential regression models engineered to capture and analyze the energy dynamics prevalent within this particular residential cluster.

RESIDENSIAL CLUSTER C
Carrodilla
Chacras de Coria
El Challao
Fray Luis Beltrán
General Gutierrez
La Cieneguita
La Puntilla
Maipú
Mayor Drummond
San Francisco del Monte (Gy





Scenario 11: RESIDENCIAL CLUSTER C kWh (C) (not normal)

y = 0.9639x + 3E+06

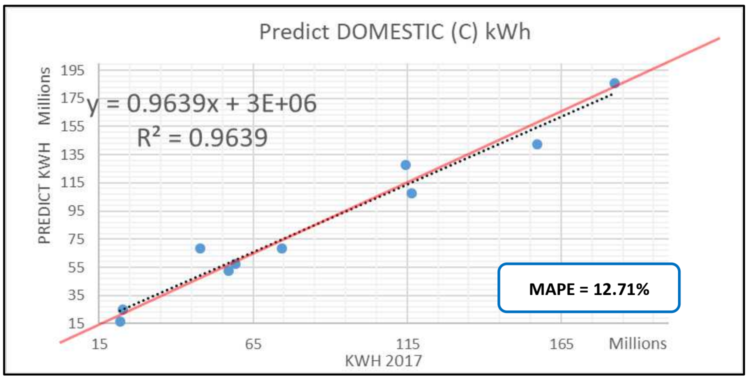
X= (-816693868.22) + (321207804.56 * MEAN Height (M)) + (75815.23* Number of families) +(-17163.08* Number of inhabitants) + (-3419986.90 * percentage MCAL1)

Regression Statistics	
Multiple R	0.981788
R Square	0.963908
Adjusted R Square	0.935035
Standard Error	14054233
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	4	2.64E+16	6.59E+15	33.38393	0.000844
Residual	5	9.88E+14	1.98E+14		
Total	9	2.74E+16			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-8.2E+08	2.8E+08	-2.92118	0.032969	-1.5E+09	-9.8E+07	-1.5E+09	-9.8E+07
MEAN Height (M)	3.21E+08	1.06E+08	3.043536	0.028635	49914455	5.93E+08	49914455	5.93E+08
Number of families	75815.23	18468.13	4.105192	0.009307	28341.39	123289.1	28341.39	123289.1
Number of inhabitants	-17163.1	5226.715	-3.28372	0.021864	-30598.8	-3727.38	-30598.8	-3727.38
percentage MCAL	-3419987	1250237	-2.73547	0.041012	-6633824	-206150	-6633824	-206150



MAPE = 12.71%

Figure 65: The Multiple Regression Result of Scenario 13 - RESIDENCIAL CLUSTER C 2-kWh{n-alt} (By Authors)

Scenario 12: RESIDENCIAL CLUSTER C 1- kWh{n-alt}

y = 0.9793x + 2E+06

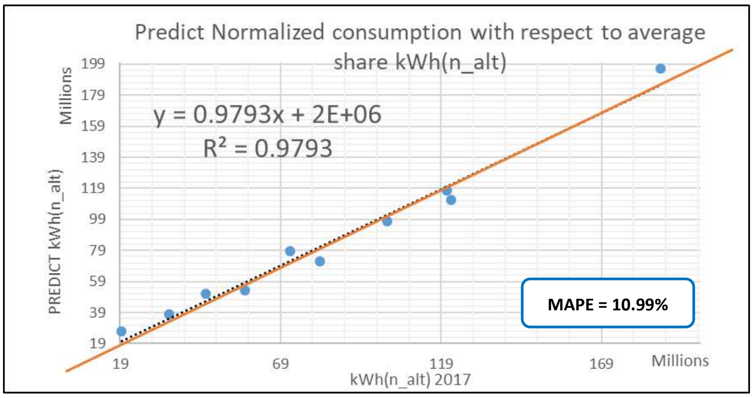
X= (108714992.61) + (18513.81 * Number of families) + (30508455.89* per of MC5 (Fiber cement or plastic sheet)) +(-2569467.38* per of MC1 (Asphaltic cover or membrane))

Regression Statistics	
Multiple R	0.990762
R Square	0.981609
Adjusted R Square	0.966896
Standard Error	9141714
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	4	2.23E+16	5.58E+15	66.71686	0.000158
Residual	5	4.18E+14	8.36E+13		
Total	9	2.27E+16			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	1.05E+08	25468090	4.124402	0.009135	39572825	1.71E+08	39572825	1.71E+08
Number of families	19175.97	1615.184	11.87231	7.47E-05	15024.01	23327.93	15024.01	23327.93
per of MC5 (Fiber cem	33261200	15378834	2.162791	0.082894	-6271353	72793752	-6271353	72793752
per of MC1 (Asphaltic	-2523069	559747.9	-4.50751	0.006355	-3961947	-1084191	-3961947	-1084191
Average of Number of	-442118	557432.6	-0.79313	0.463657	-1875044	990808.1	-1875044	990808.1



MAPE = 10.99%

Figure 63 The Multiple Regression Result of Scenario 12 - RESIDENCIAL CLUSTER C 1-kWh{n-alt} (By Authors)

Scenario 13: RESIDENCIAL CLUSTER C 2-kWh{n-alt}

y = 0.9803x + 2E+06

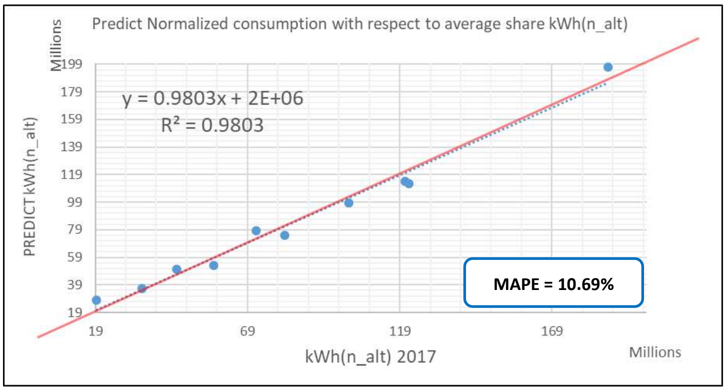
X= (101614474.49) + (16338.36* Number of families) + (24578922.78* per of MC5 (Fiber cement or plastic sheet)) +(-2318572.63 * per of MC1 (Asphaltic cover or membrane)) + (5.35* SUM of buildings heat loss surface m2)

Regression Statistics	
Multiple R	0.990084
R Square	0.980266
Adjusted R Square	0.964478
Standard Error	9469658
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	4	2.23E+16	5.57E+15	62.09086	0.000189
Residual	5	4.48E+14	8.97E+13		
Total	9	2.27E+16			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	1.02E+08	29630583	3.429378	0.018648	25446636	1.78E+08	25446636	1.78E+08
Number of families	16338.36	4614.655	3.540537	0.016553	4476.008	28200.7	4476.008	28200.7
per of MC5 (Fiber cement	24578923	19591331	1.254582	0.265082	-2.6E+07	74940043	-2.6E+07	74940043
per of MC1 (Asphaltic cove	-2318573	767128.9	-3.0224	0.029335	-4290540	-346605	-4290540	-346605
SUM of buildings heat loss	5.350716	10.7896	0.495914	0.640982	-22.3848	33.08626	-22.3848	33.08626



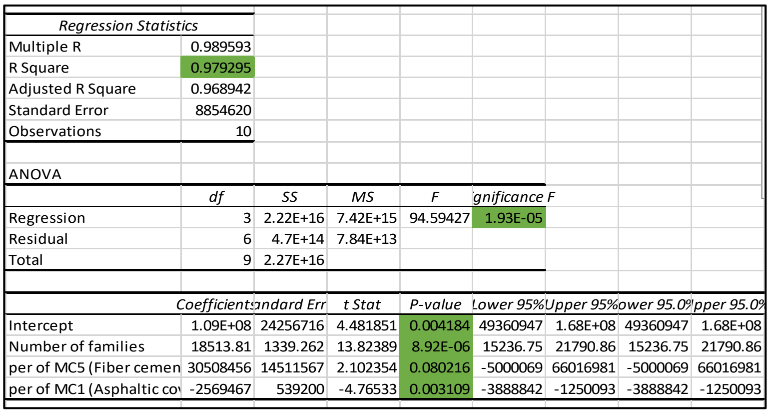
MAPE = 10.69%

Figure 64 : The Multiple Regression Result of Scenario 11 - RESIDENCIAL CLUSTER C kWh (By Authors)

Scenario 14: RESIDENCIAL CLUSTER C 3-kWh{n-alt}

y = 0.9816x + 2E+06

X= (105040634.78) + (33261199.61* Number of families) + (-2523069.00* per of MC5 (Fiber cement or plastic sheet)) +(-442117.95 * Average of Number of people per building gross volume)



Regression Statistics	
Multiple R	0.989593
R Square	0.979295
Adjusted R Square	0.968942
Standard Error	8854620
Observations	10

ANOVA

	df	SS	MS	F	gnificance F
Regression	3	2.22E+16	7.42E+15	94.59427	1.93E-05
Residual	6	4.7E+14	7.84E+13		
Total	9	2.27E+16			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	1.09E+08	24256716	4.481851	0.004184	49360947	1.68E+08	49360947	1.68E+08
Number of families	18513.81	1339.262	13.82389	8.92E-06	15236.75	21790.86	15236.75	21790.86
per of MC5 (Fiber cemen	30508456	14511567	2.102354	0.080216	-5000069	66016981	-5000069	66016981
per of MC1 (Asphaltic co	-2569467	539200	-4.76533	0.003109	-3888842	-1250093	-3888842	-1250093

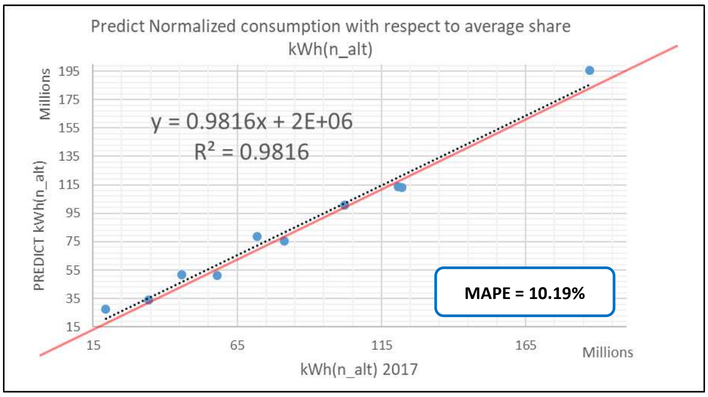
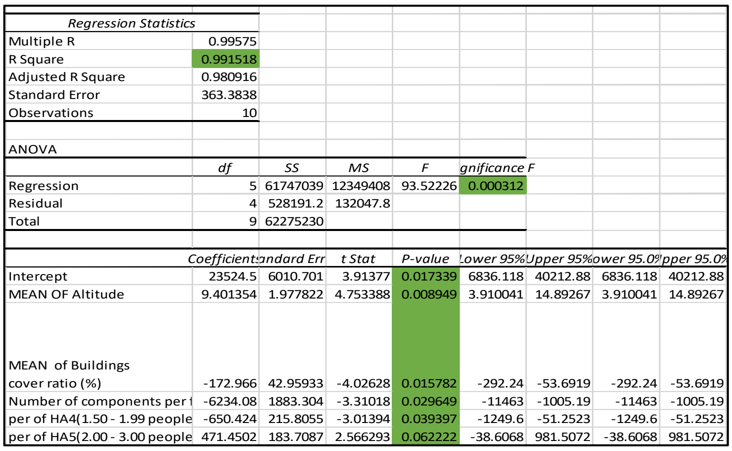


Figure 66 : The Multiple Regression Result of Scenario 14 - RESIDENCIAL CLUSTER C 3-kWh{n-alt} (By Authors)

Scenario 15: RESIDENCIAL CLUSTER C kWh/INH

y = 0.9915x + 46.322

X= (23524.50) + (9.40* MEAN OF Altitude) + (-172.97* MEAN of Buildings cover ratio (%)) +(-6234.08* Number of components per family) + (-650.42 * per of HA4(1.50 - 1.99 people per room)) + (471.45 * per of HA5(2.00 - 3.00 people per room))



Regression Statistics	
Multiple R	0.99575
R Square	0.991518
Adjusted R Square	0.980916
Standard Error	363.3838
Observations	10

ANOVA

	df	SS	MS	F	gnificance F
Regression	5	61747039	12349408	93.52226	0.000312
Residual	4	528191.2	132047.8		
Total	9	62275230			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	23524.5	6010.701	3.91377	0.017339	6836.118	40212.88	6836.118	40212.88
MEAN OF Altitude	9.401354	1.977822	4.753388	0.008949	3.910041	14.89267	3.910041	14.89267
MEAN of Buildings cover ratio (%)	-172.966	42.95933	-4.02628	0.015782	-292.24	-53.6919	-292.24	-53.6919
Number of components per f	-6234.08	1883.304	-3.31018	0.029649	-11463	-1005.19	-11463	-1005.19
per of HA4(1.50 - 1.99 people	-650.424	215.8055	-3.01394	0.039397	-1249.6	-51.2523	-1249.6	-51.2523
per of HA5(2.00 - 3.00 people	471.4502	183.7087	2.566293	0.062222	-38.6068	981.5072	-38.6068	981.5072

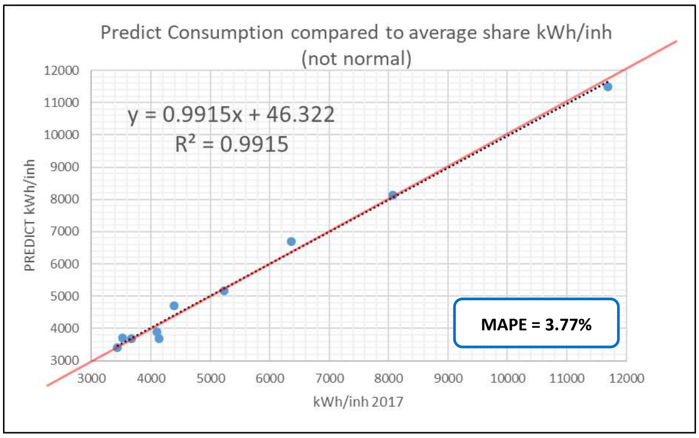
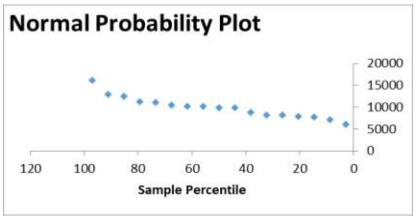


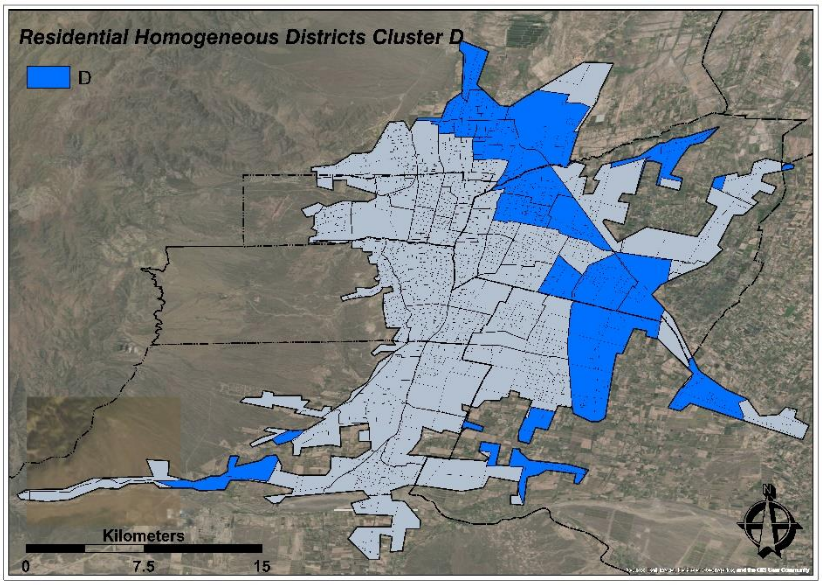
Figure 67 : The Multiple Regression Result of Scenario 15 - RESIDENCIAL CLUSTER C kWh/inh(By Authors)

5.1.1.4. Residential Regression Models for Cluster D

This section turns to Cluster D and shows the residential regression models that are designed to identify and explain the subtleties of energy use in this particular household cluster.

RESIDENSIAL CLUSTER D
Belgrano
Bermejo
Buena Nueva
Capdevila
Colonia Segovia
Coquimbito
Cruz de Piedra
El Algarrobal
El Plumerillo
El Resguardo
Jesús Nazareno
Kilómetro 11
Las Compuertas
Panquegua
Rodeo de La Cruz
Rodeo del Medio
Russel





Scenario 16: RESIDENCIAL CLUSTER D kWh (D) (not normal)

y = 0.9776x + 723114

X= (18853013.67) + (527.46* heated gross area) + (-161.82* SUM of buildings volume m3) + (6205.48* Number of families) + (-3126022.00 * per of act2(Not busy))

Regression Statistics								
Multiple R	0.988721							
R Square	0.97757							
Adjusted R Square	0.970093							
Standard Error	4005322							
Observations	17							
ANOVA								
	df	SS	MS	F	gnificance F			
Regression	4	8.39E+15	2.1E+15	130.7481551	8.74E-10			
Residual	12	1.93E+14	1.6E+13					
Total	16	8.58E+15						
	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	18853014	7674354	2.456625	0.030224576	2132032	35573995	2132032	35573995
heated gross area332	527.4586	279.5095	1.887087	0.083569006	-81.5402	1136.457	-81.5402	1136.457
SUM of buildings volume m	-161.818	87.32828	-1.85299	0.088624024	-352.09	28.45356	-352.09	28.45356
Number of families3	6205.484	1564.697	3.965934	0.001873176	2796.302	9614.665	2796.302	9614.665
per of act2(Not busy)	-3126022	1669275	-1.87268	0.085671592	-6763060	511016	-6763060	511016

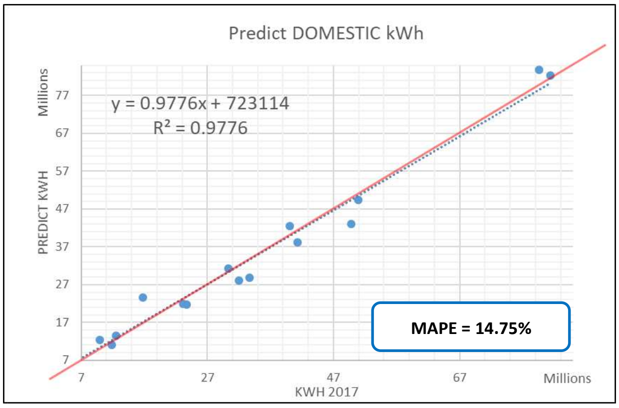


Figure 69 : The Multiple Regression Result of Scenario 16 - RESIDENCIAL CLUSTER D kWh (By Authors)

Scenario 17: RESIDENCIAL CLUSTER D -kWh{n-alt}

y = 0.9861x + 629595

X= (85741504.*32*) + (2542.80 * Number of inhabitants) + (-414398.93* Area Percentage of INSOLATED BUILDINGS) +(-13871311.69 * Average of number of components per family) + (-21628559.52 * per of MC6 (cardboard sheet))

Regression Statistics								
Multiple R	0.993034							
R Square	0.986117							
Adjusted R Square	0.98149							
Standard Error	4639064							
Observations	17							
ANOVA								
	df	SS	MS	F	gnificance F			
Regression	4	1.83E+16	4.59E+15	213.0948	4.95E-11			
Residual	12	2.58E+14	2.15E+13					
Total	16	1.86E+16						
	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	85741504	17454128	4.912391	0.000358	47712227	1.24E+08	47712227	1.24E+08
Number of inhabitants	2542.804	127.838	19.89083	1.49E-10	2264.269	2821.339	2264.269	2821.339
Area Percentage of INSOL	-414399	125226.2	-3.3092	0.006234	-687243	-141554	-687243	-141554
Average of number of components per family2	-1.4E+07	3558601	-3.89797	0.002118	-2.2E+07	-6117785	-2.2E+07	-6117785
per of MC6 (cardboard she	-2.2E+07	8331574	-2.59598	0.023399	-4E+07	-3475619	-4E+07	-3475619

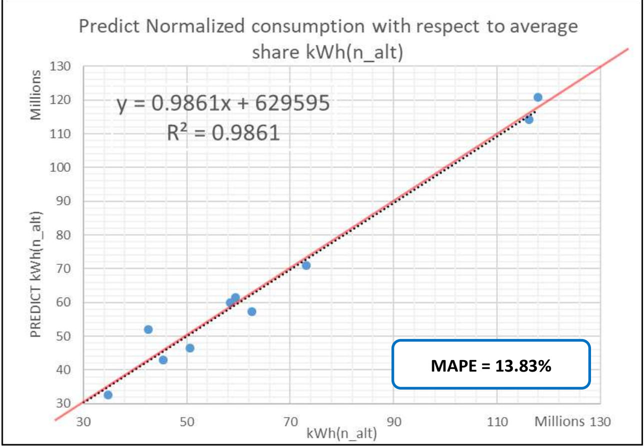
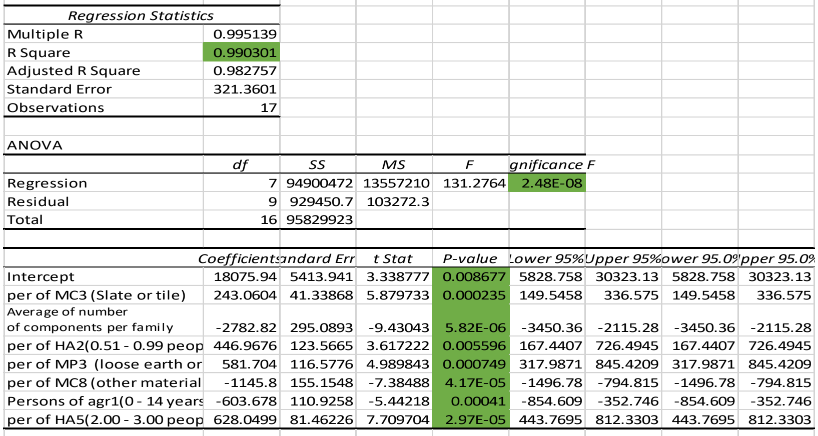


Figure 68 : The Multiple Regression Result of Scenario 17 - RESIDENCIAL CLUSTER D -kWh{n-alt} (By Authors)

Scenario 18: RESIDENCIAL CLUSTER D kWh /FAMILY (not normal)

y = 0.9903x + 96.033

X= (18075.94) + (243.06 * per of MC3 (Slate or tile)) + (-2782.82* Average of number of components per family) +(446.97 * per of HA2(0.51 - 0.99 people per room)) + (581.70 * per of MP3 (loose earth or brick)) + (-1145.80* per of MC8 (other materials)) + (-603.68* Persons of agr1(0 - 14 years old)) + (628.05 * per of HA5(2.00 - 3.00 people per room))



Regression Statistics	
Multiple R	0.995139
R Square	0.990301
Adjusted R Square	0.982757
Standard Error	321.3601
Observations	17

ANOVA

	df	SS	MS	F	gnificance F
Regression	7	94900472	13557210	131.2764	2.48E-08
Residual	9	929450.7	103272.3		
Total	16	95829923			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	18075.94	5413.941	3.338777	0.008677	5828.758	30323.13	5828.758	30323.13
per of MC3 (Slate or tile)	243.0604	41.33868	5.879733	0.000235	149.5458	336.575	149.5458	336.575
Average of number of components per family	-2782.82	295.0893	-9.43043	5.82E-06	-3450.36	-2115.28	-3450.36	-2115.28
per of HA2(0.51 - 0.99 peop	446.9676	123.5665	3.617222	0.005596	167.4407	726.4945	167.4407	726.4945
per of MP3 (loose earth or	581.704	116.5776	4.989843	0.000749	317.9871	845.4209	317.9871	845.4209
per of MC8 (other material	-1145.8	155.1548	-7.38488	4.17E-05	-1496.78	-794.815	-1496.78	-794.815
Persons of agr1(0 - 14 years	-603.678	110.9258	-5.44218	0.00041	-854.609	-352.746	-854.609	-352.746
per of HA5(2.00 - 3.00 peop	628.0499	81.46226	7.709704	2.97E-05	443.7695	812.3303	443.7695	812.3303

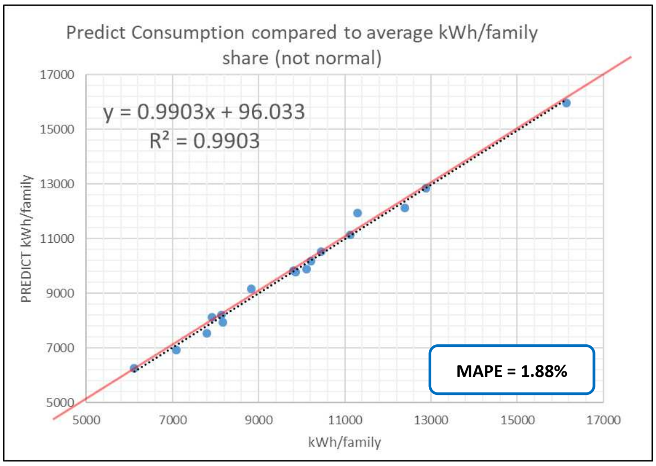
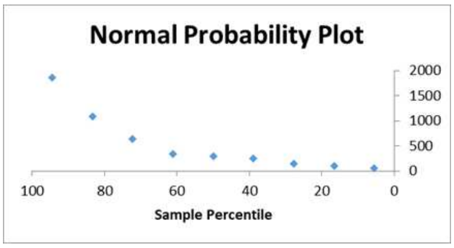


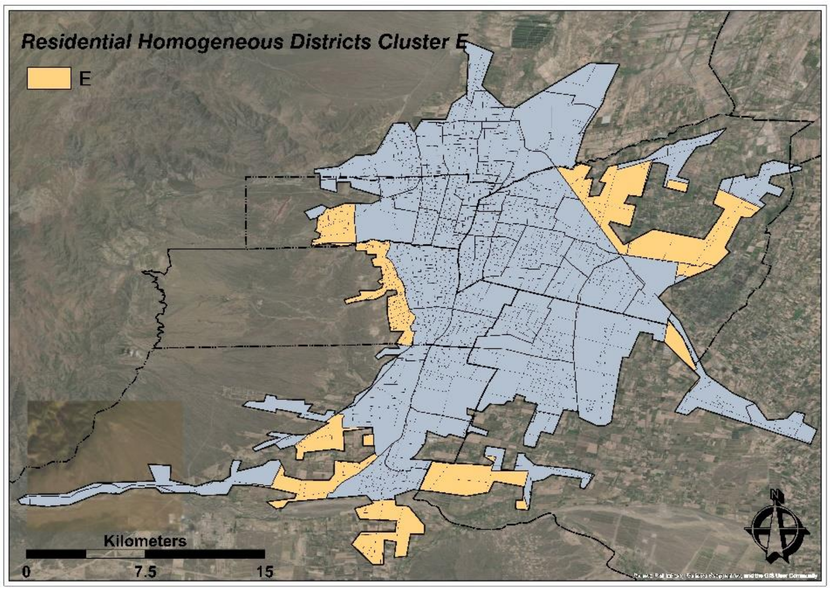
Figure 70 : The Multiple Regression Result of Scenario 18 - RESIDENCIAL CLUSTER D kWh/FAMILY (By Authors)

5.1.1.5. Residential Regression Models for Cluster E

As a last part of the residential models, this chapter describes the residential regression models created especially for Cluster E. These models provide a thorough understanding of the patterns of energy use unique to this cluster.

RESIDENSIAL CLUSTER E
Décimo Primera Sección
El Sauce
Los Corralitos
Lunlunta
Presidente Sarmiento
Vistalba
General Ortega
La Primavera (Gy)
Perdriel

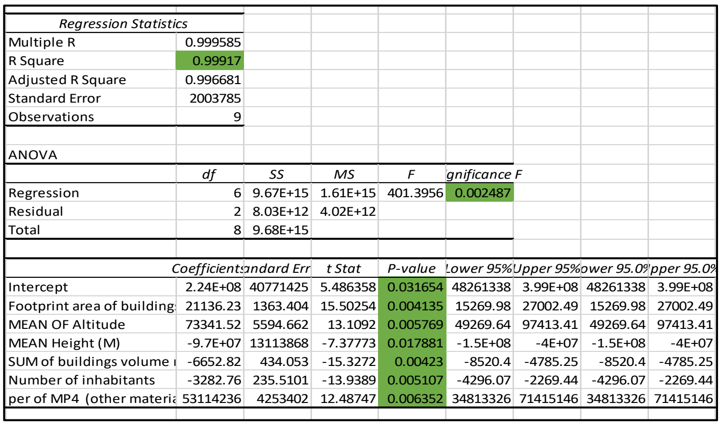




Scenario 19: RESIDENCIAL CLUSTER E kWh (E) (not normal)

y = 0.9992x + 30291

X= (223686618.66) + (21136.23* Footprint area of buildings (sum)) + (73341.52* MEAN OF Altitude) +(-96750607.85 * MEAN Height (M)) + (-6652.82 * SUM of buildings volume m3) + (-3282.76* Number of inhabitants) + (53114235.58* per of MP4 (other materials))



Regression Statistics	
Multiple R	0.999585
R Square	0.99917
Adjusted R Square	0.996681
Standard Error	2003785
Observations	9

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	9.67E+15	1.61E+15	401.3956	0.002487
Residual	2	8.03E+12	4.02E+12		
Total	8	9.68E+15			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	2.24E+08	40771425	5.486358	0.031654	48261338	3.99E+08	48261338	3.99E+08
Footprint area of building	21136.23	1363.404	15.50254	0.004135	15269.98	27002.49	15269.98	27002.49
MEAN OF Altitude	73341.52	5594.662	13.1092	0.005769	49269.64	97413.41	49269.64	97413.41
MEAN Height (M)	-9.7E+07	13113868	-7.37773	0.017881	-1.5E+08	-4E+07	-1.5E+08	-4E+07
SUM of buildings volume	-6652.82	434.053	-15.3272	0.00423	-8520.4	-4785.25	-8520.4	-4785.25
Number of inhabitants	-3282.76	235.5101	-13.9389	0.005107	-4296.07	-2269.44	-4296.07	-2269.44
per of MP4 (other materi	53114236	4253402	12.48747	0.006352	34813326	71415146	34813326	71415146

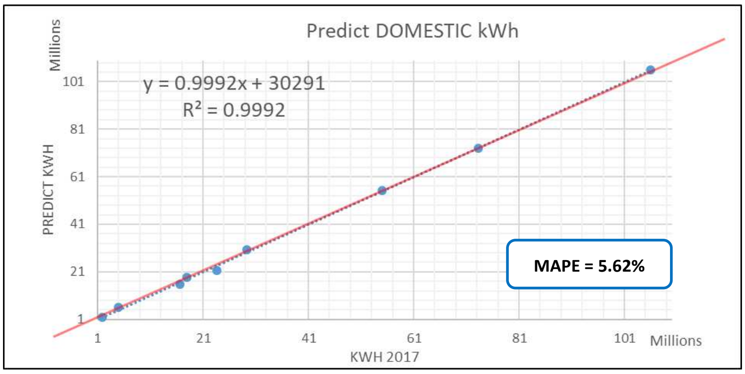
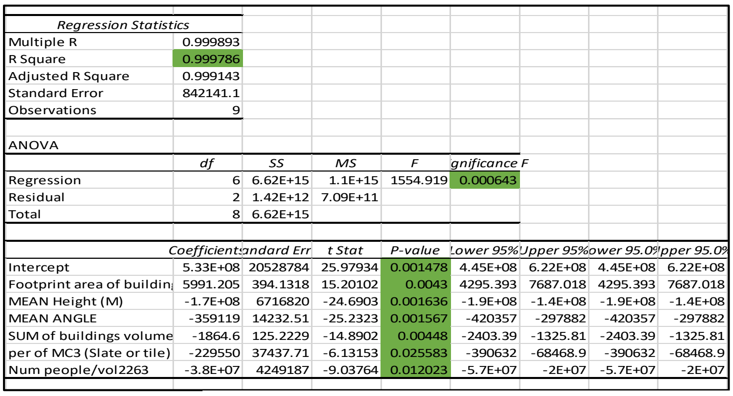


Figure 71 : The Multiple Regression Result of Scenario 19 - RESIDENCIAL CLUSTER E kWh (By Authors)

Scenario 20: RESIDENCIAL CLUSTER E -kWh{n-alt}

y = 0.9998x + 7459.7

X= (533324284.98) + (5991.21* Footprint area of buildings (sum)) + (-165839999.46* MEAN Height (M)) +(-359119.17 * MEAN ANGLE) + (-1864.60* SUM of buildings volume m3) + (-229550.35 * per of MC3 (Slate or tile)) + (-38402612.96* Num people/vol)



Regression Statistics	
Multiple R	0.999893
R Square	0.999786
Adjusted R Square	0.999143
Standard Error	842141.1
Observations	9

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	6.62E+15	1.1E+15	1554.919	0.000643
Residual	2	1.42E+12	7.09E+11		
Total	8	6.62E+15			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	5.33E+08	20528784	25.97934	0.001478	4.45E+08	6.22E+08	4.45E+08	6.22E+08
Footprint area of buildin	5991.205	394.1318	15.20102	0.0043	4295.393	7687.018	4295.393	7687.018
MEAN Height (M)	-1.7E+08	6716820	-24.6903	0.001636	-1.9E+08	-1.4E+08	-1.9E+08	-1.4E+08
MEAN ANGLE	-359119	14232.51	-25.2323	0.001567	-420357	-297882	-420357	-297882
SUM of buildings volume	-1864.6	125.2229	-14.8902	0.00448	-2403.39	-1325.81	-2403.39	-1325.81
per of MC3 (Slate or tile)	-229550	37437.71	-6.13153	0.025583	-390632	-68468.9	-390632	-68468.9
Num people/vol2263	-3.8E+07	4249187	-9.03764	0.012023	-5.7E+07	-2E+07	-5.7E+07	-2E+07

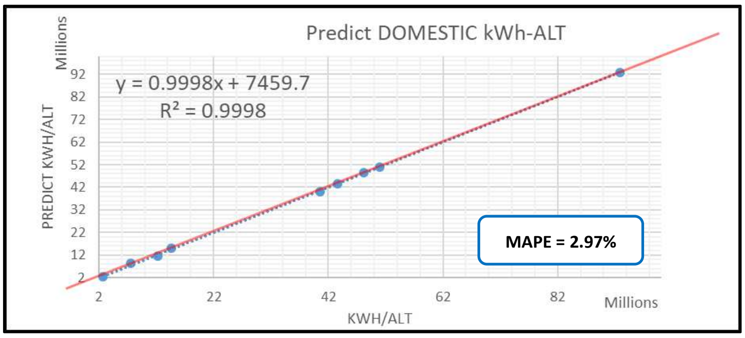
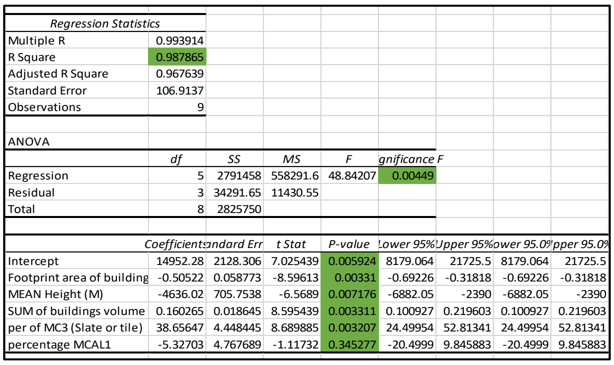


Figure 73 : The Multiple Regression Result of Scenario 20 - RESIDENCIAL CLUSTER D 3-kWh{n-alt} (By Authors)

Scenario 21: RESIDENCIAL CLUSTER E 1-kWh /m3 (E) (not normal)

y = 0.9879x + 6.4113

X= (14952.28) + (-0.51* Footprint area of buildings (sum)) + (-4636.02* MEAN Height (M)) +(0.16 * SUM of buildings volume m3) + (38.66 * per of MC3 (Slate or tile)) + (-5.33* percentage MCAL1)



Regression Statistics	
Multiple R	0.993914
R Square	0.987865
Adjusted R Square	0.967639
Standard Error	106.9137
Observations	9

ANOVA

	df	SS	MS	F	gnificance F
Regression	5	2791458	558291.6	48.84207	0.00449
Residual	3	34291.65	11430.55		
Total	8	2825750			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	14952.28	2128.306	7.025439	0.005924	8179.064	21725.5	8179.064	21725.5
Footprint area of building	-0.50522	0.058773	-8.59613	0.00331	-0.69226	-0.31818	-0.69226	-0.31818
MEAN Height (M)	-4636.02	705.7538	-6.5689	0.007176	-6882.05	-2390	-6882.05	-2390
SUM of buildings volume	0.160265	0.018645	8.595439	0.003311	0.100927	0.219603	0.100927	0.219603
per of MC3 (Slate or tile)	38.65647	4.448445	8.689885	0.003207	24.49954	52.81341	24.49954	52.81341
percentage MCAL1	-5.32703	4.767689	-1.11732	0.345277	-20.4999	9.845883	-20.4999	9.845883

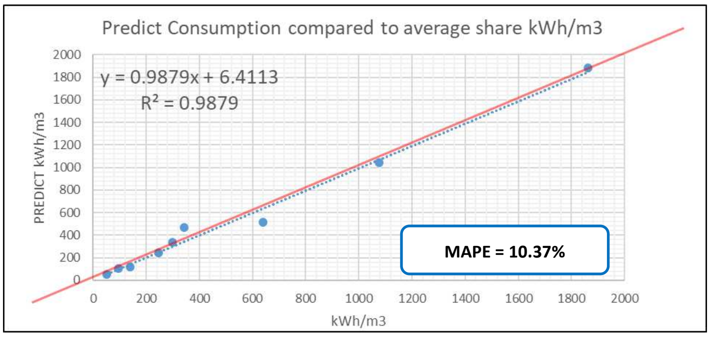
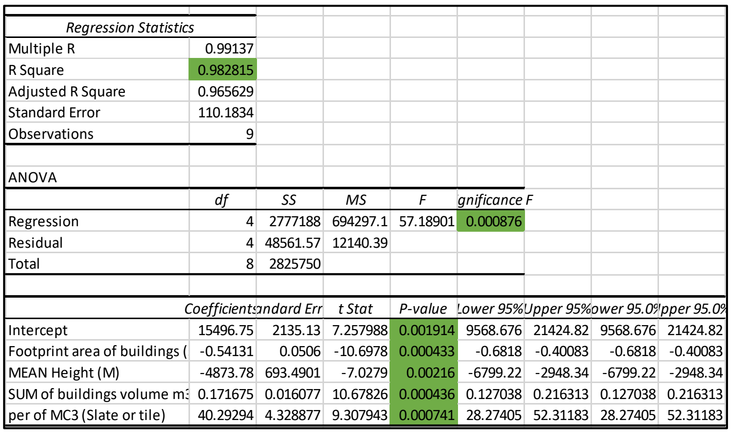


Figure 72: The Multiple Regression Result of Scenario 21 - RESIDENCIAL CLUSTER E 1-kWh/m3 (By Authors)

Scenario 22: RESIDENCIAL CLUSTER E 2-kWh /m3 (E) (not normal)

y = 0.9828x + 9.0792

X= (15496.75) + (-0.54 * Footprint area of buildings (sum)) + (-4873.78* MEAN Height (M)) +(0.17 * SUM of buildings volume m3) + (40.29* per of MC3 (Slate or tile))



Regression Statistics								
Multiple R	0.99137							
R Square	0.982815							
Adjusted R Square	0.965629							
Standard Error	110.1834							
Observations	9							
ANOVA								
	df	*SS*	*MS*	*F*	*gnificance F*			
Regression	4	2777188	694297.1	57.18901	0.000876			
Residual	4	48561.57	12140.39					
Total	8	2825750						
	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	15496.75	2135.13	7.257988	0.001914	9568.676	21424.82	9568.676	21424.82
Footprint area of buildings (	-0.54131	0.0506	-10.6978	0.000433	-0.6818	-0.40083	-0.6818	-0.40083
MEAN Height (M)	-4873.78	693.4901	-7.0279	0.00216	-6799.22	-2948.34	-6799.22	-2948.34
SUM of buildings volume m3	0.171675	0.016077	10.67826	0.000436	0.127038	0.216313	0.127038	0.216313
per of MC3 (Slate or tile)	40.29294	4.328877	9.307943	0.000741	28.27405	52.31183	28.27405	52.31183

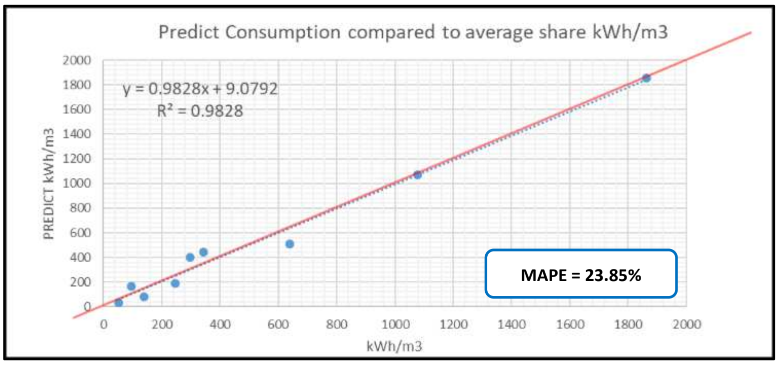


Figure 74 : The Multiple Regression Result of Scenario 22 - RESIDENCIAL CLUSTER E 2-kWh/m3 (By Authors)

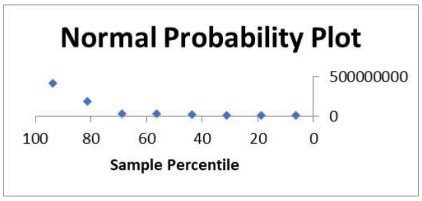
5.1.2 industrial Statistical Models

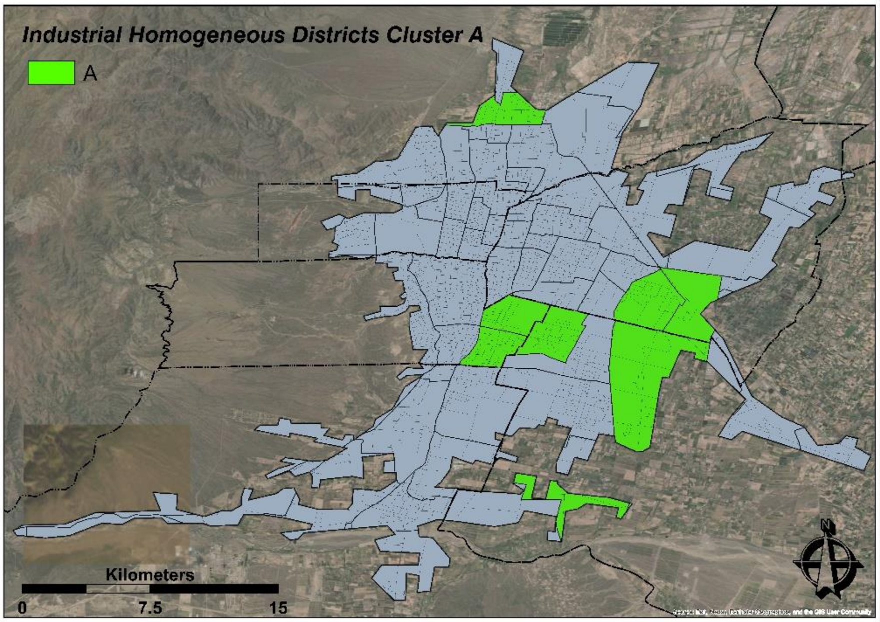
Moving on to the industrial domain, this part presents statistical models that are tailored specifically for industrial clusters. It contains distinct regression models created for each of the Clusters A through D.

5.1.2.1. Industrial Regression Models for Cluster A

The industrial regression models developed for Cluster A are discussed in this paragraph, along with the patterns of energy use and unique characteristics of this industrial cluster.

INDUSTRIAL CLUSTER A
Coquimbito
Cruz de Piedra
El Resguardo
Kilómetro 11
Las Tortugas
Luzuriaga
Rodeo de La Cruz
San Francisco del Monte –(GC)

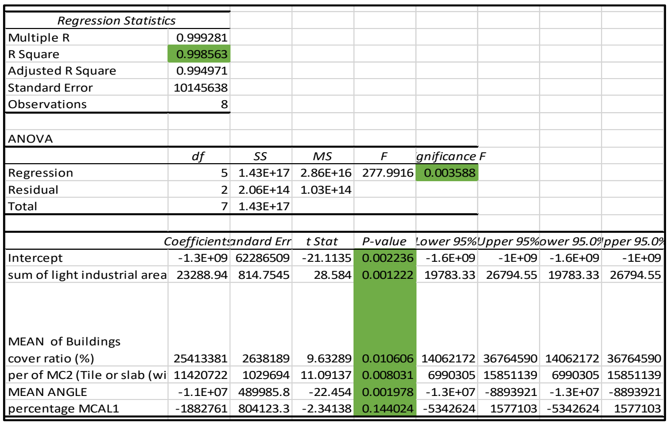




Scenario 23: INDUSTRIAL CLUSTER A 1 kWh (A) (not normal)

y = 0.9986x + 134254

X= (-1315087417.17) + (23288.94 * sum of light industrial area floor m2) + (25413380.96 * MEAN of Buildings cover ratio (%)) +(11420721.65 * per of MC2 (Tile or slab (without cover))) + (-11002160.01 * MEAN ANGLE) + (-1882760.69 * percentage MCAL1)



Regression Statistics	
Multiple R	0.999281
R Square	0.998563
Adjusted R Square	0.994971
Standard Error	10145638
Observations	8

ANOVA

	df	SS	MS	F	gnificance F
Regression	5	1.43E+17	2.86E+16	277.9916	0.003588
Residual	2	2.06E+14	1.03E+14		
Total	7	1.43E+17			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	-1.3E+09	62286509	-21.1135	0.002236	-1.6E+09	-1E+09	-1.6E+09	-1E+09
sum of light industrial area	23288.94	814.7545	28.584	0.001222	19783.33	26794.55	19783.33	26794.55
MEAN of Buildings cover ratio (%)	25413381	2638189	9.63289	0.010606	14062172	36764590	14062172	36764590
per of MC2 (Tile or slab (wi	11420722	1029694	11.09137	0.008031	6990305	15851139	6990305	15851139
MEAN ANGLE	-1.1E+07	489985.8	-22.454	0.001978	-1.3E+07	-8893921	-1.3E+07	-8893921
percentage MCAL1	-1882761	804123.3	-2.34138	0.144024	-5342624	1577103	-5342624	1577103

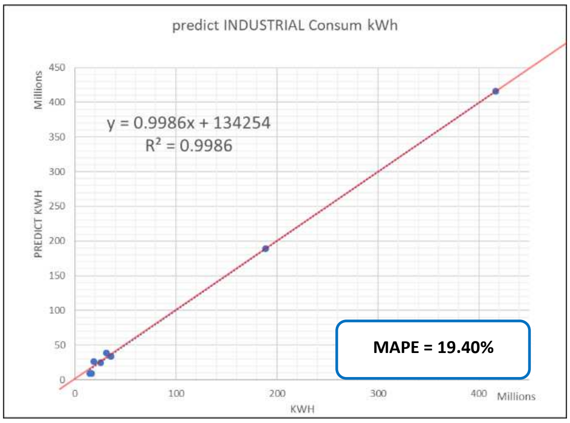
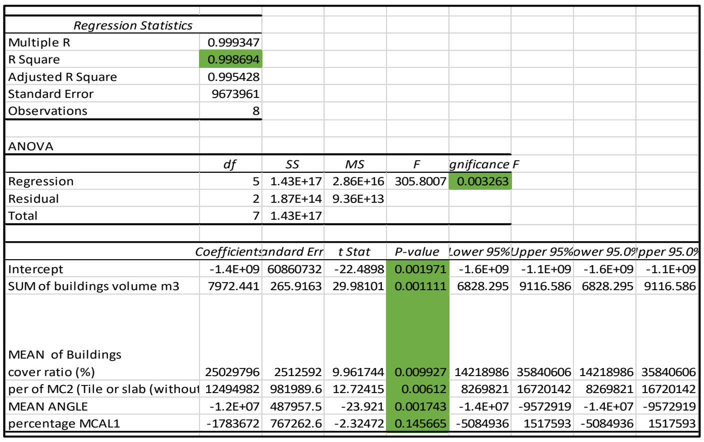


Figure 75 : The Multiple Regression Result of Scenario 23 – INDUSTRIAL CLUSTER A 1 kWh (By Authors)

Scenario 24: INDUSTRIAL CLUSTER A 2 kWh (A) (not normal)

y = 0.9987x + 122061

X= (-1368744966.76) + (7972.44 * SUM of buildings volume m3) + (25029795.99* MEAN of Buildings cover ratio (%)) +(12494981.65 * per of MC2 (Tile or slab (without cover))) + (-11672430.72 * MEAN ANGLE) + (-1783671.74 * percentage MCAL1)



Regression Statistics	
Multiple R	0.999347
R Square	0.998694
Adjusted R Square	0.995428
Standard Error	9673961
Observations	8

ANOVA

	df	SS	MS	F	gnificance F
Regression	5	1.43E+17	2.86E+16	305.8007	0.003263
Residual	2	1.87E+14	9.36E+13		
Total	7	1.43E+17			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	-1.4E+09	60860732	-22.4898	0.001971	-1.6E+09	-1.1E+09	-1.6E+09	-1.1E+09
SUM of buildings volume m3	7972.441	265.9163	29.98101	0.001111	6828.295	9116.586	6828.295	9116.586
MEAN of Buildings cover ratio (%)	25029796	2512592	9.961744	0.009927	14218986	35840606	14218986	35840606
per of MC2 (Tile or slab (withou	12494982	981989.6	12.72415	0.00612	8269821	16720142	8269821	16720142
MEAN ANGLE	-1.2E+07	487957.5	-23.921	0.001743	-1.4E+07	-9572919	-1.4E+07	-9572919
percentage MCAL1	-1783672	767262.6	-2.32472	0.145665	-5084936	1517593	-5084936	1517593

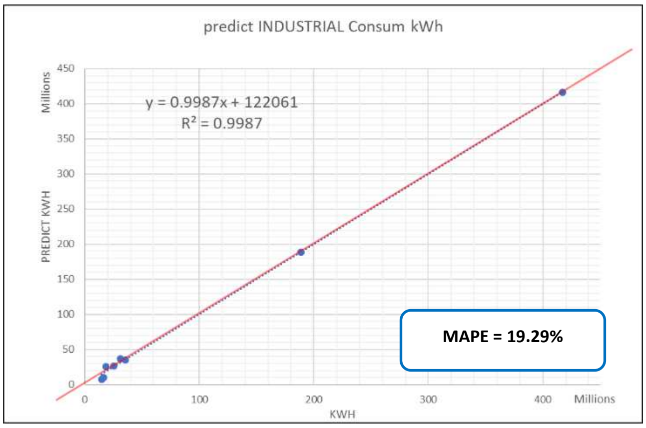
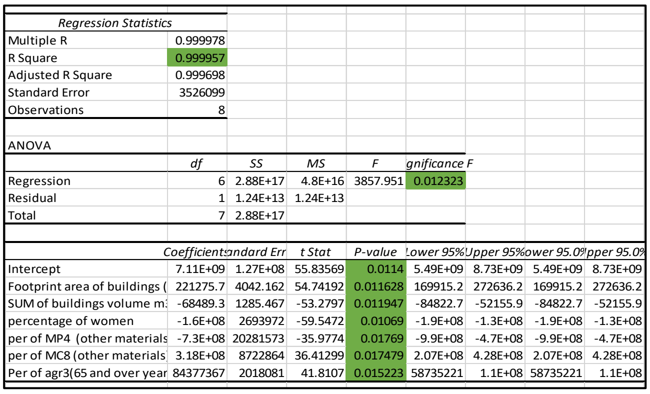


Figure 76 : The Multiple Regression Result of Scenario 24 – INDUSTRIAL CLUSTER A 2 kWh (By Authors)

Scenario 25: INDUSTRIAL CLUSTER A -kWh{n-alt}

y = 1x + 5253.3

X= (7109300413.99) + (221275.71 * Footprint area of buildings M2 (sum)) + (-68489.31 * SUM of buildings volume m3) +(-160418458.76 * percentage of women) + (-729677304.09 * per of MP4 (other materials)) + (317625555.72 * per of MC8 (other materials)) + (84377367.43 * Per of agr3(65 and over years old))



Regression Statistics	
Multiple R	0.999978
R Square	0.999957
Adjusted R Square	0.999698
Standard Error	3526099
Observations	8

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	2.88E+17	4.8E+16	3857.951	0.012323
Residual	1	1.24E+13	1.24E+13		
Total	7	2.88E+17			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	7.11E+09	1.27E+08	55.83569	0.0114	5.49E+09	8.73E+09	5.49E+09	8.73E+09
Footprint area of buildings (	221275.7	4042.162	54.74192	0.011628	169915.2	272636.2	169915.2	272636.2
SUM of buildings volume m3	-68489.3	1285.467	-53.2797	0.011947	-84822.7	-52155.9	-84822.7	-52155.9
percentage of women	-1.6E+08	2693972	-59.5472	0.01069	-1.9E+08	-1.3E+08	-1.9E+08	-1.3E+08
per of MP4 (other materials	-7.3E+08	20281573	-35.9774	0.01769	-9.9E+08	-4.7E+08	-9.9E+08	-4.7E+08
per of MC8 (other materials)	3.18E+08	8722864	36.41299	0.017479	2.07E+08	4.28E+08	2.07E+08	4.28E+08
Per of agr3(65 and over year	84377367	2018081	41.8107	0.015223	58735221	1.1E+08	58735221	1.1E+08

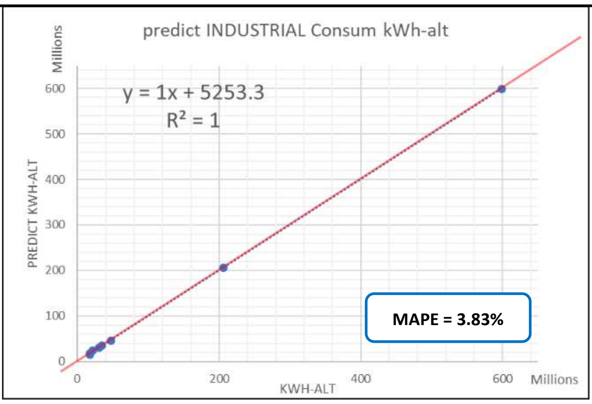
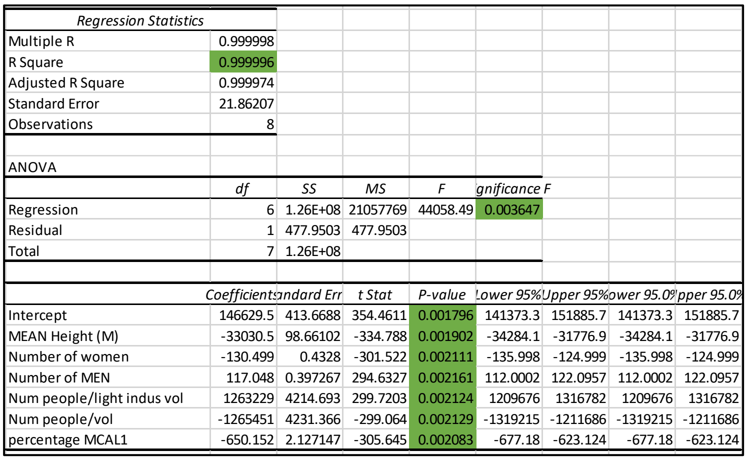


Figure 77 : The Multiple Regression Result of Scenario 25 - INDUSTRIAL CLUSTER A -kWh{n-alt} (By Authors)

Scenario 26: INDUSTRIAL CLUSTER A kWh /m3 (not normal)

$$y = 1x + 0.0155$$

X= (146629.49) + (-33030.53 * **MEAN Height (M)**) + (-130.50 * **Number of women**) +(117.05 * **Number of MEN**) + (1263229.22 * **Num people/light Industrial vol**) + (-1265450.82 * **Num people/vol**) + (-650.15 * **percentage MCAL1**)



Regression Statistics	
Multiple R	0.999998
R Square	0.999996
Adjusted R Square	0.999974
Standard Error	21.86207
Observations	8

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	1.26E+08	21057769	44058.49	0.003647
Residual	1	477.9503	477.9503		
Total	7	1.26E+08			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	146629.5	413.6688	354.4611	0.001796	141373.3	151885.7	141373.3	151885.7
MEAN Height (M)	-33030.5	98.66102	-334.788	0.001902	-34284.1	-31776.9	-34284.1	-31776.9
Number of women	-130.499	0.4328	-301.522	0.002111	-135.998	-124.999	-135.998	-124.999
Number of MEN	117.048	0.397267	294.6327	0.002161	112.0002	122.0957	112.0002	122.0957
Num people/light indus vol	1263229	4214.693	299.7203	0.002124	1209676	1316782	1209676	1316782
Num people/vol	-1265451	4231.366	-299.064	0.002129	-1319215	-1211686	-1319215	-1211686
percentage MCAL1	-650.152	2.127147	-305.645	0.002083	-677.18	-623.124	-677.18	-623.124

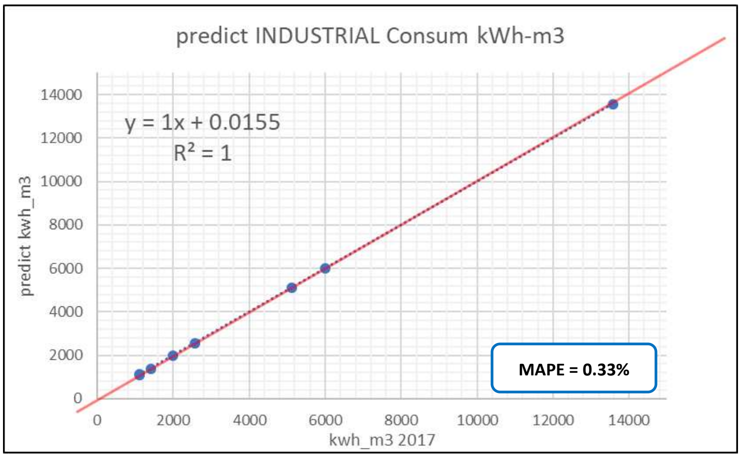
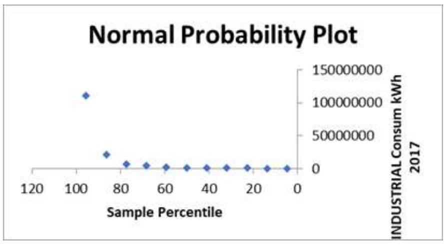


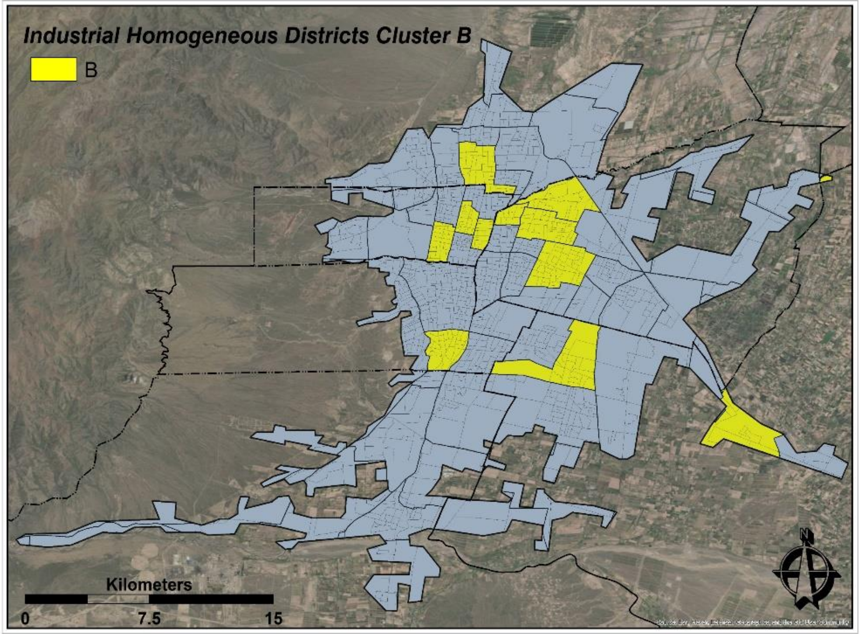
Figure 78 : The Multiple Regression Result of Scenario 26 – INDUSTRIAL CLUSTER A kWh/m3 (By Authors)

5.1.2.2. Industrial Regression Models for Cluster B

This section, which focuses on Cluster B, reveals the industrial regression models designed to identify and evaluate energy consumption patterns unique to this industrial cluster.

INDUSTRIAL CLUSTER B
Belgrano
Bermejo
Ciudad (LH)
General Gutierrez
Gobernador Benegas
Pedro Molina
Primera Sección
Quinta Sección
Rodeo del Medio
Tercera Sección
Villa Nueva

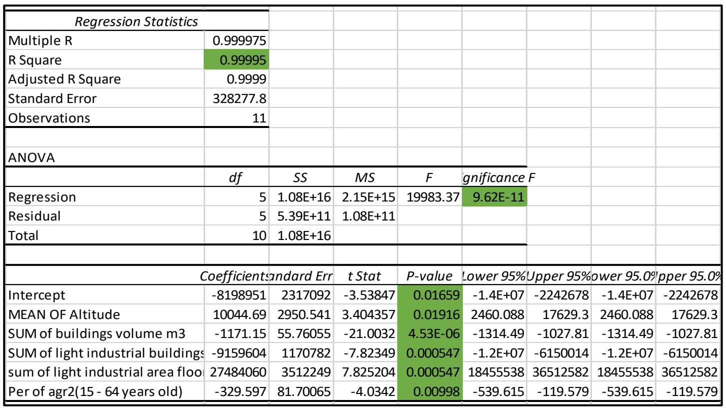




Scenario 27: INDUSTRIAL CLUSTER B kWh (B) (not normal)

y = 0.9999x + 691.66

X= (-8198951.31) + (10044.69 * MEAN OF Altitude) + (-1171.15* SUM of buildings volume m3) +(-9159604.15 * SUM of light industrial buildings volume m3) + (27484060.04 * sum of light industrial area floor m2) + (-329.60 * Per of agr2 (15 - 64 years old))



Regression Statistics	
Multiple R	0.999975
R Square	0.99995
Adjusted R Square	0.9999
Standard Error	328277.8
Observations	11

ANOVA

	df	SS	MS	F	gnificance F
Regression	5	1.08E+16	2.15E+15	19983.37	9.62E-11
Residual	5	5.39E+11	1.08E+11		
Total	10	1.08E+16			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0	pper 95.0
Intercept	-8198951	2317092	-3.53847	0.01659	-1.4E+07	-2242678	-1.4E+07	-2242678
MEAN OF Altitude	10044.69	2950.541	3.404357	0.01916	2460.088	17629.3	2460.088	17629.3
SUM of buildings volume m3	-1171.15	55.76055	-21.0032	4.53E-06	-1314.49	-1027.81	-1314.49	-1027.81
SUM of light industrial buildings	-9159604	1170782	-7.82349	0.000547	-1.2E+07	-6150014	-1.2E+07	-6150014
sum of light industrial area floo	27484060	3512249	7.825204	0.000547	18455538	36512582	18455538	36512582
Per of agr2(15 - 64 years old)	-329.597	81.70065	-4.0342	0.00998	-539.615	-119.579	-539.615	-119.579

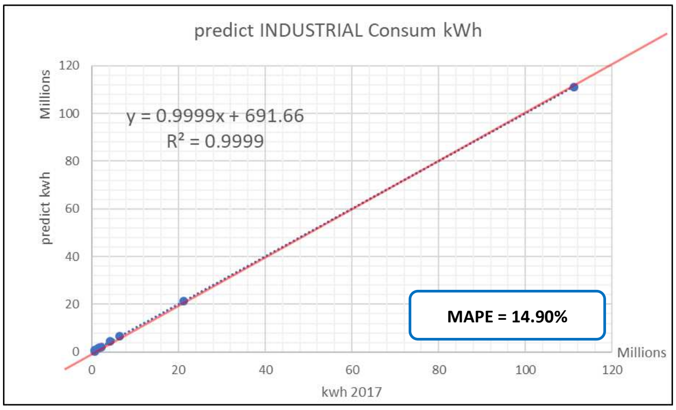
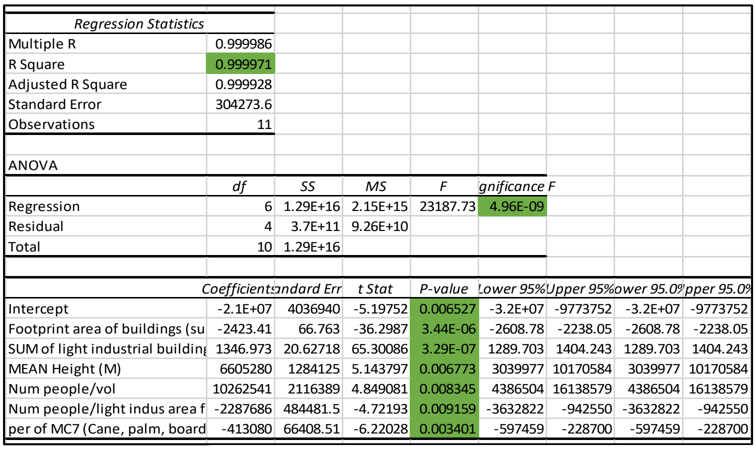


Figure 79 : The Multiple Regression Result of Scenario 27 – INDUSTRIAL CLUSTER B kWh (By Authors)

Scenario 28: INDUSTRIAL CLUSTER B -kWh{n-alt}

y = 1x - 85.825

X= (-20982094.46) + (-2423.41 * Footprint area of buildings (sum)) + (1346.97 * SUM of light industrial buildings volume m3) +(6605280.49 * MEAN Height (M)) + (10262541.13 * Num people/vol) + (-2287685.84 * Num people/light industrial area floor) + (413079.55* per of MC7 (Cane, palm, board or straw with or without mud))



Regression Statistics	
Multiple R	0.999986
R Square	0.999971
Adjusted R Square	0.999928
Standard Error	304273.6
Observations	11

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	1.29E+16	2.15E+15	23187.73	4.96E-09
Residual	4	3.7E+11	9.26E+10		
Total	10	1.29E+16			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0	pper 95.0
Intercept	-2.1E+07	4036940	-5.19752	0.006527	-3.2E+07	-9773752	-3.2E+07	-9773752
Footprint area of buildings (su	-2423.41	66.763	-36.2987	3.44E-06	-2608.78	-2238.05	-2608.78	-2238.05
SUM of light industrial buildin	1346.973	20.62718	65.30086	3.29E-07	1289.703	1404.243	1289.703	1404.243
MEAN Height (M)	6605280	1284125	5.143797	0.006773	3039977	10170584	3039977	10170584
Num people/vol	10262541	2116389	4.849081	0.008345	4386504	16138579	4386504	16138579
Num people/light indus area f	-2287686	484481.5	-4.72193	0.009159	-3632822	-942550	-3632822	-942550
per of MC7 (Cane, palm, board	-413080	66408.51	-6.22028	0.003401	-597459	-228700	-597459	-228700

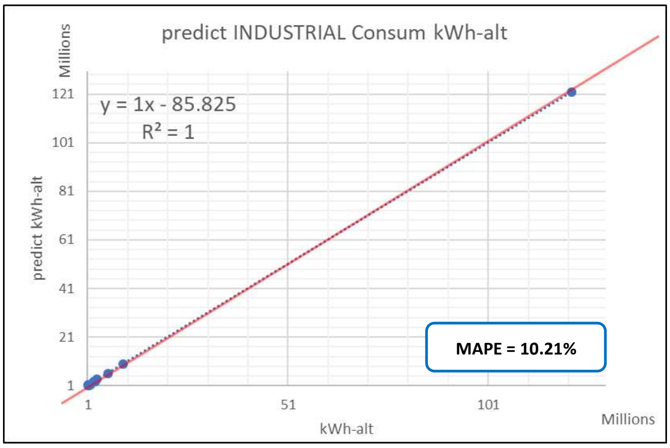
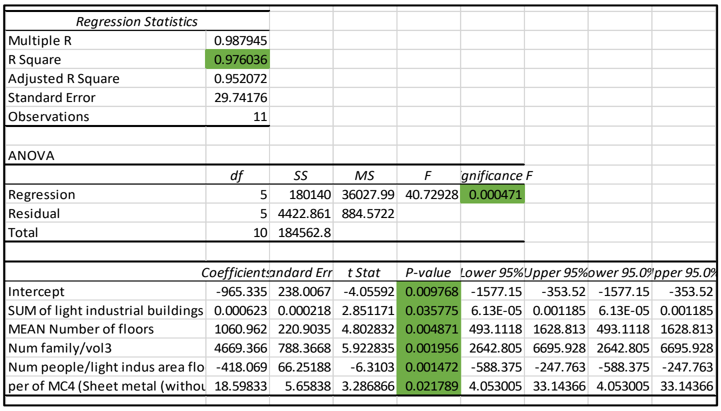


Figure 80 : The Multiple Regression Result of Scenario 28 - INDUSTRIAL CLUSTER B -kWh{n-alt} (By Authors)

Scenario 29: INDUSTRIAL CLUSTER B kWh /m3 (not normal)

y = 0.9772x + 4.3903

X= (-965.34) + (0.00062* SUM of light industrial buildings volume m3) + (1060.96 * MEAN Number of floors) +(4669.37 * Num family/vol) + (-418.07 * Num people/light industrial area floor) + (18.60 * per of MC4 (Sheet metal (without cover)))



Regression Statistics	
Multiple R	0.987945
R Square	0.976036
Adjusted R Square	0.952072
Standard Error	29.74176
Observations	11

ANOVA

	df	SS	MS	F	gnificance F
Regression	5	180140	36027.99	40.72928	0.000471
Residual	5	4422.861	884.5722		
Total	10	184562.8			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0	pper 95.0
Intercept	-965.335	238.0067	-4.05592	0.009768	-1577.15	-353.52	-1577.15	-353.52
SUM of light industrial buildings	0.000623	0.000218	2.851171	0.035775	6.13E-05	0.001185	6.13E-05	0.001185
MEAN Number of floors	1060.962	220.9035	4.802832	0.004871	493.1118	1628.813	493.1118	1628.813
Num family/vol3	4669.366	788.3668	5.922835	0.001956	2642.805	6695.928	2642.805	6695.928
Num people/light indus area flo	-418.069	66.25188	-6.3103	0.001472	-588.375	-247.763	-588.375	-247.763
per of MC4 (Sheet metal (withou	18.59833	5.65838	3.286866	0.021789	4.053005	33.14366	4.053005	33.14366

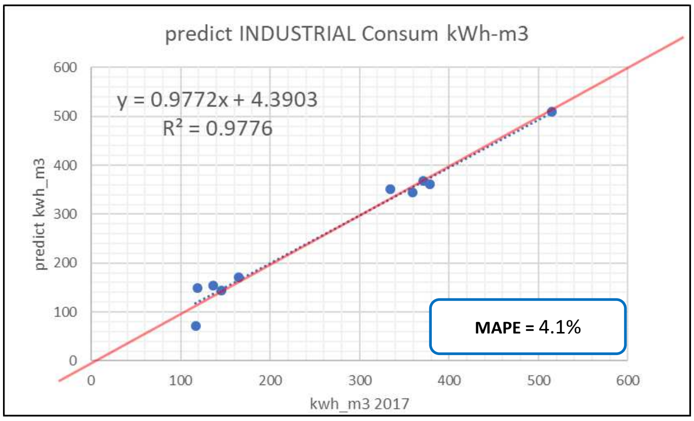
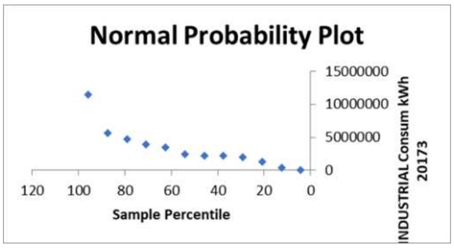


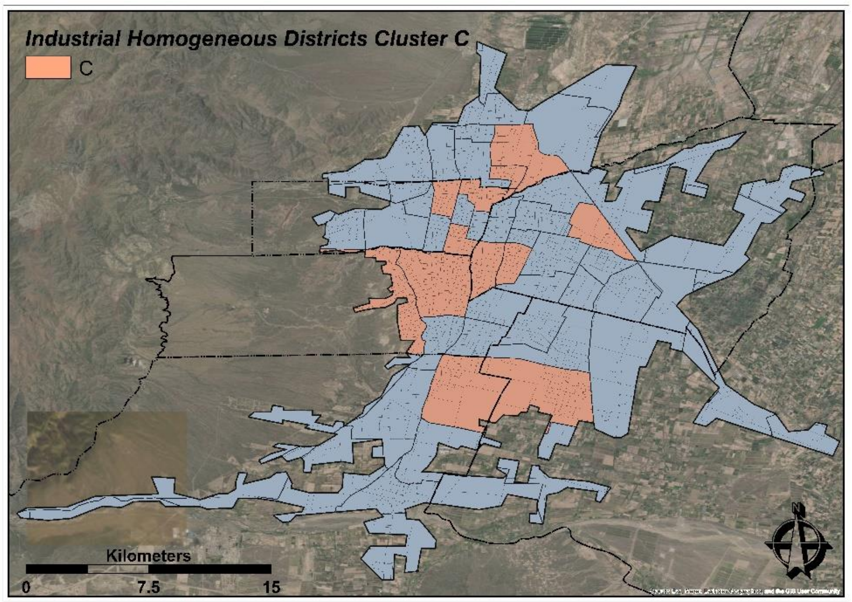
Figure 81 : The Multiple Regression Result of Scenario 29 – INDUSTRIAL CLUSTER B kWh/m3 (By Authors)

5.1.2.3. Industrial Regression Models for Cluster C

Taking a closer look at Cluster C, this section describes the industrial regression models that were carefully created to interpret the energy dynamics that are present in this particular industrial cluster.

INDUSTRIAL CLUSTER C
Buena Nueva
Carrodilla
Ciudad (GC)
Cuarta Sección
Dorrego
El Plumerillo
El Zapallar
Las Cañas
Maipú
Presidente Sarmiento
Segunda Sección
Sexta Sección

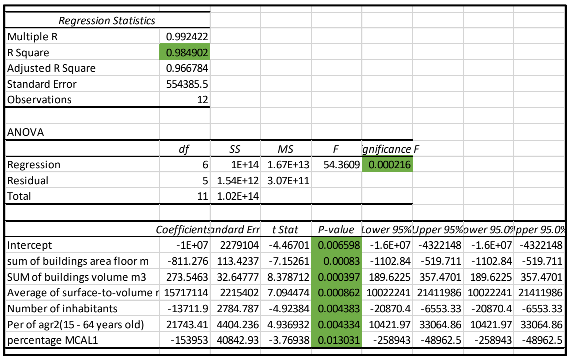




Scenario 30 : INDUSTRIAL CLUSTER C kWh (C) (not normal)

y = 0.9849x + 49852

X= (-10180771.86) + (-811.28 * sum of buildings area floor m) + (273.55 * SUM of buildings volume m3) +(15717113.63 * Average of surface-to-volume ratio) + (-13711.85 * Number of inhabitants) + (21743.41 * Per of agr2(15 - 64 years old)) + (-153952.63 * percentage MCAL1)



Regression Statistics								
Multiple R	0.992422							
R Square	0.984902							
Adjusted R Square	0.966784							
Standard Error	554385.5							
Observations	12							
ANOVA								
	df	*SS*	*MS*	*F*	*gnificance F*			
Regression	6	1E+14	1.67E+13	54.3609	0.000216			
Residual	5	1.54E+12	3.07E+11					
Total	11	1.02E+14						
	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-1E+07	2279104	-4.46701	0.006598	-1.6E+07	-4322148	-1.6E+07	-4322148
sum of buildings area floor m	-811.276	113.4237	-7.15261	0.00083	-1102.84	-519.711	-1102.84	-519.711
SUM of buildings volume m3	273.5463	32.64777	8.378712	0.000397	189.6225	357.4701	189.6225	357.4701
Average of surface-to-volume r	15717114	2215402	7.094474	0.000862	10022241	21411986	10022241	21411986
Number of inhabitants	-13711.9	2784.787	-4.92384	0.004383	-20870.4	-6553.33	-20870.4	-6553.33
Per of agr2(15 - 64 years old)	21743.41	4404.236	4.936932	0.004334	10421.97	33064.86	10421.97	33064.86
percentage MCAL1	-153953	40842.93	-3.76938	0.013031	-258943	-48962.5	-258943	-48962.5

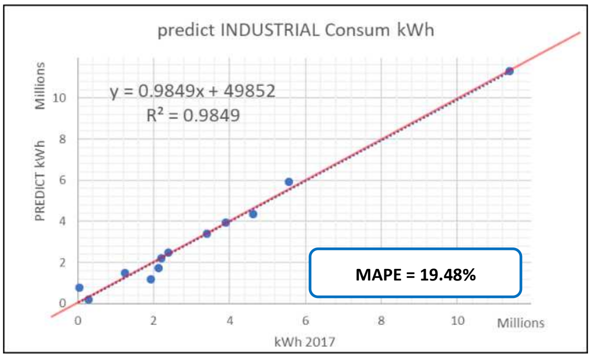
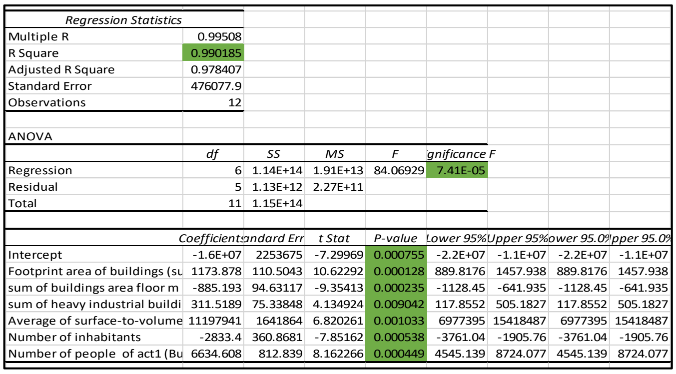


Figure 82 : The Multiple Regression Result of Scenario 30 – INDUSTRIAL CLUSTER C kWh (By Authors)

Scenario 31: INDUSTRIAL CLUSTER C -kWh{n-alt}

y = 0.9902x + 37518

X= (-16451119.05) + (1173.88 * Footprint area of buildings (sum)) + (-885.19 * sum of buildings area floor m2) +(311.52 * sum of heavy industrial buildings area floor m2) + (11197940.97 * Average of surface-to-volume ratio) + (-2833.40 * Number of inhabitants) + (6634.61 * Number of people of act1 (Busy))



Regression Statistics								
Multiple R	0.99508							
R Square	0.990185							
Adjusted R Square	0.978407							
Standard Error	476077.9							
Observations	12							
ANOVA								
	df	*SS*	*MS*	*F*	*gnificance F*			
Regression	6	1.14E+14	1.91E+13	84.06929	7.41E-05			
Residual	5	1.13E+12	2.27E+11					
Total	11	1.15E+14						
	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-1.6E+07	2253675	-7.29969	0.000755	-2.2E+07	-1.1E+07	-2.2E+07	-1.1E+07
Footprint area of buildings (su	1173.878	110.5043	10.62292	0.000128	889.8176	1457.938	889.8176	1457.938
sum of buildings area floor m	-885.193	94.63117	-9.35413	0.000235	-1128.45	-641.935	-1128.45	-641.935
sum of heavy industrial buildi	311.5189	75.33848	4.134924	0.009042	117.8552	505.1827	117.8552	505.1827
Average of surface-to-volume	11197941	1641864	6.820261	0.001033	6977395	15418487	6977395	15418487
Number of inhabitants	-2833.4	360.8681	-7.85162	0.000538	-3761.04	-1905.76	-3761.04	-1905.76
Number of people of act1 (Bu	6634.608	812.839	8.162266	0.000449	4545.139	8724.077	4545.139	8724.077

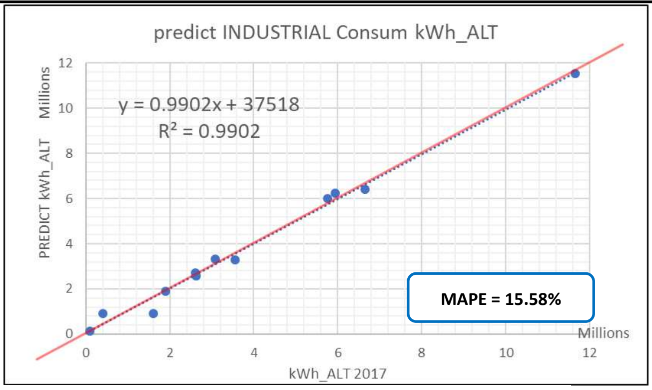
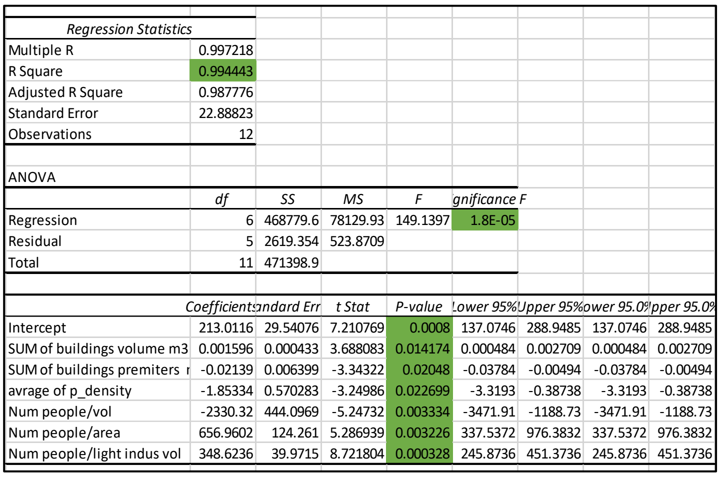


Figure 83: The Multiple Regression Result of Scenario 31 - INDUSTRIAL CLUSTER C -kWh{n-alt} (By Authors)

Scenario 32 : INDUSTRIAL CLUSTER C kWh /m2 (C) (not normal)

y = 0.9944x + 1.3589

X= (213.01) + (0.002* SUM of buildings volume m3) + (-0.02 * SUM of buildings perimeters m2) +(-1.85 * average population of density) + (-2330.32 * Num people/vol) + (656.96 * Num people/area) + (348.62 * Num people/light industrial vol)



Regression Statistics	
Multiple R	0.997218
R Square	0.994443
Adjusted R Square	0.987776
Standard Error	22.88823
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	6	468779.6	78129.93	149.1397	1.8E-05
Residual	5	2619.354	523.8709		
Total	11	471398.9			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	213.0116	29.54076	7.210769	0.0008	137.0746	288.9485	137.0746	288.9485
SUM of buildings volume m3	0.001596	0.000433	3.688083	0.014174	0.000484	0.002709	0.000484	0.002709
SUM of buildings premiters r	-0.02139	0.006399	-3.34322	0.02048	-0.03784	-0.00494	-0.03784	-0.00494
avrage of p_density	-1.85334	0.570283	-3.24986	0.022699	-3.3193	-0.38738	-3.3193	-0.38738
Num people/vol	-2330.32	444.0969	-5.24732	0.003334	-3471.91	-1188.73	-3471.91	-1188.73
Num people/area	656.9602	124.261	5.286939	0.003226	337.5372	976.3832	337.5372	976.3832
Num people/light indus vol	348.6236	39.9715	8.721804	0.000328	245.8736	451.3736	245.8736	451.3736

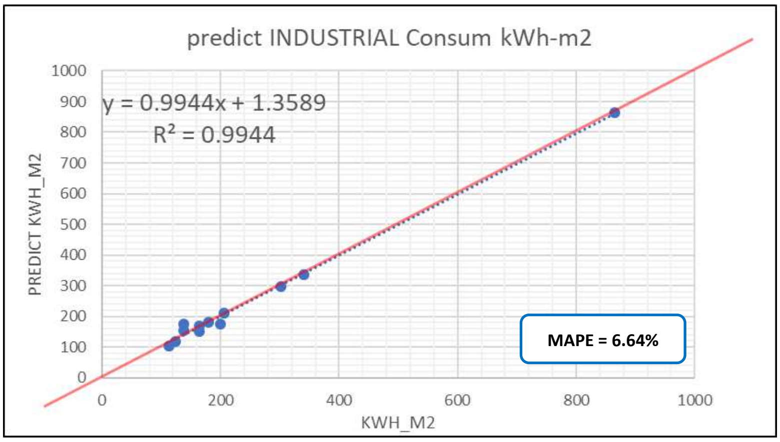
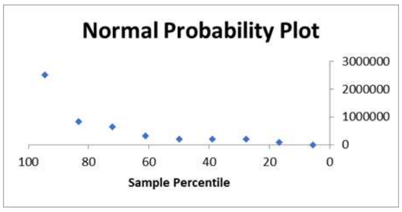


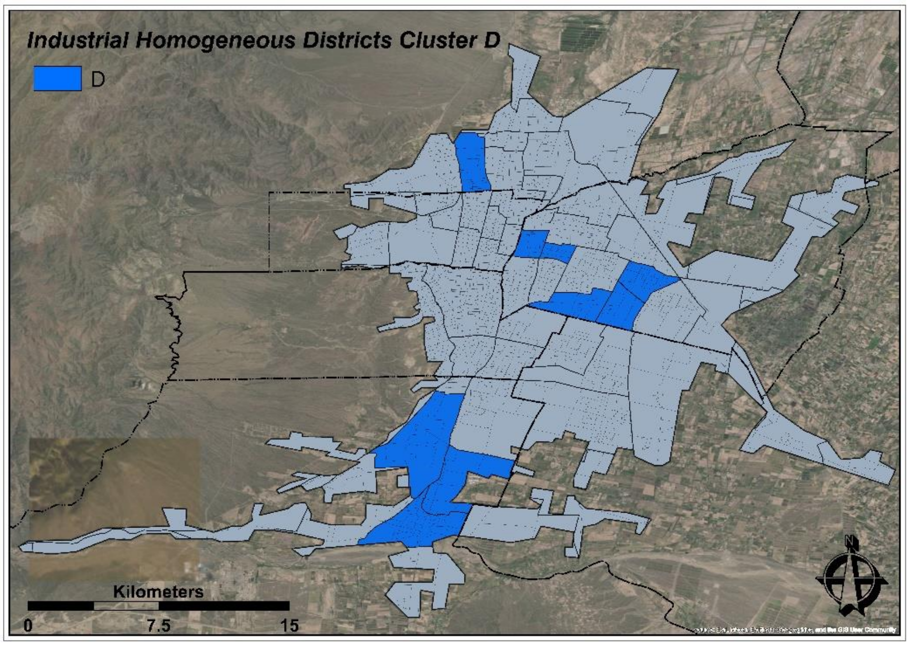
Figure 84 : The Multiple Regression Result of Scenario 32 – INDUSTRIAL CLUSTER C kWh/m2 (By Authors)

5.1.2.4. Industrial Regression Models for Cluster D

As a last section on the industrial models, this paragraph describes the regression models specifically designed for Cluster D. This provides a thorough insight into the patterns of energy use unique to this particular industrial cluster.

INDUSTRIAL CLUSTER D
Capilla del Rosario
Chacras de Coria
Ciudad (L)
Jesús Nazareno
La Cieneguita
Mayor Drummond
Nueva Ciudad
San Francisco del Monte (Gy)
San José (Gy)

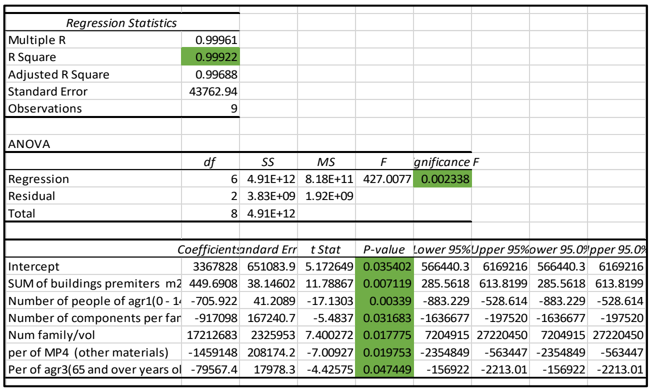




Scenario 33 : INDUSTRIAL CLUSTER D kWh (D) (not normal)

y = 0.9992x + 433.4

X= (3367828.12) + (449.69 * SUM of buildings perimeters m2) + (-705.92 * Number of people of agr1(0 - 14 years old)) +(-917098.05 * Number of components per family) + (17212682.65 * Num family/vol) + (-1459148.09 * per of MP4 (other materials)) + (-79567.40 * Per of agr3(65 and over years old))



Regression Statistics	
Multiple R	0.99961
R Square	0.99922
Adjusted R Square	0.99688
Standard Error	43762.94
Observations	9

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	4.91E+12	8.18E+11	427.0077	0.002338
Residual	2	3.83E+09	1.92E+09		
Total	8	4.91E+12			

	Coefficient	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	3367828	651083.9	5.172649	0.035402	566440.3	6169216	566440.3	6169216
SUM of buildings premiters m2	449.6908	38.14602	11.78867	0.007119	285.5618	613.8199	285.5618	613.8199
Number of people of agr1(0 - 1	-705.922	41.2089	-17.1303	0.00339	-883.229	-528.614	-883.229	-528.614
Number of components per far	-917098	167240.7	-5.4837	0.031683	-1636677	-197520	-1636677	-197520
Num family/vol	17212683	2325953	7.400272	0.017775	7204915	27220450	7204915	27220450
per of MP4 (other materials)	-1459148	208174.2	-7.00927	0.019753	-2354849	-563447	-2354849	-563447
Per of agr3(65 and over years ol	-79567.4	17978.3	-4.42575	0.047449	-156922	-2213.01	-156922	-2213.01

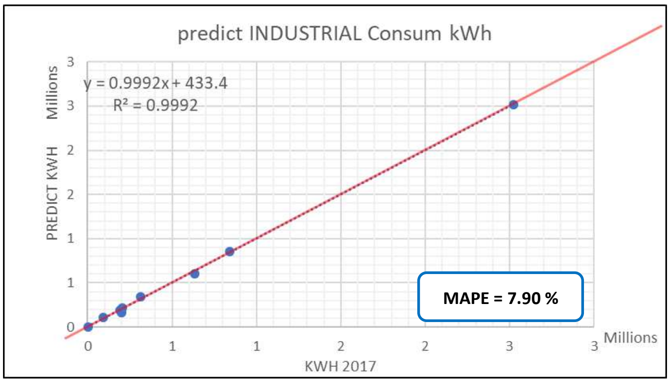
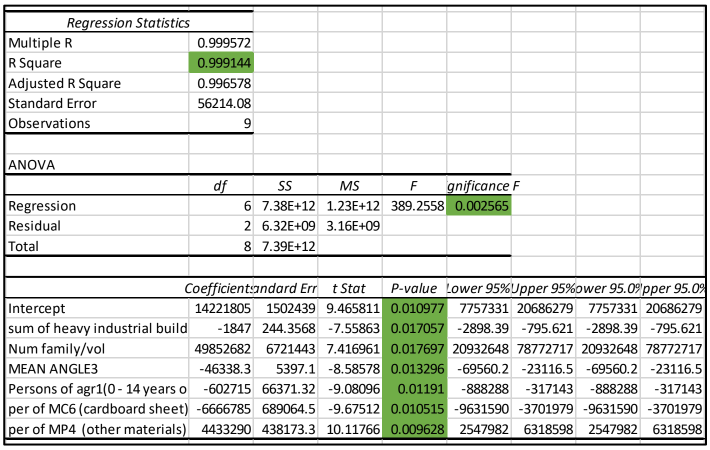


Figure 86 : The Multiple Regression Result of Scenario 33 – INDUSTRIAL CLUSTER D kWh (By Authors)

Scenario 34: INDUSTRIAL CLUSTER D -kWh{n-alt}

y = 0.9991x + 545.29

X= (14221805.06) + (-1847.00 * sum of heavy industrial buildings area floor M2) + (49852682.49 * Num family/vol) +(-46338.31 * MEAN ANGLE) + (-602715.36 * Persons of agr1(0 - 14 years old)) + (-6666784.69 * per of MC6 (cardboard sheet)) + (4433290.09 * per of MP4 (other materials))



Regression Statistics	
Multiple R	0.999572
R Square	0.999144
Adjusted R Square	0.996578
Standard Error	56214.08
Observations	9

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	7.38E+12	1.23E+12	389.2558	0.002565
Residual	2	6.32E+09	3.16E+09		
Total	8	7.39E+12			

	Coefficient	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	14221805	1502439	9.465811	0.010977	7757331	20686279	7757331	20686279
sum of heavy industrial build	-1847	244.3568	-7.55863	0.017057	-2898.39	-795.621	-2898.39	-795.621
Num family/vol	49852682	6721443	7.416961	0.017697	20932648	78772717	20932648	78772717
MEAN ANGLE3	-46338.3	5397.1	-8.58578	0.013296	-69560.2	-23116.5	-69560.2	-23116.5
Persons of agr1(0 - 14 years o	-602715	66371.32	-9.08096	0.01191	-888288	-317143	-888288	-317143
per of MC6 (cardboard sheet)	-6666785	689064.5	-9.67512	0.010515	-9631590	-3701979	-9631590	-3701979
per of MP4 (other materials)	4433290	438173.3	10.11766	0.009628	2547982	6318598	2547982	6318598

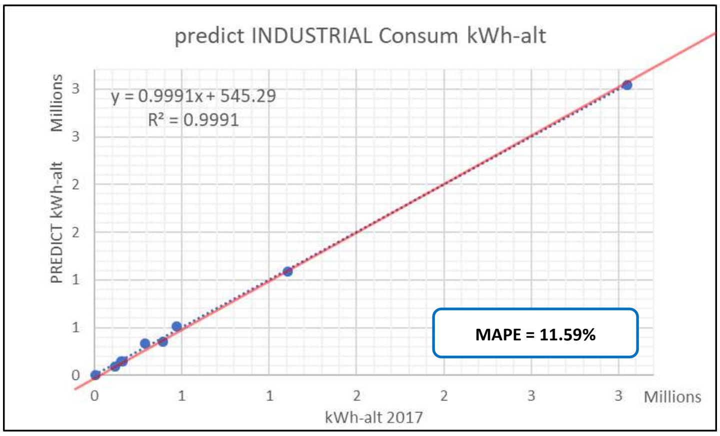
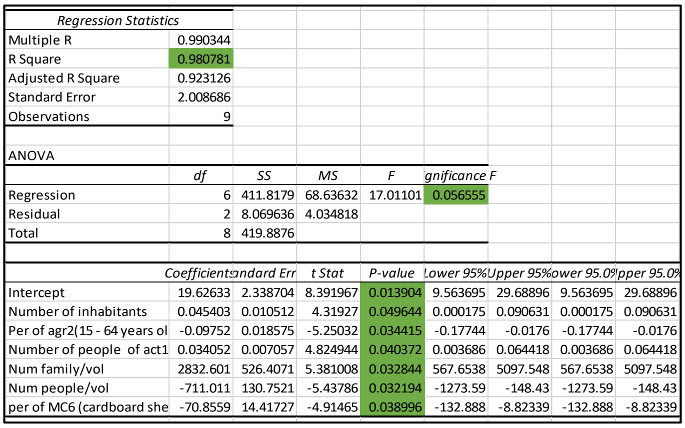


Figure 85 : The Multiple Regression Result of Scenario 34 - INDUSTRIAL CLUSTER D -kWh{n-alt} (By Authors)

Scenario 35 : INDUSTRIAL CLUSTER D kWh /m3 (D) (not normal)

y = 0.9808x + 0.1835

X= (19.626) + (0.045 * Number of inhabitants) + (-0.098 * Per of agr2(15 - 64 years old)) +(0.034 * Number of people of act1 (Busy)) + (2832.601 * Num family/vol) + (-711.011* Num people/vol) + (-70.856 * per of MC6 (cardboard sheet))



Regression Statistics	
Multiple R	0.990344
R Square	0.980781
Adjusted R Square	0.923126
Standard Error	2.008686
Observations	9

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	411.8179	68.63632	17.01101	0.056555
Residual	2	8.069636	4.034818		
Total	8	419.8876			

	Coefficient	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	19.62633	2.338704	8.391967	0.013904	9.563695	29.68896	9.563695	29.68896
Number of inhabitants	0.045403	0.010512	4.31927	0.049644	0.000175	0.090631	0.000175	0.090631
Per of agr2(15 - 64 years ol	-0.09752	0.018575	-5.25032	0.034415	-0.17744	-0.0176	-0.17744	-0.0176
Number of people of act1	0.034052	0.007057	4.824944	0.040372	0.003686	0.064418	0.003686	0.064418
Num family/vol	2832.601	526.4071	5.381008	0.032844	567.6538	5097.548	567.6538	5097.548
Num people/vol	-711.011	130.7521	-5.43786	0.032194	-1273.59	-148.43	-1273.59	-148.43
per of MC6 (cardboard she	-70.8559	14.41727	-4.91465	0.038996	-132.888	-8.82339	-132.888	-8.82339

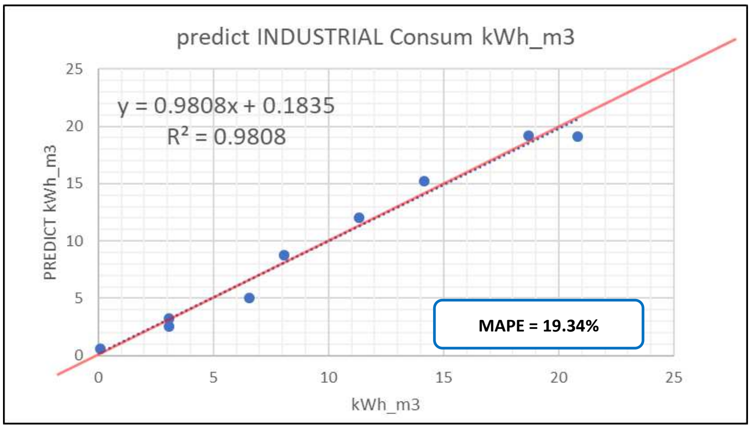


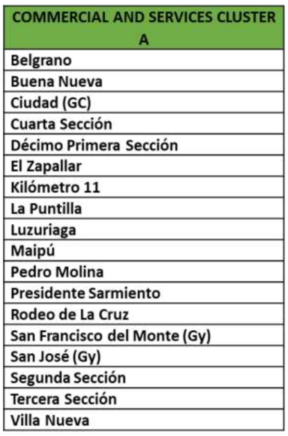
Figure 87 : The Multiple Regression Result of Scenario 35 – INDUSTRIAL CLUSTER D kWh/m3 (By Authors)

5.1.3 commercial and services Statistical Models

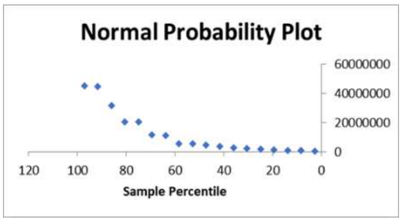
Statistical models intended for the business and services industry are the main focus of this section. It includes separate regression models for each of the Clusters A through C.

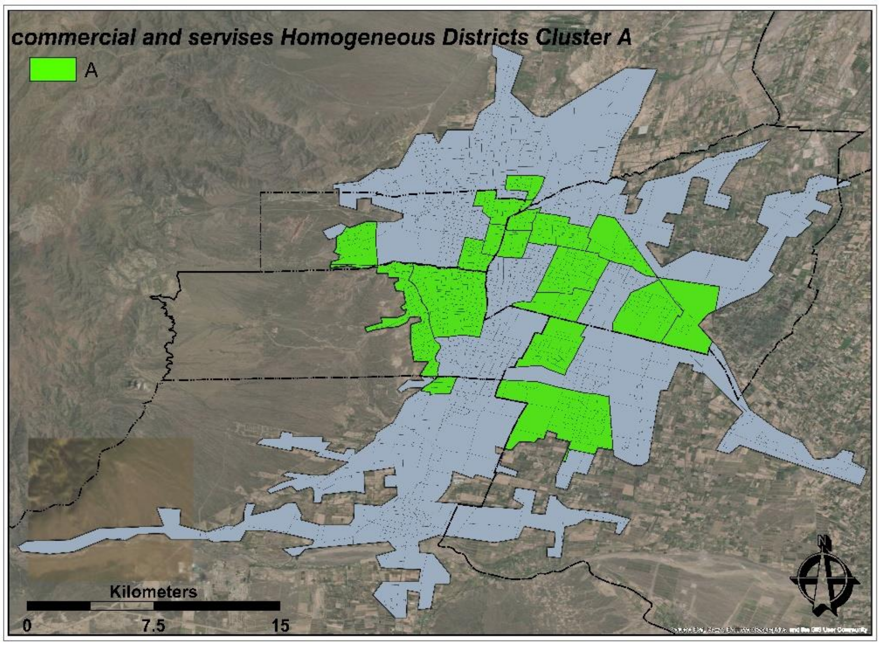
5.1.3.1. Commercial and Services Regression Models for Cluster A

Beginning with Cluster A, this part goes into the subtleties of the commercial and services regression models, offering insights into the energy usage trends within this specific cluster.



COMMERCIAL AND SERVICES CLUSTER A
Belgrano
Buena Nueva
Ciudad (GC)
Cuarta Sección
Décimo Primera Sección
El Zapallar
Kilómetro 11
La Puntilla
Luzuriaga
Maipú
Pedro Molina
Presidente Sarmiento
Rodeo de La Cruz
San Francisco del Monte (Gy)
San José (Gy)
Segunda Sección
Tercera Sección
Villa Nueva

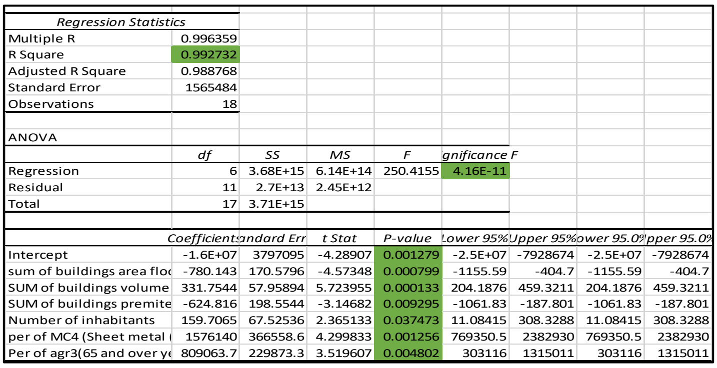




Scenario 36 : COMMERCIAL AND SERVICES CLUSTER A kWh (A) (not normal)

$$y = 0.9927x + 86780$$

X= (-16286024.42) + (-780.14 * sum of buildings area floor m2) + (331.75 * SUM of buildings volume m3) +(-624.82* SUM of buildings perimeters m2) + (159.71* Number of inhabitants) + (1576140.46 * per of MC4 (Sheet metal (without cover))) + (809063.69* Per of agr3(65 and over years old))



Regression Statistics								
Multiple R	0.996359							
R Square	0.992732							
Adjusted R Square	0.988768							
Standard Error	1565484							
Observations	18							
ANOVA								
	df	SS	MS	F	gnificance F			
Regression	6	3.68E+15	6.14E+14	250.4155	4.16E-11			
Residual	11	2.7E+13	2.45E+12					
Total	17	3.71E+15						
	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	-1.6E+07	3797095	-4.28907	0.001279	-2.5E+07	-7928674	-2.5E+07	-7928674
sum of buildings area flo	-780.143	170.5796	-4.57348	0.000799	-1155.59	-404.7	-1155.59	-404.7
SUM of buildings volume	331.7544	57.95894	5.723955	0.000133	204.1876	459.3211	204.1876	459.3211
SUM of buildings premite	-624.816	198.5544	-3.14682	0.009295	-1061.83	-187.801	-1061.83	-187.801
Number of inhabitants	159.7065	67.52536	2.365133	0.037473	11.08415	308.3288	11.08415	308.3288
per of MC4 (Sheet metal (	1576140	366558.6	4.299833	0.001256	769350.5	2382930	769350.5	2382930
Per of agr3(65 and over ye	809063.7	229873.3	3.519607	0.004802	303116	1315011	303116	1315011

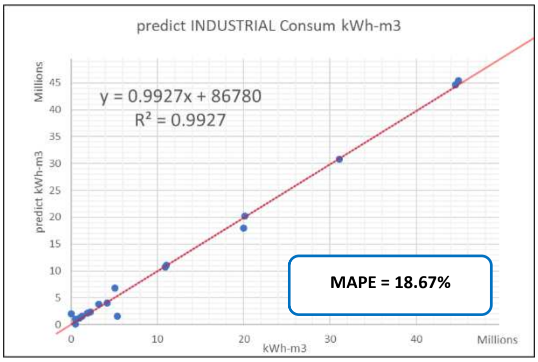
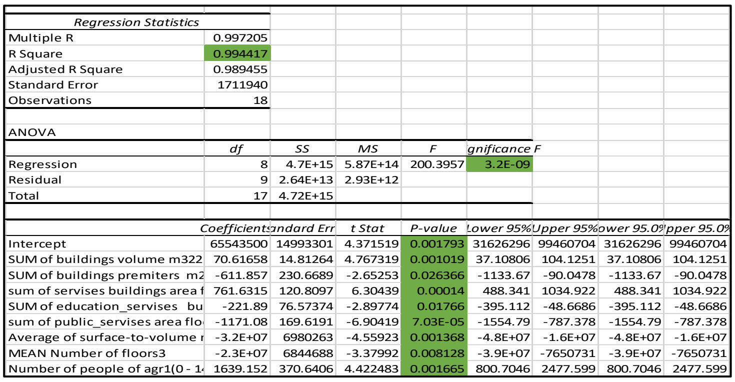


Figure 88 : The Multiple Regression Result of Scenario 36 COMMERCIAL AND SERVICES CLUSTER A kWh (By Authors)

Scenario 37: COMMERCIAL AND SERVICES CLUSTER A 1 -kWh{n-alt}

y = 0.9944x + 78758

X= (65543499.97) + (70.62 * SUM of buildings volume m3) + (-611.86* SUM of buildings perimeters m2) +(761.63 * sum of services buildings area floor m2) + (-221.89 * SUM of education _ services   buildings volume M2) + (-1171.08 * sum of public _ services area floor m2) + (-31824605.12 * Average of surface-to-volume ratio) + (-23134492.51 * MEAN Number of floors) + (1639.15 * Number of people of agr1(0 - 14 years old))



Regression Statistics	
Multiple R	0.997205
R Square	0.994417
Adjusted R Square	0.989455
Standard Error	1711940
Observations	18

ANOVA

	df	SS	MS	F	gnificance F
Regression	8	4.7E+15	5.87E+14	200.3957	3.2E-09
Residual	9	2.64E+13	2.93E+12		
Total	17	4.72E+15			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	65543500	14993301	4.371519	0.001793	31626296	99460704	31626296	99460704
SUM of buildings volume m322	70.61658	14.81264	4.767319	0.001019	37.10806	104.1251	37.10806	104.1251
SUM of buildings premiters m2	-611.857	230.6689	-2.65253	0.026366	-1133.67	-90.0478	-1133.67	-90.0478
sum of servises buildings area f	761.6315	120.8097	6.30439	0.00014	488.341	1034.922	488.341	1034.922
SUM of education_servises bu	-221.89	76.57374	-2.89774	0.01766	-395.112	-48.6686	-395.112	-48.6686
sum of public_servises area flo	-1171.08	169.6191	-6.90419	7.03E-05	-1554.79	-787.378	-1554.79	-787.378
Average of surface-to-volume r	-3.2E+07	6980263	-4.55923	0.001368	-4.8E+07	-1.6E+07	-4.8E+07	-1.6E+07
MEAN Number of floors3	-2.3E+07	6844688	-3.37992	0.008128	-3.9E+07	-7650731	-3.9E+07	-7650731
Number of people of agr1(0 - 14	1639.152	370.6406	4.422483	0.001665	800.7046	2477.599	800.7046	2477.599

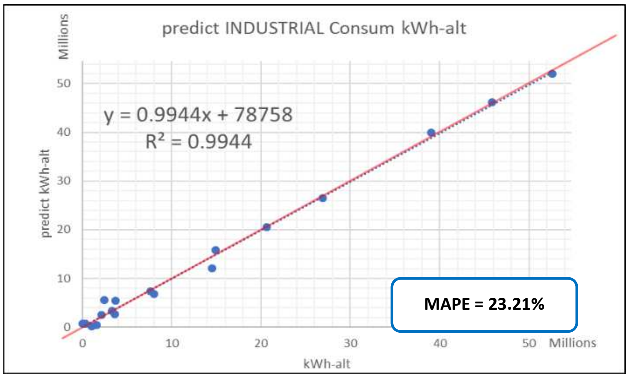
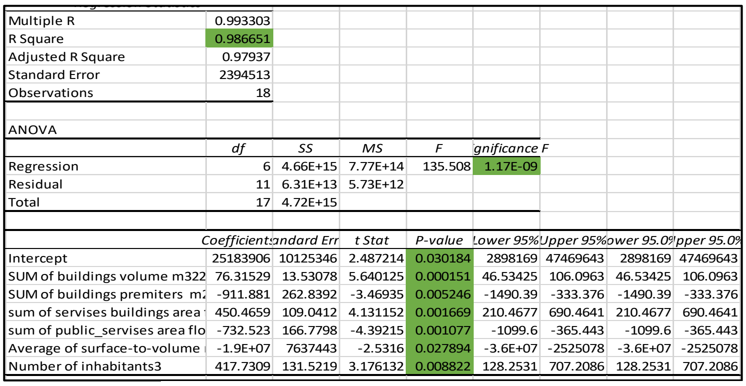


Figure 89 ; The Multiple Regression Result of Scenario 37 - COMMERCIAL AND SERVICES CLUSTER A   1-kWh{n-alt} (By Authors)

Scenario 38: COMMERCIAL AND SERVICES CLUSTER A 2 -kWh{n-alt}

y = 0.9867x + 188321

X= (25183906.06) + (76.32 * SUM of buildings volume m3) + (-911.88 * SUM of buildings perimeters m2) +(450.47 * sum of services buildings area floor m2) + (-732.52* sum of public _ services area floor m2) + (-19334977.12 * Average of surface-to-volume ratio) + (417.73 * Number of inhabitants)



Multiple R	0.993303
R Square	0.986651
Adjusted R Square	0.97937
Standard Error	2394513
Observations	18

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	4.66E+15	7.77E+14	135.508	1.17E-09
Residual	11	6.31E+13	5.73E+12		
Total	17	4.72E+15			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	25183906	10125346	2.487214	0.030184	2898169	47469643	2898169	47469643
SUM of buildings volume m322	76.31529	13.53078	5.640125	0.000151	46.53425	106.0963	46.53425	106.0963
SUM of buildings premiters m2	-911.881	262.8392	-3.46935	0.005246	-1490.39	-333.376	-1490.39	-333.376
sum of servises buildings area f	450.4659	109.0412	4.131152	0.001669	210.4677	690.4641	210.4677	690.4641
sum of public_servises area flo	-732.523	166.7798	-4.39215	0.001077	-1099.6	-365.443	-1099.6	-365.443
Average of surface-to-volume r	-1.9E+07	7637443	-2.5316	0.027894	-3.6E+07	-2525078	-3.6E+07	-2525078
Number of inhabitants3	417.7309	131.5219	3.176132	0.008822	128.2531	707.2086	128.2531	707.2086

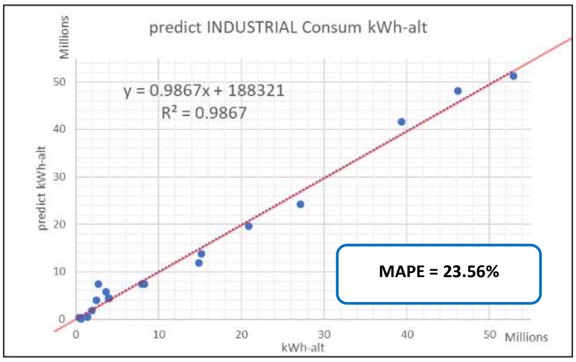
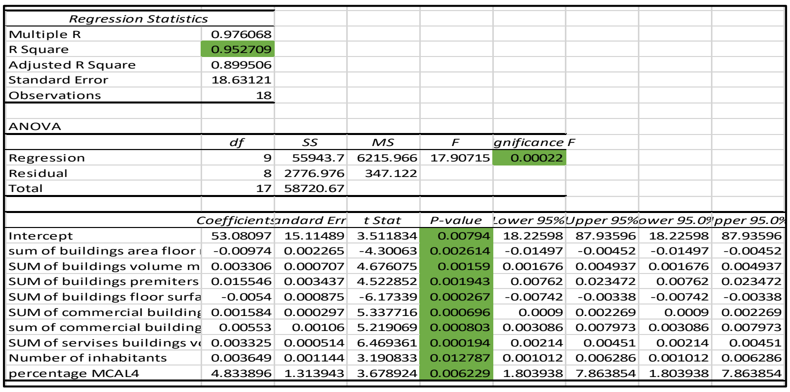


Figure 90 ; The Multiple Regression Result of Scenario 38 - COMMERCIAL AND SERVICES CLUSTER A   2-kWh{n-alt} (By Authors)

Scenario 39 : COMMERCIAL AND SERVICES CLUSTER A 1- kWh/m2 (A) (not normal)

y = 0.9527x + 6.3801

X= (53.0810) + (-0.0097 * sum of buildings area floor m2) + (0.0033 * SUM of buildings volume m3) +(0.0155 * SUM of buildings perimeters m2) + (-0.0054 * SUM of buildings floor surface m2) + (0.0016 * SUM of commercial buildings volume m3) + (0.0055* sum of commercial buildings area floor m2) + (0.0033 * sum of services buildings area floor m2) + (0.0036* Number of inhabitants) + (4.8339 * percentage MCAL4)



Regression Statistics	
Multiple R	0.976068
R Square	0.952709
Adjusted R Square	0.899506
Standard Error	18.63121
Observations	18

ANOVA

	df	SS	MS	F	gnificance F
Regression	9	55943.7	6215.966	17.90715	0.00022
Residual	8	2776.976	347.122		
Total	17	58720.67			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	53.08097	15.11489	3.511834	0.00794	18.22598	87.93596	18.22598	87.93596
sum of buildings area floor r	-0.00974	0.002265	-4.30063	0.002614	-0.01497	-0.00452	-0.01497	-0.00452
SUM of buildings volume m	0.003306	0.000707	4.676075	0.00159	0.001676	0.004937	0.001676	0.004937
SUM of buildings premiters	0.015546	0.003437	4.522852	0.001943	0.00762	0.023472	0.00762	0.023472
SUM of buildings floor surfa	-0.0054	0.000875	-6.17339	0.000267	-0.00742	-0.00338	-0.00742	-0.00338
SUM of commercial building	0.001584	0.000297	5.337716	0.000696	0.0009	0.002269	0.0009	0.002269
sum of commercial building	0.00553	0.00106	5.219069	0.000803	0.003086	0.007973	0.003086	0.007973
SUM of servises buildings vo	0.003325	0.000514	6.469361	0.000194	0.00214	0.00451	0.00214	0.00451
Number of inhabitants	0.003649	0.001144	3.190833	0.012787	0.001012	0.006286	0.001012	0.006286
percentage MCAL4	4.833896	1.313943	3.678924	0.006229	1.803938	7.863854	1.803938	7.863854

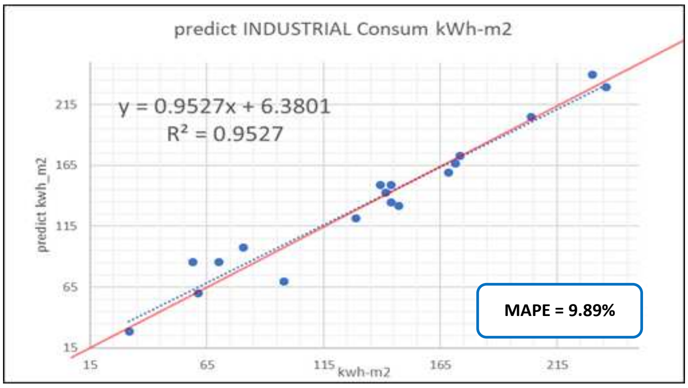
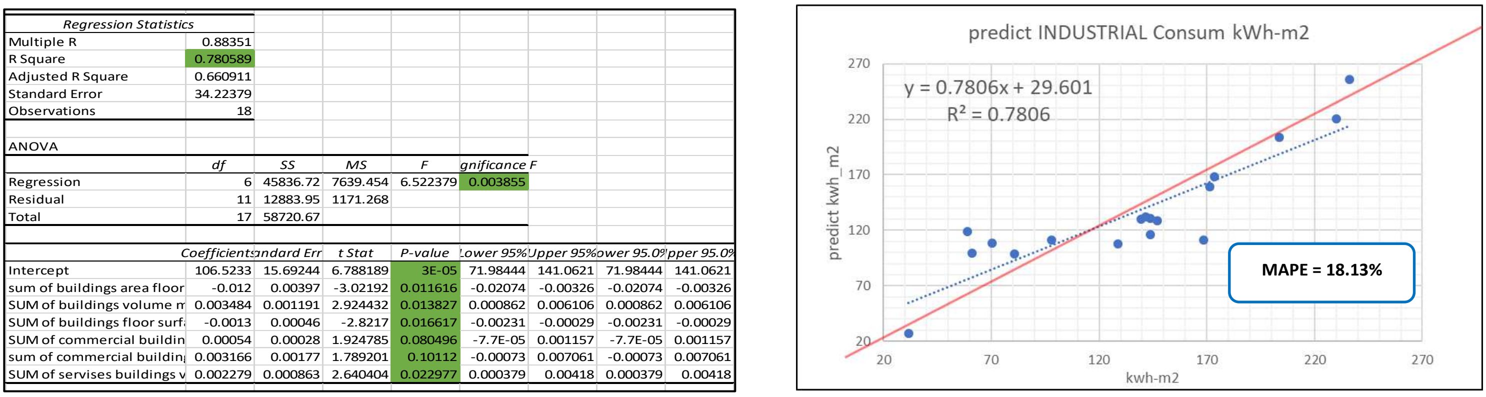


Figure 91 ; The Multiple Regression Result of Scenario 39 COMMERCIAL AND SERVICES CLUSTER A   1-kWh/m2 (By Authors)

Scenario 40 : COMMERCIAL AND SERVICES CLUSTER A 2- kWh/m2 (A) (not normal)

y = 0.7806x + 29.601

X= (106.5233) + (-0.0120* sum of buildings area floor m2) + (0.0035* SUM of buildings volume m3) +(-0.0013* SUM of buildings floor surface m2) + (0.0005* SUM of commercial buildings volume m3) + (0.0032* sum of commercial buildings area floor m2) + (0.0023* sum of services buildings volume m3)



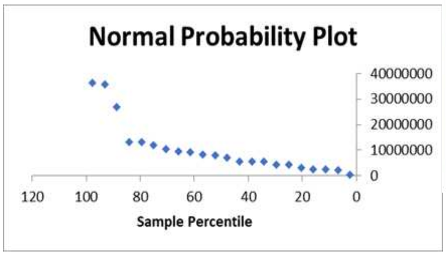
Regression Statistics								
Multiple R	0.88351							
R Square	0.780589							
Adjusted R Square	0.660911							
Standard Error	34.22379							
Observations	18							
ANOVA								
	df	SS	MS	F	gnificance F			
Regression	6	45836.72	7639.454	6.522379	0.003855			
Residual	11	12883.95	1171.268					
Total	17	58720.67						
	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	106.5233	15.69244	6.788189	3E-05	71.98444	141.0621	71.98444	141.0621
sum of buildings area floor	-0.012	0.00397	-3.02192	0.011616	-0.02074	-0.00326	-0.02074	-0.00326
SUM of buildings volume m	0.003484	0.001191	2.924432	0.013827	0.000862	0.006106	0.000862	0.006106
SUM of buildings floor surf	-0.0013	0.00046	-2.8217	0.016617	-0.00231	-0.00029	-0.00231	-0.00029
SUM of commercial buildin	0.00054	0.00028	1.924785	0.080496	-7.7E-05	0.001157	-7.7E-05	0.001157
sum of commercial buildin	0.003166	0.00177	1.789201	0.10112	-0.00073	0.007061	-0.00073	0.007061
SUM of servises buildings v	0.002279	0.000863	2.640404	0.022977	0.000379	0.00418	0.000379	0.00418

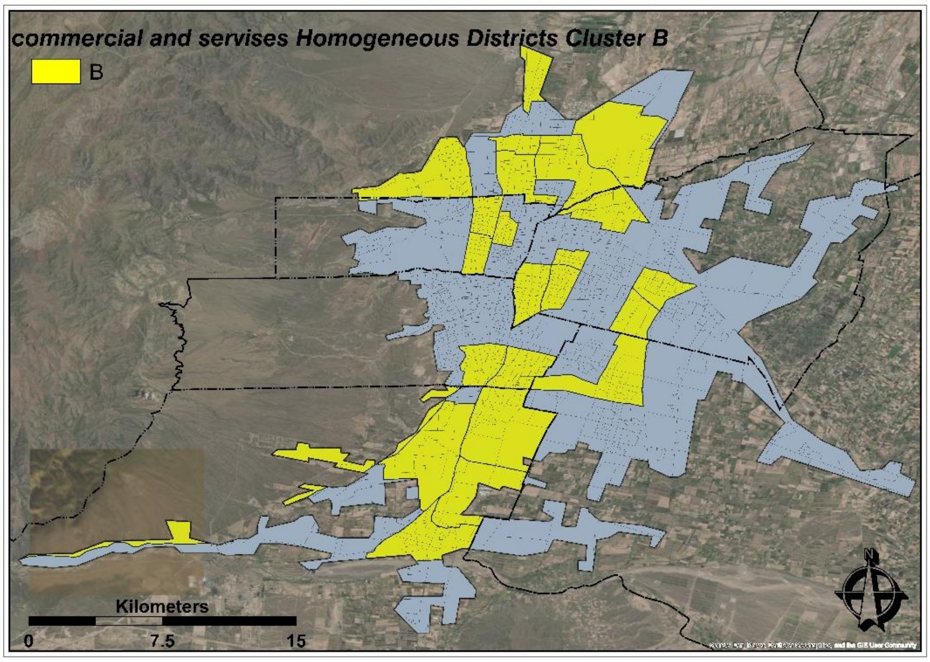
Figure 92 : The Multiple Regression Result of Scenario 40 COMMERCIAL AND SERVICES CLUSTER A 2-kWh/m2 (By Authors)

5.1.3.2. Commercial and Services Regression Models for Cluster B

In a similar vein, this section presents the regression models customized for the business and services sector's Cluster B, providing a more nuanced view of the patterns in energy use in this cluster.

COMMERCIAL AND SERVICES CLUSTER B
Bermejo
Capdevila
Capilla del Rosario
Carrodilla
Chacras de Coria
Ciudad (L)
Ciudad (LH)
Dorrego
El Algarrobal
El Challao
El Plumerillo
General Gutierrez
Gobernador Benegas
Jesús Nazareno
Las Cañas
Las Tortugas
Mayor Drummond
Nueva Ciudad
Panquegua
Primera Sección
Quinta Sección
Sexta Sección





Scenario 41 : COMMERCIAL AND SERVICES CLUSTER B kWh (B) (not normal)

y = 0.9602x + 408738

X= (54454311.32) + (784.18 * Footprint area of buildings (sum)) + (333.78* SUM of buildings volume m3) +(-595.59* SUM of buildings floor surface m2) + (1875.42* Number of people Per of agr3(65 and over years old)) + (-16682948.15* Number of components per family) + (667488.90* per of MP2 (Fixed cement or brick))

Regression Statistics	
Multiple R	0.979917
R Square	0.960237
Adjusted R Square	0.944332
Standard Error	2364213
Observations	22

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	6	2.02E+15	3.37E+14	60.3723	1.18E-09
Residual	15	8.38E+13	5.59E+12		
Total	21	2.11E+15			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	54454311	12211199	4.459375	0.000459	28426757	80481866	28426757	80481866
Footprint area of buildings (su	784.1813	131.2189	5.976129	2.54E-05	504.4948	1063.868	504.4948	1063.868
SUM of buildings volume m3	333.7848	51.90238	6.431011	1.13E-05	223.1575	444.4121	223.1575	444.4121
SUM of buildings floor surface	-595.594	83.4998	-7.13287	3.43E-06	-773.569	-417.618	-773.569	-417.618
Number of people Per of agr3(	1875.418	838.907	2.23555	0.04101	87.33054	3663.506	87.33054	3663.506
Number of components per fa	-1.7E+07	3681543	-4.53151	0.000398	-2.5E+07	-8835925	-2.5E+07	-8835925
per of MP2 (Fixed cement or b	667488.9	197907.9	3.372725	0.004186	245658.3	1089320	245658.3	1089320

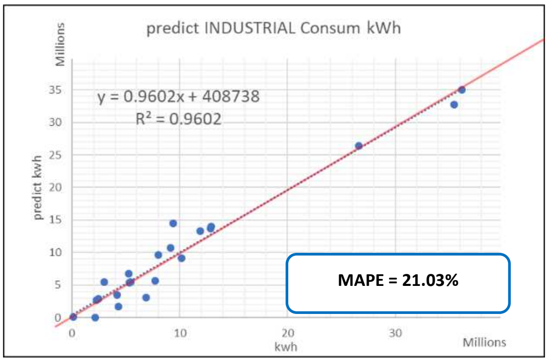


Figure 93 : The Multiple Regression Result of Scenario 41 COMMERCIAL AND SERVICES CLUSTER B kWh (By Authors)

Scenario 42: COMMERCIAL AND SERVICES CLUSTER B -kWh{n-alt}

y = 0.9949x + 60530

X= (19881865.10) + (364.44* SUM of buildings volume m3) + (2857.06 * SUM of buildings perimeters m2) +(-339.53* SUM of buildings floor surface m2) + (-504.01* SUM of commercial buildings volume m3) + (650.70* sum of commercial buildings area floor m2) + (-240.34 * sum of services buildings volume m3) + (1244602.80* Num people/ services vol) + (-163430.62* percentage MCAL1) + (-419989.57* Number of people of agr1(0 - 14 years old))

Regression Statistics	
Multiple R	0.99743
R Square	0.994867
Adjusted R Square	0.991018
Standard Error	1120941
Observations	22

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	9	2.92E+15	3.25E+14	258.4473	2.44E-12
Residual	12	1.51E+13	1.26E+12		
Total	21	2.94E+15			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	19881865	7594047	2.618086	0.022464	3335859	36427872	3335859	36427872
SUM of buildings volume m	364.4426	43.65294	8.348638	2.42E-06	269.331	459.5541	269.331	459.5541
SUM of buildings premiters	2857.06	456.8323	6.254067	4.23E-05	1861.708	3852.412	1861.708	3852.412
SUM of buildings floor surf	-339.525	87.97526	-3.85933	0.002271	-531.207	-147.844	-531.207	-147.844
SUM of commercial buildin	-504.011	26.77111	-18.8267	2.82E-10	-562.34	-445.682	-562.34	-445.682
sum of commercial buildin	650.6987	146.1567	4.452063	0.00079	332.2506	969.1467	332.2506	969.1467
SUM of servises buildings v	-240.337	44.4829	-5.40291	0.000159	-337.257	-143.417	-337.257	-143.417
Num people/servises vol	1244603	927977.8	1.341199	0.204689	-777287	3266493	-777287	3266493
percentage MCAL1	-163431	69420.81	-2.3542	0.036433	-314686	-12175.7	-314686	-12175.7
Persons of agr1(0 - 14 years	-419990	165706.2	-2.53454	0.0262	-781032	-58946.7	-781032	-58946.7

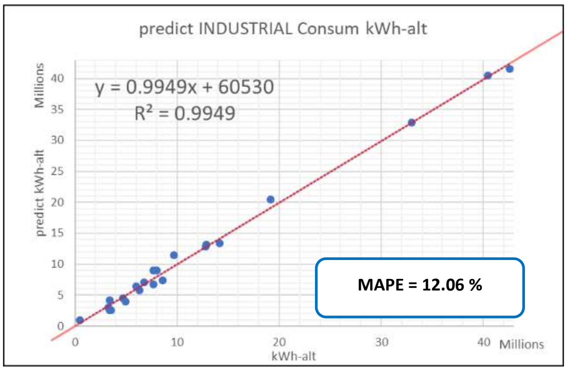


Figure 94 : The Multiple Regression Result of Scenario 42 - COMMERCIAL AND SERVICES CLUSTER B kWh{n-alt} (By Authors)

Scenario 43: COMMERCIAL AND SERVICES CLUSTER B 1-kWh_inh (B) (not normal)

y = 0.9725x + 23.063

X= (1347.246) + (0.007* SUM of buildings volume m3) + (-0.016* SUM of commercial buildings volume m3) +(0.041* sum of commercial buildings area floor m2) + (-0.035* Number of inhabitants) + (-13.693* per of MC1 (Asphaltic cover or membrane))

Regression Statistics	
Multiple R	0.986157
R Square	0.972506
Adjusted R Square	0.963914
Standard Error	162.0719
Observations	22

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	5	14865939	2973188	113.1897	6.65E-12
Residual	16	420277	26267.31		
Total	21	15286216			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	1347.246	302.8079	4.449176	0.000404	705.3215	1989.17	705.3215	1989.17
SUM of buildings volume m	0.006763	0.000887	7.625285	1.03E-06	0.004883	0.008643	0.004883	0.008643
SUM of commercial building	-0.0158	0.003617	-4.36927	0.000477	-0.02347	-0.00814	-0.02347	-0.00814
sum of commercial building	0.040588	0.010439	3.888095	0.001306	0.018458	0.062718	0.018458	0.062718
Number of inhabitants3	-0.03497	0.00498	-7.02154	2.88E-06	-0.04553	-0.02441	-0.04553	-0.02441
per of MC1 (Asphaltic cover	-13.6929	4.797852	-2.85397	0.011486	-23.8639	-3.52195	-23.8639	-3.52195

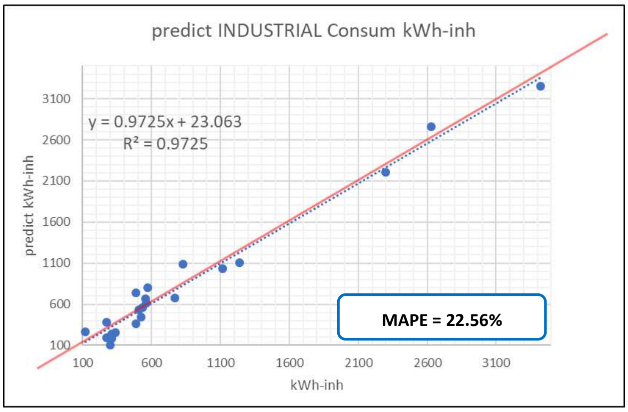
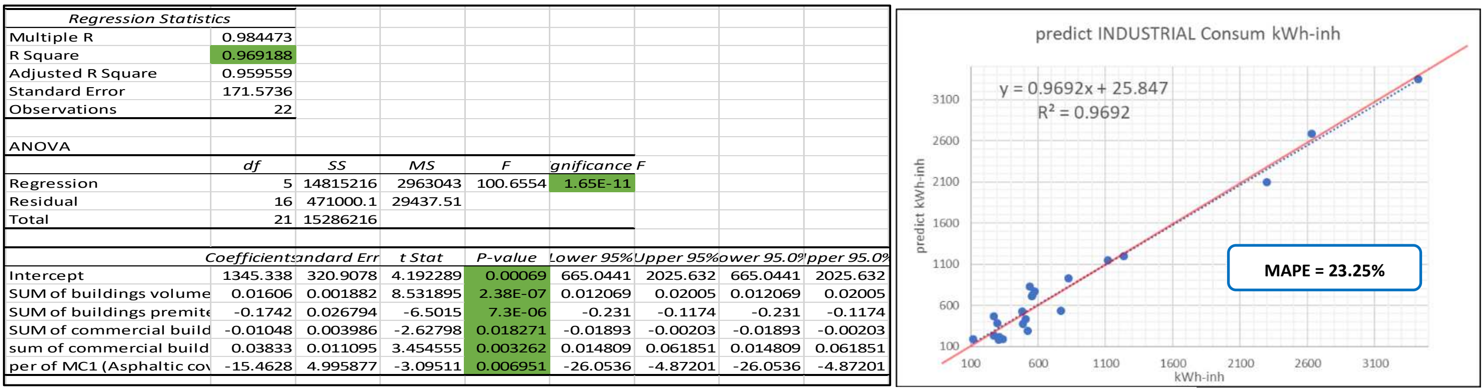


Figure 95 : The Multiple Regression Result of Scenario 43 COMMERCIAL AND SERVICES CLUSTER B 1- kWh/inh (By Authors)

Scenario 44: COMMERCIAL AND SERVICES CLUSTER B 2- kWh/ inh (B) (not normal)

y = 0.9692x + 25.847

X= (1345.338) + (0.016* SUM of buildings volume m3) + (-0.174* SUM of buildings perimeters m2) +(-0.010* SUM of commercial buildings volume m3) + (0.038* sum of commercial buildings area floor m2) + (-15.463* per of MC1 (Asphaltic cover or membrane))



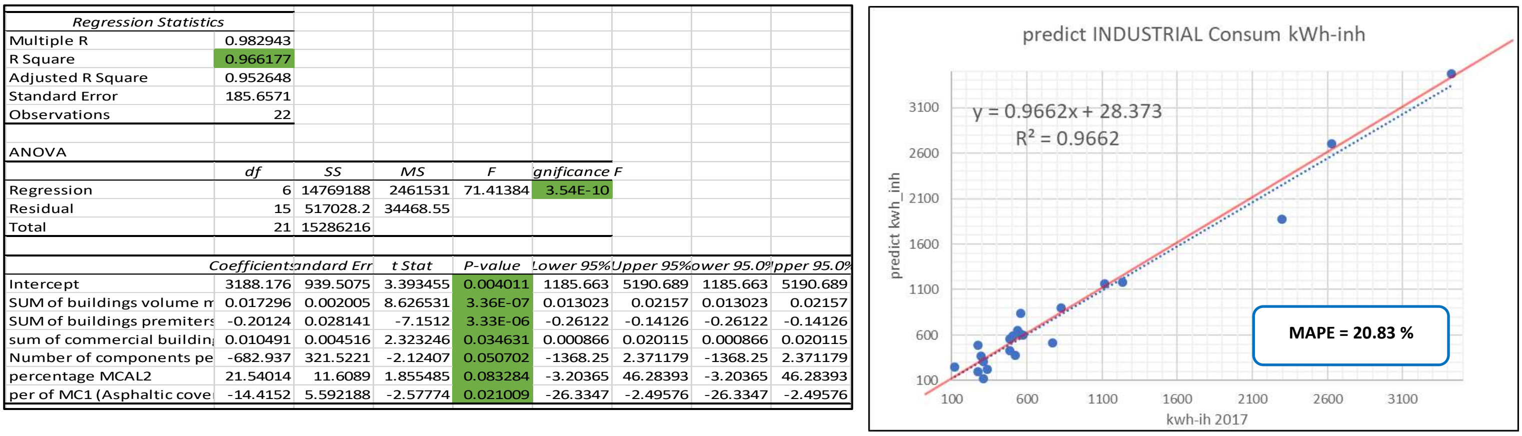
Regression Statistics								
Multiple R	0.984473							
R Square	0.969188							
Adjusted R Square	0.959559							
Standard Error	171.5736							
Observations	22							
ANOVA								
	df	SS	MS	F	gnificance F			
Regression	5	14815216	2963043	100.6554	1.65E-11			
Residual	16	471000.1	29437.51					
Total	21	15286216						
	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	1345.338	320.9078	4.192289	0.00069	665.0441	2025.632	665.0441	2025.632
SUM of buildings volume	0.01606	0.001882	8.531895	2.38E-07	0.012069	0.02005	0.012069	0.02005
SUM of buildings premite	-0.1742	0.026794	-6.5015	7.3E-06	-0.231	-0.1174	-0.231	-0.1174
SUM of commercial build	-0.01048	0.003986	-2.62798	0.018271	-0.01893	-0.00203	-0.01893	-0.00203
sum of commercial build	0.03833	0.011095	3.454555	0.003262	0.014809	0.061851	0.014809	0.061851
per of MC1 (Asphaltic cov	-15.4628	4.995877	-3.09511	0.006951	-26.0536	-4.87201	-26.0536	-4.87201

Figure 96 : The Multiple Regression Result of Scenario 44 COMMERCIAL AND SERVICES CLUSTER B 2-kWh/inh (By Authors)

Scenario 45: COMMERCIAL AND SERVICES CLUSTER B 3- kWh/ inh (B) (not normal)

y = 0.9662x + 28.373

X= (3188.176) + (0.017 * SUM of buildings volume m3) + (-0.201* SUM of buildings perimeters m2) +(0.010* sum of commercial buildings area floor m2) + (-682.937* Number of components per family) + (21.540* percentage MCAL2) + (-14.415* per of MC1 (Asphaltic cover or membrane))



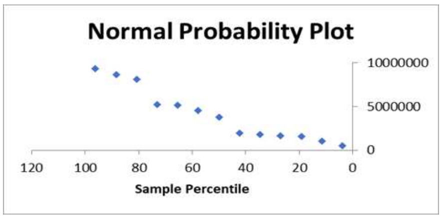
Regression Statistics								
Multiple R	0.982943							
R Square	0.966177							
Adjusted R Square	0.952648							
Standard Error	185.6571							
Observations	22							
ANOVA								
	df	SS	MS	F	gnificance F			
Regression	6	14769188	2461531	71.41384	3.54E-10			
Residual	15	517028.2	34468.55					
Total	21	15286216						
	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	3188.176	939.5075	3.393455	0.004011	1185.663	5190.689	1185.663	5190.689
SUM of buildings volume m	0.017296	0.002005	8.626531	3.36E-07	0.013023	0.02157	0.013023	0.02157
SUM of buildings premiters	-0.20124	0.028141	-7.1512	3.33E-06	-0.26122	-0.14126	-0.26122	-0.14126
sum of commercial buildin	0.010491	0.004516	2.323246	0.034631	0.000866	0.020115	0.000866	0.020115
Number of components pe	-682.937	321.5221	-2.12407	0.050702	-1368.25	2.371179	-1368.25	2.371179
percentage MCAL2	21.54014	11.6089	1.855485	0.083284	-3.20365	46.28393	-3.20365	46.28393
per of MC1 (Asphaltic cove	-14.4152	5.592188	-2.57774	0.021009	-26.3347	-2.49576	-26.3347	-2.49576

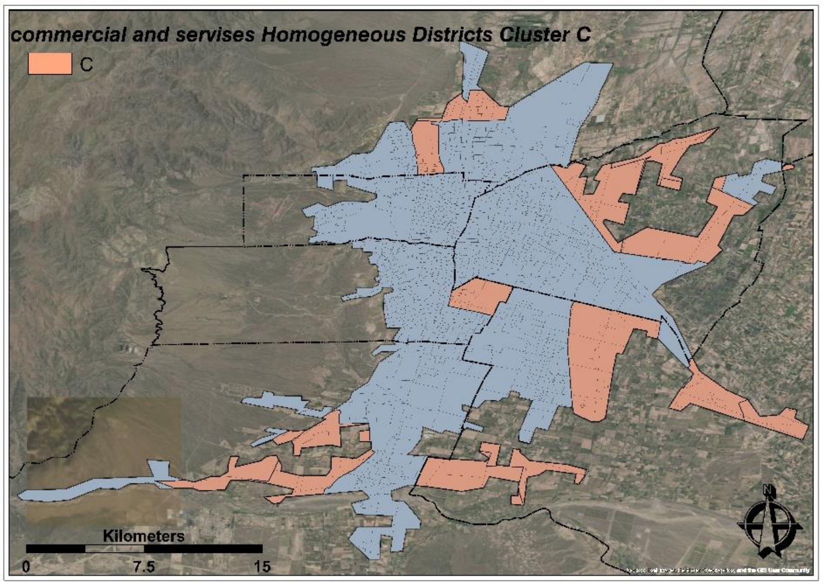
Figure 97 : The Multiple Regression Result of Scenario 45 COMMERCIAL AND SERVICES CLUSTER A 3- kWh/inh (By Authors)

5.1.3.3. Commercial and Services Regression Models for Cluster C

This portion concludes the commercial and services models and describes the regression models created especially for Cluster C, providing insight into the cluster's typical patterns of energy use.

COMMERCIAL AND SERVICES CLUSTER C
Colonia Segovia
Coquimbito
Cruz de Piedra
El Resguardo
El Sauce
Fray Luis Beltrán
La Cieneguita
Las Compuertas
Los Corralitos
Lunlunta
Rodeo del Medio
San Francisco del Monte -GC
Vistalba

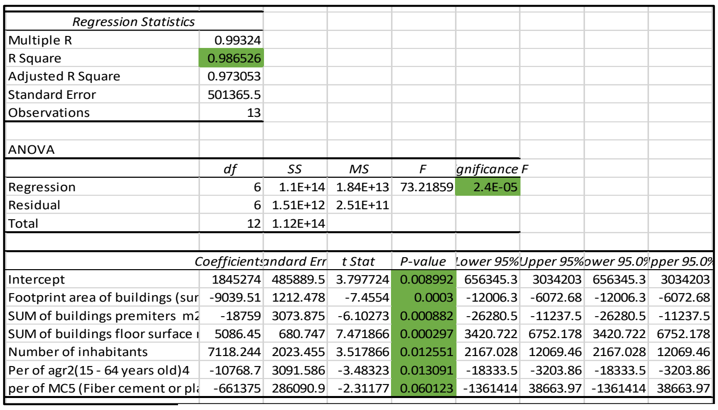




Scenario 46 : COMMERCIAL AND SERVICES CLUSTER C 1-kWh (C) (not normal)

y = 0.9865x + 55206

X= (1845274.14) + (-9039.51 * Footprint area of buildings (sum)) + (-18759.03 * SUM of buildings perimeters m2) +(5086.45 * SUM of buildings floor surface m2) + (-7118.24 * Number of inhabitants) + (-10768.70 * Per of agr2(15 - 64 years old)) + (-661375.21* per of MC5 (Fiber cement or plastic sheet))



Regression Statistics	
Multiple R	0.99324
R Square	0.986526
Adjusted R Square	0.973053
Standard Error	501365.5
Observations	13

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	1.1E+14	1.84E+13	73.21859	2.4E-05
Residual	6	1.51E+12	2.51E+11		
Total	12	1.12E+14			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	1845274	485889.5	3.797724	0.008992	656345.3	3034203	656345.3	3034203
Footprint area of buildings (sur	-9039.51	1212.478	-7.4554	0.0003	-12006.3	-6072.68	-12006.3	-6072.68
SUM of buildings premiters m2	-18759	3073.875	-6.10273	0.000882	-26280.5	-11237.5	-26280.5	-11237.5
SUM of buildings floor surface r	5086.45	680.747	7.471866	0.000297	3420.722	6752.178	3420.722	6752.178
Number of inhabitants	7118.244	2023.455	3.517866	0.012551	2167.028	12069.46	2167.028	12069.46
Per of agr2(15 - 64 years old)4	-10768.7	3091.586	-3.48323	0.013091	-18333.5	-3203.86	-18333.5	-3203.86
per of MC5 (Fiber cement or pla	-661375	286090.9	-2.31177	0.060123	-1361414	38663.97	-1361414	38663.97

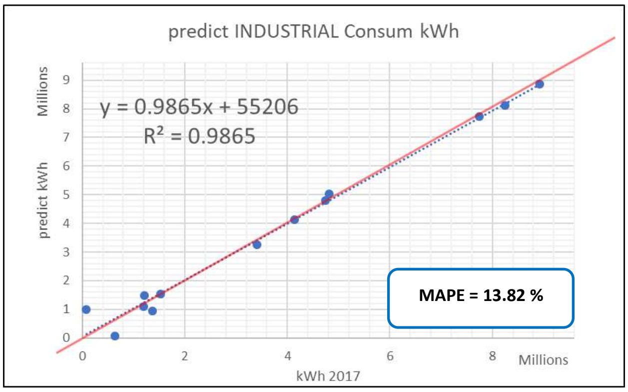
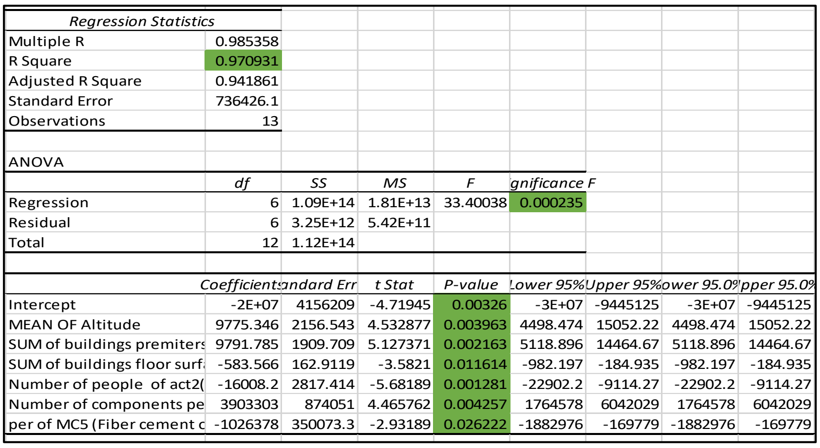


Figure 98 : The Multiple Regression Result of Scenario 46 COMMERCIAL AND SERVICES CLUSTER C 1-kWh (By Authors)

Scenario 47: COMMERCIAL AND SERVICES CLUSTER C 2-kWh (C) (not normal)

y = 0.9709x + 119107

X= (-19615002.80) + (9775.35 * MEAN OF Altitude) + (9791.78* SUM of buildings perimeters m2) +(-583.57 * SUM of buildings floor surface m2) + (-16008.24 * Number of people of act2(Not busy)) + (3903303.39 * Number of components per family) + (-1026377.56 * per of MC5 (Fiber cement or plastic sheet))



Regression Statistics	
Multiple R	0.985358
R Square	0.970931
Adjusted R Square	0.941861
Standard Error	736426.1
Observations	13

ANOVA

	df	SS	MS	F	gnificance F
Regression	6	1.09E+14	1.81E+13	33.40038	0.000235
Residual	6	3.25E+12	5.42E+11		
Total	12	1.12E+14			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	-2E+07	4156209	-4.71945	0.00326	-3E+07	-9445125	-3E+07	-9445125
MEAN OF Altitude	9775.346	2156.543	4.532877	0.003963	4498.474	15052.22	4498.474	15052.22
SUM of buildings premiters	9791.785	1909.709	5.127371	0.002163	5118.896	14464.67	5118.896	14464.67
SUM of buildings floor surf	-583.566	162.9119	-3.5821	0.011614	-982.197	-184.935	-982.197	-184.935
Number of people of act2(	-16008.2	2817.414	-5.68189	0.001281	-22902.2	-9114.27	-22902.2	-9114.27
Number of components pe	3903303	874051	4.465762	0.004257	1764578	6042029	1764578	6042029
per of MC5 (Fiber cement c	-1026378	350073.3	-2.93189	0.026222	-1882976	-169779	-1882976	-169779

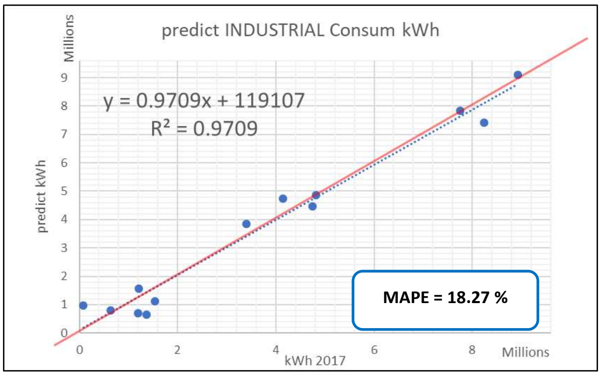
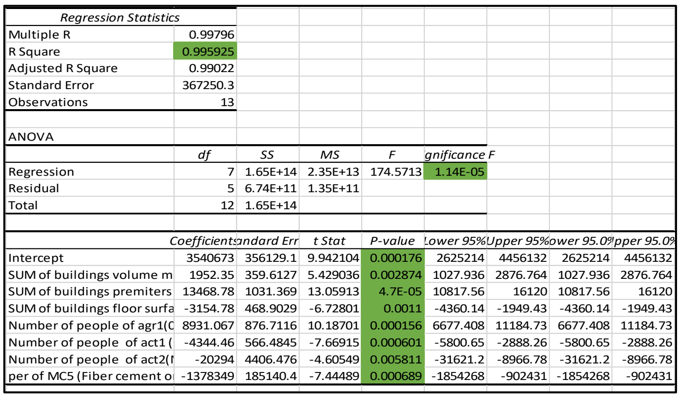


Figure 99 : The Multiple Regression Result of Scenario 47 COMMERCIAL AND SERVICES CLUSTER C 2- kWh (By Authors)

Scenario 48: COMMERCIAL AND SERVICES CLUSTER C 1 -kWh{n-alt}

y = 0.9959x + 20859

X= (3540672.65) + (1952.35 * SUM of buildings volume m3) + (13468.78 * SUM of buildings perimeters m2) +(-3154.78 * SUM of buildings floor surface m2) + (8931.07* Number of people of agr1(0 - 14 years old)) + (-4344.46* Number of people of act1 (Busy)) + (-20293.98 * Number of people of act2(Not busy)) + (-1378349.47* per of MC5 (Fiber cement or plastic sheet))



Regression Statistics	
Multiple R	0.99796
R Square	0.995925
Adjusted R Square	0.99022
Standard Error	367250.3
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	7	1.65E+14	2.35E+13	174.5713	1.14E-05
Residual	5	6.74E+11	1.35E+11		
Total	12	1.65E+14			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	3540673	356129.1	9.942104	0.000176	2625214	4456132	2625214	4456132
SUM of buildings volume m	1952.35	359.6127	5.429036	0.002874	1027.936	2876.764	1027.936	2876.764
SUM of buildings premiters	13468.78	1031.369	13.05913	4.7E-05	10817.56	16120	10817.56	16120
SUM of buildings floor surfa	-3154.78	468.9029	-6.72801	0.0011	-4360.14	-1949.43	-4360.14	-1949.43
Number of people of agr1(	8931.067	876.7116	10.18701	0.000156	6677.408	11184.73	6677.408	11184.73
Number of people of act1 (	-4344.46	566.4845	-7.66915	0.000601	-5800.65	-2888.26	-5800.65	-2888.26
Number of people of act2(	-20294	4406.476	-4.60549	0.005811	-31621.2	-8966.78	-31621.2	-8966.78
per of MC5 (Fiber cement o	-1378349	185140.4	-7.44489	0.000689	-1854268	-902431	-1854268	-902431

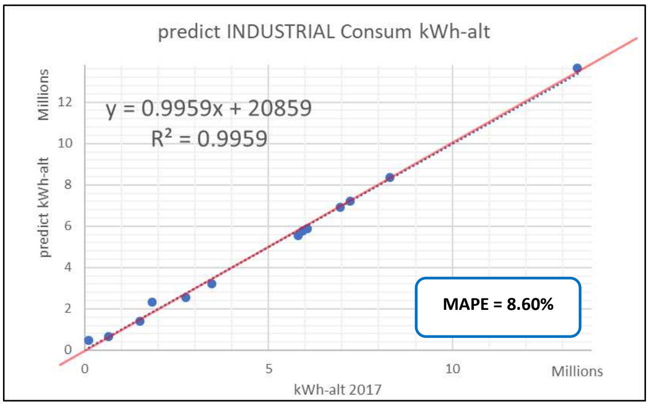
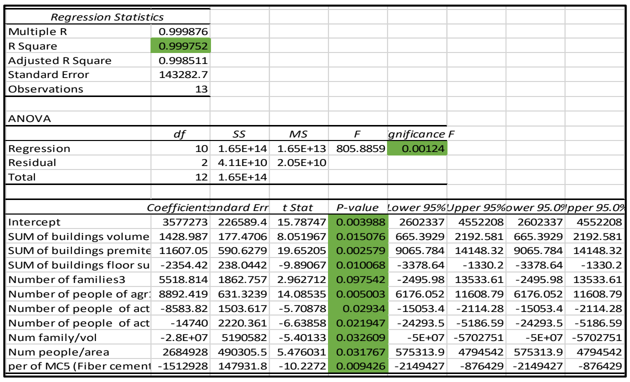


Figure 100 : The Multiple Regression Result of Scenario 48 - COMMERCIAL AND SERVICES CLUSTER C 1-kWh{n-alt} (By Authors)

Scenario 49: COMMERCIAL AND SERVICES CLUSTER C 2 -kWh{n-alt}

y = 0.9998x + 1270

X= (3577272.80) + (1428.99* SUM of buildings volume m3) + (11607.05* SUM of buildings perimeters m2) +(-2354.42* SUM of buildings floor surface m2) + (5518.81 * Number of families) + (8892.42 * Number of people of agr1(0 - 14 years old)) + (-8583.82* Number of people of act1 (Busy)) (-14740.04* Number of people of act2(Not busy)) + (-28036023.30 * Num family/vol) +(2684928.07* Num people/area) + (-1512927.88* per of MC5 (Fiber cement or plastic sheet))



Regression Statistics	
Multiple R	0.999876
R Square	0.999752
Adjusted R Square	0.998511
Standard Error	143282.7
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	10	1.65E+14	1.65E+13	805.8859	0.00124
Residual	2	4.11E+10	2.05E+10		
Total	12	1.65E+14			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	3577273	226589.4	15.78747	0.003988	2602337	4552208	2602337	4552208
SUM of buildings volume	1428.987	177.4706	8.051967	0.015076	665.3929	2192.581	665.3929	2192.581
SUM of buildings premite	11607.05	590.6279	19.65205	0.002579	9065.784	14148.32	9065.784	14148.32
SUM of buildings floor su	-2354.42	238.0442	-9.89067	0.010068	-3378.64	-1330.2	-3378.64	-1330.2
Number of families3	5518.814	1862.757	2.962712	0.097542	-2495.98	13533.61	-2495.98	13533.61
Number of people of agr	8892.419	631.3239	14.08535	0.005003	6176.052	11608.79	6176.052	11608.79
Number of people of act	-8583.82	1503.617	-5.70878	0.02934	-15053.4	-2114.28	-15053.4	-2114.28
Number of people of act	-14740	2220.361	-6.63858	0.021947	-24293.5	-5186.59	-24293.5	-5186.59
Num family/vol	-2.8E+07	5190582	-5.40133	0.032609	-5E+07	-5702751	-5E+07	-5702751
Num people/area	2684928	490305.5	5.476031	0.031767	575313.9	4794542	575313.9	4794542
per of MC5 (Fiber cement	-1512928	147931.8	-10.2272	0.009426	-2149427	-876429	-2149427	-876429

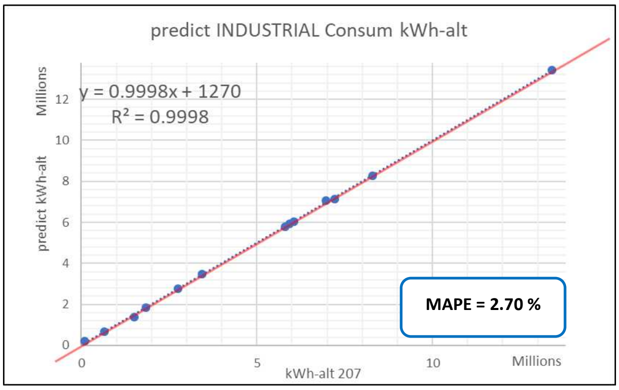
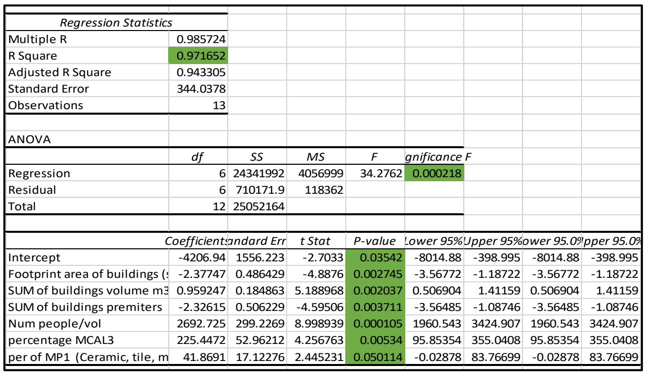


Figure 101 : The Multiple Regression Result of Scenario 49 - COMMERCIAL AND SERVICES CLUSTER C 2-kWh{n-alt} (By Authors)

Scenario 50 : COMMERCIAL AND SERVICES CLUSTER C 1-kWh (C)/m2 (not normal)

y = 0.9717x + 47.036

X= (-4206.94) + (-2.38 * Footprint area of buildings (sum) + (0.96 * SUM of buildings volume m3) +(-2.33 * SUM of buildings perimeters m2) + (2692.72 * Num people/vol) + (225.45 * percentage MCAL3) + (41.87* per of MP1 (Ceramic, tile, mosaic, marble, wood or carpe))



Regression Statistics	
Multiple R	0.985724
R Square	0.971652
Adjusted R Square	0.943305
Standard Error	344.0378
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	6	24341992	4056999	34.2762	0.000218
Residual	6	710171.9	118362		
Total	12	25052164			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-4206.94	1556.223	-2.7033	0.03542	-8014.88	-398.995	-8014.88	-398.995
Footprint area of buildings (	-2.37747	0.486429	-4.8876	0.002745	-3.56772	-1.18722	-3.56772	-1.18722
SUM of buildings volume m3	0.959247	0.184863	5.188968	0.002037	0.506904	1.41159	0.506904	1.41159
SUM of buildings premiters	-2.32615	0.506229	-4.59506	0.003711	-3.56485	-1.08746	-3.56485	-1.08746
Num people/vol	2692.725	299.2269	8.998939	0.000105	1960.543	3424.907	1960.543	3424.907
percentage MCAL3	225.4472	52.96212	4.256763	0.00534	95.85354	355.0408	95.85354	355.0408
per of MP1 (Ceramic, tile, m	41.8691	17.12276	2.445231	0.050114	-0.02878	83.76699	-0.02878	83.76699

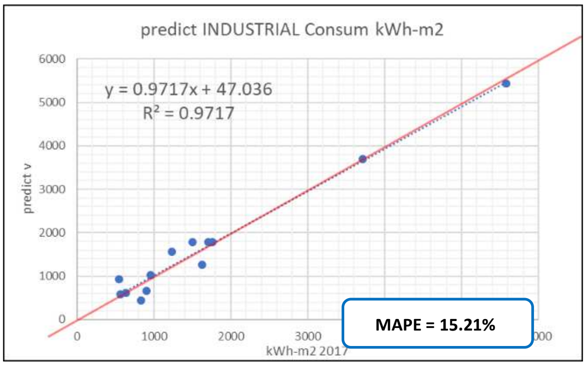
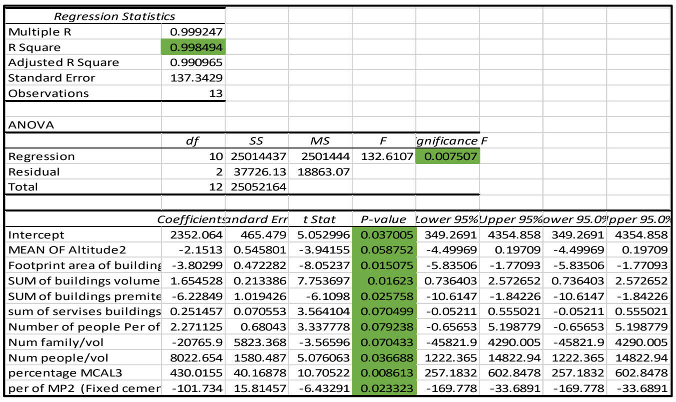


Figure 102 : The Multiple Regression Result of Scenario 50 COMMERCIAL AND SERVICES CLUSTER C 1-kWh/m2 (By Authors)

Scenario 51 : COMMERCIAL AND SERVICES CLUSTER C 2-kWh (C)/m2 (not normal)

y = 0.9985x + 2.4987

X= (2352.06) + (-2.15* MEAN OF Altitude) + (-3.80 * Footprint area of buildings (sum)) +(1.65* SUM of buildings volume m3) + (-6.23* SUM of buildings perimeters m2) + (0.25* sum of services buildings area floor m2) + (2.27* Number of people of agr1(0 - 14 years old)) + (-20765.93* Num family/vol) +(8022.65* Num people/vol) + (430.02* percentage MCAL3) + (-101.73* per of MP2 (Fixed cement or brick))



Regression Statistics	
Multiple R	0.999247
R Square	0.998494
Adjusted R Square	0.990965
Standard Error	137.3429
Observations	13

ANOVA

	df	SS	MS	F	ignificance F
Regression	10	25014437	2501444	132.6107	0.007507
Residual	2	37726.13	18863.07		
Total	12	25052164			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	2352.064	465.479	5.052996	0.037005	349.2691	4354.858	349.2691	4354.858
MEAN OF Altitude2	-2.1513	0.545801	-3.94155	0.058752	-4.49969	0.19709	-4.49969	0.19709
Footprint area of building	-3.80299	0.472282	-8.05237	0.015075	-5.83506	-1.77093	-5.83506	-1.77093
SUM of buildings volume	1.654528	0.213386	7.753697	0.01623	0.736403	2.572652	0.736403	2.572652
SUM of buildings premite	-6.22849	1.019426	-6.1098	0.025758	-10.6147	-1.84226	-10.6147	-1.84226
sum of servises buildings	0.251457	0.070553	3.564104	0.070499	-0.05211	0.555021	-0.05211	0.555021
Number of people Per of	2.271125	0.68043	3.337778	0.079238	-0.65653	5.198779	-0.65653	5.198779
Num family/vol	-20765.9	5823.368	-3.56596	0.070433	-45821.9	4290.005	-45821.9	4290.005
Num people/vol	8022.654	1580.487	5.076063	0.036688	1222.365	14822.94	1222.365	14822.94
percentage MCAL3	430.0155	40.16878	10.70522	0.008613	257.1832	602.8478	257.1832	602.8478
per of MP2 (Fixed cemer	-101.734	15.81457	-6.43291	0.023323	-169.778	-33.6891	-169.778	-33.6891

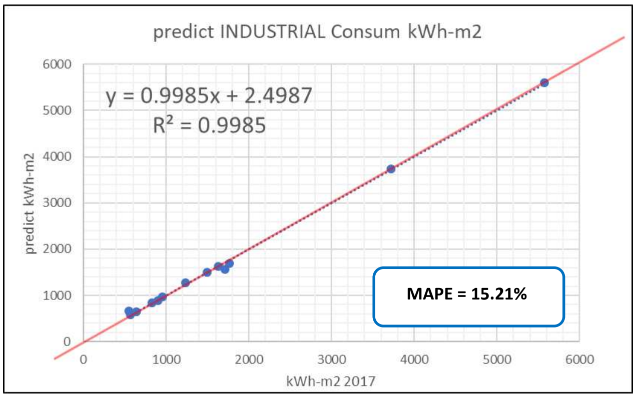


Figure 103 : The Multiple Regression Result of Scenario 51 COMMERCIAL AND SERVICES CLUSTER C 2-kWhm2 (By Authors)

5.2 Select best scenario for each district

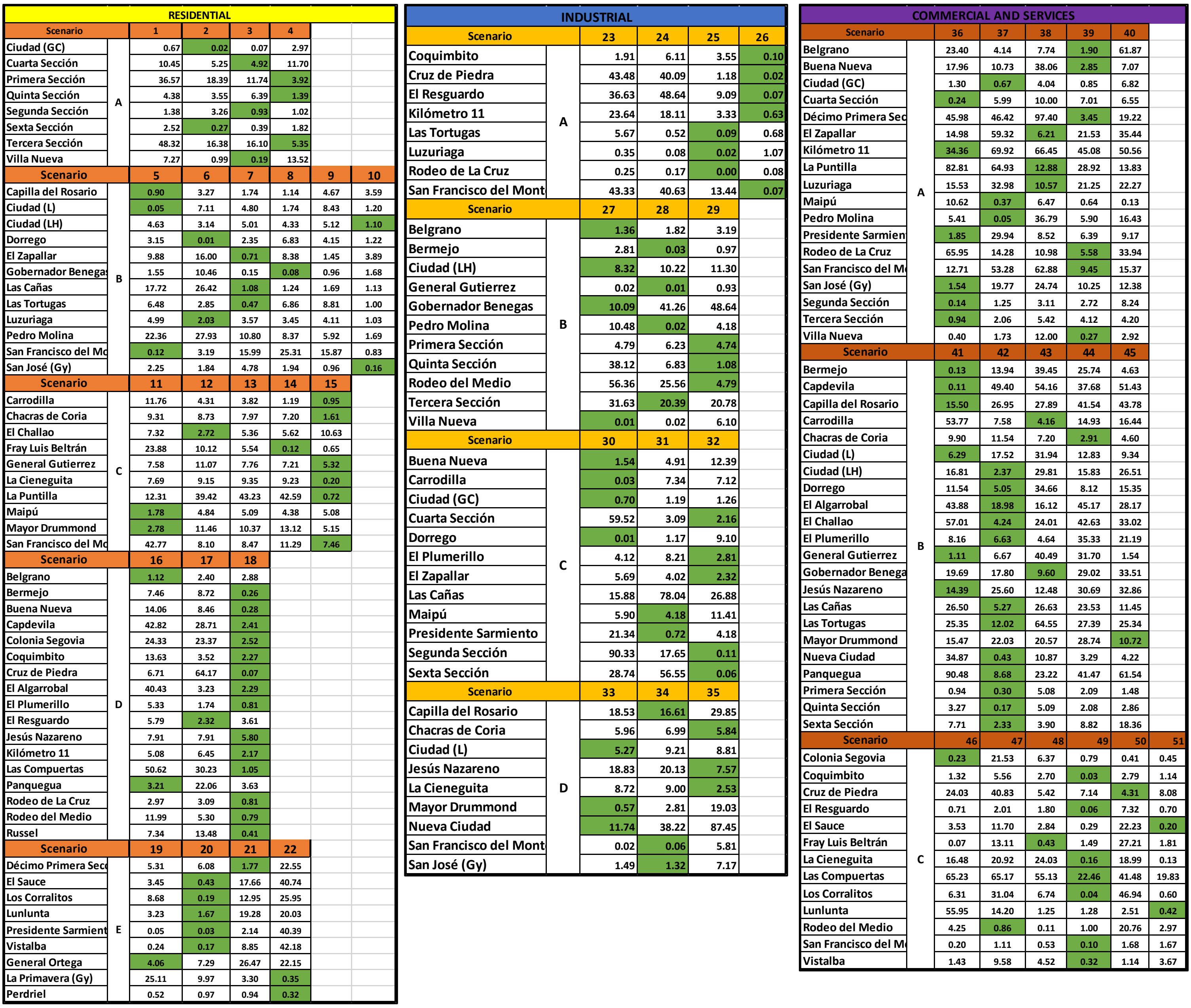
The next critical stage is determining the optimal scenario for each district once 51 regression models covering the residential, industrial, and commercial/service clusters have been developed. Initially, we describe the instances adjacent to each other for easier comprehension. We created regression models based on several variables and then thoroughly assessed the performance of each model to determine the optimal scenarios for every district. Our goal is to identify the most reliable models, with a particular focus on predicted accuracy and statistical significance. As previously stated, we evaluated each model's efficacy using three primary criteria:

- R-squared (R2): This metric calculates the percentage of the dependent variable's variance that the independent variables in a regression model can account for. Our rigorous selection procedure finds situations with an impressive R2 greater than 95%, which suggests a high degree of agreement between the observed data and the model. A better-fitting model and a greater correlation between the variables are indicated by a higher R-squared value.
- P-value and f-statistic (F-significant): These two measures evaluate the regression model's statistical significance. The regression scenarios we have selected are statistically valid if the f-significance and P-values are less than 5%. A low P-value (usually less than 0.05) denotes statistical significance for the model's coefficients and points to a solid correlation between the independent and dependent variables.
- MAPE (Mean Absolute Percentage Error): MAPE measures the average percentage error between the predicted values and the actual gas consumption data. A lower MAPE value indicates a more accurate model. Lower MAPE values signify a closer alignment between our model's predictions and the real-world data, denoting heightened accuracy.

Using these strict standards, we carefully identified the top 51 cases that have outstanding features. These scenarios frequently display high R-squared values, low P-values, and relatively low MAPE values, indicating their exceptional effectiveness in predicting gas consumption under the unique circumstances of each area. The variety of these situations is quite helpful since it gives us flexible methods to estimate gas usage depending on a wide range of factors. This variety not only improves the accuracy of our forecasts but also offers a range of choices, each catering to the complex interactions between many factors, therefore broadening our scope for analysis.

However, our discriminating methodology recognizes the variation inside each district, going beyond cluster-wide judgments. We acknowledge that different districts, not clusters, have different ideal circumstances. We rigorously examine the MAPE values of each model within particular districts to do this. By applying a rigorous procedure, we choose models that go beyond the general clusters and fit the best possible scenarios to the distinct features and patterns of energy use found in each Mendoza district. Our models are more accurate and practically relevant due to their district-specific emphasis, which also best fits the unique characteristics of Mendoza's urban energy landscape.

Table 22 : The best scenario for each district and each sector based on the MAPE (Mean Absolute Percentage Error



RESIDENTIAL							
Scenario		1	2	3	4		
Ciudad (GC)	A	0.67	0.02	0.07	2.97		
Cuarta Sección		10.45	5.25	4.92	11.70		
Primera Sección		36.57	18.39	11.74	3.92		
Quinta Sección		4.38	3.55	6.39	1.39		
Segunda Sección		1.38	3.26	0.93	1.02		
Sexta Sección		2.52	0.27	0.39	1.82		
Tercera Sección		48.32	16.38	16.10	5.35		
Villa Nueva		7.27	0.99	0.19	13.52		
Scenario		5	6	7	8	9	10
Capilla del Rosario	B	0.90	3.27	1.74	1.14	4.67	3.59
Ciudad (L)		0.05	7.11	4.80	1.74	8.43	1.20
Ciudad (LH)		4.63	3.14	5.01	4.33	5.12	1.10
Dorrego		3.15	0.01	2.35	6.83	4.15	1.22
El Zapallar		9.88	16.00	0.71	8.38	1.45	3.89
Gobernador Benegas		1.55	10.46	0.15	0.08	0.96	1.68
Las Cañas		17.72	26.42	1.08	1.24	1.69	1.13
Las Tortugas		6.48	2.85	0.47	6.86	8.81	1.00
Luzuriaga		4.99	2.03	3.57	3.45	4.11	1.03
Pedro Molina		22.36	27.93	10.80	8.37	5.92	1.69
San Francisco del Mo		0.12	3.19	15.99	25.31	15.87	0.83
San José (Gy)		2.25	1.84	4.78	1.94	0.96	0.16
Scenario		11	12	13	14	15	
Carrodilla	C	11.76	4.31	3.82	1.19	0.95	
Chacras de Coria		9.31	8.73	7.97	7.20	1.61	
El Challao		7.32	2.72	5.36	5.62	10.63	
Fray Luis Beltrán		23.88	10.12	5.54	0.12	0.65	
General Gutierrez		7.58	11.07	7.76	7.21	5.32	
La Cieneguita		7.69	9.15	9.35	9.23	0.20	
La Puntilla		12.31	39.42	43.23	42.59	0.72	
Maipú		1.78	4.84	5.09	4.38	5.08	
Mayor Drummond		2.78	11.46	10.37	13.12	5.15	
San Francisco del Mo		42.77	8.10	8.47	11.29	7.46	
Scenario		16	17	18			
Belgrano	D	1.12	2.40	2.88			
Bermejo		7.46	8.72	0.26			
Buena Nueva		14.06	8.46	0.28			
Capdevila		42.82	28.71	2.41			
Colonia Segovia		24.33	23.37	2.52			
Coquimbito		13.63	3.52	2.27			
Cruz de Piedra		6.71	64.17	0.07			
El Algarrobal		40.43	3.23	2.29			
El Plumerillo		5.33	1.74	0.81			
El Resguardo		5.79	2.32	3.61			
Jesús Nazareno		7.91	7.91	5.80			
Kilómetro 11		5.08	6.45	2.17			
Las Compuertas		50.62	30.23	1.05			
Panquegua		3.21	22.06	3.63			
Rodeo de La Cruz		2.97	3.09	0.81			
Rodeo del Medio		11.99	5.30	0.79			
Russel		7.34	13.48	0.41			
Scenario		19	20	21	22		
Décimo Primera Secc	E	5.31	6.08	1.77	22.55		
El Sauce		3.45	0.43	17.66	40.74		
Los Corralitos		8.68	0.19	12.95	25.95		
Lunlunta		3.23	1.67	19.28	20.03		
Presidente Sarmient		0.05	0.03	2.14	40.39		
Vistalba		0.24	0.17	8.85	42.18		
General Ortega		4.06	7.29	26.47	22.15		
La Primavera (Gy)		25.11	9.97	3.30	0.35		
Perdriel		0.52	0.97	0.94	0.32		

INDUSTRIAL					
Scenario		23	24	25	26
Coquimbito	A	1.91	6.11	3.55	0.10
Cruz de Piedra		43.48	40.09	1.18	0.02
El Resguardo		36.63	48.64	9.09	0.07
Kilómetro 11		23.64	18.11	3.33	0.63
Las Tortugas		5.67	0.52	0.09	0.68
Luzuriaga		0.35	0.08	0.02	1.07
Rodeo de La Cruz		0.25	0.17	0.00	0.08
San Francisco del Mont		43.33	40.63	13.44	0.07
Scenario		27	28	29	
Belgrano	B	1.36	1.82	3.19	
Bermejo		2.81	0.03	0.97	
Ciudad (LH)		8.32	10.22	11.30	
General Gutierrez		0.02	0.01	0.93	
Gobernador Benegas		10.09	41.26	48.64	
Pedro Molina		10.48	0.02	4.18	
Primera Sección		4.79	6.23	4.74	
Quinta Sección		38.12	6.83	1.08	
Rodeo del Medio		56.36	25.56	4.79	
Tercera Sección		31.63	20.39	20.78	
Villa Nueva		0.01	0.02	6.10	
Scenario		30	31	32	
Buena Nueva	C	1.54	4.91	12.39	
Carrodilla		0.03	7.34	7.12	
Ciudad (GC)		0.70	1.19	1.26	
Cuarta Sección		59.52	3.09	2.16	
Dorrego		0.01	1.17	9.10	
El Plumerillo		4.12	8.21	2.81	
El Zapallar		5.69	4.02	2.32	
Las Cañas		15.88	78.04	26.88	
Maipú		5.90	4.18	11.41	
Presidente Sarmiento		21.34	0.72	4.18	
Segunda Sección		90.33	17.65	0.11	
Sexta Sección		28.74	56.55	0.06	
Scenario		33	34	35	
Capilla del Rosario	D	18.53	16.61	29.85	
Chacras de Coria		5.96	6.99	5.84	
Ciudad (L)		5.27	9.21	8.81	
Jesús Nazareno		18.83	20.13	7.57	
La Cieneguita		8.72	9.00	2.53	
Mayor Drummond		0.57	2.81	19.03	
Nueva Ciudad		11.74	38.22	87.45	
San Francisco del Mont		0.02	0.06	5.81	
San José (Gy)		1.49	1.32	7.17	

COMMERCIAL AND SERVICES							
Scenario		36	37	38	39	40	
Belgrano	A	23.40	4.14	7.74	1.90	61.87	
Buena Nueva		17.96	10.73	38.06	2.85	7.07	
Ciudad (GC)		1.30	0.67	4.04	0.85	6.82	
Cuarta Sección		0.24	5.99	10.00	7.01	6.55	
Décimo Primera Sec		45.98	46.42	97.40	3.45	19.22	
El Zapallar		14.98	59.32	6.21	21.53	35.44	
Kilómetro 11		34.36	69.92	66.45	45.08	50.56	
La Puntilla		82.81	64.93	12.88	28.92	13.83	
Luzuriaga		15.53	32.98	10.57	21.25	22.27	
Maipú		10.62	0.37	6.47	0.64	0.13	
Pedro Molina		5.41	0.05	36.79	5.90	16.43	
Presidente Sarmien		1.85	29.94	8.52	6.39	9.17	
Rodeo de La Cruz		65.95	14.28	10.98	5.58	33.94	
San Francisco del M		12.71	53.28	62.88	9.45	15.37	
San José (Gy)		1.54	19.77	24.74	10.25	12.38	
Segunda Sección		0.14	1.25	3.11	2.72	8.24	
Tercera Sección		0.94	2.06	5.42	4.12	4.20	
Villa Nueva		0.40	1.73	12.00	0.27	2.92	
Scenario		41	42	43	44	45	
Bermejo	B	0.13	13.94	39.45	25.74	4.63	
Capdevila		0.11	49.40	54.16	37.68	51.43	
Capilla del Rosario		15.50	26.95	27.89	41.54	43.78	
Carrodilla		53.77	7.58	4.16	14.93	16.44	
Chacras de Coria		9.90	11.54	7.20	2.91	4.60	
Ciudad (L)		6.29	17.52	31.94	12.83	9.34	
Ciudad (LH)		16.81	2.37	29.81	15.83	26.51	
Dorrego		11.54	5.05	34.66	8.12	15.35	
El Algarrobal		43.88	18.98	16.12	45.17	28.17	
El Challao		57.01	4.24	24.01	42.63	33.02	
El Plumerillo		8.16	6.63	4.64	35.33	21.19	
General Gutierrez		1.11	6.67	40.49	31.70	1.54	
Gobernador Benega		19.69	17.80	9.60	29.02	33.51	
Jesús Nazareno		14.39	25.60	12.48	30.69	32.86	
Las Cañas		26.50	5.27	26.63	23.53	11.45	
Las Tortugas		25.35	12.02	64.55	27.39	25.34	
Mayor Drummond		15.47	22.03	20.57	28.74	10.72	
Nueva Ciudad		34.87	0.43	10.87	3.29	4.22	
Panquegua		90.48	8.68	23.22	41.47	61.54	
Primera Sección		0.94	0.30	5.08	2.09	1.48	
Quinta Sección		3.27	0.17	5.09	2.08	2.86	
Sexta Sección		7.71	2.33	3.90	8.82	18.36	
Scenario		46	47	48	49	50	51
Colonia Segovia	C	0.23	21.53	6.37	0.79	0.41	0.45
Coquimbito		1.32	5.56	2.70	0.03	2.79	1.14
Cruz de Piedra		24.03	40.83	5.42	7.14	4.31	8.08
El Resguardo		0.71	2.01	1.80	0.06	7.32	0.70
El Sauce		3.53	11.70	2.84	0.29	22.23	0.20
Fray Luis Beltrán		0.07	13.11	0.43	1.49	27.21	1.81
La Cieneguita		16.48	20.92	24.03	0.16	18.99	0.13
Las Compuertas		65.23	65.17	55.13	22.46	41.48	19.83
Los Corralitos		6.31	31.04	6.74	0.04	46.94	0.60
Lunlunta		55.95	14.20	1.25	1.28	2.51	0.42
Rodeo del Medio		4.25	0.86	0.11	1.00	20.76	2.97
San Francisco del M		0.20	1.11	0.53	0.10	1.68	1.67
Vistalba		1.43	9.58	4.52	0.32	1.14	3.67

Table 23 : All scenarios side by side for comparison (R Square, P-value, Significance F,MAPE)

SWCTOR	CLUSTER	NUMBER OF SCENARIO	TYPE OF ENERGY	R Square	*P-value*	*Significance F*	MAPE	Regression
RESIDENTIAL	**A**	Scenario 1	kWh (not normal)	0.98795	0.00238	0.00027	13.94473	y = 0.988x + 1E+06
		Scenario 2	kWh-ALT(normal)	0.99694	0.00064	0.00002	6.73201	y = 0.9993x + 350703
		Scenario 3	kWh-ALT(normal)(	0.99743	0.00275	0.00033	5.09004	y = 0.9974x + 332477
		Scenario 4	KWH_INH (not normal)	0.97031	0.02345	0.00164	4.02523	y = 0.9928x - 44.883
	B	Scenario 5	kWh (not normal)	0.97359	0.00096	0.00012	6.17377	y = 0.9736x + 2E+06
		Scenario 6	kWh (not normal)	0.94448	0.00363	0.00017	8.68760	y = 0.9445x + 4E+06
		Scenario 7	kWh-ALT(normal)	0.98746	0.00095	0.00014	4.28637	y = 0.9875x + 1E+06
		Scenario 8	kWh-ALT(normal)	0.97500	0.00010	0.00219	5.80627	y = 0.975x + 2E+06
		Scenario 9	kWh-ALT(normal)	0.97685	0.00172	0.00008	5.17863	y = 0.9768x + 2E+06
		Scenario 10	kWh -m3 (not normal)	0.99305	0.00002	0.00003	1.54260	y = 0.9931x + 0.266
	C	Scenario 11	kWh (not normal)	0.96391	0.03297	0.00084	12.71956	y = 0.9639x + 3E+06
		Scenario 12	kWh-ALT(normal)	0.98161	0.00913	0.00016	10.99326	y = 0.9793x + 2E+06
		Scenario 13	kWh-ALT(normal)	0.98027	0.01865	0.00019	10.69565	y = 0.9803x + 2E+06
		Scenario 14	kWh-ALT(normal)	0.97929	0.00418	0.00002	10.19368	y = 0.9816x + 2E+06
		Scenario 15	KWH_INH (not normal)	0.99152	0.01734	0.00031	3.77755	y = 0.9915x + 46.322
	D	Scenario 16	kWh (not normal)	0.97757	0.03022	0.00000	14.75324	y = 0.9776x + 723114
		Scenario 17	kWh-ALT(normal)	0.98612	0.00036	0.00000	13.83384	y = 0.9861x + 629595
		Scenario 18	KWH_FAM (not normal)	0.99030	0.00868	0.00000	1.88511	y = 0.9903x + 96.033
	E	Scenario 19	kWh (not normal)	0.99917	0.03165	0.00249	5.62845	y = 0.9992x + 30291
		Scenario 20	kWh-ALT(normal)	0.99979	0.00148	0.00064	2.97628	y = 0.9998x + 7459.7
		Scenario 21	KWH-M3(NO NOR)	0.98786	0.00592	0.00449	10.37209	y = 0.9879x + 6.4113
		Scenario 22	KWH-M3(NO NOR)	0.98281	0.00191	0.00088	23.85288	y = 0.9828x + 9.0792
INDUSTRIAL	**A**	Scenario 23	kWh (not normal)	0.99856	0.00224	0.00359	19.40637	y = 0.9986x + 134254
		Scenario 24	kWh (not normal)	0.99869	0.00197	0.00326	19.29437	y = 0.9987x + 122061
		Scenario 25	kWh-ALT(normal)	0.99996	0.01140	0.01232	3.83696	y = 1x + 5253.3
		Scenario 26	kWh -m3 (not normal)	1.00000	0.00180	0.00365	0.33975	y = 1x + 0.0155
	B	Scenario 27	kWh (not normal)	0.99995	0.01659	0.00000	14.90947	y = 0.9999x + 691.66
		Scenario 28	kWh-ALT(normal)	0.99997	0.00653	0.00000	10.21824	y = 1x - 85.825
		Scenario 29	kWh -m3 (not normal)	0.97604	0.00977	0.00047	4.1	y = 0.9772x + 4.3903
	C	Scenario 30	kWh (not normal)	0.98490	0.00660	0.00022	19.48311	y = 0.9849x + 49852
		Scenario 31	kWh-ALT(normal)	0.99018	0.00076	0.00007	15.58975	y = 0.9902x + 37518
		Scenario 32	KWH-M2 (NO NOR)	0.99444	0.00080	0.00002	6.64828	y = 0.9944x + 1.3589
	D	Scenario 33	kWh (not normal)	0.99922	0.03540	0.00234	7.90405	y = 0.9992x + 433.4
		Scenario 34	kWh-ALT(normal)	0.99914	0.01098	0.00256	11.59310	y = 0.9991x + 545.29
		Scenario 35	kWh -m3 (not normal)	0.98078	0.01390	0.05655	19.34133	y = 0.9808x + 0.1835
COMMERCIAL AND SERVICES	**A**	Scenario 36	kWh (A) (not normal)	0.99273	0.00000	0.00000	18.67300	y = 0.9927x + 86780
		Scenario 37	kWh-ALT (A)(normal)	0.99442	0.00179	0.00000	23.21347	y = 0.9944x + 78758
		Scenario 38	kWh-ALT (A)(normal)	0.98665	0.03018	0.00000	23.56873	y = 0.9867x + 188321
		Scenario 39	KWH-M2 (A) (NO NOR)	0.95271	0.00794	0.00022	9.89833	y = 0.9527x + 6.3801
		Scenario 40	KWH-M2 (A) (NO NOR)	0.78059	0.00003	0.00386	18.13428	y = 0.7806x + 29.601
	B	Scenario 41	kWh (B) (not normal)	0.96024	0.00046	0.00000	21.03999	y = 0.9602x + 408738
		Scenario 42	kWh-ALT (B) (normal)	0.99487	0.02246	0.00000	12.06829	y = 0.9949x + 60530
		Scenario 43	KWH_INH (B) (not normal)	0.97251	0.00040	0.00000	22.56871	y = 0.9725x + 23.063
		Scenario 44	KWH_INH (B) (not normal)	0.96919	0.00069	0.00000	23.25154	y = 0.9692x + 25.847
		Scenario 45	KWH_INH (B) (not normal)	0.96618	0.00401	0.00000	20.83460	y = 0.9662x + 28.373
	C	Scenario 46	kWh (C) (not normal)	0.98653	0.00899	0.00002	13.82668	y = 0.9865x + 55206
		Scenario 47	kWh (C) (not normal)	0.97093	0.00326	0.00024	18.27924	y = 0.9709x + 119107
		Scenario 48	kWh-ALT(C)(normal)	0.99593	0.00018	0.00001	8.60612	y = 0.9959x + 20859
		Scenario 49	kWh-ALT(C)(normal)	0.99975	0.00124	0.00399	2.70487	y = 0.9998x + 1270
		Scenario 50	KWH-M2 (C)(NO NOR)	0.97165	0.03542	0.00022	15.21259	y = 0.9717x + 47.036
		Scenario 51	KWH-M2 (C)(NO NOR)	0.99849	0.03701	0.00751	3.20559	y = 0.9985x + 2.4987

5.3 energy predict for districts

After choosing the best scenario for each district, we predict energy consumption for each district and each of the 3 residential, industrial, commercial, and service sectors. prediction of these values is very important for our next steps. The forecast will help us to evaluate the difference between the real amount of gas consumption and these forecasts. We will find out which areas have major problems and how they can be solved. In essence, the advantage lies in the ability to make informed decisions, optimize resources, and promote sustainability in urban energy management. Predictive models empower stakeholders to proactively address the evolving energy needs of diverse districts, contributing to efficient, resilient, and sustainable urban development.

Energy Prediction for the Residential Sector: prediction of energy usage that is accurate is essential for allocating resources to residential areas. Service providers can optimize their operations and avoid shortages or excesses of gas that could interrupt vital services by predicting patterns of usage. This keeps home activities from being disrupted and guarantees a balanced gas supply to fulfill everyone's demands. predicts at the district level to assist residential urban planning initiatives by offering important information for creating sustainable and energy-efficient neighborhoods. With the use of this information, stakeholders may create and carry out plans that support long-term objectives for urban development, resulting in a more resource- and environmentally-conscious urban environment. Mendoza can continuously improve these predictions by adding real-time data, such as population growth, weather patterns, and economic trends, into the forecasting models. This allows Mendoza to make more informed decisions regarding investments in energy infrastructure, energy conservation programs, and overall energy management strategies.

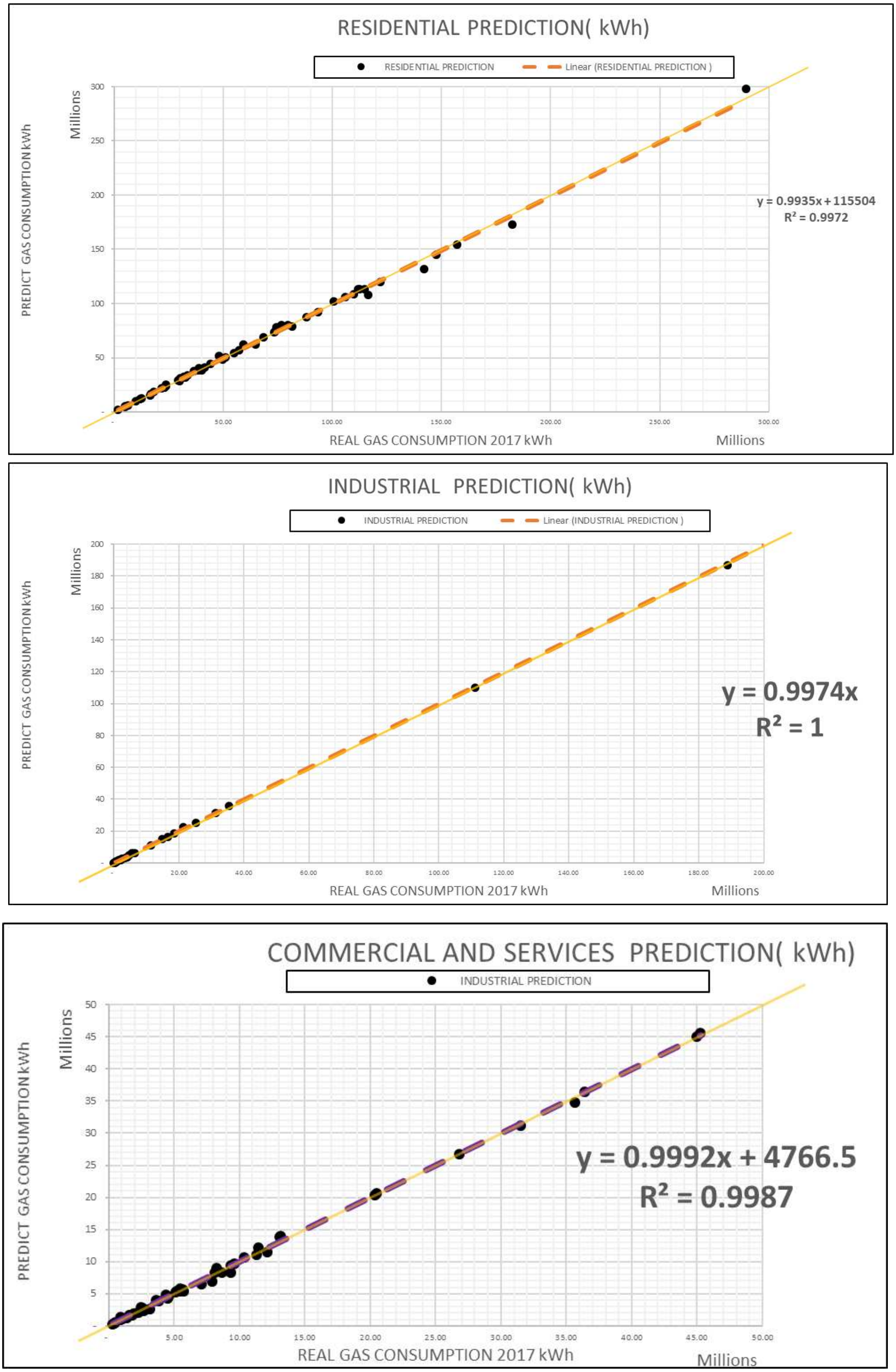
Energy prediction for the Industrial sector: To design gas infrastructure in industrial locations, energy consumption predictions are essential. Pipeline networks and storage facilities can be improved to efficiently fulfill the future gas demands of different sectors. To help companies prepare for constant gas access and reduce disruptions that might impair their operations, this guarantees a dependable gas supply for industrial output. For industrial locations, it is essential to include energy consumption estimates with energy management techniques. Businesses may maximize their energy use and cut expenses by putting demand-response strategies into place, such as adjusting energy usage during peak hours. This proactive approach to energy demand management lowers energy prices, lessens the region's need for energy imports, and moves the energy sector closer to a more sustainable future.

Energy prediction for the Commercial and Service sector : predict of accurate energy usage are crucial for maintaining corporate operations in commercial and service industries. Businesses may prepare for the regular availability of gas by predicting their demands for cooking, heating, and other necessary services. This creates a stable and dependable environment for their operations. The commercial districts' economic vitality depends on a steady supply of gas, which makes it possible for enterprises to prosper and support the local economy.

Table 24 : Predict of Gas Consumption according to models

residential			industrial			commercial and services		
	CLUSTER	PREDICT kWh		CLUSTER	PREDICT KWh		CLUSTER	PREDICT kWh
Ciudad (GC)	A	298081859.9	Coquimbito	A	25206375.24	Belgrano	A	5391307
Cuarta Sección		80342016.64	Cruz de Piedra		18478948.45	Buena Nueva		1588685
Primera Sección		38025170.33	El Resguardo		14851457.09	Ciudad (GC)		45655607
Quinta Sección		92042300.29	Kilómetro 11		31537268.69	Cuarta Sección		12239095
Segunda Sección		74384554.24	Las Tortugas		35667637.16	Décimo Primera Sección		915792.1
Sexta Sección		144817136.4	Luzuriaga		186844842.9	El Zapallar		1280516
Tercera Sección		28211502.33	Rodeo de La Cruz		416507814.9	Kilómetro 11		1392442
Villa Nueva		131726866.8	San Francisco del Monte -GC		16504362.61	La Puntilla		377282.3
Capilla del Rosario	B	62579843.41	Belgrano	B	1830112.642	Luzuriaga		4022556
Ciudad (L)		101839295.5	Bermejo		6285831.422	Maipú		20396367
Ciudad (LH)		108740828.2	Ciudad (LH)		1992071.107	Pedro Molina		2783164
Dorrego		113150346.6	General Gutierrez		110089933.2	Presidente Sarmiento		4488650
El Zapallar		40276193.75	Gobernador Benegas		1596455.184	Rodeo de La Cruz		5446696
Gobernador Benegas		120070981.1	Pedro Molina		4028953.874	San Francisco del Monte (Gy		2048262
Las Cañas		69104111.21	Primera Sección		1839025.525	San José (Gy)		11115162
Las Tortugas		113451777.1	Quinta Sección		734247.3462	Segunda Sección		45037085
Luzuriaga		87185485.32	Rodeo del Medio		617558.7719	Tercera Sección		31224433
Pedro Molina		32005934.73	Tercera Sección		778917.2034	Villa Nueva		20595359
San Francisco del Monte -GC		38687858	Villa Nueva		22611398.67	Bermejo	B	5656499
San José (Gy)		44157567.7	Buena Nueva	C	3451826.51	Capdevila		315556.8
Carrodilla	C	113486585.2	Carrodilla		3207304.325	Capilla del Rosario		2845798
Chacras de Coria		154594209.2	Ciudad (GC)		11280930.33	Carrodilla		6529076
El Challao		107858102	Cuarta Sección		1926573.333	Chacras de Coria		10642858
Fray Luis Beltrán		21583121.96	Dorrego		2037815.775	Ciudad (L)		13884761
General Gutierrez		78194517.85	El Plumerillo		2496659.635	Ciudad (LH)		8324575
La Cieneguita		57257138.51	El Zapallar		4782067.342	Dorrego		11485040
La Puntilla		22761331.96	Las Cañas		1541501.491	El Algarrobal		2660905
Maipú		173072167.6	Maipú		6252272.763	El Challao		4318340
Mayor Drummond		62250365.42	Presidente Sarmiento		2077637.741	El Plumerillo		14007242
San Francisco del Monte (Gy		51514154.42	Segunda Sección		81264.78943	General Gutierrez		5569366
Belgrano	D	79046747.56	Sexta Sección		333372.7019	Gobernador Benegas		9016008
Bermejo		41200013.44	Capilla del Rosario	D	163019.3182	Jesús Nazareno		2336093
Buena Nueva		33738624.95	Chacras de Coria		219612.0993	Las Cañas		5768265
Capdevila		5042351.81	Ciudad (L)		600516.9734	Las Tortugas		6952082
Colonia Segovia		10204484.75	Jesús Nazareno		97955.82785	Mayor Drummond		4841189
Coquimbito		48687225.75	La Cieneguita		338294.0125	Nueva Ciudad		9626226
Cruz de Piedra		11881637.64	Mayor Drummond		194126.5058	Panquegua		2135522
El Algarrobal		16384908.29	Nueva Ciudad		2021.533525	Primera Sección		26724062
El Plumerillo		80185129.96	San Francisco del Monte (Gy		2521187.909	Quinta Sección		36472597
El Resguardo		38645978.96	San José (Gy)		854273.8513	Sexta Sección		34836608
Jesús Nazaren		25077268.03				Colonia Segovia	C	1941827
Kilómetro 11		22629628.05				Coquimbito		5199638
Las Compuertas		6100321.864				Cruz de Piedra		1626777
Panquegua		31401528.58				El Resguardo		9390057
Rodeo de La Cruz		50517691.65				El Sauce		3809842
Rodeo del Medio		32248734.34				Fray Luis Beltrán		4457584
Russel		12464224.47				La Cieneguita		1618525
Décimo Primera Sección	E	15554472.79				Las Compuertas		576320.9
El Sauce		29394524.22				Los Corralitos		1611805
Los Corralitos		23733162.32				Lunlunta		1046898
Lunlunta		18245787.3				Rodeo del Medio		5374988
Presidente Sarmiento		105952453.5				San Francisco del Monte -GC		8284202
Vistalba		73362513.69				Vistalba		8326826
General Ortega		1692869.508						
La Primavera (Gy)		4949276.353						
Perdriel		54539347.01						

Figure 104 : Predict of Gas Consumption according to models



6.Discussion

We go into great detail in this chapter on the conclusions and revelations we made throughout our thorough investigation of Mendoza's urban energy environment. The previous chapters have carefully prepared the groundwork by using data-driven analysis and predictive modeling to explore the complexities of the residential, industrial, and commercial/service sectors. We now turn our attention to a more in-depth analysis of these findings, explaining their consequences, difficulties, and prospects for Mendoza's sustainable urban growth. In conclusion, this discussion chapter provides a framework for a thorough examination of our research, highlighting linkages across various industries and providing useful advice for the future. We hope to add to the current conversation on sustainable urban development and energy planning by combining the many aspects of Mendoza's urban energy environment.

Before delving into the intricacies of each sector, let us briefly recapitulate the key findings that have emerged from our analyses. Our research has identified unique patterns of energy usage, clustering properties, and prediction models in the residential, industrial, and commercial/service sectors. These results provide a thorough overview of Mendoza's urban energy dynamics and serve as a starting point for focused conversations and useful insights.

After analyzing the data, we offer prospective policy suggestions and tactics to improve gas efficiency, lower energy use, achieve our energy planning objectives by employing renewable energy sources other than gas, and promote flourishing. We highlight cross-sectoral themes and interrelated patterns that run across the residential, industrial, and commercial/service environments as we move through each sector. These underlying principles guide our broad suggestions for sustainable urban development and offer a comprehensive knowledge of Mendoza's urban energy dynamics.

6.1 Testing and Validating Models by Expanding the prediction to other Years

When we go forward with using our forecasting models outside of the first dataset, one important area that needs our focus is the assessment and verification of these models in later years. The models' temporal resilience and dependability are critical because they support the models' practical use and long-term efficacy in directing energy planning methods. In this part, we evaluate our models' performance by projecting them to later years to determine their prediction accuracy and suitability for changing urban dynamics. To compare the models' performance to actual data from various periods, we want to extend the models created in this study to include more years. This methodology fosters the ability of the models to capture temporal shifts, adapt to changing contextual factors, and maintain accuracy in predicting gas consumption trends.

1. **Temporal Consistency:** Examining the models' temporal consistency is our main goal. Are the forecasting abilities shown in the first dataset maintained in later years? This analysis provides insights into the models' ability to adapt to evolving energy consumption patterns.
2. **Generalizability**: We also want to assess the models' generalizability. How much can the models be used in various temporal circumstances and still be effective? Comprehending the extent to which the results may be applied to guide long-term energy planning strategies is crucial.

3. **Finding Trends**: We try to find any trends or changes in the patterns of gas use by extending the models to more years. To help urban planners and politicians anticipate future energy demands and develop adaptable measures, this research advances a forward-looking methodology.

6.1.1 Using HDD for predication of the different years :

Our methodological framework involves normalizing the predicted gas consumption data for each subsequent year based on the Heating Degree Days (HDD) values observed in 2017. This reference year establishes a stable baseline and enables us to recognize the impact of climate change on gas consumption forecasts while maintaining a consistent benchmark. Through the HDD normalization approach, we aim to incorporate the climate factor to provide a clearer understanding of the underlying trends in forecast energy consumption. A useful metric for estimating the length and severity of cold weather during the heating season is heating degree days. As a result, they constitute a crucial component affecting the demand for gas, especially in regions where gas is the main energy source used for heating. Understanding this inescapable connection between gas use and climate, we use HDD as a normalization factor to take annual variations in climate into account.

The potential of this HDD-based validation to improve the accuracy and applicability of our prediction models is what makes it significant. We handle the intricacies of climatic changes and go beyond simple time validation by including the impact of weather on gas use. In addition to enhancing our knowledge of gas consumption trends, this method gives policymakers and urban planners useful information for developing sustainable energy plans that consider a range of climatic circumstances. In conclusion, we obtain a more thorough grasp of gas consumption patterns and their underlying factors by extending our forecasting models to include more years and utilizing HDD normalization. Our ability to create more reliable and generalizable models thanks to this in-depth information allows us to create efficient energy planning strategies that can change with the environment and the dynamics of cities.

$$\boxed{\textbf{kWh Prediction for year } \boldsymbol{X} = \frac{\boldsymbol{HDD(year\ x) \times kWh\ predict\ of\ (2017)}}{\boldsymbol{HDD\ (2017)}}}$$

6.1.2 Analyzing Models and Gas Consumption Discrepancies Across Different Years:

Strong evidence has surfaced following simplifying the initial energy consumption models for the ensuing years and validating the developed models' dependability. An analysis of the variations in gas usage over several years reveals clear trends that provide insight into the complex processes affecting Mendoza's energy consumption. Remarkable findings draw attention to fascinating discrepancies between estimated and real gas consumption, which motivates a thorough investigation of the underlying causes. A general increase trajectory in gas use was noted, as predicted and confirmed in the information section on gas usage. But after closely examining and comparing the projected regressions with data from other years, it was clear that actual consumption in the post-2017 period exceeded projections, indicating the need for careful consideration in energy planning.

One important finding from the temporal study is the trend of which years frequently depart from the predicted patterns. Unprecedented worldwide occurrences in 2020 and 2021 serve as prime examples of anomalies' profound impact. The pandemic during these years had a significant effect on gas consumption, with a rise in the residential sector as a result of more people staying at home. In contrast, the commercial and industrial sectors experienced a decline, signaling shifts in work dynamics and economic challenges.

The pandemic's spike in domestic gas use is consistent with a worldwide trend, as the rise in remote work and at-home activities led to an increase in the need for cooking and heating, which in turn raised gas use. On the other hand, changes in work arrangements, quarantine regulations, and financial constraints are to blame for the decline in gas usage in the commercial and industrial sectors. When taken as a whole, these variables resulted in lower energy demand in various industries, highlighting how the landscape of energy consumption is changing in response to shifting social and economic circumstances.

Furthermore, a careful examination of the statistics on gas usage reveals a noteworthy trend: the industrial sector's growing reliance on gas in 2020 and 2021 to produce power. This change in the energy consumption of the industrial sector highlights the complex interaction of factors influencing Mendoza's energy environment. The combination of the industrial and residential sectors' use of gas to produce electricity highlights the complex ways in which energy dynamics change in response to local and global circumstances.

Figure 105: Industrial Test validation and Expanding models for different years

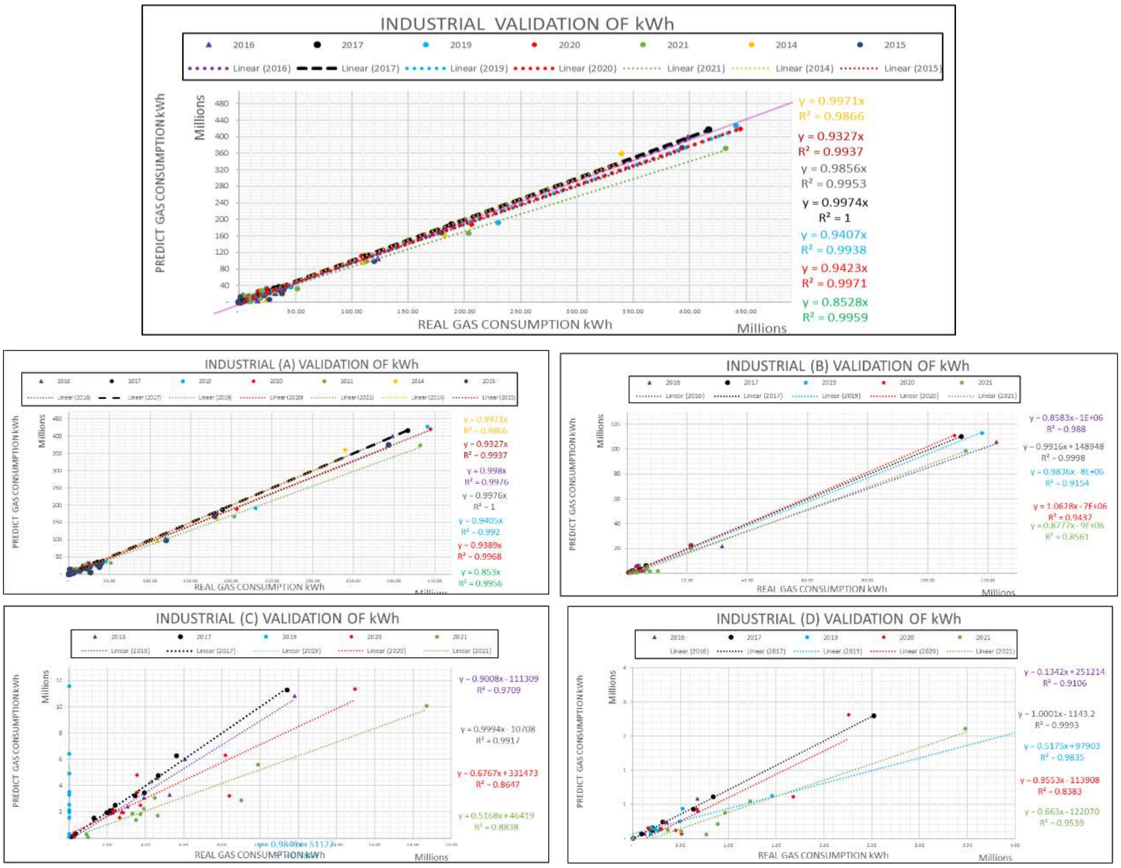


Figure 107:residential Test validation and Expanding models for different years

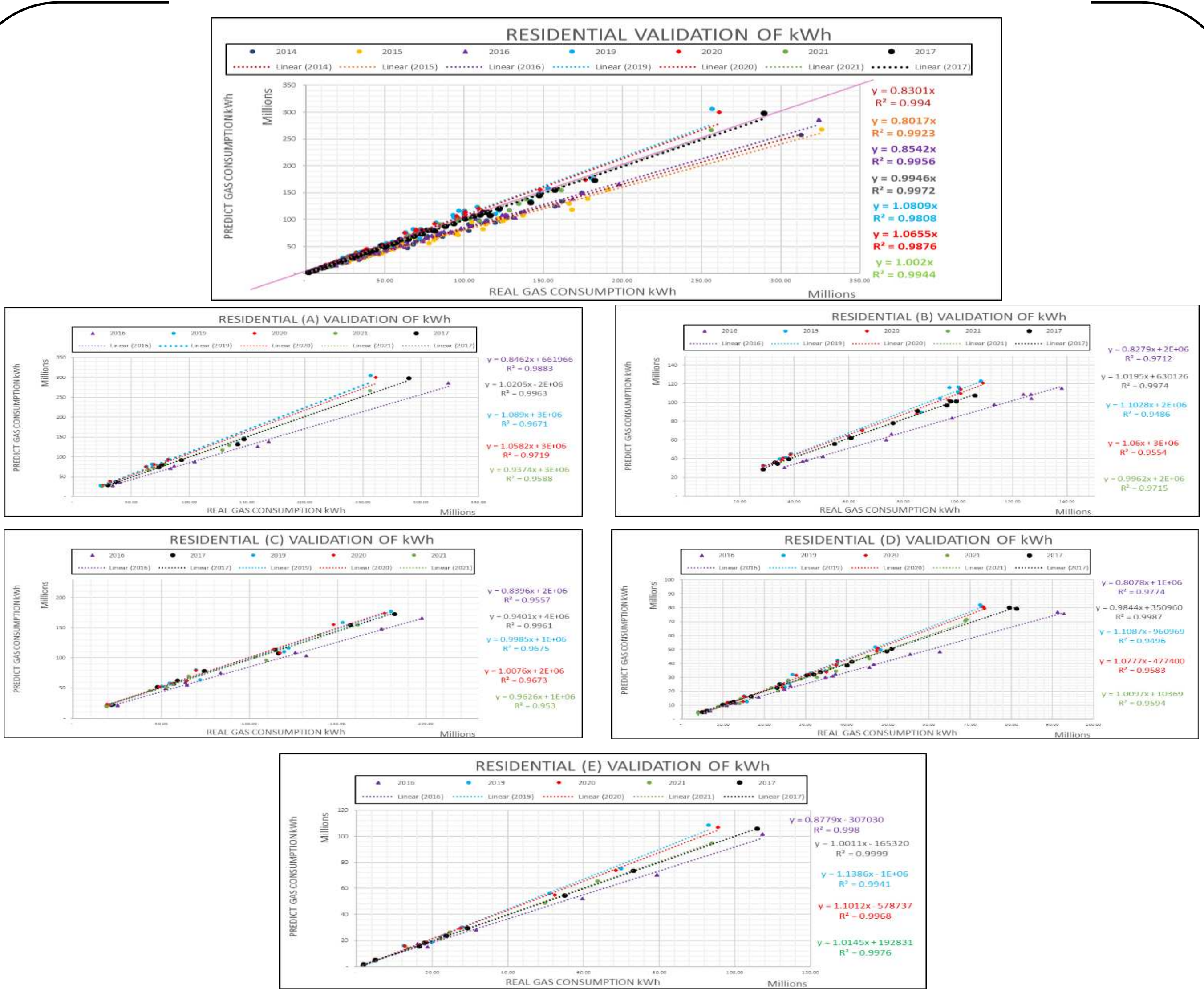
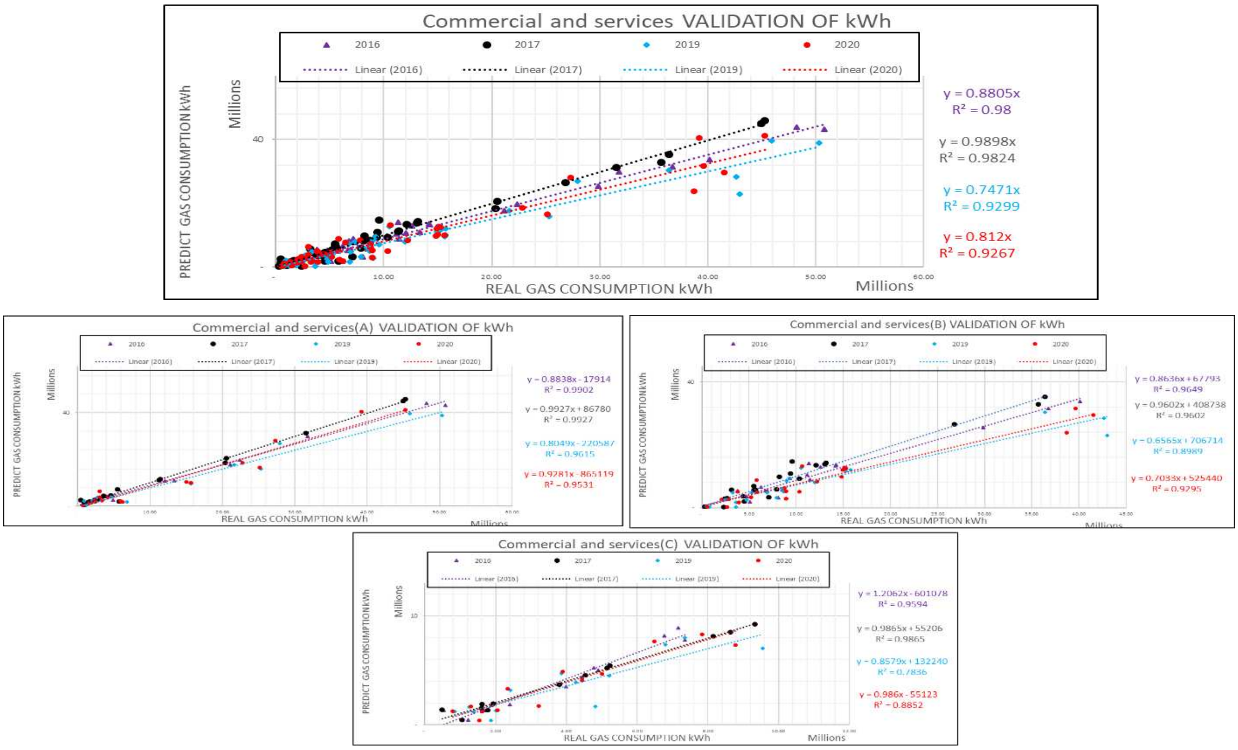


Figure 106:commercial and services Test validation and Expanding models for different years



6.2 Energy Performance Classes:

This section explores the creation of energy performance classes for various Mendoza urban regions. Using an exacting methodology, we computed annual energy consumption estimates per unit area (kWh/m2/year) for every region, enabling their division into discrete groups from A+ (best performance) to H (lowest performance). A+ zones are the pinnacles of energy efficiency, while H zones signify regions with significant potential for improvement. This comprehensive classification framework serves as a pivotal benchmark for assessment and guiding targeted interventions for sustainable urban development.

This categorization system is intended for use in the residential, industrial, and commercial/service sectors. It is designed to work in harmony with energy efficiency objectives and to provide direction for future urban development projects. Customized programs, according to the unique requirements and difficulties of every Mendoza neighborhood, may now be used with ease. Understanding the nuances of energy performance classes may help strategic policies and decision-making remain steadfastly focused on creating an urban environment in Mendoza that is more efficient, adaptive, and sustainable.

Using these household energy performance classes, urban planners may create customized interventions to target particular issues and make the most of already-existing savings. This tactful technique guarantees a harmonic balance between inhabitants' energy needs and environmental sustainability. A comparable categorization also applies to industrial and service areas, giving an unambiguous picture of energy performance. The foundation for executing focused interventions to improve the industrial and service sectors' operational efficiency is provided by this categorization.

kwh/m2	
A+	<27
A	27-44
B	44-82
C	82-143
D	143-201
E	201-249
F	249-300
G	300-435
H	>435

Table 25:energy performance classes (Professor Mutani's class booklet. Exercise 4)

Table 26:energy performance classes for districts

RESIDENTIAL		
DISTRICT CLASS	DISTRIC	ENERY PERFORMANCE CLASS
A	Tercera Sección	A
A	Primera Sección	B
A	Segunda Sección	B
B	Pedro Molina	B
B	San José (Gy)	B
A	Ciudad (GC)	C
A	Cuarta Sección	C
A	Quinta Sección	C
A	Villa Nueva	C
B	Capilla del Rosario	C
B	Ciudad (L)	C
B	Ciudad (LH)	C
B	Dorrego	C
B	El Zapallar	C
C	General Gutierrez	C
C	San Francisco del Monte (Gy	C
D	Belgrano	C
D	Bermejo	C
D	Buena Nueva	C
D	Capdevila	C
D	El Algarrobal	C
D	El Plumerillo	C
D	El Resguardo	C
D	Panquegua	C
D	Rodeo de La Cruz	C
A	Sexta Sección	D
B	Gobernador Benegas	D
B	Las Cañas	D
B	Las Tortugas	D
B	Luzuriaga	D
C	La Cieneguita	D
C	La Puntilla	D
C	Maipú	D
D	Coquimbito	D
D	Jesús Nazareno	D
D	Kilómetro 11	D
E	Presidente Sarmiento	D
B	San Francisco del Monte -GC	E
C	Carrodilla	E
C	Chacras de Coria	E
C	El Challao	E
C	Fray Luis Beltrán	E
D	Rodeo del Medio	E
C	Mayor Drummond	F
D	Las Compuertas	F
E	Vistalba	F
E	El Sauce	G
D	Colonia Segovia	H
D	Cruz de Piedra	H
D	Russel	H
E	Décimo Primera Sección	H
E	Los Corralitos	H
E	Lunlunta	H
E	General Ortega	H
E	La Primavera (Gy)	H
E	Perdriel	H

INDUSTRIAL		
DISTRICT CLASS	DISTRIC	ENERY PERFORMANCE CLASS
D	Capilla del Rosario	A+
D	Chacras de Coria	A+
D	Ciudad (L)	A+
D	Jesús Nazareno	A+
D	La Cieneguita	A+
D	Mayor Drummond	A+
D	Nueva Ciudad	A+
D	San Francisco del Monte (Gy	A+
D	San José (Gy)	A+
C	Dorrego	A
C	Presidente Sarmiento	A
C	Buena Nueva	B
C	Carrodilla	B
C	El Plumerillo	B
C	El Zapallar	B
C	Las Cañas	B
C	Maipú	B
C	Segunda Sección	B
B	Ciudad (LH)	C
B	Gobernador Benegas	C
C	Ciudad (GC)	C
C	Cuarta Sección	C
B	Belgrano	D
B	Quinta Sección	D
B	Tercera Sección	D
B	Villa Nueva	F
c	Sexta Sección	F
B	Bermejo	G
B	Pedro Molina	G
B	Primera Sección	G
B	Rodeo del Medio	G
A	Coquimbito	H
A	Cruz de Piedra	H
A	El Resguardo	H
A	Kilómetro 11	H
A	Las Tortugas	H
A	Luzuriaga	H
A	Rodeo de La Cruz	H
A	San Francisco del Monte -GC	H
B	General Gutierrez	H

COMMERCIAL AND SERVICES		
DISTRICT CLASS	DISTRIC	ENERY PERFORMANCE CLASS
A	Belgrano	A+
A	El Zapallar	A+
A	San Francisco del Monte (Gy	A+
A	Cuarta Sección	A
A	Kilómetro 11	A
A	La Puntilla	A
A	Luzuriaga	A
A	Pedro Molina	A
A	Presidente Sarmiento	A
A	San José (Gy)	A
A	Buena Nueva	B
A	Ciudad (GC)	B
A	Décimo Primera Sección	B
A	Maipú	B
A	Rodeo de La Cruz	B
A	Segunda Sección	B
A	Tercera Sección	B
A	Villa Nueva	B
B	Bermejo	B
B	Carrodilla	B
B	Ciudad (L)	B
B	Ciudad (LH)	B
B	Dorrego	B
B	El Algarrobal	B
B	General Gutierrez	B
B	Jesús Nazareno	B
B	Las Tortugas	B
B	Nueva Ciudad	B
B	Primera Sección	B
B	Capdevila	C
B	Capilla del Rosario	C
B	Chacras de Coria	C
B	El Challao	C
B	El Plumerillo	C
B	Gobernador Benegas	C
B	Las Cañas	C
B	Mayor Drummond	C
B	Panquegua	C
B	Quinta Sección	C
B	Sexta Sección	D
C	Coquimbito	E
C	San Francisco del Monte -GC	E
C	Fray Luis Beltrán	F
C	Las Compuertas	F
C	Los Corralitos	F
C	El Resguardo	G
C	La Cieneguita	G
C	Rodeo del Medio	G
C	Colonia Segovia	H
C	Cruz de Piedra	H
C	El Sauce	H
C	Lunlunta	H
C	Vistalba	H

Figure 108:Residential energy performance classes

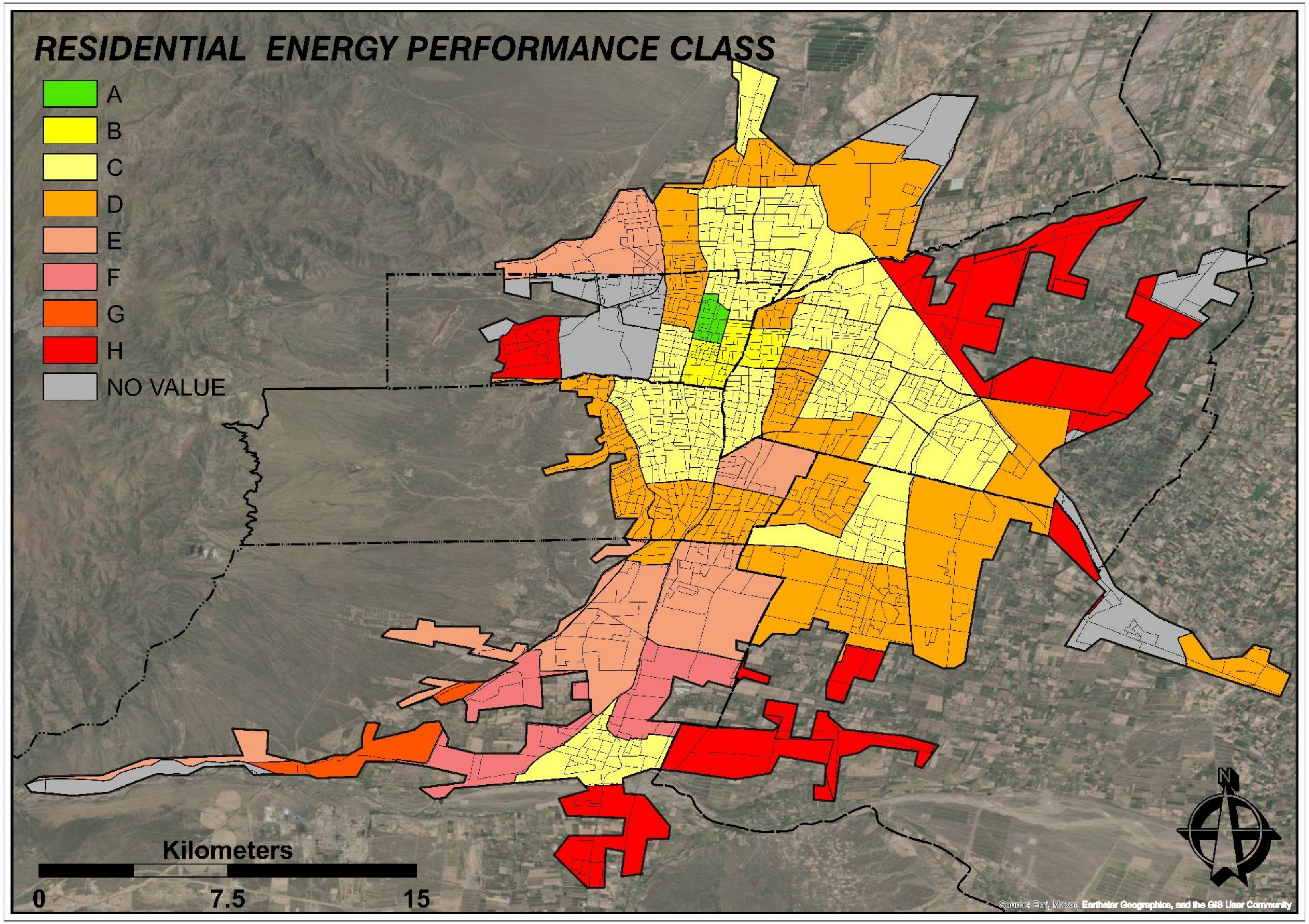


Figure 109:industrial energy performance classes

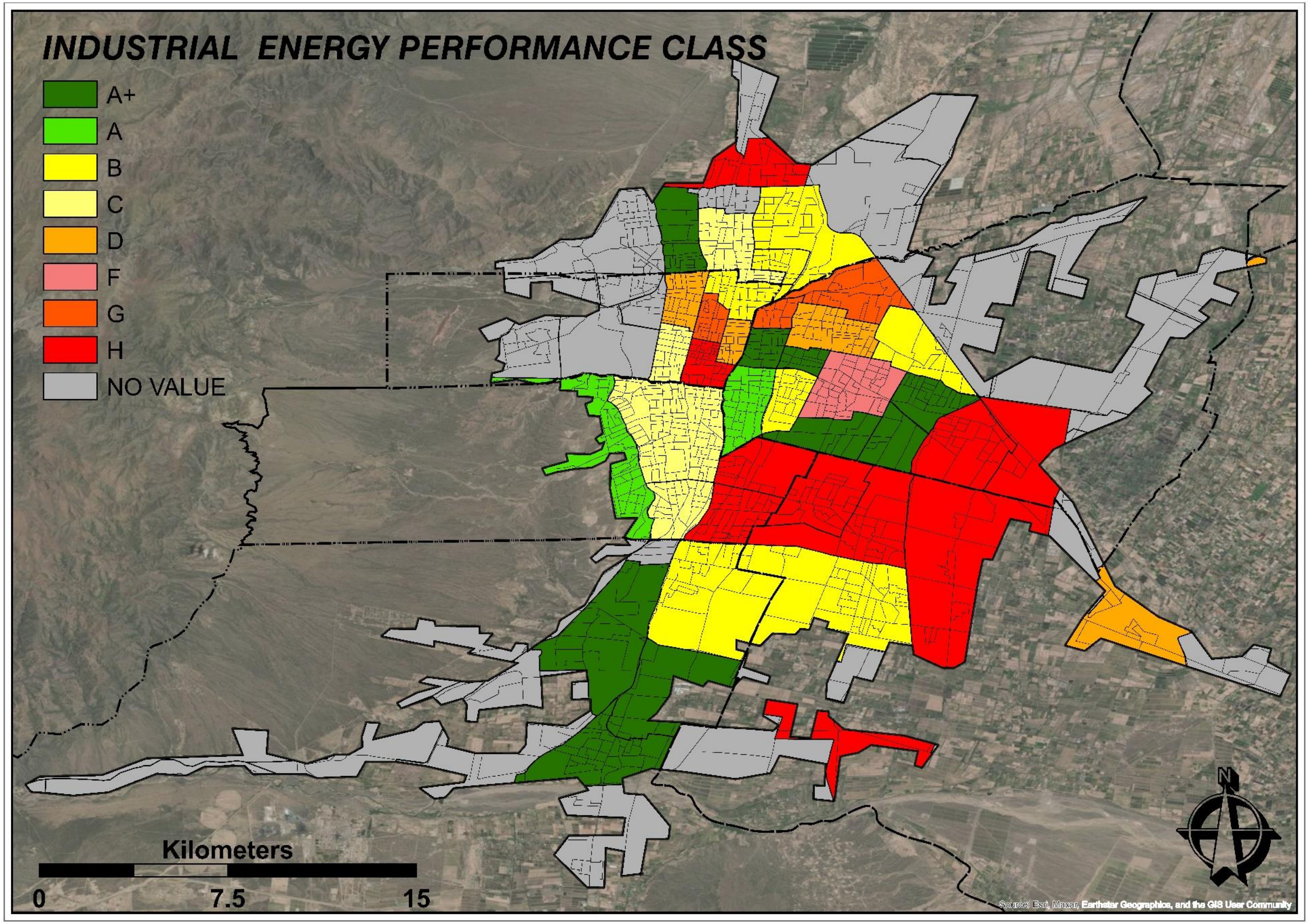
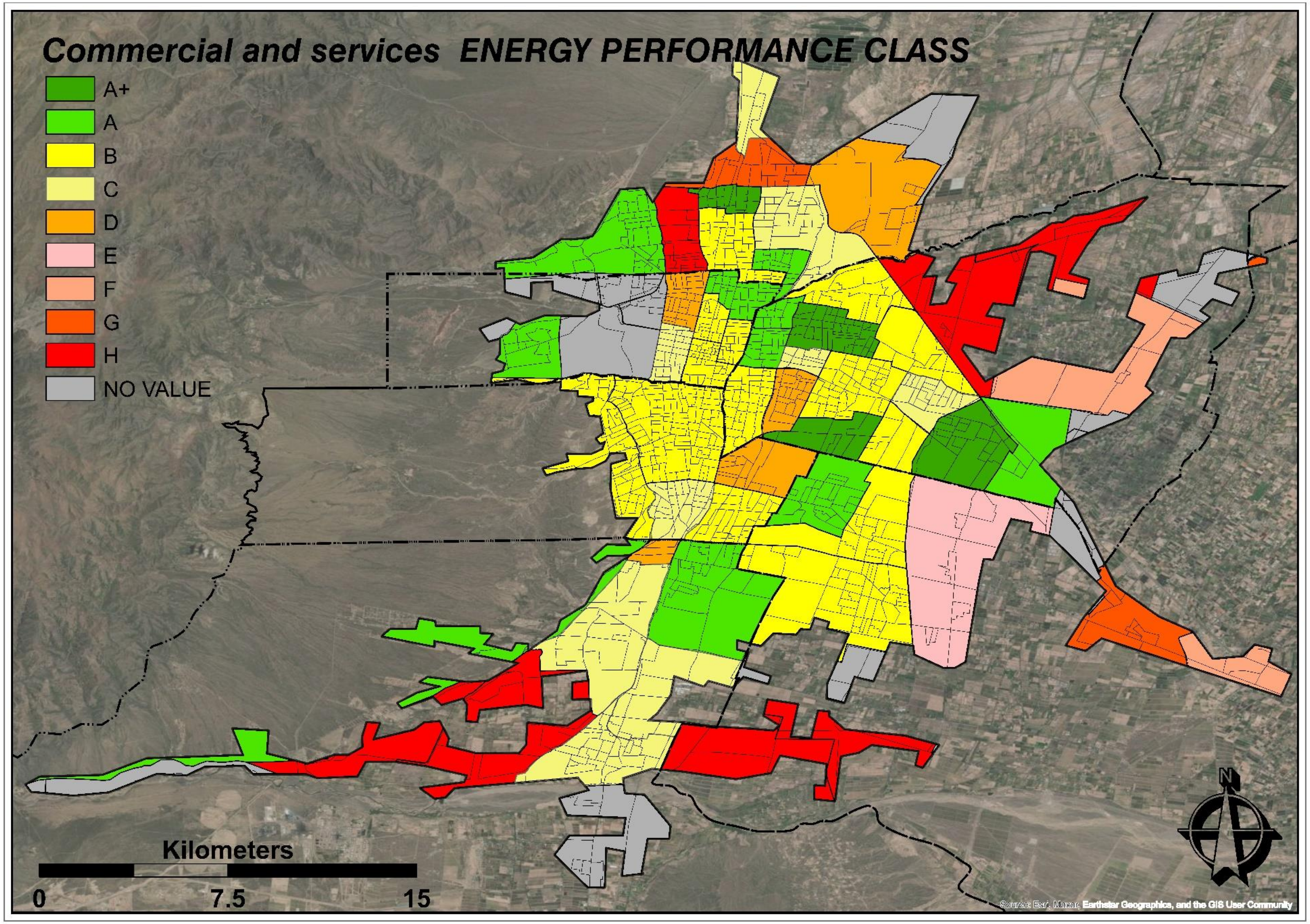


Figure 110:commercial and services energy performance classes



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

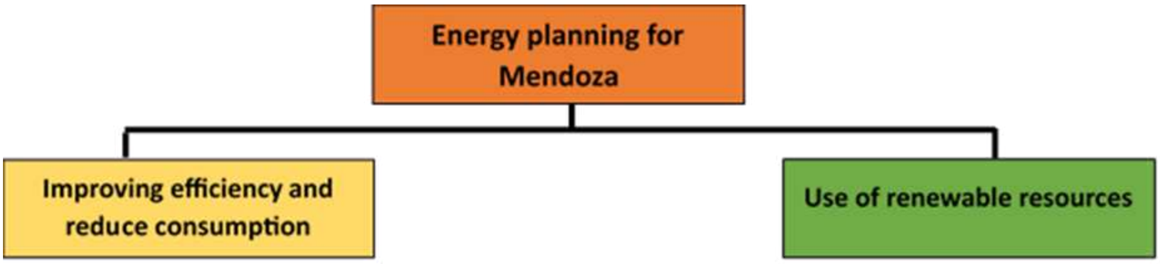
6.3 Energy planning for Mendoza

Following the validation and potential extension of our prediction models, we are currently concentrating on developing a comprehensive and customized energy planning strategy for Mendoza. Two key pillars comprise this plan, which takes a comprehensive approach: increasing efficiency and utilizing renewable resources. In addition to meeting the region's immediate energy demands, our goal is to provide the groundwork for long-term sustainability, adaptation, and environmental responsibility.

The Mendoza Energy Plan is a large-scale endeavor aimed at advancing the city's sustainability objectives. Through the implementation of focused energy programs in the commercial, industrial, and residential sectors, this plan acts as a proactive road map that is in line with the goals of sustainable development. The Mendoza Energy Plan, which aims to strengthen economic competitiveness, promote a cleaner environment, and lessen ecological impact, is meant to be a supplement to larger municipal development plans.

we hope that Mendoza will become a more sustainable, habitable, and economically active city by reducing energy use, improving energy efficiency, and utilizing more renewable energy sources. Although this idea is a great place to start, more funding is needed to achieve the city's lofty objectives in the areas of energy efficiency and renewable energy development. Therefore, by offering a strategic framework that can be improved upon and built upon as the city moves forward on its sustainability path, the plan establishes a strong foundation for Mendoza's sustainable future.

Figure 111: Energy Planning for Mendoza



6.3.1 Enhance the energy efficiency:

It has become critical in today's climate to manage the growing energy needs while minimizing the environmental effects of those demands. It is more important than ever to cut back on energy use and lessen its negative effects on the environment as climate change issues get worse. This necessity is particularly felt in areas like Mendoza, Argentina, where striking a careful balance between environmental preservation and economic advancement is a top priority. The idea of energy efficiency, a foundational idea that holds the key to opening the door to a more sustainable future, is at the center of our project.

Energy efficiency delineated as the ratio of useful energy output to total energy input, stands as an exemplar of pragmatic sustainability solutions, particularly salient in locales like Mendoza. In the residential sphere, where family comfort and financial responsibility are prioritized, energy-efficient housing not only results in lower utility costs but also improves the standard of living at home. Within the industrial sector, where output is of the utmost importance, the implementation of energy-efficient practices enhances competitiveness and promotes environmental improvement. Furthermore, in the dynamic commercial and services domain, where businesses compete for market leadership, energy efficiency becomes a critical factor in determining operational effectiveness and financial sustainability.

We delve into the very heart of energy efficiency – the optimization of existing infrastructure and practices across all sectors. By strategically enhancing efficiency levels, we aspire to propel Mendoza towards a more sustainable, resilient, and environmentally conscious energy ecosystem. At the heart of our efficiency-driven strategy lies a deep understanding of the unique energy consumption patterns in each sector. This comprehensive approach enables us to tailor our interventions to address the specific needs and challenges of residential, industrial, and commercial establishments. Mendoza's energy planning strategy is a tapestry that incorporates energy efficiency measures, energy reduction techniques, and renewable energy integration. It is not just a collection of discrete efforts. Through the integration of these components, we establish a synergistic strategy that expedites Mendoza's shift towards a sustainable energy future.

In crafting an effective framework for implementing energy efficiency measures in Mendoza, it is imperative to adopt a systematic and multi-faceted approach that addresses the diverse needs and opportunities within the region. This necessitates a structured cycle encompassing key steps aimed at identifying priority areas, establishing regulatory frameworks, incentivizing action, fostering public engagement, and ensuring robust monitoring and evaluation.

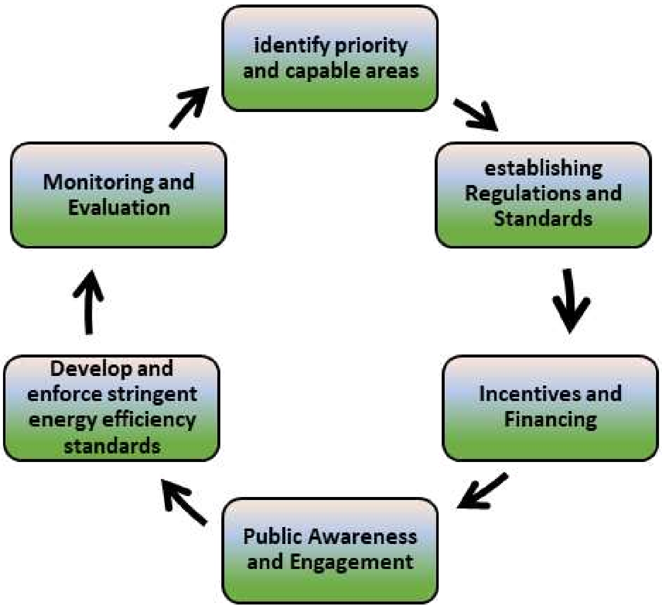


Figure 112: Cycle of increasing efficiency

6.3.1.1 Identifying Key Variables for Enhanced Building Efficiency

Following the careful creation of energy models for every district and the integration of energy-saving techniques and renewable energy sources, the next critical phase is to increase the emphasis on building efficiency. To put this technique into practice, we must first identify which factors have the most impact on our models or show the strongest link with patterns of energy usage. Examining our 51 scenarios in detail is required to determine which factors are critical to changes in energy use since they are consistently present in several models. Furthermore, factors exhibiting a connection of more than 90% with energy usage will be given priority and integrated into our framework for building efficiency.

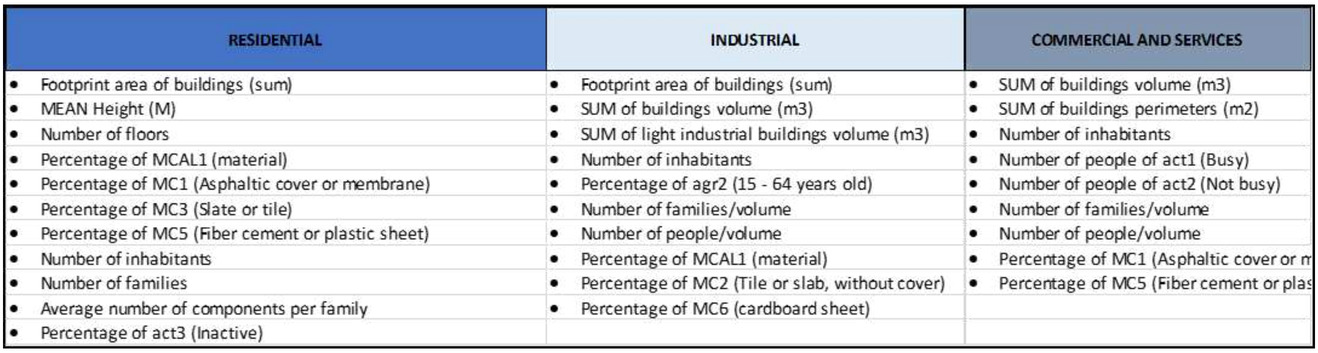
By taking a thorough approach to variable identification, we can make sure that the most significant parts of building energy usage are the focus of our optimization efforts. We can efficiently adjust our efficiency solutions to meet the principal energy-consuming aspects within buildings by giving priority to factors that consistently appear as important drivers. We will be able to accomplish considerable energy consumption savings and make a positive contribution to a more sustainable urban environment with this improved method.

By prioritizing these critical drivers, we ensure that our efforts to enhance building efficiency are strategically targeted towards the aspects that hold the greatest potential for impact. This data-driven approach allows us to:

- Focus optimization efforts on the most influential variables, maximizing the effectiveness of our interventions.
- Tailor efficiency solutions to address the specific energy-consuming characteristics of different building types within Mendoza.
- Achieve significant reductions in energy consumption, contributing to a more sustainable and environmentally responsible urban environment.

This rigorous approach to variable identification marks a pivotal step in our quest to optimize building energy performance in Mendoza. By prioritizing the factors that truly matter, we empower ourselves to unlock the immense potential of efficiency, paving the way for a more sustainable and resilient future for this vibrant city.

Table 27: key Variables for Enhanced Building Efficiency



RESIDENTIAL	INDUSTRIAL	COMMERCIAL AND SERVICES
• Footprint area of buildings (sum)	• Footprint area of buildings (sum)	• SUM of buildings volume (m3)
• MEAN Height (M)	• SUM of buildings volume (m3)	• SUM of buildings perimeters (m2)
• Number of floors	• SUM of light industrial buildings volume (m3)	• Number of inhabitants
• Percentage of MCAL1 (material)	• Number of inhabitants	• Number of people of act1 (Busy)
• Percentage of MC1 (Asphaltic cover or membrane)	• Percentage of agr2 (15 - 64 years old)	• Number of people of act2 (Not busy)
• Percentage of MC3 (Slate or tile)	• Number of families/volume	• Number of families/volume
• Percentage of MC5 (Fiber cement or plastic sheet)	• Number of people/volume	• Number of people/volume
• Number of inhabitants	• Percentage of MCAL1 (material)	• Percentage of MC1 (Asphaltic cover or m
• Number of families	• Percentage of MC2 (Tile or slab, without cover)	• Percentage of MC5 (Fiber cement or plas
• Average number of components per family	• Percentage of MC6 (cardboard sheet)	
• Percentage of act3 (Inactive)		

Table 28 : finding Key Variables for Enhanced Building Efficiency

cluster	model	scenario	variable 1	variable 2	variable 3	variable 4	variable 5	variable 6	variable 7	variable 8	variable 9	variable 10	variable 11	variable 12	variable 13	variable 14	variable 15	variable 16	variable 17	variable 18	variable 19	variable 20	variable 21	variable 22	variable 23	variable 24	variable 25	variable 26	variable 27	variable 28	variable 29	variable 30	variable 31	variable 32	variable 33	variable 34	variable 35	variable 36	variable 37	variable 38	variable 39	variable 40	variable 41	variable 42	variable 43	variable 44	variable 45	variable 46	variable 47	variable 48	variable 49	variable 50	variable 51	variable 52	variable 53	variable 54
A	kWh (not normal)	1											🟩	🟩																								🟩																		
A	kWh-ALT(normal)(S1)	2												🟩																						🟩																	🟩		
A	kWh-ALT(normal)(S2)	3												🟩											🟩											🟩																	🟩		
A	KWH_INH (not normal)	4											🟩																	🟩														🟩												
B	kWh (not normal) S1	5	🟩		🟩												🟩			🟩		🟩																																		
B	kWh (not normal) S2	6	🟩		🟩															🟩		🟩																																		
B	kWh-ALT(normal) S1	7	🟩									🟩			🟩		🟩		🟩																																					🟩
B	kWh-ALT(normal) S2	8										🟩					🟩		🟩			🟩																																		🟩
B	kWh-ALT(normal) S3	9	🟩									🟩					🟩		🟩																																					🟩
B	kWh -m3 (not normal)	10									🟩																	🟩				🟩								🟩					🟩		🟩									
C	kWh (not normal)	11										🟩			🟩																					🟩		🟩																		
C	kWh-ALT(normal) S1	12																										🟩				🟩						🟩																		
C	kWh-ALT(normal) S2	13																				🟩						🟩				🟩						🟩																		
C	kWh-ALT(normal) S3	14																														🟩						🟩					🟩													
C	KWH_INH (not normal)	15			🟩														🟩																				🟩			🟩									🟩	🟩				
D	kWh (not normal)	16		🟩																🟩																		🟩																	🟩	
D	kWh-ALT(normal)	17								🟩																							🟩			🟩			🟩			🟩														
D	KWH_FAM (not normal)	18																								🟩				🟩					🟩				🟩			🟩			🟩				🟩			🟩				
E	kWh (not normal)	19	🟩		🟩							🟩								🟩							🟩									🟩																				
E	kWh-ALT(normal)	20	🟩									🟩		🟩						🟩																				🟩																
E	KWH-M3(NO NOR) s1	21	🟩									🟩			🟩					🟩										🟩																										
E	KWH-M3(NO NOR) s2	22	🟩									🟩								🟩										🟩																										

cluster	model	scenario	variable 1	variable 2	variable 3	variable 4	variable 5	variable 6	variable 7	variable 8	variable 9	variable 10	variable 11	variable 12	variable 13	variable 14	variable 15	variable 16	variable 17	variable 18	variable 19	variable 20	variable 21	variable 22	variable 23	variable 24	variable 25	variable 26	variable 27	variable 28	variable 29	variable 30	variable 31	variable 32	variable 33	variable 34	variable 35	variable 36	variable 37	variable 38	variable 39	variable 40	variable 41	variable 42	variable 43	variable 44	variable 45	variable 46	variable 47	variable 48	variable 49	variable 50	variable 51	variable 52	variable 53	variable 54	variable 55	variable 56	variable 57	variable 58
A	kWh (not normal) S1	23										🟩		🟩		🟩																						🟩									🟩											
A	kWh (not normal) S2	24				🟩								🟩		🟩																						🟩									🟩											
A	kWh-ALT(normal)	25		🟩		🟩															🟩						🟩																			🟩								🟩						
A	kWh -m3 (not normal)	26																🟩	🟩	🟩													🟩			🟩			🟩																					
B	kWh (not normal)	27	🟩			🟩					🟩	🟩														🟩																																		
B	kWh-ALT(normal)	28		🟩							🟩							🟩															🟩					🟩															🟩							
B	kWh -m3 (not normal)	29									🟩						🟩															🟩						🟩												🟩										
C	kWh (not normal)	30			🟩	🟩							🟩										🟩			🟩													🟩																					
C	kWh-ALT(normal)	31		🟩	🟩					🟩			🟩										🟩					🟩																																
C	KWH-M2 (NO NOR)	32				🟩	🟩								🟩																		🟩	🟩		🟩																								
D	kWh (not normal)	33					🟩																		🟩		🟩				🟩	🟩														🟩														
D	kWh-ALT(normal)	34								🟩						🟩									🟩							🟩														🟩						🟩								
D	kWh -m3 (not normal)	35																					🟩			🟩		🟩				🟩	🟩																			🟩								

	cluster	model	scenario	variable 1	variable 2	variable 3	variable 4	variable 5	variable 6	variable 7	variable 8	variable 9	variable 10	variable 11	variable 12	variable 13	variable 14	variable 15	variable 16	variable 17	variable 18	variable 19	variable 20	variable 21	variable 22	variable 23	variable 24	variable 25	variable 26	variable 27	variable 28	variable 29	variable 30	variable 31	variable 32	variable 33	variable 34	variable 35	variable 36	variable 37	variable 38	variable 39	variable 40	variable 41	variable 42	variable 43	variable 44	variable 45	variable 46	variable 47	variable 48	variable 49	variable 50	variable 51	variable 52	variable 53	variable 54	variable 55	variable 56	variable 57	variable 58	variable 59	variable 60	variable 61	variable 62	variable 63	variable 64	variable 65	variable 66	variable 67	variable 68	variable 69	variable 70
36	A	kWh (not normal)	36			🟩	🟩	🟩																						🟩				🟩																													🟩										
37	A	kWh-ALT(normal) S1	37				🟩	🟩					🟩				🟩		🟩	🟩				🟩								🟩																																									
38	A	kWh-ALT(normal) S2	38				🟩	🟩					🟩						🟩	🟩										🟩																																											
39	A	KWH-M2 (NO NOR) S1	39			🟩	🟩	🟩	🟩	🟩	🟩		🟩																	🟩																									🟩																		
40	A	KWH-M2 (NO NOR) S2	40			🟩	🟩		🟩	🟩	🟩	🟩																																																													
41	B	kWh (not normal)	41		🟩		🟩		🟩																									🟩				🟩																			🟩																
42	B	kWh-ALT(normal)	42				🟩	🟩	🟩	🟩	🟩	🟩																				🟩											🟩									🟩																					
43	B	KWH_INH (not normal) S1	43				🟩			🟩	🟩																			🟩																														🟩													
44	B	KWH_INH (not normal) S2	44				🟩	🟩		🟩	🟩																																																	🟩													
45	B	KWH_INH (not normal) S3	45				🟩	🟩			🟩																											🟩															🟩							🟩													
46	C	kWh (not normal) S1	46		🟩			🟩	🟩																					🟩			🟩																															🟩									
47	C	kWh (not normal) S2	47	🟩				🟩	🟩																											🟩		🟩																										🟩									
48	C	kWh-ALT(normal) S1	48				🟩	🟩	🟩																							🟩			🟩	🟩																												🟩									
49	C	kWh-ALT(normal) S2	49				🟩	🟩	🟩																						🟩	🟩			🟩	🟩			🟩		🟩																							🟩									
50	C	KWH-M2 (NO NOR) S1	50		🟩		🟩	🟩																																🟩														🟩		🟩																	
51	C	KWH-M2 (NO NOR) S2	51	🟩	🟩		🟩	🟩					🟩																			🟩							🟩	🟩														🟩			🟩																

Residential Sector Analysis: The residential sector in Mendoza has unique characteristics impacting energy consumption. Variables such as building materials, height, floors, demographic distribution, and activities influence energy efficiency.

- **Building Material Impact:** The choice of building materials (MCAL1, MC1, MC3, MC5) significantly influences energy consumption. Encourage the use of energy-efficient materials for roofing and covering.
- **Height and Floors Management:** Building height and the number of floors impact energy efficiency. Implement efficient building designs that consider height and number of floors.
- **Behavioral Patterns:** Activity levels (act3) influence residential energy consumption. Promote energy-efficient appliances, lighting, and behavioral practices.

Industrial Sector Analysis: The industrial sector in Mendoza exhibits distinct characteristics impacting energy consumption. Variables such as footprint area, industrial building volume, demographic distribution, and material type contribute to the energy profile.

- **Footprint Optimization:** Optimizing the footprint area of industrial buildings is crucial for energy efficiency. Utilize sustainable materials for construction to improve insulation and reduce energy demand.
- **Demographic Impact:** The demographic distribution (agr2) plays a role in industrial energy consumption. Tailor energy-saving measures based on age group distribution.

Commercial Sector Analysis: The commercial sector in Mendoza demonstrates diverse characteristics that influence energy consumption. Notable variables include the sum of building volumes, perimeters, population density, and the type of building cover. These factors indicate potential areas for energy efficiency improvements.

- **Building Configuration:** Areas with larger building volumes and perimeters show higher energy consumption. Focus on optimizing building designs to balance volume and perimeter dimensions.
- **Population Density:** Higher population density correlates with increased energy demand. Implement energy-efficient lighting and HVAC systems based on population density and activity levels.
- **Building Cover:** The type of building cover (MC1 and MC5) influences energy efficiency. Promote the use of materials with high insulation properties for roofing and covering.

6.3.1.2 Strategies for Enhanced Building Efficiency

Now that each area has been thoughtfully examined, we must take the critical step of turning the major drivers that have been identified into practical action. Our objective is to provide customized, focused techniques that enable substantial energy savings in every kind of structure. During our investigation of Mendoza, we identified a wide range of features that have a substantial influence on patterns of energy usage. Among them are some noteworthy variables: building perimeters, building volumes added together, building cover type, and population density.

Although employment and population policies certainly affect productivity, a thorough investigation would need focused study outside the purview of this thesis. However, concentrating on developing retrofitting solutions has a strong chance for quick, practical advancement. Even if more fundamental social causes change, we can still make a substantial contribution to a more sustainable future by adopting planned renovations to increase energy efficiency.

Through the application of retrofit strategies, building energy consumption may be considerably decreased. Through the use of smart technology, energy-efficient appliances, and upgraded insulation, retrofitting increases the energy efficiency of existing buildings. These actions save building owners and occupiers money in addition to reducing energy use. Retrofitting is essential to our efforts to mitigate climate change and save resources and greenhouse gas emissions to build a more sustainable future. We can improve comfort, affordability, and environmental stewardship in our communities while achieving significant energy consumption reductions through retrofit programs.

Here, we explore the key elements that have led to a significant drop in gas usage, specifically in the context of Argentina. Using information from reliable Argentine sources, we illuminate the critical factors that are essential to reducing energy use. Our analysis demonstrates how important it is for many components to work together to reduce gas usage, which is in line with national energy conservation goals. Using a methodical examination and citation of reliable sources of information, our objective is to clarify the noteworthy factors that contribute to energy conservation, therefore expanding our comprehension of sustainable energy methodologies that are adapted to the conditions of Argentina.

Important factors		**RESIDENTIAL**	**INDUSTRIAL**	**COMMERCIAL AND SERVICES**
Energy Efficiency Standards	Window substitution (high-performance)	**8-12%**	**2%-5%**	**7%-10%**
	Roof insulation (R-value 30)	**10-20%**	**5%-15%**	**8%-12%**
	Lower slab insulation (R-value 15)	**7-13%**	**5%-8%**	**5%-18%**
	Vertical wall insulation (R-value 15)	**10%-15%**	**7%-10%**	**8%-10%**
	LED lighting upgrades	**3%-5%**	**8%-10%**	**7%-10%**
	HVAC system improvements (e.g., variable speed drives)	**3%-5%**	**8%-12%**	**10%-15%**
	Heat recovery systems		**15%-20% Depends on existing processes and heat sources**	
Subsidies and Incentives		**5% - 15%**		
Building Energy Audits		**5% -10%**		
Code Compliance and Enforcement		**20-30%**		
Public Awareness and Education		**3% -5%**		

Table 29:The percentage of the effects of retrofit measures on energy consumption

Resources:

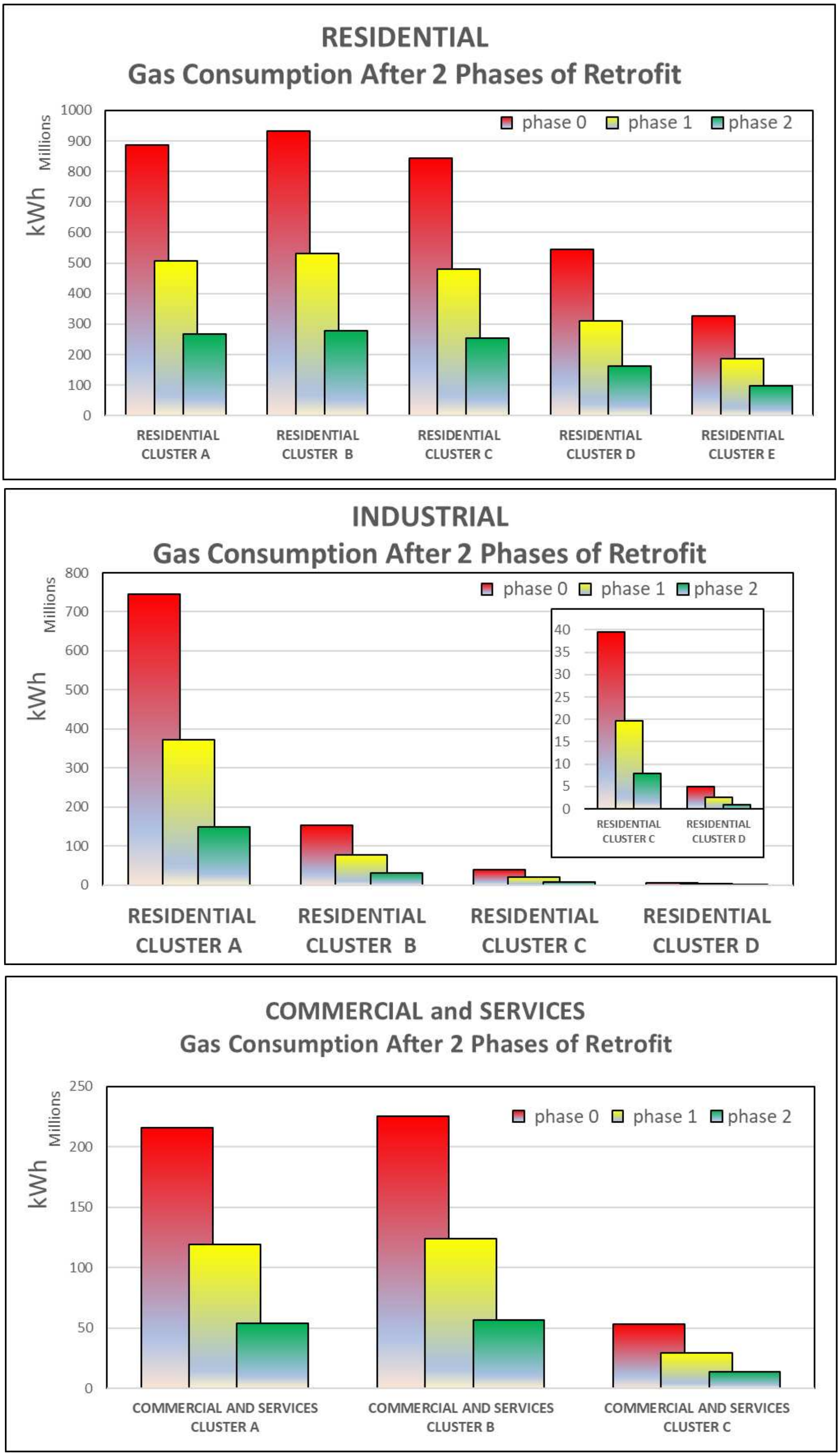
- National Ministry of Energy (Argentina): https://www.argentina.gob.ar/economia/energia
- Mendoza Provincial Government: https://www.mendoza.gov.ar/
- US Department of Energy's "Retrofit Advisor": (adapt values for Argentina)
- International Finance Corporation's "EDGE": https://www.edgebuildings.com/] (global tool, adjust settings for Argentina)

Table 30:Strategies for Enhanced Building Efficiency(authors)

		strategies and policies
Energy Efficiency Standards	**Window substitution**	• Replacing single-pane windows with double or triple-glazing • Low-E Coatings: Low-emissivity (Low-E) coatings on glass • Ensuring proper weather stripping and caulking around windows • Provide technical assistance and resources for homeowners to assess their window needs and select appropriate replacements. • Develop partnerships with local window manufacturers to promote the availability and affordability of energy-efficient window options. • Enforce stringent building codes mandating the installation of high-performance windows
	Roof insulation (R-value 30)	• Adding Insulation Material • use of energy-efficient roofing materials with built-in insulation properties, such as insulated metal panels or structural insulated panels (SIPs) • adoption of design principles such as compact building shapes, efficient floor layouts, and appropriate roof angles to minimize thermal bridging and improve insulation performance. • Increasing the thickness or adding additional layers of insulation material to the roof • Reflective Roof Coatings • Sealing Air Leaks • building designs that optimize height and floor distribution for energy efficiency. • Collaborate with manufacturers and suppliers to promote the availability and affordability of energy-efficient roofing products suitable for different building types • Green Roof Installations: the installation of green roofs as a sustainable roofing solution that provides natural insulation benefits. • Roof Ventilation Improvement: Assess and improve roof ventilation systems to enhance airflow and moisture management, optimizing the performance of insulation materials and reducing the risk of moisture-related issues.
	Lower slab insulation (R-value 15)	• Promote building designs that optimize height and floor distribution for energy efficiency. • Assess the current insulation material used in lower slabs and recommend upgrading to materials with higher R-values, aiming for a minimum R-value of 15. • Guide on selecting appropriate insulation materials, such as rigid foam boards or spray foam insulation, based on factors like durability, moisture resistance, and cost-effectiveness. • Offer technical assistance and support to ensure proper installation of insulation materials in lower slabs, including attention to detail in sealing joints and edges to minimize air leakage. • Implement moisture management strategies to prevent moisture buildup in lower slabs, which can compromise the effectiveness of insulation. • Recommend the installation of vapor barriers or moisture-resistant insulation materials to mitigate the risk of moisture-related issues and ensure long-term durability. • Address thermal bridging concerns by incorporating insulation measures at critical junctions, such as slab-to-wall connections and perimeter edges. • Utilize thermal break materials or insulation wraps to interrupt heat flow and minimize thermal bridging effects in lower slabs.
	Vertical wall insulation (R-value 15)	• Promote building designs that optimize Vertical walls for energy efficiency. • Offer information on insulation options such as fiberglass batts, cellulose, spray foam, or rigid foam boards, considering factors like thermal performance, moisture resistance, and cost-effectiveness. • installation standards for vertical wall insulation to ensure proper techniques are employed • Guide on selecting appropriate insulation materials for vertical walls to achieve a minimum R-value of 15. • Offer training programs for contractors and construction crews on the correct methods for installing insulation materials in vertical walls , • emphasizing proper sealing and addressing thermal bridging. • moisture management measures into vertical wall insulation retrofit to prevent issues • Address thermal bridging concerns by implementing insulation measures at critical junctions, such as wall-to-floor connections and around windows • Utilize thermal break materials or insulation wraps to interrupt heat flow and minimize thermal bridging effects in vertical walls. • Establish quality assurance protocols to ensure that vertical wall insulation installations meet specified standards and performance criteria.
	LED lighting upgrades	• implement energy-efficient HVAC systems and lighting fixtures • Implement intelligent lighting and HVAC systems based on real-time occupancy data • Promote energy-efficient practices such as turning off lights and appliances during off-hours. • Implement intelligent lighting systems that utilize occupancy sensors and daylight harvesting technologies to optimize lighting levels based on real-time occupancy and natural light conditions. • Provide technical support and assistance in selecting and installing intelligent lighting controls to maximize energy savings and occupant comfort. • Integrate LED lighting upgrades with energy-efficient HVAC systems to create a comprehensive approach to energy management. • Promote the use of occupancy-based lighting controls to automatically adjust lighting levels in response to occupancy patterns. • Implement daylight harvesting strategies to maximize natural light utilization and minimize the need for artificial lighting during daylight hours.
	HVAC system improvements (e.g.,	• Assess the current HVAC systems in buildings and identify opportunities for improvement and upgrade. • Energy-Efficient Heating Systems that incorporate features such as variable speed drives (VSDs) for precise control and energy savings. • Upgrade heating, ventilation, and air conditioning (HVAC) systems to more efficient models. • Upgrading to energy-efficient heating systems such as condensing boilers, heat pumps, or solar water heaters • Smart Thermostats • Recommend upgrading to more energy-efficient HVAC models t • Conduct energy audits to determine the most suitable heating system upgrades based on energy consumption patterns and building requirements. • use of smart thermostats and energy-saving features to maximize comfort and energy efficiency. • Implement variable speed drives (VSDs) in HVAC systems to modulate fan and pump speeds based on demand, reducing energy consumption and improving efficiency.
	Heat recovery systems	• Installation of Heat Recovery Systems • Install smart thermostats to regulate temperature and optimize energy usage. • Explore the implementation of cogeneration or combined heat and power (CHP) systems to generate electricity and recover waste heat simultaneously. • Upgrading to energy-efficient heating systems such as condensing boilers, heat pumps, or solar water heaters • Install smart thermostats and HVAC controls to regulate temperature settings and optimize energy usage in conjunction with heat recovery systems.

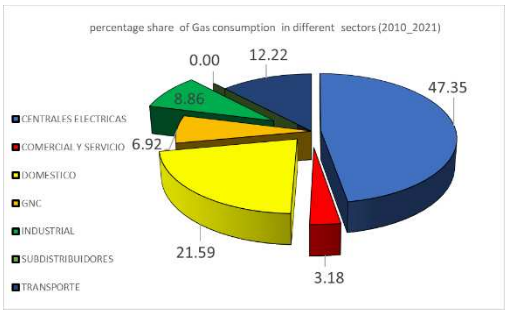
Subsidies and Incentives	• Providing subsidies and incentives is a crucial strategy for promoting energy efficiency upgrades and retrofit projects in buildings. • Offer tax breaks, subsidies, or rebates to property owners who undertake energy efficiency upgrades, such as insulation improvements, HVAC system upgrades, or renewable energy installations. • Provide low-interest loans or financing options specifically designed for retrofit projects, enabling property owners to access affordable funding for energy efficiency upgrades. • Offset upfront costs of retrofits, encouraging wider adoption • Allocate direct grants for specific retrofit measures, such as window replacements, insulation upgrades, or installation of energy-efficient appliances. • Provide technical assistance and resources to architects and builders to incorporate energy-efficient design principles into new construction projects and major renovations. • Incentivize the use of materials contributing to better insulation. • Implement incentives or rebates for homeowners who undertake energy-efficiency upgrades. • Ensure subsidies reach intended beneficiaries (e.g., low-income households). • Provide clear guidelines and training for compliance • installation of solar panels on homes through incentives, financing options, and technical support. • Encourage businesses to adopt energy-efficient practices and technologies. • Offer incentives or rebates for businesses that invest in energy-efficiency upgrades.
Building Energy Audits	• Design programs to prioritize cost-effective and impactful measures. • Moderate, combined with other measures. • Offer guidance and support to building owners on selecting the most suitable retrofit measures that provide the highest return on investment in terms of energy savings and environmental benefits. • Mandatory audits for specific building types or before major renovations. • Integrate building energy audits with other energy efficiency initiatives and retrofit programs to maximize their effectiveness. • Coordinate with utility companies, government agencies, and non-profit organizations to leverage resources and expertise in implementing comprehensive energy efficiency strategies. • Mandate energy audits for specific building types or before major renovations to ensure compliance with energy efficiency standards and regulations. • Implement auditing requirements for high-energy-consuming buildings, such as commercial properties or large industrial facilities, to identify opportunities for improvement and drive energy savings. • Develop and disseminate guidelines for choosing energy-efficient materials during construction and renovation projects based on the findings of building energy audits. • Make use of audit data collected from building energy audits for policy planning and monitoring purposes. • Encourage participation in green certification schemes, such as LEED (Leadership in Energy and Environmental Design) or ENERGY STAR, to recognize and incentivize buildings that demonstrate high levels of energy efficiency and sustainability.
Code Compliance and Enforcement	• Develop and maintain a database of qualified insulation contractors to facilitate access to skilled professionals for energy efficiency retrofits and insulation installations. • Provide training and certification programs for contractors to ensure proficiency in installing energy-efficient insulation materials and meeting quality standards. • Establish minimum energy performance standards for new construction and existing buildings to promote energy efficiency and reduce greenhouse gas emissions. • Collaborate with industry stakeholders, policymakers, and technical experts to develop robust standards that reflect best practices and advancements in building technology. • Update building codes regularly to incorporate stricter energy efficiency requirements and reflect evolving industry standards and technological advancements. • Engage with building code officials, architects, engineers, and other stakeholders in the code development process to ensure broad support and consensus on proposed changes. • Strengthen enforcement efforts and enhance monitoring mechanisms to ensure compliance with energy efficiency standards and building codes. • Implement penalties and enforcement measures for non-compliance with energy efficiency standards and building codes to deter violations and promote adherence to regulations. • Strike a balance between ambition and economic feasibility when setting energy performance standards and updating building codes.
Public Awareness and Education	• Offer incentives or rebates to encourage the purchase of energy-efficient appliances, such as ENERGY STAR-rated products, to motivate consumers to make environmentally friendly choices. • Educate citizens about energy-saving behaviors and technologies. • Develop educational campaigns to inform citizens about energy-saving behaviors and technologies, such as turning off lights when not in use, using programmable thermostats, and optimizing appliance settings. • Utilize various communication channels, such as social media, websites, and traditional media outlets, to reach a broad audience and disseminate relevant information effectively. • Implement educational programs on energy efficiency in schools and community centers to teach students and community members about the importance of conserving energy and reducing environmental impact. • Incorporate interactive activities, workshops, and demonstrations to engage participants and reinforce learning objectives. • Include energy-saving tips and information on utility bills to educate consumers about their energy usage patterns and encourage them to adopt more energy-efficient habits. • Tailor messaging to target diverse audiences with relevant and relatable messages that resonate with their values, interests, and lifestyles. • Emphasize cost savings and environmental benefits. • Partner with local organizations and influencers for wider reach. • Facilitate community workshops and events focused on energy efficiency, such as DIY home energy audits, weatherization demonstrations, and energy-saving technology showcases. • Create neighborhood-based energy-saving competitions to promote a sense of shared accountability and foster friendly competition among residents to reduce energy consumption.

Figure 113: Effects of Retrofit measures on energy consumption on 2-phase



6.3.2 Use of renewable resources:

To lessen dependency on fossil fuels involves utilizing renewable energy sources more frequently. It is essential to use renewable energy sources in the transition to a more sustainable energy future. Although the main energy source has been natural gas, renewable energy sources like solar and wind power may be highly beneficial. Having a varied energy mix can improve sustainability and flexibility. For Mendoza's energy portfolio, solar, wind, and water energy are viable choices. We discussed Mendoza's possibilities for using renewable energy in the case study of the city. The area may lessen its dependency on conventional fossil fuels and its negative environmental effects by supporting and funding renewable energy initiatives. and support international initiatives to tackle climate change. With solar energy, Mendoza, a city blessed with an abundance of sunlight, has the potential to drastically change its energy landscape. The key to lowering the city's dependency on fossil fuels, enhancing energy security, and lessening the negative consequences of climate change is solar energy captured via photovoltaic (PV) panels.



Solar energy for power plants

Given that nearly half of Mendoza's gas consumption fuels electricity generation, adopting solar energy for power plants becomes pivotal. Shifting towards renewable sources for electricity production not only curtails environmental impact but also lessens the demand on traditional gas-dependent power generation.

Solar energy for the residential sector: Solar integration has the potential to greatly assist residential areas, which account for a large portion of Mendoza's energy usage. Solar-powered rooftop panels enable homeowners to produce their own electricity while reducing their reliance on the grid. By using solar energy for cooking, heating, and hot water production, gas usage is further decreased, resulting in financial savings and a reduction in the load on city power plants.

Solar energy for the industrial sector: Adoption of solar offers significant benefits in the industrial environment, where energy-intensive operations are prevalent. Utilizing solar energy to power HVAC, lighting, and machines lessens dependency on electricity from the grid, which lowers costs and improves energy efficiency while reducing greenhouse gas emissions.

Solar energy for commercial and service sectors: Companies in the service and commercial industries can also benefit from solar energy. Solar panels cut energy expenditures and contribute to the city's total energy reduction in a variety of energy-consuming equipment, including HVAC systems, lights, and other appliances. Businesses may also sell extra solar electricity they create back to the grid by taking part in net metering schemes, which further optimizes energy costs.

The integration of solar panels across these sectors will collectively reduce pressure on electricity generation, reduce environmental impacts, and create a greener and more sustainable energy ecosystem for Mendoza. As the city embraces solar energy, it positions itself as a pioneer in the search for renewable energy solutions and is an inspiring example for other regions to follow. A comprehensive strategy is essential to successfully integrate solar energy into Mendoza's energy mix. This strategy should include the following initiatives:

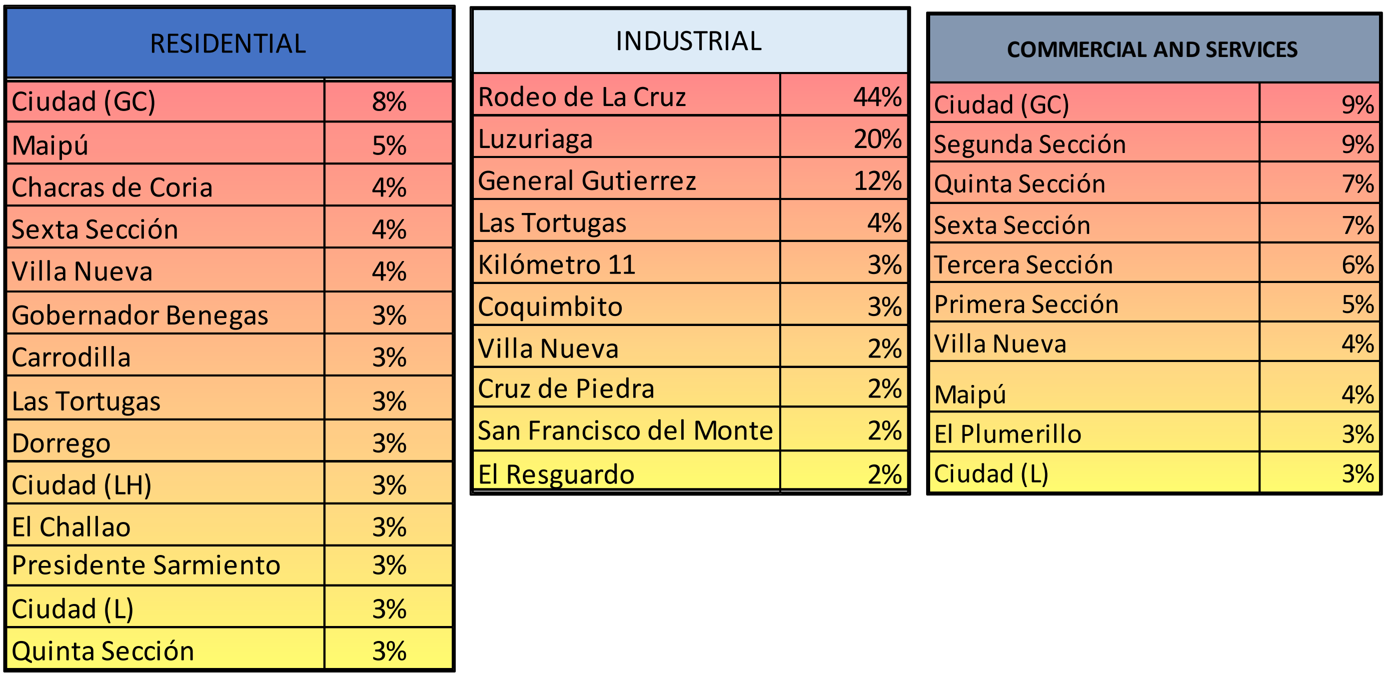
- **Incentives and subsidies**: Providing financial incentives for solar installations can encourage homeowners, businesses, and industrial facilities to go solar.
- **Rooftop Solar Requirements**: Implementing mandatory rooftop solar requirements for new buildings could significantly increase the city's solar capacity.
- **Grid-Metering Programs:** The expansion of grid-metering programs, which allow for the sale of excess solar-generated electricity to the grid, could further incentivize solar adoption.
- **Technical assistance and training:** Providing technical assistance and training to homeowners, businesses, and installers can ensure a smooth and efficient solar installation.

Mendoza can take advantage of solar energy's great potential and change its energy environment to one that is cleaner and more sustainable by putting this all-encompassing plan into practice. In addition to lowering energy prices and the city's reliance on fossil fuels, solar energy may enhance air quality and make the city more livable for its citizens.

The areas that exhibit the greatest share of levels of gas use and demand are excellent choices for the adoption of renewable energy initiatives. While encouraging Mendoza's whole population to switch to renewable energy sources is important, concentrating on these high-gas consumption regions can result in significant gas consumption reductions. Promoting the extensive use of renewable energy in these particular areas has the potential to greatly reduce the need for natural gas and contribute to a more ecologically friendly and sustainable energy landscape.

The implementation of renewable energy sources might result in a significant decrease in gas consumption in certain regions, with estimates of as much as 30%. This noteworthy effect highlights the revolutionary potential of renewable energy in promoting sustainability, lowering reliance on conventional fossil fuels, and satisfying energy demands. The anticipated decrease in gas usage highlights how crucial it is to plan and build renewable energy projects strategically in these high-demand locations.

Table 31:The best Districts to use renewable energy



RESIDENTIAL	
Ciudad (GC)	8%
Maipú	5%
Chacras de Coria	4%
Sexta Sección	4%
Villa Nueva	4%
Gobernador Benegas	3%
Carrodilla	3%
Las Tortugas	3%
Dorrego	3%
Ciudad (LH)	3%
El Challao	3%
Presidente Sarmiento	3%
Ciudad (L)	3%
Quinta Sección	3%

INDUSTRIAL	
Rodeo de La Cruz	44%
Luzuriaga	20%
General Gutierrez	12%
Las Tortugas	4%
Kilómetro 11	3%
Coquimbito	3%
Villa Nueva	2%
Cruz de Piedra	2%
San Francisco del Monte	2%
El Resguardo	2%

COMMERCIAL AND SERVICES	
Ciudad (GC)	9%
Segunda Sección	9%
Quinta Sección	7%
Sexta Sección	7%
Tercera Sección	6%
Primera Sección	5%
Villa Nueva	4%
Maipú	4%
El Plumerillo	3%
Ciudad (L)	3%

6.4 Four Intervention Priorities

After the plans for the three areas of energy conservation, use of renewable energy, and improvement of efficiency in different sectors have been defined, the attention is now directed toward the designation of priority districts. Districts within each sector are categorized into four priority categories in this critical step: Urgent, High, Medium, and Low priorities.

1. **Urgent Priorities:** Districts facing immediate energy challenges or exhibiting high consumption rates. Districts with higher energy consumption in both kWh and kWh/m² than the median. Urgent intervention is required due to immediate challenges and high consumption rates.
2. **High Priorities:** Districts with notable energy concerns, although not as critical as Urgent priorities. Districts with higher energy consumption in kWh and lower energy consumption in kWh/m² than the median. Strategic focus on districts with high overall energy use but lower efficiency.
3. **Medium Priorities:** Districts with higher energy consumption in kWh/m² and lower energy consumption in kWh than the median. Districts with moderate energy consumption patterns. Strategic initiatives in Medium priority areas help maintain a balanced and sustainable energy landscape.
4. **Low Priorities:** Districts with relatively lower energy consumption concerns. Low priority areas may still benefit from targeted energy initiatives but can be addressed systematically over a more extended timeline Districts with lower energy consumption in both kWh/m² and kWh than the median.

This methodical classification provides policymakers and energy planners with a fundamental framework. Through the identification of priority levels, policymakers may optimize resource allocation, budgetary control, and intervention planning that is in keeping with the intensity and urgency of energy-related issues in each district. This strategy guarantees a sophisticated and effective plan catered to Mendoza's particular requirements, adding to a more robust and sustainable urban energy framework.

Figure 114:Residential Quadrant Graph of Intervention Priorities (Authors)

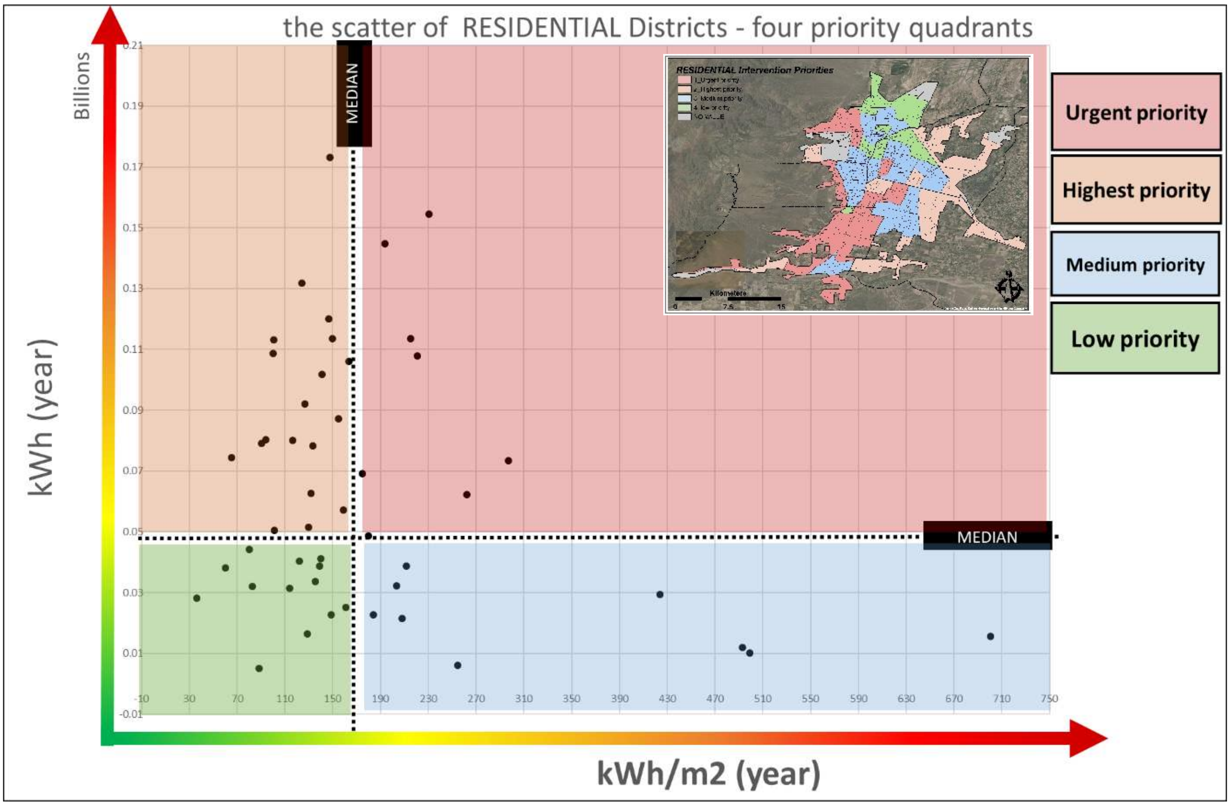


Figure 115:industrial Quadrant Graph of Intervention Priorities (Authors)

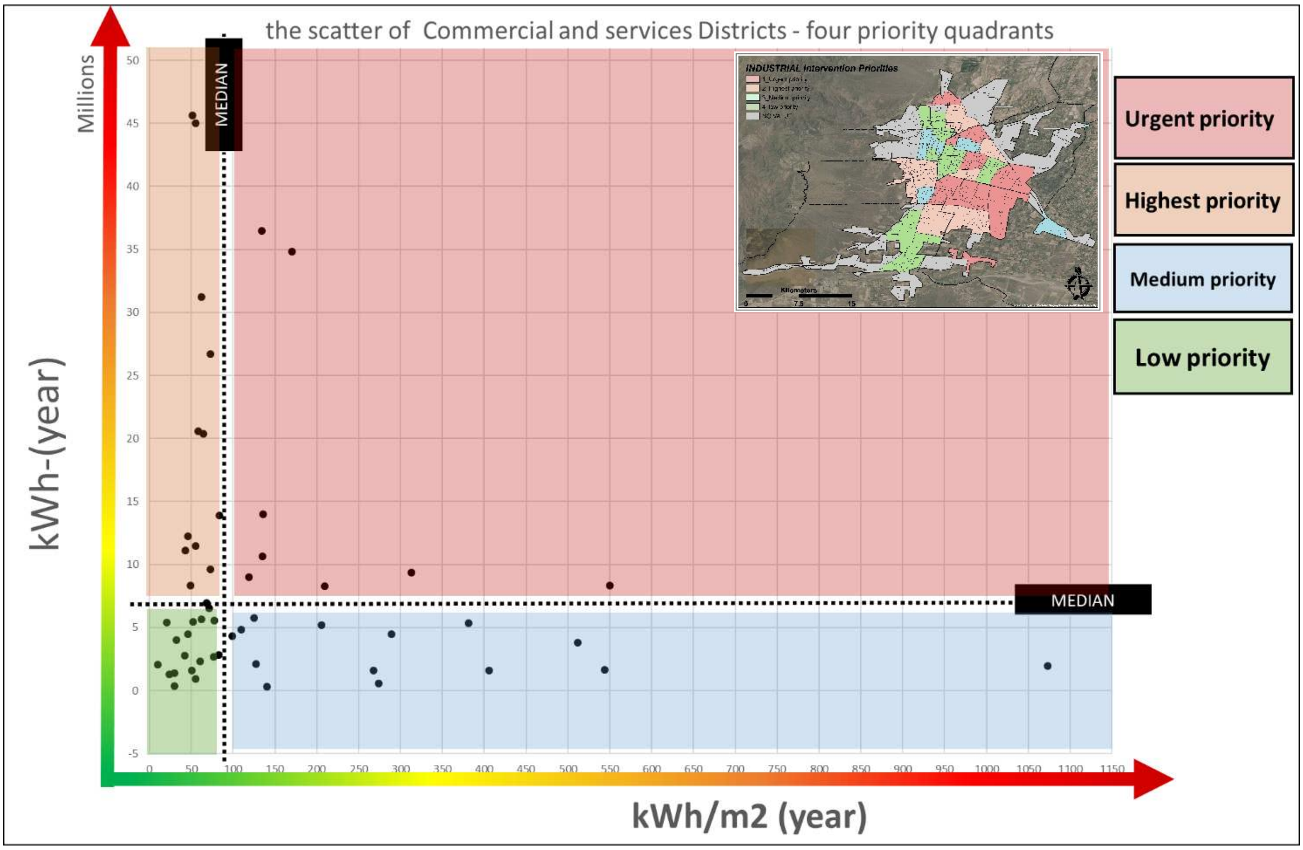


Figure 116:commercial and services Quadrant Graph of Intervention Priorities (Authors)

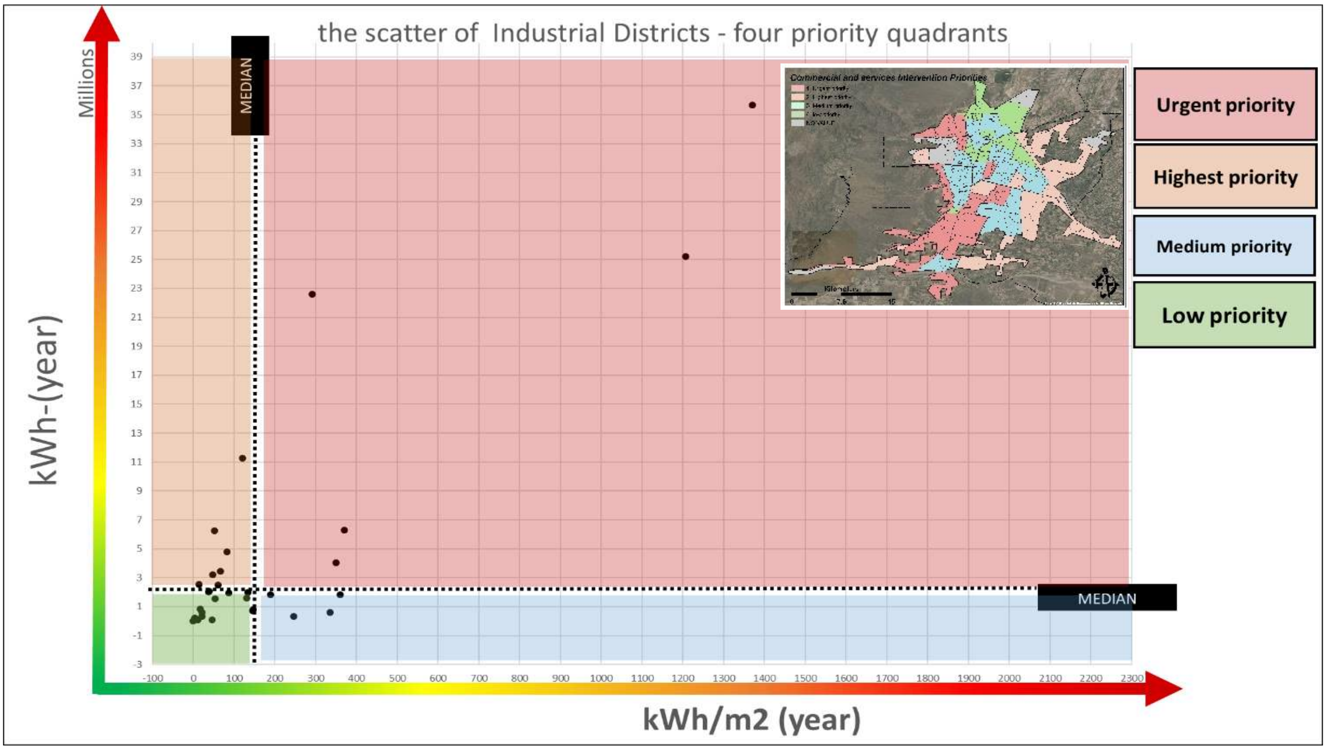


Table 32: District Quadrant Graph of Intervention Priorities (Authors)

RESIDENTIAL			
DISTRICT CLASS	DISTRIC	PERFORMANCE CLASS	priority
E	Perdriel	H	1_Urgent priority
E	Vistalba	F	
C	Mayor Drummond	F	
C	El Challao	E	
C	Chacras de Coria	E	
C	Carrodilla	E	
A	Sexta Sección	D	
E	Presidente Sarmiento	D	
B	Luzuriaga	D	
B	Las Tortugas	D	
B	Las Cañas	D	
C	La Cieneguita	D	
D	Russel	H	2_Highest priority
E	Lunlunta	H	
E	Los Corralitos	H	
E	La Primavera (Gy)	H	
E	General Ortega	H	
E	Décimo Primera Sección	H	
D	Cruz de Piedra	H	
D	Colonia Segovia	H	
E	El Sauce	G	
D	Las Compuertas	F	
B	San Francisco del Monte -	E	
D	Rodeo del Medio	E	
C	Fray Luis Beltrán	E	
D	Kilómetro 11	D	
D	Jesús Nazareno	D	
D	Coquimbito	D	
C	Maipú	D	3_Medium priority
B	Gobernador Benegas	D	
A	Villa Nueva	C	
C	San Francisco del Monte (	C	
D	Rodeo de La Cruz	C	
A	Quinta Sección	C	
C	General Gutierrez	C	
D	El Plumerillo	C	
B	Dorrego	C	
A	Cuarta Sección	C	
B	Ciudad (LH)	C	
B	Ciudad (L)	C	
A	Ciudad (GC)	C	
B	Capilla del Rosario	C	
D	Belgrano	C	
A	Segunda Sección	B	
C	La Puntilla	D	4_low priority
D	Panquegua	C	
B	El Zapallar	C	
D	El Resguardo	C	
D	El Algarrobal	C	
D	Capdevila	C	
D	Buena Nueva	C	
D	Bermejo	C	
B	San José (Gy)	B	
A	Primera Sección	B	
B	Pedro Molina	B	
A	Tercera Sección	A	

INDUSTRIAL			
DISTRICT	DISTRIC	ENERY PERFORMA	priority
B	General Gutierrez	H	1_Urgent priority
A	Coquimbito	H	
A	Cruz de Piedra	H	
A	El Resguardo	H	
A	Kilómetro 11	H	
A	Las Tortugas	H	
A	Luzuriaga	H	
A	Rodeo de La Cruz	H	
A	San Francisco del Monte -GC	H	
B	Bermejo	G	
B	Pedro Molina	G	
B	Villa Nueva	F	
C	Ciudad (GC)	C	2_Highest priority
C	Buena Nueva	B	
C	Carrodilla	B	
C	El Plumerillo	B	
C	El Zapallar	B	
C	Maipú	B	
C	Presidente Sarmiento	A	
D	San Francisco del Monte (Gy	A+	
B	Primera Sección	G	3_Medium priority
B	Rodeo del Medio	G	
C	Sexta Sección	F	
B	Belgrano	D	
B	Quinta Sección	D	
B	Tercera Sección	D	
B	Gobernador Benegas	C	
C	Cuarta Sección	C	4_low priority
B	Ciudad (LH)	C	
C	Las Cañas	B	
C	Segunda Sección	B	
C	Dorrego	A	
D	Capilla del Rosario	A+	
D	Chacras de Coria	A+	
D	Ciudad (L)	A+	
D	Jesús Nazareno	A+	
D	La Cieneguita	A+	
D	Mayor Drummond	A+	
D	Nueva Ciudad	A+	
D	San José (Gy)	A+	

COMMERCIAL AND SERVICES			
DISTRICT CLASS	DISTRIC	ENERY PERFORM	priority
C	Vistalba	H	1_Urgent priority
C	El Resguardo	G	
C	San Francisco del Monte -GC	E	
B	Sexta Sección	D	
B	Chacras de Coria	C	
B	El Plumerillo	C	
B	Gobernador Benegas	C	
B	Las Cañas	C	
B	Quinta Sección	C	
B	Ciudad (L)	B	
B	General Gutierrez	B	
B	Bermejo	B	2_Highest priority
B	Carrodilla	B	
B	Ciudad (LH)	B	
B	Dorrego	B	
B	Las Tortugas	B	
B	Nueva Ciudad	B	
B	Primera Sección	B	
A	Ciudad (GC)	B	
A	Maipú	B	
A	Rodeo de La Cruz	B	
A	Segunda Sección	B	
A	Tercera Sección	B	
A	Villa Nueva	B	
A	Cuarta Sección	A	
A	San José (Gy)	A	
C	Colonia Segovia	H	3_Medium priority
C	Cruz de Piedra	H	
C	El Sauce	H	
C	Lunlunta	H	
C	La Cieneguita	G	
C	Rodeo del Medio	G	
C	Fray Luis Beltrán	F	
C	Las Compuertas	F	
C	Los Corralitos	F	
C	Coquimbito	E	
B	Capdevila	C	
B	Capilla del Rosario	C	
B	El Challao	C	
B	Mayor Drummond	C	
B	Panquegua	C	
B	El Algarrobal	B	4_low priority
B	Jesús Nazareno	B	
A	Buena Nueva	B	
A	Décimo Primera Sección	B	
A	Kilómetro 11	A	
A	La Puntilla	A	
A	Luzuriaga	A	
A	Pedro Molina	A	
A	Presidente Sarmiento	A	
A	Belgrano	A+	
A	El Zapallar	A+	
A	San Francisco del Monte (Gy	A+	

7. The Conclusion

Mendoza, Argentina's unique metropolitan setting has drawn attention to the worldwide problem of urban energy consumption, which has consequences for sustainability and resilience. This thesis has investigated the complexities of this intricate network to fully exploit the capabilities of Building Energy Modeling (BEM) technology. Our primary goal of evaluating and optimizing energy consumption at the urban scale has unraveled layers of information intricately woven from behavioral, climatic, and architectural elements, with a focus on space heating and hot water systems in dwellings. A thorough dataset, a patchwork of building attributes, regional climatic variances, and exacting energy use logs form its foundation.

51 distinct prediction models for the residential, commercial/service, and industrial sectors were produced by combining this data. This gives a thorough overview of Mendoza's urban energy environment. However, the narrative encounters issues even in the midst of the discovery. District-level validations become more difficult, even if district-level energy consumption computation is helpful in highlighting the need for a top-down modeling approach. However, these limitations also present chances for a more thorough understanding. By using clustering strategically to find homogeneous regions based on building attributes, patterns that are necessary for focused interventions may be found.

Normalizing gas consumption concerning altitude strategically amplifies the analysis's robustness, offering nuanced insights into the interplay between gas consumption and environmental factors. As the models advance, the narrative broadens to include implications outside of the technical realm. Beyond theory, the historical narrative based on Mendoza's census statistics combines the revolutionary potential of energy-efficient measures. This multidimensional model transcends traditional boundaries and provides legislators, architects, and urban planners with useful information. The data-driven strategies described in this thesis seek to increase energy efficiency and serve as a template for other projects that might be carried out anywhere with unique climatic and architectural characteristics, not just in Argentina. To sum up, this thesis makes a substantial contribution to the conversation on sustainable urban development. In addition to bridging the theoretical-practical gap, it does so while appreciating and valuing Mendoza's unique metropolitan setting. The study presents a picture of a day when data-driven orchestration of urban energy usage will lead to a more resilient, efficient, and sustainable urban life.

7.1 Limitations:

During this extensive research project, it is imperative to openly recognize the existence of various constraints that have impacted the study's design and findings. Simultaneously, a purposeful focus on strategic foresight has been essential to overcoming these limitations and predicting the course of future developments in the area.

- **Data Restrictions:** One recognized constraint is the determination of actual energy use at the district level, which is necessary because thorough building-level data is lacking. This limitation emphasizes the need for cautious interpretation of the results and prudence when applying the models to other urban settings.
- **District-Level Analysis**: While helpful, the focus on energy usage at the district level may inadvertently mask more nuanced variations within districts. It is important to understand that downscaling the models to smaller scales requires careful thought and that more localized data could be required for targeted actions.
- **Model Validation:** Model validation is a critical step in assessing the accuracy of predictive models, such as those used in Building Energy Modeling (BEM). In this research, reliance on district-level data for validation introduces a degree of uncertainty. While recognizing the inherent challenge, it is acknowledged that validation based on actual building-level data would offer heightened robustness to the models, capturing

the nuances specific to individual structures. However, such an approach comes with potential practical constraints, including logistical challenges in acquiring and processing detailed data for a large number of buildings. By adopting a pragmatic approach and balancing the benefits of granularity with the difficulties associated with data availability, the research team emphasizes the need to make informed judgments that are in line with the study's overall objectives and available resources. In the context of urban energy dynamics, this nuanced approach represents a strategic awareness of the complexity inherent in model validation.

- **Single-Year Validation:** Single-year validation, relying on real consumption statistics for a specific temporal snapshot, introduces an acknowledgment of potential performance variance across different years due to dynamic external factors shaping energy consumption patterns. The validation process recognizes the transient nature of urban dynamics, wherein economic, climatic, and societal influences fluctuate over time. The models, calibrated based on a specific year, may reflect the intricacies of that particular period but might not entirely encapsulate the evolving nature of energy consumption trends. This calls for a detailed comprehension of the constraints imposed on extrapolating results outside of the verified timeframe. The need to consider the larger temporal landscape and the dynamic interaction of elements impacting urban energy dynamics is emphasized, underscoring the need for contextual interpretation.

7.2 Looking Ahead:

- **Detailed Building-Level Data** Promoting projects or cooperative efforts to obtain more precise building-level data is an essential requirement in the field of urban energy research. The advocacy has relevance as it can significantly improve the accuracy of energy models, offering a more detailed and precise representation of the energy consumption patterns of specific buildings. A more in-depth knowledge of the variables affecting energy usage is made possible by detailed data that includes characteristics like building materials, insulation, occupancy patterns, and particular heating and cooling systems. Such thorough data helps to identify minute differences in energy dynamics across various building typologies and improves the calibration of models. This request for more comprehensive data collection demonstrates a dedication to improving the precision and usefulness of energy models, leading to a more profound understanding of the complex interplay between building attributes and energy use in urban environments.
- **Continuous Monitoring** Adding continuous energy consumption monitoring devices is recommended as a crucial strategy for sustainable urban development. This proposal highlights the significance of real-time data collection to have a dynamic and up-to-date understanding of energy use trends. Continuous monitoring is necessary for both the progressive improvement and adjustment of predictive models as well as for the simpler ongoing validation of these models. Researchers, decision-makers, and urban planners can swiftly adjust to shifting energy dynamics and ensure that actions and policies are in step with new trends thanks to the real-time information that continuous monitoring gives. Through the use of this proactive data-gathering strategy, the research aims to provide the groundwork for a framework that is responsive and adaptable, promoting resilience and sustainability in the urban energy environment.
- **Integration of Renewable Energy** Promoting the investigation of potential research directions for the incorporation of sustainable energy sources into the urban structure is a progressive strategy for achieving sustainable urban growth. The necessity of determining if it is feasible to integrate renewable technologies—like solar and wind—into the architecture and infrastructure of urban structures is emphasized by this proposal. The project is to contribute to the progress of sustainable practices, lowering dependency on traditional energy networks and reducing the environmental impact of metropolitan areas by imagining and exploring the integration of various renewable energy sources. This proactive approach is in line with international initiatives to shift to greener and more sustainable energy sources, offering a chance to improve urban populations' resilience and environmental impact.

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