FACTORS OF SOCIO-SPATIAL VULNERABILITIES TO ENERGY POVERTY

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ABSTRACT

FACTORS OF SOCIO-SPATIAL VULNERABILITIES TO ENERGY POVERTY

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It is becoming more widely accepted that the vulnerabilities that make it more likely for households in the community to be energy poor are multifaceted and geographical. The extent that a household is vulnerable to energy poverty varies socially and geographically. Vulnerabilities are becoming more obvious because of climate change. Regions with greater degrees of vulnerability may be considered more vulnerable to energy poverty, primarily due to climate change and the connection between energy poverty and climate vulnerability. To generate activities and policies that contribute to the reduction of energy poverty, it is crucial to prioritize these vulnerabilities and identify the vulnerabilities that increase and affect energy poverty in order to minimize sustainability concerns. Starting with evaluating the places that are extremely vulnerable mainly the consequence of these variables, it is essential to comprehend the root causes of poverty.

This study intends to identify the socio-economic and physical factors that affect energy vulnerability and to define the spatial distribution of vulnerabilities. The provinces of Türkiye were evaluated as the subject of the study, and provincial-level data sets were employed. The statistical technique, Principal Component Analysis (PCA), has been used to minimize the dimensionality of a dataset and maintain as much variance as feasible. Consequently, the vulnerabilities that influence and exacerbate energy poverty may be investigated by demonstrating the data in meaningful clusters and assessing them under specific components.

Keywords: Sustainable Development, Climate Change, Resilience, Vulnerability, Energy Poverty

ÖZ

ENERJİ YOKSULLUĞUNA KARŞI SOSYO-MEKANSAL KIRILGANLIK FAKTÖRLERİ

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Toplumdaki hanelerin enerji yoksulu olma olasılığını arttıran kırılganlıklar, giderek çok boyutlu olmakta ve coğrafi olarak kabul edilmektedir. Bir hane halkının enerji yoksulluğuna karşı savunmasızlığı, sosyal ve mekansal olarak değişkendir. İklim değişikliğinin bir sonucu olarak, kırılganlıklar giderek daha belirgin hale gelmektedir. İklim değişikliği ve enerji yoksulluğu ile iklim savunmasızlığı arasındaki karşılıklı ilişki nedeniyle, daha yüksek düzeyde kırılganlığa sahip bölgelerin enerji yoksulluğuna daha yatkın olduğu düşünülebilir. Bu nedenle sürdürülebilirlik kaygılarını azalmak adına, enerji yoksulluğunun azaltılmasına katkı sağlayıcı eylem ve politikaların geliştirilebilmesi için enerji yoksulluğunu arttıran ve etkileyen kırılganlıkların belirlenmesi, bu kırılganlıkların önceliklendirilmesi önem arz etmektedir. Öncelikle yoksulluğa neden olan faktörler anlaşılmalı, ardından bu faktörler nedeniyle oldukça hassas olan alanlar değerlendirilmelidir.

Bu araştırma, enerji kırılganlığına katkıda bulunan sosyo-ekonomik ve fiziksel değişkenleri tanımlamayı ve kırılganlıkların mekansal dağılımını göstermeyi amaçlamaktadır. Çalışma alanı olarak Türkiye illeri incelenmiş, il düzeyinde veri setleri kullanılmıştır. Bir veri kümesinin boyutsallığını azaltmak ve mümkün olduğu kadar varyasyonunu korumak için kullanılan istatistik yöntemi olan Temel Bileşenler Analizi (PCA) uygulanmıştır. Böylelikle verilerin anlamlı kümeler halinde ortaya konması ve belirli bileşenler altında değerlendirilerek enerji yoksulluğunu etkileyen ve arttıran kırılganlıklar incelenebilmektedir.

Anahtar Kelimeler: Sürdürülebilir Kalkınma, İklim Değişikliği, Dirençlilik, Kırılganlık, Enerji Yoksulluğu

To my beloved family…

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CHAPTER 1

INTRODUCTION

Sustainable development requires ensuring well-being and livelihoods while protecting environmental resources (Transforming our world: the 2030 Agenda for Sustainable Development, 2015). Sustainability was initially referred to as a framework in the search for concepts to solve concerns with urban growth, particularly those that had an impact on the environment. In the context of the acceleration of climate change and notably extreme natural occurrences, the idea of resilience has been established in connection to the resilience ability of provinces in the face of rapid and dramatic changes and occurrences (IPCC, 2022). The vulnerabilities that directly affect the resilient capacity of provinces were also discussed. The connection between the vulnerabilities highlighted and energy poverty, which is the subject of this study, was also included in the literature. Investigating the relationship between energy poverty and vulnerabilities started with this approach. The vulnerabilities that enhanced energy poverty were attempted to be examined and identified. Findings indicated that areas with high vulnerability increase the probability of energy poverty.

In this context, energy poverty and vulnerabilities are closely related. Energy poverty is a fact that continues to exist in provinces and vulnerabilities enhance energy poverty. Vulnerabilities are becoming more evident in the face of climate change and areas with higher degrees of vulnerability can be considered more prone to energy poverty due to the mutual relationship between energy poverty and climate vulnerability.

For sustainable development and the reduction of poverty, energy is essential. One of the crucial sustainable development concerns in the face of climate change is reducing poverty as an urban adaptation and mitigation approach against the energy problem. As outlined in the Summary for Urban Policymakers (SUP) of The IPCC's Sixth Assessment Report Volume II (Adelekan, 2022, p.43; SUP, 2023), "Effective adaptation requires to focus on inequity in climate vulnerability and responses."

Figure 1.1. Adaptation Gaps to Current Climate Risks (IPCC, 2022)

Dramatic socio-economic and environmental changes in the world facilitate climate change. Climate change will unavoidably affect urban systems and inhabitants (Tyler & Moench, 2012, p.311). The increasing growth in the global population, the infrastructure and superstructure difficulties generated by urbanization, the environmental consequences of these problems, the usage of fossil fuels or nonrenewable energy sources, and the demand for energy have all resulted in significant social, economic, and environmental changes. Every populated area on Earth is currently having the effects of climate change, with human activity being a major factor in many known weather changes and climate extremes (IPCC, 2022). Many changes affect the world in terms of hot extremes, heavy precipitation, agricultural, and ecological drought. By limiting warming, certain changes could be slowed down and others could be stopped (IPCC, 2022). With the change in climate, the world is also trying to respond to these changes, but since this effort and speed of change are not at the same level, vulnerabilities occur in different directions. Adaptation gaps to current climate risks exist in all regions, including in developing countries. In Figure 1.1, the adaptation gaps for Europe are also visible (IPCC, 2022).

One of the most essential concerns in provinces is reducing vulnerability caused by climate change. Provinces that are able to adapt and react swiftly to change can be achieved by encouraging resilience. Building resilience and recognizing vulnerabilities is critical. One of the most significant systems of urban formations, the energy framework, is used in this study to provide a viewpoint. Understanding the principles of energy poverty and the accessibility of energy services can open significant prospects for future climate change mitigation and adaptation issues (Babiker et al., 2022). Therefore, the primary goal in the context of urban adaptation and mitigation is to achieve mitigation since this is the only method to accomplish adaptation goals.

When considering various social, cultural, and economic aspects, the inability to provide domestic energy services at a level that is necessary from a global perspective can be referred to as energy poverty (Siksnelyte-Butkiene et al., 2021). The inability to access better energy services and deteriorating environmental shocks caused by climate change are interrelated problems that constrain poverty reduction efforts. The intersection of these three aspects defines a connection between energy access, poverty reduction, and reducing climate change.

It is important to understand the reasons why vulnerabilities emphasize the need to be resilient to face threats. In this context, the concepts of resilience, urban resilience, and urban climate resilience/climate resilience development were discussed in the first part to put this research in a broader perspective. Urban climate resilience can be defined as the capacity of provinces to adapt to climate change and to survive with the least damage possible (Adelekan, 2022). It extends beyond concentrating on climate effects to combine ecological, infrastructural, social, and institutional resilience components, supporting planning for climate adaptation in provinces. In the resilience framework, energy poverty can be seen as one of the urban vulnerabilities because vulnerabilities can be reduced by promoting urban resilience (Babiker et al., 2022).

The relationship between sustainable development, climate change, resilience, and vulnerability concepts within the framework of energy poverty was included in this study to understand the vulnerability variables associated with energy poverty. It is expected that the risk of being prone to energy poverty is higher in areas where sustainability is reduced by the effects of climate change and those who cannot resist the change.

Understanding the vulnerabilities in urban areas highlights crucial connections that ensure an accurate expression of sustainable development. Investigating vulnerabilities allows the realization of multidisciplinary goals by expressing the direction and priority of the purpose. It is possible to comment on the condition of energy poverty by looking at the various aspects that contribute to it. The factors that cause poverty should be understood first, followed by evaluating areas that are highly vulnerable due to these factors. Areas prone to energy poverty due to their vulnerabilities related to climatic, geographic, and socio-economic conditions in particular, are expected to be revealed. The literature on the understanding of vulnerability is reviewed below.

1.1 Understanding of Vulnerability

When attempting to comprehend the potential of adverse effects resulting from global environmental change, vulnerability is an established concept (Cutter, 2003; Adger, 2006). The notion of vulnerability relies on the premise that vulnerability is the degree of susceptibility to stressors that are not adequately complemented by capacities to combat negative consequences in the medium to long term and to preserve levels of overall well-being (Allen, 2003). Vulnerability can be seen as a propensity or predisposition to be harmed, which comprises several notions and components, encompassing sensitivity to damage and a lack of ability to cope and adapt (Möller et al., 2022).

The adaptability of built physical structures, social processes around economic, welfare, health, and institutional structures, which are institutions, laws, cultural and political systems/norms, have an impact on human vulnerability (Dodman et al., 2022). Urban processes that affect poverty, livelihoods, and sustainable development are associated with a variety of vulnerabilities, risks, and consequences. Physical infrastructure may protect against a variety of climate risks while bringing about remarkable collateral benefits for livelihoods. However, the advantages of physical infrastructure may be constrained by factors like lack of adaptability after commissioning, risk transfer to other persons and locations, and difficulties like negative ecological effects (Dodman et al., 2022).

Recent research on people in urban areas emphasizes how household and individual variability and intersectionality further distinguish the disparities in vulnerability caused by social and economic dynamics (Kaijser & Kronsell, 2014; Kuran et al., 2020). This encompasses disparities in wealth and ability, variances in gender, including non-binary gender, education, health, political clout and social capital, age, including young and old, poor physical fitness, pre-existing disabilities, length of residency, and social and racial marginalization (Dodman et al., 2022).

The assessment of vulnerability differs depending on the individuals, the environment, and the sort of disaster outcomes (Dintwa, Letamo, & Navaneetham, 2019). Large-scale vulnerability assessment necessitates a more comprehensive and multidisciplinary methodology (Ciurean et al., 2013). Many social vulnerability assessment studies have used a semi-quantitative methodology based on demographic, socio-economic, and geographic data (Fekete, 2019).

1.2 Interrelations of Vulnerability and Energy Poverty

A connection between vulnerability and the term of energy poverty could be observed after the basis of vulnerability has been briefly understood. Energy poverty describes the problems of energy deprivation in the household (Bouzarovski & Petrova, 2015). The most vulnerable places in terms of energy poverty could be found by revealing the socio-spatial distribution of vulnerabilities that contribute to energy poverty. Energy poverty is approached from a spatial perspective by assessing the influence of socio-economic, urban, and climatic elements on a territorial scale. Indicators that are generally examined while making the evaluation are the following: building's features and location; socio-economic factors (low household incomes); an effect on the way energy is used; and household energy affordability (high energy costs). Over time, the term has been used to describe various energy-related issues, such as those connected to social equity, infrastructure, economic development, education, and health (Pachauri & Spreng, 2004). Energy poverty is not only related to people's capacity to pay their bills but also to their own well-being and to contemporary concepts of equality, justice, and honesty (Meyera et al., 2018). As seen from these definitions, it is kind of a degree of susceptibility to energy stresses.

According to the Climate Council Local Governments Commission's 2nd Online Meeting Report (Ankara, 2022), the most significant and primary cause of the worsening of the climate is the production and consumption of energy. Energy is the primary policy area that local governments will use to combat and prepare for climate change. Considering the variability of the needs and vulnerabilities of households in different geographical diversities, energy poverty policies should be shaped and adapted according to the material, cultural, political, and institutional context (Simcock & Petrova, 2017). Policies should concentrate on the larger structural and spatially contingent factors that contribute to a lack of adequate energy services to reduce vulnerability to the condition. They should also support communities, cities, and regions as they combat domestic energy deprivation with flexible and contextually appropriate solutions.

To understand which households and places are relatively vulnerable to energy poverty, there is a need to consider various factors such as individual characteristics, socio-economic conditions, socio-technical aspects, and institutional arrangements. Factors include low income, high energy costs, poor energy efficiency in buildings, higher energy demands than average, inflexible and unstable living arrangements, a lack of social support, and unhealthy energy-related practices at property all contribute to the degree of vulnerability (Bouzarovski & Petrova, 2015). This suggests that planning frameworks need to be utilized in order to guarantee that some of the larger structural issues relating to energy service poverty may be addressed methodically and comprehensively. Specific measures include assisting communities, cities, and regions to handle domestic energy deprivation by utilizing affordable, locally sourced, low-carbon energy, as well as maintaining the sharing of household resources through various informal or formal networks to reduce single need for energy (Bouzarovski & Petrova, 2015).

Assessing and alleviating energy poverty requires an understanding of vulnerabilities. Numerous techniques can be used to collect this knowledge, including focus groups, household surveys, and in-person or online interviews with community members. The patterns of energy availability and consumption, as well as the social, economic, and environmental aspects that contribute to energy poverty, may all be learned from these data sources. Additionally, mapping tools may be used to show how energy poverty is distributed and identify areas that require assistance. The design and implementation of targeted energy interventions, such as electrification projects, renewable energy facilities, and energy efficiency initiatives, that meet the unique requirements and difficulties of people in these locations can also be supported by such information. Therefore, collecting data on energy poverty is critical to comprehend the local environment and communities' unique vulnerabilities and demands. The design and implementation of efficient and sustainable energy initiatives that enhance energy access and alleviate energy poverty may then be accomplished using information.

1.3 Aim of the Research and Research Questions

The degree to which a household is vulnerable to energy poverty varies socially and spatially. The measurement of energy poverty has mostly relied on area or expenditure-based indicators. The phenomenon has not been explored from this viewpoint despite recent developments in geospatial approaches that have the potential to offer significant insights into the socio-spatial distribution of vulnerability to energy poverty (Robinson, Bouzarovski & Lindley, 2018).

The connection between energy poverty and climate vulnerability should be taken into account as vulnerabilities associated with climate change become more apparent. Due to the interdependence between energy poverty and climate vulnerability, areas with higher vulnerability levels should be analyzed in detail and require immediate and customized action regarding the factors contributing to their vulnerability. In order to comprehend the socio-spatial distribution of energy poverty, the social, economic, physical, and geographical variables related to it are analyzed based on the aims of this research work. However, there are several variables that can be linked to energy vulnerability, thus, it is important to group them into comprehendible set of limited components that explain the highest possible variability of energy poverty. Such components would help to provide a guidance for the strategies and interventions to deal with the vulnerabilities.

This study aims to define the components of energy vulnerability and demonstrate the spatial distribution of vulnerabilities at the province level. The research questions regarding the aim of this study is;

- Which vulnerability factors can be decisive for identifying the components of energy vulnerability and revealing the spatial distribution of the energy vulnerability?

The research has the following sub-objectives to help achieve the aims of the research:

- Which variables are linked to energy poverty vulnerability?
- How is energy poverty vulnerability spatially varied with respect to these variables at the province level?
- How to group several variables that are related to energy poverty vulnerability into a set of explicable components?
- How do each variable and each province contribute to vulnerability components?

1.4 Structure of the Research

This research consists of five chapters. The first chapter, the introduction, discusses the importance of energy poverty and vulnerabilities associated with energy poverty, the problem definition, the main objectives, research questions, and explains the study's outline. The second chapter includes a literature review of energy poverty. Sustainable development, climate resilient development, and energy poverty are concepts that are covered in the literature review section. The connections between vulnerability and energy poverty are overviewed. In the third chapter, methodology, and data are explained. The fourth chapter, results is presented based on analysis of vulnerability factors.

In conclusion, in the fifth chapter, the main findings from the research are briefly reviewed, all findings are critically assessed, and the study's limitations are outlined. Based on the promising research directions that are opened by this thesis, it is clear that there are other opportunities for more studies in this area.

CHAPTER 2

LITERATURE REVIEW

There are inequalities in energy access that exist between and within nations (J. Healy, 2003; Thomson & Snell, 2013) and across different household types (see Petrova, 2018; Ambrose, 2015). Energy poverty has a detrimental impact on well-being and health (Liddell & Morris, 2010), and solving energy poverty and lowering carbon emissions are related (Ürge-Vorsatz & Herrero, 2012). Connections between energy poverty and climate change have been considered (Chakravarty & Tavoni, 2013).

It was underlined that there are socio-economic and geographic variations of energy poverty (Robinson, Bouzarovski & Lindley, 2018). The socio-spatial vulnerability that causes energy poverty (Hall, Hards & Bulkeley, 2013; Bouzarovski et al., 2017; Bouzarovski & Thomson, 2018) brings insight into the complex nature of such vulnerability and demonstrates how it is "highly geographically variable and locally contingent" (Bouzarovski, 2014, p. 282). Due to the reciprocal link between energy poverty and climate vulnerability, vulnerabilities are becoming more obvious as a result of climate change, and areas with greater levels of vulnerability can be thought of as being more vulnerable to energy poverty.

Essentially, the literature outlines and attempts to understand sustainable development and climate resilience development frameworks to make an understanding of the vulnerabilities impacting energy poverty. Then, focusing on energy poverty, the framework of the notion and its interactions in the literature were studied. In this context, the research question focuses on the vulnerabilities that contribute to energy poverty and their spatial distribution. Considering energy poverty is not based on a single indication, it contains characteristics that necessitate several considerations. According to data, energy poverty varies by province, and so energy vulnerability risks have the potential to fluctuate.

2.1 Sustainable Development

The Brundtland Report, titled "Our Common Future," was issued by the World Commission on Environment and Development (WCED) in 1987, following its establishment in 1983. According to the Brundtland Report, which established guiding principles for sustainable development, the underlying problems of the world's most serious environmental issues are poverty in the South and irresponsible consumption and production patterns in the North. The idea of sustainable development became a priority as a strategy that integrates development and the environment. Sustainable development is characterized as development that matches the requirements of the present without affecting future generations' ability to satisfy their own needs (Brundtland, 1987). Meeting everyone's fundamental requirements and increasing opportunities for everyone to live better lives are essential for sustainable development. Ecological and other catastrophes will always be a possibility in a world where poverty is pervasive.

The United Nations Conference on the Human Environment (Stockholm Conference) was held in the background of the environmental movement that emerged in the 1970s because of environmental issues encountered globally. The Stockholm Conference brought environmental issues to the attention of a global audience. Following the political actions taken after this process, the Millennium Declaration, which was signed by world leaders in September 2000, set eight quantifiable goals to be accomplished by the year 2015. These goals ranged from promoting gender equality and lowering child mortality to halving extreme poverty and hunger. The United Nations Conference on Sustainable Development (Rio+20) in June 2012 started the process of creating a new set of Sustainable Development Goals (SDGs) that will build on the momentum created by the Millennium Development Goals and provide a global development framework beyond 2015.

The 2030 Agenda for Sustainable Development is a collective vision for peace and prosperity for people and the earth (Transforming our world: the 2030 Agenda for Sustainable Development, 2015), both now and in the future. It was adopted by all United Nations Member States in 2015. The 17 Sustainable Development Goals (SDGs), an urgent demand for action by both developed and developing countries in a global partnership, are at the center of it all. These aims emphasize the importance of eradicating poverty and other types of deprivation, as well as integrating policies that improve health and education, decrease inequality, and promote economic progress. They also emphasize the significance of protecting the oceans and forests while combating climate change.

The Sustainable Development Goal 7 of the United Nations aims to provide affordable, reliable, and modern energy services to everyone by 2030 (Sustainable Development Goals, 2015). It combines efforts to combat climate change with those to alleviate energy poverty by aiming to increase the global use of renewable, efficient energy sources (Belaïd & Creti, 2021). A reliable and sustainable energy path for sustainable development is critical, but it does not currently exist. Developing countries will need a lot more energy as a result of industrialization, agricultural expansion, and population growth even if the pace of rise in energy use will slow. Given this, any realistic scenario for global energy should result in a marked rise in the primary energy consumption of the developing world (Brundtland, 1987).

2.2 Climate Resilient Development

The future of the global climate depends on reducing climate change in urban and rural areas. It is often the case that urban areas have better energy efficiency than non-urban areas, but how cities are planned, constructed, powered, and renovated will significantly impact both present and future emissions (Babiker et al., 2022, p.61). Attempts to achieve sustainable development in urban settings are thwarted by the vulnerability and rise in economic and social inequities associated with such consequences and risks. For successful adaptation to occur, it is crucial to concentrate on climate vulnerability and inequity in responses. In this direction, sustainability comes to the fore because sustainable development can improve well-being, human well-being, equity, and climate justice.

The meanings of some of the terminologies used in line with the Intergovernmental Panel on Climate Change (IPCC) definitions of Working Group II and Working Group III on central concepts for understanding and taking action on cities and climate change are given briefly. Sustainable development and human rights are connected through **climate justice** to produce a rights-based approach to combating climate change (IPCC, 2022; Möller et al., 2022). A tendency or susceptibility to being negatively impacted, **vulnerability** includes several ideas and components, such as sensitivity or susceptibility to damage, as well as a lack of coping and adaptive skills (IPCC, 2022; Möller et al., 2022). The ability of social, economic, and ecological systems to respond to or rearrange to maintain their fundamental functions, identities, structures, and capabilities for adaptation, learning, and transformation is known as **resilience** (IPCC, 2022; Möller et al., 2022).

It is feasible to state that there are social, economic, geographical, technological, and political components when considering the various reasons causing difficulties. In terms of social vulnerability, communities including women, children, indigenous peoples, and those who are poor are frequently more vulnerable to the effects of climate change (Otto et al., 2017). Communities that depend on unsustainable economic activity, like those in developing countries, are frequently more susceptible to the effects of climate change because they lack the infrastructure and resources to adapt (Nath & Behera, 2011). From a geographical perspective, low-lying coastal areas, disaster-prone areas, or arid regions are frequently more vulnerable because they are exposed to increasing sea levels, a rise in the frequency of natural disasters, and a shortage of water. Since communities lack the resources to adapt to changing conditions, individuals without access to modern technology are also more susceptible. Politically unstable or poorly governed communities are often more vulnerable because they lack the institutions and systems needed to cope with shifting conditions.

Measures that increase resilience, such as incorporating climate-resilient development, enhancing access to clean and renewable energy sources, investing in energy efficient technologies and practices, and developing infrastructure and systems to mitigate climate change are crucial for addressing these inequalities and vulnerabilities in the face of climate change. Empowering communities and providing access to resources and services is critical to address the social and economic imbalances that cause vulnerability, such as poverty, lack of financial resources, and gender discrimination. Based on these perspectives, creating climate resilience offers insight into the inequalities and vulnerabilities that communities experience (Schipper et al., 2022). To overcome these challenges, one must act and develop the necessary capacities to endure and adapt to the consequences of a changing climate.

The phrase climate resilient development (CRD) refers to a framework and methodology that enables cities and urban areas to engage in activities that concurrently advance climate adaptation, mitigation, and sustainable development while emphasizing the importance of equity, inclusion, and justice in pursuing essential measures. The purpose of climate resilient development is to make communities and systems less vulnerable to the effects of climate change while achieving sustainable economic, social, and environmental outcomes. To enhance resilience in the face of changing climatic circumstances, this approach emphasizes the necessity of addressing the fundamental causes of vulnerability, such as poverty and inequality (Wardekker, 2021).

Implementing greenhouse gas reduction and adaptation strategies to achieve sustainable development for all is also called climate resilient development (Adelekan et al., 2022). To promote planetary health and everyone's well-being, CRD conceptualizes development that incorporates reduction, adaptation, and inclusive sustainable development (Singh & Chudasama, 2021). In order to fulfill the sustainable development aim, the notion of climate resilient development paths (CRDPs) is presented as development trajectories that include adaptation and mitigation (Denton et al., 2014, p.1104). The studies on CRD emphasize the necessity of swift climate action that boosts resilience in both natural and human systems while enabling considerable reductions in greenhouse gas emissions (Shindell et al., 2017; Nerini et al., 2018).

The social, economic, and environmental aspects of sustainable development and the addition of adaptation and mitigation dimensions may all be used to express climate resilient development (see Adelekan et al., 2022). Sustainable development depends on both adaptation and mitigation. When adaptation explicitly links to sustainable development and mitigation, has a longer time horizon, involves a wider range of stakeholders, actively chooses to precipitate deep transformational change, and recognizes multiple pathways with various synergies and trade-offs associated with particular actions and decisions, adaptation expands into CRD (Adelekan et al., 2022). As climate action improves the synergies of mitigation, adaptation, and sustainable development, opportunities for CRD are declining globally and are not dispersed equally across the world. The possibilities for CRD grow further constrained until greenhouse gas emissions peak and the global and regional net zero targets are not achieved. Attempts to achieve sustainable development in urban areas are complicated by the vulnerability and rise in economic and social inequities associated with such consequences and risks.

To advance sustainable development for all, climate resilient development integrates adaptation and mitigation. This is made possible by improved access to adequate financial resources, especially for vulnerable areas, sectors, and groups, inclusive governance, and collaborated policies (IPCC, 2023). Figure 2.1 represents the various pathways to climate resilient development where missed opportunities have already taken place. A liveable and sustainable future for everyone is possible. Still, there is a fast-closing window of opportunity, as illustrated by the illustrative development paths (red to green) and related consequences (right panel). Diverse knowledge and beliefs may support the establishment of climate resilient communities, change the current course toward sustainability, and facilitate reduced emissions and adaptation. Climatic and non-climatic events provide more severe shocks to development paths with lower levels of climate resilience. Actionable pathways and possibilities are determined by prior actions, enabling and restricting circumstances, climatic threats, the capacity for adaptation, and development gaps.

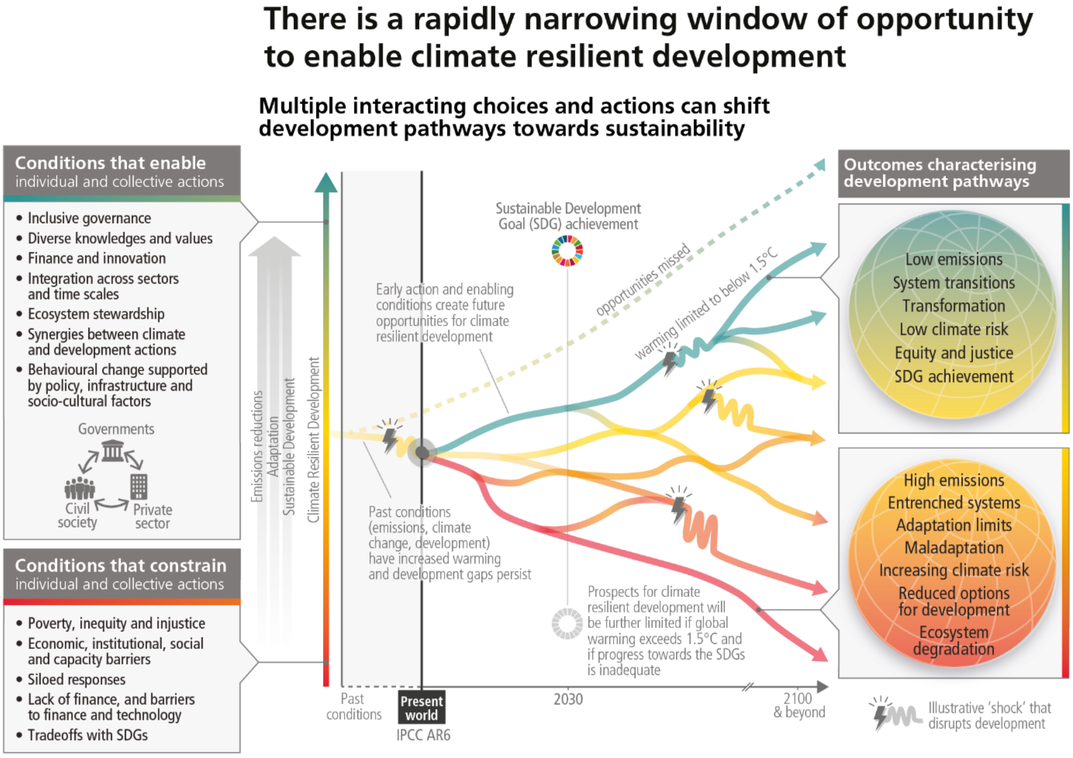

Figure 2.1. Various Pathways with Implications on Climate Resilient Development (IPCC, 2023)

Development activities can make it more difficult to adapt to and reduce the effects of climate change (Lo et al., 2020; Thomalla et al., 2018). In addition, poorly planned climate change initiatives might undermine attempts to promote sustainable development (Eriksen et al., 2021). Creating resilience to climate change impacts is called climate resilient development so communities and systems can resist, recover quickly from, and adapt to the consequences of a changing climate. As communities that are already dealing with economic, social, and environmental problems are frequently more vulnerable to the effects of climate change, climate resilience is particularly crucial for decreasing inequities and vulnerabilities. It is important to understand the numerous components that contribute to these difficulties to comprehend and solve the inequalities and vulnerabilities caused by climate change (Dodman, Archer & Satterthwaite, 2019). For CRD efforts to be successful, research, policy, and action must be integrated. One area of major continuing endeavor is community-based adaptation planning and action (Reid et al., 2009; Ayers & Forsyth, 2009; Forsyth, 2013), which has the potential to improve well-being and promote Sustainable Development Goals. It should be known that the synchronization of mitigation and adaptation activities across geographic scales and policy domains is one of the many complex trade-offs and gaps that still exist.

Finally, climate resilient development acknowledges the significance of lowering vulnerability to climate change effects and encouraging sustainable results in the areas of the economy, society, and the environment. Among the conditions constraining both individual and collective actions are poverty, injustice, and inequity (IPCC, 2023). Vulnerabilities are expected to change as a result of these conditions. Access to contemporary, dependable, and affordable energy services must be improved, and conditions that constrain individual as well as collective action must be reduced, in order to lessen vulnerability and encourage growth that is climate resilient. The relationship between energy poverty and the establishment of climate resilient communities emphasizes the need of eliminating energy poverty to improve resistance to the effects of changing climatic conditions. Energy poverty increases vulnerability and can worsen the effects of climate change. Access to contemporary energy services, such as electricity and clean cooking fuels, which are necessary for health, education, and well-being, is restricted by energy poverty (Piwowar, 2022). Due to a lack of access, people are more likely to rely on conventional energy sources like kerosene and biomass, which can have negative effects on the environment and increase indoor air pollution (Sagar, 2005). To foster development that is climate resilient, providing access to contemporary, reliable, and affordable energy services is necessary. This may be accomplished by taking a variety of steps, such as encouraging the use of renewable energy sources and energy efficient technologies, enhancing energy infrastructure, and enhancing energy governance and policy.

2.3 Energy Poverty

Meeting basic human needs, in general, requires decisive policy action as part of the broader human development process, as it is central to the goal of alleviating poverty. Meeting these necessities and enhancing well-being is essential. The universal significance of energy resources in advancing social well-being necessitates a thorough understanding of the concept of energy poverty without limiting it to specific straightforward criteria like the quantity of an energy resource's availability or the amount of money spent on it (Sadath & Acharya, 2017).

The concepts of sustainable development and energy access are frequently brought up while discussing the issue of poverty. Sustainable development is characterized as development that meets the requirements of the present without affecting future generations' ability to fulfill their own needs. This implies that reducing energy poverty involves more than just increasing short-term access to energy services; it also involves making sure that the current energy infrastructure is sustainable and able to be maintained in the long run. Since access to energy services is necessary for human development, economic growth, and poverty reduction, reducing energy poverty is perceived as a crucial part of achieving universal energy access.

Energy justice examines the causes of inequities, which and how communities are neglected, and what measures can be taken to expose and reduce these injustices. It is described as a world energy system with a transparent and unbiased energy decision-making process that fairly distributes the costs and benefits of energy services (Sovacool et al., 2017). Examining how benefits and damages are divided, recovered, and individuals are acknowledged is what energy justice entails (Heffron, McCauley & Sovacool, 2015). The concepts of climate justice and environmental justice are the foundations of the concept of energy justice (Sovacool & Dworkin, 2015). In fact, encouraging whole systems approach to energy justice demonstrates how it may give a worldwide account of the social, economic, and environmental effects of energy while evaluating the multiple injustices that may take place in the international energy systems (Jenkins, 2016).

Energy justice is directly tied to the geographical, social, and political aspects of the society, whereas injustice may have its roots in particular areas, groups, and institutional structures. The issue becomes even more important in developing countries like Türkiye, where imports account for a large portion of their energy demands (Kurkcuoglu, 2023). Injustice is fed by economic and social inequalities. Affordable, sustainable, and safe energy for everyone may ensure energy justice. It has a broad scope regarding energy supply and consumption, energy policy, energy security, climate change, and environmental concerns.

Distributive justice, recognition justice, and procedural justice are the three pillars of energy justice (McCauley et al., 2013; Bouzarovski & Simcock, 2017; Forman, 2017; LaBelle, 2017; Sovacool et al., 2017). According to distributive justice, environmental advantages and disadvantages are distributed physically inequitably, as are the responsibilities that go along with them (Walker, 2009). It serves as a reminder to all individuals in a society to share positives and negatives equally. According to recognition justice, everyone should have complete and equal access to political rights, be fairly represented, and be protected against physical harm (Schlosberg, 2003). Different types of cultural and political dominance, exclusion, and devaluation are all signs of the lack of acknowledgment. Therefore, various viewpoints motivated by social, cultural, ethnic, racial, and gender diversity are expected to be embraced to provide recognition justice (Schlosberg, 2003). Procedural justice is concerned with procedures, notably those that result in or sustain uneven distribution (Jenkins, 2016). Due to the strong correlation between a lack of cultural respect and a lack of participation and influence in decision-making, procedural justice is also intimately tied to recognition. Access to and pressure from multi-level legal systems improve procedural justice (Walker & Day, 2012).

Geographical approaches to recognition and procedural justice have also been adopted, especially in the environmental justice literature, despite this concentration on the spatial components of distributive justice (Walker, 2009). The findings of this kind of study point to the possibility that stakeholders and individuals may also experience injustice in their environments. It has been suggested that procedural and recognition of spatial inequalities are unfair and contribute to the construction and reproduction of geographic distribution inequalities. Space therefore actively creates and perpetuates inequalities in addition to serving as a foundation for their manifestation (Dikeç, 2001).

Energy poverty has a geographical component in the face of issues when it is examined from a spatial justice approach. For justice to be accomplished, it is crucial to identify the regional disparities underlying the growth and persistence of local energy poverty as a global issue and to create a spatial understanding of the connections between energy justice and energy poverty (Bouzarovski & Simcock, 2017). To achieve this, the idea of "spatial justice," which highlights the geographical aspects of inequality and inequity, is applied (Soja, 2013). A spatial justice approach, it is suggested, entails not only locating and recognizing geographic inequalities but also critically assessing such inequalities in terms of more generalized forms of injustice and their effects on human well-being (Bouzarovski & Simcock, 2017).

Due to structural geographic inequalities at different levels of the energy system as well as in the fundamental infrastructural, economic, and cultural structures of societies, there are spatial variations in energy poverty and vulnerability (Bouzarovski & Simcock, 2017). Geographically unfair energy inequalities are a result of spatial inequalities in household incomes and energy costs. Along with the national scale, significant disparities occur in cities and regions. For instance, local low-income household densities are a crucial aspect of high-energy poverty in some areas (Morrison & Shortt, 2008). Energy justice argues for a fair distribution that considers the socio-economic, cultural, and geographic diversity of communities. Therefore, identifying areas that receive or lose access to energy and which areas are more vulnerable than others are important to take measures and develop policies that are spatially responsive and energy-justice-based. To build urban resilience in various temporal and scalar frames (Bouzarovski, 2015), it is, therefore, necessary to develop policies by analyzing the connections between energy poverty and larger socio-environmental possibilities like climate change, rural and urban social segregation, and global energy supply (Bouzarovski & Simcock, 2017).

In literature, there are several definitions and perspectives for expressing energy poverty. Lack of access to contemporary energy services is a common definition of energy poverty (Li et al., 2014). Energy poverty is defined by Simcock and Petrova (2018) as the unaffordability of domestic energy, by Sovacool et al. (2013) as a reliance on solid biomass fuels for cooking and heating and an inability to get to electricity.

There has been noticed that certain energy, social and structural characteristics in households interact with energy poverty (Hernández, 2015; Martn-Consuegra et al., 2020). The term "energy poverty" is also frequently used to indicate issues with energy deprivation in the household (Bouzarovski & Petrova, 2015). This term has historically been used to refer to problems with inadequate access to electricity in developing countries, including challenges with economic development, infrastructure, social equality, education, and health (Pachauri & Spreng, 2004). The issue of exclusion and/or poverty is connected to energy poverty. It is a component of a larger famine that affects both the lives of the affected people individually and as a whole. It raises the prospect that energy poverty undermines not only people's capacity to pay their bills but also their own well-being and contemporary notions of equality, justice, and fairness (Meyera et al., 2018).

Low household incomes, high energy prices, and insufficient levels of residential energy efficiency are frequently brought up in the literature when discussing energy poverty. Which of these components is the main contributor to energy poverty in various nations, cities, regions, and specific situations varies greatly geographically and is dependent on several circumstances like different nation states, the scale of cities and regions, the scale of households and individuals and geographic variance in the dimensions of energy vulnerability can all cause this.

In these directions, concepts related to energy poverty in the literature were examined. In Figure 2.2, keywords from the literature on energy poverty are presented based on literature between 2015-2023 based on the clustering algorithm of VOSviewer (VOSviewer - Visualizing Scientific Landscapes, 2023). There are clusters of terms such as fuel poverty, energy efficiency, renewable energy, energy access, sustainability, and climate change when the distribution of words associated with energy poverty in the literature is researched. It is apparent that these clusters include related notions as well.

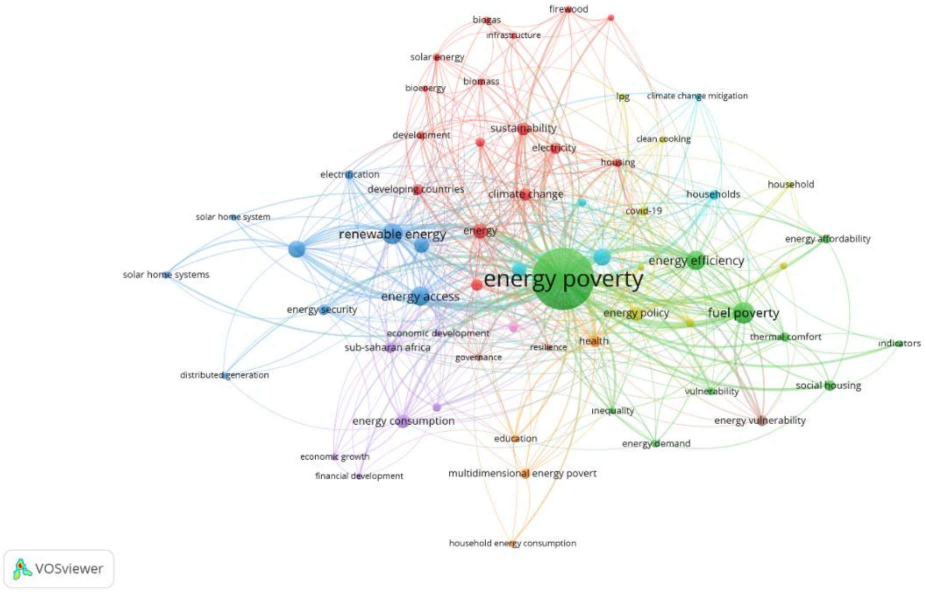

Figure 2.2. Energy Poverty-Related Keywords in The Literature

The definition and impression of energy poverty can vary depending on a country's level of development, climate and environment, cultural considerations, and individual characteristics. There is no one paradigm for energy poverty; in addition to available resources, it should consider infrastructure, social norms, appliances, and human behavior (Bates et al., 2012). The category of access, the degree of access to energy in underdeveloped urban and rural populations, or socio-demographic characteristics are regarded to be important in the context of energy poverty research (Musango et al., 2020).

Knowing the issues with basic energy services also requires understanding how energy poverty is defined variously in developed and developing countries. Studies on these problems can advance the cause of energy poverty, which is basically a lack of access and high costs. The absence of sufficient and adequate energy services, which results in vulnerabilities, is one of the most significant challenges as the root problem of energy poverty (Bouzarovski & Petrova, 2015). These vulnerabilities may result from a lack of access (developing world 'energy poverty'), a lack of affordability (developed world 'energy poverty' and 'fuel poverty'), or perhaps from both (Simcock & Petrova, 2017).

The requirement for energy and its intended usage varies depending on the climatic and environmental conditions. Countries with hot climates use energy for cooling, whereas those with cold climates use it for heating. Additionally, analyses of energy poverty in connection to climate change are available (Santamouris, 2016). A new area for investigation will open as a result of increased energy use for cooling brought on by rising air temperatures. The requirement for energy may also rise in some areas due to factors like colder winters. Technology innovation is a problem that affects the development of a low-emission economy as well as energy poverty (Chakravarty & Tavoni, 2013). The literature on this topic highlights the issues with electrification and the growth of renewable energy sources in this case. Numerous programs and measures have been suggested to solve the issue of developing countries limited access to new energy sources (Piwowar, 2022).

Another crucial area in the literature on energy poverty is renewable energy, which is frequently viewed as a remedy for the problems associated with energy poverty. Communities without access to electricity today might benefit from the affordable and sustainable energy services offered by renewable energy sources including solar, wind, hydro, and geothermal. Renewable energy technologies also benefit from being low-carbon and less environmentally damaging than fossil fuels. Although their relationship is convoluted and intertwined, renewable energy is seen as a viable solution to energy poverty (Piwowar, 2022). Nevertheless, in areas with severe energy poverty, the deployment of renewable energy may be difficult due to a lack of the required infrastructure and funding. It is necessary to take a thorough and well-rounded strategy for reducing energy poverty that considers the interactions between the distribution of renewable energy, accessibility to energy services, and energy efficiency. In order to ensure that the advantages of renewable energy are shared by everyone and that the transition to renewable energy is sustainable and fair, a complete and integrated strategy is required. Therefore, renewable energy may play a vital role in reducing energy poverty.

Individuals' characteristics for energy vary depending on their gender, wealth, age, income, degree of education, illness, unemployment, and disability (Simcock & Petrova, 2017). The mechanisms that influence consumer behavior in the area of energy are looked at in relation to the circumstances. This viewpoint can provide information on people’s attitudes and ideas about using energy, both individually and collectively. Social trends can have an impact on both the breadth and manner of usage of energy services as well as the requirements and habits of consumers. Migration, especially migration brought on by conflicts, may be a crucial new area of study on energy poverty. Conflict-related migration might have an impact on processes of adaptation, integration, and assimilation as well as energy-related behaviors (Piwowar, 2022).

Connections between energy poverty and migration, job changes, politics, social values, personal life, and consumer practices are also studied. This is relevant to the exacerbation of the problem of energy poverty because of the current geopolitical situation and rising energy prices. Health, education, and the environment are all significantly impacted by energy poverty. The use of traditional fuels for cooking and heating causes indoor air pollution, which is a serious health concern since it increases respiratory issues and other health issues. Energy availability in schools has an impact on education as well, which may reduce the opportunities and quality of education for children. The usage of traditional fuels like firewood and charcoal causes deforestation and land degradation, aggravating energy poverty. This has a severe impact on the environment.

Another crucial topic lately covered in the field literature is the connection between energy poverty and economic development. Energy insecurity impedes social welfare and economic development. The role of governmental policy, international collaboration, and private sector investment in addressing energy poverty is extensively discussed. While the private sector can offer the financial and technical understanding required to scale energy solutions, governments, and international organizations play a significant role in developing the enabling environment and regulations that enable energy access. While ensuring that energy solutions are sustainable and meet the requirements of the communities they serve, local communities' involvement is essential. From multiple perspectives, energy poverty is a complicated problem with wide-ranging effects on the environment, economic progress, and human development (Bouzarovski & Petrova, 2015). Energy poverty should be addressed using a holistic strategy that considers vulnerabilities and the interaction between sustainable access to energy services.

As the challenges of obtaining energy become more apparent, the terms "energy poverty" and "fuel poverty" are commonly used in the literature. The terminology "energy poverty" is also frequently used to indicate issues with energy deprivation in the household like “fuel poverty”. For this reason, energy poverty can be described as individuals or households who cannot reach their energy needs at the welfare level (Bouzarovski & Petrova, 2015). The below section includes research on fuel poverty and its differences with energy poverty.

2.3.1 Fuel Poverty

Fuel poverty was first defined by Lewis (1982) as the inability to afford basic heating in the home (Li et al., 2014). Over time, the understanding of fuel poverty has evolved. Insufficient home heating was referred to as fuel poverty by Bradshaw and

Hutton in the 1980s (Bradshaw & Hutton, 1983). Later, it was modified by Boardman as spending more than 10% of a household's income on energy services, as is emphasized most in the literature. The "low income-high costs" (LHIC) term, often referred to as the Hills Definition and derived from the Boardman definition, was first used in the UK in 2013 (Baker et al., 2018). Fuel-poor households are those who have above-average fuel costs (the national median level) and, if they spend that much, a residual income that is below the official poverty line (Fuel Poverty Methodology Handbook 2020: Low Income High Costs (LIHC), 2020). This Low Income-High Costs guide finds the most recent study outlining how fuel poverty was calculated up to 2020. Finally, using the Low Income Low Energy Efficiency (LILEE) metric described in the Sustainable Warmth: Protecting vulnerable households' strategy in the UK, which was released on February 11, 2021, an updated document for measuring fuel poverty was prepared (Fuel poverty methodology handbook 2022: Low Income Low Energy Efficiency (LILEE), 2022).

In Figure 2.3, keywords from the literature on fuel poverty are presented based on literature between 2015-2023 based on the clustering algorithm of VOSviewer (VOSviewer - Visualizing Scientific Landscapes, 2023). The topics of energy poverty and energy efficiency are at the forefront of the literature when it comes to fuel poverty, but additional topics including energy justice, thermal comfort, and health are also brought up. Researchers on a range of topics contribute to fuel poverty. They want to clarify the idea of fuel poverty and identify at risk populations. Studies look at the amount of fuel poverty and household energy demand. They also investigate energy justice, focusing on how it connects to energy poverty. The goal is to create empirical models by concentrating on measures and policies that address fuel poverty. Some studies use energy efficiency as a political factor when evaluating fuel poverty. Studies have looked at the relationship between factors that are thought to be significant contributors to fuel poverty, such as income poverty, energy pricing, and home energy efficiency (Belaïd, 2022).

The importance of decreasing poverty in enhancing people's well-being is being increasingly recognized. The fundamental to lowering inequality is eliminating fuel poverty. Since fuel poverty is a complicated and multi-scale issue that affects both households and nations, it continuously interacts with the idea of energy poverty in the literature. Reducing fuel poverty is anticipated to enhance health outcomes and lessen health disparities. Increasing energy efficiency can also aid in lowering residential greenhouse gas emissions (Belaïd, 2022).

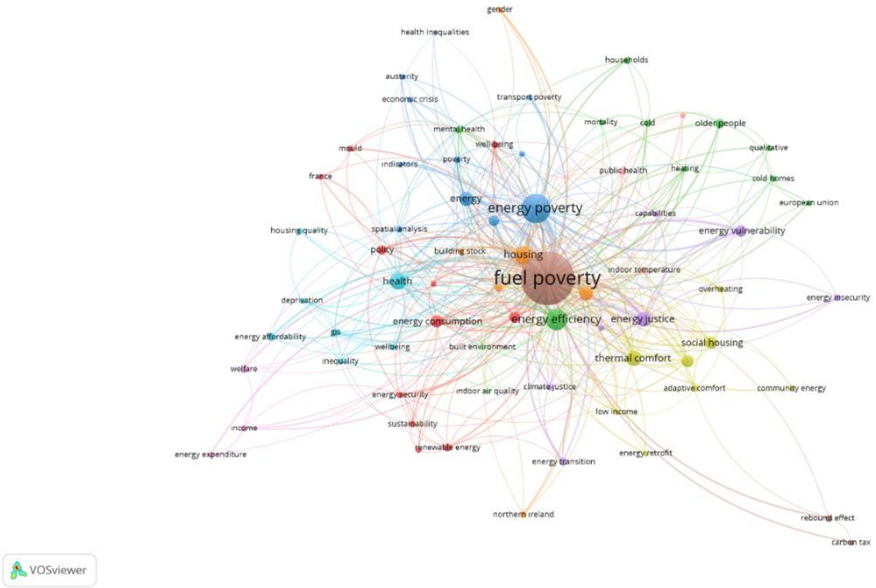

Figure 2.3. Fuel Poverty-Related Keywords in The Literature

Fuel poverty can be significantly impacted by climate change. It is predicted that climate change will influence how fuel poverty affects people and how mitigation methods should be developed. Therefore, understanding the future directions of fuel poverty may make it easier to create policies that account for climate change. Numerous research concluded that while examining structures, climate change should be considered as well. Thanks to the climate evolution predictions made by the intergovernmental panel on climate change (IPCC), the impact of climate change on buildings can be discussed due to changing environmental loads (Bienvenido-Huertas et al., 2021). Regarding the effect of climate change on the risk of fuel poverty, although it depends on the Representative Concentration Pathway (RCP) scenarios, climate change is anticipated to modify the patterns of fuel poverty ratio distributions (Bienvenido-Huertas et al., 2021).

2.3.2 Differences Between Energy Poverty and Fuel Poverty

Although energy poverty and fuel poverty may be used interchangeably, there are certain nuances between them. It is stated that these differences are in terms of definition, measurement, research targets, research organization, and climate features (Li et al., 2014). The concept of energy poverty refers to poverty on a global scale in the literature, in general (Bazilian et al., 2010; Sovacool et al., 2012). Fuel poverty, on the other hand, represents poverty at the household scale (Boardman, 1991; Lewis, 1982) and primarily addresses to the household affordability rather than physical access to energy. Li et al. (2014) state that "energy poverty" and "fuel poverty" should be considered as separate concerns and that it is not reasonable to merely conflate the two in order to prevent confusion. They propose that the term "energy poverty" should only be used to describe problems with access to electricity and contemporary cooking equipment, whereas the term "fuel poverty" should concentrate on whether households can afford adequate space heating (Simcock & Petrova, 2017).

Fuel poverty is the inability to afford proper heating and lighting, particularly at home (Lewis, 1982). The percentage of households that cannot afford to heat their houses adequately is typically used to quantify it. Low income, high energy costs, and dwellings that are not energy efficient can all contribute to fuel poverty (Robinson, Bouzarovski & Lindley, 2018). Conversely, the term energy poverty refers to a larger concept that embraces fuel poverty and other energy usage and access characteristics, including the availability of contemporary energy sources and services like electricity and clean cooking fuels. Access to energy, the quality and reliability of energy services, and the cost of energy are frequently used as a combination of indicators to assess energy poverty.

Energy poverty is described in the literature as a multifaceted concept that includes a lack of access to energy services and its consequences on livelihoods, health, and education. Inversely, fuel poverty is sometimes described as a more constrained and particular term that is centered on the inability to afford appropriate heating and lighting.

Another difference between two is that energy poverty is generally observed in relatively poor countries, while fuel poverty is experienced in wealthy countries. The only persons who may experience both fuel and energy poverty simultaneously are those who live in cold climates, struggle to afford indoor heating, and access modern cooking equipment, or electricity. They include rural parts of northern China, Nepal, India, and scattered instances of homeless people in developed countries (Simcock & Petrova, 2018; Bouzarovski & Petrova, 2015; Li et al., 2014).

In this study the term energy poverty is adopted due to the concept having a broader meaning and a wider inclusivity both in terms of the geographic scope and variety of the issues.

2.4 Energy Poverty and Sustainable Development

It is commonly acknowledged that one of the most important objectives for combating poverty and advancing economic, social, and environmental well-being is sustainable development. The Sustainable Development Goals (SDGs), created by the United Nations, aim to eliminate poverty and improve access to energy through specific targets and indicators for sustainable development. Providing reliable, economical, and contemporary energy services, expanding, and improving technology are among the goals of sustainable development. Energy is a fundamental resource for ensuring sufficient living circumstances, not only a need (Najam & Cleveland, 2003). Nevertheless, supplying modern energy services is essential for sustainable development (Nussbaumer et al., 2012).

The goal of making cities and human settlements “inclusive, secure, resilient, and sustainable” is stated as the SDG 11, and to "guarantee that everyone has access to appropriate, safe, and affordable housing as well as basic services" is one of the targets of this goal (Sustainable Development Goals, 2015). Access to energy services is indispensable for sustainability and human well-being.

Within the context of the SDGs, energy poverty has been assessed by being one of the focal points with the phrase offering universal access to “affordable, reliable and modern energy services” in Goal 7. Access to clean and modern energy is essential for achieving the Sustainable Development Goals (SDGs) related to poverty reduction, education expansion, and public health improvement. Access to energy besides the adequate, affordable, and fair use of energy services are expected to alleviate energy poverty. For instance, reliable, uninterrupted, and safe access to electricity makes it possible to employ contemporary technology to support economic growth; or access to clean heating and cooking fuels can improve health by reducing exposure to indoor air pollution, one of the major causes of respiratory illness.

Even while the world attempts to achieve sustainable energy goals, it seems like the rate of advancement could be faster for Goal 7 to be accomplished by 2030. To achieve the climate objective of reducing greenhouse gas emissions, energy efficiency improvements must be made at a faster pace. There are still hundreds of millions of people without access to energy. The health of 2.4 billion people is in danger because clean cooking solutions are not being developed quickly enough (The Sustainable Development Goals Report, 2022). There are still significant disparities in access to contemporary sustainable energy, placing the most vulnerable even further behind.

Energy efficiency is a critical component of energy poverty and increasing energy efficiency is a prerequisite for achieving the targets for the global climate goals. Energy intensity is expected to increase by 2.6 percent annually by 2030, which is double the rate seen between 1990 and 2010 (The Sustainable Development Goals

Report, 2022), while promoting energy efficiency and renewable energy can help to reduce greenhouse gas emissions and alleviate the negative impacts of climate change, which disproportionately affect vulnerable communities.

Initiated by the UN Secretary-General in 2011 with the participation of governments, private sector, and civil society, the Sustainable Energy for All (SEforALL) initiative has three interconnected goals that need to be accomplished by 2030. These include ensuring that everyone has access to contemporary energy services, doubling the rate at which energy efficiency is advancing worldwide, and doubling the proportion of renewable energy in the world's energy mix (Sustainable Energy for All, 2016). These goals work with each other. Advancement in one can aid advancement in others. The UN General Assembly declared 2014–2024 to be the Decade of Sustainable Energy for All, which is supported by the Sustainable Energy for All initiative.

To summarize, the interconnection of economic, social, and environmental well-being and the significance of access to energy services for reducing poverty and advancing sustainable development are the strong correlations connecting sustainable development, poverty, and SDG 11. Reaching sustainable development and realizing the targets of SDG 11 would require addressing energy poverty and encouraging access to clean, dependable, and affordable energy.

2.5 Energy Poverty and Climate Change

Climate change and energy poverty are connected issues with associated causes and consequences. Energy poverty contributes to climate change by increasing greenhouse gas emissions using conventional, fossil fuel-based energy sources with a high carbon footprint, such as coal, and oil. Climate change also makes it more difficult for individuals in low-income and rural areas to access reliable and affordable energy services by raising the cost and unpredictability of the energy supply. The increased frequency and severity of extreme weather events like excessive precipitations and droughts, which can harm energy infrastructure and disrupt energy supply, are among the effects of climate change on energy systems. Furthermore, variations in temperature and precipitation patterns can impact the availability of water resources essential to several kinds of energy production.

Energy poverty is a concern since it relates to a national priority of reducing carbon emissions and energy use in general. For several interconnected issues, such as poverty reduction, health and well-being, energy efficiency, and carbon reduction, energy poverty is a primary concern (Hills, 2011). For this reason, energy poverty should receive the same amount of attention as any other conventional, fundamental issue confronting the world in these times of serious climate change. Without paying enough attention to efficiency, energy usage leads to environmental degradation, which poses a danger to sustainable development.

Energy poverty and climate change are interrelated challenges requiring a comprehensive strategy incorporating adaptation and mitigation strategies. In the face of a changing climate, adaptation strategies, such as strengthening energy infrastructure to withstand extreme weather events, can assist guarantee that energy systems remain reliable and resilient. Additionally, initiatives that promote the creation of local energy options can contribute to ensuring that communities in underserved areas have access to electricity, even in the event that energy sources are disrupted. To provide transitioning to renewable energy sources, which have fewer emissions and are more resistant to the effects of climate change, such as solar, wind, and hydropower. Energy efficiency measures can also benefit in lowering energy use and emissions, such as enhancing the energy efficiency of buildings and appliances. Maintaining high-efficiency energy standards may resolve the issue of decreasing energy poverty and mitigating climate change (Ürge-Vorsatz & Herrero, 2012). High-efficiency measures can help reduce energy poverty, but the problem is complicated and cannot be solved in a single step. Therefore, carefully thought-out plans and strategies are necessary, including the construction of massive infrastructure using plenty of resources (Walker & Day, 2012). It should be underlined that the issue of energy poverty, with all of its complexities and nuances, may be remedied by thoughtfully coordinated actions and policies, for which an accurate comprehension and evaluation of the current state of energy poverty is necessary (Nussbaumer et al., 2012).

A coordinated and integrated strategy that acknowledges the links between these problems and the requirement for action on both mitigation and adaptation is needed to address energy poverty and climate change. By aiming to provide reliable and affordable energy services and switching to low-emission energy sources, both energy poverty and the effects of climate change can be eliminated. Additively, according to Chakravarty and Tavoni (2013), concerning the impact of energy poverty alleviation on the environment, it was underlined that a comprehensive program to eliminate energy poverty by 2030 would result in an increase in world final energy consumption of almost 7%, also the additional energy infrastructure required to eliminate energy poverty will result in the production of 44–183 GtCO2 and maximum additional warming of 0,13 °C by the year 2100.

Energy-related climate change mitigation strategies have the ability to lower greenhouse gas emissions and improve the situation for those living in energy poverty (Streimikiene et al., 2020). Governments use a variety of policy strategies to combat energy poverty. Providing subsidies is the most typical strategy for addressing concerns about energy affordability. The installation of energy-saving strategies or the energy-renewal of households, however, is not sufficiently encouraged by them. They are often short-term initiatives that have an environmental impact. Therefore, new policies and programs to combat climate change are required that focus on household energy efficiency, enhance the quality of life, and provide energy efficiency enhancements like domestic energy renewal with long-term energy poverty reduction effects. However, they must be specifically designed to overcome behavioral barriers, especially those related to low-income demographic groups. Although a synthesis of the available literature has not yet been done, it should concentrate on energy poverty, one of the key issues in the direction of sustainable development, where carbon-free energy is intended, as well as climate change mitigation strategies connected to energy use (Streimikiene et al., 2020).

To address the interconnected economic, financial, social, regulatory, and behavioral barriers impeding climate change mitigation in households, new climate change mitigation policy packages must be created. The economic and financial impediments to domestic climate change mitigation efforts are the focus of traditional climate change mitigation methods. Additionally, because they overlap with the main causes of energy poverty, behavioral barriers are particularly significant for those who are energy poor. To address these crucial behavioral obstacles of energy-poor families and to create well-structured policies and initiatives that target them, it is necessary to investigate the behavior and attitudes of energy-poor households, about which there is a lack of information. Households can be assisted in eliminating energy poverty in this way. In the end, properly formulated climate change mitigation policies may aid with consumer education, household decision-making assistance, household quality improvement, energy conservation, and the development of programs to combat energy poverty.

Sovacool et al. (2014) have made significant contributions to capability theory that will help solve the problem of energy poverty. This study offered crucial explanations for evaluating the affordability of energy in terms of justice. The notion of energy consumption was developed from the point of capabilities (Sarto et al., 2015). Considering the connections between energy and human well-being, the idea of energy deprivation was conceived. Finding numerous areas for policies and initiatives to create synergy is made possible by understanding energy poverty and vulnerability in terms of capabilities. It also makes it possible to examine the challenges of energy poverty in the context of climate change and work toward a future where society produces no carbon.

To accomplish the low-carbon energy transition, the idea of energy justice may also assist in the creation of climate change mitigation strategies (Mundaca, Busch & Schwer, 2018). Energy poverty is related to distributive injustice caused by restricted access to energy services as a result of high energy costs, poor housing, and other income-related disparities. Interrelated aspects of energy justice must be addressed since distributional injustice is also characterized by underestimation of the issue of energy poverty and procedural injustice (Streimikiene et al., 2020). Policies that address energy poverty must consider the requirements of disadvantaged households and promote procedural justice through influencing information availability, a clear legal system, and efficient decision-making. In this approach, distributive inequality in the provision of energy services is related to a lack of procedural and recognition justice.

Energy poverty is one of many different types of deprivation that affect several facets of human life. Because poverty reduction and climate change are at the top of quite diverse local political agendas, it is not the most obvious place for policy convergence. For two reasons—namely, that buildings provide the potential for mitigation and that an important mitigation strategy in buildings to capture these potentials could also alleviate/eliminate energy poverty and benefit priorities—energy poverty alleviation offers strong synergies with climate change mitigation agendas (Ürge-Vorsatz & Herrero, 2012).

Although challenges related to energy poverty and the mitigation of climate change are intricately linked to policy objectives, it has been discovered that these topics of scientific inquiry and policy development remain largely disconnected in the literature (Ürge-Vorsatz & Herrero, 2012). Combating climate change has frequently been a top priority for environmental policy. This made it possible to reframe a lot of things that at first glance seemed unconnected. From certain viewpoints, building settings may be impenetrable or difficult to comprehend. This is seen in the connection between reducing energy poverty and mitigating climate change.

Ürge-Vorsatz and Herrero (2012) concluded from their studies that energy poverty and climate change are two very different phenomena, usually resulting from the inefficient use of energy in buildings, the taxonomy of interactions between energy poverty and climate change, problem areas, and mitigation strategies. Therefore, it demonstrates that although the majority of connections between climate change and energy poverty issues are made on the side of mitigation, features of adaptation may become more significant in the future. Warmer winters in temperate areas will help to lessen energy poverty, whereas rising summertime temperatures will make summertime energy poverty a bigger problem. Depending on how it is solved, cooling-related energy poverty will have trade-offs and synergies with reducing climate change. Increased air conditioning use, the primary adaptation strategy, will be harmful to energy poverty alleviation and climate change mitigation. On the other hand, it is argued that climate actions like heat island elimination and climate-resistant structural engineering help reduce energy poverty brought on by cooling.

2.6 Approaches and Insight on Measurements of Energy Poverty

Energy poverty, fuel poverty, and energy justice are searched for in the literature study, and potential interpretations of energy poverty and its metrics are considered (Siksnelyte-Butkiene et al., 2021). Economic indicators are frequently chosen as the primary metrics, but social and environmental factors should also be taken into consideration. Then an energy poverty indicator reflects the most recent issues.

It has been suggested that the physical, economic, and technological aspects of these methods may evaluate access to energy (González-Eguino, 2015). The basic minimum amount of energy required to fulfill fundamental demands is used to create a physical measurement. Households below the minimum energy consumption are measured as energy poor. This measurement discusses the amount of energy consumption for basic needs.

The issue of income becomes more prominent economically. It seeks to ascertain the highest proportion of income needed for energy expenditure. In other words, the proportion of household income spent on energy, with high levels indicating that energy is becoming increasingly unaffordable. The lack of physical access to energy sources and/or the incapacity to use contemporary energy for a variety of reasons are used to analyze the idea of energy poverty (Siksnelyte-Butkiene et al., 2021). The issues brought on by addressing energy requirements are evident in developed countries. In developed countries, determining energy poverty by the percentage of income spent on energy costs is a common practice. With components for income, energy costs, and energy demand, it is intended to measure energy poverty, particularly in the UK. Since it is relative, comparing nations with different economic standings is challenging when evaluating energy poverty from an economic perspective (Pachauri & Spreng, 2011). In addition, many developing countries still struggle with universal access to energy resources. Energy poverty has two aspects - limited access to modern energy services and inability to use modern energy. This poses challenges when creating indicator systems to measure it.

Although the inability to access contemporary energy services is also a definition of energy poverty, this expression may be assessed within the category of technological measurement in its evaluation. In other words, based on the energy services utilized, there are methods for diagnosing energy poverty. The quantity of energy necessary to offer sufficient energy services is not described by this technique. Nussbaumer et al. (2012) created the indicator of multi-dimensional energy poverty (MEP). It incorporates metrics such as having access to power for lighting, a refrigerator, a phone, and contemporary cooking fuel. It assesses whether households can meet minimum standards for access to services. These energy service-oriented metrics are thorough methods for identifying and assessing energy poverty (Streimikiene, 2020). These measures are frequently combined to offer a thorough understanding of energy poverty and its effects on people and communities. Siksnelyte-Butkiene et al. (2021), as mentioned to measure energy poverty, suggested the development of the concept of energy poverty in terms of limited access to modern energy services and poverty of energy expenditure. The terms "energy access poverty" and "energy expenditure poverty" are used in this approach. It has been suggested that energy access poverty is particularly evident in developing countries that have difficulty getting access to contemporary energy services. It has been highlighted that energy expenditure poverty refers to households in developed countries that struggle with high energy costs and low incomes.

From another view, the development of a set of indicators or an index that considers economic, social, and environmental factors is necessary to measure energy poverty, which is defined as a lack of sufficient options for obtaining adequate, affordable, reliable, high-quality, safe, and environmentally responsible energy services to promote the development of the economy and of people (Reddy et al., 2000). Although income, energy prices, and energy efficiency are the focus of most research, the objective indicators used to measure these factors differ significantly depending on whether developed or developing countries are being assessed. Therefore, researchers create and employ a variety of composite measures and indicator sets to better examine energy poverty. Although some are more specialized, others concentrate on certain areas of energy poverty.

Based on these approaches and insights, energy poverty measurement is a challenging issue that fluctuates with time and place. To quantify this, a variety of indexes have been created. Energy poverty indexes should consider social and environmental concerns in addition to economics. Energy poverty is a result of several factors, including an energy deficit, a lack of resources, energy consumption, energy-efficient construction or technology, the design and execution of energy poverty reduction efforts, and many more.

2.7 Repercussions of Energy Poverty

Climate change-related temperature rises are predicted to have a negative impact on a variety of outcomes. For instance, climate change brought on by global warming increases the likelihood of violent conflict (Scheffran et al., 2012), natural disasters (Benevolenza & DeRigne, 2019), crime rates (Ranson, 2014), and health consequences (Woodward et al., 2014). The impact of global warming on the phenomena of energy poverty is one outcome that receives little attention (Churchill, Smyth & Trinh, 2022).

One of the most prominent manifestations of energy poverty is spatial inequality. Energy poverty has varying effects on various groups. For instance, it is reasonable to expect that vulnerabilities will grow as a result of those who spend a lot of time at home, such as the physically disabled, the elderly, and children, as well as being prone to chronic illnesses and their inability to consume enough energy (limited/inability to meet their needs such as heating, cooking, and internet communication). In particular, low-income households usually live in less energy-efficient dwellings and use equipment that consumes more energy and costs more to operate, which makes energy inefficiency a significant factor in households experiencing energy poverty (Churchill, Smyth & Trinh, 2022). The interplay between low incomes and high energy prices is the focus of energy affordability (Farrell and Fry, 2021).

The repercussions of energy poverty are extensive and have an impact on people, communities, and nations on many different levels. Energy poverty has repercussions that can be categorized under the categories of health, economics, politics, and environment. Firstly, health is significantly impacted by the lack of access to contemporary energy resources as well as by individuals' inefficient biomass, coal or wood burning, and inadequate ventilation. There are illnesses brought on by indoor pollution, particularly in developing nations where it contributes significantly to death rates. The usage of modern energy services and income in many nations are both predicted to rise. A balance in population growth will not be attained, it is stressed if particular steps are not adopted for this development (González-Eguino, 2015).

Secondly, considering the economic consequences of energy poverty, all production and development potentials are affected. Energy poverty can exacerbate poverty by raising the cost of living because people in energy-poor communities may need to spend a significant amount of their income on energy. Also, the impact areas of the change in energy access are multifaceted. Energy poverty has wide-ranging consequences in a variety of spheres, including education, health, transportation, and communication.

Politics are the third consequence of energy poverty. Energy poverty may cause instability in politics, security issues, and environmental harm nationally. Volatile energy prices pose economic and political dangers to nations that rely largely on imported fossil fuels. Energy-intensive sectors can harm the environment by accelerating climate change and air pollution. Energy poverty can also cause social instability and migration, which can be problematic for national security.

Lastly, the acts that cause deforestation, desertification, and land degradation for energy are an interaction between energy poverty and the environment (González-Eguino, 2015). The lack of measures to protect forested areas may also jeopardize the only energy source accessible to the poor, worsening already existing energy poverty. In addition, the loss of forests will reduce their capacity to absorb CO2 and exacerbate climate change, which will be felt first and most in the poorest, most vulnerable countries that have historically contributed little no to this issue. This is true from a global perspective as well as the situation between the environment and energy (Raupach et al., 2014).

Based on these evaluations, energy poverty has broad consequences that can affect many aspects of people's life both individually and collectively, undermining both social and economic advancement. Improving the quality of life and reducing poverty, inequality, and environmental degradation depend on addressing energy poverty.

2.8 Energy Poverty and Vulnerability

Recent research on people in urban areas highlights the disparities in vulnerability caused by social and economic dynamics (Kaijser & Kronsell, 2014; Kuran et al., 2020), including wealth, ability, gender, education, health, political clout, age, physical fitness, pre-existing disabilities, residency, and social and racial marginalization (Dodman et al., 2022). All these inequalities are featured in many assessments and studies. The vulnerabilities of energy poverty are investigated within the context of this research, and an attempt is made to give a discussion on the socio-spatial context of such vulnerabilities. Therefore, the social-spatial vulnerability frameworks have been expressed as well as the vulnerabilities of energy poverty.

Vulnerability is the degree of susceptibility to stresses caused by global environmental change, which is not adequately counterbalanced by capabilities to resist negative impacts and sustain well-being (Cutter, 2003; Adger, 2006). When studying global environmental change, a social vulnerability index is a well-established method for addressing its complexity. This approach aggregates indicators in a meaningful way to determine the significance of indicators and the distribution of vulnerability (Cutter, Boruff & Shirley, 2012).

Physical structures, social processes, and institutional structures have an impact on human vulnerability (Dodman et al., 2022). There are many different vulnerabilities, risks, and effects that come along with urban processes that have an impact on poverty, livelihoods, and sustainable development. Although physical infrastructure may provide some protection from climate risks, its benefits may be limited by issues like poor adaptability, risk transfer, and unfavorable ecological effects. The global components could be utilized to direct policy mechanisms toward reducing aspects of vulnerability, such as more equitable energy-related financial mechanisms, policies catered toward individual energy-related needs, or comprehensive and equitable energy-efficiency programs (Robinson, Lindley & Bouzarovski, 2019).

Energy poverty is a condition when there is insufficient or limited access to energy as a result of various dynamics. Energy poverty vulnerabilities can be characterized under broad categories including economic, geographical, social, political, technical, and environmental. In the context of climate resilient development, it may also be framed in terms of social, economic, environmental, adaptation, and mitigation (see Revi et al., 2022). The socio-spatial vulnerability that leads to energy poverty has been focused on in the studies (Hall, Hards & Bulkeley, 2013; Bouzarovski et al., 2017; Bouzarovski & Thomson, 2018). Studies highlight the complexity of this type of vulnerability.

Concepts of justice (G. Walker & Day, 2012), capabilities (Day, Walker & Simcock, 2016), and precarity (Petrova, 2017) have been combined with vulnerability framings to open relatively small debates currently taking place in policymaking and reveal various household types and geographic areas where energy poverty is likely to manifest (Bouzarovski & Petrova, 2015). Energy poverty can be distinguished from other types of poverty since household and networked energy infrastructures play a significant role in its manifestation (Boardman, 1991).

Bouzarovski and Thomson (2018) used household-scale survey data to develop a typology of energy vulnerability at the neighborhood level, enhancing our understanding of energy vulnerability's spatial patterns. Following this realization, vulnerability to energy poverty is acknowledged as a highly socio-spatial phenomenon (Bouzarovski et al., 2017). At the same time, energy processes are one of the vulnerabilities in the scope of energy poverty. Therefore, vulnerability to domestic energy deprivation may be seen as a dispersed occurrence along the energy chain rather than a household issue (Chapman, 1989). This indicates that it is necessary to reconsider the essential principles of sustainability transition frameworks, taking into consideration location and its physical and infrastructural characteristics as contingencies deserving of specialized conceptual attention.

Despite the fact that the majority of study on energy transitions has been on decarbonizing commercial activities, more systemic changes in energy recovery and distribution patterns have historically always been linked to the formation of new patterns of socio-spatial inequality (Bridge et al., 2013). The well-being of households and local communities has been impacted by socio-spatial inequality and unequal regional and urban landscape development. Energy transitions can also negatively impact the social, economic, and political vulnerabilities of those participating in and impacted by them, including organizations working at various dimensions, from small-scale households to large governments (Bouzarovski et al., 2017). This circumstance has the potential to lead to energy poverty and its vulnerabilities from several angles.

By emphasizing the factors and risks that render a household incapable of obtaining sufficient heating, lighting, and other similar services in their home, vulnerability thinking enables the underlying causes of domestic energy poverty to be addressed (Bouzarovski & Petrova, 2015). It is not clear where the energy gap occurs and what causes it. This is because there is a complex relationship between the transition processes and the local factors that affect households. To better understand the impact of inequality on deprivation at the household level, there is a need to consider the different ways in which it is influenced by disparities that occur across various geographical scales (Bouzarovski et al., 2017).

The socio-spatial factors contribute to energy vulnerability in complex and complicated interactions. Energy poverty exists in the theoretical and political spheres that permit tracing the connection between vulnerability and energy transitions. A reasonably wide range of various socio-demographic groups are often impacted by energy poverty, particularly those who live in affordable but inefficient homes or have higher-than-average energy demands. However, energy poverty has expanded to many countries and even affects middle-class households. The above-average population percentage of those who cannot afford to heat their houses adequately or who have high housing expenditures serves as proof of this (Bouzarovski et al., 2017).

2.8.1 Vulnerabilities that Affect or Enhance Energy Poverty

Energy poverty is frequently caused by a combination of vulnerability factors. In other words, there are several vulnerabilities that might exacerbate or affect energy poverty. People who are poor or have low incomes may find it difficult to afford energy services like electricity and have limited access to energy-efficient technologies and appliances. Social injustices like gender discrimination that restrict marginalized groups from participating in energy services and decision-making processes can make energy poverty severe. Another vulnerability factor is geographical, due to their possible distance from energy infrastructure and limited access to energy services, those who live in distant or rural locations may be more vulnerable to energy poverty. Communities may become more sensitive to energy poverty and limited in their capacity to participate in the global economy if they lack access to current energy technology. Political unrest and corruption can make it more difficult to execute energy policies and initiatives to alleviate energy poverty, which can worsen the problem of energy poverty. Energy poverty may be exacerbated by natural disasters and climate change, particularly in areas that are vulnerable to extreme weather occurrences and lack the resources and infrastructure to mitigate their effects.

As it is generally understood, energy poverty is caused by the interaction and aggravation of several vulnerability factors. When addressing energy poverty, a framework should be used that considers numerous vulnerabilities that might contribute to or exacerbate energy poverty and works to lessen those vulnerabilities while enhancing positive characteristics. It also calls for a multidimensional strategy that aims to widen access to energy services, lower energy prices, and enhance energy efficiency.

2.9 Energy Poverty in Türkiye

Due to poor agricultural income and high energy prices in rural regions, energy poverty has begun to be noticed among farmers in Türkiye. With the 2008 financial crisis, the electricity poverty suffered by households that sacrifice essentials in order to pay their electricity bills became apparent (Erdogdu, 2020). The literature shows that there has not been much research on energy poverty in Türkiye. The consideration of research on energy poverty from an economic viewpoint also highlights the gaps in Turkish literature on the subject.

Using the expenditure data from the 2003 Household Budget Survey, Bagdadioglu et al. (2009) looked at the impacts of the electricity, gas, and water tariffs, which are anticipated to be cost-oriented following privatization, on the use of electricity, natural gas, and water by the poor. The study covered the many aspects of energy poverty and developed a household-level profile of energy poverty in Türkiye for both electricity and natural gas. A notable conclusion of the study is that during the pre-privatization pricing period, the percentage of electricity and natural gas expenditures in household expenditures—including those of the top 10% of poorest households—did not rise over the poverty threshold of 10%.

The economic and demographic aspects influencing Turkish families' energy usage were investigated by Ozcan et al. in 2013. The energy preferences of the households were examined in the study, which employed data from the household budget survey, and it was shown that either the monthly household income or the welfare of the household had a substantial impact on the energy preferences generally. Additionally, it has been shown that people who live in residential areas choose natural gas, whereas people who live in rural areas favor conventional fuels. It has also been found that individuals’ ages affect their energy choices.

Determinations and suggestions about energy poverty in Türkiye are presented in the World Bank's Transformation Key Stages and Challenges (2015) Report in the Turkish Energy Sector. Although it has been claimed that most Turkish energy users view high energy costs as a necessary cost of development, this does not necessarily imply that households can afford their energy bills. The report also emphasized that consumers in Türkiye who may depend on electricity for their livelihoods, such as precarious segments without a regular annual income, rural households, farmers, or small urban businesses, are more vulnerable to increases in electricity prices than consumer households countrywide.

Emec et al. (2015) used information from the 2012 Household Budget Survey to assess the disparities between rural and urban households' preferences for wood, coal, electricity, natural gas, dung, and other forms of energy in relation to household demographics. It is said that income influences, energy preferences, and low-income households are more likely to utilize conventional energy considering Türkiye's energy poverty. The studies show that people in Türkiye with low incomes prefer wood, coal, electricity, manure, and other forms of energy more than those with high incomes. When the rural-urban distinction is examined, the dominant finding is that people who live in rural areas use wood, coal, electricity, manure, and other conventional energy sources compared to those who live in cities and that they prefer natural gas. Those who lack access to contemporary energy resources due to poverty are more likely to utilize conventional biofuels, which have been shown to have several detrimental socio-economic effects. Many households still use conventional fuels like wood and coal for heating and cooking, which can negatively impact people's health and cause indoor air pollution. When the education categories are examined, it is seen that the consumption of wood and coal decreases as the education level increases compared to the primary school graduate education category.

Türkiye's energy poverty situation is particularly concerning for low-income households and rural areas. High energy expenses for households, particularly those in low-income groups, can result in energy poverty. Nearly one-fourth of Turkish households and around half of those with the lowest income levels, it has been reported, are struggling with energy poverty, according to Household Budget Surveys 2017 (Selcuk et al., 2019). Using the data obtained from the Household Budget Surveys 2003 and 2017, the housing characteristics and habits of energy-poor households in Türkiye were investigated. According to the investigation, natural gas, floor heaters, hot water, and toilets were not present in 10.3%, 63%, 11.5%, and 72% of the energy-poor households, respectively (Selcuk et al., 2019). However, there was a decline in the proportion of energy-poor households from 2003 to 2017. Despite a decrease, the energy problem among the poorest households has not been remedied.

The Turkish government has developed several projects and programs to expand access to energy and lower energy costs to combat energy poverty. To enhance the availability of low-cost and clean energy, the government, for instance, has invested in energy-saving strategies, renewable energy projects like wind and solar power, and rural electrification initiatives. Addressing energy poverty still faces several obstacles, including a lack of funding, the expense of constructing new energy infrastructure, and a shortage of contemporary energy technology, particularly for low-income homes and communities. Additionally, some places could have poor energy distribution and infrastructure, which could restrict access to energy services.

Although Türkiye has made progress in combating energy poverty, low-income households and rural areas continue to face this issue. Increasing access to contemporary energy technology, widespread use of renewable energy sources, lowering energy costs, increasing energy efficiency, and continuous efforts by the public, private, and civil society spheres are all necessary to address energy poverty in Türkiye. Nonetheless, it appears to be a generalized form of social support, with procedures intended to help underprivileged households. To combat energy poverty in Türkiye, professional organizations, and labor unions have devised a strategy that calls for an end to privatization practices and the provision of low-cost, reliable, and high-quality energy services to the overall population (Türkyılmaz, 2020).

2.9.1 Socio-spatial Vulnerability to Energy Poverty

When a household lacks access to enough home energy services (such as heating, lighting, and cooling), they cannot secure their well-being or engage in meaningful social interaction. This circumstance is known as energy poverty (Buzar, 2007). Because of its significance in the development of household and networked energy infrastructures, energy poverty varies from other types of poverty (Boardman, 1991). According to Liddell and Morris (2010), the absence of socially essential energy services has a detrimental impact on people's physical and mental health, access to education, and interpersonal connections. These outcomes might be considered signs of energy poverty. Several of these symptoms are frequent in households with weak energy sources (Clinch & Healy, 2000). With the awareness of several variables that might help the situation, determining the root causes of energy poverty is increasingly difficult (Dubois, 2012). Therefore, it is crucial to investigate the vulnerabilities that worsen Türkiye's energy poverty to comprehend the root causes of it and develop policies and actions that would help to do so.

In terms of energy poverty, the extent and magnitude of energy poverty vulnerability vary greatly across the European Union. Figure 2.4 shows the percentage of people living in energy poverty in each country based on their inability to afford basic heating at home (Belaïd, 2022). Türkiye is projected to have a high energy poverty level in 2020. It is also apparent that the bordering nations of Türkiye have a comparable degree of energy poverty. In the north of Europe, energy poverty is low.

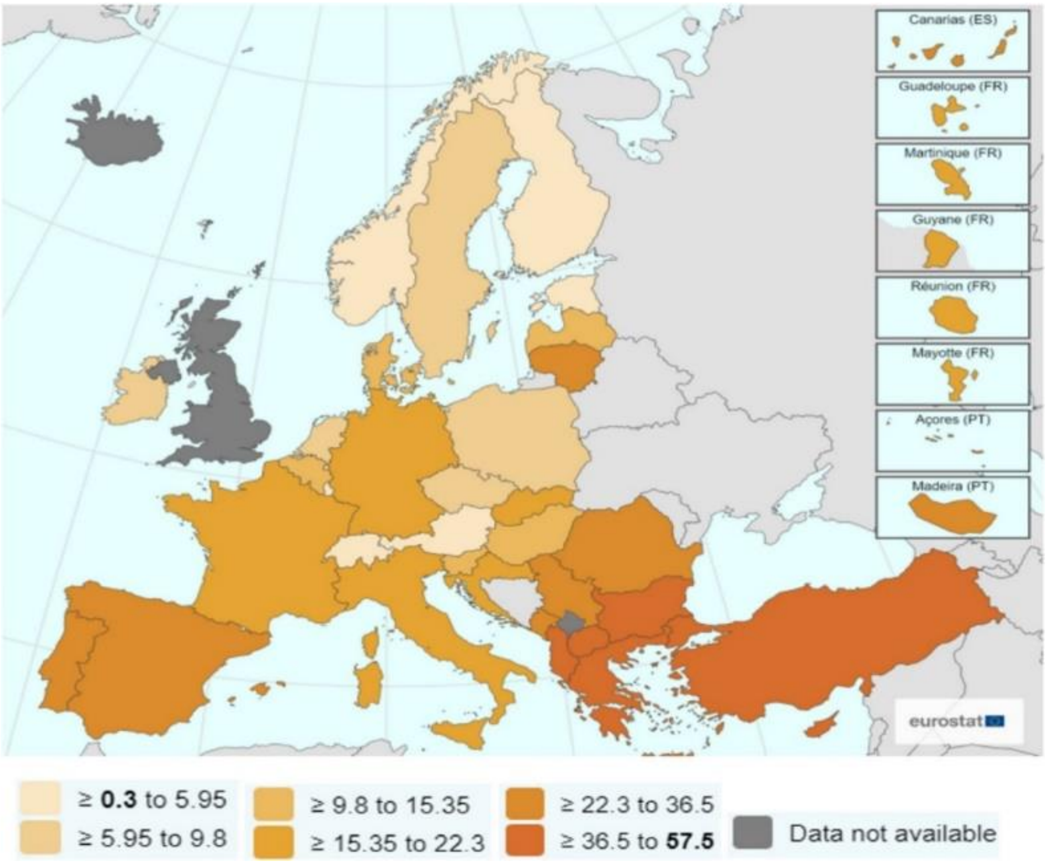

Figure 2.4. The Population at Risk of Energy Poverty in Europe in 2020. Note: Geopolitical entity (reporting)/Time: 2020 Time-frequency: Annual Type of household: Total Income situation in relation to the risk of poverty threshold: Below 60 % of median equivalized income. Unit of measure: Percentage.

The European Union (EU) is paying attention to energy poverty in this aspect. Energy poverty reduction objectives are relevant to all areas covered by the Clean

Energy for All Package, which the EU adopted in 2019 (Bouzarovski et al., 2020). Eight legislative tools are included, with a focus on energy security, building energy performance, electricity market design, energy efficiency, renewable energy sources, governance guidelines for the Energy Union, and eco-design (Belaïd, 2022). States are making efforts to address energy poverty. The most recent report from the EU Energy Poverty Observatory goes into great depth about the many policies and initiatives for reducing and alleviating energy poverty that has been enacted at the municipal, regional, and national levels throughout the EU (Bouzarovski et al., 2020). However, the present framework for policies addressing energy poverty differs greatly from one nation to another.

In Türkiye, some households are still highly energy poor even though it has decreased over time. Likewise, whereas 8.2% of people in the EU could not heat their homes effectively in 2017, this number was 22.3% in Türkiye (Koktas & Selcuk, 2018). Compared to the EU average of 8.2%, Türkiye is significantly higher. In Türkiye, the percentage of people who cannot sufficiently heat their homes reduced to 20.3% in 2021, per Eurostat data. When households with financial difficulties in paying their utility bills such as those for electricity, water, and gas are considered to be in energy poverty, the rate of these households in the EU is 8.1%, but it is 24.2% in Türkiye (Koktas & Selcuk, 2018). Therefore, Türkiye has a far higher percentage of energy-poor households than the EU average and households that have difficulty paying their bills.

As a result, examining the factor that causes or exacerbates energy poverty is required to contribute to its alleviation. It is important to look at how all these factors relate to energy poverty and to each other. These findings allow conclusions to be established regarding the energy poverty situation in Türkiye and possible solutions.

CHAPTER 3

METHODOLOGY

In this chapter, the analysis methods are introduced while it is aimed to provide a solid foundation for subsequent chapters by describing the methodology and allowing for a thorough and rigorous examination of the research questions and objectives. First, the study area is given, which aims to provide an overview of the geographical location and the context in which the research has been conducted. It is relevant to have background information about the study area to fully understand the following analysis and the findings. The next part of the methodology section describes the data. Subsequently, the research methodology is discussed.

3.1 Study Area

The research focuses on the vulnerabilities that lead to or exacerbate energy poverty in Türkiye and the research is conducted at the province level. Turkish Statistical Institute (TURKSTAT) reported that the population of Türkiye is 85 million 279 thousand 553 as to the results of the Address Based Population Registration System for 2022 (TURKSTAT, 2022). Türkiye, which accounts for 1.1% of the world's population and has a population around 85 million people, was placed 18th in terms of population size among 195 nations in 2021 (TURKSTAT, 2022). The country has a larger child population referring to those under 18 than other EU members, with the ratio of 26.9%. The ratio of young people, referring to those 15–29, is also higher than that of other EU members, with 15.3%. Elderly population referring to those over 65, on the other hand, is lower than that of the 27 EU members with the ratio of 9.7%.

The climatic conditions of various regions are determined by climate classifications. To minimize energy poverty, it is important to understand how regional climatic conditions affect energy usage, efficiency, the potential for renewable energy, and the development of infrastructure. Regarding the climate, Türkiye is located between the temperate zone and the subtropical zone. The length of the mountains, the variety of landforms, and being bordered by seas on three sides all contribute to the country's diverse climate (Sensoy et al., 2008). There are climate classifications for Türkiye using six different approaches: Aydeniz, De Martonne, Erinç, Thornthwaite, Köppen, and Köppen-Trewartha (see Appendix A). These approaches use different methodologies, but the fundamental point is that various climate conditions are present in Türkiye, depending on the location and geographic conditions of the provinces. Temperature variations have various effects on the provinces while climate change is expected to amplify these impacts. Climate change could also have various connections with energy poverty since the vulnerabilities become more critical with the climate change. Climate vulnerability and energy poverty are interdependent, therefore areas with higher degrees of vulnerability may be thought of as being more prone to energy poverty.

In general, the country has a moderate Mediterranean climate. Its diverse terrain and mountainous parts give rise to a variety of climate variants, including temperate continental, oceanic climates, and dry mid-latitude steppes (Gumus et al., 2023). The climate is warmer towards the coast, but mountainous areas like North Anatolia and the Taurus Mountains lie parallel to the sea, blocking the spread of marine effects inland (Oruc, 2022). Due to this, the interior region has little rainfall and continental climate conditions, with cold winters and hot, dry summers (Amjad et al., 2020).

Regarding the expected change in climate in Türkiye, climate change projections based on multiple models are being employed. At this point, the forecast issued as part of the Eighth National Communication and Fifth Biennial Report of Türkiye Under the UNFCCC was discussed. The transition from the 2021-2100 projection period to the 1971-2000 reference period was examined, under two different scenarios which is RCP4.5 and RCP8.5 (UNFCC, 2023).

The Representative Concentration Pathways (RCPs) are different scenarios used in climate models to predict future concentrations of greenhouse gases and their impact on the Earth's climate. The radiative forcing will rise by a target amount by 2100 compared to pre-industrial levels at the quantities of greenhouse gases specified by RCPs. The difference between the radiation entering the atmosphere and the radiation leaving it is known as total radiative forcing. The RCPs, RCP2.6, RCP4.5, RCP6.0, and RCP8.5, are named after the respective radiative forcing targets for 2100, which are 2.6, 4.5, 6.0, and 8.5 watts per square meter (W m-2) to cover a broad range of possible future emissions scenarios. For the 21st century, the global mean temperature rises that arise from each pathway fall into distinct ranges.

RCP 8.5 is frequently regarded as the most severe. A scenario characterized by unchecked increases in greenhouse gas emissions throughout the 21st century is represented by RCP 8.5. It assumes that there won't be any major attempts to reduce emissions, which will lead to heavy reliance on fossil fuels and sharp rises in atmospheric CO2 concentrations. Compared to the other RCP scenarios, this pathway results in more severe consequences on ecosystems, sea levels, and weather patterns as well as considerable global warming and climatic changes. Because of its predictions about continuously growing emissions, RCP 8.5 is frequently described as the most extreme, even though it's important to remember that all RCPs indicate conceivable but diverse futures.

The average temperature in coastal areas ranges from 14°C to 19°C, while the Marmara Region has an average temperature of 12°C. Eastern regions experience a decrease to 2°C, with the Mediterranean Region experiencing the highest average temperature of 20°C (Figure 3.1.a). By the end of the century, the RCP4.5 scenario predicts an increase in average temperature values of around 2.5°C in the eastern half of the nation and at least 1°C in the remaining part (Figure 3.1.b). According to the RCP8.5 scenario, Türkiye’s average temperature is projected to rise by around 2.5°C until the 2060s, and by the end of the century, it will have risen by more than 5°C. The Marmara Region is predicted to get warmer by at least 3°C and the Eastern

Anatolia Region by nearly 5°C for the years 2081-2100 (Figure 3.1.c) (UNFCC, 2023).

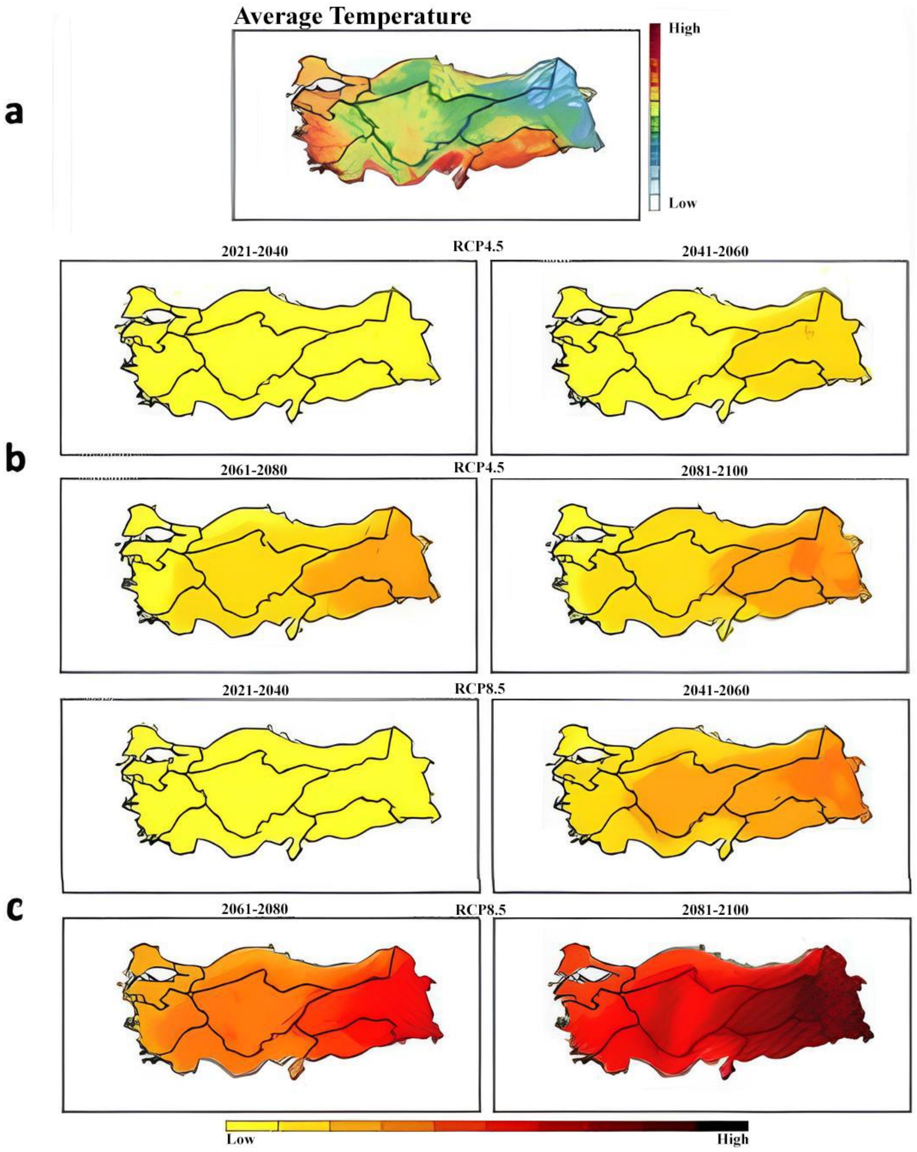

Figure 3.1. Average Temperature (a) in the Reference Period with Changes in RCP4.5 Scenario (b) and RCP8.5 Scenario (c)

The overall amount of precipitation in Türkiye is predicted to rise in the north while falling significantly in the south, which includes the Aegean and Mediterranean, in the future (Figure 3.2.d) (UNFCC, 2023). Despite identical distribution patterns, significant precipitation changes occurred in both scenarios. The RCP4.5 scenario predicts an average increase of 50 mm in Marmara and Black Sea regions, while in the Mediterranean region, there is a drop of 200 mm between 2061 and 2080 (Figure 3.2.e). According to the RCP8.5 scenario, precipitation would fluctuate between -100 and +100 mm until the 2060s, with the Black Sea Region expected to experience an increase of 150 mm over the reference period and the Mediterranean Region forecast to have a reduction of 300 mm (Figure 3.2.f) (UNFCC, 2023).

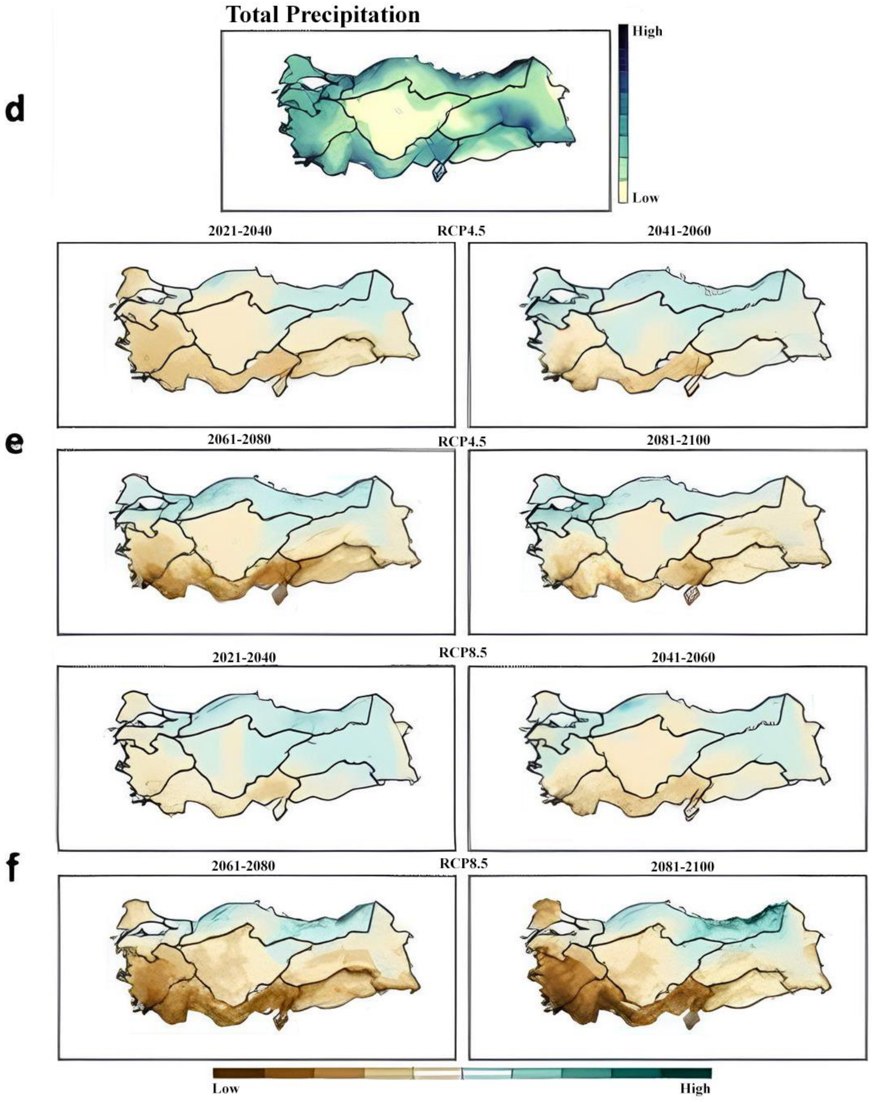

Figure 3.2. Total Precipitation (d) in the Reference Period with Changes in RCP4.5 Scenario (e) and RCP8.5 Scenario (f)

3.2 Data

Based on the intentions of this research, social, economic, physical, and geographic aspects are investigated to understand the socio-spatial distribution of energy poverty. This study attempts to outline the socio-economic and physical variables that affect energy vulnerability and show the spatial distribution of vulnerabilities. A vulnerability index can be used to examine the socio-spatial distribution of vulnerability at local or regional scales. Since the level of vulnerability to energy poverty that a household experiences varies socially and geographically.

A household utilizes multidimensional indicators as proof of several vulnerabilities (Dubois, 2012; Bouzarovski & Petrova, 2015; Middlemiss & Gillard, 2015) that raise the possibility of falling into energy poverty (Fahmy, Gordon & Patsios, 2011; Liddell et al., 2012; Walker et al., 2012). It can be difficult to arrange, examine, and visualize these indicators. An established method for addressing this multidimensionality in the study of global environmental change is the social vulnerability indicator, which integrates indicators in a meaningful way to examine their weighting factor and the distribution of vulnerability (Cutter, Boruff, & Shirley, 2003). In these indicators, vulnerability is frequently characterized as a mix of social and geographic inequalities to challenge the notion that everyone is equally vulnerable. This allows for comprehension of the socio-spatial distribution of vulnerability (Robinson, Bouzarovski & Lindley, 2018). To reach the aim of the thesis and to maintain the compatibility of different data sources, the most recent available data at the province level has been used in the analysis.

3.2.1 Vulnerability Factors of Energy Poverty in Türkiye

The vulnerability factors that can be relevant for Türkiye are presented in this part by giving the energy poverty variables that were produced in accordance with the literature review. The scope of this review included 15 vulnerability factors for Türkiye. The next paragraphs offer insights into these vulnerability factors.

Age Risk Group

Energy poverty is a problem that is especially prevalent in the life and living situations of elderly people and young children, owing to their sensitivity to health impacts. Certain aging-related factors necessitate adjusting the temperature (Day & Hitchings, 2011). The often-used illustration shows an old individual using inefficient or useless heating equipment to attempt to stay warm in a poorly insulated home. Nonetheless, it is a circumstance where elderly persons with limited incomes who live in their own homes, outside of institutional shelters, struggle to pay their energy costs and may be more vulnerable to possible detrimental health and wellbeing issues (Chard & Walker, 2016). A growing body of research addresses older people's perceptions and experiences (Middlemiss & Gillard, 2015). To date, research on energy poverty and older people has heavily focused on patterns of death and illness (Healy & Clinch, 2004; Rudge & Gilchrist, 2005). Discussing the diverse viewpoints and opinions of people who have encountered various difficulties is crucial (Chard & Walker, 2016).

Similar to the elderly, areas with a greater percentage of children under the age of four may be predicted to have a high vulnerability to energy poverty due to factors like the length of time spent at home, the amount of energy used to meet children's physical needs, and the requirement for domestic heating due to climate. Few studies have particularly looked at the effects of energy poverty on children (O'Sullivan et al., 2016).

The requirement for energy consumption would likely be significant in provinces with a high proportion of elderly households and young children due to the duration of homestays and age-related health issues. It can be expected that the households will not be able to meet their energy needs in sufficient amounts in relation to their income level. To continue living in a way that tries to deal with the ongoing concerns about energy costs and the converging dynamics of many physical, social, economic, and climatic aspects, the need to be warm and comfortable should be determined (Harrison & Popke, 2013).

Lone Parent

Certain households, such as those with elderly residents or families with small children, use more energy than others because of the length of time it takes to heat the home or the requirement for higher temperatures. Heating expenses can be disproportionately expensive for some homes, such as those with a single adult because they might be borne by just one person. However, according to broad studies on poverty and deprivation, some households experience significant financial challenges (Healy & Clinch, 2004).

Lone-parent households may find it more challenging to accurately depict the intricacies of hardship since they are more likely to struggle to balance work and childcare (Gingerbread, 2013). It may go unrecognized because these vulnerabilities are underrepresented, expenditure is the primary emphasis of existing indicators, and infrastructure efficiency, availability, flexibility, and complicated socio-spatial distributions for various family requirements are all important factors. Several elements affect the likelihood that particular family types may experience energy poverty.

Unemployment

Energy accessibility and affordability are directly impacted by unemployment since it essentially makes it impossible to meet requirements for energy on a financial level. It is anticipated to establish crucial connections between the vulnerabilities to energy poverty. It makes sense to predict a connection between unemployment and vulnerability to energy poverty (Healy & Clinch, 2004).

The capacity of energy vulnerability to lessen its own vulnerabilities is restricted. Due to low or inconsistent income, households in crisis may benefit from financial security, independence, and flexibility opportunities. Changing how money is distributed can be uncomfortable and disempowering because there are few employment possibilities, and households cannot manage their money. While some households maintain strict financial discipline, others may tend to spend less prudently as independence rises (Middlemiss & Gillard, 2015).

Full-time Student

Young adults are at risk of experiencing energy poverty owing to low-income and energy-inefficient homes, but there is no concrete evidence of the prevalence of this problem (Petrova, 2018). It has been noticed that occasionally only students and young adults experience short-term energy poverty (Baker, Starling & Gordon, 2003). Healy and Clinch (2004) question the notion that domestic energy poverty among young adults, including students, is of a transient nature and that chronic energy poverty among students is most likely caused by the high proportions of them who live away from home on low incomes and in inadequate housing.

It is also recognized that young adults value non-heating energy services more than other age groups, especially access to communication and information technology (Petrova, 2018). Contrary to popular belief, which holds that young adults are more resilient to substandard housing conditions because of their more active lifestyles, thermal comfort research has also demonstrated that the indoor environments that young adults require and inhabit are similar to those that characterize other groups in society (Ormandy & Ezratty, 2012). For this reason, it is important to comprehend the potential for young adults to organize around the problem of energy poverty. Young adults, particularly students, have frequently been accused of not knowing enough about energy-related concerns, particularly home efficiency measures (Clugston & Calder, 1999).

Shared Property

Children, the elderly, those with disabilities, and people who have chronic illnesses are at risk of energy poverty, according to the discourse on energy poverty (Hills, 2012). Such common depictions of the energy poor have an impact on culture. Youth and students, who frequently reside in shared property but are seldom seen as a vulnerable group to energy poverty, also suffer from high levels of deprivation (Bouzarovski et al., 2013). The same appears to be true for immigrants, the homeless, and refugees.

Compared to single-family households, shared tenants sometimes have less control over essential energy services like heating and hot water. Energy vulnerability in shared properties is made worse by societal preferences for conventional single-family houses, pervasive tenure bias based on negative perceptions about shared properties, and a lack of representation and acknowledgment of housing in multiple occupancies in official systems and information on the housing stock (Cauvain & Bouzarovski, 2016).

Large Household Size

Chronic energy-poverty households are those that are energy-poor and have four or more dependents. A relatively high percentage of households with four or more dependent children experience persistent energy poverty (Healy & Clinch, 2004). This demonstrates the ongoing difficulty large families have had heating their houses effectively. This conclusion is concerning because children are more vulnerable to the adverse health impacts of exposure to cold and humidity.

Private Renting

In many countries around the globe, including the UK, the private rental sector has some of the lowest quality and less energy-efficient houses. In comparison to other forms of hosting, it also accommodates more vulnerable households (Ambrose, 2015). Due to landlords' lack of motivation to improve the energy efficiency of their properties, private renters, who are frequently low-income, are seen as being particularly vulnerable (Walker & Day, 2012). Residents of such buildings experience energy poverty and dangerously cold house, but they have little direct influence over how energy-efficient their dwellings are. For fear of higher rent or dispossession, households may be reluctant to request property improvements.

Central Heating

According to Eyre (2001), central heating frequently causes an increase in average indoor temperatures. Customers have been shown to utilize less efficient or more expensive methods to heat their homes as a result of the lack of heating fuel alternatives (Burholt & Windle, 2006). According to legislation governing residential and domestic energy supply, subgroups of houses that rely on district or central heating and do not have individual consumption meters are not included in the reported metrics (Herrero, 2017). It is important because studies looking at how energy poverty is affected do not include central heating.

Energy-inefficient Property

Throughout all tenures, households that are energy poor are more likely to live in inefficient properties (Stockton & Campbell, 2011). According to Boardman (1991), the most significant causes of energy poverty are energy-inefficient buildings and heating systems. Therefore, policies to combat energy poverty have mostly concentrated on giving individuals who are at risk of becoming energy-poor more resources to pay their energy bills, such as winter fuel subsidies, and increasing the energy efficiency of homes and heating systems (Walker, 2008).

Due to structural problems in the homes, there is a rise in the requirement for energy consumption, but this condition also pulls households into energy poverty. The age and duration of a home's usage are strongly correlated with its energy efficiency (Dowson et al., 2012). Researchers contend that older buildings often have lower energy efficiency and are more challenging to heat efficiently during cold weather (Wright, 2004). In addition, a chance to lower CO2 emissions is provided by improving the energy efficiency of residential structures.

Climate Exposure

Severe weather events significantly impact urban residents' quality of life, energy use, and health (Santamouris & Kolokotsa, 2015). The quality of life is also seriously impacted by energy poverty. It is acknowledged that the low-income and vulnerable inhabitants of cities are strongly affected by local climatic phenomena like the urban heat island (Beg et al, 2002). Many studies evaluate the effects of extreme weather on energy use, global environmental quality, and the health of low-income communities (Santamouris et al., 2014). According to an analysis of the current situation in Europe, a sizable portion of the population has energy, environmental, and health issues that are closely tied to interior circumstances as well as the worsening of weather conditions as a result of climate change (Santamouris & Kolokotsa, 2015).

Understanding the intensity of the heat or cold in a city might help determine when households need to use more energy for heating or cooling. Degree days are a metric for measuring how hot or cold a place is and how much of a 24-hour period is hot and how much is cold (U.S. Energy Information Administration, 2022). Compares the measured high and low average outside temperatures for a place during a degree day to a reference value. The number of graded days increases as the outdoor temperature becomes more intense. Increased energy demand for room heating or cooling is frequently a result of warmer days.

The two types of degree days are heating and cooling. Heating Degree Days (HDD) consider both the indoor and external temperatures at a specific moment to determine the degree of cold. Cooling Degree Days (CDD) consider the outside temperature at a certain moment when describing the severity of the temperature. Even though there is no threshold temperature that has been formally established, the building industry's energy management procedures consider 22°C as the threshold temperature. When calculating the amount of energy needed to heat or cool a structure, it is vital to know the total number of heating or cooling days. Heating is not essential if the outside temperature is higher than 15°C. Turkish State Meteorological Service is calculated over 18°C in HDD calculation. The yearly HDD directly relates to the cost of heating. For this, the annual HDD is multiplied by the fuel cost per year, and the heating cost for one HDD is subtracted (Sensoy et al., 2007). This index is applied to subsequent calculations. HDD is also used to assess how severe this winter has been in comparison to previous and prolonged years. While constructing new structures, the construction sector also uses HDD as a criterion to estimate insulation, heating, and cooling expenses.

Internet

There is a need to investigate if the growth of the internet helps reduce energy poverty in the context of the internet and energy. The Internet's favorable effects on the supply chain of the energy industry are a direct result of its development's effects on energy poverty (Zhang, Yang & Feng, 2023). The Internet enhances each energy subsystem's input and output information interaction in terms of energy supply, accomplishes dynamic energy control, and promotes high-speed energy information flow. It also helps in the coordination and integration of the whole energy system, as well as in the efficient use of energy resources (Iqbal et al., 2018).

Connection types that offer fast internet access, such as DSL or cable, are commonly referred to as broadband connections. It has been tried to comment on the effect of broadband internet subscriptions on energy poverty by constituting the ratio of broadband internet subscriptions to population. The reason for this, energy poverty can be reduced with the growth of the Internet. The Internet may increase energy affordability by fostering technical and economic development. Promoting technical advancements and raising general awareness, also contributes to increasing the availability of energy, and the growth of the Internet has nonlinear and regionally varied impacts on the reduction of energy poverty (Zhang, Yang & Feng, 2023).

Natural Gas Network Access

Being disconnected from the gas grid is another significant risk factor for energy poverty since households without gas are forced to utilize more expensive fuels. For this reason, the issue worsens as settlements spread out and houses constructed outside the gas grid become considerably more common in rural regions than urban ones (Baker, White & Preston, 2008).

Household Disposable Income

Energy poverty is a diverse experience influenced by expenses, income, housing, and personal and societal circumstances (Meyer et al., 2018). Energy poverty can be decreased by determining the maximum income that can reasonably be set aside for energy expenses (González-Eguino, 2015). Therefore, one of the key vulnerability variables impacting energy poverty is the level of disposable income in a household.

Household disposable income is determined as the sum of the individual disposable incomes of all household members (total of the income in cash or in kind such as salary-wage, daily wage, enterprises income, pension, widowed-orphan salary, old-age salary, unpaid grants, etc.), adding the total yearly income for the household (such as real property income, unreturned benefits, incomes gained by household members less than age 15, etc.) and deducting taxes paid during the reference period of income and regular transfers to other families or individuals.

Refugees

The research that already exists on energy access emphasizes energy deprivation on a regional or national level but frequently ignores groups like refugees and displaced people (Lehne et al., 2016). To increase energy access for refugees and displaced people and to acknowledge energy as a crucial priority in humanitarian operations, a solid humanitarian, economic, and environmental situation is needed (Lahn & Grafham, 2015). Despite the SDGs' commitment to leaving no one behind, it may be argued that refugees and displaced individuals are among those who have been most neglected in terms of energy.

In Türkiye, there are numerous refugees from Syria who have temporary protection status. Additionally, it is known that many Afghans and other ethnicities have irregular migration records. These groups are not included in the migration statistics. For this reason, the situation of Syrians in Türkiye along with migration has been evaluated in the study, because the increase in the number of households increases the energy demand and puts pressure on the system in many social, economic, environmental, and political aspects.

Migration

Migration between and within districts among various ethnic groups has the potential to reduce energy poverty by improving employment and income prospects. Depending on existing levels of energy poverty, the type of migration, the technology transfer from migrants, or the degree to which the host community can adjust to the new racial groupings, the impact of ethnic diversity on energy poverty might vary across various racial groups (Koomson, Afoakwah & Ampofo, 2022).

3.2.2 Indicators of Socio-spatial Vulnerability to Energy Poverty

The socio-spatial vulnerability factors that constitute the index represent the aspects of a household that either strengthen or weaken its ability to withstand a loss of well-being and the indicator data sets represent each vulnerability factor and offer quantifiable data (Table 3.1). Based on a study of the literature on energy poverty research, the vulnerability factors and indicator data sets were prepared. More than one indicator data set may be linked with a vulnerability factor.

Table 3.1. Indicators and Vulnerability Factors

Indicator	**Associated vulnerability factors** (Extracted from Robinson et al., 2018.)
Age risk group (older old and young children)	Lack of availability to appropriate fuel types, inability to effectively make use of new technology, caregiving responsibilities for dependents, high energy consumption per person, physiological demand for energy services; spending a significant amount of time at home; harmful warmth-related behaviors, a lack of understanding of available help, having a not much control and choice over everyday activities, a reduction in energy service autonomy, a lack of social connections within and outside of the house, and living alone; underrepresentation or misrepresentation in policymaking
Lone parent	Depending on a single payment; part-time or unstable work, dependent on a low income; providing unpaid care for dependents; understating or misrepresenting policies; spending a considerable percentage of time at home; lack of choice and control over regular activities
Unemployment	Dependent on a limited income, unemployed, and unable to make investments in energy efficiency
Full-time student	Low-income dependence, difficulty to switch to a more affordable plan, and incapacity to make investments in energy efficiency measures
Shared property	Reduced autonomy over energy services, restricted availability of energy-efficiency measures, and inability to invest in energy-efficiency measures
Large household size	Large household size
Private renting	Lack of housing rights, unstable living situations, the cost of owner-occupation, restricted availability of efficiency solutions, incapacity to invest in energy efficiency, limited autonomy over energy services, and under- or misrepresentation of policy
Central heating	Inadequate access to the right fuel types and ineffective appliance energy conversion

Table 3.1 (cont'd)

Energy-inefficient property	Energy-inefficient property
Climatic exposure	Low or high outdoor temperature
Internet	Lack of coordination and integration of the entire energy system, lack of technological advances and general awareness
Natural gas network access	Incapacity to switch to a more affordable tariff or obtain the right fuel types
Household Disposable Income	Low income, dependent on a limited income, ineligible for financial support for heating or cooling, unemployed, and unable to make investments in energy efficiency
Refugees	Precarious living arrangements, unemployed, lack of housing rights, under or misrepresentation of policy
Migration	Lack of housing rights, unstable living situations, under or misrepresentation of policy

Provincial-based energy poverty estimates are intended to be made by looking at various socio-economic, demographic, and socio-technical variables to investigate where and to what extent current energy poverty indicators reflect the socio-spatial distribution of vulnerabilities associated with a lack of adequate energy.

This study has constructed a vulnerability index to comprehend the socio-spatial distribution of vulnerability at a provincial scale. The impact that place has on this kind of deprivation is highlighted by vulnerability thinking, yet efforts to address energy poverty policies and assess the phenomena seldom take place with any appreciation for the significance of place (Robinson, Bouzarovski & Lindley, 2018).

In research, vulnerability indexes frequently employ principal component analysis (PCA), a statistical technique that divides a large, multivariate collection of vulnerability indicators into principal components. This allows for the evaluation of differential vulnerability between small areas (Jolliffe, 1986). The vulnerability indicator data sets and their specifics are listed in Table 3.2. In PCA, these data sets are provided. The indicators presented here were developed as a consequence of literature research. At the same time, efforts were made to take attention to Türkiye's potential vulnerabilities to energy poverty. On a provincial level, indicator data sets were gathered from several sources. The indicators have been retrieved for the 81 provinces of Türkiye for the most recent data.

Table 3.2. Information on Indicator Data Sets

Indicator	**Reference**	**Indicator data set**	**Retrieved from**	**Year**
Age risk group (older old and young children)	Healy & Clinch, (2004), Chard &Walker (2016); O'Sullivan et al. (2016)	Households with at least one elder person (age 65 or older); Households with children (4 years or below)	Number of households that the elderly population resides in by province and type of household – TurkStat ; Child population by provinces and age group - TurkStat	2021
Lone parent	Healy & Clinch (2004), Gingerbread (2013)	Lone parents with at least one resident child	Number of one-family households by type and provinces – TurkStat	2021
Unemployment	Healy &Clinch (2004), Middlemiss & Gillard (2015)	Unemployment (over 15 years)	İŞKUR (Turkish Employment Agency)	2021
Full-time student	Healy &Clinch (2004), Ormandy & Ezratty (2012), Petrova (2018)	Students ((Preschool (57 months or older), Primary School, Middle School, High School)	National Education Statistics - Strategy Development Department (2021-2022 academic year)	2021
Shared property	Cauvain & Bouzarovski (2016)	Multi-person no-family households	Number of households by type and provinces - TurkStat	2021

Table 3.2 (cont’d)

Large household size	Healy & Clinch (2004)	Extended-family households	Number of households by type and provinces - TurkStat	2021
Private renting	Walker & Day (2012), Ambrose (2015), Middlemiss & Gillard (2015)	Private renting	Households by provinces and ownership status of the dwelling - TurkStat	2021
Central heating	Burholt & Windle (2006)	Households with central heating	Number and proportion of households by provinces and main type of heating system in the residential dwelling - TurkStat	2021
Energy-inefficient property	Walker (2008), Stockton & Campbell (2011), Dowson et al. (2012)	Households residing in dwellings constructed in 2000 and before	Number and proportion of households by provinces and construction year of the residential building - TurkStat	2021
Climatic exposure	Santamouris et al. (2014), Santamouris & Kolokotsa (2015)	Annual heating/cooling energy requirement of the building (Heating degree days (HDD) & Cooling degree days (CDD))	TSMS (Turkish State Meteorological Service)	2021
Internet	Zhang, Yang & Feng (2023)	Broadband Subscriptions (Internet)	Information Technologies and Communications Authority, 2016-2021 Annual Provincial Statistics	2021
Natural gas network access	Baker, White & Preston (2008)	Active natural gas users	GAZBIR (Natural Gas Distribution Companies Association of Türkiye)	2021
Household Disposable Income	González-Eguino (2015), Herrero (2017), Meyer et al. (2018), Dong et al. (2022)	Distribution of Annual Household Disposable Income (Average, TL)	TurkStat	2021

Table 3.2 (cont’d)

Refugees	Lahn & Grafham (2015), Lehne et al. (2016)	Syrian Refugees in the scope of temporary protection	Presidency of Migration Management	2023
Migration	Koomson, Afoakwah & Ampofo (2022)	The population migrating to Türkiye from abroad (2016-2021) (to reside in Türkiye)	TurkStat	2021

All these factors influence the probability of certain household groups’ likelihood of experiencing energy poverty (Table 3.2). The analysis in this section examines various household types and individuals based on variables associated with energy poverty. Table 3.3 represents descriptive statistics of the indicators. This table includes the minimum, maximum, sum, and mean of the data obtained and the standard deviation values. To standardize the indicator data, first, the percentage of the data was obtained (dividing the household number by the total number of provincial households’ number and the population number by the total provincial population number), and the ratio of the indicators at the province level was obtained. Then, by standardizing the percentage data obtained by dividing the difference between the desired value and the arithmetic mean by its standard deviation, the relationships between the indicators were examined accurately and comparably.

Table 3.3. Descriptive Statistics of Indicators

Indicator	**N**	**Min.**	**Max.**	**Sum**	**Mean**	**Std. Deviation**
Age risk group (# households)	81	17240	3035145	17586807	217121	374482,76
Lone parent (# households)	81	1929	488938	2549400	31474	61078,66
Unemployment (# person)	81	3276	460892	3171600	39155	58262,81

Table 3.3 (cont’d)

Full-time student (# person)	81	10900	3414035	19155571	236488	418704,96
Shared property (# households)	81	648	262236	798990	9864	30016,54
Large household size (# households)	81	3284	652823	3425631	42291	77532,00
Private renting (# households)	81	4706	1763740	6991721	86317	208901,13
Central heating (# households)	81	10041	4225864	14912298	184102	505806,73
Energy-inefficient property (# households)	81	10212	2244109	11014397	135980	270739,68
Climatic exposure (# degree days)	81	1260	4505	192741	2379	654,73
Internet (# person)	81	69179	21498280	88139504	1088142	2519105,27
Natural gas network access (# person)	81	0	15650000	55670000	687283	1854595,65
Household disposable income (Annual average, TL)	81	53314	105132	5320935	65690	9490,25
Refugees (# person)	81	46	531381	3350971	41370	98030,34
Migration (# person)	81	715	1250783	3181962	39283	142408,57

3.3 Method

The data analysis includes mixed methods covering correlation analysis, PCA and visualization in terms of thematic mapping and generating 2D and 3D graphs. Regarding methodology, vulnerability indices frequently use principal component analysis (PCA), a statistical technique that allows for the assessment of relative vulnerability between small domains by condensing a large, multivariate set of vulnerability indicators into principal components (Jolliffe, 1986). Due to this, a study within the scope of this research is attempted to be conducted in a way that includes Türkiye using a method and framework similar to those used by Robinson, Lindley, and Bouzarovski (2019). With this research, it is intended to learn more about the situation in a variety of geographic areas that are vulnerable to energy poverty, as well as the vulnerabilities that practitioners and policymakers frequently conceal while addressing energy poverty (Buzar, 2007).

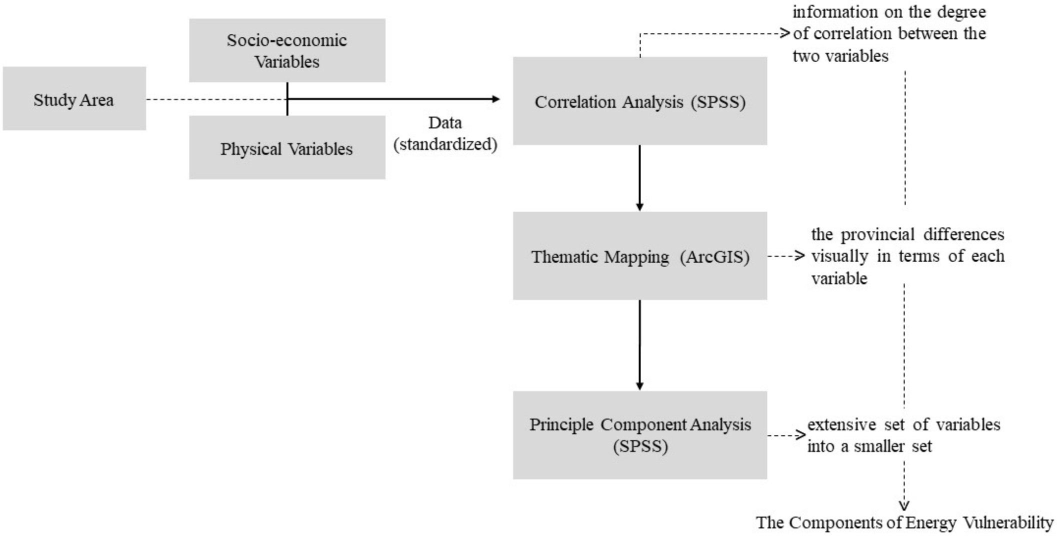

Figure 3.3. Summary of The Method

3.3.1 Correlation Analysis

A measure of the relationship between two variables is correlation analysis (Nelson, Christopher & Milton, 2022). It provides information on the degree of correlation between the two variables. The correlation could be either positive (+) or negative (-). Perfect positive correlation between the variables exists when the correlation coefficient is equal to 1; perfect negative correlation between the variables exists when the correlation coefficient is equal to -1. If the value is more than 0.5, the variables are strongly correlated. The association is moderate if the value is equal to 0.5. If the value is less than 0.5, the variables are weak correlated. The correlation is highly weak if the value is less than zero.

The strength and significance of the association are examined in correlation analysis (Nelson, Christopher & Milton, 2022). The two variables are said to be traveling in opposite directions if the correlation coefficient is negative: as one variable rises, another falls. The assumption is that the two variables are going in the same direction if the correlation coefficient is positive: if one variable rises, the other rises as well.

There is a clear relationship between the correlation coefficient (r) and the coefficient of determination (R^2). If R^2 is expressed in decimal, taking the square root of R^2 is what is required for obtaining r. The predicted slope coefficient b_1's sign determines the sign of r. r takes a negative sign if b_1 is negative. r takes a positive sign if b_1 is positive. r and the estimated slope always have the same sign. Moreover, r is always a value between -1 and 1, since R^2 is always a number between 0 and 1. r has the benefit of being unitless, which enables researchers to interpret correlation coefficients determined using various data sets and units. The correlation coefficient r is a function of the estimated slope coefficient b_1, as demonstrated by the formula for r that it may encounter in the regression literature: $r = \left[\sqrt{\sum_{i=1}^{n}(xi - x)^2} \big/ \sqrt{\sum_{i=1}^{n}(yi - y)^2}\right] \times b_1$

3.3.2 Principle Component Analysis (PCA)

PCA is the technique for data exploration and analysis (Jolliffe, 1986). It is a technique used to reduce the number of variables in huge datasets. In other terms, it is one technique for size reduction. It does this by simplifying an extensive set of variables into a smaller set that contains the majority of the information in the larger set. The aim is to decrease the dimensionality of the dataset while preserving the variability information from high-dimensional datasets. PCA is very helpful when the data are large, big, and strongly related. With such high-dimensional data, the objective is to construct a condensed feature set that accurately reproduces the original data in a lower-dimensional subspace (Kherif & Latypova, 2020). In essence, PCA is a technique for minimizing the number of variables in a data collection while retaining as much data as feasible and increasing the interpretative capacity.

A huge multivariate collection of vulnerability components is condensed using PCA into a smaller number of principal components while preserving important statistical data and spatial patterns (Jolliffe, 1986). In this study, each vulnerability indicator in the input data set has a loading value for the components. Loadings provide details on the pattern of vulnerability within the data set that each component is likely to reflect by describing the kind (negative or positive) and strength of the link between an indicator and a principal component (Robinson, Lindley & Bouzarovski, 2019).

PCA is an important tool used in various fields. First, it makes it easier to analyze high-dimensional data sets and retain the majority of the crucial information by lowering the size of the data collection. With its robustness property, PCA can eliminate noise in data and insignificant variance, resulting in a more focused and clear data representation without loss of information. The variability in the data and the connections between the variables can both be shown through PCA. The main components of the data can be used to understand how different variables are connected to each other.

In this study, PCA is utilized to demonstrate the basic components of energy vulnerability among several socio-economic, physical, and climatic variables. The vulnerabilities can contribute to energy poverty positively or negatively. First, energy poverty has been thoroughly examined and energy vulnerabilities have been investigated. Accordingly, fifteen vulnerability factors were identified within the scope of the research, based on the literature survey. Data on these vulnerability factors were obtained at province level. Data were standardized and different units were structured to ensure straightforward interpretations of the results and contribution of each variable equally to the analysis. As a standardization method "$z = (x-\mu)/\sigma$" formula was used. x is the observation (a specific value that you are calculating the z-score for). Mu(μ) is the mean. Sigma(σ) is the standard deviation. PCA is sensitive to the variances of the initial variables, which is why standardization is essential before PCA. Variables with larger ranges will take precedence over those that have smaller ranges if there are significant variations in the ranges of the initial variables, which would also lead to biased results and standardization would prevent such potential biases. After standardizing the data, correlation analysis was applied to reveal whether there is a relationship between two or more variables, and if there is, the severity of this relationship.

Examining the basic approach of PCA as an exploratory data analysis tool, a dataset with observations on p number variables for each of n entities or individuals is the typical setting (Jolliffe & Cadima 2016). These data values create n × p data matrix X, whose j^{th} column is the vector x_j of observations on the j^{th} variable, or alternatively, p n-dimensional vectors $x_1, \ldots, x_p$. The columns of matrix X with the greatest variance are combined linearly.

Data standardization, covariance matrix computation, eigenvalue and eigenvector determination, principal component selection, and data projection onto the new subspace are all crucial phases in the PCA process (Jolliffe & Cadima 2016). To make sure that each feature contributes proportionately to the analysis, the input data is first standardized.

The covariance matrix is calculated using the formula $\mathrm{Cov}(X)= \frac{1}{n-1} X^T X$, where X represents the standardized data matrix and X^T denotes the transpose of X. The covariance matrix is then used to determine the eigenvalues and matching eigenvectors. Consider the covariance matrix's $V_1, V_2, \ldots, V_p$ eigenvectors to be the appropriate eigenvalues, $\lambda_1, \lambda_2, \ldots, \lambda_p$. Larger eigenvalues are indicative of more variance in the data, and these eigenvectors, which represent the primary components, are chosen according to their corresponding eigenvalues.

The original data can be projected into the newly formed subspace using the chosen primary components, grouped in a matrix V_k, which helps reduce dimensionality while maintaining the most crucial information. In exploratory data analysis and pattern detection, the methodical PCA procedure is a potent tool that promotes a deeper comprehension of complex datasets. Using the formula PCA = X × V_k, where PCA stands for the matrix of principal components, the original data is projected onto the subspace specified by the chosen principal components (Jolliffe & Cadima 2016). This procedure makes it possible to reduce the dimensionality of the data while keeping the important information.

3.3.3 Visual Representation

Visual demonstration of the findings makes the spatial and conceptual inferences more practical. Thus, thematic mapping and graphical representation techniques have been utilized.

3.3.3.1 Mapping of the Vulnerability Factors

The spatial distribution of the fifteen vulnerability factors was shown using data mapping techniques. Thematic maps have been created based on five classes using the Natural Breaks (Jenks) method. Natural Breaks provide a relevant data classification method since its algorithm works in a way that “class breaks are created in a way that best groups similar values together and maximizes the differences between classes.” (Data Classification methods- ArcGIS Pro| Documentation, n.d.). As indicated in North (2009), the natural breaks, as a standard algorithm, tends to divide the dataset into a pre-determined number of homogeneous classes. Mapping would help to demonstrate the provincial differences visually in terms of each variable.

3.3.3.2 Graphical Representation

Distribution of vulnerability factors among each province in terms of the impact level of the related variable have been demonstrated by radar charts, to make the most prominent variables increasing or decreasing the energy poverty vulnerability more comprehendible and comparable. The loadings of vulnerability indicators on components and the rate of their contribution have been represented graphically as well. Percent contribution of the provinces to each component has also been calculated and graphed. 3-dimensional (3D) representation of the component loadings have been utilized. Here, being aware of the chances of having more than 3 components, graphical representation is possible up to 3 components which constitute the highest share of variability. Chart representations have been generated by Excel, and the 3D representations have been generated by XLSTAT software.

CHAPTER 4

RESULTS

This chapter of the thesis addresses the connections between vulnerabilities assessed within the context of energy poverty. The components that emerged in the direction of these relations were interpreted. The vulnerability factors included by the scope of the study, namely the indicator data sets, were assessed.

4.1 Statistical and Spatial Assessment of Vulnerability Factors

In this part, the variables that impact energy vulnerability are determined and their connections with each another are investigated. The correlation between the data is displayed in the table below. In order to establish accurate correlations, data were standardized. There are both positive and negative associations between the variables in the table. Although some variables have a strong correlation, this does not imply that they explain one another; in other words, even though there are substantial connections, it does not follow that the data are the same. In the PCA analysis, it is plausible to be cautious about the correlation coefficients (r) since they have a potential to reflect the similar variables. In Table 4.1, since the two variables do not refer to the same phenomena, both are included in the analysis. Full-time students and age risk group have a 0.860 significant positive correlation. While young children are dependent on their parents, full-time students spend part of the day at school and the energy they use at home (computer, tablet, phone, etc.) may differ. Both of these groups include individuals who spend a lot of time at home and require high energy. There are also strong correlations between the age risk group and large household size as well as age risk group and energy inefficient property with the r values of the former 0.768 and the latter -0.709. Age risk group, comprised of both elderly and young children, thus, a large household is expected to be correlated whereas they also require a more stable and living environment in terms of temperature that is expected to be resulting in a relatively high negative correlation.

Table 4.1. Correlation Matrix

	Age risk group	Lone parent	Unemployment	Full-time student	Shared property	Large household size	Private renting	Central heating	Energy-inefficient property	Climatic exposure	Internet	Natural gas network access	Household disposable income	Refugees	Migration
Age risk group	1	-.063	.607	.860	-.422	.768	.243	-.372	-.709	.382	-.636	-.232	-.671	.118	-.207
Lone parent	-.063	1	.103	.153	.114	-.064	.252	.009	-.155	-.446	.186	-.011	.106	.266	.130
Unemployment	.607	.103	1	.500	-.201	.526	.124	-.337	-.531	.355	-.499	-.348	-.546	-.186	-.200
Full-time student	.860	.153	.500	1	-.327	.580	.486	-.299	-.744	.151	-.380	-.249	-.498	.362	-.031
Shared property	-.422	.114	-.201	-.327	1	-.169	.234	.162	.104	-.099	.239	-.171	.386	.000	.364
Large household size	.768	-.064	.526	.580	-.169	1	.141	-.356	-.515	.279	-.480	-.292	-.482	.044	-.093
Private renting	.243	.252	.124	.486	.234	.141	1	.093	-.450	-.136	.086	.001	.155	.477	.419
Central heating	-.372	.009	-.337	-.299	.162	-.356	.093	1	.246	.019	.449	.784	.543	.029	.293
Energy-inefficient property	-.709	-.155	-.531	-.744	.104	-.515	-.450	.246	1	-.302	.530	.210	.435	-.083	.057
Climatic exposure	.382	-.446	.355	.151	-.099	.279	-.136	.019	-.302	1	-.451	.011	-.388	-.278	-.173
Internet	-.636	.186	-.499	-.380	.239	-.480	.086	.449	.530	-.451	1	.296	.706	.277	.469
Natural gas network access	-.232	-.011	-.348	-.249	-.171	-.292	.001	.784	.210	.011	.296	1	.443	.079	.240
Household disposable income	-.671	.106	-.546	-.498	.386	-.482	.155	.543	.435	-.388	.706	.443	1	.222	.578
Refugees	.118	.266	-.186	.362	.000	.044	.477	.029	-.083	-.278	.277	.079	.222	1	.598
Migration	-.207	.130	-.200	-.031	.364	-.093	.419	.293	.057	-.173	.469	.240	.578	.598	1

Spatial distributions of the variables are also mapped in the following part. The standardized values of the variables provide comparable outputs at province level.

Figure 4.1 shows the distribution of the age risk groups referring to the total value of households with at least one elderly person (65 years and older) and households with children aged 4 and below. The age risk group is more prevalent when looking at Southeast Anatolia. Similarly, the east of the country has a higher concentration of those in the age risk group than the west, which particularly indicates the high levels of fertility. It has been observed that the age risk group is lower in major provinces like Istanbul and Ankara. In large metropolitan areas fertility rates are relatively lower and the chaotic and cosmopolitan lifestyles of such areas do not provide comfortable living conditions for elderly, as well.

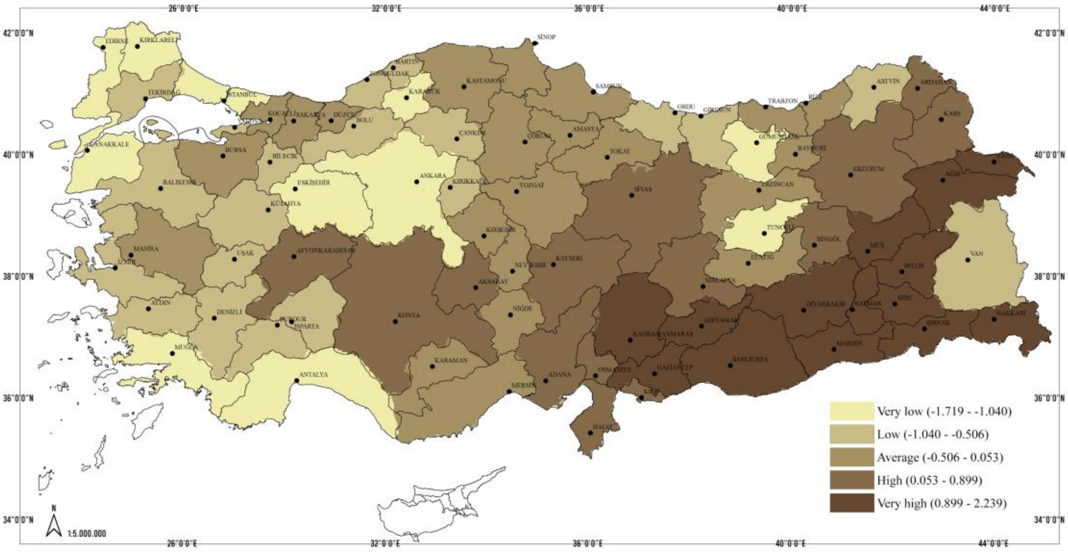

Figure 4.1. Spatial Distribution of Age Risk Group

As shown in the map in Figure 4.2, it can be stated that there are more lone parents with at least one resident child in Izmir, Ankara, Eskişehir, Adana, Mersin, Hatay, Kilis, and some provinces in the southeast compared to other provinces. Nevşehir, Yozgat, Tokat, Burdur, Bayburt and Bitlis are the provinces with the least number of lone parents.

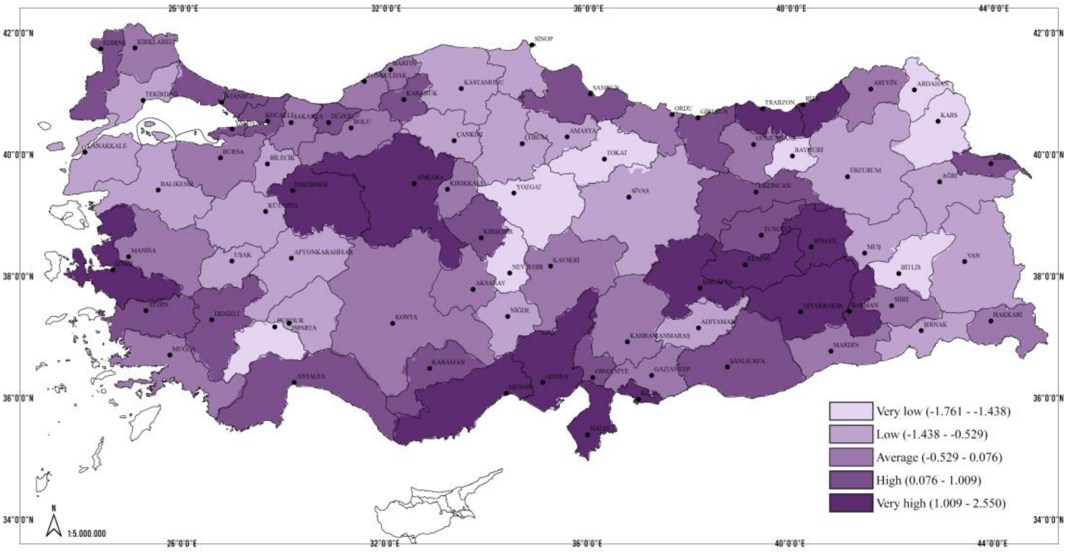

Figure 4.2. Lone Parents with at Least One Resident Child

Figure 4.3 displays the unemployment rate for those aged 15 and older. While the unemployment rate is low in the Aegean region it appears to be higher in the eastern part of the country. The annual number of registered unemployed people is expressed in unemployment accounts. Seasonal labor migration from east to west is high throughout the year, meaning the number of seasonal workers in the east is high.

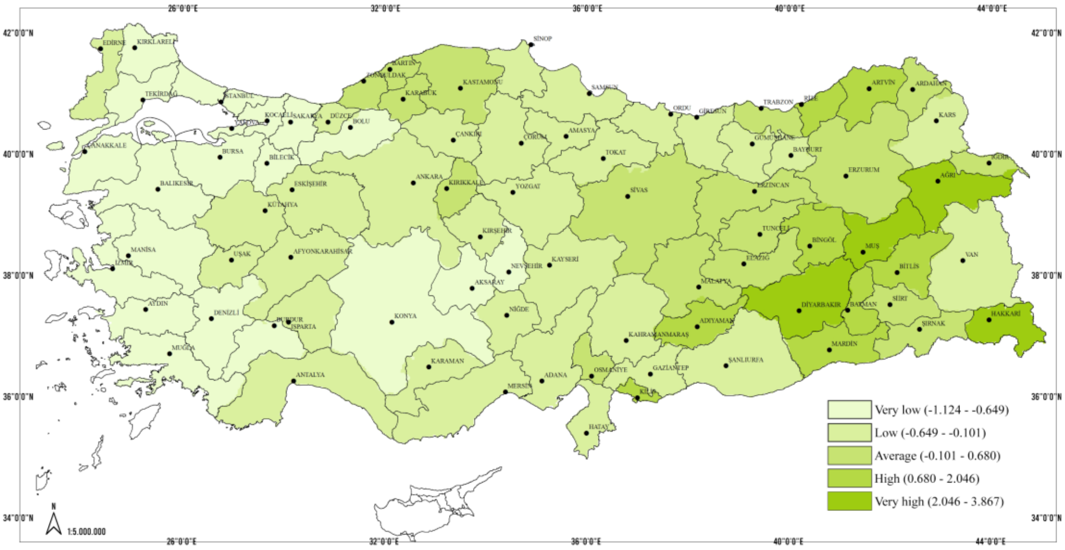

Figure 4.3. Unemployment

Figure 4.4 shows the total number of preschool (57 months and above), primary, secondary, and high school students by province for the 2021-2022 academic year. It is clearly seen that the student population is high in the southeast, which can be linked to the relatively higher percentages of children population.

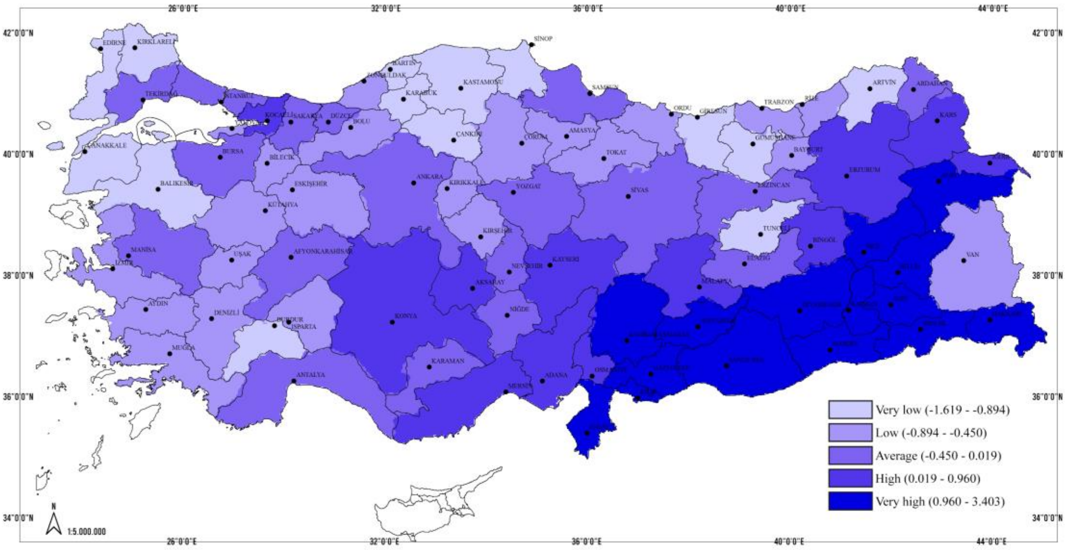

Figure 4.4. Full-time Student

The distribution of shared property by province is shown in Figure 4.5. Shared property in this map includes multi-person households without families. Shared properties are concentrated in provinces such as Istanbul and Antalya, which experiences significant internal and external migration. It can be claimed that those who live in shared properties in Istanbul are mostly immigrants, students, and people who are active in the business world. The prevalence of shared properties in Antalya could be related to tourism.

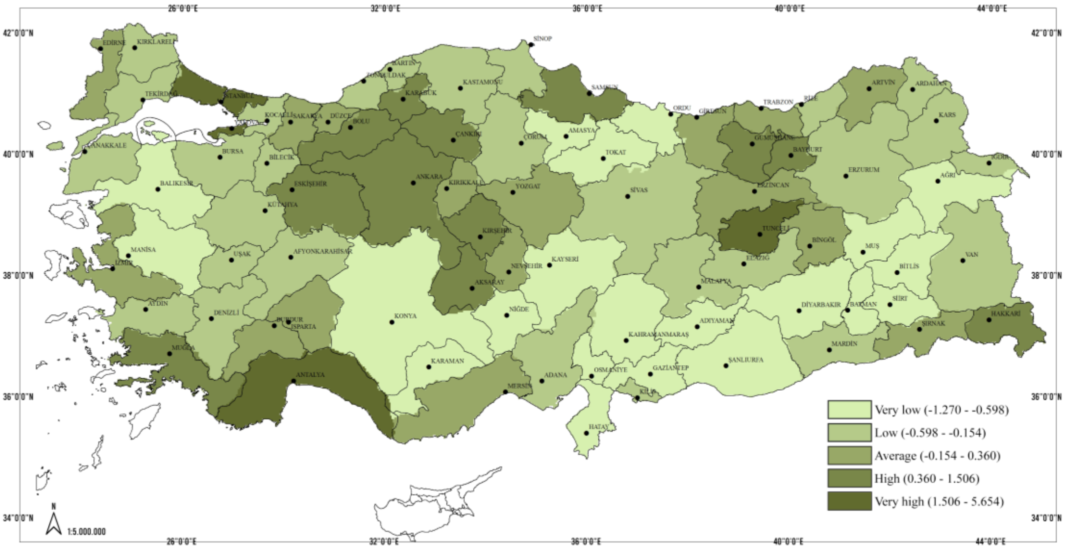

Figure 4.5. Shared Property/ Multi-Person No-Family Households

In Figure 4.6, the situation of large households by province is given. Households in southeast Türkiye used to have the cultural tendency of families to live together can explain this situation.

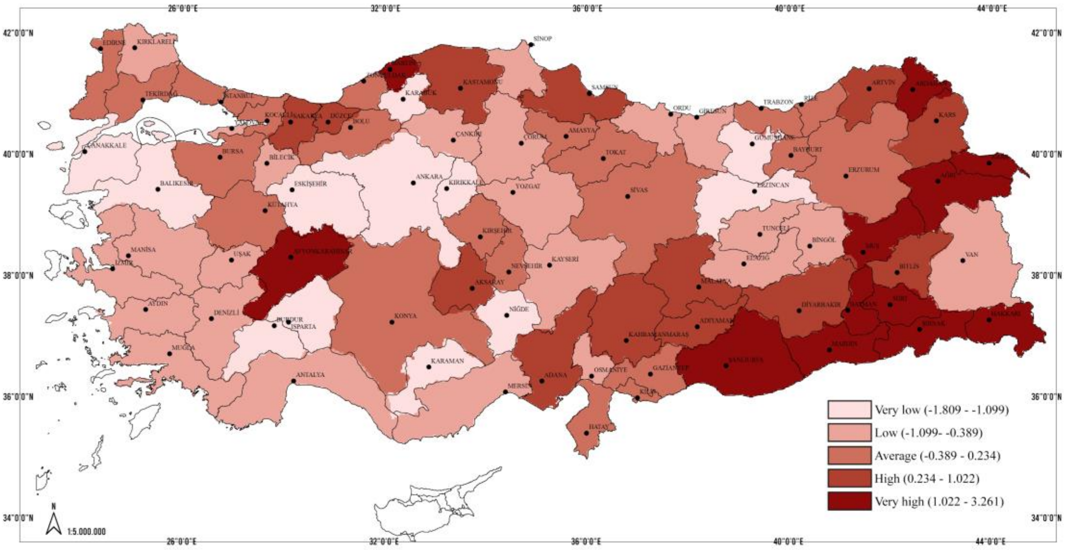

Figure 4.6. Large Household Size/ Extended-family Households

Private renting is mapped in Figure 4.7. Homeownership is more common than rental housing in the north of the country. One may argue that Marmara, Central Anatolia, Aegean, and Southeast have more private renting properties available.

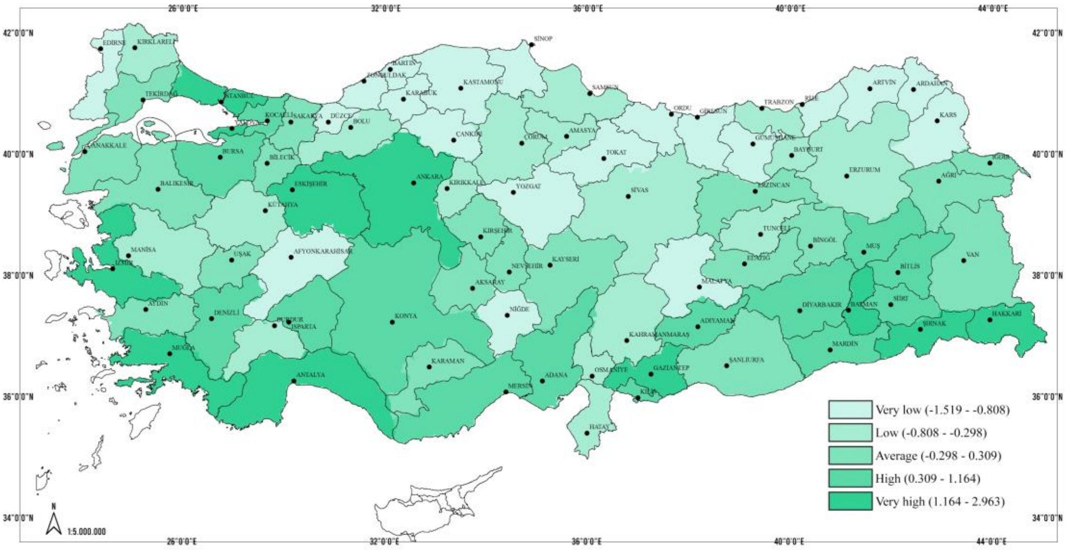

Figure 4.7. Private Renting

Figure 4.8 shows the households with central heating. In the southern and western coasts as well as the south-eastern provinces such as Gaziantep, Şanlıurfa and Adıyaman, central heating is not that common due to high average temperatures and less heating needs. Some local-specific cases may decrease the use of central heating, as well, that the households may prefer individual heating options. For instance, in Zonguldak and Karabük, coal ores are present and households, particularly the ones living in rural areas, opt for the use of coal in the stove. Similarly in Gümüşhane and Bayburt, for instance, households may prefer the use of wood burning stoves thanks to the availability of woodlands. In areas with harsher winters and low average temperatures, on the other hand, such as Erzurum and Hakkari central heating is more preferred. Both low temperatures and high rates of urbanization, such as Ankara, Kayseri and Eskişehir, results in higher prevalence of central heating.

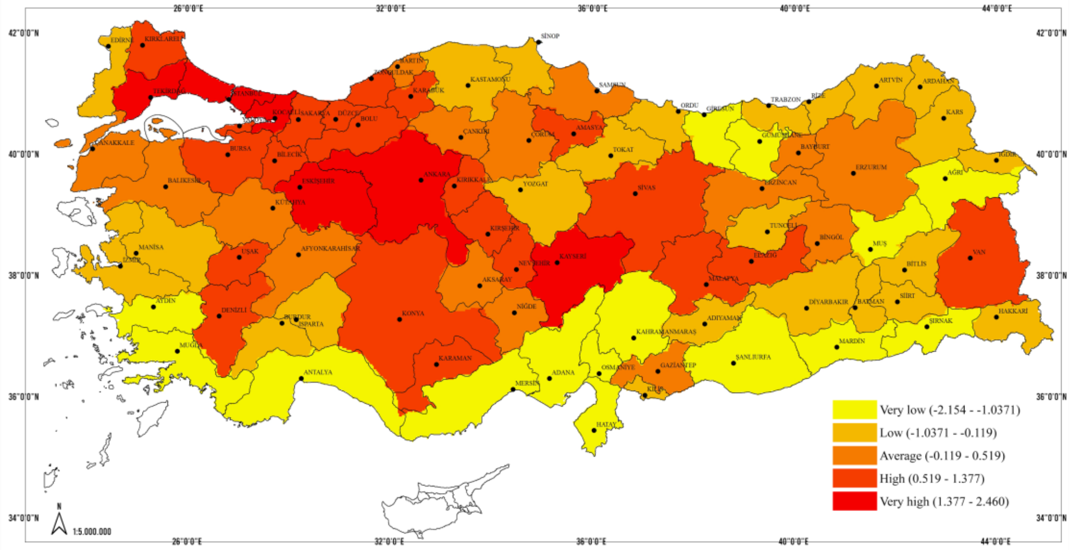

Figure 4.8. Central Heating/ Households with Central Heating

Figure 4.9 depicts the number of households dwelling in homes constructed in or before 2000 and their geographic distribution. Darker colors tend to be more energy inefficient. The prevalence of locally significant properties may be the reason why homes in the southeast are often energy efficient. These homes employ natural approaches to promote energy efficiency. The abundance of homes constructed before 2000 in the Aegean and Black Sea regions might mean that more people reside in inefficient properties in these provinces. Unfortunately, the energy efficiency status of every building in Türkiye has not been recorded yet. Although attention has been drawn to energy efficiency in the constructions made in recent years, it has been accepted that the households residing in the properties built in 2000 and before living in energy-inefficient properties are within the scope of this research.

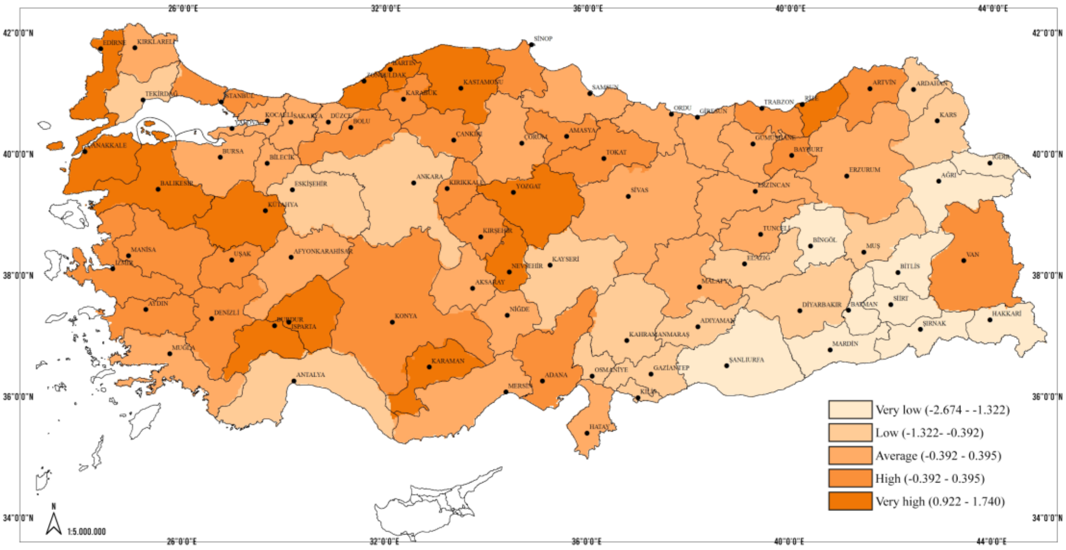

Figure 4.9. Energy-inefficient Property/ Households Residing in Dwellings Constructed in 2000 and before

In Figure 4.10, the annual heating/cooling energy requirement of the building is shown under the heading of climate exposure. The building's annual heating/cooling energy requirement is obtained from the sum of Heating Degree Days (HDD) and Cooling Degree Days (CDD). In provinces with various climatic classifications, it may be claimed that the consequences of climate exposure can differ. The effects of climate change are expected to influence how much cooling or heating is required. The important point here is that energy poverty is not only for the heating needs of households but also for the cooling needs of households due to climate change. It can be concluded from the map that HDD prevail over CDD, in general since the climatic exposure tends to increase from coastal areas to the inner parts. The north-east, where winters are long and average temperatures are low, the total climatic exposure tends to be the highest.

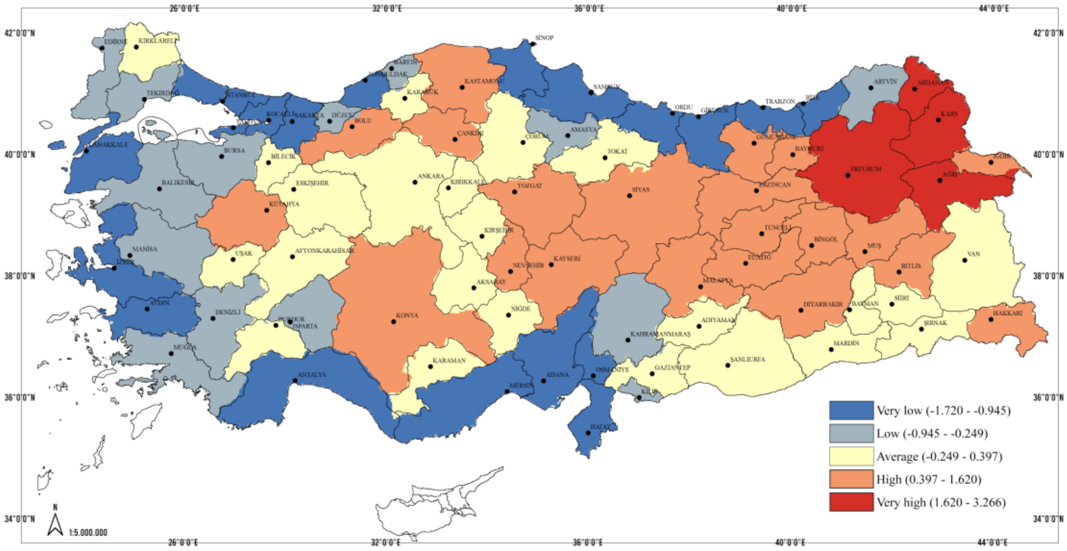

Figure 4.10. Climate Exposure/ Annual Heating or Cooling Energy Requirement of The Building (Heating Degree Days (HDD) & Cooling Degree Days (CDD))

Internet access is shown in Figure 4.11. Access is seen in the provinces according to Internet Broadband Subscriptions. It is seen that internet access is higher in the west of the country as well as the large provinces such as Ankara and Eskişehir, and there are problems in accessing the internet in the east compared to the west.

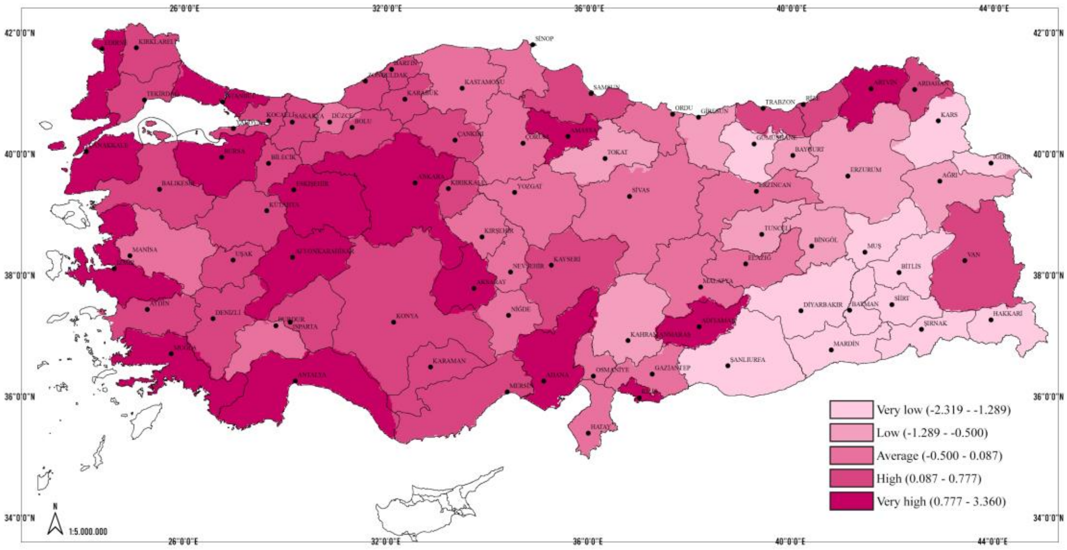

Figure 4.11. Internet Access

A map of the geographical locations of active natural gas users is shown in Figure 4.12. This map demonstrates that natural gas utilization is widespread throughout Türkiye. Additionally, it should be mentioned that the Mediterranean area uses relatively little natural gas due to its climate and has a propensity to employ renewable energy sources like solar energy. It can be stated that active natural gas users are high in the Marmara and Central Anatolian regions. Natural gas access is higher in provinces with stronger industrial base since the natural gas was supplied to these areas much before the rest of the country. In İzmir, for instance, the provision of natural gas in residentials has been as late as 2006 (Senyel Kurkcuoglu & Zengin, 2021) whereas in Ankara, natural gas had been supplied in residentials in 1992 and soon after in İstanbul and Bursa (Kurkcuoglu, 2023).

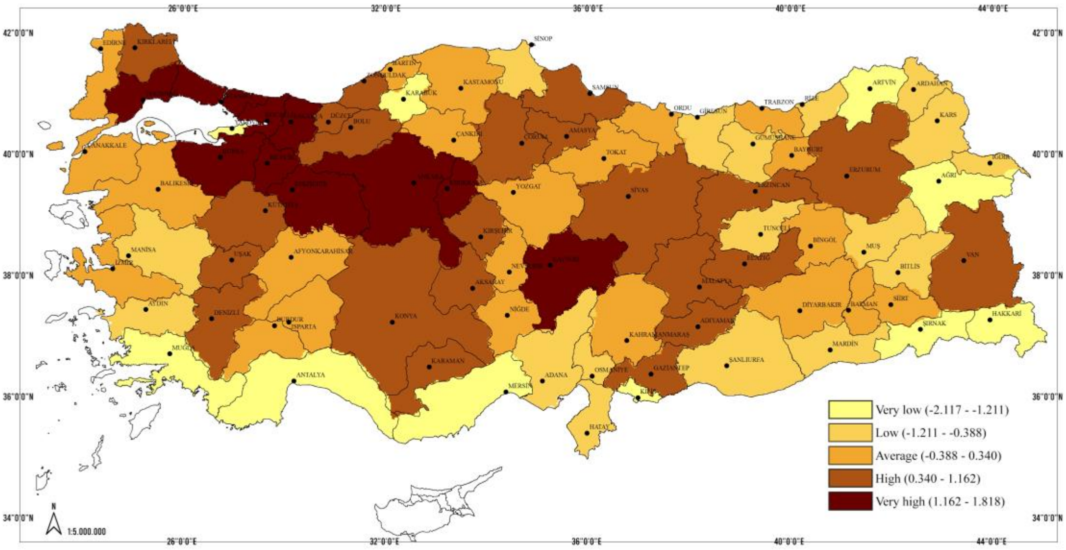

Figure 4.12. Natural Gas Access/ Active Natural Gas Users

Household disposable income can cause energy poverty because it directly restricts financial accessibility and the budget that the households can allocate for energy expenses. The average annual household disposable income is shown in Figure 4.13. household disposable incomes the three most populated provinces, Istanbul, Ankara, and Izmir are greater than the national average income. It is evident that the southeast and eastern areas have lower incomes than other provinces.

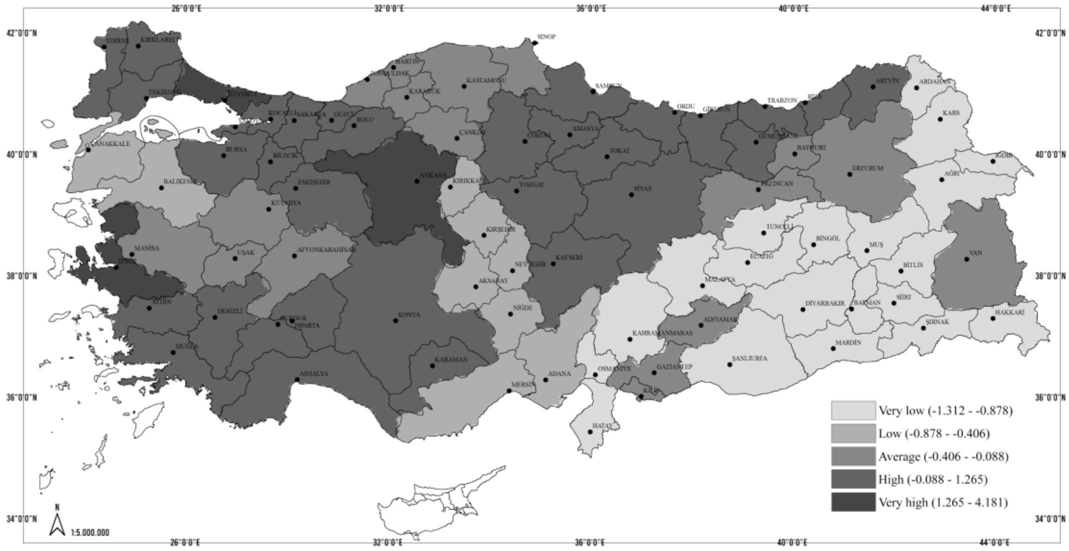

Figure 4.13. Annual Household Disposable Income (Average, TL)

Figure 4.14 shows the number of Syrian refugees living in Türkiye by province with temporary protection status. Here it is important to remind that only Syrians receive the status of temporary protection. It is noticeable that there are a lot of refugees in the southeast, particularly in provinces like Mersin, Adana, Hatay, Gaziantep, Kahramanmaraş, Kilis, and Şanlurfa due to having geographical proximity to the Syrian borders. Likewise, a large number of refugees reside in metropolitan provinces due to the cosmopolitan characteristics of these areas as well as more and diversified job opportunities.

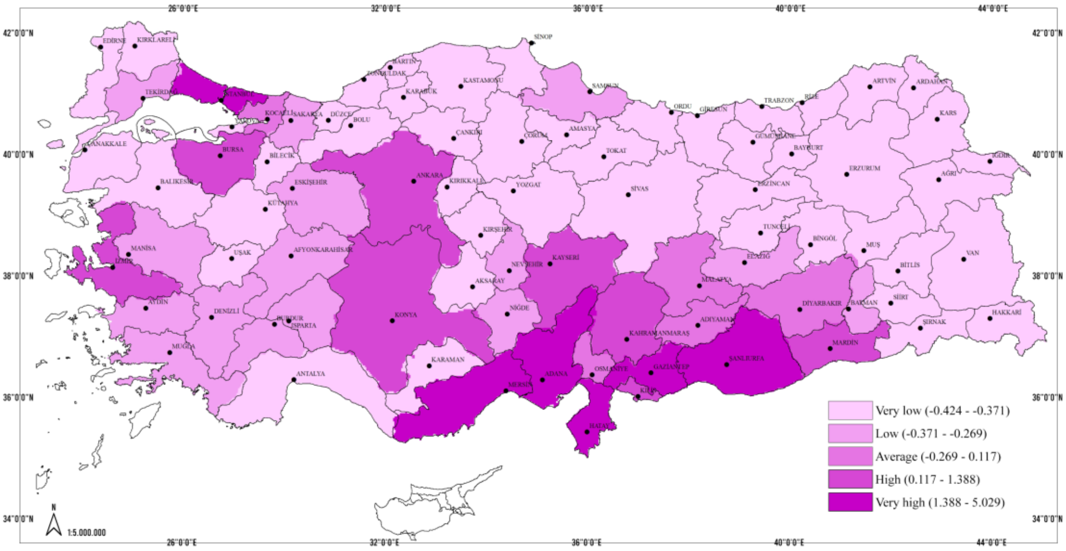

Figure 4.14. Syrian Refugees in The Scope of Temporary Protection

Figure 4.15 displays the total number of immigrants to Türkiye between 2016 and 2021 in order to reside in Türkiye. It is the total number of persons who moved to Türkiye from another country in the previous six years. Foreigners and Turkish citizens who were present during the reference year Address Based Population Registration System (ABPRS) but not the prior year ABPRS are considered immigrants. Foreigners holding visas or residence permits for less than three months for training, travel, scientific study, etc. are not covered, in addition to Syrians under temporary protection.

It is known that there are Syrian immigrants in Türkiye under temporary protection status, and Afghans and other ethnicities have a record of irregular migration. However, migration statistics under the authority of TurkStat data include immigrants with residence permits. Therefore, contrary to common forecasts, migration rates are low in several provinces. Although many Syrian citizens are under temporary protection in the Southeastern Anatolia region, this is not reflected in the migration data. Within the scope of this study, the reason for including the number of persons who migrated abroad to reside in Türkiye in the migration statistics is because Turkish citizens and foreign citizens/households resident in the country are also included in the other data sets utilized. It is clear that major provinces like Istanbul and Ankara have greater migration rates. Due to its potential as a tourist spot, Antalya has a greater migration rate than other provinces.

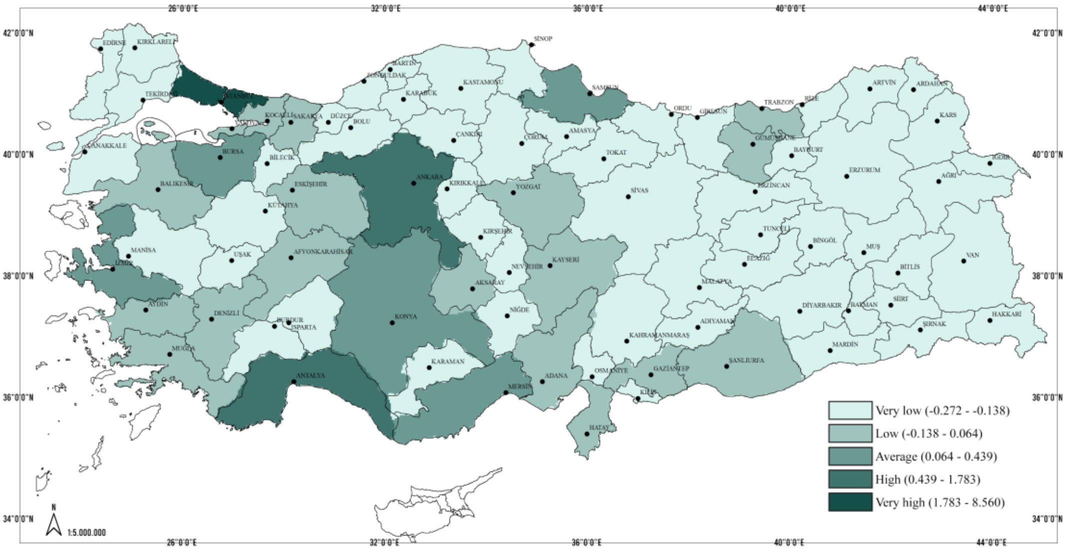

Figure 4.15. Migration/ The Population Migrating to Türkiye from Abroad (2016-2021) (To Reside in Türkiye)

To sum up, energy vulnerability is influenced by several socio-economic, demographic, and socio-technical factors. It is helpful to comprehend and analyze these factors to understand energy poverty. First and foremost, these factors were investigated on a provincial level within the parameters of the research.

4.2 The Socio-spatial Distribution of Energy Vulnerability

This section focuses on the situation of vulnerability factors in provinces. The impact of vulnerability factors against energy poverty has the potential to change due to climatic, economic, political, and social changes in provinces. So, it is important to reveal the situation of vulnerability factors at the provincial level to see which.

Several factors that contribute to vulnerability are seen to emerge in different provinces. The contribution is the positive and negative reflections of the vulnerability factors affecting provinces. It can be argued that certain factors of vulnerability have a greater impact on certain provinces, while other factors have less of an effect on energy vulnerability.

It would be more informative to assess total vulnerability as a whole rather than individually assessing each vulnerability that contributes to energy poverty. Factors that enhance energy vulnerability are viewed as positive when assessing the total vulnerability. In contrast, those that lower it, central heating, internet accessibility, household disposable income, and access to natural gas, are considered negative. In other words, as the map below illustrates, it may be assumed that provinces with positive values are more vulnerable than other provinces, while those with negative values are more resistant to energy vulnerability (Figure 4.16). At that point, it is important to indicate that in this analysis no weighting scheme is considered. All variables are assumed to have equal impact on vulnerability levels.

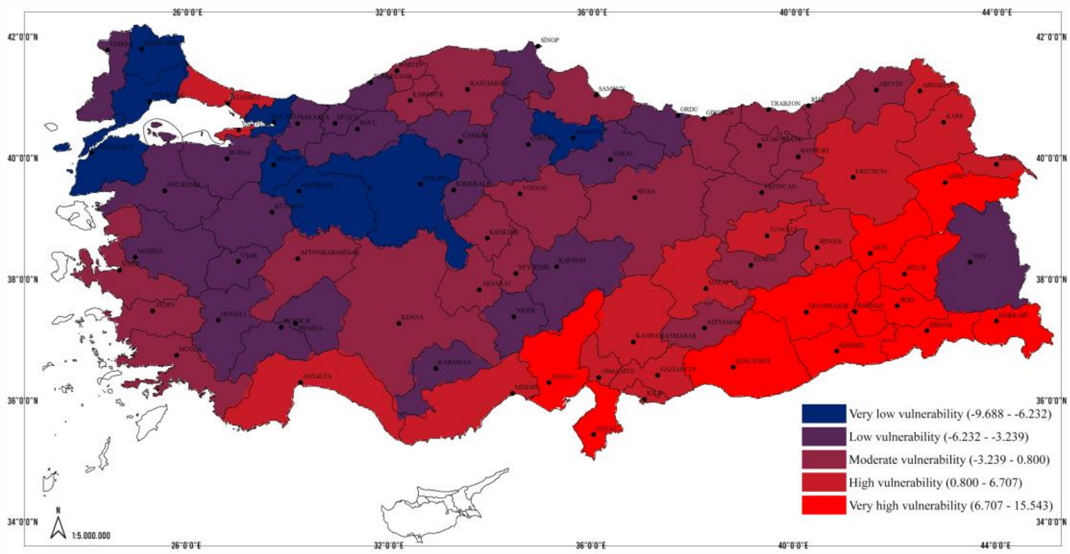

Figure 4.16. Total Vulnerability of Provinces

The map displays provinces with varying degrees of energy vulnerability, with blue indicating lower vulnerability and red indicating higher vulnerability. Variable values are summed up and the output has been ranked in equal intervals. Since the variable values are standardized, equal interval is considered to be consistent for this analysis. Factors that reduce energy vulnerability, which are central heating, internet access, household disposable income, and access to natural gas, were considered as negative values while adding the vulnerability factors. All other factors seem to contribute to energy poverty vulnerability in a positive direction.

Provinces located in the Southeast Anatolia area suffer from a greater level of energy vulnerability when considering the general condition of the country. In a same vein, it could be argued that provinces in the region of the Mediterranean are particularly vulnerable to energy poverty. Considering that significant temperature changes are expected to increase the demand for energy and put provinces in a more vulnerable position, this could potentially be a reflection of climate change. Furthermore, the significant energy vulnerability in Istanbul can be assigned to a variety of factors. Due to the wide variety of household types and financial circumstances as well as the high population density, Istanbul is particularly prone to energy poverty. Additionally, this condition is impacted by the existence of fragile groups like immigrants and fragile areas. One of the energy vulnerability groups is in the foreground for Istanbul since the absence of infrastructure is unavoidable owing to the city's high population density. The Central Anatolia region, the Aegean region, the Northern regions, and the Marmara region are relatively more resilient to energy vulnerability.

The findings reveal that the top five provinces are Tekirdağ, Kırklareli, Bilecik, Eskişehir, and Çanakkale when the provinces with the lowest energy vulnerability are listed (Figure 4.17). Conversely, the last five provinces are Hakkari, Batman, Şanlıurfa, Muş, and Şırnak appear to have the highest vulnerability (Figure 4.18). This is based on the total vulnerability as measured by the fifteen vulnerability factors. This chart can help determine which factors contribute to a provinces' exposure to energy vulnerability. Upon examining the correlation between provinces and vulnerability factors, high unemployment rate and large household size in Hakkari have a significant impact on energy vulnerability. In Şanlıurfa, for instance, the number of refugees increase total vulnerability of the province in a prominent way. Batman seems to suffer from high rates of age risk groups and private renting.

Climatic exposure is evident for all highest vulnerable provinces. When the lowest vulnerability group is investigated, it is seen that Çanakkale is benefiting from high income and natural gas access, while Eskişehir is benefiting from lower percentages of energy inefficient properties and age risk group. Migration and refugee levels are comparably low for all lowest vulnerable provinces.

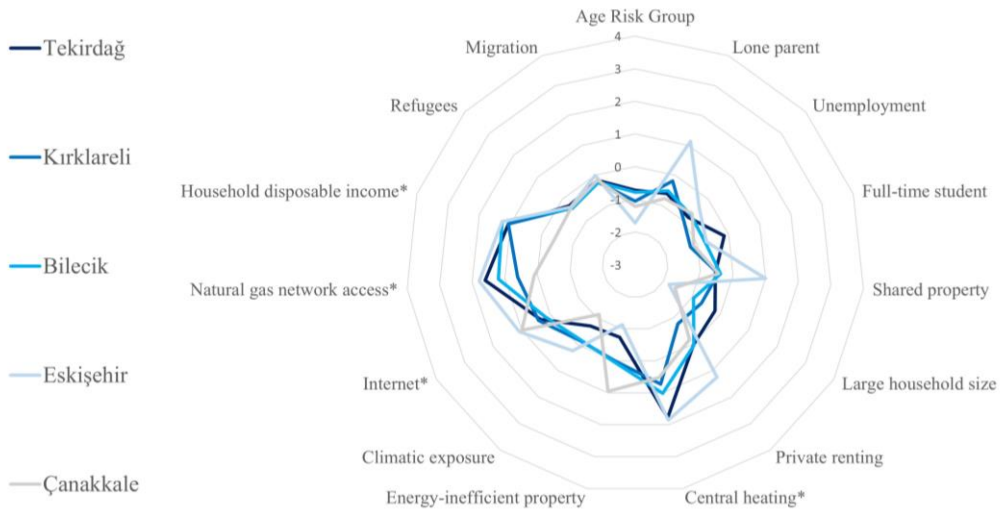

Figure 4.17. The Values of Vulnerability Factors in Provinces with the Lowest Energy Vulnerability. *Variables that are negatively related to vulnerability.*

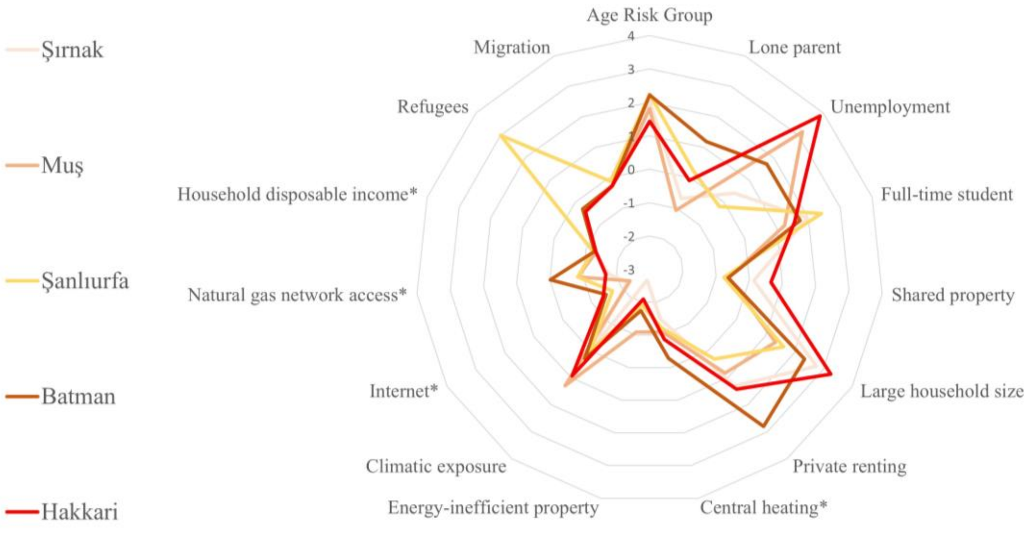

Figure 4.18. The Values of Vulnerability Factors in Provinces with the Highest Energy Vulnerability. *Variables that are negatively related to vulnerability.*

Following that, the substance of the components and how they can be categorized using PCA is discussed. In that multiple factors may influence the actions and policies that are taken to establish significant objectives and alleviate energy vulnerability.

4.3 Principal Component Analysis of Vulnerability Factors to Energy Poverty

Principal Component Analysis (PCA) is a statistical approach used to minimize the dimensionality of a data set while maintaining as much of its variance as feasible. A specific amount of the original data's fluctuation is captured by each principal component (PC). The first PC captures the most variety, followed by the second PC, and so on. How much of the original variation is preserved by the smaller data set may be calculated using the sum of the variance explained by all the PCs.

The Kaiser-Meyer-Olkin (KMO) statistic is a measure of sampling adequacy, in general, and for individual variables (Kaiser, 1970; Cerny & Kaiser, 1977; Dziuban & Shirkey, 1974). In comparison to the original (zero-order) correlations, the partial correlations' smallness is summarized by the KMO statistic. After removing the influence of all other factors in the factor analysis, the partial correlation between each pair of variables is calculated. The correlation between those variables is used to calculate the partial correlation. The KMO and Bartlett tests are used to evaluate all relevant data simultaneously. If the KMO value is greater than 0.5 and the significance threshold of Bartlett's test is less than 0.05, then there may be a significant correlation in the data. The degree to which one variable is related to other variables is called variable collinearity. Values greater than 0.4 are regarded as suitable. Each variable's KMO measurements can also be computed. Values greater than 0.5 are acceptable. The statistic, which is 0.727 and is not linear as a consequence of the analysis conducted with 15 components, is acceptable (Table 4.2).

Table 4.2. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.727
Bartlett's Test of Sphericity	Approx. Chi-Square	861.453
	df	105
	Sig.	<.001

The results of the study are used to specify the PCA model. In this situation, PCA initially produces 15 components, which is the same number of components as indicators. These components' eigenvalues can be utilized to evaluate their relative importance (Table 4.3).

Table 4.3. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.430	36.198	36.198	5.430	36.198	36.198
2	2.801	18.673	54.870	2.801	18.673	54.870
3	1.657	11.047	65.917	1.657	11.047	65.917
4	1.237	8.246	74.164	1.237	8.246	74.164
5	.990	6.603	80.767			
6	.614	4.097	84.863			
7	.498	3.319	88.182			
8	.466	3.104	91.287			
9	.359	2.397	93.684			
10	.291	1.942	95.626			
11	.213	1.417	97.043			
12	.169	1.129	98.172			
13	.130	.867	99.039			
14	.104	.693	99.731			
15	.040	.269	100.000			

Extraction Method: Principal Component Analysis.

Each following component is generated by partially removing the one before it, starting with the initial component. The first component thus accounts for the greatest variation, whereas the last component accounts for the least. It may find the total variance explained by each component using the Total Variance Explained table (Table 4.3). For example, Component 1 is 5.430 or (5.430 /15) % = 36.198% of the total variance.

It would be helpful to have a criterion for choosing the ideal number of components, which is obviously fewer than the total number of items, as the objective of performing a PCA is to minimize our set of variables. The Scree Plot (Figure 4.19) shows the eigenvalue (total variance explained) by the component number. In essence, an eigenvalue is a ratio of the shared variance to the unique variance that each factor obtained from the principal component extraction accounts for in the construct of interest. The existing literature has accepted an arbitrary criterion of 1.0 or higher for determining whether a factor warrants further interpretation. The rationale for the 1.0 criterion stems from the idea that a factor should, at minimum, account for the same proportion of common variance as it does unique variance within the concept.

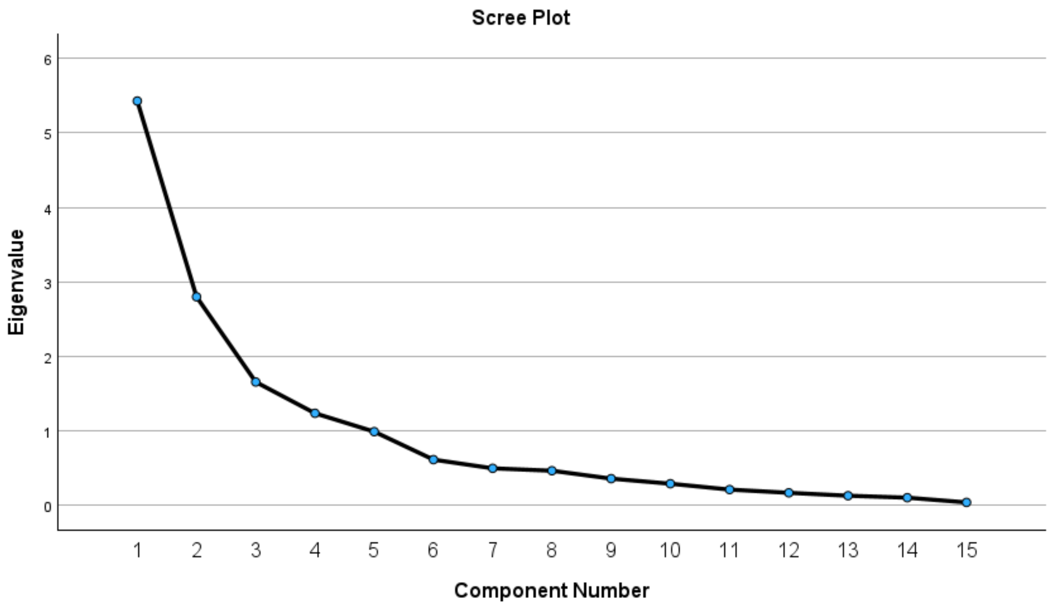

Figure 4.19. The Scree Plot

According to their commonalities, samples are grouped in Component Plots. PCA does not exclude any features (variables) or samples. Instead, it creates principal components, which minimize the overwhelming number of dimensions. Each of the four components offered by PCA has a unique geographic distribution. The sort of vulnerability a component is likely to represent can be determined by loading vulnerability indicators on these finished components. Due to the possibility of indicators loading components both positively and negatively, each component has the capacity to reflect two different aspects of vulnerability (Table 4.4).

Table 4.4. Loading of Vulnerability Indicators on Four Finalized Components (Component Matrix[a])

	C1	C2	C3	C4
Age Risk Group	-0.903	0.234	0.218	-0.100
Lone parent	0.075	0.477	-0.384	-0.323
Unemployment	-0.735	0.050	-0.004	0.127
Full-time student	-0.751	0.533	0.092	-0.175
Shared property	0.379	0.191	-0.309	0.766
Large household size	-0.736	0.185	0.075	0.109
Private renting	-0.104	0.817	0.041	0.202
Central heating	0.588	0.129	0.659	0.033
Energy-inefficient property	0.727	-0.406	-0.133	-0.141
Climatic exposure	-0.444	-0.299	0.548	0.442
Internet	0.786	0.263	-0.068	-0.107
Natural gas network access	0.479	0.080	0.758	-0.265
Household disposable income	0.838	0.282	0.081	0.124
Refugees	0.106	0.780	-0.025	-0.217
Migration	0.418	0.678	0.111	0.276

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

C means Component

Four components are retained for additional diagnostic testing because they have eigenvalues over one (Figure 4.20). How much the vulnerability indicators load positively (colored circles) and negatively (white circles) on the finalized four components is visualized in the graph below. For example, it is seen that the age risk group loads negatively on the first component and loads positively on the second and third components. It is seen that household disposable income is loaded positively on all components and mostly on the first components. In the next heading, the components of the energy vulnerability obtained with these indicators are explained.

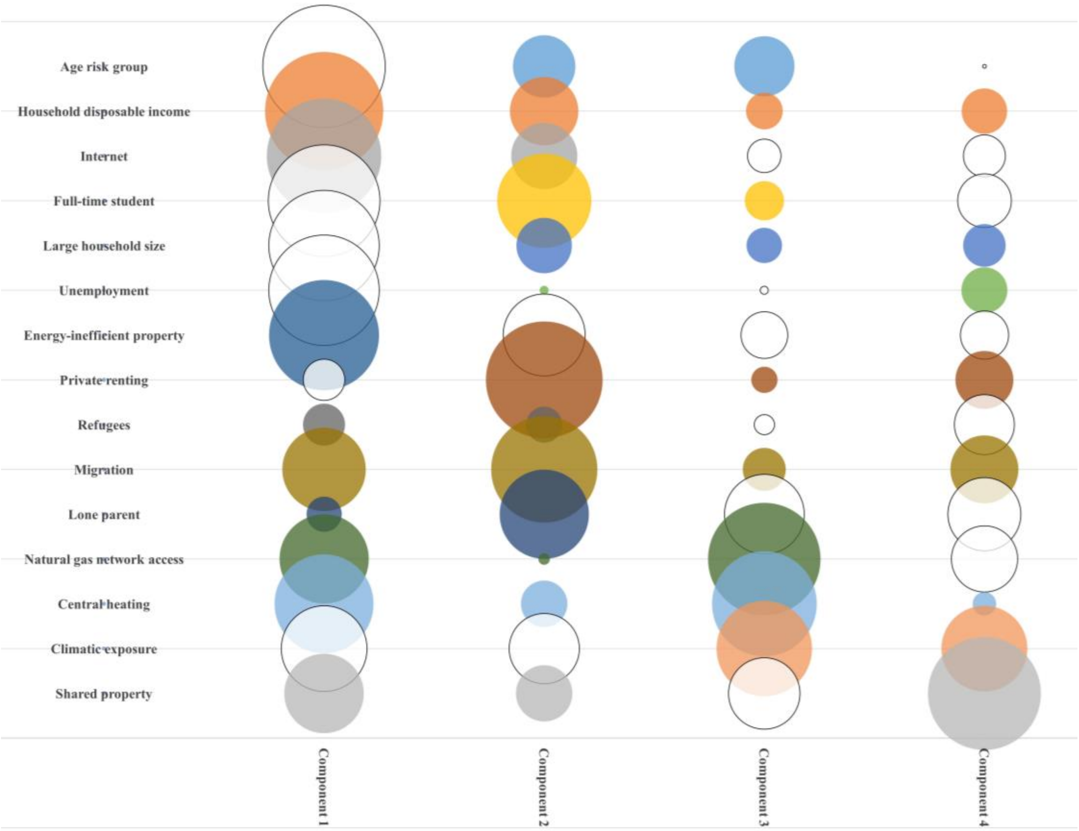

Figure 4.20. Values for Components

4.4 The Components of Energy Vulnerability

This part conveys the interpretation of the four components that the PCA presents. The evaluation of the preceding section, which indicates the extent to which a variable is represented in the component, reveals that the first four components have a greater representation of the components. It is more meaningful to explain the relationships in these components.

Giving these finished vulnerability indicators makes it possible to assess the kind of vulnerability a component is likely to represent. Since indicators can load components both positively and negatively, each component represents two distinct aspects of vulnerability. In the below figure, blue circles represent a positive loading of the indicator on the component, whereas white circles represent a negative loading. The strength of the loading is indicated by the size of the circle.

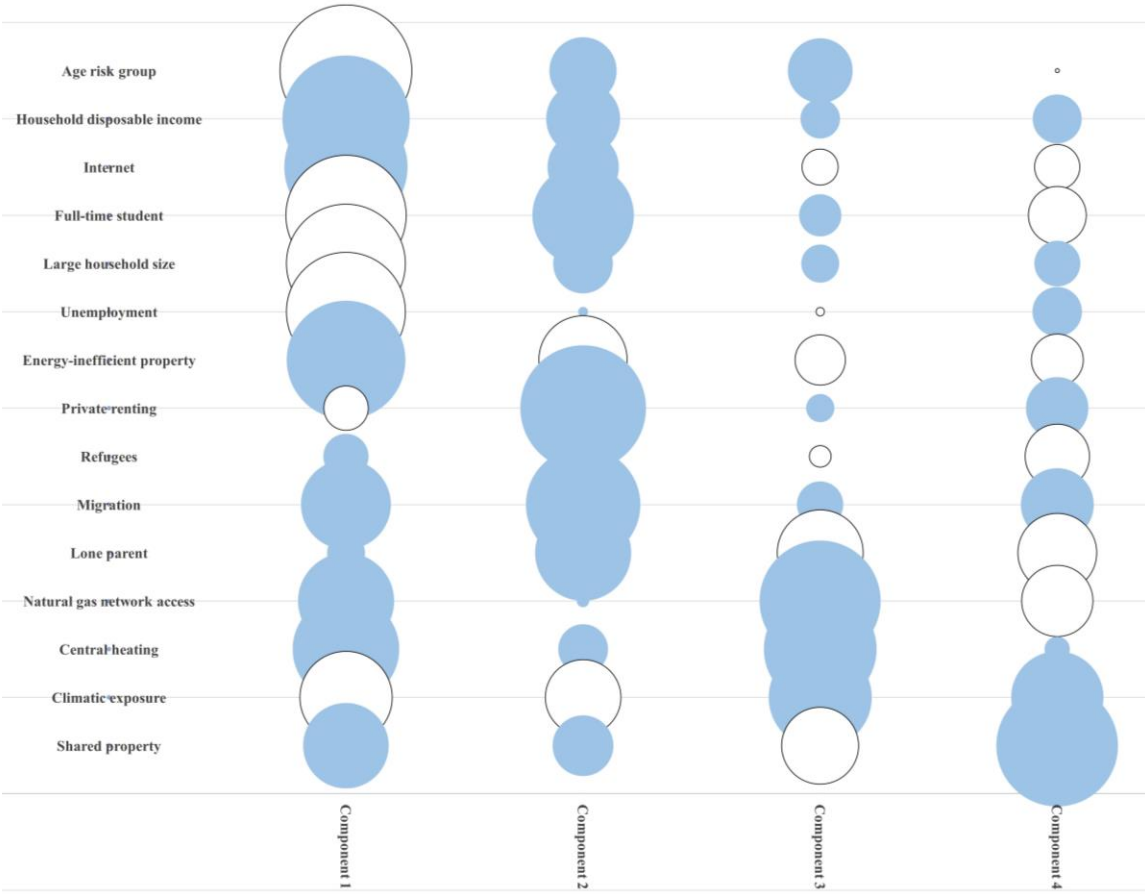

Figure 4.21. Loading of Vulnerability Indicators on Final Components

These four components provide classifications that contribute to energy vulnerability. These classifications serve as a framework for research on the issue of energy vulnerability. Components are given below in terms of their thematic implications regarding the contribution of each variable on each component.

1st Component, C1, refers to “socio-economic status and technology”. The first component is related to the social characteristics including demographic profile and economic conditions such as income and employment. Access to internet defines the technological opportunities that are available to the households. The component consists of both positive and negative variables. The increase in the age risk group, unemployment, full-time student, and large household contributes to this component in a negative direction while income and the internet access have positive contribution. An increase in negatively related variables and a decrease in positively related variables would contribute to vulnerability in a positive direction via C1.

2nd Component, C2, refers to “residency status”. Refugees and migration variables are related to the residency status of the people. Private renting refers to the ownership status of the property and is a situation where the household does not own the property but lives by renting a property. Shared property refers to housing occupied by multi-person, non-family households. This type of residency status affects this component. All variables, which are refugees, migration, private renting, shared property, lone parent, age risk group, etc., have positive loadings on C2, while their increase would lead to higher vulnerabilities, and vice versa.

3rd Component, C3, refers to “heating and energy”. This component is subject to both positive and negative loadings, similar to C1. Central heating and natural gas access have positive, and energy inefficient buildings have negative loadings.

4th Component, C4, refers to “climate and living conditions”. Two variables, climatic exposure and shared property contribute to this component while increasing value of each would lead to higher vulnerabilities, and vice versa.

Contribution of each variable to the four components is given in Figure 4.22 (see Appendix B). Those greater than 10% contribution are demonstrated, which shows the most influential variables on each component. Here, when a component has similar loadings on more than one variable, it is assigned to the most relevant component increasing interpretability based on researchers’ subjective assessment. For instance, full time student variable has 10.39% contribution to C1 and 10.15% on C2. Since C1 is related to the socio-economic characteristics, being a full-time student is associated with C1 more than C2. Climatic exposure has similar percent loadings on C3 and C4, with 18.14% and 15.77%, respectively. However, when the sign of the variable is investigated it has controversial results in C3, since all other variables have inverse relationship with vulnerability via the component whereas climatic exposure has a direct relationship. Thus, the variable is considered under C4 together with shared property, composing a composite component in terms of the climate conditions together with the living conditions of residents.

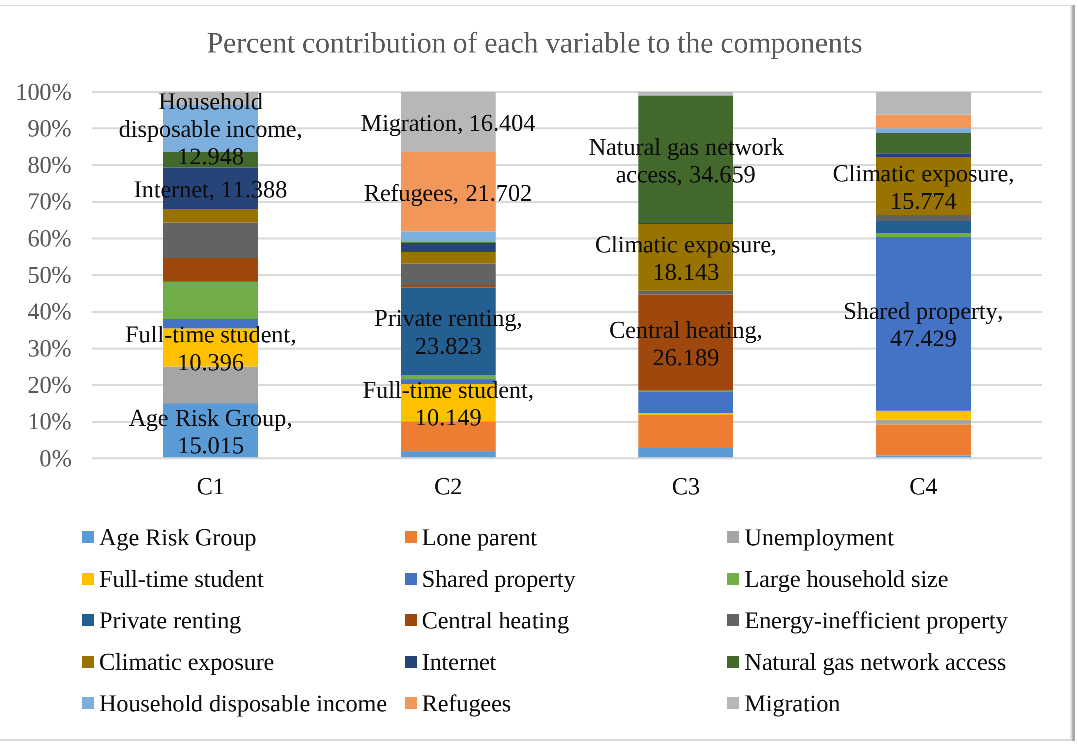

Figure 4.22. Contribution of Variables to C1, C2, C3 and C4

C1 accounts for 36.1% of the percentage of variance (PTV). Indicators that are positively related to C1, such as household disposable income, natural gas network access, internet, and central heating, provide a positive effect on decreasing energy vulnerabilities. The high positive correlation could be brought on by financial stability, which decreases the possibility that these families with children and students (Healy & Clinch, 2004), older olds, large families might not be able to invest in energy efficiency or purchase necessary energy services. The requirement for heating and cooling in dwellings with no or low energy efficiency makes households with children, extended families, renters, and unemployed households more exposed to energy vulnerability. This emphasizes increased exposure since the age risk group which includes elderlies and children have a more vital physiological requirement for heat (Ormandy & Ezratty, 2012) and are more exposed to lower indoor temperatures after spending much time indoors during the day (Chard & Walker, 2016).

C2 accounts for 18.6% of the PTV and has a strong positive relationship with refugees, migration, and private renting. Indicators adversely related to the component, such as exposure to the climate and energy-inefficient property are also highlighted in here. Age, having children, where people live, and lifestyle choices all affect demographic changes. Demographic change has a significant influence on the economy, social and health systems, as well as housing and infrastructure requirements. Groups such as refugees and displaced people can have a significant impact on energy deprivation. It needs a solid economic and environmental context to improve energy accessibility for refugees and displaced people which is fragile groups. The concentration of displaced people and refugees in provinces might lead to a serious energy vulnerability.

Migration can have an impact on energy poverty by influencing employment and income expectations amongst diverse ethnic groups and locations. The effects of ethnic diversity on energy vulnerability may vary between different races depending on the current levels of energy poverty, the type of migration, the nature of technology transfer from immigrants, or the degree to which the host community adapts to new racial groups (Koomson, Afoakwah & Ampofo, 2022). C2 also has a positive relationship with private renting and shared property. These can be the outcome of city reflections brought on by demographic changes. Immigrants tend to favor shared property and rented accommodation, depending on whether they migrate independently or with their families.

Energy vulnerability is associated with sensitivity to climatic exposure and with groups that are vulnerable to energy-inefficient property. Since it is more difficult to provide the fundamental heating and cooling needs of households in energy-efficient properties, there is a greater chance that fragile groups will become energy-poor. Climate exposure is another element that could be a contributing factor to migration. Climate change-related weather variations could also make it more difficult for vulnerable groups to access enough energy.

C3 accounts for 11% of the PTV and has a strong positive relationship with the availability of appropriate and efficient networked, and domestic energy infrastructures. The component and the energy-inefficient characteristics indication are closely associated. The connection between requirements for infrastructure and climate impacts is additionally an ongoing concern. The need for heating and cooling in buildings energy varies according to the temperature patterns in provinces as a result of climate change.

A significant risk factor for energy vulnerability is being disconnected from the gas grid since households without gas are compelled to utilize more expensive fuels. The issue gets worse as communities grow and residences built off the gas grid become considerably more prevalent in rural than in urban regions (Baker, White & Preston, 2008). However, having access to natural gas offers advantages in satisfying demands. Infrastructure issues including a lack of central heating and energy-inefficient property can have an impact on the types and amounts of energy utilized by families, which can exacerbate energy vulnerability. Energy vulnerability is additionally rendered more vulnerable by households' inability to make improvements to their infrastructure.

C4 accounts for 8.2% of the PTV. Indicators that are positively related to this component are climatic exposure and shared property, which provide an adverse effect on decreasing energy vulnerabilities. The climate is the primary factor impacting populations and areas. The requirement for cooling and heating in buildings varies in provinces where the impacts of climate change occur more strongly. Every day, it is vital to consider not only the demand for heating but also the requirement for cooling. Days with a high demand for heating occur in some provinces, whereas days with a strong demand for cooling occur in other areas. Climate exposure is thus a vulnerability element that affects energy poverty. Energy vulnerability is predicted to increase due to climate change.

The component also explains vulnerability is in households with variable living conditions, such as renters in shared properties, where it might be challenging to reach an agreement with a landlord or other tenants on energy usage and energy conservation measures (Ambrose, 2015; Cauvain & Bouzarovski, 2016). Students are considered part of vulnerable populations that frequently reside in shared properties (Petrova, 2017).

Variable loadings on the first 3 components are given in Figure 4.23. At this point, both the distance between variables and the variables' distance to the component axis are considered. The first 3 components have the capacity of explaining 66% of the variability, while the last component, C4, has the marginal 8.7% increase. All 3D graphs have been produced by XLSTAT software, as an extension to Microsoft Excel. Some of the clustering of variables are still obvious in the graph, since they are located close and in the same quadrant with regard to C1, C2 and C3. The first clustering indicated with green includes age risk, household size, unemployment and full-time student constituting the direct relationship with vulnerability via C1. The other two variables having inverse relationship and locating along C1 are internet access and income clustered together on the positive side of C1. The second clustering, indicated with yellow covers refugees, migration, private renting, lone parent as well as shared property. Although shared property tends to fall into C4, if the components were limited to 3, it would likely be included in C2. All variables fall into the positive side of C2. The third clustering indicated with orange include natural gas access, central heating and energy inefficient buildings are located within the same quadrant, along the positive side of C3. Although climatic exposure is included in C4, if three components were considered, climatic exposure would likely fall into the third component, yet, with an unexpected sign.

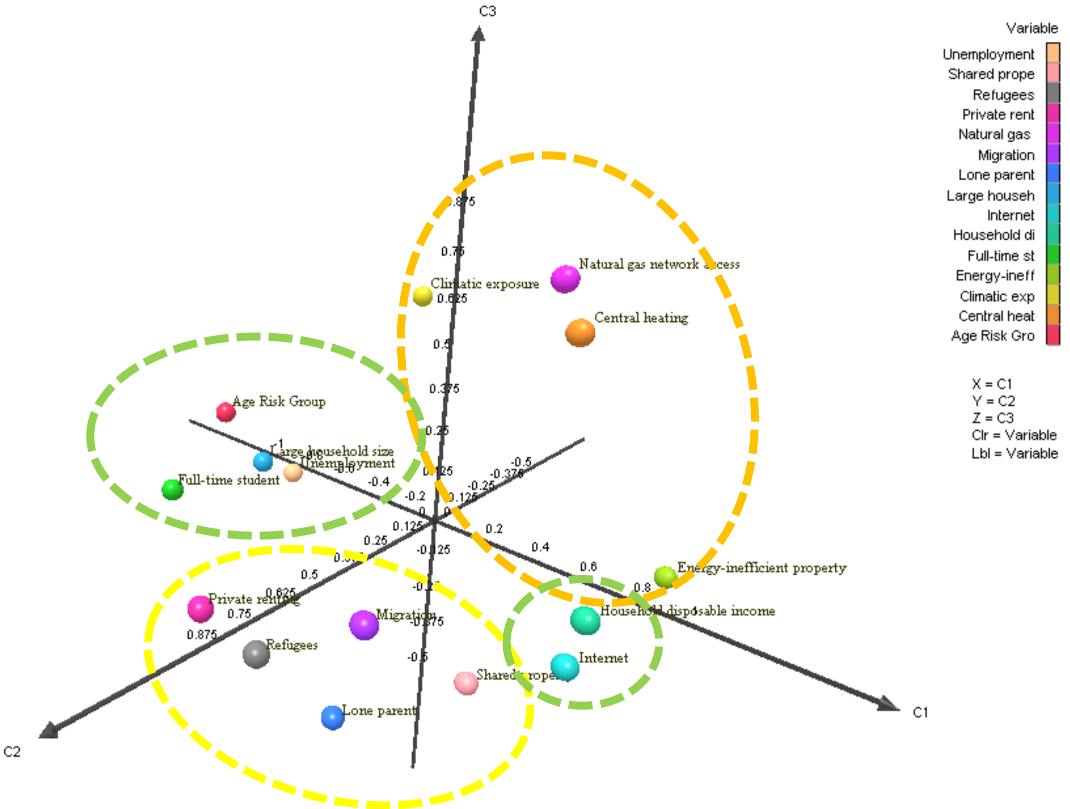

Figure 4.23. 3D Representation of The Variables Regarding Their First 3 Component Loadings

Province loadings and the vulnerability levels (Figure 4.16) are analyzed together, to see the contribution of each province to the components as well as their vulnerability levels at the same time (Table 4.5). When the individual component scores are investigated, it is seen that the least vulnerable provinces such as Ankara, Eskişehir, Çanakkale, Bilecik and Kocaeli have higher positive loadings on the 1st component, which help to decrease their vulnerability levels. Some of the most vulnerable provinces, that are particularly located on the south-west, such as Ağrı, Bitlis, Diyarbakır, Hakkari, Mardin, Muş, Batman, and Şanlıurfa have higher negative loadings on the 1st component, which tend to increase their vulnerability.

Thus, socio-economic status and the technology conditions are the most vital contributors to their vulnerability levels which requires immediate action. Gaziantep, İstanbul and Kilis have considerably high loadings on the 2nd component, which is the residency status. The highest levels of migration to these provinces seem to increase their vulnerability in a significant way. Some coastal provinces, such as Adana, Aydın, Giresun, Mersin, Hatay, Muğla, Trabzon, Karabük have negative loadings on the 3rd component, which seems to contribute to their vulnerability the most. Heating and energy efficiency measures are better prioritized in these areas.

Table 4.5. Component Scores of Provinces and Their Vulnerability Levels

Province	**C1**	**C2**	**C3**	**C4**	**Vulnerability**
Adana	-0.429	2.108	-2.445	-1.820	1
Adıyaman	-1.954	0.823	1.078	-0.802	3
Afyonkarahisar	-0.099	-0.947	0.386	0.061	3
Ağrı	-5.091	-0.222	0.669	1.085	1
Amasya	1.208	-0.822	1.026	-0.691	5
Ankara	3.989	2.769	1.846	0.610	5
Antalya	1.145	1.864	-3.297	2.177	2
Artvin	0.256	-0.994	-1.895	0.479	3
Aydın	1.225	-0.639	-1.929	-0.636	3
Balıkesir	1.811	-1.229	-0.395	-0.694	4
Bilecik	1.991	-0.543	1.222	-0.265	5
Bingöl	-1.915	0.647	0.036	-0.290	2
Bitlis	-3.937	-0.322	1.200	0.992	1
Bolu	1.784	-0.540	0.800	0.838	4
Burdur	1.718	-1.678	-0.277	0.234	4
Bursa	2.177	1.626	1.480	-0.892	4
Çanakkale	2.257	-1.221	-0.382	-0.734	5
Çankırı	1.427	-1.729	0.295	0.974	4
Çorum	0.779	-0.863	0.785	-0.246	4
Denizli	1.933	0.004	0.157	-0.829	4
Diyarbakır	-3.675	1.100	0.429	-0.462	1

Table 4.5 (cont'd)

Edirne	2.198	-1.239	-0.613	-0.204	4
Elazığ	-0.425	0.337	0.725	-0.948	3
Erzincan	0.401	-0.652	0.386	0.123	3
Erzurum	-1.214	-1.252	2.248	0.741	2
Eskişehir	2.970	1.045	1.266	0.611	5
Gaziantep	-1.126	4.190	1.060	-1.406	2
Giresun	0.866	-1.244	-2.153	-0.394	3
Gümüşhane	0.714	-1.645	-1.426	1.746	3
Hakkari	-5.677	1.369	-0.396	2.142	1
Hatay	-1.261	1.716	-2.552	-2.745	1
Isparta	1.674	-0.448	-0.245	0.245	4
Mersin	0.128	1.929	-2.763	-1.062	2
İstanbul	6.892	9.036	1.578	2.618	2
İzmir	2.874	1.967	-1.332	-0.878	3
Kars	-2.432	-1.783	1.422	1.149	2
Kastamonu	0.070	-1.914	0.305	0.533	3
Kayseri	0.708	0.412	2.354	-0.627	4
Kırklareli	2.073	-1.054	0.545	-0.358	5
Kırşehir	1.209	-0.595	0.646	0.765	3
Kocaeli	2.011	1.300	1.653	-1.181	5
Konya	0.871	0.530	1.524	-0.699	3
Kütahya	1.166	-1.575	0.742	-0.027	4
Malatya	-0.663	0.095	0.531	-1.257	2
Manisa	0.544	-1.000	-0.542	-0.787	4
Kahramanmaraş	-1.991	0.176	-0.110	-1.486	2
Mardin	-4.392	1.502	-0.404	0.086	1
Muğla	1.105	0.062	-2.635	1.250	3
Muş	-5.058	-0.049	0.596	1.081	1
Nevşehir	0.756	-1.149	0.977	0.584	3
Niğde	0.309	-1.478	0.424	-0.565	4
Ordu	0.756	-1.066	-1.058	-0.893	4

Table 4.5 (cont’d)

Rize	0.128	-0.788	-1.708	-0.824	3
Sakarya	1.589	0.352	0.878	-0.473	4
Samsun	0.926	0.122	-0.164	-0.266	3
Siirt	-3.789	0.735	0.764	-0.054	1
Sinop	0.551	-1.494	-0.990	-0.416	4
Sivas	-0.072	-0.837	1.520	0.224	3
Tekirdağ	1.666	0.117	1.857	-0.621	5
Tokat	0.369	-2.029	0.340	-0.259	4
Trabzon	1.050	-0.075	-1.585	-0.782	3
Tunceli	0.388	-1.341	-1.465	1.800	2
Şanlıurfa	-4.207	2.583	-0.178	-1.139	1
Uşak	1.381	-1.013	0.642	-0.078	4
Van	-4.449	0.586	0.667	0.573	4
Yozgat	0.550	-1.863	0.719	0.596	3
Zonguldak	1.580	-1.296	-0.273	-1.168	4
Aksaray	0.427	0.065	0.302	0.352	3
Bayburt	0.181	-1.608	0.661	1.778	3
Karaman	1.386	-0.576	0.642	-1.017	4
Kırıkkale	1.350	-0.870	0.912	-0.054	4
Batman	-4.586	2.465	0.654	0.012	1
Şırnak	-5.334	1.285	-0.633	1.169	1
Bartın	0.538	-1.780	-0.528	-0.306	3
Ardahan	-2.252	-2.103	1.131	1.518	2
Iğdır	-3.224	0.228	-0.038	0.151	2
Yalova	2.386	1.322	-2.735	4.272	2
Karabük	1.170	-1.134	-1.881	1.328	3
Kilis	-1.671	2.436	-1.674	-0.857	2
Osmaniye	-1.545	-0.007	-1.727	-1.926	2
Düzce	0.857	-0.192	0.351	-0.778	4

The percent contribution of provinces to each component is investigated and the ones with more than 2% contribution have been denoted in Figure 4.24 (see Appendix C). Here, the most important issues that each province faces in terms of socio-economic status and technology, residency status, heating and energy, climate and living conditions are demonstrated.

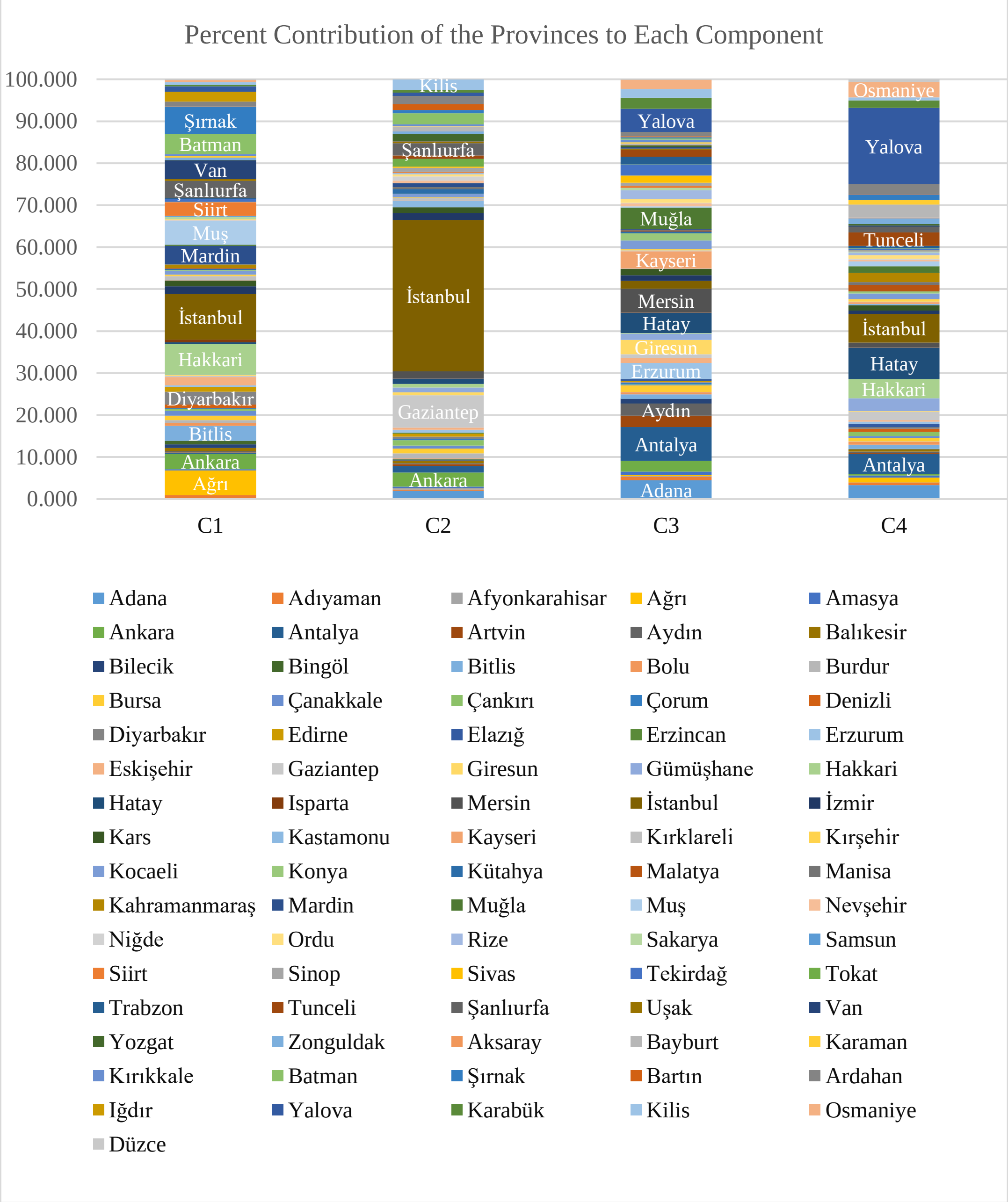

Figure 4.24. Contribution of Provinces to C1, C2, C3 and C4

The 3D graph of the provinces with regard to the first 3 components are given in the Figure 4.25. In this way, the location of each city at least in the first 3 components, C1, C2, and C3, can be detected, which explains the 66% of the variability.

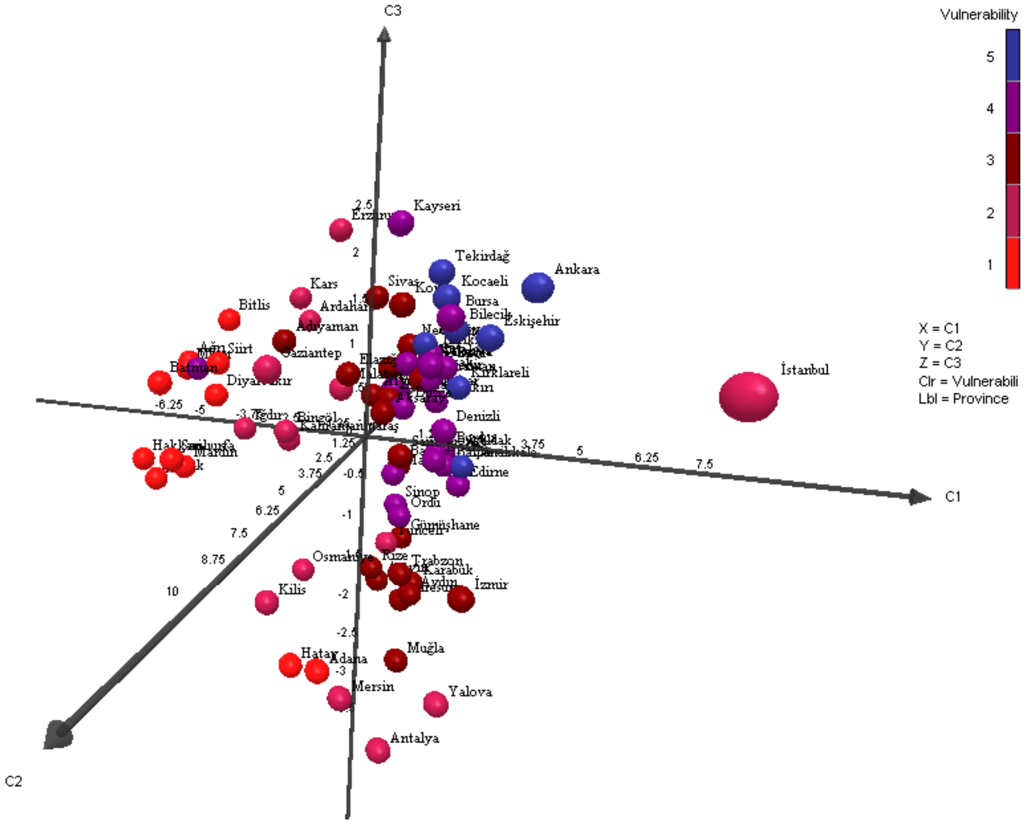

Figure 4.25. 3D Representation of The Provinces Regarding Their First 3 Component Loadings

The 1st component explains the largest variability, while the most vulnerable provinces' loadings are clustered around this component more than the others. Provinces, especially in the South-eastern part of the country seems to struggle in terms of household attributes, financial situations and additionally technology, which are clustered around the higher values of the 1st component.

Some of the most obvious provinces with relatively high contribution to the 2nd components are İstanbul, Gaziantep, Kilis, Şanlıurfa where the fragile groups in terms of refugees and migrants are common besides the climate prone moderately vulnerable coastal provinces such as Adana, Mersin, Sinop have higher loadings in this axis as well.

The 3rd component has the lowest marginal contribution to the total variance. Some provinces among lower levels of vulnerability such as Kayseri and Erzurum have higher loadings on this component. However, infrastructure problems for energy and heating seem to be solved easier than the rest of the issues such as climate exposure and socio-economic deficiencies, thus, such areas do not require immediate action when compared to the other provinces.

The clustering of the highly vulnerable provinces in the negative C1, negative C3 and positive C2 quadrant can be observed in the 3D representation as well (Figure 4.26), while the low-vulnerable provinces are clustered around in the opposite direction in positive C1, positive C3 and negative C2 quadrant. İstanbul stands out as an outlier here, with considerably high loading on the 2nd component, which increases its vulnerability in spite of its positive and relatively high loadings on the 1st and the 3rd component.

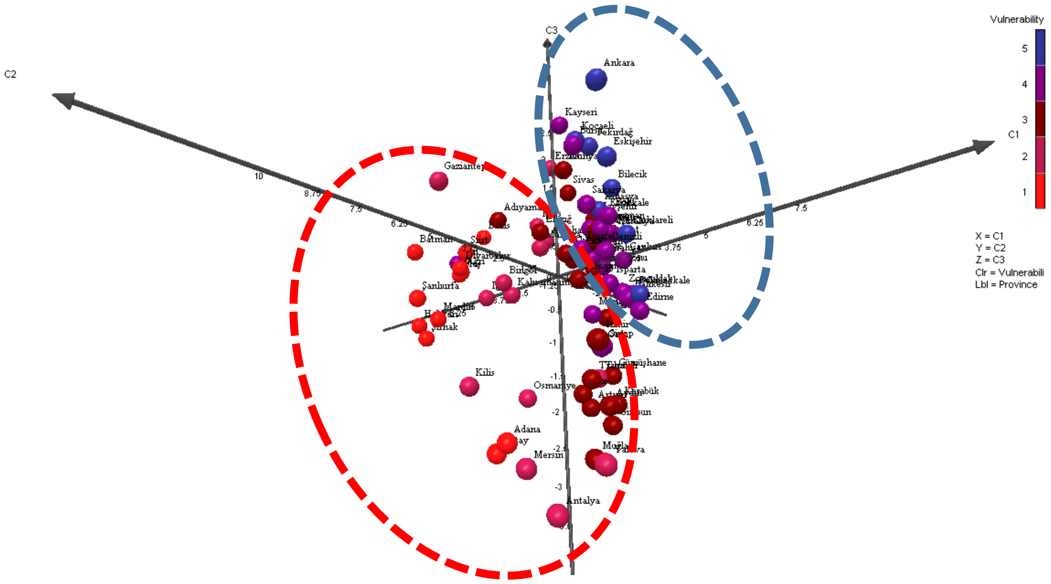

Figure 4.26. Clustering of The High and Low Vulnerable Provinces Regarding the C1, C2, and C3

CHAPTER 5

CONCLUSION

In this final chapter of the thesis, first, an overall overarching summary of the research is provided. Then, the reflections of the key findings are evaluated, and the connections are described, to offer guidance for future research in Türkiye. The limitations of the study are stated. Finally, further research areas are emphasized, and suggestions for future energy poverty research are given.

5.1 The Summary of The Research

The effects of climate change are becoming more obvious, and the repercussions of these impacts on people and provinces continue to become clearer. Vulnerabilities are exacerbated by climate change and there is a growing awareness of the link between energy and vulnerability to climate change impacts. Efforts to eliminate these vulnerabilities can have a resilience-enhancing effect if the causes and correlates of vulnerabilities can be more thoroughly investigated and vulnerabilities can be recognized with energy poverty. To assure sustainability, climate resilient development would need to be addressed.

To be resilient in the face of climate change and energy poverty, it is valuable to first understand the influences and vulnerabilities. In Turkish provinces, research is being conducted to examine the factors that contribute to energy poverty, including social, economic, physical, and geographic factors. The primary goals of this research are to understand these vulnerability factors and to investigate the spatial distribution of the impacts of energy poverty.

To promote well-being and livelihoods while protecting environmental resources, sustainable development, energy, and energy accessibility have been discussed.

Following that, vulnerabilities to energy, understanding of vulnerability, and the fundamental relationship of energy with human needs are examined. Energy is a crucial element. It is evident that energy has a variety of consequences on human life and is an essential requirement. This thesis, which is based on understanding the vulnerabilities that affect energy poverty, examines the relationship between energy poverty, climate change and sustainability. It is emphasized that by reducing the vulnerabilities that affect energy poverty, resilience can be created and thus closer to a climate resilient and sustainable development.

The methodology that was provided in the third chapter enabled a detailed analysis of the research questions. In this scope, the research questions have been addressed through the method and results of this thesis. The research question in this context focuses on the vulnerabilities that lead to energy poverty and how they are distributed geographically. Several variables that are related to vulnerability of energy poverty are retrieved from the literature. Since a single indicator does not define energy poverty, it has features requiring action for several considerations. Data indicate that energy poverty changes by province, which means that the risks associated with energy vulnerability may change over time. The review of the accessibility and affordability of energy in Türkiye was conducted. Türkiye, like many countries in Europe, is likely to have energy-poor households. According to research, households struggle to pay their energy, water, and gas bills and are not appropriately heated or cooled their properties in Türkiye. However, insufficient research has been done in Türkiye on energy vulnerability. The aim of this thesis is to contribute to the existing knowledge on energy poverty in Türkiye by identifying the vulnerabilities that contribute to energy poverty. This will help in better understanding the condition of energy vulnerability in Türkiye.

In accordance with the literature review, the vulnerabilities that may impact energy deprivation in Türkiye were determined to include age risk group (older old and young children), lone parent, unemployment, full-time student, shared property, large household size, private renting, central heating, energy-inefficient property, climatic exposure, internet, natural gas network access, household disposable income, refugees, and migration. It was examined how these fifteen components were distributed throughout Türkiye.

Through the analyses, it has been attempted to identify which provinces are more vulnerable and which ones are more resilient based on vulnerability factors. An evaluation was created by considering the vulnerability factors in this manner. When the variables that are considered as influential on energy poverty vulnerabilities are overlayed without any weighting, southeast provinces appear to have comparably higher vulnerabilities whereas the lowest vulnerable provinces are distributed across the country particularly on the central and the north-western part. Factors that negatively affect energy poverty and positive vulnerability factors that reduce energy poverty, which are household disposable income, internet connection, central heating, and accessibility to natural gas networks, were discussed and total vulnerability was revealed. The provinces that are most at risk in this situation include Hakkari, Batman, Şanlıurfa, Muş, and Şırnak. On the other hand, compared to other provinces, Tekirdağ, Kırklareli, Bilecik, Eskişehir, and Çanakkale have lesser energy vulnerability.

To better comprehend energy poverty, it would be beneficial by looking at the vulnerabilities that impact it. Vulnerability is influenced by both positive and negative factors, which can be categorized. It is possible to explore the connection between energy poverty and the vulnerability that these categories attempt to convey. In terms of provinces, several factors are related to provinces at various levels. By disclosing these components, specific vulnerability factors can be highlighted, resulting in outcomes that have an impact on decision-makers choices for policies and strategies to address energy poverty. PCA is an effective method in reduce the dimension of the data into a set of components that are practical to interpret and act.

The outcomes of this thesis addressed vulnerability factors and the directions in which these components are progressing regarding energy poverty. The investigation resulted in a determination to categorize these factors into four components. The primary variables within these categories were socio-economic status and technology, residency status, heating and energy, and climate and living conditions. These components have allowed for the identification of primary energy poverty vulnerabilities. Examining the scores of different components, it was determined which provinces placed a higher load on specific components. The least vulnerable provinces, including Ankara, Eskisehir, Çanakkale, Bilecik, and Kocaeli, have been found to have greater positive loads in the first component, which is socio-economic status and technology. Higher negative loadings in the first component are seen in some of the most vulnerable provinces, including Ağrı, Bitlis, Diyarbakır, Hakkari, Mardin, Muş, Batman, and Şanlıurfa. Regarding the second component, residency status, the burdens of Gaziantep, İstanbul and Kilis are quite high. Excessive migration to these provinces seems to make them far more vulnerable. Adana, Aydın, Giresun, Mersin, Hatay, Muğla, Trabzon, and Karabük are a few coastal provinces with negative loadings on the third component, which appears to be the main factor in their vulnerability. In these places, energy-saving and heating solutions are prioritized more.

As a conclusion, it should be mentioned that evaluating the degree of energy deprivation necessitates a thorough study framework and a carefully considered approach. This thesis has been presented in this context as a first step toward measuring energy vulnerability. Türkiye's vulnerability factors impacting energy poverty were identified, and it was possible to look at the pressures these vulnerability factors place on the provinces. Based on my findings, the research has led to the development of a scientific resource that offers recommendations and solutions for vulnerability issues that are concentrated in the provinces, requiring multiple approaches to thought. To facilitate the development of policies and actions that support increasing sustainability by reducing energy poverty, fundamental knowledge has been made available to policymakers and decision-makers. First and foremost, identifying and classifying the vulnerabilities that cause energy poverty and transferring the geographical distribution of vulnerabilities is a process that possesses to be understood first.

5.2 Limitations of the Study

The limitations of this study are crucial to acknowledge. Understanding and evaluating energy poverty poses certain challenges. While this topic falls under the broader category of energy accessibility, it also encompasses concerns related to infrastructure, social equality, economic development, education, and health.

When discussing energy poverty, the literature often highlights low household incomes, high energy costs, and inadequate domestic energy efficiency as primary factors. However, it is important to note that energy poverty is not a single paradigm. The way energy vulnerability is perceived and understood can vary depending on a country's level of development, climate and environment, cultural factors, and individual characteristics. Along with the available resources, it is necessary to consider infrastructure, social norms, instruments, and human behavior. Although it was not practical to examine all the related in this research, the vulnerability factors that impact energy poverty were identified, and the research framework was built with fifteen vulnerability factors.

The data used in the research have been obtained from various open sources and have been tried to be presented in the most up-to-date format. However, another restriction is the inability to access the data on a provincial and local level. To evaluate the conditions in both urban and rural areas, it is important to collect information on energy poverty at the neighborhood level while conducting a city-based study. By examining a city on a large to small scale, it is possible to expand the scope of the research and obtain valuable insights.

5.3 Further Studies

It should be acknowledged that collecting a trustworthy and comprehensive database of vulnerability factors that can be applied to understand the extent of energy poverty among households is fraught with challenges. It is evaluated vital to draw attention to the limitations that continue to require being addressed for similar methods to be used in future studies.

It would help future research by providing extensive information on households' energy demands and consumption behavior as well as climatic conditions and living space features. Furthermore, it is recommended that developing vulnerability maps would produce more beneficial outcomes to predict, plan, and respond to emergency and crisis management decision-makers by utilizing complex socio-demographic, environmental, and economic data with the most appropriate scientific methods.

By assessing the province level energy vulnerabilities, modeling could potentially accomplished. Priority vulnerabilities in the provinces can be highlighted using these models. In this method, evaluation and mitigation techniques may be focused starting with the most pressing vulnerabilities. Within the parameters of the study, the impact weight of each variable on energy vulnerability was observed and assessed on an equal basis. Expert views can be considered to establish the variants' weights. By knowing which risks are more serious in provinces, it is possible to target research more properly toward those areas.

Last but not least, considering the limitations of the research's scope, it was not possible to identify all the challenges to reaching sustainability goals and potential new vulnerabilities brought on by the effects of climate change. Therefore, this study might be expanded within the alternatives framework to highlight important geographical issues about energy and explain the vulnerability factors.

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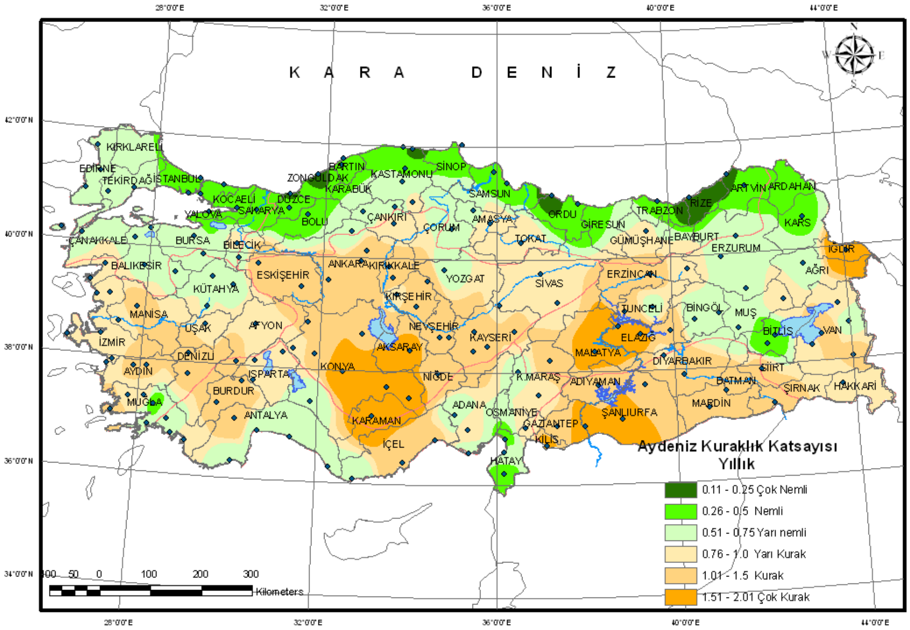
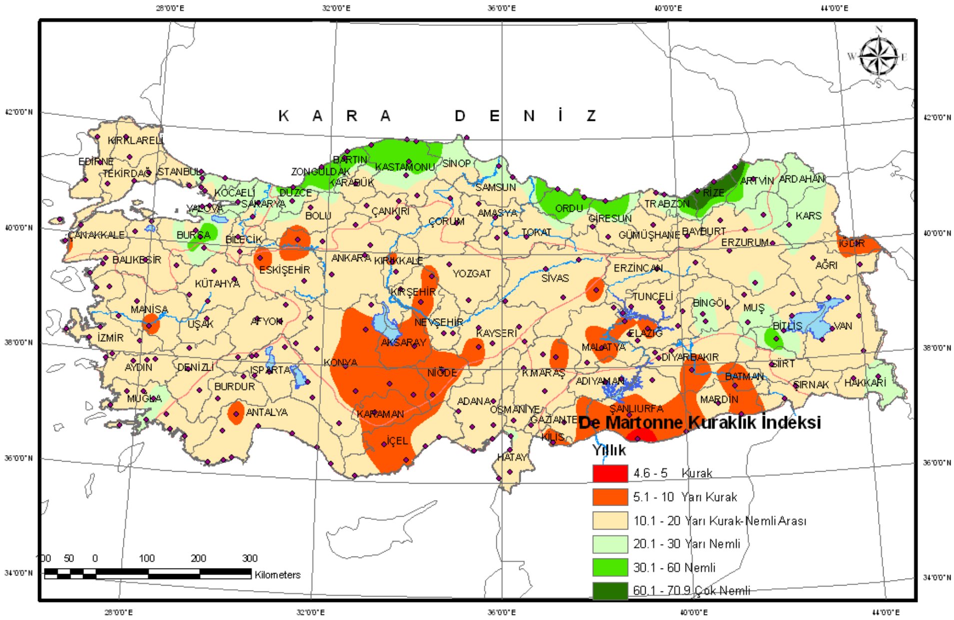
APPENDICES

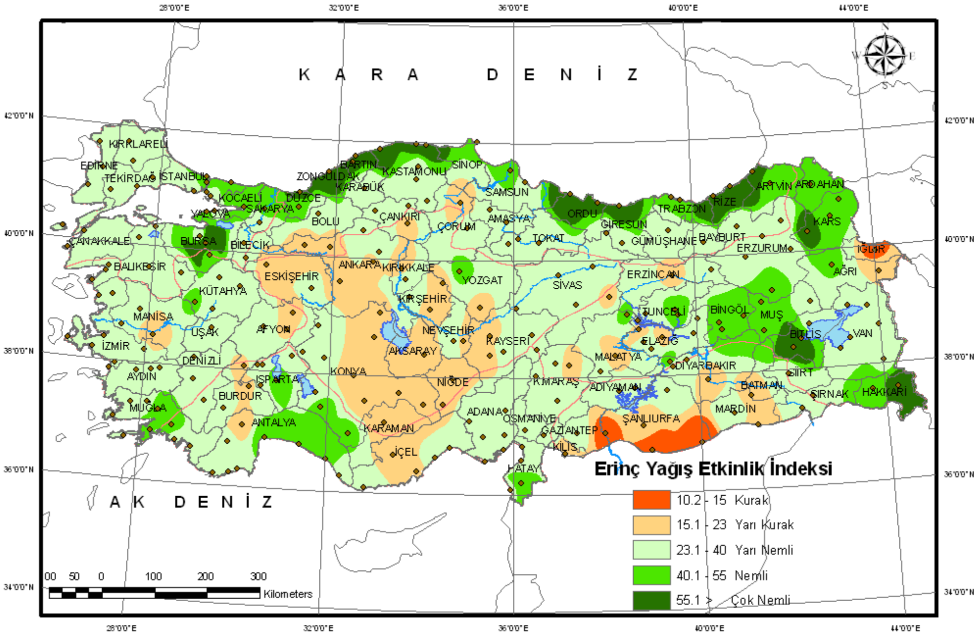
A. The Climate of Türkiye According to Climate Classifications



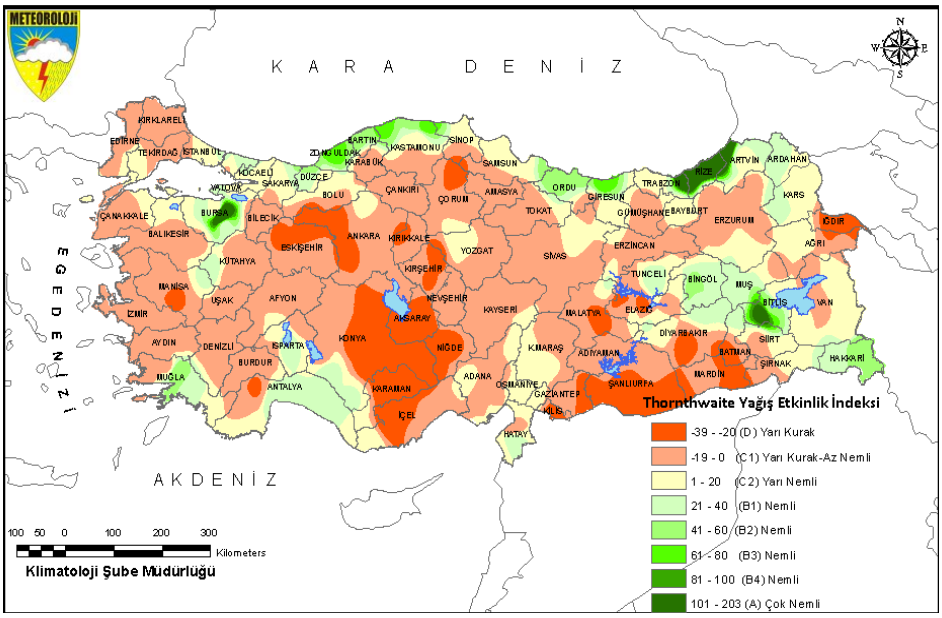
According to Aydeniz



According to De Martonne

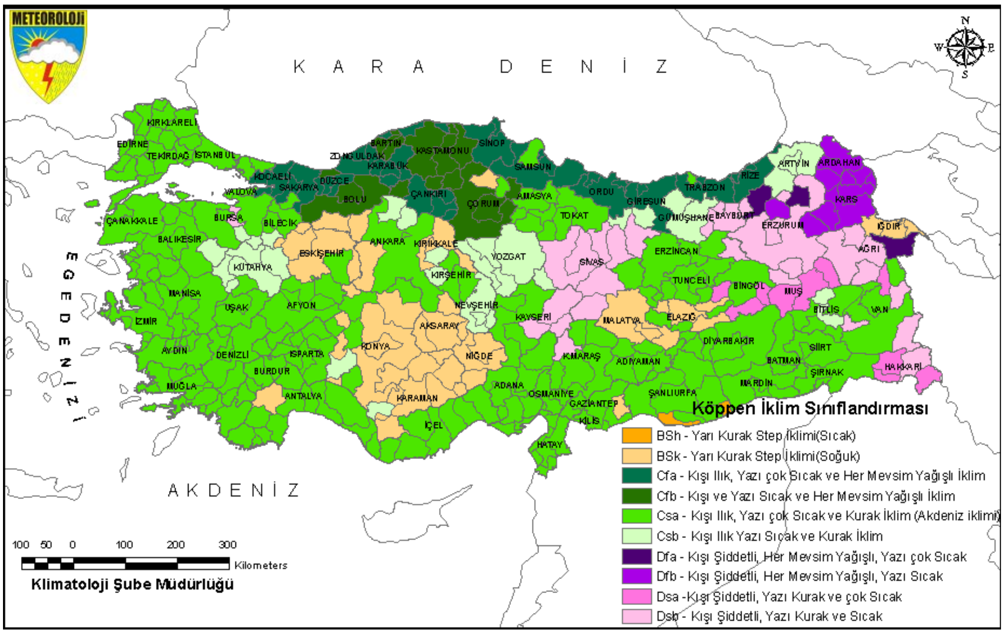


According to Erinç



According to Thornthwaite

According to Köppen-Trewartha



According to Köppen

B. The Contribution of Variables (%)

	C1	C2	C3	C4
Age Risk Group	15.015	1.950	2.873	0.816
Lone parent	0.105	8.126	8.903	8.425
Unemployment	9.940	0.089	0.001	1.300
Full-time student	10.396	10.149	0.507	2.482
Shared property	2.650	1.307	5.770	47.429
Large household size	9.989	1.223	0.337	0.968
Private renting	0.199	23.823	0.100	3.300
Central heating	6.357	0.593	26.189	0.089
Energy-inefficient property	9.728	5.893	1.065	1.600
Climatic exposure	3.631	3.198	18.143	15.774
Internet	11.388	2.475	0.278	0.919
Natural gas network access	4.230	0.227	34.659	5.690
Household disposable income	12.948	2.840	0.397	1.235
Refugees	0.206	21.702	0.038	3.811
Migration	3.219	16.404	0.739	6.161

C. The Contribution of Provinces (%)

Province	C1	C2	C3	C4
Adana	0.042	1.958	4.452	3.306
Adıyaman	0.869	0.298	0.865	0.642
Afyonkarahisar	0.002	0.395	0.111	0.004
Ağrı	5.892	0.022	0.334	1.175
Amasya	0.332	0.297	0.785	0.477
Ankara	3.617	3.379	2.538	0.372
Antalya	0.298	1.531	8.100	4.729
Artvin	0.015	0.435	2.675	0.229
Aydın	0.341	0.180	2.772	0.404
Balıkesir	0.746	0.666	0.116	0.481
Bilecik	0.901	0.130	1.112	0.070
Bingöl	0.834	0.185	0.001	0.084
Bitlis	3.525	0.046	1.072	0.982
Bolu	0.723	0.129	0.476	0.702
Burdur	0.671	1.242	0.057	0.055
Bursa	1.077	1.166	1.631	0.795
Çanakkale	1.158	0.657	0.108	0.538
Çankırı	0.463	1.318	0.065	0.946
Çorum	0.138	0.328	0.460	0.060
Denizli	0.850	0.000	0.018	0.686
Diyarbakır	3.072	0.533	0.137	0.213
Edirne	1.099	0.677	0.280	0.041
Elazığ	0.041	0.050	0.392	0.897
Erzincan	0.037	0.187	0.111	0.015
Erzurum	0.335	0.691	3.764	0.548
Eskişehir	2.006	0.481	1.194	0.372
Gaziantep	0.288	7.740	0.837	1.972
Giresun	0.170	0.682	3.454	0.155
Gümüşhane	0.116	1.193	1.515	3.041
Hakkari	7.328	0.826	0.117	4.581
Hatay	0.362	1.298	4.854	7.520
Isparta	0.638	0.089	0.045	0.060
Mersin	0.004	1.640	5.688	1.125
İstanbul	10.800	35.985	1.856	6.839
İzmir	1.879	1.705	1.322	0.769
Kars	1.345	1.401	1.506	1.318
Kastamonu	0.001	1.616	0.069	0.284
Kayseri	0.114	0.075	4.128	0.392
Kırklareli	0.977	0.490	0.222	0.128

Kırşehir	0.332	0.156	0.311	0.584
Kocaeli	0.920	0.745	2.036	1.391
Konya	0.173	0.124	1.731	0.488
Kütahya	0.309	1.093	0.410	0.001
Malatya	0.100	0.004	0.210	1.577
Manisa	0.067	0.441	0.219	0.619
Kahramanmaraş	0.901	0.014	0.009	2.205
Mardin	4.385	0.994	0.122	0.007
Muğla	0.277	0.002	5.175	1.559
Muş	5.817	0.001	0.264	1.166
Nevşehir	0.130	0.582	0.711	0.340
Niğde	0.022	0.963	0.134	0.319
Ordu	0.130	0.501	0.833	0.797
Rize	0.004	0.273	2.174	0.677
Sakarya	0.574	0.055	0.574	0.223
Samsun	0.195	0.007	0.020	0.071
Siirt	3.265	0.238	0.435	0.003
Sinop	0.069	0.983	0.730	0.173
Sivas	0.001	0.309	1.722	0.050
Tekirdağ	0.631	0.006	2.569	0.384
Tokat	0.031	1.814	0.086	0.067
Trabzon	0.251	0.003	1.872	0.610
Tunceli	0.034	0.792	1.600	3.232
Şanlıurfa	4.024	2.941	0.024	1.295
Uşak	0.433	0.452	0.307	0.006
Van	4.500	0.151	0.332	0.328
Yozgat	0.069	1.530	0.385	0.355
Zonguldak	0.567	0.740	0.056	1.361
Aksaray	0.041	0.002	0.068	0.123
Bayburt	0.007	1.140	0.326	3.154
Karaman	0.437	0.146	0.307	1.032
Kırıkkale	0.414	0.334	0.620	0.003
Batman	4.782	2.677	0.319	0.000
Şırnak	6.469	0.728	0.298	1.364
Bartın	0.066	1.397	0.207	0.094
Ardahan	1.153	1.950	0.954	2.299
Iğdır	2.364	0.023	0.001	0.023
Yalova	1.294	0.771	5.572	18.211
Karabük	0.311	0.567	2.637	1.761
Kilis	0.635	2.615	2.088	0.733
Osmaniye	0.543	0.000	2.222	3.703
Düzce	0.167	0.016	0.092	0.605