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Towards Better Understanding of Energy Poverty in Jordan: A Multidimensional Phenomenon

Ph.D. Dissertation

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List of Abbreviations

Abbreviation	Meaning
CO_2	Carbon Dioxide
EKC	Environmental Kuznets Curve
EPI	Energy Poverty Index
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
HDI	Human Development Index
INDCs	Intended Nationally Determined Contributions
Km	Kilometer
kWh	Kilowatt-hour
MEMR	Ministry of Energy and Mineral Resources
MEPI	Multidimensional Energy Poverty Index
MJ/$	Megajoule per US Dollar
SDGs	Sustainable Development Goals
W	Watt

Acknowledgments

"***And say, My Lord, increase me in knowledge***" (The Quran, Ta Ha 20, 114).

This dissertation represents the culmination of a profound intellectual adventure. It was a journey punctuated by both exhilarating discovery and challenging self-doubt. Looking back, I recognize that none of it would have been possible without the support of a remarkable network of individuals. I express my deepest gratitude to those who provided invaluable guidance and encouragement within and beyond the academic sphere.

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Köszönöm!

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1. The rationale of the research and justification of energy poverty

This chapter is an introductory section of my research topic, questions, and objectives. Firstly, I present an overview of the Jordanian energy sector and how my research will contribute to bridging the current gap in the literature. Additionally, I discuss the main theories and concepts related to my research. Within this chapter, I also describe the preparation process of this dissertation, including the formulation of the hypotheses. Finally, I justify the relevance and significance of my doctoral research. **Figure *1*** visualizes the research scope and connections on which this dissertation is based.

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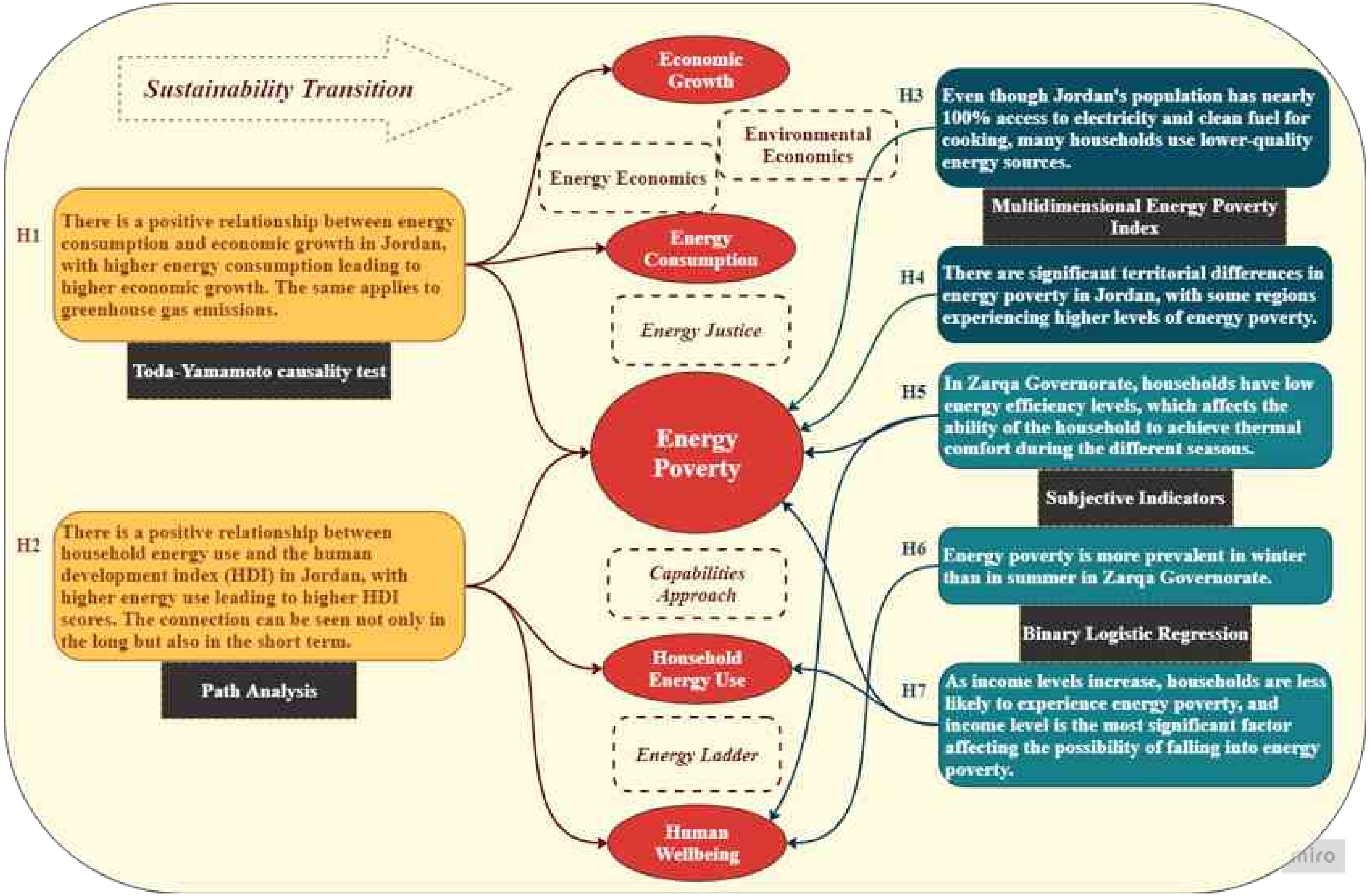

Figure 1. Visualizing the Research Scope and Connections.

Source: Own compilation.

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1.1. Jordan’s Energy Landscape: Challenges and Transition to Renewable Sources

1.1.1. Jordan

Jordan is a middle-upper-income country (*World Bank Country and Lending Groups – World Bank Data Help Desk*, 2020) and the most politically liberal country in the Arab world. Jordan, a young country that became an independent kingdom in 1946, has a strategic location in the Middle East region with its capital, Amman, the country’s largest and most populated city; its total area is 89,342 km^2. The country mostly has no port on the sea except 26km of coast in Aqaba city. It is a non-oil producing country, relies mainly on importing its energy needs from surrounding countries, and has a high abundance of renewable energy resources, mainly solar and wind energy (Jaber and Probert, 2001a, 2001a; Jaber, Badran and Abu-Shikhah, 2004). Jordan consumes more energy per unit of economic output than other countries with similar social and economic structures (Saeedan and Friedrich-Ebert-Stiftung Amman office, 2011).

- *Population pyramid*

Over time, Jordan's population has experienced significant growth due to various events in the region. As evidenced by the population pyramid displayed in **Figure *2***, the country's population is relatively young. This presents an opportunity for a skilled workforce to contribute to the economy. However, Jordan is also grappling with high unemployment rates due to excess university graduates that the labor market cannot accommodate. High population growth in developing countries like Jordan would slow development (Peterson, 2017).

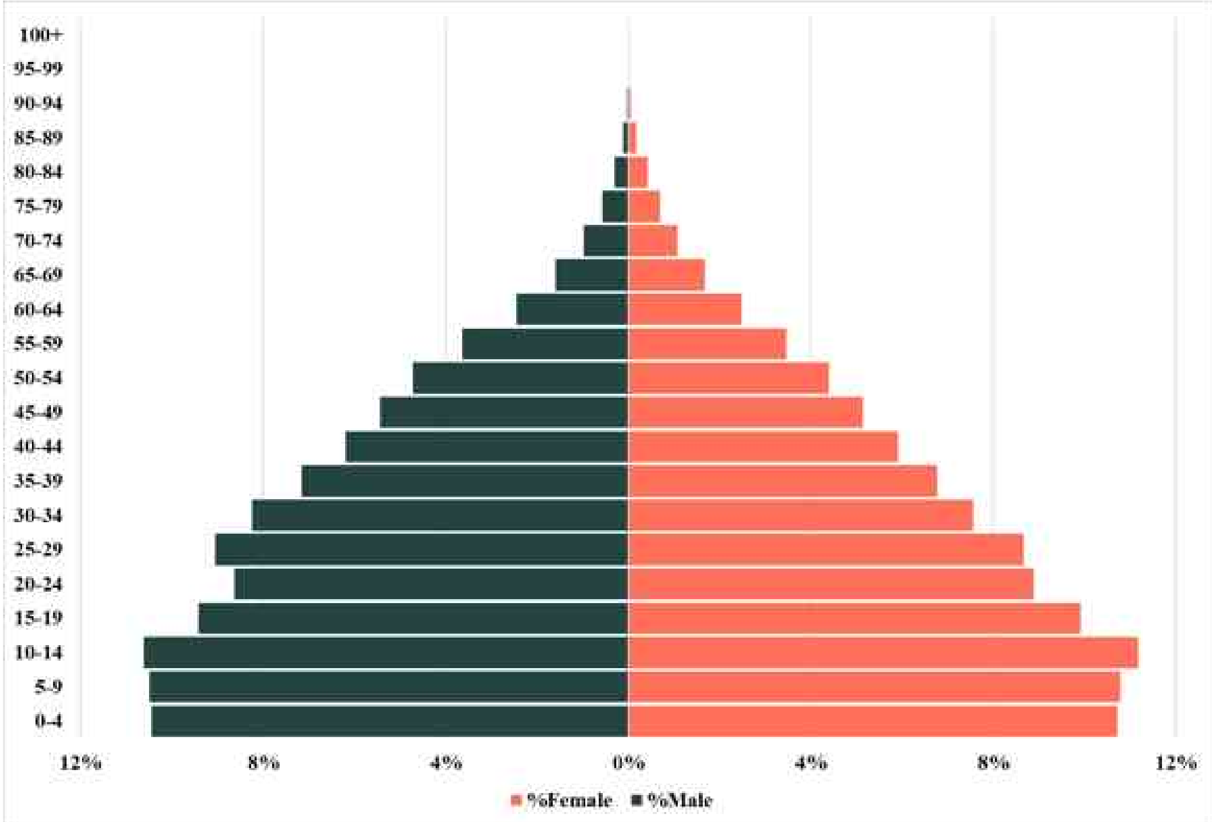

Figure 2. Jordan population pyramid, 2022.

Source: Own edit based on data retrieved from (*Population Pyramids of the World from 1950 to 2100*, no date).

- *National poverty estimates*

Since implementing standardized poverty metrics in the early 2000s, the absolute national poverty rate has exhibited variability, oscillating within the range of 11% to 16% of the total populace, noting that, since 2012, no reports on poverty were published by the Government of Jordan (Lenner, 2023). However, a study by Aljaloudi (2020) estimated the poverty rates in 2017 and revealed that poverty has increased to 22.2%. Lack of data of official data and estimates would hinder any efforts directed toward addressing poverty and any related socio-economic issues.

1.1.2. Jordan Energy and Climate Change

Before 2003, Jordan purchased oil from Iraq below market rates, and the government subsequently transferred some of these cost advantages to consumers. After 2003, Jordan lost this affordable oil source, and the rise in global prices followed. While global food prices doubled between 2002 and 2008, global energy prices increased more than threefold (Atamanov, Jellema and Serajuddin, 2017). Although the government was compelled to raise prices in 2005 and once more in 2006, it managed to keep them below levels elsewhere. As a result, government spending on petroleum subsidies alone accounted for 5.8% of GDP in 2005 (Coady *et al.*, 2006). After Palestine, Jordan has the second-highest fuel and electricity prices in the Arab world, attributed to price liberalization initiatives in recent years and a fixed tax on oil derivatives (Jordan News, 2022). A new electricity tariff was introduced in the first third of 2022 and targeted Jordanian families, holders of permanent Jordanian passports, and Gazans will also benefit, as well as subscription service meters for households (The Jordan Times, 2021). The subsidized tariffs are divided into three categories: consumers who use between 1 and 300 kWh of electricity pay 50 fils per kWh (1 Jordanian Dinar equals 1000 fils), those who use between 301 and 600 kWh pay 100 fils per kWh, and those who use more than 600 kWh pay 200 fils per kWh (The Jordan Times, 2021).

In 2007, the Jordanian Government introduced a transformation strategy to include more renewable energy resources, oil shale, and nuclear energy. Furthermore, to decrease the reliance on oil and natural gas in the energy mix (*Updated Master Strategy of Energy Sector in Jordan for the period (2007-2020)*, 2016). Fossil fuel is the primary source of energy in Jordan that has a pivotal role in increasing GHG emissions, while it is essential to consume energy to sustain economic and social development. Since 1990, Jordan's primary energy consumption has dramatically increased, with a notable increase in carbon dioxide (CO_2) emissions as well. This increase mainly resulted from the rapid growth of the population (Ritchie, Rosado and Roser, 2020, 2023; Ritchie *et al.*, 2023). Figure 3 shows a strong correlation between primary energy consumption, CO_2 emissions, and population growth.

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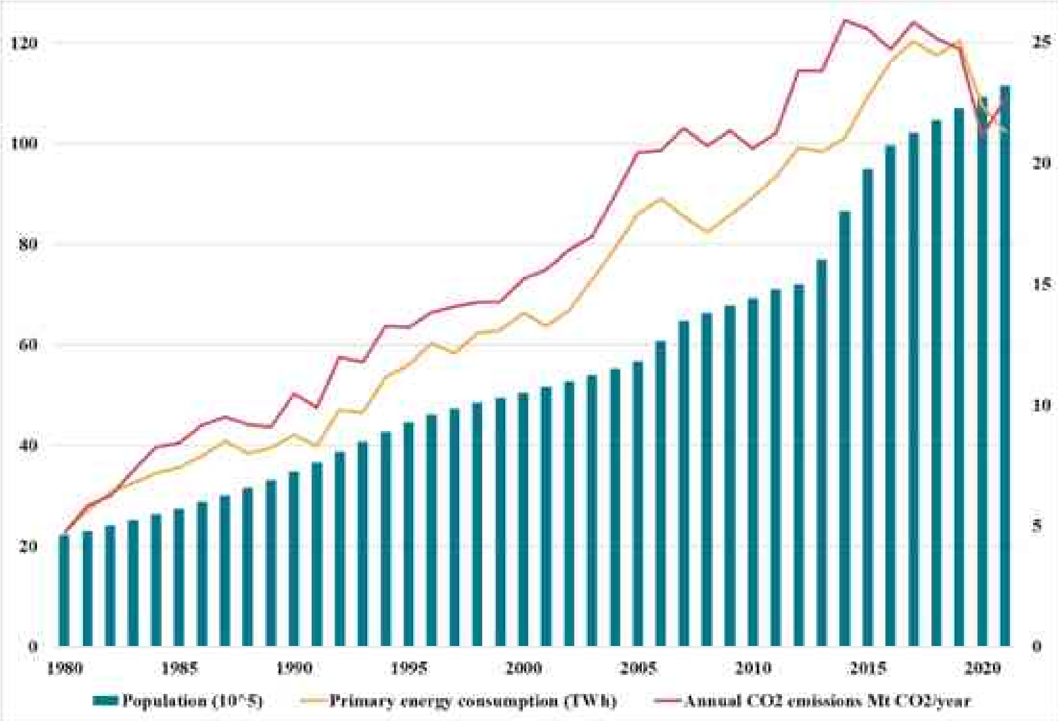

Figure 3. The change in primary energy consumption, CO_2 emissions, and population in Jordan 1980-2021.

Source: Ritchie et al. (2023b, 2023a, 2020)

Jordan's climatic profile exhibits a diverse range, transitioning from Mediterranean influences to arid desert conditions, a testament to its geographic location and topographical variations (Hamdi *et al.*, 2009). Predominantly, aridity dominates the landscape, typified by prolonged periods of scorching summers marked by low humidity and scant precipitation, juxtaposed against winters characterized by cooler temperatures and sporadic rainfall. This climatic dichotomy contrasts arid summers and relatively wetter, colder winters, a hallmark of Jordan's seasonal variability (Al-Addous *et al.*, 2023). Notably, this climatic tapestry is further nuanced by regional disparities, as evidenced by milder winter temperatures in the southern reaches compared to the northern territories (Hamdi *et al.*, 2009). Such climatic nuances underscore the intricate interplay of geographical features and atmospheric dynamics shaping Jordan's climatic mosaic.

Figure *4* shows the number of heat stress days when the average temperature was above a threshold of 32 and 39 degrees and frost days when the temperature was less than 0 degrees in Jordan from 2008 to 2023. As shown in the figure, the frequency of extreme weather events may threaten energy-poor households dealing with excessive heat or cold, affecting their ability to cool or warm their households adequately. Thus, the coping mechanisms of energy-poor households may differ based on the characteristics of the income, area, and usage of cooling devices, among other factors.

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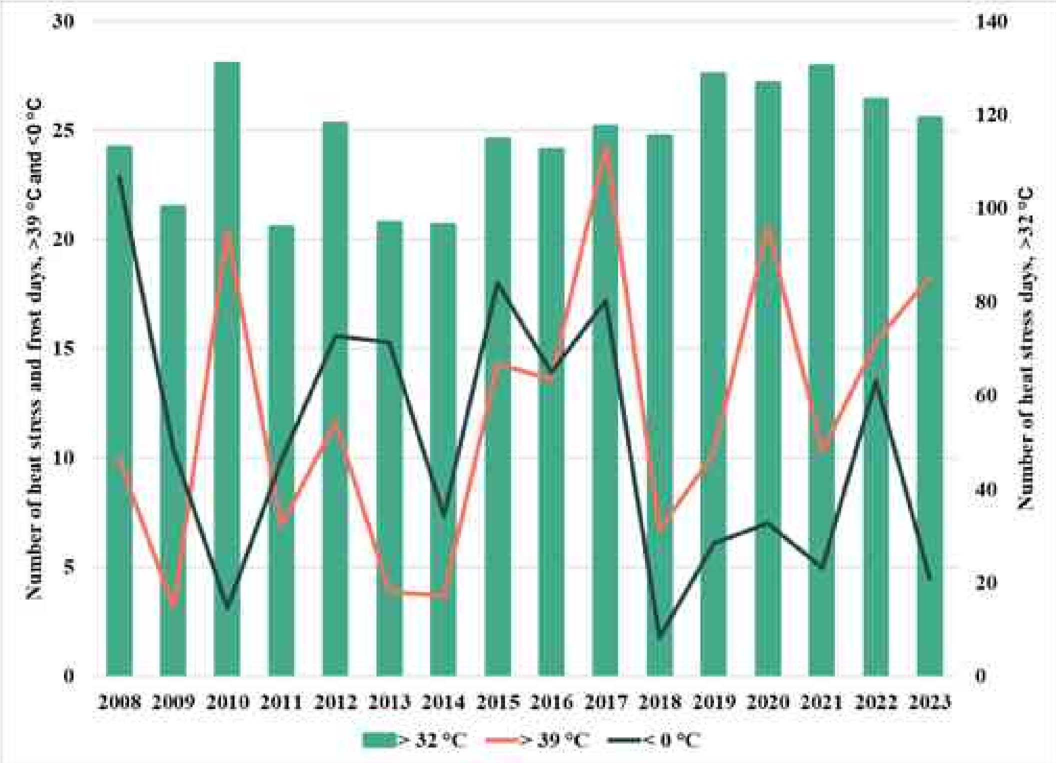

Figure 4. Number of extreme weather days in summer and winter.

Source: (Morales *et al.*, 2023).

According to Jordan's Third National Communication Report on Climate Change (Jordan. National Communication (NC). NC 3. | UNFCCC, 2014), and based on the 2006 GHG emissions inventory, the energy sector (including transportation) has contributed to 73% of the total GHG emissions which only increased to around 76% according to 2017 emissions inventory (MoE and UNDP, 2022). In 2015, Jordan signed and ratified the Paris Agreement, which resulted in submitting the official Intended Nationally Determined Contributions (INDCs); Jordan pledged to reduce their GHG emissions by 14% below the "Business As Usual" (BAU) target by the year 2030, 12.5% of these emissions are conditional to the availability of international financial aid and support to means of implementation (*Intended Nationally Determined Contribution*, 2015). In addition, as of 2017, the Jordanian Government, in collaboration with the Global Green Growth Institute, prepared and published the national green growth plan, which identified six sectors with a high potential for growth areas; one of these was the energy sector, the plan identified Jordan as insecure in term of energy resources because of the reliance on external resources, and as a result, the plan identified renewable energy represented by solar energy as the primary source to play a significant role in greening the energy sector (A National Green Growth Plan for Jordan, 2018). In general, the percentage of GHG emissions produced in Jordan is low. **Figure *5*** shows the annual share of global CO_2 emissions in Jordan to be less than 0.075%, which provides evidence that Jordan is still considered affected by climate change, not a major contributor, compared to the pledged INDCs. Moreover, when evaluating the CO_2 emission intensity in Jordan for the years 1980-2021, it is noticed that there is an annual decrease in emission trend (**Figure *6***), where 2020 has the lowest emission value of 0.196 $kgCO_2/kWh$, which was the year of COVID-19 pandemic.

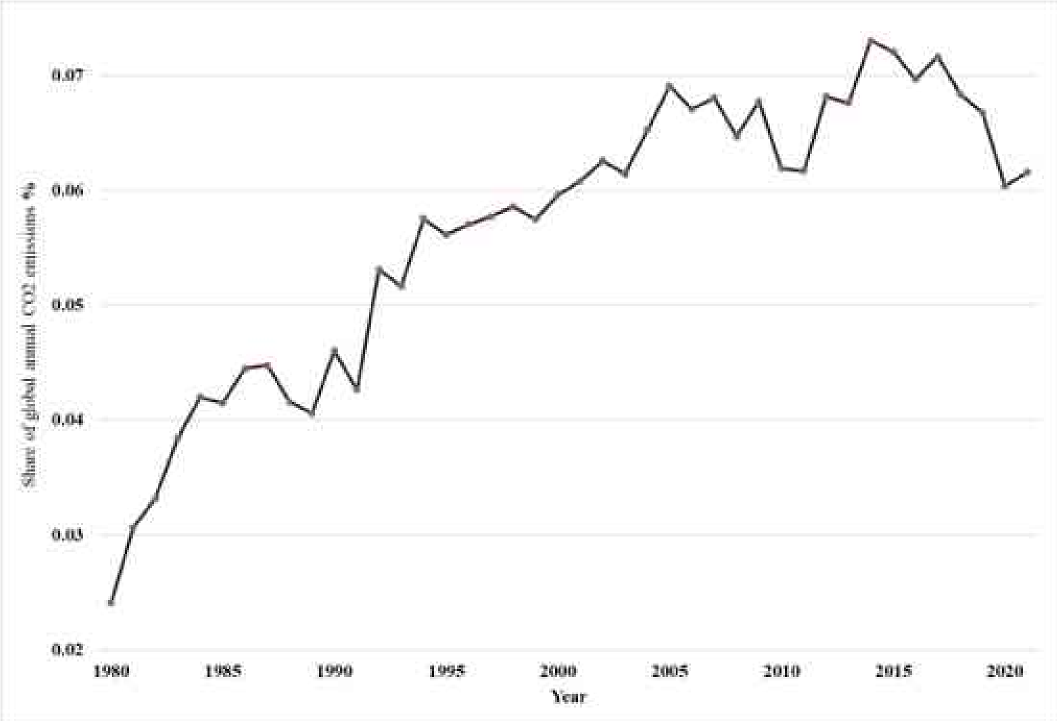

Figure 5. Annual share of global CO_2 emissions 1980-2021.

Source: Ritchie, Rosado and Roser (2020)

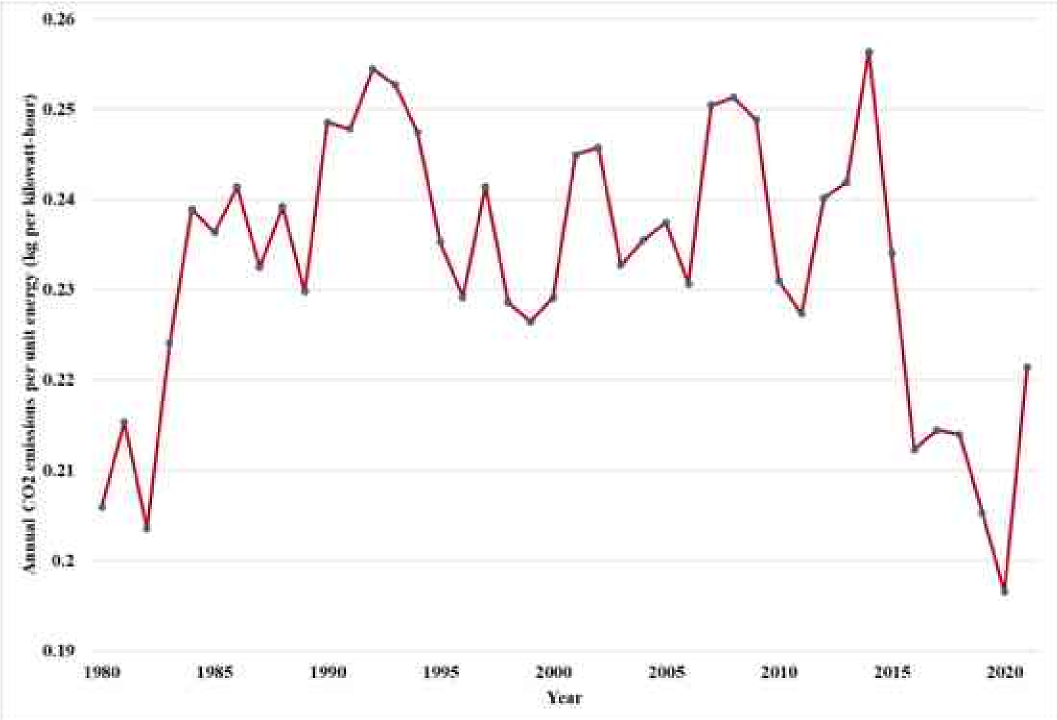

Figure 6. Jordan CO_2 emission intensity 1980-2021.

Source: Ritchie, Rosado and Roser (2020)

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1.2.Theoretical Background

Energy poverty is a complex issue widely studied in the literature, often in conjunction with related concepts such as fuel poverty, energy vulnerability, energy insecurity, and energy justice. In this chapter, I will examine the main theories and concepts that help us understand and explain energy poverty within the context of energy insecurity and vulnerability. Additionally, I will explore the role of justice in analyzing energy poverty and consider how various theories can inform our understanding of this issue. Energy poverty is multidimensional and can be studied from different angles and scientific and social disciplines. The main theories and ideas discussed in this section align with this dissertation's research goals, and the main results in each chapter reflect the theories mentioned.

While writing the dissertation, I followed the process in **Figure *7***. The process started with reviewing theories mostly about energy poverty from various perspectives. After reviewing the theories, hypotheses were formulated regarding energy economics and energy poverty in Jordan. The selection of the methods used in my dissertation was controlled by the fact that data availability and credibility forced me to test the methods and explore the ones that fit with the available data. Calculations followed data collection from different sources to test my hypotheses. Lastly, based on the results, I could formulate theses in line with the hypotheses.

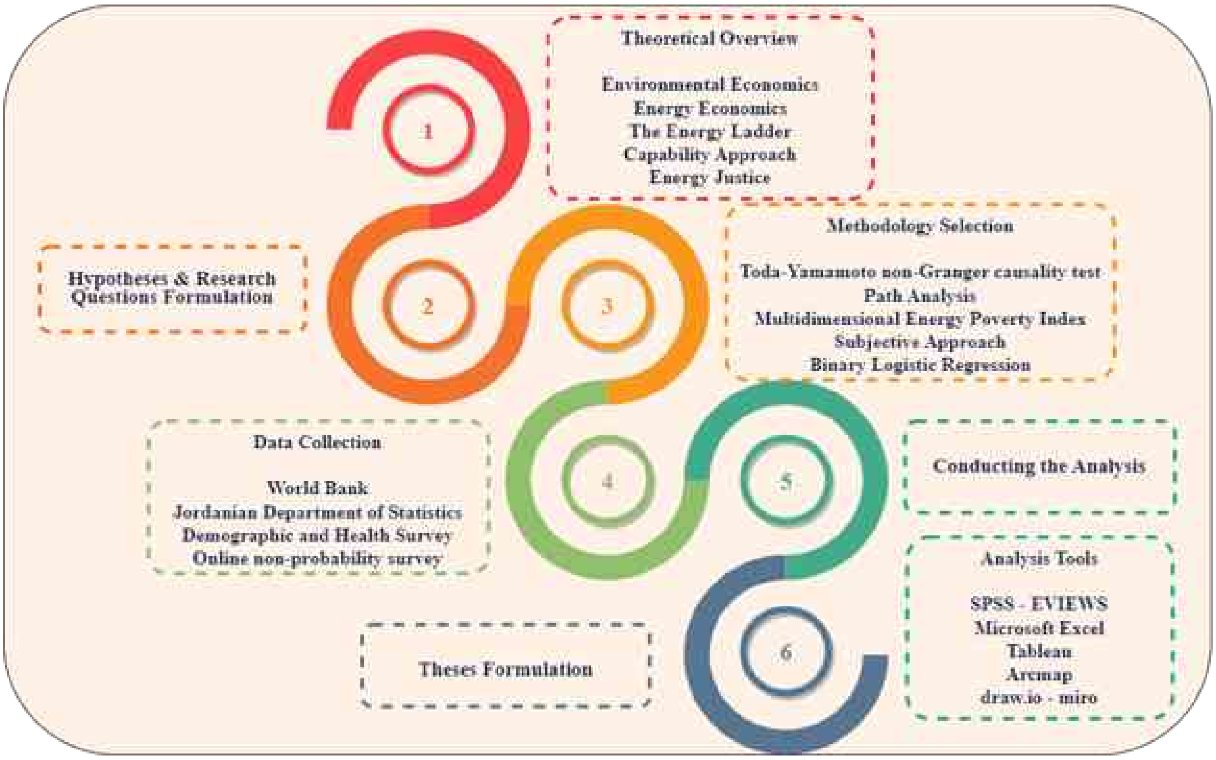

Figure 7. Dissertation Development Process.

Source: own compilation.

The main goal of my dissertation is to examine the characteristics of energy poverty in Jordan. While energy poverty is recognized as a multifaceted and complex issue, I studied the relationship between energy and economic growth and climate change on the one hand and the relationship to human well-being on the other hand. I use multiple methods based on various data sources and types to achieve this goal.

1.2.1. Energy Poverty

Energy and fuel are related but distinct concepts. Energy is the ability to do work or to produce heat (Bhattacharyya, 2011), while fuel is a substance that possesses internal energy and produces heat when burned or obtains energy from sources such as solar radiation or geothermal reservoirs beneath the Earth's surface (Bhattacharyya, 2011). In other words, fuel is a source of energy. For example, gasoline is a standard fuel used to power cars, while the energy released by burning gasoline makes the car move. The difference between energy and fuel can be thought of as the difference between the potential to do work and the means of releasing that potential. However, they are frequently used interchangeably; fuel and energy poverty are not always the same.

Energy poverty refers to the more general idea of a household's inability to access and purchase sufficient amounts of energy for their requirements, whereas fuel poverty mainly refers to the circumstance in which a household cannot pay to heat their home effectively. However, because it focuses on the particular need for heating and the difficulties that households may encounter in meeting this need, fuel poverty is seen as a distinct instance of energy poverty. In this regard, fuel poverty is a more specific type of energy poverty that is frequently used to describe the difficulties that households encounter in meeting their heating demands.

The literature on energy poverty is extensive and continues to grow as more researchers from different disciplines are interested in studying this important issue. These researchers use a variety of approaches and data sources to examine energy poverty and its impacts on individuals, communities, and societies. The growing interest in energy poverty is reflected in the increasing number of publications on the topic and the development of diverse approaches and policy implications for addressing the issue in different countries. This section of the literature review will explore the existing research on energy poverty within different contexts, highlighting the key findings and recommendations from these studies. It is important to note that while energy poverty is a global problem, its specific causes and consequences vary depending on the social, economic, and political context in which it occurs. As such, it is necessary to consider these contextual factors when examining the literature on energy poverty and developing strategies to address it.

Energy poverty is one of the issues that modern societies face. Millions of people are affected by energy poverty, even if the context of the causes and consequences are different (Bouzarovski, 2018). The definitions of energy poverty vary and primarily depend on the geographical characteristics of how it occurs in various communities. At the beginning of this chapter, the terminology of energy poverty should be clarified and distinguished from other

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issues, such as energy vulnerability and fuel poverty. It is worth noting that to the author's knowledge and while reviewing the literature, there is no official definition used in the context of Jordan as a country or the Middle East as a region.

Some other concepts shall be defined before diving into energy poverty and discussing some differences with fuel poverty. Energy insecurity, which is thought to be the broader concept of energy and fuel poverty, is one of those concepts that should be identified. Hernández (2016) defined energy insecurity as an inability to meet household energy needs adequately. The occurrence of energy insecurity is linked to socioeconomic and ethnic household characteristics in the U.S. for example, African Americans appear to suffer from energy insecurity more than other ethnic groups, such as Asians and Latinos (Hernández *et al.*, 2016). Energy insecurity is linked to health hardships; some studies proved that compared to children from energy-secure homes, children from moderately and severely energy-insecure homes are more likely to experience food insecurity, hospitalizations, lower health ratings, and developmental issues (Cook *et al.*, 2008). In addition, Cook *et al.* (2008) defined household energy security as consistent access to enough energy needed for a healthy and safe life in the geographic area where a household is located (Cook *et al.*, 2008). When a household is energy secure, its members can afford to pay to obtain needed energy in the form of heating/cooling, lighting, and refrigeration, besides their ability to fulfill other expenditures such as paying rent, clothing, transportation, childcare, and medical care (Cook *et al.*, 2008).

The vulnerability of a system can be identified as the degree to which that system is unable to cope with selected adverse events, as it is not possible to take all harsh events into account, some criteria should govern the selection of relevant contingencies (e.g., likelihood, criticality, and damages) (Gnansounou, 2008). Gatto and Busato (2020) introduced a modified definition to include energy and stated the degree to which an energy system or entity is more likely to get exposed to adverse events or change and risk falling into traps in economic, social, environmental, and governance terms.

Energy poverty arises when a household struggles to achieve adequate levels of necessary energy services in the home, including heating, cooling, lighting, and using appliances (Thomson, Bouzarovski and Snell, 2017). A combination of three factors causes energy poverty: low income, high energy prices, and poor building quality (Bouzarovski, 2014). Researchers still debate the definition of energy poverty, the differences between energy and fuel poverty, and the approach used to measure those issues. Over the years, there has been a broadening of the scope and comprehension of energy poverty, aiming to connect different policy domains and reveal underlying factors contributing to energy poverty. Intrinsic to the "conventional drivers" such as unemployment, housing tenure, age and size of the dwelling, and geographical location, socio-demographic, housing, and infrastructure characteristics have been increasingly incorporated into data collection efforts to assess the extent of energy poverty (Stojilovska *et al.*, 2022). Economic privation, housing quality, type of tenure, and energy access are highlighted by Jessel et al. (2019) as factors determining energy poverty as a chronic phenomenon. Several tools have been used to combat energy poverty. Economic subsidies, social tariffs on energy prices, social bonuses that limit the impact of the price on bills, and house energy efficiency improvement are examples of the tools mentioned (Vurro et al. 2022).

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It is crucial to identify the characteristics of households living in energy-poor conditions. However, in the literature, there is often an interchangeable use of the terms energy and fuel poverty. As a result, it becomes difficult to differentiate between the two concepts, even when describing definitions and measurement procedures. Moreover, the literature interchangeably uses fuel and energy poverty (Thomson and Snell, 2013; Thomson, Bouzarovski and Snell, 2017). Li et al. (2014) thoroughly examined the distinctions and commonalities between energy and fuel poverty. Their research elucidated that energy poverty predominantly pertains to challenges associated with energy availability, particularly prevalent in developing countries.

On the other hand, fuel poverty primarily pertains to the issue of energy affordability in developed nations. However, it is vital to acknowledge the existence of a specific group facing concurrent energy and fuel poverty challenges. This group resides in regions characterized by cold climates, encountering substantial difficulties in obtaining reliable electricity supply, accessing modern cooking facilities, and acquiring affordable indoor heating solutions. By incorporating these additional insights, a more comprehensive understanding of the multifaceted nature of energy and fuel poverty can be attained. Adding to the above, in developed countries, the problem is represented by issues related to energy affordability, season-related mortalities, and the technological infrastructure of the household. In contrast, the main issues studied in developing countries are the modern energy service supply, unfavorable living conditions, limited economic opportunities, and health problems (Guevara et al. 2022, Samarakoon 2019).

Fuel poverty is a personal issue that only affects those who live in their homes, varies through time and location, and has a multifaceted, culturally sensitive meaning (Simcock, Walker and Day, 2016). While reviewing the literature on fuel poverty, it happened that energy poverty is used as well. The characteristics of fuel poverty can differ from one country to another, considering the energy system in each country and the climate and socio-economic factors that affect household energy expenditure. For example, Bouzarovski and Petrova (2015) state that these issues have a common condition in developed and developing countries: "the inability to attain a socially and materially necessitated level of domestic energy services." For them, fuel and energy poverty can be encompassed within the same conceptual framework, as they represent domestic energy situations that hinder individuals from engaging in the lifestyles, customs, and activities integral to being a part of society.

Additionally, at the European level, both concepts were used separately and together in different policy documents, as proved by (Thomson, Snell and Liddell, 2016). Primc et al. (2021) reported that in the UK, the term "fuel poverty" is used to describe the issue, while other countries use the term "energy poverty." This suggests that "fuel poverty" is becoming less widespread and is starting to fade. This can be noticed in studies that use original fuel poverty indicators and refer to energy poverty (Bouzarovski and Petrova, 2015; Thomson *et al.*, 2019; Sareen *et al.*, 2020; Jiglau *et al.*, 2023). In this section, we will simultaneously use energy and fuel poverty to be consistent with these terms' sources.

Another definition of fuel poverty is 'the inability to heat the home adequately because of low household income and energy-inefficient housing' (Healy and Clinch, 2002). Fuel poverty is also defined as the inability of a household to achieve the required level of energy services (Bouzarovski, 2014). The definition of energy poverty has evolved, although Pellicer-Sifres

(2019) criticized that most definitions underline concepts such as low temperature, low household income, and energy sources. Further, it was suggested that using terms such as vulnerability, precariousness, or energy deprivation is more appropriate in cases where people do not want to be stigmatized as poor, which can be permanent. Low-income households usually reduce their food spending and cut their energy consumption to keep up with essential financial commitments (Anderson, White and Finney, 2012). In general, low-income people react to burdens by lowering their living standards, which, with time, becomes a normal lifestyle; even heating all rooms would look luxurious (Brunner, Spitzer and Christanell, 2012). Hards (2013) summarized these issues related to heating or cooling, where sometimes people who have, for example, poorly lit, damp, and cold homes are stigmatized as "poor" or "stingy." Moreover, those who could not afford to warm their homes may be stigmatized as "too mean to supply it."

Bouzarovski (2014) mentioned the concept of "domestic deprivation" as the mainstream theorization of energy poverty and noted that there is a shift towards a more complex issue of household necessities, built environment flexibility, and social resilience. Moreover, it refers to the fact that energy poverty's driving forces are embedded in certain local social, political, and environmental conditions. Fuel poverty hinders the fuel poor's ability to participate in their societies effectively, and they suffer from long-term and short-term health issues. The energy poor are limited in their energy aspiration level and the types of energy-relevant decisions they can make because they cannot afford energy efficiency in homes and appliances or because there is not an optimal income level available (Walker and Day, 2012). DellaValle and Czako (2022) reported that the energy poor face conditions where they cannot get information on energy poverty, pricing, and solutions or participate in the policies relating to energy, housing, climate change, and finances.

Fuel poverty echoes a relationship between energy efficiency and low income, and the process of identifying fuel poverty uses the expenditure or consensual approach (Thomson and Snell, 2013). The causes of fuel poverty are extensively discussed in the literature. The multidimensional nature of fuel poverty recognizes three main factors: the household's economic situation, energy efficiency, and energy prices (Fabbri, 2015a; Fizaine and Kahouli, 2019). In addition to the mentioned causes, Dobbins et al. (2019) added inefficient technologies and limited access to clean and affordable energy sources. These causes also include those that are technical, economic and attitude-related to the practical and responsible use of energy (Biernat-Jarka, Trębska and Jarka, 2021). It extends beyond income (Streimikiene *et al.*, 2020).

Moreover, these issues became extensively recognized as societal challenges among academics, practitioners, and policymakers (Bouzarovski and Petrova, 2015). The efforts to measure fuel poverty in the Middle East are still limited (Belaïd, 2022a). There is limited coverage of energy poverty in middle-income countries (Urquiza *et al.*, 2019); Jordan is not an exception as an upper-middle-income country. Fuel poverty and energy poverty are both recognized in the literature. However, the latter is used more frequently on the European scale to describe domestic deprivation (Thomson, Bouzarovski and Snell, 2017). Energy poverty is complex to measure quantitatively (Thomson, Bouzarovski and Snell, 2017; Zhang, Li and Han, 2019). Studies in developing countries mainly focus on modern energy accessibility (Sadath and Acharya, 2017). In contrast, affordability is the primary concern of researchers in developed countries (Bouzarovski and Petrova, 2015).

González-Eguino (2015) argued that studies focusing on energy poverty in developing countries refer to the problem of energy access, whereas the same features are being studied in more prosperous countries as fuel poverty. In the same context, Bouzarovski and Petrova (2015) indicated that fuel poverty is more related to the developed world, while energy poverty reflects the situation of the developing ones. Fuel poverty was widely used in the United Kingdom using the capability approach for the first time and defined in the earliest studies as the inability to provide warmth at home (Bradshaw–Hutton 1983). Boardman (1991) later provided a more specific definition of the inability to afford adequate warmth because of the inefficiency of the home and added that an energy-poor household is when more than 10% of income is spent on energy by a householder to achieve comfortable temperatures. Moore (2012) raised the question of the relativity of fuel poverty because poverty has a relative definition. Setting a threshold that can change with time can be more accurate than using an absolute threshold (such as 10% income). In later years, fuel poverty was linked with subjective well-being and how poverty can impact it, especially with the release of the annual World Happiness Report by the United Nations. Issues such as productivity, healthcare, education, employment, and energy-related tariffs higher prices can lead to fuel poverty can be associated with subjective well-being (Awaworyi Churchill et al. 2020). Thomson et al. (2019) defined energy poverty as when a household is incapable of securing a degree of domestic energy services. According to this definition, studying energy poverty should focus on heating and cooling spaces. More frequent and intense heat waves can significantly pressure human life.

Energy poverty is a young field of science (Guevara et al. 2022). The methods, concepts, and approaches used to understand this phenomenon are evolving. Defining energy poverty can vary depending on the case and metrics used to measure it. According to Rademaekers et al. (2016), there are two energy poverty scenarios. The first is when energy expenditure consumes a high proportion of income, and the second is when a household cannot afford sufficient energy expenditure. Both concepts of poverty can be intertwined, and examining energy poverty can provide insights into fuel poverty in return. Day et al. (2016) proposed a definition for energy poverty: an inability to realize essential capabilities as a direct or indirect result of insufficient access to affordable, reliable, and safe energy services and considering available reasonable alternative means of realizing these capabilities. **Table *1*** lists the main definitions of the concepts related to energy poverty identified in the literature.

Table 1. Main Definitions of Energy Poverty and related issues.

Author	Year	Definition	Terminology
Bradshaw-Hutton	1983	The inability to provide warmth at home.	Fuel Poverty
Boardman	1991	When more than 10% of income is spent on energy by a householder to achieve comfortable temperatures.	Fuel Poverty
Cook et al.	2008	Consistent access to enough energy for a healthy and safe life in the geographic area.	Energy Security
Hernández	2016	The inability to meet household energy needs adequately.	Energy Insecurity

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Day et al.	2016	The inability to realize essential capabilities due to insufficient access to affordable energy services.	Energy Poverty
Thomson, Bouzarovski, and Snell	2017	When a household struggles to achieve adequate levels of necessary energy services in the home.	Energy Poverty
Gatto and Busato	2020	The degree to which an energy system or entity is likely to be exposed to adverse events or change.	Energy Vulnerability

Source: own compilation based on the literature.

The study of energy poverty and fuel poverty reveals that there are some similarities and differences. Framing both concepts under energy insecurity and vulnerability, **Figure *8*** summarizes those similarities and differences from the literature. In the third and fourth chapters, energy and fuel poverty are examined in detail, among other terminologies upon which the figure was built.

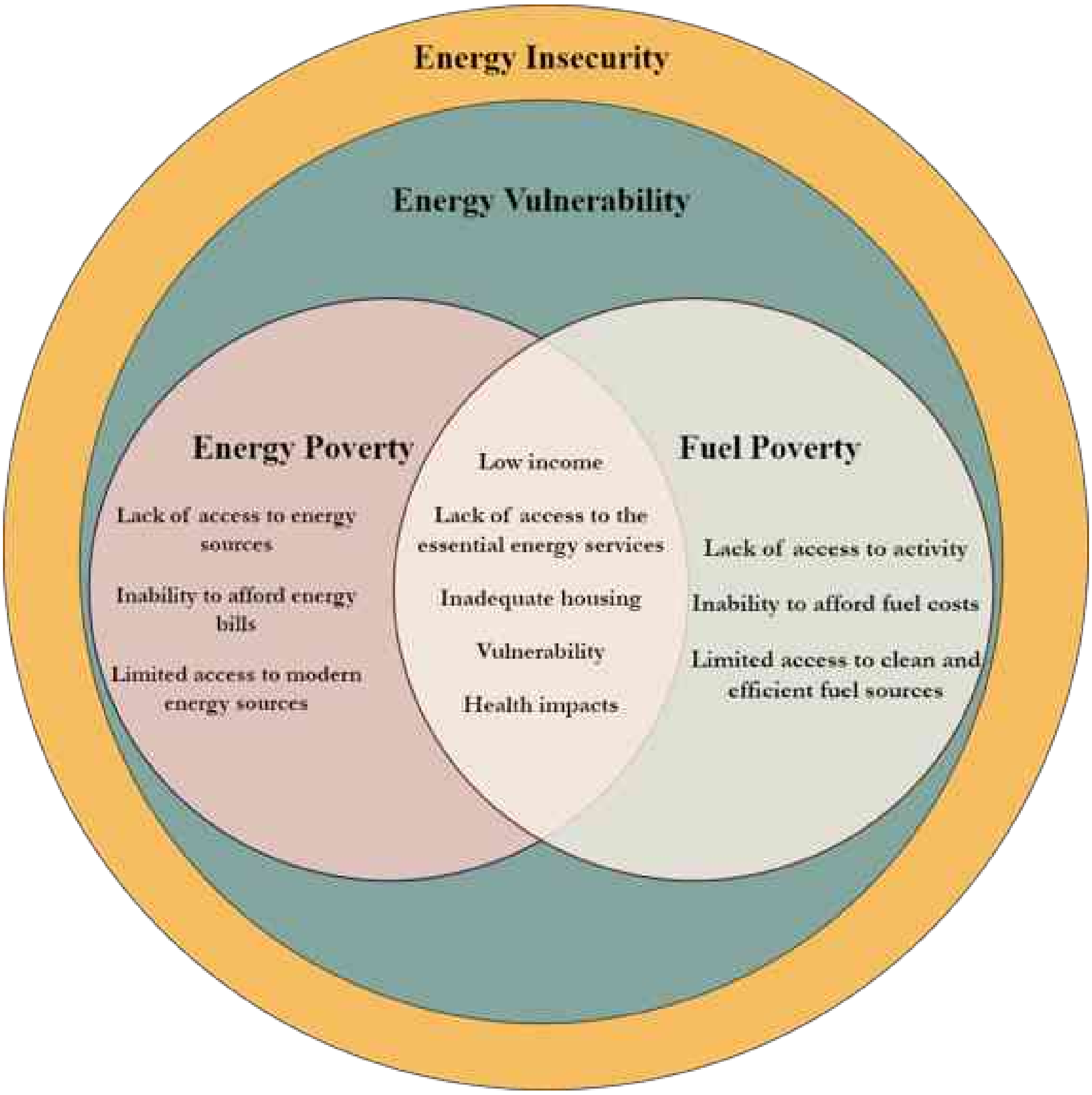

Figure 8. Conceptualizing the framework of energy and fuel poverty.

Source: Author's compilation based on the discussed literature.

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Energy poverty policies are formed and unified in developed countries. In contrast, in developing countries, people face energy-related problems, and relevant resource constraints make it challenging to pay much attention to energy poverty (Xiao *et al.*, 2021). A few European and UK countries have an official definition of fuel poverty (Pellicer-Sifres, 2019). Regardless of how fuel poverty is defined, it might not be easy to pinpoint which homes need to increase their energy efficiency the most (Walker *et al.*, 2014).

Measuring energy poverty remains part of the debate among scholars. Sovacool (2012) identifies four obstacles hindering energy poverty alleviation: technical, economic, political, and social. The author argues that all the above obstacles must be addressed, and solving one issue will not change energy poverty status. Moreover, the author claims governments should shift their focus from technical solutions to social, political, and cultural dimensions.

Creutzfeldt et al. (2020) state that a lack of a unified definition, an inability to figure out who is responsible for energy poverty, and no agreed indicators to measure the issue can be obstacles to solving it. Measuring energy poverty can be complex; it varies depending on the time and place (Siksnelyte-Butkiene et al. 2021). According to the European Parliament (2016), three measurement methods exist. First is the direct measurement of energy services such as heating achieved compared to a standard. Second is the expenditure approach, which measures the household income ratio to energy expenditure against absolute and relative thresholds. The third is the consensual approach, in which individuals report their ability to achieve particular necessities. The methods used to study the characteristics and extent of energy poverty at different levels have been growing steadily in terms of both quantity and complexity. Nevertheless, there is no agreement favoring a particular measurement approach over others (Herrero 2017), and perhaps the household level is the most important.

In the objective or the expenditure-based approach, it is essential to have information on household income and energy service expenditure (Atsalis *et al.*, 2016). Several studies used the 10% energy expenditure threshold introduced by Boardman in 1991, for example (Walker *et al.*, 2014; Legendre and Ricci, 2015; O'Sullivan, Howden-Chapman and Fougere, 2015). Hills (2012) Introduced an indicator where the energy poor are classified based on having two conditions: low income and high energy expenditure (LIHC). Lastly, Fuel poor households are defined as having energy costs less than half or greater than twice the median of all households within the region of interest (M/2 and 2M indicators) (Lyra, Mirasgedis and Tourkolias, 2022). The expenditure approach is criticized for not capturing a household's actual energy spending, as families often spend less on energy services than required (Thomson and Snell, 2013).

The subjective approach identifies a household's socially regarded necessities, the absence of which can be used as a sign of fuel poverty (Atsalis *et al.*, 2016). In this approach, households self-assess their living conditions. Examples of indicators used in this approach are the inability to keep the home adequately warm, arrears of utility bills, and the presence of leaks, dampness, and rot in the dwelling (Thomson and Snell, 2013; Halkos and Gkampoura, 2021). The main criticism of the subjective approach is how the households perceive their ability to achieve or afford those services. People experiencing poverty may feel ashamed of admitting such difficulties, or families tend not to identify themselves as energy-poor (Moore, 2012; Herrero, 2017). On the other hand, these indicators can be helpful when capturing the multidimensional nature of fuel poverty issues.

Adding to the previous debate on the measurement of energy poverty approaches to measurement can take objective, subjective, and composite forms (Fizaine and Kahouli, 2019; Kelly *et al.*, 2020). The objective approach is based on a measurable criterion. One example is the income/expenditure indicators, such as the 10% indicator discussed above. Low-income/high-expenditure energy poverty studies are shown in earlier studies by Hills (2012). The subjective approach is based on a household's self-assessment of living conditions. Using this indicator, the researcher asks household questions about the ability to heat the home adequately or pay utility bills on time without arrears. The last approach considers the multidimensional nature of energy poverty. It measures energy poverty using a set of sub-indicators. An example of this approach is the multidimensional poverty index used in this study. Various examples can be found regarding composite indices, such as (Healy and J. Peter, 2003; Nussbaumer *et al.*, 2013; Thomson and Snell, 2013; Fabbri, 2015a; Bouzarovski and Tirado Herrero, 2017b; Castaño-Rosa, Sherriff, *et al.*, 2019; Castaño-Rosa, Solís-Guzmán, *et al.*, 2019; Charlier and Legendre, 2019; Gouveia, Palma and Simoes, 2019; Recalde *et al.*, 2019; Sokołowski *et al.*, 2019, 2020; Mahoney, Gouveia and Palma, 2020; Santillán, Cedano and Martínez, 2020; Koďousková *et al.*, 2023).

In their paper, Nussbaumer, Bazilian and Modi (2012) reviewed and discussed the adequacy and applicability of the instruments used to measure energy poverty. Again, considering this, during that time, most of the studies focused on linking energy issues to the Millennium Development Goals (MDGs). The researchers criticized previous studies focusing mainly on people's ability to access energy. They proposed a new index that focuses on the deprivation of access to modern energy services, called the multidimensional energy poverty index (MEPI)". The MEPI is derived from "the general multidimensional poverty index" (Alkire–Foster 2011, Alkire–Santos, 2010). It quantifies energy access and deprivation. The model assumes that a person is energy-poor if the combination of the deprivations faced exceeds a pre-defined threshold. The model considers many dimensions: cooking, lighting, services provided through household appliances, entertainment/education, and communication. **Table *2*** summarizes the methods used to measure energy poverty, as discussed earlier.

Table 2. Overview of Energy Poverty Measurement Methods.

Measurement Method	Description	Sources
Direct Measurement	Involves measuring energy services (e.g., heating) achieved compared to a standard.	European Parliament (2016)
Expenditure Approach	Measures household income ratio to energy expenditure against absolute and relative thresholds. Examples include the 10% energy expenditure threshold and the Low Income/High Energy Expenditure (LIHC) indicator.	Hills (2012), Legendre and Ricci (2015), O'Sullivan et al. (2015), Walker et al. (2014), Lyra et al. (2022)
Consensual/Subjective Approach	Individuals report their ability to achieve particular necessities, capturing the subjective aspect of energy poverty. Examples include the	Atsalis et al. (2016), European Parliament (2016), Halkos and Gkampoura (2021), Thomson and Snell (2013), Herrero (2017), Moore (2012)

	inability to keep the home adequately warm, arrears of utility bills, and dwelling conditions.	
Objective Approach	Based on measurable criteria, such as income/expenditure indicators like the 10% indicator and studies on low-income/high-expenditure energy poverty.	Fizaine and Kahouli (2019), Kelly et al. (2020), Hills (2012)
Composite Approach	Considers the multidimensional nature of energy poverty by using a set of sub-indicators. Examples include the Multidimensional Energy Poverty Index (MEPI), which quantifies energy access and deprivation across various dimensions.	Fizaine and Kahouli (2019), Kelly et al. (2020), Nussbaumer et al. (2012), Bouzarovski and Tirado Herrero (2017), Castaño-Rosa et al. (2019), Charlier and Legendre (2019), Fabbri (2015), Gouveia et al. (2019), Healy and J. Peter (2003), Koďousková et al. (2023), Mahoney et al. (2020), Nussbaumer et al. (2013), Recalde et al. (2019), Santillán et al. (2020), Sokołowski et al. (2020, 2019), Thomson and Snell (2013)

Source: Based on the literature discussed on energy poverty.

In the following sections, I preview and discuss various theoretical approaches related to energy, environment, and society.

1.2.2. Environmental, Natural Resources, and Ecological Economics

The processes of extracting resources from the earth have also been of significant concern to environmentalists and economists. Economics is “the study of how and why individuals and groups make decisions about the use and distribution of valuable human and nonhuman resources” (Field and Field, 2017, P2). Environmental economics can be defined as “the application of the principles of economics to the study of how environmental resources are managed” (Field and Field, 2017, P2). Environmental economics, as a subfield of economics, emerged in the 1960s, representing a comparatively recent development compared to resource economics. In contrast, resource economics has been an integral part of the economic discipline since its inception, evolving through the integration of fields such as agricultural economics, energy economics, and land economics (Aruga, 2022). Policymaking aims to enhance the economy and society; economics has long been employed as an analytical instrument. Given the inherent interconnection between the environment and economics, integrating environmental issues into the economic sphere was inevitable (Aruga, 2022). Figure 9 shows how the economy fundamentally forms a small part of society and that human economic activities are part of the more extensive system, the environment.

The economic approach to environmental issues is often referred to as the moral approach. This approach holds that unethical or immoral human behavior causes environmental degradation. As a result, for instance, people pollute because they lack the moral and ethical fortitude to refrain from acting in a way that harms the environment (Field and Field, 2017). Thus, increasing people's environmental awareness is the first step to solving such issues and realizing the importance of incentive motives to allow people to change their behavior. In his book, Kolstad (2000) states that the essence of the environmental problem is the economy—producer behavior and consumer desires.

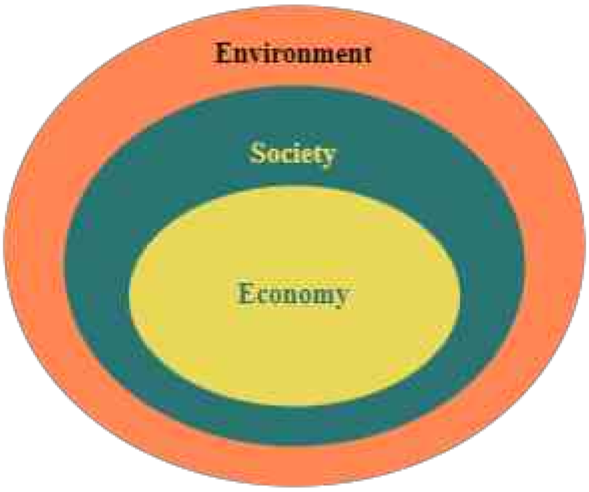

Figure 9. Relationship between the environment, society, and economy.

Source: own editing based on Daly (1977) and Aruga (2022).

Natural resource economics studies nature as the provider of raw materials (Field and Field, 2017). Within this field, energy economics is recognized, and this realization brings energy to identify energy from two dimensions. The first dimension is that energy is a power source as a critical input (developed countries rely on energy for manufacturing while developing countries that rely on agriculture use energy from the sun). The second dimension recognizes energy as a source of pollution (for example, fossil fuel burning and air pollutants) (Field, 2015). It is important to note that both sides of energy are closely connected; thus, a shift from one energy source will shift the number of pollutants produced.

Energy utilization, especially fossil fuel, causes environmental pollution in many ways during production and consumption. Modeling economic growth is needed to estimate future energy demands and supplies better and to limit future pollution requirements (Jorgenson and Wilcoxen, 1985).

While economics is concerned with the idea of scarce resource allocation among desirable alternative ends (Daly and Farley, 2010), in its broadest sense, ecological economics examines the connections between ecosystems and economic systems. (Costanza and King, 1999). The way that ecological economics views the economic system as a component of the sustaining and containing global ecosystem sets it apart from mainstream economics (Daly and Farley, 2010). Ecological economics is driven by ecology as a branch of biology, but environmental economics belongs to the field of economics. These classifications are essential and can be

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noticed when studying the approaches of each field. **Figure *10*** shows the differences between environmental and ecological economics. Since economics examines human economic endeavors, environmental problems are analyzed from a human-centric standpoint. Conversely, environmental issues are explored within ecology through a lens that prioritizes the natural world. It is posited that environmental problems result from human actions that inflict harm upon the ecosystem, which comprises a biotic community of organisms within the environment (Aruga, 2022).

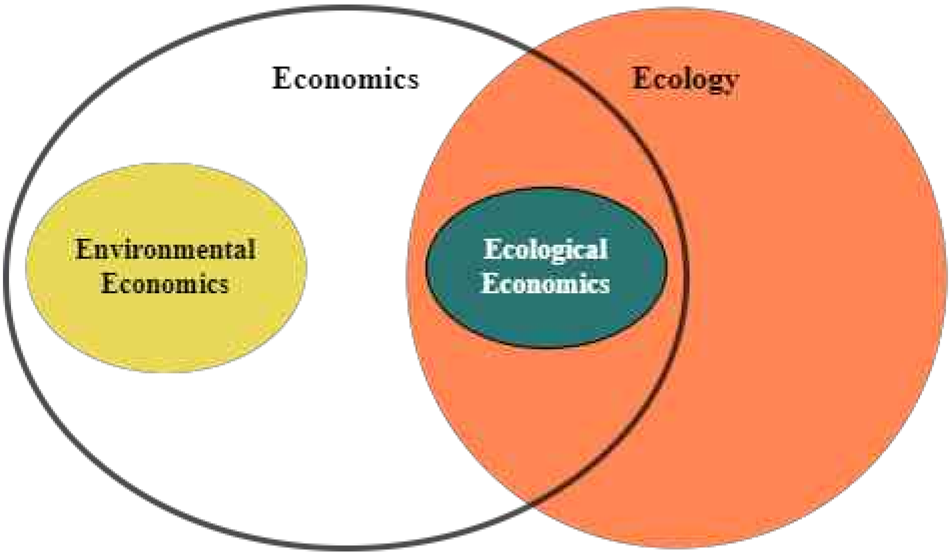

Figure 10. Difference between environmental economics and ecological economics

Source: own editing based on Aruga (2022).

Environmental economics has garnered considerable attention from governments and economists, coinciding with the introduction of sustainable development goals (SDGs) on a global scale. Orchestrated by the United Nations, the SDGs serve as a universal framework for all nations to actively achieve global development while simultaneously prioritizing the delicate balance between social, economic, and environmental sustainability (Setioningtyas *et al.*, 2022). Furthermore, sustainable development is defined by environmental economists as the development that preserves capital for future generations, where capital refers to the total human capital (skills, knowledge, and technology), human-made capital such as machinery and buildings, and natural capital (environmental goods) (Setioningtyas *et al.*, 2022).

Since 2015, the world, led by the United Nations (UN), has launched the Sustainable Development Goals (SDGs) (Rosa, 2017). Of the 17 goals the world aims to achieve in 2030, goal 7 was concerned with energy and states exactly as affordable and clean energy to be achieved by 2030. Energy is a critical sector in the transition to sustainable development, while resilient energy systems can promote energy transition (LaBelle and Szép, 2022; Szép, Pálvölgyi and Kármán-Tamus, 2022). Sustainable Development Goal number 7 has five targets, which are to ensure universal access to affordable, reliable, and modern energy services, increase substantially the share of renewable energy in the global energy mix, double the global rate of improvement in energy efficiency, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology, and expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, following their respective programs of support. **Figure *11*** shows the critical achievements of SDG 7 in Jordan in 2019 and 2020.

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7.1.1.	Share of the population with access to electricity	99.9%
7.1.2.	Share of the population with access to clean fuels for cooking	99.9%
7.2.1.	Share of final energy use that comes from renewable sources	8.17%
7.3.1.	Energy intensity (MJ/$)	3.80
7.A.1.	International finance received for clean energy (million $)	73.76
7.B.1.	Renewable electricity-generating capacity per person (W)	186.5

Figure 11. SDG 7 statistics in Jordan for 2019 and 2020.

Source: Own compilation based on data extracted from *Goal 7: Affordable and Clean Energy - SDG Tracker* (2023)

Achieving the SDGs is still in progress, mainly with the primary objective of not leaving anyone behind. Not leaving anyone behind means that developed and developing countries should get their chance of achieving those goals. A mission that may call for improving equalities and ensuring a safer transition of systems It is sure that developed countries have better energy capabilities, but still must think about making a safe transition to more clean and efficient resources, in the sense of environmentally friendly transition that does not contribute to environmental problems such as climate change. Those ideas related to energy governance and poverty were discussed by (O'Brien, O'Keefe and Rose, 2007), and the paper concluded with three points. First, energy and poverty are interrelated; solving one problem means considering the other. Second, developed countries did not benefit from top-down approaches. Third, the importance of international agreements cannot be overstated. For the last point, international agreements are not binding to those countries who sign them, making it easy for those who want to withdraw after a while (Newberry, 2017). Furthermore, pursuing environmental economics and attaining sustainable development goals (SDGs) pose increasingly formidable challenges, particularly for developing nations. These challenges stem from multifaceted constraints, encompassing inadequate financial resources, limited access to advanced technologies, a dearth of specialized knowledge, and insufficient public awareness regarding the significance of engaging in economically sustainable practices (Setioningtyas *et al.*, 2022).

The explored theories offer various approaches to addressing energy poverty, with sustainable financing expected to encourage investments in clean energy projects and significantly reduce carbon emissions on a large scale (Baiwei *et al.*, 2023). It is also emphasized that policies addressing energy poverty must consider environmental concerns (Ehsanullah *et al.*, 2021). Additionally, sustainable development is highlighted as a crucial dimension of sustainable growth, and understanding the relationship between ecological footprint and economic growth is essential for practical solutions to energy poverty (Ansari *et al.*, 2022a). Overall, the theories covered in this section provide a solid framework for studying energy poverty at different levels.

1.2.3. Energy Economics

Energy economics is thought to have emerged as a field after the oil crisis in 1973, but historically, "The Coal Question" was the first book to discuss the depletion of coal resources, published in 1865 by W.S. Javos (Worthy, 2011). Allocating limited resources in the economy is a fundamental economic problem energy economics addresses. As a result, an integral aspect of the topic is the microeconomic concerns of energy supply and demand and the macroeconomic considerations of investment, financing, and economic ties to the rest of the economy (Bhattacharyya, 2011).

Energy is a vital resource that plays a critical role in modern economies. It is used to power homes, businesses, and industries and is an essential input for many economic activities. There are many different energy sources, including fossil fuels (such as coal, oil, and natural gas), nuclear energy, renewable energy (such as solar, wind, and hydroelectric), and others. Harvesting energy resources will produce energy commodities, such as gasoline, diesel fuel, natural gas, propane, coal, and electricity, which can be used to meet the energy needs of human activities like lighting, heating, water heating, cooking, and powering electronic devices (Sweeney, 2001).

Energy as a concept is used in physics and energy sense, where the laws of thermodynamics apply. The laws of thermodynamics are fundamental principles governing energy conversion from one form to another. The first law of thermodynamics, also known as the law of energy conservation, states that energy cannot be created or destroyed; it can only be converted from one form to another (Sweeney, 2001; Bhattacharyya, 2011). The second law of thermodynamics, also known as the law of entropy, states that an increase in the total entropy of the universe accompanies any energy conversion process (Bhattacharyya, 2011). These laws have important implications for energy economics, as they help to understand the limitations and costs of energy production, distribution, and consumption. For example, the second law of thermodynamics suggests that using energy directly rather than converting it from one form to another is generally more efficient, as energy conversion is always associated with losses. These laws also help to explain why renewable energy sources, which can be replenished naturally, may be more sustainable in the long run than non-renewable sources, which are finite and will eventually be exhausted. In addition, realizing the role of thermodynamics in the governance of the change in energy state helps environmental economists understand energy resources and their conversions as an environmental commodities.

Energy economics is the field that studies the human utilization of energy resources and energy commodities and the consequences of that utilization (Sweeney, 2001). The production, distribution, and consumption of energy are all important aspects of energy economics, and they are influenced by a wide range of factors, including technological developments, economic

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policy, and environmental concerns. Understanding the complex interplay between these factors is essential for effectively managing and maximizing the value of energy resources in the economy. However, from a physical perspective, energy is not a commodity that can be brought to the market, but the individual fuels are; some researchers refer to energy economics as the economics of fuel markets (Weyman-Jones, 2009).

Considering the abovementioned issues, energy economics can play a vital role in understanding energy and fuel poverty. The connection can be understood when looking at the relationship between people's (consumers) demand for specific fuel to achieve a certain level of service. For example, people used to collect wood and biomass for heating and cooking, but as modern forms of fuel appeared, a shift occurred towards more complicated forms of fuel, such as natural gas for heating and cooking and electricity for lighting and using different appliances. Thus, one part of the issue is the ability to access those modern energy services, while the other is being able to afford those services most efficiently. However, it is evident that as income increases, energy consumption increases, and the human development index (HDI) improves (Bhattacharyya, 2011).

Zweifel, Praktiknjo and Erdmann (2017) discussed the analysis of energy demand from two points of view: the bottom-up approach (microeconomics) and the top-down approach (macroeconomics). In the bottom-up approach, energy demand is determined by 1) the existing stock of energy-using capital, 2) the intensity of its use, and 3) its energy efficiency (Zweifel, Praktiknjo and Erdmann, 2017). Furthermore, a set of long and short-term factors should be included to model the energy demand according to this approach. Long-term factors (that can affect the stock of energy-using capital and improvements in energy efficiency) include disposable income and wealth, prices of energy relative to other goods and services, and business sales, among others. On the other hand, short-term factors (affecting the intensity with which the stock of capital is used) include fluctuations in income, energy prices, temperature, and business cycle.

The bottom-up approach realizes the importance of energy efficiency as the productivity of the single input energy. This comes with the possibility of forgetting that energy is not the sole factor in manufacturing. Reduced energy use necessitates higher capital inputs, particularly for insulating buildings and land (e.g., for solar panels or growing crops for energy generation) (Zweifel, Praktiknjo and Erdmann, 2017). On the other hand, the top-down approach is linked to macroeconomic variables such as per capita income, Gross Domestic Product (GDP), and relative energy prices. Indeed, as the population grows, the demand for energy increases in this context but only in relationship with income and economic growth (Zweifel, Praktiknjo and Erdmann, 2017).

Energy and fuel poverty can be understood in terms of energy demand from different perspectives in energy economics. Household income greatly influences energy consumption since low-income people may have to choose between heating their houses and buying food and other essentials. Similarly, families unable to renovate their homes or buy energy-efficient appliances may experience higher energy expenses and fuel poverty. Also, weather factors significantly impact energy demand because homes need more heating and cooling when it is extremely hot or cold.

Fuel and energy poverty are both greatly influenced by energy efficiency. Electricity bills can be lowered and made more affordable for low-income households with the help of energy-efficient appliances, home insulation, and weatherization techniques. Moreover, public policies that reduce energy use, such as energy efficiency requirements, energy conservation initiatives, and financial incentives for renewable energy sources, can reduce fuel and energy poverty.

1.2.4. The Energy Ladder and Energy Stacking

As human activities require some energy, finding energy sources has been a mission for humankind. Utilizing energy in the household depends on several factors, such as the type of energy available, the type of activity needed, and the affordability of specific types of energy. Throughout history, humankind could use energy in several forms; some come with no costs, such as biomass that animals produce, while others require some effort to collect, such as wood for cooking and heating. Switching to modern energy can significantly improve the productivity of poor people. It allows labor, biomass, and land resources to be redirected from fuel collection and production to income-generating purposes. Choosing between different types of fuel in households considering what was mentioned is known as the energy ladder theory.

The energy ladder is a concept that illustrates the dominant sources of household energy at different levels of income. It suggests that as people's incomes increase, they tend to move up the "ladder" to more efficient and cleaner energy sources (Roser, 2021). According to this model, households will behave as utility-maximizing neoclassical consumers, which means that when their income rises, they will switch to more advanced energy sources (van der Kroon, Brouwer and van Beukering, 2013). During the 1990s, the energy ladder theory emerged as a conceptual framework to illustrate the sequential movement of household fuel preferences in developing nations (Baldwin, 1987; Hosier and Dowd, 1987; Leach, 1992). Subsequently, a considerable volume of existing scholarship has concentrated on investigating the factors influencing this energy transition process and its underlying mechanisms. Despite accounting for demographic patterns, infrastructural development, and economic attributes, a body of research has consistently demonstrated that the energy ladder model adheres to a linear and unidirectional trajectory, wherein households progress from traditional biomass fuels to modern alternatives as their income levels rise (Han, Wu and Zhang, 2018).

Hiemstra-van der Horst and Hovorka (2008) presented three observations regarding the relationship between economic growth, the use of modern fuels, and the energy transition. First, a positive correlation was found between economic growth and the use of modern fuels when comparing countries. This suggests that as countries become more industrialized, their dependence on petroleum and electricity increases while biomass use decreases. Second, research in Asia indicated that the transition to modern fuel use is due to urbanization and development trends that increase access to modern fuels and household income. Finally, while transitioning to modern fuel use in sub-Saharan Africa was hypothetical, differences in energy use among income groups and the urban-rural divide indicated that a widespread shift away from traditional biomass fuels would be a fundamental feature of economic growth, urbanization, and industrialization.

According to Heltberg (2004), the energy ladder model provides three distinct phases. A general dependence on biomass characterizes the first phase. The second phase of fuel switching assumes households switch to "transitional fuels" such as kerosene, coal, and charcoal in response to higher incomes, urbanization, and biomass scarcity. The third and final phase of fuel switching is households switching to LPG, natural gas, or electricity for cooking. The constituents of the classical 4A paradigm, namely availability, affordability, accessibility, and acceptability, hold significant influence in the selection of fuel sources. As individuals ascend the energy ladder, their overall well-being also experiences a corresponding enhancement. This correlation is closely intertwined with the theory of consumption, which posits that as income levels rise, households consume more goods and opt for higher-quality commodities. The underlying assumption of this theory is that households utilize a singular fuel type for each specific household activity (Szép, Pálvölgyi and Kármán-Tamus, 2023). Moreover, as an integral component of the broader energy system discourse, the 5D model, proposed by Wagner and Götz (2021), delineates five fundamental dimensions crucial to transforming energy systems. These dimensions encompass decarbonization, digitalization, decentralization, democratization, and the diversification of service orientation, collectively defining the critical pillars of the energy transition.

In a study by Leach (1992) on energy transition in developing countries, it is stated that the transition towards sustainable energy sources is not primarily motivated by a growing demand for modern fuels but rather by socioeconomic changes that alleviate the barriers to their broader adoption, particularly for low-income households relying on traditional biomass. The most significant of these changes are enhancements in the distribution of sustainable fuels, spanning urban and rural areas, and the ability to afford modern fuel technologies, facilitated either by financial means or favorable market conditions that reduce appliance costs.

However, some studies suggest that the “energy ladder” concept is a theoretical myth, and the reality of household energy use is more complex (Szép, Pálvölgyi and Kármán-Tamus, 2023). Masera, Saatkamp and Kammen, (2000) criticize the energy ladder theory because it cannot adequately describe the dynamics of household fuel consumption. Instead, they note that fuel stacking is common in developing countries' urban and rural areas. Fuel stacking corresponds to multiple uses of fuels, with households choosing a combination of fuels from the lower and upper rungs of the ladder. Modern fuels can replace traditional fuels only partially but not fully (Muller and Yan, 2018). Fuel stacking is prevalent in households at the beginning and mid-way in their ascension up the energy ladder, where households cannot fully let go of their traditional energy sources (Yadav, Davies and Asumadu-Sarkodie, 2021). The energy ladder model may help predict trends in energy use in the household sector in many developing countries; however, it may not fully explain the dynamics of fuel used in households. **Figure *12*** shows the energy ladder and stack models.

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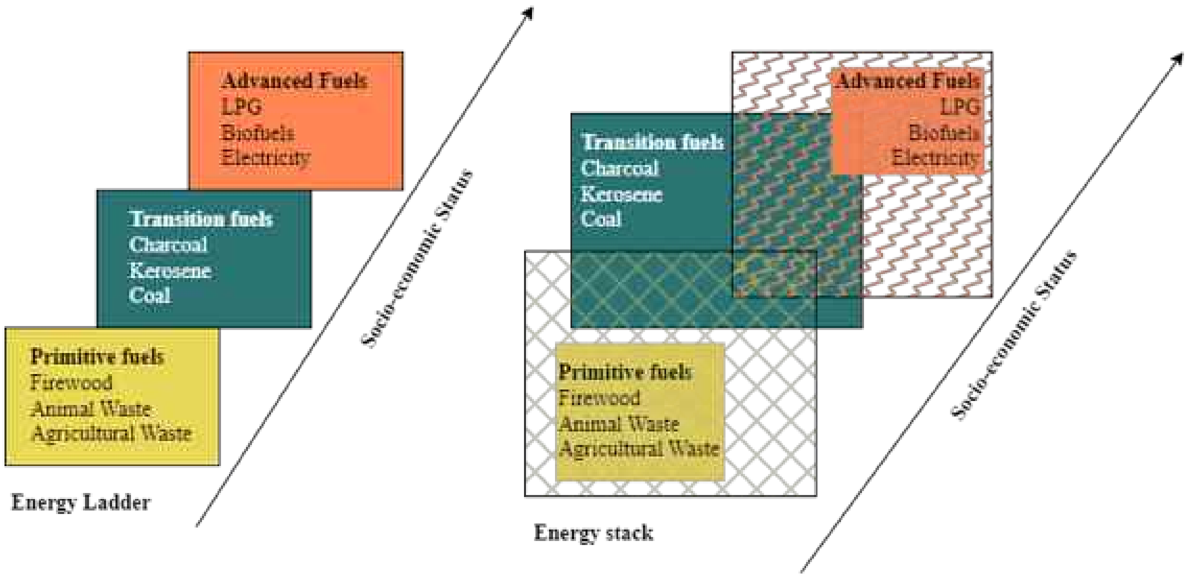

Figure 12. The energy ladder and energy stack models.

Source: own compilation based on Schlag and Zuzarte (2008).

Unlike the energy ladder, the stacking model expands upon the aforementioned analysis and provides a more comprehensive understanding of energy transition by portraying it as a multifaceted process wherein households do not strictly follow a linear progression towards cleaner fuels. Instead, they employ a combination of different fuel sources concurrently to fulfill their daily energy needs. With an improvement in their socioeconomic status, households begin to reduce their reliance on primitive fuels while simultaneously increasing their utilization of modern fuels as part of the transition process (Waleed and Mirza, 2023). The simultaneous consumption of various fuels is contingent upon the specific nature of household tasks and the range of technologies accessible to households. The factors influencing household decisions regarding stove and fuel selection are complex and multifaceted, encompassing a range of socio-economic and cultural considerations and aspects related to the availability and accessibility of clean cookstoves and fuels. Additionally, socio-political and environmental influences play a significant role. One crucial determinant is the household's income level and the associated costs of acquiring and utilizing devices and fuels, including upfront and recurring expenses (Shankar *et al.*, 2020).

1.2.5. The Capability Approach

Amartya Sen and Martha Nussbaum initially created the concept of capability theory (Nussbaum and Sen, 1993; Sen, 1995). Both Sen and Nussbaum criticized the development approach as it aims to measure success in terms of increased household income, focusing on material wealth. In addition, for them, the development approach ignores the position of people experiencing poverty, and they argue that what people can achieve and do should be the focus of social and economic development (Day, Walker and Simcock, 2016).

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Within the capability approach, functionings and capabilities are proposed as an alternative to economic development (Sen, 1995). Functionings refer to a person's state of being and actions, such as being healthy or working (Oosterlaken, 2009). On the other hand, capabilities refer to the practical opportunities available to a person to achieve specific functionings, regardless of whether they choose to pursue them at a particular time. Encouraging capabilities increases possibilities while allowing individuals to choose their preferred life (Day, Walker and Simcock, 2016). The capability approach emphasizes that natural resources and the environment can provide opportunities and impose limitations; highlighting how individuals utilize these resources is crucial (Ballet *et al.*, 2011).

Sen presents a powerful argument to explain why individuals cannot achieve outcomes at an equal rate through income conversion. He suggests that personal factors, such as age, gender, disability, and illness, as well as environmental factors, such as climate and pollution, and social factors, such as crime and social networks, play a role. Differences in community requirements, such as social norms and behavior, and family distribution also contribute to this disparity (Sen, 1999).

Day, Walker and Simcock (2016), in particular, have applied this line of theorization about human well-being to energy deprivation, proposing a framework for examining energy poverty. They draw on the distinction between basic capabilities, such as maintaining good health, having social respect, or being educated, and secondary capabilities, which underpin basic capabilities, such as washing clothes, storing and preparing food, or accessing information and resources. Day et al. argue that many of these secondary capabilities often require energy in some form and relate to different energy services. This conceptualization can be illustrated in **Figure 13**.

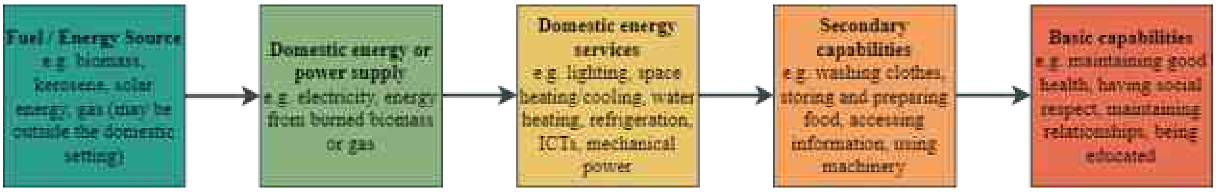

Figure 13. Conceptualizing the relationship between energy, services, and outcomes

Source: Own compilation based on Butler (2022).

Therefore, the approach has become widely accepted in conceptualizing energy poverty (Chipango, 2023). Cole (2018) evaluated the effectiveness of a renewable energy initiative in Bamyan, Afghanistan, to determine the significance of the Capability Approach. The research suggested that the availability of electricity has improved people's capabilities, expanded their options for living, and consequently enhanced their freedom. Middlemiss *et al.* (2019) expand on the capabilities approach to describe how people's social relationships influence the intricate and multifaceted experience of energy poverty in the UK. Their findings suggest that the relationship between social relations and energy poverty is mutually reinforcing, whereby positive social relations can facilitate access to energy services, while access to energy services can also foster positive social relations. Corvino *et al.* (2021) contend that capabilities play a crucial role in assessing the benefits and drawbacks of energy infrastructure projects. They suggest that installing an energy infrastructure should not be permitted if it cannot restore a fundamental capability through non-monetary means and if monetary compensation is inadequate. Chipango (2023) study of energy poverty in Zimbabwe states that energy poverty

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arises due to the inadequate relationship between the state, the market, civil society, and citizens. The study concludes that energy poverty results from social and political-economic relationships that are currently dominant. In the third chapter, under the “Selected dimensions and variables” subsection, I justified this issue in terms of what capabilities a society needs to achieve a better quality of life.

1.2.6. Energy Justice

Studying energy justice was based on earlier work on defining the concept of environmental justice concerning societies, activism, and movements, among other issues such as climate change (Schlosberg, 2003, 2013; Vanderheiden, 2008; Dawson, 2010). McCauley *et al.* (2013) provided a look at both the policies and systems of energy concerning the justice dilemma, referring to the fact that the social responsibility is shared between the government, private sector, and the public altogether, and the choices these mentioned sectors can impact both climate change and intergenerational justice. Sovacool and Dworkin defined energy justice as a global energy system that fairly disseminates the benefits and costs of energy services and has representative and impartial energy decision-making (Sovacool and Dworkin, 2014). The definition involves the following key elements: costs, which refer to the uneven imposition of hazards and externalities of the energy system on communities, particularly impacting the poor and marginalized; benefits, which highlight the unequal access to modern energy systems and services; and procedures, which pertain to exclusionary forms of decision-making lacking due process and representation in many energy projects (Gerrard, 2015). For Sovacool *et al.* (2016), energy poverty can be a form of violation of distributing justice, and this is because a large portion of human communities lack access to clean energy resources. Some scholars suggested that more studies should focus on energy justice; for them, the issue was still muted compared to other justice movements like climate change (Jenkins *et al.*, 2016).

In the same context, the study of justice was expanded later to introduce the spatial dimension and inequality concepts of energy poverty (Bouzarovski and Simcock, 2017; Bouzarovski and Tirado Herrero, 2017a). While the first focused on revealing and evaluating energy-related inequalities in general, the latter focused on the case of three central and eastern countries. This indicated that spatial inequalities could differ based on the distance from the capital cities and the urban-rural relationships. For McCauley (2018), energy justice is an application of social and environmental rights within the energy system. It can be at the heart of what he mentioned as the “energy justice trilemma,” which are accessibility (poverty-focused), availability (security-focused), and sustainability (carbon-focused). Adding to the literature, Szulecki (2018) brought up the question of whether energy justice can be a synonym for energy democracy and that the two concepts can meet because the first one focuses on the consequences of our energy decisions, while the other concerns the political implications. In the same context, he argued that for a long time, the energy sector was highly dominated by engineers and scientists because of the involvement levels of sitting infrastructure and technology, and the process should include societies and economists. The energy democracy concept is still in a state of evolution, and it is founded on three distinct understandings, namely: a) a process that is propelled forward by a grassroots movement; b) an outcome resulting from the decarbonization of energy systems; and c) a desired objective or ideal that stakeholders strive to achieve (Szulecki and Overland, 2020).

McMonagle et al. (2021) added to the previous discourse, arguing that energy justice is a climate change and health issue. While mistakenly “a just transition” is perceived as an "environmentalists' and economists' mission," they imply that it is a health equity and public health issue. To progress in a just transition, public health organizations can be essential in guiding the process. In the same context, researchers looked closely at the link between justice, energy poverty, and gender (Pachauri and Rao, 2013; Bradshaw, 2018; Moniruzzaman and Day, 2020; Husu, 2022). Pachauri and Rao (2013) argued that women are massive energy users but are not involved in the decision-making related to energy, such as the type of fuel used or even purchasing. Bradshaw (2018) suggested that energy is not an energy-neutral term, and research focused on gender aims not to improve efficiencies but equality; in return, improving equalities based on gender analysis can enhance energy efficiency. (Moniruzzaman and Day, 2020) suggested that energy poverty should recognize the energy access differences based on gender, as the differences can be in terms of the ability to access different energy resources.

1.2.7. Climate Change

It is widely accepted now that human activities have changed our climate, and the resulting crisis is posing a real threat to all aspects of life (Allen *et al.*, 2018); governments around the world are trying to reach a consensus on the ideal methods to solve this issue by introducing measures, policies, agreements, and financial programs (Reckien *et al.*, 2023). Climate change is related to energy problems because energy is a leading contributor to emitting greenhouse gases (GHGs) into the atmosphere (Szlavik and Csete, 2012). In return, the impacts may vary depending on the geographical area and the nature of weather patterns there.

Energy poverty is no exception; realizing the links between both issues can help introduce and implement holistic policies. Many researchers tried to shed light on this issue; Ürge-Vorsatz and Tirado Herrero (2012) argued that establishing the link between climate change and energy poverty would address both challenges. In the same context, they tried to classify the different policy leverage points that can arise from different scenarios based on the geographical impact of climate change. In conclusion, concerning residential energy users in developed and economies in transition, the essential trade-off is that a decisive climate change action, increasing energy prices through carbon prices, would increase energy poverty levels. This conclusion suggests that integration into policy goals would likely solve the two problems.

Understanding energy poverty includes a thorough study of different factors that may impact the availability of adequate energy resources to people; it can affect the economic growth of poor economics; estimates by international organizations imply that until 2018, around 89% of the world population had access to electricity while around 82% of rural areas inhabitants have access to electricity. In this context, Chakravarty and Tavoni (2013) tried to answer whether accessing modern means of energy may significantly increase energy demand and associated CO_2 emissions. They introduced a simple model to estimate the number and distribution of energy poor and calculate energy consumption on the global level with predictions for the next 30 years. Based on an energy poverty eradication policy, the results mainly predicted that energy consumption may increase by 7% worldwide by 2030. The study also predicted that this increase would produce 44-183 $GtCO_2$ over the 21st century, which would, in return, contribute to warming by at most 0.13°C.

Regarding the energy transition, Meza, Amado and Sauer (2020) implied that economic growth could not be decoupled from energy use and the release of GHGs. Moreover, it was justified that after any crisis such as COVID-19, the world's energy demand can rise to unprecedented levels. The study concluded that more coordination between countries is needed to improve the

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prices of RES to encourage a faster transition. At the same time, a remarkable shift is required regarding political decisions, prices, and behavior.

In this dissertation, I am testing the following hypotheses, noting that more literature is covered in each chapter, which has helped in developing the hypotheses:

H1

- There is a positive relationship between energy consumption and economic growth in Jordan, with higher energy consumption leading to higher economic growth. The same applies to greenhouse gas emissions.

H2

- There is a positive relationship between household energy use and the human development index (HDI) in Jordan, with higher energy use leading to higher HDI scores. The connection can be seen not only in the long but also in the short term.

In the second chapter, I test the first hypothesis using the Toda-Yamamoto non-Granger causality test using three indicators: final energy consumption, economic growth, and greenhouse gas emissions covering 1990-2018. The first and second hypotheses are examined using the path analysis test on cross-sectional data from the Jordanian governorates for 2009 and 2017. The chapter seeks to answer the following questions: What are the characteristics of energy, economic growth, and climate change nexus? Can a substantial relationship between household energy use and HDI be identified in Jordan? Does increasing residential energy expenditure have a positive effect impact on HDI? And what are the major socio-economic factors influencing Jordan’s human well-being?

H3

- Even though Jordan's population has nearly 100% access to modern energy sources, many households suffer from energy poverty.

H4

- There are significant territorial differences in energy poverty in Jordan, with some regions experiencing higher levels of energy poverty.

In the third chapter, I use the multidimensional energy poverty index on two health and demography surveys from 2009 and 2018 to estimate energy poverty in Jordan at different geographical and socio-economic levels. In this chapter, the research questions under investigation are: What characteristics of energy poverty in Jordan are based on the multidimensional energy poverty index? Did energy poverty decrease between 2009 and 2018 as a timeframe of the study? Do Jordanian households benefit more from solar energy as a source of energy? And what are the territorial differences regarding energy poverty in Jordan?

H5

- In Zarqa Governorate, households have low energy efficiency levels, which affects the ability of the household to achieve thermal comfort during the different seasons.

H6

- Energy poverty is more prevalent in winter than in summer in Zarqa Governorate.

H7

- As income levels increase, households are less likely to experience energy poverty, and income level is the most significant factor affecting the possibility of falling into fuel poverty.

The fourth chapter examines the characteristics of fuel poverty in the Zarqa governorate through the consensual approach. The method used in this chapter is data collection through an online survey targeting people living in the Zarqa governorate in central Jordan and analysis using contingency tables, binary logistic regression, and composite indicators. This chapter investigates the following questions: What are energy efficiency characteristics in the sample households? What is the difference between summer and winter regarding reported energy poverty in the sample households? How are arrears on utility bills connected to other energy poverty subjective indicators and income levels? And what are the socio-economic determinants of subjective energy poverty in the sample households?

2. Exploring the nexus between economic growth, energy, climate change, and human well-being

2.1. Energy Consumption and Economic Growth in Jordan: Theoretical Perspectives

Several factors and relationships can be observed when studying energy poverty in Jordan.

- First, energy is needed to meet basic human needs. Energy consumption is, therefore, critical to economic and social development and prosperity (Halkos and Gkampoura, 2021).
- Second, Jordan's energy system and energy security have been a topic of concern and exploration in recent years. Jordan imports almost 94% of its energy supply (Sandri, Hussein and Alshyab, 2020).
- Third, the sustainability of the energy sector is represented by the share of renewable energy in the energy mix and the contribution of renewable energy consumption to economic growth (Ministry of Energy and Mineral Resources, 2020).
- Finally, Jordan is an emergent economy with universal access to electricity; residents rely primarily on modern energy sources, so they do not spend time gathering wood or utilizing unclean energy sources.

Energy is one of the leading drivers of economic growth, employment, and sustainable development (Gatto and Busato, 2020). Improving access to sustainable and affordable energy sources would alleviate poverty, contribute to protecting the environment, and build solid institutions (Rosa, 2017). In Jordan, fossil fuel is the primary source of energy. The country's energy consumption in 2021 is dominated by the transport sector (around 40%), followed by the residential sector (around 25%). By source, oil products followed by electricity are the dominant ones. Net energy imports in Jordan reached 378.9 TJ by 2019 (IEA, 2022), which accounts for nearly 94% of Jordan's total energy in Jordan. In addition, the energy sector suffers from several challenges, such as increasing demand, limited domestic energy resources, the unstable political situation in the surrounding countries, and the resulting security/price issues, poor planning, and losses in the sector (Albezuirat *et al.*, 2018).

Figure *14* compares energy imports vs. final energy consumption in each sector in Jordan. Over the years, while the energy demand has increased, the local energy sources have not been contributing enough to the system. Even with the country's ambitious goals to increase the share of renewable energy, the storage problem still exists.

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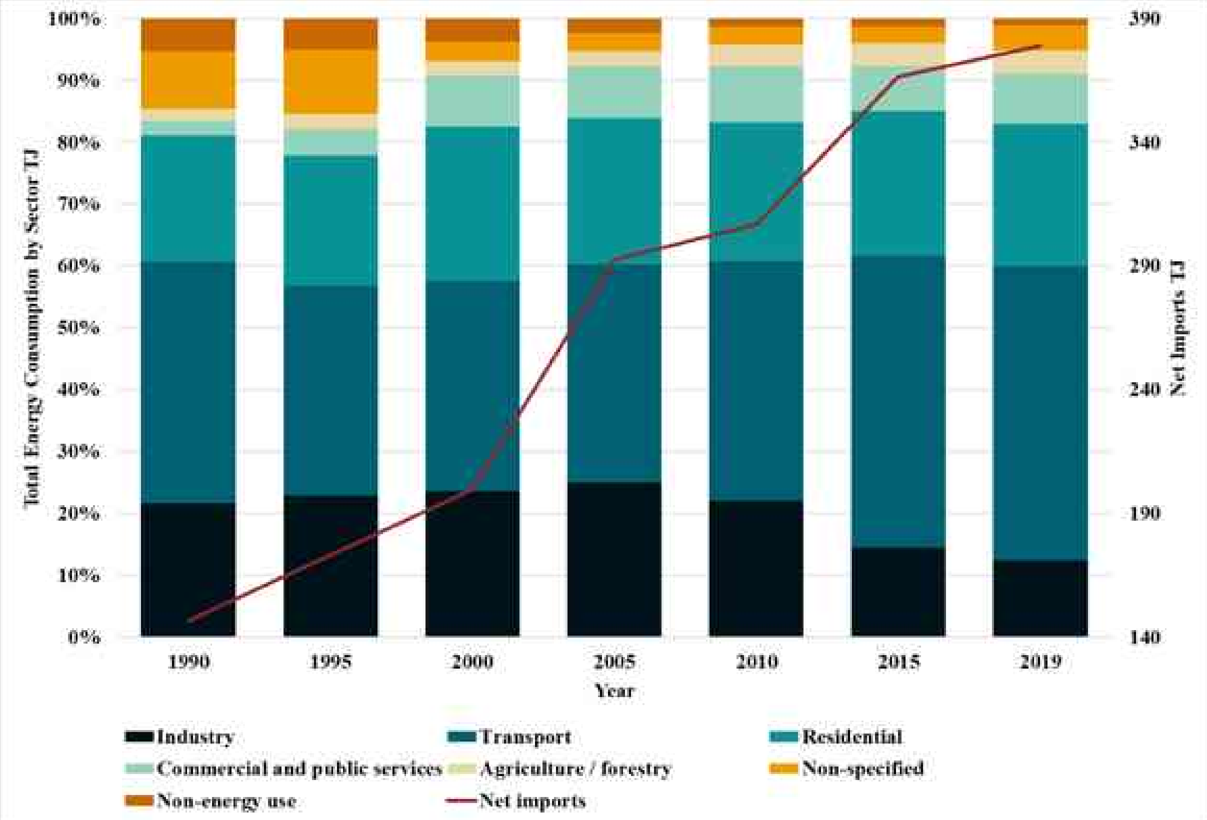

Figure 14. Energy imports vs. total energy consumption by sector in Jordan.

Source: IEA (2022).

2.1.1. Energy Trilemma Index: Where is Jordan located?

The Energy Trilemma Index published by the World Energy Council is one of those sources that can tell the energy story according to three dimensions: energy security, energy equity, and environmental sustainability of the energy system. The World Energy Trilemma Index has been published annually since 2010, showing the balance score between the mentioned dimensions (*World Energy Trilemma Index*, 2022). The three dimensions measure the following:

- Energy security: Measures a country's ability to endure and recover quickly from system shocks with minimum supply disruption and its ability to reliably meet current and future energy demand. The effectiveness of managing internal and external energy sources, as well as the dependability and resilience of the energy infrastructure, are all covered by this part.
- Energy equity: evaluates a nation's ability to provide easy access to a plentiful energy supply for domestic and commercial use. The dimension includes fundamental access to power, clean cooking methods, energy consumption levels supporting prosperity, and electricity, gas, and fuel costs.
- Environmental sustainability: The shift of a nation's energy system toward reducing and avoiding potential environmental harm and climate change impacts is represented by the environmental sustainability of energy systems. The aspect emphasizes air quality, decarbonization, transmission and distribution productivity, and efficiency.

According to the index, Jordan's trilemma rank in 2022 was fifty-seven. On the energy security dimension, Jordan's score is D (41.8/100), the energy equity score is C (68/100), and for environmental sustainability, the score is C (65.3/100) as well. Overall, Jordan's worldwide rank improved compared to 2021, when it was sixty-six, but it still declined compared to the baseline year. On the regional level, Jordan's situation is not the best compared to other Middle Eastern and Gulf countries. Jordan ranked ninth out of eleven countries. **Figure *15*** details the country's performance since 2000, the baseline year.

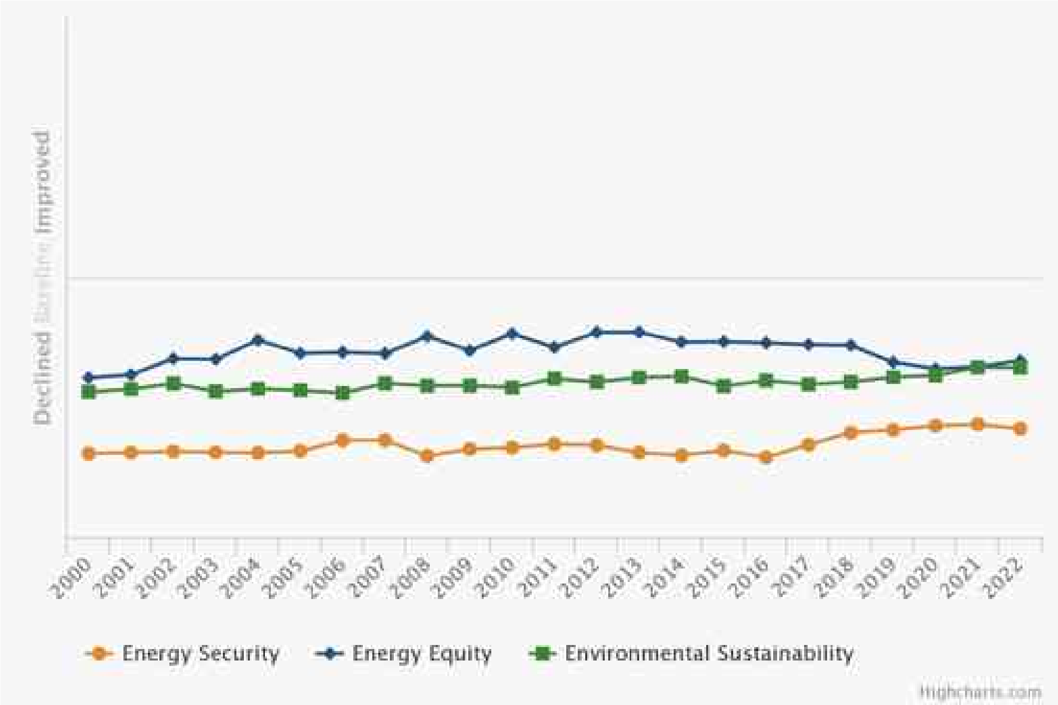

Figure 15. Jordan's Historical Trilemma Scores.

Source: Downloaded from *World Energy Trilemma Index* (2022).

2.1.2. Theorizing the energy-economic growth nexus

Four main hypotheses concerning the relationship between energy consumption and economic growth are recognized in the literature. Those hypotheses have been studied and proved by many researchers; the following is a summary:

- The conservation hypothesis: When GDP growth unidirectionally causes energy consumption, conserving energy will not necessarily decrease GDP. However, different energy conservation strategies may have different economic consequences, just as energy can be used to boost GDP growth or otherwise. It is reasonable to anticipate that some energy-saving measures will, at the very least, not impede economic growth (Sari, Ewing and Soytas, 2008; Menegaki and Tugcu, 2016). On the one hand, this hypothesis means that households can spend their extra income on energy-intensive activities, such as buying computers. On the other hand, economic growth would expand activities requiring more energy (Mahadevan and Asafu-Adjaye, 2007).
- The growth hypothesis results when a unidirectional causality runs from energy consumption to economic growth. Because energy consumption is crucial for economic

growth to occur, either directly or indirectly, as a complement to labor and capital in this environment, conservation measures will impede it (Stern, 2000; Apergis and Payne, 2012).

- The existence of bidirectional causality between energy use and economic growth lends credibility to the feedback hypothesis. This interdependence means energy conservation measures that lower energy use may also affect economic growth. Similar variations in economic growth may also be reflected in energy usage (Mahadevan and Asafu-Adjaye, 2007; Apergis and Payne, 2012).
- Finally, the neutrality hypothesis indicates that causality between energy consumption and economic growth is absent. When energy consumption does not play a role in economic growth or vice versa, it means that growth is led by other factors (Payne, 2010; Payne and Taylor, 2010).

To understand better the connections and pathways of energy relationships in Jordan, this chapter asks the following questions:

(1) What are the characteristics of energy, economic growth, and climate change nexus?
(2) Can a substantial relationship between household energy use and HDI be identified in Jordan?
(3) Does increasing residential energy expenditure have a positive effect impact on HDI?
(4) What are the major socio-economic factors influencing Jordan's human well-being?

Because of data availability issues, instead of using energy consumption data in the path analysis, I use energy expenditure as a proxy for consumption on the governorate level. This chapter is divided as follows: section 2.2 reviews the related literature; Section 2.3 provides a detailed description of the methods used; Section 2.4 details the results and deeply discusses them; and Section 2.5 deals with the conclusions and the formulated theses.

The following hypotheses are examined:

H1

- There is a positive relationship between energy consumption and economic growth in Jordan, with higher energy consumption leading to higher economic growth. The same applies to greenhouse gas emissions.

H2

- There is a positive relationship between household energy use and the human development index (HDI) in Jordan, with higher energy use leading to higher HDI scores. The connection can be seen not only in the long but also in the short term.

2.2. Literature Review

Energy is one of the essential resources required for daily human life; energy can come in many forms, i.e., electricity and heating. Modern societies rely heavily on energy resources to maintain their needs in different sectors where sectoral and economic development is energy-driven. Improving access to sustainable and affordable energy sources would alleviate poverty, protect the environment, and build solid institutions (UN General Assembly, 2015). In 2017, 11.2% of the world's population had no access to electricity. More than 95% of the population without access to electricity lives in developing Sub-Saharan Africa, Asia, and Latin America (Panos, Densing and Volkart, 2016).

The literature on the energy-growth relationship is extensive; researchers studying the issue related to energy consumption utilize different methods and techniques. One of the predominant methods used in this field is the causality test, which can be applied using various steps and detailed techniques. In recent years, there has been a growing interest in the relationship between energy consumption and economic growth. This is because energy is essential in driving economic development, and understanding the link between these two factors can help policymakers and researchers develop effective strategies for promoting economic growth and reducing poverty.

The relationship between energy consumption, economic growth, and poverty is complex and interconnected. Energy consumption is vital for economic growth, as energy demand increases as economies grow (Topolewski, 2021). However, if energy is constrained, GDP growth may suffer. It is important to note that the relationship between energy consumption and economic growth is not straightforward. While short-term production increases may result in a statistically significant increase in energy consumption, short-term increases do not cause economic growth rate changes (Topolewski, 2021).

However, the good news is that economic growth can alleviate energy poverty, which can provide the resources needed to invest in energy infrastructure. It is essential to note that if the energy consumed is not sustainable, it can lead to environmental issues, which, in turn, can negatively impact economic growth (Doğanalp, Ozsolak and Aslan, 2021a; *How to End Energy Poverty And Reach Net-Zero Emissions*, 2021). Therefore, it is crucial to focus on increasing energy consumption and employment levels to boost growth and employ renewable energy sources to ensure sustainability (*How to End Energy Poverty And Reach Net-Zero Emissions*, 2021).

While energy consumption drives economic growth, it is vital to address energy poverty and ensure the energy consumed is sustainable to maintain long-term economic growth and environmental health.

In this chapter, several studies that have investigated the relationship between energy consumption and economic growth in different contexts, including Jordan and other countries worldwide, will be reviewed. Also, the literature review will explore the role of energy consumption in environmental change and its impact on human development. Finally, the link between energy poverty and economic growth and what the literature says about this relationship will be discussed.

2.2.1. Energy consumption and economic growth: examples from around the world

Several studies examined the links between energy consumption and economic growth. Lee (2005) investigated the causality relationship between energy consumption and GDP in 18 developing countries using the panel unit root, heterogeneous panel cointegration, and panel-based error correction models. The results showed that in the long and short term, energy consumption caused GDP and concluded that energy conservation measures might hinder economic growth in the examined countries. Twenty net energy exporters' and net energy importers' energy consumption, GDP, and price index were reviewed by (Mahadevan and Asafu-Adjaye, 2007) between 1971 and 2002. The outcome demonstrated differences between industrialized and developing nations in the causal relationship between energy use and economic growth. (Payne, 2010) surveyed 101 studies, and the main findings with no consensus between the four hypotheses studies' findings almost split evenly between them. At the same time, Ozturk (2010) reviewed 130 studies, and the conclusion is that there is no consensus either on the existence or the direction of causality between these variables. Costantini and Martini (2010) applied the panel cointegration and error correction model to data from 71 countries divided into two groups: 45 non-OECD countries and 26 OECD countries. The data covered four energy sectors, and the empirical results suggested that alternate country samples hardly change the causal relations, particularly in multivariate and multi-sector frameworks. Warr and Ayres (2010) examined the relationship between energy and GDP in the United States (US) using exergy to measure the quantity of energy supplied and the efficiency of energy used with economic output. The outcome revealed that unidirectional causality runs from energy to the GDP, concluding that it was necessary to either increase energy supplies or increase the efficiency of energy usage to sustain long-term growth.

, and Lu (2018) used the panel autoregressive distributed lag and the panel quantile regression to analyze data from 29 OECD countries from 1990 to 2013. The study introduced a new growth model considering economic complexity as an economic growth factor. The results indicated that energy consumption and economic complexity boost economic growth in the studied countries. Pala (2020) conducted an empirical investigation to study the relationship between energy consumption and economic growth for a panel of G20 countries from 1990-2016. The paper used the Panel Cointegration and Panel Vector Error Correction Model to test the long-run equilibrium relationship. The study concluded that energy consumption and economic growth are interrelated, which backs the "feedback hypothesis." At the same time, in the long run, it has been suggested that there will be unidirectional causality, which would be critical to any energy conservation policies with time.

Leiva and Rubio-Varas (2020) studied the causality nexus between energy and GDP for 20 Latin American countries from 1900-2010; the study highly recommends reconsidering the theoretical understanding of the issue because the results were highly spatially and temporally heterogeneous. Cevik, Yıldırım and Dibooglu (2020) performed the Markov switching VAR method to study the causal relationship between non-renewable energy, renewable energy consumption, and economic growth in the USA. The results revealed that renewable energy consumption does not cause economic growth, whereas non-renewable ones cause economic growth. Pala (2020) used a Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS); the long-term relationship between energy consumption and economic growth was examined for the G20 countries over a period from 1990-2016. The results showed that causality runs from energy consumption toward economic growth. Ahmad et al. (2020) conducted a systematic literature review of the top 50 influential papers that focus on the energy-growth nexus; in the process, the researchers examined 1041 peer-reviewed articles, with the main conclusion that nexus results are generally inconclusive, with significant conflicting policy implications. Publications related to the world's energy and economic growth nexus are summarized in Table 3.

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Table 3. The main results of the relevant studies focus on energy and economic growth globally.

Authors	Year	Method	Country (Study Area)	Main Findings
Lee (2005)	2005	Panel unit root, panel cointegration, panel-based error correction models	18 developing countries	Energy consumption caused GDP in both the long and short term; energy conservation measures may hinder economic growth.
Costantini and Martini (2010)	Different periods	Panel cointegration, error correction model	71 countries divided into 45 non-OECD and 26 OECD countries	Alternate country samples do not significantly change the causal relationships, especially in multivariate and multi-sector frameworks.
Warr and Ayres (2010)	1946–2000	Granger Causality Test	United States (US)	Unidirectional causality runs from energy to GDP, suggesting the need to increase energy supplies or enhance energy usage efficiency for sustainable long-term growth.
Gozgor, Lau, and Lu (2018)	1990-2013	Panel autoregressive distributed lag, panel quantile regression	29 OECD countries	Energy consumption and economic complexity positively influence economic growth in the studied countries.
Pala (2020)	1990-2016	Panel cointegration, panel vector error correction model	G20 countries	Energy consumption and economic growth exhibit an interrelationship, supporting the "feedback hypothesis." Unidirectional causality exists in the long run, which has long-term implications for energy conservation policies.
Leiva and Rubio-Varas (2020)	1900-2010	Granger Causality Test, Error Correction model	20 Latin American countries	Highly spatially and temporally heterogeneous results call for reconsidering the theoretical understanding of the energy-GDP nexus.
Cevik, Yıldırım, and Dibooglu (2020)	1973Q1-2019Q4	Markov switching VAR	USA	Non-renewable energy consumption causes economic growth, while renewable energy consumption has no causal effect.
Pala (2020)	1990-2016	Fully Modified OLS, Dynamic OLS	G20 countries	Causality runs from energy consumption to economic growth in the long term.

Source: Own compilation.

2.2.2. Energy consumption and economic growth in Jordan

Shahateet (2014) examined the relationship between energy consumption and economic growth in 17 Arab countries. The auto-regressive distributed lag (ARDL) model results revealed that 16 of 17 countries, including Jordan, support the neutrality hypothesis, where energy conservation will not hinder economic growth. Shahateet, Al-Majali and Al-Hahabashneh, (2014) studied the causal relationship between economic growth and energy consumption in Jordan, and the study modeled the relationship using data on energy consumption, labor, capital, and economic growth for the period between 1970-2011. In contrast to the results from (Shahateet 2014), the results indicated a long-term causal relationship running from GDP to EC, concluding that introducing a new energy constraint may not limit Jordanian economic

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growth. In the same context, Al-Bajjali and Shamayleh, (2018) studied electricity consumption in Jordan between 1985-2015. They built a multivariate time series model including six variables: GDP, electricity prices, population, urbanization, the structure of the economy, and aggregate water consumption. Their results showed that factors such as GDP, urbanization, the economy's structure, and aggregate water consumption have a positive relationship with electricity consumption, while consumption is negatively linked to electricity prices. Khawaldeh and Al-Qudah (2018) studied the impacts of electric and oil energy consumption on economic growth in Jordan from 1992-2016. The multiple linear regression model was used to test the variables. The results showed that both energies have a significant and positive relationship with economic growth.

Dar-Mousa and Makhamreh, (2019) studied energy consumption patterns in Amman using Global Moran's I analysis. They indicated an inverse relationship with population distribution, family size, and building characteristics. The study concluded that small families in some parts of the city could consume more energy related to their income and household size. (2020) indicated that Jordan is sensitive to regional conflicts due to its high dependency on imported energy and the lack of diversity in energy resources. They concluded that policies should focus on increasing the local share of energy resources and enhancing strategic energy storage to increase Jordan's resilience. Azzuni *et al.*, (2020) studied the impact of energy transition on achieving energy security in Jordan. The fact that Jordan has the potential to achieve 100% energy transition by 2050 (Kiwan and Al-Gharibeh, 2020) can contribute to more security and reduce GHGs. They concluded that utilizing renewable energy can contribute to solving water scarcity. Al-Qudah (2022) studied the impacts of renewable energy consumption, labor, and capital on Jordan's economic growth from 1996-2018. The methodology used was the Johansen co-integration test, the Cobb-Douglas production function, and the dynamic ordinary least squares (DOLS). The results revealed that renewable energy consumption, labor, and capital have a significant positive relationship with economic growth. The study recommended developing policies to increase investment in renewable energy in Jordan. Publications related to energy and economic growth nexus in Jordan are summarized in Table 4.

Table 4. Main results of the studies focusing on energy and economic growth in Jordan.

Authors	Year	Method	Country (Study Area)	Main Findings
Shahateet (2014)	2014	ARDL model	17 Arab countries	Neutrality hypothesis supported in 16 out of 17 countries, including Jordan, suggesting that energy conservation does not hinder economic growth.
Shahateet, Al-Majali, and Al-Hahabashneh (2014)	2014	Causal relationship analysis	Jordan	Long-term causal relationship observed from GDP to energy consumption.
Al-Bajjali and Shamayleh (2018)	2018	Multivariate time series model	Jordan	GDP, urbanization, economy's structure, and aggregate water consumption positively related to electricity consumption, while electricity prices negatively linked to consumption.
Khawaldeh and Al-Qudah (2018)	2018	Multiple linear regression model	Jordan	Both electric and oil energy consumption have significant positive relationships with economic growth in Jordan.
Dar-Mousa and Makhamreh (2019)	2019	Global Moran's I analysis	Amman, Jordan	Inverse relationship observed between energy consumption patterns and factors such as population distribution, family size, and building characteristics. Small families in certain parts of the city consume more energy relative to their income and household size.
Al-Qudah (2022)	2022	Johansen co-integration test, Cobb-Douglas production function, dynamic ordinary least squares	Jordan	Renewable energy consumption, labor, and capital have a significant positive relationship with economic growth in Jordan. Recommended policies include increasing investment in renewable energy.

Source: own compilation.

2.2.3. The role of energy consumption and economic growth in environmental change

Acaravci and Ozturk (2010) examined the long-run causal relationships between CO_2 emissions, energy consumption, and economic growth using an autoregressive distributed lag and the Granger causality test for 19 European countries. Their results show a long-run causal relationship between energy consumption and CO_2 emissions and a long-run elasticity between carbon emissions and real gross domestic product. Pao, Yu and Yang (2011) used the cointegration technique and the causality test to determine the dynamic relationships between pollutant emissions, energy use, and real output for Russia. The results showed a significant bidirectional causality relationship between emissions, energy use, and output. Moreover, the real output does not support the environmental Kuznets curve hypothesis and has a negative impact on emissions. Li *et al.* (2011) used a combination of path analysis and STIRPAT (stochastic impacts by regression on population, affluence, and technology) model. The outcomes revealed that CO_2 emissions are mainly influenced by five macro factors: GDP per capita, industrial structure, population, urbanization, and technology. The studied factors showed various impacts, while improving the technology level has the highest impact in terms of reducing CO_2 emissions.

Arouri *et al.* (2012) test the environmental Kuznets curve hypothesis in the Middle East and North Africa (MENA) region by applying bootstrap unit root tests and a panel cointegration method to explore the relationship between real GDP, energy consumption, and CO_2 emissions. Their results show that EKC is only verified for Jordan and that, in the long run, energy consumption significantly impacts CO_2 emissions in the region. Hamit-Haggar (2012) applied cointegration analysis to investigate the long-term relationship between GHG emissions, energy consumption, and economic growth in the Canadian industrial sector. The findings of the analysis reveal that there is a significant long-run impact of energy consumption on GHG emissions. In contrast, a non-linear relationship between GHG emissions and economic growth is consistent with the EKC. Saboori, Sapri and bin Baba (2014) employed the fully modified ordinary least squares cointegration approach to examine the bi-directional long-term relationship between road sector energy consumption with CO_2 emissions and economic growth in OECD countries. The results showed a significant positive long-term bidirectional relationship between the variables. Moreover, when testing the response of each factor to shocks in the other variables, the results showed that CO_2 emissions response to GDP is shorter than that of energy consumption.

Mugableh (2015) investigated the equilibrium and dynamic causality relationships among economic development, CO_2 emissions, energy consumption, financial development, foreign direct investment inflows, and gross fixed capital formation in Jordan between 1976 and 2010. One of the paper's main results is that the EKC hypothesis exists between economic development and CO_2 emissions in the long and short run. The results also indicate strong evidence of unidirectional causality from financial development to energy and growth in Jordan. Saidi and Hammami (2015) investigated the impact of economic growth and CO_2 emissions on energy consumption for 58 countries using the generalized method of moments. They find that CO_2 emissions correlate positively with energy consumption for all the sample countries—Europe and North Asia, Latin America, and the Caribbean, as well as the MENA and the Sub-Saharan African regions. However, economic growth positively correlates with MENA and Sub-Saharan African energy consumption. Jamel and Derbali (2016) studied the causality between CO_2, energy consumption, and economic growth from panel data from eight Asian countries using the cointegration test, the fully modified OLS, and the panel causality tests. The outcomes revealed that a long-term relationship exists between environmental degradation, energy consumption, economic growth, financial development, trade openness, capital stocks, and urbanization as control variables. Spetan (2016) investigates the causal relationships between renewable energy consumption, CO_2 emissions, labor, capital, and economic growth in Jordan between 1986 and 2012. The results show that in the short term, bidirectional causality runs from capital and renewable energy consumption, while unidirectional causality runs from renewable energy consumption to real GDP. Additionally, a unidirectional causality runs from real GDP to capital and from renewable energy consumption and CO_2 emissions. Moreover, CO_2 emissions can be reduced with an increase in renewable energy consumption.

Gui *et al.* (2017) used the partial least square method of path analysis combined with a regression model to investigate the factors influencing the intensity of CO2 emissions. The factors included in the study are GDP per capita, technology effect, energy price, industrial structure, energy structure, and foreign direct investment. The results show that carbon intensity is mainly affected by the effect of technology. Moreover, the study stresses that research and development are essential in controlling carbon intensity in China. Chen and Lei (2017) study the transportation sector as one of the main driving forces that produce higher CO_2 emissions. They use the path analysis model to estimate the direct, indirect, and total influence of driving factors on CO_2 emissions in Beijing. The results show that controlling CO_2 emissions can be reduced if energy and transportation intensities are reduced. Furthermore, it is indicated that population has the most significant impact on CO_2 emissions, as population growth will increase the pressure on the transportation sector.

2.2.4. Energy and the Human Development Index

Martínez and Ebenhack (2008) studied the correlation between the Human Development Index (HDI) and energy consumption in 120 nations. The results showed a strong correlation in most parts of the world. The results also showed three main pathways where three regions are isolated: a sharp rise in human development relative to energy consumption for energy-poor nations, a moderate rise for nations in transition, and essentially no rise in human development for energy-advantaged nations, consuming significant amounts of modern energy. Razmi *et al.* (2021) used the nonlinear autoregressive distributive lag model to investigate the asymmetric short- and long-term impacts of renewable and non-renewable energy consumption on HDI in Iran using data from 1990-2018. The results showed that natural gas has the most significant effect on HDI, while renewable energy has no effect. Moreover, reduction of crude oil and natural gas consumption impacts HDI negatively in the short and long term.

LaBelle, Tóth and Szép (2022) used the path analysis to study the relationship between residential energy use per capita and human well-being represented by the HDI in the European Union. The study aimed to measure the change over 2000-2018 and examine the effect of the Fit for 55 policy packages on the post-communist member states compared with the old member states. Direct and indirect effects were detected between the studied variables, with a conclusion stating that implementing the Fit for 55 packages would prevent reducing the gap between the two country groups. In the same context, Szép, Tóth and LaBelle (2022) examined the relationship between human well-being and the per capita residential energy use in the EU-27 countries from 2000 to 2018. Qualitative and quantitative methods highlighted the inequality between the studied countries. The results showed that per capita residential energy use has a moderate positive relationship with human development. Moreover, the results indicated that while the delinking process became dominant in the EU in 2018 and 19, the classification of the EU countries needs to be redefined.

Musakwa and Odhiambo (2022) used the autoregressive distributed lag method to investigate the impact of oil products, electricity, renewable energy, natural gas, coal, lignite, and overall energy consumption on the HDI for 1990-2019 in South Africa. The results indicated that renewable energy has a positive impact on HDI, while on the other hand, oil products, natural gas, and total energy have a negative impact in the short run. Kaewnern *et al.* (2023) investigated the impact of economic growth, research and development expenditure, renewable energy consumption, and total natural resources rents on the HDI in the top ten human development countries. The study used the Driscoll-Kraay, feasible generalized least square (FGLS), and generalized method of moments (GMM) on a time series from 1996-2007. The results showed that all the used variables tested positive on the HDI, while the Dumitrescu-Hurlin panel causality tests showed a bidirectional relationship between economic growth and HDI.

Moreover, the results revealed that causality runs from HDI towards renewable energy consumption and research and development expenditure. Kashour (2023) studied the influence of the HDI on residential energy consumption inequality in the EU-27 countries. The study used the Gini coefficient and the least squares dummy variables (LSDV) on data from 2010-2018. It also analyzed the HDI’s three components: life expectancy, education, and gross national income on residential energy use. The results showed that life expectancy had a negative effect on energy use, education had no effect, and GNI had a positive effect. In addition, energy efficiency significantly impacted the HDI for all the countries.

2.2.5. Linking energy poverty: What can the literature tell?

Linking energy poverty and economic growth is becoming of interest in the academic field. Some researchers confirmed that energy poverty is always associated with economic poverty (Chevalier and Ouédraogo, 2013). Moreover, the impact of the financial crisis on electricity usage appears to be delayed, which illustrates that it takes time for families to adjust to the new economic circumstances and modify their habits and way of life (Dagoumas and Kitsios, 2014). The number of studies on energy poverty is also growing in many directions. In Pakistan, Murtaza (2014) studied the causality relationship between energy poverty, income poverty, income inequality, and GDP per capita using data from 1973-2012. The study employed the Toda-Yamamoto non-Granger causality test. The results indicated a bi-directional causality between growth and energy poverty, and unidirectional causality runs from income poverty to income poverty and from income inequality to energy poverty. On the African level, Ghodsi and Huang (2015) studied the causality between economic growth and energy consumption in selected African countries using two Methods. The results showed a strong relationship between the studied variables. In India, Acharya and Sadath (2019) used household data to assess the impacts of energy poverty on economic development. The results indicated that energy poverty adversely impacts economic development and correlates with socio-economic retardation. Moreover, the results showed that income and education levels significantly reduced energy poverty.

Amin *et al.* (2020) studied the impacts of energy poverty on economic development in South Asian Countries. The study used access to electricity as a proxy for energy poverty and applied the panel cointegration, autoregressive distributed lag, and penalized quantile regression (PQR) estimators on a data series from 1995 to 2017 to estimate the long-term cointegration. The results revealed that long-term cointegration exists between energy poverty, employment, education, per capita income, inflation, and economic development. The study concluded that the public and private sectors need to accelerate the adoption of modern energy sources. Aigheyisi and Oligbi (2020) studied the relationship between economic development and energy poverty in Nigeria. Using data from 1990-2017, the study analyzed the relationship between per capita gross national income, access to electricity, gross fixed capital formation, foreign direct investment, trade openness, labor force, and exchange rate. The main result indicated that alleviating energy poverty by enhancing the electrification rate can boost development. Doğanalp, Ozsolak and Aslan (2021) used the panel data analysis to study the effects of energy poverty on economic growth in BRICS countries. The PVAR, FMOLS, and DOLS analysis used data representing economic growth, education, inflation, energy consumption, and employment. Despite the study’s mixed results, it concluded that energy poverty does not exist in the BRICS countries.

Shafiullah and Rahman (2021) investigated the impacts of economic growth, industrialization, urbanization, and employment on energy poverty in South Asia’s most energy-intensive countries between 1995-2000. The results showed that economic growth reduces energy poverty, while industrialization increases the issue. Furthermore, energy poverty is positively associated with urbanization but negatively with employment. Ansari *et al.* (2022) used the second-generation panel unit root tests and panel cointegration tests to explore the dynamic relationship between ecological footprint and energy poverty in sub-Saharan African countries from 1995 to 2018. The results indicated a long-term relationship among the used variables and that energy poverty negatively affects ecological footprint, while economic growth is unaffected by energy poverty. The study concluded that energy poverty can be used as a development indicator for protecting the environment. Nguyen and Dinh Thanh (2022) studied the relationship between energy poverty and economic vulnerability in 73 low and middle-income countries. The study used the Granger causality test and two-step system generalised method of moments estimate to a system equation of two variables. The results revealed that bi-directional causality was detected between energy poverty and economic vulnerability with a positive influence between both variables.

The literature review discussed several studies that examined the relationship between energy consumption and economic growth. The studies used different methods and techniques, and their results are mixed. Some studies find a positive relationship between energy consumption and economic growth, while others find the relationship negative or nonexistent. Some studies also find that energy conservation measures hinder economic growth in some countries while others do not. The review discusses the relationship between energy consumption, CO_2 emissions, and economic growth. Some studies find a positive relationship between energy consumption and CO_2 emissions, while others conclude that the relationship is negative or nonexistent. Some studies also conclude that economic growth can positively or negatively impact CO_2 emissions, depending on the country and other factors.

In addition, the literature review examined the impact of energy consumption on human development. The results of these studies are mixed. Some show a positive relationship between energy use and human development, while others show no significant or negative relationship. The impact of energy poverty on economic growth has also been examined, with some studies finding a negative impact and others finding no relationship. The literature also concludes that measures to increase the share of local energy resources and improve strategic energy storage could increase Jordan’s energy security and resilience. It concludes that increased access to sustainable and affordable energy sources would benefit Jordan's economic growth, poverty reduction, and environmental protection. The literature suggests that the relationship between energy use and economic growth is complex and can vary by country, energy source, and other factors. Further research is needed to understand these relationships better.

The literature reviewed offers insights into energy, economic growth, energy poverty, the human development index, and climate change. The first section highlights some of the extensive literature on the relationship between economic growth and energy consumption worldwide. The results in this section varied depending on many factors, particularly the methodology and data used and the geographic context. The second section focused on Jordan, where results varied by time, data, and methods. The causality analysis mainly indicated that the relationship between energy consumption and economic growth was neutral or ran from GDP to energy consumption. The researchers suggested that increased energy consumption did not affect economic growth. This chapter re-examines this relationship to include the environmental factor of greenhouse gas emissions and compares and updates the findings on this topic. The third section examined the studies that address the relationship between climate

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change, economic growth, and energy consumption. The results in this section agreed that emissions are affected by economic growth and energy consumption, regardless of the data or geographic scale used. The findings of the studies covered in the literature show that using different methods produces mixed results, which impact the way energy policies form. Although, the presence of different methods and approaches is needed, which can produce different policy approaches in return to deal with energy-economic growth issues on the country and regional levels.

In addition, the literature on the relationship between HDI and energy consumption is growing, and the results show a consensus that energy consumption positively influences HDI. The final section focused on the link between energy poverty and economic growth. The literature covered showed that economic growth patterns affect energy poverty.

2.3. Data and Methodology

2.3.1. Study Area

Jordan is divided into three regions and twelve governorates (four in each region). Ajloun, Irbid, Jerash, and Mafraq are in the northern region; Amman, Balqa, Madaba, and Zarqa are in the central region; while Aqaba, Karak, Ma’an, and Tafila are in the southern region. **Figure *16*** shows Jordan’s map and the population distribution in 2020. Over 90 percent of the population is urban and mostly condensed in the capital, Amman, and the Northern region, while the southern region is less populated. The geographical distribution of the population shows where the demand for services, including energy, is the highest and which areas have a lower demand or consumption.

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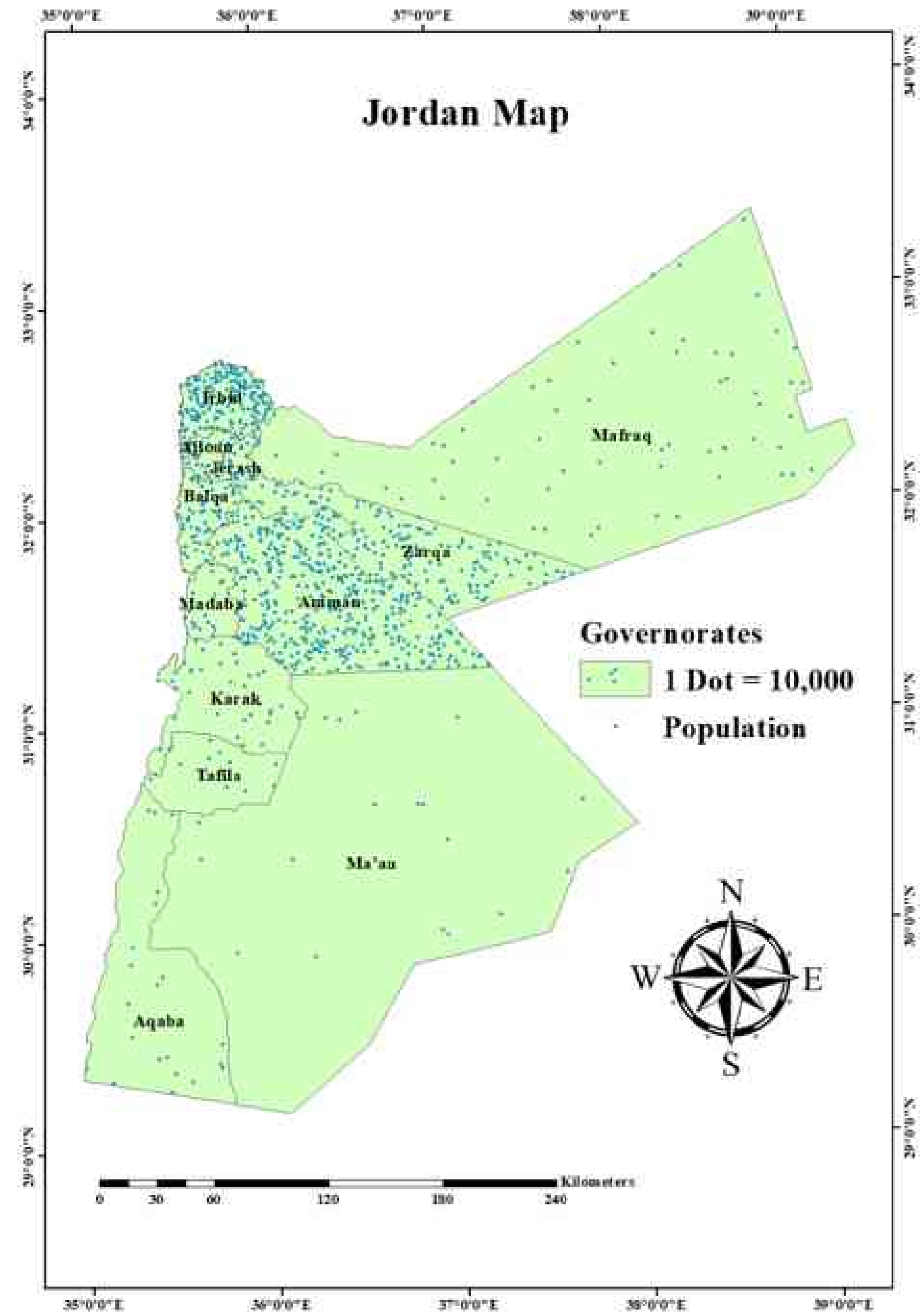

Figure 16. Jordan map with the distribution of the population in 2020.

Source: Own editing.

2.3.2. Description of the time series

This chapter uses two data sets to perform two types of analysis. First, The Toda-Yamamoto non-Granger causality test is used to determine the causal relationship between energy consumption (EC), gross domestic product (GDP) in constant prices US$ of the year 2015, and greenhouse gas emissions (GHGs), including land use changes in carbon-dioxide equivalent. The primary energy consumption is chosen instead of the final energy consumption to provide a more comprehensive view of the energy system and its impacts. Understanding the relationship between energy consumption and economic growth is essential, and the literature

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review section provides an overview of the various methods and approaches used to study this relationship. This understanding can help Jordan formulate policies that achieve sustainability in the energy sector while continuing economic growth. Climate change is also an urgent topic, and studying the relationship between energy consumption, economic growth, and GHG emissions can provide insight into how growth actions can affect those emissions and help formulate policies to reduce them.

To better understand the relationship between energy poverty and other topics, this chapter begins by examining the Jordanian system. The causality test, a well-established method in literature, will be used to analyze the causal relationship between multiple variables over a long period. Additionally, traditional path analysis will be performed on cross-sectional data collected from two household expenditure and income surveys conducted in 2008 and 2017. Unfortunately, the latest data available from Jordan is from 2017 because of data availability issues. I hope that new data will be available and more analysis can be conducted to update energy expenditures in the country. While data availability may limit the ability to perform complex analysis, the data retrieved from the surveys will provide insight into geographical differences between Jordanian governorates regarding income, energy, health, education expenditures, urbanization, and the use of wood for heating. These variables will be evaluated concerning human well-being, as measured by the HDI. **Table *5*** defines the variables included in the analysis in this chapter.

Table 5. Definition and sources of the data used in the causality and path analysis.

Abbreviation	**Indicator**	**Source**
	Granger Causality Test	
EC	Primary energy consumption (TWh)	Our World in Data Database
GDP	Gross domestic product (GDP) in constant prices US$ for the year 2015	World Bank
GHG	Annual greenhouse gas emissions, including land-use change and forestry, are measured in ‘carbon dioxide equivalents (CO_2e).	Our World in Data Database
	Path Analysis	
EE	Annual energy expenditure	Jordanian Department of Statistics
IN	Average annual total income	Jordanian Department of Statistics
WD	Percentage of households that use wood/coal/jift as a main source of heating	Jordanian Department of Statistics
UB	Urbanization level	Jordanian Department of Statistics
HE	Average annual household expenditure on health	Jordanian Department of Statistics
ED	Average annual household expenditure on education	Jordanian Department of Statistics

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HDI	Human development index in every governorate	Global Data Lab

The descriptive analysis results in **Table *6*** show the mean, the maximum, the minimum, the skewness, the kurtosis, and the Jarque-Bera probability for the time series included in the Toda-Yamamoto causality test. Standard deviation results show that only GDP deviates above the average mean, while the rest of the variables deviate below the average mean. The skewness coefficients show that EC, GDP, and GHG are skewed positively; Kurtosis results show that all the values are positive, and the data distribution is leptokurtic; Jarque-Bera P-value reveals that all the variables are normally distributed during the study period. **Figure *17*** shows more details regarding the trend characteristics of the variables included in the analysis.

Table 6. Descriptive analysis of the variables used in the Granger causality test and the path analysis.

	EC	**GDP ($ billions)**	**GHG**
Mean	77.717	25.30	26130690
Median	79.277	23.10	23959999
Maximum	120.709	41.00	37070000
Minimum	39.966	11.60	18629999
Std. Dev.	23.453	09.91	5576837
Skewness	0.194	0.197	0.637
Kurtosis	2.023	1.522	2.132
Jarque-Bera	1.335	2.827	2.873
Probability	0.513	0.243	0.238
Sum	2253.802	7.34E+11	7.58E+08
Sum Sq. Dev.	15400.94	2.75E+21	8.71E+14
Observations	29	29	29

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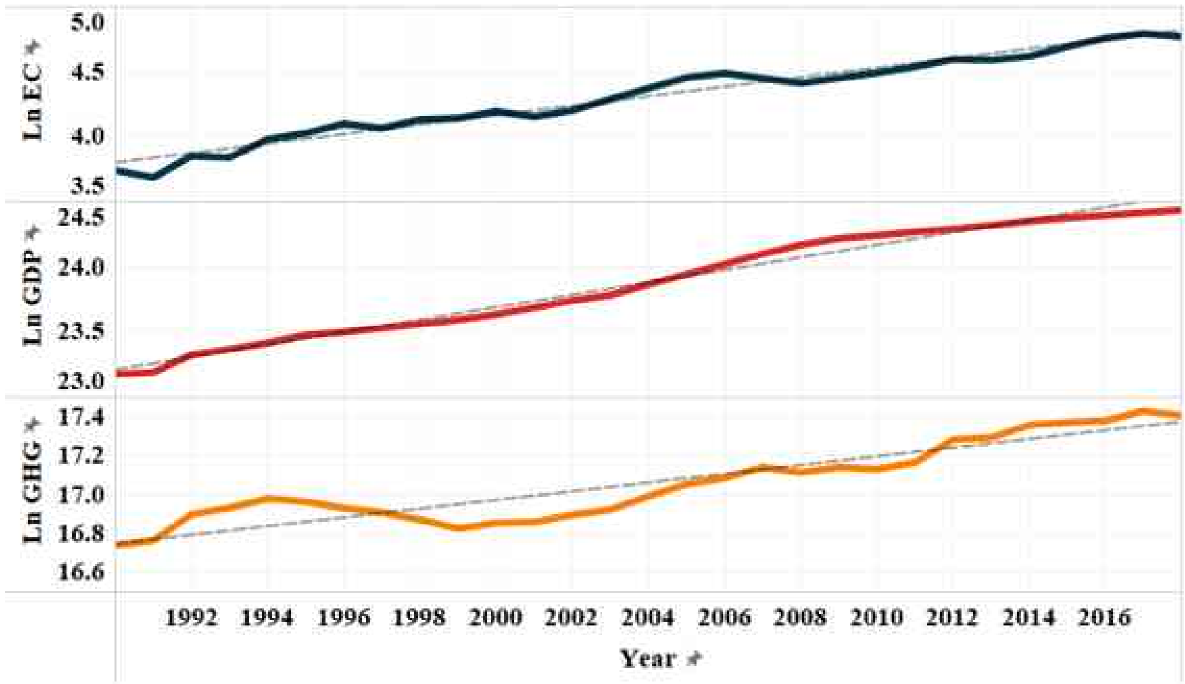

Figure 17. Trend characteristics of the data included in the Toda Yamamoto causality test.

2.3.3. Unit Root Test

Economic time series show a trend in either mean, variance, or both (Das, 2019). If the time series mean and variance remain constant, it is stationary (Szép, 2014). Thus, the stationarity of the time series should be evaluated. Before testing, it is crucial to overcome the problem of non-stationarity; this can be done by first differencing and de-trending (Das, 2019). There are multiple methods to test the time series stationarity of unit root; among those, the most popular one is the augmented Dicky-Fuller (ADF) test developed by Dickey and Fuller (1979). The ADF test tends to reject the null hypothesis of non-stationarity. Thus, using another test, such as Phillips-Perron-Perron, to confirm the results of the ADF test is favorable. Developed in 1988, the Phillips–Perron (PP) (PHILLIPS and PERRON, 1988) test is used to test the existence of unit roots in the time series and confirm the results of the ADF test.
When testing the non-stationarity of the time series, we can choose from three options that we can include in the equation: first, there is no intercept or trend; second, only intercept but no trend; and third, including both an intercept and trend (Enders, 2015).

2.3.4. Toda-Yamamoto Technique

The long-term relationship between energy consumption and economic growth for the study period is investigated using the non-Granger causality test by Toda and Yamamoto (1995). The Toda and Yamamoto causality method is effective and applicable regardless of the order of integration of the series or whether they are cointegrated. This method applies to stationary time series at level, first, or second difference. The technique was structured based on the augmented Vector Autoregressive (VAR) modeling method and the Wald test statistic. The test is based on asymptotic chi-square (χ^2) values that are distributed regardless of the cointegration properties and the stationarity of the data series. In this technique, the $(k + d_{max})^{th}$-order VAR is estimated, where k is the determined lag length, and d_{max} is the maximal order of integration. The analysis performed the Toda-Yamamoto long-run non-Granger causality test using VAR with 4 lags (k=3 and d_{max}=1). The equation is written in equation (2.1).

$$\begin{bmatrix} lnGDP_t \\ lnEC_t \\ lnGHG_t \end{bmatrix} = \eta_0 + \eta_1 \begin{bmatrix} lnGDP_{t-1} \\ lnEC_{t-1} \\ lnGHG_{t-1} \end{bmatrix} + \eta_2 \begin{bmatrix} lnGDP_{t-2} \\ lnEC_{t-2} \\ lnGHG_{t-2} \end{bmatrix} + \eta_3 \begin{bmatrix} lnGDP_{t-3} \\ lnEC_{t-3} \\ lnGHG_{t-3} \end{bmatrix} + \eta_4 \begin{bmatrix} lnGDP_{t-4} \\ lnEC_{t-4} \\ lnGHG_{t-4} \end{bmatrix} + \begin{bmatrix} \mu_{lnGDP} \\ \mu_{lnEC} \\ \mu_{lnGHG} \end{bmatrix} \ldots(2.1)$$

Here, ln is the natural logarithm sign, $lnGDP_t$ represents the natural log of GDP, $lnEC_t$ represents the natural log of EC, and lnGHG represents the natural log of GHG. $\eta_1 \ldots \ldots \eta_4$ represent the 4*4 matrices of quantities with η_0 identity matrix. The disturbance terms that have zero mean and constant variance are represented by μ_s.

The logical steps for performing the Toda-Yamamoto non-Granger causality test are shown in **Figure *18***.

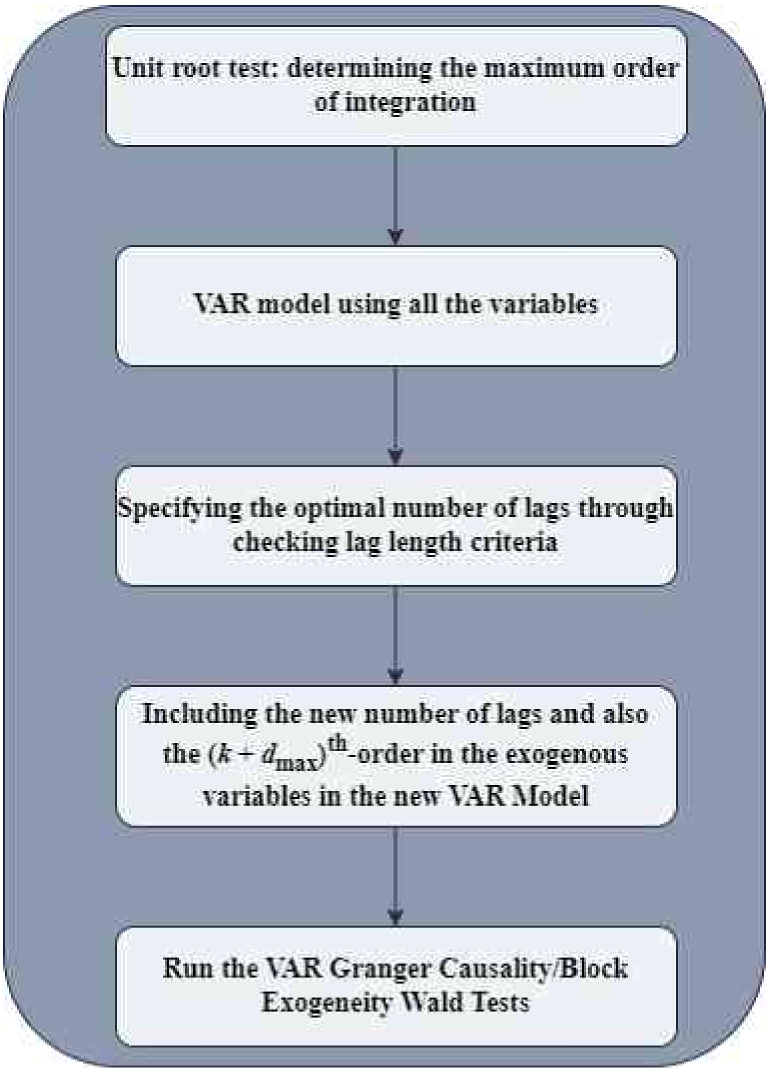

Figure 18. The Toda Yamamoto non-Granger causality test using EViews.

Source: Own compilation.

2.3.5. Path Analysis

Path analysis uses multiple regression to formulate causal models explicitly. Causality cannot be established using this method; it can examine the pattern of relationships between three or more variables, but it can neither confirm nor reject the hypothetical causal imagery. This type of analysis aims to provide quantitative estimates of the causal connections between sets of variables (Bryman, 2004). Path analysis was conducted to estimate the direct and indirect effects influencing the HDI in Jordan. Direct, or zero-path, assesses the linear relationship between the primary explanatory variable and the dependent variable. On the other hand, the indirect or secondary path determines those effects through a set of secondary explanatory variables. Figure 4 shows the path diagrams of the factors that were included in this paper.

The model is measured based on the specific factor analytic with the assumption that the explanatory variable influences the outcome variable:

$$Y = \beta Y + \gamma X + \varepsilon \quad (2.2)$$

Where Y is the vector of observable dependent variables, X is the vector of observable independent variables, ε is the vector of errors, and β and γ are coefficient matrices.

The multiple linear regression is:

$$y_i = \beta_0 + \beta_1 x1_{1,i} + \beta_2 x1_{2,i} + \cdots + \beta_k x1_{k,i} + \epsilon_i \quad (2.3)$$

where k is the number of explanatory variables.

In their research, LaBelle, Tóth and Szép (2022) summarise the path analysis in five steps:

1. Identifying the primary and secondary influencing factors taking into consideration multicollinearity where applicable.
2. Running a simple multivariate linear regression, including the primary and secondary variables, to estimate the impact of these factors on the dependent variable.
3. Estimating the bivariate regression model to analyze the relationship between the primary explanatory factor and the dependent variable.
4. Determining the path's strengths. On the one hand, indirect paths may cross over secondary variables; at this point, all paths from the start to the dependent variable must be added together, and the correct path segments must be multiplied together, i.e., regardless of significance. The consequences of the relevant indicators and the revealed paths are next examined.
5. The fourth step is to determine the direct and indirect effect of the primary factor on the dependent variable by breaking down the β coefficients of the binary linear regression.

Thus, the model performs a chain of simple linear regressions to best interpret the relationships between the explanatory factors and the targeted (dependent variable). This method is simple and can reveal the desired relationships between the variables under study (Jaber, 2022). **Figure *19*** shows the constructed path diagram of the explanatory variables.

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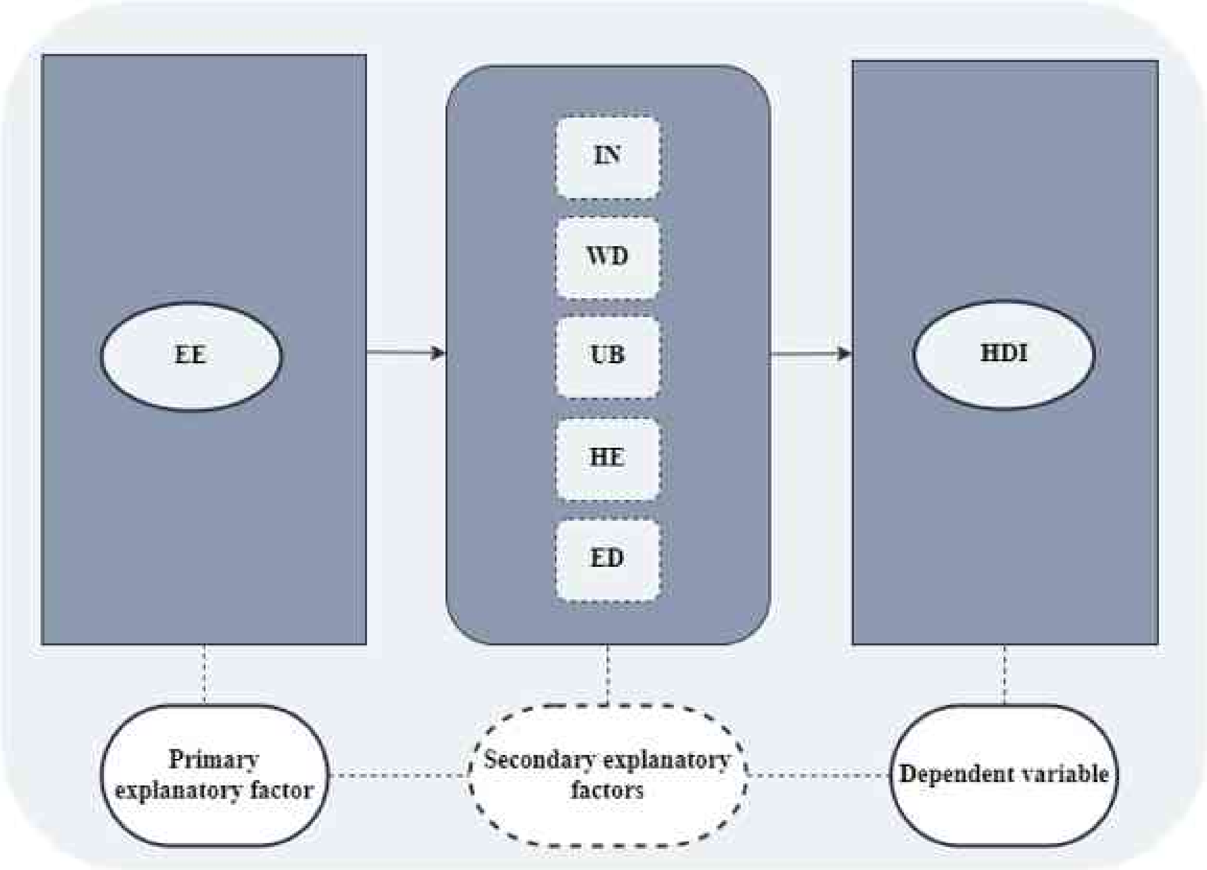

Figure 19. Path diagram of the explanatory variables.

Source: Own compilation

2.3.6 Study Limitations

This chapter employs two distinct methodological approaches, offering a nuanced and comprehensive understanding of the relationships investigated within the study. However, several inherent limitations arose at different stages of the research. Firstly, data availability in Jordan presented a significant obstacle. The temporal brevity of existing datasets and their infrequent updates constrained in-depth analysis. Furthermore, specific crucial data, such as household energy consumption, remained completely absent from publicly available records. Researchers implemented alternative proxy variables to address these data gaps, acknowledging the potential caveats introduced by such substitutions. Secondly, Jordan's evolving energy sector suffers from a dearth of clearly defined and consistent policies. This ambiguity hinders researchers' ability to compare their findings effectively and formulate concrete policy recommendations.

2.4. Results and discussion

I tested the relationship between EC, GDP, and GHG in this chapter using the Toda-Yamamoto technique. A simple VAR equation was estimated. Using the optimal lag length criteria, the VAR model was re-estimated to include the order of integration of the variables and the number of lags. Then, the non-Granger Causality, or the Toda-Yamamoto causality test, was performed. On the other hand, path analysis was used to test the relationship between EE and HDI, among other secondary explanatory variables, as discussed in the previous section. Path analysis uses a series of ordinary least squares which are built upon each other. The first step examines the primary variable effects on the secondary variables' groups. The second step examines the impacts of the primary and secondary dependent variables on the dependent variable. The last step includes all the variables in the regression against the dependent variable.

2.4.1. Results of the Toda-Yamamoto causality test

Understanding the relationship between energy consumption and economic growth is essential. The outcomes regarding the direction of the causality relationships have significant policy associations. As mentioned earlier in the chapter, energy is one of the main factors incentivizing economic growth. Thus, determining which one of the four hypotheses the relationship follows would result in better policy suggestions.

Unit root test

The unit root of energy consumption and economic growth was tested using the Augmented Dicky-Fuller (ADF) and Phillips–Perron (PP) tests. The unit root test for both level and first difference forms was performed, including constant only and constant and linear trends. The results of the unit root tests in **Table *7*** and **Table *8*** show that the time series are integrated at first difference. The order of integration value will be used later when testing the modified VAR model and the causality test.

Table 7. ADF unit root test results

	Maximum Lag (AIC)	**ADF unit root test Intercept**		**ADF unit root test Intercept and trend**	
		I(0)	**I(1)**	**I(0)**	**I(1)**
ln**EC**	**6**	-1.813 (0.366)	**-6.631 (0.000)****	**-3.697 (0.041)***	**-4.596 (0.006)****
ln**GDP**	**6**	-2.200 (0.211)	**-3.798 (0.008)****	-0.925 (0.938)	**-4.483 (0.007)****
lnGHG	**6**	1.077 (0.996)	**-3.717 (0.011)***	-1.378 (0.845)	**-4.395 (0.010)****

Note: Values in () are P-values, whereas * and ** are the 5% and 1% significance levels, respectively.

Table 8. PP unit root test results

	PP **unit root test Intercept**		PP **unit root test Intercept and trend**	
	I(0)	**I(1)**	**I(0)**	**I(1)**
ln**EC**	-2.190 (0.214)	**-6.502 (0.000)****	-2.190 (0.476)	**-6.674 (0.000)****
ln**GDP**	-1.499 (0.519)	**-3.950 (0.006)****	-1.040 (0.922)	**-4.612 (0.005)****
lnGHG	-0.539 (0.869)	**-4.136 (0.004)****	-1.785 (0.685)	**-4.042 (0.019)***

Note: Values in () are P-values, whereas * and ** are the 5% and 1% significance levels, respectively.

After determining the variables' integration level, the next step is determining the model's optimal lag length to ensure it is free from serial correlation and other problems. The model indicates that the optimal lag order is eight, as indicated by four criteria. This number is used in the modified VAR model alongside the order of integration, as noted earlier in the methodology. **Table *9*** shows that the optimal number of lags is two according to three criteria.

Table 9. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	54.69618	NA	3.76E-06	-3.97663	-3.83147	-3.93483
1	168.4664	192.5343	1.20E-09	-12.0359	**-11.45522***	-11.8687
2	178.501	14.66586	1.14E-09	-12.1155	-11.0993	-11.8228
3	196.4648	**22.10931***	**6.25e-10***	**-12.80498***	-11.3533	**-12.38696***

Note: Indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion

The causal relationships between energy consumption, economic growth, and greenhouse gases are listed in **Table *10***. The Toda Yamamoto causality test results show that energy consumption significantly causes economic growth and greenhouse emissions. On the other hand, the null hypothesis of no causality is accepted in the other direction. Energy consumption in Jordan is increasing yearly, as the data deceptive in the previous section shows, and such an increase resulting from the high demand will boost economic growth and increase GHG emissions. The results support the growth hypothesis and can be applied to GDP and GHGs. As energy demand keeps increasing, policies should focus on accelerating the energy transition, improving efficiency, enhancing storage capacity, and incentivizing the adoption of clean technologies.

Table 10. Toda-Yamamoto causality test results.

Null Hypothesis	Chi-Square (χ^2)	P-value
Energy consumption does not cause economic growth	28.900	**0.000**
Energy consumption does not cause greenhouse gases emissions	8.788	**0.032**
Economic growth does not cause energy consumption	3.212	0.360
Economic growth does not cause greenhouse gases emissions	1.633	0.652
Greenhouse gas emissions do not cause energy consumption	4.618	0.202
Greenhouse gas emissions do not cause economic growth	3.354	0.340

Source: own calculations.

2.4.2. Energy Expenditure and Income Regional Inequality

Before proceeding to the path analysis results, this section highlights the regional inequalities between the Jordanian Governorates in this section. Regional data regarding annual average energy expenditure and income were collected from DOS while preparing the data for the path analysis for 2008 and 2017. Then, using a scatter plot, I built two charts to show the position of each governorate in terms of energy expenditure and income against the arithmetic mean (which represents the horizontal and vertical lines, respectively). The resulting charts can be seen in **Figure *20*** and **Figure *21***.

The two arithmetic mean lines divide the chart into four corners:

1. the upper right corner represents the governorates that have higher average income and energy expenditure,
2. the lower right corner for those who have higher income and lower energy expenditure,
3. the lower left corner represents those who have low income and energy expenditure and
4. The upper left corner represents the governorates with lower incomes than average and higher energy expenditures. Income and energy expenditure levels have generally grown between the two years.

Comparing the two years of measurement, we notice that Amman has the highest income and energy expenditure levels in the observed years. Amman hosts the capital city of Amman, and it is the most populous governorate in Jordan, where jobs are primarily available and higher income levels and services are available. When examining the two charts together, we can see that a shift had happened, and the governorates' situation regarding income and energy expenditure changed.

In 2008, Balqa, Zarqa, and Irbid had the highest energy expenditure levels compared to the other governorates. This situation changed, especially for Irbid and Balqa, where income levels had increased above the average and moved from the "unfortunate corner" to better conditions. Zarqa, on the other hand, shows that energy expenditure compared to 2008, energy expenditure and income levels became less than the average, meaning that most households in Zarqa managed to adapt to lower energy consumption or improvements in energy efficiency helped them to shift energy expenditure to a lower level than the national average.

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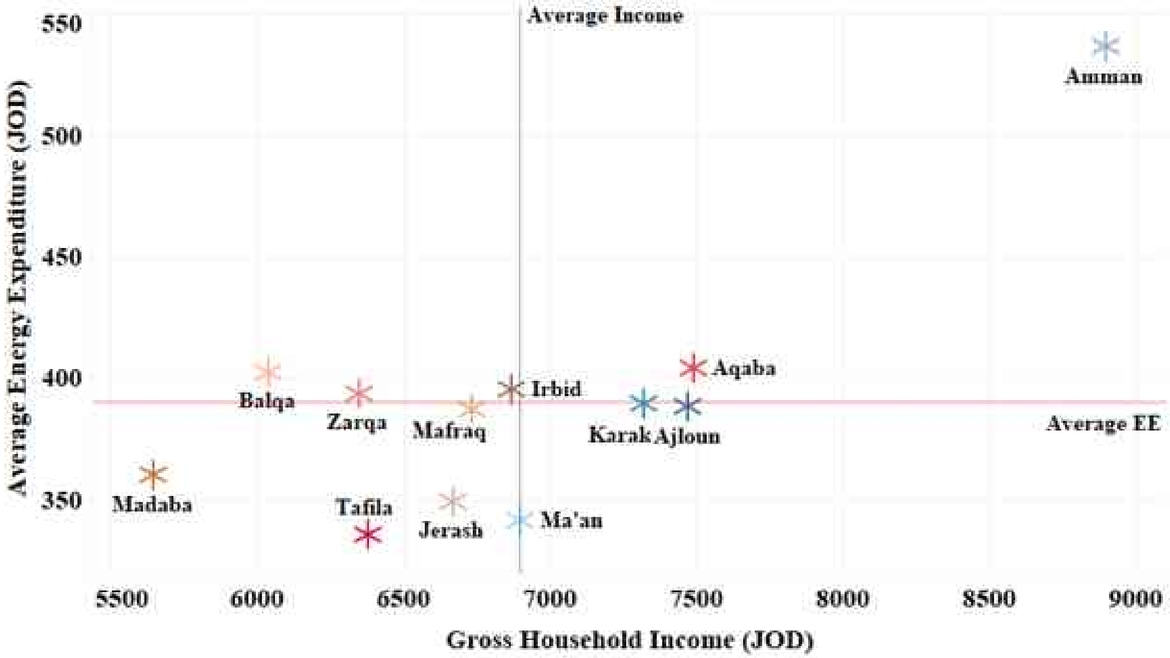

Figure 20. The relationship between the Jordanian Governorates regarding energy expenditure and income levels in 2008.

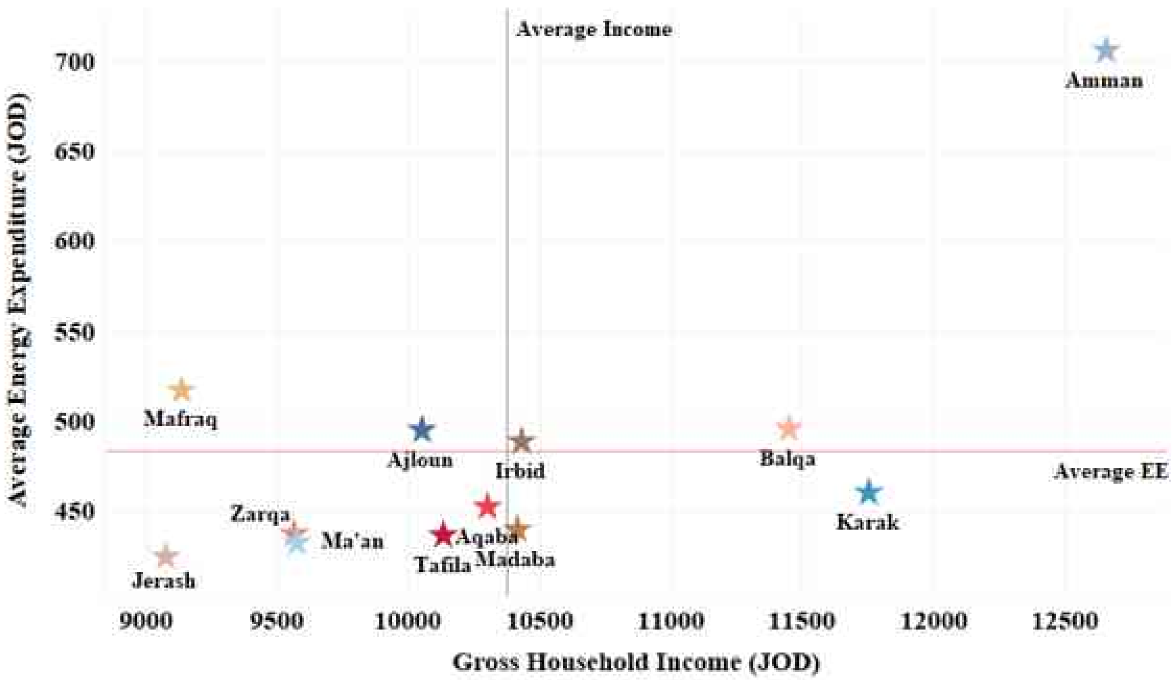

Figure 21. The relationship between the Jordanian Governorates regarding energy expenditure and income levels in 2017.

When examining the lower left corner in 2008, we can find four governorates: Madaba, Mafraq, Tafila, and Jerash, and out of these four, Mafraq shifted from the low-expenditure, low-income corner to the low-income high-expenditure corner, indicating that this governorate did not benefit economically or improved energy efficiency during the study period. Moreover, Madaba's situation changed positively; the energy expenditure levels remained below average, while income levels were boosted to be higher than the average. This observation indicates that households in Madaba may have adapted to lower energy consumption levels or, while income increased, energy efficiency levels increased. Tafila and Jerash remained in the same corner, and the income level in Jerash was the lowest among the 12 governorates in 2017.

Finally, we can notice that Ajloun witnessed a dramatic change in income levels, from above the average to less than the average, and most importantly, from low energy expenditure to higher-than-average expenditure. This situation in Ajloun requires more investigation to assess the factors that led to this change. Overall, the charts show a vast gap between households in Amman and the other governorates in terms of income and expenditure levels.

2.4.3. Results of the path analysis

Path analysis is used in this section to study the main primary and secondary causes of HDI in the Jordanian governorates. Factors examine the relationship between household annual energy expenditure and HDI in 2008 and 2017. The analysis directly assesses the primary explanatory factor's effect on the independent variable or through other intermediate (secondary explanatory) factors (Jaber, 2022; LaBelle, Tóth and Szép, 2022). Path analysis uses a set of ordinary least squares (OLS) built on one another.

The selected factors included in the path analysis are a proxy for energy consumption represented by average annual energy expenditure in each governorate and HDI on the governorate level, among other factors, as mentioned in the previous section. The initial number of variables was filtered and excluded from part of the list to eliminate the multicollinearity issues. The path analysis compares the geographical differences between the Jordanian governorates regarding energy expenditure relationship to HDI directly and indirectly. The cross-sectional data used are based on the Expenditure and Income Survey conducted by the Department of Statistics in 2008 and 2017.

The application of simple multivariate linear regression, including all the variables' results, is listed in **Table *11***. HDI is used as the dependent variable in this step. The variables included in the analysis explain that the regional ratio of HDI with R^2 in the two-year analysis is slightly the same. Changes in the weights of the variables show a significant change through the years. In 2008, urbanization had the most significant effect on HDI, while in 2017, energy expenditure and income were the significant factors. Regardless of significance, it is noted that the coefficient values changed between the two years.

Table 11. Regression results for the primary and the secondary indicators against HDI.

Coefficients	Variable	HDI, 2008	Std. Error	HDI, 2017	Std. Error
β_1	EE	-0.016	0.000	-0.789*	0.000
β_2	IN	-0.285	0.000	1.072*	0.000
β_3	WD	-0.243	0.000	0.428	0.000
β_4	UB	0.731**	0.029	0.303	0.038
β_5	HE	-0.316	0.000	-0.126	0.000
β_6	ED	0.664	0.000	0.562	0.000

R^2	0.814	0.813

Note: * 10% significance level, ** 5% significance level, and *** 1% significance level.

The regression analysis results between energy expenditure and HDI are listed in **Table *12***. The findings indicate that energy expenditure explains itself in 30% and 10% of the variances of the HDI. Energy expenditure plays a vital role in the distribution of the dependent variable. It is also noticed that the relationship between the variables in 2017 is insignificant, and the coefficient value has decreased compared with 2008, showing a slightly significant effect. The positive values indicate that energy expenditure motivates HDI, enhancing human well-being. On the contrary, declining energy expenditure hinders human well-being.

Table 12. Binary regression results between EE and HDI.

Coefficients	HDI, 2008	Std. Error	HDI, 2017	Std. Error
β	0.527*	0.000	0.316	0.000
R^2	0.278		0.100	

Note: * 10% significance level, ** 5% significance level, and *** 1% significance level.

Indirect paths should be constructed to understand how energy expenditure influences secondary explanatory factors (step 4). In 2008, energy expenditure significantly affected income, urbanization, health, and education expenditures. On the other hand, in 2017, energy expenditure significantly affected income, health, and education expenditures. **Figure *22*** and **Figure *23*** show the constructed path results for the years under study. The results show that using wood for heating has no significant relationship with energy expenditure in the two years and that when a household chooses to spend more on energy services, the tendency to use wood for heating decreases. In general, in the model, energy expenditure alone did not influence HDI in Jordan in 2008 but only in 2017. It is also noted that increasing the expenditure on energy affects HDI negatively.

Regarding the secondary explanatory variable effect on the dependent variable, in 2008, urbanization was the most significant effect on HDI, while in 2017, average annual income significantly affected HDI. The shift from urbanization to income indicates that in Jordan, while the urbanization level stabilized in recent years, income became more vital in determining the value of HDI. Energy expenditure only had a significant effect on HDI in 2017.

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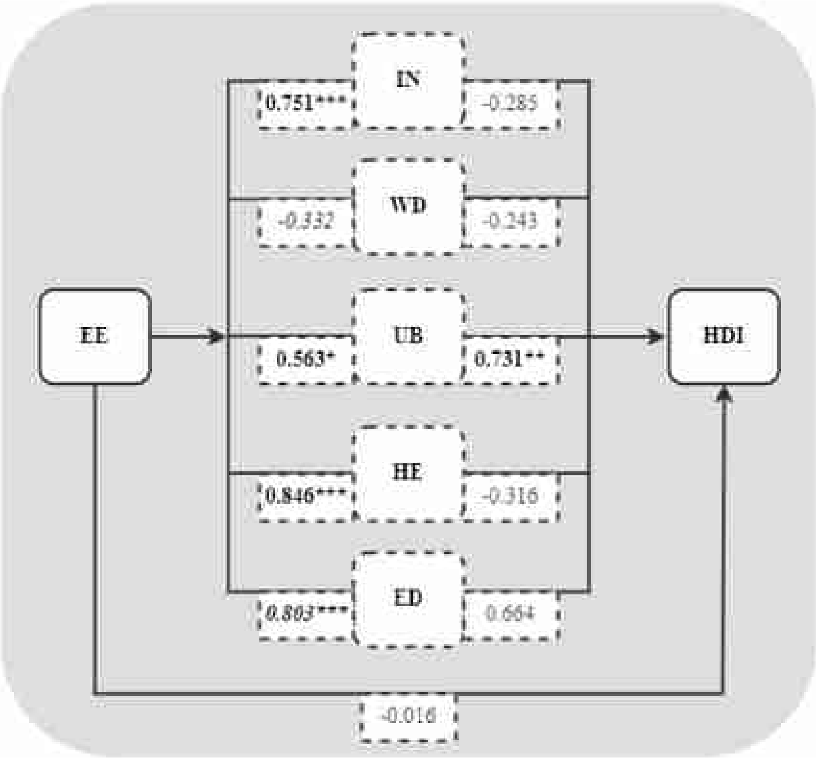

Figure 22. Role of EE in explaining HDI in Jordan in 2008.

Note: Significant values are bold.

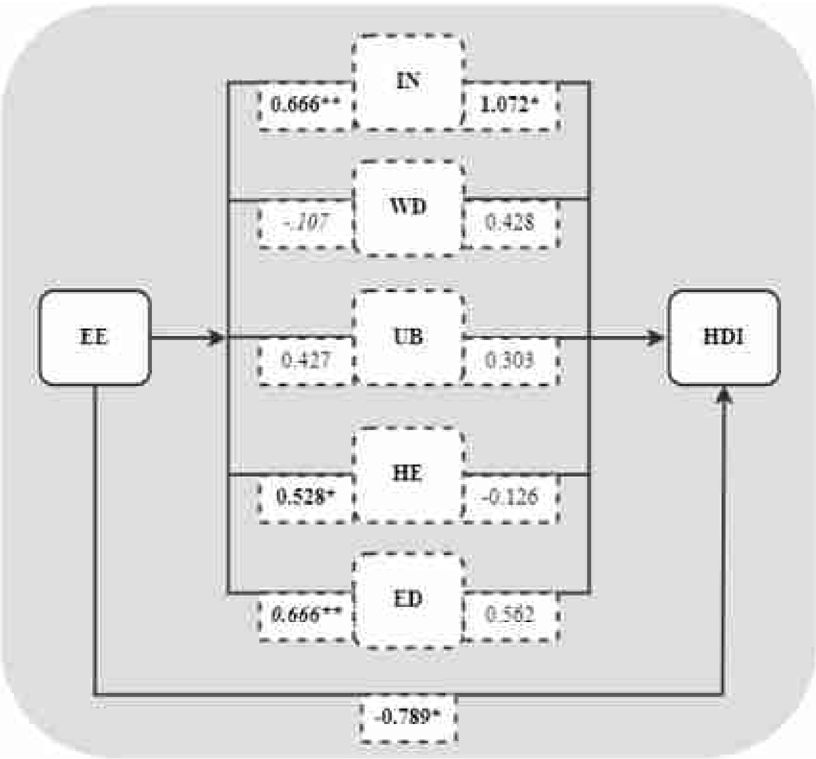

Figure 23. Role of EE in explaining HDI in Jordan in 2017.

Note: Significant values are bold.

Direct and indirect impacts on HDI

In the previous section, the strength of the paths was identified. In this step, the territorial impacts of energy expenditure are identified. Here, the reason behind identifying the paths' strengths is to understand whether energy expenditure directly or indirectly (through the secondary explanatory variables) impacts human well-being. β coefficient values of the binary regression are broken into two parts (direct and indirect). **Table *13*** lists the results.

Table 13. The roles of the direct and indirect paths in explaining the HDI.

	HDI, 2008	HDI, 2017
Indirect	0.543	1.105
Direct	-0.016	-0.789
Total	0.527	0.316

The direct effect of energy expenditure on HDI over the two years is negative. While appropriate path parts are multiplied, indirect paths may pass across the primary and secondary variables, combined from the beginning to the dependent variable (irrespective of significance). In 2008 the indirect effect was calculated as follows: (0.751*-0.214) + (-0.332*-0.243) + (0.563*0.731) + (0.846*-0.316) + (0.803*0.664) = 0.543. On the other hand, in 2017, it is calculated as follows: (0.666*1.072) + (-0.107*0.428) + (0.427*0.303) + (0.528*-0.126) + (0.666*0.562) = 1.105.

The results of the path analysis show that the indirect effect of energy expenditure through other economic and social factors is more significant than the direct effect. The results indicate that human well-being will improve if energy expenditure is accompanied by increased income, improved health and education, and urbanization development. Since the indirect impacts are more significant, the change in the explanatory variable will take longer for the impacts to affect the HDI.

2.5. Conclusions

This chapter asked several questions related to energy consumption, economic growth, climate change, and Human well-being. The first part of the chapter employed the Toda-Yamamoto causality test on annual data from 1990-2018. This part was concerned with offering a better understanding of the situation at the national level and how each factor can impact the other. On the other hand, the second part studied the relationships between energy expenditure and HDI, considering several socioeconomic factors (secondary explanatory factors). The analysis was based on cross-sectional data from two Jordanian surveys from 2008 and 2017.

The Toda-Yamamoto non-Granger causality test showed that energy consumption in Jordan causes economic growth and greenhouse gas emissions. The results back the growth hypothesis, which means that if Jordan continues in the growth process, energy will play an essential role. Moreover, while the energy mix in Jordan is still dominant in fossil fuel, more emissions will be released from consumption. Policies in Jordan should focus on offering incentives for adopting renewable energy, upgrading the energy network, decentralizing the energy sector through energy community initiatives, and improving energy efficiency. Such improvements would decrease GHG emissions and ensure healthy economic development.

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Path analysis results showed that energy expenditure in Jordan does not directly play a role in HDI. On the other hand, the relationship is more significant through the indirect explanatory variables. In 2008, urbanization was the primary significant explanatory variable where energy expenditure in urban areas enhances the HDI, while in 2017, this relationship shifted from urbanization to total annual income. Moreover, while the total indirect effect on HDI increased in 2017, the direct impact became higher, and the results of the total effect showed a decrease between the two years. Based on the findings, if people in Jordan spend more on household energy due to increased consumption, it will reduce their well-being because it has a negative relationship with the Human Development Index (HDI). However, combining energy expenditure with other factors like income, health, and education expenditure will have a positive effect in the long term, but it will take longer to see the results. Improving the quality of education and universal health services alongside growth in income levels would enhance the level of human well-being in Jordan.

This chapter concludes with the following theses:

T1

- Energy consumption Granger causes both economic growth and greenhouse gas emissions in Jordan. The analysis confirms the growth hypothesis. Since the relationship is significant, as energy consumption increases, economic growth will increase but at the expense of emitting more GHG emissions.

T2

- T2a: The path analysis indicates that human development in Jordan is not directly affected by energy consumption, where the relationship is negative and increased between 2008 and 2017. The impact of energy expenditure on human development is slow and takes more time to appear.
- T2b: Indirect impact of energy expenditure through income, urbanization, health, and education expenditure has a positive impact on HDI, and investing in improving those services would boost HDI in the future. The path analysis also indicates that Jordanian society reacts slowly to new policy adjustments.

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3. Measuring Energy Poverty in Jordan using the Multidimensional Approach

Energy poverty is a complex and multifaceted issue affecting individuals, households, and communities worldwide. It refers to the inability of people to afford or access sufficient energy to meet their basic needs and can have severe consequences for health, education, and economic development. In this chapter, I aim to measure energy poverty in Jordan using a multidimensional energy poverty index (MEPI) developed by Nussbaumer, Bazilian, and Modi (2012). Specifically, I seek to answer the following questions:

1. What characteristics of energy poverty in Jordan are based on the multidimensional energy poverty index?
2. Did energy poverty decrease between 2009 and 2018 as a timeframe of the study?
3. Do Jordanian households benefit more from solar energy as a source of energy?
4. What are the territorial differences regarding energy poverty in Jordan?

I will use data from the Demographic and Health Survey (DHS) conducted by the Jordanian Department of Statistics in 2009 and 2017-2018 to address these questions. The DHS provides detailed information on households' health, fertility, and socio-economic profiles, including indicators of multidimensional energy poverty. I will use the capabilities approach and the MEPI to measure energy poverty in the Jordanian governorates and examine the urban and rural areas to understand any differences in energy poverty between these two regions.

The analysis builds on the previous chapter, which examined the relationship between energy expenditure and human well-being in Jordan and showed that other intermediatory factors facilitated the relationship between these variables. By measuring energy poverty in Jordan using a multidimensional approach, I aim to provide a nuanced understanding of the issue and its impacts on the country's individuals, households, and communities. However, it is worth noting that the availability of data and the need for sufficient literature on energy poverty in Jordan force limitations on this study.

The previous chapter examined the relationship between energy expenditure and human well-being to connect expenditure patterns in the Jordanian governorates to human development while considering other socio-economic factors using path analysis. The results showed that human well-being in Jordan is not related directly to energy expenditure (consumption); other intermediatory factors facilitated the relationship. Energy poverty must be measured after setting the broader context of Jordan's energy situation. This chapter is concerned with measuring energy poverty in Jordan, recognizing the multidimensional nature of the issue. In contrast, using the subjective approach, the next chapter measures fuel poverty in one governorate.

The chapter is divided as follows: Section 3.1. contains the review of the relevant literature on energy poverty in Jordan; section 3.2. provides a review of the methods used to measure energy poverty, section 3.3. discusses the methodology and the data used in detail; section 3.4. explains the results of the multidimensional poverty index on different levels; and section 3.5. provides further discussion and conclusions.

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In this chapter, I aim to test the following hypotheses:

H3

- Even though Jordan's population has nearly 100% access to modern energy sources, many households suffer from energy poverty.

H4

- There are significant territorial differences in energy poverty in Jordan, with some regions experiencing higher levels of energy poverty.

3.1. Energy Poverty In Jordan

In the Jordanian context, research pertaining to fuel and energy poverty is notably limited, revealing a significant gap in the current body of literature. While several studies have made efforts to explore energy-related challenges (Jaber and Probert, 2001b; Jaber, 2002; AlKurdi and Alshboul, 2014; Belaïd, 2022b), they have exhibited a diverse range of methodologies and indicators. Most of these investigations have refrained from explicitly adopting “fuel” or “energy poverty” terminologies, even though they have scrutinized facets intricately connected to these overarching concerns.

Among the earliest contributions to this discourse in Jordan, Jaber and Probert (2001) conducted a pioneering study in 2001 that focused on energy demand and its implications for impoverished communities. This research underscored the adverse effects associated with the use of open fires and portable stoves, particularly the health risks of suffocation and other related issues.

Furthermore, Jaber (2002) highlighted a prominent energy consumption pattern within Jordan’s residential sector, where approximately 61% of energy usage was attributed to using kerosene for space heating. Due to its cost-effectiveness, this practice was especially prevalent among economically disadvantaged households who resorted to kerosene. Consequently, this reliance on kerosene engendered health and environmental challenges and highlighted the pressing need for improved housing conditions characterized by better ventilation and thermal insulation.

Subsequent research endeavors, exemplified by AlKurdi and Alshboul (2014) and Belaïd (2022), delved into examining fuel poverty and thermal comfort among various segments of the Jordanian population. For instance, AlKurdi and Alshboul (2014) centered their study on households occupied by public school teachers representing a middle-income community. They employed a threshold of 10% of the monthly net salary as a criterion for fuel consumption in a sample of 25 apartments in the capital, Amman. This analysis, considering family size, revealed income levels falling short of meeting the minimum requirements necessary for ensuring basic energy needs.

Additionally, Belaïd (2022) conducted an investigation using the Low-income High-Consumption index (LIHC) and logistic regression, drawing from data sourced from the 2013 Jordanian Household Expenditure and Income Survey and the 2015 Egyptian Household Expenditure and Income Survey (HEIS). The outcomes disclosed a significant prevalence of fuel poverty in Jordan, with 15.8% of households experiencing energy insecurity. Economic inequality emerged as the principal driver of fuel poverty, a pattern mirrored in neighboring Egypt.

3.2. Measuring energy poverty using multidimensional indices

Since energy poverty is multidimensional, it is more appropriate to measure it based on a composite indicator (Sadath–Acharya 2017); the researchers used MEPI to assess the intensity and extent of energy poverty for Indian households. The dimensions used were lighting, cooking, and other additional measures. The results indicated extensive energy poverty in India, particularly in rural areas. Moreover, within the Indian context, Sharma et al. (2019) examined the socio-economic elements of energy poverty in Mumbai City as a case study. A field survey was distributed to 1000 households, with each 250 representing a different income group. The analysis used the consumption expenditure approach. The results showed that electricity consumption could be affected by monthly expenditure, house size, and education. This study suggests that improving efficiency and energy policies can help achieve sustainable energy for Indian households by implying that reducing energy poverty can be more complex than income poverty.

Ogwumike and Ozughalu (2015) constructed MEPI to study the incidence and determinants of energy poverty in Nigeria using the Nigeria Living Standards survey data in 2004. The study results indicated that 75 percent of the population is affected by energy poverty. Moreover, the analysis using simple logistic regression revealed that household size, educational level, gender and age of household head, general poverty, region of residence, and proportion of working members in the household are the main determinants of energy poverty in Nigeria. Adusah-Poku and Takeuchi (2019) examined energy poverty in Ghana based on the fifth and sixth Ghana Living Standards Survey datasets, measuring the progress in eradicating energy poverty, the gap between urban and rural areas, and a comparison based on regional differences. They used a MEPI that included five dimensions: cooking, lighting, services represented by means of appliance ownership, entertainment/education, and communication. The outcomes revealed that between 2006 and 2013, energy poverty decreased in Ghana by approximately 6%.

Moreover, despite this change, they concluded that the rates of energy poverty are still high and regional differences are still present. They emphasized the importance of enhancing modern energy services. In the same context, Nsenkyire *et al.* (2022) studied the multidimensional energy poverty in Ghana and its impact on children’s health, education, and cognitive skills. Their study was based on the Ghana Living Standard Survey (GLSS 7) to measure the index and use structural equation modeling (SEM) to study the factors affecting it. The results revealed that nearly 59% of children in Ghana suffer from energy poverty, and the factor analysis showed that an increase in the standard deviation of energy poverty adversely impacts children’s health, education, and cognitive skills.

Mendoza et al. (2019) utilized a MEPI to measure energy poverty in 17 regions and 81 provinces. Using seven indicators, the researchers included two additional indicators: space cooling and personal computer ownership. This study measured the characteristics of regional energy poverty and its intensity between 2011-2016 using data generated from the 2015 Household Energy Consumption Survey. The results showed that energy poverty in the Philippines is slightly lower than in other Asian countries, indicating regional differences. Additionally, the results implied that the applied policies were more likely to reduce energy poverty while stressing future improvement space. Pablo et al. (2019) studied energy poverty in Ecuador. The study constructed a MEPI using inputs from the European Union Energy Poverty Observatory (EPOV), which included three indicators: electricity bill payment delay, disproportionate expenditure, and hidden energy poverty, and a fourth indicator based on Boardman (1991) of 10%. The results indicated that measuring energy poverty can be difficult on a large scale. The use of pre-defined methods could also be limited, mainly because there was no precise definition of the phenomenon. In conclusion, Ecuadorian households may have suffered from energy poverty in urban and rural areas but more severely in rural areas. Recent studies such as Abbas et al. (2020) examined multidimensional energy poverty and provided more details on the socio-economic factors that may affect households suffering from such issues. This study used a multidimensional energy poverty index to examine energy poverty in six South Asian countries. Researchers have also suggested that policies that aim to improve the socio-economic status of households will mitigate the occurrence of MEPI. Abbas *et al.* (2021) assessed the relationship between energy poverty and domestic health issues in South Asia in the same geographical context. The study first examined the MEPI for the selected countries and then estimated the relationship between energy poverty and health issues using the one-way multivariate analysis of variance (MANOVA). The results revealed that the sources of drinkable water, access to clean water, risks of mosquito bites, obesity, sterilization, marital status, literacy, occupation, and residence are significantly related to energy poverty. Castaño-Rosa and Okushima (2021) used a multidimensional energy index to study energy poverty in Japan. The model covered energy affordability and accessibility issues alongside the risks imposed on energy poverty by new technology. The results showed that the northern parts of Japan suffer from energy poverty in the winter and the southern parts in the summer.

Further, (Fabbri, 2015a) introduced the Building Fuel Poverty Index (BFP) for the Italian case. By emphasizing the interplay between building energy performance and fuel poverty, Fabbri posits a targeted approach, considering energy efficiency, housing affordability, and housing stock condition. This work underscores the potential for direct and localized actions to alleviate fuel poverty, laying the groundwork for subsequent research endeavors.

Following this, Castaño-Rosa, Sherriff, *et al.* (2019) present their study on fuel poverty vulnerability in England, utilizing the Index of Vulnerable Homes (IVH). Employing quantitative data, the authors assess monetary poverty, energy efficiency, thermal comfort, and health-related quality of life. This research unveils the comprehensive nature of the IVH, offering a nuanced understanding of fuel poverty. However, challenges such as data complexity and adaptability between countries are duly acknowledged. Recalde *et al.* (2019) investigated the structural energy poverty vulnerability and its association with excess winter mortality in the EU. The study combines descriptive statistics, principal component analysis, Structural Energy Poverty Vulnerability (SEPV) index validation, hierarchical cluster analysis, and regression analysis. By adopting a multidimensional approach, the authors unravel the intricate relationship between energy poverty and health, highlighting the broader structural

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determinants. Subsequently, Gouveia, Palma and Simoes (2019) contribute to the Energy Poverty Vulnerability Index (EPVI) discourse, focusing on Portugal. This spatially detailed composite index maps energy-poor regions and identifies local action hotspots. Integrating socioeconomic indicators with building characteristics and energy performance, the EPVI provides a novel tool for addressing energy poverty challenges, emphasizing localized approaches to intervention.

In 2020, Mahoney et al. explored the potential for a common approach to energy poverty assessment across devolved UK countries. Employing a descriptive and analytical approach, the authors review policy differences, emphasizing data availability and regional variations within the UK. The study aligns with the contemporary trend toward high-resolution data analysis and local-scale initiatives Mahoney, Gouveia and Palma (2020). The most recent addition to our discourse is Koďousková et al., examining district heating transition, energy poverty, and vulnerability in Czechia. The authors integrate quantitative and qualitative aspects by adopting a two-phased sequential explanatory research design. Their focus on indicators such as household energy expenditures, energy efficiency, housing affordability, housing stock condition, and district heating penetration offers a unique lens to understand urban energy vulnerability (Koďousková *et al.*, 2023).

The literature review presented in this section discusses the concept of energy poverty, its various definitions, and how it differs from related concepts such as energy insecurity and fuel poverty. It also examines the various contextual factors that can influence the causes and consequences of energy poverty, including socio-economic and ethnic characteristics, geographic location, and political and economic context. The review highlights the impacts of energy poverty on individuals, communities, and societies, including negative impacts on health and well-being, and the importance of considering these impacts when developing strategies to address energy poverty.

Overall, the literature review suggests that energy poverty is a complex and multifaceted issue that requires a nuanced understanding of the specific contexts in which it occurs. It is clear that energy poverty is a global problem affecting millions of people, and addressing it requires considering the diverse and often intersecting factors that contribute to it. Given the importance of energy access in supporting economic development and improving health and well-being, policymakers and practitioners must work to address energy poverty comprehensively and sustainably.

A few criticisms could be made of the literature review presented in this section. One potential criticism is that it focuses primarily on energy poverty in developed countries and does not adequately consider developing countries' challenges and contexts. The second criticism regarding the review is the usage of energy poverty in different contexts, primarily for developing countries, while the literature does not provide this unified allocation. In contrast, in the literature, energy poverty is used interchangeably with fuel poverty and energy vulnerability, which makes the distinction unclear and suggests that the usage of different terminologies serves the main aim of the researcher, not the definition itself. In addition, using different terminologies to refer to energy poverty can be confusing and may not accurately reflect the complexities and nuances of the issue. It is essential to be clear and consistent in terminology and to carefully consider the definitions and contexts in which different terms are used.

In conclusion, the literature review presented in this section highlights the complexity and importance of energy poverty and the need for a nuanced understanding of the contextual factors that influence it. It also underscores the importance of addressing energy poverty comprehensively and sustainably to support economic development and improve health and well-being for individuals, communities, and societies.

3.3 Methodology: The Multidimensional Energy Poverty Index

3.3.1. Selected Indicators and Data

The data used to estimate the MEPI for Jordan were based on the Demographic and Health Survey (DHS) conducted by the Jordanian Department of Statistics (Department of Statistics (DOS) and ICF, 2019). The United States Agency for International Development (USAID) funded the survey through the DHS Program (The DHS Program 2021). The DHS has been conducted in many countries worldwide. The data collected are related to households' health, fertility, and socio-economic profiles, providing detailed information on housing characteristics, household possessions, and members. These data include many indicators of multidimensional energy poverty (Abbas et al. 2020). The data collected through the survey are nationally representative. The datasets are available in raw form (survey outputs), which provides a tremendous advantage for treating the data and test indicators at the sub-national level. For this study, data from 2009 and 2017-2018 surveys were collected, cleaned, and used to calculate the MEPI in Jordan.

Recreating Nussbaumer, Bazilian and Modi (2012) and considering Jordan's context, the MEPI is estimated using five energy deprivation indicators. These indicators are cooking, represented by access to modern cooking fuel and indoor air pollution (availability of a separate room used as a kitchen), household appliances, communication, entertainment/education tools, and sustainable energy sources. Unlike the original index, access to electricity through the lighting indicator was not included because Jordan has 100% electricity access. Moreover, the 2017 survey did not include information about electricity access. **Table *14*** lists the dimensions used to describe energy deprivation in detail.

Table 14. Dimensions, indicators, and deprivation cut-off, including weights.

Dimension	**Indicator (weight)**	**Variable (weight)**	**Deprivation Cut-off (Poor if…)**
Cooking	Modern cooking fuel (0.2)	Type of cooking fuel (0.2)	Use any fuel beside electricity, LPG, kerosene, natural gas, or biogas

	Indoor pollution (0.2)	The household has a separate room used as a kitchen (0.2)	False
Services provided by means of household appliances	Household appliances ownership (0. 15)	Has refrigerator (0.15)	False
Communication	Telecommunication means (0.15)	Has internet access at home (0.07)	False
		Has mobile telephone (0.08)	False
Entertainment	Entertainment devices (0.15)	Has computer (0.15)	False
Sustainable Energy Source	Solar heater (0.15)	Has a solar heater (0.15)	False

Source: Authors' estimation based on Nussbaumer, Bazilian and Modi (2012).

3.3.2. Selected dimensions and variables

According to (Nussbaumer, Bazilian and Modi, 2012; Nussbaumer *et al.*, 2013), choosing variables should reflect the demand for household energy services. Nussbaum (2003) listed central human capabilities. The proposed list is open-ended, and its capabilities can be increased or decreased according to societal needs and changes. Sen (2004) states that a list of capabilities cannot be fixed or considered complete. Moreover, choosing capabilities depends on why we use them. Sen (2004) argued that the priorities of societies can differ. The rationale behind selecting the dimensions and indicators described in the previous table is discussed here.

This chapter selected several dimensions with assigned indicators based on the Jordanian context. Cooking is one of the basic needs of any household to prepare meals, and energy is needed as heat. Moreover, cooking can take significant time to prepare food, especially for women. In addition, different types of stoves are used for cooking. To conclude, a household can be considered energy-deprived if the cooking fuel is not modern. In this case, modern fuels include LPG, kerosene, electricity, natural gas, and biogas. Indoor pollution is a significant concern for households. A household with no separate room for the kitchen may suffer from poor indoor air quality and can be considered deprived of this dimension.

When selecting "modern energy means," one would ask what defines energy sources as clean or modern. Perhaps one of the major theories that try to explain energy choices is the energy ladder theory which was discussed in the theoretical background chapter. The energy ladder theory states that households may move between different types of fuels based on their socio-economic status, where those fuels represent the ladder's rungs (Schlag and Zuzarte, 2008). The lowest stage of the ladder represents unclean energy sources, such as animal dung; the next step represents transition fuels, such as coal and kerosene, while the last stage represents advanced fuels, such as LPG and biofuels. Households can be influential in minimizing waste, saving

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energy, recycling, preferring services over goods, and promoting a sharing economy (Kortetmäki *et al.*, 2021).

Ownership of household appliances is essential. Modern houses contain refrigerators. Communication and entertainment are vital for modern houses. Apart from communication, these tools can be used for work and learning purposes. The COVID-19 pandemic has taught us that a household lacking modern means of communication is considered deprived.

Finally, a solar heater was used to represent sustainable energy. Jordan has more than 360 sunny days, which ensures that solar energy is abundant and available for households that use solar panels or heaters for water. Based on the DHS surveys, in 2018, only 13.7% of households owned a solar heater, compared to 10.8% in 2009. Using this indicator in the analysis highlights the importance of renewable energy sources, especially solar energy, and the fact that it is not utilized enough in Jordanian households.

3.3.3. Measurement of the MEPI

The MEPI allows for measuring the severity and extent of energy poverty. For population n in individuals and dimension d, $Y=y_{ij}$ represents the achievement matrix of $n \times d$ of an individual i across variables j. $y_{ij} \geq 0$ represents the degree to which an individual's achievements $i = 1,2,3 \ldots n$ on variables $j = 1,2,3 \ldots d$. Every row represents the achievements of individual i in various variables j, whereas the column vector represents the distributive achievements in variable j among individuals.

The MEPI recognizes the unequal "importance" of the relevant selected indicators (Nussbaumer, Bazilian and Modi, 2012). Variable j is weighted according to the following formula:

$$\sum_{j-1}^{d} wj = 1 \ \ldots. (3.1)$$

where w represents the weight.

Variable zj is defined as the deprivation cut-off in variable j, which defines all individuals deprived of any variable. The deprivation matrix is defined as $g = [g_{ij}]$, $g_{ij} = w_j$ when $y_{ij} < z_j$ and $g_{ij} = 0$ when $y_{ij} \geq z_j$. Referring to Table 1, while the achievement matrix elements are not numeric, the cut-off is defined as a set of conditions to be met. When a person i is deprived of variable j, the entry ij of the matrix is equivalent to the variable weight w_j, and zero when the person is not deprived.

To sum up, a column vector c is constructed across the i entries for all the deprivation counts a person suffers.

$$ci = \sum_{j}^{d} = 1gij \ldots. (3.2)$$

To define a person as "multidimensionally energy poor," the cut-off $k > 0$ is defined. This cut-off is applied across the column vectors. When $c_i > k$, a person is considered an energy-poor. Thus, $c_i(k)$ equals zero when $c_i \leq$ k and equals c_i when $c_i > k$. In short, $c(k)$ is the censored vector of the deprivation counts. Defining the value of k depends on the level of deprivation cut-off of

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interest. According to (Nussbaumer, Bazilian and Modi, 2012), there are three identified deprivation cut-offs: severe (1/2), acute (1/3), and vulnerable (1/5). This study applies an acute poverty cut-off to determine multidimensionally energy-poor households. Accordingly, a cut-off $k \geq 0.3$ is used in the process. A person can be considered energy-poor if deprived in one or two dimensions or does not benefit from different energy services supplied by electricity.

The incidence of energy poverty is represented by:

$$H = q/n \ldots (3.3)$$

Where H is the headcount ratio, representing the proportion of people considered energy-poor, q is the number of multidimensionally energy-poor people (where $c_i > k$), and n is the total population.

The intensity of multidimensional energy poverty “A” is calculated according to the following equation:

$$A = \sum_{i=1}^{n} Ci(k)/q \ldots. (3.4)$$

where A is the intensity, $Ci(k)$ is the deprivation count of the multidimensional energy-poor, and q is the number of multidimensionally energy-poor people.

Finally, to estimate the MEPI, information based on the incidence and intensity of energy poverty can be formulated as follows:

$$\text{MEPI} = H \times A \ldots. (3.5)$$

3.3.4. Study Limitations

While the study leverages a valuable multidimensional energy poverty index (MEPI) approach, several areas offer opportunities for further refinement. Utilizing data from surveys a decade apart (2009 vs. 2017-2018) may not fully capture recent energy access and utilization dynamics. Additionally, relying solely on the DHS survey might limit the inclusion of relevant information from other sources. Furthermore, the lack of granularity regarding specific energy sources hinders a nuanced understanding of fuel choices and potential health impacts. While the chosen dimensions address fundamental needs, their scope might not comprehensively encompass Jordan's multifaceted nature of energy poverty.

Similarly, further justification would strengthen the rationale behind assigned indicator weights and the sole implementation of an "acute poverty" deprivation cut-off. Moreover, the absence of spatial analysis and exploration of causal relationships limits the study's insights into potential geographical disparities and underlying factors driving energy poverty. Finally, explicitly addressing sustainability considerations and potential policy implications would enhance the study's long-term value and actionable insights.

3.4. Results and Discussion

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3.4.1. Estimation of energy poverty in Jordan

A MEPI was estimated for Jordan in 2009 and 2018. Moreover, the index was estimated for the governorates, wealth index, and urban/rural levels. **Figure *24*** and **Figure *25*** show the spatial distribution of the MEPI at the governorate level for 2009 and 2018, respectively. The results show that the MEPI in Jordan was 0.20 in 2009 and 0.21 in 2018. The results reveal that the MEPI has increased by 0.01 during the nine years between the two surveys. However, if MEPI<0.6, households suffer moderate energy poverty (Nussbaumer, Bazilian and Modi, 2012).

Nonetheless, with an average of 0.20 over nine years, energy poverty means the issue is persistent and not truly realized. Ignoring energy poverty can lead to unfavorable consequences in the future. Energy poverty is connected to social welfare, other factors such as the socio-economic situation of households, and environmental impacts such as climate change. Considering the headcount ratio results, it shows that 53% of the population in 2009 experienced energy poverty, which increased in 2018 to 60%. In addition, energy poverty intensity results show that the severity of energy poverty decreased between the two years from 0.38 to 0.36, suggesting that poverty among poor households or individuals is relatively severe. **Table *15*** lists more details regarding the values of the headcount ratio, intensity of energy poverty, and the MEPI.

Table 15. Detailed MEPI results in Jordan, governorates, and the urban/rural levels.

Comparison Level/Year	Headcount Ratio (*H*)		Intensity of Energy Poverty (*A*)		MEPI	
	2009	2018	2009	2018	2009	2018
Jordan	0.53	0.60	0.38	0.36	0.20	0.21
Mafraq	0.65	0.78	0.38	0.36	0.25	0.28
Zarqa	0.52	0.63	0.39	0.39	0.20	0.24
Jerash	0.56	0.71	0.38	0.32	0.22	0.23
Madaba	0.51	0.62	0.38	0.38	0.19	0.23
Ma’an	0.54	0.61	0.39	0.36	0.21	0.22
Balqa	0.51	0.55	0.40	0.38	0.20	0.21
Tafila	0.52	0.56	0.38	0.37	0.19	0.21
Ajloun	0.49	0.62	0.38	0.32	0.19	0.20
Karak	0.60	0.56	0.39	0.37	0.23	0.20
Aqaba	0.51	0.56	0.39	0.35	0.20	0.20
Irbid	0.47	0.56	0.38	0.34	0.18	0.19
Amman	0.44	0.46	0.38	0.37	0.17	0.17
Urban	0.48	0.59	0.38	0.36	0.18	0.21
Rural	0.62	0.64	0.38	0.36	0.24	0.23

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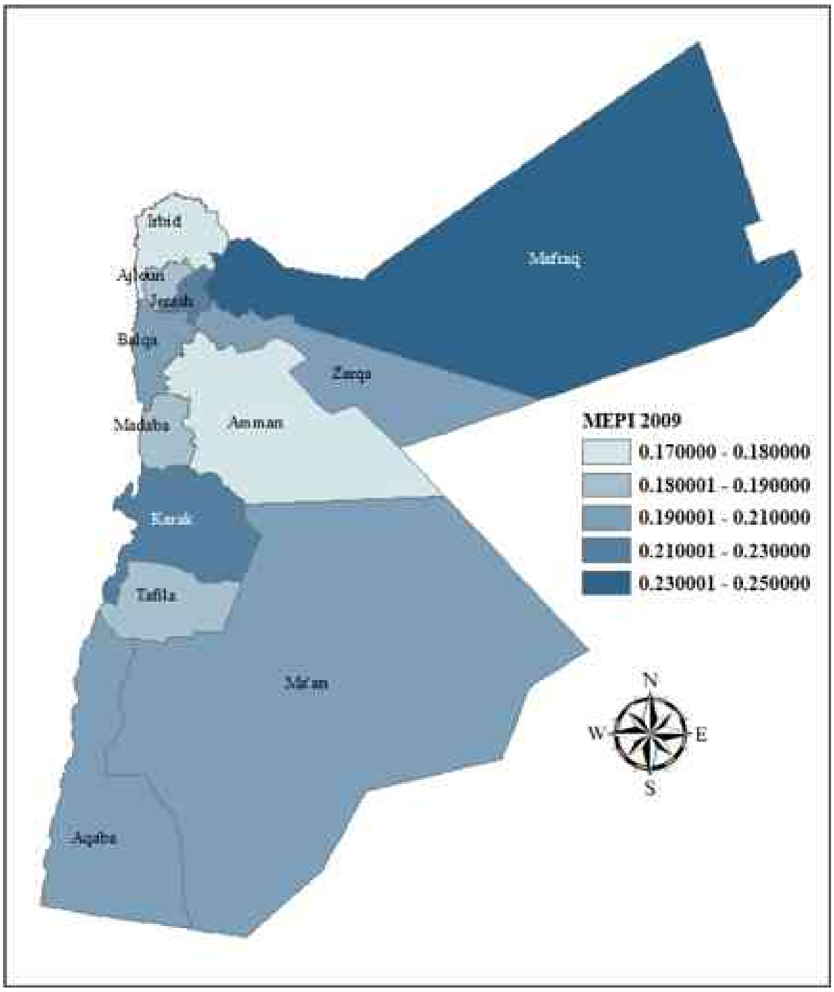

Figure 24. MEPI Results in Jordan for the year 2009.

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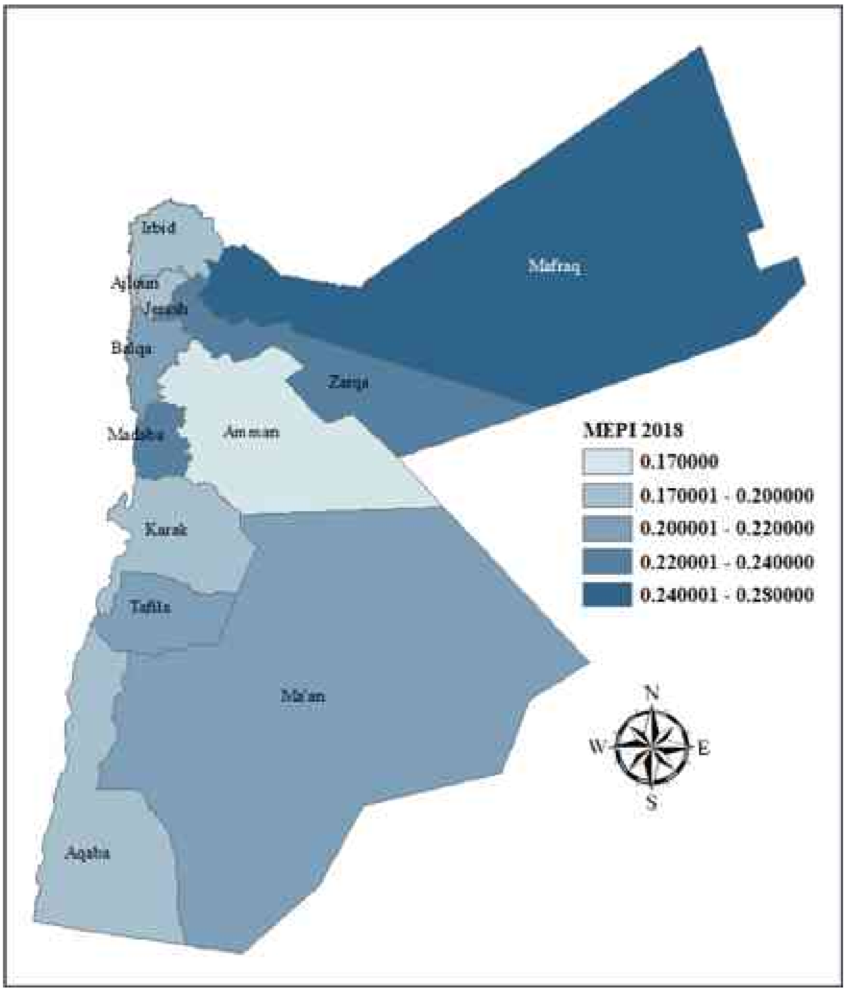

Figure 25. MEPI Results in Jordan for the year 2018.

Amman and Irbid are the least multidimensionally energy-poor regions in both years, with a MEPI value of 0.17 and 0.18, respectively. Mafraq, a governorate in the country's northern region, has the highest MEPI values of 0.25 and 0.28 in 2009 and 2018, respectively. The city of Mafraq accommodated the biggest refugee camp in the country, which was established after the civil war in Syria. The sudden increase in the number of inhabitants placed pressure on resources and opportunities in Jordan. Zarqa witnessed an increase in the MEPI of 0.04; in Karak, the MEPI decreased by 0.03. It is worth noting that Amman is the densest governorate in the country; **Figure *26*** shows the population growth in Jordan from 2009 to 2018.

Regarding urban/rural residences, the results show that the energy poverty of urban residences increased by 0.03. However, rural residences show a decrease in energy poverty of 0.01. It is worth noting here that 0.98 of the population lives in urban areas, which means that an increase in energy poverty is not a good sign regarding development, among the other social circumstances of the urban areas. The results also show that the differences between urban and rural areas are insignificant regarding modern and sustainable energy availability.

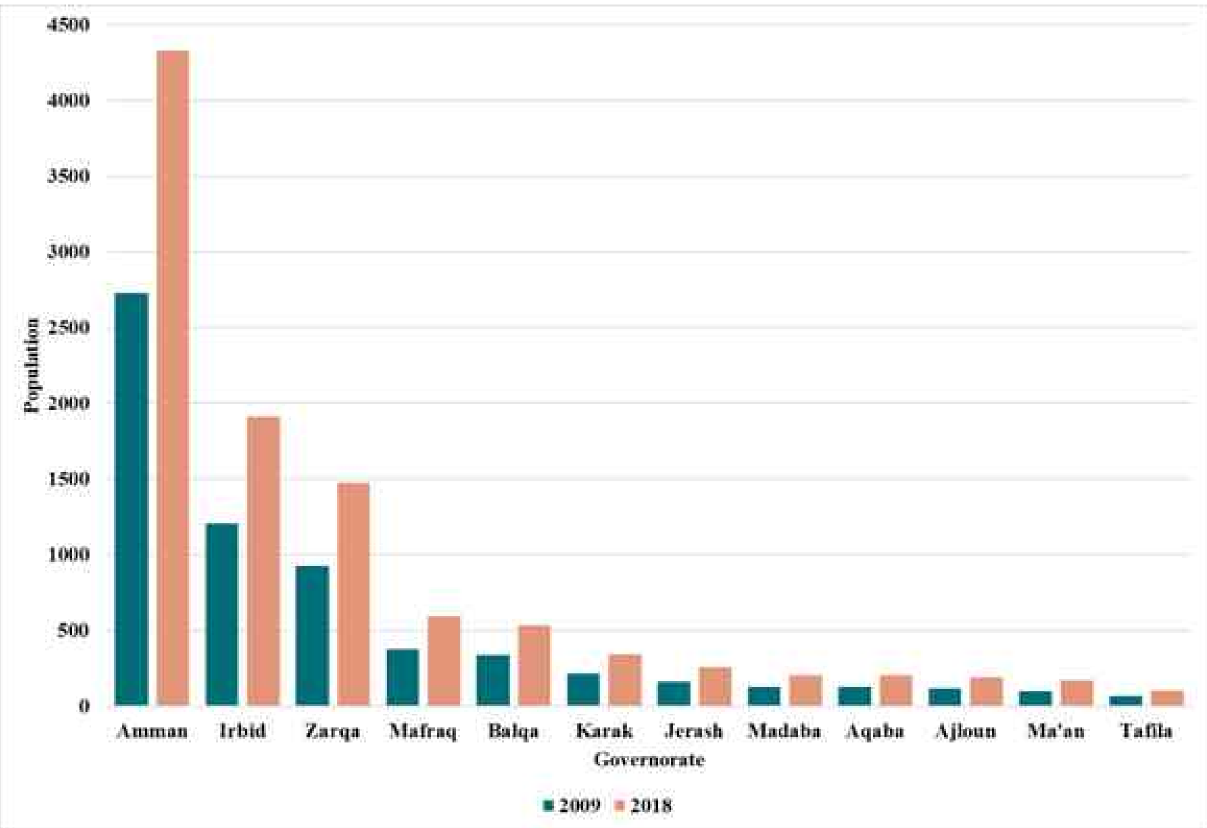

Figure 26. Population (×1000) in Jordan in 2009 and 2018.

Source: (Department of Statistics 2020)

Figure ***27*** illustrates more information about the status of the MEPI in Jordanian governorates for the years of study. Some governorates showed a slight change in MEPI from 2009. Nine out of twelve showed an increase in MEPI from 2009 to 2018. In contrast, Amman and Aqaba showed no change between 2009 and 2018, whereas Karak slightly improved the MEPI within the study period.

Figure ***28*** illustrates the difference in the MEPI based on the wealth index. Overall, the MEPI changed over the study period. The poorest and poorer categories improved over time. The MEPI for the poorest category decreased from nearly 0.36 to 0.25, while the poorer showed a lesser charge. However, the situation for the other categories showed an increase in the MEPI. While an increase in the MEPI itself was not a good sign concerning households, it was evident that the differences between the different categories decreased.

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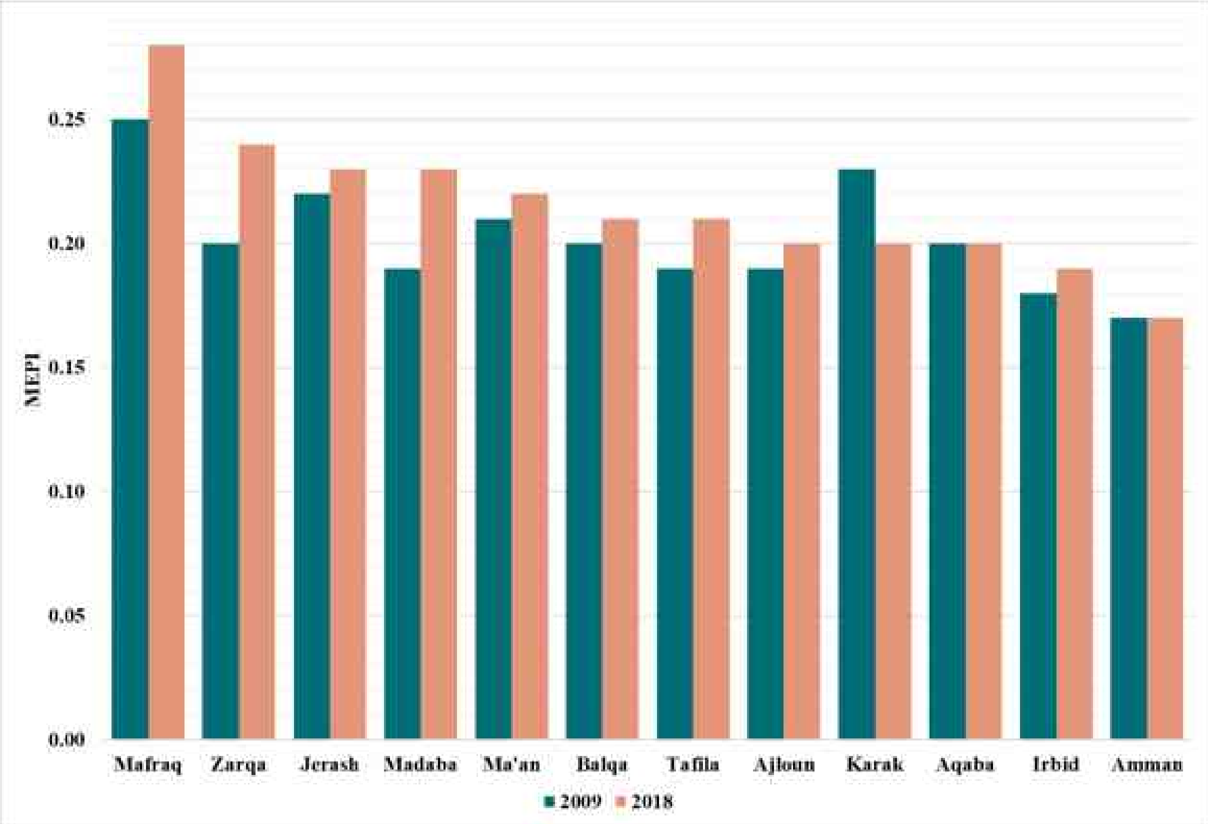

Figure 27. MEPI in Jordanian governorates for the years 2009 and 2018.

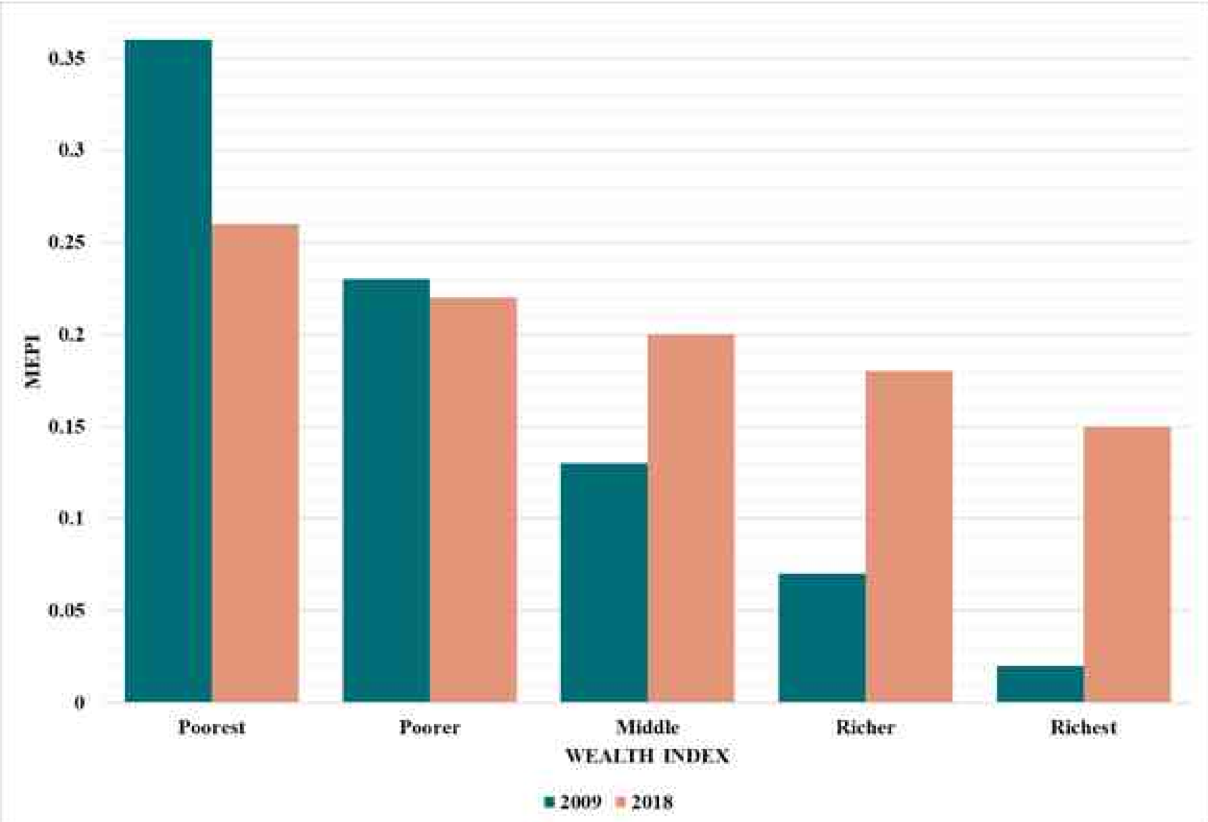

Figure 28. MEPI based on the wealth index for the years 2009 and 2018.

3.4.2. Testing the relationship between MEPI and HDI, the case of 2018.

The results of MEPI showed a difference between the Jordanian governorate, where Amman recorded the lowest energy poverty level, and Mafraq had the highest. I drew an XY scatter plot between MEPI and HDI in 2018 to examine the relationship between energy poverty and human well-being. The results showed a significant negative relationship between the two indices, meaning that human well-being decreases whenever energy poverty increases and vice versa. **Figure *29*** shows the relationship, including the trendline.

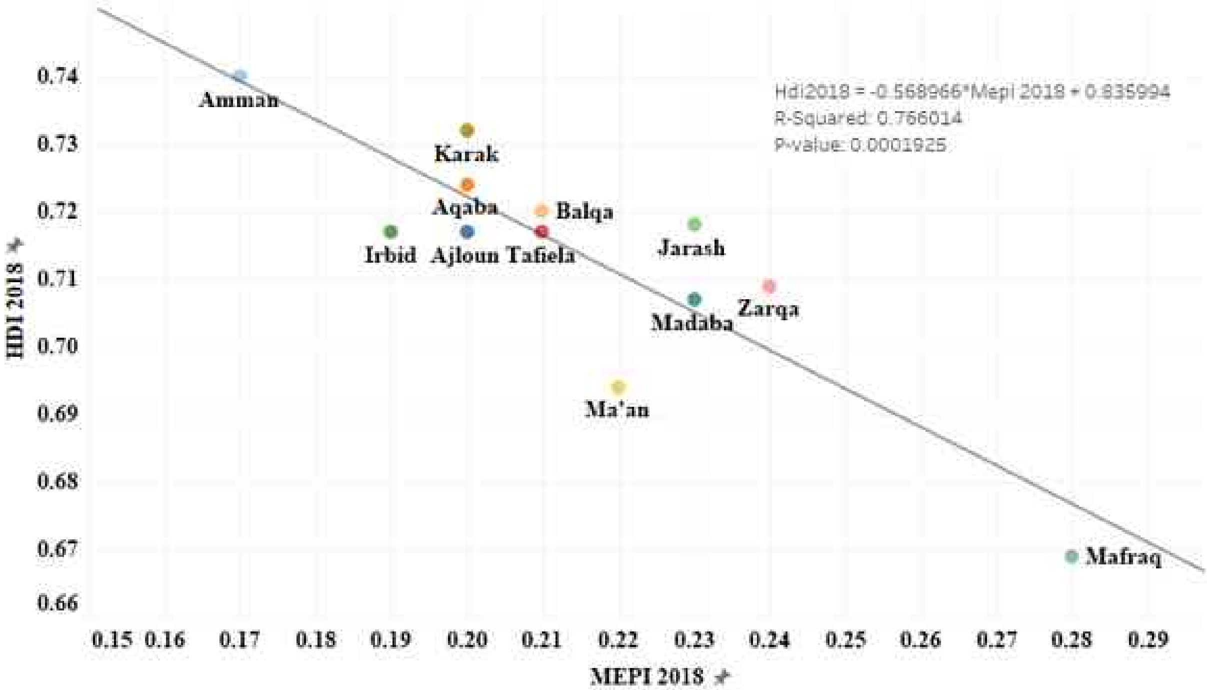

Figure 29. The relationship between MEPI and HDI in 2018.

Source: own calculations.

The relationship between the two indices was also tested using a correlation matrix, and the results showed that a strong correlation exists with a Pearson correlation coefficient equal to -0.875 (p-value < 0.001).

3.5. Conclusions

Multidimensional energy poverty was examined in this chapter for the years 2009 and 2017/2018. In addition, the main factors affecting energy poverty were tested using the binary logistic regression for 2017/2018 survey data. Despite the well-established literature on energy poverty, there is still a research gap on the situation and extent of energy poverty in the Middle East and Jordan. The results revealed that the MEPI in Jordan slightly increased between 2009 and 2018, expressly by 0.01. Considering these results, it can be concluded that Jordanian households suffer from moderate energy poverty. Furthermore, the results indicated that energy poverty might increase if not addressed early. The problem of energy poverty is linked to many other issues, such as climate change, health, and social justice.

In addition, the spatial distribution of energy poverty was estimated. The results showed that disparities between Jordan's governorates are not high. However, nine governorates witnessed an increase in energy poverty, especially in Mafraq, a region that hosts the largest refugee camp in the country. Amman and Aqaba witnessed no change, while Karak's energy poverty decreased. Urban areas showed increased energy poverty, while rural areas showed the opposite. Finally, energy poverty based on the wealth index was estimated. The results showed variations between the two years of concern. Poor houses showed an improvement in energy poverty, improvement in living conditions, and ownership of modern energy means. On the other hand, the rich showed signs of increased energy poverty, which requires more research and shows a continuous decrease in inequalities between different social levels.

Based on the results discussed earlier, the following recommendations are suggested to identify energy poverty in Jordan:

1. Include the concept of energy poverty in the national energy plan by identifying the scope of energy poverty within the context of Jordan. The current Jordan Energy Strategy and Energy Efficiency Plan do not mention energy poverty. On the contrary, it only focuses on energy efficiency, which is not the only determining factor of energy poverty.
2. Assess the differences in residential energy consumption during the different seasons to understand better the impacts of climate variations on household energy consumption.
3. It is recommended to start collecting fuel/energy poverty data by adding more questions to the national surveys about utility bill arrears and coping with indoor ambient temperatures during the summer and winter. The MEPI lacks information on this because it tries to capture energy poverty through the lens of available energy services and does not consider other factors or dimensions.
4. It is recommended to broaden the programs launched by the government to support poor people in improving house efficiency by creating house renovation fund programs.
5. The results suggest a revision of current energy subsidy programs to benefit energy-poor households and increase the support to households that utilize solar energy for electricity generation.

The results prove that energy access does not necessarily mean that energy poverty is alleviated; however, achieving energy access can solve this issue. The problem of energy poverty is still not fully realized at the household and policymaker levels. The empirical results of this study shed light on the need to understand better the causes and effects of energy poverty on Jordanian households. Further studies are needed to understand the socio-economic factors, health impacts, financial burdens, or, more precisely, the multidimensional impacts of energy poverty on Jordanian households.

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By the end of this chapter, the following hypotheses were formulated:

T3

- Based on the MEPI, Jordanian households suffer from moderate energy poverty. Energy poverty may increase if not appropriately addressed and targeted interventions implemented to enhance the capability of Jordanian households to utilize energy effectively.

T4

- The levels of energy poverty in Jordan vary by governorate, with the highest levels observed in Mafraq, where the largest refugee camp is located. These results highlight the need to consider the unique socioeconomic and structural factors contributing to each region's energy poverty when designing and implementing policies and programs to address this issue in Jordan.

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4. Quantifying Household Energy Poverty Indicators in the Zarqa Governorate Using the Subjective Approach

In chapter three, I estimated the multidimensional energy poverty index, which reflects modern energy services availability at home and the household's capability to achieve these services. The index included data on the type of fuel cooking, indoor pollution, availability of household appliances, telecommunication services, entertainment devices, and sustainable energy sources utilized in the household.

This chapter aims to fill the gap in energy poverty in Jordan and understand the significant factors that affect fuel poverty in Jordanian houses as households report their energy-related hardship. The importance of this chapter is represented by not focusing on income and energy expenditure as the main factors of energy poverty but also the significant characteristics of homes' energy efficiency, thermal comfort, and financial difficulties related to not being able to pay utilities on time. Additionally, this chapter addresses the characteristics of energy poverty in the summer and winter seasons. Finally, the outcomes of this study will motivate the movement beyond traditional energy poverty assessment in developing countries that focuses on energy access represented by electricity access or the type of cooking fuel.

In this chapter, I seek to answer the following questions:

1. What are energy efficiency characteristics in the sample households?
2. What is the difference between summer and winter regarding reported energy poverty in the sample households?
3. How are arrears on utility bills connected to other energy poverty subjective indicators and income levels?
4. What are the socio-economic determinants of subjective energy poverty in the sample households?

In this chapter, the following hypotheses are tested:

H5

- In Zarqa Governorate, households have low energy efficiency levels, which affects the ability of the household to achieve thermal comfort during the different seasons.

H6

- Energy poverty is more prevalent in winter than in summer in Zarqa Governorate.

H7

- As income levels increase, households are less likely to experience energy poverty, and income level is the most significant factor affecting the possibility of falling into fuel poverty.

The remaining sections of the chapter are presented in the subsequent order: Section two discusses the current situation regarding household energy characteristics in Jordan, section three provides a brief literature review, section four describes the methodology and data collection, section five shows the main results of the study, while the last section discusses the results and provides conclusions.

4.1. Evaluating Household Energy Consumption and Ownership Patterns in Jordan: A Snapshot from Historical Data

At the data collection stage, I searched for previously available energy data in Jordan through the Department of Statistics database. The latest data published concerning energy at homes dates back to 2008. The database details the quantity of energy used for heating, cooling, lighting, cooking, and other home applications and the state of energy consumption in homes for these purposes (Department of Statistics (DOS), 2008). Unfortunately, the database was never been updated ever since, but DOS provided newer data on the ownership of heating and cooling devices in 2017.

In 2008, the Zarqa had the highest household expenditure on energy among all the governorates, exceeding the 10% ratio (**Figure *30***). The figure also shows that rural areas in Zarqa, Amman, and Madaba spent more than urban areas on energy. Newer data is unavailable, making it harder to investigate such indicators. Since the offered data is more than ten years old, recent data is needed to measure whether the expenditure on energy has increased or decreased compared to income.

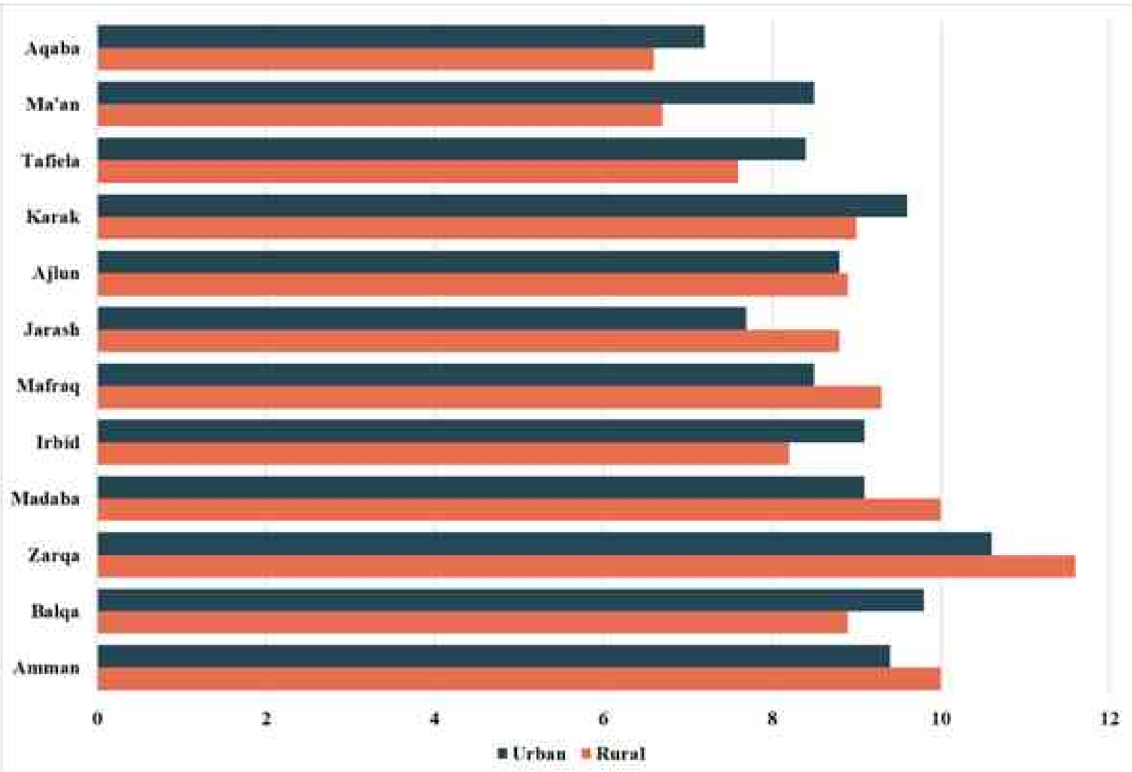

Figure 30. The Expenditure ratio from Total Income on Energy by Governorate (Urban/Rural) 2008.

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Source: Own compilation based on official data published by the DOS (Department of Statistics (DOS), 2008).

The variety of energy sources in Jordan allows the households to choose those means that fit with their social and income levels. **Figure *31*** shows that two primary heating sources are predominantly used in Jordan: kerosene/diesel and gas heaters, except for Aqaba, where households use electric heaters. In Zarqa and compared to other governorates, around 40 percent of the households use kerosene heaters, while almost 45 percent use gas heaters. Only 2.2 percent of the homes in Zarqa use burning wood or charcoal for heating. Other heating sources include those who do not need heating and those who do not have the means of heating in the household.

Figure 32 shows that nearly 50 percent of households in urban areas use gas heaters, which is higher than in rural areas. In urban and rural areas, kerosene/diesel heaters are used with a slight difference of 5 percent. However, it is worth noting that nearly 25 percent of rural households use wood/charcoal/jift burning to heat the home, while only 5 percent of urban dwellings use this method. Furthermore, rural areas have a higher percentage of households using electric heaters due to the high electrification in the country. This can indicate the household's burden, as electric heaters may not be energy-efficient, resulting in higher electricity bills.

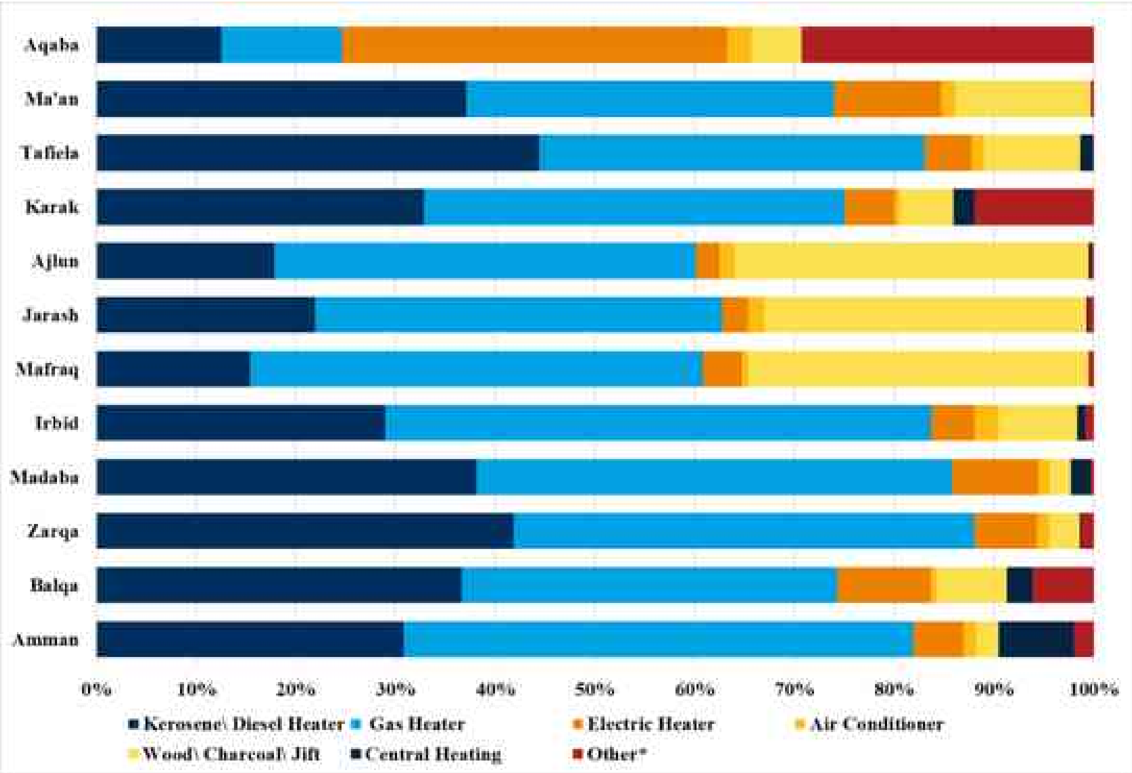

Figure 31. Distribution of Housing Units by Main Source of Heating and Governorate (%).

Source: own compilation based on official data published by the DOS (Department of Statistics (DOS), 2017).

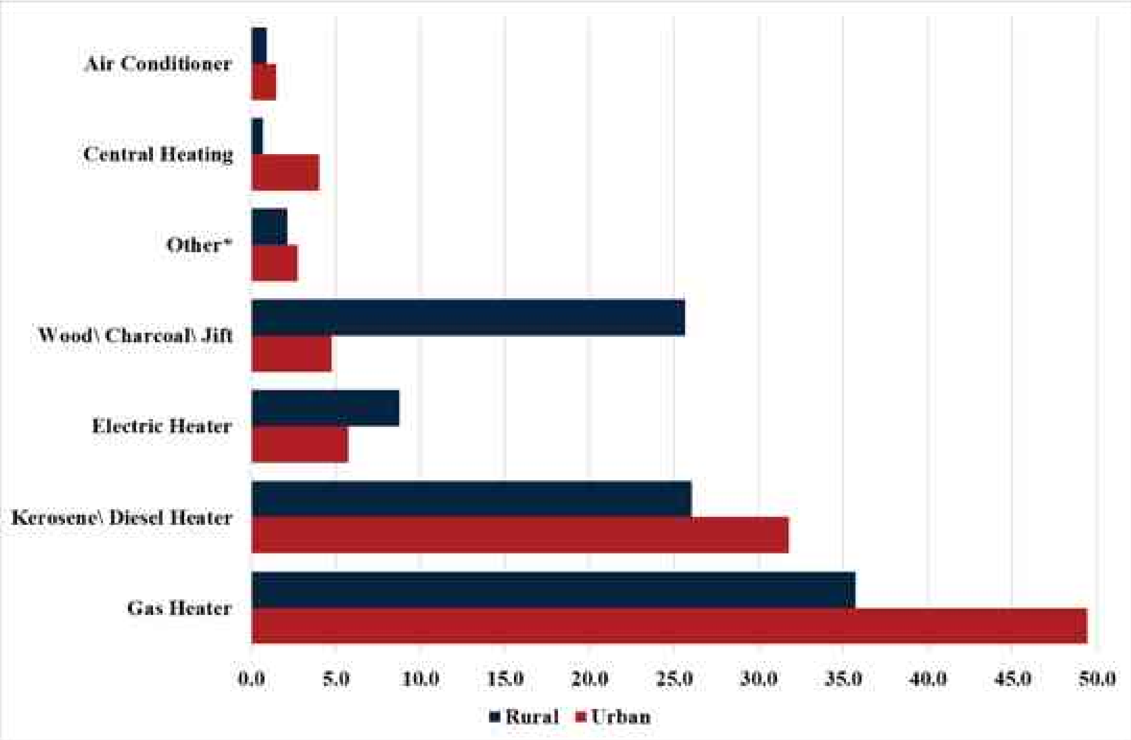

Figure 32. Distribution of Housing Units by Main Source of Heating in urban and rural areas.

Source: own compilation based on official data published by the DOS (Department of Statistics (DOS), 2017).

Regarding the households' cooling, **Figure *33*** shows that around 90 percent of the households in Aqaba, the only coastal city in Jordan, have air conditioners. Compared to Aqaba, the ratio of households who own air conditioners is low. Zarqa, for example, is like the capital, Amman, where only 33 percent of households own an air conditioner. Lastly, 33.2 percent of urban households own an air conditioner compared to 22.5 percent in rural households. The figure shows more details about the change in air conditioner ownership in each governorate through four Household Expenditure and Income Surveys (HEIS). Households have increased the number of air conditioners over the last years to deal with the hot weather in Jordan. In a warm climate, there might be overheating problems, represented by the formation of urban heat islands, which affect people living in such conditions (Fabbri, 2015a). Moreover, Fabbri (2015) referred to the fact that people with a good economic situation can afford to buy an air conditioner while those with low income will not be able to do so. Thus, the poorest proportion of the community will be excluded from securing summer comfort in their households.

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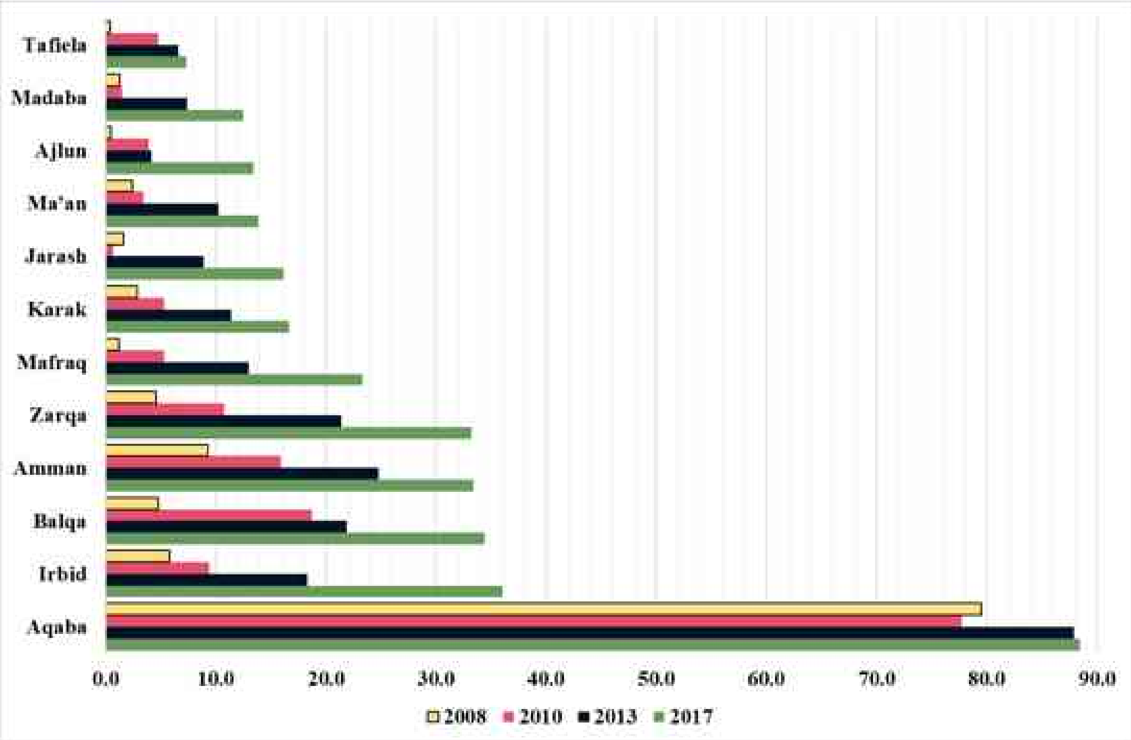

Figure 33. Distribution of Housing Units by Household ownership of air conditioner.

Source: Own compilation based on official data published by the DOS (Department of Statistics (DOS), 2017).

4.2. Data and Methodology

4.2.1. Study Area

In this chapter, the target group is the population living in the Zarqa Governorate. The governorate consists of 3 districts, Zarqa, Russeifa, and Hashemiyya, and three sub-districts as part of Zarqa district, namely Beren, Al-Dulail, and Azraq. Zarqa governorate is located northeast of the capital, Amman, and extends east on the border with Saudi Arabia. The governorate's population is 1,509,000 inhabitants, according to 2022 statistics at the time of collecting the sample. The reason behind choosing Zarqa governorate is the importance of the location near the capital, Amman, and the familiarity of the context of the area. Moreover, this chapter extends our knowledge and understanding of fuel poverty beyond the capital region. **Figure *34*** shows the geographical location of the Zarqa governorate.

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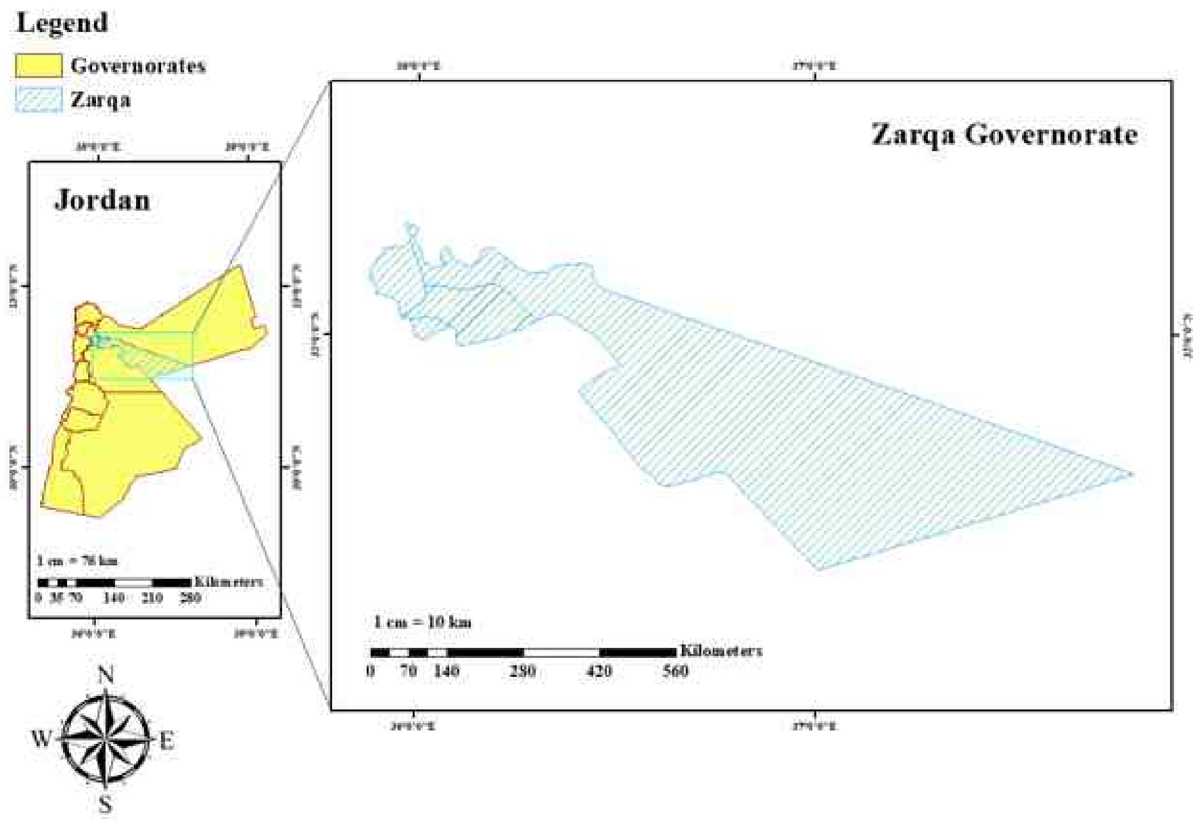

Figure 34. Location of Zarqa Governorate in Jordan.

Source: Own work.

4.2.2. Data collection

Instead of aiming for conceptual or methodological novelty, which is becoming an established practice in the social sciences, the fundamental goal of the survey's design was to achieve empirical novelty (Sovacool, Martiskainen and Furszyfer Del Rio, 2021; Lowans *et al.*, 2023). This approach helps researchers explore unchartered territories of knowledge, which can lead to discovering new phenomena or patterns.

The questionnaire comprised four sections and 35 questions and was designed to be completed within 15-20 minutes. Each section was dedicated to capturing information related to household characteristics, income, energy expenditure, and consensual fuel poverty factors. Most of the questions had two options: yes or no. The questions used in the survey are based on the Jordanian Household Expenditures and Income Survey (HEIS) published in 2017 and the EU Statistics on Income and Living Conditions (EU-SILC). The questions were kept dichotomous to keep the questionnaire in line with the questions' sources and because the study aimed to explore fuel poverty. At this level, the interest is to identify the subjective measures of fuel poverty as reported by the survey respondents. The only difference from the source surveys was that questions regarding energy expenditure and the usage of solar energy as a source of electricity were included. Adding a question related to solar energy is to capture the possible effect of having such systems on fuel poverty.

Google Forms was the platform used to build the questionnaire. Before closing the collection process, the questionnaire was available to the respondents for one month, from March 10 to April 10, 2022. Because of the nature of this study, I used convenience sampling through online tools. Convenience sampling is appropriate for exploratory research (Malhotra, Nunan and Birks, 2017). Using the formula provided by (Gill and Johnson, 2010), a sample size of 385 respondents is considered acceptable, and the likelihood of falling into bias is minimal. In our case, the total number of respondents has exceeded 385, which indicates a higher level of capturing a representative sample.

The data was collected through online tools represented by the Facebook platform to communicate with the local communities in the study area because of limited resources. During COVID-19, Facebook and social media showed potential for collecting data (Neundorf and Öztürk, 2021). In 2021, Jordan had over 6 million Facebook users out of the around 10 million total population ("Facebook Users by Country 2022," 2022). This majority of users can increase the opportunity of capturing the target population in the study area and increase the number of respondents within a brief time. Nowadays, every city or community has its own Facebook group to enhance communication and discuss urgent topics related to its areas. Communicating with local communities using their platforms can give credibility to the questionnaire goals and, at the same time, ensure the confidentiality of the respondents. The survey distribution used social media platforms to reach the target group through local community groups. However, the sample collection process did not include paid advertisements. In Jordan, only 4% of the population are elderly of the age of over 65 years and usually, older people tend to live with their family members in one house as 66% of Jordanian households believe that elderly care should be provided at home with their family (*Jordanian Family's Second Periodic Report*, 2018). By realizing this fact about the family structure in Jordan, there is a high possibility that the older people population is included in the collection process.

After the collection process was closed, the data quality was checked to eliminate any responses with missing entries or other issues such as "flat-liners." Respondents may sometimes give the same answer for a block of questions, causing inconsistencies between the answers and making them unrealistic. Based on the quality checks, 17 respondents out of 490 were removed, leaving 473 valid responses. These responses were then re-weighted to match the geographical distribution of the inhabitants of the Zarqa districts. **Table 16** displays the demographic and socioeconomic profiles of the respondents. The total number of observations for the variables in Table 15 is 472, which can vary in contingency tables due to the influence of case weight on the aggregates of the variables ('SPSS WEIGHT Command', 2023).

4.2.3. Energy Poverty Index (EPI)

Several studies used the composite index to measure energy poverty in Europe using three indicators, namely: being unable to afford to keep the household warm, having arrears on utility bills, and living in a home with a leaking roof or the presence of damp and rot (Thomson and Snell, 2013; Bouzarovski and Tirado Herrero, 2017b; Healy, 2017). While the mentioned studies captured difficulties in cold climates, I am using data from both summer and winter in this chapter. The original index, the metric "Inability" is assigned a more significant weighting following our evaluation's emphasis on self-reported thermal discomfort levels relative to the metric "Arrears," which primarily monitors tardy payment rates concerning energy and utility bills. Simultaneously, it should be noted that "Housing faults" exhibits a strong association with, though not being a direct proxy for, energy poverty.

When calculating the summer and winter index, I will keep the original formula used in the literature as follows:

$Energy\ Poverty\ Index = (0.5\ \times \%\ Inability + 0.25\ \times \%\ Arrears + 0.25\ \times \%\ Housing\ faults) \times 100$ …(4.1)

On the other hand, the adjusted indicator that will calculate the index, including difficulties related to summer and winter, will be as follows:

$Energy\ Poverty\ Index = (0.25\ \times \%\ Inability_S + 0.25\ \times \%\ Inability_W + 0.25\ \times \%\ Arrears + 0.25\ \times \%\ Housing\ faults) \times 100$ …(4.2)

Where $Inability_S$ means the inability to cool the household during summer and $Inability_W$ This means the inability to warm up during winter.

4.2.4. Statistical Analysis

To achieve the results of this research, we employed multiple analysis methods. As the data varies in nature, we used various approaches to analyze it, including logistic regression, chi-square tests, and Phi and Cramer's V tests. The Chi-square test was used to evaluate whether there was a statistically significant difference between observed and expected results in categorical variables. Additionally, we used Phi and Cramer's V tests, which are other association tests based on the chi-squared test. The first measures the association between two nominal variables, while the other measures the association between a nominal and variables with multiple categories. We conducted all significance tests at the 0.05 level.

Logistic regression is a well-established method to quantify fuel poverty as it is applied when the dependent variable is binary, which fits well with the indicators this study estimates (Healy and Clinch, 2004; Thomson and Snell, 2013; Lyra, Mirasgedis and Tourkolias, 2022; Belaïd, 2022a).

Binary logistic regression extends from linear regression (Field, 2009). Instead of predicting the change in the dependent variable *Y* using a predictor *X* or several predictors *(Xs)*, it predicts the probability of *Y* occurring given known values of *X* or *Xs*. The logistic regression takes the following form:

$$P\ (Y) = \frac{1}{1+\ e^{-(b_0+b_1X_{1i}+b_2X_{2i}+\cdots+b_nX_{ni})}} \quad (4.3)$$

Where *P(Y)* is the probability of *Y* occurring, *e* is the base of the natural logarithm, and b is the regression coefficient of predicting variable *X*.

Table 16. Demographic profile of the respondents.

Demographics					
Nationality			**Type of the Dwelling**		
	Frequency	Percent		Frequency	Percent
Jordanian	453	95.8	Detached house	242	51.2
Palestinian	14	2.9	Apartment	217	46
Egyptian	4	0.8	Villa	6	1.3
Syrian	2	0.5	Other	7	1.5
Sex of the Head			**Tenure Type**		
	Frequency	Percent		Frequency	Percent
Male	433	91.7	Owned by the household or one of its members	304	64.3
Female	39	8.3	Owned by Relative	34	7.3
Age of the Head			Rented	118	24.9
	Frequency	Percent	For free	12	2.5
24 or younger	4	0.8	Other	5	1
25 - 34	78	16.5	**Occupation of the head of the head**		
35 - 44	134	28.3		Frequency	Percent
45 - 54	123	26.1	Employed	294	62.2
55 or older	133	28.3	Unemployed	40	8.4
Marital Status of the Head			Economically Inactive	28	6
	Frequency	Percent	Retired	111	23.4
Single	26	5.4	**Total disposable income**		
Married	425	89.9		Frequency	Percent
Divorced	6	1.3	Less than 260 JOD	69	14.6
Widowed	16	3.3	261 – 400 JOD	135	28.5
District of the Respondents			401 – 550 JOD	79	16.8
	Frequency	Percent	551 – 700 JOD	60	12.7
Zarqa	224	47.4	701 – 850 JOD	51	10.8
Russiefah	167	35.4	851 – 1000 JOD	38	8
Hashemia	27	5.7	More than 1000 JOD	41	8.6
Azraq	19	4	**Source of Income**		
Beren	8	1.8		Frequency	Percent
Dulail	27	5.7	Salaries and wages	263	55.6
Urban/Rural			Household business	49	10.4
	Frequency	Percent	Pensions	103	21.7
Urban	395	83.6	Remittances from the country or abroad	10	2.1
Rural	78	16.4	Other	48	10.2

Note: Weight applied after applying case weighting based on the percentage of the inhabitants of each district.

4.2.5. Study Limitations

Overall, limitations related to surveying as a methodology are identified as the acquiescence bias in responses, respondent knowledge, survey length, and inaccuracy related to disclosing information on income levels (Lowans *et al.*, 2023). As convenience sampling is used, we are concerned with the length of the survey and the time required by the participants to answer all the questions. Moreover, respondents usually do not quickly disclose information about their income levels, which is usually considered a personal issue in Jordanian communities.

4.3. Findings

4.3.1. Utility arrears in the past 12 months

The question about this indicator is, "In the past twelve months, has the household been in arrears, i.e., has been unable to pay the utility bills (heating, electricity, gas, water, etc.) of the main dwelling on time due to financial difficulties?". The results show that 64.7% of the respondents reported having utility arrears during the last twelve months, while the rest had no problems paying the bills.

4.3.2. Characteristics of Households' Energy Efficiency

The study uses three questions to identify issues related to the energy efficiency status of households, focusing on the presence of humidity, poor ventilation, leaks, dampness, and rotting window frames. The descriptive results of the responses are summarized in **Table *17***.

Table 17. Subjective characteristics of Households' energy efficiency

The dimension	Yes	No
Does the household suffer from humidity	288 (**61.1%**)	184 (38.9%)
Does the household suffer from Poor ventilation of the dwelling	157 (33.2%)	316 (**66.8%**)
Does the household suffer from a leaking roof, damp walls/floors/foundation, rot in window frames or floor	336 (**71.1%**)	137 (28.9%)

As shown in the table, despite 61.1% of the respondents reporting humidity, 66.8% report good ventilation in their households. In addition, the results also show that 71.1% of households suffer from leaking roofs, damp walls/floors/foundations, or rotting window frames.

4.3.3. Characteristics of Summer Energy Poverty

Regardless of the literature on winter fuel poverty, this study tries to capture both summer and winter characteristics. This section discusses summer energy difficulties and then moves to winter-related ones. The questions related to summer are whether the household suffers from high temperatures during summer, whether the household can keep the household cool during summer, and whether the household members have difficulty sleeping due to feeling too hot.

Table *18* summarizes the descriptives of the mentioned questions. The table shows that 85.8% of the respondents' households suffer from high temperatures during summer, 64.5% cannot afford to keep their homes adequately cool, and 65.2% have difficulties sleeping due to feeling too hot.

Table 18. Subjective characteristics of summer energy poverty

The dimension	Yes	No
High temperatures during summer	405 (**85.8%**)	67 (14.2%)
Can your household afford to keep its home adequately cool?	176 (35.5%)	305 (**64.5%**)
In the past twelve months, have the household members had any difficulties sleeping due to feeling too hot?	308 (**65.2%**)	164 (34.8%)

4.3.4. Characteristics of Winter Energy Poverty

Understanding the difference between summer and winter energy difficulties is essential. It can lead to better formulation of policies that fit the Jordanian context and help predict the possible adaptation measures to respond to future climate change. The same questions were used, but this time focusing on Winter times. **Table *19*** summarizes the descriptive statistics. The results show that despite 65.3% of the households being cold during winter, only 36.8% had difficulties sleeping due to feeling cold.

Table 19. Subjective characteristics of winter energy poverty

The dimension	Yes	No
Cold and difficult to heat during winter	308 (**65.3%**)	164 (34.7%)
Can your household afford to keep its home adequately warm?	222 (46.9%)	251 (**53.1%**)
In the past twelve months, have the household members had difficulties sleeping due to feeling too cold?	174 (36.8%)	298 (**63.2%**)

4.3.5. The association between variables, utility arrears under the lens

Since the variables of interest are categorical, the relationship is tested using the crosstabulation function with Pearson's chi-square test. Contingency tables compare observed frequencies with expected ones (Field, 2017). In this section, there is an interest in comparing how respondents describe the characteristics of energy poverty. Thus, this section will compare the data collected about utility arrears with those collected on some energy poverty characteristics.

- *Utility arrears vs. the presence of roof leaks/wall damps/rot window frames*

Table 20 shows the contingency table between the two variables. The outcomes show that 79.3 percent of the respondents with utility arrears suffer from a leaking roof, damp walls, or a rot window frame. However, around 55 percent of respondents who suffer from the issue have no problems with utility arrears. The chi-square test value is 29.313, with a significance level of <0.001; this result indicates that utility bill arrears are significantly associated with poor household efficiency. Testing the strength of association revealed that the Phi value is 0.249

and P<0.0001, indicating a statistically significant association between the two variables. In addition, the relationship is positive, meaning that the relationship between the variables is direct and moderate.

Table 20. Utility arrears vs. the presence of leaks, damp, or rot.

			presence of leaks, damp, or rot		**Total**
			Yes	No	
Utility arrears	Yes	Count	242	63	305
		% within Utility arrears	79.3%	20.7%	100.0%
	No	Count	93	74	167
		% within Utility arrears	55.7%	44.3%	100.0%
Total		Count	335	137	472
		% within Utility arrears	71.0%	29.0%	100.0%

- *Utility arrears vs. the ability to keep the household adequately cool.*

Comparing the utility bills arrears with the ability to cool the household shows that only 20.9 percent of the households suffering from arrears can afford to cool, while 79.1 percent cannot. At the same time, 62.3 percent of the respondents who can cool their households do not have arrears on utility bills. The chi-square value is 80.697 with a significance level of <0.001; this result indicates that utility bill arrears are significantly associated with the ability to cool the household. **Table *21*** shows more details on the associated relationship. The Phi value of the test (-0.413) and significant (P-value<0.0001) indicates that the relationship between the two variables is inversely moderate.

Table 21. Utility arrears vs. the ability to keep the household adequately cool.

			Ability to keep home adequately cool		**Total**
			Yes	No	
Utility arrears	Yes	Count	64	242	306
		% within Utility arrears	20.9%	79.1%	100.0%
	No	Count	104	63	174
		% within Utility arrears	62.3%	37.7%	100.0%
Total		Count	168	305	473
		% within Utility arrears	35.5%	64.5%	100.0%

- *Utility arrears vs. the ability to keep the household adequately warm*

When examining the responses related to keeping the household warm, **Table *22*** shows that 74.3 percent of the respondents reported that they could heat their household with no utility arrears. On the other hand, 68.2 percent of those with bills in arrears cannot heat their homes adequately. The chi-square value is 78.093 with a significance level of <0.001; this result indicates that utility bill arrears are significantly associated with the ability to warm the household. Like the ability to keep the household cool, the Phi value (-0.407) shows an inverse significant moderate association between the variables with a p-value<0.0001.

Table 22. Utility arrears vs. the ability to keep home adequately warm.

			Ability to keep home adequately warm		**Total**
			Yes	No	
Utility arrears	Yes	Count	97	208	305
		% within Utility arrears	31.8%	68.2%	100.0%
	No	Count	124	43	173
		% within Utility arrears	74.3%	25.7%	100.0%
Total		Count	221	251	472
		% within Utility arrears	46.8%	53.2%	100.0%

- *Characteristics of income levels and fuel poverty.*

The questionnaire respondents were asked to report their income within seven categories. In Jordan, the minimum monthly wage is 260 Jordanian Dinars (JOD) according to 2022 regulations. Among the respondents, those with a monthly income of 261 – 400 JOD have a higher ratio of utility arrears, followed by those whose income is less than 260 JOD. The chi-square value is 58.187, with a p-value of <0.0001. In the income level, Cramer's V was estimated, and the results revealed a direct significant moderate relationship with a value of 0.351 and P-value<0.0001. **Table *23*** shows more details on the association between income level and utility arrears

Table 23. Utility arrears vs. income levels

			Total disposable income							
			< 260 JOD	261 – 400 JOD	401 – 550 JOD	551 – 700 JOD	701 – 850 JOD	851 – 1000 JOD	>1000 JOD	Total
Utility arrears	Yes	Count	62	98	49	40	24	22	10	305
		% within utility arrears	20.3%	32.1%	16.1%	13.1%	7.9%	7.2%	3.3%	100 %
	No	Count	7	37	30	20	27	15	30	166
		% within utility arrears	4.2%	22.3%	18.1%	12.0%	16.3%	9.0%	18.1%	100 %
Total		Count	69	135	79	60	51	37	40	471
		% within utility arrears	14.6%	28.7%	16.8%	12.7%	10.8%	7.9%	8.5%	100 %

4.3.6. Composite measurement of energy poverty in Zarqa governorate

Calculating the composite index of energy poverty in Zarqa governorate yielded an important result. This framework operates under the assumption that relying solely on consensual measures, such as self-reported inability to maintain adequate warmth, is inadequate for comprehensively grasping the intricate economic and material foundations of energy poverty. Hence, it advocates the incorporation of supplementary indicators elucidating the housing and financial circumstances of the populace to achieve a more comprehensive and holistic understanding (Dubois, 2012; Bouzarovski, 2014).

The results of estimating the Energy Poverty Index are listed in **Table *24***. In general, when using an equal weight for all the indicators, energy poverty is high (64.27). On the other hand, when the Inability to cool during summer takes a weight of 0.5 and is used with arrears (0.25) and house faults (0.25), energy poverty increases slightly to 66.97, while when focusing on the inability to warm the household, energy poverty decreases to levels lower than the general index (61.58). In general, the results are relatively stable in all three cases, while it is important to note that summer energy poverty is higher than in the winter season.

Table 24. Energy Poverty composite levels in Zarqa governorate.

	$Inability_W$	$Inability_S$	Arrears	House faults	EPI
Equal Weights (0.25)	0.14	0.16	0.17	0.18	64.27
Summer EPI		0.32	0.17	0.18	**66.97**
Winter EPI	0.27		0.17	0.18	61.58

4.3.7. Determinants of fuel poverty indicators in Zarqa governorate

Four logistic regression models were built to determine the factors that affect the occurrence of arrears on utility bills, the household's inability to pay to keep the home adequately warm or cool, and the presence of leaks, dampness, or rot. Following the literature, the backward likelihood ratio is advised as it enters all the variables in the first step of the analysis and removes the variables that can affect the model fit to observed data (Field, 2009; Thomson and Snell, 2013). The explanatory variables were selected based on the literature and the interest in exploring the relationship of new variables to fuel poverty. In each model and by using the backward likelihood ratio, we aimed to include different socio-economic variables in the initial model and allow SPSS to eliminate the variables with no relationship to the dependent variable. As mentioned earlier, this study aims to explore the factors that can influence the fuel poverty different characteristics in Zarqa Governorate, and thus, instead of including only those mentioned in the literature, we included new factors in each model. For clarity, all the factors entered in the model's first step are mentioned under the results tables.

- *Modeling the determinants of arrears on utility bills.*

A logistic regression uses sociodemographic variables to predict if a household will struggle with utility arrears. According to Table 25, the model chi-square result suggests that the overall model is statistically significant and that the predictors are related to the outcome value. The -2 log-likelihood result indicates that the model fits the mode well, whereas Nagelkerke's R-square revealed that the model explains 40.6% of the variance in the dependent variable. Lastly, the Hosmer and Lemeshow Test results indicate that the logistic regression model fits the observed data well.

Table 25. Logistic regression model statistics to predict utility arrears.

		df	significance
Model chi-square	165.379	22	0.000
-2 log-likelihood	448.008		
Nagelkerke R Square	0.406		
Hosmer and Lemeshow Test	9.142	8	0.330

The results in Table 26 indicated that living in a rural area increases the odds of having utility arrears by 39.9% more than living in urban areas. The results also suggest that homes not using solar energy to produce electricity have a higher odd of 31.52% of experiencing utility arrears, which indicates that households who manage to install solar panels to produce electricity can save money compared to those who do not have such technology Additionally, retired household heads decrease the odds of having utility arrears by 2.56% compared with employed household heads. On the other hand, economically inactive or unemployed households cannot predict utility arrears.

Compared to income levels less than 260 JOD, the odds of experiencing utility arrears decrease with increasing income levels; the relationship is significant except for households with 551 – 700 JOD and 851 – 1000 JOD. Income levels and occupation of the head results suggest that increasing the minimum wages and improving life quality can help households escape fuel poverty by decreasing the chances of having utility arrears. In addition, leaks, dampness, rot, and the inability to cool or warm the households increase the odds of having utility arrears more than in households without such problems. The results indicate that if a household has one of the difficulties related to fuel poverty, it will have a higher chance of suffering from all other energy-related hardships.

Table 26. Logistic regression model to predict utility arrears.

	B	Sig.	95% C.I.for EXP(B)		
			Lower	Exp(B)	Upper
Rural (1 = yes)	1.383	0.000	1.85	3.989	8.598
Using solar energy to generate electricity (1 = no)	1.148	0.024	1.166	3.152	8.524
Occupation of the head of the head		0.063			
Unemployed	0.247	0.694	0.375	1.28	4.365
Economically Inactive	-0.601	0.293	0.179	0.548	1.679
Retired	-1.363	0.014	0.086	0.256	0.761
Source of Income		0.117			
Household business	1.024	0.019	1.186	2.785	6.542
Pensions	1.13	0.051	0.995	3.097	9.633
Remittances from country or abroad	0.63	0.473	0.336	1.877	10.5
Other	0.205	0.707	0.422	1.227	3.574
Total disposable income		0.003			
261 – 400 JOD	-0.869	0.093	0.152	0.419	1.157
401 – 550 JOD	-1.154	0.037	0.107	0.315	0.933
551 – 700 JOD	-0.79	0.174	0.145	0.454	1.417
701 – 850 JOD	-1.756	0.003	0.054	0.173	0.549
851 – 1000 JOD	-0.731	0.237	0.143	0.481	1.617
More than 1000 JOD	-2.306	0.000	0.028	0.1	0.354
Ability to keep home adequately warm (1 = no)	0.875	0.002	1.377	2.398	4.175
Ability to keep home adequately cool (1 = no)	1.185	0.000	1.904	3.271	5.62
presence of leaks, damp, or rot (1 = yes)	0.522	0.045	1.011	1.685	2.808
Constant	-1.118	0.141		0.327	

Variable(s) entered on step 1: District, Urban/rural, Type of dwelling, Tenure type, Dominant means of cooling, Main source of heating, Does the dwelling use solar energy to generate electricity? Occupation of the head, Source of Income, Total disposable income, can your household afford to keep its home adequately warm? Can your household afford to keep its home adequately cool? Presence of leaks, damp, or rot.

- *Determinants of the ability to cool*

In **Table *27***, the binary logistic regression model results suggest that the model is statistically significant (Chi-square = 215.645, $p < 0.001$), indicating that the independent variables included in the model are collectively associated with the ability to pay to cool home. The -2 log-likelihood of 398.459 shows an acceptable model fit to the data. The Nagelkerke R Square of 0.504 suggests that approximately 50.4% of the variance in the dependent variable can be explained by the independent variables included in the model. Moreover, the Hosmer and Lemeshow Test results indicate that the logistic regression model fits the observed data well.

Table 27. Model statistics of the ability to pay to keep the household adequately cool.

		df	**significance**
Model chi-square	215.645	13	0.000
-2 log-likelihood	398.459		
Nagelkerke R Square	0.504		
Hosmer and Lemeshow Test	11.024	8	0.200

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The results in **Table *28*** revealed that the coefficients of the variables Arrears on utility bills in the last twelve months, High temperatures during summer, and Difficulty sleeping due to feeling hot increase the odds of difficulty keeping the home cool and are statistically significant at the 0.05 level. Being retired, compared to being employed, shows a statistically significant association with a higher likelihood (2.104 times higher odds) of being unable to keep the household cool. In addition, households with a larger area in the range of 100-199 m^2 and 200-299 m^2 exhibit a statistically significantly higher likelihood of keeping the household cool compared to households with an area less than 50 m^2. Moreover, households with incomes in the 261-400 JOD and 851-1000 JOD range showed a statistically significantly higher likelihood of maintaining a cool household compared to households with incomes less than 261 JOD. However, income ranges of 401-550 JOD, 551-700 JOD, 701-850 JOD, and more than 1000 JOD did not demonstrate a significant relationship with the ability to keep the household cool.

Table 28. Logistic regression results of the factors affecting the ability to keep the household cool.

	B	Sig.	95% C.I.for EXP(B)		
			Lower	Exp(B)	Upper
Occupation of the head of the head		0.045			
Unemployed	-0.692	0.200	0.173	0.5	1.444
Economically Inactive	-0.253	0.665	0.247	0.777	2.44
Retired	0.744	0.022	1.111	2.104	3.981
Total disposable income		0.049			
261 – 400 JOD	-1.084	0.045	0.117	0.338	0.976
401 – 550 JOD	-0.964	0.099	0.121	0.381	1.201
551 – 700 JOD	-0.113	0.854	0.268	0.893	2.98
701 – 850 JOD	-0.643	0.297	0.157	0.526	1.76
851 – 1000 JOD	-1.702	0.009	0.051	0.182	0.657
More than 1000 JOD	-0.883	0.184	0.113	0.414	1.519
Arrears on utility bills in the last twelve months (1 = yes)	1.471	0.000	2.566	4.354	7.388
Difficulty sleeping due to feeling hot (1 = yes)	1.875	0.000	3.719	6.518	11.424
High temperatures during summer (1 = yes)	1.351	0.000	1.806	3.859	8.246
Dwelling Area		0.000			
100 199 m^2	-1.129	0.005	0.148	0.323	0.705
200 – 299 m^2	-2.267	0.000	0.037	0.104	0.287
More than 300 m^2	-1.083	0.150	0.078	0.339	1.478
Constant	-0.743	0.281		0.475	

Variable(s) entered on step 1: District, Urban/rural, Does the dwelling use solar energy to generate electricity? Occupation of the head, Source of Income, Total disposable income, a leaking roof, damp walls/floors/foundation, rot in window frames or floor, Utility arrears in the past 12 months, hot/difficulties sleeping, High temperatures during summer, area of the dwelling.

- *Determinants of the ability to heat*

The binary logistic regression model results in **Table *29*** revealed a significant chi-square value of 206.838 and a p-value of 0.000, indicating that the model is statistically significant. The -2 log-likelihood of 445.995 shows an acceptable model fit to the data. The Nagelkerke R Square suggests that approximately 47.4% of the variance in the dependent variable can be explained by the independent variables included in the model. Furthermore, the Hosmer and Lemeshow Test results indicate that the logistic regression model fits the observed data well.

Table 29. Model statistics of the ability to pay to keep the household adequately warm.

		df	significance
Model chi-square	206.838	13	0.000
-2 log-likelihood	445.995		
Nagelkerke R Square	0.474		
Hosmer and Lemeshow Test	6.339	8	0.609

The results in Table 30 revealed that households that do not use solar energy have less chance of having heating difficulties during winter, but the significance of the relationship is slightly low (>0.05). As the results previously showed, difficulties in warming the household are significantly related to leaks, dampness, rotting window frames, and arrears on utility bills. In terms of dwelling area, the results show that compared to households with 50-100 m2, larger households will have less likelihood of having difficulties warming the household, but with odds ratios that are very low. Moreover, households with difficulty heating during winter and their members having difficulty sleeping due to feeling cold have a higher likelihood of experiencing difficulties in warming their households properly by increasing the odds by 41.58% and 33.09%, respectively.

Table 30. Logistic regression results of the factors affecting the ability to keep the household warm.

	B	Sig.	95% C.I.for EXP(B)		
			Lower	Exp(B)	Upper
Using solar energy to generate electricity (1 = no)	-1.04	0.065	0.117	0.353	1.068
presence of leaks, damp, or rot (1 = yes)	0.532	0.048	1.005	1.702	2.883
Arrears on utility bills in the last twelve months (1 = yes)	1.361	0.000	2.364	3.900	6.433
Area of dwelling		0.000			
100 199 m^2	-1.503	0.000	0.115	0.222	0.431
200 – 299 m^2	-1.818	0.000	0.067	0.162	0.391
More than 300 m^2	-1.774	0.007	0.047	0.17	0.613
Cold and difficulty of heating during winter (1 = yes)	1.425	0.000	2.515	4.158	6.876
Difficulty sleeping due to feeling cold (1 = yes)	1.197	0.000	1.979	3.309	5.532
Constant	-0.212	0.751		0.809	

Variable(s) entered on step 1: District, Urban/rural, Does the dwelling use solar energy to generate electricity? Occupation of the head, Source of Income, Total disposable income, a leaking roof, damp walls/floors/foundation, rot in window frames or floor, Utility arrears in the past 12 months, area of the dwelling, Main source of heating, Cold, and difficulty of heating during winter, Cold/difficulties to sleep, type of dwelling.

- *Determinants of the presence of leaks, damp, or rot*

Table 31 shows that the model statistics and fit are statistically significant. Moreover, the Nagelkerke R Square suggests that the independent variables included in the model can explain approximately 46.9% of the variance in the presence of leaks. Finally, the Hosmer and Lemeshow Test results indicate that the logistic regression model fits the observed data well.

Table 31. Model statistics of the presence of leaks, damp or rot.

		df	significance
Model chi-square	192.820	15	0.000
-2 log-likelihood	375.391		
Nagelkerke R Square	0.479		
Hosmer and Lemeshow Test	6.202	8	0.625

Modeling the determinants of leaks, dampness, or rot in Table 32 revealed that compared to the employed head of the household, other categories decrease the odds of having the problem, and the retired head category shows a significant relationship. The results indicate that homes with utility arrears, humidity problems, and poor ventilation have increased odds of having leaks, damp, or rot issues. For instance, humidity has increased the odds by 140%, increasing the probability of leaks, dampness, or rot in the household. Finally, compared to household salaries and wages, households with income sources "business or pensions" have higher odds of having issues related to leaks.

Table 32. Logistic regression results of the factors affecting the presence of leaks, damp, or rot.

	B	Sig.	95% C.I.for EXP(B)		
			Lower	Exp(B)	Upper
Occupation of the head of the head		0.099			
Unemployed	-0.637	0.280	0.167	0.529	1.679
Inactive economically	-1.192	0.066	0.085	0.304	1.081
Retired	-1.233	0.030	0.096	0.291	0.888
Source of Income		0.041			
Household business	0.983	0.033	1.082	2.671	6.596
Pensions	1.557	0.008	1.511	4.747	14.915
Remittances from country or abroad	0.388	0.714	0.185	1.474	11.763
Other	1.109	0.091	0.839	3.032	10.961
Arrears on utility bills in the last twelve months (1 = yes)	0.899	0.001	1.45	2.458	4.169
Humidity (1 = yes)	2.641	0.000	8.053	14.023	24.417
Poor ventilation of the dwelling (1 = yes)	0.88	0.013	1.201	2.41	4.836
Constant	-1.23	0.000		0.292	

Variable(s) entered on step 1: District, Urban/rural, Does the dwelling use solar energy to generate electricity? Occupation of the head, Source of Income, Total disposable income, Utility arrears in the past 12 months, area of the dwelling, Main source of heating, type of dwelling, Can your household afford to keep its home adequately warm? Can your household afford to keep its home adequately cool? Cold and difficulty of heating during winter, High temperatures during summer, Humidity, and Poor ventilation of the dwelling.

4.4. Discussion and Conclusions

The present chapter aimed to examine households' energy poverty indicators by surveying the self-reported summer and winter fuel poverty indicators, observe the association between

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different subjective indicators and income and arrears on utility bills and evaluate the factors determining the possibility of fuel poverty with the respondents' group in the Zarqa governorate. The results shed light on several key issues related to fuel poverty and energy efficiency in the Zarqa governorate.

One significant finding of this chapter is that respondents' households suffer from problems related to building efficiency. Even when the respondents report good ventilation in their homes, they still face humidity-related issues and a leaking roof, damp walls/floors/foundation, or rot window frames. This indicates that households in the Zarqa governorate face significant challenges related to building conditions, which can contribute to higher energy usage and fuel poverty.

The results also highlight the significant impact of summer-related energy problems on households in the Zarqa governorate. Many households reported suffering from high temperatures in the summer season but cannot afford to cool down. This not only affects their comfort but also poses sleep difficulties. It also shows that many households cannot afford to cool down even if they recognize that they suffer from high temperatures in the summer season. Even though most respondents reported that they suffer from cold indoor temperatures and difficulties adequately warming, most do not have difficulties sleeping due to feeling cold. This difference might be referred to as the fact that people can use different mechanisms to deal with cold rooms by wearing extra layers of clothes (and/or) using extra blankets to warm themselves. It is worth noting that the heating system in Jordan, as shown previously, is centered around using gas and kerosene heaters, which are portable devices usually used in one or two rooms in the house, leaving the rest of the rooms unheated.

Moreover, unlike in summer, in winter, people cannot keep heaters on while sleeping, so they turn them off to avoid the risk of suffocating or burning the house. In addition, the Energy Poverty Index was calculated using four indicators that reflect seasonal differences represented by the ability to heat or cool the household, arrears on utility bills, and house faults. The results revealed that using the index energy poverty levels are high, especially in summer, highlighting the possible impacts of Jordan's climate on people's ability to cope with summer energy needs.

Modeling the determinants of fuel poverty revealed interesting results. For example, utility arrears are more likely to happen in rural areas. In addition, the results also show that income is critical in increasing fuel poverty, as higher-income households are less likely to experience utility arrears. The results showed that when income increases, utility arrears decrease, indicating that a better economic situation means a lower chance of falling into fuel poverty situations. The results indicate that improving household income levels can help eliminate fuel poverty.

Modeling the inability to cool the households revealed similar results to utility arrears regarding the relationship to income. In Jordan, the number and frequency of heat stress days can pose a threat in summer over families in terms of their ability to adequately cool their households (Jaber, 2023). The results also indicate that the inability to cool and warm the household adequately has a negative link to the dwelling size. The results suggest that within the sample, those with smaller dwellings may suffer from issues related to achieving thermal comfort, which is also linked to the household's energy efficiency characteristics. Finally, modeling the presence of leaks, dampness, or rot revealed that this issue is more likely to appear in households with negative energy efficiency characteristics, have arrears on their utility bills, and happen in households relying on pensions and private business as a source of income. The results indicate that the survey respondents generally live in households with poor insulation and cannot afford to maintain a comfortable indoor temperature during the different seasons, which probably leads to higher energy consumption and accumulation of bills.

The findings highlight the challenges faced by households in terms of building efficiency and energy affordability, particularly during the summer and winter months. These challenges are more severe for low-income households and those living in rural areas.

Regarding policy interventions, improving building efficiency through insulation and weatherization measures and promoting the use of renewable energy sources could alleviate the burden of energy costs on households. Additionally, targeted subsidies and financial assistance programs could relieve households experiencing fuel poverty. Policies must consider the specific needs and circumstances of vulnerable households in the Zarqa governorate.

In conclusion, while the limitations should be acknowledged, the findings highlight the urgent need to address fuel poverty in the Zarqa governorate and Jordan. Targeted policy interventions are necessary to improve building efficiency and energy affordability, particularly for vulnerable households. Further research is needed to understand the factors contributing to energy poverty and develop practical policy solutions.

T5

- Households in Zarqa Governorate suffer from poor energy efficiency, represented by humidity and the presence of leaks, wall dampness, and rotting window frames.

T6

- Energy poverty in summer is more prevalent than in winter in Zarqa Governorate; this was reported as high temperatures, inability to cool efficiently, and difficulty sleeping due to high temperatures.

T7

- The empirical evidence establishes a clear correlation between income and energy poverty on utility arrears and the inability to cool residential dwellings adequately. Conversely, this correlation lacks significance concerning the inability to heat premises sufficiently and the occurrence of leaks, wall dampness, and deteriorated window frames.

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5. Conclusions and Policy Recommendations

5.1. Main Findings

Theories perceive energy in different ways. While environmental economics is the field where the moral approach of allocating resources is counted, natural resources economics has a better recognition for energy economics. Natural resources economics recognizes two dimensions of energy economics: first, energy is a critical input as a power source, and second, energy is a source of pollution.

Through reviewing relevant theories, energy economics shows a better point of view when it comes to energy poverty. I examined how energy demand can determine societies' probability of achieving the desired service. In the review, I showed that energy demand could be understood from two different points of view: microeconomics and macroeconomics. For example, the first is determined by energy use intensity and efficiency, while the latter focuses more on per capita income, GDP, and relative energy prices. Finally, Zweifel, Praktiknjo and Erdmann (2017) argue that energy demand would increase if the population grows, alongside income and economic growth.

In the later parts, I reviewed the energy ladder and energy stacking theories. I showed that the main difference between the two concepts is that the energy ladder shows that when the economic status improves, a household can move from low-quality fuel to a better and cleaner one. On the other hand, energy stacking shows that households can switch between different types of fuels as the economic situation may change with time.

In the second chapter of my study, I aimed to examine the interplay between energy poverty, economic growth, and climate change while also considering the theories of environmental and energy economics, as well as energy justice and the energy ladder concept.

To explore these relationships, I employed two distinct approaches. Firstly, I utilized the Toda-Yamamoto non-Granger causality test to analyze the connection between economic growth, energy consumption, and greenhouse gas (GHG) emissions in Jordan. The outcomes of this analysis demonstrated that as energy consumption increases in Jordan, it contributes to economic growth. However, it also leads to a simultaneous rise in GHG emissions, highlighting the environmental challenges associated with energy use. These findings align with environmental and energy economics principles, emphasizing the importance of sustainable energy practices to balance economic development and environmental concerns.

Secondly, while considering energy justice and the energy ladder concept, I delved into the relationship between energy expenditure (as a proxy for energy consumption) and the Human Development Index (HDI). Employing path analysis within the 12 governorates of Jordan, I investigated the direct and indirect associations between energy expenditure and HDI using various socioeconomic indicators. The results revealed a negative direct relationship between energy expenditure and HDI, indicating potential energy justice issues where higher energy expenditure does not necessarily translate into improved human well-being. However, the indirect relationship, encompassing intermediate indicators, displayed a positive association. This finding aligns with the energy ladder concept, highlighting the importance of transitioning to cleaner and more sustainable energy sources to enhance human development outcomes. In the third chapter of my study, I employed a modified version of the Multidimensional Energy Poverty Index (MEPI) to assess changes in energy poverty in Jordan between 2009 and 2017. By examining these changes through the capabilities approach and the energy ladder theory lenses, I gained more profound insights into the dynamics of energy poverty in the context of human capabilities and sustainable energy transitions.

The MEPI, incorporating dimensions such as cooking fuel, kitchen location, appliance ownership, access to modern communication means, and the presence of a solar water heater, allowed for a comprehensive assessment of energy poverty. Drawing from the capabilities approach, which emphasizes individuals' freedom to live fulfilling lives, my study recognized the crucial role of access to modern energy services in enhancing human capabilities and well-being.

Analyzing the results of the MEPI, I found that the overall index did not undergo significant changes between the two study years, indicating that energy poverty in Jordan remained relatively stable. However, variations were observed at the governorate, rural/urban, and wealth index levels. Notably, the highest MEPI score was recorded in Mafraq Governorate, suggesting lower energy poverty, while the Capital Region Amman had the lowest score, indicating relatively higher energy poverty levels.

These findings, when viewed through the lens of the energy ladder theory, shed light on the progress made in transitioning to cleaner and more sustainable energy sources. The presence of a solar water heater as a clean energy source in households correlated with higher MEPI scores, reflecting advancements along the energy ladder. Moreover, the slight decrease in MEPI scores in rural areas and the increase in urban areas indicated a potential upward movement within the energy ladder for urban households. The fourth chapter aimed to deepen the understanding of energy poverty in Jordan by examining household energy-related challenges. Due to data limitations, a survey was constructed based on existing literature, and responses were collected from residents of the Zarqa Governorate. Through the analysis of the collected data, several key findings emerged, which can be understood within the frameworks of the energy ladder, energy stacking, energy justice, and the capabilities approach.

The findings revealed poor building energy efficiency as a prominent characteristic of energy poverty, indicating the need for transitioning along the energy ladder towards cleaner and more efficient energy sources. Additionally, households faced challenges in adequately cooling or warming their homes, suggesting reliance on multiple energy sources, aligning with energy stacking.

Moreover, the results indicated issues related to utility bill arrears and disparities between rural and urban areas, highlighting the relevance of energy justice considerations. Ensuring equitable access to affordable and reliable energy services is crucial to addressing these disparities and promoting household energy justice.

Drawing from the capabilities approach, the findings emphasized the impact of energy-related challenges on individuals' capabilities. Enhancing energy infrastructure and implementing policies that improve energy access can empower individuals to overcome fuel poverty and fully realize their capabilities. Based on the results of my dissertation, I formed the following theses:

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H1. Accepted

- T1: Energy consumption Granger causes both economic growth and greenhouse gas emissions in Jordan. The analysis confirms the growth hypothesis. Since the relationship is significant, as energy consumption increases, economic growth will increase but at the expense of emitting more GHG emissions.

H2. Partially Accepted

- T2a: The path analysis indicates that human development in Jordan is not directly affected by energy consumption, where the relationship is negative and increased between 2008 and 2017. The impact of energy expenditure on human development is slow and takes more time to appear.
- T2b: Indirect impact of energy expenditure through income, urbanization, health, and education expenditure has a positive impact on HDI, and investing in improving those services would boost HDI in the future. The path analysis also indicates that Jordanian society reacts slowly to new policy adjustments.

H3. Accepted

- T3: Based on the MEPI, Jordanian households suffer from moderate energy poverty. Energy poverty may increase if not appropriately addressed and targeted interventions implemented to enhance the capability of Jordanian households to utilize energy effectively.

H4. Partially Accepted

- T4: The levels of energy poverty in Jordan vary by governorate, with the highest levels observed in Mafraq, where the largest refugee camp is located. These results highlight the need to consider the unique socioeconomic and structural factors contributing to each region's energy poverty when designing and implementing policies and programs to address this issue in Jordan.

H5. Accepted

- T5: Households in Zarqa Governorate suffer from poor energy efficiency, represented by humidity and the presence of leaks, wall dampness, and rotting window frames.

H6. Rejected

- T6: Energy poverty in summer is more prevalent than in winter in Zarqa Governorate; this was reported as high temperatures, inability to cool efficiently, and difficulty sleeping due to high temperatures.

H7. Accepted

- T7: The empirical evidence establishes a clear correlation between income and energy poverty on utility arrears and the inability to cool residential dwellings adequately. Conversely, this correlation lacks significance concerning the inability to heat premises sufficiently and the occurrence of leaks, wall dampness, and deteriorated window frames.

5.2. What is energy poverty and how the results of this dissertation can be translated in reality?

In this dissertation, I applied multiple methods to assess energy poverty in Jordan. This issue is multifaceted, and thus, to understand it better, especially in the case of Jordan, where the concept is relatively related to the traditional energy access percentage in any developing country.

In the second chapter, as energy consumption determines economic growth, any strategic plans for the energy system should be cautious that reducing energy consumption will negatively impact the Jordanian economy. Thus, a transition in the system should be gradual, and the consumption patterns in the different sectors should be considered. Moreover, future plans should consider a gap between the Jordanian governorates on the one hand and the Amman governorate on the other. I proved in my analysis that residential energy expenditure (consumption) has a direct negative relationship with human well-being, indicating a gap between households' energy needs and practices and what can be optimum for Jordanian households. Future energy plans that target improving efficiency in the residential sector should include the users' perspective and consider the population growth and the energy consumption differences in the different regions.

The results in chapters three and four have a direct recommendation in terms of alleviating energy poverty. While energy poverty is multidimensional, ownership of modern appliances comes with the cost of being able to afford and maintain it in the long term. The results from the third chapter recommend that development projects target governorates with the highest energy poverty score. Moreover, energy poverty as an issue that affects households should be included in future policies and laws to result in programs that support the households that fall under energy poverty. Policies should include improving energy efficiency, implementing

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retrofitting programs in older buildings, and further investigating the pricing of fuels and affordability to households.

In conclusion, I suggest a modified definition of energy poverty based on my results for Jordan: "*A situation arises when a household has poor energy efficiency; is incapable of achieving appropriate energy services which are modern, and sustainable due to economic or social barriers.*"

The suggested definition realizes the multidimensional nature of energy poverty, emphasizing the importance of improving energy efficiency and enhancing the economic and social position of the energy poor in Jordan. As the country is moving forward with an energy transition to increase the reliance on renewable energy and achieve energy security, it is essential to include those who have energy hardships in the strategies and the plans from the beginning so they will not suffer from further implications of energy poverty.

My research results are important because they shed light on an issue that was neglected for a long time. Current results show that households in Jordan face different forms of energy poverty. These forms hinder people's access to new technologies or benefit from energy efficiency improvements.

5.3. Future Research Plan

While writing my dissertation, I encountered several research-oriented areas and topics I plan to study. These are the following:

1. Investigating the impact of energy prices on households' energy consumption patterns in Jordan.
2. Investigating the coping strategies that the energy-poor households in Jordan follow in dealing with energy hardships.
3. Investigating energy and transport poverty in Jordan.
4. Assessing energy transition in Jordan and the possible impacts on energy poverty.
5. Investigating energy inequality and the consequences on energy transition in Jordan.
6. Investigating the impacts of severe weather events in both winter and summer on Jordanian households' energy consumption, especially those who suffer from energy poverty.
7. Examining the relationship between energy and water poverty in Jordan.
8. Analysis of possible impacts of energy transition in Jordan on the prevalence of energy poverty.
9. Study the impact of urban heat island occurrence in cities and thermal comfort.
10. Investigating the nexus between climate change, energy transition, and energy poverty in Jordan.
11. Study the inequality in solar panel uptake by Jordanian households.
12. Expand the study of energy poverty and energy poverty alleviation possibilities in the Middle East and North Africa region.

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Appendix I: Energy Poverty in Zarqa Governorate Questionnaire

Introduction

This questionnaire aims to collect data on studying the energy poverty phenomenon in Al-Zarqa Governorate. This questionnaire is part of a research study that may contribute to a better understanding of the dimensions of the energy poverty issue; specifically, this study seeks to examine the geographic prevalence of energy poverty in Al-Zarqa and understand the social and demographic factors contributing to this phenomenon.

This questionnaire comprises five sections, and the information will be collected randomly. No personal information, such as names and contact details, will be collected to preserve privacy and ensure the randomness of the data. Therefore, please answer the questions honestly and based on the head of the household's information. Providing accurate information will contribute to presenting accurate results regarding the reality of energy poverty and the factors that impact it. Furthermore, the results will also contribute to providing solutions to address this problem or reduce its effects on citizens.

First Section: Household characteristics

1	Nationality	• Jordanian • Palestinian • Syrian • Egyptian • Other……
2	Sex of the head of the household	• Male • Female
3	Age of the head of the household	• 24 years or younger • 25 – 34 • 35 – 44 • 45 – 54 • 55 or older
4	Marital status of the head of the household	• Single • Married • Divorced • Widowed
5	District	• Qaṣabah az-Zarqā' • Ar-Ruṣayfah • Al-Hāshimiyah • Azraq • Beren • Dulail
6	Household area	• Urban • Rural
7	Number of household members	
8	Type of dwelling the household is living in?	• Villa • House\ Dar

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<table>
<tr><td></td><td></td><td>• Apartment
• Slum\ hut
• Other</td></tr>
<tr><td>9</td><td>Area of dwelling in square meters</td><td>• 50 – 99 m^2
• 100 199 m^2
• 200 – 299 m^2
• More than 300 m^2</td></tr>
<tr><td>10</td><td>Type of dwelling possession?</td><td>• Owned by a household or one of its members
• Owned by Relative
• Rented
• For Free
• For work (supported by employer)
• Other</td></tr>
<tr><td>11</td><td>Total number of rooms of the dwelling (Except the kitchen)</td><td></td></tr>
<tr><td>12</td><td>Location of the kitchen in the house</td><td>• Separate room
• Part of a room in the house
• No kitchen</td></tr>
<tr><td>13</td><td>Main source of energy used for cooking?</td><td>• Gas
• Kerosene
• Electricity
• Firewood\ charcoal\ jift
• Other</td></tr>
<tr><td>14</td><td>Main source of heating in the dwelling?</td><td>• Kerosene or diesel heater
• Gas heater
• Central heating
• Air-conditioner
• Electrical heater
• Firewood\ charcoal\ jift
• No heating
• No need for heating
• Other</td></tr>
<tr><td>15</td><td>Dominant means of cooling in the dwelling?</td><td>• Fan
• Air-conditioner
• Central cooling
• No means of cooling
• No need for cooling
• Other (specify)</td></tr>
<tr><td>16</td><td>Does the household suffer from any of the following phenomena within the dwelling parts?</td><td><table>
<tr><td colspan="3"></td></tr>
<tr><th>Phenomena</th><th>Yes</th><th>No</th></tr>
<tr><td>Cold and difficulty of heating during winter</td><td></td><td></td></tr>
<tr><td>High temperatures during summer</td><td></td><td></td></tr>
<tr><td>Humidity</td><td></td><td></td></tr>
<tr><td>Poor ventilation of the dwelling</td><td></td><td></td></tr>
</table></td></tr>
</table>

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		Rodents
17	Does the housing unit utilize solar energy to generate electricity?	• Yes • No

18. Does the household have any of the following durable goods (usable), and how many?

	Item Name	Yes	No	NO.		Item Name	Yes	No	NO.
18.1	Washing machine				18.12	Fan			
18.2	Freezer				18.13	Solar water heater			
18.3	Gas oven\ Gas cooker				18.14	Water heater (electrical, gas)			
18.4	Gas oven for baking				18.15	Telephone			
18.5	Microwave								
18.6	Dishwasher								
18.7	Vacuum cleaner								
18.8	Internet Connection								
18.9	Mobile phone								
18.10	Smart mobile phone								
18.11	Air-conditioner								

Second Section: Household Income Characteristics

19	Occupation of the head of the head	• Inactive • Employed • Unemployed • Retired
20	Sector of employment of the head	• Government • Public Sector • Private Sector • Other
21	Source of Income	• Household business • Salaries and wages • Remittances from the country or abroad • Pensions • Other
21	Number of earners	• 0 • 1 • 2

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		• 3 • 4 • 5 or More
22	Total disposable income	• Less than 260 • 261 -400 • 401 - 550 • 551 – 700 • 701 – 850 • 851 – 1000 • More than 1000

Third Section: Household Energy Expenditure Characteristics

23	Average electricity monthly expenditure in winter	• 1-50 JOD • 51 – 100 JOD • 101 – 150 JOD • 151 – 200 JOD • More than 200 JOD
24	Average electricity monthly expenditure in summer	• 1-50 JOD • 51 – 100 JOD • 101 – 150 JOD • 151 – 200 JOD • More than 200 JOD
25	Average gas monthly expenditure in winter	• 7 – 14 JOD • 15 – 21 JOD • 22 – 28 JOD • More than 28 JOD
26	Average gas monthly expenditure in summer	• 7 – 14 JOD • 15 – 21 JOD • 22 – 28 JOD • More than 28 JOD
27	Average kerosene monthly expenditure in winter	• 1 – 10 JOD • 11 – 20 JOD • 21 – 30 JOD • More than 30 JOD
28	Average kerosene monthly expenditure in summer	• 1 – 10 JOD • 11 – 20 JOD • 21 – 30 JOD • More than 30 JOD
29	Other energy expenditures	

Fourth Section: Energy poverty

30	Can your household afford to keep its home adequately warm?	• Yes • No
31	Can your household afford to keep its home adequately cool?	• Yes • No

32	In the past twelve months, has the household been in arrears, i.e. has been unable to pay the utility bills (heating, electricity, gas, water, etc.) of the main dwelling on time due to financial difficulties?	• Yes • No
33	Do you have any of the following problems with your dwelling/accommodation?	• a leaking roof • damp walls/floors/foundation • rot in window frames or floor
34	In the past twelve months, have the household members had difficulties sleeping due to feeling too cold?	• Yes • No
35	Have the household members had difficulties sleeping in the past twelve months due to feeling too hot?	• Yes • No