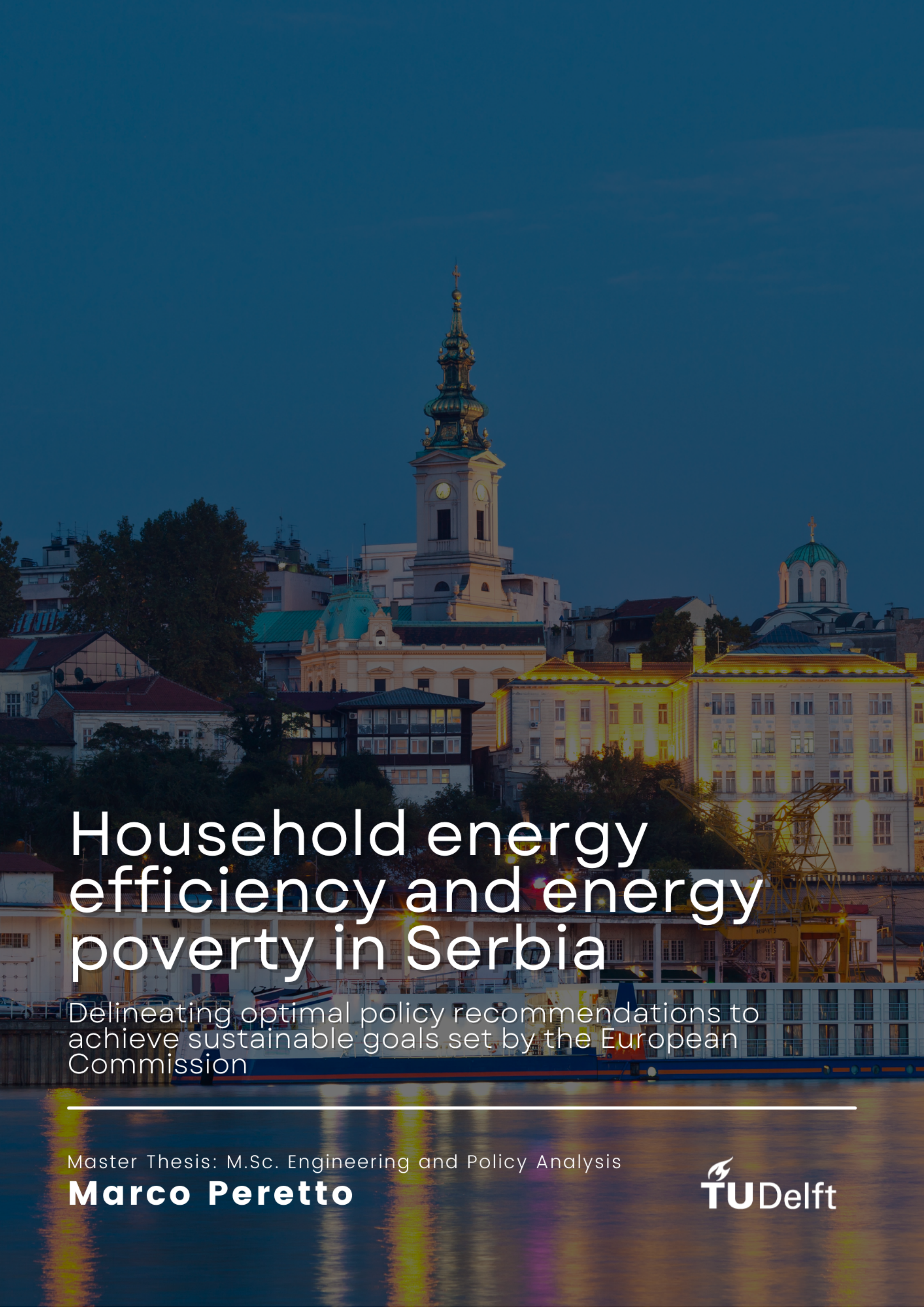

Household energy efficiency and energy poverty in Serbia

Delineating optimal policy recommendations to achieve sustainable goals set by the European Commission

Master Thesis: M.Sc. Engineering and Policy Analysis

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TU Delft

Household energy efficiency and energy poverty in Serbia:

Delineating optimal policy recommendations to achieve sustainable goals set by the European Commission

by

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TU Delft

Preface

Combating climate change and reducing our carbon footprint are perhaps two of the greatest challenges today's society needs to face. These are two multifaceted, interdisciplinary, and wicked problems. As such, these are affected by a myriad of factors pertaining to different fields. Indeed, to solve these problems, there's a need to co-operate and connect expertise from various disciplines. Policies have the power to do exactly that. It is vital to establish a link connecting technical experts, politicians and institutional bodies, and society.

Energy generation and utilisation is one of the primary sources of carbon emissions in the world. Nonetheless, in a more and more industrialized world, these are not envisioned to diminish. Therefore, there is an inevitable need to introduce new eco-sustainable technologies, making the whole process more efficient and renewable. The European Union has set out to make Europe the first climate neutral continent. This involves great political cooperation and investments. Indeed, no great technological and paradigmatic change is possible without great financial investments. This may put nations presenting lower monetary capacity in a disadvantaged position.

Around a year ago, while walking through the lively streets of Belgrade, I understood I wanted to work on a research project involving the country I like to consider as one of my homes, and sustainability. Serbia is one of the poorer countries present in the European continent, presenting high levels of energy poverty and energy inefficiency, together with considerable dependence on fossil fuels. Therefore, one way I could put my expertise learned during these last years spent studying, trying to make a difference, however small, was by analysing ways to improve the energy status quo in Serbia by delineating optimal policies. And that is what I ended up doing.

None of this would have been possible without the unconditional support, inspiration, and love of my parents, Aleksandra and Nicola. Thank you for always believing in me, the desire to make you happy and proud was the main source of fuel of this research. I would also like to thank my brother Alessandro, for always being there and showing great interest in my work. A very special thanks goes to my grandpa, Deda Milan, for inspiring me to pursue an academic path in the field of engineering, just as he had done.

I am forever grateful to my family and friends, that were always there to motivate me when needed, help me when required, and most importantly laugh and smile together. Thank you to my uncle Uroš, for being a constant source of help, inspiration, and laughter. From the first moment I expressed my research idea, you did everything you could to assist me in this quest. I would also like to thank my dear friend Ziad, with whom I have had the pleasure to share all of my student years. Thank you for always being there, helping each other out with our endeavours and finishing the academic path we started, together.

Thank you to my academic supervisors, Dr. Aad Correljé and Dr.Ir. Bert Enserink, for showing great availability, supervision, and interest in my research proposal, and Dr. Haiko van der Voort, for happily and readily stepping in to help when needed. Thank you to my external supervisor, Dr. Vlasis Oikonomou, for greatly helping me throughout this research quest, providing me with great professional insights and experienced guidance.

To conclude, I am very glad to have undertaken this academic journey and to have realized a research project that I feel greatly proud, satisfied, and happy about. I truly hope this can serve as inspiration for any future research.

Marco Peretto
Delft, July 2022

Executive Summary

Energy poverty, understood as a situation in which one household is not able to afford essential domestic energy services, is a phenomenon spread throughout Europe. In the following study, the Republic of Serbia will be considered specifically. The latter is, as other Western Balkan countries, affected by inefficient dwellings and housing appliances. These are characterised by outdated technological devices that further hamper their energy efficiency and carbon footprint. Additionally, the majority of the buildings in Serbia are outdated and need to be refurbished. This is aggravated by the fact that the residential sector represents the largest final consumer of energy in the country. Countries presenting a higher range of low-quality and energy-inefficient dwellings tend to present higher levels of energy poverty (and vice versa). Typically, residents living in energy inefficient households present below-average disposable incomes. Similarly, low-income groups are more subject to energy poverty. This hints to the "vicious cycle of energy poverty", where households presenting low disposable incomes eventually end up spending more on energy since these are unable to afford efficient dwellings and/or house appliances. The correlation between household energy efficiency and energy poverty has been recognised throughout the literature and among governmental institutions. In fact, increasing energy efficiency is a target present both in the Fit for 55 package delineated by the European Commission and the Sustainable Development Goals developed by the United Nations.

Considering the previously mentioned "vicious cycle of energy poverty" and the fact that low-income groups are more affected by energy poverty, it was decided to focus on this specific strait of society. Additionally, being a contracting party of the Energy Community Treaty, the Republic of Serbia adheres to implementing EU climate directives (sustainable goals) in the country. Stemming from this, the following Main Research Question was delineated, around which the whole research process was structured: *Which energy policy strategy should the Ministry of Mining and Energy implement in Serbia as to achieve household energy efficiency and energy poverty objectives set by the European Commission directed towards low-income groups?*

A case study-mixed methods approach was utilised for the following study. By merging the two methodologies, the proposed policies presented elements, and were analysed, both from a qualitative and quantitative perspective. On the one hand, the institutional, legal, and policy framework in the field of energy in Serbia was analysed, as to ensure the proposed policies were politically and socially feasible. On the other hand, the technical effectiveness in terms of final energy consumption and expenses reduction was also considered. To that end, a MS Excel linear and static simulation model was employed. It was found that performing a simulation-backed analysis of the available policy strategies in Serbia, delineating an optimal one to reduce energy poverty levels and improve household energy efficiency among low-income groups in Serbia, satisfying the sustainable targets set by the European Commission, represented a knowledge gap in the literature.

Three main policies were delineated corresponding to three different simulated scenarios. Namely, (i) the implementation of an emissions trading scheme extended as to also include the residential sector; (ii) the phasing out of heating oil and fossil fuels in 2030, followed by natural gas in 2040; (iii) the implementation of Minimum Energy Performance Standards (MEPS) in the residential sector. The latter resulted as the best performing policy, presenting the highest reduction in final energy consumption and expenses, resulting politically and socially feasible, delivering a positive social impact among low-income households in Serbia.

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1
Introduction

As recognised in the European Green Deal, across the European Union, 50 million people do not have the capacities and opportunities to have access to indoor thermal comfort (European Commission, 2019). Such a situation, where households are incapacitated to present adequate levels of energy services, can be defined as energy poverty. Whereas this inability to afford energy services stems from different causes pertaining to different fields, a clear path dependency between *energy poverty* and *household energy efficiency* can be observed (Thomson, Bouzarovski, & Snell, 2017). The latter essentially represents the ratio between the needed energy to power the household and the energy output generated (World Bank and IEA (International Energy Agency), 2013).

The UN has placed energy efficiency as one of its Sustainable Development Goals. Namely, doubling the energy efficiency global rate of improvement by 2030 is Target 7.3 (United Nations, 2021). Similarly, as part of the renewed Green Deal, the European Commission has set an improvement of at least 36% in energy efficiency as one of the key targets to be achieved by 2030 (European Commission, 2021b). Inefficient ways of gathering, producing, and distributing energy impact different straits of society in different ways; low-income groups being the most affected ones (Deller & Waddams Price, 2018). Inefficient energy production and distribution entails higher costs, which often hampers the affordability of the latter. Ensuring universal access to reliable, modern, and affordable energy services is another Sustainable Development Goal, namely Target 7.1 (United Nations, 2021).

The Republic of Serbia is, unfortunately, particularly characterised by energy poverty and low household energy efficiency. The latter is mainly due to inefficient heat generating house appliances, low insulation, and household energy losses. In Serbia, 55.9% of households utilise solid fuel as their main resource for heating (Statistical Office of the Republic of Serbia, 2020). Additionally, 58.9% of households did not present central heating installations (Macura, 2017). The residential sector is the largest consumer of energy in Serbia, representing 34% of total final energy consumption in the country (Odysse Mure, 2021). Thus, to reduce energy poverty in Serbia, an improvement in terms of energy efficient heating devices is required. Substituting outdated heating systems with newer better-performing ones outside the realm of natural gas, oil and coal represents an opportunity. In fact, such an operation could greatly improve figures related to energy poverty in the country, displaying potential to massively increase savings while at the same time presenting short payback periods on investments (Young & Macura, 2020). This change to efficient heating must happen in tandem to a better insulation and refurbishment of households.

A case study-mixed methods approach will be utilised for the following study. The case study here proposed is delineating optimal policies concerned with household energy efficiency and energy poverty for the Serbian context specifically, making this thus the “parent” case study. Thereafter, mixed methods for analysing, collecting and combining qualitative and quantitative data will be employed. In this case, qualitative data will mainly comprise research about past, present and future policies and directives in both the Serbian and European context. But also, past research papers and academic knowledge in general. On the other hand, quantitative data will be gathered from several repositories to then perform specific scenario simulations. By merging the two methodologies, proposed policies (based on mainly qualitative knowledge) will be strengthened, or better will present numerical data, to support the delineation and proposal of these.

Stemming from the literature review and in-depth research regarding the Serbian energy policy framework, household energy efficiency and energy poverty status quo, different policies will be delineated and proposed to tackle the previously mentioned issues. These will be tested by running a static and linear modelling simulation. The obtained quantitative results will be considered and utilised as technical backing with regards to preferring one policy over the other. Nonetheless, in addition to the envisioned degree to which the proposed policy would reduce final energy consumption and expenses, qualitative factors will also be examined, such as the political and social feasibility, and the social impact each policy would entail. Indeed, the present study aims to answer the following Main Research Question: *Which energy policy strategy should the Ministry of Mining and Energy implement in Serbia as to achieve household energy efficiency and energy poverty objectives set by the European Commission directed towards low-income groups?* To conclude, the best performing policy is expected to reduce final energy consumption and expenses, being both politically and socially feasible, presenting sustainable and affordable implementation costs, diminishing energy poverty and thus bringing a positive social impact among low-income households in the Serbian residential sector.

The structure of the present study will hereby be explained. Firstly, an in-depth literature review concerning the key subjects of the intended study will be realized. This will constitute the main part of the theoretical background (Chapter 2), followed by the delineation of the research questions that will guide the research process. Hence, the research approach undertaken will be clarified in Chapter 3. Thereafter, the Serbian energy policy framework will be scrutinized, analysing past, present, and future envisioned energy policies and targets (Chapter 4). This will be followed by a holistic overview of the relations between energy poverty and low-income households in Serbia, understanding the status quo, which indicators are utilised to define these and how (Chapter 5). Thenceforth, linear simulations of the proposed policies will be carried out by utilising a MS Excel model (Chapter 6). At this stage, an initial quantitative comparison of the embedded results of the different proposed policies will be achieved, delineating a best-performing one. In Chapter 7, the social and political feasibility of the proposed policy will be examined, considering also available resources and existing policy mechanisms/instruments. Finally, in Chapter 8, recommendations to the Ministry of Mining and Energy will be given, thus answering the Main Research Question the current study is set out to resolve. Finally, Chapter 9 will conclude the report by summarising the main findings and answering explicitly each Sub-research Question, followed by a discussion regarding the future reproducibility of the present study, the benefits of applying EU sustainable standards in the Serbian context, the main national stakeholders involved, and finally the main limitations encountered during this study and the areas to further research.

This Master thesis also marks the last research project and thus the ending of the author's studies in the *Engineering and Policy Analysis* MSc programme offered by TU Delft. This programme presents as its two fundamental pillars policy and analytical modelling, with climate change policy adaptation representing a particularly fitting topic to be analysed taking such a multifaceted and interdisciplinary approach. Indeed, energy poverty is a wicked problem. Reducing energy poverty is a grand challenge. Policies in Serbia are failing to improve the situation and there is thus a need to improve these. This can be done by gathering both qualitative and quantitative data, performing simulations, and finally providing policy recommendations based on such an interdisciplinary analysis. To conclude, the project at hand aspires to support policy making in Serbia, attempting to improve the daily lives of people, the country's environment, and the pertaining scientific field.

2

Theoretical Background

In the following chapter a literature review will be performed analysing the main subjects considered in the current research, namely: energy poverty, household energy efficiency, and low-income household groups. Furthermore, the indicators utilised to analyse and describe the latter three will be researched together with the current energy policy framework in the EU. In fact, to delineate optimal policy recommendations to achieve sustainable goals set by the European Commission, it is vital to have a broad while at the same time detailed knowledge with regards to the previously mentioned subjects. Energy poverty and household energy efficiency will be both analysed from three different perspectives, namely: theory, Europe, and Serbia. Essentially, firstly insights from theory on each subject will be considered, thereafter the differences between various European countries on the matter, and finally how this subject is being treated in Serbia. This allows to give a holistic overview of both energy poverty and household energy efficiency while at the same time having a detailed overview of the subject in Serbia. A similar process will be employed also for low-income household groups, seeing how these have been displayed in theory but also analysing the differences across different European countries. On the other hand, the indicators utilised to describe the previously mentioned subjects and how these differ throughout Europe will be analysed more from a theoretical perspective. This will conclude the more "scholarly" part of the theoretical background. Thereafter, the energy policy framework will be analysed. Since the goal of the current study is to help Serbia delineate optimal policies to achieve sustainable targets set by the European Commission, these targets will be researched, analysed, and portrayed. Thus, the EU energy policy framework will be studied. On the other hand, the Serbian energy policy framework will be analysed more in detail in the following sections of this report. Indeed, more detailed knowledge will be needed for the latter. Nonetheless, the knowledge gathered in the literature review will spur the analysis of the Serbian policy framework, individuating more precisely which aspects will need to be covered in greater detail. Finally, the theoretical background will end with the delineation of the research questions, which will guide the research process.

2.1. Energy Poverty

2.1.1. The Interdisciplinary Nature of Energy Poverty

Various definitions of energy poverty can be found throughout the literature. This is mainly due to the multidimensional nature of the subject. The relation between energy and poverty has often been misinterpreted or misunderstood by experts pertaining from different fields (Bouzarovski, 2018). The political and economic (both macro and micro) consequences of energy poverty are broad and not easily definable, making it unclear how the latter affects and is affected by household consumption practices (Bouzarovski, 2018). A wide range of factors can be considered when analysing energy, spanning from the price of fossil fuel resources to the type of building being inhabited by a given household. The definition can also change from country to country, as national socio-economic conditions play a pivotal role in defining energy poverty.

In the following report, the definition given by Bouzarovski will be adopted. "Energy poverty occurs when a household is unable to secure a level and quality of domestic energy services - space cooling and heating, cooking, appliances, information technology - sufficient for its social and material needs" (Bouzarovski, 2018, p.1). Implicitly, *energy services* are also defined. The definition is rather broad and qualitative in nature. In fact, there are no universal methods to define when domestic energy services can be deemed as sufficient for a household's material and social needs. It is perhaps this scarcity of definite and quantitative indicators to be accounted for as the culprit for the lack of consensus among experts within and outside the field on the implications and consequences of energy poverty.

Due to the multifaceted nature of the discipline being discussed, defining one single indicator to measure energy poverty results in being an intricate operation. Depending on the indicator being utilised, different conclusions can be reached, as only one facet of the problem is being analysed (Deller et al., 2021). Several methods to measure energy poverty have been applied in the literature. The energy services standards within households have been examined, obtaining data via direct measurement (Bouzarovski, 2018). This method however has not been used on a larger scale due to the difficulty in defining global energy standards, as these are influenced by cultural aspects that change depending on the geographical location being analysed (Walker & Day, 2012). The expenditure patterns related to energy consumption distributed across the population have also been analysed as a means to identify energy poverty (Bouzarovski, 2018). Lastly, several studies have utilised self-reported data by households, or have directly gathered self-reported data by surveying households with regards to their situation in relation to the affordability of energy services (Bouzarovski, 2018).

Energy poverty, and thus affordable energy services, are not legally binding. Thus, governments throughout the world are not bounded by law to offer affordable energy services. However, the occurrence of energy poverty hints to potential violations of other essential human rights. Namely, *the right to life with dignity* and *the right to adequate housing* (Antepara et al., 2021). Nonetheless, several progress towards an ideal right to energy has been made. For example, article 36 of the EU Charter of Fundamental Rights, recognises electricity and gas provision as services of general economic interest which, as such, must be accessible to EU citizens (European Union, 2016). In addition, principle 20 of the EU Pillar of Social Rights states that "everyone has the right to access essential services of good quality, including water, sanitation, energy, transport, financial services and digital communications" (European Union, 2017). That being said, in Europe specifically, it is not the accessibility to energy being problematic but rather its affordability (Antepara et al., 2021).

Closely related to energy poverty is energy justice. Bouzarovski (2018) delineates three main forms of justice analysed in energy justice studies, namely: procedural justice, distributive justice and justice as recognition. Walker & Day (2012) argue that energy poverty is influenced, at its core, by distributive injustice, as the distribution of resources across households is inherently flawed. On the other hand, procedural justice refers to the degree of fairness involved in the decision-making process and recognition to the degree of acknowledgment of different minorities pertaining to different straits of society (Bouzarovski, 2018). However, energy justice is not purely influenced by socioeconomic factors, but also by geographical ones. Bouzarovski (2018) argues that the environmental features of a given location will inevitably influence the vulnerability of the latter to energy poverty. The scholar further argues that the location of one subject's household presents the same importance as the socioeconomic group it is part of (Bouzarovski, 2018). On a more general note, indeed energy poverty is not evenly distributed across Europe, with the former being more prominent in Eastern and Southern regions of Europe (Bouzarovski & Tirado Herrero, 2017). Even though energy justice is an important element related to energy poverty, this will not be further touched upon throughout the present research project.

2.1.2. The Geographical Characteristic of Energy Poverty

As recognized in the European Green Deal, across the European Union (EU), 50 million citizens do not have the capacities and opportunities to have access to indoor thermal comfort (European Commission, 2019). This inability entails a variety of health consequences, varying from cardiovascular diseases to decreased mental health (Thomson, Snell, & Bouzarovski, 2017). Energy poverty was first recognised as a social and political subject in the United Kingdom and the Republic of Ireland. In the past two decades, various helping funds and energy poverty policies were introduced in the two countries to help alleviate this issue (Bouzarovski, 2014). This resulted in the related literature being mainly British-centric (Thomson, Bouzarovski, & Snell, 2017). Nonetheless, in recent years more and more governments started recognising energy poverty as a socioeconomic issue (Bouzarovski, 2014). In 2013, the European Economic and Social Committee (EESC) called for a coordinated action of EU governments to tackle energy poverty. In 2016, in an attempt to address the issue by the European Commission, the EU Energy Poverty Observatory (EPOV) was established (European Commission, 2022a). The project lasted 40 months and aimed at fostering knowledge and European coordinated action to develop policies aimed at combating energy poverty. The project was thereafter succeeded by the Energy Poverty Advisory Hub (EPAH).

Being the United Kingdom (UK) and the Republic of Ireland the first two countries to have addressed institutionally and academically energy poverty, the latter has been predominantly studied in this specific cultural and geographical context. Isherwood & Hancock (1979) are regarded as the first scholars to have addressed energy poverty, whose work aimed “to identify consumers for whom the payment of fuel bills raises difficulties and to examine their characteristics in terms of income, age etc.” (Isherwood & Hancock, 1979). This was followed by Boardman’s (1991) work that set the foundations to measure the previously mentioned issue. Building on the initial definition cited beforehand, Boardman (1991) focused on low-income groups unfacilitated in the payment of utility bills, to define energy poverty as a situation in which a household spends more than 10% of its income on energy expenditures (Deller et al., 2021). This notion was used as the main indicator to measure energy poverty and the percentage of the households affected by it in England until the start of the previous decade, when the metric was changed following the work by Hills in 2012 (Deller et al., 2021). The latter regarded as *energy poor* households that spent more than the national median expenditure on energy services, following which their residual income fell below 60% of the national median level (Deller et al., 2021). This is also known as the “Low Income High Cost” (LIHC) indicator. The changes that happened in terms of indicators used to measure energy poverty in the UK indicate the novelty and the evolvement of the field and policies related to it. In addition, depending on the indicator utilised, different policies will be delineated and/or opted for. As previously mentioned, energy poverty is inherently a socioeconomic issue; therefore, different indicators will be optimal depending on the country in which these are being applied to.

When comparing member states of the EU (and Europe in general), countries located in the Southern and Eastern region of Europe present a higher energy poverty incidence compared to the other geographical regions of the continent (Bouzarovski & Tirado Herrero, 2017). From an economic perspective, Southern member states of the EU have had stricter budgetary restrictions (austerity) which hindered the transition to more efficient and renewable methods of energy generation. Notwithstanding the general higher temperatures of Southern European countries, these have constantly been providing higher percentages of households unable to keep adequately warm (Bouzarovski & Tirado Herrero, 2017). As illustrated by Serra (2016), in 2013, Cyprus, Greece and Portugal registered respectively 30.5%, 29.5%, and 27.9% of its total population unable to keep its household adequately warm. All the mentioned figures have kept on growing compared to previous years. In addition, when considering lower income groups, defined as the share of the population below 60% of median equivalized income, the three previously mentioned countries had over 40% of this population segment unable to keep adequately warm (with the addition of Italy). The average rate in Europe was 24.1% (Serra, 2016). This region presented also above-average rates when considering the share of the population presenting difficulties in paying the bills (Serra, 2016). Other issues affecting Eastern European states include a late liberalization of the energy market, inefficient thermal insulation of buildings and a historically unstable energy supply mix (Bouzarovski & Tirado Herrero, 2017).

2.1.3. The Relevance of Energy Poverty in Serbia

The Western Balkans region is, unfortunately, particularly characterised by energy poverty. The latter is mainly due to inefficient heat generating house appliances, low insulation, and household energy losses. When analysing Serbia alone, it can be found that 55.9% of households utilise solid fuel as their main resource for heating (Statistical Office of the Republic of Serbia, 2020). Additionally, 58.9% of households did not present central heating installations (Young & Macura, 2020). Across the whole country, 36% of households utilise “wood-fuelled” stoves as their main source of heating (RES Foundation, 2021). In 2017, Serbia ranked as the 35th most energy intensive and the 15th most carbon intensive nation in the world (Macura, 2017). The residential sector is the largest consumer of energy (Figure 2.1), representing 34% of total final energy consumption in the country (Odysse Mure, 2021). In 2013, it was registered that 18% of the Serbian population was unable to keep its home adequately warm (Serra, 2016). In addition, 21.6% of the population lived in dwellings presenting poor living conditions (Serra, 2016).

Energy poverty in Serbia was defined as a state in which households do not have the necessary means to afford the required amount of energy as to live a healthy and dignified life, in a way that does not harm other households or larger communities (RES Foundation, 2021). As mentioned in previous sections, socioeconomic factors affect the optimality of indicators being utilised to measure energy poverty. If one were to use the indicator proposed by Boardman (1991), namely that a household is energy poor when it spends more than 10% of its income on energy services, the majority of Serbia's population would be found to be energy poor. Indeed, on average, a Serbian household consumes 12.4% of its total income on energy expenditures (RES Foundation, 2021). It thus becomes clear that indicators are context-dependent, and that those utilised in Western European countries will not always be directly applicable in Serbia.

In November 2020, Serbia was one of the signatories of the *Sofia Declaration of the Green Agenda for the Western Balkans* (European Commission, 2020b). Essentially, the Republic of Serbia agreed to align to and endorse the objectives set in the EU Green Deal. In addition, it endorsed the launch of a *Green Agenda for the Western Balkans* (European Commission, 2020b). This marked a great step towards the achievement of sustainability goals and showed the country's devotion and willingness to improve its energy status quo. Reducing energy poverty would be both a direct and indirect consequence of the agreement. Furthermore, this opened the doors to Serbia to the *Economic and Investment Plan for the Western Balkans*, which plans to deploy up to 9 billion euros of EU grants in the region in the time period from 2021 to 2027 (RES Foundation, 2021). This fund is directed towards helping the region recover from the COVID-19 pandemic, accelerate its transition to renewable energy generation and further amplify its economic convergence to the EU.

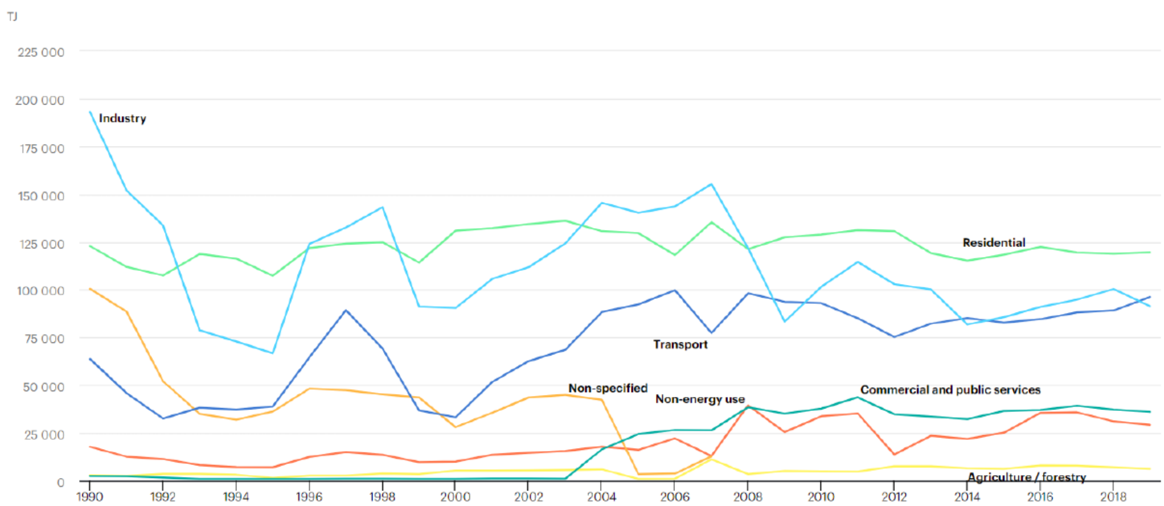


Figure 2.1: Total Final Consumption per Sector, Serbia 1990-2019 (International Energy Agency (IEA), 2021).

2.2. Household Energy Efficiency

2.2.1. The Multifaceted Ramifications of Household Energy Efficiency

Household energy efficiency can be defined as the ratio between the energy needed to power the household (input) and the end-use service (output) generated (World Bank and IEA (International Energy Agency), 2013). A country's general energy efficiency will inevitably be comprised of smaller specific segments. Household energy efficiency is one of them. The latter assumes greater importance when considering that, worldwide, the buildings sector consumes a large share of the total energy being produced (Filippidou et al., 2019). Energy demand of households can be divided into four main purposes, namely: appliances, lighting, heating and cooling (Matić et al., 2015). Related to all these demands, apart from the efficiency of the household, are also the health and well-being of residents, the economic and financial situation of residents, and the household-related greenhouse gas emissions (Matić et al., 2016). Household energy efficiency is also closely related to the dwelling's characteristics, such as its construction age, building type and thermal insulation. Hence, tackling the energy efficiency of the residential sector entails undertaking and dealing with several socio-economic, physical and technical ramifications.

Countries presenting a higher range of low-quality and energy-inefficient dwellings tend to present higher levels of energy poverty (and vice versa) (Omić, 2019). Indeed, the higher inefficiency of the building, such as a lower thermal insulation, will lead to higher energy expenditures. Typically, residents living in energy inefficient households present below-average disposable incomes (Figure 2.2) (Omić, 2019). Similarly, low-income groups are more subject to energy poverty (Deller & Waddams Price, 2018). This hints to the "vicious cycle of energy poverty", where households presenting low disposable incomes eventually finish spending more on energy since these are unable to afford efficient dwellings and/or house appliances (Jones et al., 2016). Indeed, the severity of energy burden to households is frequently regarded as a reliable predictor of the sociodemographic groups affected by energy poverty (Bouzarovski, 2014). This relation further illustrates how energy poverty is not purely an economic issue, characterised only by energy expenditures and incomes; but also, a geo-spatial and physical one, with the type of building and living area also playing a substantial role. The focus should be shifted from the narrow triad of incomes, prices and energy efficiency to a more holistic one comprising household needs, social resilience and built environment flexibility (Bouzarovski, 2014).

Improvements in terms of energy of buildings have the potential to both diminish energy poverty while increasing household energy efficiency (Filippidou et al., 2019). Policies aimed at addressing the issue from the demand side by, for example, retrofitting the buildings or transforming the appliance market, have the potential to practically alleviate energy poverty while also providing direct tangible benefits to the households (Bouzarovski, 2014). Concurrently, by improving the efficiency of dwellings, both greenhouse gas emissions and total energy consumption can be lessened (Filippidou et al., 2019). A reduction in terms of energy consumption would, in turn, reduce energy expenditures. This could potentially crack the previously mentioned "vicious cycle of energy poverty". Nonetheless, there is a risk of a "rebound" effect occurring (Omić, 2019). What this entails is lower-income households utilising the extra savings stemming from reduced energy expenditures to consume more energy than they previously had. Whereas this may seem counterintuitive, households living in a precarious state often only heat parts of their dwelling (e.g., bedrooms). Hence, the extra savings are spent on ameliorating overall living conditions (Jones et al., 2016). From a macroeconomic perspective, a country's fiscal position can be improved by reducing government expenditures, such as energy related subsidies, allowing more room for public investments focused on other segments. A higher energy efficiency would entail lower energy related subsidies (Omić, 2019). Lastly, an increased efficiency can also improve the citizen's wellbeing. As shown by Thomson, Snell, & Bouzarovski (2017), non-optimal living conditions dictated by energy poverty are related to medical issues, such as cardiovascular diseases, worsened mental health and cold-weather related mortality.

Figure 2.2: Low-quality dwellings correlated with energy poverty (Omić, 2019).

2.2.2. The Socio-Economic and Socio-Political Nature of Household Energy Efficiency

The buildings sector accounts for around 40% of the total energy consumption within the EU and 36% of energy-related greenhouse gas emissions (European Commission, 2020a). During the most critical phases of the COVID-19 pandemic, homes acquired even more importance, with people seeing their mobility being restricted. This exacerbated several issues related to buildings. These include high energy expenditure and consumption, low energy efficiency, low thermal insulation and poor living conditions. Within the EU, 85% of the buildings were constructed before 2001 (European Commission, 2020a). A considerable share of these buildings was constructed post-world war, thus in a period of high necessity in which efficiency was often not regarded as crucial. Hence, leaving a burden for future generations. Furthermore, it is envisioned that 85-95% of the buildings currently in use will still be present in 2050 (European Commission, 2020a). Therefore, an improvement of the energy efficiency of these buildings must happen in tandem with the refurbishment of existing constructed dwellings. The European Commission, in its Climate Target Plan 2030, set cutting net greenhouse gas emissions within the EU by at least 55% compared to 1990 by 2030 as one of its objectives (European Commission, 2019). To achieve this target by 2030, the EU needs to reduce buildings' greenhouse gas emissions by 60%, energy consumption for cooling and heating by 60%, and total final energy consumption by 14% (European Commission, 2020a).

Whereas all European countries are affected by energy inefficient dwellings in the residential sector, every country presents different characteristics. Even when analysing one specific region such as the Mediterranean, country-specific socioeconomic factors and climate conditions do not allow for a simple comparison (Serra, 2016). Final household energy consumption is affected by several factors, including energy availability, dwelling size, dwelling construction age, dwelling type, urbanization rates, climatic conditions and appliances standards, to name a few (Serra, 2016). To understand how national socioeconomic factors affect the final energy consumption, one can consider the overcrowding rate as an example. In 2012, the average overcrowding rate in Europe was 17%; whereas in Italy, Croatia and Serbia it was 26.2%, 44.4% and 54.3% respectfully (Serra, 2016). One pattern found by Serra (2016) in Mediterranean countries was that, even when analysing newer buildings, in several instances the national standard of energy efficiency did not match the minimum requirements delineated by the EU. Indeed, it is up to the individual country to enforce regulations and promote policies. The rate at which this is done differs from country to country, often dictated by the national socio-political and socio-economic conditions.

2.2.3. Energy Efficiency Among Serbian Households

The buildings sector represents the largest final consumer of energy in Serbia and the Western Balkans (Energy Community, 2021). The reason being the presence of energy inefficient buildings but perhaps even more importantly, inefficient house appliances. In Serbia, 59% of buildings were constructed before 1962 (Robić, 2016). Individual heaters, such as stoves and ovens, are the most popular heating devices throughout the Western Balkans region (RES Foundation, 2022). In addition, biomass is the most utilised fuel in household energy balances. It is estimated that more than 125,000 newly made solid fuel burning appliances are sold annually in the region, for an economic value of more than 38 million euros (RES Foundation, 2022). These devices are not compliant with European eco-design directives, essentially meaning that every year thousands of households invest in inefficient and outdated appliances, further worsening their finances and locking themselves in the infamous "vicious cycle of energy poverty". In Serbia, it was found that biomass is the most utilised fuel for space heating, presenting a share of 45.7% (Eurostat, 2021). However, amongst vulnerable consumers, this number increased up to 69.7% (RES Foundation, 2022). Furthermore, 38.5% of socially vulnerable households utilise the same device for heating and cooking (RES Foundation, 2022). Therefore, there is a need to both refurbish existing buildings while contemporarily replacing inefficient housing appliances.

As committed by the contracting parties in the *Green Agenda for the Western Balkans*, energy efficiency should become the "first fuel". Nonetheless, the pace at which these countries are transitioning towards the set energy efficiency objectives is still rather slow (Energy Community, 2021). As part of the *Economic Investment Plan for the Western Balkans*, the European Commission has been greatly helping the whole region. The previously mentioned plan has as its main objectives to triple energy saving in existing buildings, triple the rate of renovation and refurbishment of existing buildings, and achieve close to zero energy consumption in the newly constructed buildings (Energy Community, 2021). Serbia managed to achieve its energy efficiency 2020 target with regards to the reduction of energy consumption (Energy Community, 2021). With regards to energy efficiency in buildings specifically, Serbia invested approximately 105 million euros in the period between January and May 2021. This represents a considerable increase, considering that in the last decade (2010-2020) Serbia had spent a total of 455 million euros (Energy Community, 2021). Nonetheless, to reach the energy efficiency goals in the buildings sector, it is estimated that an extra 1636 million euros of investments are needed (Energy Community, 2021).

2.3. Low-income Household Groups

2.3.1. The Relationship Between Income and Energy Poverty

The term *low-income group* is commonly used to describe the strait of society located in the lower part of the income spectrum of a given country. A quantitative way of doing this is by dividing the national income dataset into deciles, meaning in 10 equally large subsections. Thereafter, low-income groups can be defined as those people pertaining to the lowest decile, or the lowest 2 or 3 deciles depending on the required definition and given problem set. Low-income groups must not necessarily be delineated purely in terms of financial capabilities. Nonetheless, the economic sphere manages to encapsulate various factors. Indeed, as discussed in previous sections, low-income groups are the ones most affected by energy poverty and household energy inefficiency (Deller & Waddams Price, 2018; Deller et al., 2021). The rates of energy poverty found in the lower 20% of the income distribution in Europe were found to be from two to six times greater when compared to the national averages (Figure 2.3). Low income has been regarded throughout the literature as the principal cause for energy poverty (Santamouris, 2016; Ürge-Vorsatz & Tirado Herrero, 2012). Citizens located in the lower part of the income spectrum are often relegated to non-profit or social housings, located in neighbourhoods presenting inefficient buildings, characterised by low thermal insulation (Filippidou et al., 2019). Inevitably, the income level affects the amount of capital assigned for paying energy services, the level of energy consumption and ultimately the ability to keep the household warm. Filippidou et al. (2019) related the ability to keep ones dwelling warm and the income levels of the population, divided in deciles (Figure 2.4). The figure clearly illustrates how lower income groups present more difficulties in warming their houses compared to the rest. Nonetheless, economic and energy poverty do not overlap completely. This has been also shown by unsuccessful subsidies targeted exclusively at lowering energy prices in an effort to reduce energy poverty (Ürge-Vorsatz & Tirado Herrero, 2012). Without implementing energy efficiency improvement measures, lower income households, due to the temporarily-reduced energy prices, devote their earnings to other services or needs, consequently locking themselves in the vicious cycle of energy poverty (Filippidou et al., 2019; Omić, 2019). Therefore, energy poverty cannot be analysed and tackled by considering only income levels as it is a socioeconomic issue. Nonetheless, low-income groups give a very clear indication of the most affected strait of society by energy poverty.

The part of the population which, after analysing economic and socio-demographic indicators, is found to be more prone to be energy poor, can be defined as the *vulnerable groups* of the country (Robić, 2016). The latter encompasses various factors which give it a more holistic definition. It has been found in the literature that energy poverty is more recurrent in households inhabited by the elderly, by people presenting diseases or disabilities and by families with children (Bouzarovski, 2014; Legendre & Ricci, 2015; Liddell, 2009; Robić, 2016; Wright, 2008). It was found that single parent households are more susceptible to energy poverty compared to two-parent ones (Robić, 2016). In addition, recipients of social welfare are more prone to be energy poor compared to the rest of the population (Bouzarovski, 2014; Robić, 2016). Regional patterns were also found in Europe, once again delineating the Southern European region as more affected by energy poverty, particularly when considering multifamily apartment blocks (Bouzarovski, 2014). Nevertheless, it needs to be noted how affordability of services, and thus more generally income, is the common denominator of all these sociodemographic conditions. For example, generally, the elderly will face higher expenditures as they tend to spend more time indoors compared to the rest of the population. Similarly, single-parent households will have smaller incomes compared to two-parent ones.

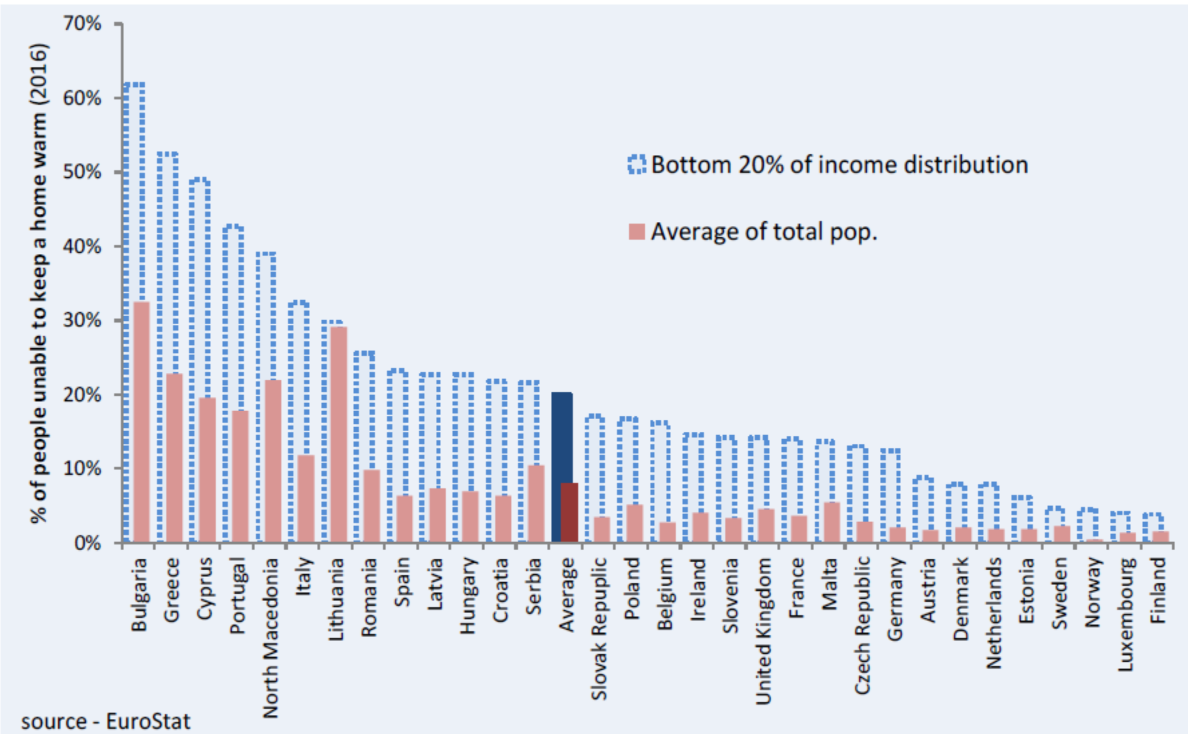


Figure 2.3: Comparison of ability to keep household warm between bottom of 20% income distribution and average population (Omić, 2019).

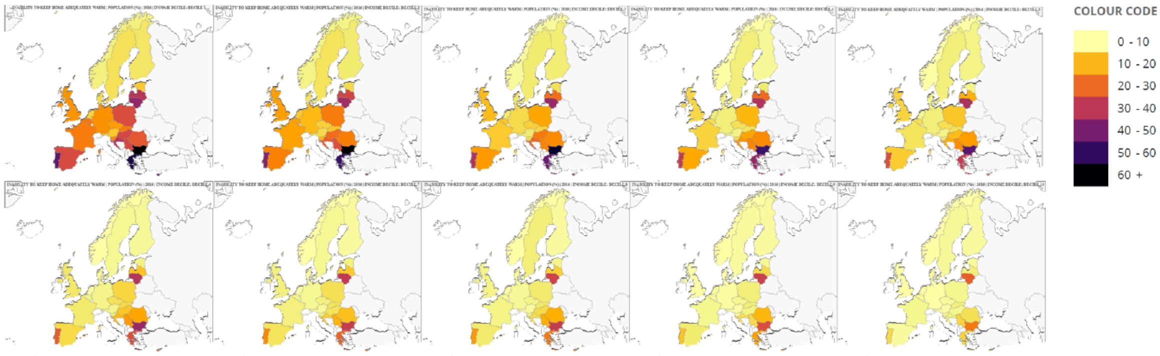


Figure 2.4: Correlation for European countries between inability to keep household warm and represented income decile, with the top left picture representing the first one and the bottom right the tenth one (Filippidou et al., 2019).

2.3.2. Institutional Differences Across Europe

Due to the specific national and regional socio-demographic and economic differences, it is not possible to define a definition of *vulnerable consumers* or *groups* for the EU (Robić, 2016). Nonetheless, several directives have been put in place to delineate common guidelines (Ban et al., 2021). According to Directives 2009/72/EC and 2009/73/EC set by the European Commission, each member state and/or contracting party needs to define guidelines and the concept of vulnerable consumers related to energy poverty (among other things) (European Union, 2009a,b). Ten years later, in Article 28 of Directive 2019/944/EU, it was specified that the vulnerable consumers concept may include "income levels, the share of energy expenditure of disposable income, the energy efficiency of homes, critical dependence on electrical equipment for health reasons, age or other criteria" (European Union, 2019). Additionally, in Article 29 of the same directive it is mentioned how each member state and/or contracting party should have a set of indicators and criteria that define energy poverty (European Union, 2019). These directives have as main goal to try to develop a common ground in the EU with regards to energy poverty and all the affected segments of society. At the same time, they give each state the freedom and possibility to define and delineate policies according to their specific national and social characteristics.

The definitions adopted by various countries in Europe to describe *low-income groups* vary but however present some common patterns (Baptista & Marlier, 2020). In the majority of European countries, subsidies directed at specific societal groups to facilitate their access to essential services are based on two main types of indicators. The first one being income criteria, utilised to determine which households are eligible for means-tested benefits; and the second one being eligibility criteria, used to provide housing-related benefits or allowances to households (Baptista & Marlier, 2020). However, these eligibility criteria are often based on means-tested benefits. For example, in the Netherlands, any household whose income is lower than the *sociaal minimum* (social minimum) is entitled to receive social assistance and benefits (Baptista & Marlier, 2020). This is a clear example of income criteria utilised to determine low-income, or vulnerable, groups. However, minimum income (MI) schemes were found to also present some difficulties. For example, in Croatia, to be eligible to be a vulnerable consumer of energy, one must be also a recipient of the MI scheme; de facto limiting the vulnerable consumers to those strictly financially poor (Baptista & Marlier, 2020). In Italy, depending on the essential service being needed, different means-testing conditions apply; however, all based on one single indicator of economic conditions (Baptista & Marlier, 2020).

In Serbia, no national definition of low-income groups in the context of access to services is present (Pejin Stokić & Bajec, 2020). People pertaining to lower income groups are considered to be those that receive the Financial Social Assistance (FSA) and child benefits (Pejin Stokić & Bajec, 2020). In 2019, the monthly income limits for eligibility of these two services were respectfully EUR 72 and 77,7 (converted from national currency) (Pejin Stokić & Bajec, 2020). However, following the Act on the Energy Sector (145/14), the status of vulnerable energy buyer was recognised to households that due to social status or health conditions have the right to, under specific conditions, provision of energy (Robić, 2016). This status may be acquired by households at their own request if it satisfies two main conditions (Robić, 2016). Namely, if it is part of the lowest-income groups (considering earnings per household member and immovable property) and if it does not own any other residential unit except the one being inhabited. Finally, the vulnerable energy user status can also be obtained if the interruption of electricity or natural gas supply would hamper the life or health of a household's member (Robić, 2016). Therefore, the criteria used to define low-income groups are mainly related to income criteria but also health status. However, social benefits result in pure economic subsidies. Thus, running the risk of reinforcing the energy poverty vicious cycle.

2.4. Indicators Utilised to Measure and Analyse Energy Poverty

Various indicators exist and are used to study, analyse and compare energy poverty. These indicators can be broadly condensed into three main subgroups, namely: (i) indicators that analyse energy expenditure rates, or shares; (ii) indicators that report the households' ability to keep adequate temperature (and thus living experience); and (iii) proxy indicators, such as ratios between the achieved domestic energy services and some pre-defined standards (Deller, 2018; Tirado Herrero, 2017). A graphical overview is given in Figure 2.5. The first two subgroups are the most established and commonly used and can also be termed as *objective* and *subjective* indicators (Deller et al., 2021; Tirado Herrero, 2017; Waddams Price et al., 2012). These will be further touched upon in the next subsections. Income/expenditure-based indicators are constructed on factual data regarding the spending and earnings of households, and thus termed as objective. On the other hand, subjective indicators are gathered by directly questioning the households concerning their living conditions and their assessment of it (Tirado Herrero, 2017). Proxy indicators depend on the previous two, with the validity of the former being stronger when the statistical relationships between the other indicators is more robust (Deller, 2018). These are more attractive when targeting specific policies.

A fourth typology of indicator, or better approach, can be delineated known as the *direct measurement approach*. What this entails is directly measuring the level of warmth in households to understand whether these are receiving adequate energy services (Thomson, Bouzarovski, & Snell, 2017). Hence, an optimal temperature level needs to be decided. This may indeed vary between countries but usually a range outlined by the World Health Organization is considered (WHO, 1987). However, utilising temperature as an indicator entails also considering personal preferences as indicators, with a potential *social desirability bias* (Healy, 2004). Furthermore, households connected to central district heating (common in Central and Eastern Europe), do not always have the possibility of selecting with detail their indoor temperature (Tirado Herrero & Ürge-Vorsatz, 2012). The direct measurement approach has rarely been used in the literature, mainly due to the technical and physical difficulties of performing such process but also due to privacy concerns. Therefore, this method has never been applied at the continental level (Thomson, Bouzarovski, & Snell, 2017).

Throughout the literature, no single "official" or "best" indicator was delineated. Indeed, depending on the indicator used, different insights can be gained pertaining to energy poverty (Deller, 2018; Deller et al., 2021; Tirado Herrero, 2017; Waddams Price et al., 2012). Essentially, the indicators used can be rather case-specific. Therefore, these different metrics should be rather triangulated and combined to gain a more holistic understanding of the issue at hand. In addition, when analysing objective or subjective indicators separately, various incongruencies and challenges can be found (Tirado Herrero, 2017).

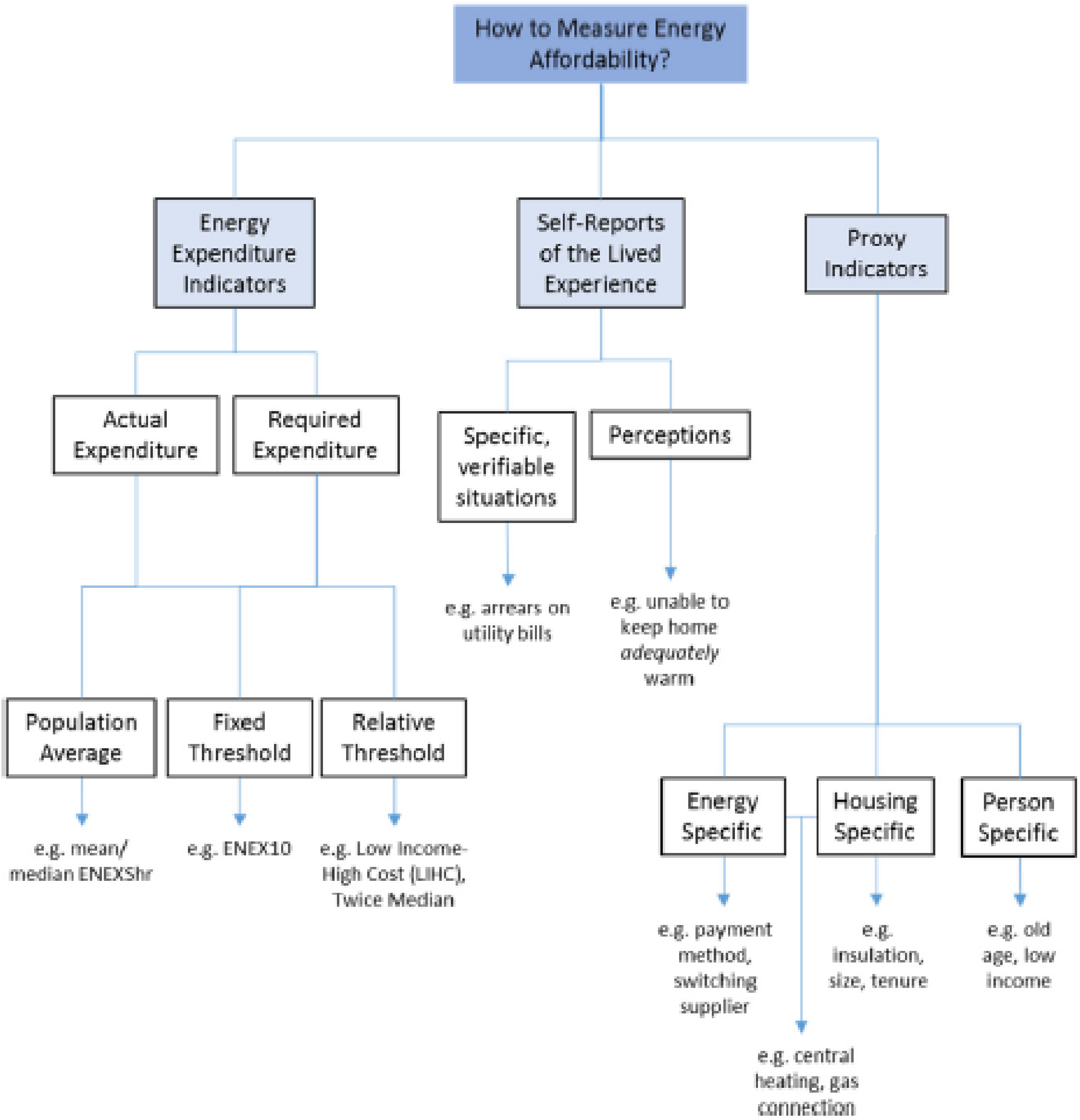


Figure 2.5: Graphical overview of indicators available to measure energy poverty (also known as energy affordability) (Deller, 2018).

2.4.1. Objective Indicators

Boardman's (1991) definition and consequent indicator for fuel poverty as a household that spends more than 10% of its income on energy expenditures (ENEX) is perhaps the most notorious and used metric, together with LIHC proposed by Hills (2012). These two have been used by the UK government as official indicators (Deller et al., 2021). These metrics treat energy poverty as a strictly economic phenomena and fail to capture other aspects not directly related to income. Indeed, the risk related to ENEX shares indicators is that of individuating people with low incomes rather than those suffering from energy poverty (Deller & Waddams Price, 2018). However, being these the first metrics to be utilised in the UK and, being the latter one of the first countries to tackle the energy poverty problem, these metrics have been and still are being utilised throughout Europe to assess energy poverty. As previously mentioned, utilising same indicators for different countries will not always be beneficial, but these are not the only issues encountered with so-called objective indicators.

Income/expenditure-based indicators present a series of issues and challenges. Firstly, due to the narrative presented by Boardman (1991), where an emphasis was put on delivering affordable warmth to cold dwellings, even today space heating is the most considered energy service and embedded in official UK indicators (Tirado Herrero, 2017). However, a more balanced attention should be devoted to all subcategories of services, namely also: water heating, cooking, space cooling (in countries where it is needed), light and appliances (Simcock et al., 2016). Nonetheless, these indicators offer good insights in expenditure rates of all energy services. Although, poor households could reduce their cooking and/or showering habits as to reduce expenditures, which would not be seen as a precarious situation when analysing purely expenditure indicators (Tirado Herrero, 2017). In addition, households presenting same income levels may present different welfare outcomes. Households with more family members will be less affected due to economies of scale, as energy expenditure is not strictly linear and proportional per household member (Tirado Herrero, 2017). To counter this issue, income equivalisation methods have been put in place and are now common practice. Nonetheless, these methodologies still may fail to highlight regional differences, or differences between household typologies and years (OECD, 2013).

Objective indicators often involve the utilisation of thresholds, such as the one devised by Boardman (1991) in the UK. Tirado Herrero (2017) divides them into three main subgroups. Firstly, indicators aimed at individuating households suffering from energy burden or excessive expenditures. Secondly, a household can be termed energy poor when its residual income left after paying energy expenditures is below a monetary poverty line, such as the LIHC indicator. Thirdly, indicators devoted to localising households with low energy consumption, which could indicate forced energy expenditure reductions and thus discomfort. However, due to the different possibilities when it comes to setting thresholds, these may provide discrepancies. This is also illustrated by Deller (2018), who further argues how emphasis on high-level energy poverty metrics should not be aimed for, as the resources of energy poverty alleviation and how these are allocated are not considered when focusing purely on numerical indicators. Figure 2.6 illustrates different energy poverty numbers depending on the threshold, however the economic situation and living experiences of households remains the same.

Energy expenditure rates can provide differing information and results depending on whether these are actual or required ones. As previously mentioned, poor households tend to ration their consumption of energy. Thus, if one were to analyse the actual energy expenditure, it would not capture the rationing element and consequently a proportion of energy poor households. Nonetheless, such data is the most easily accessible one as it is present in the national Household Budget Surveys (HBS) and it is thus utilised in many official indicators throughout nations in Europe (Tirado Herrero, 2017). To counter this issue, indicators of "hidden" energy poverty have been proposed by Trinomics (Rademaekers et al., 2016). It must be also noted that actual spending on energy services tends to be lower than the required amount, especially in lower income households, as found in 2009 for England (Hills et al., 2011) (Figure 2.7).

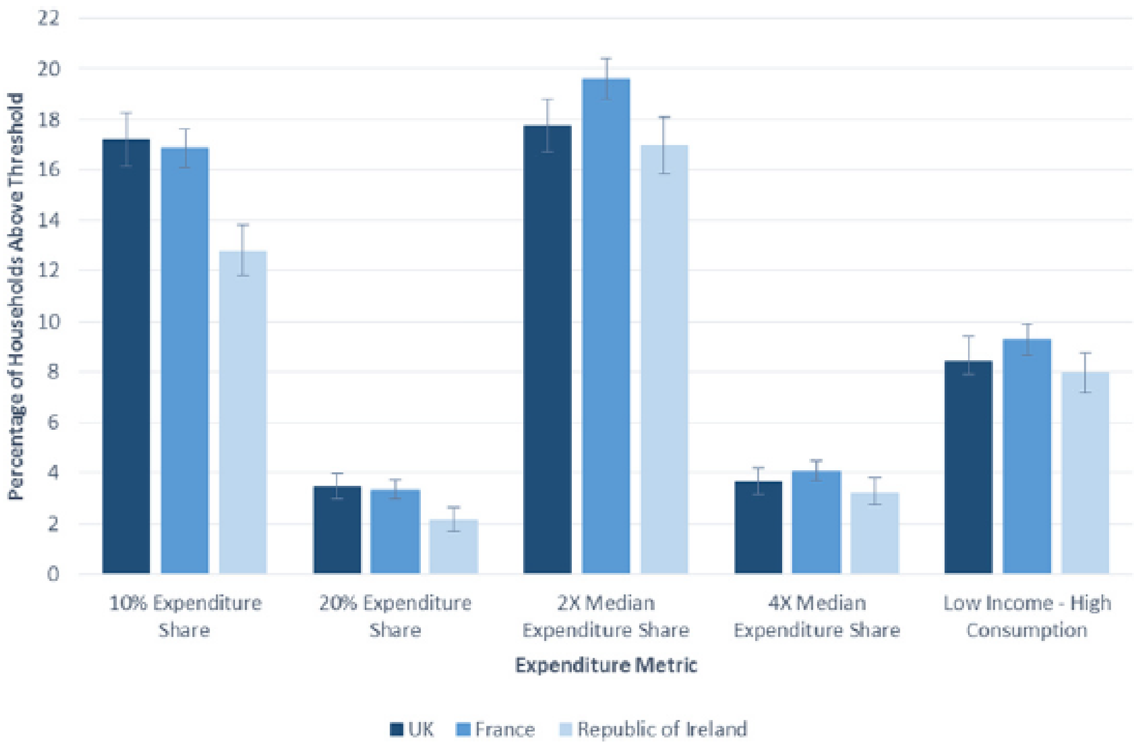


Figure 2.6: Illustration of percentage of households classified as energy poor depending on different thresholds in the UK, France and Republic of Ireland (95% confidence interval is shown by the whiskers) (Deller, 2018).

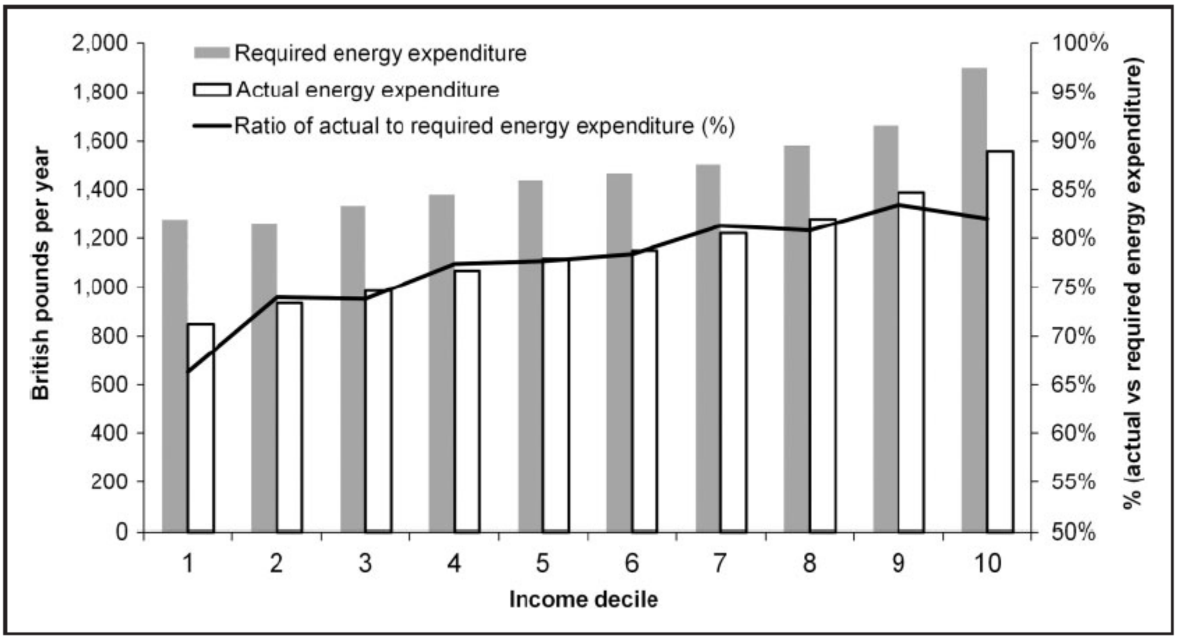


Figure 2.7: Required vs. actual energy spending in England, 2009 by gross income groups (Hills et al., 2011).

2.4.2. Subjective Indicators

The European Union Statistics on Income and Living Conditions (EU-SILC) is the most utilised and researched subjective indicator, with various scholars utilising it in their publications (Thomson, Bouzarovski, & Snell, 2017; Tirado Herrero, 2017; Waddams Price et al., 2012). This indicator is obtained by directly asking the household residents whether they feel unable to pay household expenditures or present arrears on utility bills, together with other metrics that may suggest energy poverty (Deller, 2018). Whereas these typologies of questions allow for only binary answers, further quantitative value may be achieved from them. Indeed, by gathering self-reported subjective data, yearly increases in trends can be seen, highlighting an increase in intensity and severity of energy poverty. Tirado Herrero (2017) shows this for Spain, indicating how a higher prevalence of households reporting arrears in utility bills over the years was not only happening, but was fuelled by an increase in the severity of payment delays (Figure 2.8). Subjective indicators manage to consider the temporal variations associated to the perception of energy poverty; as by directly asking the residents, actual perceptions and socially perceived necessities will be considered (Tirado Herrero, 2017). Taking into account that energy poverty is a sociodemographic and economic issue, data such as the EU SILC allows for an analysis of the phenomenon that is not purely monetary based, capturing factors such as social exclusion and material deprivation (Healy & Clinch, 2002). Another advantage, especially in countries lacking comprehensive HBSs, is the simplicity of the data gathering process. In addition, such data also allows for comparison between countries (Thomson, Bouzarovski, & Snell, 2017).

Indicators relying on self-reported data have received criticism due to their very subjective nature. Households tend to under-declare the severity of difficulties they encounter in their daily lives, ranging from thermal discomfort to income levels, with the latter being often underreported in HBSs (Tirado Herrero, 2017). Underreporting may be due to several reasons, with the most common ones being due to a feeling of shame in admitting financial difficulties (both thermal discomfort and income level) or due to the household being satisfied with, or used to, having lower living standards (e.g., rationing energy services) (Eurostat, 2009). This unwillingness to report living discomfort is also known as the “denial of reality bias” (Nussbaumer et al., 2012). This can result in energy poor households, when considering objective indicators, that do not result as such when being analysed by consensual ones (Thomson, Bouzarovski, & Snell, 2017). In addition, cross-country comparisons become difficult due to cultural differences in what is considered thermal comfort (Thomson, Bouzarovski, & Snell, 2017; Tirado Herrero, 2017). When not taken into account, this can result in households being termed as energy poor due to their lifestyle preferences rather than living discomfort (McKay, 2004). Other concerns include the under-representation of certain population segments, such as the homeless and difficult-to-reach affluent; sampling sizes and strategies that are defined on national levels and finally temporal scales, as the data gathered is a snapshot (a month or a week) out of a given year (Tirado Herrero, 2017).

The overlap between the two types of indicators has not been always satisfactory. Deller et al. (2021) found that, when considering two expenditure based indicators (ENEX and LIHC) and one subjective (self-reported, inability to afford adequate warmth (IAAW) in the home) indicator, only 5% of those recognized as energy poor in the UK also self-reported as such. Of those self-reporting thermal discomfort, less than 45% were identified by using the LIHC indicator (Deller et al., 2021). Only 1.1% of the households resulted energy poor according to all three indicators simultaneously in a particular year (Deller et al., 2021). The three indicators also show different general levels of energy poverty in the country (Figure 2.9). Households presenting older people (aged 65 or over) were found to have a lower probability of self-reporting as energy poor, notwithstanding having a higher probability of resulting as such when considering expenditure based indicators (Deller et al., 2021). This can be seen both as unwillingness of the elderly to report unsatisfactory living conditions or as lower temperatures being perceived as adequate by the elderly. Both are social factors that can hamper or improve the reliability of subjective indicators. Nonetheless, the authors refrain from defining one of the two indicators as better (Deller et al., 2021). Similar studies were also performed in other countries (Agbim et al., 2020; Fizaine & Kahouli, 2019; Meyer et al., 2018; Ntaintasis et al., 2019; Papada & Kaliampakos, 2016; Phimister et al., 2015; Scott et al., 2008; Sokołowski et al., 2020).

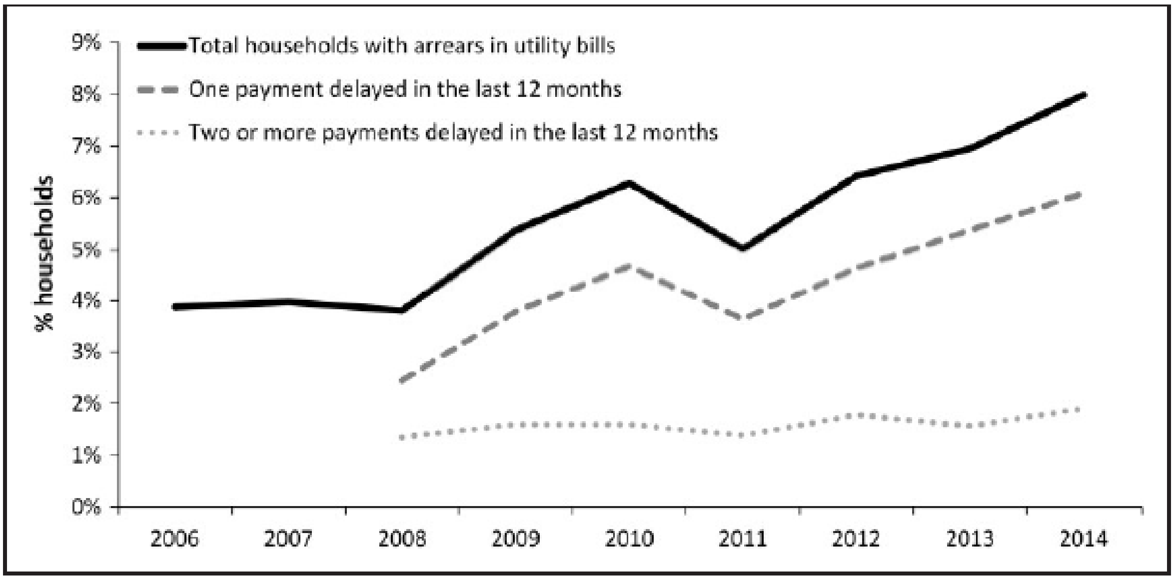


Figure 2.8: Arrears in utility bills (EU SILC) in Spain (2006-2014) disaggregated by yearly payment delays (Tirado Herrero, 2017).

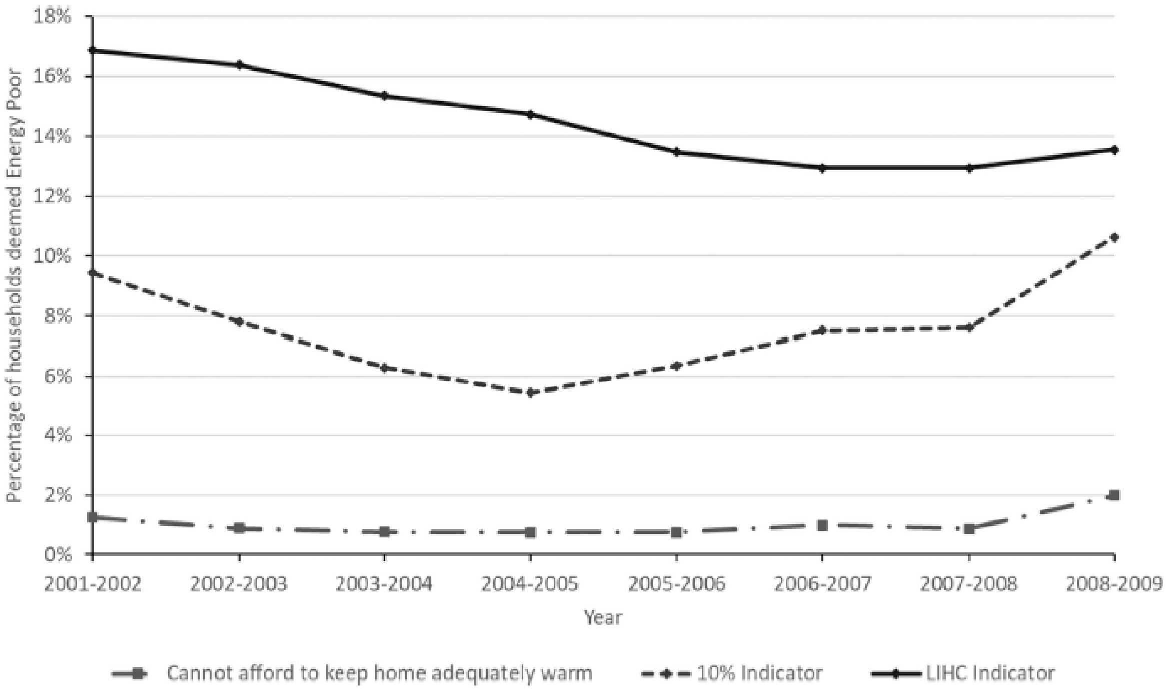


Figure 2.9: Alternative UK energy poverty rates according to different indicators (Deller et al., 2021).

2.4.3. Indicators Utilised Across Europe

Due to the socioeconomic nature of energy poverty, delineating an indicator capable of accurately representing the latter on a European level has proven to be difficult. Deller (2018) analysed energy expenditure shares across member states of the EU, finding various substantial differences between them. The most noticeable discrepancies were found between the EU15 and the New Member States (NMS). When analysing the ENEX shares in 2010, the EU15 states had an average value of 4.6%, while among the NMS this was more than double (10.9%) (Deller, 2018). This already goes to show how Boardman's threshold of 10%, as was for Serbia, would prove to be rather problematic when analysing

NMS (mostly represented by Eastern European countries). Indeed, such a metric that identifies severe fuel poverty in one country would at the same time cover a larger spectrum of the population in another country. This difference in devoted income to expenditure shares is also dictated by lower average nominal incomes and lower quality housing (Deller, 2018). In addition, when considering the EU, such a scenario would suggest for policies involving resource transfers from "better off" member states to those presenting higher rates of energy poverty. This would undoubtedly find resistance among local political parties, as every country can regard different energy inequality levels as being acceptable or not. The energy divide among EU states shows doubts about the possibility and efficacy of adopting common pan-European expenditure rate indicators. This goes in line with the European Commission's Vice-President Maroš Šefčovič's position of not adopting a common EU definition of energy poverty and /or indicators to measure it (Teffer, 2016). Due to this lack of harmonization between member states, the Eurostat does not release pan-EU HBSs, but rather researchers need to rely on HBS pertaining to individual countries (Thomson, Bouzarovski, & Snell, 2017). This further shows a lack of data availability at a pan-EU level, often paired with a lack of resources at a national level. Thomson, Bouzarovski, & Snell (2017) advocate for a shift in energy poverty measurement, by developing a new pan-EU household survey for monitoring energy poverty at the pan-European level, but also national and regional. Similarly, Thomson et al. (2016) argued that having a definition of energy poverty common to all member states would be beneficial in clarifying the term's meaning and prominence throughout Europe. Whereas Deller (2018) stands in contrast with such notion, the scholars do find common ground on the fact that by increasing the availability of pan-EU data and comparison between data from different countries the EU could enhance policy synergies across member states.

2.5. Energy Policy Framework in the EU

Energy poverty received legal recognition in 2009 by the EU with the completion of the Third Energy Package (European Commission, 2009). Nonetheless, energy poverty-related issues had already been acknowledged by the EU in 2001 (Bosseboeuf et al., 2021). The legal recognition of the problem was perceived as a wake-up call for the majority of Member States (MS). This also resulted in an increase of interest and academic publications in the field of energy poverty. Fast forward 10 years from the Third Energy Package and energy poverty became a policy focus at the EU level with the delineation of the "Clean Energy for all Europeans" Package (European Commission, Directorate-General for Energy, 2019). The latter demands MSs to undertake "appropriate" action to tackle energy poverty once the issue has been properly identified. This encouragement and promotion of energy poverty policies at MS level was further strengthened through the Recommendation on energy poverty (EU) 2020/1563, part of the Renovation Wave package. Essentially, the latter further promotes the delineation of renovation strategies focused on tackling energy poverty and household energy efficiency, as part of a wider goal to improve general housing conditions for all residents (Bosseboeuf et al., 2021).

The "Clean Energy for all Europeans" Package aimed to reform the energy sector of the EU by implementing new directives targeted at specific aspects of energy and sustainability. However, directives were not the only means involved in the new package. As a result of the new legislative framework, the EPOV was officially launched (Filippidou et al., 2019). This was intended to help the MSs by providing reliable data pertaining to energy poverty. In fact, as written in the Long Term Renovation Strategy, MS were obliged to address and report energy poverty (Filippidou et al., 2019). Such binding schemes obliging MSs to monitor and report energy poverty really pushed forward the recognition of the latter as a primary issue. The need for tangible and detailed energy policy interventions was also reflected in the delineation of two directives focused respectively on energy efficiency and the performance of building stocks from an energy perspective.

The Energy Efficiency Directive (EED) is aimed at promoting long term energy savings while at the same time reducing costs for consumers (Filippidou et al., 2019). The directive was first adopted in 2012 and then amended in 2018. The EED, or more specifically Article 7 of the latter, obliges MSs to achieve a predefined amount of end-use energy savings (Tzani et al., 2021). Thus, the directive was revised as these pre-set goals can also vary. Every MS delineates its expected energy savings as part of its National Energy Efficiency Action Plan (NEEAP). In addition, the EED suggests that these energy savings and improvements should be more focused towards low-income households (Filippidou et al., 2019). All the targets set under Article 7 are spread over a time range. The first time period was from 2014 until 2020, whereas the current second time period which started in 2021 will continue until 2030 (Tzani et al., 2021). Every MS needs to present verified and state-of-the-art systems for measuring, controlling and verifying energy efficiency practices. As of 2019, in the context of Article 7, 16 Energy Efficiency Obligation Schemes (EEOS) were put in place throughout Europe (Broc et al., 2020). These policy instruments help obligated parties to achieve energy saving requirements. Regulators set energy saving goals to be achieved but leave it up to the obligated parties to choose the methods by which to accomplish these (Rosenow et al., 2019). Other aspects touched upon as part of the directive involve energy audits and energy management systems (Article 8), which should be promoted and utilised by MS. Issues related to the metering and billing of individual energy consumption are considered in Articles 9,10 and 11 of the EED.

The Energy Performance of Buildings Directive (EPBD) is aimed at ameliorating the buildings stock from an energy perspective, making these more efficient and sustainable. Indeed, energy poverty can be mitigated by improving household energy efficiency. Whereas the directive was first introduced in 2002, it was updated various times. In its 2010 recast, additional guidelines were implemented for Energy Performance Certificates in dwellings, a core element of the EPBD first introduced in Article 4 in 2002 (Tzani et al., 2021). When analysing the 2010 recast of the EPBD (Directive 2010/31/EU), Article 9(1) states two objectives to be achieved, namely ensuring that: “(a) by 31 December 2020, all new buildings are nearly zero-energy buildings; and (b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings” (European Commission, 2013, p.4). In the 2016 progress report written by the European Commission’s in-house science service, it was affirmed that progress was seen in MSs if compared to the previous report. Nonetheless, not all MSs managed to achieve the set objectives (D’Agostino et al., 2016). The directive was further revised in 2021. The revision of the EPBD was part of the “Fit for 55” package, which aims to achieve a zero-emission building stock by 2050 (European Commission, 2021c). The EPBD is considered as an essential element to achieve carbon neutrality goals. The revised directive also pushes for more investments in the building sector. The EPBD is also crucial to achieve the energy efficiency goals set in the EED. In fact, various directives of the EU are delineated and calibrated to work together. For example, the EPBD also boosts the utilisation of renewables in households, which is one of the objectives of the Renewable Energy Directive (RED). Finally, the EPBD introduces a legal basis for the phasing out and national ban of fossil-fuel powered boilers (European Commission, 2021c).

2.5.1. European Green Deal

The European Green Deal was presented by the European Commission to the EU institutions on December 11th, 2019 (European Commission, 2019). The European Parliament expressed its support for the Green Deal in January 2020, however pointing out that stronger actions needed to be taken. As expressed by the European Commission, the Green Deal “aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use” (European Commission, 2019, p.2). Whereas the latter two can be considered as the main objectives of the policy strategy (not a law in itself), the Green Deal is constructed by eight key areas which can be seen in Figure 2.10. When considering energy specifically, the policy mix focuses on three key principles. The first one is to ensure a secure, affordable and clean EU energy supply. Secondly, develop a fully interconnected, digitalised and integrated EU energy market, allowing for a circular European economy. Thirdly, prioritise energy efficiency, renovating and improving the buildings in a resource and energy efficient way (European Commission, 2019).

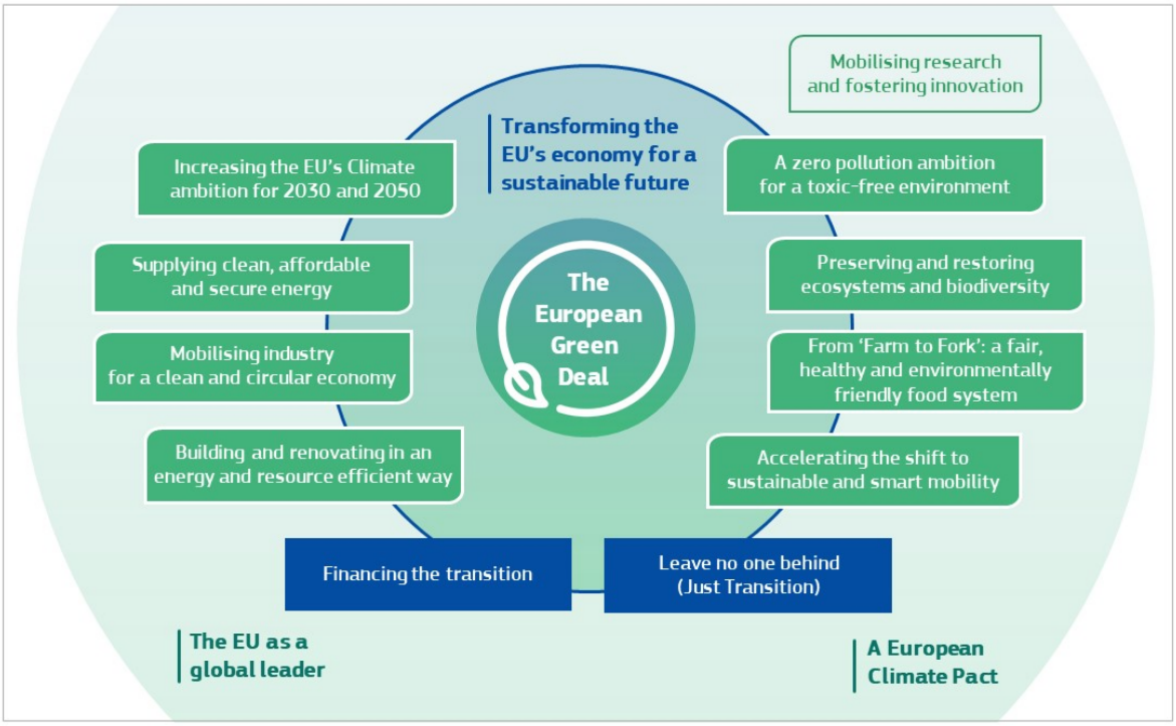


Figure 2.10: Eight key areas of the European Green Deal (European Commission, 2019)

2.5.2. Fit for 55 Package

The "Fit for 55" package was adopted and presented by the European Commission on July 14th, 2021. The latter is a set of calibrated and interconnected proposals, also containing revisions of several already existing directives, such as the previously mentioned EED and EPBD. The name stems from the EU's aim of reducing its net greenhouse gas (GHG) emissions by 55% by the year 2030, compared to its 1990 levels. This was increased from the previous target of 40% GHG emissions reduction. Furthermore, the EU aims to be the first carbon neutral continent by 2050 (European Commission, 2021b). In addition. the package increased the target for the share of renewables in the final energy mix to 40% instead of 32% by the year 2030 and the target for energy efficiency in final energy consumption to 36% instead of 32.5% and to 39% for primary energy consumption. These became obligations once laid down in the first European Climate Law (July 29th, 2021) (European Commission, 2021b). The legislative package aims to deliver and ensure a green, fair and competitive transition by 2030. Thus, to do so, the proposed policy mix is a careful balance between targets, standards, pricing and support measures (European Commission, 2021b). Minimum Energy Performance Standards (MEPS) were delineated in the package, aimed at reducing energy poverty and improving energy efficiency of the residential sector, considering possible socio-economic differences. In addition, the EU Emissions Trading Scheme (EU ETS) was revised, to tighten and reduce the allowed quantity of emissions (or "cap") and to create a new separate scheme for the residential and transport sector. The package also includes and tackles other aspects and goals outlined in the European Green Deal. Following the Russian invasion of Ukraine on February 24, 2022, the European Commission decided to fasten the process of reducing its dependency from Russian fossil fuels. Thus, on May 18, 2022, the *REPower EU Plan* was presented (European Commission, 2022b). The latter envisions reducing its Russian energy dependence by fast-forwarding the green energy transition. As such, some of the targets presented in the Fit for 55 package were further updated. The energy efficiency target of achieving a 9% reduction in energy consumption by 2030 compared to the base year was updated to 13% in the new proposal (European Commission, 2022b). The target for the renewable energy share in 2030 was further increased to 45% from the previous 40%; envisioning a doubled rate of deployment of heat pumps (European Commission, 2022b). Additionally, as part of the *EU External Energy Strategy*, energy partnerships with Western Balkan countries will be further enhanced (European Commission, 2022b).

2.6. Research Questions

Energy poverty is a socioeconomic issue that affects different segments of society in different ways (Bouzarovski, 2018; Deller et al., 2021). Household energy efficiency represents a key element in combating energy poverty, which is also demonstrated by the directives outlined by the European Commission (Deller, 2018; European Commission, 2021c). No single best indicator for measuring energy poverty and household energy efficiency was found in the literature (Deller, 2018; Tirado Herrero, 2017; Waddams Price et al., 2012). Depending on the country being analysed, different indicators might be preferred, although it is good practice to consider both objective and subjective indicators in general (Bouzarovski, 2018; Tirado Herrero, 2017). The Western Balkans region is characterised by high levels of energy poverty and inefficiency, and so is Serbia (Bouzarovski & Tirado Herrero, 2017; Serra, 2016). There is a lack of coordination between different institutional bodies in the country in delineating structured plans and policies aimed at reaching energy transition goals (Energy Community, 2021; Young & Macura, 2020). Nonetheless, Serbia is one of the contracting parties of the Green Agenda for the Western Balkans and as such has declared its willingness to achieve sustainable goals delineated by the European Commission (European Commission, 2020b).

Performing a simulation-backed analysis of the available policy strategies in Serbia, delineating an optimal one to reduce energy poverty levels and improve household energy efficiency among low-income groups in Serbia, satisfying the sustainable targets set by the European Commission, represents a knowledge gap. Therefore, the present work aims to analyse and resolve such knowledge gap. To do so, a Main Research Question will be delineated, around which the whole report will be structured. The answer to it will also represent the final recommendation to the Ministry of Mining and Energy (Chapter 8). Namely, the Main Research Question is the following:

Main Research Question: *Which energy policy strategy should the Ministry of Mining and Energy implement in Serbia as to achieve household energy efficiency and energy poverty objectives set by the European Commission directed towards low-income groups?*

To facilitate the understanding and answering of the latter, four Sub-research Questions (SRQs) were delineated to guide the research process. Stemming from the literature review, it was understood that a deep understanding of the Serbian energy policy framework was needed. Essentially, the previously implemented policies, the ones being currently implemented, and the envisioned future ones and targets are needed to be known. In fact, without having a clear image of the policy, and thus institutional and legal framework in Serbia, proposed policies would risk being politically and socially unfeasible. Therefore, SRQ1 was delineated:

SRQ1: *Which energy policies, measures, and targets have been previously implemented in Serbia, which ones are currently being employed and which future ones are envisioned?*

Once the Serbian energy policy framework is understood and clearly portrayed (Chapter 4), household energy efficiency and energy poverty among low-income groups specifically can start being analysed. Whereas these were tackled holistically in the literature review, a more detailed analysis of the Serbian situation needs to be undertaken. Additionally, it is needed to know how household energy efficiency, energy poverty, and low-income groups are defined. Additionally, which type of indicators are being employed to define the latter. This calls for the delineation of SRQ2 to be answered in Chapter 5:

SRQ2: *What is the current status quo concerning household energy efficiency as well as energy poverty in low-income groups in Serbia, how are the latter defined and which indicators should be chosen to measure these?*

Having at hand all the previously mentioned elements, different policies can be delineated, proposed, and thereafter tested through the employment of a simulation model. Hence, firstly different energy policies to improve household energy efficiency and energy poverty among low-income groups in Serbia will be proposed. Thereafter, these will be tested by utilising a simulation model. Thenceforth, the initial results stemming purely from the simulation will be analysed and discussed. This will be done in Chapter 6, answering SRQ3 postulated as follows:

SRQ3: *Following a linear simulation, which policy mix (strategy) would result as optimal for Serbia to achieve the sustainable goals established by the European Commission?*

The feasibility of the proposed policies will have to be explored. Indeed, depending on the available resources, policy instruments/mechanisms, and policy framework certain proposals will result more feasible compared to others. Essentially, not only quantitative and technical aspects (e.g., final energy consumption) can be taken into account; but rather also qualitative factors such as the political framework and social impact of the proposed policies. This will be discussed in Chapter 7, responding to SRQ4 defined as follows:

SRQ4: *Which feasible policy instruments/mechanisms are available for Serbia to improve household energy efficiency as well as energy poverty in low-income groups and how much extra costs would this entail?*

3

Research Approach

To answer the postulated research question, an in-depth understanding of the specific characteristics of the issue being investigated is needed. A complex issue, such as household energy efficiency and energy poverty, needs to be explored in a multi-faceted way in order to then transpose it into its real-life setting. Crowe et al., (p.1) (2011) define the case study as “a research approach that is used to generate an in-depth, multi-faceted understanding of a complex issue in its real-life context”. In this particular case, a complex issue is being contextualized in a real-life setting within specific national and policy boundaries. Whereas the following study could be replicated in other countries presenting similar characteristics (e.g., bordering Balkan countries), the “natural” real-life context dictated by economic, national and socio-political factors will always remain unique. Hence, the research approach taken herein can be defined as an *intrinsic* case study (Crowe et al., 2011). The value of a case study approach is highly recognised in the field of policy (Crowe et al., 2011). The causal link and pathways resulting from the implementation of a given new policy initiative or directive can be better understood through the utilisation of a case study approach (Yin, 2009).

To analyse and delineate optimal policy recommendations, both qualitative and quantitative type of data and methodologies will need to be utilised. “Research in which the investigator collects and analyses data, integrates the findings and draws inferences using both qualitative and quantitative approaches or methods in a single study” (Tashakkori & Creswell, 2007, p.4) can be defined as mixed-methods research. When adopting such an approach to research, quantitative and qualitative methodologies are viewed as being complementary to each other (Jick, 1979). The advantage of utilising a mixed methods approach is that by analysing a phenomenon from different perspectives a unique variance can be uncovered, providing insights that would be otherwise neglected when adopting a single method approach (Creswell & Plano Clark, 2007). Another rationale for utilising such approach is that the limitations of one method are neutralised by the strengths of the other (Doyle et al., 2009). Creswell & Plano Clark (2007) distinguish several typologies of mixed methods research. In this specific case, an *embedded correlational* model will be utilised. The latter is employed when a quantitative design (e.g., simulation model), presenting embedded qualitative data, is utilised to further prove and explain the outcomes of the proposed correlational model (e.g., policy). In this case, qualitative data will be gathered before performing any quantitative simulations, and thus the type of methodologies will be employed sequentially. Indeed, integration will happen only at the interpretation phase (Doyle et al., 2009). This was also mentioned in the literature as *exploratory sequential design* (Guetterman & Fetters, 2018).

As previously highlighted, both a case study and mixed methods approach can be applied in this specific case. The two approaches present various similarities and the integration of the two has been discussed in the literature. Qualitative and quantitative data are analysed to gather a more holistic understanding of the issue when adopting a case study approach. Similarly, a more complete understanding is sought by mixing two methods in the second approach (Guetterman & Fetters, 2018). Simply put, mixed methods case studies enable the researcher to address broader or more sophisticated questions than one methodology alone (Yin, 2009). Guetterman & Fetters (2018) distinguish two ways of combining the two approaches: A mixed methods-case study design (MM-CS) or a case study-mixed methods design (CS-MM). In the former, the mixed methods study is considered as "parent" with the case study being conducted for the qualitative component. In the latter, "researchers employ a parent case study that includes a nested mixed methods design" (Guetterman & Fetters, 2018, p.902).

A case study-mixed methods approach will be utilised for the following study. The case study here proposed is delineating optimal policies concerned with household energy efficiency and energy poverty for the Serbian context specifically, making this thus the "parent" case study. Thereafter, mixed methods for analysing, collecting and combining qualitative and quantitative data will be employed. In this case, qualitative data will mainly comprise research about past, present and future policies and directives in both the Serbian and European context. But also, past research papers and academical knowledge in general. On the other hand, quantitative data will be gathered from several repositories to then perform specific scenario simulations. By merging the two methodologies, proposed policies (based on mainly qualitative knowledge) will be strengthened, or better will present numerical data, to support the delineation and proposal of these. A graphical overview of how the different sub research questions are connected within the chosen research approach can be found in Figure 3.1.

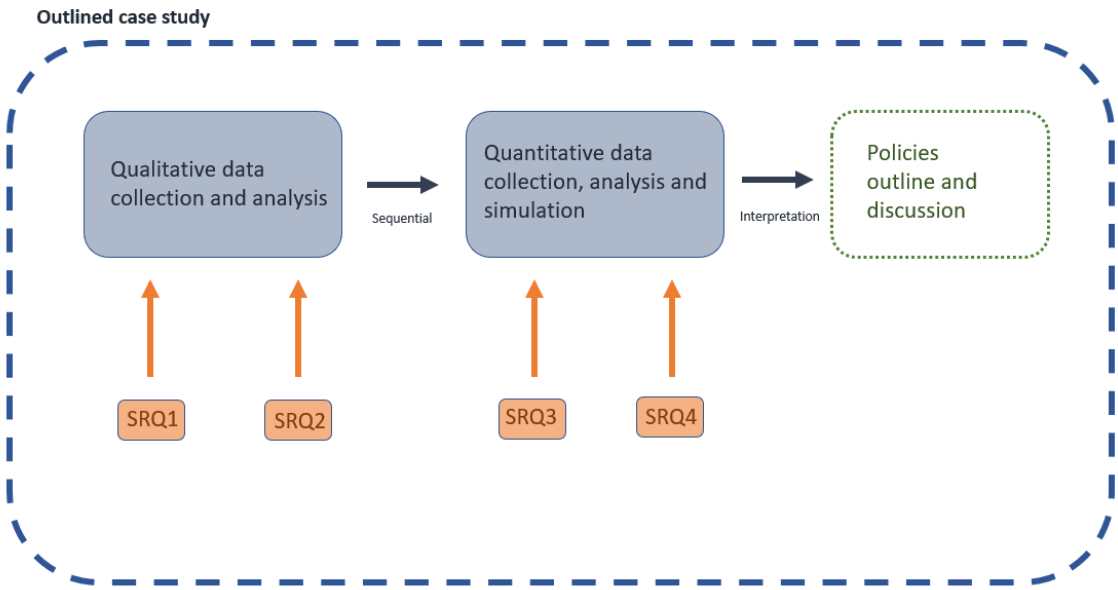


Figure 3.1: Graphical illustration of chosen CS-MM research approach.

4

Serbian Energy Policy Framework

4.1. Historical Context

Throughout its recent history, Serbia has changed its national, political and geographical context several times. Since after the Second World War until the early 1990s, Serbia was part of the larger Socialist Federal Republic of Yugoslavia. During this period, the whole Republic and specifically its capital city Belgrade, witnessed important architectural projects aiming to rebuild cities in a fast and intensive manner. Therefore, from the start of the 1950s until the 1980s followed a period of intensive socialist construction of buildings, adopting a modernist approach characterised by prefabricated buildings built in large numbers. This type of buildings constitutes still today a considerable proportion of total buildings, characterised by excessive final energy demand (Matić et al., 2015). Another characteristic of communist and socialist countries in Central and Eastern Europe were low energy prices (Ürge-Vorsatz & Tirado Herrero, 2012). The latter allowed for the construction of energy intensive buildings. These subsidised energy prices can be attributed to the current energy poverty rates and high building carbon emissions in the region (Ürge-Vorsatz & Tirado Herrero, 2012). Following the dissolution of socialist regimes such as that of Yugoslavia, the energy market was liberalised, bringing residential energy tariffs back to almost full recovery costs in such country. Nonetheless, this happened in a period of strict economic slowdown in the region.

The energy sector in Serbia was inevitably affected by the dissolution of Yugoslavia, which brought turmoil in the region to say the least. As other Western Balkan countries, Serbia's economy was heavily damaged and its transition to a market economy delayed (OECD, 2008). Data from the energy sector during the period from 1990 to 2003 is not reliable, as the economic conditions of that time heavily affected all sectors (OECD, 2008). Energy intensity heavily increased following the start of the 1990s, with traditional imports of coal being replaced by domestic reserves of lignite and thus lower quality coal (OECD, 2008). Indeed, it can be argued that Serbia already went through a relatively quick energy transition, requiring political and investment decisions, profoundly affecting the economy and society (Young & Macura, 2020). From 1965 to 1985, the lignite-fuelled power capacity increased more than 13 times, trebling between 1975 and 1985 (Young & Macura, 2020). Nowadays, lignite is still the main source of Serbia's primary energy supply, with an estimated 60 years of coal reserves remaining being consumed in plants that are inefficient and on average more than 44 years old (Young & Macura, 2020). This was already highlighted in an UNDP report in 2004, analysing Serbia and Montenegro's energy environment and poverty (Kovačević, 2004). In addition, in the report it was also noted how fuel wood was the most widespread energy source for households, a situation that has not changed today (RES Foundation, 2022). Following a referendum in 2006, Montenegro acquired its independence from the Federation of Serbia and Montenegro and almost two years later Kosovo unilaterally proclaimed its independence. Thus, data antecedent to 2008 concerning general Serbian energy figures might include households from these two geographical entities.

4.2. The Delineation of the Energy Policy Framework in Serbia (2000-2010)

Efforts to improve the energy sector in Serbia began in October 2000, when the Ministry of Mining and Energy began to delineate a new institutional, legal and regulatory framework. These changes were undertaken in harmonisation with EU objectives and principles, already aiming to develop an energy market that would be compatible with the European one (OECD, 2008). As part of this reform process, the national *Energy Law of 2004* was approved and the *Energy Sector Development Strategy of Republic of Serbia to 2015 (ESDS to 2015)* was adopted in 2005 (OECD, 2008). The former regulated four features of the energy sector, namely: the distribution, generation, transmission and supply of electricity; the functioning and organisation of the electricity market; the distribution, trade, transportation, storage and supply of natural gas and oil products; and finally, the distribution and production of heat (OECD, 2008). Thus, the law encompassed the main sources of fuel used to generate energy and the main macroeconomic factors related to it. On the other hand, the *ESDS to 2015* outlined five main priorities. Namely, to ensure the continuous modernisation of facilities, systems and sources used throughout the energy sector; to increase general energy efficiency by utilising high quality products; to enhance the use of sustainable, modern and new sources of renewable energy; to assess required investments in the sector; and finally, to construct new energy infrastructures (OECD, 2008). The delineated strategy promised important changes and sent a strong message towards improvement of the national energy infrastructure. The generation of energy from renewable sources was already one of the priorities delineated in the *ESDS to 2015*, with objectives to increase its share in primary supply. However, the share of renewable sources in total primary energy supply (TPES) was expected to not surpass 7% by 2015 (OECD, 2008). This expectation was unfortunately quite precise, as the actual share of renewables in TPES in 2015 in Serbia was approximately 6.98% (IEA, 2022).

Since the Republic of Serbia restored its independence as a sovereign state in 2006, various directives and policies in the field of energy have been implemented. On July 1st, 2006, the Republic of Serbia signed and ratified the Treaty becoming a member of and establishing the Energy Community. The latter is an international organization which sets as main objectives the establishment of a common regulatory framework for energy sectors between its members (referred to as "Contracting Parties"), as well as the creation of a regional energy market to be potentially integrated into the EU's energy market. Indeed, the treaty involves countries of the South-Eastern European region and the EU, represented by the European Council. The organisation serves as an important body to promote cooperation both between countries in the region and the EU, focusing on common and individual goals for sustainability. This is exemplified by Article 20 of the Energy Community Treaty, by which "the Republic of Serbia accepted the commitment to apply European Directives in the field of renewable energy sources" (Ministry of Energy, Development and Environmental Protection, 2013, (p.3)). Namely, Directive 2001/77/EC promoting the generation of electricity from renewable sources and Directive 2003/30/EC promoting the utilisation and production of biofuels or other renewable fuels for transport (Ministry of Energy, Development and Environmental Protection, 2013). These were subsequently replaced in January 2012 by the Directive 2009/28/EC promoting the use of renewable energy (Ministry of Energy, Development and Environmental Protection, 2013). Whereas the Energy Community cannot enforce the implementation of policies and regulations in the individual countries, its Secretariat does monitor the process of legislation adaptation and implementation.

4.3. Energy Policy Progress Finalised in Serbia in the Last Decade (2010-2020)

Improving energy efficiency is one of the key steps when reducing carbon emissions and improving the energy sector. The *Law on Efficient Use of Energy* ("Official Gazette of the Republic of Serbia", No. 25/2013) is the law concerned with regulating an efficient use of energy in its consumption, distribution, production and transmission in Serbia (HERON project, 2015). The latter delineates a legal framework for the implementation of several EU directives concerned with energy efficiency. Namely, Directive 2006/32/EZ on end-use energy efficiency and services; Directive 2010/30/EU on the labelling and standard product's information with regards to its energy consumption; and finally, Directive 2010/31/EU on the energy performance of dwellings (HERON project, 2015). More specifically, with regards to energy efficiency, the Ministry of Mining and Energy is responsible for delineating, monitoring and evaluating national action plans to achieve set targets in this field. The first National Action Plan for Energy Efficiency (NAPEE) was adopted by the Serbian Government in 2010. The latter stipulated objectives to be achieved in a two-year period directed to three sectors, namely: buildings, industry and transport. The ultimate goal delineated in the action plan was to achieve 9% savings of final energy by 2018 compared to 2008 levels. The same target was kept also for the second two-year NAPEE adopted by the Government in 2013 (HERON project, 2015). Ultimately, as written in the fourth NAPEE, 88% of the 2018 target was achieved; namely, 0.661 Mtoe of energy were saved in 2018 compared to the set target of 0.7524 Mtoe (Ministry of Mining and Energy, 2021a).

Similarly to the Energy Efficiency Action Plans, the Ministry of Mining and Energy is also responsible for delineating a National Renewable Energy Action Plan (NREAP). The latter was stipulated following the Decision of the Council of Ministers of the Energy Community of 18 October 2012 and in accordance with Directive 2009/28/EC (Ministry of Energy, Development and Environmental Protection, 2013). The set target for the Republic of Serbia was to achieve 27% of Renewable Energy Sources (RES) in its Gross Final Energy Consumption (GFEC) in 2020 and a 10% of RES in the transport sector. Since 2009, a series of incentive measures (or "feed-in" tariffs) are available in Serbia to promote investments and the production of renewable energy facilities. This resulted in the construction of 265 new facilities (from 2009 to December 2020) for producing electricity from renewable sources with a total installed capacity of 514,262 MW (Ministry of Mining and Energy, 2021d). Whereas most of these facilities were small hydropower plants and solar power plants, respectively 121 and 107, the wind power plants presented the highest installed capacity (Figure 4.1). A set of bylaws regulating the usage of biofuels and developing market conditions for biofuels in Serbia was adopted in the end of 2019 (Ministry of Mining and Energy, 2021d). This was the last step for fully transposing Directive 2009/28/EC in the Serbian legal framework within the energy sector. In addition, the Rulebook on calculation of renewable energy sources utilised by the European Union (Eurostat) was officially adopted in March 2020 (always in accordance with Directive 2009/28/EC) (Ministry of Mining and Energy, 2021d). All this contributed to improving the sector and making it more appealing for international investments. Nonetheless, Serbia reached 26.3% of RES in its GFEC in 2020 (Ministry of Mining and Energy, 2022). According to Eurostat figures, Serbia presented a 25.983% share of renewable energy in its GFEC in 2020 (Eurostat, 2022h).

In 2016, the Ministry of Mining and Energy published a strategy for the development of the Serbian energy sector for the period by 2025 with projections by 2030. This document illustrates the main scenarios envisioned by the Ministry and future projections of the energy sector (Ministry of Mining and Energy, 2016). The document utilises data from 2010 and simulates two main scenarios, namely a Reference scenario (with 2010 data) and a second one envisioning the application of energy efficiency measures. The latter mainly involves the attainment of set targets, namely a reduction of 9% in GFEC by 2018 (compared to 2008 levels), a 27% share of renewable energy in GFEC by 2020 and a 10% of biofuel in final consumption in the traffic sector (Ministry of Mining and Energy, 2016). These are all targets hereby previously discussed and proposed respectively in the NEEAP and NREAP. Whereas the degree to which the first two goals were achieved was mentioned in the previous two paragraphs, it must be noted that the actual share of renewables in the transport sector in Serbia in 2020 was 1.174% (Eurostat, 2022h). Achieving a 10% share of renewables in the transport sector was defined as "very demanding" goal in the document itself, as Serbia at the time (2016) had no facilities to produce biofuels from biomass of second generation and lacked a legal regulation in this field (Ministry of Mining and Energy, 2016). A necessary investment from 100 to 120 million euros was stated as a requirement. This clearly did not happen, as the report on the implementation of the NREAP for 2018 and 2019 stated that the percentage of RES in the transport sector were respectfully 1.18% and 1.14% in 2018 and 2019 (Ministry of Mining and Energy, 2021d). Nonetheless, even when considering all these objectives as achieved, these measures were found to be not ambitious (in the field of energy efficiency in particular) by a study performed by the Energy Community on the overall targets for 2030 of contracting parties (Resch et al., 2019).

The Republic of Serbia has implemented several policies and protection schemes directed towards vulnerable consumers, trying to combat energy poverty. Such schemes provide both financial assistance to vulnerable consumers in terms of gas and electricity but also bill deductions (Ban et al., 2021).

In the previously mentioned development strategy for the energy sector, further development of the protection mechanisms already in place is discussed (Ministry of Mining and Energy, 2016). Similarly, vulnerable energy consumers are mentioned in the third NEEAP. In fact, measure D3 promotes the utilisation of energy-efficient lighting and electric appliances, proposing to provide free-of-charge LED light bulbs to the more vulnerable consumers (Ban et al., 2021). In the fourth NEEAP, measure D3 is analysed through a more pragmatic lens, comparing the planned savings in the third NEEAP (0.1169 Mtoe) to the achieved ones in 2018 (0.0840 Mtoe) (Ministry of Mining and Energy, 2021a). Nonetheless, the proposed measure promoting the use of energy efficient housing appliances was continued from the third NEEAP to the fourth one, adding the promotion of energy efficiency also by eco-design (Ministry of Mining and Energy, 2021a). Vulnerable consumers are recognised and defined accordingly in various policy documents in Serbia. The *Consumer Protection Act* (OG 62/2014, 6/2016, 44/2018) defines, in Article 84, a vulnerable consumer as “a consumer who, due to economic or social position, living conditions, special needs, or other difficult personal circumstances, procures goods or uses a service under particularly difficult conditions, or is disabled” (Ban et al., 2021, (p.92)). Vulnerable electricity and gas consumers are also mentioned in: the *Social Protection Strategy* (2019), the *Energy Act*, the *Ordinance on Energy Vulnerable Consumers*, the *Decree on Energy Vulnerable Consumers* and the *Act on Energy Efficiency and Rational Use of Energy* (Ban et al., 2021).

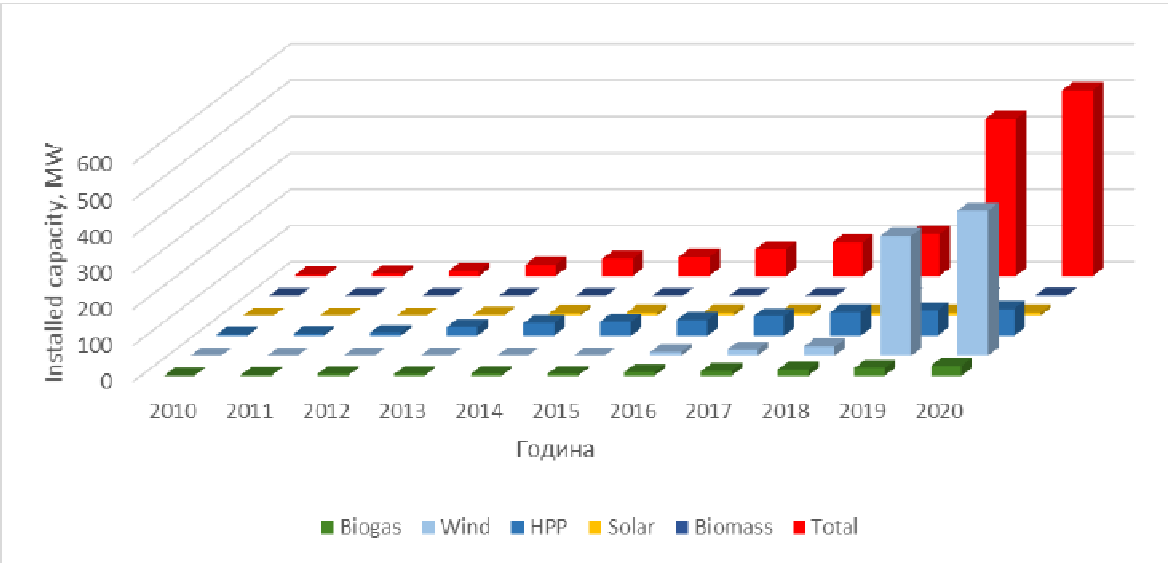


Figure 4.1: Graphical illustration of installed capacity of all power plants on RES since introducing the ”feed-in” tariffs system in Serbia (Ministry of Mining and Energy, 2021d).

4.4. Current Energy Policy Framework in Serbia (2020-Present)

The Republic of Serbia has made important improvements in the field of energy efficiency and poverty in the last decade by implementing several directives, decrees and initiatives as discussed in the previous subsections. It must be noted that in addition to the NEEAP and NREP, Serbia also presents and implements a National Emission Reduction Plan (NERP), which however will not be discussed in the present study. In accordance with Article 29 of the Energy Community Treaty, Serbia also delivers statements every two years concerning the national security of supply. However, Serbia has failed to provide its updated Nationally Determined Contributions (NDCs), or NDC2 (Energy Community, 2022a). The NDC should summarise the country’s plan to reduce GHG emissions under the Paris Agreement (2015) and should be updated every five years. On a more positive note, in April 2021, the Serbian National Assembly adopted two new laws as well as amendments to two existing laws in the field of energy (Spasić, 2021a). The two new laws are respectfully: the *Law on Renewable Energy Sources* and the *Law on Energy Efficiency and Rational Use of Energy*. Whereas the amendments were applied to the *Law on Energy* and the *Law on Mining and Geological Research*. These innovations in the Serbian legal framework will be further discussed in the following subsections.

Aimed at mitigating climate change and improving sustainability, the Law on Renewable Energy Sources regulates extensively the most significant aspects related to the use of renewable energy sources (RES). The new Law adds more detail and structure concerning the regulation of RES, which were previously regulated by Section V of the Energy Law (Djordjević & Vujošević, 2021). As the name suggests, the Law aims to promote and fasten the transition to renewable energy by stimulating investments in the sector. This is done by providing two incentive systems, namely: market premiums and feed-in tariffs for small projects. The former can be seen as a form of operational state aid (Djordjević & Vujošević, 2021). Expressed in Eurocents per kWh in the auction process, the premium is a supplement to the market price of electricity that will be delivered to the market by the premium users. This will be paid monthly based on the amount of electricity delivered to the grid by the plant. The right to the premium can be acquired by participating in auctions conducted by the devoted Ministry (Djordjević & Vujošević, 2021). Similarly, the right to a feed-in tariff is also awarded by the Ministry through auctions. The tariffs apply only for power plants and wind plants with a capacity below 500 kW and 3 MW respectively, and demonstration projects (Djordjević & Vujošević, 2021). The Law sets a legal framework allowing end-users to produce their own energy from RES and thus becoming *prosumers* (e.g., consuming energy produced from rooftop solar panels). The energy produced "in-home" by prosumers can also be stored or delivered as electricity surplus to the grid, which will lead to either a monetary compensation or a reduction of the upcoming electricity bill (Djordjević & Vujošević, 2021). In addition, prosumers are allowed to form so called *renewable energy communities*, recognised as legal entities, constituted by voluntary members willing to produce energy from RES. Finally, the Law also introduces strategic partnership schemes between public and private entities devoted to increase investments in building plants and promoting innovative technologies utilising RES (Djordjević & Vujošević, 2021).

The Law on Energy Efficiency and Rational Use of Energy aims to improve the whole energy sector, by ameliorating the general efficiency, thus reducing waste and the climatic impact of the energy sector, but also increasing economic competitiveness and reducing energy poverty. The Law harmonizes the Serbian regulations in the energy sector with EU directives. Energy efficiency policy and measures are introduced, regulating the financing of and incentives in the energy sector to promote a more efficient use of the latter (Aleksić, 2021). The Law implements an energy management system, where a set of measures and regulations are present to monitor and analyse the consumption and activities of energy within the system. The contributors and members of such system will be chosen by the Government, and these will comprise both private companies and public ones, including city municipalities with more than 20,000 inhabitants as well as local self-government units (Aleksić, 2021). The Law imposes several obligations to the contributors of the system, such as appointing energy managers and monitoring the energy consumption. Failure to adhere to these measures will result in fines (Aleksić, 2021). Similarly to the Law on RES, subsidies will be provided to both individuals and legal entities, in this case to promote the installation of efficient gas and biomass boilers, carpentry, and isolation systems. Lastly, the Law deals with energy labelling and sets requirements for labelling devices as eco-design (Aleksić, 2021). These were already mentioned in previous NEEAPs (third and fourth), as improving the labelling of products in the market can highly improve the efficiency of household electrical appliances.

The amendments to the Law on Energy will contribute to create a legal basis and framework in which to implement the National Energy and Climate Plan (NECP) (Spasić, 2021a). The Energy Agency of the Republic of Serbia (AERS) was given new powers which resulted in guidelines being issued to introduce Network Codes for gas and electricity into the national grid codes (Energy Community Secretariat, 2021). In addition, the amendments push for the creation of a legal basis on which to assess the risks and investments related to strategic infrastructure projects covering electricity, coal and natural gas. Hence, the Government will delineate in greater detail conditions for promoting energy infrastructure projects, in line with Regulation (EU) 347/2013 (Energy Community Secretariat, 2021). This should facilitate projects such as the Transbalkan corridor and gas interconnectors. On the other hand, amendments to the Law on Mining and Geological Exploration were more focused on internal matters. The competencies of the geological institute of Serbia were expanded and a chamber of geological and mining engineers in Serbia was formed (Spasić, 2021a).

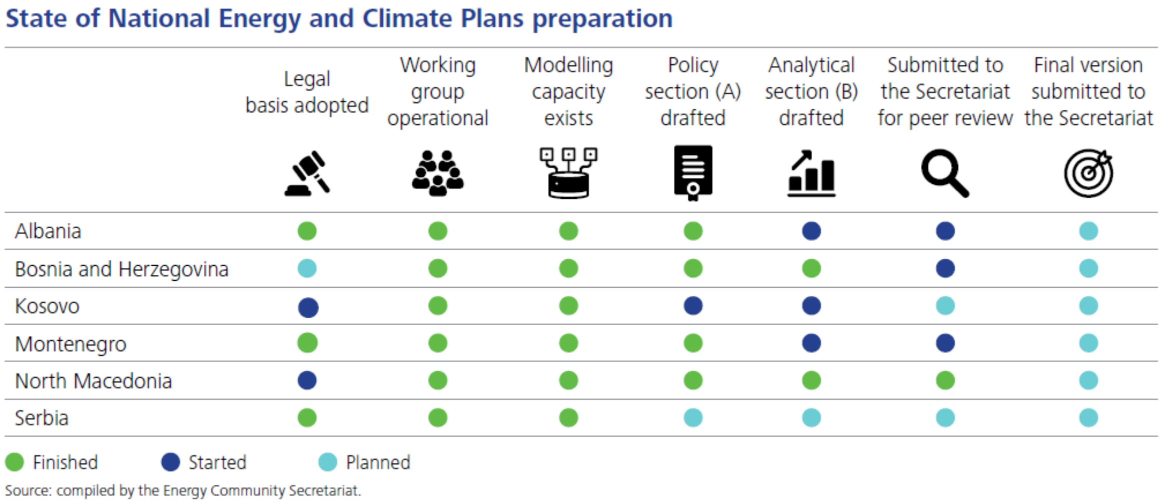
4.5. Envisioned Future Energy Policy Targets in Serbia

The Republic of Serbia has developed and implemented various tools to improve the energy sector and accordingly has outlined several targets, more or less objectively defined, to be achieved in the future. These tackle various aspects and industries of the sector and are delineated in accordance with both national requirements but also EU directives. The vision of the Ministry of Mining and Energy is one of an energy-safe and climate-neutral economic development of the country, allowing it to be the regional leader in energy production (Ministry of Mining and Energy, 2022). As mentioned in previous subsections, four new laws have been implemented in 2021 to establish a legal framework in which to act and improve the energy sector; in addition to these, a *Law on Climate Change* was also adopted to fasten the implementation of national low-carbon development strategies (Ministry of Mining and Energy, 2022). An investment plan for projects concerning energy and mining was defined by the Ministry, with more than 35 billion euros being devoted to it, of which 21 billion focused on the development of hydropower, solar and wind power plants (Ministry of Mining and Energy, 2022). Decarbonisation is indeed one of the pillars of the Serbian strategic development of its energy sector, with achieving carbon neutrality and reducing net emissions to zero by 2050 as one of its main targets (Ministry of Mining and Energy, 2022). Nonetheless, Serbia has not introduced an emissions trading system (ETS) in the country; no regulating mechanism for the calculation of the price of CO2 is currently available; and no taxing system for CO2 has been established (Ministry of Mining and Energy, 2022).

To achieve carbon neutrality by 2050, all aspects of the energy sector need to be improved and updated regularly. As a short-term objective, the Ministry of Mining and Energy has set to increase the production, especially from RES, of electricity and heat as to facilitate the energy transition and reduce consumption in the industry and transport sectors (Ministry of Mining and Energy, 2022). With regards to the production of thermal energy, replacement of current fossil fuel boiler plants with more efficient ones, which would be possible to adapt in the future as to run on alternative forms of fuel such as hydrogen, is considered as a viable short-term solution (Ministry of Mining and Energy, 2022). In fact, the whole distribution network of thermal energy could be replaced by more efficient and advanced boiler rooms. The transition to new systems in the field of thermal energy allowing for an economically sustainable functioning of the network can be achieved by applying the Decree on the formation of the price of heating (Ministry of Mining and Energy, 2022). In addition, the share of RES in district heating will need to be inevitably increased, developing district heating systems fully harmonized with grids and networks of other fuels such as gas. Incentives for producing thermal energy from heat pumps, solar energy, biomass and geothermal energy are planned to be implemented (Ministry of Mining and Energy, 2022).

The share of renewables in energy consumption will have to be increased throughout all areas of the energy sector. The Ministry of Mining and Energy has set a as a target the achievement of a minimum of 49.6% share of RES in gross final energy consumption by 2040 (Ministry of Mining and Energy, 2022). The current Minister of Mining and Energy, Zorana Z. Mihajlović, stated that achieving a 50% share of RES in national energy production by 2050 was another goal of the Ministry (Ministry of Mining and Energy, 2021c). To achieve these targets, the general efficiency of the whole sector will need to be improved. Improving the energy efficiency of dwellings by providing incentives is seen as a short-term solution which could reduce excess energy consumption already by 50% (Ministry of Mining and Energy, 2022). Specific programmes devoted to the energy rehabilitation of public buildings at a local level are envisioned to reduce energy consumption by approximately 40% in the short-term (Ministry of Mining and Energy, 2022). As a long-term solution, the Ministry envisioned expanding incentives as to promote also the usage of RES for household needs and thus rehabilitate starting from 2021 up until 2050 a living space area of approximately 100 million square meters. This would result in electricity savings of up to 500,000 MWh annually and a reduction of 37% of CO2 emissions compared to 2020 levels (Ministry of Mining and Energy, 2022).

The Ministry of Mining and Energy has set various targets, both short-term and long-term, in different areas of the energy sector. To achieve these, detailed plans, strategies and budgets need to be delineated. The last strategy for the development of the energy sector was outlined by the Ministry in 2016 for the period by 2025 including projections until 2030 (Ministry of Mining and Energy, 2016). The new development strategy for the period until 2040 with projections until 2050 is still being drafted as this Master thesis is being written (Ministry of Mining and Energy, 2022). As agreed in the Energy Community Treaty and following the new EU directives, every contracting party is requested to submit a National Plan for Energy and Climate (NECP) defining the set targets and measures to reduce GHG emissions, improve energy efficiency and increase the share of renewables in the energy sector. Serbia is still in the process of drafting its NECP, even though having planned and announced to deliver it by the end of November 2021 (Spasić, 2021b). Unfortunately, Serbia is behind all other contracting parties in the drafting of its NECP, as can be seen in Figure 4.2. As of June 2021, the first three chapters (Policy Section A, describing current and planned policies, measures and objectives) were still only in the planning phase (Energy Community, 2021). No justification or reasoning has been officially given for this delay.



State of National Energy and Climate Plans preparation

	Legal basis adopted	Working group operational	Modelling capacity exists	Policy section (A) drafted	Analytical section (B) drafted	Submitted to the Secretariat for peer review	Final version submitted to the Secretariat
Albania	Finished	Finished	Finished	Finished	Started	Started	Planned
Bosnia and Herzegovina	Planned	Finished	Finished	Finished	Finished	Started	Planned
Kosovo	Started	Finished	Finished	Started	Started	Planned	Planned
Montenegro	Finished	Finished	Finished	Finished	Started	Started	Planned
North Macedonia	Started	Finished	Finished	Finished	Finished	Finished	Planned
Serbia	Finished	Finished	Finished	Planned	Planned	Planned	Planned

Finished Started Planned

Source: compiled by the Energy Community Secretariat.

Figure 4.2: Overview of the progress made by contracting parties in developing National Plans for Energy and Climate (Energy Community, 2021).

5

The Multifaceted Interconnections and Relations Between Energy Poverty and Low-Income Households in Serbia

5.1. The Societal Consequences of Energy Poverty and Household Energy Efficiency in Serbia

In Article 3 of the Law on Energy Efficiency and Rational Use of Energy, energy poverty is defined as a situation resulting from a "combination of low household income, large expenditure of available income on energy and insufficient energy efficiency" (Ministry of Mining and Energy, 2021b). This definition is quite focused on the economic aspects of the issue rather than the more societal ones. A more comprehensive definition was suggested in Serbia, defining the latter as a state in which households do not have the necessary means to afford the required amount of energy as to live a healthy and dignified life, in a way that does not harm other households or larger communities (Section 2.1.3) (RES Foundation, 2021). This definition is rather similar to the one proposed by Bouzarovski which, as mentioned in Section 2.1.1, is adopted in the following study; namely a situation occurring when "a household is unable to secure a level and quality of domestic services – space cooling and heating, cooking, appliances, information technology – sufficient for its social and material needs" (Bouzarovski, 2018, (p.1)). Other definitions found in the literature were not always applicable to Serbia specifically. For example, applying the 10% threshold proposed by Boardman (1991), the majority of Serbian households would be found to be energy poor as, on average, these spend 12.4% of their total income on energy expenditures (Section 2.1.3) (RES Foundation, 2021). Being a socioeconomic issue, energy poverty presents various ramifications. The most concerning ones for the present study will be analysed in the following paragraphs specifically applied to the Serbian context, where the close relationship between household energy efficiency and energy poverty will be further illustrated.

Energy expenditures in Serbia represent a considerable part of general expenses, as on average more than a tenth of the income is devoted to this. This is also due to the high costs related to the functioning and maintenance of energy infrastructures utilised for space heating (gas infrastructures but also district heating) (Kovačević, 2022). Energy prices are envisioned to increase in the upcoming years throughout Europe, with Serbia being inevitably affected. This trend could therefore increase the number of people suffering from energy poverty. In 2020, 21.9% of the population in Serbia was at persistent risk of poverty (Eurostat, 2022f). The increase of energy prices could increase this number. A symptom of energy poverty is also reducing the heating during colder months as to reduce energy expenses. In a survey performed in Serbia in 2021, it was found that over 40% of the interviewees were not able to heat all the rooms in their household, but rather only the sleeping rooms (Jovančević & Popović, 2021). This number was higher when analysing socially deprived households (48%) and slightly lower (37%) when considering households that utilise wood or coal fuelled stoves as heating device (Jovančević & Popović, 2021). Indeed, these households were not able to secure a sufficient level and quality of domestic services, lowering their living standards. This can result in a higher risk of health problems, but also more social issues such as inability to study at home for teenagers, loss of privacy and general material and social deprivation. In 2020, Serbia presented a total material and social deprivation rate of 22.6%, which amounted up to 28.4% when considering rural areas (Eurostat, 2022d). In addition, the total population presented an overcrowding rate of 52.5% in 2020 (Eurostat, 2022e).

The price of energy per se affects energy poverty only to a certain extent. The direct relationship between energy prices per kWh, energy consumption and final energy bill needs to be further illustrated and understood. Serbia presents the lowest prices for electricity when compared to the EU nations and neighbouring Western Balkan countries (Petovar, 2022). This has often been publicized by politicians in the country as a powerful asset in the fight against energy poverty in the country. Nonetheless, when analysing an average monthly electricity bill, the amount dedicated to paying the electricity consumption represents only 38.2% of the total energy bill (Petovar, 2022). In fact, the majority of the bill is constituted by costs not related to the consumption of energy; such as the computational power per kWh and the costs given to the guaranteed supplier. However, an increase in total costs of energy bills can affect energy poverty if related specifically to district heating. Since district heating does not affect the individual but larger communities, this can have a knock-on effect. Indeed, if individuals start exiting the district heating system, the prices for the remaining users will increase. This will inevitably cause conflicts between users and increase difficulties in paying bills. Indeed, in the last decade, district heating prices in Serbia have increased since it has virtually stopped being subsidised (Petovar, 2022).

Energy inefficient buildings highly affect energy poverty, as these entail higher energy expenses and consumption (Section 2.2.1). There are various aspects that hinder the efficiency of dwellings. Nonetheless, older buildings tend to present lower energy efficiency levels compared to newer ones, especially block buildings built during the Socialist period of the country. In Serbia, 47.5% of the dwellings were constructed between 1971 and 1990, 28.9% between 1994 and 1970 and only 19.4% after 1990 (Statistical Office of the Republic of Serbia, 2020). These older buildings often do not match EU energy efficiency standards and are not being renovated in high numbers. The need to renovate buildings in Serbia was also recognised by the Ministry of Construction, Transport and Infrastructure (2019). Specifically, in Serbia 20% of dwellings do not present thermal protection; 64% of the buildings do not present a thermal insulation layer within the thermal envelope of the building; 60% of dwellings do not match the standards delineated in 1980 regarding construction physics (RES Foundation, 2021). In addition, it was found that 8.5% of buildings in Serbia were illegal and 13.5% were in the process of being legalized (RES Foundation, 2021). These buildings are often built with inefficient materials without respecting efficiency standards and without complying to construction regulations. It must be noted that Serbia has increased investments in the buildings sectors, however it is estimated that an extra 1636 million euros of investments are needed to reach energy efficiency goals (Section 2.2.3) (Energy Community, 2021).

Similarly to buildings, energy inefficient appliances also increase energy expenses and thus affect energy poverty. Whereas the utilisation of such devices is also a result of poverty and inability to afford better appliances, it is also due to a lack of information concerning potential benefits of improved devices. It is estimated that only around 20% of users of inefficient heating devices in the Western Balkans are aware of the benefits related to upgrading their devices (RES Foundation, 2022). These inefficient heating devices are usually solid-fuel or wood-fired stoves. Devices that burn wood for heating are carbon-neutral and considered as utilising biomass, nonetheless in an inefficient manner. The real life efficiency of wood-fired stoves, as defined in (RES Foundation, 2022), is estimated to be between 30 to 40%. The minimal type test efficiency required for eco-design is 65%, whereas the benchmark value set by the regulation is 86% (RES Foundation, 2022). Replacement of inefficient wood-fired stoves with eco-design certified ones could reduce emissions as much as 90%, as even factors such as moisture of the wood increase the degree of emissions (RES Foundation, 2022). The type of fuel also plays a role, as for example for the same quantity of produced energy, fuel wood requires 6 to 30 times less energy compared to pellet production (RES Foundation, 2022). According to a survey, in Serbia 57% of households utilise firewood for heating; this number rises to 66% when considering socially deprived households (RES Foundation, 2021). In addition, the latter often utilise raw wood presenting even lower efficiency standards. This is often the case when analysing rural households. The production of smoke from wood-fuelled devices indoor can have lasting health consequences for the residents (RES Foundation, 2022).

Energy poverty affects different straits of society in different ways. In 2019, 9.9% of the total population in Serbia was unable to keep its home adequately warm (Eurostat, 2022g). In 2020, this number was reduced by 0.4 percentage points to 9.5%, suggesting a minimal improvement. However, when analysing the poorer straits of society (below 60% of median equivalised income) the situation changes. In 2019, 19.7% of the population could not keep its home adequately warm; in 2020, this number increased to 26.2% (Eurostat, 2022g). This represents quite a substantial increase, which is not seen if considering the population as a whole. This goes to show how people on the lower side of the equivalised income line are more affected by energy poverty, as seen also in the literature (Deller & Waddams Price, 2018; Deller et al., 2021). Indeed, poorer people will tend to live in old and inefficient buildings, utilise outdated and inefficient heating devices and generally be less aware of the benefits and possibilities related to modernising their devices. For this reason, the following study focuses on low-income household groups.

5.2. Low-Income Household Groups in the Serbian Context

5.2.1. Available Policy Mechanisms to Alleviate Energy Burden

Serbia has recognised the need to protect most vulnerable energy consumers in line with the requirements and regulations delineated in the third EU Energy Package (Ban et al., 2021). Several policies and directives attempting to protect vulnerable consumers have been implemented, mostly focused on electricity and gas consumers. Various acts and directives have defined vulnerable consumers in different ways and the main directives mentioning vulnerable consumers have been discussed in Section 4.3. However, there is no definition of low-income groups in the context of access to essential services (Section 2.3.2), with the latter also missing a definition (Baptista & Marlier, 2020). This does not mean that there are no existing support measures that people can access based on specific eligibility conditions, but rather that these are defined differently. For example, services such as the Financial Social Assistance (FSA) and child benefits are present in Serbia (Baptista & Marlier, 2020). Nonetheless, no protection mechanisms and/or schemes to alleviate the causes and dimensions of energy poverty, such as the ones described in the previous section, have been implemented (Ban et al., 2021). These should be present in the National Energy and Climate Plan (NECP), which is still under development (Section 4.5).

Reduced tariff mechanisms to help alleviate the financial burden related to access to energy services for poorer people are present in Serbia, mainly focused on electricity and gas (Pejin Stokić & Bajec, 2020). These are present both at a local and national level, however here only the latter will be analysed. In order to qualify for such tariffs, households need to match a number of requirements. Recipients of the FSA or child benefits are considered directly eligible, whereas other conditions are set for other categories of vulnerable consumers (Pejin Stokić & Bajec, 2020). The three factors analysed to determine the eligibility of consumers are the size of the household, its monthly income and monthly consumption of electricity and gas. The monthly income ceiling for a single-person household to be eligible for reduced tariffs is 125 EUR (14,645 RSD) (Pejin Stokić & Bajec, 2020). This number increases (non-linearly) depending on the size of the household. For comparison, the threshold defined in 2018 for a single-person household to be defined as "at-risk-of-poverty" was a monthly income of 141.40 EUR (Pejin Stokić & Bajec, 2020). Accordingly, depending on the number of people present in the household, different consumption caps for electricity and gas are applied, called "allowances" (e.g., 120 kWh of electricity for a single person household). Additionally, reductions change depending on the amount of consumed energy. If the household consumes up to 4 times the amount of energy corresponding to its obtainable electricity allowance, then it will have a full reduction; whereas if it spends between 4 to 6.5 times the value, it will have a reduction of 50%; no reduction will be applicable if it spends more (Pejin Stokić & Bajec, 2020). To put this into context, if a two-member household consumes up to 640 kWh of electricity in a 30-day period, it will be entitled to a full reduction for 160 kWh (allowance), and thus only 480 kWh will be charged (Figure 5.1). Similar methodologies are applied to the consumption of gas, with the cap being 2.5 times the allowance (Pejin Stokić & Bajec, 2020). Electricity tariffs are applicable throughout the whole year whereas those for gas only spanning through a period of 6 months. Reduced tariffs for gas and electricity cannot be obtained contemporarily (Pejin Stokić & Bajec, 2020).

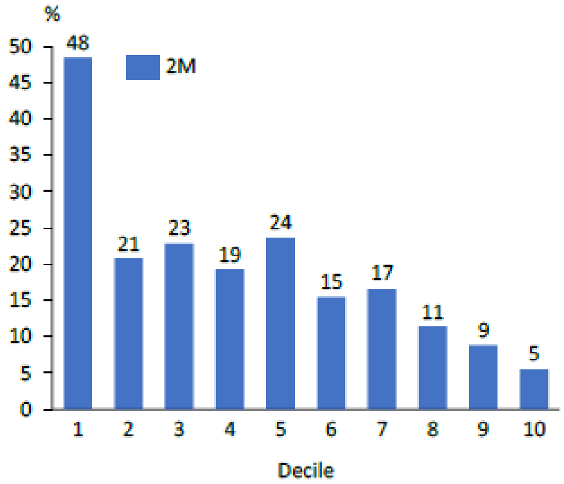
Household size	Monthly income limit per household member*	Electricity			Gas		
		Allowance (kWh)	30-day ceiling (kWh) Reduction		Allowance (m^3)	30-day ceiling (m^3) Reduction	
			100%	50%		100%	50%
Single person	€125 (RSD 14,645)	120	480	780	35	70	87.5
2-3 members	€181 (RSD 21,323)	160	640	1,040	45	90	112.5
4-5 members	€238 (RSD 27,996)	200	800	1,300	60	120	150
6+	€300 (RSD 35,207)	250	1,000	1,625	75	150	187.5

Figure 5.1: Reduced tariffs scheme in Serbia (2019), relating household size, monthly income and monthly energy consumption (Pejin Stokić & Bajec, 2020).

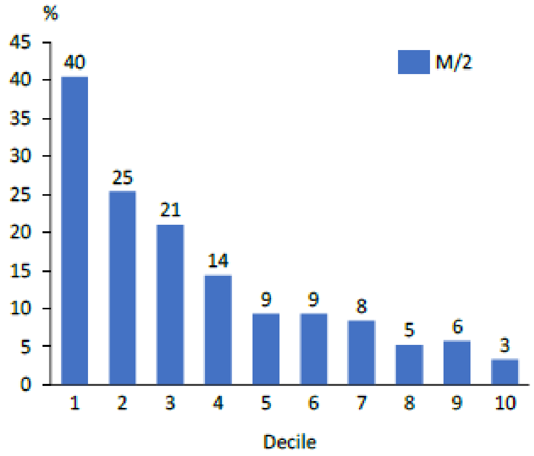
5.2.2. Indicators of Energy Poverty Within Low-Income Household Groups

Ban et al. (2021) analysed some key indicators to understand how energy poverty affects different straits of society in Serbia. As previously mentioned, one of the symptoms of energy poverty is devoting a large part of one's income to energy expenditures, thus making the latter not affordable. Another connected symptom however is also reducing the amount of energy expenses to an unhealthy and low-quality level such as to reduce the energy burden. To account for both scenarios, Ban et al. (2021) took into consideration two indicators, named respectively 2M and M/2. The former is calculated by taking the weighted median of the share of household energy expenditure and doubling it, whereas the latter is obtained by halving the weighted median of the equivalized absolute household energy expenditure. It was found that 19% of the total population presented energy expenditures which were double the national median (Ban et al., 2021). This number more than doubled when considering the first decile. In the latter, 48% of households paid a share of energy expenditures which were double than the weighted median (Figure 5.2a). For comparison, in the second decile, only 21% of households presented the same expenditure situation. When analysing the M/2 indicator, it was found that 14% of the total population had energy expenditures below half of the national median (Ban et al., 2021). Once again, this number more than doubled when considering the first decile, where it was 40% (Figure 5.2b). For comparison, the second decile presented 25% of households in the same situation.

The first decile of the population in Serbia is particularly affected by difficulties in paying energy expenditures. Ban et al. (2021) analysed the energy burden to households by considering both the median and mean share of energy expenditures in disposable income. When considering the whole population, these were respectively 8% and 14% (Ban et al., 2021). These values drastically change when considering the first decile, becoming 16% and 44% (Figure 5.3). Not surprisingly, the first decile presented the highest difficulty with paying utility bills, with 48% of households having arrears compared to the national average of 25% (Ban et al., 2021). More importantly, when analysing the inability to keep homes adequately warm, 30% of households in the first decile were affected, presenting a share close to three times the national average and double compared to the second decile, respectively of 11% and 15% (Ban et al., 2021). Similarly, 39% of households in the first decile were experiencing condensation, leaking roofs and/or rot in windows, compared to 21% and 19% for the second decile and national average respectively (Ban et al., 2021). To assess the total number of energy-poor households in Serbia, Ban et al. (2021) delineated a range of households taking as the lower bound the share of households that self-stated unable to keep their homes adequately warm; and as the upper bound a combination of the share of households that spend twice the equivalised median on energy expenditures (2M) and the share of households that spend half of the national median (M/2). By so doing, it was found that the number of energy-poor households ranges between 17% and 22% of all households, resulting in 176,00 to 529,000 households (Ban et al., 2021).



(a) Share of households in Serbia in 2019 spending more than double of the average median energy expenditure share of disposable income (Ban et al., 2021).



(b) Share of households in Serbia in 2019 spending less than half of the average absolute median energy expenditures (Ban et al., 2021).

Figure 5.2

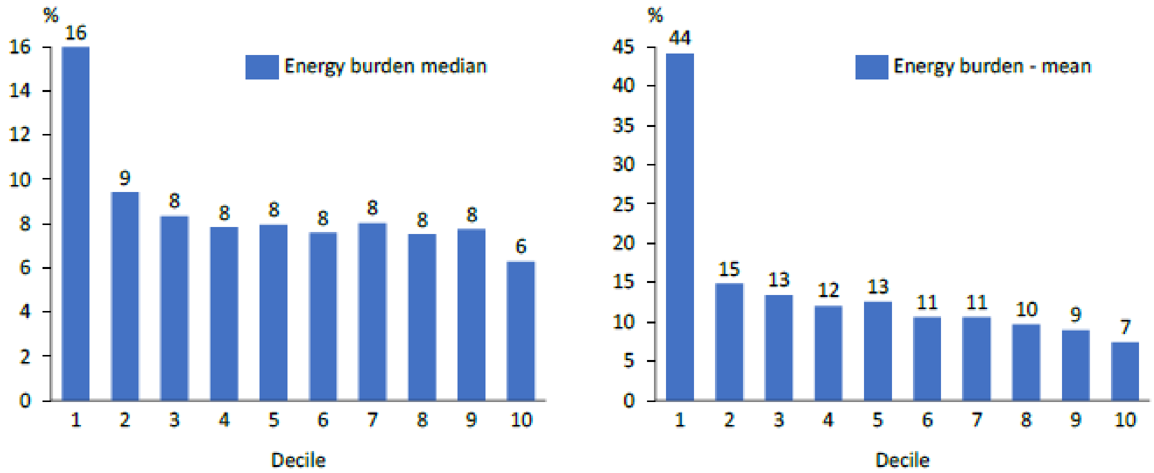


Figure 5.3: Median share (left-hand side) and mean share (right-hand side) of energy expenditures in disposable income in 2019 for Serbia (Ban et al., 2021).

5.3. Analysis-Specific Characteristics and Features Chosen for the Present Research

5.3.1. Definition of Low-Income Household Groups

Stemming from the points expressed in the previous paragraphs, it was decided to define the first decile of the income spectrum as low-income household groups. The first decile represents people having the least economic capabilities and resources. Whereas energy poverty is not a purely economic issue, it has been discussed in the previous paragraphs how the first decile is always more hit by energy poverty indicators compared to the rest of the population. In 2019, the average income in the first decile per consumption unit was 11,703 RSD, corresponding to roughly 99 EUR per month (Social Inclusion and Poverty Reduction Unit, 2021). This value is below both the “at-risk-of-poverty” threshold of 141.40 EUR and the income cap to be eligible for the tariff reductions of 125 EUR (14645 RSD) (Pejin Stokić & Bajec, 2020). According to the Household Budget Survey performed in 2019, 246,705 households belonged to the first decile in Serbia (Statistical Office of the Republic of Serbia, 2020). This is within the range delimited by Ban et al. (2021). Additionally, previous studies analysing the impact of policies on low-income household groups were found in the literature defining the latter as households belonging to the first income decile (Rogulj et al., 2022). Therefore, throughout the rest of the report, low-income household groups will be considered as those belonging to the first income decile.

5.3.2. Typology of Utilised Indicators

For the following study it was decided to consider only objective indicators. In Section 2.4 a holistic overview of the different types of indicators available was given. Objective indicators were defined as those that analyse expenditure rates or shares, constructed on financial data concerning the spending and earnings of households. A distinction between actual and required expenditure was also made. Indeed, when analysing actual expenditure rates, these do not manage to consider rationing phenomena, i.e., households lowering their standards of warmth and comfort as to reduce their energy expenses. Additionally, when considering low-income groups, the actual spending on energy expenses tends to be lower than the required amount (Hills et al., 2011). Nonetheless, these indicators provide good insights in how the households are affected by energy expenses. Even though the financial sphere is not the only one affecting energy poverty, it is still the most prominent one, with low income being regarded as the principal cause for energy poverty (Santamouris, 2016; Ürge-Vorsatz & Tirado Herrero, 2012). Furthermore, economic data related to energy expenses is the most easily accessible one, especially in countries not presenting a state-of-the-art working framework related to energy poverty. Hence, the great popularity and use of objective indicators. According to Figure 2.5, actual energy expenditure rates will be utilised, however not related to the population average but rather to the first income decile average. Indeed, the goal of this study is to see how different policies would affect the low-income groups. The latter were defined more from an economic perspective, for the reasons delineated in the previous section. In line with that train of thought, actual economic indicators will be considered when analysing the effects of policies on low-income groups.

Objective indicators were not chosen as to represent and better delineate energy poverty figures in Serbia, but rather to understand the effect that different policies would have on countering energy poverty in Serbia. To have a better understanding of how energy poverty affects different straits of society, a combination of both actual and required, objective and subjective indicators would be suggested. However, in this case more emphasis is put on understanding the consequences of policies on low-income groups. These will be analysed more from an economic perspective, and thus purely economic actual indicators will be insightful. The energy prices and final energy consumption will be the two main indicators analysed. The former directly affects citizens, either by lowering or increasing energy expenditures; whereas the latter affects both the citizens and the climate, as lower consumption is directly related to lower emissions. It must be noted that energy expenditures will be related to equivalised consumption units within the household rather than the latter itself. This allows to avoid the bias related to economies of scale, as energy expenditure is not strictly linear and proportional per house member (Tirado Herrero, 2017). The analysed data will be gathered from the Eurostat repository and the Household Budget Survey for Serbia in 2019. Such analysis considering actual indicators related to energy prices and final energy consumption, gathering data from the Eurostat repository and national Household Budget Surveys was already performed in the literature (Rogulj et al., 2022).

6

Model Simulation

6.1. Introduction

To better understand how different policies would affect low-income groups in Serbia, it was decided to perform simulations for each policy (scenario) utilising a linear and static model. The tool utilised to perform these simulations will be Microsoft Excel. Whereas several tools to simulate climate policies exist, MS Excel was chosen as most of the data found was compatible with the latter. In addition, it was found that this computational tool was utilised to perform various graphical representations and statistical projections, both from governmental organizations and independent ones (Ban et al., 2021; Ministry of Mining and Energy, 2021d; Rogulj et al., 2022). As previously mentioned, the data was gathered from the Eurostat repository (in MS Excel format) and the Household Budget Survey (HBS) for Serbia in 2019. The latter was the most recent HBS available (Statistical Office of the Republic of Serbia, 2020). The performed simulation will be of a static nature as static data from 2019 will be utilised. It must be noted that the most recent projections outlined by the Ministry of Mining and Energy for Serbia were performed by utilising static data from 2010 (Ministry of Mining and Energy, 2016). The simulated time horizon will be from 2019 (baseline year) to 2050, as this represents the year considered in most long-term plans, targets and projections (European Commission, 2021b; Ministry of Mining and Energy, 2022).

A few remarks with regards to the employed simulation model need to be expressed. Firstly, since it utilises static and linear data, non-linear behaviours will not be visible. Whereas MS Excel as a tool has been utilised throughout the literature by various institutions as previously mentioned, the type of data and simulations being developed constitute a big difference. In this specific case, behaviours such as energy price trends or the final energy consumption will be represented linearly, which in real life is not the case as these might be affected by various factors. More sophisticated models are present in the literature and have been employed by different institutions. The European Commission et al. (2021), when delineating its EU Reference Scenario 2020, applied a combination of models, interlinking technical and economic methodologies. The central model utilised when delineating the previously mentioned simulation study, was PRIMES, an energy system model allowing for the handling of multiple targets associated to some specific constraints. Since 2016, this modelling suite has been upgraded to include PRIMES-BuiMo and PRIMES-Maritime, covering both the residential and maritime sector (European Commission et al., 2021). PRIMES-BuiMo includes 28 different heating and cooling devices, each divided in four categories depending on their technological level, and eleven categories of electric appliances. Apart from the PRIMES energy system model, other modelling software were utilised in the delineation of the EU Reference Scenario 2020, such as POLES-JRC, GEM-E3, CAPRI, GAINS, and GLOBIOM (European Commission et al., 2021). Nonetheless, these are all very sophisticated software not easily accessible. Additionally, the utilisation of such model for the problem at hand would be overwrought. Hence, even though the model being employed is a static and linear one, not offering a high level of computational abstractness, for the issue at hand, seeing also the past literature (e.g., (Ban et al., 2021; Ministry of Mining and Energy, 2021d; Rogulj et al., 2022)), was deemed as particularly applicable.

6.1.1. Data Gathering

The data collection process consisted in gathering data related to the socioeconomic characteristics of the first income decile, the distribution of fuel sources throughout different energy end-uses and the prices of these fuel sources in Serbia. The socioeconomic characteristics considered were the number of low-income households, the average income of the first decile, the average number of household members, the average living area and the average expenses for electricity. It must be noted that with “average number of household members” it is meant the “average consumption unit”. In line with Eurostat recommendations, an equivalence scale (consumption unit) was applied as to allow comparison between household sizes (members). Namely, a weight of 1 is given to the head of the household, a weight of 0.7 per grownup (14+) and a weight of 0.5 per child (below 14 years of age) (Statistical Office of the Republic of Serbia, 2020). All monetary values were gathered in the local currency (RSD) and thereafter converted to euros (EUR). The chosen exchange rate was the average exchange rate from RSD to EUR in 2019, namely 117.8524 (National Bank of Serbia, 2022). Table 6.1 gives an overview of all the gathered values and the corresponding sources.

The distribution of fuel sources throughout different end-uses and the prices per fuel were considered as to have a better insight in how energy is distributed in Serbia and how the corresponding prices could change. Five main end-uses of energy were considered, namely: space heating, cooling, water heating (domestic hot water or DHW), cooking, and electric appliances and lighting. Firstly, the average consumption per end-use per household was obtained; thereafter it was multiplied by the number of low-income households; and hence multiplied by the share of fuel type. This way, the total final energy consumption of low-income groups per end-use per fuel type were obtained. Thereafter, prices for every type of fuel were gathered and costs per end-use obtained. Several assumptions were taken when estimating prices. For electricity and natural gas, the average prices in Serbia for the first and second semester in 2019 were taken. For heating oil, it was assumed that 1L of the latter produces 10.35 kWh of heat. For LPG, it was assumed that 1 Kg of the latter produces 14.019 kWh of heat. For biomass, it was considered that wood is the most common type of biomass utilised, with the first decile producing on average 2608 kWh of energy from 3.5 cubic meters of wood (RES Foundation, 2022). Finally, for “coal and other”, the price of lignite was considered with an energy production rate of 7.5 MJ/Kg (Brkić, 2018). The fact that lignite was the main type of coal utilised throughout Serbia, mainly in low-income households, was found in various literature sources (RES Foundation, 2022; Young & Macura, 2020). Table 6.2 gives an overview of the different prices per source of fuel.

Low-income household characteristics (2019)		**Source**
Number of low-income households (dwellings)	246,705	(Statistical Office of the Republic of Serbia, 2020)
Average income (€)	99	(Social Inclusion and Poverty Reduction Unit, 2021)
Average number of household members (Average consumption unit)	2.21	(Statistical Office of the Republic of Serbia, 2020)
Average living area (m2)	64	(Statistical Office of the Republic of Serbia, 2020)
Average expenses for electricity (€)	34	(Statistical Office of the Republic of Serbia, 2020)

Table 6.1: Overview of socioeconomic characteristics of low-income household groups.

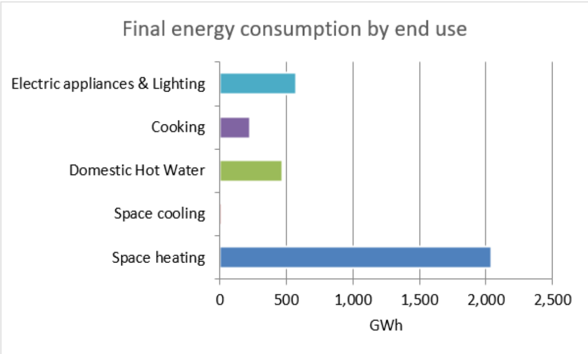
Fuel type	Price (EUR/MWh)	Source
Electricity	55	(Eurostat, 2022b)
Heating oil	149	(Energy Agency of the Republic of Serbia, 2014)
LPG	91	(Energy Agency of the Republic of Serbia, 2014)
Natural gas	31	(Eurostat, 2022c)
Solar thermal	135	(Serbia Energy, 2021)
Biomass	66	(Energy Agency of the Republic of Serbia, 2014)
Ambient heat	-	*
District heating	85	(Macura, 2017)
Coal and other	27	(Energy Agency of the Republic of Serbia, 2014)

Table 6.2: Overview of fuel prices. *no prices for ambient heat were found as its utilisation is currently too low to be even surveyed (Macura, 2017).

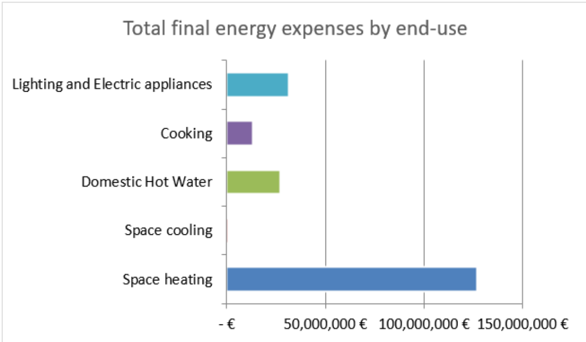
6.1.2. Analysis of the Status Quo

Before analysing the different insights found when studying data pertaining to 2019, a few considerations must be expressed. Indeed, a few assumptions were made when analysing the data. As previously mentioned, data concerning household energy consumption per end use and type of fuel were obtained from the Eurostat repository (Eurostat, 2022a, 2021). The data distinguished between seven types of fuels, namely: oil and petroleum products (excluding biofuel portion), natural gas, solid fossil fuels, electricity, renewables and biofuels, derived heat, and other fuels (n.e.c.). The latter was found to always have a value of zero when considering Serbia and was thus excluded. Thereafter, four assumptions were taken, namely that "oil and petroleum products (excluding biofuel portion)" could be considered as "heating oil"; "solid fossil fuels" as "coal and other"; "renewables and biofuels" as "biomass"; and "derived heat" as "district heating". Whereas the first assumption is rather straightforward, the second one was assumed since the main solid fossil fuel exploited in Serbia is coal, of which brown coal specifically amounts to over 95% (Brkić, 2018). In turn, 98.7% of the brown coal produced is lignite (Brkić, 2018). As previously mentioned, this is the main type of coal used by low-income households, and thus the price of lignite was applied when evaluating the type of fuel "coal and other". Biomass is considered as a renewable fuel and according to (RES Foundation, 2022, (p.16)), "biomass represents the largest quantity […] in household space heating in the contracting parties of the Energy Community Treaty". Hence, the "renewables and biofuels" share was assumed to be "biomass". Finally, "derived heat" was assumed to be from "district heating", as the percentages matched according to Macura (2018). Household space cooling was assumed to be purely electric. For the share of fuels concerning DHW specifically, biomass and coal were not considered as these presented very low values (0.4% and 0.5%), district heating was assumed to be zero and heating oil was increased up to 4% to compensate. In addition, the shares of coal and heating oil used for cooking (1.4% and 4.9%) were not considered.

Several insights can be found analysing the energy distribution by end use and the related expenses. Firstly, it becomes clear that space heating is the main energy end-use (Figure 6.1a), representing alone 61% of final energy consumption. For comparison, "electric appliances and lighting", which was the second largest energy end-use, represented only 17% of final energy consumption. Not surprisingly, the same pattern could be found when analysing the costs related to energy end-uses (Figure 6.1b). Thereafter, the energy consumption and related costs per type of fuel were analysed. Electricity was found to be the main type of fuel utilised followed by biomass and district heating; however, with the former two representing much larger shares compared to the latter (Figure 6.2a). Once again, the same pattern was maintained with regards to the related costs (Figure 6.2b). However, it could be noticed how district heating represented a larger share of expenses compared to consumption, and the other way around for coal. This is due to the respectively high and low costs of district heating and coal (Table 6.2). Figure 6.3 gives an overview of the distribution of fuels and their consumption across different energy end-uses. For a detailed overview of all consumptions and costs, please consult Section A.1 of the Appendix. For a more detailed analysis of the distribution of fuels per single end-use, please consult Figures A.1, A.2, A.3 of the Appendix (space cooling and “electric appliances and lighting” are not shown as these are purely electricity-fuelled).

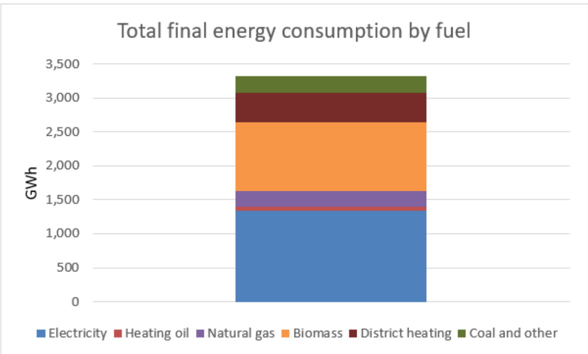


(a) Final energy consumption by end-use.

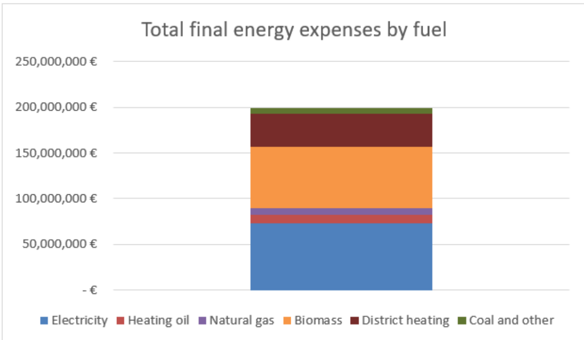


(b) Energy related costs by end-use.

Figure 6.1



(a) Share of fuels in final energy consumption.



(b) Share of fuels in final energy expenses.

Figure 6.2

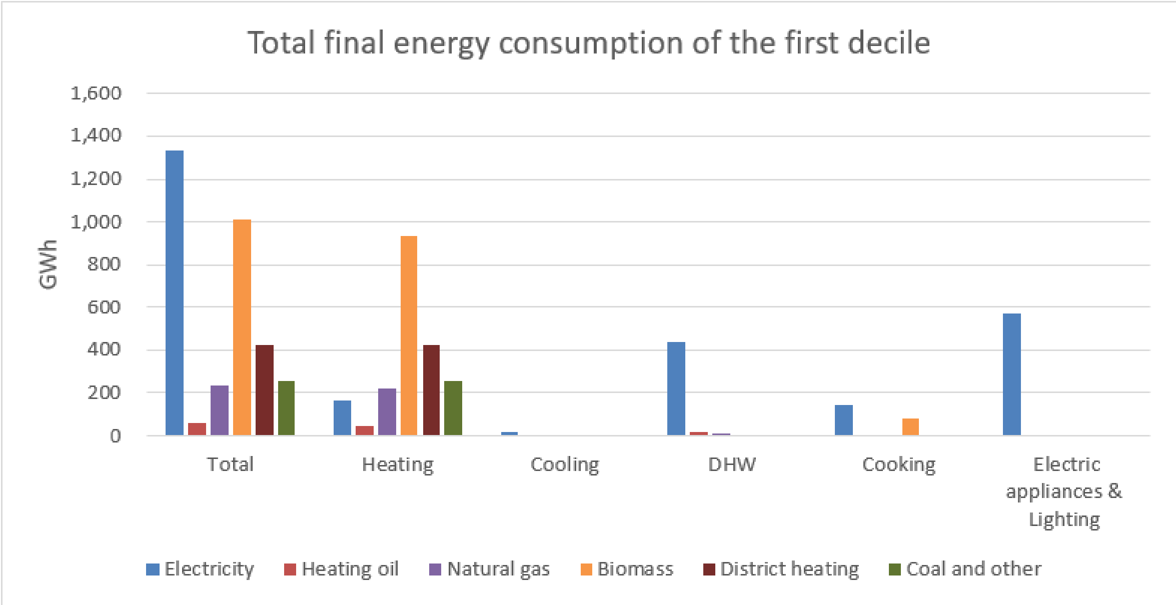


Figure 6.3: Overview of the distribution of fuels and their consumption by energy end-use.

6.2. Policy Scenarios

6.2.1. Description of Policies

Three different policies to reduce energy consumption and prices of energy thus positively affecting low-income households were delineated. The three policies will thereafter be simulated by utilising a static MS Excel model. In addition, a baseline scenario will also be simulated. This represents the case in which no additional policies are implemented, and the energy prices keep on increasing according to the EU Reference Scenario (European Commission et al., 2021). The chosen policies will be described in the following section, including also the assumptions considered per scenario.

Scenario 1

The implementation of an emissions trading scheme in Serbia is here considered. In addition to the foreseen increase in energy prices, here it is also taken into account how prices would further grow due to carbon pricing. Specifically, ETS2 prices were considered for carbon pricing, as proposed by a Vivid Economics study conducted for the European Climate Foundation. It must be noted that these prices were obtained when analysing the EU Member States and not Serbia. Nonetheless, these prices were taken as reference as Serbia has not implemented any carbon pricing scheme (Ministry of Mining and Energy, 2022).

Scenario 2

A mandatory phase-out of heating oil and solid fossil fuels in 2030, followed by natural gas in 2040 is here considered. It is assumed that it will take five years to carry out the actual phase out. Thus, no heating oil or solid fossil fuels will be present as of 2035 and no natural gas as of 2045. The existing space heating systems utilising these types of fuels will be replaced by heat pumps (ambient heat). It is further assumed that ambient heat does not have a price, and that the operational costs related to the implementation of heat pumps are considered via the increased amount of electricity. On the other hand, when considering DHW, the phase-out of heating oil, solid fossil fuels and natural gas is assumed to be replaced by electricity, as it already covers 94% of the energy consumption for DHW. The installation costs per heat pump are assumed to be 8,000 EUR (Rogulj et al., 2022).

Scenario 3

The establishment of Minimum Energy Performance Standards (MEPS) (Section 2.5.2) as to achieve energy class E in 2035 is here considered. It is assumed that 75% of total low-income dwellings (185,209) will need to be refurbished by 2035. Of these 185,209 dwellings, 50% will be renovated in

2030 and the other half by 2035. Renovation costs are assumed to be 10,000 EUR per household with delivered final energy savings of 30% (Rogulj et al., 2022). Thereafter, it is assumed that all refurbished dwellings will be upgraded to energy class D in 2040. In this case, renovation costs are assumed to be 5,000 EUR per dwelling, delivering final energy savings of 10% (Rogulj et al., 2022).

6.2.2. Socio-Economic and Political Relevance of Delineated Policies

The outlined and tested policies corresponding to the different simulation scenarios were delineated considering both EU and national targets in the energy sector. The baseline scenario was developed to give an insight on how the situation would keep developing maintaining the 2019 energy characteristics, but also to compare the developed scenarios and provide an idea on the implied energy and monetary savings per policy. All three policies were developed considering the envisioned changes and updated targets expressed in the latest EU energy package, namely the Fit for 55 package. Indeed, each delineated policy tackles aspects mentioned both in updated EU energy directives and energy targets suggested by the Ministry of Mining and Energy. The reasonings behind each policy will be discussed in detail in the following subsection.

Scenario 1

The first scenario considered the implementation in Serbia of a carbon pricing system, similar to the EU-ETS. As mentioned in Section 4.5, Serbia has not yet implemented any form of emissions pricing or trading scheme. Meanwhile, in line with the objectives set in the Fit for 55 package, the EU proposed to expand the EU-ETS to both the transport and buildings sector (European Commission, 2021b). This step is seen as complementing existing EU policies and thus providing an extra push to drive changes both in public and private investments. The application of such system would "help bring cleaner heating fuels to the market, shorten payback periods for investments in renovation and accelerate fuel-switching in heating and cooling in existing buildings" (European Commission, 2021b, (p. 7)). As mentioned in previous sections, such improved system would be focused on fuel suppliers rather than end-users, as to ensure a just transition, providing support to those most in need (European Commission, 2021b). Additionally, a carbon taxing system needs to be applied in Serbia as to remain competitive with EU member states. Indeed, Serbia risks to be "'left out" by its trading partners, especially in the case in which the EU would apply this new upstream trading system to the buildings and transport sector and Serbia would be yet to implement it to the power and heat generation sectors. Failure to phase out coal-fuelled production could entail higher export costs due to the carbon pricing being applied by trading partner countries. Finally, revenues resulting from the implementation of such a system could thereafter be spent on refurbishing residential buildings, as is the case in Czech Republic (Trubacik, 2021).

Scenario 2

The second scenario considered the gradual phasing out of fossil fuel boilers. It was assumed that heating oil and coal would be phased out in 2030 and natural gas in 2040, with these heating systems being substituted with more efficient heat pumps. Boilers have an average lifetime of 20 years; hence, to reach carbon neutrality by 2050, the sale and implementation of these would have to be phased out by 2030. The replacement of outdated and inefficient boilers with heat pumps was also mentioned in the proposal to revise the Energy Performance of Buildings Directive (EPBD), as part of the Fit for 55 package (Section 2.5) (European Commission, 2021c). Additionally, the Ecodesign Directive (ED), focused on setting energy performance standards and requirements on energy-related products (e.g., boilers, lighting appliances or heat pumps), also requires new energy products to satisfy higher efficiency requirements (European Commission, 2021c). One of the outlined provisions in the EPBD proposal, attaining specifically to articles 8, 10 and 15, was for Member States to be forbidden to subsidise fossil-fuel boilers as of 2027. Furthermore, in Article 11, a clear legal basis is introduced regarding the ban of fossil-fuel boilers, allowing Member States to establish precise requirements concerning GHG emissions related to heat generators (European Commission, 2021c). As mentioned in Section 4.5, the replacement of fossil-fuel boilers is seen as a short-term solution in the field of thermal energy production in Serbia together with the allocation of incentives for building renewable heat pumps (Ministry of Mining and Energy, 2022). Hydrogen is mentioned as an alternative fuel for boilers together with the reconstruction of boiler rooms.

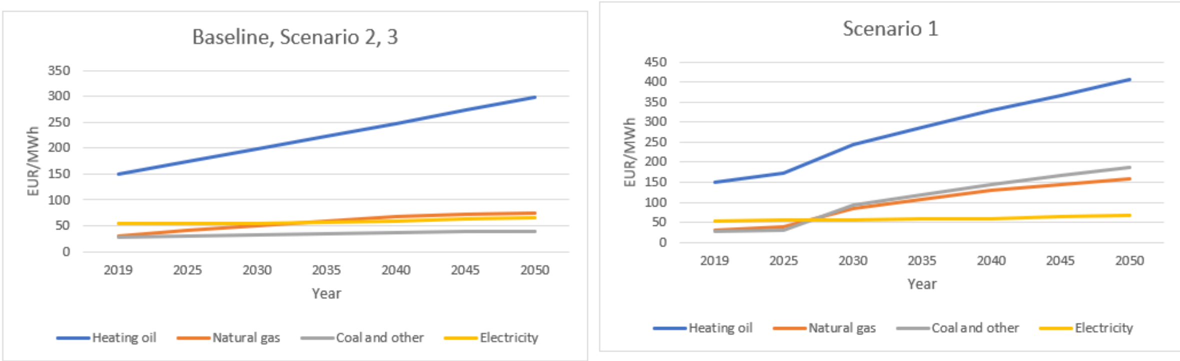
Scenario 3

The third scenario considered the implementation of Minimum Energy Performance Standards (MEPS) in the buildings sector. As previously mentioned, the revised EPBD greatly stresses the importance of improving household energy efficiency and the direct impacts this can have on lowering energy poverty. It is estimated that to achieve the 55% emissions reduction goal by 2030, the GHG emissions of buildings in the EU would need to be reduced by 60%, their FEC by 14% and the space heating and cooling energy consumption by 18%; all compared to 2015 levels (European Commission, 2020a). The introduction of MEPS was the main novelty of the revised EPBD proposal. Together with decreasing energy bills, by increasing the value of energy performing buildings, citizens can be further protected from the energy price increases and volatility (European Commission, 2021c). Whereas the outlined standards have been designed as to mitigate negative social effects, these must be nonetheless supported by a comprehensive framework providing technical assistance and financial support to low-income households. The revised directive includes the renovation of buildings which, according to the Energy Performance Certificate (EPC), are in classes G or F. Buildings rated as class G correspond to the 15% worst performing buildings in the country (Rogulj et al., 2022). The revised EPBD requires all class G buildings to be renovated to at least class E at the latest by 2030 (European Commission, 2021c). The focus on the lowest-performing buildings is dictated by the fact that these present the biggest opportunities for decarbonisation, improving energy efficiency and alleviating energy poverty. In addition, it is left to the single country to establish further targets for achieving higher EPC classes by 2040 and 2050 (European Commission, 2021c). In this specific simulation scenario, 2040 was set as a timeline to refurbish all low-income dwellings up to class D. In Serbia, energy efficiency of buildings is seen as a strategic direction of development (Ministry of Mining and Energy, 2022). Indeed, short-term solutions in the field of energy efficiency include providing incentives for ameliorating household energy efficiency and providing funds for energy rehabilitation programmes in buildings (Ministry of Mining and Energy, 2022). As mentioned in Section 4.5, it is foreseen to rehabilitate approximately 100 million of square meters of living space from 2021 to 2050, with envisioned emissions reductions of 37% compared to 2020 levels (Ministry of Mining and Energy, 2022).

6.3. Empirical Results of Simulated Policies

Before proceeding to analyse the results obtained by applying the various scenarios, a few considerations must be exposed. Firstly, only space heating, cooling and DHW will be considered as energy end-uses. These account for 75.56% of final energy consumption (Eurostat, 2022a), but most importantly would be the most affected by the three proposed policies. Therefore, it was decided to exclude cooking and “electrical appliances and lighting” from the scenario simulation. Secondly, it is assumed that the prices of biomass and district heating will remain unaltered. This means that the consumption of the two types of fuels will also stay unchanged. Thirdly, price elasticities of demand are assumed also for space heating and electricity, respectively of -0.5 and -0.55. This means that, e.g., if the price of electricity increases by one percent, the demand of electricity will decrease by 0.55 percent. In this case, the price elasticities of demand are of a linear and static nature, and remain constant throughout the simulation period. This is also another assumption, as in real life price elasticities would change every year or month depending on a variety of factors. Additionally, different elasticties of demand would be present depending on the analysed strait of society of one country. In fact, the hereby utilised price elasticities were found to be applicable when considering the *total* population of countries from Central and Eastern Europe (Rogulj et al., 2022). Nonetheless, it was decided to apply these values also to low-income groups specifically. Lastly, the increase in energy prices for Serbia in this model follows the projections foreseen in the EU Reference Scenario 2020 (European Commission et al., 2021). Figure 6.4a shows the energy price trends for Serbia without the implementation of any carbon pricing scheme. On the other hand, Figure 6.4b shows the energy price trends with the implementation of the latter. When comparing the two situations, it can be noticed that the price of electricity remains the same, while natural gas more than doubles, and coal more than quadruplicates. Thus, whereas heating oil remains the most expensive choice in both cases, electricity becomes clearly cheaper in Scenario 1. For a more detailed analysis of energy price trends for Serbia, please consult Section A.3

of the Appendix.



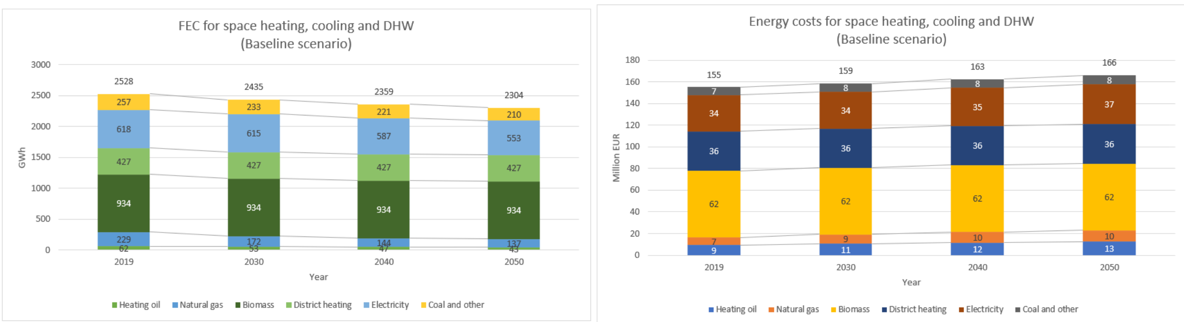
(a) Energy prices projections for Serbia.

(b) Energy prices projections for Serbia considering prices related to ETS2.

Figure 6.4

6.3.1. Baseline Scenario

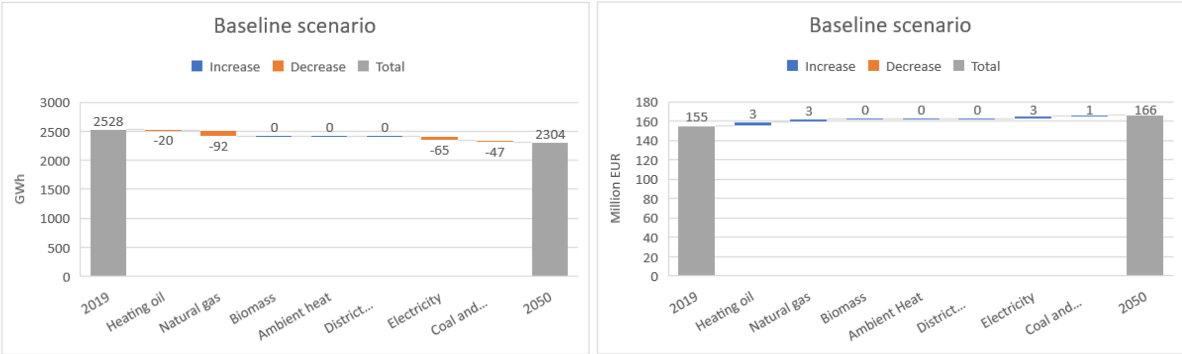
By not implementing any policies or regulations, the Final Energy Consumption (FEC) of the low-income households in Serbia would diminish steadily (Figure 6.5a), whereas the related energy expenses would increase steadily (Figure 6.5b). Energy prices in general are envisioned to increase; thus, due to the price elasticity of demand, the consumption will inevitably diminish. However, this would mean that households would not be able to pay any more for their energy expenses, and they would hence reduce their consumption. This is not ideal, as rationing energy usage is itself a symptom of energy poverty. It can be stated that without implementing any energy policies, energy poverty within low-income households in Serbia would increase. Whereas this would entail no implementation costs, it is virtually unsustainable. A detailed overview of the results can be found in Section A.4 of the Appendix.



(a) Graphical overview of energy consumption for the Baseline Scenario.

(b) Graphical overview of energy expenses for the Baseline Scenario.

Figure 6.5



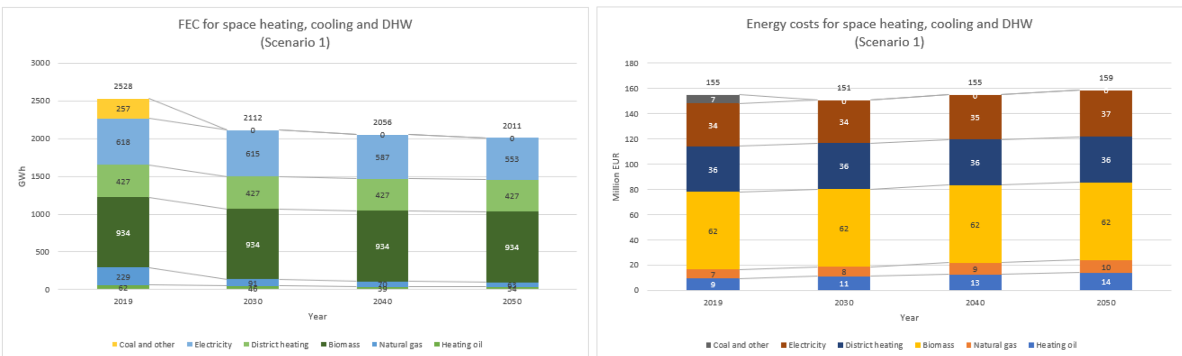
(a) Illustration of consumption trend changes per type of fuel for the Baseline Scenario.

(b) Illustration of expenses trend changes per type of fuel for the Baseline Scenario.

Figure 6.6

6.3.2. Scenario 1

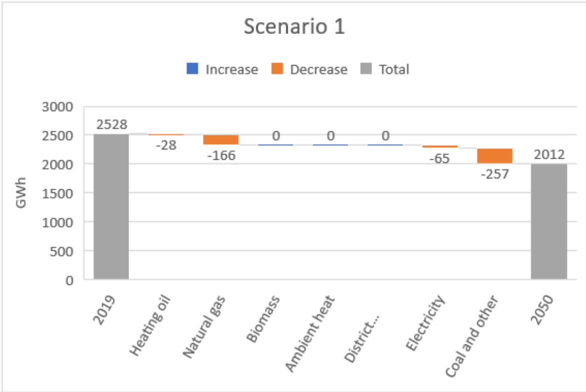
By implementing an emissions trading scheme in Serbia, the FEC of the low-income households would decrease rather sharply in the first 10 years, and thereafter more steadily (Figure 6.7a). On the other hand, the energy related expenses would steadily increase (Figure 6.7b). In fact, except for coal that would exit the market already after 10 years due to its unsustainable carbon pricing, the prices of the rest of the fossil fuels and electricity would continue to steadily increase. This would inevitably decrease the consumption of fossil fuel sources, and thus energy in general, however harming the low-income households as was the case for the baseline scenario. Emissions trading schemes such as the EU-ETS are usually directed at the industrial sector, finding cost-effective ways to reduce carbon emissions. Indeed, the EU-ETS managed to reduce emissions by 42.8% since 2005 in the three sectors covered, namely: energy-intensive industrial installations, power and heat generation (European Commission, 2021d). To achieve the updated targets outlined in the Fit for 55 package, the European Commission has proposed to include the buildings and transport sector within the new updated pricing system (Section 2.5.2) (European Commission, 2021d). However, this would be a separate upstream system that would regulate fuel suppliers, rather than households and car drivers directly (European Commission, 2021d). This would incentivise suppliers to decarbonise their products, without directly targeting end-users. This new system is designed to start in a flowing, efficient and slow-paced manner as of 2026. However, the European Commission already stressed how the implementation of such an upstream system alone would not provide satisfying results, but that it rather must be combined with an efficient refurbishment of buildings (European Commission, 2021d). This goes in line with the results achieved from the simulation, showing how the introduction of such a policy alone in Serbia would hamper the buildings sector, increasing energy poverty especially among low-income households. A detailed overview of the results can be found in Section A.5 of the Appendix.



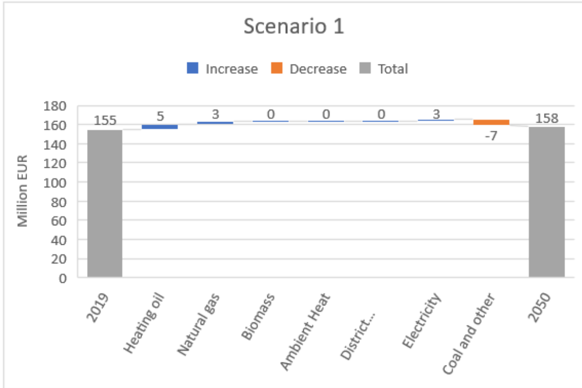
(a) Graphical overview of energy consumption for Scenario 1.

(b) Graphical overview of energy expenses for Scenario 1.

Figure 6.7



(a) Illustration of consumption trend changes per type of fuel for Scenario 1.

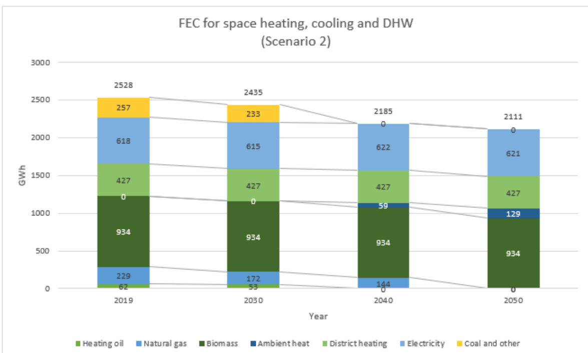


(b) Illustration of expenses trend changes per type of fuel for Scenario 1.

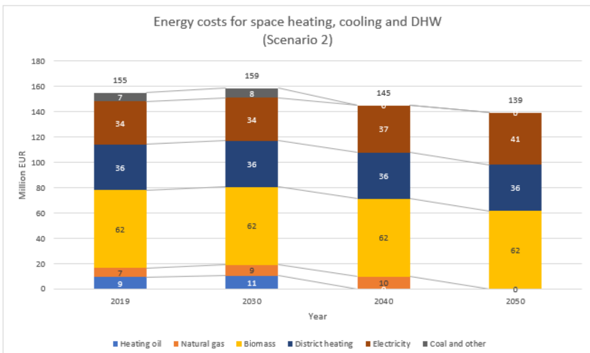
Figure 6.8

6.3.3. Scenario 2

By applying a mandatory phase-out of heating oil and solid fossil fuels first, followed by natural gas, both the FEC and energy costs would be reduced. The FEC steeply declines following the phase-out of heating oil and coal in 2030, and thereafter continues declining steadily until 2050 following the phase-out of natural gas (Figure 6.9a). Interestingly, as can be seen in Figure 6.10a, the consumption of ambient heat increases severely whereas that of electricity mildly, yet it increases compared to the base year. This is due to the assumption that heat pumps would replace existing heating systems, and more electricity would be consumed to implement these changes. On the other hand, only the costs of electricity increase (Figure 6.10b). Indeed, this increase also considers the operational costs that would be incurred when implementing the heat pumps throughout the energy network. In addition, it is assumed that following the phase-out of the three non-renewable sources, DHW would become purely electricity fuelled; nonetheless consuming a smaller amount compared to 2019, unlike for space heating. It must be also noted that ambient heat is assumed to have no price in the current model. When analysing the incurred costs specifically, these increase steadily until 2030, whereas they start decreasing following the phase-out of the three types of fuel (Figure 6.9b). Assuming the costs and thus consumption of biomass and district heating remain untouched, the costs distribution of the year 2050 becomes clearer; as compared to 2019, all other fuels except electricity have been phased out, with the latter representing higher expenses compared to the base year. Finally, an important aspect to consider are the implementation costs related to the heat pumps. From 2030 to 2035, these would amount to approximately 296 million euros (59.2 million EUR/year), and from 2040 to 2045 another 217 million euros (43.4 million EUR/year). A detailed overview of the results can be found in Section A.6 of the Appendix.

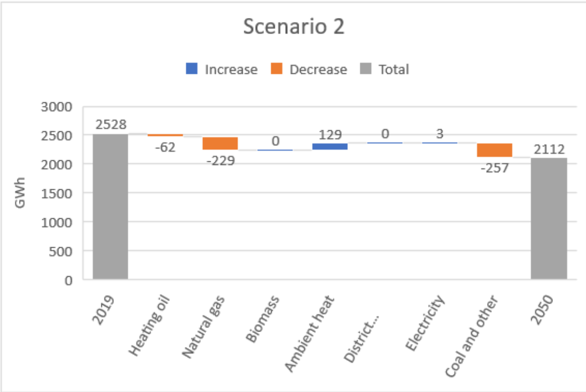


(a) Graphical overview of energy consumption for Scenario 2.

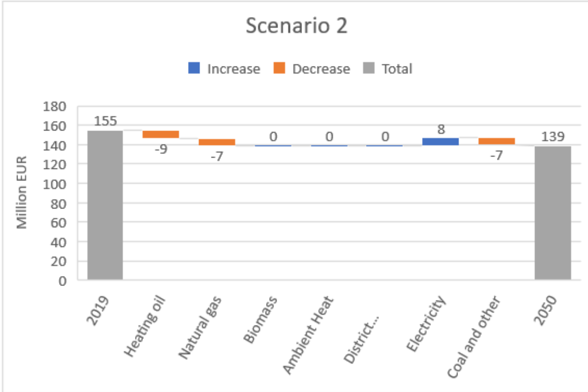


(b) Graphical overview of energy expenses for Scenario 2.

Figure 6.9



(a) Illustration of consumption trend changes per type of fuel for Scenario 2.

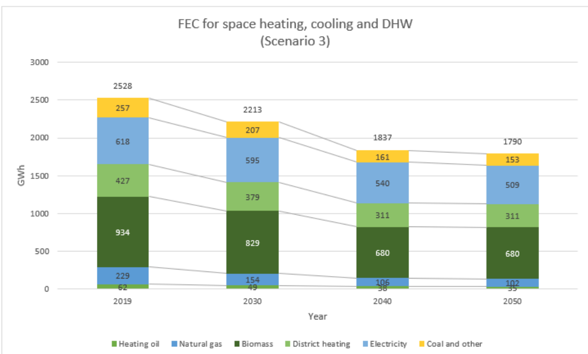


(b) Illustration of expenses trend changes per type of fuel for Scenario 2.

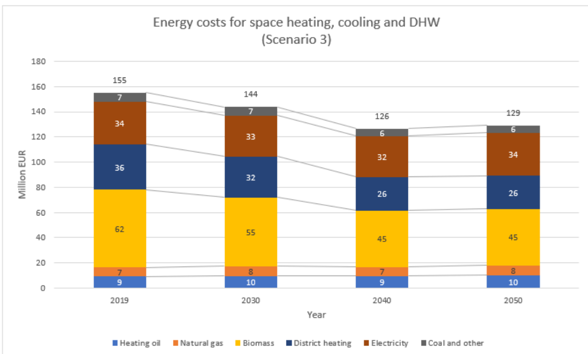
Figure 6.10

6.3.4. Scenario 3

By refurbishing the buildings belonging to low-income households, both the energy consumption and costs would decrease. The consumption would decrease rather sharply from 2019 to 2040, thereafter acquiring a steadier decreasing pace (Figure 6.11a). Interestingly, the consumption of fuel sources would decrease in a uniform and proportional manner. Indeed, in this case the general efficiency of the whole building is targeted rather than some specific fuel sources. When analysing the consumption trend of fuel sources individually, it can be seen that all types of fuels experience a decrease in their consumption, with biomass being the most affected one (Figure 6.12a). This is because biomass is the most utilised fuel type representing approximately 46% of the space heating energy consumption. However, whereas natural gas represents only approximately 11% of space heating energy consumption, it is nonetheless the type of fuel seeing the second largest reduction in consumption. This is due to the increasing energy prices related to natural gas that will lower its demand. When considering energy expenses, these will diminish, rather steeply from 2030 to 2040, followed by a slight increase from 2040 to 2050 (Figure 6.11b). Indeed, the refurbishment of buildings from 2030 to 2040 will highly improve household energy efficiency and thus lower greatly expenses. Once these changes are applied however, general expenses will increase due to the general increase of energy prices. Interestingly, only expenses related to biomass and district heating will decrease substantially, whereas for the rest of types of fuels these will remain rather unaltered (Figure 6.12b). Essentially, their decrease in consumption is levelled by their increase in energy prices. Lastly, costs related to the refurbishment of buildings need to be taken into account, namely 925 million euros every five years from 2030 to 2045. In other words, 185 million EUR/year for 15 years in a row. A detailed overview of the results can be found in Section A.7 of the Appendix.

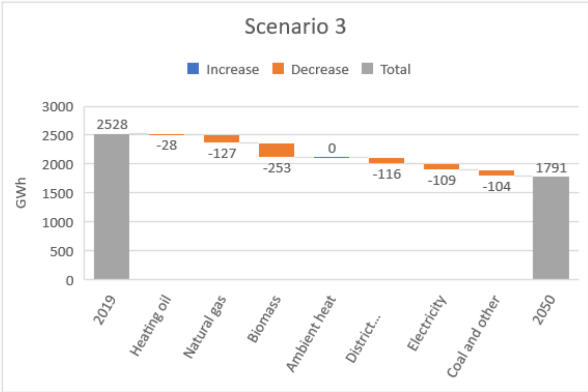


(a) Graphical overview of energy consumption for Scenario 3.

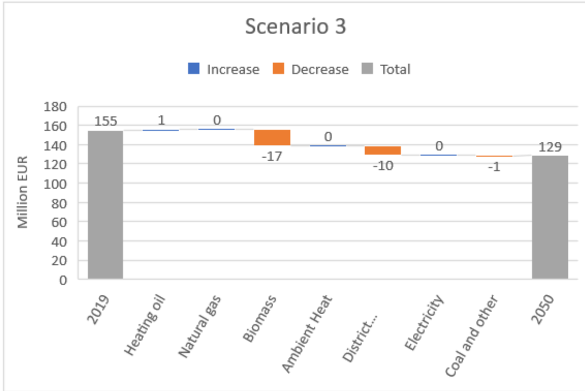


(b) Graphical overview of energy expenses for Scenario 3.

Figure 6.11



(a) Illustration of consumption trend changes per type of fuel for Scenario 3.



(b) Illustration of expenses trend changes per type of fuel for Scenario 3.

Figure 6.12

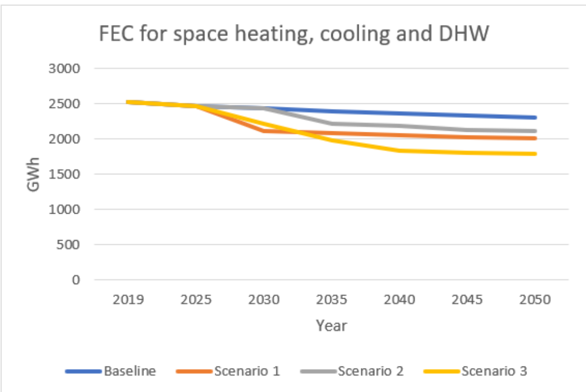
6.4. Best Performing Policy

Scenario 3, namely implementing MEPS for buildings in Serbia specifically pertaining to low-income households, was selected as the best policy, yielding the most desirable results out of the three analysed ones. The baseline scenario, as expected, yielded the worst results both from an energy consumption and expenses perspective and will not be further discussed, as not implementing any policies to improve energy efficiency and poverty in Serbia can be deemed as irrational, as shown by the simulation results. In the following subsection, the advantages and disadvantages of each policy will be discussed, considering both energy consumption and expenses. Thereafter, reasonings for choosing the third policy as the most satisfying one will be laid out. It must be noted that the discussed results stem from a static model that utilises several assumptions, and therefore cannot be considered binding. Nonetheless, it provides interesting insights and points of discussion.

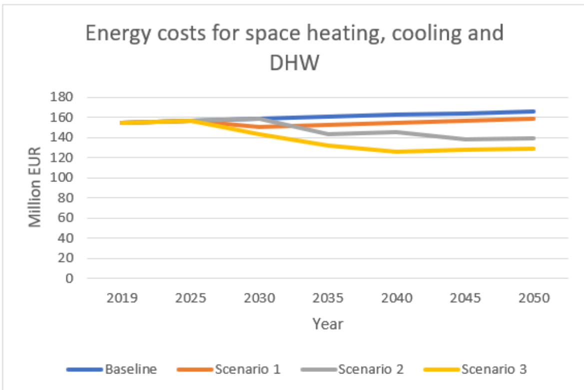
Scenario 3 yielded the best results from an energy consumption perspective. As can be seen in Figure 6.13a, starting from approximately the year 2035, this policy generated the lowest FEC. Interestingly, Scenario 1, namely applying an emissions pricing/trading scheme in Serbia, was the best performing policy for a period of approximately 10 years, from 2025 to 2035. However, the initial impact this policy brought proved to be unsustainable. Indeed, this policy only reduced expenses due to the increased costs resulting from the implementation of such system. Nonetheless, after experiencing the initial shock, energy prices kept on increasing as usual and so did the consumption. The ETS has never been intended as a policy that could single-handedly improve the energy efficiency situation, but rather as a policy to be coupled with others (European Commission, 2021c,d). It must be also noted that ETS2 prices were applied to Serbia, and that these could be deemed as unrealistic and/or too expensive. In addition, the ETS system was applied directly to the households, whereas in reality such a system would be different from the existing one; more upstream and targeting fuel-suppliers rather than end-consumers. On the other hand, with a complete refurbishment of buildings, equally spread between the various sources of fuel, the reduction in consumption is more constant. The slope of the consumption line becomes less steep after 2045, namely when all the buildings have been refurbished. However, this is completely normal and expected. Indeed, once improved, the buildings will be more efficient and thus consume less energy, nonetheless this reduction in consumption will never equal the initial shock due to the refurbishment of the whole buildings sector.

Scenario 3 yielded the best results also from an energy expenses perspective. The MEPS policy produces the lowest energy expenses constantly throughout almost the whole analysed time period (Figure 6.13b). Indeed, a more energy efficient building will consume less and thus reduce expenses as expected. On the other hand, Scenario 1 manages to reduce expenses only initially, since after the implementation of the trading system these keep on increasing following the energy price trends. Considering that in Scenario 1 the FEC kept on decreasing throughout the simulation period, this further goes to show that such reduction was purely due to the increasing costs and thus rationing of energy consumption, rather than any other factors. When considering Scenario 2, it can be seen how the reduction in expenses is closely related to the phasing out of fossil fuels, namely in 2030 and 2040. It must be noted that, even though Scenario 3 presents the lowest energy expenses values, and these keep on decreasing steadily throughout all the refurbishment period (2030-2040), these mildly increase after 2040. This is purely due to the increasing energy prices. In fact, in this scenario, it is considered that the distribution of fuels will remain the same, without envisioning any phase out. This means that solid fuels will continue to be utilised in buildings up until 2050. These would be consumed in a lower quantity but nonetheless would represent high prices in the energy market.

Scenario 3 presents the highest implementation costs out of all the analysed scenarios. Namely, a total of 2775 million euros spread over 15 years. Whereas the envisioned refurbishment prices per building were assumed considering EU standards, and thus these could be actually lower for Serbia, the policy suggesting the implementation of MEPS in buildings presents the highest implementation costs. The phase out of fossil fuel boilers would cost a total of 513 million euros spread over 10 years. Whereas such costs would not be paid directly by end-users, these could result in higher energy expenses and/or taxes if not implemented correctly. However, no great changes can be achieved without proper investment. As mentioned in Section 2.2.3, the Republic of Serbia has already invested approximately 105 million euros in the buildings sector just in the period between January and May 2021. However, it is estimated that an extra 1636 million euros of investments are needed (Energy Community, 2021). The need to invest in household energy efficiency is clear, with the European Commission having already set aside 9 billion euros as part of the Economic Investment Plan for the Western Balkans (Section 2.2.3). The latter includes as its three main objectives: tripling the refurbishment rate of existing buildings, tripling energy savings in existing dwellings and finally achieving nearly zero FEC in new buildings (Energy Community, 2021). Additionally, over 35 billion euros have been delineated in the new investment plan set by the (Ministry of Mining and Energy, 2022). Already 1.07 billion euros of state investment are envisioned only in the field of thermal energy (heat pumps) (Ministry of Mining and Energy, 2022). In the field of energy efficiency, including the refurbishment of residential buildings, the Ministry has planned investments for a value exceeding 3 billion euros (Ministry of Mining and Energy, 2022). Therefore, whereas Scenario 3 presents the highest implementation costs, these should be able to be sustained by applying correct measures and policies and efficient investment planning.



(a) Graphical comparison of FEC trends over time per scenario.



(b) Graphical comparison of energy expenses trends over time per scenario.

Figure 6.13

7

Discussion

7.1. Available Fuel Resources in Serbia

The proposed policies in this study look at the future of the energy sector in Serbia. Nonetheless, current available sources of fuel in the country must also be considered. In the following subsection, the main types of fuels currently present in Serbia will be analysed and discussed. Indeed, proposed policies must take into account the status quo of available sources in the country and the possible development strategies related to the latter. Suggesting improvement of energy efficiency and higher share of renewable energy is not enough, as also technical and economic factors need to be considered. As highlighted throughout the study, Serbia finds itself in a delicate situation in which it must also choose on which type of fuel, and thus strategic direction, to focus on in the upcoming years.

7.1.1. Power Engineering

Electricity is the most utilised type of fuel in household energy consumption in Serbia (Figure 6.2a). As mentioned in Section 6.1.2, the energy end-use presenting the second highest consumption, electric appliances and lighting, is purely electricity fuelled. In addition, space cooling can also be considered purely electricity fuelled. Nonetheless, the current electricity production in Serbia is insufficient for its required level of energy security (Ministry of Mining and Energy, 2022). Since 1991, not a single new power plant for the generation of electricity has been constructed in the country (Ministry of Mining and Energy, 2022). As can be imagined, this entails technological backwardness in the sector. Hence, the country resorts to importing electricity to cope with frequent electricity shortages. The latter happen due to the outdated and undermaintained infrastructure of the electricity distribution system, with many rural areas being unable to receive electricity at all (Ministry of Mining and Energy, 2022). Approximately 3.5 TWh of electricity (over 13%) are lost in the distribution network; resulting in over 300 million euros per year, which could have been invested to modernize the distribution network or build new plants (Ministry of Mining and Energy, 2022). Additionally, there is no concrete strategic planning of any capacity development utilising RES, with private energy production plants utilising RES being underdeveloped. This leads to most of the domestic electric production being generated by brown coal, or more specifically lignite. The latter is still considered to be the cheapest fuel option for energy production, however this might change in the close future, as illustrated in Figure 7.1. It becomes thus paramount for Serbia to improve its electricity generation capacity, as to improve both its energetic independence and security of supply. Electricity is not envisioned to disappear in the upcoming years, but rather be even more utilised to replace existing polluting technology and fuel types (e.g., Scenario 2). An overview of the possible types of fuels from which electricity could be produced, and their specific characteristics, can be found in Figure 7.2.

When first introduced, large lignite burning energy facilities greatly helped the economic development of the country; nonetheless, nowadays this type of fuel is becoming obsolete and too costly both from an economic and environmental perspective (Macura, 2017). In Serbia, there are an estimated 60 years left of coal reserves, specifically lignite, and these amount to 780 million tons of oil equivalent

(Young & Macura, 2020). The stocks of coal in Serbia, according to projected levels of consumption, should suffice for exploitation even after 2050 (Ministry of Mining and Energy, 2016). Nonetheless, locking into lignite is a very risky strategy to say the least. Firstly, more advanced systems would be needed to extract energy from a source of fuel presenting low productivity and high environmental externalities such as lignite. Secondly, and most importantly, trading with partner countries would be greatly affected by carbon pricing and taxing systems such as the EU-ETS (Young & Macura, 2020), as shown in Scenario 1. Considering that the EU is Serbia's main trading partner, it is vital for its economy to have continued participation in the EU market (Young & Macura, 2020). As proposed in the Fit for 55 package, if the EU were to implement the Carbon Border Adjustment Mechanism (CBAM) (essentially a carbon border tax), Serbia would be highly affected and would lose trading interest due to its high carbon intensity, which by locking into lignite would remain constant. Whereas other options exist to counterbalance the emissions related to coal, such as "clean coal" technologies and storing CO2 underground, these are currently being implemented in the EU as ways to phase-out from such technologies. Hence, relying on "clean coal" as a means to secure energy supply by utilising lignite, as mentioned in (Ministry of Mining and Energy, 2016), which would entail investing in an obsolete technology to improve its efficiency, might not be the most advisable strategy. In fact, energy security can be seen by two different perspectives. From a short-term perspective, this would entail focusing on the energy system's ability to promptly react to sudden changes in the network. On the other hand, from a long-term aspect, this results in choosing to invest in the technology which will be most beneficial considering economic development and environmental needs (Young & Macura, 2020). All things considering, it might be time for Serbia to consider long-term aspects when deciding on which fuel resource to focus on and invest in.

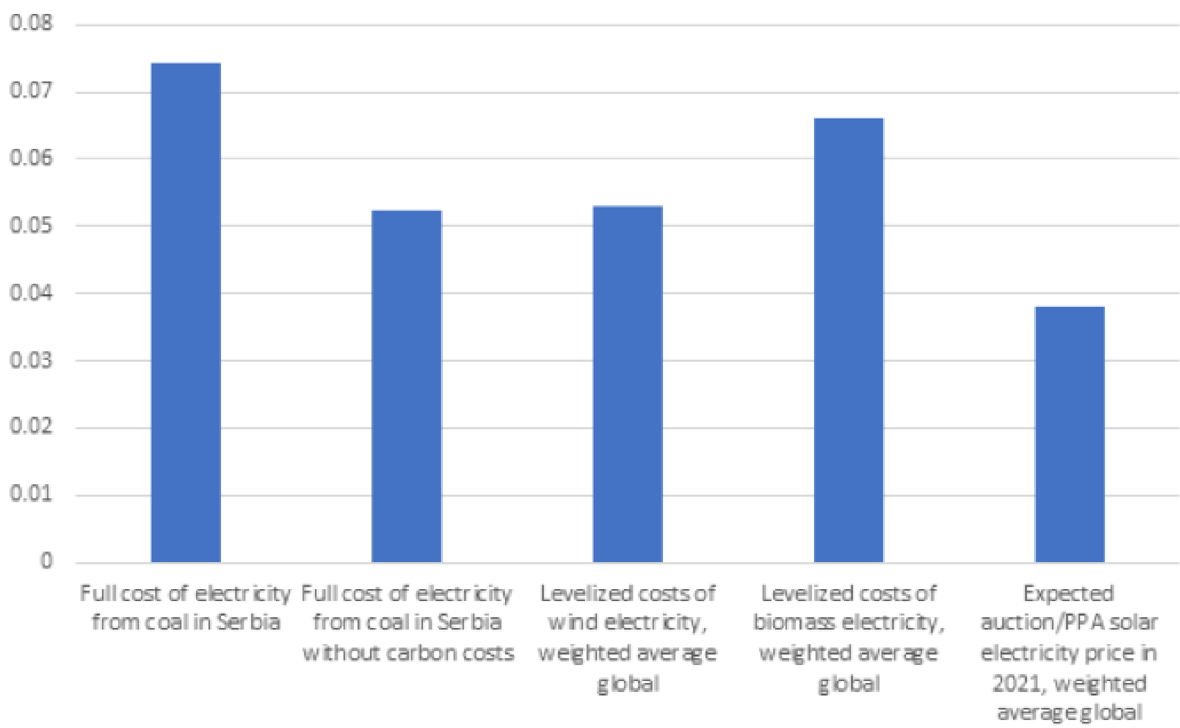


Figure 7.1: Cost in USD/kWh of electricity depending on the method/fuel type used for its production (Young & Macura, 2020).

Fuel/ Technology	Strengths	Weaknesses	Opportunities	Threats
Coal	Local availability Employment opportunity	Inherently low extraction productivity Inefficiency in exploitation Huge local and global externalities Aged fleet reaching end of lifetime	None	Environmental, climate and trade policies Long term power prices Low availability of finance
Large hydro	Local availability Cheap production Repowered and rehabilitated major plants Flood management Flexible provision by pumped storage	Environmental impact	Some untapped potential for further development	Climate change impacts on water availability
Wind	Local availability GHG emissions	Intermittent power source	Decreasing technology costs Regional flexibility management	
Solar	Local availability Citizens' energy production GHG emissions Could occupy marginal land well equipped with infrastructure including abandoned open pits	Intermittent power source Managing life cycle externalities	Decreasing technology costs Regional flexibility management	
Biomass	Local availability Employment opportunity Life cycle GHG emissions	Stringent sustainability management required	Technology development	Global image affects financing opportunities
Natural gas	Flexible energy carrier Lower environmental impact compared to coal	Security of supply GHG emissions Trade deficit	LNG market development Pipeline infrastructure development	Carbon neutrality requirements Geopolitical stability

Figure 7.2: SWOT analysis of the available type of fuels from which to generate electricity in Serbia (Young & Macura, 2020).

7.1.2. Natural Gas

Serbia is greatly import-dependent when considering natural gas, providing only 10% of its consumption from domestic production and the remaining 90% from imports from the Russian Federation (Ministry of Mining and Energy, 2022). On February 1, 2022, the construction of the gas interconnector Serbia-Bulgaria (Nis-Dimitrovgrad) was commenced, and the latter will be operational in 2024 (Ministry of Mining and Energy, 2022). Until then, Serbia will have to rely on its only gas inflow, namely Russia-Ukraine-Hungary-Serbia. Whereas the construction of other gas interconnections had been planned for decades, this only happened in 2022, which in turn made Serbia ever more dependent on its gas influx from Russia, thus reducing its gas security of supply, as having several modes of import of the resource inevitably increases its security of supply. The current level of gasification in Serbia is regionally uneven and insufficient (Ministry of Mining and Energy, 2022). In 2019, only approximately 8.7% of households were connected to gas networks (Pejin Stokić & Bajec, 2020). Additionally, by continuing current exploitation trends of gas, domestic stocks of natural gas are envisioned to be finished by 2030 (Ministry of Mining and Energy, 2016). Nonetheless, increased construction of a gas distribution network and the substitution of solid fossil fuels with natural gas was envisioned as a medium to long term solution for Serbia (Ministry of Mining and Energy, 2022). Furthermore, achieving gas supply security of 30 days to be used in emergency situations was also envisioned as a solution, thus increasing strategic reserves of natural gas supply. However, it must be noted that natural gas is a fossil fuel. Therefore, strategic and wide-scale use of gas is inconsistent with ambitious sustainability goals. Hence, as suggested by Young & Macura (2020), a deeper analysis and study of the economic benefits related to the development of a gas infrastructure and an increase of gas consumption in the country should be realized first.

7.1.3. Oil and Petroleum Products

Whereas in the context of household energy consumption, oil and petroleum products did not represent a substantial share, these are nonetheless present in the country as a means of fuel resource. In Serbia, 64 oil fields with 796 active boreholes can be found (Ministry of Mining and Energy, 2022). Total consumption of semi-finished products and crude oil increased by 0.3% more in 2021 compared to the previous year and further growth in consumption is envisioned (Ministry of Mining and Energy, 2022). Once again, the country is greatly import-dependent, as in 2021, of the 3.575 million tonnes consumed, more than 76% were imported. Additionally, domestic oil reserves are envisioned to be depleted in the next 15 years. On the other hand, reserves of crude oil and petroleum products increased by 30% from 2020 to 2021 (Ministry of Mining and Energy, 2022). The reason being improving energy security of supply and ensuring a smooth operation of 25 days with plans to reach a total of 61 days. By doing so, Serbia has risen to the top of energy reserves in the region (Ministry of Mining and Energy, 2022). Construction of oil pipelines is envisioned as another short-term solution for Serbia. Once again, this does not go in line with decarbonisation plans and policies.

7.1.4. Thermal Energy

Average consumption of thermal energy in households in Serbia, compared to the EU average, is approximately 2.5 times higher. Serbia presents a total of 61 heating plants, of which 33 use natural gas as primary energy source, 18 use heavy fuel oil, 6 use coal and the remaining 4 biomass (Ministry of Mining and Energy, 2022). However, when analysing the total consumption of fuel sources utilised for the production of thermal energy, it can be seen that natural gas participates with 80.6%, petroleum products with 9.2%, coal with 9.7% and biomass not even reaching 1% (Ministry of Mining and Energy, 2022). Nonetheless, increasing the utilisation of solid biomass entails various ramifications that need to be accurately planned. As stated by Young & Macura, (p. 2) (2020), "decision making in this case needs to consider the state of forests and forestry, population density, regional development, workforce skills and numbers, the environmental functions of forests including erosion prevention, flood management carbon stocking and others, marginal land availability and other factors". However, this is a step that needs to be undertaken to substitute low-calorie and low-quality coal with RES, such as biomass, and achieve future renewable energy security and stability. Currently, Serbia has a total capacity of approximately 2.91 GW obtained from power plants utilising RES. On the other hand, it is estimated that by 2050 around 21 GW of RES capacity will be needed (Ministry of Mining and Energy, 2022).

7.2. Available Policy Instruments in Serbia

The implementation of one single policy covering one specific aspect of energy poverty will not be able to substantially influence the latter, and thus specific policy combinations and instruments need to be delineated. Additionally, for one new policy to be effective and make an impact the moment it is implemented, policy mechanisms will need to be put in place to smoothen the introduction process. Whereas there are various definitions of policy instruments/mechanisms, hereby these are understood as government funds and services directed towards ameliorating energy efficiency and poverty in Serbia. Although energy poverty has been officially defined by Law and recognised as an important task in the field of energy (Section 5.1), specific governmental programmes aimed at eradicating energy poverty in low-income households are not present (Section 5.2.1). In the following subsection, available funds/programmes aimed at aiding low-income households to have a better access to energy services and funds devoted to improving the energy transition in general in Serbia will be discussed. These are analysed in light of their capacity to help with the correct implementation of new proposed policies.

7.2.1. Protection Mechanisms for Low-Income Households

Energy-vulnerable consumers have been defined and recognised in Serbia, with several assistance and reduced tariff mechanisms in place to support these (Pejin Stokić & Bajec, 2020). Whereas not explicitly stated, the recipients of such services will be typically belonging to the low-income household groups and be suffering from energy poverty. As explained in Section 5.2.1, the reduced tariff mechanisms are mainly focused on alleviating financial burdens related to access to electricity and gas services. The conditions that must be satisfied to be eligible for such services can be found in Figure 5.1. On the other hand, beneficiaries of the FSA or child benefits are directly eligible. However, since the implementation of this measure in 2013, constantly less households than those legally eligible have been classified as energy vulnerable. This is clearly illustrated by Figure 7.3, comparing the recipients of the different service and financial aid programmes. Hence, it becomes clear that the reduced tariff mechanism has not been working properly and needs to be improved. Several reasons can be outlined for this. One of these is that the dwelling size prerequisites are rather strict. In fact, the average housing space in Serbia per household in 2019 was 64 square meters for the first decile (Statistical Office of the Republic of Serbia, 2020). However, to be considered as an energy vulnerable consumer, the maximum housing space allowable is 30 square meters with an additional 14 per household member (Pejin Stokić & Bajec, 2020). The type of dwelling might also play a role depending also on the type of fuel utilised for space heating. For example, households utilising biomass will have lower consumption levels of electricity and gas compared to others. These are just two flaws within the programme that make it easier to understand why, considering that 25% of Serbians are deemed to be at risk of poverty, approximately only 1% of the population was registered as energy vulnerable (from 2016 to 2018) (Pejin Stokić & Bajec, 2020).

Reduced tariff mechanisms in Serbia present the potential to greatly ease the implementation of energy policies directed towards low-income households. However, these need to be also improved. Differentiation between utilised fuels in the households needs to be the first step. This becomes apparent when confronting the number of households covered by reduced tariffs of monthly electricity and gas bill obligations. In fact, in 2019, 74615 households obtained a reduction on their electricity bills, corresponding to approximately 9.7 million euros of annual financial expenditures (Ban et al., 2021). On the other hand, only 50 households received a reduction on their gas bills, corresponding only to approximately 500 euros of expenditures (Ban et al., 2021). Whereas this is also due to the limited gas coverage in the country (Section 7.1.2), households utilising types of fuels other than electricity, such as district heating, will be inevitably advantaged (RES Foundation, 2021). Finally, it must be clearly noted that such measures are aimed at reducing the energy burden of end-consumers in the short-term, and not energy poverty in the long-term. Obligations to tackle the latter have been set out in the Law on Energy Efficiency and Rational Use of Energy and should be delineated in the NECP. Such policy mechanisms offer a vital role in complementing energy policies, focusing specifically on the lower income groups.

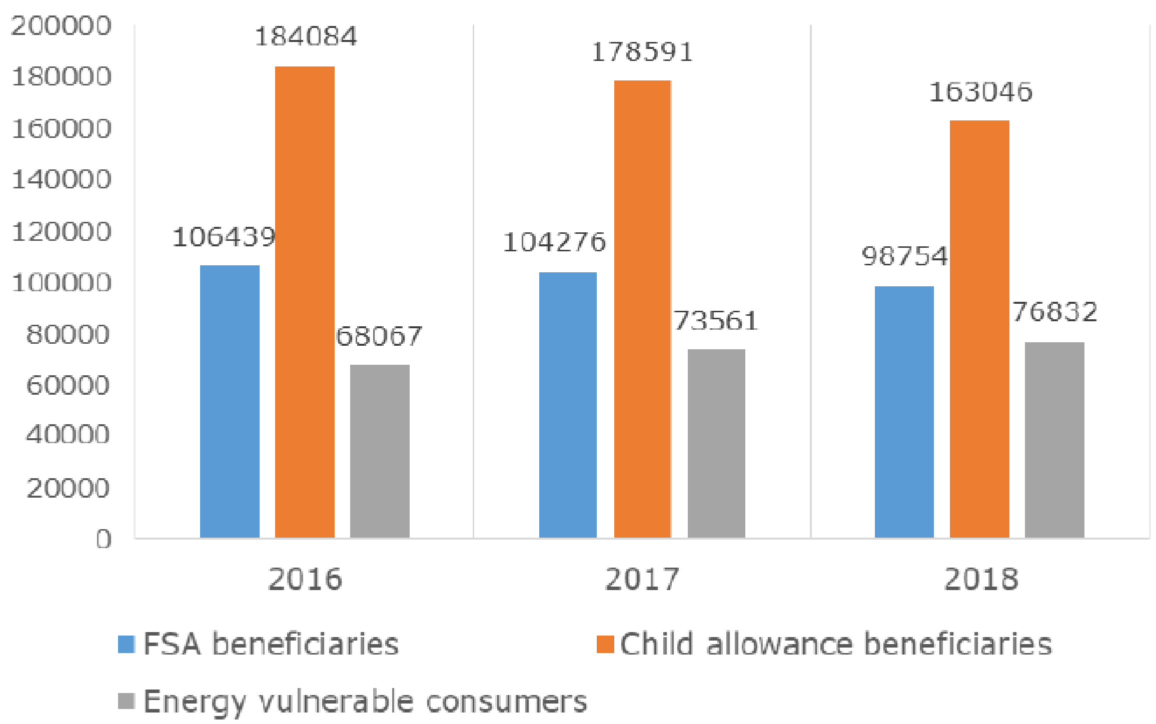


Figure 7.3: Comparison between number of households eligible for reduced tariff mechanism and energy vulnerable consumers in Serbia (Pejin Stokić & Bajec, 2020).

7.2.2. Energy Transition Funds

The efficiency and degree to which policies will change the status quo by improving it is also dictated by the available budget and funds. Careful delineation of budgets and decisions regarding how to allocate funds to different aspects is key. Inevitably, the magnitude of the impact is also related to the devoted monetary amount. Funds are indeed policy mechanisms, as they contribute to the efficiency and efficacy of proposed policies. The previously mentioned reduced tariff mechanisms and social programmes are all funded from the central budget (Pejin Stokić & Bajec, 2020). Nonetheless, Serbia has a series of funding options and budgets devoted to the green energy transition and energy efficiency specifically. The new investment plan delineated by the Ministry of Mining and Energy (2022), as well as the Economic Investment Plan for the Western Balkans, have already been discussed in Section 6.4. Another potential source of financing would be a carbon pricing/taxing mechanism as proposed in Scenario 1. It is estimated that the implementation of such programmes could generate as much as 26 billion euros from 2020-2050 (Lindenau & Gasperić, 2019). Already just by recycling half of this sum into improving energy efficiency measures, a great difference could be done. Finally, international financing is also available. Both from the EU but also other bilateral and multilateral funds and partners such as the European Investment Bank (EIB), the World Bank, the European Bank for Reconstruction and Development (EBRD), just to name a few (Lindenau & Gasperić, 2019). Already with the introduction of the Law on Fees for the Use of Public Goods in 2018, approximately 9 million euros will be collected annually, which will be allocated to the budget for the implementation of energy efficiency measures (Ministry of Mining and Energy, 2021a). These are different options available for the funding of policies. A careful combination of public and private investments, with the former executed as to increase the latter, will contribute to the effectiveness of delineated policies.

7.3. Institutional and Legal Framework Concerning Energy Policies in Serbia

The proposed policies all fit within the institutional and legal framework of the Republic of Serbia. The policy framework within the field of energy has been extensively discussed in Chapter 4. The legislative framework in Serbia focusing on environmental protection, energy development and security builds on four main pillars. Namely: energy efficiency growth, increased share of RES in the energy mix, increased regional energy connectivity, and investments in the sectors of energy and mining (Ministry of Mining and Energy, 2022). The three proposed policies all tackle energy efficiency, entail an increase in the final consumption of RES and consequently investments in the energy sector. As mentioned in Section 4.4, in April 2021 the Republic of Serbia implemented four new laws in the energy and mining sector as to improve energy independence and further harmonize with EU directives and regulations set in the Third Energy Package and the Fit for 55 package. All the proposed policies stem from proposals included in the previously mentioned package and thus clearly follow proposed EU directives. However, it must be noted that the proposed policy of extending the EU-ETS system to the buildings and transport sector, thus covering 61% of total EU greenhouse emissions instead of the current 43%, was rejected by the European Parliament on June 8, 2022 (Todorović, 2022). The proposal was thereafter redrafted, reproposed and adopted by the European Parliament on June 22, 2022 (Malingre, 2022). Hence, such policy might find political opposition also in Serbia if proposed.

The importance of improving household energy efficiency has been stressed in both European and Serbian government laws, directives and proposals (European Commission, 2021b,c; Ministry of Mining and Energy, 2022). The positive effects this could have on energy poverty and thus low-income groups are clear and apposite policy mechanisms to ease the energy burden of affected households are already in place in the country (Section 5.2.1). Energy efficiency of buildings is indeed a strategic direction of development chosen by the Ministry of Mining and Energy (2022). In addition to the new laws implemented in 2021 concerning explicitly renewable energy sources and energy efficiency, these two factors have been detailly analysed in the NEEAP, NREAP and in the NECP being currently drafted (Section 4.4). Finally, all these features have been accounted for in the investment plan defined by the Ministry of Mining and Energy (2022). Thus, whereas the first scenario might find greater political opposition (also since in Serbia there is no carbon pricing/trading mechanism at all), the refurbishment of buildings and substitution of outdated fossil fuel boilers are both solutions that have been mentioned in the Serbian energy policy framework and whose potential has been recognised.

7.4. Feasibility of Proposed Measures

7.4.1. Social Feasibility

Social feasibility of energy policies can be defined in various ways. In this context, it is understood as the capacity of a policy to bring a positive social impact to one segment of the population without harming another one. Ideally, such policy would positively affect the whole population; however, in practice, it is more achievable and efficient to focus only on one segment, e.g., low-income households. Out of the three proposed measures/scenarios, two are envisioned to reduce the environmental impact, monetary expenses, and total consumption of energy within low-income households thus providing a positive social impact. In fact, Scenario 1 was found to finally increase the energy expenses of the first income decile, failing to tackle fuel providers and hampering end-consumers, causing rationing phenomena (Section 6.3.2). On the other hand, both Scenario 2 and 3 managed to reduce final energy consumption and expenses while also increasing the energy efficiency of the buildings. Coupled with improved existing mechanisms to alleviate the financial burden related to energy expenses, these policies would ultimately reduce energy poverty and be welcomed by low-income groups. The only risk related to the two previously mentioned proposed policies is that these would entail slight initial increases of expenses (more pronounced for Scenario 2 (Section 6.3.3)). Whereas these are mostly related to general increases in energy prices rather than the actual proposed measures, these could bring social turmoil if not adequately addressed and explained to the population. In fact, as also found by the HERON project (2015), two of the key social barriers are: the belief among citizens that prices will remain low and unchanged (due to previous political strategies), and the insufficient education and information related to the benefits of energy efficiency. Indeed, especially in rural areas, consumers are not aware of the additional incurred expenses and health risks due to the utilisation of outdated heating systems and housing appliances (RES Foundation, 2022). Nonetheless, it must be noted that policies trying to improve this situation have been implemented, such as the eco-labelling of energy appliances (Ministry of Mining and Energy, 2021a) (Figure 7.4). To conclude, in order to provide the best results possible and achieve immediate social consensus and impact, proposed policies need to be coupled not only with financial assistance programmes but also adequate, detailed and straightforward information, education and explanations with regards to energy poverty and efficiency.

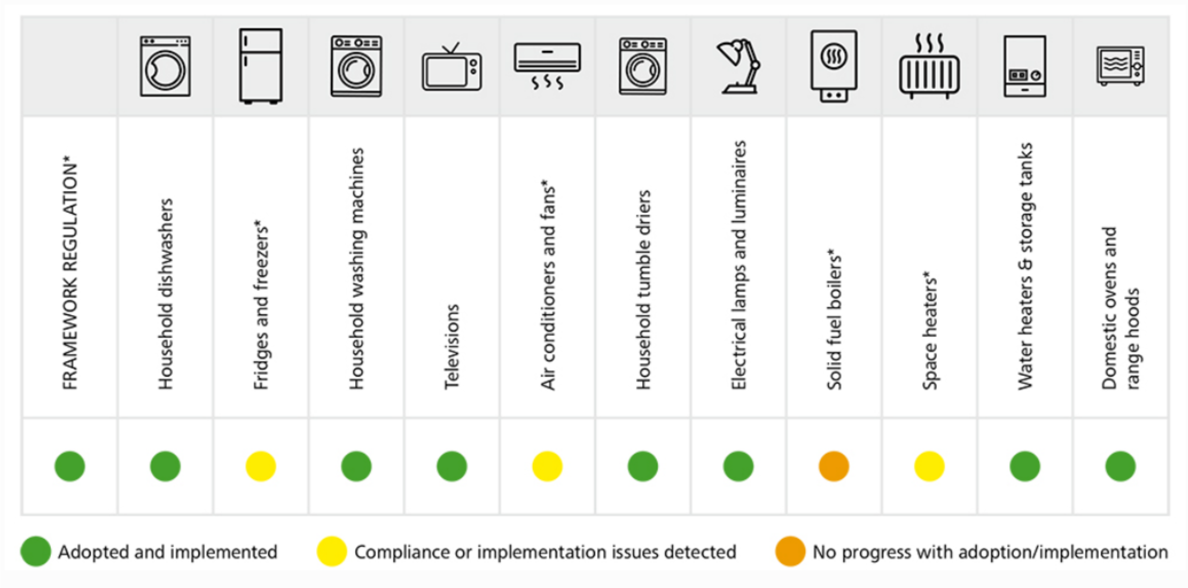


Figure 7.4: Overview of the implementation of energy efficiency labelling of housing appliances in Serbia (Energy Community, 2022b).

7.4.2. Political Feasibility

Political feasibility of energy policies is hereby understood as the capacity of a given proposed policy to fit in the political, legal and institutional framework of the country. For the case of Serbia, this has been extensively described in previous sections. Household energy efficiency and energy poverty are indeed two aspects related to the energy transition that have been addressed in the various laws concerning the energy sector in Serbia. Indeed, there are devoted public monetary funds allocated for the cause. Nonetheless, the first proposed policy, the introduction of a carbon pricing/trading mechanism extended to the buildings sector as well, is deemed not to be politically feasible. As previously mentioned, such proposal has been already rejected by the European Parliament in a first moment (Todorović, 2022). Therefore, in a country such as Serbia where no basic ETS is present, proposing to implement such a system already including the buildings sector would be very politically demanding and would be most certainly at least partially altered by amendments, thus incurring into bureaucratic practices such as lobbying, both by governmental and private institutions. To improve the energy transition, immediate actions are needed. The other two policies offer solutions already envisioned in governmental documents and strategies and thus are more politically feasible, with Scenario 3 being even more so compared to Scenario 2. The reason being that, to increase its energy security, Serbia has envisioned an increase of gasification levels in the mid-to-long-term (Ministry of Mining and Energy, 2022). This could potentially create disputes over the phasing out of natural gas in 2040, as proposed by the second scenario. To conclude, the introduction of MEPS in buildings is deemed as the most politically feasible proposed policy, perfectly fitting the Serbian energy policy framework and envisioning positive and substantial results.

8
Recommendations

In its last report analysing the progress made by Serbia in the various fields and clusters involved in its accession process to the EU, the European Commission evaluated Serbia as *moderately prepared* in the field of energy (European Commission, 2021a). With regards to energy efficiency specifically, important progress was recognised due to the implementation of the new Law on Energy Efficiency and Rational Use of Energy. Nonetheless, it was also expressed that "Serbia still needs to adopt further primary and secondary legislation to achieve full alignment with the Directive on the energy performance of buildings and on energy labelling" (European Commission, 2021a, (p. 112)). Therefore, the need to enhance energy efficiency in the residential sector and housing appliances in Serbia was also stressed by European institutions. Additionally, it was recommended that Serbia set ambitious targets for energy efficiency and RES in its final energy consumption when delineating its NECP (European Commission, 2021a). Taking this into account; in the following section, recommendations on how to achieve ambitious targets, in line with those set by the European Commission, concerning household energy efficiency and energy poverty specifically directed towards low-income groups will be given to the Ministry of Mining and Energy, stemming from the results and insights found during the present research. Thus, answering the postulated Main Research Question (Section 2.6).

Improving the energy efficiency of the residential sector, specifically targeting low-income and energy poor households, is recognised as being a viable long-term solution for eradicating energy poverty (Ban et al., 2021). As mentioned throughout this study, the strong correlation between household energy efficiency and energy poverty is recognised throughout the literature. Similarly, the need to improve the energy performance of residential buildings is understood by governmental institutions in Serbia. Ban et al. (2021) proposed a combination of four long-term measures to combat energy poverty in Serbia. Namely, the refurbishment of residential buildings; the replacement of outdated housing appliances; the improvement of heating systems; and finally implementing a programme for mitigating energy poverty. The latter should be delineated as to include tangible energy efficiency improvements extending beyond financial support (Ban et al., 2021). Whereas measures aimed at improving and promoting higher efficiency of household appliances and heating systems were delineated (Ministry of Mining and Energy, 2021a), it is proposed that these be further upgraded by providing financial incentives and support schemes to the lower income groups as to replace such outdated devices (Ban et al., 2021). Similarly, additional financing schemes for the refurbishment of buildings belonging to low-income households are proposed. This goes in line with the findings found throughout the present study.

To achieve household energy efficiency and energy poverty objectives set by the European Commission directed towards low-income groups, the Ministry of Mining and Energy is advised to implement Minimum Energy Performance Standards (MEPS) in buildings inhabited by low-income groups coupled with financial aid programmes, such as reduced-tariff mechanisms, further promoting the replacement of outdated housing devices and an improved understanding of the benefits related to improved household energy efficiency. Existing policy mechanisms aimed at alleviating the financial burden of vulnerable energy consumers need to be improved, providing more tangible energy efficiency improvements, and reaching a higher breadth of people. Additionally, promotion of energy efficient housing appliances needs to be coupled with an improved consumer education related to the benefits of more efficient devices, especially in rural areas. Previous good practices can be found in Serbia; nonetheless these need to be improved, as measures delineated for increasing energy efficiency in households obtained fewer savings than have had been planned (Ministry of Mining and Energy, 2021a). Finally, it is suggested that a 100% financing rate be used for energy efficiency improvements directed at low-income households, as these represent the most affected strait of society by energy poverty while at the same time presenting the greatest potential for improvement.

The proposed policy was found to be both socially and politically feasible. Indeed, the proposed measures fit the institutional, legislative, and political framework in Serbia. The social impact of such policy strategy was made clear through the utilisation of simulation models, indicating both a reduced final energy consumption and energy expenditures. Additionally, this would entail a positive environmental impact and gradual phasing out of fossil fuels. A more efficient residential sector would entail less energy losses and costs, further reducing energy poverty. Appropriate funding opportunities, both public and private, national and international, fitting the current political framework were found to be available. Therefore, the refurbishment of buildings belonging to low-income households through the introduction of MEPS, would potentially enable the Republic of Serbia to eradicate energy poverty, reduce energy network losses, diminish its environmental impact, and amplify international trade and market opportunities.

9 Conclusion

The present study set out with the aim to delineate optimal policy recommendations directed towards the Serbian Ministry of Mining and Energy as to achieve targets set by the European Commission in the field of household energy efficiency and energy poverty, specifically affecting low-income households. To do so, following an initial literature review, one Main Research Question and four Sub-research Questions were delineated to guide the research process. Additionally, a static linear model was utilised to simulate different scenarios pertaining to the implementation of different proposed policies. This was done to provide more quantitative backing to the selection process of the optimal suggested policy strategy. Each section aimed at answering different research questions. The Main Research Question was resolved in the previous chapter (8). The proposed optimal policy was found to be both politically and socially feasible, having a strong social impact, as well as reducing final energy consumption, costs, and poverty among low-income households.

In the following concluding section, each Sub-research Question will be answered individually. This is done as to provide the reader with a detailed summary and overview of the research undertaken, summarising the obtained results per section. The questions will be answered following the order in which they were postulated. Thereafter, the volatility of energy prices will be discussed, and how this will affect the scientific and academic value of the present study. This will be followed by a discussion pertaining to the role that the European Union and its sustainable standards plays within the socio-economic and political environment in Serbia. Consequently, the national stakeholders to whom this paper may be of interest will be specified. Thenceforth, the various limitations of this paper and the suggested areas to further research will be expressed. The limitations mostly correspond to the various assumptions undertook during this study. All the assumptions considered can be understood as presenting the same level of importance/abstractness; entailing that no major discrepancy between “stronger” or “weaker” assumptions can be found.

***SRQ1**: Which energy policies, measures, and targets have been previously implemented in Serbia, which ones are currently being employed and which future ones are envisioned?*

The energy policy framework in Serbia began its reformation process at the beginning of the millennium, aiming to implement sustainability targets and thus aligning to the European energy market. In 2005, the national *Energy Law of 2004* was approved and the *Energy Sector Development Strategy of Republic of Serbia to 2015 (ESDS to 2015)* was adopted. The law encompassed the main sources of fuel used to generate energy and the main macroeconomic factors related to it. On the other hand, the *ESDS to 2015* outlined five main priorities. Namely, to ensure the continuous modernisation of facilities, systems and sources used throughout the energy sector; to enhance the use of sustainable, modern and new sources of renewable energy; to increase general energy efficiency by utilising high quality products; to assess required investments in the sector; and finally, to construct new energy infrastructures. Nonetheless, already in the *ESDS to 2015*, it was envisioned that the share of RES in the total primary energy supply would decrease below 7% by 2015, which was indeed the case. On July 1st, 2006, the Republic of Serbia signed and ratified the Treaty becoming a member of and establishing the Energy Community. By becoming a contracting party of the latter, Serbia agreed to commit to the implementation of EU directives in the country in the field of renewable energy sources.

The Ministry of Mining and Energy is responsible for delineating National Action Plans for Energy Efficiency (NEEAP) and National Renewable Energy Action Plans (NREAP). The NEEAPs are updated every two to three years. In the first NEEAP (2010), it was set as a goal to achieve 9% savings of final energy by 2018 compared to 2008 levels. Similarly, in the first NREAP (2012), it was agreed to set as target a 27% of RES in Gross Final Energy Consumption (GFEC) and a 10% of RES in the transport sector by 2020. These targets were all included in the "strategy for the development of the Serbian energy sector for the period by 2025 with projections by 2030", published by the Ministry of Mining and Energy in 2016. Nonetheless, it must be noted that none of these targets were achieved. In fact, by 2018, 88% of the energy savings goal was achieved, 26.3% instead of 27% of RES in GFEC were realized and only around 1.14% instead of the envisioned 10% RES in the transport sector by 2020 were fulfilled. On the other hand, it must be noted that Serbia has implemented various incentive measures (or "feed-in" tariffs) to spur investments in the renewable energy field, resulting in the construction of 265 new facilities. Additionally, various policies and protection schemes directed towards energy vulnerable consumers have been enacted. Vulnerable consumers are mentioned in various governmental documents such as the fourth NEEAP, where measures to increase energy efficiency of housing appliances of low-income groups were proposed and analysed.

The most important progress from a regulatory and legislative perspective was realized in 2021 with the introduction of two new environmental laws. Namely, the *Law on Renewable Energy Sources* and the *Law on Energy Efficiency and Rational Use of Energy*. The former adds more detail and structure concerning the regulation of RES; whereas the latter aims to improve the whole energy sector and to harmonize Serbian regulations with EU directives. Additionally, amendments were applied to two existing laws; namely, the *Law on Energy* and the *Law on Mining and Geological Research*, further contributing to creating a legal basis and framework in which to implement the National Energy and Climate Plan (NECP). Nonetheless, the latter is yet to be delineated. The vision of the Ministry of Mining and Energy with regards to the future of Serbia is one of an energy-safe and climate-neutral economic development of the country, allowing it to become the regional leader in energy production. Public investments were delineated for a total of 35 billion euros devoted to projects concerning energy and mining. Achieving carbon neutrality and reducing net emissions to zero by 2050 is one of the pillars of the Serbian strategic development of its energy sector. Nonetheless, the new development strategy for the period until 2040 with projections until 2050 is still being drafted. All in all, in Section 4, a comprehensive picture of the past, present and future energy policies, measures, and targets in Serbia was obtained, individuating both good practices and areas to be improved. Most importantly, the energy policy framework in which the proposed policies would have to be implemented was understood.

SRQ2*: What is the current status quo concerning household energy efficiency as well as energy poverty in low-income groups in Serbia, how are the latter defined and which indicators should be chosen to measure these?*

Energy poverty in Serbia has been recognised and defined in official governmental documents. The provided definition focuses more on economic factors rather than societal ones. Energy poverty in Serbia is mainly due to high energy expenditures, which are envisioned to continue increasing in the upcoming years. It was found that, on average, a Serbian household spends 12.4% of their total income on energy expenditures. Additionally, 21.9% of the population was found to be at persistent risk of poverty, with the number increasing when analysing rural areas. The relation between household energy efficiency and energy poverty was found to be a direct one, as lower-income households are generally relegated to energy inefficient buildings which in turn entail higher energy expenditures and higher environmental impacts. In Serbia, the majority of buildings were built between 1971 and 1990, during the Socialist period of the country. Similarly, energy inefficient housing appliances greatly increase final energy bills. Furthermore, not all straits of society are equally affected by energy poverty. Whereas in 2019, 9.9% of the total population was unable to keep its home adequately warm, this number increased up to 19.7% when analysing poorer households (below 60% of median equivalised income).

In Serbia, there is no definition of low-income groups in the context of access to essential services. Rather, "vulnerable consumers" have been defined in several ways. For example, services such as the Financial Social Assistance (FSA) and child benefits are present in Serbia. Often, societal groups entitled to such financial services are also found to be energy vulnerable consumers. Nonetheless, other than providing financial assistance as to reduce the monetary burden, such policy mechanisms do not tackle directly the causes of energy poverty. Several indicators of energy poverty within low-income household groups were found, mainly revolving around the weighted median of the share of household energy expenditure and the equivalized absolute value of the expenditures. It was found that the first income decile was the most affected by energy poverty considering various aspects and indicators. Therefore, it was decided to take the latter as the definition of low-income household groups. Therefore, the utilised indicators to define these groups were purely monetary, or "objective". Whereas by so doing not all socio-economic aspects of energy poverty are considered, these still give an accurate insight into the issue. Additionally, more accurate data is available differentiating between the first income decile and the rest of the population. Finally, indicators were not chosen to describe energy poverty, but rather to delineate it to a specific strait of society and see how the implementation of different policies would alter the status quo. This was all carried out in Chapter 5, which was followed by the model simulation.

SRQ3*: Following a linear simulation, which policy mix (strategy) would result as optimal for Serbia to achieve the sustainable goals established by the European Commission?*

The policy strategy proposing the implementation of Minimum Energy Performance Standards (MEPS) in the residential sector resulted as the best policy when simulating the various scenarios. This yielded the best results both in terms of final energy consumption and expenses. The other two policies examined proposed respectively: the implementation of an emissions trading system extended as to include also the residential sector; and the mandatory phasing out of heating oil and solid fossil fuels by 2030, followed by natural gas by 2040 (Chapter 6). The refurbishment of inefficient dwellings was recognised as a vital step in tackling energy poverty and reducing energy consumption both by the EU and the Republic of Serbia. As proposed in the updated Energy Performance of Buildings Directive (EPBD), part of the Fit for 55 package, the 15% worst-performing buildings, rated as class G, would have to be updated to at least class E by 2030 the latest. Indeed, the lowest-performing buildings present the highest potential for improvement. Compared to the other two, scenario 3 entailed the lowest energy consumption and expenses as previously mentioned; however, also the highest implementation costs. Additionally, scenario 3 did not envision the phasing out of any type of fuel, but rather considered the simulated price trends of the latter and how this would affect their demand. Thereafter, the political and social feasibility of the different policies was examined, hinting to the next Sub-research Question.

SRQ4*: Which feasible policy instruments/mechanisms are available for Serbia to improve household energy efficiency as well as energy poverty in low-income groups and how much extra costs would this entail?*

To obtain the best results possible, the implementation of MEPS in the residential sector needs to be coupled together with improved financial services directed towards low-income groups aimed at reducing energy poverty rather than the financial burden related to energy expenses. Additionally, awareness related to the direct benefits of improved energy efficiency for the residents needs to be increased. This can be done by specific policies aimed at educating the end-user with regards to the efficiency of utilised housing appliances for example. Such policy strategy was found to be both politically and socially feasible, delivering a positive social impact. Indeed, by applying the proposed policy, energy poverty in Serbia among low-income households would be reduced. The envisioned implementation costs of such policy strategy are assumed to be a total of 2775 million euros spread over 15 years, namely 185 million euros per year. The costs related to the improvement of financial services aimed at tackling the sources of energy poverty were not calculated as this was outside the scope of the study and since these would inevitably represent a minority compared to the refurbishment costs. Various available fund possibilities, both private and public, were found. Considering that improving household energy efficiency was defined as one of the national targets in the field of energy, the allocation of public funds to the previously mentioned cause should not encounter major political resistance and was thus deemed feasible (Chapter 7). To conclude, the coupling of improved available policy mechanisms together with new proposed policies, funded by available public budgets, are envisioned to manage to improve household energy efficiency and reduce energy poverty among low-income households in Serbia.

9.1. Future Reproducibility of the Present Study

9.1.1. Price Uncertainty and Related Socio-Economic Consequences

Energy prices in general are very volatile and inconstant in nature. These are easily susceptible by the actual demand of energy; but also other socio-political events, such as economic recessions, political international alliances or, sadly, wars. The last year was characterised by the COVID-19 pandemic recovery process and the Russian invasion of Ukraine, both events which have affected current and future energy prices, political alliances, and the delineation of future climate policies (e.g., *REPower EU Plan*). Whereas it is out of the scope of the current research to discuss how such events will affect both the European and the Serbian energy market, the possibility and unpredictability of considerable changes in energy prices needs to be considered. Indeed, just by comparing electricity prices for household consumers pertaining to the second semester of respectively 2020 and 2021, it can be noticed how these increased by approximately 10% in Serbia (Figure 9.1). The price of energy generated from traditional fossil fuel sources such as petroleum, oil products, and natural gas is somewhat more characterised by the political international alliances and contracts ratified by partner countries. This is the case for most European countries, which are dependent on energy imports, such as Serbia (Section 7.1.2). On the other hand, when analysing renewable energy sources (RES) such as biomass, wind, and solar energy, the price of the latter is more dependent on its demand and utilisation. Indeed, a higher utilisation of, for example, wind energy would entail higher production and investments and thus a reduction in prices. However, an increase in demand might also increase its price. This further goes to show the difficulty in simulating, predicting, and analysing the development of energy prices.

Energy price volatility needs to be countered by implementing both short-term and long-term measures to stabilise the energy market and demand. Various strategies exist and are already in place to do this. These include security of supply and securing reserves of fuel sources, but also investing in new (renewable) sources for generating energy. These were all already discussed in Section 7.1. Indeed, improving household energy efficiency and reducing energy poverty is another tool for reducing any foreseeable energy burden to the population. In fact, the increase in energy prices is considered as a socio-economic issue, as access to energy and essential services is deemed as a right for European citizens (Section 2.1.1). Difficulties in accessing essential energy services are envisioned to generate great socio-political turmoil. Therefore, increased energy prices have the potential to greatly destabilise one country's societal and political system. As expressed throughout the current research paper, improving household energy efficiency has great potential to not only bring a positive social impact, but also protect more vulnerable consumers, and possibly the country's economy, against increasing energy prices. An improved general energy efficiency and reduced energy poverty will further stabilise the country's energy infrastructure. Hence, the proposed optimal policy can also be deemed as a strategy to counter inconstant energy prices.

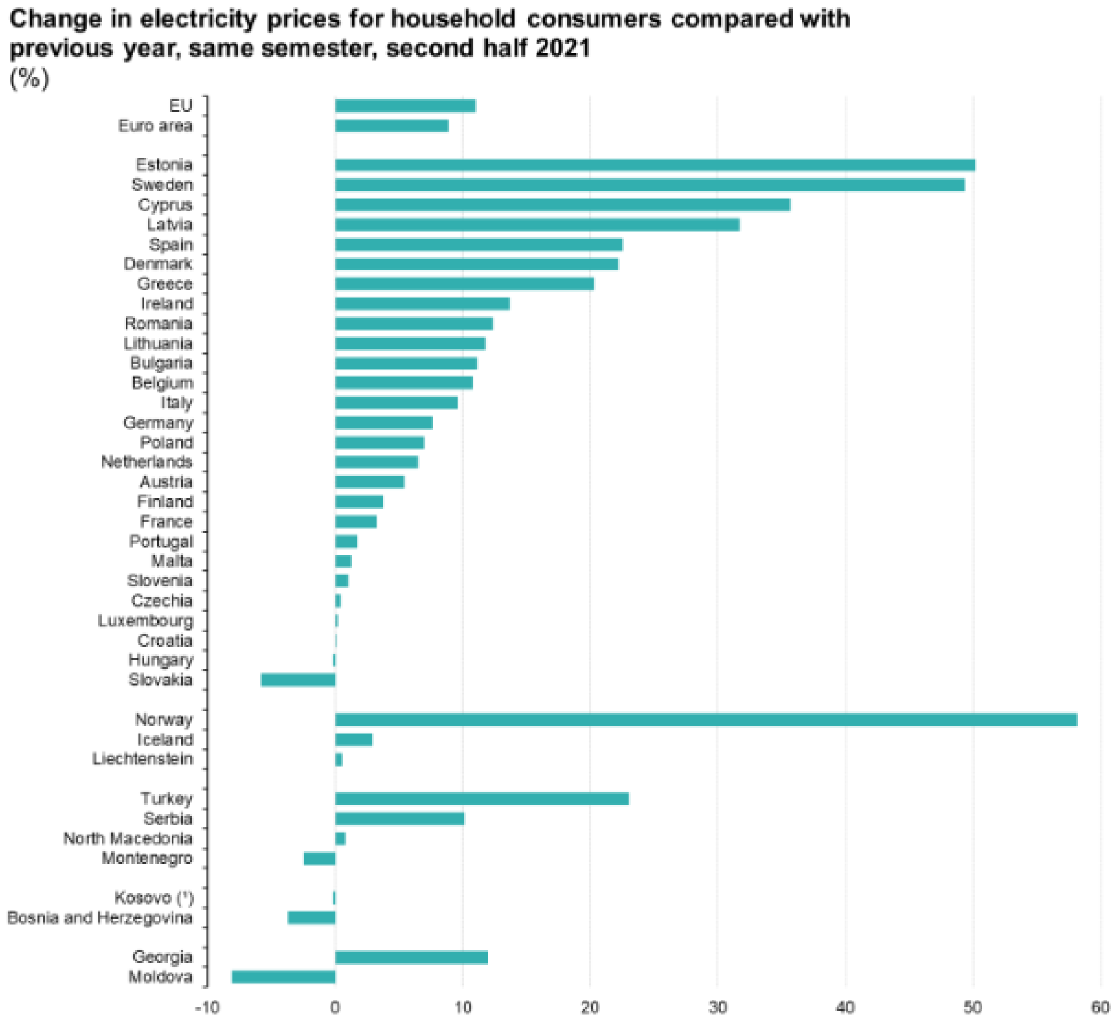


Figure 9.1: Comparison of electricity prices considering the second semester of respectively 2020 and 2021 (Eurostat, 2022b).

9.1.2. The Added Value of Analysing the Present

In the following research, an empirical analysis and simulation was realized utilising the most recent available data, essentially studying, and tackling, the present. Nonetheless, the utilised methodology can be easily employed with more updated figures making it robust and reproducible. As previously mentioned, energy prices in general are rather varying and inconstant in nature. Indeed, different prices could provide different results, potentially favouring one policy over the other. In this specific case, varying energy prices are not expected to change the selection of the proposed optimal policy, as these were already acknowledged to be increasing and other qualitative factors such as the political and social feasibility of the policy were also considered when selecting the optimal strategy. Additionally, it must be noted that the most recent publicly available national targets and projections realised by the Ministry of Mining and Energy were performed in 2016 utilising data from 2010. Nonetheless, the methodology hereby employed, and thus potentially the whole research, could be easily reproducible considering not only more updated energy prices, but potentially the whole national context. Meaning that such research could be performed to analyse also other (e.g., Western Balkan) countries. Indeed, the value of the research at hand can be found in the methodology employed, performing static simulations with a low level of statistical abstractness, nonetheless considering most-recent data, analysing the *present* and examining both quantitative and qualitative factors. This allows the current research to be reperformed considering new situations and standards, potentially achieving different results that, however, would not devaluate the proposals hereby expressed.

9.2. The Strength and Benefits of Applying EU Sustainable Targets in the Serbian Context

The energy and environmental directives, policies, and strategies proposed by the European Union (EU) are the result of consultations, research, and analyses realised by experts coming from 27 different European countries, working together to reach the European Commission's goal of being the first climate neutral continent by 2050 (European Commission, 2021b). Within Member States, environmental directives and policies specifically have supremacy over national laws (EUR-Lex, 2022). This further highlights the severity of such policies, and the effort Member States are undertaking to improve sustainability in Europe. Nonetheless, climate neutrality in the continent cannot be achieved without cooperating with neighbouring non-EU nations. This was clearly understood by the European Commission, resulting in political and economic plans to help neighbouring countries achieve desired EU sustainable targets. As mentioned in Section 2.1.3, Serbia is one of the signatories of the Green Agenda for the Western Balkans, and the Economic and Investment Plan for the Western Balkans. The willingness of the EU to cooperate with countries from the Balkan peninsula was further demonstrated with the REPower EU Plan and its EU External Energy Strategy (Section 2.5.2). Additionally, the achievement of EU climate targets is one of the prerequisites for Serbia to join the Union, described in Chapter 15 of Cluster 4 of the negotiations for Serbia's accession to the EU. Therefore, Serbia does not only have a technical and scientific interest in adhering to possibly the most solid, advanced, and organized climate policies in the continent, but also a political and economic one, also considering that the EU is its main trading partner (Young & Macura, 2020).

Working towards achieving challenging climate goals greatly benefits the country from a socio-economic perspective. As discussed throughout this research paper, the socio-economic benefits of ameliorating energy efficiency and poverty are various. Hence, cooperation with the EU in the energy field needs not to be seen as a strictly political endeavour, but rather as one that can greatly benefit the country both socially and economically. The focus should be on utilising in the most efficient manner the funds made available by the EU, directed towards reaching both energy and economic standards of EU Member States. Indeed, the present Master thesis does not wish to be political in nature by discussing the political benefits of collaborating with the EU for the Republic of Serbia. Rather, it wants to stress that the latter has great technical, social, and regulative interest in adhering to such established environmental standards, plans, and directives; notwithstanding the political commitments ratified by Serbia by adhering to the Energy Community Treaty and the Green Agenda for the Western Balkans. European institutions such as the Eurostat greatly help by providing publicly available data concerning EU Member States but also neighbouring countries as Serbia. This kind of cooperation, where sustainability is put on a pedestal as main objective, should be strived for, as it ultimately benefits society in its entirety.

9.3. National Stakeholders Involved with Energy Poverty and Household Energy Efficiency

The main national stakeholder to whom the findings of the present research are directed is the Ministry of Mining and Energy. As expressed throughout the report, this is the Ministry which has a direct say on the energy policies being implemented in the country. Consequently, it also possesses the institutional and legal power to implement optimal policies directed at delivering a positive social impact. Various documents realised by the Ministry of Mining and Energy were analysed and discussed in this study. This was done as to provide suggestions in line with the strategies undertaken until now by the Ministry and to provide proposals that can be easily empirically proven. Another powerful national stakeholder that could implement positive changes directed towards improving household energy efficiency specifically is the Ministry of Construction, Transport, and Infrastructure. Indeed, the latter has a direct say on the infrastructure issues, such as constructing more energy efficient public and private buildings and refurbishing existing ones. Additionally, if including the transport sector in the energy consumption and expenses analysis, the previously mentioned stakeholder would assume a vital role. Other concerned stakeholders are the state-owned electric utility power company *Elektroprivreda Srbije* (EPS), and the national transmission system operator company *Elektromreža Srbije* (EMS). The latter are the main producers and distributors of energy and specifically electricity in the country. These have the engineering and technical power to ameliorate the energy production and distribution efficiency, potentially making the whole network system more sustainable. Lastly, the Energy Agency of the Republic of Serbia (AERS) is another national stakeholder involved in the delineation of energy policies and guidelines. The latter also gathers and analyses energy price trends of the different fuel sources in Serbia. Thus, these could provide updated fuel source energy prices to improve the accuracy of the present report and potentially provide new insights. To conclude, the author would like to stress that the present Master thesis is intended as to provide help to any national stakeholder in providing a positive social impact in the field of energy, specifically concerning low-income groups.

9.4. Limitations & Further Research

The following study presents a series of limitations which will be hereby discussed, proposing further research strategies to tackle these. Firstly, only space heating and cooling, and the heating of domestic water were considered as energy end-uses. Whereas these do represent the majority of final household energy consumption, important insights related to cooking, and lighting and electrical appliances are left out. Indeed, being the latter 100% and cooking 59% electricity fuelled (Eurostat, 2022a), the final share of electricity consumption would be substantially higher. In fact, when considering only space heating, cooling, and DHW as FEC, electricity presents a share of approximately 24%. Whereas when considering also cooking and lighting and electrical appliances, the final share increases up to approximately 40%, becoming the type of fuel with the highest share of FEC. This will inevitably change the figures related to final energy consumption and expenses. Additionally, the transport sector was also not considered. Following the residential and industrial sector, transport represents the third highest share in FEC, namely 23% (Odysse Mure, 2021). Compared to 2000, the share of the transport sector has more than doubled (Odysse Mure, 2021). The transport sector is also involved in many targets set by the Fit for 55 package. Indeed, the ETS2 proposal, in the current report comprised only the buildings sector, whereas in its original proposal it was also extended to the transport sector (European Commission, 2021b). Therefore, the current study should be upgraded as to include all energy end-uses and the transport sector, presenting a more holistic overview of the energy field in Serbia, extending Scenario 1 to the transport sector as proposed by the European Commission (2021).

Secondly, various prices throughout the study were assumed. Price elasticities of demand were assumed for space heating and electricity. Whereas the values chosen were found to be applicable when considering the total population of countries from Central and Eastern Europe (Rogulj et al., 2022), these do not accurately represent the trends of the low-income households in Serbia. Additionally, these are all linear and static elasticities. This is not realistic, as elasticities of demand can vary easily depending on various factors happening in one specific year. Sudden events such as the coronavirus pandemic or the Russian invasion of Ukraine can greatly affect price elasticities of demand of space heating and electricity. Therefore, further research should be initiated considering more accurate and non-static price elasticities, specifically tailored to low-income households in Serbia. Similarly, the prices related to the refurbishment of buildings and implementation of heat pumps were also assumed not considering characteristics of low-income groups in Serbia but rather those of other European countries (Rogulj et al., 2022). Other assumptions include the price of ambient heat produced from newly implemented heat pumps, assumed to be free due to lack of data related to this type of fuel in Serbia. Similarly, the prices of heating oil, biomass and coal considered in this study date back to 2014 as these were the most recent figures found. Finally, it was assumed that the prices of biomass and district heating will remain unaltered, and thus also their consumption. This was done for simplicity and to put more focus on fossil fuels. Nonetheless, district heating prices are indeed envisioned to increase (Petovar, 2022). On the other hand, the price of biomass is more complex to predict since it is a natural and renewable source. Therefore, further research should be undertaken with updated energy prices for Serbia, presenting less assumptions. This would entail the creation of new primary data specifically focused on Serbia and preferably on its low-income groups. Additionally, estimates with regards to the actual prices of building refurbishments and implementation of improved heat pumps should be obtained.

Thirdly, average national figures related to household energy consumption were transposed to the first income decile. Indeed, the percentages related to the consumption per type of fuel and end-use considered were gathered analysing the total population, and not just the first income decile. This was due to a lack of secondary data considering specifically the first income decile (RES Foundation, 2021). Whereas there is data available proving that the share of fuels used for heating changes depending on the income decile being analysed (Statistical Office of the Republic of Serbia, 2020), and that poorer households will utilise more solid fossil fuels when compared to the rest of the population (RES Foundation, 2021), no detailed information differentiating between the type of solid fossil fuel, or between other end-uses (e.g., DHW) was available. Additionally, here low-income groups were assumed to be those belonging to the first income decile. Whereas common practice in the literature, this does not necessarily represent the whole spectrum of low-income groups, and depending on the academic and technical backing provided, a larger share of the population could be considered. Additionally, only economic factors were considered, which reflect only one, nonetheless vital, aspect of energy poverty. Therefore, further research should be performed to gather primary data related to the household energy consumption characteristics of the low-income households in Serbia, providing precise fuel and end-use share distributions across the considered strait of society. Other subjective data obtained by surveying low-income households should also be considered. Thereafter, the simulation model hereby employed should be utilised with the updated and improved primary data. Finally, in the present study, the notion of energy justice was not considered. Nonetheless, this would be an interesting lens through which to analyse the reduction of energy poverty among low-income households. Would such reduction be equally distributed throughout each household? Or would other factors such as geography play an important role? These are all insightful questions to be answered through further research.

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A

Appendix

A.1. Detailed Overview of Final Energy Consumption and Expenses

Total (GWh)	Total	Heating	Cooling	DHW	Cooking	Electric appliances & Lighting
Electricity	1,335	163.4	16.0	438.9	144.2	572.5
Heating oil	62	42.9		19.5		
LPG	0	0.0			0.0	
Natural gas	235	218.6		10.2	6.3	
Solar thermal	0	0.0		0.0		
Biomass	1,012	933.7			78.1	
Ambient heat	0	0.0				
District heating	427	427.0		0.0		
Coal and other	257	257.4				
Total	3,329	2,043	16	469	229	572

Table A.1: Detailed overview of final energy consumption of low-income households in Serbia in 2019.

Final Energy Expenses per Fuel Type	
Electricity	72,889,136 €
Heating oil	9,291,888 €
LPG	- €
Natural gas	7,290,752 €
Solar thermal	- €
Biomass	66,814,943 €
Ambient heat	- €
District heating	36,294,353 €
Coal and other	7,025,026 €
Total	199,606,098 €

Table A.2: Detailed overview of expenses per fuel type for low-income households in Serbia in 2019.

Final Energy Expenses by End-use	
Space heating	127,062,740 €
Space cooling	874,344 €
Domestic Hot Water	27,187,277 €
Cooking	13,225,195 €
Lighting and Electric appliances	31,256,543 €
Total	199,606,098 €

Table A.3: Detailed overview of expenses per end-use for low-income households in Serbia in 2019.

A.2. Share of Fuels per Individual End-use

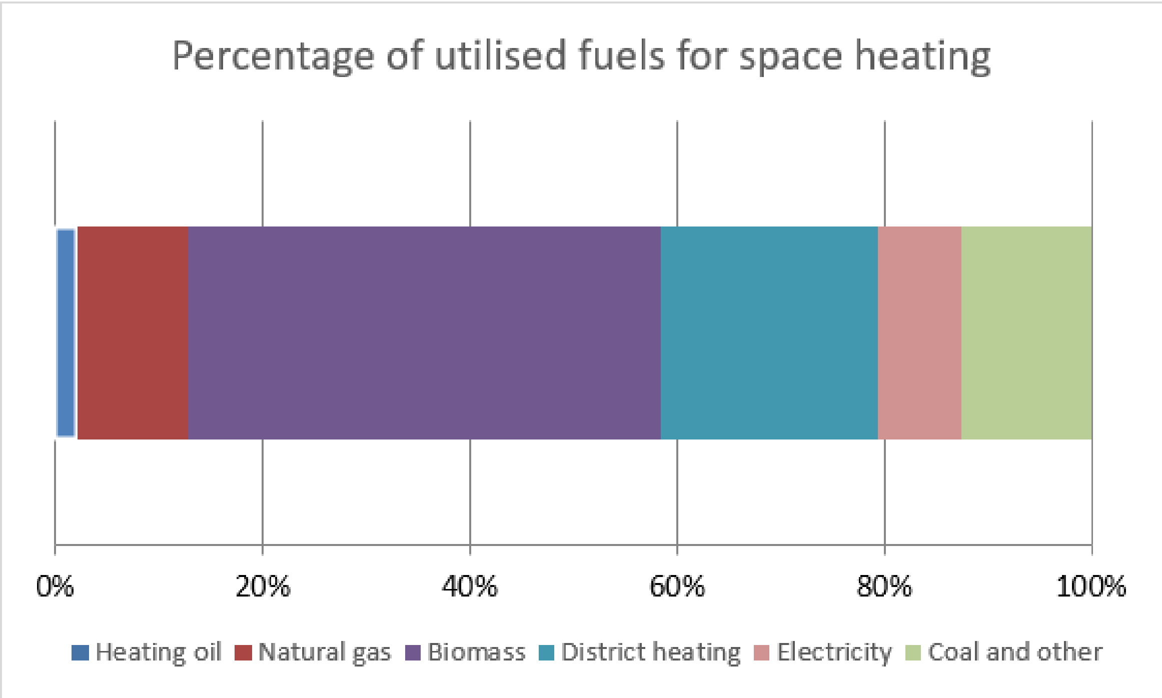

Figure A.1: Distribution of fuels utilised for space heating.

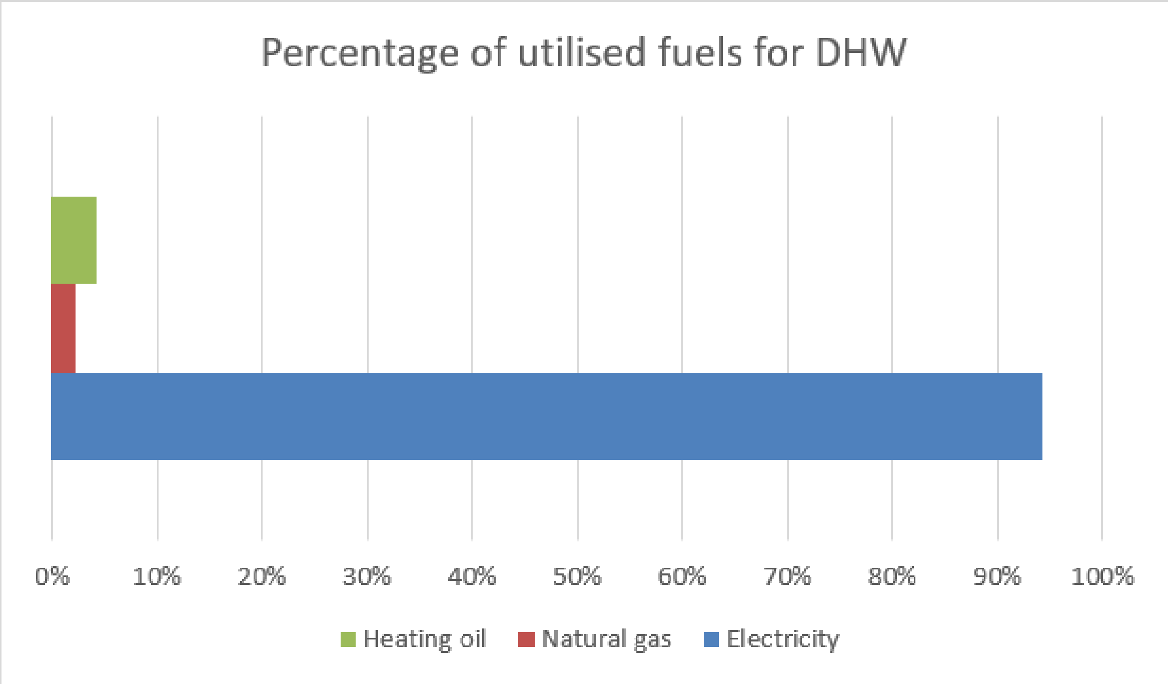

Figure A.2: Distribution of fuels utilised for domestic hot water.

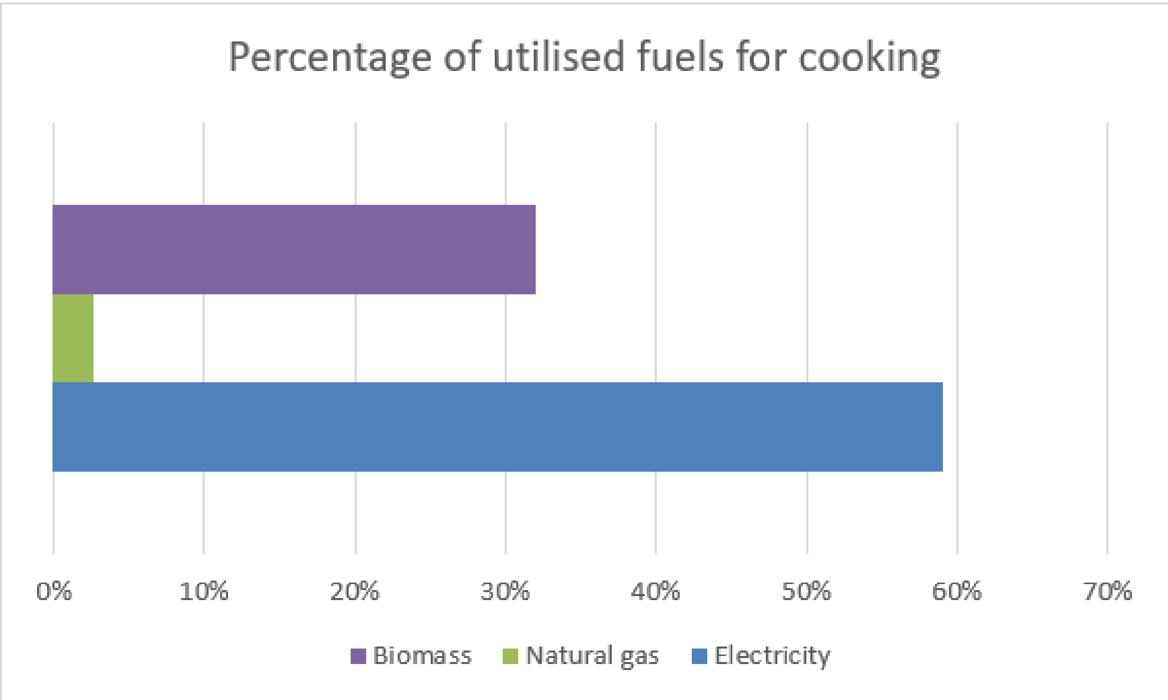

Figure A.3: Distribution of fuels utilised for cooking.

A.3. Detailed Overview of Energy Price Trends

	2019	2025	2030	2035	2040	2045	2050
Heating oil	149	174	198	223	248	273	298
Natural gas	31	40	50	59	68	71	74
Coal and other	27	30	33	35	36	38	40
Electricity	55	55	55	58	60	63	67

Table A.4: Energy price trends for Baseline, Scenario 2 and Scenario 3 in EUR/MWh as foreseen in the EU Reference Scenario 2020 (European Commission et al., 2021).

	2019	2025	2030	2035	2040	2045	2050
Heating oil	149	174	243	286	328	367	406
Natural gas	31	40	83	106	129	143	157
Coal and other	27	30	93	119	145	166	188
Electricity	55	55	55	58	60	63	67

Table A.5: Energy price trends for Scenario 1 in EUR/MWh as foreseen in the EU Reference Scenario 2020 (European Commission et al., 2021).

A.4. Detailed Overview Baseline Scenario

Space heating	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	43	39	37	34	32	31	29
Natural gas	219	186	164	149	137	134	131
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	163	163	163	159	155	150	146
Coal and other	257	245	233	227	221	215	210
Total	2043	1993	1958	1930	1906	1891	1878
Space cooling	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	16	16	16	16	15	15	14
Total	16	16	16	16	15	15	14
Domestic hot water (DHW)	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	439	438	437	426	416	404	393
Natural gas	10	9	8	7	6	6	6
Heating oil	20	18	17	16	15	14	13
District heating	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Coal and other	0	0	0	0	0	0	0
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
Total	469	464	461	449	437	424	412
Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	62	57	53	50	47	45	43
Natural gas	229	195	172	156	144	140	137
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	618	617	615	600	587	569	553
Coal and other	257	245	233	227	221	215	210
Total	2528	2474	2435	2394	2359	2330	2304

Table A.6: Detailed overview of energy consumption in GWh for Baseline Scenario.

Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	9	10	11	11	12	12	13
Natural gas	7	8	9	9	10	10	10
LPG	0	0	0	0	0	0	0
Biomass	62	62	62	62	62	62	62
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	36	36	36	36	36	36	36
Electricity	34	34	34	35	35	36	37
Coal and other	7	7	8	8	8	8	8
Total	155	157	159	161	163	164	166

Table A.7: Detailed overview of energy expenses in million EUR for Scenario 1.

A.5. Detailed Overview Scenario 1

Space heating	2019	2025	2030	2035	2040	2045	2050
Heating oil	43	39	32	29	27	25	24
Natural gas	219	186	87	75	67	63	60
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	163	163	163	159	155	150	146
Coal and other	257	245	0	0	0	0	0
Total	2043	1993	1641	1623	1609	1599	1590
Space cooling	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	16	16	16	16	15	15	14
Total	16	16	16	16	15	15	14
Domestic hot water (DHW)	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	439	438	437	426	416	404	393
Natural gas	10	9	4	3	3	3	3
Heating oil	20	18	14	13	12	11	11
District heating	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Coal and other	0	0	0	0	0	0	0
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
Total	469	464	455	443	432	418	406
Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	62	57	46	42	39	36	34
Natural gas	229	195	91	78	70	66	63
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	618	617	615	600	587	569	553
Coal and other	257	245	0	0	0	0	0
Total	2528	2474	2112	2081	2056	2032	2011

Table A.8: Detailed overview of energy consumption in GWh for Scenario 1.

Space heating, cooling and DHW	2019	2025	2030	2035	2040	2045	2050
Heating oil	9	10	11	12	13	13	14
Natural gas	7	8	8	8	9	9	10
LPG	0	0	0	0	0	0	0
Biomass	62	62	62	62	62	62	62
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	36	36	36	36	36	36	36
Electricity	34	34	34	35	35	36	37
Coal and other	7	7	0	0	0	0	0
Total	155	157	151	153	155	157	159

Table A.9: Detailed overview of energy expenses in million EUR for Scenario 1.

A.6. Detailed Overview Scenario 2

Space heating	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	43	39	37	0	0	0	0
Natural gas	219	186	164	149	137	0	0
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	60	59	133	129
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	163	163	163	183	178	203	197
Coal and other	257	245	233	0	0	0	0
Total	2043	1993	1958	1752	1735	1697	1687
Space cooling	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	16	16	16	16	15	15	14
Total	16	16	16	16	15	15	14
Domestic hot water (DWH)	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	439	438	437	439	429	421	410
Natural gas	10	9	8	7	6	0	0
Heating oil	20	18	17	0	0	0	0
District heating	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Coal and other	0	0	0	0	0	0	0
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
Total	469	464	461	446	435	421	410
Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	62	57	53	0	0	0	0
Natural gas	229	195	172	156	144	0	0
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	60	59	133	129
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	618	617	615	637	622	639	621
Coal and other	257	245	233	0	0	0	0
Total	2528	2474	2435	2213	2185	2133	2111

Table A.10: Detailed overview of energy consumption in GWh for Scenario 2.

Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	9	10	11	0	0	0	0
Natural gas	7	8	9	9	10	0	0
LPG	0	0	0	0	0	0	0
Biomass	62	62	62	62	62	62	62
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	36	36	36	36	36	36	36
Electricity	34	34	34	37	37	40	41
Coal and other	7	7	8	0	0	0	0
Total	155	157	159	144	145	138	139

Table A.11: Detailed overview of energy expenses in million EUR for Scenario 2.

A.6.1. Calculation of implementation costs

It was assumed that the implementation of one heat pump would cost 8000 EUR. In 2030, heating oil and coal would be phased out. These represent 15% of space heating energy consumption. Thus, it is assumed that in 15% of households a heat pump would have to be implemented. Therefore, 37,005 households multiplied by 8000 EUR yields approximately 296 million euros expenses. Similarly, in 2040, all natural gas would be phased out, representing 11% of space heating energy consumption. Again, assuming in 11% of households new heat pumps would be implemented, this results in 27,137 households multiplied by 8000 EUR and thus approximately 217 million euros.

A.7. Detailed Overview Scenario 3

Space heating	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	43	39	32	27	24	22	21
Natural gas	219	186	146	117	100	98	96
LPG	0	0	0	0	0	0	0
Biomass	934	934	829	735	680	680	680
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	379	336	311	311	311
Electricity	163	163	144	125	113	110	107
Coal and other	257	245	207	179	161	157	153
Total	2043	1993	1737	1520	1389	1378	1368
Space cooling	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	16	16	14	12	11	11	10
Total	16	16	14	12	11	11	10
Domestic hot water (DWH)	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	439	438	437	426	416	404	393
Natural gas	10	9	8	7	6	6	6
Heating oil	20	18	17	16	15	14	13
District heating	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Coal and other	0	0	0	0	0	0	0
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
Total	469	464	461	449	437	424	412
Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	62	57	49	43	38	36	35
Natural gas	229	195	154	124	106	104	102
LPG	0	0	0	0	0	0	0
Biomass	934	934	829	735	680	680	680
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	379	336	311	311	311
Electricity	618	617	595	563	540	524	509
Coal and other	257	245	207	179	161	157	153
Total	2528	2474	2213	1981	1837	1813	1790

Table A.12: Detailed overview of energy consumption in GWh for Scenario 3.

Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	9	10	10	9	9	10	10
Natural gas	7	8	8	7	7	7	8
LPG	0	0	0	0	0	0	0
Biomass	62	62	55	49	45	45	45
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	36	36	32	29	26	26	26
Electricity	34	34	33	32	32	33	34
Coal and other	7	7	7	6	6	6	6
Total	155	157	144	133	126	128	129

Table A.13: Detailed overview of energy expenses in million EUR for Scenario 3.

A.7.1. Calculation of implementation costs

It is assumed that 75% of low-income household buildings will be refurbished, that is 185,028 households. However, 50% of these will be renovated in 2030 and the other half in 2035. Thus, in 2030, 92,514 buildings will be renovated to meet class E standards (10,000 EUR costs) and thus in total approximately 925 million euros will be spent. Same goes for 2035. Thereafter, in 2040, all these buildings will be improved to Class D, involving costs of 5,000 EUR per building. Thus, 185,028 households times 5,000 EUR yields again 925 million euros.