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ENERGY USE CAPS UNDER SCRUTINY: AN ECOLOGICAL ECONOMICS PERSPECTIVE

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1.INTRODUCTION

According to the Special Report issued in 2018 by the Intergovernmental Panel on Climate Change (IPCC), human activities are estimated to have caused approximately 1.0°C of global warming compared to the pre-industrial level. This IPCC report reveals that between 2030 and 2052 global warming is likely to increase by a further 1.5°C. This increase has the potential to cause further long-term changes in the climate system (IPCC, 2018). According to World Energy Outlook, energy production and energy use are the largest sources of global greenhouse-gas (GHG) emissions (International Energy Agency, 2015) and contributors to global warming. In order to avoid additional the harmful impacts of climate change on humanity and nature, global CO_2 emissions need to be reduced well before 2030. In order to achieve the necessary transformation, synergies for mitigation and adaptation need to be maximized while trade-offs are minimized. The Covid-19 crisis provides an opportunity to rethink our consumption-based economic model, which does not consider the physical limits of natural systems.

If we want to stop global warming at 1.5°C and meet the climate goals suggested by scientists, we need to develop energy policies based on a vision of a low-carbon economy/society and implement policy instruments that radically reduce our energy demand. One of the scientific proposals for radically decreasing global CO_2 emissions is capping energy use. Schemes for energy capping, which are quantitative environmental policy instruments, define absolute limits for energy use. They are usually claimed to be able to enhance ecological sustainability together with social justice, while – within the defined quantitative boundaries – promise allocative efficiency, too.

Since energy-capping instruments have been developed more extensively in relation to households and their potential implementation affects households, in my doctoral research I will scrutinize the impacts of energy capping instruments on households. Following an ecological economics approach, I will examine energy capping proposals that target household energy consumption according to the three goals of ecological economics: 1) sustainable scale, 2) fair distribution, and 3) efficient allocation. In my thesis, I aim to identify whether the energy-capping schemes proposed for addressing climate change can contribute to the well-being of people if they are implemented. Therefore, I will tackle more thoroughly the second goal of ecological economics – namely, whether and how energy capping instruments that target households incorporate concerns about social justice.

In order to examine household energy consumption from an ecological-economics inspired social justice perspective, I analyse household energy consumption in Hungary. The reason I have chosen Hungary for the subject of my analysis is twofold. On the one hand, I am doing my PhD studies in this country and have obtained national data on household energy consumption. On the other hand, one of the investigated energy-capping schemes was developed and proposed for Hungary. In order to reveal the social justice implications of the energy capping instruments in question, I strive to identify whether the equal per-capita allowances proposed by most of the energy capping proposals represent a fair way of operating with regard to a collective cap on energy use. Through examining Hungarian household energy consumption from a social justice perspective, my research reveals what kinds of social-justice-related indicators have a significant role to play in household energy consumption patterns. Furthermore, I reveal whether specific groups or clusters of households (grouped based on their energy use) can be detected in the Hungarian population, and what kinds of socioeconomic factors specify those clusters. Furthermore, I aim to reveal how an energy quota scheme based on equal per-capita distribution would impact households in each of the clusters, with their different socioeconomic characteristics and energy use patterns.

In order to evaluate the potential impact of energy-capping schemes (in the case that they are implemented) on the Hungarian population, on the one hand, quantitative statistical instruments are applied. On the other hand, I aim to better interpret and contextualise the analysis based on quantitative statistical data through expert-based qualitative inquiry. Therefore, to put into context the secondary statistical data, I carry out expert interviews with key informants who can assist in revealing the connections (patterns and causal mechanisms) between poverty and household energy use. By triangulating data sources and data collection methods, I aim to draw a clearer picture of Hungarian energy use patterns, the socioeconomic drivers behind them and the potential impacts of an energy quota scheme based on equal per-capita distribution on households with different socioeconomic background and energy consumption patterns. I aim to inform climate and energy policies about the potential social justice implications of the policy instruments proposed for reducing household energy use.

In this chapter, I will approach my research problem by introducing the trends of fossil energy use, both concerning the international and the Hungarian context. In order to reveal the social consequences, beyond the more evident environmental ones, of the current patterns of fossil energy use and policies aimed at changing these patterns, including Personal Carbon Trading systems, I follow the problem conceptualisation of ecological economics (see Chapter 1.2). After screening the problem situation, as well as introducing ecological economics as my research paradigm, I locate my research more precisely and specify my research goals.

1.1. Research problem

The production and use of energy across economic sectors account for more than 75% of the EU's greenhouse gas emissions. (European Commission, 2019). Notwithstanding efforts to increase efficiency, carbon dioxide emissions from energy grew by approximately 2% in 2018 globally (IEA, 2018; UNEP, 2019; Enerdata, 2019). Further increase can be expected until 2040 unless governments take radical action. The International Energy Agency's recent and ambitious 'efficient world' scenario to 2040 (IEA, 2018), suggests a higher global energy demand than today, as Figure 1 shows.

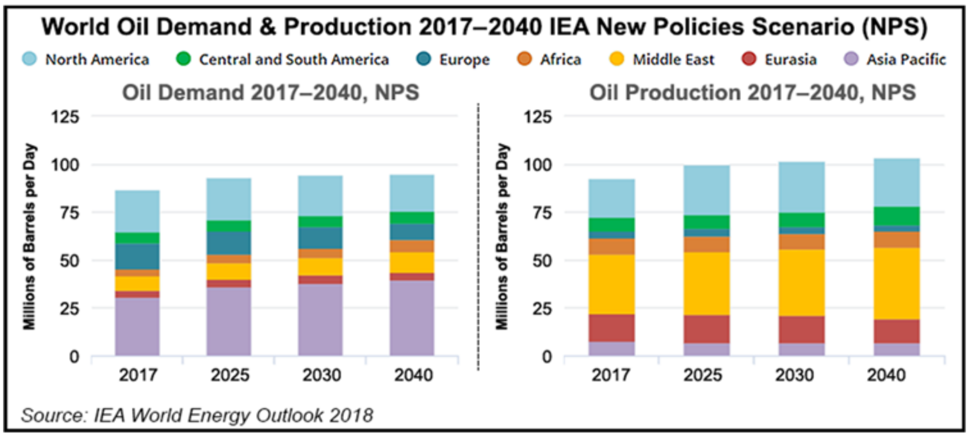

FIGURE 1: CHANGE IN ENERGY USE BETWEEN 2017 AND 2040

The acceleration in energy consumption in 2018 (+2.3%) was driven by high growth in electricity and gas demand. From 2017 to 2018, record-high energy demand (+2.1%) was recorded, and that of gas and electricity grew (+6%), but demand for coal and oil also increased (+2-3%), thus energy-related CO_2 emissions also grew (+1.7%) (Enerdata, 2019). Final energy consumption increased by 1.3% from 2016 to 2017 in the EU (Eurostat, 2019a) and by 1.04% in Hungary (Eurostat, 2019b). These data do not account for, however, all the energy needed to produce the huge amount of products delivered to the EU. Furthermore, this level of internal energy consumption happens on a territory which is known to be committed to reducing its CO_2 by 51-55% compared to projected levels by 2030 (European Commission, 2019), but at the same time outsources many production activities that emit the related CO_2 outside the EU's borders.

At the EU level, the share of energy from renewable energy resources is 17.7%, while in Hungary it is 13.3% (Eurostat, 2018b). In 2017, 81% of renewable energy resources came from biomass (mekh.hu, 2019; Sáfián, 2019). This proportion is even higher than the European average (64%) (IEA, 2018). Fossil fuel subsidies are stimulating the growing demand for fossil energy use. Fossil fuel post-tax subsidies add up to five trillion USD per year globally (6% of global GDP) (Coady et al., 2017), while in Hungary subsidies also goes primarily on fossil fuels (Ürge-Vorsatz, 2019). According to the IPCC Global Warming of 1.5°C special report, under the emissions scenario in line with current pledges made in line with the Paris Agreement, global warming is expected to surpass 1.5°C above the pre-industrial level (Masson-Delmotte et al., 2019). The annual cost of climate change damage due to inaction in Europe has already reached €13.3 billion. Delays and current inaction that may lead to failing to meet the 1.5 degree target risk a 3- to 10-fold increase in costs in the future (Carey, 2018). Based on methodology by the World Health Organization (WHO) and the European Commission, the Chronic Coal Pollution report shows that every year air pollution from Western Balkan coal power plants is responsible for an estimated 3,900 premature deaths, 8,500 cases of bronchitis in children, and other chronic illnesses. The health issues these plants cause create lost-productivity-related and health costs of up to EUR 11,535 million (HEAL, CAN Europe, Sandbag, CEE Bankwatch Network and Europe Beyond Coal, 2019).

Therefore, the dramatic strengthening of national commitments is needed to stop the harmful effect of global warming and other consequences of fossil energy use. Nations need to 'triple efforts to reach the 2°C target' in their unconditional National Determined Contributions (NDCs) under the UNFCC (UNEP, 2018, UNEP2019), which is less demanding than the 1.5 °C target in the IPCC report. Countries must increase their National Determined Contributions under the UNFCCC ambitions more than fivefold to achieve the 1.5°C goal (UNEP, 2019). Radical steps are urgently needed to save the planet (Díaz et al., 2019), In order to spur governments to take the necessary steps to mitigate the effects of climate change, difference activities have occurred. One of them is that 15,000 scientists from 184 countries expressed their views and urged nations to start acting now (Ripple et al., 2017). Furthermore, the IPCC has also called for action: "the state of nature, and the state of the equitable distribution of nature's support is in serious decline. Only immediate transformation of global business-as-usual economies and operations will sustain nature as we know it, and us, into the future". Therefore, increased action and transformative systematic change is required (Masson-Delmotte et al., 2019). Besides international scientific bodies and network of scientists, action-oriented groups have also been formed, such as the Extinction Rebellion movement, which calls for radical system-level change to reverse the trends of the climate emergency (Extinction Rebellion, 2020).

Because in the EU 27% of final energy consumption is attributable to households (Eurostat, 2017), while this proportion in Hungary is 31-35% (MEKH, 2017; Sáfián,

2019) (none of these proportions contains gasoline), controlling household energy use would have significant consequences in terms of regulating energy-related CO_2 emissions and thus in mitigating the impacts of climate change. Even though neither statistic (neither the EU level nor the Hungarian one) includes the use of fuels or other fossil energy for transport, the potential for reducing household energy consumption is high (Tombácz and Mozsgai, 2009). To tackle residential fossil energy use, so-called Personal Carbon Trading (PCT) schemes have been developed; this started in the UK, but has also spread to the US, Finland, and Hungary. I detail them in the chapter on Personal Carbon Trading schemes (2.1.4.). Because the schemes aim to put an overall cap on residential energy use or on the carbon emitted by households, their contribution to reducing energy use to sustainable levels is quite clear. In my dissertation, I seek to reveal not only their environmental but also their social consequences.

The actuality of my research is that at the EU level, the European Commission has proposed a European 'Climate Law' enshrining the 2050 climate-neutrality objective (European Commission, 2019), while the Hungarian PCT, called the Hungarian Climate Bill, started to be renegotiated and campaigned for in 2020 (Botár, 2018).

1.2. Ecological economics as research paradigm

In this chapter, the complexity of the current intertwined ecological, social and economic challenges is first referred to. Then those proposals that ecological economics make for dealing with these complex issues are detailed, and the concrete ideas and solutions proposed by ecological economists are identified that aim to promote fair and sustainable resource use. Furthermore, theories and concepts that have similarities to ecological economics are also touched upon. This chapter ends with a justification of why I chose ecological economics as a research paradigm, and I summarise the relevance of it to my dissertation.

Despite the related knowledge and the technology that is available, humanity still uses more resources than can be regenerated (EEA, 2015). Since 1967, Earth has been 'too small' for humankind, putting humanity's own future at huge risk due to the unsustainable use of natural resources (Global Footprint Network, 2021). Growth in energy consumption has been experienced in the form of carbon dioxide emissions (in the so-called carbon footprint), as well as in the form of an increase in the ecological footprint (Kerekes et al., 2018).

Our current level of production and consumption, including energy use, is not only unsustainable, but also unjust (UN, 2018). Intensive rates of depletion and growing social inequality cannot be maintained in the long term (Future Earth Knowledge Action Network, 2018b). A piece of research that incorporated data from 150 nations used indicators to estimate a 'safe and just' development space for humanity, revealing that if all seven billion people or more are to live well within the limits of our planet, then radical changes are required (O'Neill et al., 2018). To meet the expectations of the urgency and scale of change and transformation that is required, we need to move beyond the perception and mind-set that sustainable development will decrease our quality of life. It is possible to imagine a good quality of life and healthier societies in a sustainable future, where planetary boundaries are recognized (O'Neill et al., 2018). Complex issues, however, require complex responses (Luda, 2013; O'Neill et al., 2018; CEEweb for Biodiversity, 2012), which tackle several interconnected and multi-layered factors. The interlinked drivers and the multitude of involved actors urge policy makers to apply a systemic approach that overcomes single-sector biases and sectoral silos (Hirschnitz-Garbers, 2017). This poses a great challenge to policy-makers with regard to identifying priority areas for action and effective points for intervention. In addition to policy makers, however, all of us have a role to play in formulating and implementing policies that affect energy use patterns (O'Neill et al., 2018). One step that is often proposed to tackle the current interconnected crises is set a limit on resource consumption, particularly energy consumption, in order to move towards more sustainable and just resource use globally.

Without a guiding vision of sustainability, it is not possible to target any single issue of global concern effectively, or to model the complex and interdependent systems of ecological, economic, and societal issues. This is why one of the founding fathers of ecological economics, Herman Daly (1992), proposed conceptualizing the three main goals any sustainability science in general and ecological economics in particular need to tackle. Daly (1992) suggested using the terms "sustainable scale", "fair distribution", and "efficient allocation". The three goals of ecological economics and how they are embedded are shown in Figure 2.

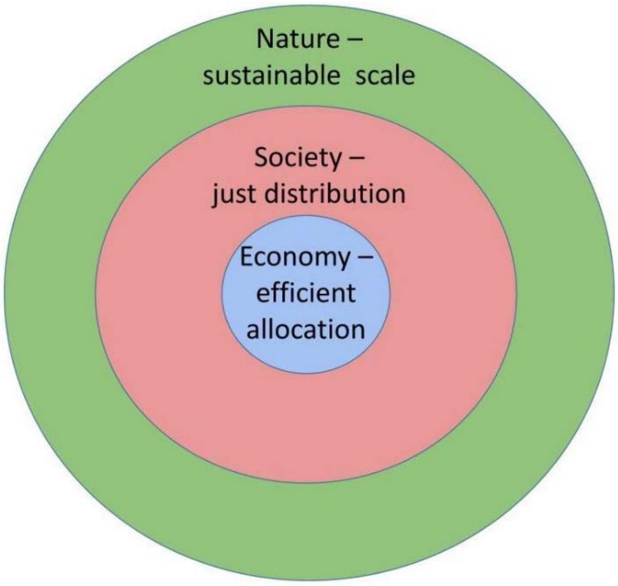

FIGURE 2: THE THREE GOALS OF ECOLOGICAL ECONOMICS (AUTHOR'S WORK BASED ON DALY (1992))

Daly, in the related paper, clearly set out the preconditions for a sustainable and just economic model, or, in other worlds, the basics of ecological economics. 'Scale' refers to the amount of resources that are extracted and traded due to global economic activities. The physical limits of our globe, which are currently far trespassed, define the scale of sustainable resource use. Analysis of the distribution of resources and the distribution of benefits obtained from their use reveals the issue of fair distribution. The fair distribution of resources, as well as the fair distribution of benefits arising from resource use, are preconditions for just societies and thus for sustainability. The third aspect of ecological economics involves how efficient the allocation of resources is, which is the primary concern of neoclassical environmental economics.

Ecological economics awards significance to all three issues separately, but also to their interconnectedness. The first concern, sustainable scale, refers to the amount of resources that are extracted and traded in global economic activities. The physical limits of our globe, which have already been trespassed (Rockström et al., 2009), define the scale of sustainable resource use and set limits on any kind of physical growth. Following a systems approach (Norgaard, 1990), it seems clear that sustainable scale (living within planetary boundaries) is the primary issue because that nature is the larger system (which cannot be expanded due to its physical limits), in which society and the economy are co-evolutionary embedded (Norgaard, 1990). This position clearly differentiates ecological economics from environmental economics – the latter being a form of applied microeconomics that operates through applying a lens of relative scarcity, has no conceptualisation regarding limits to growth (Bajmócy and Málovics, 2020), and tries to solve environmental problems through internalizing externalities. Environmental economics suggests using Pigouvian taxes to control negative externalities, distributing locally negotiable property rights based on the Coase theorem, or creating a market for tradable emission credits (Bajmócy and Málovics, 2020), while a techno-critical ecological economics aims to achieve a stable economic scale that respects planetary boundaries (Bajmócy and Málovics, 2020). Furthermore, according to ecological economics, natural capital cannot be substituted, and all economic and social activities need to consider the boundaries of natural systems. Attention to sustainable scale ultimately raises concern for future and non-human living and non-living beings. Thus, the perspective has both a temporal (intergenerational) and a non-anthropocentric component.

The second issue is the intra-generational as well as inter-generational distribution of resources. The benefits deriving from natural resource use also require an ecological-economic analysis and management, considering that fair distribution and a shared notion of social justice are also constitutive elements of sustainability. Any sustainable society and economy can only exist if it respects the ecological limits (fragility, resilience) of planet Earth. Since all economic activities gain meaning in particular social contexts, the economy needs to be designed to respect societal concerns, including social justice. Consequently, the issue of fair distribution prevails over that of economic efficiency. To put it differently, there are social limits to growth (Hirsch, 1995) beyond the ecological (biophysical) ones. Obviously, there are competing conceptions of social justice, and it is not at all clear in which societal context which conception of justice prevails, or should prevail, when deliberated by citizens (Kiss, 2018). I touch on this issue in more detail in the fair and sustainable energy chapter of this dissertation (Chapter 2.1.2).

The third aspect of ecological economics is efficient allocation. In the case of market failures and missing markets, mainstream economics proposes some forms of collective intervention in order to correct failures and/or create markets that operate efficiently. The third aspect of ecological economics, efficient allocation, acknowledges, however, the relevance of free markets as a means of delivering efficient economic outcomes only if they contribute to the first two principles of ecological economics; namely, to achieving a sustainable scale, and just distribution. Not surprisingly, proposals for resource caps, including energy-use capping, involve, to some extent, the application of market mechanisms not only for the sake of resource-efficient outcomes, but rather for the sake of achieving sustainable scale and just distribution (Kiss, 2018).

One of the concrete ideas that has arisen from ecological economics regarding how to achieve a sustainable scale and just distribution is the concept of the steady state economy, developed by Herman Daly: "*An economy with constant stocks of people and artifacts, maintained at some desired, sufficient levels by low rates of maintenance 'throughput', that is, by the lowest feasible flows of matter and energy from the first stage of production to the last stage of consumption*" (Daly 1992, p. 16).

In the part of this chapter that follows, I identify concrete ideas connected to ecological economics, although these might differ to some extent. As scale is the first aspect, and also because scientific literature has dealt with this concern most frequently, in the following paragraphs I summarize current insights regarding the issue of sustainable scale.

When identifying a critical, sustainable scale, intra-generational (space) and inter-generational (time) issues need to be taken into account. The former includes the spatial scarcity and heterogeneity of allocation and distribution (Jordan and Fortin, 2002). The latter is the temporal scale, which involves consideration of ecological turnover times and the rate at which humanity uses resources and disposes of waste, together with how future generations will be affected due to environmental degradation caused by today's activities. Therefore, these two concerns of space and time need to be taken into consideration when trying to identify sustainable scale.

Another approach to achieving sustainable scale is distinguishing between maximum and optimal scale (Lawn, 2001). The maximum sustainable scale is the largest macroeconomic scale that can be sustained using a given throughput of matter and energy. This scale is within the ecosphere's regenerative and waste assimilative capacity, thus it has a biophysical reference. The optimal scale maximises the net benefits of economic activity, while it usually does not include all expenditures, especially social and environmental externalities (Kiss, 2018). Thus, it has macroeconomic relevance. These two scales need to be harmonized so that the optimal scale does not exceed the maximum sustainable scale. In line with the optimal and maximum scale dilemma, others (Wetzel and Wetzel, 1995) distinguish between ecological and economic carrying capacity. Ecological carrying capacity involves consideration of how many people can live on Earth, while the economic perspective involves what resource demand is associated with the standard of living they maintain.

A popular approach to defining sustainable scale is the IPAT (I=PAT) equation, which expresses the idea that environmental impact (I) is the product of three factors: population (P), affluence (A), and technology (T). The equation (I=PAT) developed by Ehrlich (Ehrlich and Holdren, 1971) (Pogutz and Micale, 2011) based on the Global Welfare Curve (Wetzel and Wetzel, 1995) shows that all economic activity requires throughput, which implies environmental impacts. These impacts can be mitigated using appropriate technology, but never eliminated completely. Similarly, Alcott, for example, classifies strategies for reducing environmental impact according to the I=PAT formula (Alcott, 2009). The research argues for giving preference to direct, 'left-side' (i.e. found on the left side of the equation) strategies over indirect 'right-side' strategies for reducing I(mpact), such as resource depletion and environmental pollution. This would avoid a rebound effect and result in impact reduction. In contrast, lessening any of the right-side factors (P: population, A: Affluence, T: Technology) will cause or at least enable the other two to rise or 'rebound' (Alcott, 2009). Teixidó-Figueras and Duro (2015) call for replacing the above-mentioned IPAT, which, according to the authors, utilizes only an aggregated measure of technology, rather than quantifies specific drivers or tests hypotheses (Teixidó-Figueras and Duro, 2015). Therefore, they suggest a so-called STIRPAT model (Stochastic Impacts by Regression on Population, Affluence and Technology) to identify the driving forces of natural resource consumption. They find that the affluence driver, measured by GDP per-capita, becomes the larger contributor to international ecological footprint inequality (48.9%).

Besides IPAT and STRIPAT, 3" models or Environmental Integrated Assessment Models (IAMs) link energy, economic, and environment systems (Sanz et al., 2017), but they mainly lack feedback between subsystems. Moreover, most models consider that both fossil and renewable energy resources are abundant. Sanz and colleagues (2017) developed the so-called MEDEAS model that is restricted by at least four environmental limits: 1. energy resources, 2. climate change, 3. availability of materials, and 4. availability of land. The initial results of running MEDEAS, simulating a business-as-usual scenario, show that current global GDP per-capita growth cannot be maintained in the following decades. Sanz and colleagues (2017) found that growth may stop in the 2020s due to oil depletion. The results also indicate that global average GDP per-capita will in 2050 be around 10,000$ (very similar to the present level). Renewable sources could cover nearly 100% of electricity demand in 2050 but not replace all energy consumption. Even in the case of a strong renewable scenario development, GDP per-capita would reach 11,500 $ by 2050. These initial results also show that if the consumption of non-renewable sources does not stop, the impact of climate change will have the potential to substantially impact our society in the next few decades

Degrowth scientists (Martinez-Alier, 2009) also argue that economic growth is not compatible with environmental sustainability, and it is not 'the economy' that has to shrink, but the throughput thereof (Alcott et al., 2017) in order to achieve a sustainable scale. In other words, if economic growth is manifested in the growth of culture, education, recreation, health-care (or whatever contributes to an increase in wellbeing) with a simultaneous reduction in resource consumption, this is the ideal world we want. There seems to be no other way of modifying the internal structure of a profit-driven growth economy to create a non-growth economy. This is where resource caps have a vital role to play: they create an opportunity to define an absolute limit to resource use, thereby institutionalizing a maximum physical size for the economy (Spangenberg, 2013). Even if the need to apply resource-use-capping instruments is accepted, others argue (Ropke, 2015) that there are implementation challenges to be addressed. The challenges, inter alia, include the difficulty of implementing completely new and quite complicated policy instruments, the lack of proper technical infrastructure and institutions, cultural expectations, and entrenched everyday practices. All the challenges have evolved through long historical processes that favour the substitution of labour mainly by fossil energy.

According to advocates of negative economic growth, the economy and human activity must be maintained within the ecological carrying capacity of the Earth (Harangozó et al., 2018); namely, within a sustainable scale. There are, however, obstacles in the way of implementing negative growth policies. These include the fact, inter alia, that transitioning is not always popular, especially in times of crisis and among poorer people/countries. Fear of unemployment and a potential decrease in living standards can result in low civil and political support in any democratic system. A negative growth approach also suffers from the lack of sufficient practical experience (Harangozó et al., 2018).

The three concerns of ecological economics and their interconnectedness may be interpreted in another way than Daly seemed to call for (1992). Researchers (Prakash and Gupta, 1994) suggest first setting the ideal scale, then letting the market achieve efficient allocation through price mechanisms, and only then calling for a form of collective intervention to correct or compensate for any undesirable distributional outcomes through the use of public policy tools (incl. fiscal instruments). Here, effective allocation comes second, followed by just distribution. According to the advocates of a zero-growth economy (Harangozó et al., 2018), there is an optimal size of economy that maximizes well-being. In the case of developed countries, this can be created through downscaling production and consumption while increasing well-being. An economy with zero growth still gives the opportunity, for instance, for cultural development. There are, however, obstacles to implementing zero-growth strategies (Harangozó et al., 2018). These include the issue of specifying the optimal size of the economy on a global, regional, and local level. Another issue is that the zero-growth approach is applicable to large and wealthy economies, but not to the majority of countries, and still there is little practical experience with such a proposal (Harangozó et al., 2018).

Concerning the implementation-related difficulties of attempts to achieve sustainable scale and just distribution, I aim to investigate justice theories (Chapter 2.1.2) and apply those in my research through which energy-capping schemes can potentially be implemented in a fair manner.

The three principles of ecological economics can also be linked to energy use, since energy is an overarching resource that affects the use of all other resources. "*All three pillars of sustainability (society, environment, and economy) are inseparable from the energy sector, because energy consumption causes so many externalities that threaten welfare in the long run. Most environmental problems are [closely connected] with energy use and production, such as nuclear waste management, oil spills, emission, etc. Furthermore, energy is an integral part of the economic and social development, and sustainable energy is a core issue" (*Sebestyén Szép and Nagy, 2017, p.1). My topic of my dissertation is linked to ecological economics through evaluating residential energy-capping schemes that have been developed for households based on the three principles of ecological economics.

In my research I follow the original order defined by Daly (1992); namely, setting a sustainable scale for human activities, then ensuring the fair distribution of resources among members of society, followed by the effective allocation of resource use. So-called Personal Carbon Trading schemes (PCTs) involve capping the economy's energy consumption or carbon emissions (this depends on the scheme – i.e. whether it controls inputs/energy or the outputs/carbon of economic and social activities) of a country/region in line with national/regional carbon emissions targets, and then essentially rationing the energy/carbon that is available as defined by the cap, thus contributing to achieving a sustainable scale. The approach ensures that every individual receives energy/carbon units that cover their fair share of energy use, which is assumed to guarantee a minimum share for all, and thus to contribute to just distribution. If consuming less or more than this amount, consumers can trade with saved units as effectively as possible in line with the defined cap and thus contribute to the ecological economics component of efficient allocation. Trading (within absolute limits) allows people to consume based on their lifestyle choices and avoids the unnecessary penalization of ordinary people who wish to trade. Besides evaluating PCTs using data about Hungarian residential energy use, I also reveal whether the equal per-capita distribution of energy entitlements of the PCTs would promote just distribution in Hungary, as well as what kinds of implications for reaching a sustainable scale and efficient allocation the implementation of a PCT would entail.

1.3. Research goals

I would like to advance, both on the scientific as well as policy agendas, the idea of the need to set a cap on the use of energy resources in order to effectively reduce their consumption and re-adjust the economy to within sustainable ecological boundaries (Alfredsson et al., 2018) (Calwell, 2010). This capping should, however, consider social justice implications and fairly share the benefits arising from resource use to all societal parties, particularly vulnerable ones. Therefore, I investigate how so-called Personal Carbon Trading systems (PCTs) contribute to the three principles of ecological economics. PCTs involve setting a cap on residential energy use or carbon emissions (this depends on the PCT scheme, which can either control the input/energy or the output/carbon of economic and social activities) and distributing equal per-capita entitlements for individuals that are in line with the defined and annually decreasing cap.

Personal research goals: why am I personally interested in this topic?
I have been advocating since 2007 at the UN and EU level for sustainable development and thus for appropriate energy policies, including energy-capping schemes, as one example of institutionalising absolute limits to growth. I studied ecological economics, and I became interested in not only the environmental but the socioeconomic impacts of these policies. I am convinced that we need to respect planetary as well as social boundaries (even if our knowledge is always socially constructed), and thus we need to reduce the level of our consumption in absolute terms while taking into account the principle of social justice (i.e. the need for poor people's basic needs to be satisfied in sustainable ways). In explicitly recognizing these commitments, I aim to tackle the risks and biases that influence my research.

Practical research goals: what kind of problems and public policy issues need to be addressed?
Sustainable development is meant to be development within the limits of our environmental space that ensures dignity for all. The Brundtland report's (World Commission on Environment and Development, 1987) praise for economic growth must be understood within this framing: it suggests that economic growth (or in the terms of ecological economics, efficient allocation) is justified and necessary as far as it is instrumental to achieving both objectives (i.e. sustainable scale and social justice). All current policies, as I will show (Chapter 2.1.3), still prioritise efficiency, yet fail in the other two areas (sustainable scale and social justice). This is because efficiency as well as productivity still define the mainstream of policies, which still do not properly address the need for an absolute reduction in energy use (notwithstanding the scientific evidence) and rarely even incorporate social justice considerations. Therefore, with my research I aim to contribute with relevant knowledge and insights to energy policies, both at the EU level and at the Hungarian state level, since my empirical research is based on Hungarian household energy consumption data. At the EU level, I aim to influence negotiations concerning the development and implementation of policy instruments aimed at achieving carbon neutrality by 2050 considering the involvement of social justice in the European Green Deal. The European Green Deal defines an EU-wide Climate Law for ensuring climate neutrality by 2050, and plans to enhance EU commitments on reducing energy poverty. In Hungary, I aim to provide suggestions that will improve the National Energy and Climate Plan in order to deliver real results in terms of reducing CO_2 emissions and fossil energy use, as well as putting more emphasis on reducing energy poverty, especially among the poor and marginalized.

Intellectual research goals: what does the research aim to explore and understand?
In my PhD thesis, I investigate PCTs that aim to set absolute limits on residential energy use while enhancing social justice in the form of equal per-capita entitlement distribution. I assume that the environmental impacts of the schemes, if they are implemented properly, would contribute to achieving a sustainable scale as defined by ecological economics due to their defined limit on energy resource use. At the same time, the schemes have implications for social justice through their variable distributional impacts on different groups of society. Proponents of the latter systems assume that they would benefit the poor, who presumably use less energy than the rich.

Through examining data related to Hungarian household energy consumption, I seek to reveal what kinds of connections exist between residential energy consumption and social justice. Moreover, I am interested in how PCTs impact the interrelations between household energy consumption and social justice.

1.4. Research questions

Because most of the PCT schemes would allocate energy entitlements on an equal per-capita basis, I assess the equal per-capita energy entitlement distribution of PCT and scrutinize it based on the principles of ecological economics – most importantly, in relation to the second issue: the fair distribution of benefits arising from energy use. It means in practise that through examining data related to Hungarian household energy consumption (this includes dwelling characteristics and energy saving strategies that significantly influence the amount of energy needed to ensure fair living conditions), I aim to reveal what kinds of connections exist between residential energy consumption and social justice. Moreover, I am interested in how an equal per-capita energy entitlement distribution of PCT impacts interrelations between household energy consumption and social justice. I carry out my research in order to understand how to enhance social justice when implementing capped energy consumption schemes. Therefore, I pose the following research questions, to be answered within the chapter on personal research goals (1.3):

Q1. What are the interlinkages between residential energy consumption and social justice?

Q2. How do Personal Carbon Trading schemes influence the interconnectedness of residential energy consumption and social justice?

Due to the availability of official data about the situation in Hungary that I use in my analysis, I need to modify the second research question to the following:

Q2': How would an energy entitlement scheme with equal per-capita distribution mechanism influence the interconnectedness of residential energy consumption and social justice in Hungary?

1.5. Structure of the dissertation

In the dissertation I aim to respond to my research questions (Chapter 1.4). First, I have compiled theoretical as well as methodological literature reviews (Chapter 2). In the theoretical literature review (Chapter 2.1), I have screened scientific findings about sustainable, fair, and efficient energy use, while in the methodological review (Chapter 2.2), I analyse how household energy consumption is researched and what patterns characterize the Hungarian population's household energy use.

Based on the literature reviews, I carried out my empirical research. In the empirical research chapter (Chapter 3), I detail the methods that were used – both quantitative (Chapter 3.1) and qualitative (Chapter 3.2), and the research analysis and results. Based on the results, the discussion chapter follows (Chapter 4), which includes my main findings, the research limitations, and some recommendations for further research. I end the dissertation by concluding (Chapter 5).

2.LITERATURE REVIEW

The literature part of my dissertation consists of two parts. The first one is designed to reveal the theoretical background of my research, while the second part reveals the methods applied in residential energy use research. Based on these two types of literature review, I implemented my empirical research, having narrowed down the theoretical background and research methods.

2.1. Theoretical literature review

Understanding complex environmental issues requires dialogue between scientists from different disciplines (Norgaard, 1990). All the aspects of complex systems can only be understood through multiple methodologies. Ecological economics seeks to understand the co-evolutionary dynamics between nature, society, and economy, and it explicitly calls for the application of diverse methodologies (Norgaard, 1989). Therefore, ecological economists have learnt from the methodological failures of neoclassical economics and now embrace a broader pool of transdisciplinary methods. Norgaard (2007) claims that ecological economists deliberate the strengths and weaknesses of different ways of framing a problem, and by incorporating insights from separate areas can better understand complex problems.

The theoretical section starts with a literature review of the scholarly literature that is relevant to the three main issues ecological economics is concerned with (Figure 3).

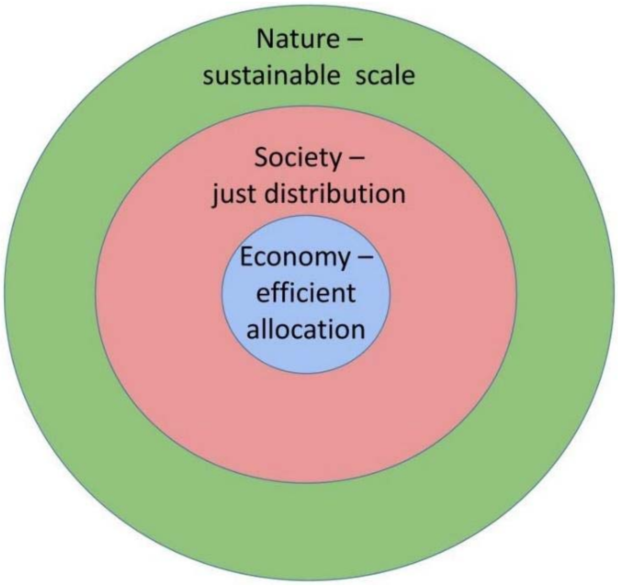

FIGURE 3: THE THREE GOALS OF ECOLOGICAL ECONOMICS AND HOW THEY ARE CONNECTED TO SUSTAINABLE AND FAIR ENERGY USE (AUTHOR'S WORK, BASED ON DALY (1992))

First, I review literature about sustainable energy use as this links to the issue of sustainable scale (i.e. absolute limits on energy use). Second, the literature on energy use and justice is discussed as a particular case of social justice. Finally, I review current policies that aim to promote energy efficiency and examine how they are linked to the issue of efficient allocation as defined by ecological economics (Illustrated in Figure 4).

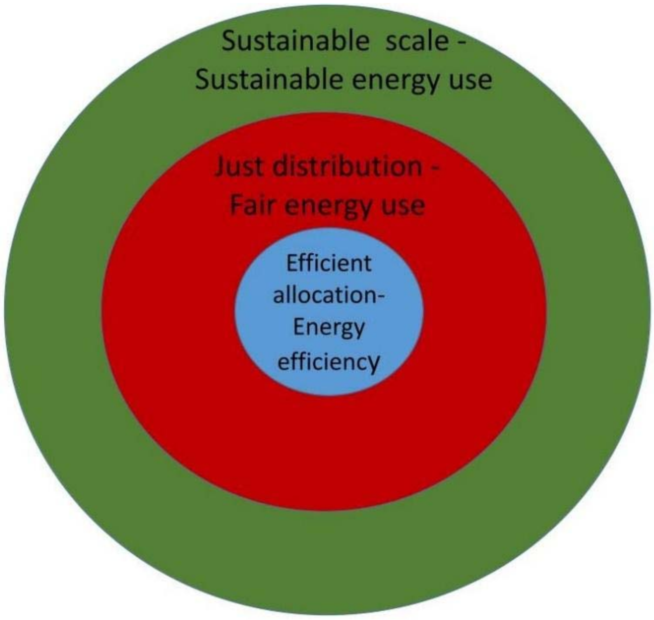

FIGURE 4: THE THREE GOALS OF ECOLOGICAL ECONOMICS AND HOW THEY ARE CONNECTED TO SUSTAINABLE AND FAIR ENERGY USE (AUTHOR'S WORK, BASED ON DALY (1992))

Of the three topics, I put more emphasis on the fair and sustainable energy use chapter (Chapter 2.1.2) to ground my research in the justice concepts that touch upon energy use. All of the literature chapters end with a description of how my theme fills a research gap in the area, or how the latter can contribute to the research field.

2.1.1. Sustainable energy use

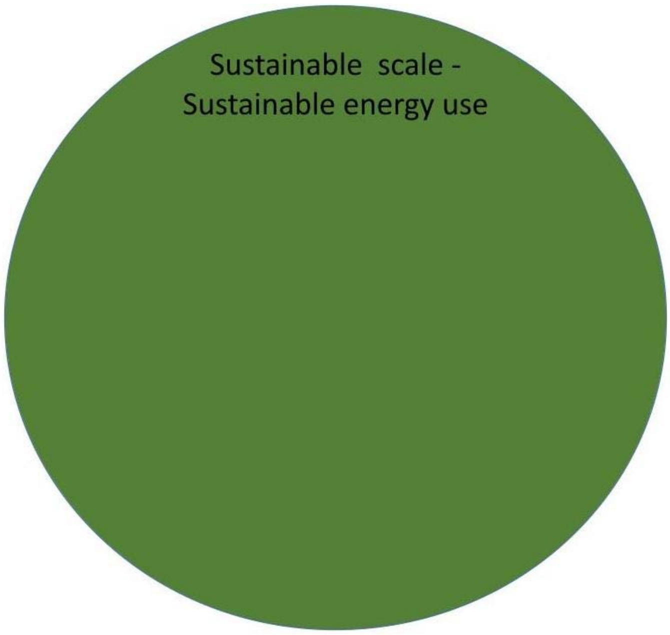

FIGURE 5: SUSTAINABLE SCALE DEFINES THE LIMITS OF ECONOMIC ACTIVITY, INCLUDING ENERGY USE

There are three reasons that underpin the need for an absolute reduction of resource use (Alfredsson et al., 2018) for staying within a sustainable scale (Figure 5). The first reason is that private consumption and the associated production are among the key drivers of greenhouse gas emissions, especially among the industrialized, biggest emitter economies. The second reason is that, due to the investment in sustainable infrastructure that will be necessary (e.g. renewable energy, and energy efficiency) in the coming decades, extensive amounts of energy will be required, largely from fossil sources. This transformation from a fossil-fuel-based to a renewable and efficient infrastructure will use up a significant share of the two-degree carbon budget. The third reason is that improving the standard of living of the world's poor will also consume a major portion of the two-degree carbon budget (Alfredsson et al., 2018).

Even though the intensity of material throughput has decreased, the extraction of resources, including energy resources, has accelerated worldwide, causing environmental and social problems (see more in Chapter 1.1) This phenomenon is so-called relative decoupling, and can be observed in the case of changes in energy efficiency due to the so-called rebound effect (Alcott, 2009; CEEweb for Biodiversity, 2011). The rebound effect refers to behavioural or other systemic responses to the introduction of new technologies that increase the efficiency of resource use. These responses, without limiting resource use in absolute terms, usually offset the beneficial effects of the new technology or other measures taken. More and more scientific evidence underpins the claim that the decoupling of economic growth from environmental pressures is not possible, and the more severe finding is that it will not be possible either in the future. Therefore, increasing efficiency, or the green growth paradigm, without setting limits on energy consumption, will not result in sufficient decoupling in time without reaching the dangerous 1.5°C level of global warming (Parrique et al., 2019; Hickel and Kallis, 2019). There are several reasons why decoupling will not work without limiting resource use, one of which is the shifting of the problem in space or time, as has occurred during the transition of our energy system from fossil-fuel based to renewables (Alfredsson et al., 2018; McGrath, 2019). In the case of biofuels, the burning of Indonesian rainforest to grow palm oil has been happening, and the phenomenon has also just started occurring in the case of the rising emissions of so-called SF6 gas, which is used, inter alia, for insulating switchgears in wind power plants. One kilo of this gas warms up the planet 23,500 times more than one kilo of CO_2 because it cannot be absorbed and stays in the atmosphere for 1,000 years (McGrath, 2019). In this case, in order to satisfy our energy demand from renewables (Alfredsson et al., 2018), we are putting pressure on the environment and other areas in terms of SF6 emissions (McGrath, 2019).

My research does not aim to specify details of the rebound effect deeply; however the following paragraph details the rebound effect of residential energy use. Regarding household energy consumption, direct rebound effects are attributed to the increase in demand for cheaper energy services, while indirect rebound effects are attributed to the increase in demand for other goods and services that also require energy to create. In the UK, the rebound effects in households are typically in the range of 5–15% and arise mainly from indirect effects (Chitnis et al., 2013). In Germany, economically disadvantaged groups are often associated with the largest rebound effects, but they usually have the lowest absolute levels of energy consumption (Galvin, 2015). In line with the above, Chitnis and colleagues (2013) found that rebound effects, in greenhouse gas (GHG) terms, are modest; namely, between 0 and 32% for measures affecting domestic energy use, but larger; namely, between 25 and 65%, for measures affecting vehicle fuel use. Furthermore, measures undertaken by low-income households are associated with the largest rebound effects.

Research has also shown that a fossil-fuel free economy is already profitable (Figueres et al., 2017). A report from 2017 by the International Renewable Energy Agency and the International Energy Agency (IEA and IRENA, 2017) showed that efforts to stop climate change could boost the global economy by $19 trillion. In order to create a fossil-fuel free economy, renewables would need to supply at least 30% of the world's electricity demand, which proportion was 23.7% in 2015 (Figueres et al., 2017). Furthermore, no coal-fired power plants could be approved beyond 2020, and all existing ones should be closed.

To boost the necessary transformative change in the energy system, we need to use science to guide decisions and define targets (Figueres et al. 2017). Policies and actions must be based on robust scientific evidence. Furthermore, all countries need to adopt plans for achieving 100% renewable electricity production, while ensuring that markets should be designed to make this transition. Finally, we need to encourage optimism, since it is crucial that success stories are shared. For instance, demonstrating where countries and businesses have over-fulfilled their targets will motivate others to achieve theirs.

In sum, we can see that limiting fossil energy use is necessary for achieving sustainable energy use. However, in addition to environmental sustainability, social justice considerations need to be taken into account when developing energy-capping schemes. Therefore, I investigate in the next chapter how energy use can be socially just and fair.

2.1.2. Fair energy use at a sustainable scale (fair and sustainable energy use)

In accordance with a sustainable scale, the just distribution of resource use should be ensured in order to enhance the well-being of all members of society (Figure 6).

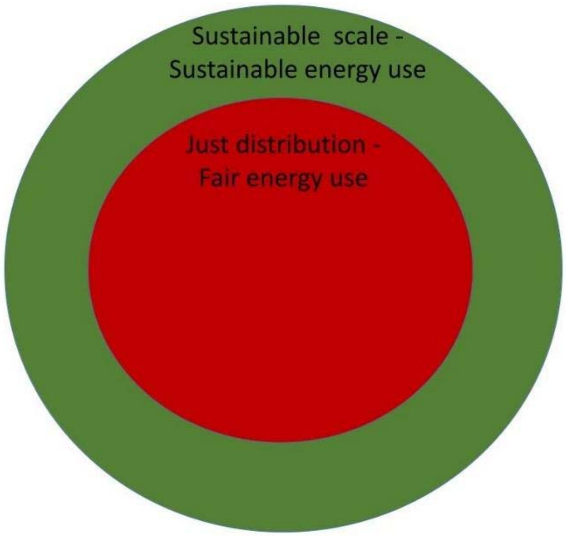

FIGURE 6: MORE JUST DISTRIBUTION OF RESOURCES WOULD ENHANCE SOCIAL WELL-BEING WHILE A SUSTAINABLE SCALE ENSURES THAT ECONOMIC AND SOCIAL ACTIVITIES STAY WITHIN PLANETARY BOUNDARIES (AUTHOR'S CONSTRUCTION)

One can assume that growing resource use implies enhanced well-being for all. Social inequalities, however, are rising both within and between nations, and hunger and malnutrition have not been eliminated globally. The concentration of wealth keeps rising (Piketty, 2017). This social challenge has a detrimental effect on achieving environmental goals. The more unequal the income per-capita, the more difficult it is to make environmental agreements (Teixidó-Figueras and Duro, 2015). Income as well as economic growth leads not only to a larger ecological footprint, but greater ecological footprint inequality between countries. This is due to the imbalance between the competing nature of economic, political, and environmental gals (Heffron et al., 2015). According to Yuval Noah (2018), the richest 1% own half of all the wealth on Earth.

Even more disappointing is the fact that the 100 richest people possess more wealth than the poorest four billion people (Yuval Noah, 2018). The richest 10% emit 50% of all CO_2, while the poorest half of the globe is responsible for emitting only 10% of all man-made CO_2 (Ürge-Vorsatz, 2019). The average North American uses 6,881 kg of oil equivalent per year, while the average Bangladeshi uses only 222 kg (Ürge-Vorsatz, 2019).

Climate change is triggered primarily by fossil energy use (United Nations Environment Programme, 2019; Masson-Delmotte, et al., 2019), which enhances not only environmental, but also social problems, including social inequalities. There are not only inequalities in terms of quantity, but also in terms of quality of the energy sources that are used. Climate change affects the poor and marginalized more (Ürge-Vorsatz, 2019; Lambert, 2014; Vadovics and Živčič, 2019), including those living in degraded and polluted areas (OECD; Islam and Winkel, 2017; UN Human Rights Council, 2019). Moreover, poor people are usually the ones who are forcefully resettled or harmed due to energy infrastructure projects (Heffron et al., 2015) or other facilities, such as factories, mills, and contaminated sites (Lambert, 2014). In developed states, energy consumption is underpinned by electricity and gas, while the three billion people living in energy poverty use wood, charcoal, or animal waste to cook their food and stay warm (Vadovics and Živčič, 2019). Therefore, political decisions should address social justice issues, as proposed by moral and political philosophy.

In this chapter, I detail and group social justice theories linked to sustainable and fair energy use. Among social justice theories, I first touch upon concepts related to environmental or climate justice, and second I detail research connected to the concept of sufficiency. Last but not least I review energy poverty as a form of energy injustice. I end this chapter by narrowing down the concepts to the ones I link my dissertation to most strongly.

2.1.2.1. Environmental justice – climate justice

With regard to environmental and climate justice, scholars (Solomon and Lee, 2000; Lambert 2014; Teixidó-Figueras and Duro, 2015; Haddad and Palmisano, 2001; Clark et al., 2016) call for international climate negotiations, as well as emission cap-and-trade schemes to consider the different backgrounds of participating states. The present unjust climate-change-related institutions, such as the UNFCCC (which less affluent nations have less power to influence) identify inequalities of power and resources, the spread of GHG, an increase in the tragedy of the commons phenomenon, as well as the mismatch between those who are responsible and those who bear the consequences (both in space and time) (Gardiner, 2012; Martins, 2015) as issues Moreover, carbon-intensive economies, political ignorance and consumerism make a just and sustainable transformation even more difficult.

Therefore, during international climate-related negotiations, it is important to differentiate between poor (developing) and rich (developed) countries, social justice, varying social and economic backgrounds, and the diverse opportunities that arise from these factors. The lobbying power of less developed states is much weaker during climate-policy-related negotiations, which is a factor to which attention should also be paid, and addressed (Solomon and Lee, 2000; Lambert, 2014; Teixidó-Figueras and Duro, 2015; Haddad and Palmisano, 2001; Clark et al., 2016). Furthermore, cap-and-trade regimes that contribute to paying for the research of clean energy may establish funds using sources from influential polluters, but this process lets companies pollute and trade without considering where the pollution occurs and how to tackle it (Lambert, 2014).

Poor and marginalized people are affected the most by the harmful consequences of climate change (Ürge-Vorsatz, 2019; Lambert, 2014, Peeters et al., 2015), however climate negotiations and the established cap-and-trade regimes have not attempted to enhance their situation so far (Solomon and Lee, 2000). Under cap-and-trade regimes, for instance, nations can reduce their emissions, but if reduction measures are too expensive, they can buy additional quotas that allow them to emit (Clark et al., 2016). In our world, however, where inequity exists among nations, the choice to trade is not always a free one: developing nations may also be forced to trade. Underdeveloped states are pushed to sell their quotas distributed under a cap-and-trade regime when they strive to satisfy the basic needs of their citizens (e.g. to import drinkable water), rather than investing in long-term sustainable solutions (e.g. establishing water reservoirs). Furthermore, developed states are free to emit if they have the capital to buy additional quotas. Trade should ideally occur when both parties have the same power, and neither party is exposed to using short-term solutions to solve their social problems. I agree with the proposition that Clare as well as Peeters and colleagues (2015) develop; namely, that the emissions of developed nations must be capped, while the emission rights of developing nations must be aligned with the principle of sufficiency, considering the need of future generations.

Poor people living in the present, future generations, and nature are affected by climate and energy-related policies and are more exposed to the impacts of these policies than those who are currently more affluent. Therefore, climate-change-related international negotiations and cap-and-trade regimes (that combine sustainable and efficient energy use) need to consider the second aspect of ecological economics: fair distribution via distributing and trading energy quotas. Furthermore, they need to incorporate not only intergenerational, but also intragenerational equity (Martins, 2015; Berthe and Elie, 2015). Moreover, consideration of distributive justice should be applied in terms of who is now allowed to emit, to what extent, and with what justification. In addition to distributional justice, corrective justice needs to be applied in order to handle historical emissions (Gardiner 2012). At the EU level, the EU ETS, and at the UN level the Paris Agreement will only be effective if they build on the principle of equity; namely, that the diversity of all parties (states) is considered and paid attention to (Carraro, 2018). When equity is incorporated, it can contribute to achieving agreements associated with real enforcement (enhancing efficiency), while efficiency can increase the surplus obtained from cooperation. In states participating in cap-and-trade regimes, emission reduction effort increases with income per-capita. Increasing efficiency can contribute to equalizing/reducing the differences in the cost of making emissions reductions among participating states.

There are plenty of practical suggestions concerning how to achieve justice in climate-related negotiations and implement related cap-and-trade regimes. A C&T law is called for that recognizes the hazards of co-pollutants (Lambert, 2014) as well as the development of zonal permits and trading ratios (Solomon and Lee, 2000). Furthermore, access to pollution data and to pollution hotspots is also called for to stop inter-pollutant trade, since there is a high level of uncertainty involved in measuring inter-pollutants. According to Gardiner (2012), distributive justice needs to be incorporated through balancing between the interests of current and future generations when setting the ceiling for energy use. The most stringent CO_2 restrictions for most developed nations, whose human development is least likely to be impacted, and restrictions on the emissions of underdeveloped countries based on their future human development needs are also called for (Clark et al., 2016). Moreover, research suggests that emission trading should be prohibited between countries with large development disparities. Teixidó-Figueras and Duro (2015) advise that in order to reduce inequality, environmental policies should consider sustainable scale and equity. They also call for the absolute decoupling of resource use from economic growth. Limiting growth and economic redistribution underpinned by decoupling policies is explicitly called for (Teixidó-Figueras and Duro, 2015). In terms of especially energy-use-related policies, York and McGee (2017) suggest that growing renewable sources of electricity supply will be the most effective means of reducing CO_2 emissions in less developed nations, especially those without nuclear power. At the same time, this strategy will be less effective in developed nations, where renewables may be more likely to substitute nuclear power than fossil fuels (York and McGee, 2017). This suggests that renewable energy sources in developing nations may be a particularly important part of mitigating climate change, while trying to reduce overall electricity consumption in more developed nations is needed. Additionally, York's results suggest that decoupling CO_2 emissions from economic growth is not likely to happen if non-fossil energy sources are developed without essential changes in the political-economic structures that influence fossil fuel use.

In relation to environment or climate justice theories, I agree that the emissions of developed nations must be limited, while the emission rights of developing nations must incorporate their current and future needs. Furthermore, environmental- or climate-justice-related theories stress the importance of protecting the interests of the poor and marginalized nations. In line with these theories, I emphasize the need for considering the poor and marginalized people of countries when developing policies that target the harmful effects of climate change. Moreover, while applying distributive justice corrective justice should be incorporated too to tackle the challenge that it is the poor who are more exposed to environmental problems and pollution. Additionally, it is important to define who is allowed to use more than their 'fair share' of energy, to what extent, and with what justification.

2.1.2.2. Sufficiency

Staying below 1.5°C of global warming requires the transformation of energy demand to become more equitable and sustainable. In terms of defining sustainable energy, or from the perspective of ecological economics, sustainable scale, it is necessary to start with the scientific consensus on atmospheric physics, and geo and biochemical flows. Even though the ideas of limits conflict with concepts about economic growth and with classical economic theory, defining 'sustainable energy' is much easier than defining 'sufficient energy'. Defining what a sufficient amount of energy is a complex issue: this is place- and time-sensitive, and also influenced by history, by infrastructure, and by cultural norms. Based on these factors, when defining the distributional aspect of ecological economics, the acknowledgement of the needs and allocation of resources between people is arguably the most difficult challenge (Fawcett and Darby, 2019).

Recognizing this, so-called energy-sufficiency-related literature has emerged since 2016. The first model related to the sufficient concept is the Doughnut model, which aims to define the 'safe' (sustainable scale) and 'just' (sufficient for satisfying basic needs) space for humanity. The model aims to help humanity avoid crossing planetary boundaries and respect the principle of sustainable scale, while revealing the social foundations, including the need for a sufficient amount of energy for satisfying basic needs. Figure 7 shows how social foundations can be integrated into the idea of planetary boundaries, or sustainable ecological scope (Raworth, 2017)

Energy: 13% of the world's population lack access to electricity, 38% to cooking facilities (Raworth, 2017)

Bringing electricity to people who currently lack it could be achieved with a less than one percent increase in global CO2 emissions (Raworth, 2016)

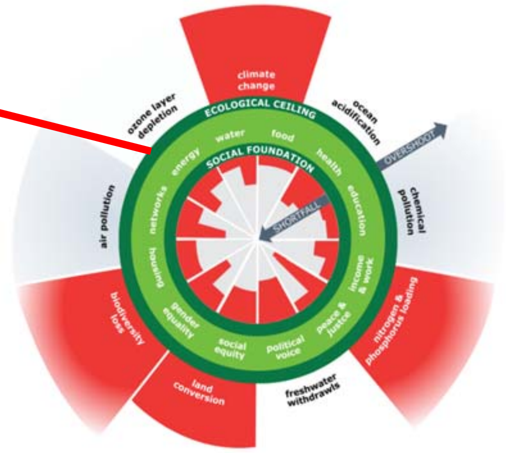

FIGURE 7: DOUGHNUT MODEL (RAWORTH, 2017)

In Figure 7, we can see that *the ecological ceiling consists of nine planetary boundaries (four of them that are marked in red have been already trespassed,* and a minimum of a further two have possibly been passed, but this cannot be quantified), *"as set out by Rockstrom et al. (2009), beyond which lies unacceptable environmental degradation and potential tipping points in Earth systems. The twelve dimensions of the social foundation (none of them reached the adequate level) are derived from internationally agreed minimum social standards, as identified by the world's governments in the Sustainable Development Goals of 2015. Between social and planetary boundaries lies an environmentally safe and socially just space in which humanity can thrive"* (Raworth, 2017, online)

According to a more recent definition, energy sufficiency is a state in which people's basic needs for energy services are met equitably, and ecological limits are respected (Fawcett and Darby, 2019). Based on this, a sufficient amount of energy services needs to be identified to meet basic needs such as shelter, health, work, mobility and communication. If all basic needs for all members of society are met without exceeding the sustainable scale, the remaining amount of energy can be used based on proper discussion (Fawcett and Darby, 2019). According to another definition, energy sufficiency within limits is reached when "*everyone has access to a sufficient amount of energy to satisfy their basic needs in a way that respects the ecological limits of the planet"*. This definition *"does not only focus on the reduction of the carbon footprint, but is more inclusive and holistic in terms of allowing for the satisfaction of the basic needs of those in energy poverty, thus recognising the potential to increase the carbon footprint of some"* (Vadovics and Živčič, 2019, p.159). Therefore, it connects the necessary limitation of global energy consumption with the need to make consumption and distribution more just. Furthermore, it strengthens efficiency perspectives through setting an absolute ceiling on energy use, below which efficiency measures can play a crucial role in order to avoid crossing the defined ceiling. For example, the size of our homes needs to be limited in order to stay within a sustainable scale, but the latter need to be energy efficient in order to create sufficient energy to satisfy our basic needs.

In line with sufficiency considerations, a capability approach is also applied in research (Peeters et al., 2015, Martins, 2015, Holland, 2008) regarding guaranteeing a threshold level of each capability for each person that is required for them to fulfil their basic needs. For this, the provision of affordable sufficient energy needs to be ensured. This approach would allow people to emit and use fossil energy until their capability threshold is reached: "*As long as the lack of affordable sustainable energy makes many or most dependent on fossil fuels, they should be allowed to emit the GHGs necessary to reach the capability threshold level*" (Peeters et al., 2015, p.16). TheEquitable and sustainable distribution of energy resources should on the one hand consider social and material (including environmental) preconditions for ensuring capabilities, while reducing aggregate environmental impacts so that ecosystems can further provide their essential services that underpin human well-being. Equitable distribution needs to include developing and distributing fair developmental entitlements of basic capabilities to all members of society. In order to use capabilities, social conditions must be distributed equally, while material (including environmental) conditions must be distributed sufficiently. Through these kinds of proper redistributive energy policies, it is possible to avoid further environmental harm impacting more severely the poor and future generations (Peeters et al., 2015).

As touched upon in ecological economics as research paradigm chapter (Chapter 1.2), humanity faces the challenge of understanding how to create a high quality of life for over seven billion people without destabilizing critical planetary processes. According to O'Neill and his colleagues (2018), physical needs such as nutrition, sanitation, access to electricity and the elimination of extreme poverty could likely be met for all people without crossing planetary thresholds. O'Neill and his colleagues show that achieving more qualitative goals (for example, a high level of life satisfaction) would require a level of resource use that is two to six times the sustainable level. The authors suggest that strategies for improving physical and social provisioning systems, with a focus on sufficiency and equity, should be better supported. These systems have the potential to move nations towards sustainability, but the challenge remains substantial. Policy instruments for energy-use capping, as detailed below, might have the potential to tackle this significant challenge.

Energy savings made through energy efficiency measures are partly compensated by income growth and the connected rebound effects. Therefore, to be effective, efficiency measures have to be embedded in a concept of sufficiency, which aims to reduce energy consumption in absolute terms as well as puts emphasis on distributional justice (Potocnik et al., 2018) (Lorek and Spangenberg, 2019). Considering that the focus of my PhD is on household energy consumption, I find that sufficiency can also be investigated in the housing sector; namely, in the goal of reducing the overall level of energy consumption in the residential sector.

Another argument (Otto et al., 2014), for achieving sufficient and sustainable energy use is creating ownership among people so that their intrinsic motivation increases to an extent to which they are willing to cut their energy consumption and change their energy-intensive habits even though their level of convenience drops. I would, however, opt for both upstream legislation (proper energy-use policies in line with sustainable and sufficiency requirements), and downstream motivation. These two can go hand in hand in changing energy consumption, especially for those who have the chance to change their lifestyles. This proposal is line with what other scholars (Bertoldi, 2017) argue for: policies need to be formulated in a way that impacts people's energy consumption behaviour, or, alternatively, sufficiency-related energy scenarios should consider lifestyle changes involving less energy consumption (Fischer, 2015; Samadi et al., 2016).

I have already referred at the beginning of this chapter to the complexity of identifying what a sufficient amount of energy is. In order to distribute energy services equitably, distributional justice definitely needs to be discussed within the energy community to help define what is enough and a sufficient amount of energy to satisfy basic needs (Fawcett and Darby, 2019) (Vadovics and Živčič, 2019). In order to identify what the sufficient amount of energy services is, we need to understand more deeply the patterns of household energy consumption, the underlying factors driving these patterns, the variability of these underlying causes, and energy-use patterns between households, their links to income, access to infrastructure, and the relationship between resources and energy services (Fawcett and Darby, 2019). Initiatives aimed at defining the sufficient level of energy can contribute to this debate. One of them is the '2000-Watt Society' campaign, within which participating households are encouraged to reduce their energy consumption to 2000 watts through making lifestyle changes. Another initiative is the 'On débranche' research project that has organized citizen discussions about what it means to live without electricity, and what the minimum amount of energy is that we need. A third initiative exists in a small town in Hungary, Gödöllő. The Gödöllő Climate Club is a small, voluntary grassroots group that is designed to reduce the carbon footprint of its members. The 'sustainable and just' footprint concept is clearly communicated to members as well as with the wider local community, aligned with the energy reduction impacts of the Club's members. Decisions in the Club are made in a participatory way, taking into account everyone's needs and ideas (Vadovics and Živčič, 2019). Despite these initiatives, energy sufficiency is far from being widely applied or implemented in sustainable energy initiatives that focus on households in Europe. This can be attributed to the lack of awareness of the link between staying within ecological limits and satisfying the basic needs of all. In order to put energy sufficiency higher on the political agenda, open discussion and quantitative research are needed about both sufficient and sustainable amounts of energy consumption in households.

2.1.2.3. Energy poverty as energy injustice

Synergies in achieving climate goals and eradicating energy poverty need to be exploited, requiring radical change in climate and energy finances (Ürge-Vorsatz, 2019) (e.g. moving from fossil-fuel-based subsidies to favouring energy savings, energy efficiency and renewables). Therefore, in this chapter I analyse those concepts that touch on energy poverty as energy injustice (which impact the poor), but before the analysis I show how energy poverty is conceptualized. I end this chapter with a solution for how to reduce the energy poverty level of marginalized people.

The definition of energy poverty varies between countries, but may be due to three different phenomena (Neuberger, 2017): 1. low income, 2. low heat efficiency and bad housing conditions, or 3. high household energy costs. In the UK, the energy poor are defined as having below 60% of the median income, and energy expenses of more than 10% of their revenues, while in France the 'energy poor' are those who are unable to pay their utility bills (Sanquist et al., 2012). Brunner et al. (2012) merge these two definitions to show that people living in fuel poverty often modestly try to provision themselves with affordable warmth and illumination, but at the same time often postpone paying their energy bills. According to another definition developed for Hungary, energy poverty is the inability to secure a socially and materially necessary level of domestic energy services (Fülöp and Fellegi, 2011). Since 2011, the so-called elosztoprojekt (elosztoprojekt.hu, 2019a), which ran between 2019 and 2020, developed a definition according to which a household is energy poor if it is unable to pay for a level of energy services necessary to live a decent life. According to another definition, energy poverty can be attributed to those kinds of domestic energy circumstances that do not allow the affected people to participate in the lifestyles, customs, and activities that define the membership of society (Bouzarovski and Petrova, 2015).

As mentioned above, in relation to environmental justice/climate justice, inequalities between nations are emphasized as needing to be tackled. Not only between, but also within nations, socioeconomic inequalities and social justice must be incorporated in terms of energy use (Bartiaux et al., 2016; Bartiaux et al., 2019; Heffron et al., 2015; Chancel, 2014) and the costs and benefits of resource use, including energy consumption, must be distributed just and equally (Heffron et al., 2015). The book *XX. Century, A Theory of Justice*, by John Rawls (Rawls, 1971), an American political philosopher, has greatly contributed to a revival of social justice considerations in science and public policy. According to the Rawlsian conception of justice ("justice as fairness"), a just society is structurally arranged in a way that benefits the least advantageous social groups (where advantage is measured in the space of so-called "primary goods"). Decisions affecting society are just in the case that the benefits arising from the concerned decisions (including investments, or in my case defining the patterns of energy consumption) are proportionally distributed among members of society (Köves, 2019). Proportional distribution means that well-being, as affected by the concerned decision, is enhanced. Namely, the rich cannot get even richer at the price of making the poor even poorer and marginalized. Further, impact assessments of decisions that affect society need to reveal the impacts of the potential implementation of the related decisions, especially on the poor and marginalized.

In order to formulate decisions that affect the poor and marginalized, there is an emerging need in the scholarly community to address energy poverty as energy injustice. For instance, poor people are blocked in terms of not being able to insulate their homes due to lack of capital (Chancel, 2014; Heffron et al., 2015). Therefore, all stakeholders must be involved so that poor people are not harmed (Heffron et al., 2015; Fernández-Baldor et al., 2013). Moreover, Grösche (2010) calls for allocating allowances to the poor to cover their housing and space heating costs, while Brunner et al. (2012) call for a guaranteed minimum power provision based on actual consumption and basic needs.

Besides sufficiency, when distributional justice in terms of income distribution and the diffuse level of housing energy efficiency are tackled, energy poverty as energy injustice requires touching upon the other two aspects of justice. Procedural justice addresses, for instance, access to information, such as information about loans for energy efficiency investments. Recognition justice touches upon the recognition of the poor and marginalized, or, for example, whether it is prestigious to have solar panels or retrofit a house (Bartiaux et al., 2019; Heffron et al., 2015). All three justice concepts (distributional justice, procedural justice, and recognition justice) reinforce each other. Among the studies, in Portugal (Bartiaux et al., 2016), for instance, solar panels have increased inequalities since support for this kind of investment has been underpinned by an increase in taxes, which increases the burden on the poor. Moreover, poor people may not be able to afford such investments as they may lack the ability to put in their own contribution, or even be aware of the opportunity at all.

Considering these facts, energy policies should be formulated in such a way that they incorporate all three justice concepts and therefore reduce inequalities between social groups in terms of accessing sufficient energy. According to Bartiaux et al., (2019), to achieve sustainable and just energy use, a capability approach might be a feasible option. This approach therefore is linked both to energy poverty defined as energy injustice as well as sufficiency-related theories. According to the capability approach, capabilities are reinforcing. For instance, the capability to create social relations and capability to access energy support each other. An individual with a social network can more easily access energy and one with access to energy might more easily be able to create a social network. Therefore, different capabilities based on social justice should be considered when formulating energy policies, since the "….*affordability of energy is crucial to reduc(ing) inequalities related to several capabilities. Therefore, policy instruments that enhance this affordability without increasing energy consumption to limit climate change should be developed*" (Bartiaux et al., 2019, p.238). Progressive tariffs for gas and electricity, the better provision of public transport services, or equipment through which the 'heat or eat' trap can be avoided are among the measures that can potentially help provide affordable energy to all members of society (Bartiaux et al., 2019).

There are, however, plenty of suggestions about how to reduce the level of energy poverty of the poor. Some scholars argue that residential energy inefficiency is the main reason for energy poverty, which cannot be eliminated simply by raising income (Bouzarovski, 2014, Bouzarovski et al., 2016b). This is especially true of post-communist states which have many centrally heated housing panel blocks, and where changing suppliers or fuels is difficult, and few options exist to make individual improvements (Tirado Herrero and Ürge-Vorsatz, 2012). In Hungary poor thermal performance and the dominance of single-family houses play a significant role in maintaining or even enhancing energy poverty. Within the whole EU, however, Herrero (2016) found that energy efficiency schemes financed through public funds very seldom prioritise disadvantaged groups. This shortcoming in policy definition can be seen in the EU's decision-making as well, as there are energy-poverty-relevant measures which enhance rather than reduce energy poverty, inequalities, and vulnerabilities (Herrero and Meneses, 2016; Bouzarovski et al., 2016b; Tirado Herrero and Ürge-Vorsatz, 2012). It is necessary that these phenomena are definitely taken into account when formulating energy policies in order to ensure that marginalized people are not harmed and the real effect of energy efficiency policies can be felt after policy implementation (Herrero and Meneses, 2016; Bouzarovski et al., 2016; Tirado Herrero and Ürge-Vorsatz, 2012; Sanquist et. al, 2012; Brunner et al., 2012).

In post-communist countries, another cause of energy poverty is the increase in fuel prices after communism. In these states, those most affected by energy poverty are older people, families with children, and households where there are individuals with disabilities or long-term illness (Bouzarovski, 2014). Therefore, there have been suggestions (Sanquist et. al, 2012) and also governmental steps in Hungary to reduce energy bills (Bouzarovski et al., 2016a), but in the chapter of this thesis about Hungarian household energy consumption (Chapter 2.2.2) I show that governmental efforts to reduce energy bills have not benefited the poor and marginalized. Beside these factors, in Hungary the inability to switch fuel providers and the high level of energy dependence also prevents a drop in energy consumption. This often results in arrears in utility bills, as well as in substituting more modern energy carriers – mostly natural gas – with traditional or solid fuels for domestic energy heating. For this reason, illegal firewood collection has been on the rise in Hungary (Bouzarovski et al., 2016a).

The capability approach to energy-based projects has been also examined (Gonzalez, 2008; Fernández-Baldor et al., 2013). This approach permits a deeper understanding of the processes within such projects and of how these processes lead to certain effects. Furthermore, it allows people to assess the development process they are impacted by. Results show that renewable-energy-based electrification projects in Latin-America can improve people's education level (electricity can promote studying at night at home or at school), health status (reduction in the use of candles and kerosene), and comfort level, as well as enhance a feeling of belonging to the community (connecting people during the night time, organizing get-togethers, the lighting of streets enables women to get home safely after get-togethers, etc.). It can also improve communication through increasing access to television and radio, listening to music and individual self-confidence if the proper stakeholder involvement that incorporates a social justice and capability approach is applied (Gonzalez, 2008; Fernández-Baldor et al., 2013). Improvements that arise through energy projects are not equally distributed, however; they depend on power relationships, customs and values, access to information and one's social context in the community (Gonzalez, 2008; Fernández-Baldor et al., 2013). This needs to be considered when designing projects with a view to correcting pre-existing inequalities.

2.1.2.4. Concluding remarks from social justice theories linked to energy use

I end this chapter by summarizing what I find to be useful from the detailed justice theories in terms of sustainable and fair energy use in relation to investigating the impact of energy-capping schemes on households. In my dissertation, I aim to reveal how an equal per-capita energy entitlement distribution impacts households with different socioeconomic backgrounds. Therefore, I investigate to what extent energy-capping schemes deliver benefits for marginalized groups in society so that their well-being is enhanced. I consider that environmental or climate justice touches upon distributive justice and corrective justice (i.e. on who can use more than their fair share and to what extent) that are associated with it in order to tackle unequal intra- and intergenerational opportunities, not only between but also within nations. Furthermore, I also consider that sustainable and sufficient energy use, according to sufficiency scholars, needs to take into account distributional justice in order to ensure that every member of society can afford sufficient amounts and quality of energy. Moreover, with regard to energy poverty as energy injustice I consider that, besides distributional justice, procedural and recognitional justice need to be considered when attempting to reduce the energy poverty level, especially of the poor and marginalized.

2.1.3. Policies still target energy efficiency

Policies that are designed to influence energy use still mainly target energy efficiency, which is originally meant to be a means of adhering to the first two principles of ecological economics (sustainable scale and just distribution).

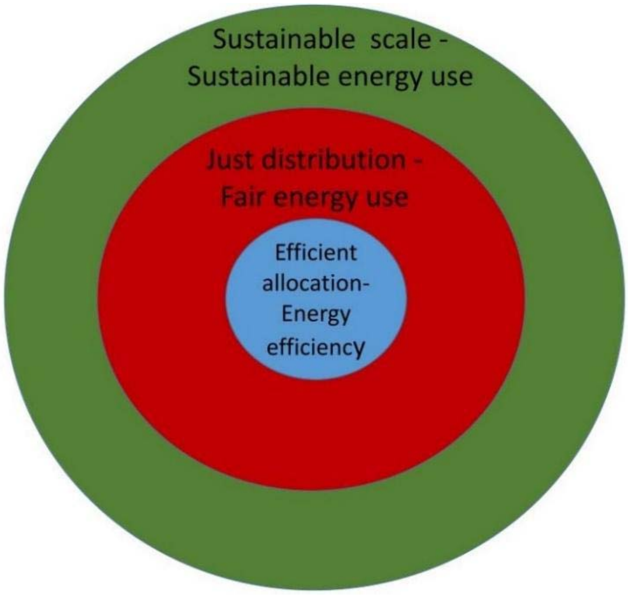

FIGURE 8: EFFICIENT ALLOCATION WAS SUPPOSED TO BE A MEANS OF IMPLEMENTING THE FIRST TWO PRINCIPLES OF ECOLOGICAL ECONOMICS (SUSTAINABLE SCALE AND JUST DISTRIBUTION)

In 1987, the World Commission for Environment and Development (Brundtland

Commission) defined sustainable development as: "…*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". The definition contained two key concepts:

"1. The concept of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given, and,

2. The idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs" (World Commission on Environment and Development, 1987, p.43).

Usually, the first part (1) of the definition is quoted, lacking mention of the need for limitations. This can be attributed to the fact that definitions of sustainable development are thought to need to be in harmony with the ideas of neoclassical economics and neoliberal politics. There are several interpretations of the definition that do not contradict such ideas. These include, for instance, the call for (more) green growth, and for more market regulations, which ideas clearly contradict the second part of the definition (2) (Spangenberg, 2011).

Limits (1) can include those on social development (including redistribution mechanisms, as referred to in the Doughnut Model, Raworth, 2017) and technological development. International policy documents, such as the OECD's Green Growth (OECD, 2019) and UNEP's Green Economy (UNEP, 2020), however, call for unlimited growth, and limits to growth – in other words, resource capping is not a part of these policy concepts. So these policies are calling for the further commodification of nature. The former documents consider that regulating green growth using market instruments is the most promising way forward. This approach, however, makes nature an exchangeable good, while ignoring local human needs and local natural carrying capacity, not to mention the dignity of nature itself.

The international climate negotiations instrument (UN Framework Convention on Climate Change - UNFCC), which very much influences the fossil energy use patterns of nations worldwide, is very sluggish due to the extremely different interests of developed and developing countries (see more under Chapter 2.1.2) (Faragó, 2017). Therefore, national commitments need to be strengthened in 2020 (United Nations Environment Programme, 2019). In order to achieve net zero anthropogenic CO2 by 2040, which is necessary to limit global warming to 1.5°, annual reductions of at least 5% of current emissions are required (IPCC, 2018). In 2019, the UNFCC COP in Madrid, however, did not deliver any concrete joint action to stop global warming, thus the next COP, the COP26 in the UK, has the urgent task of delivering results: pushing countries to act. Although the number of countries that are announcing net-zero GHG emission targets for 2050 is increasing, only a few countries have so far formally submitted long-term strategies to the UNFCCC (United Nations Environment Programme, 2019). Increasing the number of countries with zero GHG emission targets is especially urgent since the current Nationally Determined Contributions (NDCs) are collectively inconsistent with the Paris Agreement. The global 2030 emissions associated with the presently adopted NDCs might lead to warming of 2.3 °C. Therefore, country efforts should be further enhanced to meet the 1.5 °C and well-below 2 °C thresholds (Robiou du Pont and Meinshausen, 2018; United Nations Environment Programme, 2019).

At the EU level, as early as in 2009 the EU defined its 20-20-20 climate and energy targets for 2020. These targets were:

1. A 20% cut in greenhouse gas emissions (from 1990 levels) – the EU is on the way to meeting this target
2. 20% of EU energy from renewables
3. A 20% improvement in energy efficiency (European Commission, 2009)

There is research, however, that reveals, for instance, that the 20% target related to the share of renewable energy in the energy mix by 2020 is too low, since renewables have the potential to contribute much more to the energy mix. These unambitious targets are preventing the energy transition towards a decarbonized economy (Bertram and Primova, 2018).

Almost one decade later, during the winter of 2018/2019, the EU was in the process of updating its energy policy framework in a way that will facilitate the clean energy transition and make it fit for the twenty-first century. The so-called Clean Energy for All Europeans package aims to empower European consumers to become fully active players in the energy transition. This package also aims to set two new targets for the EU by 2030. One of these two targets is a binding renewable energy target of at least 32%. The other one of these two targets is an energy efficiency target of at least 32.5%. If these policies are implemented properly, they will lead higher rates of emission reductions for the whole EU than had been anticipated; namely, approximately 45% by 2030 relative to 1990 (European Commission, 2018a; Cetkovic and Buzogány, 2019; Bertram, 2018). This package underlies the Commission's vision for a climate-neutral future and covers nearly all EU policies. The Clean Energy for All Europeans package is in line with the Paris Agreement objective; namely, to keep the global temperature increase below 2°C and enhance efforts to keep it below 1.5°C (European Commission, 2018b). Underpinning efforts to the achieve the defined targets, energy performance certificates (EPC) were introduced in the European Union to support meeting energy efficiency targets by informing actors in the building sector about energy efficiency in buildings (Pasichnyi et al., 2019).

The European Green Deal, adopted in December 2019, sets more ambitious targets than the Clean Energy for All Europeans package; namely, concerning how to make Europe the first climate-neutral continent by 2050 (European Commission, 2019). It has even increased the emissions reductions target to 50-55% by 2030 relative to 1990. The European Green Deal aims for "*transforming 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. It also aims to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts*" (European Commission, 2019, p.1). To achieve these aims, in 2020 the Commission has produced:

- guidance to assist Member States in addressing the issue of energy poverty
- proposal on a European 'Climate Law' for enshrining the 2050 climate neutrality objective
- a comprehensive plan to increase the EU 2030 climate target to at least 50% and towards 55% in a responsible way
- a 'renovation wave' initiative for the building sector because buildings account for 40% of all energy consumed (Cao et al., 2016), and today's annual renovation rate of the building stock is very low, varying from 0.4 to 1.2% in the Member States (Esser et al., 2019).

Even though six CEE countries vote more frequently against the adoption of climate-related energy legislation at EU level, they do not represent a regional coherent opinion, thus the 2030 goals may still be met (Cetkovic and Buzogány, 2019). The European Green Deal might contribute to the urgent need to find and utilize synergies in achieving climate goals, while the possibility of eradicating energy poverty should be exploited, which would need radical changes in climate and energy finances (Ürge-Vorsatz, 2019) (e.g. moving from fossil-fuel-based subsidies to favouring energy savings, energy efficiency and renewables).

The EU Emission Trading System is the implementation arm of EU emission reductions policies, and is the biggest cap-and-trade regime in the world, entering into its next phase in 2021 (Climate Policy Info Hub, 2019). The impact of the EU ETS in terms of stimulating low-carbon investment has proven to be quite limited (FSR Climate 2019, 2019) due to the surplus of allowances and their impact on prices of the latter as well as freely allocated allowances based on historic emissions (grandfathering) (Borghesi, 2018). The current and next phases of the EU ETS should tackle these challenges. The third phase, which runs between 2013 and 2020, covers 45% of EU CO_2 emissions. It applied an annually decreasing cap on emitted allowances with a linear reduction factor of 1.74% of the average total quantity of allowances issued annually in 2008-2012 (designed to be in line with the EU 2020 climate and energy targets). In the next phase, from 2021, the annually decreased cap will be put in place with a linear reduction factor of 2.2% in line with the 2030 targets. During these two phases, auctioning is the default method for allocating allowances instead of the previously freely allocated quota (European Commission, 2018a; Borghesi, 2018). Such policy, however, will be successful and effective inasmuch as it considers equity issues, since when agreement is reached considering equity, enforcement is more likely (Carraro, 2018). Effectiveness can be further enhanced when cooperation is increased among participating entities, which might be more likely when equity issues are considered. Additionally, efficiency can equalize or at least mitigate differences in the cost of emission reduction Therefore, the distributional effect of the allocation mechanism of the EU ETS (equity issues) should be considered too, thus the revision of the EU ETS (the fourth phase) will consider equity issues through establishing a Modernization fund and free allowance allocation (10%) for less developed Member States to support modernizing their energy systems (Life Side project, 2018). The EU also emphasizes the need for cooperation that enhances the efficiency of achieving the emission reduction targets (Borghesi, 2018).

Outside the EU, in the US some progress has been made even though at the national level the country has not taken significant steps towards sustainable energy use. California aims to reduce emissions of greenhouse gases. It has established and enforced the California Greenhouse Gas Cap-and-Trade Program by applying an aggregate greenhouse gas allowance budget on the covered entities and creating a trading mechanism. This program helps put California on the path to meeting its goal-reduction aims from 1990 levels by 2050. Under cap-and-trade, an overall limit on GHG emissions from capped sectors is established by the cap-and-trade program and facilities subject to the cap are able to trade permits (allowances) to emit greenhouse gases (Office of Administrative Law, 2018). Besides California, as early as in 2017 the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) announced regulation 310 CMR 7.74, which establishes a new cap-and-trade system in the state (mass.gov, 2017). The system is limited to the electricity sector, covering 21 fossil-based power plants. The system started in 2018 with the free allocation of allowances to utilities. From 2019, however, utilities have been required to purchase all their allowances through auction. The cap-and-trade program aims to achieve an 80% reduction in emissions from the participating facilities by 2050 compared to the level of 2018. The regulation was accompanied by a Clean Energy Standard requiring an increasing share of electricity from clean energy generation (fossil fuels with carbon capture, nuclear, and renewables), that reaches 80% by 2050 (mass.gov, 2017).

In Hungary, however, significant improvements have not occurred either in energy efficiency or in reducing carbon intensity of primary energy production (Szajkó et al., 2019) that could pave the way to decoupling economic development from GHG emissions (Szajkó et al., 2019). The re-structuring of the economy after the regime change in 1989 is the only driver of reductions in GHG emissions. Its impact, however, could not be felt in recent years, resulting in the fact that Hungary has recently increased its emissions both in the ETS as well as non-ETS sectors. The regulation of the support and use of renewable energy resources blocks the proper development of this sector both from environmental and economic points of view (Bartek-Lesi et al., 2019). The proportion of renewables in the energy mix is very low in Hungary. At EU level, the share of energy from renewable energy resources is 17.7%, while in Hungary it is 11-13.3% (Eurostat, 2018b; Sáfián, 2019). According to 2018 data the proportion of burnable renewable energy resources in Hungary, such as biomass is 10%, while that of non-burnable renewable energy resources such as solar or wind is only 1% (Sáfián, 2019). This low proportion of renewables is due to favouring old technologies over the more economic renewable ones, and not taking ambitious steps towards reducing energy use (Barotányi, 2019). In Hungary, for instance, establishing a wind power plant within 12.5 km of any settlement is banned, meaning no wind power plants will be built in the country while this legislation is in place (Ámon, 2019). This is even though it has been proved that investing in renewables is cost efficient due to enhanced technological development as well as the contribution to improving human health (Major, 2019); namely, that the health-related benefits of the energy transition from fossil-fuel-based energy to renewables proves to be greater than transition-related costs.

In 2017, in Hungary, 81% of renewable energy resources were derived from biomass (mekh.hu, 2019; Sáfián, 2019). This proportion is even higher than the European average (64%) (IEA, 2018) (see also Chapter 2.1 on trends in fossil energy use). Due to the inclusion of all kinds of biomass in the proportion of renewable energy consumption, renewable targets were achieved until 2020 notwithstanding the weak national support for the dissemination of renewable energy resources (Bartek-Lesi et al., 2019). It is also questionable how heating with illegal waste was deducted from the tally for solid fuel use, including firewood usage (Levegő Munkacsoport, 2017). (According to a survey carried out in Hungary, 9% of respondents reported to trying to decrease their heating bills by heating with garbage; this more often happens in detached and semi-detached single family houses (Csutora et al., 2017). Based on this claim, heating using waste is not negligible in Hungary.) According to the regulations of the European Commission (European Commission, 2014), statistics related to biomass usage, should be compiled in a way that only biomass from sustainable resources (e.g. from officially sold firewood from sustainably managed forestry) can be included in the renewable proportion. This regulation would significantly impact the renewable energy proportion in the Hungarian energy mix.

In early 2020, Hungary issued its National Energy and Climate Plan, which contains the country's national climate-related energy targets for the period until 2030. It sets a 40% emission reduction target (compared to 1990 as baseline year) by 2030, which is questionable regarding the ability to reach a state of carbon neutrality by 2050. Emission reductions in 2020 had already reached 32% compared to the 1990 level. The planned shutdown of the lignite block in the Mátra power plant in 2030 would by itself result in an 8% emission reduction, in line with which the 40% would be easily achievable. Furthermore, the Plan lacks suggestions about how to mitigate energy consumption and utilize energy-saving potential in the residential sector (Előd, 2020, Szentannai, 2019, Portfolio, 2020). About 35-40% of the primary energy consumption of the country goes on residential heating, hot water production and electricity usage, 40% of which could be saved if residential energy-saving potential were utilized (Bertram and Primova, 2018). With regard to reaching the defined 21% renewable target in final energy consumption by 2030 (Előd, 2020, Szentannai, 2019, Portfolio, 2020), the Plan aims to enhance the proportion of biomass in renewable energy production. The proportion of renewables in the energy mix, however, is very low in Hungary and even lower if we check the proportion of RES in the electricity provision (for this, Hungary is second to last of the EU states). This is due to still favouring old technologies over the most economical renewable ones, and not taking ambitious steps to reducing energy use (Barotányi, 2019). With regard to energy efficiency, the Hungarian Climate and Energy Plan sets the goal of achieving an 8-10% increase in energy efficiency by 2030 (Előd, 2020, Szentannai, 2019, Portfolio, 2020). Furthermore, while the European Green Deal aims to address energy poverty, instead of the Hungarian Climate and Energy Plan, the so-called eloszto-project (eloszto.hu, 2019) aims to address this issue in Hungary. By 2020 they had come up with the following definition: "*A household is energy poor in the case that its members are unable to pay [for] the level of heating or any other energy costs that would be necessary for [achieving] sufficient living standards*" (eloszto.hu, 2019).

Table 1 summarizes emission reduction, renewable, and energy-efficiency targets at the EU level (by 2020 and 2030) and in Hungary (by 2030).

	EU 2020 Target	EU2030 Target	Hungary for 2030
CO_2 reduction	20%	50-55%	40% (baseline 1990)
Energy efficiency	20%	32.5%	8-10%
Renewables	20%	32%	21%

Table 1: Emission reduction, renewables, and energy-efficiency targets

As the previous pages showed, we can see that current policies are still focusing on increasing energy efficiency and enhancing renewable energy in the energy mix. International intergovernmental platforms see energy efficiency improvements and the spread of renewable energy as the solutions for achieving sustainable energy use (United Nations Environment Programme, 2019; Sebestyén Szép and Nagy, 2017; Banja et al., 2017). Despite all the recent achievements in eco-efficiency, the currently dominant market economic structure is still responsible for driving these trends of unsustainable resource use patterns and the unfair share of benefits arising from resource use. Therefore, the need to re-adjust our economic model to our environmental space while taking into account social justice is desirable and, eventually, unavoidable. We can see that production is generally more energy- and emission-efficient but this is attributed partly to structural changes in the global economy. These changes include the fact that carbon-intensive production is outsourced to developed countries where labour is cheaper (Alfredsson et al., 2018).

Only after setting absolute ceilings on energy consumption should efficiency comes into the picture in order to serve the goal of absolute energy consumption reduction (Shove, 2017). Energy efficiency policies and related policy instruments should only be tools for achieving the necessary level of energy consumption reduction. Policies, however, still do not touch upon the need for absolute energy use reduction even though absolute decoupling proves to be unsuccessful without setting absolute limits on energy consumption (Parrique et al., 2019; Hickel and Kallis, 2019; Bertoldi, 2017; Future Earth Knowledge Action Network, 2018a). Therefore, none of these policies (OECD Green Growth, UNEP Green Economy, UNFCC, EU climate and energy policies, or even the European Green Deal, which focuses on growth) is sustainable. Technological efficiency solutions that target the complex challenge of climate change are urgent and necessary but in order to achieve sustainable scale, they need to be accompanied by absolute reductions in the consumption and production of goods and services (Alfredsson et al., 2018). On the other hand, there are claims that long-term support for energy efficiency and saving investment, including renovation, will bring benefits (ENABLE, 2019b; Csutora et al., 2017; Charlier et al., 2018). Additionally, the comfort in-door temperature should be changed, and practical advice on easy-to-use techniques, and proper but not overly detailed information and concrete examples from households with similar problems should be disseminated (Csutora et al., 2017).

Going back to the research paradigm underlying this dissertation, ecological economics, calls efficient allocation (as a set of instruments that includes efficiency measures and cap-and-trade regimes) market instruments for achieving just and sustainable energy use. Incorporating this into energy policies is especially important, as energy efficiency policies have not resulted in a decline in absolute energy use (Fischer, 2015; Charlier et al., 2018; Alfredsson et al., 2018), thus much more radical steps are needed (Fawcett and Darby, 2019; Bajmócy and Málovics, 2020). Due to the rebound effect, for instance, the increase in the efficiency of the fuel consumption of cars has resulted in more cars and kilometres travelled by those cars, or due to while efficiency improvements at home have resulted in bigger dwellings in which the temperature is kept at a higher level, and more appliances are used (Bajmócy and Málovics, 2020). The direct and indirect rebound effect of energy efficiency in households has been estimated for the EU-27 countries (the first twenty-seven Member States of the European Union). The estimation shows that energy policy at the European level needs to be rethought if efficiency measures seek to reduce energy consumption and tackle climate change (Freire-González, 2017; Charlier et al., 2018).

Moreover, in the case that energy efficiency measures are introduced, they might handle significant social disparities across households. Therefore, the government should consider equity issues in energy policies, put more emphasis on addressing monetary poverty in relation to inadequate dwelling conditions (Charlier et al., 2018), and subsidize renovation costs (ENABLE, 2019b; Csutora et al., 2017; Charlier et al., 2018). Going deeper in terms of equity issues related to energy consumption, a distributional mechanism as well as (García-Álvarez and Soares, 2018) the concept of sufficiency needs to be an integrated as part of energy policies that contain targets on absolute energy consumptions limits (kWh/person/year) rather than efficiency requirements (kWh/m2 /year). A pilot study for Germany (Förster et al., 2019) that involved integrating sufficiency concerns into modelling for stringent climate protection was found to be feasible, providing a helping hand to integrate sufficiency into energy policies. Germany is a good country to investigate in terms of sufficiency, since absolute energy-saving targets are already in place and absolute energy savings for the household sector and capping electricity sales have also been discussed (Fischer, 2015). (see more suggestions in the fair and sustainable energy use chapter under Sufficiency (Chapter 3.2.2) and Chapter 3.2.3 on energy poverty).

Without setting absolute limits on energy use, decarbonizing our economy based totally on renewable energy sources will also be challenging in energy terms. Even with continuous increases in Energy Return on Energy Invested (EROI) for renewable sources, the time horizon for meeting projected energy demand with renewables is long

(Alfredsson et al., 2018). Furthermore, without limiting energy consumption in absolute terms, shifting environmental pressures in space and time can easily occur when transitioning our energy system from fossil-fuel based to renewables (Alfredsson et al., 2018) – as has happened in the case of biofuels or use of the extremely strong greenhouse gas SF6 gas for insulating wind power plants (McGrath, 2019).

Without properly regulated policies, nice and seemingly ambitious energy policy targets are easily overwritten if the market, profit seeking, and competition require it (Torontáli, 2017). This phenomenon can be seen in the fact that EU corporate policies go against the interest of meeting energy policy targets. While the energy intensive industry sectors in the EU are not willing to reduce their greenhouse gas emissions, nor open to investing in solutions for decarbonisation, energy targets are unlikely to be met (CAN Europe, 2018a). Due to the fact that an energy intensive industry is still benefiting from watered down regulation, soft tax deals and the current pricing/subsidy mechanisms, these sectors prevent the development of ambitious climate-related energy policy development. Therefore, the rest of society bears the cost of tackling climate change. Through the EU's Emission Trading System (ETS), EU governments lost more than €143 billion due to their giving out pollution permits for free between 2008 and 2015 (CAN Europe, 2018b). Between 2014 and 2016, European governments provided a yearly nearly €15 billion of financial support that encourages the ongoing use of fossil fuels in industry and business. This might change, as the current third phase and the forthcoming fourth phase of the ETS do not involve free allocation. Moreover, the European Investment Bank plans to stop funding oil, gas, and coal projects at the end of 2021 (Unwin, 2019). Proper reform of subsidies for fossil fuels might bring their consumption down, (Burke and Yang, 2016), but in the next chapter I show several arguments that subsidy reform, while necessary for stopping funding fossil fuels, could be accompanied by other mechanisms to bring energy saving results.

Even though some of the Members of European Parliament (MEPs) see energy-use capping as a solution for tackling complex interrelated environmental and social issues, they think advocating for it and starting a whole campaign around it would be political suicide (Derruine et al., 2017). These MEPs are struggling hard even to keep environmental issues on the political agenda as they are. Therefore, these MEPs have defined their priority as ing inequality, instead of advocating for absolute energy use limitation; even these two issues together would contribute to achieving fair and sustainable energy use. These MEPs use the argument for fighting inequality that the rich who emit the most, should lead by example, because if people feel that fairness is being considered, introducing caps will be a viable political project. A post-growth conference was organized in 2018 in Brussels. The aim of this event, organised by MEPs from five different political groups, alongside trade unions and NGOs, was to explore the possibilities for a "post-growth economy" in Europe. On the occasion of the conference, 238 academics called on the European Union and its member states to plan for a post-growth future in which human and ecological well-being is prioritised over GDP (The Guardian, 2018). Even though MEPs themselves do not advocate for energy use caps, during the event energy use caps were also debated (Alcott et al., 2018).

One small-scale solution is the spreading initiative of Community Energy, whereby communities or municipalities that own and operate renewable-energy-generating equipment serve their members with energy (power). At the EU level there are also steps to encourage local communities to develop community owned and used renewable energy facilities (Botár, 2018). The core of the idea of community energy is that choices related to energy supply and energy systems are in the hands of people. The latter has the potential to change the current energy system tom make it more energy independent and energy secure. The EU Renewable Energy Directive and Energy Efficiency Directive accepts these communities (individuals, families, local authorities, SMEs) as players in the energy system and calls them electricity prosumers (European Parliament, Think Tank, 2016). In Germany, 50% of the capacities of renewable energy are under prosumer ownership. In the UK, through the Brixton Solar programme, there is free electricity for energy-poor residents which is created by either local authority or cooperatives renting their roofs for solar power plants. Twenty percent of their revenues go into the energy efficiency fund, from which residents can insulate their dwellings (Botár, 2018). The National Energy and Climate Plan of Hungary, publicized in early 2020, however, provides a weaker definition of prosumers, thus supports fewer community initiated renewable projects. At the same time, within the EU the number of prosumers is growing (e.g. CO-POWER, 2020; REScoop.eu, 2020; Tarhan, 2020; PROSEU, 2021).

Even with the high number of policies, fossil energy resource use is on the rise and inequality in terms of accessible energy is significant, as I showed in the previous chapters. In order to avoid shifting environmental problems in space and time (as it is detailed regarding SF6 gas or biofuels, above), it is not the output of economic activities such as greenhouse gas emissions but those of the inputs of economic activities such as energy consumption that should be addressed (Bertoldi, 2017). Politicians should call for limits on resources, including energy use and land use (as inputs to the economy), and fully support the just distribution of the benefits arising from energy use and thus contribute to wellbeing of all members of society. As ecological economics shows, these two things are not contradictory at all (it is a question whether these two can be combined with GDP growth, but it does not matter). The first (energy-use capping) is an undeniable scientifically proven necessity (like addressing climate change), and the second (the just distribution of benefits arising from energy use, contributing to the enhancement of well-being) is what people want in reality (Derruine et al., 2017). High level events that address these problems and issues (such as the one in 2018 September in the European Parliament on Post-growth) could elevate these issues on the political agenda. It is necessary to continue investing in regulatory measures that allow the production, distribution, and use of energy in a more sustainable and fair way (García-Álvarez and Soares, 2018). These should be applied at all levels of society (consumers, producers, local governments) in order to enable living within ecological limits and social justice.

My dissertation is linked to this chapter by highlighting the importance of ambitious energy policies, such as the proper formulation and enforcement of energy-capping instruments. Furthermore, my research also contributes to the more ambitious environmental policy development that is required through analysing a regulatory measure; namely, how equal per-capita energy entitlements of energy-capping schemes would result not only in sustainable but also in just energy use in the residential sector. The output of my research is its identification of those vulnerable households which would not benefit from equal per-capita energy entitlements and how these groups of households could be addressed in order to ensure they benefit from the system. This outcome would also serve valuable input into the emerging debate not only about proper energy policies but also energy poverty.

2.1.4. Policy tools for achieving just and sustainable resource use

In this chapter, I first aim to compare carbon taxes with cap-and-trade schemes to ascertain how effective these mechanisms are in terms of contributing to the three goals of ecological economics (Figure 9): 1. sustainable scale (in the case of this dissertation, sustainable energy use), 2. fair distribution (in the case of this dissertation, fair energy use), and, 3. efficient allocation (in the case of this dissertation energy, efficiency and the enhanced use of renewable energy resources).

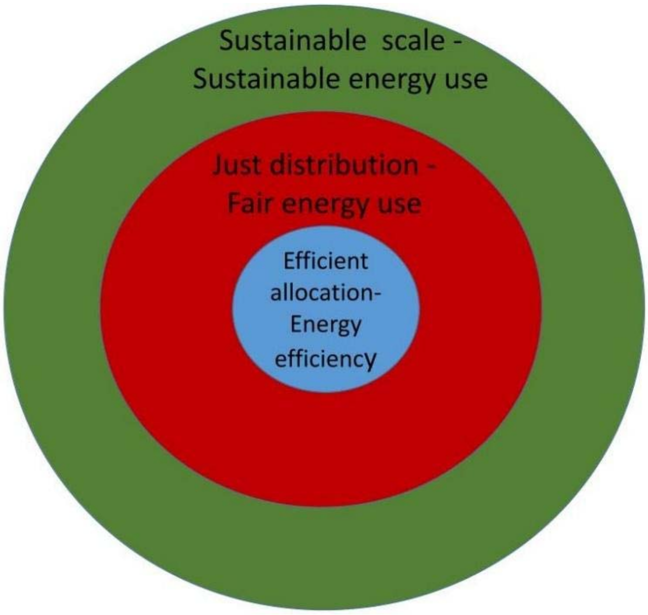

FIGURE 9: THE THREE GOALS OF ECOLOGICAL ECONOMICS IN LIGHT OF FAIR AND SUSTAINABLE ENERGY USE (AUTHOR'S GRAPH BASED ON DALY (1992))

In the second part of this chapter I aim to compare different personal carbon and energy trading schemes to identify their use as effective market mechanisms in terms of contributing to fair and sustainable energy use.

2.1.4.1. Carbon tax versus cap-and-trade regimes

In this chapter, I compare carbon taxes with cap-and-trade systems in terms of how effectively they contribute to accomplishing the first two goals of ecological economics: 1. sustainable energy use, and 2. fair energy use. I structure this chapter in the following way: first, I analyse similarities between the two policy options (cap-and trade (C&T) and carbon taxes), then I touch upon arguments for and against implementing C&T regimes.

A rational consumer always chooses consumption bundles that are within their budget in order to maximize utility. In line with this claim, Li and his colleagues assume that all participants of both C&T as well as tax schemes are price takers and behave competitively (Clarke-Sather et al., 2011). Both carbon tax and C&T systems are market-based instruments that contain price signals for internalizing environmental damage. Both schemes are said to be flexible and cost effective (Archer, 2015).

There is, however, significant academic debate about whether to favour C&T over carbon taxes. Agreements favouring C&T include the fact that the carbon tax burden on bills often disproportionately affects poor households (Bouzarovski and Petrova, 2015; ENABLE, 2019b; Blonz et al., 2010), and that producers pass the cost onto their customers, further enhancing the burden (Li et al., 2015). While C&T also targets the residential sector (such as Personal Trading Schemes – PCTs; see in detail in the next chapter), welfare change happens due to its progressivity (Li et al., 2015). Namely, poorer consumers, whose emissions are generally lower, are mainly the 'winners' due to the allowance that flows from 'under-emitters' to over-emitters, thus money flows from the wealthy to the less wealthy. Furthermore, in the case of taxation, producers pass the cost onto their customers, further enhancing the burden. The carbon tax burden includes, inter alia, the fact that reducing payroll or income taxes in combination with a carbon price is likely to be regressive, benefiting high-income households more than low-income households (Blonz et al., 2010). Therefore, carbon taxes and carbon pricing alone tend to create diffuse benefits and concentrated costs (Levin et al., 2012) if there are no sufficient mechanisms to compensate for the unintended distributional cross-sector, cross-nation effects (Masson-Delmotte, et al., 2019). Therefore, a carbon tax alone cannot be the incentive needed to promote a sustainable or fair energy transition. The diffuse benefits of a carbon tax can produce stronger oppositional coalitions than supportive ones (Levin et al., 2012). Whether C&T schemes are publicly more acceptable, however, is not so clear (Gevrek and Uyduranoglu, 2015). Due to the diffuse social benefits of a carbon tax, the proposal for a carbon dividend has been promoted, through which revenue from the carbon tax would be redistributed to members of society in the form of cash or a carbon coupon based on the vulnerability level of the household the member belongs to (Paul, 2019). This idea is similar to the Carbon Fee and Dividend (CF&D) scheme that has been developed in the US. CF&D progressively tax the use of fossil based fuels (the FEE part of the scheme), while the revenue collected from taxation is given back partly or wholly to society (the DIVIDEND part of the scheme). The scheme aims to incentivize decarbonisation, while protecting consumers from potential growth in energy costs. Under the CF&D (Fawcett, 2010b), income is fully recycled to the general population on an equal per-capita basis, meaning that below-average emitters benefit financially from the scheme. The potential impact of a fee and dividend programme in the three coolest regions in the US with the highest fuel prices was examined (Colt, 2015). The fee paid by a household depends on the quantity of energy used, while dividends depend on household size. The survey found that in 2016 more than 91% of all households in the study area, covering 97% of the population, would receive more dividends than their fees, on average. Net benefits would likely increase over time, if energy efficiency increased and diesel use was displaced (Colt, 2015).

A call for a global carbon tax (Raghuram Rajan, Financial Times, December 17, 2019) was proposed and published in the Financial Times, whereby countries that emit more than the average per-capita emission should pay into an incentive fund, from which countries with below-average per-capita emissions would receive incentives for investing in carbon-mitigating measures. The payment would be calculated based on the fact that each tonne of emitted carbon has a price, so all countries, whether developing or developed, would have the same incentive to reduce their emissions.

Another argument that favours C&T is that within these schemes consumers are involved, and, due to the defined cap, are obliged to reduce their original consumption by a certain proportion (Bye and Bruvoll, 2008; Kempener, 2009). The proportion will vary among consumers because of different demands for electricity. Thus, the system introduces a trading scheme for energy savings among consumers through which cost efficiency is attained. In addition, this instrument would serve as an indirect tax on energy consumers and a subsidy for energy-saving appliances (Bye and Bruvoll, 2008). Therefore, C&T systems are more effective than taxes because the total of tradable permits can be traded in line with an absolute cap on emissions (Kempener, 2009). This indicates that the behavioural change and demand-side management encouraged by C&T regimes that address residents can significantly reduce emissions (Masson-Delmotte, et al., 2019), while simple tax increases may not result in energy savings (ENABLE, 2019b, Chitnis et al., 2013) – since subsidies, or measures that impact highly taxed energy commodities might be less effective at reducing aggregate emissions (Chitnis et al., 2013). According to the double-dividend hypothesis, however, an increase in taxes on polluting activities can create two kinds of benefits. The first benefit is an improvement in the environment, while the second benefit is an improvement in economic efficiency driven by the environmental tax. The double-dividend hypothesis suggests that there is the potential to improve both environmental and economic conditions, as since a carbon tax would generate revenue, other pre-existing taxes could be reduced (Freire-González, 2018; Fullerton and Metcalf, 1997). According to scholars that favour the application of taxes, the environmental benefit of a carbon tax regime can be almost always achieved, although others disagree (ENABLE, 2019b, Chitnis et al., 2013 – see above).

Another reason for favouring a C&T system is that, in the case of taxation, the taxation authority should have full knowledge of all relevant external costs, which is a huge challenge. Within C&T schemes, transaction costs can be low and property rights can be established well without knowing all information. The core issue is that the responsible authority definitely has the responsibility to determine the total amount of pollution that is acceptable. If the maximal amount of emissions is identified properly, the market can reveal the marginal cost of reductions (Crals and Vereeck, 2005, Perrels, 2010). However, if taxes are set too low, suboptimal emission reductions occur (as overly high, unwarranted losses occur) (Crals and Vereeck, 2005). In a C&T system, however, more information is accessible on (transaction) costs than in a taxation regime. Based on the latter, a C&T program in which the right price for permits is set and emission permits are traded on the market and monitored upstream seems to be more effective approach (and involves lower transaction costs) than a carbon tax scheme (Crals and Vereeck, 2005).

Policy instruments that leave the choice of action in people's hands are usually preferable (Perrels, 2010, Chamberlin et al., 2015). These kinds of instruments, however, need to be designed to be user-friendly, understandable, personalised, interesting, reliable, and transparent. Therefore, adequacy, accessibility, and the transparency of information are also preconditions for successful implementation (Perrels, 2010). To ensure proper information flow, allowances within the system could be provided via a personalised internet-based monitoring system with monthly updates about current credit in order to allow the tracking of personalized emissions more easily. According to Perrels (2010), such a C&T system would produce significant revenue for the government. Furthermore, C&T is liable to be more economically efficient and transparent than regulation, subsidies, or other regulatory, informational or financial incentives because it reduces emissions wherever it is the cheapest. Most literature regards C&T as a conceptually sound, simple and cost-effective system for pollution control (Kempener, 2009). It also provides predictable revenues for households through the low-carbon transition.

As regards public acceptability, research shows that PCT (those C&T schemes that also target residential energy use) could be at least as socially acceptable as an alternative taxation policy (Fawcett, 2010a), since people think both could be fair and effective. Carbon taxation with revenue recycling (Paul, 2019; Rajan, 2019), however, may be perceived much more positively in terms of fairness than carbon taxation in isolation (Fawcett, 2010a). Careful consideration and justification of the conversion factors and scheme boundaries are needed to increase public acceptability of a PCT policy (Howell, 2012) Furthermore, earmarking carbon tax revenues increases public acceptability (Gevrek and Uyduranoglu, 2015). People prefer a carbon tax with a progressive cost distribution rather than one with a regressive cost distribution, as well as prefer a carbon tax that promotes public awareness of climate change. However, we need to be very careful regarding acceptability, since how PCT is presented and the context of opinions significantly influence outcomes. There is, for instance, neither a clear definition of ‘socially acceptable’ nor clear findings about what this means to different actors (Fawcett, 2010a). With regard to the acceptability of PCT, support for PCT is not obviously greater than for alternative instruments (e.g. taxes) Starkey (2012).

On the other hand, there are also arguments against implementing C&T systems. These concerns include the fact that their implementation would be complex, pose administrative burdens, and may be non-transparent (Archer, 2015). C&T can also underpin the growing concentration of power and wealth among the political and economic elites due to the need for centralized monitoring. In contrast, tax administration is light and transparent. It can be regulated easily if setting the tax is in the hands of the strongest ministry (either the finance or tax ministry). A taxation scheme would cost less to set up than a C&T scheme (Crals and Vereeck, 2005; Fawcett, 2010a, 2010b, 2012). For instance, some Personal Carbon Trading schemes are designed to achieve downstream public engagement (Gyulai, 2011; Chamberlin et al., 2015) without the need for the expensive impracticality of downstream emissions measurement or enforcement, nor lifecycle analysis of every possible product and service. Nonetheless, extensive public engagement is intrinsically costlier than the lack of it, and so alternative upstream policy frameworks such as CF&D are inherently cheaper than these kinds of Personal Carbon Trading regimes (Chamberlin et al., 2015a).

Another advantage of setting a tax instead of introducing C&T is the ability to reduce pre-existing distortionary taxes on the economy, such as income and payroll taxes; this can improve the overall efficiency of reducing energy use. Others, however, think that achieving the economic benefit of carbon taxes is far from evident and requires further research (Freire-González, 2018; Fullerton and Metcalf, 1997). Another potential disadvantage of a C&T program is so-called grandfathering, which is regressive and concentrates wealth in high income groups (Blonz et al., 2010). Another view is that increasing the scope of C&T would pose the greatest burden for middle-income households, where current consumption often reflects past income (Waxman, 2009).

Price-based policy frameworks (e.g. taxes) act to raise the price of carbon-rich purchases in the belief/hope that consequent emissions reductions will be sufficient to avoid climate catastrophe, while quantity-based frameworks (e.g. PCTs) act to place a cap on emissions in the belief/hope that the price rises this is likely to cause will not cause economic catastrophe (Chamberlin, 2015b). The fixed quantity of energy available under TEQs and the Hungarian Climate Bill Proposal (see more in Chapter 3.4.2) make it obvious that high consumption by one person will leave less for everyone else.

In my dissertation, in light of the findings in this chapter, as well as considering the first aspect of ecological economics (sustainable scale) and what research suggests in terms of achieving sustainable energy use (namely, putting an absolute ceiling on energy use), I will focus on C&T schemes. C&T schemes, when the cap is set properly, have the potential to contribute to achieving sustainable energy use (and thus sustainable scale). From the next chapter on, I narrow down my focus on those C&T schemes that target at least partially household energy use, since the aim of my dissertation is to reveal whether equal per-capita allowances would contribute not only to promoting sustainable scale, but also to supporting the second principle of ecological economic: the just distribution of energy, and the benefits arising from its use.

2.1.4.2. Personal Carbon Trading Schemes

Energy-use caps not only influence the size of the economy and thus contribute to sustainable scale, but, if they are properly combined with allocation/distribution mechanisms, could facilitate (or if they are not combined with appropriate distribution measures, could hinder), the necessary transformation towards a fairer distribution of resources (Spangenberg, 2013). In this chapter I review those cap-and-trade systems (personalized trading schemes – PCTs) which primarily target residents and aim to decrease their household energy usage / carbon emission. First, I introduce the PCTs, then I analyse them based on how they contribute to the three principles of ecological economics in terms of energy use: 1. sustainable energy use considering sustainable scale, 2. fair and sustainable energy use considering just distribution, 3. effective use of the schemes considering efficient allocation. PCTs are assumed to contribute to achieving sustainable scale through setting an absolute ceiling on energy use that is reduced step by step. Furthermore, they are assumed to be designed in a way that they ensure fairness through the equal energy entitlement distribution. In terms of efficient allocation, they usually use trading as a mechanism to help people (and companies and other entities in some schemes, when all players in the economy are involved) satisfy their energy needs within the reduced energy cap. Figure 10 shows the flow of quotas in Personal Carbon Trading schemes.

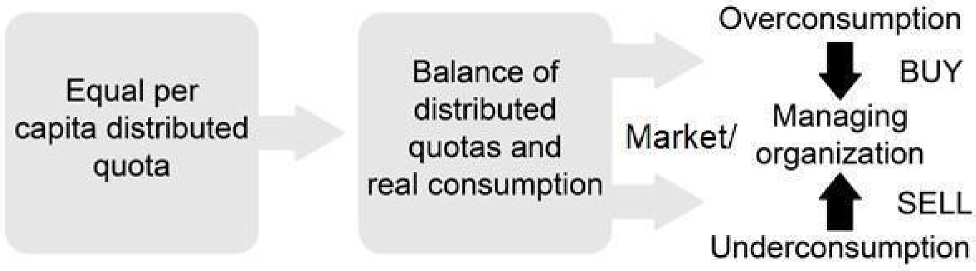

FIGURE 10: FLOW OF QUOTAS (ENTITLEMENTS) IN PCTS (BASED ON GYULAI (2011))

Since satisfaction of the second principle, fair energy use considering just distribution, is the more complex issue to analyse, I detail my analysis most deeply regarding this aspect. Therefore, social aspects will be highlighted and discussed more extensively.

2.1.4.3. Description of the schemes

PCTs were developed in the UK, where the energy and carbon context have encouraged and facilitated the development of this idea (in 2019, the country became the first state to define the goal of achieving carbon neutrality by 2050 (gov.uk, 2019)). However, the concept of PCT has been relatively slow to spread to the wider academic and research community, as well as to achieve international scope (Fawcett, 2010a), possibly due to the lack of an EU-wide energy tax, and concerns about the successful enforcement of EU ETS. This trend might change due to the new EU level 2050 carbon neutrality target defined by the European Green Deal (European Commission, 2019).

Even though PTC schemes vary, they have one similarity: namely, to involve citizens in controlling their energy consumption and thus their carbon emissions. In terms of controlling residential energy use, 35%-40% (based on Hungarian and UK data, Fawcett, 2010a) of energy consumption outside the ETS can be regulated. Furthermore, this sector has high energy-saving potential (Tombácz and Mozsgai, 2009). Under a personal carbon allowance (PCA) scheme, allowances are assigned only to individuals, excluding the rest of the economy. The PCA would manage and reduce carbon emissions from energy use in households and for personal travel, including air travel. Individuals would be given equal, free allowances that would be tradable and reduced year-by-year in line with national emissions reduction targets (Fawcett, 2012). Children would receive a partial allowance, managed by their parents. Through controlling the energy use of the residential sector, 40% of the carbon emitted in the UK economy could be regulated. Therefore, policies aiming to reduce carbon in the commercial and public sectors should be also enforced to achieve absolute energy reduction while implementing the PCA (Fawcett, 2010a).

The other most popular scheme within PCTs is Tradable Energy Quotas (TEQs). TEQs were initially developed by Fleming (2011) (Fleming and Chamberlin, 2011; Chamberlin et al., 2015). The scope of implementation is wider than with PCA, as TEQs are designed to reduce all energy-related carbon emissions in an economy (Fawcett, 2012; Fleming and Chamberlin, 2011; Chamberlin et al., 2015). Individuals would get free tradable energy quotas (TEQs) that would cover average household and (non-air) travel-related energy use, while organizations would pay for the tradable energy quotas they need through auction. All types of energy use would have a carbon rating; therefore, energy consumer entities would have to sell some of their TEQs corresponding to their emissions. All stakeholders involved in the system could trade with their TEQs, all transactions would be carried out electronically (Fleming and Chamberlin, 2011; Chamberlin et al., 2015). The major difference between PCAs and TEQs is that the first scheme covers household energy use and private travel, including air travel, whereas the second is an economy-wide scheme that also includes emissions from the industrial and commercial sectors (Fawcett, 2012).

Another PCT scheme that has been worked out is the Cap and Share (C&S) system. C&S covers global carbon emissions and sets an annual limit for them. The system would issue permits for fossil-fuel extraction that are aligned with the defined cap; these permits would then be bought at auction by (multinational) corporations (Matthews and Matthews, 2017). Regarding individuals, the scheme would provide annual, individual entitlements in which the individual fair share of the national carbon budget is indicated; in other words, the amount of carbon each individual could emit (Fawcett, 2010a). It is assumed that most people would sell their entitlements to obtain additional income. In contrast to individuals, suppliers would buy entitlements corresponding to the amount of emitted GHG. The cap on carbon emissions would internalise the climate externalities of fossil fuels and produce a strong carbon price signal (Matthews and Matthews, 2017).

The Carbon Health and Saving System (CHSS) (Guzman and Clapp, 2017) engages individuals and enhances collective action to reduce energy use. It connects long-term climate mitigation goals with short-term personal and social targets. In addition to the PCT schemes listed above, it also targets health, recreation and social reinforcement. Within the proposed CHSS, the enabling of the tracking of daily activities that emit carbon and provision of personalized information about how these activities interact with climate change would enhance the desire to reduce personal carbon emission but also the desire to cooperate. CHSS would include the functionality of personal carbon tracking and making reductions without trading, penalties, or direct costs of any kind (Guzman and Clapp, 2017).

The Hungarian Climate Bill proposal (Gyulai, 2011) aims to set a cap on non-renewable energy use (including biomass from non-sustainable sources) in Hungary based on present use rates. The cap would be lowered progressively year by year. Individuals would be given the same sized free non-renewable energy entitlement, which would be tradable and reduced year-by-year in line with national emissions reduction targets (similarly to TEQs, PCAs, and C&S). Children would receive a partial allowance, managed by their parents (similarly to PCA). In regard to other energy users, non-renewable energy entitlements would be assigned per sector and distributed to entities through a participatory approach involving all stakeholders. Fossil energy entitlements could be sold for interest-free "entitlement money" or quota money, which could be spent on an environmentally and socially certified market. A Revolving Fund would also be established that helps to finance investment in energy efficiency and renewable energy through interest-free loans in quota money. The loan would have a payback period adjusted to the energy savings or income generation realised through the investment. This makes such investments accessible to everybody, including the poor, if they are well informed about such opportunities. An advisory service would be also established that is designed to help all stakeholders to receive all relevant and important information on how they can benefit from the scheme, change their behaviour and adapt to the energy transition.

The Cap and Dividend (C&D) (On the Commons, 2011) proposal was developed in the US and is aimed at limiting the supply of fossil energy in the economy. Therefore, it does not target energy consumers, such as households, but those who introduce fossil energy – e.g. the first sellers of oil, coal and natural gas – to the economy. In Germany, a cap on electricity sales was proposed, involving setting a limit on the electricity sales of each supplier. This limit can be decreased year by year, and rights are tradable. It is assumed that the instrument provides an incentive for suppliers to promote energy savings in households because otherwise they would have to buy certificates (Fischer, 2015). Even though these two schemes do not target directly households, their implementation would have a significant impact on them.

PCTs differ in whether they are aimed at capping carbon when it is emitted due to economic and social activity (as PCAs and C&S are), or when it enters the economy and social activities in the form of fossil energy (as TEQs and the Hungarian Climate Bill and C&D are). The former is called a *downstream* cap or output-side regulation, while the latter is called an *upstream* cap, or input-side regulation. In choosing where to define the cap, it is important to recognize how carbon differs from other pollutants. "*Most pollutants can be regulated or removed where they are emitted. Carbon, however, is emitted not just from a few pipes, but from hundreds of millions. Capping carbon emitters is therefore extremely difficult. To the extent it can be done, it will be an administrative nightmare for businesses, consumers and government. And it will never catch all of the carbon that flows into the atmosphere*" (On the Commons, 2011, website). By contrast, capping carbon as it enters economic and social activities is relatively simple. This so-called input-side regulation has the potential to transform more effectively the structure of a complex system, such as the energy system.

2.1.4.4. Sustainable scale – sustainable energy use

The aim of PCT schemes is to deliver reductions in carbon emissions equitably, effectively, and efficiently and give individuals responsibility for managing their energy-related carbon emissions (Fawcett, 2012) through the proposal that all adults receive tradable carbon entitlements to cover emissions from household energy use and/or personal travel. The entitlements would be reduced over time, in line with national emissions reduction goals, ensuring that the reduced energy use stays within a sustainable scale, as ecological economics calls for. C&D is designed, however, solely with regard to climate change, and so an additional energy rationing system – like TEQs and the Hungarian Climate Bill proposal – would be needed to deal with any oil or gas supply disruptions, which would rather negate the cost savings of such a scheme. Yet even if we were to ignore the realities of energy resource depletion, the shrinking carbon cap is itself going to mean a shrinking supply of energy to the economy.

PCAs, TEQs, C&S and the Climate Bill schemes would similarly impact individuals.

When people use energy– e.g. pay their energy bills, fill up their cars, or in the case of PCA, buy flights – they need either to use carbon units from their account, or if they have run out, to buy carbon units from the responsible authority at the entitlement price defined either by the market (PCA, TEQs) or by a central authority. Since these schemes allow stakeholders to trade with their units, people who use less energy because they live low-carbon lives, travel less, or have smaller, energy efficient homes, would have units to sell. Those who travel more or live in large or inefficient homes would need to buy units to maintain their lifestyles. This means that carbon-intensive lifestyles would cost more than they currently do. The equally distributed allowances, however, would not mean that everyone could emit the same amount (Chamberlin et al. 2015, Gyulai, 2011, Fawcett, 2010a). In contrast, due to the moderate annual reduction in the amount of entitlements, the schemes would let people adapt to the changing requirements easily. Either they could buy additional units, or invest in energy efficiency measures or change their carbon-intensive lifestyles in order to stay within the limits defined by the tightening national cap, thus finally within a sustainable scale.

According to Fawcett, PCT is unlikely to be introduced on an EU-wide basis, at least initially. Most probably, it would first be introduced in one or more Member States and then adopted at the EU level if it proved successful (Fawcett, 2010a). Subnational, state-level implementation, however, may be relevant in the USA (Fawcett, 2010a). On the other hand, the Energy Budget Scheme, based on the Climate Bill and the TEQ proposals, aims to cover the EU and thus has been already discussed by EU decision makers (RCC, 2015).

2.1.4.5. Just distribution – just energy use

All PCTs address equity issues from the ‘opposite’ direction from sufficiency energy advocates, since most of the PCTs propose an equitable amount of energy consumption rights, the total of would not exceed the sustainable scale. Advocates for sufficient energy services, however, call for identifying the minimum amount of energy to meet basic needs, and if some scope is left for more energy consumption within planetary boundaries (sustainable scale), this amount could be used based on further discussions. However, some of the PCTs (e.g. the Hungarian Climate Bill Proposal) explicitly stress the need to ensure the satisfaction of basic needs (NFFT, 2010).

Distribution justice (the concept of which is detailed in the chapter on fair and sustainable energy; Chapter 3.2) appears in PCTs in the form of equitable energy entitlements, since all schemes would distribute entitlements on an equal per-capita basis among residents, and none of them would consider variability in social, economic, and living conditions. There are, however, PCTs which would include other entities beside the residential sector. In the Hungarian Climate Bill, industrial sectors would discuss among themselves how to distribute the entitlements dedicated to the sectors concerned (Gyulai, 2011), while under the TEQs and C&S schemes businesses and other non-residential entities would receive their entitlements through auctions (Fleming and Chamberlin, 2011; Matthews and Matthews, 2017). Some PCT proposals (e.g. the Hungarian Climate Bill, and German cap on electricity sales), however, touch upon the issue of procedural justice, since they put extra emphasis on how people obtain accessible information, as well as practical advice about the opportunities PCT would bring to their lives. The Hungarian Climate Bill would establish a Support System of 2-3000 employees (Tombácz and Mozsgai, 2009) who would reach out to citizens, including marginalized residents, and provide valuable information to them about how they can benefit from the system. According to social experts (Herpaine et al., 2011), however, this system would need to involve all NGOs working in the field, and 2-3000 people would be far from enough to reach all marginalized people. The German cap on electricity sales would include large-scale, targeted and quality-assured energy advice. In the case that the systems are developed properly, incorporating social justice considerations, they could stimulate residential energy use reduction (Szurovecz, 2018).

Equity is the aspect that needs to be incorporated while formulating PCTs. Starkey (2012) compared TEQs, PCAs, C&D, and C&S in terms of their equity. This comparison shows that these schemes can be equally fair: none of the schemes is inherently more equitable than another. Scholars argue that PCTs based on equal per-capita allowances are generally progressive – namely, low-income households would receive more allowances than they need to cover the carbon they emit (Gyulai, 2011; Tombácz and Mozsgai, 2009; Dresner and Ekins, 2004; Niemeyer, 2010; Fawcett, 2012), while high-income households would not receive enough to cover theirs (Dresner and Ekins, 2004; Niemeyer, 2010; Fawcett, 2012). The German cap on electricity sales is expected to have positive distributional effects. In Germany low-income households generally consume less energy, therefore it is expected that suppliers would compete for these households and try to attract them – e.g. by offering a progressive tariff structure with low prices if consumption is low (Fischer, 2015). In the UK, welfare change happens due to the progressivity of PCT; namely, poorer consumers are mainly 'winners' and those whose emissions are generally lower. This means in practise that the allowance would flow from under-emitters to over-emitters and money would flow from the wealthy to the less wealthy (Li et al., 2015).

There are arguments, however, that the equal-per-capita allowances of most of the proposed PCTs are not seen as 'fair' by everyone. The assumption that equal per-capita allowances are a vital feature of PCT design may not be valid in the case of other countries than the UK or Germany. For the UK, the proposal for equal allowances was largely based on the principle of equal rights to emit carbon, but also on an understanding of how personal carbon emissions vary across the population. It is possible that outside the UK there is more reason for having differentiated personal allowances, particularly related to climate or other factors that are beyond individual control (Fawcett, 2010a). Without knowing much emissions vary in other countries, it is far from sure that equal allowances are the only possible fair way of operating with a collective cap on carbon emissions.

It might be the case in some countries that some people have access to near zero carbon energy, and others do not (Starkey, 2012; Herpaine et al., 2011), which factor needs to be taken into account when determining allowances (e.g. in France, people who use very low-carbon electricity / wood for heating and hot water would have much lower carbon emissions than those using natural gas. In France there is much greater diversity in the carbon intensity of residential energy options than there is in the UK). Furthermore, even in the UK and in Germany it can happen that there are a minority of higher-carbon-emitting low-income households (big family houses with inefficient insulation), that would be worse off under a PCT scheme (White and Thumim, 2009; Herpainé Márkus et al., 2011). These households need to be considered very carefully when formulating the PCT. Moreover, distributional analysis has shown that PCT could be a progressive policy overall, yet poorer individuals would be worse off (Starkey, 2012; Herpaine et al., 2011). Based on these findings, it can be seen that there is no linear relationship between household income level and the impact of PCT on households (Kempener, 2009, Herpaine et al., 2011). Poorer or more disadvantaged individuals (in terms of education, employment, or location in relation to the provision of public services) unintentionally use more energy due to energy-poor living spaces or inappropriate heating systems. Therefore, it is important to explore alternatives to the equal distribution of emissions rights based on knowing country household energy use patterns and carrying out research on the distributional impacts of PCTs in order to identify potential winners and losers under a PCT scheme (Herpainé Márkus et al., 2011).

On average, poor people would use less than their allocated energy entitlements, especially when such a system is introduced, when the cap is quite high (Fischer, 2015; Li et al., 2015; Tombácz and Mozsgai, 2009). In Hungary, it is, however, questionable whether poor people could really use the opportunities a system could provide, often living in the countryside far from any information hub and thus having much more difficulty receiving information about the opportunities and benefits of PCT (Herpainé Márkus et al., 2011). Among the latter, the poorest live from one day to the other, cannot think of tomorrow, thus would fail to save on energy entitlements and thus might quickly sell them to obtain income in the short term. In the UK, where other PCT schemes are developed, however, poor people have easier access to information than in Hungary. In general, in both countries, skill is required to 'manage' carbon budgets. These critical areas (access to and use of information, managing carbon budgets) are currently under-developed in PCT theory and thus more research is needed to understand the wider set of personal and social factors that are involved (Seyfang et al., 2009; Herpaine et al., 2011). In order to help the disadvantaged access and perceive the necessary information, having direct social networks, especially in small settlements, is vital.

It can also be claimed that trading might not increase social justice and benefit the poor; on the contrary, trading might favour the rich who are much more informed and aware of the advantages of trading. In the Hungarian Climate Bill, however, poor people can sell their saved entitlements only through a central authority, which would ensure (if established properly) that they receive an appropriate amount of money for their saved entitlements (Gyulai, 2011; Herpaine et al., 2011). Quota money is an interest-free form of currency, thus not worth collecting, but for spending quickly on the so-called green market for sustainable products and services.

Middle-income households and those who used to belong to the middle class and have household energy conditions impacted by past energy consumption are those who might benefit least from energy capping (Tombácz and Mozsgai, 2009; Herpaine et al., 2011). This is because their consumption is neither so low that they can save energy entitlements that they can sell, but their financial situation is not so good that they can afford to buy additional quotas. A revolving fund (as defined e.g. in the Hungarian Climate Bill proposal) could help manage this situation through providing interest-free loans to every citizen without requiring their own financial contribution.

Some of the proposed PCTs would generate government revenue– e.g. through auctioning emissions rights (as TEQs or C&S would). The free entitlement of TEQ units to the general population is a form of revenue recycling, while the revenue generated by the auction of TEQs units to organizations would support the energy transition. The Hungarian Climate Bill would also use free entitlements for individuals and would generate state revenue through taxes paid on products and services sold on the green market. If this state revenue were spent either on mitigating climate change (liable to disproportionately impact the poor and disadvantaged, as detailed in Chapter 2.1.2) or to enhance public services, it would promote social justice. Thus, PCTs have progressive effects, defending those below-average emitters, who are mainly the poorest in society (Chamberlin et al., 2015, Fischer, 2015, Tombacz and Mozsgai, 2009).

Summing up this chapter, PCTs would have a variety of economic impacts through the imposition of an energy use capping policy on households with different levels of income and capacity to invest in energy efficiency (Lorek and Vadovics, 2016). At the social level, living conditions might be enhanced and absolute poverty might be mitigated, but the mitigation of the current level of inequalities cannot be assured and relative poverty might be maintained if proper mechanisms underpinned by appropriate research do not address those who would not otherwise benefit from such systems.

2.1.4.6. Efficient allocation – efficient use of energy resources

In order to promote the first two principles of ecological economics: sustainable scale (in the case of energy: sustainable energy use) and fair distribution (in the case of energy: fair energy use), PCTs can include mechanisms aimed at more efficiently allocating energy. Although PCTs are designed to maintain emissions or energy use within limits, it is unsure if they are really effective at allocating entitlements wherever needed. Use of a PCT would not necessarily result in a carbon/energy entitlement price that reflects the marginal costs of applying the necessary technologies (Kempener, 2009) to achieve sustainable energy use. In terms of comparing the different PCTs, TEQs, C&D and C&S cannot be significantly differentiated in terms of efficiency and/or effectiveness (Starkey, 2012). Accordingly, it would be helpful for proponents of PCT to make a case for implementation by developing an efficiency or effectiveness argument (Starkey, 2012).

The effective implementation of the schemes might depend on the level of social acceptability and sense of common purpose to reduce energy use collectively, which would entail human engagement and motivation to reduce personal energy use and thus carbon emissions. PCTs could influence energy use beyond through the price signal, through creating the motivation for enhanced environmental behaviour at the intrapersonal, interpersonal and external levels (Gyulai, 2011, Chamberlin et al., 2015). Some scholars, however, argue that the success of PCT schemes would depend upon the level at which common purpose is built (Seyfang et al., 2009). The term common purpose reflects the need for shared aims and targets to foster collective action and mutual understanding and the transfer of knowledge (Seyfang et al., 2009). Comparisons are sometimes made to post-war rationing, when the British government imposed significant and long-lasting cuts in consumption on the population. The sense of everyone being 'in it together', and strong leadership from the government to promote the public good, contributed to the acceptability of drastic measures. The notion of 'common purpose' might not be found today to be strong enough to generate a sense of personal responsibility for current and future generations (in terms of support for PCT). Our consumerist culture rewards individualism and personal spending: climate change impacts are visible enough to cause concern, but far enough away to hinder individual action. Furthermore – for instance, in Hungary – so-called social capital is very weak, thus needs to be enhanced before any joint action towards common goals can be imagined (Herpaine et al., 2011) There are, however, alternative opinions regarding the creation of common purpose. For instance, in the case of TEQs their developers are convinced that the scheme has the potential to create common purpose and joint action towards reducing energy consumption even in today's consumerist society (Chamberlin et al., 2015). Based on these claims, PCTs are potentially capable of motivating people to act and to create ownership in relation to decreasing individual or household energy use.

According to mainstream economics, the market is an effective means of allocating resources. According to ecological economics, however, the market is only one of the instruments for effectively allocating resources, including energy, to achieve sustainable scale and just distribution. There are different claims about whether PCTs are market-based instruments or policy frameworks that target absolute energy capping. According to scholars who agree that the PCT model is a market mechanism built upon utilitarian principles, PCT advocates do not necessarily endorse a neoclassical economic perspective (Seyfang et al., 2009; Kempener, 2009). An efficient emission/energy entitlement market, however, requires well-informed, rational consumers, who can make rational decisions that result in sufficient demand for permits. The idea of a perfect market does not consider the complexities associated with multiple actors in an imperfect world. The poor and marginalized, especially in countries (e.g. in Hungary) in which they are not able to access and use proper information, cannot make such decisions (Herpaine et al., 2011) or may simply be reluctant or unable to trade (Kempener, 2009). Others (Chamberlin et al., 2015) argue that among the PCTs TEQs is not a market instrument, since its main aim is the absolute capping of energy use. Trade is just a means of achieving the aim. TEQs are rather a climate policy framework that combines a hard cap on emissions with the use of market mechanisms to distribute quotas within that cap. In other words, for achieving the overall aim of the scheme: namely, to reduce energy use in absolute terms and in a fair way. "*At the heart of TEQs is a non-negotiable respect for the limits set by physical reality, as revealed by climate science*" (Chamberlin et al., 2015, p.418). I would agree with Chamberlin in this respect, since trade is just a means of achieving the aim of an absolute energy cap, while in ecological economics efficient allocation is just a means of promoting sustainable scale and just distribution.

The PCTs differ in terms of how they define the price of entitlements. The price of the entitlements should reveal the value of the premium that should be paid by energy consumers to compensate for the harmful impacts energy use imposes on the climate. The price of the entitlements would be defined by the market (TEQs, PCA) or by an established central authority (Hungarian Climate Bill). If the usable amount of energy is capped, the market can determine the price for the energy entitlements based on the demand and supply relationship. In the case of the TEQs, for instance, the price for energy entitlements could be recalculated weekly considering actual demand for them and the defined annual cap. All sectors buy and sell TEQs units at a single national price. Supply of the units would be fixed by the hard cap, thus only the national demand determines the fluctuations in the price of the units (Chamberlin et al., 2015). The national demand determines the price of TEQs, resulting in transparency and motivating everyone to help each other reduce energy demand (Chamberlin et al., 2015), in the end creating a sense of common purpose (as detailed above). Less demand means lower prices, so it becomes in the collective interest that the price of allowances should be low. There is an incentive to collaborate to make this happen, and TEQs and the Hungarian Climate Bill proposal would thus create a social and economic culture that is intelligently, effectively, and collectively working towards the shared goal of living happily within our energy and emissions constraints. C&D unfortunately, might have the opposite effect. While it incentivises individuals to reduce their personal energy use, it also appears to encourage them to increase energy use in the world as a whole, as by doing so they would push up the demand for emissions permits and so increase the dividend they receive. Such a perverse incentive is entirely at odds with the required common purpose (Chamberlin, 2008)

The market-defined price, however, cannot incorporate the extent of individual overconsumption. For example, if I consume all my entitlements for the year by March, I can buy entitlements in October for the same price as another person who only uses up their entitlement budget that month. In the case that a central authority determines the price for entitlements, one can easily assume that soviet-type economic planning would need to take place, especially if the central authority is not proven credible and accountable. If we assume, however, that the central authority is credible and accountable, it would need to ensure that at the defined price overconsumers would not be able to buy so many entitlements that the defined cap would be exceeded. Progressive pricing (as the year goes by, additional entitlements for the same consumer would be more and more expensive, so that the price curve of their entitlements would exponentially grow) would provide a solution to this challenge. This method would be more acceptable by society than a state-initiated restriction. Progressive pricing would mean that even that the super-rich could not afford to buy a fifteenth plane ticket to the Bahamas within the same year, since it would be extremely expensive even for them. Besides controlling extreme and luxury over-consumption, under-consumers need to be motivated too in terms of selling their saved entitlements. Therefore, the price of entitlements should be high enough to be worth selling so that a substantial proportion of entitlements would be on the market. Another issue is that the proportion by which the concerned nation overshoots the defined national cap needs to be considered when identifying the price for entitlements. In other words, the greater the extent to which the nation overshoots the cap, the higher the price could be for overconsumption and avoiding switching off the energy supply when the cap is reached. In order to incorporate social justice into this price-setting process, consumers who significantly over consume should pay more of the penalty than those who only slightly over-consume.

All PCTs require the establishment of new institutions as well as new regulations, and most of them (TEQs, and the Hungarian Climate Bill) would require the development of an electronic system for the energy allocation card with a personalized PIN code. For instance, the German cap on electricity sales would contain incentive mechanisms and regulatory instruments that facilitate meeting the savings targets. These instruments on the one hand would in part be developed by suppliers, thus a conducive national or European framework would be helpful that involves revised energy labels, incentives, or regulations that support energy-saving features in appliances (Fischer, 2015). Furthermore, new institutions include, inter alia, the central authority in the case of the Hungarian Climate Bill, or a central registry of TEQs that would announce a full year's supply of TEQs units on the first day of the scheme, then issue weekly the new units. The Hungarian Climate Bill would contain a Revolving Fund (Gyulai, 2011) that would provide interest-free loans in so-called quota money that could be only spent on the Green Market also established by the system. The loans would require no own contribution thus would be accessible to everyone. There are, however, dilemmas related to the efficiency of the Revolving Fund, since investments do not always return and small-scale investments are not as effective as renovating a whole piece of real estate. Would there be any criteria based on which the Fund could support investments? If it were to give financial support for renewable energy investment owned and used by local communities, this would enhance well-being of the locals (Tombácz and Mozsgai, 2009), but it is questionable how such opportunities of a revolving fund would reach the poor (Herpainé Márkus et al., 2011). Institutions also include the advisory service under the Hungarian Climate Bill that could provide accessible and personalized information about the system and about how consumers, especially the case of poor and disadvantaged, can benefit from it.

New regulations include the energy use cap of the concerned year aligned with national emission reduction targets, as well as regulation that defines how the system is financed from the state budget. Furthermore, specific regulation should be developed that aims to govern opportunities and limitations for buying fuel abroad, as well as energy and fuel allocations for foreign individuals. Regulations also include import tariffs in order to protect domestic producers. Until recently, such tariffs were politically unrealistic, but the rules of the World Trade Organization do not prohibit such tariffs any longer, (Chamberlin et al., 2015) and the President of the European Commission van der Leyen also proposed such tariff for the EU in 2019 (European Commission, 2019).

Comparing TEQs and the Hungarian Climate Bill proposal with C&D systems, the biggest difference is whether the system is up or downstream. Upstream advocates of Carbon Fee and Dividend systems want to regulate the few fuel and energy companies that facilitate the entry of carbon into the economy, arguing that this is cheaper and simpler than addressing the behaviour of tens of millions of 'downstream' consumers as TEQs and the Hungarian Climate Bill proposal would do. At first glance, this seems a convincing argument, but there is one important regard in which an upstream scheme fails – it does not engage the general populace in the changes that are required (Chamberlin, 2008). Due to the simplicity of C&D, it would be cheaper and faster to implement and less challenging for politics/markets than TEQs and the Hungarian Climate Bill proposal (Chamberlin, 2015b). Climate change and energy challenges are definitely large-scale problems, but these challenges do not require large-scale solutions. In contrast, through small-scale solutions within a large-scale framework results could be achieved. Upstream regulations (like C&D) are designed to solve large-scale problems at a large scale, but C&D only involves fossil fuel companies in achieving the dramatic change in infrastructure necessitated by climate change, thus these systems do not address the need for cooperation between the different sectors of society that is united in a single simple scheme.

The energy allocation card, proposed to be established under the Hungarian Climate Bill, TEQs and PCA, would have a running account indicating the amount of non-renewable energy available to the consumer for their yearly use. Furthermore, it would register consumption at fuel stations and at households and settle accounts at the same time. Energy providers would register the quantity of non-renewable energy that has been consumed on the card at the time of accounting for the service, while card owners could check their balance at any time (Gyulai, 2011; Fleming and Chamberlin, 2011; Chamberlin et al., 2015). Additionally, the CHSS can track carbon emitters' daily activities and provide personalized information about how these activities interact with climate change. This information would enhance the desire to reduce personal carbon emissions but also the desire to cooperate. CHSS would include these functions of personal carbon tracking and reduction without trading, penalties, or direct costs of any kind (Guzman and Clapp, 2017).

PCT would be expensive to implement, as already mentioned in the chapter that compares C&T and carbon tax policy tools (Fawcett, 2010a, 2010b, 2012) (Chapter 3.4.1). The cost would include an initial set-up cost, and annual running costs. The minimum cost for a research trial is estimated to 600,000 EUR (Fawcett, 2012), while the estimated one-year loan budget for the Revolving Fund, which would be established under the Hungarian Climate Bill would be 21 billion EUR. In the case of the Hungarian Climate Bill, the operation of the system would be financed by 0.5% of each entitlement purchase, the 20% commission paid when exchanging the quota money to national currency, and the 1.5% of credit and 0.5% of each transaction provided by the Revolving Fund.

Most of the PCA schemes differ in terms of the level of self-monitoring. In the case of TEQs, energy units surrendered by energy consumers at a petrol station are then surrendered by the petrol station when it buys its fuel from a fuel supplier. When the fuel supplier applies to produce or import fuel, it surrenders these same units back to the agency that they originated from. This cycle means that every recipient of TEQs units needs to surrender those units later. The units flow through the economy just as energy does (Fleming Policy Center, 2017a). In the case of the Hungarian Climate Bill proposal, the trade in energy quotas would go through a central authority, which would make the transaction visible and accountable to the public, while a manager would check two parallel balances, one at the consumer end and one at the producer, which would have to be in harmony with each other.

Different countries would be most likely to implement PCT differently. The variation in current national carbon emissions, personal carbon emissions, the effectiveness of current policy and its related equity and distributional effects need to be considered while adopting PCT at the national level. Furthermore, the responsible authorities and scientific bodies need to consider specific national research and detailed national rules (Fawcett, 2010a).

TEQs and the Hungarian Climate Bill proposal could be introduced at a small scale, the national scale, or at the scale of multiple countries. TEQs, the Hungarian Climate Bill and (CF&D) allow adoption by individual countries or groups of countries. Any countries that do so will necessarily introduce import tariffs alongside this to ensure that their manufacturers are not disadvantaged relative to international competitors (Chamberlin, 2015b). Effective implementation of the schemes can be underpinned by small-scale pilot projects, such as the one in the case of CHSS. This project aims to set goals for reductions in the consumption of gasoline, electricity, and natural gas for transportation, heating, cooling, lighting and operating household appliances, with minimal disruption to individuals' lifestyles beyond the provision of information (Guzman and Clapp, 2017). Another small-scale example is Carbon Rationing Action Groups (CRAGs). A CRAG is a group of people who cooperate strongly to reduce their individual and collective carbon footprints (Fawcett, 2012). The members of these groups assign themselves carbon entitlements each year and provide support to each other on how to reduce their direct carbon emissions from household energy use and personal transport (Howell, 2012). CRAG participants have made significant behavioural changes and thus emissions reductions (Howell, 2012; Starkey, 2012). Many CRAGgers, however, would be unwilling to sell the carbon allowances they have saved within a national PCT system. Another small-scale example can be found in a small Finnish town, where a cap-and-trade app has been tested (CiTiCAP, 2019), which accounts for participant's transport-related CO_2 emissions. The system, one of the PCT schemes, allocates CO_2 quotas to participants, which are used based on their travel choices. If they save CO_2 quotas by choosing sustainable mobility methods, they can spend them in a sustainable market. The quotas are distributed weekly and aligned with the city CO_2 reduction targets.

The table below compares the different PCTs discussed in this chapter based on specific criteria: a hard cap on carbon emissions or energy use, energy or carbon regulation, behaviour change, etc. The table has been checked by Tina Fawcett, whom I have cited most in this chapter, because she has written many scientific papers on PCTs.

In this chapter, I have compared different PCTs. In this comparison, it turns out that a provisional research agenda for enhancing PCT-related research has been proposed that details the data, methodological development, and debates required to make progress (Fawcett, 2012, Herpeine et al., 2011). It also turns out that there are critical areas – such as access to and use of information, as well as which types of citizens are able and which are not able to manage their carbon or energy budgets – that are currently under-studied in PCT thinking. Therefore, more research is needed to understand the wider set of personal and social factors that influence the impacts of PCTs (Seyfang et al., 2009), especially the distributional impacts of PCTs, in order to identify potential winners and losers of a PCT scheme. For instance, in countries with higher income inequality than the UK (e.g. Hungary), the equity aspect of PCT might be more important. My PhD contributes to filling this research gap partly by revealing how poor people in Hungary would benefit from an energy-capping scheme with equal per-capita entitlements. My PhD attempts to reveal how residential energy use varies in Hungary across the population and thus strives to identify whether equal entitlements are a fair way of operating within a collective cap on carbon emissions or energy use. My results show that it is important to explore alternatives to the equal distribution of emissions rights based on understanding the relevant country's household energy-use patterns.

2.2. Methodological literature review

After the theoretical review that introduces the principles of ecological economics as a research paradigm, in the methodological review, in order to base the methodology used in my research on robust foundations, I have collected and reviewed those scientific articles and other resources that have attempted to estimate households' energy consumption. I start this chapter by reviewing papers related to household energy use in order to gain insight into the methodologies used in assessing household energy use (Chapter 2.2.1). Then, I collect information on energy use and its social consequences in Hungary (Chapter 2.2.2). Based on these two chapters, I validate my research with concrete quantitative and qualitative methodological suggestions concerning how to achieve my research goals, as detailed in Chapter 1.3.

2.2.1. Review of international household energy use literature

In this review, I have collected and reviewed those articles that aimed to estimate household energy consumption. The overall purpose of this review is to reveal what kind of data from which databases and methods have been used to analyse household energy consumption. Furthermore, I have also summarized the conclusions authors have made so far about what factors play a role in household energy consumption. The Hungarian data and methodologies are detailed in the next chapter (Chapter 2.2.2).

2.2.1.1. Research goals of the studies

All articles are designed to analyse the patterns of household energy consumption. There are, however, differences in their approaches. There are articles that aim to reveal whether increasing energy efficiency in the household sector leads to a reduction in energy consumption through defining rebound effects (Galvin, 2014; Freire-González, 2017) and how to improve the energy efficiency performance of the poor and marginalized (EPEE, 2009; Chancel, 2014). Other papers analyse CO_2 emissions at the household level and what kinds of factors, including density, impact them (Fremstad et al., 2018; Gill and Moeller, 2018, Chancel, 2014; Golley and Meng, 2012). Household energy consumption can be estimated either by data on the amount of energy used (Golley and Meng, 2012) or data on energy expenditure (Bouzarovski, 2014). The impacts of the EU Energy Label and of a newly designed monetary lifetime-oriented energy label in the field have also been assessed; namely, the purchase of household appliances, especially freezers, vacuum cleaners, and tumble dryers (Stadelmann and Schubert, 2018). Papers also investigate 1000 Sustainable Energy Consumption Initiatives (SECIs) and their impacts on energy consumption, since SECIs varies in scopes, scales and objectives, types and methods of intervention and outputs across Europe (Jensen et al., 2018; Vadovics and Živčič, 2019)

2.2.1.2. Datasets used

Some studies aim to make cross-country estimations of household energy consumption, particularly across Europe (Odyssee, Eurostat, or the European Community Statistics on Income and Living Conditions (EU-SILC)) as well as in the OECD countries

(Bouzarovski and Herrero, 2015; Jalas and Juntunen, 2015; Schaffrin and Reibling, 2015; Giovanni and Palma, 2017; EPEE, 2009). Other research uses single-country datasets, including non-European countries: the US (Sanquist et al., 2012), Canada, and China (Golley and Meng, 2012) and European countries: Switzerland (Stadelmann and Schubert, 2018), Finland (Laur et al., 2006), Germany (Gill and Moeller, 2018), the Netherlands, Poland, and the UK (Saunders, 2013; Fremstad et al., 2018; Brounen et al., 2012; Longhi, 2015; Bouzarovski, 2014). Some studies are based on the author(s)' own questionnaires (Ohler and Billger, 2014; Niemeyer, 2010; Kennedy et al., 2014; Sütterlin et al., 2011; Freire-González, 2017), while others involved conducting their own primary data collection (Jensen et al., 2018; Vadovics and Živčič, 2019).

We can see that the databases that have been used are widely variable, but include:

- national databases: e.g. the Statistical Office of Estonia Household Income and Expenditure Survey, and the UK Household Longitudinal Survey (UKHLS),
- surveys implemented by scientific institutions (Questionnaires of Alberta Survey conducted by the Population Research Lab (PRL) at the University of Alberta),
- international databases: e.g. Eurostat, European Community Statistics on Income and Living, The European Union Statistics on Income and Living Conditions, EU's Odyssey database for efficiency and consumption figures, and the European Community Household Panel.

Based on the literature review, most of the articles use national datasets in order to analyse patterns of household energy consumption.

2.2.1.3. Variables used

The variables authors used to model household energy consumption vary to a great extent. I collected through scientific search 32 scientific papers that estimated household energy use. After reviewing them, I assembled the variables from these papers. They are categorised into the following groups: 1. Household characteristics, 2. Energy use of the household, 3. Attributes of the property, 4. Socioeconomic data, 5. Environmental attitude, 6. Other. In the case of each variable, I counted how many times it was cited in the analysed papers. Table 2 shows the most variables most often used. Counting variables shows that 'annual income' was used most – in almost two-thirds of the sample of articles. Income was followed by the variable of 'energy-saving behaviours and attitudes', with nine cites. Then the variable of 'energy prices' and the variable 'number of household members' (structure of the family) were most popular, with 7-8 cites. Also, the variables 'housing conditions/level of energy efficiency'/dampness, leaking roofs, defective insulation, mould, utility cost, energy expenditure (proportion of income) and keeping dwelling warm, and how much energy is needed for the latter are used very often. The variables age, electricity consumption, whether the dwelling is located in a rural or urban area, size of dwelling, arrears on utility bills, level of education, as well as access to energy are also used in 4-5 cases in the analysed papers. In Table 2, I illustrate the more often used variables: the darker the cell, the more often the variable has been used to estimate household energy-use patterns.

Group of variables	Variables	No. of cites	Authors
1. Household characteristics	age of household head	4	Bartiaux et al., 2019; Ohler and Billger, 2014; Brounen et al., 2012; Sahakian and Bertho, 2018
	No. of household members (structure of the family)	7	Kennedy et al., 2014; Sanquist et al., 2012; Ohler and Billger, 2014; Brounen et al., 2012; Longhi, 2015; Schaffrin and Reibling, 2015
2. Energy use of the household	electricity consumption (kWh)	4	Golley and Meng, 2012; Salim et al., 2017; Laur et al., 2006; Brounen et al., 2012
	how much energy is needed to keep the household warm and for lighting	6	EPEE, 2009; Bartiaux et al., 2019, Bouzarovski and Herrero, 2015; Schaffrin and Reibling, 2015
	utility cost, energy expenditure (proportion of income)	6	Chitnis et al., 2013; Laur et al.; 2006; Longhi, 2015; Schaffrin and Reibling, 2015
3. Attributes of the property	size (no. of rooms)	4	Fischer, 2015; Fawcett and Darby, 2019; Schaffrin and Reibling, 2015; Sahakian and Bertho, 2018
	house conditions: dampness, leaking roofs, defective insulation, mould	7	EPEE, 2009; Schaffrin and Reibling, 2015, Charlier, 2014; Sharma and Singh, 2019; Bartiaux et al., 2016; Bouzarovski and Herrero, 2015; Schaffrin and Reibling, 2015
	rural/urban	5	Sanquist et al., 2012; Ohler and Billger, 2014; Laur et al., 2006
4. Socio-demographic	arrears in utility bills	5	Bartiaux et al., 2016; EPEE, 2009; Charlier, 2014;

data			Bouzarovski and Herrero, 2015
	level of education	5	Kennedy et al., 2014; Ohler and Billger, 2014; Longhi, 2015; Sahakian and Bertho, 2018
	annual income	20	Bartiaux et al., 2016; Chitnis et al., 2013; Brounen et al., 2012; Goll and Moeller, 2018; EPEE, 2009; Chancel, 2014; Fawcett, 2016, González et al., 2008; Bouzarovski and Herrero, 2015; Clarke-Sather et el., 2011; Salim et al., 2017; Kennedy et al., 2014; Saunders, 2013; Sanquist et al., 2012; Ohler and Billger, 2014; Laur et al., 2006; Longhi, 2015; Schaffrin and Reibling, 2015; Bouzarovski, 2014; Sahakian and Bertho, 2018
5. Environmental attitude	Energy-saving behaviors and attitudes	9	Bartiaux et al., 2016; Charlier, 2014, Brounen et al., 2013, Fischer, 2015; Monni and Smaliukiene, 2019; Kennedy et al., 2014; Sütterlin et al., 2011; Longhi, 2015; Sahakian and Bertho, 2018
6. Other	energy price	8	EPEE, 2009; Sanquist et. al 2012, Laur et. al 2006, Salim et. al 2017, European Climate Foundation, 2016; Fawcett and Darby, 2019 Bouzarovski and Herrero, 2015; Salim et al., 2017; Sanquist et al., 2012; Laur et al., 2006
	access to energy	4	González et al., 2008; Sanquist et al., 2012

Table 2: Summary of the most frequently used variables in household energy consumption analysis

2.2.1.4. Methods applied

After screening what kind of databases and kinds of variables authors use when analysing household energy consumption, I collect the methods they apply in their research, which I illustrate in Table 3.

Method used	Authors
input-output analysis using indirect and direct energy use	Golley and Meng, 2012; Saunders, 2013; Jalas and Juntunen, 2015; Freire-González, 2017
Economic models	Chitnis, 2013; Longhi, 2015; Freire-González, 2017
Specified models: logarithmic models	Ghosh and Blackhurst, 2014; Ohler and Billger, 2014
Specified models: probit models	Ohler and Billger, 2014
Models that assess panel data to estimate the long and short-term impacts and dynamics of different variables (e.g. income, socioeconomic factors, including the identification of vulnerable households) on energy consumption	Charlier et al., 2018; Salim and colleagues, 2017
Multinominal regression	Schaffrin and Reibling, 2015; Sanquist et al., 2012; Mulder et al., 2014; Kennedy et al., 2014

Table 3: Methods applied when assessing household energy consumption

In-depth qualitative analysis has also been applied, although this was in the case of 80 sustainable energy consumption initiatives (SECIs) in Europe selected from a larger 1000-item database (Jensen and colleagues, 2018; Heiskanen et al., 2018). Mixed methods involving quantitative and qualitative analysis, including in-depth, semi-structured interviews with household members, have also been used (Sahakian and Bertho, 2018) resulting in suggestions concerning reducing or improving household energy use.

Based on a review of the methods used for assessing household energy consumption, we can see that the most frequently used method is econometric modelling, involving multinomial regression. There are, however, articles that used qualitative data analysis to reveal the patterns of residential energy use. Therefore, I chose to assess Hungarian household energy consumption with econometric instruments, as well as in-depth semi-structured interviews with experts working in the field of energy and poverty because the capacity constraints of this dissertation did not allow me to carry out a significant number of interviews with household members. Therefore, I approached gatekeepers, who probably have an overview of Hungarian household energy use in relation to social justice; namely, concerning the energy-use patterns of the poor and marginalized.

2.2.1.5. Main findings of papers that estimated household energy consumption

Here, I summarize the main findings of the 32 papers that were reviewed.

1. Income

The most evident fact is that income levels are the primary predictors of material and energy consumption and GHG emissions. The promotion of a culture of consumerism in highly industrialized countries continuously redefines upwardly the expected basic level of comfort, which translates into growing consumption of materials and energy per-capita (Alfredsson et al., 2018). With regard to income, many scientists find that higher income groups consume more energy: the more you earn, the more, especially indirect energy you use (Li, 2011, Golley and Meng, 2012, Kennedy et al. 2014, Laur et al., 2006, Longhi, 2015, Bouzarovski, 2014; Schaffring and Reibing, 2015, Galvin, 2014; Büchsand et al., 2011). In Poland it is not only that the better off spend a larger absolute amount on energy than the poor, but energy also accounts for a larger proportion of their expenditure (Bouzarovski, 2014). In Hungary, however, this is not case: the poor and marginalized spend relatively more on energy (their energy cost/income ratio is higher) than the better-off (see more in the next chapter, 4.2). Sounders (2013) finds that high income earners consume a notably larger proportion of embedded energy than direct energy. More surprisingly, however, Salim et al. (2017) reveals that a 1% increase in human capital reduces energy consumption by a range of between 0.18% and 0.45%.

2. Poverty

Research (EPEE, 2009, Chancel 2014; González and colleagues, 2008) reveals that poor people are locked into a situation of high energy consumption because energy efficiency investments or even access to proper energy in general need capital, thus efficiency investments or adequate energy in most cases are not accessible to them. Therefore, to reduce household energy consumption, the opportunities of these vulnerable groups must be considered and enhanced. Charlier et al. (2018), for instance, suggests that the government should focus more on monetary poverty as a cause of low home improvement rates and consider subsidizing renovation costs as a potential solution. There is disagreement, however, about whether improving the energy efficiency performance of buildings can reduce energy consumption. According to Galvin (2014; Sharma and Singh, 2019; Lecca et al., 2014), energy efficiency measures for residential building stock naturally and automatically reduce domestic energy consumption, but the authors also emphasize that the rebound effect of energy efficiency is underestimated significantly, and thus more research is needed to reveal more precisely what drives consumption levels (Galvin, 2014). Lecca et al. (2014) estimate the impacts of household energy efficiency, concluding that when the direct household consumption of energy falls, the indirect consumption of energy also declines, reducing the total rebound. According to scholars, those who do not favour energy efficiency even suggest that energy efficiency measures are insufficient in themselves (Charlier et al., 2018; Saunders, 2013).

3. Environmental consciousness

The picture, however, is not that clear concerning whether environmental consciousness really impacts energy consumption. Some research (Sanquist et al., 2012, Galvin, 2014, Sahakian and Bertho, 2018) concludes that social and behavioural patterns also account for energy consumption. In line with this, Ohler and Billger (2014) reveal that self-interest has a bigger impact on energy savings than social/community interest, suggesting that energy policies will have a greater impact if they motivate self-interest rather than social interest. For instance, those people who are better organized tend to drive more efficiently, and thus save more. These people are also more aware of their residential energy consumption (Brounen, 2013). Sahakian and Bertho (2018) emphasize, however, the role of enhancing emotions through collective action and social learning in order to decrease energy consumption, while Niemeyer (2010) emphasizes the role that education can play in energy use reduction. There is research, however, which warns us that information about economic benefits that is typically communicated may not be enough to change people's behaviour and create less energy-intensive lifestyles (Fischer, 2015; Monni and Smaliukiene, 2019). Instead of economically rational motives, sufficiency-related behavioural changes (such as the purchase of appliances with low absolute energy consumption, or the reduction of the number of appliances in the household, sharing cars, etc.) (Fischer, 2015) or value-based approaches are needed to bring energy consumption down (Monni and Smaliukiene, 2019). One of the findings is that limiting areas of living (e.g. square meters of flats per capita) can bring down energy consumption (Fischer, 2015; Fawcett and Darby, 2019). Another group of studies argues, however, that behaviour only has a minor role in decreasing energy use, thus policies designed to improve citizens' pro-environmental behaviour have a questionable impact on energy use reduction (Longhi, 2015; ENABLE, 2017; Sütterlin et al., 2011). According to the so-called information-impact gap, the rich are aware of environmental problems, but are not aware of how their high-level consumption contributes to the acceleration of problems (Chancel, 2014), or are aware of the energy-related problem but are still unmotivated due to their comfort zone convenience (Longhi, 2015; ENABLE, 2017; Sütterlin et al., 2011).

4. Energy prices

There is debate concerning whether energy price has any role to play in energy consumption, as well as how energy prices need to be structured. One argument is that energy prices also play a role in household energy consumption (Galvin, 2014; Longhi, 2015). In contrast, Mulder and his colleagues (2014) find a limited role for energy prices in explaining variation in energy productivity, while climate conditions clearly impact energy productivity. Additionally, in relation to the structure of price, fixed energy bills need to be minimised to incentivize energy savings and support the participation of demand responses within market timeframes (European Climate Foundation, 2016; Fawcett and Darby, 2019). A fixed cost would ensure that all energy users share the cost of transmission, distribution, metering and billing infrastructure equally. Energy consumption, however, would be paid for separately in the form of rising block tariffs, which are designed so that the cost per kWh rises along with consumption. Furthermore, changing demand is also proposed by applying a premium charge for operating several large appliances at once (Fawcett and Darby, 2019)

5. Household composition

Additionally, some studies highlight that energy consumption also depends on household composition (Brounen et al., 2012; Longhi, 2015); namely, that one additional individual decreases per-capita energy expenditure on average by 32–38%. Moreover, energy consumption may also be affected by population density (rural vs urban) of the area where the dwelling is found (Brounen et al., 2012). Several pieces of research conclude that rural households tend to use more energy than urban ones (Büchsand et al., 2011; Sanquist et al., 2012; Fremstad et al., 2018; Gill and Moeller, 2018), in contrast to Longi's (2015) findings that energy expenditure is greater in urban regions than in rural ones. Beside density level, the energy efficiency conditions of the dwelling (type of housing, insulation, dampness, etc.) also play a role in household energy consumption (Bouzarovski and Herrero, 2015).

Research (Sütterlin et al., 2011; Longhi, 2015) claims that for any decrease in energy consumption to happen in full consideration of social justice, proper policy formulation is needed. Scientific recommendations include enhanced support for different strategies for different consumer groups to change their consumption (Sütterlin et al., 2011) as well as the consideration of the demographic-economic characteristics of energy consumption patterns, , beside physical ones, when designing energy efficiency policies (Longhi, 2015). Jensen et al. (2018) found that reducing residential energy use and related CO_2 emissions across society requires more complex approaches than exist today. This calls for more knowledge on the variation in energy use across households, social groups, and societies, but this is not well reflected in current relevant policy making. My dissertation contributes to this debate in terms of revealing whether an equal per-capita energy entitlement distribution would promote social justice, and, if not (as these authors foresee: Sütterlin et al., 2011; Longhi, 2015; Jensen et al., 2018), suggestions are made regarding how to modify the equal per-capita distribution method so that social justice is really enhanced.

2.2.2. Review of Hungarian household energy consumption

In this chapter, I summarise the factors found in the literature that affect or help specify Hungarian household energy use. At the end of the chapter, I also touch upon suggestions that have been made to mitigate the current negative situation.

In Hungary, people in the richest income decile (approximately 900,000 people) spend almost three times more on energy than the people from the poorest income decile (KSH, 2016a). The amount spent by the poorest, however, does not reflect non-reported energy resource consumption, such as non-officially collected firewood. Thirty-three percent of Hungarian households spend more than 15% of their income on energy (Kőszeghy, 2019; Jelinek, 2019), while 8.5% of households spend more than 25% of their income on energy (Kőszeghy, 2019). In terms of how income and wealth (measured in terms of financial instruments, non-financial instruments, and liabilities) relate to each other, the following data are available from 2016: the proportion of households without any wealth was 70% in the lowest income decile, while it was 19% in the highest income decile (Kolosi and Fábián, 2016). Wealth inequalities are much higher than income inequalities (Magyar Nemzeti Bank, 2019; Kolosi and Fábián, 2016). While the latter between the lowest and the highest income deciles is 7%, wealth inequality may be as much as 27-fold between the lowest and highest wealth deciles, even when 3-5% of the wealthiest population is removed from the sample (Kolosi and Fábián, 2016). According to another assessment carried out by the Hungarian National Bank, the decile of population with the least wealth even have a negative status, since their assets are less than their liabilities (Magyar Nemzeti Bank, 2019). Based on this data, we can assume that for those in the lower wealth deciles, affording energy represents a significant burden to households

On average, 74-76% of Hungarian household energy consumption goes on heating (MEKH, 2017; Pénzcentrum, 2019; Sáfián, 2019). This may be caused by the fact that in Hungary dwellings are typically overheated: 22C° is the average internal temperature in the winter for 66% of the Hungarian population, and 24% of households maintain an indoor temperature of 24 C° or more (ENABLE, 2019b). A typical dwelling in Vienna, for instance, consumes only half the energy consumed by a Hungarian dwelling with similar attributes (Enable, 2017b). Proper insulation could result in a 35-40% or even 61-65% reduction in household energy use during winter time, while during summer it could reduce by 5-7 Celsius the temperature in dwellings depending on the state of the walls. Thus through the latter not only could energy bills be halved, but health could be enhanced too by reducing the pollutants created from heating (Harmat and Vaszkó, 2017). Furthermore, the proportion of family houses in the Hungarian building stock is extremely high compared to in other EU states, especially Germany, and this covers a huge portion of household energy use (Enable, 2017b).

The cost dispersion of different energy types is the following: electricity (33.5%), piped gas (35.1%), solid fuels (19%), heat energy (9.5%), propane-butane gas (3%), which dispersion is illustrated in Figure 11.

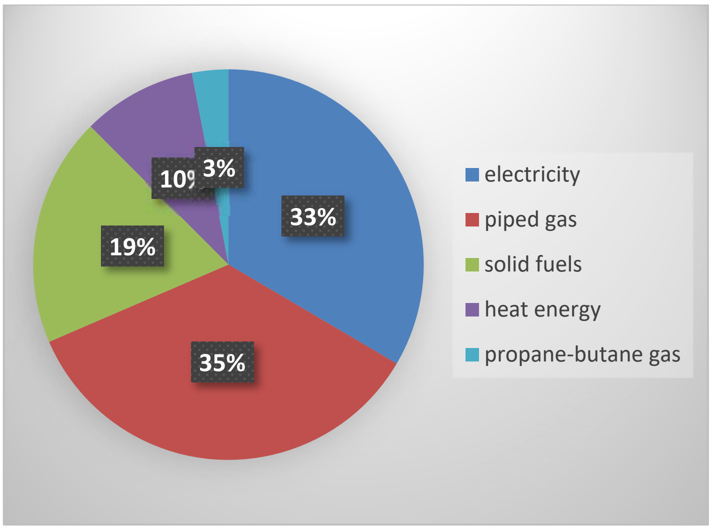

FIGURE 11: COST DISPERSION OF DIFFERENT ENERGY TYPES (AUTHOR'S CONSTRUCTION)

The use of solid fuels is more common in rural households. Approximately 33-39% of the 3.9 million occupied properties use solid fuel for heating (Mihalicz, 2016; Szentannai, 2019). There are, however, significant differences between income deciles. In the lowest income quintiles, almost half (48%) of households use only firewood for heating, while this proportion is only 10% in the highest income quintile (KSH, 2016a). Besides firewood, lignite is also used more by households in the low-income decile, although it is not suitable for household heating (Levegő Munkacsoport, 2017; Szurovecz, 2019). The types of coal usually sold in poorer settlements and burnt in homes are dangerous and have low heating value (elosztoprojekt.hu, 2019b). Annually, 1.8 million tonnes of wood and 400 thousand tons of coal (three-quarters of which is lignite) is used (Mihalicz, 2016). The reported amount spent on firewood usage, however, does not mirror the reality; namely, the fact that poorer households use more firewood for heating. According to 2009 data, the amount spent on firewood was the same in the lowest as in the highest income decile (Szajkó et al., 2009). The difference between the reported amount spent on firewood and the amount of firewood reported to be used may be attributed to the fact that 50-60% of the firewood that is used originates from non-reported sources (Levegő Munkacsoport, 2017; Szajkó, 2019).

The Hungarian building block is very energy inefficient (Ürge-Vorsatz, 2019). Two-thirds of the building stock is very outdated and badly in need of renovation (Sáfián, 2019). 23-27% of the Hungarian housing stock is in bad condition, with leaking and damp roofs and walls, rotting windows and floors (Jelinek, 2019; Eurostat, 2018a; Bertram and Primova, 2018). Fifty-five percent of the population lack additional insulation (Galev and Gerganov, 2018), and 2.5 million out of the 3.9 million do not receive any financial help with insulation (Enable, 2017b). These flats or houses consume much more energy than modern-engineered houses. Modernizing the quite old housing stock would significantly reduce household energy use. The Hungarian government has been in power since 2010, but has not attempted to play a role in fostering this modernization (Neuberger, 2017). Additionally, they have decided not to renovate pise houses (adobe houses), in which approximately one million, mainly marginalized people live (Feldmár, 2021).

Especially poor people are locked into living in inefficient houses (Ürge-Vorsatz, 2019). According to a national survey, 44-46% of respondents say that the major obstacle to reducing household energy costs for heating and cooling is a lack of loans and subsidies for renovation and refurbishment (Csutora, 2017). 11-14% of the Hungarian population are in arrears with their utility bills, while the EU average is 6.6% (Jelinek, 2019; Eurostat, 2020). Furthermore, 9.2% of the Hungarian population cannot keep their homes adequately warm due to financial constraints (Bertam and Primova, 2018, Neuberger, 2017). With the current proportion of 9.2%, Hungary is approaching the EU average (8.7%), which however is worsened by the inclusion of Bulgaria, Lithuania, Greece, Cyprus, and Portugal. Without these five states, the EU average would be less than 5% (Eurostat, 2018a). Residents in 56% of the dwellings in Hungary find it difficult to save on heating costs. Two-thirds of these residents turn down the heating during the night and when they are not at home. One-third of them do not heat their homes adequately even when they are at home, and one quarter do not heat all of the rooms in their dwelling and also heat with waste (KSH, 2016a), resulting in the fact that 15% of illegal waste burning is caused by poverty (Kantar Hoffman, 2017). Long-term support for energy efficiency and savings-related investment, however, would bring benefits (ENABLE, 2019b). Forty percent of CO_2 emissions is attributed to the operation of buildings (CEE Bankwatch, 2017), the savings potential of which is high. With proper renovation, the heating cost could be reduced to one quarter (Sáfián, 2019).

Most of the Hungarian population, however, are not interested in finding solutions for reducing their energy use or how to improve the energy efficiency performance of the flats/buildings they live in. This can happen since extra costs are not reflected in their bills (Csutora et al., 2017) (in the case of blocks of flats, the heating cost is paid by the whole house, or artificially reduced utility bills do not reflect the real price of energy – see more on this below). Low utility costs and a reduced energy price may be an obstacle to saving energy as residents are not motivated to change their energy-use practices (Sebestyén Szép and Nagy, 2017; Csutora et al., 2017). This finding is also mirrored in the results of a national survey: only 14% of respondents reported that they do not get enough feedback about their actual energy consumption (Csutora, et al., 2017).

Significant differences can be experienced in access to modern energy services between urban and rural areas (Bouzarovski et al., 2016b).

The government-led utility cost reduction programme that started in 2013 resulted in a 36-38% decline in household energy prices, but put a heavy burden on the industry, where energy prices are very high compared to other OECD states. Even with the utility cost reduction programme, Hungary is still among those OECD states where household energy prices are rather high compared to 26 other OECD states (Bartha, 2016). Between 2012 and 2018, the price of piped gas dropped by 26%, while the price for firewood (used more by poor households, as stated above) grew by 39% (elosztoprojekt, 2019, based on data provided by the HCSO – the Hungarian Central Statistical Office). The low electricity and gas prices do not fully reflect production costs. This contributes to a low responsiveness to energy prices that does not fully take environmental externalities into account (ENABLE.EU, 2017b). Sixteen percent of flats have district heating and 50% of flats haves central heating (Balogh et al., 2018), so in these properties dwellers cannot regulate the amount of energy they use for heating. This may also contribute to the fact that Hungarian dwellings are overheated (see also above, Enable, 2019b). On the other hand, according to the Enable project survey, 20% of respondents stated that their dwelling was too large, with a high heating cost, but they did not want to or could not afford to move (Csutora et al., 2017).

Furthermore, the government-led utility cost reduction of electricity and gas prices does not incorporate social justice considerations and favours those households where electricity and gas consumption are higher (poor rural households use more solid fuels; see above). Therefore, the government-led utility cost reduction programme does not favour poor households that use firewood for heating, thus it rather conserves the state of energy poverty (Bertram and Primova, 2018; Ürge-Vorsatz, 2019). This is mirrored in the state budget dedicated to social firewood for households, which is centrally distributed (Szurovetz, 2018). In 2016, only three billion Hungarian Forints (8.6 million EUR) was dedicated for this purpose, while for a family home improvements program the amount was 44 billion HUF (126 million EUR) and state support for property-saving banks was 54 billion HUF (154,3 million EUR) (Bajomi, 2018). Since 2016, the amount of firewood that is distributed has been defined according to the proportion of public workers and those aged above 80 within the population of a settlement. The state, based on these criteria, distributes social firewood among local authorities so that those settlements receive less which are heavily in need. The criteria and thus also distribution should favour those settlements where lots of people use firewood for heating and cooking, since wood often goes to those villages where it is not needed (Szurovetz, 2018). Distributing social firewood properly and sufficiently, however, could be managed for the cost of building one football stadium (Kovács-Angel and Katz, 2018), the latter which is a quite popular means of spending public money during the Orbán era in Hungary. During winter periods, if the social wood allowance has been used up, some people burn anything can provide some heat (Kovács-Angel and Katz, 2018), causing black smoke to emerge from chimneys. Air pollution arising from heating waste poses a medium or even a severe problem in half of all settlements. Most local governments try to solve this rising challenge through their fuel programs. One tenth of them, however, distribute coal or the even more polluting and dangerous lignite (elosztoprojekt.hu, 2019b) instead of wood among socially disadvantaged people (Harmat and Vaszkó, 2017).

The state also charges a high rate of VAT (27%) on energy, and applies a so-called Robin Hood tax on energy providing companies (31% above 19% of corporate tax, resulting in a total 50% tax), while taxing each meter of cable (125 HUF/meter), and putting a product tax on solar energy too. International energy agencies (OECD, IEA) as well as the EU have urged the Hungarian government to change these energy price regulation mechanisms (Bertram and Primova, 2018). Due to these steps, the EU has even initiated an infringement process (Jászai, 2017).

Due to the above-mentioned regulated energy prices, energy efficiency investments have longer payback periods (in the case of a full renovation. this can even be 20 years) (Bertram and Primova, 2018). Furthermore, these investments are not or hardly accessible for the 10-21% of the residents living in energy poverty (Bertram and Primova, 2018). In the post-communist countries, panel apartment blocks have poor energy efficiency because they are typically district-heated buildings whose residents are not urged to invest in efficiency since this would not reduce their energy bill (Tirado Herrero and Ürge-Vorsatz, 2012). Most energy-poor households, however, can be found in rural areas in rather large family houses (Fülöp and Fellegi, 2011). Due to the significant number of energy-poor households, Hungary is in second lowest place in the EU energy poverty ranking based on the so-called European Energy Poverty Index (OpenExp, 2019).

Some (Jászai, 2017) argue that the situation of Hungarian household energy consumption will not change while the major state interventions (far-reaching regulation of energy markets, artificially decreased household energy prices, expansion of nuclear energy) remain the government's main steps for defining energy-use patterns. Furthermore, more financial support for renovation as well as changing the comfort of heat is needed. Additionally, practical advice on easy-to-use techniques, and appropriate but not too detailed information underpinned by concrete examples from households with similar problems would be useful for reducing household energy consumption (Csutora et al., 2017).

Based on the theoretical literature review underpinned by the concept of ecological economics, however, I assume that Hungarian energy consumption patterns will not become more sustainable until absolute energy-use caps are developed and implemented. In order to tackle social inequality issues, such as energy poverty, caps should be implemented the incorporate social justice concerns. My empirical research aims to contribute to the debate on developing proper energy-capping schemes that do this.

3.EMPIRICAL RESEARCH

My research focuses upon analysing instruments that target household energy consumption, since household energy consumption plays a huge role in the final energy consumption picture. Furthermore, policy tools called Personal Carbon Trading (PCT) schemes that have been developed and partly implemented to limit household energy consumption have received significant attention. Even though we are aware that energy consumption is increasing, and many technologies and suggestions are on the table to reduce it, policy making is still not in the situation to be able to step in and change the energy production and consumption patterns. Furthermore, there are also concerns about whether the implementation of the suggestions for reducing energy consumption would create benefits for all members of society. Based on the literature reviews (see Chapter 2), we need to be very careful when designing and formulating energy-capping schemes to ensure that, besides environmental benefits, they also serve the interests of marginalized, disadvantaged groups and thus promote not only environmentally sustainable but also socially just and sufficient energy use. Among the justice theories, I consider throughout my research distributive justice, defined both by environmental or climate justice, and sufficiency concepts (Chapter 2.1.2). Namely, the fact that sufficient energy needs to be ensured for all, and it should be defined who can use more energy than their share, to what extent, and with what justification. Furthermore, attached to the concept of energy poverty as energy injustice, I also consider in my research procedural justice as access to information, as well as recognitional justice, as the poor and marginalized have to be recognized and supported by society.

Furthermore, there is lack of research that would reveal energy-saving strategies and energy-related characteristics of dwellings, both of which significantly influence energy consumption patterns. These strategies and characteristics may include, inter alia, what kinds of energy source are used for heating, and whether the whole dwelling is heated to an adequate temperature. Research that targets these challenges would contribute not only to the analysis of energy consumption patterns, but also to an examination of circumstances, conditions, and efficiency-defining energy consumption patterns, as well as help define possibilities for their enhancement. My dissertation aims to fill this knowledge gap.

To answer my research questions (Chapter 1.4):

Q1. What are the interlinkages between residential energy consumption and social justice?

Q2': How would an energy entitlement scheme with an equal per-capita distribution mechanism influence the interconnectedness of residential energy consumption and social justice in Hungary?

…first, I carry out quantitative research, which is followed by qualitative research. The aim of the latter is to help the interpretation and underpin the validity of the quantitative results, especially when interpreting quantitative data poses difficulty. Based on this, the primary method of my research is quantitative, validated by qualitative research.

Since the theme of this dissertation is complex, it cannot address some issues. The first issue which is not covered in this dissertation is the mechanisms that define the energy-use reduction of other sectors beside the residential one. Proper regulation of these sectors is needed because these industries are highly responsible for fossil energy use and produce a vast amount of carbon. Second, I need to make the assumption that an energy-use cap is being developed and implemented in a country in which political decision makers are really striving to promote the well-being of their citizens and are not influenced by their own greed or by corporate lobby interests, or by any interests that run counter to use of a (decreasing) energy cap. Furthermore, in this hypothetical country (albeit using Hungarian data, thus assuming it is Hungary) the defined cap on energy use would be set in line with scientific targets to ensure that the country stays within her ecological limits.

3.1. Quantitative research method, analysis and results

3.1.1. Hypotheses

Through quantitative research, I aimed to find the answers to the following research questions (Chapter 1.4):

Q1. What are the interlinkages between residential energy consumption and social justice?

Q2': How would an energy entitlement scheme with equal per-capita distribution mechanism influence the interconnectedness of residential energy consumption and social justice in Hungary?

Therefore, I defined three hypotheses for testing.

H1: Household clusters can be formed based on variables that define costs spent on different energy sources.

H2: Social justice related variables significantly influence the household clusters defined as in H1.

H3: The implementation of an energy entitlement scheme with an equal per-capita distribution mechanism would not benefit all poor households.

Through setting up H1 and H2, I aimed to find out whether there are different groups of households based on their energy costs (thus H1 is a precondition for the other hypotheses), as well as whether these groups differ in terms of social-justice-related indicators. I measure the fulfilment of H1 by examining if clusters of households can be generated based on the money they spend on different energy sources. Household energy consumption can be estimated either using data on the amount of energy used (Golley and Meng, 2012) or data about energy expenditure (Bouzarovski, 2014). I chose to create clusters based on energy costs, since studies that deal with residential energy consumption use this variable and it can be found in the database I used. I assess the fulfilment of H2 if social-justice-related variables are correlated with the clusters defined in H1 as well as have a significant impact on them. Revealing the potential correlation and impacts of these variables in terms of their extent and direction contributes to answering my first research question (Q1. What are the interlinkages between residential energy consumption and social justice?).

Through setting up H3, I aimed to find out whether the goal of an energy entitlement scheme based on equal per-capita distribution aimed at enhancing social justice, including benefiting the poor, would be met if it is implemented. Literature (Chapter 2.1.4.5) suggests that the implementation of a scheme with an equal per-capita allowance would not in all cases benefit the poor, since energy consumption varies among nations, and it can happen that the latter not only spend proportionately more on energy, but also in absolute terms. Therefore, it is questionable whether current unjust energy consumption patterns can be eliminated via implementing energy-use caps based on equal per-capita distribution. In the light of this, I aimed to find out whether the poor really use less energy in absolute terms in Hungary, based on which the scheme might need refinement. I measure the fulfilment of H3 by revealing if the cluster(s) containing more marginalized households (i.e. whose social-justice-related variables are less favourable) use more energy than the Hungarian average. Testing H3 contributes to answering my second research question (Q2: How would an energy entitlement scheme with an equal per-capita distribution mechanism influence the interconnectedness of residential energy consumption and social justice in Hungary?), with help from the implications of the qualitative research.

3.1.2. Quantitative research method

To carry out the quantitative research, I first chose the database from which the most appropriate data could be obtained. I aimed to identify variables from the chosen database based on the justice theories mentioned earlier (environmental or climate justice, sufficiency, and energy poverty as energy injustice) and concepts (distributional, corrective, procedural and recognitional justice). Then, I compiled a list of variables and finally defined the method for quantitative data analysis. I end this chapter by revealing the research gaps in my quantitative analysis and how these gaps can at least partially be filled by my qualitative research.

3.1.2.1. Selection of database

Based on the literature reviews and also by contacting researchers, I screened the options for accessing and analysing small-scale datasets containing all the data that were needed to provide the answers to my research questions. I found three possible datasets, but none of them turned out to be appropriate for my research. A survey carried out by GreenDependent Institute since 2011 has collected information from residents on how they can reduce their household energy consumption (GreenDependent Intézet, 2020). The survey contains data on energy consumption habits and patterns, as well as on how the energy consumption of survey participants has changed throughout their participation in the survey. Social as well as economic data, however, are missing from the questionnaire. A survey that targeted residential energy use was carried out in Kispest, one of the districts in Budapest, Hungary (Bouzarovski and Thomson, 2017). This survey, however, lacks detail of the money the sample household spent on different energy resources. Furthermore, the Budapest University of Technology and Economics carried out a survey of household energy consumption patterns in the Borsod-Abaúj-Zemplén county of Hungary, which covers one of the most marginalized areas of the country. This survey, however, also lacks social and economic data (e.g. about education and employment), from which implications for social justice could have been elaborated (elosztoprojekt.hu, 2020). A survey containing all the data that I would have needed to answer my research questions was carried out in a small settlement called Ág, in Baranya County in Hungary (Társadalomtudományi Kutatóközpont et al., 2018). Participants of the survey, however, are not representative of the Hungarian population, since in general they are members of the poorer strata of society, living in a small rural village that lacks many social services.

Considering the small-scale surveys that were available, I decided to search for better nationwide data. Therefore, I tried to access Hungarian national data through different channels. Through Eurostat, I could access the Hungarian Central Statistical Office database on the Household Budget Survey (HBS). This dataset is reliable and used by several researchers; however, the most recent dataset of the HBS is from 2010. There is another reason not to use this dataset even though it contains per household spending on different types of energy sources (gas, electricity, solid fuel, liquid fuel, heat energy, fuels and lubricants): the dataset lacks information on dwelling conditions (such as size of flats, year of renovation, quality of dwellings including damp walls and leaking roofs) and some information related to the justice theories about sustainable and fair energy use. There are variables and proxies related to justice theories and concepts, however, which can be found in the EU-SILC database (EU Statistics on Income and Living Conditions). Through an official agreement between the Corvinus University of Budapest and the Hungarian Central Statistical Office,[1] I was finally able to access the Hungarian dataset of SILC from 2018.

3.1.2.2. Selection of variables

From an assessment of 32 papers found in the literature (Chapter 2.2.1), I collected 38 variables. I separated them into the following groups of variables: 1. Household characteristics, 2. Energy use of the household, 3. Attributes of the property, 4. Socioeconomic data, 5. Environmental attitude, 6. Other. Then, I counted how many times each variable was used, and grouped them according to the frequency of their use. By far the most frequently used variable was 1. income, followed by 2. environmental attitude, 3. number of household members (structure of the family), 4. energy price and 5. dwelling conditions (dampness, leaking roofs, defective insulation, mould). These variables were followed by variables defining 6. how much energy is needed to keep the household warm, and for lighting, 7. the utility cost - energy expenditure (proportion of income), 8. whether the dwelling can be found in a rural or urban area, 9. arrears in utility bills, 10. level of education. These variables were followed by 11. age of the household head, 12. electricity consumption, 13. size of the dwelling, 14. access to relevant energy types.

Beside the results of the review of papers on household energy use, I analysed two articles more thoroughly that had similar research goals to mine and collected the variables used therein. Schaffrin and Reibling (2015) estimated household energy consumption using the variables 1. disposable household income in purchasing power parity, 2. inactive members, 3. maintaining home warmth, 4. lighting, 5. type and size (no. of rooms), 6. dampness, 7. electric appliances, 8. utility cost, 9. rent + interaction terms of income*equipment and income*no. of. rooms. Brounen et al. (2012) used variables: 1. electricity consumption (kWh), 2. gas consumption (m^3), 3. age of the household head, 4. number of persons in the household, 5. family composition, 6.

[1] after 10 month of continuous negotiation between BCE administration and the HCSO office

ethnicity, 7. annual income, and 8. heating type to describe household energy consumption habits. Table 4 shows the most commonly used variables in the international literature and also those that were used by the two selected papers.

Type of variables	Variables most often used in the international literature	Schaffrin and Reibling (2015)	Brounen et al. (2012)
Household characteristics	age of household head No. of household members	None	age of the household head No. of household members
Energy use of the household	electricity consumption how much energy is needed to maintain required temperature and for lighting utility cost, energy expenditure (proportion of income)	electrical appliances keeping the house warm lighting utility cost rent + interaction terms of income*equipment and income*no. of. rooms	electricity consumption gas consumption (m3) heating type
Attributes of the property	size (no. of rooms) house conditions: dampness, leaking roofs, defective insulation, mould rural/urban	type and size (no. of rooms) dampness	None
Socio – demographic variables	annual income arrears in utility bills level of education	disposable household income in purchasing power parity inactive members	annual income composition ethnicity
Environme	Energy-saving behaviours and	None	None

ntal attitude	attitudes		
other	energy price	-	-

Table 4: Variables used in the literature in general and in the two selected scientific papers

There is no data that assesses the relation between wealth and energy consumption (see more on the relation between income and wealth in Chapter 2.1.2). Therefore, in my empirical research that was based on the papers assessed in the international literature review on household energy consumption, I use income, income deciles, and thus income inequality as one of the variables that refers to social justice. Based on the theoretical literature review, income inequality is also reflected in distributional justice within social justice theories that are linked to the environment.

In addition to income, I also considered which other variables to include into my analysis that influence social justice based on the justice theories linked to sustainable and fair energy use. According to the sufficiency concept, a sufficient amount of energy should be distributed fairly among all members of society. The sufficient amount of energy can be linked to some of the variables I used in my research. These include arrears in utility bills / ability to keep flat warm / ability to make ends meet / extent of burden of dwelling maintenance cost / income. Some of these variables (arrears in utility bills / ability to keep dwelling warm) are also reflected in official EU indicators that measure the level of energy poverty (Thema and Vondung, 2020). In connection with energy poverty as an energy injustice concept, proxies related to procedural justice are also reflected in the SILC database, such as the level of education and economic activity of household members, and the geographical location of the dwelling. As the capability approach appears in both sufficiency and energy poverty concepts linked to fair and sustainable energy use, I also aimed to find proxies for it among the variables that were used. These include education (higher education enhances capabilities through enhanced information gathering and understanding), health (better health status enhances capabilities), food-and-beverage-related costs (eliminating hunger means capabilities are enhanced), beside the above-mentioned variables (e.g. ability to keep dwelling warm).

Regarding social justice and exclusion in Hungary the following factors play a significant role: level of education, employment status, number of children (household size), and size and geographical location of dwelling (Herpainé Márkus et al., 2011), which findings are in line with justice theories related to sustainable and fair energy use. Even though environmental attitude and energy price are quite often used in the international literature, based on the Hungarian situation (the government-led utility reduction program that results in bills that do not reflect real energy consumption, and the lack of motivation for saving energy; Chapter 2.2.2) I did not put these variables into my analysis.

Based on both theoretical and methodological literature, I modified the compiled list of variables based on the international literature review. Furthermore, I extended the list with the variables used in a co-authored article by colleagues from MTA KRTK on Hungarian food consumption habits (Bakucs et al., 2017). Moreover, I read the Hungarian Central Statistical Office (HCSO) report "What we live in" (KSH, 2016b) as well as checked which kinds of variables were used during the Evaluate project (Bouzarovski et al., 2016a), based on which I completed my list with further relevant variables. The final list contained 37 variables grouped into the following four categories: 1. Household characteristics, 2. Energy use of the household, 3. Attributes of the property, 4. Socioeconomic data.

With this final variable list, I screened the variables of the HBS and SILC database of the Hungarian Central Statistical Office, and found more relevant variables in the SILC database. Thus I used the Hungarian SILC database from 2018 for my quantitative analysis. In order to answer the quantitative research questions, I use the variables included in Table 5 from the SILC database.

Groups of variables	Variable name
1. Household characteristics	number of household members
	age structure of household
2. Maintenance and energy costs	heating source (energy type used for heating - created variable)
	cost of rent
	loan for dwelling
	total housing cost
	cost of energy
	share energy (created variable: energy cost per total
	cost of electricity
	cost of gas
	cost of firewood, other solid fuels
	cost of central heating
	Car-related energy cost (e.g. fuel)
3. Attributes of property	settlement type
	region
	dwelling type (created variable)
	size of dwelling
	bathroom, shower, WC in dwelling
	quality, conditions of dwelling (including whether the floor & roof is damp, conditions of doors and windows, pollution in the local neighbourhood)
4. Socio-demographic data	level of education
	economic activity of household members
	cost of food and beverage
	spending on culture+vacation, education, health,
	burden of dwelling maintenance cost
	arrears in utility bills/mortgage
	ability to keep dwelling warm
	ability to make ends meet
	satisfied with place of living
	income decile

Table 5: Variables used in the quantitative research

3.1.2.3. The chosen methodology

In this section, the hypotheses and the methods for their testing are presented. In order to answer my research questions (Chapter 1.4) I used different econometric and multinomial statistical methods. To carry out multinomial regression and discriminant analysis, I first needed to create household clusters based on the variables for different energy resources (cost of electricity, cost of gas, cost of firewood and other solid fuels, cost of central heating). With cluster analysis, I tested my first hypothesis:

H1: Household clusters can be formed based on variables that define spending on different energy sources.

Before developing the clusters, I defined the outliers based on the Mahalanobis test (Todeschini et al., 2013), and eliminated these outliers from of my analysis. In order to test my hypothesis, I carried out k-means cluster analysis of the defined clusters (Szüle Borbála, 2016, Kovács, 2014; Simon, 2006). In the cluster analysis, I investigated whether the amounts spent on each type of energy source played a significant role in defining the clusters.

After creating household clusters based on the amount spent on different energy sources, I investigated the interlinkages between the created clusters and variables related to social justice. Therefore, my second hypothesis is:

H2: Social justice related variables significantly influence the household clusters defined as in H1.

H3: The implementation of an energy entitlement scheme with an equal per-capita distribution mechanism would not benefit all poor households.

Before testing my second and third hypothesis, I used a data reduction technique. With cross tabulation I distinguished those variables that correlated with the cluster membership. For this, I transformed scale variables to ordinal scale ones. After I revealed those explanatory variables that correlated cluster membership significantly, I tested my hypothesis with multinomial regression (Bakucs et al., 2017, Wooldridge 2012) as well as with discriminant analysis (Füstös and Tárnok, 2017). Using both quantitative methods, I was able to define the extent and direction of influence of social-justice-related variables on the household clusters. Multinomial logistic regression is used when more than two outcomes are in the dependent variable and are nominal, so no order of outcome exists. Predictor or independent variables explain the dependent variable. Discriminant analysis is similar to logistic regression, since it determines the probability of group membership and variety of roles of explanatory variables in specific clusters. Discriminant analysis uses discriminant functions to classify cases and the probability of their classification into a certain group – in my case, the developed clusters. Coefficients indicate how the function contributes to the cluster membership. The advantage of this approach is that it does not require as strict mathematical and statistical assumptions as regression (e.g. a lack of multicollinearity is not a precondition in the discriminant function). With these two statistical methods, I aimed to reveal the interlinkages between household energy use patterns as well as some dimensions of social justice defined by the specified variables.

In the regressions, I choose the independent variables from the data of the SILC database based on social justice theories (Chapter 2.1.2), and on international as well as Hungarian methodological literature reviews (Chapters 2.2.1. and 2.2.2). These variables are the following: income, level of education, employment status, age structure of the household, amount spent on recreation, amount spent on education, amount spent on health, dwelling conditions and location, arrears in utility bills, and the ability to keep the dwelling adequately warm during winter. Furthermore, I created three variables for using in the regression models, all of which reflect social justice. One of them was the so-called *share_energy,* which is the proportion of energy expenses to total housing cost. This reflects what kind of financial burden paying energy bills causes. This created variable is also found in the EU indicators to reveal the level of energy poverty. The other one is the so-called heating source, which reveals the energy source used for heating. This can be connected to social justice, since solid fuels are mainly used by poorer households in Hungary (see more in Chapter 2.2.2). The third one is the dwelling type, which reveals the kind of dwelling (in relation to different dwelling conditions: year of build, type of wall, dwelling size, etc.). This variable can also be connected to social justice, since the energy efficiency of different types of dwelling varies significantly in Hungary (see more in Chapter 2.2.2).

It is questionable whether cluster(s) of households containing more marginalized households use more or less energy than the Hungarian average. Therefore, my third hypothesis is:

H3: The implementation of an energy entitlement scheme with an equal per-capita distribution mechanism would not benefit all poor households.

In order to test the fulfilment of H3, I identified cluster(s) containing households that are socially disadvantaged (their social-justice-related variables are less favourable), but at the same time use more energy at the individual level than the per-capita Hungarian average. Therefore, energy entitlement schemes with equal per-capita distribution mechanisms would have an non-beneficial impact on them.

In my analysis, I also tested assumptions related to discriminant analysis as well as related to multinomial regression, such as the multicollinearity and homoscedasticity of the residual, and if its expected value equals zero and has a normal distribution.

3.1.3. Analysis and results of the quantitative research

In this chapter, I summarize the results of the quantitative research, detailing the steps of analysing and evaluating household-level energy use data provided by the SILC database. I started analysing secondary data on Hungarian residential energy use, starting with data cleaning. After this, I created clusters based on the spending on different energy sources. Then I carried out cross tabulation, multinomial regression and discriminant analysis on the latter clusters to reveal their differences from a socioeconomic point of view.

3.1.3.1. Cleaning the database and creating new variables

First, I investigated whether I needed to clean the database. This required identifying the reasons for the missing values. I asked for some clarification questions from the HCSO, and checked the data sheet that should be filled in by household reference persons. It turned out that missing values indicated that the relevant household did not spend anything on that item (e.g. an empty cell in the database on education-related costs meant that the household did not have education-related expenditure, based on the household reference person's opinion).

After clarifying the reason for the missing values, I created three new variables, as mentioned in the methodology chapter (Chapter 3.1.2) The first one was the so-called *share_energy*, which is the proportion of energy expenditure and total housing-related costs. The second one was the so-called *heating_source*, which reveals what kind of energy source is primarily used for heating. I created this variable using the other three variables found in the original database. The first variable reveals the primary source used for heating; and the second one reveals the secondary source (if it existed) used for heating. There are, however, plenty of households that did not provide any information regarding their heating source. I then checked the third variable, which also reveals the energy source used for household heating, but asked in a different way. I revealed that those households that did not provide an answer about their primary and secondary heating source typically chose central heating as their heating type in another question. Therefore, I did not delete those households from the database that did not provide information regarding their primary and secondary heating sources, but instead created the *heating_source* variable to tackle this challenge. Since the variables for primary and secondary heating sources are nominal variables, they can be compared using cross tabulation. Using the Chi test, I revealed that the correlation between these two nominal variables is significant. Using other indicators (Phi for the smaller and Cramer's V for the bigger sample) can reveal how strong their association is, I found that these two nominal variables are dependent upon each other. Based on these findings and using the third variable that revealed the heating type of the households, I created a new variable, called *heating_source*. I created six subcategories under this variable, the dispersion of which are illustrated in Figure 12.

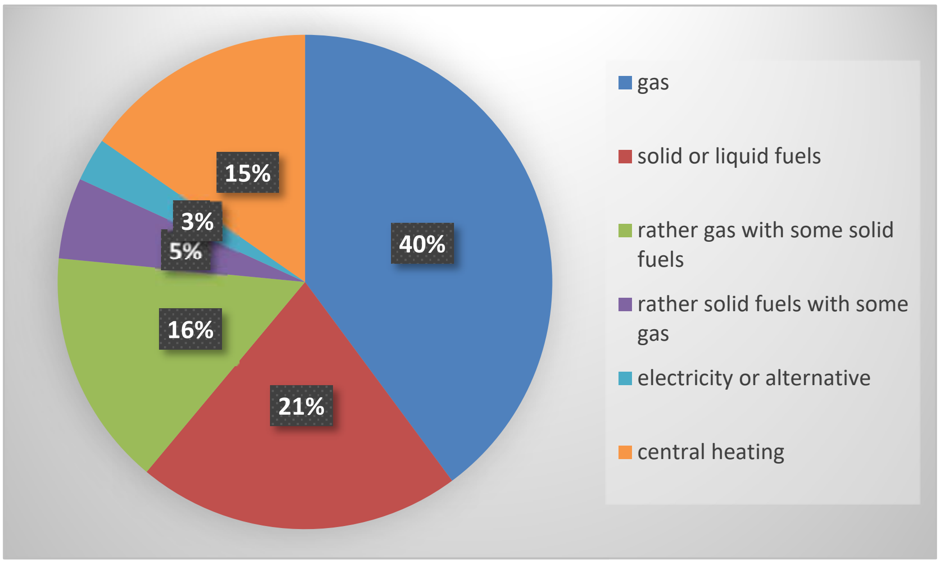

FIGURE 12: DISPERSION OF DIFFERENT ENERGY TYPES USED BY HOUSEHOLDS FOR HEATING

The third newly created variable is called *dwelling_type,* which specifies dwelling conditions. These conditions include whether the dwelling is a family house or an apartment block, the year of build, as well as the type of walls of the dwelling. Based on these conditions I created six subcategories (see Figure 13, below) under this variable, for which I used the methodology developed by a Hungarian expert group (AACM, 2020, p.3).

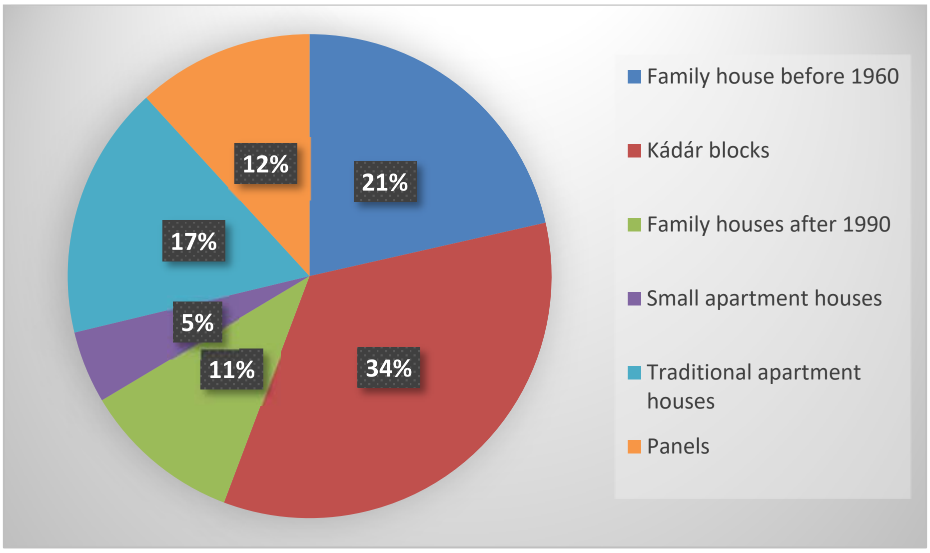

FIGURE 13: PROPORTIONS OF DIFFERENT TYPES OF DWELLINGS OF HUNGARIAN HOUSEHOLDS

The subcategories of the created *dwelling_type* variable and their distribution are illustrated in Figure 13, above.

3.1.3.2. Cluster analysis based on energy cost variables

After data cleaning and creating the new three variables, I carried out cluster analysis, using k-means clustering. For this, I used energy-cost-related variables: spending on electricity, on gas, and on 'other' fuels (I created the latter by summing up spending on firewood, on coal and on other solid and liquid fuels, as well as on bottled gas), and spending on central heating. In the database, however, energy spending at the household level is presented, from which I calculated the calibrated and rounded per-capita spend (Department of Business, Energy and Industrial Strategy, 2020). The results of this calibration can be seen in the below Table 6.

Number of household members	Calibrated and rounded values*
1	1
2	1.3
3	1.4
4	1.7
5+	1.8

* single-member households use one unit of energy; households with more members use the energy units based on the calibrated and rounded values

Table 6: Calibrated and rounded values at for individual-level spending on energy

With the calibrated and rounded values, I apportioned the energy costs of the households. Based on these calibrated energy cost variables (calibrated per-person spending on electricity, gas, central heating and other fuels) I carried out k-means cluster analysis. I chose k=4 since in the case of k=3, households that mainly use central heating are not distinguished in a separate cluster. In the case of k= 5 non-adequate sample numbers can be found in all created clusters. Clusters with a small sample size, also can be called offal clusters, and should disappear from the statistical analysis. I used a pairwise option with 50 iterations. The pairwise option here is justified since in this database there are many missing values. In this case, the weight variable, which is meant to reveal representativity, could be violated.

To test whether the created cluster centroids (i.e. the clusters) are significantly different from each other, I used ANOVA and also the Levene test for homogeneity for variance. The latter test shows whether the variance of samples (in my case, the three clusters) are equal. In Figure 14 (below), the results of these tests are shown.

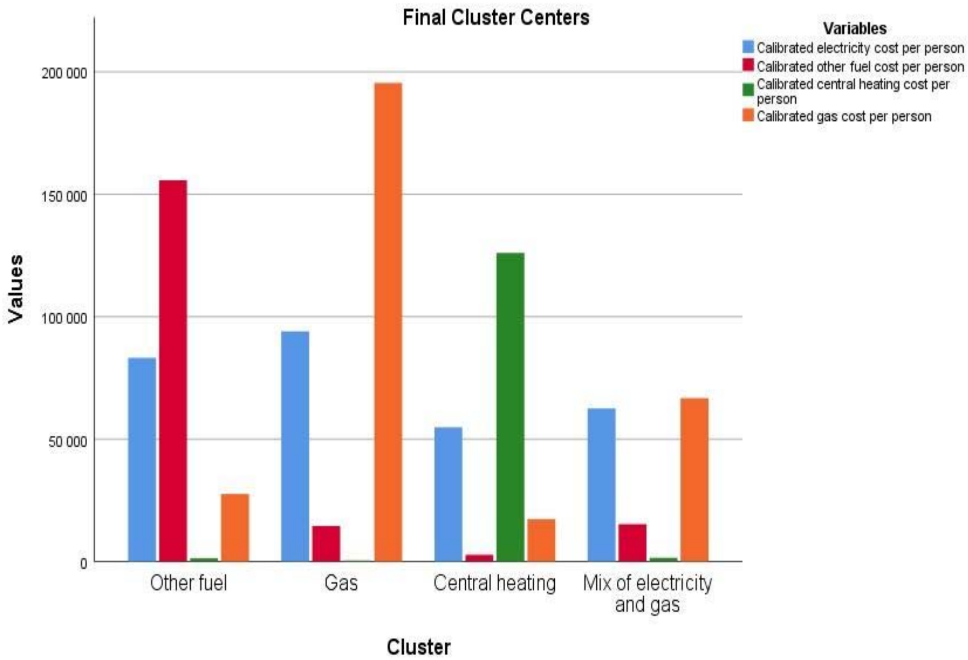

FIGURE 14: CLUSTERS CREATED BY CALIBRATED PER-PERSON ENERGY COST VARIABLES (SPENDING ON GAS, ON ELECTRICITY, ON CENTRAL HEATING, AND ON OTHER FUELS INCLUDING FIREWOOD, COAL, LIQUID FUELS AND BOTTLED GAS)

Both the ANOVA and the Levene statistics were significant, based on which fact we can say that the groups (clusters) are statistically significantly different. In Figure 14, the four clusters are illustrated.

3.1.3.3. Cross-tabulation for determining explanatory variables

In Chapter 3.1.2., I listed all the socioeconomic- (including social-justice) related variables I used in the quantitative analysis. In considering justice theories and the methodological literature review, I chose 29 variables from this list to be used in the cross tabulation. These variables (illustrated in Table 7, below) were used to reveal socioeconomic differences among the clusters.

Groups of variables	Variable name	Codes in the database	Type of variable
1.Household characteristics	1. number of household members	HLETS	ordinal
	2. age of household members	DF22	nominal
2.Maintenance and energy	3. heating source (energy type used for heating - created variable)	heating_source	nominal
	4. rent	Rent	scale
	5. share energy (created variable: energy cost and household maintenance cost ratio)	share_energy	scale
3.Attributes of property	6. settlement type	DF2	nominal
	7. region	DF5	nominal
	8. dwelling type (created variable)	dwelling_type	nominal
	9. size of dwelling	HD035M	scale
	10. bathroom, shower in the	HH081M	nominal
	11. WC in dwelling	HH091M	nominal
	12. conditions of dwelling	HLAKA	nominal
	13. whether roof is damp	HH041M	nominal
	14. whether floor is damp	HH042M	nominal
	15. whether doors and windows are inadequate	HH043M	nominal
	16.pollution, environmental problems	HS180	nominal
4.Socio-demographic data	17. level of education of the reference person	DF21	nominal
	18.economic activity of household members	DF27	nominal
	19. loan for dwelling	HLAKHI	nominal
	20. spending on food and beverages	SUM01	scale
	21. education cost	SUM10	scale
	22. health cost	SUM06	scale
	23. spending on culture + entertainment + vacation	SUM13	scale
	24. ability to keep dwelling warm	HH050	nominal
	25. burden of dwelling	HS140	nominal
	26. arrears in utility bills/mortgage	HS021M	nominal
	27. ability to make ends meet	HS120M	nominal
	28. satisfied with place of living	SZINT	ordinal
	29. income decile	DF1	ordinal

Table 7: Variables assessed in the cross tabulation: assessment of their inclusion in the regression analysis

To reveal which of the 29 variables is correlated with cluster membership variable, I used cross tabulation. For this, I transformed scale variables and, where appropriate, nominal variables to ordinal ones. Before the cross tabulation, I checked the deviations of each of the 29 variables based on their histograms. As appropriate (when there were not so many cases in each category), I merged categories to ensure that each category possessed an adequate number of cases. Then I carried out cross tabulation between the 29 ordinal or nominal variables and the cluster membership variable. According to this cross tabulation, all the 29 explanatory variables are significantly correlated with the cluster membership variable. During the cross tabulation, I also examined which of the variables of these 29 can be used in the multinomial regression and in the discriminant analysis.

In relation to household characteristics, the proportion of one-member households is highest in the case of households that primarily use central heating, and the lowest in the case of those that primarily use other fuels (44% and 27%, respectively), as illustrated in Figure 15, below. There is no significant difference between the four clusters in terms of two- and three-member households, representing on average 32% and 15% of all households, respectively. Eight per cent of households that primarily use central heating, 10% of households that primarily use gas, 14% of households that primarily use other fuels, and 15% of households that primarily use a mixture of electricity and gas have four members. In the case of households with five or more members, the proportion of households that primarily use other fuel is the highest (10%), while this proportion is 6%, 6%, and 3% in the case of electricity and gas mixture, gas heated, and centrally heated households, respectively. In terms of the age of the household members I did not find a significant difference among the clusters, thus I did not put this variable into the multinomial regression or into the discriminant analysis.

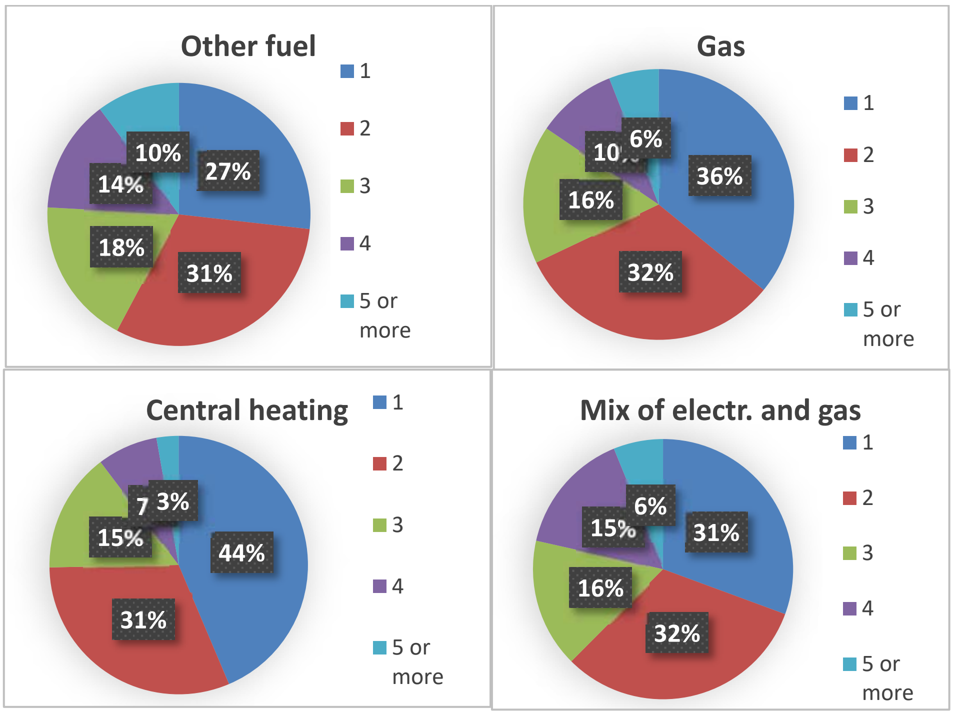

FIGURE 15: DISTRIBUTION OF DIFFERENT HOUSEHOLD SIZES IN THE FOUR CLUSTERS

Regarding household energy and maintenance cost, according to the cross tabulation, those who primarily use gas and those who primarily use other fuel to satisfy their energy demands less often pay rent (only 4-5% of the total) than those who use central heating or a mixture of electricity and gas (17% and 13%, respectively). Since in the sample the proportion of those households that do not pay rent is large, varying between 83% (in the case of centrally heated households) to 96% (in the case of households using other fuels), I did not put this variable into the regression. Furthermore, with 19% of those households that use other fuels for heating and cooking (primarily firewood), the *share_energy* variable is higher than 0.31, while this is true of 16% of gas-heated households and only 5% and 6% of centrally heated and mixed-fuel households, respectively (see more in Annex II).

Regarding the *heating_source* variable, not surprisingly, other fuels dominate in households of the Other fuel cluster, and gas in the gas cluster. Electricity and gas including alternative energy resources are represented in households with mixed fuel use, while, not surprisingly, central heating is overrepresented in the central heating cluster. The clusters were created using cost variables representing spending on the respective type of energy, while the *heating_source* variable was created based on respondents' answers about the primary source of energy they use for heating. Accordingly, putting this variable into the cross tabulation with the cluster membership variable serves as a means of double checking the creation of clusters based on spending on energy.

In relation to the characteristics of the dwelling, from the dwelling size and the household members variables I created a new variable to reveal living area per person. The distribution of this variable is the following: app. 60% of primarily gas-using households and app. 45% of primarily-other-fuel-using households have a living space of more than 40 square meters per person. This proportion is 35% and 37% in the case of central-heating- and mixed electricity-and-gas-using households, respectively (see more in Annex II). There is no significant difference between the clusters concerning whether households possess bathrooms, and how many of the latter. Therefore, I eliminated this variable from the explanatory variables in the multinomial regression and the discriminant analysis. Ninety-six percent of households have a toilet in their dwelling, so I did not include this variable into the multinomial regression and the discriminant analysis. However, among those who do not have a toilet in their dwelling there is a difference among clusters. Ten percent of those who primarily use other fuel do not have a flush toilet, which proportion is significantly less in other clusters (0.5%, 0%, and 3% in the case of gas, centrally heated and mixed electricity-and-gas-using households, respectively).

The ‘dwelling condition’ variable has four levels: excellent, good, satisfactory, and bad. Regarding this variable, 10% of households that primarily use other fuels live in dwellings that are in bad condition, while this proportion is 1%, 1%, and 7% in households that primarily use gas, central heating, and a mixture of electricity and gas, respectively. There are another three variables related to dwelling condition: whether the roof is damp, whether floors are damp, and whether windows and doors are inadequate. For all the three variables, households in the cluster of ‘other fuels’ perform worst. Namely, 7% of them have a damp roof, 15% of them have damp floors, while almost 30% of them have inadequate doors and windows. These proportions are significantly smaller in other clusters. In the case of mixed electricity and gas households, the proportions are 6%, 9%, and 21%, respectively. In the case of gas-heated households, these proportions are 2%, 6%, and 14%, respectively, while in centrally heated households the proportions are 2%, 2%, and 10%, respectively. These dwelling-condition-related variables and their dispersion are summarized in Table 8.

Dwelling conditions	Other fuel	Mix of electr. and gas	Gas	Central heating
Bad condition	10%	7%	1%	1%
Damp roof	7%	6%	2%	2%
Damp floor	15%	9%	6%	2%
Inadequate doors and windows	30%	21%	14%	10%

Table 8: Distribution of variables indicating bad dwelling conditions of households among the four clusters

In Table 8, we can see that the most common problem related to dwelling conditions is having inadequate doors and windows, which makes it harder heat homes adequately and pay energy bills.

I also checked the distribution of households in each of the four clusters with one, two, three, or four dwelling-related problems among those households that have at least one dwelling-condition-related problem. Findings are summarized in Table 9 below.

No. of dwelling related problems	Other fuel	Mix of electr. and gas	Gas	Central heating
1 problem	50%	64%	76%	83%
2 problems	24%	21%	18%	17%
3 problems	21%	11%	6%	0%
4 problems	6%	4%	0%	0%

Table 9: Dispersion of households in each cluster with one, two, three or four dwelling-related problems (among households that have at least one issue)

In Table 9, we can see that in the Other fuel cluster the dispersion of households in which three or four dwelling-condition-related problems emerge is the highest among those households that have at least one dwelling-condition-related problem. This means that in this cluster an accumulation of dwelling-related problems can be found most frequently.

In terms of whether there is pollution or other environmental problems in the neighbourhood of the dwelling, 14% of the centrally heated households reported problems, while 10% of the cluster of mixed electricity and gas, 8% of other-fuel-using households, and 7% of gas-using households.

In terms of settlement type, proportionally by far the most (57%) households that use other fuel can be found in small settlements, while proportionally by far the most households (54%) that use central heating can be found in big cities, an additional 29% of households that use also central heating can be found in Budapest. In the other two clusters, households that use mainly gas or a mixture of electricity and gas are distributed in a more balanced way among the four categories of settlement types: 1. Budapest, 2. big cities, 3. small sites and 4. villages, with the greatest proportion of households from both clusters in small cities (36% and 30% in gas-heated and in mixed-electricity-and-gas-heated clusters, respectively) (see more in Annex II). Since there are no significant differences in terms of the distribution of households according to region in the clusters, I did not enter the region variable into multinomial regression or the discriminant analysis.

In terms of the created *dwelling_type* variable, in the Other fuel cluster, proportionally the most households (49%) live in so-called Kádár-era blocks,[2] which are family houses built between 1960 and 1989, and an additional 36% of the mainly other-fuel-heated households live in family houses built even before 1960 (shown in Table 10). Also, almost half (47%) of the primarily gas-using households live in Kádár-era blocks, while 23% of them live in family houses built before 1960, but 14% (almost 10%) of them live in family houses built after the Kádár era and in traditional apartment houses, respectively. Central-heating-using households can be found most often in panels (64%) followed by traditional apartment houses (29%). Households belong to the mixed electricity and gas cluster are represented in every kind of dwelling type, but most often they can be found in Kádár-era blocks (28%), followed by traditional apartment houses (28%), but they are also well represented (20%) in family houses built before 1960.

Dwelling type	Family houses bef. 1960	Kádár-era blocks	Family houses aft. 1990	Small apartment	Traditional apartment	Panel-block housing
Other fuel	36%	49%	13%	1%	1%	0%
Gas	23%	47%	14%	5%	10%	1%
Central heating	0%	3%	1%	3%	29%	64%
Mix of electr. and gas	20%	28%	11%	8%	28%	5%

Table 10: Distribution of dwelling types within the distinguished clusters

Related to socio-demographic indicators, in all clusters half of the households spend annually between 300,000 and 700,000 HUF (867 and 2023 EUR[3]) on food and beverages. The other half of the households that use mainly central heating or a mixture of electricity and gas spend less on food and beverages than the other half of households that use mainly gas or other fuels. Regarding educational costs, 84% of households reported no expenditure, therefore I did not use this variable in the multinomial regression and the discriminant analysis. Among the rest, however, households that use mainly a mixture of electricity and gas spend more on education than the other households. In relation to health costs, there was no significant difference between the clusters defined by households' primary energy type. In general, approximately 15% of the dataset was missing in each cluster for this parameter, while approximately one-third of households in each cluster spend between 75,000 and 200,000 HUF (217 and 578 EUR) / year on health-related costs, and the other third spend less, while the rest (app. 13-20%) spend more. Additionally, 47% of primarily gas-using households, 45% of households using central heating, 40% of households that use a mixture of electricity and gas, while only 31% of households that use other fuels spend more than 200,000 HUF (578 EUR) on culture, entertainment, and vacations (see more in Annex II).

[2] János Kádár was a communist politician and leader of Hungary between 1956 and 1989.
[3] Based on the currency exchange rate on 2 June 2021

I investigated five variables related to living conditions: 1. whether households can keep their homes warm, 2. whether household maintenance is a significant burden on them, 3. whether they can pay their bills on time, 4. whether they can meet their needs, and, 5. what their level of satisfaction is with regard to their living conditions (see Table 11). In all cases, households that use mainly other fuel reported the worst situations. Ten percent of them reported that they are not able to keep their homes warm; this proportion was 8% in those households using a mix of electricity and gas, 5% in those households using mainly gas, while 1% in those that use central heating the most. For thirty-three percent of other-fuel-using households paying for their household maintenance cost is a significant burden, while this proportion is 23%, 19%, and 18% in the case of mixed electricity and gas-, central heating-, and gas-using households, respectively. Almost 90% of households reported to having no arrears in utility bills, thus I did not use this variable in the regression. Among those who reported to being in arrears, it happened most frequently in households that primarily use other fuels (it had happened once in the case of 4% of them, and more than once to 11% of them), followed by those households that use a mix of electricity and gas (3% and 7% respectively), then households with central heating (2% and 5% respectively, while only 1% and 3% of gas-heated households had had arrears in utility bills once or more than once, respectively. Almost half of the households that heat with other fuels can meet their needs only with difficulty, while 36%, 28%, and 25% of households claim this in the mixed electricity and gas, and gas and central heating clusters, respectively. Those less satisfied with their place of living were again those who live in dwellings that primarily use other fuels (using a range of between 0 and 10, the proportion of these households was highest in all of the lowest 4 categories), followed by those who use a mixture of electricity and gas, then those that use central heating, while those that use gas are the most satisfied.

Living conditions	Other fuel	Mix of electr. and gas	Gas	Central heating
Cannot keep their homes warm	10%	8%	5%	1%
Maintenance is a significant burden	33%	23%	18%	19%
Arrears in utility bills	15%	10%	4%	7%
Satisfy their needs only with difficulty	50%	36%	28%	25%

Table 11: Distribution of living-condition-related variables in the four clusters

There is no significant difference in terms of whether households are repaying a loan for their dwellings among the clusters, therefore, I did not use this variable in multinomial regression and the discriminant analysis. In terms of income, however, there is a difference between the clusters. Between 9% and 12% of the households that use either other fuel or a mixture of electricity and gas can be found in each income decile, from the first (with the lowest income) to the fifth. This approximately balanced distribution of households is also similar in the other five income deciles (from the sixth to the tenth) but the proportion of households varies between 9% and 12% in each of the income deciles of the ‘Other’ fuel, and mixture of electricity and gas-using clusters. An exception to this balanced distribution is the proportion of households in the tenth income decile (the richest decile) in the Other fuel cluster, which is only 6%. In contrast, in terms of the clusters that use gas and central heating, the higher the income decile, the greater the proportion of households in it. The proportion in the case of gas heating households is the largest in the five top income deciles (see more in Annex II).

In terms of the education of the reference person in the given households, in the cluster of other fuels, only 9% of the latter had a high level of education, while this proportion is much higher (varying between 25% to 30%) in the case of households that use mixed electricity and gas, central heating, or mainly gas, respectively (see more in Annex II). In terms of the economic status of the household members I did not find significant differences among the clusters, thus I did not put this variable into multinomial regression and the discriminant analysis.

To determine more deeply the probability of group membership based on the variables assessed above, I applied multinomial logistic regression and discriminant analysis.

3.1.3.4. Multinomial logistic regression

In multinomial logistic regression, the independent variable is the cluster membership variable previously created by the energy cost variables. Based on the results of the cross tabulation (Chapter 3.1.3.3), I left 20 predictor variables in the regression that are shown in Table 12, below.

Groups of variables	Variable name	Codes in the database	Type of variable
1. Household characteristics	1.number of household members	HLETS	ordinal
2. Maintenance and energy costs	2.heating source (energy type used for heating - created variable)	heating_source	nominal
	3.share energy (created variable: energy cost and household maintenance cost ratio)	share_energy	ordinal
3. Attributes of the property	4.settlement type	DF2	ordinal
	5.dwelling type (created variable)	dwelling_type	ordinal
	6.size of dwelling	living_area_pps	ordinal
	7.conditions of dwelling	HLAKA	ordinal
	8.whether roof is damp	HH041M	ordinal
	9.whether floor is damp	HH042M	ordinal
	10.whether doors and windows are inadequate	HH043M	ordinal
	11.pollution, environmental problems	HS180	ordinal
4. Socio-demographic data	12.level of education of the reference person	DF21	ordinal
	13.spending on food and beverages	SUM01	ordinal
	14.health cost	SUM06	ordinal
	15.spending on culture+entertainment+vacation	SUM13	ordinal
	16.ability to keep dwelling warm	HH050	ordinal
	17.burden of dwelling maintenance cost	HS140	ordinal
	18.ability to make ends meet	HS120M	ordinal
	19.satisfied with place of living	SZINT	ordinal
	20.income decile	DF1	ordinal

Table 12: Variables used as explanatory variables in the multinomial regression

Before carrying out the regression, I transformed the values of dichotomous variables so that if a household is characterized by having a certain feature (a damp roof, environmental problems in the neighbourhood, etc.), the value was defined as 1; if it lacked it, the value was defined as zero, instead of two (as it was in the original dataset provided by HCSO).

This transformation enables the proper analysis of these dichotomous variables and transforms them from nominal ones to original ones. In the regression, the null hypothesis is the following:

Null hypothesis: There is no significant impact of the independent variables on the dependent variable.

The alternative hypothesis is the following:

Alternative hypothesis: There is a significant impact of the independent variables on the dependent variable.

In my case, the null hypothesis is that the predictor variables have no significant impact on the cluster membership variable. According to the model-fitting information in the analysis, there is a significant relationship between the independent variables and the dependent variable (its *p* value is less than 0.05). According to the Likelihood ratio test, all predictor variables contribute significantly to the model, a finding which is in line with the cross-tabulation results.

The multinomial regression examines the overall impacts of the predictor variables on the dependent variable; however, I tried to reveal which of the examined 20 variables play the leading role in affecting the cluster membership variable. According to the Parameter estimates, we can see what kinds of role predictor variables play in the clusters. In my case, the baseline cluster was defined as the Other fuel cluster (mainly solid fuel – e.g. firewood)

Gas cluster

In this cluster, all 20 variables had a significant impact on grouping households into this cluster. Compared to the baseline cluster (the Other fuel cluster) households in this cluster are less likely to have a damp roof ("no" damp roof: B=0.102[4], Wald=63,214[5], p<0,05) and inadequate doors and windows ("no" for inadequate doors and windows: B=0,143, Wald=400,506, p<0,05). These households (not surprisingly) much more frequently use gas as a heating source (B=2,496, Wald=3153,955, p<0,05) than households in the baseline cluster. Households belonging to this cluster are more frequently located in Budapest than households from the baseline cluster (B=1,214282, Wald=7723,558, p<0,05). Households in this cluster are able to keep their dwellings warm (for subcategory they cannot make their dwelling warm: B=-0,181072, Wald=325,978, p<0,05) than households belonging to the Other fuel cluster.

Central heating cluster

In this cluster, all variables had a significant impact on grouping households into this cluster. Compared to the baseline cluster (the Other fuel cluster) households in this cluster were less likely to have a damp roof ("no" damp roof: B=0,804991, Wald=1204,250088, p<0,05), damp floor ("no" for damp floor: B=0,152900, Wald=43,153, p<0,05) or inadequate doors and windows ("no" for inadequate doors and windows: B=0,380, Wald=999,347932, p<0,05). Households in this cluster (not surprisingly) much more frequently use central heating as a heating source (in the case of all *heating_source,* B is strongly negative compared to the baseline category, which is central heating), than households in the baseline cluster. In this cluster, household have a smaller *share_energy* ratio (proportion of energy cost as a share of the total housing cost) than households in the baseline cluster (in the category where *share_energy* is between 0 and 0.1, B=1,159311, Wald= 3661,138, p<0,05, and in the category, where *share_energy* is between 0.11 and 0.15, B=1,462583, Wald=4534,367817, p<0,05).

[4] B estimated multinomial logistic regression coefficient
[5] Wald chi-square test tests the null hypothesis that the estimate equals 0.

Households that belong to this cluster are more frequently found in Budapest than households from the baseline cluster (B=1,214282, Wald=7723,558, p<0,05). Households in this cluster are better able to keep their dwellings warm (for subcategory they cannot make their dwelling warm: B=-1,494564, Wald=3909,857, p<0,05).

Mixed of electricity and gas cluster

In this cluster, all variables had a significant impact on grouping households into this cluster. Compared to the baseline cluster (the Other fuel cluster) households in this cluster are less likely to have inadequate doors and windows ("no" for inadequate doors and windows: B=,183, Wald=881,105915, p<0,05). Households in this cluster unsurprisingly use gas much more frequently as a heating source than households belonging to the baseline cluster (B=1,181224, Wald=783,861, p<0,05), and much less frequently use Other fuels than households belonging to the baseline cluster (B=-4,085776, Wald=9546,349662, p<0,05). In this cluster, household have smaller *share_energy* ratio (proportion of energy cost as a share of the total housing cost) than households in the baseline cluster (in the category where *share_energy* is between 0 and 0.1, B=3,591396, Wald=120446,924, p<0,05, and in the category, where *share_energy* is between 0.11 and 0.15, B=2,095899, Wald=67071,530, p<0,05).

Other fuel cluster

In this cluster, all variables had a significant impact on grouping households into this cluster.
Compared to other clusters, households in this cluster more often have damp roofs and inadequate doors and windows. Furthermore, households in this cluster are less able to keep their dwellings warm and are less frequently found in Budapest than households belonging to other clusters and the central heating clusters. Moreover, in this cluster, household have higher *share_energy* ratio (proportion of energy cost as a share of the total housing cost) compared to households in the central heating and the mixed clusters.

3.1.3.5. Discriminant analysis

I carried out discriminant analysis to further examine whether the clusters differ from each other based on the 20 explanatory variables. To carry out the discriminant analysis properly, I aimed to ensure that all ordinal explanatory variables were more or less normally distributed. Therefore, I checked their distribution according to their histograms even before carrying out the cross tabulation. In the case of those variables whose distribution was not normal, I merged categories to avoid empty cells in the categories. Furthermore, I also ensured that the analysis met the assumption of discriminant analysis that the number of cases in the smallest case cluster was greater than the number of the explanatory variables (20).

After this, I created normally distributed explanatory variables and carried out the discriminant analysis. In the analysis, the test for the equality of group means shows whether the means of the explanatory variables are statistically different in the different clusters. For this test, Wilks' Lambda coefficient is used, which has a similar role as the correlation coefficient (correlation coefficient = 1 - Wilks' Lambda) in explaining correlation. The value of Wilks' Lambda should be significant for every variable, which is the case in my research, meaning that all explanatory variables have different mean values in each of the created clusters. This indicates that the clusters are distinguished properly. The correlation matrix of the discriminant analysis shows that predictors are not strongly correlated; here, the furthest value from zero is 0,581. This indicates that the problem of multicollinearity has not arisen. In the structure matrix in Table 13, the three discriminant functions that were created can be seen. The first discriminant function, in which the *heating_source* and the *dwelling_type* variables have greatest explanatory power, explains the most from the model. Both of these variables are created ones, which means that their creation was worthwhile. Looking at the second function, the *settlement type* variable and the ordinal version of the third (created) variable *share_energy_ordinal* play a significant role in the discriminant functions and thus in creating the clusters. This means that the creation of a share_energy variable was also worthwhile.

Structure Matrix

	Function		
	1	2	3
Heating source	,716*	,550	-,027
Dwelling type	,658*	-,408	,150
Pollution, environmental problems	,060*	-,003	-,059
Settlement type	-,284	,619*	-,312
Ordinal share energy	-,171	,519*	,352
Income decile	,065	-,096	,738*
Satisfied with place of living	,029	-,142	,419*
Education of the ref person	,106	-,384	,412*
Ordinal living area per person	-,101	,036	,399*
Dwelling condition	-,054	,154	-,370*
Ability to make ends meet	,065	-,197	,361*
Doors and windows are inadequate	-,069	,140	-,323*
Burden of dwelling maintenance cost is significant	,060	-,194	,306*
Ordinal health cost	-,026	-,036	,249*
Floor is damp	-,077	,137	-,245*
Ordinal cult and vac cost	,019	-,126	,236*
Household number	-,080	,080	-,235*
Ability to keep dwelling warm	,058	-,052	,228*
Roof is damp	-,029	,045	-,204*
Ordinal food and beverage cost	-,084	,143	,204*

Pooled within-group correlation between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.
*. Largest absolute correlation between each variable and any discriminant function

Table 13: Structure matrix of the discriminant analysis

The discriminant analysis classification statistics in Table 14 show how what proportion of cases are classified according to the discriminant functions into the clusters they originally belonged to. On average, 64% of cases are grouped correctly, which is a much greater a posteriori probability than the a priori probability, which is 25%. This proportion, however, is significantly larger for cases belonging to Other fuel and central heating clusters (73% and 88%, respectively), which indicates that cases originally belonging to these clusters are even more satisfactorily grouped by the model than the average 64%.

Classification Results[a]

		Cluster Number of Case	Predicted Group Membership: Other fuel	Gas	Central heating	Mix of electr. and gas heated	Total
Original	Count	Other fuel	658534	158818	6341	83633	907326
		Gas	215984	558880	7586	151194	933644
		Central heating	8277	17246	512322	44167	582012
		Mix of electr. and gas	313231	211264	99356	646517	1270368
	%	Other fuel	72,6	17,5	,7	9,2	100,0
		Gas	23,1	59,9	,8	16,2	100,0
		Central heating	1,4	3,0	88,0	7,6	100,0
		Mix of electr. and gas	24,7	16,6	7,8	50,9	100,0

a. 64,3% of original grouped cases correctly classified.

Table 14: Discriminant analysis classification statistics

Since it cannot be done in a 3D space, and the third discriminant function does not play a significant role in distinguishing clusters, the clusters containing the cases are illustrated using a two-dimensional diagram. Figure 16 illustrates the cases and their clusters in a two-dimensional space, defined by the first two discriminant functions.

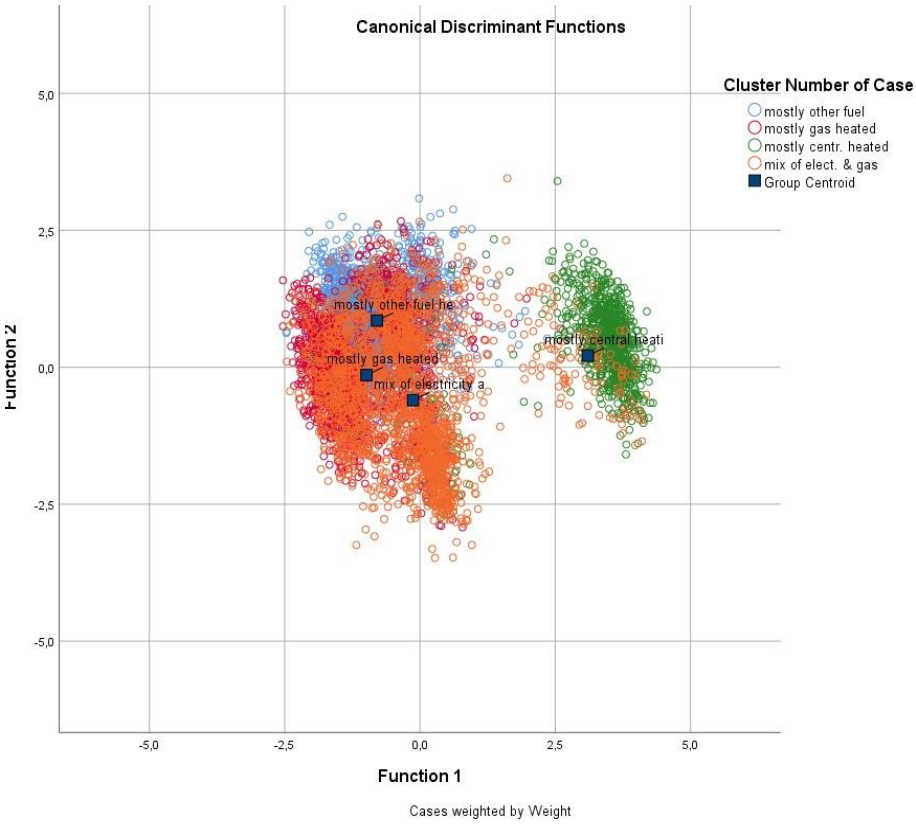

FIGURE 16: CASES AND THEIR CLUSTERS IN TWO-DIMENSIONAL SPACE, DEFINED BY THE FIRST TWO DISCRIMINANT FUNCTIONS

In Figure 16, even though the clusters are distinguished, we can see that the cluster of central heating differs the most from the other three, while the gas cluster is more similar both to the Other fuel and the mixed clusters.

Impacts of equal per-capita energy quota scheme on households

To reveal how the equal per-capita distribution mechanism of an energy capping scheme would impact households in the four distinguished clusters, I analysed the created *energy_cost_pps* variable, which reveals energy cost at the individual level in households with different numbers of members (see more about its creation in 3.1.2). From the descriptive statistics it turned out that on average, Hungarian households spend 229,049 HUF (655 EUR) / person / year on energy related expenses. Half of the Hungarian population spend less than 196,758 HUF (563 EUR) / person / year on energy-related expenses, while the other half spend more than this amount. The distribution of energy cost at the individual level is illustrated in Figure 17 (below).

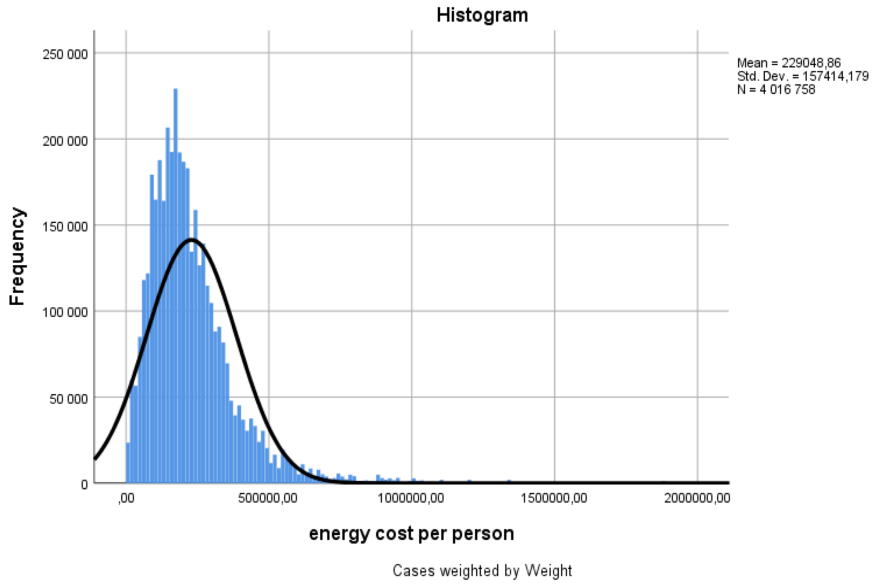

FIGURE 17: THE DISTRIBUTION OF ENERGYCOST_PPS VARIABLE

Beyond the Hungarian average, I investigated whether on average households belonging to the four clusters spend more or less than the Hungarian average. Table 15 below contains this information.

Clusters:	Other fuel	Gas	Central heating	Mix of electricity and gas	All households
Mean	239,408	313,342	227,263	158,699	229,049
Median	210,000	271,561	192,000	137,226	196,758

Table 15: Mean and median of spending on energy (energy cost, in Hungarian Forint) at the individual level in different clusters

Table 14 shows that households that mainly use gas pay much more, while other fuel-using households spend slightly more on energy than the Hungarian average. Central-heating-using households mirror the Hungarian average in terms of energy expenditure, while households belonging to the mixed cluster pay much less than the Hungarian average.

3.1.3.6. Evaluation of quantitative results considering the hypotheses

To find the answers to my research questions (Chapter 1.4), I first distinguished clusters based on spending on energy types. Furthermore, I chose from the database (SILC) or created new variables from existing ones to define 1. household characteristics, 2. maintenance and energy costs, 3. attributes of the property, 4. socio-demographic data. In all the four variable groups, social-justice-related variables are found, which I incorporated based on both theoretical as well as methodological literature. I ran different statistical tools on the thus created clusters to find out whether the chosen variables related to social justice significantly influenced them.

According to the multinomial regression, all the chosen 20 explanatory variables play a significant role in defining the clusters. Based on the discriminant analysis, clusters are clearly distinguished in a two-dimensional space defined by the first two discriminant functions. *Heating_source* and *dwelling_type* created variables have the greatest explanatory power in terms of defining the clusters from among the 20 explanatory variables. The first one, *heating_source,* nicely reflects what I found from the cross-tabulation; namely, results mirror the creation of clusters by energy cost variables, since the *heating_source* variable reveals households' primary source of energy used for heating. The *dwelling_type* variable consists of six categories, from family houses to traditional apartment blocks (see more in Chapter 3.1.3.1). The discriminant analysis shows that this newly created variable has a significant role in distinguishing clusters. In other words, households in different dwelling types use different energy sources to satisfy their energy needs. According to the first discriminant function of the discriminant analysis, it can be seen that the higher the value of the *heating_source* variable (1. Gas, 2. Solid fuel, 3. Rather gas with some solid fuel, 4. Rather solid fuel with some gas, 5. Electricity or alternative, 6. Central heating), the larger the *dwelling_type* variable (1. Family houses before 1960, 2. Kádár-era block, 3. Family houses after 1990, 4. Small apartment houses, 5. Traditional apartment houses, 6. Panel-blocks). This means that gas and solid fuels are typically used in family homes, while electricity and central heating in apartment houses, including panel-blocks. The second discriminant function shows that *settlement type* and the ordinal version of the *share_energy* variables also play a significant role in distinguishing the clusters. If the value of one of these increases (1: Budapest, the capital, 2: big cities - county seats, 3: towns, 4. villages), the value of the other variable is liable to increase too. Namely, the smaller a settlement in which a household is situated, the greater the proportion of the spending on energy in the total housing cost.

Based on the quantitative analysis, I was able to measure the fulfilment of the three defined hypotheses:

H1: Household clusters can be formed based on variables that define costs spent on different energy sources.

H2: Social justice related variables significantly influence the household clusters defined as in H1.

H3: The implementation of an energy entitlement scheme with an equal per-capita distribution mechanism would not benefit all poor households.

According to my quantitative research, H1 is confirmed, since clusters of households can be generated based on spending on different forms of energy using k-means cluster analysis as well as discriminant analysis. H2 is also confirmed due to the fact that the variables that reflect elements of social justice…

- correlate with the cluster membership variables based on the cross-tabulation,
- influence cluster membership variables significantly as dependent variables in the multinomial regression,
- (the mean values of which, as dependent variables) are statistically different in the different clusters according to the discriminant analysis.

H3 is also confirmed, since I found that households of clusters with the least favourable values of variables reflecting social justice (namely, the Other fuel cluster) spend at the individual level more on energy than the Hungarian average. Through the confirmation of the hypotheses and carrying out the quantitative research, I was able to answer my research questions to some extent. Below, I summarize household characteristics in line with each of the four clusters, thereby revealing interlinkages between residential energy use and poverty, as well as the potential impacts of energy entitlement schemes based on the results of cross-tabulation, multinomial regression, and discriminant analysis.

Households that use mainly Other fuels

More people usually live than in households that use Other fuels (mainly firewood) than in other dwellings. The proportion of one-member households is the smallest in this cluster, while the proportion of five-or-more-member households is the greatest. The Share_energy variable is the greatest in these households, meaning that they proportionally spend more on energy from the total housing cost than households in other clusters. The share for energy is high, even though these households may use energy from unreported or illegal sources that are not accounted for in this proportion. This means that covering energy costs represents an even larger burden for these households than the 'share_energy' proportion shows. Households that primarily use other fuel and gas live in larger dwellings than those which primarily use central heating or a mixture of electricity and gas. In addition, the proportion of those households that do not have toilets is by far the greatest in households belonging to this cluster. Furthermore, proportionally more households that use Other fuel live in dwellings that are in bad condition. Households of this cluster are have the worst dwelling conditions (damp roofs, damp floors, and inadequate doors and windows), followed by households belonging to the cluster of mixed use of electricity and gas. Furthermore, in this cluster an accumulation of dwelling-related problems is found most frequently; namely, the dispersion of households having three or four dwelling-condition-related problems is greatest among those households that have at least one problem of this kind. Such poor dwelling conditions indicate a greater heating burden as well as more difficulty paying energy bills.

Households that primarily use Other fuels can be found mainly in small settlements. Those households which are found in small settlements spend proportionally more on energy from the total housing cost than those households that are found in bigger settlements (their share_energy ratio is the largest among the clusters, as earlier mentioned). This is in line with the fact that their living conditions (see more below) are the worst of the four clusters. Almost 85% of these households live in Kádár-era blocks or family houses built before 1960.

Food-and-beverage-related costs are higher in households that primarily use other fuels, similarly to households that primarily use gas to satisfy their energy needs. However, households that use other fuels spend significantly less on culture, entertainment, and vacations than households belonging to the other three clusters.

Regarding their living conditions (1. keeping their homes warm, 2. covering household maintenance cost, 3. paying their bills on time, 4. ability to meet their needs and 5. the level of satisfaction with their living space) they are the worst in the case of households using Other fuel. According to the income decile, households in each income decile in this cluster are represented in a balanced way, except for households in the richest income decile that use other fuels (they are underrepresented) This means that there are proportionally more households in the lower income deciles that use other fuel, followed by a mixture of electricity and gas, than those who use central heating or gas, while in the latter cluster proportionally more households can be found in the five top income deciles. In terms of the education of the reference person in the given households, in the cluster of Other fuels there are proportionally far more less educated people than in the other three clusters.

In relation to how an energy quota scheme based on equal per-capita energy entitlement distribution would impact those households that primarily use firewood and coal, I found that the implementation of such a scheme would not benefit them automatically. Households in this cluster spend slightly more on energy than the Hungarian average. In the case (the application of an equal per-capita distribution based on the Hungarian average that does not incorporate social justice considerations), households in this cluster would not be able to save any of their quota from their allocated budget that they could sell to receive financial support in exchange. In contrast, their quota budget would not cover their energy cost, so they would be forced to buy extra quotas to satisfy their energy needs. This overconsumption of energy compared to the Hungarian average is reported, even though it turns out from the interviews that many of these households use energy from non-reported or illegal sources that are not mirrored in the reported energy cost. In the case that an energy quota scheme is planned for implementation, it is crucial that social justice and other factors, including dwelling conditions, are incorporated instead of simple equal per-capita distribution.

Households that use mainly gas

The value of the created *share_energy* variable is the second greatest in this cluster, following closely households in the Other fuel cluster, meaning that these households spend proportionally more of the total housing cost on energy than households in the mixed use of electricity and gas and the central heating clusters. Similar to households in the Other fuel cluster, households in this cluster typically live in larger dwellings than those which primarily use central heating or a mixture of electricity and gas.

Household distribution within this cluster according to the size of the settlement is more balanced than in the Other fuel and central-heating clusters. Almost 70% of the primarily gas heated households are homed in Kádár-era blocks or family houses built before 1960.

Food-and-beverage-related costs are higher in households that primarily use gas, similarly to households in the Other fuels cluster. Households that use gas, however, reported (besides households with central heating) the best living conditions in terms of ability to keep their homes warm, cover the cost of household maintenance, pay their bills on time, ability to meet their needs, and level of satisfaction with living. Within this cluster, similarly to the households belonging to the central heating cluster, the higher the income decile, the larger the proportion of households in it (i.e. proportionally more households belong to the top five income deciles than in the Other fuel and the mixed clusters).

With regard to how an energy quota scheme based on equal per-capita energy entitlement distribution would impact those households that primarily use gas, I found that the implementation of the scheme would not benefit them at all. Households in this cluster spend significantly (almost 1.5 times) more on energy than the Hungarian average. If the energy entitlement distribution were based on a per-capita distribution and did not incorporate social justice considerations and dwelling conditions, households in this cluster would be forced to buy extra quotas to satisfy their energy needs or to drastically decrease their energy consumption.

Households that use mainly central heating

Households in this and the mixed use of electricity and gas clusters pay significantly less for energy from the total housing cost than households that use mainly gas and Other fuels. It is interesting that the greatest proportion of those households which reported pollution or other environmental problems in their neighbourhood are found in the central heating cluster. It is well known (as detailed in Chapter 4.2), however, that serious pollution is caused by the inadequate heating habits of households that use non-reported heating sources, including waste. According to the interviews, this happens mainly in those dwellings where other fuels (namely, firewood and coal) are used. Therefore, these households may not want to report environmental problems caused by their heating habits, or may not even be aware of the scale of the problem improper heating habits cause.

Centrally heated households can be found mostly in Budapest and in big cities in apartment houses, as households that use a mix of electricity and gas, but centrally heated households are overrepresented in panel-block housing. Within this cluster, similarly to the households in the gas cluster, the higher the income decile, the larger the proportion of households in it is. Proportionally more households can be found in the five top income deciles in this cluster than in the other fuel and mixed clusters.

With regard to how an energy quota scheme based on equal per-capita energy entitlement distribution would impact those households that primarily use central heating, I found that the implementation of the scheme would be neutral for them, since households in this cluster spend approximately the same amount on energy as the Hungarian average.

Households that use mainly a mixture of electricity and gas

Households in this and the central heating clusters pay significantly less for energy from the total housing cost than households that use mainly gas and other fuels. Households in this cluster are similar to households from the Other fuel cluster in relation to the fact that their dwellings are in bad conditions. Households in this cluster are listed as second worst in terms of performance on the other three variables that reflect dwelling conditions (damp roofs, damp floors, and inadequate doors and windows), followed by households belonging to the cluster of central heating and the cluster of gas. Households in this cluster are similar to centrally heated households in terms of having pollution and environmental problems in their neighbourhood (according to the household member reports).

Distribution within this cluster according to size of settlement is more balanced than in other fuel and central heating clusters, which means that households of this cluster are located in a more balanced way across the capital, big cities, and towns, as well as in villages.

Regarding health-related costs, there is no difference among households from different clusters, while among households that spend anything on education, those that primarily use a mixture of electricity and gas spend more. With regard to living conditions, which are shown by the following five variables: 1. keeping their homes warm, 2. covering household maintenance costs, 3. paying their bills on time, 4. their ability to meet their needs and 5. the level of satisfaction with living, households in this cluster are in the second worst position following households in Other fuel clusters. According to the distribution of these households within the income deciles, they are the second less likely to be found in the top income deciles, following households of the Other fuel cluster, but their distribution is quite balanced across all the ten income deciles, varying from 9 to 11%.

Regarding how an energy quota scheme based on equal per-capita energy entitlement distribution would impact those households that use a mixture of electricity and gas, I found that the implementation of such a scheme significantly would benefit them. Households in this cluster spend significantly (almost 1.5 times) less on energy than the Hungarian average. If the energy entitlement distribution is based on a per-capita scheme, households in this cluster could sell their unused quotas and receive support in exchange.

3.1.4. Limitations of the quantitative research

I have carried out quantitative analysis on what factors, including social-justice-related ones, influence household energy consumption, as well as how energy entitlement schemes with equal per-capita distribution mechanisms influence the interconnectedness of residential energy consumption and social justice in Hungary. I was able to gather and analyse these types of data from the Hungarian database on Statistics on Income and Living Conditions (SILC), the most updated version containing all necessary information of which is from 2018. There are, however, factors which are not mirrored in the official datasets that can be at least partially revealed by carrying out qualitative research that help interpret and increase the validity of the quantitative results. One of these data constraints is that, regarding justice theories related to fair and sustainable energy use, there were no variables nor proxies for reflecting recognitional justice in the secondary dataset. Therefore, I carried out expert interviews with people working in the field of energy and poverty. The research is detailed in the following chapter (Chapter 3.2).

3.2. Qualitative research method, analysis and results

In this chapter I detail the process of my qualitative research and introduce the related analysis and results.

3.2.1. Qualitative research method

To better interpret the preliminary results of the quantitative research, I aimed to use a qualitative method through which I could obtain better insight into the connection between poverty and energy consumption as well as the potential impacts of the implementation of an energy-capping scheme on equal per-capita distribution in Hungary. Therefore, I chose to conduct expert interviews through which I could obtain the necessary information for interpreting the results of the quantitative research, thereby helping form more relevant and valid conclusions. The methodology of this qualitative method is detailed in this chapter. To carry out my qualitative analysis, I applied deductive reasoning, in which assumptions arising from the quantitative analysis were complemented by the qualitative research results.

3.2.1.1. Qualitative research questions

Throughout this research effort I aimed to explore and understand better the links between residential energy consumption and social justice, and how an energy entitlement scheme with equal per-capita distribution mechanism would influence this interconnection in Hungary, and whether the quantitative research method was appropriate for achieving these aims. In order to obtain a better understanding and interpretation of the quantitative research, I solicited the opinions of experts both from environmental and social fields on the connections between household energy consumption and the poverty level (as an indicator of social justice), including how they see the links between poverty (financial income, and other factors that contribute to social injustice) and energy consumption. Using the information I gathered about the connection between household energy consumption and social justice indicators (e.g. poverty, and level of education), I aimed to assess how poor and social marginalized households would be affected by an equal per-capita energy entitlement scheme if one were implemented. Therefore, I raised the following questions in my qualitative research:

- What are the links between poverty and household energy consumption?
- How do experts from different fields of expertise see the connections between poverty and household energy consumption?

- What do they think about (how do they conceptualise) the links between poverty and household energy consumption when sustainability is taken into account?
- After briefly introducing the goals, methods, and preliminary results of my quantitative research, including revealing the potential impacts of a fossil energy entitlement scheme with equal per-capita distribution, I asked the following questions:
- What effects would poor households experience due to an energy entitlement scheme developed in Hungary that involved an equal per-capita distribution?
- What kinds of challenges do the experts see in relation to the implementation of my quantitative research? (What shortcomings can they potentially identify?)

Since I used content analysis and coding in line with the justice theories that were considered, I structured the results based on the assessed theories, not on the questions that were raised. The concrete interview outline, a summary of the interviews, and the coding of the interviews can be found in Annex I (Chapter 10).

3.2.1.2. Sampling

Qualitative research samples tend to be small, but their small size creates no issues if the sample is selected based on well-defined purposive or theoretical sampling. Purposive sampling requires defining purposive selection criteria (derived from understanding the purpose of the research), designing a sample matrix on which the criteria can be mapped, and the number of participants that are sought are specified. Furthermore, this may require setting quotas for selection. The selection of participants needs to be monitored carefully to ensure that the final sample meets the requirements of diversity and symbolic representation (Ritchie and Lewis, 2003). To select interviewees, I used a deductive sampling approach, since before carrying out the interviews, I had already obtained knowledge about the linkages between energy and poverty due to the quantitative research.

First, I considered that carrying out expert interviews would contribute to answering my research questions (Mason, 2017). I demonstrated the clear rationale to my choice of interviewees: in my research, I interviewed experts who work in the fields of poverty and household energy use. Then, I also considered their access to the appropriate contextual and situated knowledge, as well as how the quality of the data could be guaranteed (Bogner et al., 2009). For this, I created a stakeholder map of experts working at the border of the two areas: energy and poverty. In order to ensure this was sufficient, I screened ongoing relevant projects and programmes (that were targeting the field of energy and poverty) in Hungary, as well as used my previous work experience, through which I had got to know who deals with energy and poverty and social-justice-related issues. While putting together the table of interviewees (see Table 15), I also considered with whom I could establish the most productive relationship. In order to validate the potential interviewees, I carried out desktop research using the words “energy and poverty”. I marked in a column called “Desktop” (see Table 16 below) with an “x” those potential interviewees from whom I could obtain “energy and poverty” related information during the desktop research.

Background, relevance	Institute	Sector	Desk-top

Research projects regarding fuel poverty in Hungary, scientific article.	Energiaklub / Védegylet Association	Thinktank / NGO	x
Revealing greater scientific understanding of the social and cultural influences on energy consumption (Energise). Understanding how communities can save energy and money through changing their behaviour (EnergyNeighbourhoods).	GreenDependent	Thinktank	x
Responsible state actor for energy-related issues	State Secretariat for Energy and Climate policies	State	
Responsible state actor for poverty-related issues	State Secretariat for social matters and inclusive society	State	
Coordinating project on residential waste incineration (report)	Clean Air Action Group	NGO	
Running project on residential waste incineration (report)	Hungarian Anti-Poverty Network	NGO	x
Consequences of social fuel support in Hungary (report)	Habitat for Humanity	NGO	x
Working on decentralized energy system owned by communities (project running until 2020)	Friends of the Earth Hungary	NGO	x
Working for equal opportunities and social integration for the poor, following the theory "Everything is connected to everything else".	Real Pearl Foundation	NGO	x
Advocating for the dissemination of photovoltaic power plants	MNNSZ (Hungarian photovoltaic and solar panel association)	Business association	x
Writing the social impact assessment for the Hungarian Climate Bill proposal	Social entrepreneur	Business	x
Linking poverty and energy (lecture)	Hungarian Social Forum	NGO	x
Providing customers with a reliable and environmentally responsible energy supply based on the sustainable	Alteo	Business	

use of renewable energy			
Running the 'Biobrikett' programme	Védegylet Foundation	NGO	
Running the 'Lightbringing' programme (using solar energy)	Romaversitas Foundation	NGO	
Raising the environmental awareness, strengthening the independence and self-esteem of local communities in relation to finding the path to a responsible, sustainable and peaceful lifestyle	Profilantrop Association	NGO	

Table 16: Potential interviewees for the qualitative analysis

3.2.2.3. Data collection - expert interviews

I used interviewing as a method for data collection, since it can help achieve depth and generative data and capture data in its natural form (Ritchie and Lewis, 2003). An interview is a data collection method that is an interactional, sometimes face-to-face exchange of dialogue that has a relatively informal style. Most qualitative interviews are designed to have a fluid and flexible structure, thus allowing researcher and interviewee(s) to develop unexpected themes. Most of the qualitative studies assume that knowledge is situated and contextual, thus the role of the interview is bringing relevant contexts into focus due to which situated and contextual knowledge can be generated (Mason, 2017). Researchers from qualitative fields have not come to a conclusion about whether expert interviews can be distinguished as a separate method from other forms of interview (Bogner et al., 2009). According to researchers who distinguish expert interviews, expert interviews require careful validation and a solid theoretical basis. Carrying out expert interviews can shorten time-consuming data gathering, particularly if the experts possess practical insider knowledge and are interviewed as gatekeepers for a wider circle of players (Bogner et al., 2009). Bearing this in mind, I tried to identify for the interviews so-called gatekeepers who presumably possess the knowledge of the stakeholders they are representing or working for.

The contacts I had obtained due to my previous work experience as well as the quantitative research of my dissertation, contributed to increasing the level of motivation on the part of the experts to participate in an interview, as well as to the successful execution of successful interviews (Bogner et al., 2009). As the interviewer, I determined a structure and a purpose, and ensured professional interaction, and a careful questioning and listening approach. According to Bogner and Menz (2009), the expert interview is an "interaction model", referring to its constitutive and productive elements in the data production process. According to Pfadenhauer (2009), the interviewer needs to become a "quasi expert" in order to successfully carry out an expert interview. The authors consider the role of experts to be "stakeholders" who have a specific interest in the results of interview evaluation, which also entails evaluating socio-political measures. I aimed to assess this "stakeholder" problem from a methodological perspective. In order to carry out individual expert interviews properly (Bogner et al., 2009), I had to decide which type of interview would be the best (in light of my research questions (Chapter 1.4) and in relation to the purpose of the expert interviews). The term 'qualitative interviewing' refers to in-depth, semi-structured or loosely structured forms of interviewing (Mason, 2017). The difference between loosely and semi-structured interviews may be seen in Table 17 (Pataki, 2014), from which I chose for my research the semi-structured interview format.

Unstructured	Semi-structured
Exploring a topic intensively and broadly from the participant's point of view	Pre-prepared outline of topics
Some guiding questions to ask	Ensures flexibility in terms of different wording and order of questions
Free to move the conversation in any direction of interest that may come up	Systematic as well as conversational
Requires good interpersonal skills	At least somewhat skilled interviewer is needed
Likely to produce insights that you could not have anticipated	Most challenging: covers all topics and get in-depth responses

Table 17: Unstructured and semi-structured interviews (based on Pataki, 2014 presentation)

The interviewer needs to possess key communication skills such as the ability to listen and to hear, as well as to be able to play a role as active facilitator (Ritchie and Lewis, 2003). Before carrying out the interviews, I had to think over the following: what determines and characterizes communication in expert interviews; which personal skills, competences and attributes are beneficial in this form of interaction; as well as how can the particular interaction structures be used to benefit the data-gathering process; and, finally, which research ethics issues have to be considered (Bogner et al., 2009). Furthermore, I chose the type of recording: tape-recording, as well as notes written during the interviews, not notes written afterwards (remembering). Because many of the identified experts work in the field and even abroad, I conducted online interviews as well as face-to-face ones.

I began the interviews by informing participants about the overall purpose as well as the main design features of the interview. Furthermore, at the beginning I raised the issue of confidentiality; namely, that private data identifying participants would not be reported. While implementing the interviews, I considered the use of different types of questions in order to enhance the interaction. For improving interview results, I combined content-mapping questions (to map the themes and identify the component elements of the relevant topic) with content-mining questions (to explore the latter in detail). The use of clear, non-leading questions is extremely important. Dichotomous questions, while of less value, can be combined with open questions (Ritchie and Lewis, 2003). Therefore, I used structured questions to introduce a new topic, while if something could be explained in more depth I asked for details. Furthermore, if I was not completely sure about the meaning of the answer, I raised interpreting questions to clarify with the interviewee.

During the interviews, I paid attention to turn assumptions, comments and a temptation to questions, while I stayed empathetic but neutral in attitude. I was also careful not to raise any topic that would catalyse sensitive issues or strong emotions (Ritchie and Lewis, 2003). Thus, I tried not to share personal information during the interviews, since this could have hindered the in-depth interview process. There are a range of strategies for dealing with sensitive issues and strong emotions if they still emerge, but first of all recognition and acknowledgement of the participant's reactions are key. Therefore, I paid attention to using proper body language, I followed-up answers by nodding (when the interview took place personally), saying “mm”, and repeating significant words from respondents’ answers as well as staying silent after asking questions to give interviewees time to think of their answer.

3.2.2.4. Method for data analysis

To identify a proper method for data analysis, I screened potential strategies in light of the form and function of the expert interviews included in my research design (Bogner et al., 2009). I also considered that different experts with diverse knowledge and varying quality requirements in their work might provide correspondingly different information.

I analysed the interviews through qualitative content analysis (QCA), which is one of the most commonly used research techniques in social sciences for making replicable and valid inferences about data from their context (Krippendorff, 1989). Data required for this technique vary between verbal discourse, written documents, and visual representation. There is a difference between deductive and inductive content analysis (Elo and Kyngas, 2008). I chose deductive content analysis, since it is used when the structure of analysis is operationalized based on previous knowledge. This deductive approach is appropriate since the general aim of the qualitative research was to interpret more deeply and, where possible, to validate goals and the preliminary results of my quantitative research.

First, I categorized the answers according to how alike they were and in what ways they were different. I use coding to “fracture” (Krippendorff, 1989) data and to re-arrange the former into categories that facilitated comparison. (Human coders tend to be unreliable but good at interpreting semantically complex texts, while computers have no problem with reliability but must be programmed to simulate much of a native speaker’s linguistic competence). I grouped the thus-created data segments by category, highlighting similarities. Under the main categories, I created also sub-categories as well as links from data segments to the justice theories under examination (Annex I. – Chapter 10.3).

Second, I looked for relationships that connected statements within the context until I reached a coherent whole. These inferences were aimed at framing knowledge about how the coded data are related to the phenomena I wished to understand. Through the content analysis, I also revealed patterns and contradictions that emerged due to the inclusion of different experts with different backgrounds. I aimed to tackle uncertain points and contradictions through asking clarification questions. Finally, I allowed space for my own reflection on the research as part of the knowledge-production process through thinking over the information I had obtained from the experts and discussing the analyses of the interviews.

3.2.2. Analysis and results of the qualitative research

From the potential Hungarian interviewees I had identified, I managed to carry out four interviews with six experts working in the field of energy and poverty. (During two interviews there were two experts) During the interviews, interviewees were asked whether their names could be mentioned in the dissertation. All of them agreed that their names could be mentioned in the acknowledgements chapter of the thesis. From the interview scripts, I compiled a summary table that contained categories linked to those theoretical concepts I had defined in relation to fair and sustainable energy use, such as energy poverty as energy injustice, capability, environmental justice, and sufficiency. I mainly used deductive content analysis since my qualitative research was designed with the aim of better interpreting the findings of my quantitative research. Therefore, I strove to reveal how and to what extent the defined fair and sustainable energy use concepts (such as energy poverty as energy injustice, capability, environmental justice, and sufficiency) were mirrored in the interviews, as well as revealed those points that were not mirrored in fair and sustainable energy-use-related justice theories.

3.2.2.1. Energy and poverty linked to environmental or climate justice theory

Environmental-justice-related concepts mainly touch upon power and background inequalities between developed and developing nations (as detailed in Chapter 3.2.1). In terms of analysing the energy use of poor Hungarian households, justice concepts are mainly linked to sufficiency and energy-poverty-related theories, the latter defining energy injustice within nations. I would like, however, to mention environmental concerns driven by the heating habits of poor households in Hungary that are linked to environmental or climate justice, since this theory defines that the poor and marginalized are more exposed to environmental pollution and problems. All of the interviewees stress that poor households heat their homes in a way that is harmful to the environment as well as to their own health. External particulate pollution as well as indoor air pollution can cause severe environmental and health problems. Another phenomenon that underpins the claim that poor people are exposed more to environmental pollution and problems is that in Hungary they are often required to heat using waste. It may happen that they are not aware of the environmental and health consequences of heating by burning clothes or even shoes. *"They are more affected in terms of damage to health and the environment due to the presence of old, obsolete assets. They often burn waste…"*– one of the interviewees reported.

Poor people are often also exposed through the nature of the sales of firewood. The schedule of distributing social firewood to vulnerable people is usually not negotiated with them and does not consider when these people need firewood the most. For instance, social firewood allocation can happen on an *ad hoc* basis. If it happens during a week when small children are not at home or are mainly away during the day, the beneficial impact of social firewood is hardly felt. Using firewood would be better during the weekend when everyone is at home. Furthermore, poor people are often exposed to usury.[6] Moreover, due to their vulnerability they may be given firewood of poor quality. "*When they buy firewood based on weight, sellers often give them damp wood or soak it before selling it*" – according to one of the interviewees, reporting about the vulnerability of poor people.

Moreover, vulnerable people must also adapt to opportunities as they arise. "*When a neighbour goes to the nearby town for firewood, they must join so as not to miss out on this opportunity*" –one of the interviewees reported.

Vulnerable people often miss out on different opportunities – e.g. they cannot access various investment resources, including those that are designed to promote renewable energy use. Besides investment opportunities, they usually cannot access adequate information and proper energy infrastructure since the poor and marginalized do not have the power or information to advocate for their interests. Moreover, much traditional and useful knowledge has disappeared. *"A lot of information has disappeared. If you leave one piece of central firewood, and do not destroy the wood rings, the wood produces much more heat"* – according to one of the interviewees about disappearing traditional knowledge in regards of using firewood effectively. This

[6] Usurers in Hungary are usually found in marginalized settlements; they usually lend money at excessive rates of interest. The marginalized are often exposed to them financially as they cannot borrow money through other means.

information and knowledge gap mean that they are left behind, increasing social inequality.

Some of the interviewees mentioned the situation of the Roma population in Hungary, the situation of which is sometimes even worse than that of other poor people. "*Gas pipes do not reach the Roma part of the settlement, but even when they used to reach them they could not pay for it*" – according one of the interviewees.

According to the interviewees, energy and poverty-related problems can be attributed to the lack of holistic approaches and system-level thinking at a governance level, which has also led to gaps in data collection and analysis at the household level regarding energy consumption. "*System-level thinking is lacking in Hungary"*. To achieve change, interviewees suggest approaching these poor and vulnerable people directly for a longer period and working hard together. Furthermore, increasing their education and training are also vital for achieving a change in their energy consumption patterns. *"We have to go there and work with them personally. Any other way is impossible".*

3.2.2.2. Energy and poverty linked to sufficiency as justice theory

The concept of sufficiency in relation to justice theories related to fair and sustainable energy defines the need for affordable and good quality energy for all. Within the sufficiency concept, the capability approach plays a significant role (Chapter 2.1.2). Due to the limited energy consumption opportunities of the poor, they are also limited in their capabilities. They live from day to day without planning their days in advance. Their life is characterized by unpredictability. *"A lack of social sustainability is caused by unpredictability"*, and the energy consumption of poor people is characterized by "*a lack of planning, reactivity, short-term problem solving*", *"whereas planning skills are lacking due to their living from day to day – survival strategies are not going (do not promote) in the direction of (planning)*" – according to an interviewee.

To ensure that poor people can afford adequate energy, interviewees stressed the importance of grants for adequate and efficient housing equipment, well-insulated dwellings as well as good quality firewood. "*How to survive the winter: with proper equipment and good quality firewood in an insulated dwelling – these would be the solutions"* – according to one of the interviewees about tackling energy and poverty issues. Furthermore, interviewees stressed the necessity of involving poor people in the process of developing supporting schemes that are aimed at mitigating their financial burden that their energy consumption patterns cause.

3.2.2.3. Energy and poverty linked to energy poverty as energy injustice

In terms of energy poverty defined as energy injustice, interviewees agreed that poor households spend proportionally more on covering their energy costs, meaning that energy costs represent a greater burden on household budgets than in better-off households. They also stressed that the conditions of dwellings belonging to poor households are poor. They live in less energy-efficient dwellings with uninsulated windows and doors and use inefficient household equipment. All the interviewees agreed that in poor households stoves play a crucial role in energy consumption. These are often not looked after properly. Furthermore, poor households usually use stoves that are unable to store heat adequately. This is a significant contributor to the poor situation of homes in bad condition that often forces inhabitants to heat their homes to a very warm temperature in the evening so that their dwellings do not get extremely cold by the morning during the winter time. *"Doors and windows are in terrible condition, even in log houses. They heat enormously, and even take off their clothes to their underwear in the evening so as to stay a little warm until morning"* – one of the interviewees stated.

Interviewees also mentioned that, since covering energy costs represents a greater financial burden, poor households cannot afford to invest in energy-reduction measures, including better and more efficient stoves. This often results in people living in poor households in inefficient dwellings and thus being forced to save on heating. Being cold during the winter time contributes to limiting their capabilities. "*Acquiring certain things and the need to ensure the provision of energy on an ongoing basis pose a far greater burden, creating many forced trajectories and decisions".* These statements reveal the role that low income and high household energy costs play in the relationship between energy use and poverty. Due to their significant role, they have also become At the EU level the official determining factors of energy poverty.

Half of the interviewees mentioned that poor and marginalized people are not recognized by members of society; they are often left alone with their problem of not being able to afford adequate energy to satisfy their basic needs. This can be attributed to *"the lack of sensibility that characterizes the Hungarian population..."* – inferring a lack of recognitional justice; namely, weak recognition of the poor and marginalized.

In order to enhance the situation of poor households trapped in inefficient homes, interviewees stressed the need to develop and implement holistic approaches that tackle environmental and social trade-offs, and thus enhance distributional justice. For this, strong governmental commitment embedded in "*long-term strategy development"* and access to proper relevant data is essential.

3.2.2.4. An energy-entitlement scheme developed in Hungary with equal per-capita distribution, and its link to fair and sustainable energy-use-related justice theory

Interviewees stated that the so-called Climate Bill Proposal (Gyulai, 2011), which is an energy-use capping scheme developed in Hungary is a "*good or at least not a bad initiative"* for limiting fossil energy use while incorporating social justice concerns. They also, however, mentioned some aspects that should be considered if this or a similar scheme were to be implemented in Hungary. To ensure procedural justice, which is one of the preconditions for mitigating energy poverty and energy injustice, access to information on energy efficiency loans needs to be granted. Interviewees did not agree to what extent the interest-free loans developed within the Proposal (designed to finance energy-efficiency- and renewable-energy-source-related investment), would be beneficial. Some of them said that interest-free loans are beneficial; others were convinced that, instead of loans, direct financial transfers (e.g. state aid) needs to be ensured. Other interviewees warned that interest-free loans can be beneficial, but their payback time should be considered carefully, while easy-to apply conditions must be defined. The interviewees, however, were concerned to what extent the poor and vulnerable would be motivated to ask for these kinds of loans. Those who could not access such information, those who heat with illegal resources, or those who have tiny dwellings to heat will not be motivated to participate. "*Here, the flow of information also plays a crucial role in order to ensure that poor people choose the most beneficial solution*".

Linked to environmental justice, all of the interviewees agreed that ensuring proper information flow about the system and the benefits it provides for the poor and marginalized is crucial. The vulnerable must be properly approached through the involvement of a vast variety of intermediaries, including local priests, local authorities, and village caretakers. "*Undoubtedly, if it (the Climate Bill Proposal) were to be supported by decision-makers, it could only be implemented on the ground – I think if the professionals still connected to local communities – from the village caretaker to the priest, not to mention community developers and organizers – were involved in the* *process*".

Connected to energy justice, interviewees suggested that during the proper formulation of an energy-entitlement scheme, the principles of conscious consumption, education starting from childhood, as well as proper data collection (e.g. about the dwelling conditions of poor households) need to implemented. "*If there is ever another attempt at this, a very serious, complex sensitization, attitude-changing campaign should precede it"*. Almost all interviewees mentioned a card-based subscription[7] service as being a good example to follow or to utilize during the formulation of an energy-entitlement scheme.

Interviewees also provided their opinion in relation to what extent the social impacts of a potential energy entitlement scheme could be measured and revealed through analysing official household energy consumption data and the data that reveal social justice issues. All of them stressed that official data sources do not mirror real energy consumption, since the latter does not include the use of illegal sources – e.g. burning waste, non-reported firewood use, or the deliberate slowing down of gas and electricity meters. "*Clothes, shoes, and combustible household waste are used for heating... It is not possible to distinguish how much of this material is used for heating. It is common that donated clothes are taken away in winter, even when they are not needed, for burning"* – according to one of the interviewees about illegal sources of heating.

Experts' opinions varied regarding to what extent energy-source-related spending is a good indicator of household energy consumption. Half of them said that the latter is not a bad indicator for providing an overview of household energy consumption, but does not mirror the situation fully. One of them advised that it would be better to use the amount of energy that is actually used, not the cost related to it, while another expert stressed that poor people heat mainly with firewood, of which only social firewood is reported properly, while self-collected, illegal wood or waste is not.

In terms of income as an indicator of social justice, all of the interviews agreed that it does not mirror the full picture about income due to the significant black market. "*Legal income is only a relative figure. Unfortunately, the black economy has grown so much in recent years that the actual income of families cannot be traced"*. Furthermore, financial income does not reveal social inclusion. Interviewees suggest using other indicators, in addition to income, to reveal social justice – e.g. the size of the dwelling, the amount households spend on education, dwelling conditions, or energy cost as a proportion of housing cost.

3.2.2.5. Energy and poverty are not mirrored in the justice theories under analysis

There are, however, some aspects that were mentioned by the interviewees and are not covered by the social justice theories linked to fair and sustainable energy use. One of them is habituated behaviour; namely, the fact that in Hungary even the poor are accustomed to heating their homes to a temperature warmer than the average European home. "*The link between energy use and poverty is a complex issue. Many think that poor people use less energy. But according to our experience, this is not the case all the time: they use a lot of energy wastefully"* – one of the interviewees said about the heating habits of the poor.

This wasteful energy consumption is because household energy-consumption regulation[8] is counterproductive, since consumers do not know their real consumption.

[7] Energy entitlements can be loaded onto cards in order to avoid them being stolen, or sold below price.
[8] In 2013 the Hungarian government introduced household utility cost cuts and has been regulating them via the latter law.

This can happen if energy bills do not capture real consumption, but also because the latter cannot control their energy consumption due to inadequate heating equipment.

Another point that is not reflected in justice theories is that poor people sometimes use firewood from illegal sources for heating and cooking. They do this sometimes despite being aware of the illegality of the practice. Either they collect it themselves illegally, where logging is forbidden or restricted, or they buy firewood from illegal sources even if they are not aware of its source. "*They rent out a chainsaw, hang it on the tree, the noise goes from this spot, while they go to another location and take the tree from there*" – according to one of the interviewees about illegal firewood-collecting methods. If Roma collect their wood illegally, they may be reported by others and fined.

To mitigate the financial burden caused by the energy use of poor people, interviewees also suggested exploiting local opportunities associated with members of the impacted local society. Through collecting even a small amount of savings they can enhance their livelihoods significantly. "*Money saved by the poor has a bigger effect: their children can be educated*". Locals can be supported to utilize what they have, thus building on local initiatives can bring enormous benefits.

3.2.2.6. Evaluation of the qualitative results in light of the Research Questions

Regarding my first research question: Q1. What are the interlinkages between residential energy consumption and social justice? I found that environmental-justice-related concepts are mirrored in household energy use and the poverty level. Namely, that poor and marginalized are often exposed more to environmental problems and pollution due to inadequate heating equipment and heating sources, not to mention usurers who heavily exploit their vulnerabilities. Furthermore, they are also exposed to rapidly emerging opportunities while they cannot access others (e.g. investing in energy efficiency measures) sometimes due to the lack of information, creating procedural injustice (see more in Chapter 2.1.2). According to the expert interviews, poor households often live in dwellings that are in bad condition and which use inefficient household equipment, especially inadequate stoves, leading to difficulty satisfying energy needs and thus to an increase in energy poverty as a form of energy injustice. Because they cannot afford to invest in energy-use reduction measures – e.g. purchasing proper stoves, they are forced to try to save on heating, violating the principle of the sufficient use of energy and deteriorating their capabilities. These people are stuck in their unbeneficial situation of living day to day without the ability to plan, which violates their capability to relax in a properly heated home. Moreover, poor and marginalized people are often not recognized by members of society and are left alone with their problems of affording fair energy, revealing recognitional injustice.

Regarding my second Research Question, Q2': How would an energy entitlement scheme with equal per-capita distribution mechanism influence the interconnectedness of residential energy consumption and social justice in Hungary?, interviewees stress that ensuring procedural justice, which is one of the preconditions for mitigating energy poverty and energy injustice, is crucial. This means that access to information on energy efficiency opportunities needs to be granted, paying extra attention to those who are not motivated to reduce (i.e. who use illegal sources, have small dwellings to heat, etc.) and also to education from childhood onwards. Furthermore, proper data collection about the links between different socioeconomic characteristics and energy use is needed. In relation to revealing the impact of an energy-capping scheme using statistical data, interviewees suggest not using energy-cost-related variables as indicators of household energy use, since these fail to mirror the full picture of household energy use. They suggest using instead the total energy resource use, although this kind of data is lacking in official databases which also contain indicators on social justice. Furthermore, interviewees suggest using other indicators, in addition to financial income, to reveal social justice – e.g. the size of the dwelling, education, dwelling conditions, or proportion of energy cost to housing cost. Based on the literature review and also on the interviewees' suggestions, I have included into my analysis these indicators since they are available in the official dataset.

To tackle injustice in the field of energy and poverty, interviewees urged applying holistic approaches and system-level thinking, while paying attention to the education and training of people in need. This would also include providing them with adequate equipment and involving them in developing supporting measures to ensure that they are supported in what they really need. Furthermore, the use of illegal energy sources should also be tackled and proper data collection about the factors underlying energy use should be carried out if an energy-capping scheme is implemented.

3.3. Social-justice-related implications of the quantitative and qualitative research

Among the justice theories, I consider throughout my research, distributive justice is defined both by environmental or climate justice and sufficiency concepts (Chapter 2.1.2.4). Namely, the principle that sufficient energy for all needs to be ensured, while it should be defined who can use more energy than their fair share, and to what extent and with what justification. Furthermore, attached to the concept of energy poverty as energy injustice, I also consider in my research procedural justice as access to information as well as recognitional justice, as the poor and marginalized have to be recognized and supported by society.

In light of this, in this section I reveal how the quantitative and qualitative research supplement each other, with social-justice-related implications, while I detail in the Discussion (Chapter 4) to what extent I found the answers to my Research Questions through my quantitative and qualitative research.

With regard to Q1 (What are the interlinkages between residential energy consumption and social justice?), both pieces of research revealed that poor households often live in dwellings in bad conditions and with bad living conditions. Interviews, however, additionally emphasized that due to inefficient household equipment (especially stoves), poor and marginalized people are often exposed more to environmental problems and pollution. Qualitative research revealed that the poor and marginalized often cannot afford to invest in energy efficiency, thus they are stuck in their unbeneficial situation. Both types of research revealed the importance of using other social-justice-related indicators to investigate the interlinkages between residential energy consumption and social justice, in addition to income. These indicators include, for example, the size of the dwelling, education, dwelling conditions, and proportion of energy cost and housing cost.

With regard to Q2 (How would an energy entitlement scheme with equal per-capita distribution mechanism influence the interconnectedness of residential energy consumption and social justice in Hungary?), linked to environmental justice, qualitative research revealed the importance of proper information flow. Namely, that the poor and marginalized need to be approached properly; this includes their education from childhood, which is not reflected in quantitative research. Connected to energy justice, proper data collection is needed according to the qualitative research findings in order to adequately measure the interlinkages between energy consumption and social justice (as detailed in Chapter 4). This includes, inter alias revealing illegal sources of energy use – e.g. waste burning, non-reported firewood usage or the slowing down of gas and electricity meters. Regarding the use of income as a variable for revealing social justice, qualitative research revealed its questionability due to the significant black market. Interviews also showed that energy costs should also be addressed with caution when attempting to reveal the interlinkages between household energy consumption and social justice, since some energy sources are not included in energy costs. This is specifically true in the case of poor people who heat mainly with firewood, out of which only social firewood use is reported properly, while self-collected, illegal wood and waste are not.

4.DISCUSSION AND RECOMMENDATIONS

In the discussion, on the one hand I argue to what extent I found the answers to my research questions (Chapter 1.4):

Q1. What are the interlinkages between residential energy consumption and social justice?

Q2': How would an energy entitlement scheme with equal per-capita distribution mechanism influence the interconnectedness of residential energy consumption and social justice in Hungary

On the other hand, I provide recommendations concerning how energy entitlement schemes need to be developed in order to serve the benefit of the poor and marginalized and thus enhance social justice.

Therefore, in the first part of the discussion, I reveal how the analysed energy-capping scheme based on an equal per-capita distribution mechanism would contribute to fulfilling the principles of three ecological economics: sustainable scale, just distribution, and effective allocation. Then, I touch upon the limitation of this research and end this chapter with recommendations (Chapter 4.3), where I provide concrete recommendations about how the analysed schemes need to be modified to enhance social justice.

4.1. The contribution of an energy-capping scheme to the three aspects of ecological economics

To achieve **sustainable scale,** a low-carbon energy transition is required that should be designed to disrupt the current energy system, which is based on fossil-fuels, centralised generation, supply-side orientation, and all the practices, policies, technological development, business models, norms and attitudes linked to this system, while at the same time developing and introducing sustainable alternatives (Vladimirov and Galev, 2017). This raises the challenge of good governance and of consistent policy-making that is predictable and based on a long-term strategy that cannot be easily overturned in the future. The analysed energy quota schemes aim to contribute to achieving sustainable scale through striving to reduce energy consumption and thus the size of the economy. The proposals would achieve their goal through setting an absolute ceiling on fossil energy use, which would be lowered year by year. The continuous ceiling reduction would ensure that energy use decreases gradually until it reaches sustainable levels. Fossil-energy-use caps are necessary and need to be fixed in physical terms, independent of any allocation mechanisms like trading. For the allocation there are several options: measuring resource consumption on the consumer side would require an elaborate accounting system that determines the resource content of every single product – a heroic undertaking requiring lots of effort and implementation bureaucracy, still prone to failure. Rationing at the entry gates appears to be much easier. The defined energy-use caps define the frame of energy consumption under which trading can take place. Caps should be established at ‘entry gates’ of the economy, which is the case when limiting fossil energy use (Alcott et al., 2018).

Regarding **just distribution**, energy-capping schemes also have a role to play. The equal per-capita distribution mechanism is built based on equality – the world’s resources are the common heritage of humankind and should be shared fairly. The fair share is then given by what environmental space there is, divided by the number of inhabitants. The challenge lies in how to distribute these consumption allowances amongst inhabitants. For any sustainable society, distributional justice is a major concern and should be taken into account in the allocation of consumption opportunities and the choice of instruments related to using the latter (Alcott et al., 2018). Distributional justice is also mirrored in all of the three theories linked to fair and sustainable energy use: environment or climate justice, sufficiency, and energy poverty defined as energy injustice (Chapter 2.1.2). Equal per-capita quota distribution aims to achieve distributional justice, as primarily defined by sufficiency; namely, to ensure adequate, sufficient amounts of energy for all. Distributional justice as defined by environmental or climate justice also needs to be incorporated via developing and implementing energy-capping schemes in terms of eliminating he situation that the poor and marginalized are usually more exposed to environmental problems and pollution. Last but not least, distributional justice as defined by the energy-poverty-as-an-energy injustice concept needs to be enhanced in order to enhance the livelihood and well-being primarily of the poor and marginalized.

Giving citizens energy quotas to cover their direct energy consumption would have numerous positive effects. First, it would create the opportunity for them to have a clear and tangible sense of their ‘fair share’ of the overall national energy budget, which they can choose what to do with (use, save, and sell). Creating ownership and the motivation to reduce household energy consumption is also part of the sufficiency debate (Chapter 2.1.2). It is also advantageous if well-designed information supporting system is developed in tandem with the policy tool, through which continuous information may be provided to citizens about how their carbon use compares to their budget (i.e. every time they pay an energy bill). Ensuring proper information and knowledge flow would enhance procedural justice as defined by energy poverty as an energy injustice concept. For this, however, the information system and knowledge flow have to be well developed, including the identification of

- different target groups,
- the latter’s knowledge and information-processing capabilities,
- what kinds of information are needed for the respective target groups (paying extra attention to those in need in order to ensure that through their enhanced knowledge they benefit from the scheme),
- how and through what channels the target groups receive the necessary information, and
- how to monitor that such information is processed and used.

While developing the information system, extra attention should be paid to eliminating any trade-offs that would be unfavourable to the poor and marginalized. Furthermore, studies that have involved learning from pre-existing cap-and-trade regimes should be addressed to avoid the less powerful remaining in their disadvantaged situation.

This issue of procedural justice is also raised indirectly in the social impact assessment that was delivered for the Hungarian Climate Bill proposal (Herpainé Márkus et al., 2011, p.43). Namely, that the access to and proper usage of information and knowledge as a means of enhancing procedural justice need to be ensured for marginalized people, who have not even seen an electronic card so far. Digital inequalities are defined primarily by education, the type of settlement, level of income, and wealth. These need to be enhanced to a level at which the misuse of saved entitlements can be mitigated. For this, well-informed individuals with proper social capital are essential who are open to innovation and are able to trust, and thus capable of making changes (Herpainé Márkus et al., 2011). This would also enhance social capital and the procedural justice which is essential for just energy transition. Proper information could focus on the necessary lifestyle/technology changes than just giving details of a higher energy price. Creating ownership of decisions (linked to sufficiency) and ensuring proper information flow (enhancing procedural justice) about quota usage can contribute to a more rapid adaptation to a cap as it tightens over time, creating citizen engagement (Alcott et al., 2018).

Among the social benefits, the expenses of households could be reduced if energy-capping schemes were implemented. Those who consume less energy than the fairly shared units under the energy cap would obtain extra income from the system through selling their unused units through a central authority to those who consume more than their share. The systems would include assistance for those poor people who consume more energy due to use of cheap and inefficient appliances or to lack of control over home insulation ((Fleming and Chamberlin, 2011; Gyulai, 2011; White and Thumim, 2009). This would happen either through providing interest-free loans (in Hungary) or governmental support (in the UK). With these kinds of income they could invest in energy reduction, thus lower their energy use and reduce their household costs. Via reducing the energy cost of the poor, energy poverty as energy injustice can be mitigated while the capabilities of the poor and vulnerable can be enhanced through making them capable of heating their home adequately.

According to the SEA of the Hungarian Climate Bill Proposal (Tombácz and Mozsgai, 2009), this energy-capping system would create jobs directly in the construction, renewable energy, and energy-efficiency sectors. Namely, only in the construction sector 40,000 new workplaces would be created. Currently, the solar industry is growing worldwide. According to solar experts (Energy Shifts, 2021, first panel '45), coal industry workers can be trained to become solar industrial workers very easily. Thus if an energy quota scheme is implemented, those who lose their jobs in the fossil energy sector can be trained to work in the renewable sector. Due to the increase in the level of investment in these sectors, further demand for related products and human labour would occur. Due to the newly created jobs, wages would increase and demand for vital goods would increase, leading to further job creation. Additionally, the stimulus of these energy sectors would have the potential to increase demand in other related industrial and service provider sectors. Furthermore, new jobs would be also directly established through the advisory and support system set up to provide proper lifestyle-related recommendations for citizens affected by the schemes. Moreover, due to the spread of sustainable, labour-intensive practices and the income generation of quota under-consumers, access to environmentally friendly goods and services would be enhanced, enhancing wellbeing. Even though new jobs would be created and people who could not afford to consume would be able to do so, the overall system would move towards sustainability due to the absolute consumption ceiling, which would constantly decrease.

A defined limit on energy use would push all stakeholders impacted by the system to use their allocated units as effectively as possible, and thus help realise the third goal of ecological economics, **effective allocation**. The proposals, however, give the choice to stakeholders about how to do this through letting them choose from different options (buying extra quotas, investing in energy reduction, or changing energy-use patterns) according to the effectivity of the latter (Delors, et al., 2017). At the beginning, over-consumers could choose between three options. Either they would start economizing (i.e. using less energy), or they would invest into energy efficiency, or they would pay for surplus quotas to compensate their energy demand. Since it is difficult to save without investing, to some extent, the choice would narrow between investing and buying surplus quotas to satisfy their energy demand.

Furthermore, the schemes provide an alternative to the casual and popular 'rationing-by-price' approach that is currently in effect. While the energy cap instruments incorporate a market mechanism to do what markets do best – find a price for scarce goods and facilitate their exchange – they should not be market-based frameworks. The ongoing financial crises of recent times show that markets are not good at regulating freely. Therefore, the energy-capping tools first and foremost need to ensure the framework within which the market would be constrained in line with the defined energy use ceiling. Namely, energy-capping tools can contribute to achieving sustainable scale through ensuring the existence of an absolute ceiling on energy use, while efficient allocation can be done via trading. They also address just distribution via an equal per-capita distribution mechanism, which I question the choice of as an adequate mechanism for achieving distributional justice in the later subchapters. Here, however, I will just mention some cases which indicate why an equal per-capita distribution mechanism should be fine-tuned to incorporate the needs of individuals with different social and economic backgrounds.

- Mothers, especially single parents living with small children (even if they are breastfeeding), might need more quotas than the equal per-capita distribution would allow.
- The elderly and those who need assistance to undertake everyday tasks might also need more quotas.
- People who are constrained in their mobility due to physical limits/disability would need more quotas.
- People who live in areas where social services (educational, health, social) are lacking or difficult to access might also need more quotas to help them order access the same quality services as those who live nearby.

4.2. Limitations

The research described herein has some limitations, some of which I have already touched upon in the empirical research chapter (Chapter 3), including its lack of treatment of the development of regulations for non-residential energy use, especially of the business sector. Furthermore, I assumed that the assessed energy-use cap would be developed based on scientific evidence in a country where political decision-makers are really striving to achieve achieving environmental sustainability and promote social justice. I need to add, however, to the limitations which already were mentioned in Chapter 3. In the articles assessed in the literature review, environment consciousness was one of the indicators that plays a role in determining household energy consumption. The SILC database, however, does not contain any variables for measuring environmental consciousness. Furthermore, this database does not contain information on the amount of income a household earns (they are only classified into one of the ten income deciles). Moreover, there are proxies for revealing the three kinds of justice concepts: distributional, procedural, and recognitional, which are not found in the official database. I provide concrete recommendations about what kinds of variables also need to be measured to reveal the drivers behind household energy consumption that enhances social justice in the next section (Chapter 4.3).

4.3. Recommendations and suggestions

Based on the justice theories linked to the fair and sustainable energy use, an energy-quota scheme is expected to be implemented in a socially just manner. Therefore, the scheme should ensure equal access to fair and sustainable energy use, especially for the poor and marginalized, while enhancing their livelihood and well-being. Furthermore, an energy-capping scheme should ensure the fair share of any burden that arises from energy use. Based on the results and discussion of my qualitative and quantitative research, with regard to developing an energy quota scheme that ensures not only environmental sustainability but also social justice (including distributional, procedural, and recognitional justice), I have collected the following recommendations.

In addition to those variables that reflect social justice that I used in the quantitative research (see Chapter 3.1), I recommend monitoring the health status of household members, since health status and health-related costs might influence household energy consumption habits. In relation to income, not only should income levels be monitored, but also the proportion of income from work and social transfers, as well as capital and income obtained from financial capital (wealth). This should be analysed while evaluating the role that socioeconomic household characteristics play in energy consumption. This is especially important since wealth inequalities are much greater than income inequalities (Magyar Nemzeti Bank, 2019; Kolosi and Fábián, 2016). Furthermore, access to basic services (such as education, health, social and communication services – e.g. the internet) should be analysed when evaluating household energy consumption. Furthermore, the social capital of households should be monitored and considered when analysing their energy consumption. This might include assessing the level of trust in public institutions, the strengths of network relations (at the neighbourhood or at community level), the level of civil activity, and openness to innovative ideas. These factors indicate the level of acceptance and openness to an energy quota scheme well, and without a high level of acceptance and openness the implementation of an innovative tool might be impossible. Regarding new variables, the level of household equipment efficiency is not mirrored in the official database but can be used as a variable or proxy to reveal energy poverty as energy injustice, since it is a significant driver of energy poverty. Besides these socioeconomic indicators, further research would be necessary to reveal the impacts on energy-capping schemes and to collect data about other forms of energy consumption, such as car usage and other non-renewable energy resource use.

Implementing a hard cap on resource use is not a popular topic among politicians, businesses, and often not among NGOs either (Hajdu, 2017). The governance of the transition to low-carbon energy faces a complex set of regulatory, legislative, and financial obstacles that hinder the promotion and implementation of respective policies on local, national and international levels. The two major challenges associated with the success of policy implementation are the level of involvement and proactive support of the local and/or central government, and the level of public engagement and participation (Vladimirov and Galev, 2017). Energy transition policies, such as the proposed systems for energy capping, require strong and consistent public support and understanding, self-directed change in many domains of society, and collaboration among diverse social actors. Without strong public and governmental-level support, the level of inequalities might, however, stay the same – also due to the possibility that the information services associated with energy-capping schemes might not reach the most disadvantaged groups. In other words, absolute poverty might decrease, well-being increase, and housing and energy poverty moderate due to the implementation of energy-capping tools, but relative poverty would remain due to still existing inequality (Herpainé Márkus et al., 2011). To tackle this situation, energy-capping schemes would need to ensure proper information flow considering the energy-use patterns of the respective population. According to the strategic environmental assessment of the Hungarian Climate Bill Proposal (one of the proposed energy-capping schemes), 2-3,000 people should be involved in its social and advisory system to ensure the smooth implementation of the scheme, meaning 2-3 people per microregion in Hungary (Tombácz and Mozsgai, 2011). As most poor and marginalized people in Hungary live in the countryside (Herpainé Márkus et al., 2011), access to information as well as rural energy are difficult issues to solve. My research indicates that this number may not be enough for ensuring smooth and proper information flow. This number is questionable if we consider that marginalized and poor people often do not possess information or knowledge even in regard to much simpler areas (e.g. composting in the countryside) than how to save on energy or how to invest in energy reduction measures.

There are also concerns whether the schemes would decrease household energy cost. The provision of appropriate information (enhancement of procedural justice) and the increase in awareness have the potential to reduce energy use, but some studies in Hungary (Hoffmeister-Tóth, 2016) on environmentally conscious behaviour show that this impact is rather limited, and reinforcement is needed to identify appropriate alternatives for activities.

To enhance fair and socially more equal relations, focused mechanisms designed to increase social justice are needed instead of the equal per-capita distribution mechanism. These include the consideration of dwelling characteristics. Both the quantitative and qualitative research indicated that households that use mainly firewood and coal more often live in dwellings that are in bad condition than households that use other energy sources to satisfy their needs. The distribution of households in this cluster with more dwelling-related problems is greater than in other clusters, meaning that problems with bad dwelling conditions may accumulate in their case. Due to these inefficient dwellings these households pay slightly more for energy than the Hungarian average, thus an equal per-capita energy quota scheme would not enhance their living conditions. Furthermore, households living in panels or other apartment houses with central heating cannot influence their energy bills, since these are allocated centrally. This often leads to energy bills not mirroring real consumption, thus people are not motivated to change their heating or other energy-use related habits. Furthermore, households mainly use central heating to satisfy their energy needs and consume energy at the Hungarian average, thus implementing an energy quota scheme based on an equal per-capita distribution mechanism would be rather neutral for them.

In terms of defining quota distribution mechanisms, the energy use of additional household members should also be considered. There are different approaches to this, including the claim that one additional individual decreases per-capita energy expenditure on average by 6-30% (Department of Business, Energy and Industrial Strategy, 2020) or by 32–38% (Longhi, 2015). The Hungarian Climate Bill Proposal, for instance, suggests that the following method should apply to quota distribution: 100% after the first, 75% after the second, and 50% after the third child, and so on (Gyulai, 2011). This, however, does not consider the social and economic differences between members of society. There seems a simple ideological case for the energy quotas being distributed on an equal per-capita basis (resources are not man-made: if they are a 'free gift' from nature they ought to be considered our common inheritance). But there are at least two problems with this approach: Since we live in a diverse and deeply unequal society, some groups are clearly more able than others to adapt to a tightening cap. In order to solve this challenge, one solution might be to allocate a share from the energy budget to assist vulnerable groups who consume extremely high amounts of fossil energy, often through no fault of their own. This is the case of people with disabilities who cannot choose to cycle and walk, and of elderly people living in big family houses with inadequate energy systems (Alcott et al., 2018). Another point that should be taken into account when designing quota distribution mechanisms is that even if the distribution of energy quotas is supposed to be equitable, there will be have-nots. For them, one could imagine an unconditional basic income, partly consisting of essential resources (e.g. heat, water, and mobility access). This basic income, combined with progressive tariffs for bigger consumers of energy that would pay for the basic operation of the system, would build an element of social justice and redistribution into the supply system for basic goods, at no extra cost to society. It would also constitute an incentive to reduce consumption for the affluent consumers, in particular if prices increased due to their limited availability under the cap (Alcott et al., 2018).

When designing the distribution mechanism, considering the poor and marginalized is essential. According to national research (White and Thumim, 2009; Dresner and Ekins, 2004), TEQs, the system developed in the UK (Fleming and Chamberlin, 2011) primarily rewards marginalized people who use less energy. According to the Strategic Environmental Assessment (SEA) of the Hungarian Climate Bill proposal (Tombácz and Mozsgai, 2009) the Hungarian proposal also benefits the poor. However, the results of my research do not confirm this; they are more in line with the finding of the social impact assessment of the Hungarian Climate Bill Proposal (Herpainé Márkus et al., 2011). Poor people in efficient dwellings can actually consume more energy than the Hungarian average. Therefore, quota distribution mechanisms should consider the country-level differences of energy consumption patterns, too. Furthermore, in every country there are people currently slipping into poverty, who need extra attention. These people already cannot afford the kind of environmentally friendly, energy-efficient solutions which are affordable to the rich and middle-class, but they created their living conditions and consumption habits before becoming poor, thus they would definitely consume their entitlements rapidly (Tombácz and Mozsgai, 2009). If the schemes which are implemented pay extra attention to the poor and vulnerable, they have the potential to prevent an excessive burden on them in times of transition through ensuring fair and just access to energy at times of scarcity.

Another recommendation is related to the trading mechanism by which under-consumers can sell their saved quotas to those who would pay for their overconsumption. This should be implemented with proper consideration so the remaining quotas are not sold below the appropriate price. Therefore, I support those energy quota scheme proposals that would nominate a central authority (e.g. the Hungarian Climate Bill proposal) through which each quota transfer could take place. In this case, quotas would be sold at the national market price and through a central authority. Although this system would require more administrative work, it would avoid the outcome that those who need financial compensation would sell their quotas at below market price, as happens in Hungary in the case of the holiday vouchers or hot meal vouchers[9] that are usually distributed, and not only among the poorest. In the case of an energy quota, the savings of the poorest might rapidly be sold at very much under

[9] In Hungary, employees receive monthly or yearly defined allowances on voucher cards (in addition to their salaries), which can be spent only on holidays or hot meals.

the market price, since the latter usually are unable to plan, to live from one day to another, and thus are much more liable to wish to receive financial compensation rapidly. If a central authority or a registrar were established to implement each quota transaction, speculation with quotas and the associated black market could be mitigated. However, this would not mean that financial speculation with quotas could be fully eliminated, since any citizen not familiar with financial speculation could be taken advantage of, as can happen with every kind of product and service. Therefore, any additional measures that could be built in to minimise such speculation are needed in the case of minimizing this harmful effect on society.

With regard to creating workplaces, according to the strategic environmental assessment of the Hungarian Climate Bill Proposal, 40,000 new workplaces would be created (Tombácz and Mozsgai, 2009). It is questionable, however, whether such job opportunities would be available to those who live in marginalized areas, are less well educated, and have been unemployed for a longer time.

In terms of the impacts of the scheme on middle-class people, who can choose between investing in energy reduction or simply changing their way of living, their choice would need to be examined more deeply. Arguments support the choice of investing because this does not require any additional expenditure (in contrast to purchasing entitlements), it adds value, and it also avoids future quota-shortage-related problems. On the one hand, this would be very beneficial, since it is assumed that implementing the scheme would result in a significant reduction of energy use. On the other hand, it would mean that everyone might choose to invest and not to purchase, which would result in a lack of utilization of quotas saved by under-consumers. Managing this challenge may be difficult. A combination of setting a ceiling for investment-related costs might be a solution to this mixed problem.

As the results of and discussions reported in the qualitative research point out, energy sources from non-reported or illegal sources often play a role in poor and marginalized households. Formulating and implementing energy quota schemes should address and mitigate the use of these kind of resources as well. When attempting to enhance social justice it is important to consider what kinds of energy use the poor and marginalized can afford. Through mitigating waste burning in heating dwellings, we can tackle negative trade-offs between social and environmental impacts. The questions below are critical ones to answer if the proposed schemes are to be implemented adequately:

- How and by whom would illegal heating be monitored and managed?
- How can illegally collected wood, waste, or even the coal used in small stoves be accounted for and the data followed up?
- How would the energy that is created by burning these energy resources be counted?
- How can extremely unhealthy small stoves be phased out through the implementation of the system?

These questions are also important to answer from an environmental point of view, since firewood from sustainable sources is a proper fuel source for heating from a climate perspective (Bajomi, 2018; Agrárminisztérium and Herman Ottó Intézet, 2021), aside from its health-related consequences. Pollution that arises from solid-fuel burning depends on the quality of the energy source as well as the quality of the heating system. The amount of pollution that is produced, as well as heating-related costs, can be mitigated and the energy efficiency of dwellings can be enhanced by using the proper quality and quantity of firewood and a heating system in good condition.

5.CONCLUSIONS

To tackle climate change from an ecological economics perspective, systematic approaches are needed that maximize environmental and social benefits, while minimizing harmful trade-offs. To avoid climate catastrophe, radical solutions are needed, but these solutions should incorporate social justice considerations while striving for environmental sustainability. Since energy use contributes significantly to carbon dioxide emission, I analysed pre-existing energy-capping schemes from an ecological economics perspective. Since energy-capping schemes have been better developed for the residential sector, I narrowed down my focus to so-called Personal Carbon Trading schemes (PCTs). These schemes define an absolute limit for fossil energy use or the carbon emissions of a country/region in line with national/regional carbon emissions targets, and then lower the defined cap until it reaches a sustainable scale. Among the PCTs, I focused on those that would limit energy use as an input side regulation mechanism. Since two goals of ecological economics (achieving sustainable scale and effective allocation) are relatively easily achievable through implementing energy caps on the residential sector, I scrutinized more deeply the third goal: achieving just distribution.

To answer my research questions, I analysed Hungarian household energy-use data as well as carried out expert interviews to enable a more robust interpretation of the quantitative data as well as provide information about data missing from the official datasets. I aimed to reveal the interlinkages between residential energy use and social justice, as well as how a potential residential energy-capping scheme would influence the well-being of the Hungarian population, For this, I used for the secondary data analysis the SILC database collected at the EU level by Eurostat and variables based on a theoretical literature review, including justice theories linked to fair and sustainable energy use as well as methodological reviews concerning the methods and data for assessing residential energy use. After data cleaning, I created three new variables to reflect social justice. The first one revealed the proportion of spending on energy in the total housing cost; the second one revealed the primary energy the household uses; and the third one referred to the type of dwelling in which the household lives. I then created four groups of households based on their spending on different energy sources (gas, electricity, other fuels, and central heating). Statistical methods (ANOVA and Levene test) indicated that the groups were statistically significant from each other. After creating the clusters (Other fuel, Gas, Central heating, Mix of electricity and gas), I used cross-tabulation to reveal the correlations between the cluster membership variables and different socioeconomic variables. Considering justice theories and the methodological literature reviews, I looked through the SILC database and chose 29 socioeconomic variables, including three created ones to be used in the cross-tabulation. Based on the cross tabulation, I shortened the list of socioeconomic variables to be used in the multinomial regression and the discriminant analysis to 20.

The quantitative analysis indicated that all three newly created variables could help characterize energy use. Based on spending on different energy sources, groups of the Hungarian population were created. The first group of households use mainly solid fuel, the second mostly piped gas, the third mostly central heating, while the fourth a mixture of electricity and gas to satisfy their energy demands. The 20 socioeconomic variables that were selected, including the three created variables, help define these four groups. Households that use mainly solid fuel live in bigger dwellings with bigger families with poor living conditions and pay more for energy as a proportion of total housing costs than households in the other three clusters. They spend more on food and beverages and less on culture, entertainment, and vacations. The reference person of these households has a lower level of education, while these households are underrepresented in the highest income decile compared to the other three household clusters. They consume slightly more energy than the Hungarian average, meaning that if an energy quota scheme based on equal per-capita distribution were implemented, it would not benefit them automatically.

Households that primarily use piped gas also live in bigger dwellings, mainly in family houses. They are similar to households from the Other fuel clusters in that they spend proportionally more on energy from the total household budget, but they are reported to have the best living conditions (along with the centrally heated households cluster) in terms of ability to keep their homes warm, cover household maintenance costs, pay bills on time, ability to meet their needs, and level of satisfaction with living. Households belonging to this cluster are proportionally found more often in the five top income deciles than households from the other fuel and the mixed clusters. The implementation of an energy-capping scheme would not benefit them at all, since in general they use 1.5 times more energy than the Hungarian average. Households from the central heating and the mixed clusters spend proportionally much less on energy as a proportion of total housing costs than their counterparts from the other fuel and the gas clusters. Centrally heated households mainly live in the panel-block housing of the capital and other big cities, and an energy-capping scheme would be neutral for them, since they use the average amount of energy of Hungarian households. Households from the mixed clusters reported to having the second worst dwelling and living conditions as well as financial income, while spending the most on education. These households, however, would definitely benefit from an energy capping scheme based on equal per-capita distribution, since they use much less energy than the Hungarian average.

In order to validate and underpin the results of the quantitative secondary data analysis, I carried out expert interviews and collected primary data on the interlinkages between energy and poverty, and how an equal per-capita energy-capping scheme would impact these relations. The interview results were in line with environmental justice theories that claim that the poor and marginalized are more often exposed to pollution and environmental problems, while miss out on opportunities to reduce household energy use. Due to the poor conditions of their dwelling and equipment, they suffer a greater burden paying energy-related costs, which increases energy poverty and thus energy injustice. These people live day to day but cannot access sufficient energy and their human capabilities are also harmed. These violations of capabilities are not recognized by members of society, leading to recognitional injustice. Based on experts' views about the interlinkages between energy and poverty in Hungary, any energy-capping schemes need to be implemented with caution. Procedural justice, meaning access to information on opportunities provided by the scheme, as well as education from childhood on energy use, needs to be granted, thus ensuring one of the preconditions for mitigating energy poverty and energy injustice. Furthermore, modifying heating habits as well as the use of illegal energy sources and ensuring proper data collection that reveals the underlying causes of energy use is necessary for mitigating energy injustice and achieving sufficiency for all in energy use.

Based on the results of the quantitative and qualitative analysis, I compiled recommendations on how an energy-capping scheme needs to be modified in order to be implemented in a socially just manner. To mitigate challenges in the field of energy and poverty, holistic approaches are needed that tackle social and environmental trade-offs, and thus enhance distributional justice. Further data collection is needed that sheds light on social justice elements and reveals their contribution to household energy use. Moreover, strong public support needs to be established through, inter alia, sound information flow. My research also shows that if an energy quota scheme is being planned for implementation, it is crucial if social justice and other factors, including dwelling conditions, are considered instead of only equal per-capita distribution. Furthermore, trading mechanisms should be consciously developed to mitigate loopholes and protect citizens, especially the poor and marginalized, from financial speculation. Furthermore, job creation should also consider those who have a lower level of education and aim to increase their employment rate too, not only that of the well-educated or trained people, while investment costs need to be limited in order to ensure the motivation to use fewer and fewer quotas. Last but not least, non-reported and illegal energy use also should be mitigated when implementing an energy-capping scheme. With these findings, I would like to contribute to the policy negotiations associated with the European Green Deal, which aims to achieve a state of carbon neutrality by 2050 as well as the energy-poverty policies of the EU in a just way.

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7.1. Related own publications

Kiss, V., Hajdu, K. (2020): New approach in educating about innovative climate policy - a case study at the ISDRS in Sustainability in Transforming Societies: Proceedings of the 26th Annual Conference of the International Sustainable Development Research Society p. 42

Potocnik, J., Spangenberg, J., Blake, A., Kiss, V., Coote, A., Reichel, A., Lorek, S., Mathai, M. V., Rijnhout, L., Mastini, R. (2018): Sufficiency: Moving beyond the gospel of eco-efficiency (48 p.) Friends of the Earth Europe. Brussels.

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8.Annex I.

8.1. Interview thread

Interview on the interlinkages between poverty and energy consumption

Research background:
In my doctoral dissertation I investigate policy instruments that targets absolute fossil fuel energy consumption, while aiming for enhancing social justice. Namely, they are designed to benefit the poor, who presumably consume less energy than the rich. With this research I strive to know more and understand the interlinkages between Hungarian poverty and household energy consumption. Throughout the interviews, I aim to get to know the opinions of environmental and social science experts on the links between household energy consumption and poverty level.

Interview analysis:
If the interviewee accepts, I sound record the interview and also make notes during it. I use the sound recording and the notes only for my research related to my dissertation. The interview takes approximately 60 minutes. I use the results only cumulatively with the results of other interviews, thus the interviewees based on their answers will not be identified. I will not use the data for any other purposes beside my dissertation. Would you allow me to cite you anonymously or using your name in my dissertation? Could I mention you in the acknowledgement of my dissertation?

I. **Part – GENERAL QUESTIONS ON THE LINKAGES BETWEEN POVERTY AND ENERGY CONSUMPTION**

General (content mapping, prompts - Ritchie and Lewis, 2003)

1. Introductory question: What do you think about the interlinkages between poverty and energy consumption?

2. During your work and based on your experience how poverty and energy consumption appear?

More specific, asking for details questions (content mining, probes - Ritchie and Lewis, 2003)

3. What characterises the energy consumption of the poor?

4. What do you think about the interlinkages between poverty and household energy consumption if sustainability is being considered?

5. What kinds of shortcomings do you see in the interlinkages between poverty and energy consumption?

6. What kind of obstacles emerge in your way while revealing the interlinkages between poverty and energy consumption?

7. Based on your professional knowledge (being aware of relevant professional literature) relevant question in the theme of poverty and energy consumption

II. **Part: IMPACT OF THE CLIMATE BILL PROPOSAL ON THE POOR**

1. After shortly presenting the analysed energy-capping schemes: what kinds of households do they impact? How do they influence poor households?

III. **Part: INTRODUCING RESULTS OF THE QUANTITATIVE RESEARCH AND REVEALING ITS SHORTCOMINGS**

1. After shortly introducing the quantitative research, what is your opinion about its shortcomings?
    - Illegal waste burning, other non-reported energy consumption?
    - How sufficient to measure energy consumption through the variables of the costs spent on consuming different energy resources?
    - Income as poverty indicator?

IV. Part: END/CLOSING

2. Clarifying questions

3. Whom you suggest being interviewed (even opinion leader of communities?)

8.2. Interview summary form

Spot:
Date:
Personal/Skype:
Participant(s):
Professional background:
Institute:

Question types

I. **Part – GENERAL QUESTIONS ON THE LINKAGES BETWEEN POVERTY AND ENERGY CONSUMPTION**

- **General (content mapping, prompts - Ritchie and Lewis, 2003)**
    - Introductory question: What do you think about the interlinkages between poverty and energy consumption?

    - During your work and based on your experience how do poverty and energy consumption appear?

- **More specific, asking for detailed questions (content mining, probes - Ritchie and Lewis, 2003)**
    - What characterises the energy consumption of the poor?

    - What do you think about the interlinkages between poverty and household energy consumption if sustainability is being considered?

- What kinds of shortcomings do you see in the interlinkages between poverty and energy consumption?

- What kind of obstacles emerge when revealing the interlinkages between poverty and energy consumption?

- Based on your professional knowledge (being aware of relevant professional literature) which are the relevant questions in the theme of poverty and energy consumption?

II. **Part: IMPACT OF THE CLIMATE BILL PROPOSAL ON THE POOR**

- After shortly presenting the analysed energy-capping schemes: what kinds of households do they impact? How do they influence poor households?

III. **Part: INTRODUCING RESULTS OF THE QUANTITATIVE RESEARCH AND REVEALING ITS SHORTCOMINGS**

- After shortly introducing the quantitative research, what is your opinion about its shortcomings?
    - Illegal waste burning, other non-reported energy consumption?
    - How sufficient is the measure of energy consumtion through the variables of the costs spent on consuming different energy resources?
    - What do you think of income as poverty indicator?

IV. **Part: END/CLOSING**

- Clarifying questions

- Whom you suggest being interviewed (even opinion leader of communities?)

8.3.Categorizing data segments of the expert interviews

Themes	**Data segments**	**Category**	**Sub-category**	**Link to theory**
Energy and poverty	often much and wasteful	Behaviour	inefficiency	
	inappropriate homes	energy poverty as energy injustice	home infrastructure	low heat efficiency and bad housing conditions
	m higher share of housing costs is spent on energy	energy poverty as energy injustice	household economics	low income + high household energy costs
	no money to invest	capability	household economics	low income + high household energy costs
	environmentally polluting energy use	environmental justice	pollution, health	poor are more affected
	burn waste	environmental justice	energy source / exposure	exposure
		environmental justice	power	exposure
	illegal tree cutting	behaviour	energy source	
	no option to exploit renewables	energy poverty as energy injustice	renewables	poor and marginalized do not have the power and information
	excluded from opportunities	energy poverty as energy injustice	state support	poor and marginalized do not have the power and information
	spare on heating, cold dwelling	energy poverty as energy injustice	household economics	low income + high household energy costs.

9.Annex II. – Results of the cross tabulation

Crosstab

			ordinal share energy					
			0 thru 0.1	0.11 thru 0.15	0.16 thru 0.2	0.21 thru 0.3	0.31 thru Highest	Total
Cluster Number of Case	mostly other fuel heated	Count	43913	155824	188192	351127	176334	915390
		% within Cluster Number of Case	4,8%	17,0%	20,6%	38,4%	19,3%	100,0%
	mostly gas heated	Count	76227	185402	192386	335557	148106	937678
		% within Cluster Number of Case	8,1%	19,8%	20,5%	35,8%	15,8%	100,0%
	mostly central heating heated	Count	136803	195491	113788	113437	31477	590996
		% within Cluster Number of Case	23,1%	33,1%	19,3%	19,2%	5,3%	100,0%
	mix of electricity and gas heated	Count	403401	332433	239436	238866	77963	1292099
		% within Cluster Number of Case	31,2%	25,7%	18,5%	18,5%	6,0%	100,0%
Total		Count	660344	869150	733802	1038987	433880	3736163
		% within Cluster Number of Case	17,7%	23,3%	19,6%	27,8%	11,6%	100,0%

Crosstab

			ordinal living area per person					
			3,2 to 10	10,1 to 20	20,1 to 40	40,1 to 100	above 100,1	Total
Cluster Number of Case	mostly other fuel heated	Count	21968	129676	394627	413448	31190	990909
		% within Cluster Number of Case	2,2%	13,1%	39,8%	41,7%	3,1%	100,0%
	mostly gas heated	Count	1811	80567	336233	559630	52863	1031104
		% within Cluster Number of Case	0,2%	7,8%	32,6%	54,3%	5,1%	100,0%
	mostly central heating heated	Count	7322	138023	262521	221181	298	629345
		% within Cluster Number of Case	1,2%	21,9%	41,7%	35,1%	0,0%	100,0%
	mix of electricity and gas heated	Count	21900	249456	585466	487048	21530	1365400
		% within Cluster Number of Case	1,6%	18,3%	42,9%	35,7%	1,6%	100,0%
Total		Count	53001	597722	1578847	1681307	105881	4016758
		% within Cluster Number of Case	1,3%	14,9%	39,3%	41,9%	2,6%	100,0%

Crosstab

			Pollution, environmental problems		Total
			yes	no	
Cluster Number of Case	mostly other fuel heated	Count	86297	904612	990909
		% within Cluster Number of Case	8,7%	91,3%	100,0%
	mostly gas heated	Count	70140	960964	1031104
		% within Cluster Number of Case	6,8%	93,2%	100,0%
	mostly central heating heated	Count	89131	540214	629345
		% within Cluster Number of Case	14,2%	85,8%	100,0%
	mix of electricity and gas heated	Count	134635	1230765	1365400
		% within Cluster Number of Case	9,9%	90,1%	100,0%
Total		Count	380203	3636555	4016758
		% within Cluster Number of Case	9,5%	90,5%	100,0%

Crosstab

			Settlement type				Total
			Budapest	Big city	Town	Village	
Cluster Number of Case	mostly other fuel heated	Count	13579	66112	349395	561823	990909
		% within Cluster Number of Case	1,4%	6,7%	35,3%	56,7%	100,0%
	mostly gas heated	Count	210167	184415	371843	264679	1031104
		% within Cluster Number of Case	20,4%	17,9%	36,1%	25,7%	100,0%
	mostly central heating heated	Count	182146	338594	97045	11560	629345
		% within Cluster Number of Case	28,9%	53,8%	15,4%	1,8%	100,0%
	mix of electricity and gas heated	Count	374069	282956	404200	304175	1365400
		% within Cluster Number of Case	27,4%	20,7%	29,6%	22,3%	100,0%
Total		Count	779961	872077	1222483	1142237	4016758
		% within Cluster Number of Case	19,4%	21,7%	30,4%	28,4%	100,0%

Crosstab

			Education of the ref person				Total
			no or primary	secondary, without graduation	secondary, with graduation	higher education	
Cluster Number of Case	mostly other fuel heated	Count	319294	364762	220042	86811	990909
		% within Cluster Number of Case	32,2%	36,8%	22,2%	8,8%	100,0%
	mostly gas heated	Count	136305	258801	325721	310277	1031104
		% within Cluster Number of Case	13,2%	25,1%	31,6%	30,1%	100,0%
	mostly central heating heated	Count	57011	133036	252035	187263	629345
		% within Cluster Number of Case	9,1%	21,1%	40,0%	29,8%	100,0%
	mix of electricity and gas heated	Count	236233	317616	464406	347145	1365400
		% within Cluster Number of Case	17,3%	23,3%	34,0%	25,4%	100,0%
Total		Count	748843	1074215	1262204	931496	4016758
		% within Cluster Number of Case	18,6%	26,7%	31,4%	23,2%	100,0%

Crosstab

			ordinal cult ent vac cost						
			missing	292 to 10000	10001 to 100000	100001 to 200000	200001 to 1000000	above 1000000	Total
Cluster Number of Case	mostly other fuel heated	Count	128045	27994	349121	183250	278216	24283	990909
		% within Cluster Number of Case	12,9%	2,8%	35,2%	18,5%	28,1%	2,5%	100,0%
	mostly gas heated	Count	91207	25642	256840	173370	406266	77779	1031104
		% within Cluster Number of Case	8,8%	2,5%	24,9%	16,8%	39,4%	7,5%	100,0%
	mostly central heating heated	Count	58821	21609	150491	115325	261274	21825	629345
		% within Cluster Number of Case	9,3%	3,4%	23,9%	18,3%	41,5%	3,5%	100,0%
	mix of electricity and gas heated	Count	138704	63058	387722	227228	486124	62564	1365400
		% within Cluster Number of Case	10,2%	4,6%	28,4%	16,6%	35,6%	4,6%	100,0%
Total		Count	416777	138303	1144174	699173	1431880	186451	4016758
		% within Cluster Number of Case	10,4%	3,4%	28,5%	17,4%	35,6%	4,6%	100,0%