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Original research article

Energy taxes recycling as an instrument for the mitigation of the expenditure on energy products of vulnerable households in the European Union

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ABSTRACT

Environmental problems, particularly climate change, have raised awareness of the need to decarbonize the energy sector. Several policies have been followed worldwide, including high energy taxes in European countries. However, simultaneously, many countries still suffer from energy poverty, and energy taxation only aggravates this problem. Considering this situation, this research proposes implementing green tax reform in European countries where energy tax revenues would be used to alleviate energy poverty. This article analyzes the situation of European Union Member States regarding some relevant variables such as energy tax revenues and energy poverty indicators (inability to keep the home adequately safe, low final energy consumption in households, arrears on utility bills, and electricity prices). The results show a significant variation in the total share required for energy bills, ranging from 5 % to 40 %. Countries with high energy tax revenues suffering from energy poverty are identified as potential candidates for the proposed reform. It was found that Bulgaria, Cyprus, Greece, Italy, Portugal, Romania, and Slovakia are good candidates for reform. This situation is combined with an inefficient tax policy, resulting in a large amount of money being transferred for direct and indirect fossil fuels and environmentally harmful subsidies. An energy tax recycling scheme focused on reducing energy consumption using energy efficiency measures, for example, under a scheme of Public Energy Services, can be optimally combined to redistribute the energy tax income to reduce energy poverty and contribute to decarbonization if combined with a new scheme that removes harmful fossil fuel subsidies.

1. Introduction

In the face of growing concern about climate change [1] and the European Green Deal's aim of achieving net zero greenhouse gas emissions (GHG) in Europe by 2050 [2], the revision of energy taxation is critical to achieving the EU's highest emission reduction goals [3]. Energy is necessary daily to enhance human development, economic growth, and productivity [4]. Moving to a carbon-neutral world is a pressing issue and a favorable circumstance for creating a better future for all [5]. In this regard, because the energy sector is critical to achieving GHG cutbacks, it shall be at the center of this shift [6].

It is worth mentioning the fact that, within the European Union, a clear roadmap for low-carbon energy security has emerged [7] to make increased use of renewables, reduce greenhouse gas emissions, and improve energy efficiency as an integral part of the Energy Union (EU) strategy [8–10]. In September 2020, the European Commission presented its 2030 Climate Target Plan, which included a proposal to raise the EU's 2030 objective for emissions reductions from 40 % [11] to at least 55 % [12,13] compared to 1990 levels [14–16] and to achieve climate neutrality by 2050 [17,18]. As it has been called, this "Fit for 55" package implements the European Climate Law, which was published in the Official Journal on July 9, 2021 [19,20]. The 2030 Framework updates and enhances the EU's climate and energy legislation without reinventing it, placing the EU on the road towards a low-carbon society over time [21]. Still, this energy transition should be "just" and avoid

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Nomenclature

CHP	Combined heat and power
CO_2	Carbon dioxide
ECB	European Central Bank
EEF	Energy efficiency first principle
EHS	Environmentally harmful subsidies
ESCO	Energy Services Company
ETD	Energy Taxation Directive
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas emissions
GTR	Green Tax Reform
HCPI	Harmonized Index of Consumer Price
USA	United States of America

Table 1
Effects of carbon recycling schemes.

Carbon recycling measure	Lump-sum	Payroll tax reduction	Corporate income tax
Benefits	Positive impact on progressivity	Better progressivity Improves output Improves employment	Significant increase in R&D investment Increase in output Increases pretax wages
Cons	Impact on employment and output	–	Decreases the progressivity Lower employment rates

Adapted from [86].

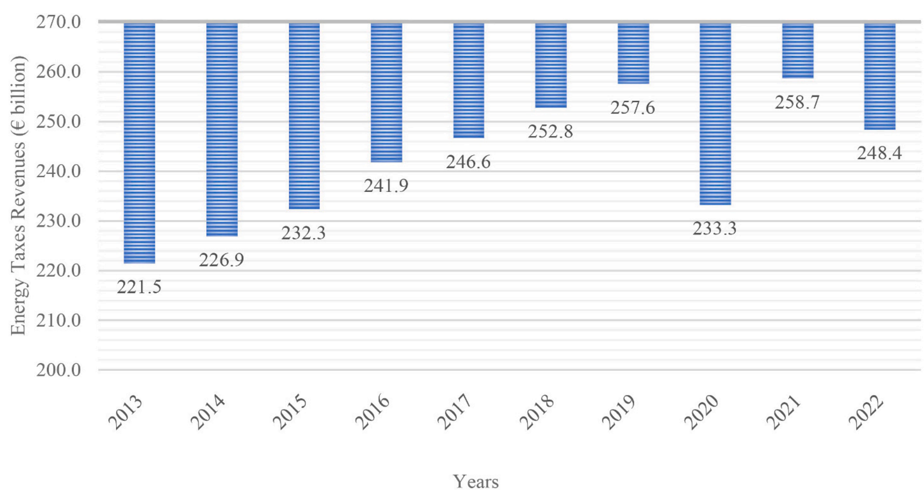

Fig. 1. Energy tax revenues in the EU.
Source: [69].

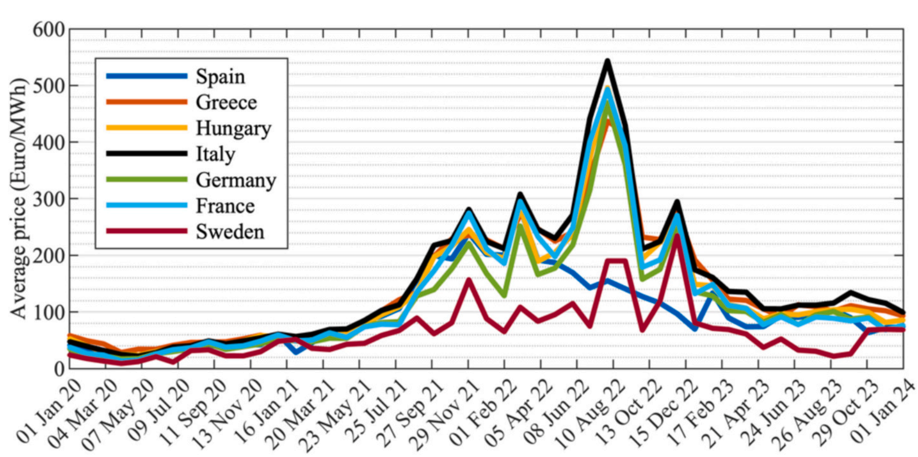

Fig. 2. Average monthly power wholesale costs (in euros per megawatt-hour) for a few EU member states from January 2020 to March 2023.
Source: [84].

harming vulnerable agents [22].

The final cost of energy products is strongly influenced by taxes, which differ according to consumers, energy types, and countries [23]. Furthermore, energy taxes in the EU can significantly impact consumption patterns and the type of energy utilized [24,25]. The 2003 Energy Taxation Directive (ETD) established minimum tax rates for all energy supplies and uses, including coal, gas, and electricity [26,27]. Above the minimum, Member States can determine their national rates and levy additional taxes [28]. The current Energy Taxation Directive exists to avoid distortions of competition and contribute to a low-carbon

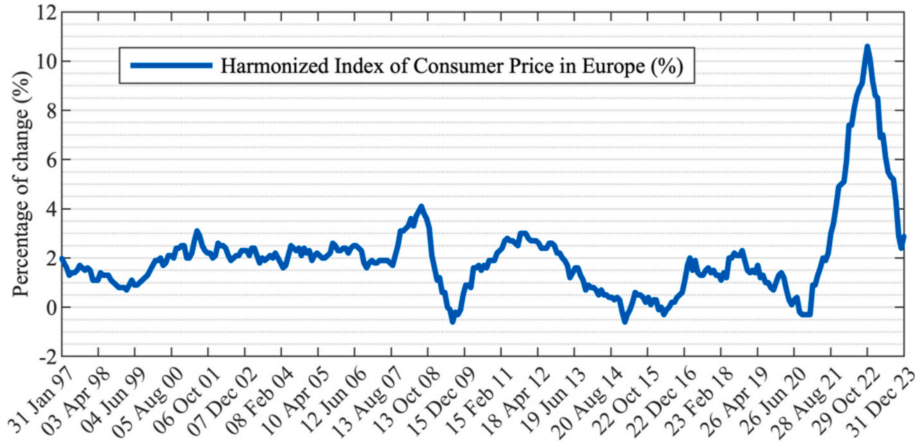

Fig. 3. Evolution of HCIP in Europe. Self-made from European Central Bank [89] data.

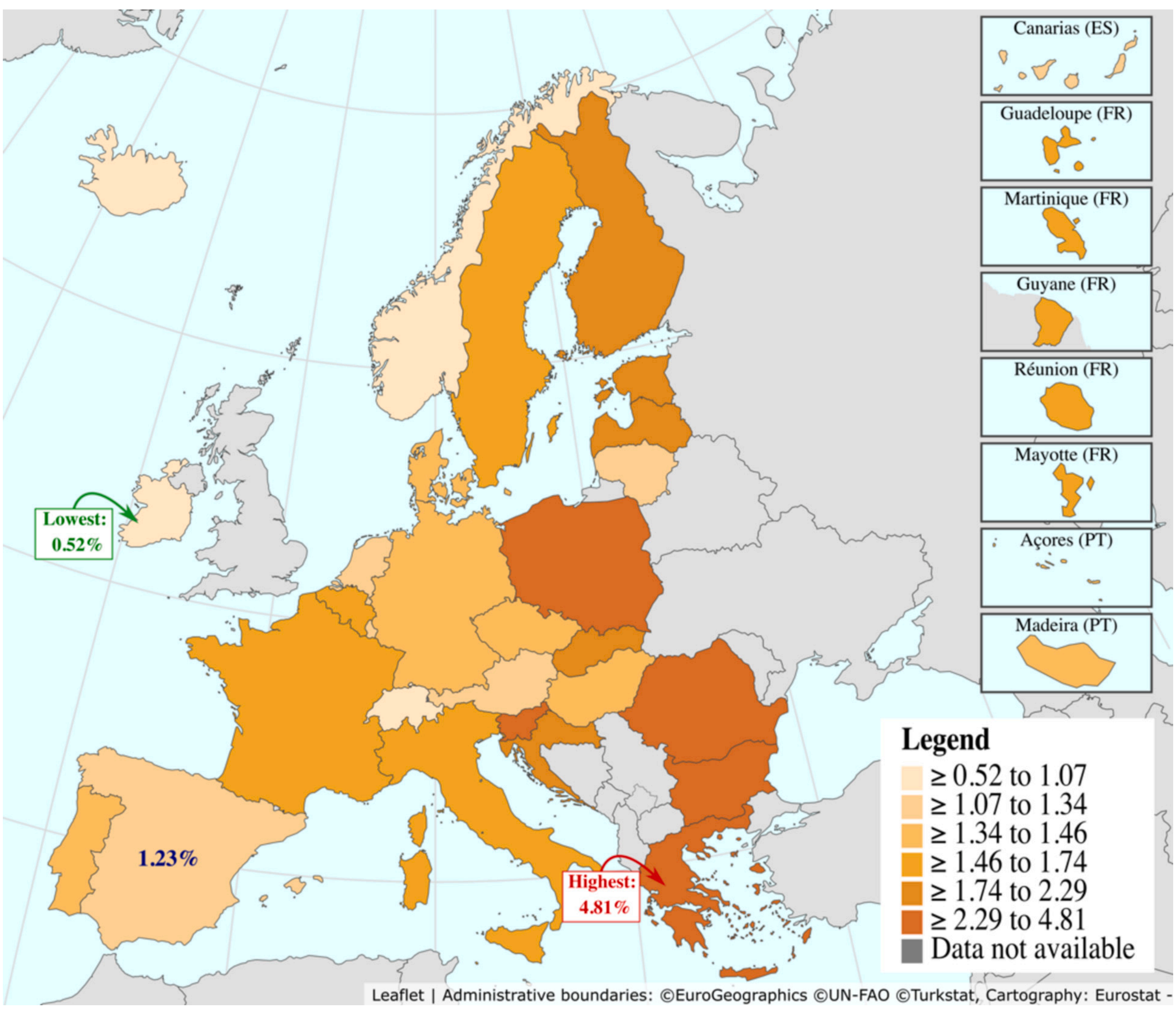

Fig. 4. Energy tax revenues in the EU by region as a percentage of gross domestic product.
Source: [69].

and energy-efficient economy [29]. Nevertheless, due to the inconsistency and misalignment between the EU energy tax policy and its climate pledges [30], the current Energy Taxation Directive has come under fire for falling short of the EU's goals in energy and climate change [31]. In the EU, the share of energy taxes, which account for a large part of the end-users energy bill [32], has been continuously increasing since 2008 [33] until the second half of 2022, when several Member States introduced subsidies and rebates [34]. In general, and on an EU-wide

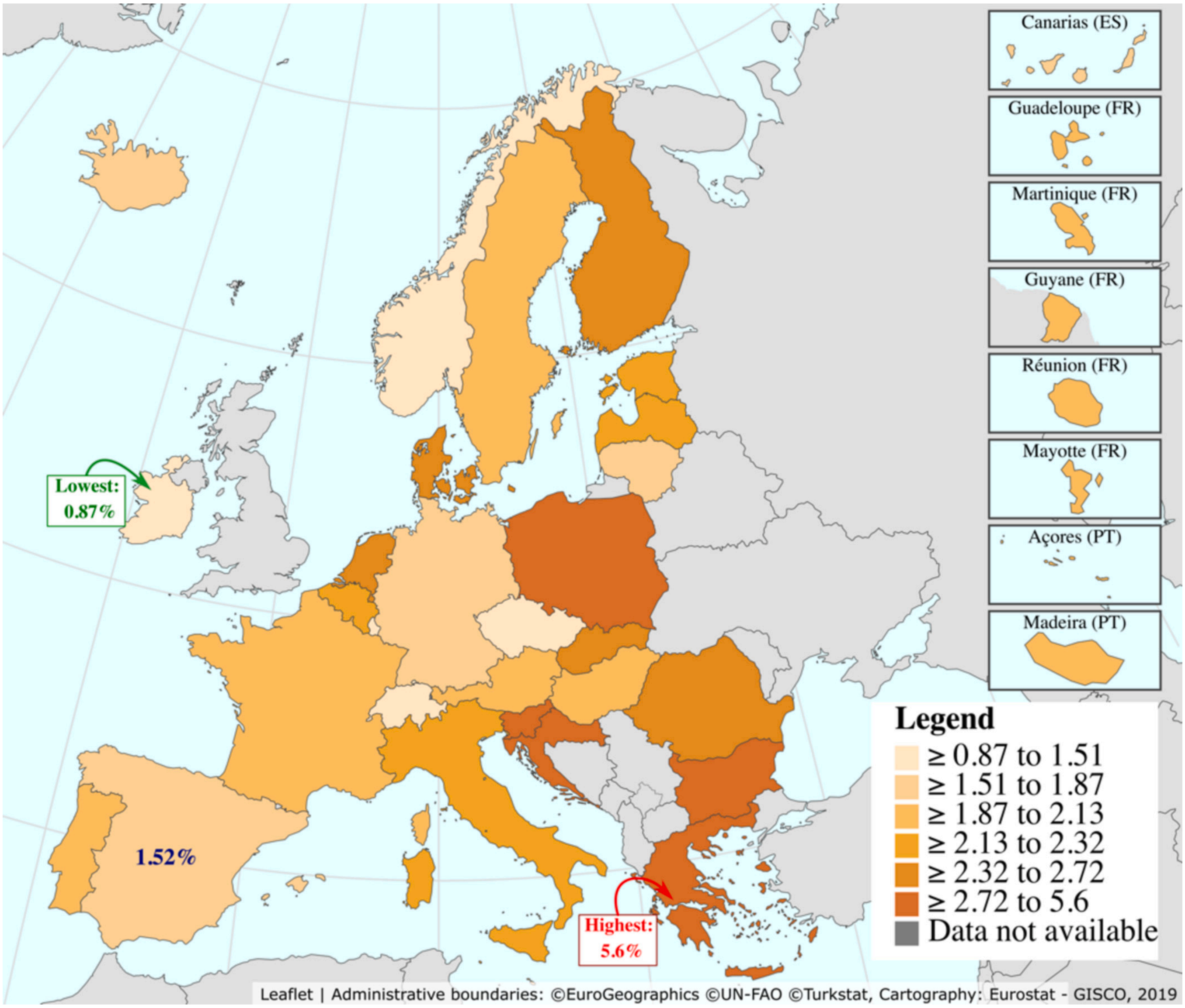

Fig. 5. Total environmental tax revenues in the EU by region as a percentage of gross domestic product.
Source: [69].

basis, taxes and levies contribute 40 % of final residential electricity pricing [35]. EU has included energy efficiency as a critical aspect of its energy policy and has established it as a guide to further establishing energy policies. This guideline, known as Energy Efficiency First (EEF), is based on three principles, presented as follows: i) produce only the energy that is required in each moment and situation, ii) palatine reduction and avoid investing in stranded assets, such as fossil fuels and iii) reduce energy demand and manage it under the most cost-effective strategy. It is important to remark that this EEF is stablished in all the aforementioned EU legislation and, therefore, it must guide the energy policy as a whole.

These higher energy prices will affect all types of consumers, both richer and poorer, but the effect tends to be regressive, placing a higher burden on lower-income groups [22]. Hence, there are potential adverse distributional effects implicit in energy taxation. If energy poverty already exists [36], it can be worsened by higher energy taxes. However, if energy tax revenues can support vulnerable households, energy poverty can be alleviated [37], and public acceptability of environmental taxation may increase [22]. This type of policy combination has been referred to in the literature as an Environmental or Green Tax Reform (GTR) [38]. GTR has started in the Nordic countries in the 90s. In the first generation of these reforms, environmental tax revenues were used to cut labor and capital taxes. Several evolutions have occurred in the last decades, and currently, more recent GTRs accept the idea of using environmental tax revenues to support renewable energies or energy efficiency, for example. Another possible use of tax revenues is to help lower-income consumers, which is the possibility considered in this paper.

Numerous research papers in the scientific literature investigate the impact of energy taxation in the European Union. Among the most prominent are those carried out by Shmelev and Speck, who used an econometric approach to analyze the effectiveness of energy and carbon taxes in Sweden [39]; those carried out by Heffron, who focused on the issue of taxation (collection, revenue, and expenditure) and inequality about natural resource management [40]; the research carried out by Wang et al. who assessed the economic impact of energy taxes, the environment and the quality of public health in Tianjin [41]; or the research conducted by Voulis et al. [42], who suggested a series of recommendations to policymakers for the design of energy taxes that grants enough financial incentives for residential and service sector

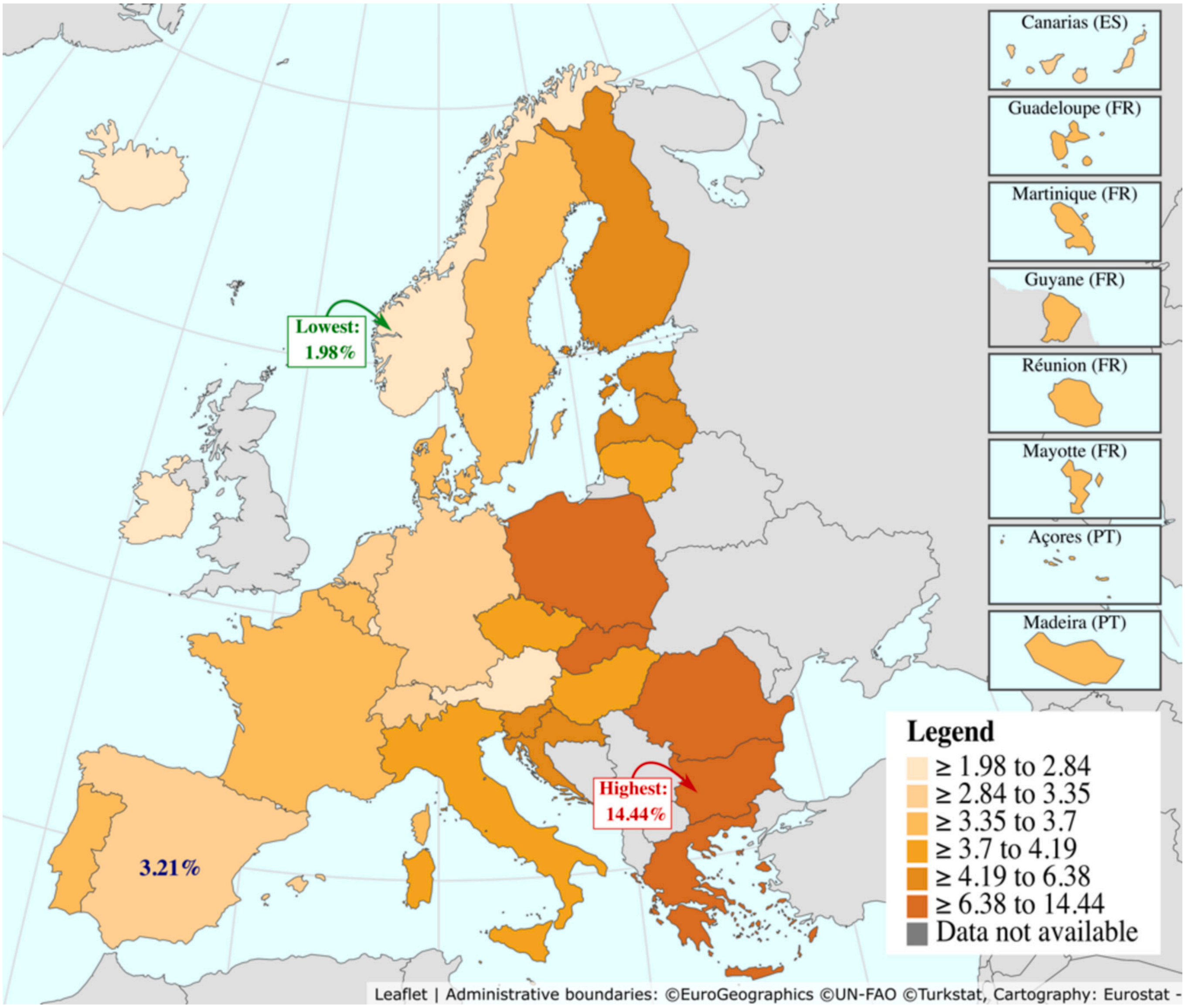

Fig. 6. Total revenue from taxes and social contributions (including imputed social contributions) from energy taxes.
Source: [69].

users for participation in demand response.

However, the impact of energy taxation on the economically disadvantaged citizens of the European Union in the current political context and household energy prices have not been given the same attention, and a study addressing them is needed. Furthermore, the possibility of using tax revenues to reduce energy poverty, in the spirit of a GTR, has never been studied for the EU.

Based on an in-depth study of the most recent literature on the subject at hand, it has been found that this work complements the existing body of knowledge by providing an insight that, according to the literature review, has not been explicitly addressed in any scientific article to date.

This research aims to study the feasibility of a GTR where energy tax revenues would be used to alleviate energy poverty in several EU Member States. With this in mind, it presents a complete review of energy taxation, covering the current policy background. Furthermore, the study explores several indicators useful to assess energy poverty, such as the inability to keep the home adequately climatized, low final energy consumption in households, arrears on utility bills, and high electricity prices.

The article's structure is as follows: After this introduction, the theoretical background of the analysis is explored, particularly on the topics of energy taxation and energy poverty. The third section presents the data analysis, highlighting the most relevant results. Section 4 discusses the results, and Section 5 concludes the paper.

2. Theoretical background

2.1. Energy taxes in EU

Before the 1980s, when applied, energy taxes were not considered an environmental measure but a fiscal tool used exclusively to collect taxes [43]. Within energy public policies, taxation of energy products has been applied with varying intensity and scope in several European countries for several decades. However, it is now reasonably widespread worldwide and has experienced notable increases since the 1980s [44]. Since the late 1990s, growing worry about climate change has prompted policymakers to experiment with regulatory instruments whose implications were uncertain at the time [45]. Taking emissions pricing as the basis of their climate policy governance [46], in the 1990s, several

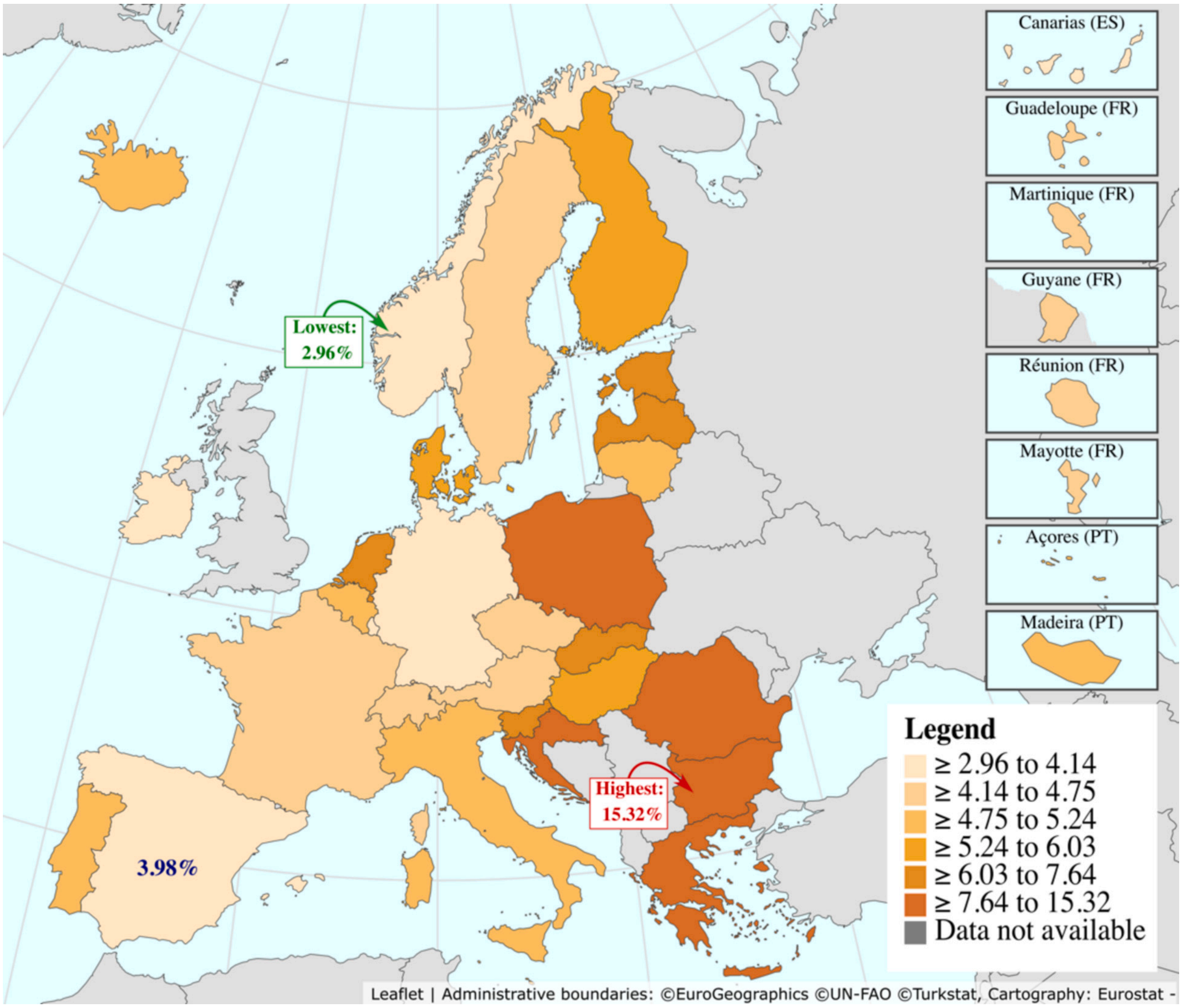

Fig. 7. Total environmental taxes percentage of total revenues from taxes and social contributions (including imputed social contributions).
Source: [69].

northern European countries (Finland, Norway, Sweden, and Denmark, closely followed by the Netherlands) [47] imposed carbon taxes to limit their greenhouse gas emissions [48–50]. In 1999, several large countries, including France, Germany, and Italy, followed [47].

The debate in the European Union faced numerous alterations [51]. Already in 1992, the EU Commission had proposed a "radical" [52] new CO_2/energy tax for environmental reasons [53]. However, there was a dispute in the Community on the necessity for and content of a CO_2/energy tax, and a group of Member States led by the UK blocked its implementation [54] on sovereignty grounds [55]. Despite the setback in CO_2 taxing, gentler tools for energy efficiency and renewable energies were agreed upon [54]. A few years later, in 1997, a proposal for reorganizing the Community framework for energy product taxation emerged, expanding the system of minimum rates for hydrocarbons to other energy products, including electricity [56]. The idea includes an initial low-rate tax on electricity consumption [56]. This proposal, which addressed environmental issues, was primarily motivated by the desire to secure the smooth operation of the internal market [57]. Despite the efforts of numerous Presidency, the Council could not adopt this idea due to a lack of agreement [58]. It took until March 2003 for a proposal on energy taxes to culminate in official Directive establishing minimum levels of taxation of energy goods in the Member States [59].

The 2003 Directive on the Taxation of Energy Products was a significant improvement over the 1992 legislation in that it broadened the scope of energy taxation to include all energy products, including natural gas, coal, and electricity, and raised the minimum rates that countries must consider when enacting their national implementation [60,61]. Currently in force, this Energy Taxation Directive (Directive 2003/96/EC) is considered obsolete and out of sync with the EU's climate and energy objectives [3]. According to the conventional Pigouvian paradigm, environmental taxes should equalize marginal harms and be paid directly by the source of emissions [62]. The prevailing Pigouvian approach to excise taxes in the Energy Taxation Directive (Directive 2003/96/EC) implicitly implies that electricity use is equally detrimental to the environment regardless of consumption. This is true for fossil-fuel-generated electricity and the picture becomes more complicated for electrical systems that rely heavily on renewable resources [42]. Consequently, the Energy Taxation Directive (Directive 2003/96/EC) fails to bring about a global transformation of our societies towards carbon neutrality [63].

There is empirical evidence that the most common forms of energy taxes, which impact the costs of heating, electricity, and transportation (all of which might be regarded as necessities of contemporary living), place a more significant burden on low-income households than on high-income households because the former spend a more substantial proportion of their income on these products [64]. The regressive nature of environmental taxes is sometimes regarded as politically unpalatable and hinders the implementation of environmental tax reforms [65].

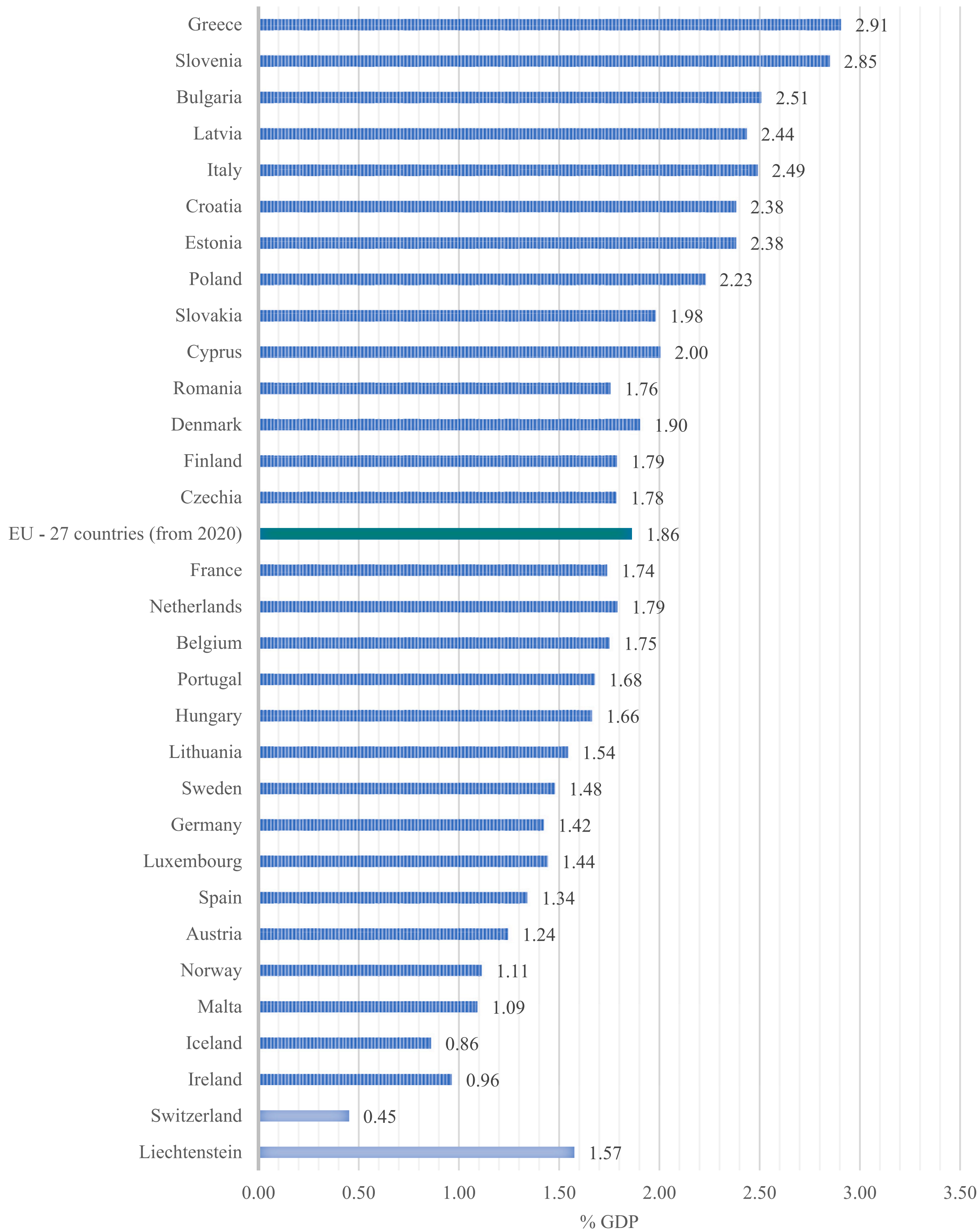

Fig. 8. Average share of energy taxes in GDP for EU. Self-made with [69] data.

Given that lower-income households spend a higher proportion of their income on energy needs such as electricity, there is a consensus that these households are expected to experience a disproportionate impact from energy taxes if revenues are not returned to them in some way [29,64,66,67].

In 2021, energy taxes in the European Union accounted for more than three-quarters of total environmental tax revenues (78.4 % of the total), well ahead of taxes on transport (18.1 %) and on pollution and resources (3.5 %) [68]. Specifically, EU environmental tax revenues totaled 325.8€ billion (1000 million) in 2021, accounting for 5.4 % of overall public income from taxes and social payments [68]. Fig. 1 depicts energy tax revenues between 2013 and 2023. Despite a decline in 2020, energy taxes have not stopped increasing from 2013 to 2022.

2.2. Energy poverty

According to Eurostat, energy poverty "occurs when a household must reduce its energy consumption to a degree that negatively impacts the inhabitants' health and wellbeing" [70]. As referred to by Chien et al. [37], high energy costs are one of the factors contributing to this phenomenon, along with economic hardship and inefficient systems. EU's rising energy prices during the last years are caused by various factors affecting supply and demand conditions, such as the geopolitical environment, the country's energy mix, import diversification, or the degree of energy taxes [71–73]. Rising energy prices, especially in the short term, can also be attributed to stringent climate policies motivated by the global climate change agenda [74]. Although rising energy prices raise the cost of life for all Europeans, the burden is not uniformly

Table 2
Share of energy taxes in gross domestic product by Member State (GDP).

Country/year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
EU - 27 countries (from 2020)	1,92	1,93	1,9	1,93	1,89	1,87	1,84	1,73	1,77	1,56
Liechtenstein	0,35	0,39	0,39	0,37	0,37	0,32	0,38	0,36	0,33	:
Switzerland	0,91	0,92	0,93	0,97	0,97	0,99	0,98	0,96	0,94	0,89
Ireland	1,52	1,45	1,15	1,16	1,09	0,97	0,85	0,74	0,74	0,52
Iceland	1,26	1,21	1,17	1,07	1,14	1,11	1,15	1,17	0,87	0,99
Malta	1,34	1,48	1,36	1,39	1,29	1,22	1,25	1,06	0,9	0,83
Norway	1,21	1,26	1,3	1,34	1,32	1,33	1,29	1,32	1,19	0,86
Austria	1,57	1,51	1,52	1,48	1,5	1,4	1,4	1,21	1,31	1,08
Spain	1,58	1,56	1,61	1,54	1,52	1,52	1,45	1,43	1,42	1,23
Luxembourg	1,9	1,75	1,61	1,52	1,5	1,58	1,62	1,26	1,35	1,12
Germany	1,72	1,67	1,59	1,54	1,51	1,47	1,46	1,4	1,52	1,36
Sweden	1,86	1,73	1,68	1,74	1,64	1,6	1,55	1,5	1,41	1,46
Lithuania	1,53	1,59	1,67	1,74	1,73	1,78	1,71	1,74	1,63	1,3
Hungary	1,84	1,83	1,86	1,93	1,83	1,75	1,75	1,69	1,56	1,41
Portugal	1,66	1,66	1,77	1,89	1,86	1,85	1,83	1,78	1,78	1,38
Belgium	1,67	1,72	1,74	1,88	1,92	1,92	1,87	1,73	1,75	1,55
Netherlands	1,91	1,88	1,85	1,89	1,85	1,87	1,94	1,8	1,74	1,17
France	1,6	1,61	1,75	1,85	1,92	1,98	1,94	1,82	1,82	1,72
Czechia	1,94	1,97	1,9	1,95	1,87	1,82	1,91	1,8	1,73	1,45
Finland	1,95	1,93	1,97	2,09	1,97	1,96	1,92	1,9	1,82	1,81
Denmark	2,41	2,32	2,21	2,17	1,99	1,95	1,71	1,66	1,52	1,43
Romania	1,78	2,12	2,21	2,19	1,81	1,82	1,97	1,76	2,03	2,56
Cyprus	2,11	2,38	2,39	2,3	2,34	2,22	1,99	1,81	1,77	1,53
Slovakia	2,2	2,22	2,2	2,18	2,24	2,19	2,22	2,21	2,15	2,26
Poland	2,16	2,24	2,27	2,35	2,34	2,36	2,21	2,23	2,61	2,55
Estonia	2,23	2,31	2,38	2,61	2,51	2,41	2,92	2,19	2,13	2,1
Croatia	2,01	2,28	2,48	2,57	2,57	2,68	2,63	2,5	2,43	2,04
Italy	2,79	2,94	2,75	2,85	2,7	2,66	2,62	2,43	2,39	1,62
Latvia	2,63	2,82	2,95	3,05	2,97	2,87	2,46	2,53	2,25	1,77
Bulgaria	2,51	2,48	2,6	2,6	2,44	2,25	2,64	2,67	2,45	4,5
Slovenia	3,3	3,25	3,27	3,29	3,1	2,85	3,12	2,7	2,64	2,41
Greece	3,32	3,36	3,42	3,38	3,57	3,3	3,37	3,28	3,42	4,81

Source: [69].

distributed [75]. Higher energy prices impose an even more significant burden on low-income households in most European countries as they spend more on electricity [76].

It is necessary to remark that energy costs represent an important part of every household expenditure for a year. Still, this data cannot be used as a global indicator among the EU as the relationship between purchase capacity and real income in comparison with energy prices has significant variations among the whole EU. Therefore, the percentage of final income is a parameter that equally considers the impact of real purchase capacity and energy poverty.

The price of electricity for residential customers consists of three main components: i) the price in the wholesale market, ii) fees for using the electricity grid, and iii) state-imposed price components, such as taxes [77,78]. These elements may vary depending on market conditions and government policy [78].

Before the global energy crisis, Member States benefited from decreased electricity costs due to the European Union's single market offering cheaper electricity, which was increasingly derived from renewable sources [79]. The merit order approach may decrease electricity rates for several years before 2022 due to the growing use of renewable energy sources [80]. Although the decline in wholesale electricity prices due to the merit order effect could threaten conventional power producers, it would benefit electricity consumers [81]. As this helped to offset high historical consumer subsidy payments for renewables, consumer savings resulting from the merit order effect were sometimes considered a "co-benefit" of the expansion of renewables [82]. That said, due to the recent escalation of gas prices to unprecedented levels - due in large part to Moscow's decision to reduce supplies to Europe [83], the cost of electricity has also been dragged upwards, and average monthly wholesale electricity prices set a record high in August 2022 (Fig. 2).

Grid investments are needed to facilitate the development of renewables and to replace and modernize aging infrastructure, and they are primarily driven by regulation [85]. In particular, grid investment to connect new energy sources is a priority to ensure the security of supply as the system moves towards a low-carbon economy [86]. That said, accepting the importance of grid investments, taxes, and levies influence the final price the most. Specifically, for the case of electricity in EU member countries, their share has steadily increased in recent years, from 25.6 % of the electricity price in 2011 to 40.3 % in 2020 [35].

Traditional research in the tax recycling field focuses on using carbon tax incomes and its application. Several analyses are presented for possible reutilization of carbon taxes, the most relevant mechanisms: 1) a lump-sum dividend for each of the country's consumers, 2) a reduction of the employee payroll taxes for companies, or 3) a reduction of corporate taxes [87]. Significant attention has been paid to designing the best possible taxation scheme that improves revenue reutilization and maximizes policymakers' and popular support. The most important conclusions for an analysis performed in the USA showed the effects of different carbon recycling measures, Table 1.

It is necessary to emphasize that despite the intensive previous research about how to use the carbon tax income to improve the whole economy and, at the same time, boost the country's decarbonization, very little attention is focused on the citizens' access to energy and associated energy poverty. Some exciting research has focused on the effects of carbon taxes on the most vulnerable households and the impact of these measures on the final income. ESRI [88] presented a study on the impact of carbon taxes and carbon tax recycling schemes for different households. The results show that higher carbon taxes could reduce the GDP while boosting household inequality and reducing the poorest household's income. Using carbon taxes to reduce associated wages or general taxes directly will impact households in energy poverty situations, reducing their energy taxes. Still, paradoxically, the highest incomes will obtain a more significant benefit, enhancing inequality. An increase in carbon taxes will directly impact final energy prices. The EU forecast for 2019 estimated an energy cost increase of up to 10 % by

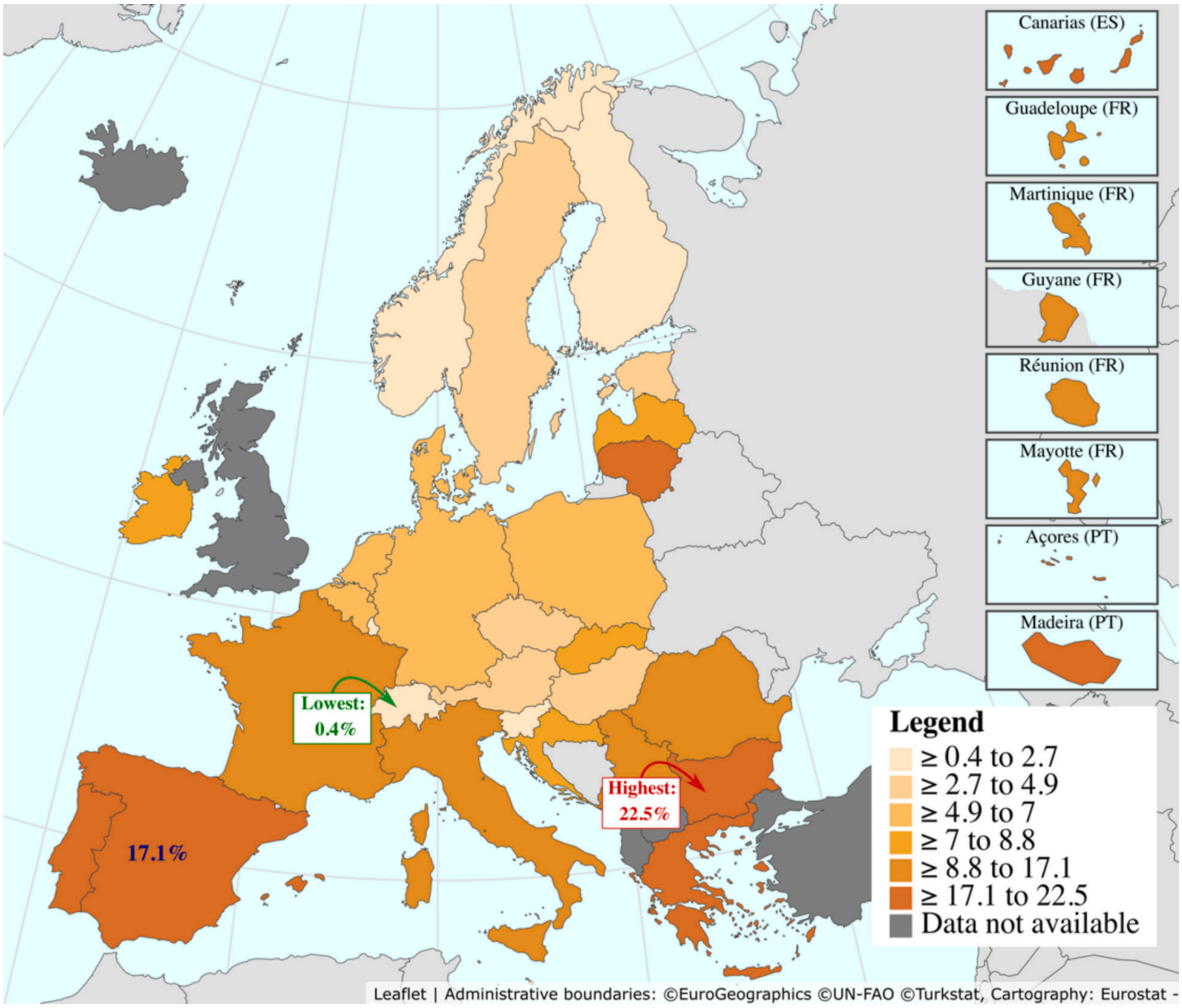

Fig. 9. Inability to keep home adequately warm (% of population) in 2022.
Source: https://ec.europa.eu/eurostat/databrowser/view/ilc_mdes01/default/map?lang=en.

2030 as a direct consequence of carbon taxes, with a general price increase of 0.3 % on average. Similarly, the estimation of the increase of the Harmonized Index of Consumer Price (HCPI) was an average of 2 % [88]. The last events related to the Russian invasion of Ukraine and subsequent reduction in gas supply to Europe and the associated rise in international gas prices have entirely changed the prediction, and HCPI has reached, driven by energy costs, a peak of 10.6 % in October 2022. This phenomenon has been more relevant in EU countries that are more natural gas dependent than Russia and has directly impacted the household's income, costs, and energy costs, Fig. 3.

The European Union has recently analyzed the distribution of energy taxes in each country. The results show that taxes can directly impact consumption, access to energy, new investments, or competition, among others. The most important industrial manufacturing countries in Europe, with a particular focus on Germany, are suffering a significant increase in their energy costs and reducing their industry's competitiveness. They have obliged the Government to extend vast subsidies to avoid deindustrialization. In 2022, Germany introduced a subsidy package of 200€ EU billion and expects to continue subsidies of up to 4€ billion each year for the following years, which are planned to finish in 2030. This directly reduces industrial consumer costs by up to 80 % [90]. The EU has analyzed the most relevant impacts of energy taxation and has concluded that the taxation varies in the EU countries in three main aspects: i) the total tax percentage for each energy product, ii) the taxation for each different energy product, such as natural gas or electricity and iii) the taxation scheme in households and industries. The taxes for electrical energy in households range from 7 % to 70 %, making it necessary to develop a unified EU strategy on energy taxation. Generally speaking, the taxes on power supply are higher for larger households than for small households. This study also reflects that taxation directly subsidizes fossil fuels, with about 40€ billion for 2016 [24].

Based on these results, a completely new taxation scheme aligned with the EU climate objectives is required to reduce all the inconsistencies among countries and harmonize the tax burden for households and industries. Despite the interest in this field, the EU has not focused on lowering household energy poverty using an optimized taxation strategy and reutilizing energy taxes as a direct measure to reduce energy poverty and ensure access to energy.

According to Chien et al. [37], improving buildings' energy efficiency can reduce energy poverty but direct financial aid and energy subsidies are only temporary solutions because they do not address the root cause of energy poverty. Other possibilities could include lump-sum transfers to lower-income households. In that sense, investments in energy efficiency can be more effective in the long run.

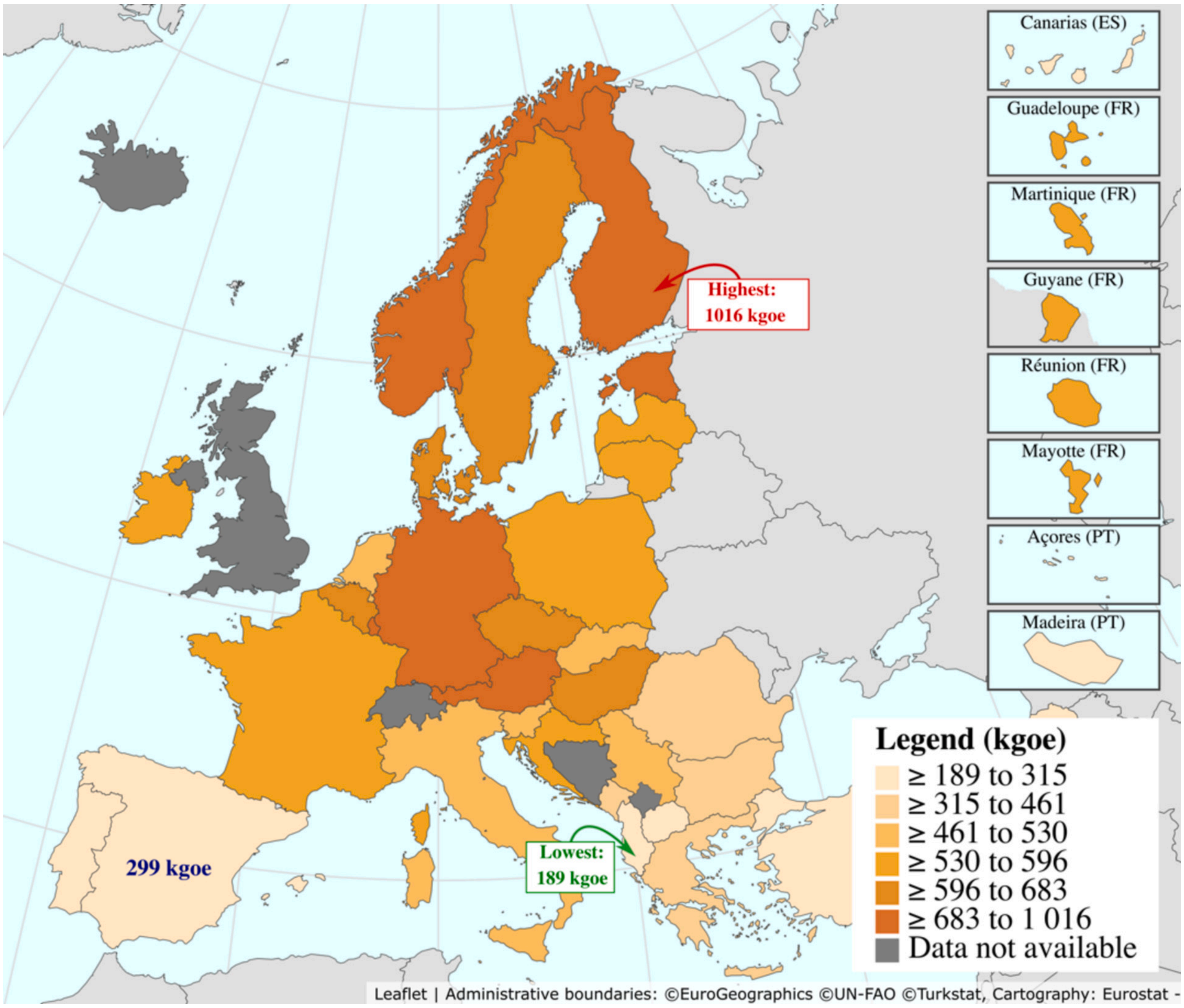

Fig. 10. Final household energy consumption per capita in 2022 (unit: kilogram of oil equivalent).
Sources: Eurostat (https://ec.europa.eu/eurostat/databrowser/view/sdg_07_20/default/map?lang=en). Source: [69].

3. Data analysis and results

This study analyzes the most relevant indicators regarding the possibility and the need for the proposed GTR.

3.1. Potential for a Green Tax Reform

The first step is analyzing the potential for a GTR in all EU member states. The revenues are collected through environmental taxation, particularly energy taxation. Countries with sufficient revenues could use them to promote energy efficiency and reduce energy poverty.

Environmental taxation practices and levels vary considerably from country to country. Fig. 4 represents energy tax revenues in the EU by region as a percentage of gross domestic product. In contrast, total environmental taxes as a proportion of Gross Domestic Product (GDP) in 2022 are depicted in Fig. 5. As can be deduced from Figs. 4 and 5, in practically every country, energy tax receipts are the most significant component of environmental tax income. The legend in Fig. 5 on the share of environmental taxes in gross domestic product shows a rather large fluctuation between Member States. Ireland had the lowest share of environmental taxes (0.87 %), while Greece had the highest (5.6 %). When it comes to energy taxes (Fig. 4), Ireland has the lowest percentage (0.52 %), while Greece has the largest (4.81 %).

In general, the percentage of environmental taxes varies significantly among Member States. The nations with the largest share of GDP derived from environmental taxes included Greece, Croatia, the Netherlands, Italy, Poland, and Denmark (Fig. 5). Generally, the proportion of environmental levies varies significantly across Member States. Countries with the largest share of environmental taxes in GDP included Greece, Croatia, the Netherlands, Italy, Poland, and Denmark (Fig. 5).

Fig. 6, which contains the share of energy taxes in total revenues from taxes and social contributions (including imputed social contributions) in 2022, has also been included to get a clearer picture of how environmental taxes compare with other taxes. The same is shown in Fig. 7 for total environmental taxes as a percentage of overall tax and social contribution receipts (including imputed social contributions).

Current energy taxation in EU countries and the tax share in the GDP do not reflect or correlate access to energy supply and the share of households' income to pay energy costs. Fig. 8 presents the EU average and the countries where this percentage has its maximum values.

It is shown that some countries, such as Bulgaria or Slovakia, where the percentage of household income to pay energy taxes is higher, also collect higher amounts (in relation to their GDP) in the form of energy taxes. This depicts a taxation system failure and an opportunity to reconfigure energy taxes to reduce energy poverty and household energy costs.

Energy taxes constitute a significant source of government revenue.

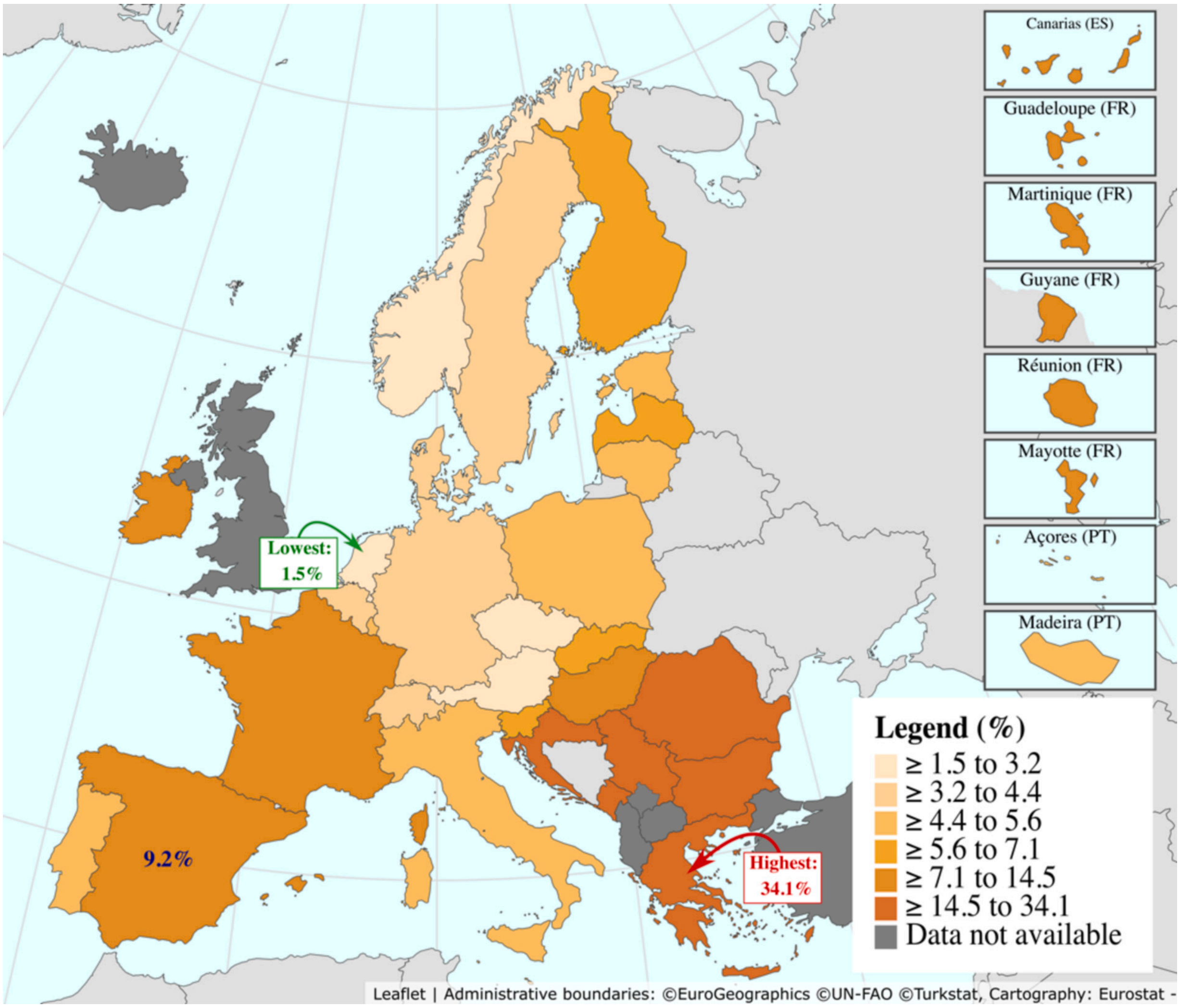

Fig. 11. Arrears on utility bills in 2022 (% of population).
Source: https://ec.europa.eu/eurostat/databrowser/view/ilc_mdes07/default/map?lang=en.

Some Member States rely substantially on energy taxes, accounting for up to 3 % of GDP. Table 2 details the evolution for each country from 2013 to 2022.

3.2. Energy poverty

Risk indicators suggested in the literature are used to analyze energy poverty (e.g., [91]). Several aspects can be included in this analysis. For example, one commonly used factor is the percentage of households unable to heat their homes adequately. Notwithstanding, this indicator has some limitations; for example, there are geographical variations in temperature among countries [91]. Southern European countries may need cooling more than they need heating. Still, Fig. 9. shows this indicator as a proxy of energy poverty in the EU.

Fig. 9 shows Bulgaria, Portugal, Spain, Greece, Romania, Cyprus, and Lithuania's vulnerable positions.

Furthermore, energy poverty translates into low energy consumption per capita. Fig. 10 shows the final energy consumption in households per capita. The countries with the lowest energy consumption per capita are Portugal, Spain, Greece, Bulgaria, Romania, and Cyprus, coinciding with the information previously depicted on the inability to keep the household warm. Additionally, it is possible to see from the figure that some countries, such as Portugal and Italy, have very high revenues from energy taxation but relatively low per capita energy consumption levels. This could indicate a potential for the proposed GTR.

Another indicator commonly used for energy poverty is arrears on utility bills, as seen in Fig. 11. In this case, the countries that show the worst situation are Spain, Greece, Bulgaria, Romania, Hungary, and Croatia.

As mentioned before, the higher the share of the household budget spent on energy, the higher the risk of energy poverty. According to the most recent publicly accessible data, the poorest households in the EU (those in the bottom 10 % of income) spend a yearly average of 945€ on energy [92], accounting for 8.3 % of their total consumption expenditure [92]. The poorest households spent slightly >20 % in Slovakia and the Czech Republic and <5 % in Luxembourg, Finland, and Sweden [92] (Fig. 12).

Energy cost is also a relevant indicator. Higher energy and electricity costs represent a higher burden for consumers. Fig. 13 shows the electricity prices (€/kWh) for medium-sized households in 2022. Of the previously identified countries, only Spain and Cyprus are within the group with the highest costs. Still, Portugal, Greece, and Romania depict a vulnerable situation.

4. Results and discussion

This study proposes that revenues from energy taxes be reinvested to alleviate energy poverty across the EU, particularly in Member States

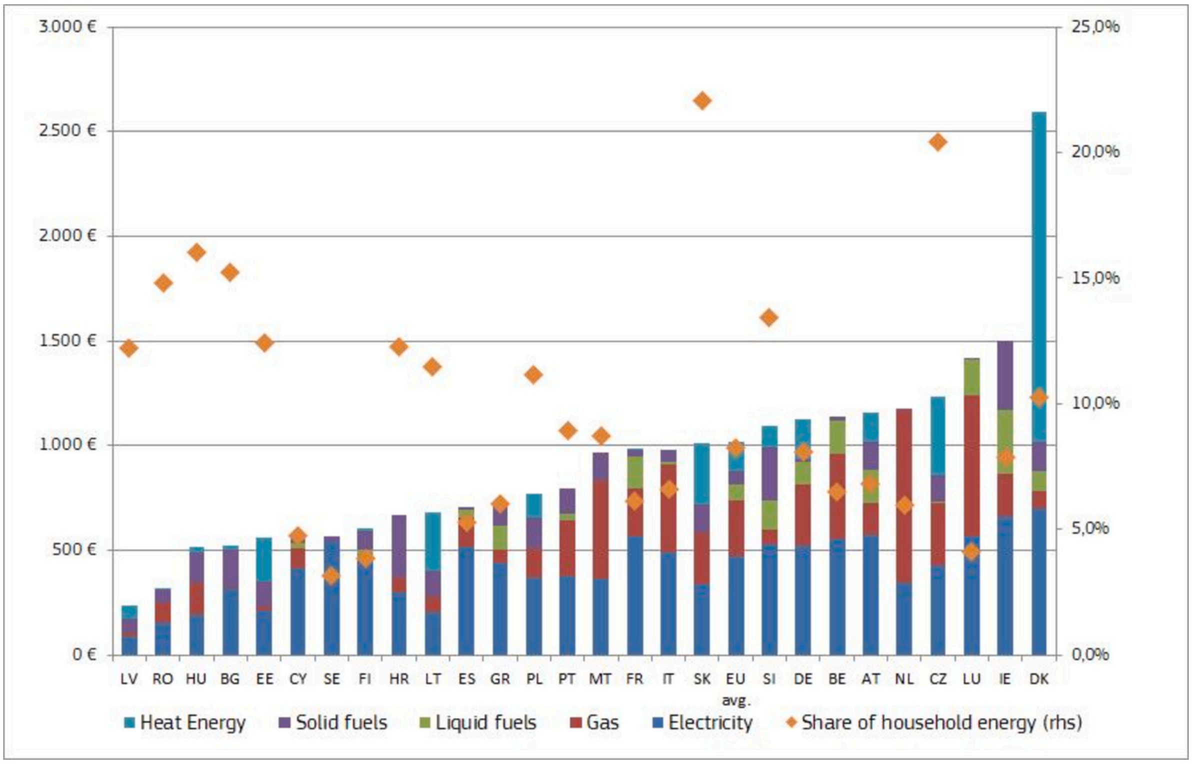

Fig. 12. Spending on energy-related products by the poorest households and its proportion in overall household consumption spending by EU Member State. Source: [92].

that exhibit both high energy tax revenues and significant vulnerability in energy access. Energy efficiency upgrades help reduce electricity costs, while targeted financial assistance or tax relief can mitigate the social and economic impacts of energy taxes on vulnerable populations [93].

4.1. Comparative analysis of key indicators

Table 3 provides a comparative analysis of the key indicators across EU Member States, as well as Norway, Switzerland, and Iceland. Level 3 (L3) represents countries with the most pressing need for a GTR and Level 0 (L0) indicates those less aligned with the need for GTR intervention. The table highlights countries such as Bulgaria, Cyprus, Greece, Italy, Portugal, Romania, and Slovakia as having both high energy tax revenues and critical energy poverty challenges. These nations are particularly strong candidates for GTR due to the combination of financial resources and pressing need for reform.

Countries like Bulgaria, Cyprus, Greece, Romania, and Spain demonstrate high levels of energy poverty (L3), suggesting a substantial portion of the population struggles to afford basic energy needs ($\geq$ 9.5 to 35.8 % of population). In parallel, these countries also exhibit low energy consumption (L3), which may indicate either energy efficiency or limited access to energy services. For countries such as Bulgaria, Cyprus, Greece, and Romania, where both energy poverty and low energy consumption coexist, structural challenges in energy access are likely, necessitating targeted interventions through GTR.

The figures presented before support and expand upon these findings, providing a detailed visual analysis of energy tax revenues, energy poverty, and energy consumption across the EU.

Based on energy tax revenues and environmental taxation, Fig. 4 highlights that countries such as Greece, Bulgaria, and Slovakia have the highest energy tax revenues as a percentage of GDP, with Greece leading at 4.81 %. This suggests that these nations have substantial resources that could be reinvested into programs to alleviate energy poverty through the GTR. By contrast, Ireland has the lowest energy tax revenue share at 0.52 %, indicating limited fiscal space for such reinvestment. Additionally, countries like Greece, Croatia, and Denmark stand out with the largest environmental tax revenues, further supporting the notion that these funds could be channeled into GTR initiatives. Greece once again leads, with 5.6 % of GDP from environmental taxes (Fig. 5). The data indicates that energy taxes make up the majority of environmental tax revenues in many countries, reinforcing the potential for energy tax recycling. Fig. 6 compares energy taxes to total revenues from taxes and social contributions, highlighting how significant energy taxes are for certain countries' overall tax base. This figure shows that Bulgaria and Slovakia rely heavily on energy taxes, which presents an opportunity for GTR to redistribute these revenues into programs that reduce the energy cost burden for households.

Analyzing energy poverty and household energy consumption, Fig. 9 presents the percentage of the population unable to keep their homes adequately warm—a direct indicator of energy poverty [91]. Countries such as Bulgaria, Cyprus, Greece, Romania, and Spain have high percentages of populations experiencing this problem. These countries, which also have high energy tax revenues, are prime candidates for GTR interventions. Energy tax recycling can be used to provide financial assistance and energy efficiency upgrades to reduce the cost of heating homes. Fig. 10 depicts final household energy consumption per capita in 2022. Bulgaria, Greece, Romania, Cyprus, and Spain show low energy consumption per capita, which could indicate a lack of access to energy services. At the same time, countries such as Portugal and Italy, which have high energy tax revenues but low energy consumption per capita, have an untapped potential for GTR to improve energy access while promoting sustainability. This figure aligns with the findings of Table 3, emphasizing the need for energy efficiency upgrades in these regions. Fig. 11 highlights arrears on utility bills, with Spain, Greece, Bulgaria, Romania, Hungary, and Croatia facing significant issues. The combination of high arrears and energy poverty points to an urgent need for GTR policies that can relieve the financial burden on households by

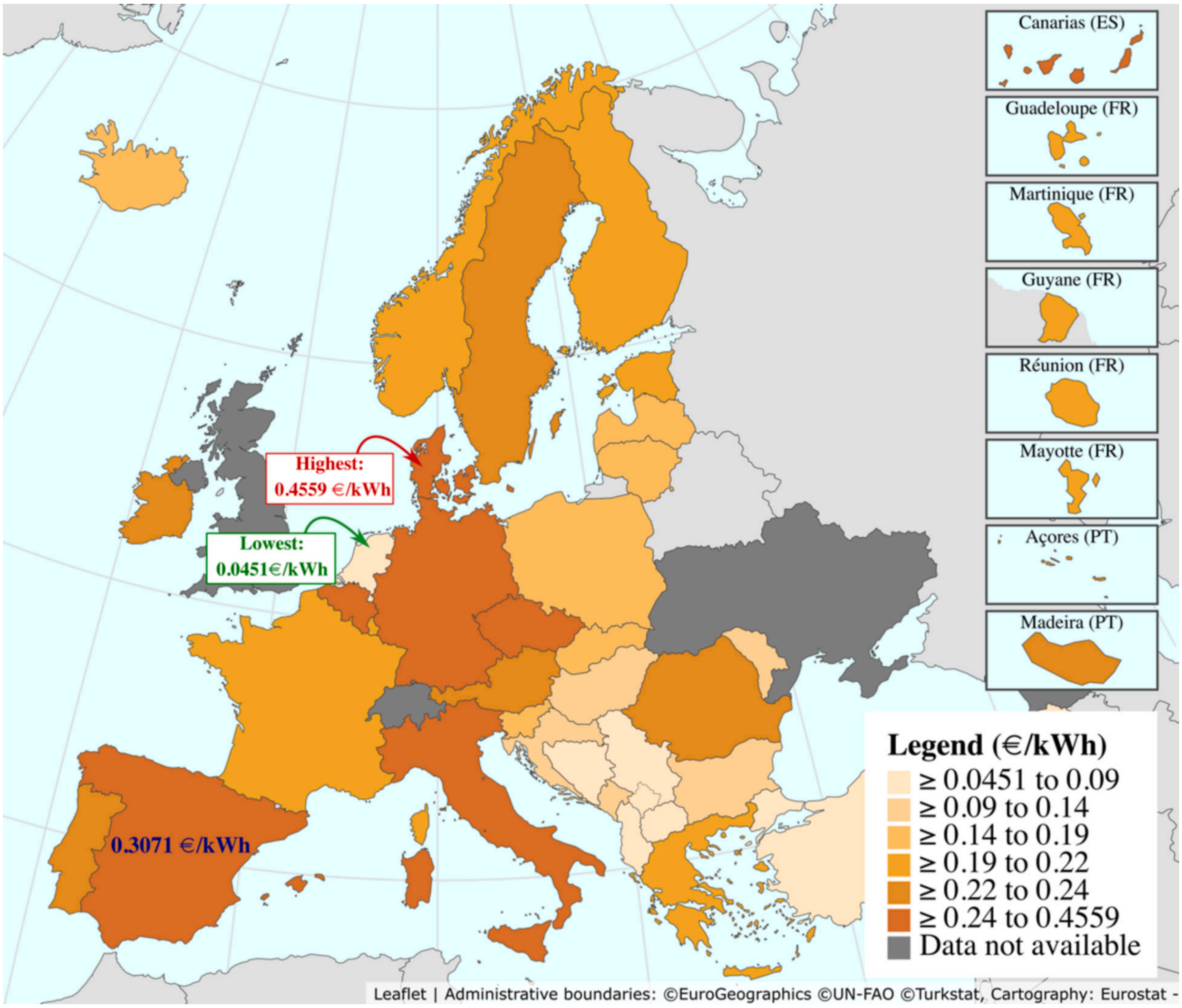

Fig. 13. Electricity prices for medium size households (€/kWh) in 2022.
Source: https://ec.europa.eu/eurostat/databrowser/view/ten00117/default/map?lang=en.

investing in energy-saving measures and lowering the overall energy costs through improved infrastructure.

Considering energy costs and vulnerability, it can be seen in Fig. 13 that countries such as Spain and Cyprus feature among those with the highest electricity prices, adding to the vulnerability of these populations. Still, Portugal, Greece, and Romania depict a vulnerable situation. These findings are consistent with the high energy poverty levels observed in Table 3 and emphasize the importance of implementing GTR measures that reduce electricity prices through subsidies for renewable energy and energy efficiency upgrades. In addition, several countries, including Bulgaria, Croatia, Cyprus, Greece, Latvia, Lithuania, Romania, Slovenia, and Spain, face significant arrears on utility bills (L3), suggesting financial distress among households. These countries not only experience high energy costs but also struggle to meet payment obligations, contributing to rising arrears. Bulgaria, Greece, Cyprus, and Romania stand out as they face high energy poverty and arrears, highlighting the depth of their energy challenges and the need for immediate policy action under the GTR framework.

4.2. Addressing the challenges of energy poverty

The comparative analysis has shown that countries with the highest energy poverty and income requirements to meet energy costs are often the ones where energy taxes make a higher contribution to GDP. This highlights the potential of recycling energy tax revenues into programs that mitigate energy poverty and reduce energy costs. Rather than focusing solely on reducing energy prices, the best measure to reduce the energy cost burden must be focused on reducing the energy consumption itself. Energy efficiency measures and energy-saving plans are the keys to lowering large-scale energy consumption. These strategies would not only alleviate the energy cost burden but also help reduce external energy dependency for countries with high energy vulnerability.

To address the core challenges faced by households suffering from energy poverty, two key obstacles must be overcome: the knowledge gap and upfront investment costs. The knowledge gap refers to households' lack of information on how to detect the most effective energy-saving measures for their homes (this applies also to apartment blocks) to ensure maximum energy savings while reducing the required investment. If financial aid is offered without governmental support, the beneficiaries will fail to have an investment roadmap and technical support. The second challenge is that, although the energy measures are identified, the poorest households cannot afford the required up-front investments. Their low financial capacity also reduces the possibility of credit access. The continuous increase of European Central Bank's (ECB) marginal interest rates (from 0.25 % in 2016 to 4.75 % in 2023) reduces credit access, especially for vulnerable populations that cannot offer credit endorsements, among others [94].

Table 3
Summary of results.

Country	Energy taxes revenue	Energy poverty (heating)	High electricity costs	Arrears on utility bills	Low energy consumption
Austria	L0	L0	L0	L0	L0
Belgium	L2	L1	L3	L0	L0
Bulgaria	L3	L3	L0	L3	L3
Croatia	L3	L2	L0	L3	L1
Cyprus	L3	L3	L3	L3	L3
Czechia	L1	L1	L3	L0	L0
Denmark	L1	L1	L3	L0	L0
Estonia	L3	L1	L2	L0	L0
Finland	L2	L0	L2	L3	L0
France	L2	L2	L2	L2	L1
Germany	L1	L1	L3	L0	L0
Greece	L3	L3	L2	L3	L3
Hungary	L1	L2	L0	L3	L0
Ireland	L0	L2	L3	L3	L1
Italy	L3	L2	L3	L2	L2
Latvia	L3	L1	L1	L3	L1
Lithuania	L1	L3	L1	L3	L2
Luxembourg	L1	L1	L2	L0	L0
Malta	L0	L2	L0	na	na
Netherlands	L1	L1	L0	L0	L2
Poland	L3	L1	L1	L0	L1
Portugal	L2	L3	L3	L0	L3
Romania	L2	L3	L3	L3	L3
Slovakia	L3	L2	L1	L2	L2
Slovenia	L3	L1	L1	L3	L2
Spain	L0	L3	L3	L3	L3
Sweden	L0	na	L3	L0	L0
Norway	L0	L0	na	na	L0
Switzerland	L0	L0	na	L0	na
Iceland	L0	na	L1	na	L0

Energy tax revenues (% of GDP): L0: ≥0.75 to 1.52; L1: ≥1.52 to 1.76; L2: ≥1.76 to 1.82; L3: ≥1.82 to 3.05.
Energy poverty (% of population): L0: ≥0.2 to 3.3; L1: ≥3.3 to 5.85; 2: ≥5.85 to 9.5; L3: ≥9.5 to 35.8.
Electricity prices (€/kWh): L0: ≥0.0451 to 0.14; L1: ≥0.14 to 0.19; L2: ≥0.19 to 0.22; L3: ≥0.22 to 0.4559.
Arrears on utility bills (% of population): L0: ≥1.5 to 4.7; L1: ≥4.7 to 6.3; 2: ≥6.3 to 9.4; L3: ≥9.4 to 31.5.
Low energy consumption (ktoeq): L0: ≥661 to 1344; L1: ≥585 to 661; L2: ≥520 to 585; L3: ≥195 to 520 (the methodology opted for this classification to highlight the situation of countries with low energy consumption, i.e., countries that potentially need the GTR).
Source: Own elaboration.

Countries such as Bulgaria, Cyprus, Greece, Portugal, Romania, and Spain, which experience both high energy poverty and arrears (as shown in Table 3, Figs. 9 and 11), stand out as critical targets for GTR intervention. These countries, particularly those with significant tax revenues from energy, offer a crucial opportunity for recycling energy tax revenues into targeted programs.

4.3. Green Tax Reform (GTR) and energy tax recycling scheme

Considering the high share of tax collection in these countries' GDP, the design of an energy tax recycling scheme focused on financial aid and technical guidance for vulnerable households in energy poverty is proposed. For example, these measures must be accomplished with a fossil fuel subsidy reform to avoid vulnerable homes that use coal or oil heating systems directly impacted by reducing or eliminating feed-in tariffs for energy heating. As presented in the previous section, extensive research has been carried out for carbon tax reallocation and recycling. Still, there is a lack of particular focus on energy poverty, energy costs, and the influence of energy taxes. The proposed recycling schemes below are based on applying the EEF principle and, therefore, will directly apply this core principle.

The recycling measures for energy taxes can include, among others,

i) financial aid and technical support for modernizing electrical appliances (lighting or heating systems). This measure should be designed using a carbon or energy abatement analysis to detect and prioritize the measures that present a higher energy savings share with the lower investment, such as massive bulb substitution by LED systems.
ii) financial and technical plans for massive self-consumption system deployment, mainly based on photovoltaic systems. These self-generation systems will ensure a reduction of grid energy consumption and, at the same time, have a large-term impact, as the energy supply will continue for several years and contribute to achieving the decarbonization objectives.
iii) progressive decarbonization strategy for household heating systems by the deployment of heat pump systems and district heating systems driven by low-carbon systems. This measure will be optimal if combined with the development of self-generation energy systems.
iv) public energy services contracts. Energy Services Companies (ESCOs) offer final energy supply (electricity, heat, cold, etc.). Generally speaking, a part of the energy supply costs is paid using the energy savings produced by the introduced energy efficiency measures. When the contract period finishes, the energy systems are transferred to the owner, who benefits from the cost savings, or the contract is renewed. This renewal includes the possibility of new investments in energy-saving measures to establish a continuous improvement cycle.

There is a lack of development of energy services for citizens as these companies are mainly focused on private companies or large public buildings (hospitals, schools, etc.). A public energy services policy utilizing energy tax recycling would allow the investment in energy-saving devices, control systems, or no-cost energy-saving measures (such as specific energy-saving training for energy-poverty households). The energy cost savings will partially finance these investments. Each household could, therefore, benefit from a direct reduction in their energy bills and the installation of more efficient systems that will reduce energy consumption not only in the aid period but also in future years. This demonstrates the feasibility and the need of designing a new taxation scheme focused on reducing energy poverty. An effective energy tax recycling scheme that will ensure that the tax burden is not increased. This recycling will help to boost energy systems-related activities and the economy.

5. Conclusions

The energy taxation scheme is quite variable among EU countries, and there is a need to harmonize the tax policy to ensure that the EU objectives are achieved and simultaneously reduce inequality between EU citizens. The analyzed data in this research shows that energy poverty is an essential issue for many households and that this problem worsens due to European countries' high external energy dependency. The distribution of required income for energy payments is quite variable as the results show a significant variation among the total share required for energy bills ranging from 5 % in Luxembourg, Finland, or Sweden to 20 %–25 % in some countries such as Slovakia, where 40 % of the population needs to spend 20 % of their annual income for energy costs. A detailed review of the current development in the field and previous research shows that several previous studies have analyzed potential tax recycling schemes for carbon taxes. Still, no focus is on developing an energy taxation recycling system to reinvest these taxes to reduce energy poverty in vulnerable households utilizing energy efficiency measures. At the same time, some countries such as Bulgaria, Cyprus, Greece, Italy, Portugal, Romania, and Slovakia face a large share of energy poverty. Their energy tax contribution to GDP is higher than the EU average. These results show that it is possible to establish a new energy taxation recycling scheme focused on reducing household energy consumption using energy efficiency measures. This strategy could provide a solution to credit access and investment requirements as the poorest households cannot challenge up-front investments and, simultaneously, the technical capacity to select the optimal measures to be applied. It is important to remark that using this taxing strategy is directly aligned with the most important energy principle established in the EU; the EEF strategy. In this research, several measures are proposed, such as developing self-generation systems or introducing more efficient energy systems, all of them following the three fundamental guidelines of the EEF. It is suggested that a recycling scheme combined with Public Energy Services can be optimally combined to redistribute the energy tax income to reduce energy poverty and, simultaneously, energy consumption, being an optimal solution for decarbonization if combined with a new energy taxation scheme that removes harmful fossil fuel subsidies.

The main limitation of this work is the lack of information regarding energy efficiency (detailed information on, for example, buildings, would be very useful). Hence, for future research, if this information is made available, it would be interesting to explore a specific tax reform (for example, for a specific country), where we would apply energy taxes directly on energy efficiency improvements that would reduce energy poverty. In this sense, we would move from a macroeconomic study to a more microeconomic one.

CRediT authorship contribution statement

David Borge-Diez: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Susana Silva:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Pedro Cabrera:** Writing – review & editing, Validation, Supervision, Formal analysis, Data curation. **Paula Sarmento:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Formal analysis. **Enrique Rosales-Asensio:** Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

I have shared the link to my data

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