JUSTEM

D3.1

Impact Matrix Report

Marco Peretto, Zografia Andreosatou, Diana Süsser

Institute for European Energy and Climate Policy

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Authors, Organisation	Marco Peretto (Institute for European Energy and Climate Policy) Faye Andreosatou (Erasmus+ student at Institute for European Energy and Climate Policy) Diana Süsser (Institute for European Energy and Climate Policy)
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LEGAL NOTICE

ABOUT

Energy transition plans may challenge the social ecosystem of the regions where coal is still king: if energy transition plans don't consider local factors, they may cause higher unemployment rates, aggravated energy poverty, and economic migration. Energy poverty is already a big challenge today in the EU, with coal-dependent regions generally being more affected by the issue.

In the spirit of the EU principle to "leave no one behind" in the transition, JUSTEM addresses the energy transition planning through a double-sided approach: (1) it helps regional authorities to develop 'just' energy transition plans that are sensitive to regional impacts such as job losses and energy poverty; and (2) it helps citizens build their capacity and find their place in a greener economy.

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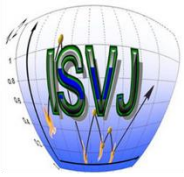

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ABBREVIATIONS

EC	European Commission
EU	European Union
JTF	Just Transition Fund
JTM	Just Transition Mechanism
TJTP	Territorial Just Transition Plan

EXECUTIVE SUMMARY

Coal regions are particularly vulnerable to and affected by the planned changes needed to reduce pollution and move towards a climate neutral society. The Just Transition principle aims to ensure that decarbonisation policies do not harm some parts of society and communities more than others. As such, countries that are part of the European Union have developed so called Territorial Just Transition Plans (TJTPs). The following research aims to develop an impact matrix and a set of indicators to assess the extent to which TJTPs address key impacts related to just transition and how these can be quantified. We conducted a literature review to select key impacts and then conducted both a qualitative and quantitative analysis in six just transition regions. We find that the impacts of decarbonisation on communities in coal regions are negative, mostly social and demographic, but there are gaps in the definition and measurement of multiple transition impacts. These gaps should be addressed in each region to define tailored policies and investments that can help minimise negative impacts and capitalise on positive benefits for communities. The multiple-impacts approach outlined in this report can contribute to better define and assess regional impacts of transition towards climate neutrality and support the development of measures that minimise negative impacts and enable truly just transitions.

1. INTRODUCTION

The European Green Deal is a major policy strategy at European level that aims to "transform the EU into a fair and prosperous society with a modern, resource-efficient and competitive economy, where there are no net greenhouse gas emissions in 2050 and economic growth is decoupled from resource use" (European Commission, 2019, p.2). As part of this ambitious plan, the Just Transition Mechanism (JTM) is a key tool to ensure that "no person and no region is left behind in the transition to a low-carbon economy" (European Commission, 2021, p.1). Achieving a just transition will require significant investment in regions that are most affected by the transition and face the greatest challenges. For this reason, the Just Transition Fund (JTF) has been set up with a budget of €19.2 billion to provide funding to territories over the period 2021-2027. Figure 1 shows the JTF eligible areas.

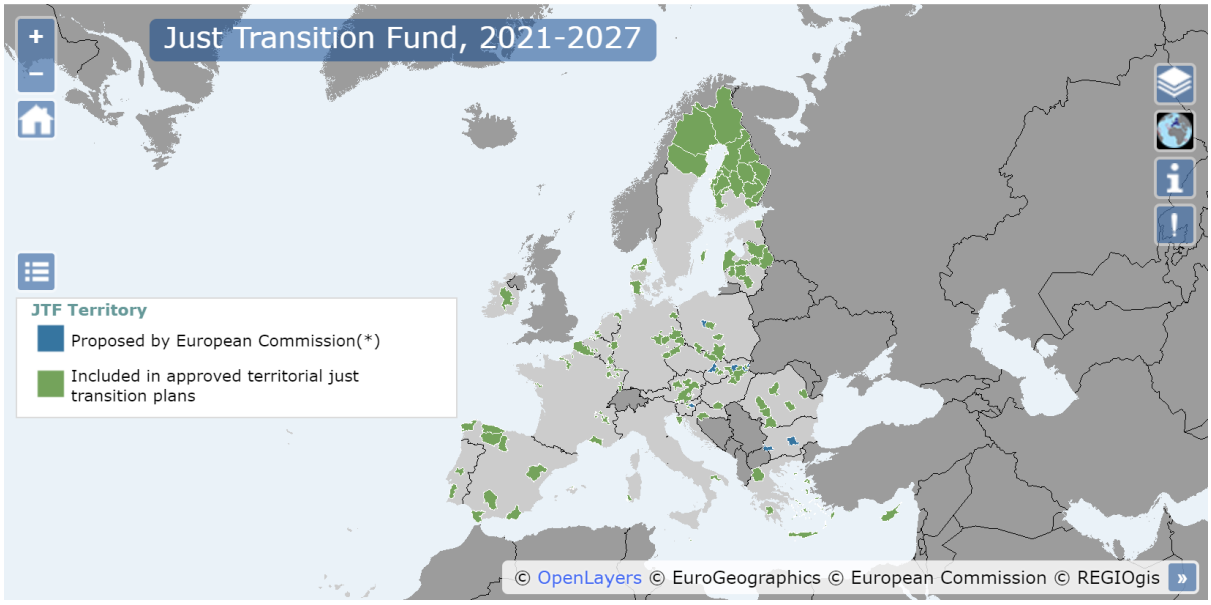

Figure 1: Eligible Just Transition Fund territories (CINEA, 2023).

The JTF will support coal, peat and oil regions and regions with carbon-intensive industrial production where a large part of the region' population is employed in such businesses. The fund aims to support the restructuring of the employment activities, ensuring the transfer of these workers in more sustainable activities, while delivering environmental benefits (Official Journal of the European Union, 2021). In order to receive part of the earmarked fund, each Member State must develop its Territorial Just Transition Plan (TJTP) and associated cohesion policy programmes. These plans must provide a clear outline and timeline of the path to achieve the 2030 and 2050 decarbonisation targets, in line with the European Green Deal, and identify which territories will be most affected by such a transition. In addition, the TJTP will address the impacts of the transition, as outlined in the JTF Regulation (Official Journal of the European Union, 2021).

TJTP must also provide "a description of the expected contribution of the JTF support to addressing the social, demographic, economic, health and environmental impacts of the transition to a climate-neutral economy of the Union by 2050, including the expected contribution in terms of job creation and preservation" (Art. 11, d).

The JTF regulation was introduced as part of the cohesion policy framework, through which the European Union (EU) aims to reduce inequalities and manage Europe's structural change. But how have "impacts" of transitions been defined in the literature? What are appropriate indicators to measure how regions are positively or negatively affected by the transition? And how can we deal with trade-offs between different economic, social and environmental objectives?

Research that performed quantitative analyses of the impacts of TJTPs has mainly focused on individual case studies and has addressed different impacts of just transitions (Frankowski, et al., 2023; Janikowska & Kulczycka, 2021; Pavloudakis, et al., 2023; Streimikiene, et al., 2021). However, so far there is no framework or matrix that can be applied to assess how TJTPs consider all the impacts of just transitions, both qualitatively and quantitatively. In fact, what is needed is not only a list of basic impacts that need to be addressed by TJTPs, but also a quantification method to understand how each impact is being treated and which one deserves more attention depending on the individual characteristics of the territory being analysed.

In this report we aim to i) identify the multiple impacts of just transitions in coal regions; ii) develop and apply a framework for assessing whether TJTPs address the multiple impacts of just transitions; and iii) assess how these impacts can be quantitatively assessed through the use of indicators.

As noted in the description of TJTPs in the previous section, it is essential that the plans provide clear timelines for decarbonisation targets, not in a steady state but looking forward. We will take such a forward-looking stance throughout the report. In addition, we will pay particular attention to the measures to be implemented under the TJTPs and how they will be assessed in terms of territorial impacts.

Defining just transitions

In order to assess the impact of a just transition, it is important to define the term. The term originated in the labour movement and encompassed a range of social measures to secure workers' rights and livelihoods (Schuster, et al., 2023). Today, the term is often defined more holistically as an approach to transition to a more sustainable energy system. For example, García-García et al. (2020) define a just energy transition as a "long-term technological and socio-economic process of structural change that affects the generation, distribution, storage and use of energy, bringing about transformations

at micro (innovation), meso (social networks, rules and technical elements) and macro (exogenous environment) levels, while also ensuring that the desired socioeconomic functions can be accomplished through decarbonised and renewable means of energy production and consumption, safeguarding social justice, equity and welfare".

There is a widespread public and political consensus that a coal phase-out must consider different forms of justice, including environmental, social, labour, and energy justice (Harrahill & Douglas, 2019) in order to address the emerging social hardship and reduce resistance. Justice can be composed of four key dimensions (Abram, et al., 2022):

- *Procedural justice* is about the meaningful and ongoing involvement of affected parties in the decision-making process;
- *Distributive justice* is about a fair and equal distribution of the costs and benefits of the transition;
- *Recognition justice* is about valuing and representing all members of society equally and ensuring that they have political rights;
- *Restorative justice* is about repairing past harms and implementing measures to reduce the likelihood of future harms or to compensate for them, such as implementing transition frameworks for coal workers.

Such a holistic approach to just transition can help to identify socio-economic, institutional and socio-technical challenges and develop systemic solutions that enable improvements in regional infrastructure, new employment opportunities and the necessary national and regional capacities and resources, including financing. Indeed, in line with the global decarbonisation goals, it is important to ensure that existing social inequalities and injustices connected to the realm of energy and climate vulnerability are considered and not ignored, as this could exacerbate the current situation and lead to future backlashes from vulnerable communities towards climate and environmental policies (Abram, et al., 2022). The concept of Just Transition needed to be fully embedded in new climate policies and regulations and not be seen as an optional "add-on" to newly developed policies (Galgoczi, 2018).

The Just Transition concept has evolved from being a rather abstract term coined in the 1970s to being formally considered as one of the prerequisites for an optimal decarbonisation of the European continent. As such, also its literature has also grown. Nevertheless, due to the relative novelty of the field, most of the literature has focused on its definition, applicability, and evolvement as a concept rather than on its application (Abram, et al., 2022; Carley & Konisky, 2020; García-García, et al., 2020; McCauley & Heffron, 2018; Wang & Lo, 2021). Additionally, in cases where the application of the concept was investigated, this was mostly done qualitatively (Harrahill & Douglas, 2019; Snell, 2018).

What emerges from the definitions, and is also expressed in the European Green Deal, is that today's carbon-intensive industries and their transition have multiple impacts that need to be considered. We focus here on the outcome dimension, distributional justice, which underpins the existing TJTP and takes into account social, economic, demographic and environmental developments.

2. METHODOLOGY & CASE STUDIES

This section outlines the methodology used and presents our case studies to investigate multiple impacts of the transition. We define multiple impacts as positive or negative social, economic, demographic or environmental impacts caused by the transition to climate neutrality in specific regions. It is important to note that some commonly identified impacts are impacts of the current industry, which has already changed or will change.

2.1 Methodology

Figure 2 provides an overview of the methodology, which consists of a literature review, the development of an impact matrix and the impact assessment of TJTP and quantitative data.

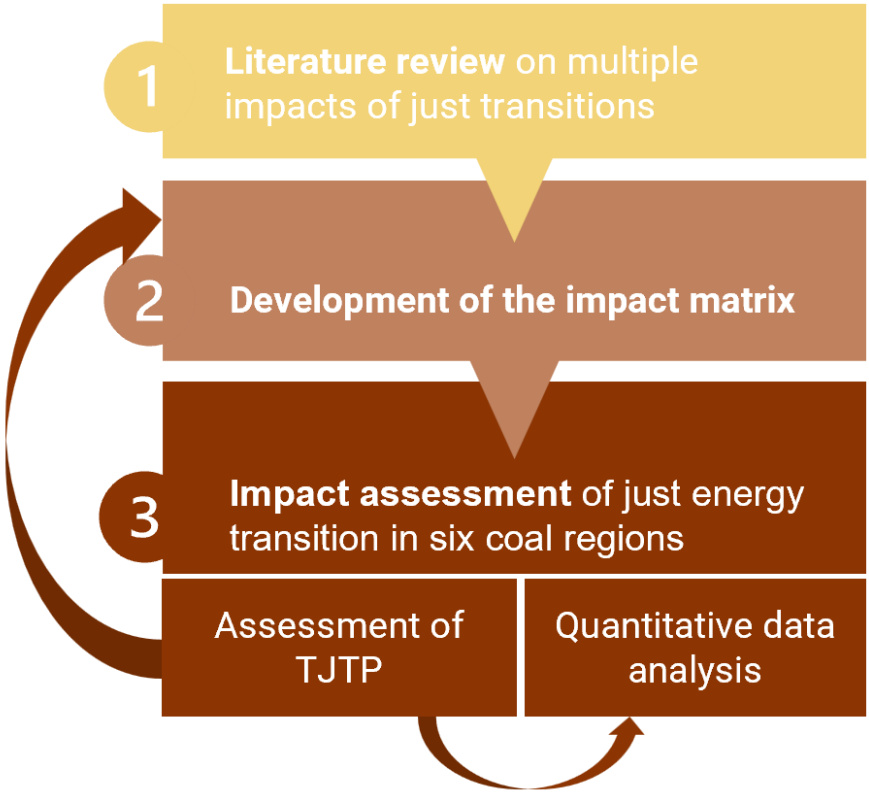

Figure 2: Methodology employed.

First, we conducted a literature review to identify the most common impacts that are considered in the just transition literature, but also ways to quantify them. The review included both academic literature and policy documents. We used the Scopus search engine to find relevant academic papers and reviewed academic articles from 2018 to 2023. We performed two different searches within the TITLE-ABSTRACT-KEYWORDS search engine; the first was: (("impact" OR "assessment") AND "just transition") AND

("factors" OR "indicators"), which yielded 99 results; and the second was: "just transition" AND "factors", which gave 54 results. After an initial analysis, we selected 31 papers on the basis of accuracy, impact and relevance. The literature review also included other sources of information such as Google Scholar and general grey literature (e.g., 4official websites of EU institutions).

Based on the identified impact dimensions and concrete indicators, we developed an impact matrix. The matrix aims to provide an overview of the key impacts that need to be considered when analysing the multiple regional impacts of a just energy transition, and a framework/score sheet for assessing existing TJTPs. The impact matrix follows the four main impact dimensions defined by the EC (European Commission, 2021) and presents for each category a number of impacts identified in the literature review. For each dimension, we selected criteria for qualitative analysis and indicators for quantitative analysis.

The approach of multiple impacts or benefits is not new but has rather been applied by other H2020 projects such as MICAT[1] and ODYSSEE-MURE[2]. Such a division of impacts into different sub-categories arises from the multidisciplinary nature of the energy transition and equity aspects. Here, we reviewed existing ways to quantify multiple impacts and searched for different data sources to quantify impacts. We also applied an inductive logic by reflecting on the impacts mentioned in the TJTP to define impact categories.

We applied the impact matrix to assess (1) whether and how the current TJTPs of six European coal regions address multiple, positive or negative, impacts of the transition process, and (2) how the socio-economic situation has changed and is expected to change. We analysed the TJTP of six coal regions (Table 1). The TJTPs were translated into English where they were only available in the national language. We analysed the documents using pre-defined categories to categorise themes related to just transition impacts and to quantify the content in a systematic and replicable way (Bryman, 2012). In addition, we used statistical data from Eurostat to analyse the development of specific indicators.

[1] https://micatool.eu/micat-project-en/
[2] https://www.odyssee-mure.eu/

Table 1: Analysed territorial just transition plans.

Country, region	Reference of the territorial just transition plan (TJTP)
Bulgaria, Stara Zagora.	Ministry of Energy of the Republic of Bulgaria, 2023, Territorial plan for a just transition of Stara Zagora region.
Croatia, Istria. Plan for Croatia, including Istria County.	Republika Hrvatska, 2021, Teritorijailni Plan za Pravednu Tranziciju.
Greece, Western Macedonia.	Government Committee SDAM, 2021, Εδαφικό σχέδιο δίκαιης και αναπτυξιακής μετάβασης Δυτικής Μακεδονίας.
Poland, Silesia.	Województwo Śląskie, 2022, Terytorialny Plan Sprawiedliwej Transformacji Województwa Śląskiego 2030.
Spain, Asturias. The plan is for Spain including "Territorio: P1_Asturias"	Gobierno de Espana, Plan Territorial de Transición Justa de España 2021-2027, Version 1.2.
Romania, Jiu Valley. Plan for Romania including NUTS region Hunedoara:	Ministerul Investițiilor și Proiectelor Europene 2022, Tranzitie Justa, Version 1.2.

2.2 Case studies

It is important to note that the impact of transitions will differ between so-called declining and transforming sectors. Coal, lignite and other fossil fuel-based energy production are declining sectors as their economic activity will have to be phased out. On the other hand, metals, chemicals, cement and other industries are transforming sectors that need to change to eliminate their dependence on fossil fuels. Given the context of the JUSTEM project, we focus here on the impacts on declining sectors, particularly coal and coal-related industries.

We have applied the impact matrix in six European territories that are eligible for the JTF (see overview Figure 3):

- Stara Zagora in Bulgaria;
- Istria in Croatia;
- Western Macedonia in Greece;
- The Silesian Voivodeship in Poland;
- Jiu Valley in Romania;
- Asturias in Spain;

Figure 3: JUSTEM pilot regions.

It is interesting to look at these territories because they represent different socio-cultural situations, different geographical areas and different levels of progress towards a just energy transition. In general, all regions are highly dependent on coal, either directly or indirectly, for example through the employment of workers in coal-related industries. Although all countries have plans to reduce coal use, they have set different targets for the complete phase-out of coal. Greece has committed to phase out coal by 2028, Spain by 2030 (with mine closures by 2023), Romania by 2032, Croatia by 2033, and Poland by 2049. On the other hand, Bulgaria is considering a phase-out (European Commission, 2021). It is estimated that between half and two thirds of the current coal-fired power capacity in the EU will be retired by 2030 (European Commission, 2021). Positive signals have also come from governments; for example, in its preliminary National Energy and Climate Plan (NECP) presented to the EC in June 2023, Spain envisioned to phase out coal in 2025 rather than 2030 (Beyond Fossil Fuels, 2023). Similarly, the Romanian government accelerated its coal phase-out to 2030 by publishing a new emergency law in June 2022, which also envisaged a scheme to transfer funds from coal mines to renewable energy plants (Beyond Fossil Fuels, 2023). Lastly, in its NECP submitted in October 2021, the Bulgarian government pledged to phase out coal in 2038 or 2040 (Beyond Fossil Fuels, 2023).

3. LITERATURE REVIEW ON MULTIPLE IMPACTS OF JUST TRANSITION

We conducted a literature review to investigate the relevance, accuracy and importance of different transition impacts. Based on the impacts collected, we developed the impact matrix.

3.1 Impacts of (just) transitions

The "Commission Staff Working Document on territorial just transition plans" distinguishes between social, economic, demographic and environmental impacts associated with just transitions (European Commission, 2021). The different impacts listed have been selected as an initial list of impacts to be considered. Table 2 provides an overview of the key criteria mentioned under each impact dimension. We complemented the list of impacts (Table 2) with a literature review to highlight the importance of certain categories and their quantification.

Social impacts

The literature review identified main social impacts, namely: *employment and reskilling/upskilling of workers; gender impacts, social inclusion/exclusion and community cohesion; access to public infrastructure and services; energy poverty and living conditions*. In the following subsections, we provide further details on the importance and relevance of each impact.

Table 2: List of impacts delineated in the European Commission's staff working document on the territorial just transition plans (2021).

Impact dimension	Impact criteria
Social impacts	• Employment (both direct and indirect jobs), • Change in skills profile (need for reskilling or upskilling workers in industrial sectors) • Need for workers' mobility to accompany the needed technological transformations • Social inclusion, or exclusion; community cohesiveness • Living conditions • Gender implications • Access to public services and infrastructure • Energy poverty
Economic impacts	• Closure of mines and extraction sites • Decommissioning of fossil fuel-fired power plants • Structural changes in related industries
Demographic impacts	• Attractiveness to live and work in the region • Migration (of young people) • Vulnerable people (e.g., people with disabilities, or (mental) health issues)
Environmental impacts	• Derelict land • Contamination of soil and water • Geophysical instability • Environmental hazards, including health risks

Employment and reskilling/upskilling of workers

Unemployment and lack of training certificates are a central issue in regional just transitions (Snell, 2018; Yanguas-Parra, et al., 2023). This is a social impact, which includes both direct and indirect jobs (or loss of the latter), presenting direct consequences for the livelihoods of communities, families, and households. For instance, in the EU, close to 237 000 people are employed in coal-related activities, whereas almost 10 000 people are employed in peat extraction activities and around 6 000 are employed in the oil shale industry; which are all considered declining sectors (European Commission, 2021). It is thus vital that TJTPs clearly describe and delineate steps concerning how to deal with affected workers losing their jobs due to the transition to a decarbonised world. This is explicitly mentioned by the EC, stating that "economic activities based on the production of fossil fuels are expected to face an irreversible decline in economic output and employment levels" (European Commission, 2021, p.5). Similarly, other industrial activities producing high GHG emissions will need to undergo transformational processes to undertake more sustainable alternatives, hampering the employment of its workers. Additionally, higher unemployment levels are often associated with rural communities/counties/regions, presenting also lower levels of education, lower incomes and a higher share of elderly population (Gouveia at al., 2019).

To combat the possible negative repercussions which the transition to a decarbonised society might imply for more vulnerable regions, it is important that TJTPs present opportunities to aid in the upskilling and reskilling of workers and jobseekers, as to increase the local employment potential. The plans should really support the active inclusion of workers and jobseekers in the labour market, also by supporting job-search assistance activities (European Commission, 2021). This is in line with Article 2 of the JTF, whose specific objective is "enabling regions and people to address the social, employment, economic and environmental impacts of the transition towards the Union's 2030 target for climate and a climate-neutral economy by 2050, based on the Paris Agreement". Additionally, the TJTP will need to ensure the workers' mobility to accompany the needed technological transformations. This entails both improving the access to public services but also ensure accommodations for workers in case of displacement. To conclude, TJTPs should explicitly address employment, considering the present but more importantly involving long-term measures, focused on the future.

Gender implications, community cohesiveness and social inclusion/exclusion

The social impact related to employment involves also elements of social exclusion and gender implications, as coal regions often present a gender mismatch when analysing the employed workforce (Janikowska & Kulczycka, 2021). The gendered nature of the energy transition has been recognised (Jasanoff, 2018), as men and women are involved in different ways in the energy sector (Njenga et al., 2021). Any change

resulting from the energy transition will affect women differently, as they have different roles in the workplace but also in society, community and households (Lahiri-Dutt, 2023). This is particularly the case in coal-intensive regions experiencing closures of mines and power plants. Geography will also play a role, as how women are affected by the transition process is also dependent on the individual country characteristics; with countries in the Global South being affected differently than the ones in the Global North (Lahiri-Dutt, 2023). Women in carbon-intensive regions tend to have less time available and lower financial resources and thus less agency and space for promoting their interest and perspectives in the policy making process (Lieu et al., 2020). Indeed, the division of labour between genders is more pronounced in carbon-intensive regions, with different job allocations stemming also from sociocultural backgrounds, generally presenting a higher female unemployment rate compared to national averages (Walk, et al., 2021). Walk et al. (2021) concluded that the gender sphere is still a factor in assigning men and women employment positions within the sustainable transition, finding a substantial lack of both quantitative and qualitative data aggregated by gender and a rather minor number of relevant studies. This specific aspect of a just transition offers little scientific basis, as the literature has been more focused on analysing broader economic effects such as unemployment, opposed to what effect does the transition have on specific groups (Walk, et al., 2021). Nonetheless, as expressed by García-García et al. (2020), "the gender implications of the energy transition are an analytical bias we can no longer afford" (p.13).

Closely connected to the gender implications and social exclusion/inclusion is the community cohesiveness. Regions that are affected by the sustainable transition and are thus fossil-fuel dependent often have predetermined roles within the community that stem from cultural norms, particularly in mining-regions. For example, in the Silesian Region in Poland, women would remain at home taking care of the more caretaking duties, as a miner's wife being employed was seen as dishonourable (in 1975, a ban on employing women for underground mining activities was passed in Poland) (Janikowska & Kulczycka, 2021). This solidified the family role of women and the working one of men. Hence, the changes stemming from the sustainable transition will undoubtably change the social roles, both excluding and including different people in different societal roles. Traditionally, women were in charge of community activities. Nonetheless, once women became more active in the job market, the community activities saw a decrease in many coal-intensive regions (Miewald & McCann, 2004). Nonetheless, the community cohesiveness and social patterns are unique to each region (Walk, et al., 2021); and whereas it is known that the sustainable transition will affect the latter, it is not possible to precisely assess how it will be affected in general terms.

Access to public infrastructure and services

Access to public infrastructures and services, such as public transport, need to be increased in vulnerable regions. The focus of the EU in reducing emissions in the

transport sector can also be seen by the new policy measures presented in the "Fit for 55" package. In fact, the EU Emissions Trading Scheme (EU ETS) was revised and expanded as to include also the residential and transport sector, thus covering 61% of total EU greenhouse emissions instead of the current 43% (European Council, 2022). Additionally, the connection between transport poverty and energy poverty has become more evident and a topic of discussion both among European Institutions but also the literature (Koukoufikis & Uihlein, 2022; Louwans et al., 2021). Transport poverty can be further divided among mobility poverty, understood as a lack of access to either a vehicle or safe route; accessibility poverty, meaning a difficulty in accessing services related to mobility; and transport affordability, referring to the cost of mobility compared to the income (Upham at al., 2022). Whereas only one part of public infrastructure and services, several indicators are available to determine mobility, ranging from survey-gathered data (frequency of public transport) to quantified data (percentage of households living more than 1 Km from nearest public transport station) (Covenant of Mayors, 2022). Lastly, connected to transport but also other issues, is the environmental pollution, being this the main environmental indicator encompassing and connecting the other ones. The impacts and benefits of a reduced pollution are multiple, with a series of indicators available to quantify this, such as air quality indexes and amount of land remediation. Whereas not explicitly mentioned as an indicator in relevant documents, the environmental pollution impact is connected to a reduction in emissions and a transition to a decarbonised economy and should be thus quantified with appropriate indicators.

Energy Poverty and living conditions

Bouzarovski (2018, p.1) defines energy poverty as a situation which "occurs when a household is unable to secure a level and quality of domestic energy services – space cooling and heating, cooking, appliances, information technology – sufficient for its social and material needs". However, energy poverty presents various definitions throughout the literature. This is due to its multifaceted nature, being a socioeconomic issue presenting many ramifications. Definitions vary also across countries, as national socioeconomic conditions play a vital role in defining energy poverty. Within the European Union, not all countries present an official, legally recognised definition. For all these reasons, a universal definition of energy poverty cannot be obtained. Nonetheless, it is agreed within the literature that this intricate phenomenon will always include both economic components, such as the available disposable income, and energy components, such as the energy performance of the dwelling where one household lives, and all the socioeconomic interactions that can result, such as the inability to keep the home adequately warm. However, this phenomenon does not have only socioeconomic ramifications, but for example also environmental ones. Indeed, households in a situation of energy poverty will utilise more outdated forms of technology for energy consumption, resulting in more environmental harm.

Economic impacts

The literature review confirmed that all three economic impacts delineated in Table 2 were indeed important and relevant for assessing TJTPs.

Closure of mines and extraction sites

The closure of fossil-fuel related mines and extraction sites will greatly impact dependent regions. Throughout the EU, 208,000 people are directly employed in coal activities, with 76% being employed in the mining sector (Kapetaki, 2021). Nonetheless, between 2010 and 2019, 19 lignite mines closed, whereas 63 hard coal mines closed in the same time period (Kapetaki, 2021). Between 2010 and 2018, the coal mining jobs declined from 239,400 to 161,930 (~32%) (Kapetaki, 2021). Poland, and in particular the upper Silesia region, remains the largest employer of coal-related activities in the EU. One factor to consider is the high multiplier effect mining employment has. In Poland, in December 2019, 83,297 people were employed in the coal mining sector, with 64,259 people working underground; however, approximately 400,000 people were employed in mining facilities sector (Janikowska & Kulczycka, 2021). This means that for every job loss in the hard coal mining sector, another 3 to 4 job losses could result. This has consequences both in terms of employment losses and the larger macroeconomy of the country.

Decommissioning of fossil fuel-fired power plants

Estimates show that between half and two thirds of the current coal-fired power capacity will be retired by 2030 (Kapetaki, 2021). Fossil fuel-fired power plants include coal, peat and oil shale as prime resources. Coal-powered plants represent the majority. Nonetheless, peat-fired energy plants generated approximately 76,179 TJ of energy, mainly for heat production and employing about 6,313 people, with the country presenting the highest heat generation being Finland (being also the biggest producer of peat) (Kapetaki, 2021). Similarly, oil shale power plants are found only in Finland, directly employing 4,000 people (Kapetaki, 2021). From 2010 to 2019, lignite production dropped by 22% whereas hard coal production dropped by 43% (Kapetaki, 2021). Similarly, from 2017 to 2020 (included), roughly 26 GW of coal-fuelled generation capacity was decommissioned (Kapetaki, 2021). In Poland, 77% of the power generated in 2018 came from hard coal and lignite (Tomaszewski, 2020). A reduction in such figure, does not only mean potential job losses, but also energy price increases and an energy system revolution. Nonetheless, in Poland specifically, a survey showed that 64% of citizens were favourable in abandoning such resource of power, with 60.5% stating being in favour of paying increased heating and energy prices (Tomaszewski, 2020). As for the closure of mines, the decommissioning of carbon-fuelled power plants will have huge economic impacts both at micro and macro level.

Structural changes in related industries

A just transition involves a regional development towards a decarbonised economy. Therefore, the local economy needs to be changed and restructured. This does not

necessarily mean building it newly from scratch, but rather transforming and modernising it (Pavloudakis et al., 2023). Whereas potentially difficult to quantify, the impacts and benefits of an increased regional investment in local activities to diversify the regional economy are multiple.

Demographic impacts

The just transition will also have demographic consequences. The decline in employment in coal regions is linked to a decline in the attractiveness of the region as a place to live and work for young people. The latter will not only be predisposed to lower levels of employment but will also be more likely to migrate outside the region, making it a less attractive place to live and work (European Commission, 2021). Coal regions therefore not only have a higher proportion of older people, but also a higher rate of out-migration of young people, which increases the average age of the region and affects its demographics. In addition to the elderly (retired and over 65), people with disabilities are likely to remain in the affected regions, as they are more vulnerable and difficult to relocate.

The out-migration of (young) people from coal regions is strongly linked to unemployment and we therefore considered it to be the most important demographic impact to be considered. Similarly, a higher emigration rate increases the proportion of vulnerable people in coal regions and reduces the attractiveness of living and working in coal regions. Emigration leads also to changes to the population density and people in working age.

Environmental impacts

The just transition will inevitably bring some environmental impacts in the affected regions. The just transition concept is itself rooted in the environmental justice concept, which has always been involved in combating the disproportion of population affected by environmental degradation (Farrell, 2012). Advocates of environmental justice highlighted how disadvantaged communities should not bear a higher burden related to damages caused by environmental changes (Williams & Doyon, 2019). Nonetheless, in the literature, environmental impacts are rather considered in general terms rather than specific. On the other hand, environmental pollution and related health risks are mentioned as a key environmental impact of the industry today (Wang & Lo, 2021). However, positive environmental impacts are expected to result from the renaturation of coal regions.

3.2 Impact matrix

In the previous subsections we have identified several impacts following the literature review. The list of all impacts considered is presented in Table 3, and this list will form the impact matrix. This matrix will be used as a tool to assess if and how different TJTPs address the most important multiple impacts related to a just transition.

*Table 3: Selected impacts forming the Impact Matrix. *Impacts will be only qualitatively assessed with the analysis of the TJTP.*

Impact dimension	Impact categories
Social impacts	Employment
	Reskilling/upskilling of workers
	Gender implications, social inclusion/exclusion
	Community cohesiveness
	Socio-cultural identity*
	Access to public infrastructure and services
	Energy poverty
	Living conditions*
Economic impacts	Closure of mines and extraction site
	Decommissioning of fossil fuel-fired power plants*
	Structural changes in related industries*
Demographic impacts	Migration of (young) people
	Population density
	Attractiveness to live and work in the region*
Environmental impacts	Greenhouse gas emissions
	Health, incl. pollution
	Nature restauration / revitalisation*

4. DEFINITION OF INDICATORS TO QUANTIFY MULTIPLE IMPACTS OF JUST TRANSITIONS

The following section defines a set of indicators to quantify the multiple impacts outlined in the previous section, forming the impact matrix (Table 3). Once again, the analysis follows the distribution of impacts by category, with the only difference that the social and economic indicators are analysed simultaneously. This is due to the high correlation found between the two categories of indicators, also due to the socio-economic nature of one of the impacts listed. In conclusion, a list of indicators will be defined to quantify the multiple impacts of just transitions in coal regions. We conducted a literature review to assess which indicators best represent the different impacts and which indicators have been more widely used, taking into account both their accuracy and relevance.

4.1 Definition of indicators

Social & economic indicators

When analysing the literature review with regards to the quantification of impacts, we found that one impact in particular, energy poverty, presented a variety of literature on its indicators. Similarly to its definition, there is no one single indicator to be used to assess energy poverty. Due to the multidisciplinary nature of the phenomenon being analysed, depending on the indicator being used, different conclusions can be obtained, as only one facet of the issue is being considered (Deller et al., 2021). As such, several indicators can be found within the literature. Data obtained via direct measurement of services standards has been considered (Bouzarovski, 2018). Nonetheless, this method has not been utilised on a large-scale due to the difficulty in defining global energy standards, being these influenced by cultural standards, but also geographical location (even just within Europe) (Walker & Day, 2012). Purely economic indicators such as expenditure patterns related to the energy consumption have also been considered, defining a share of the population spending more than a certain percentage on energy services as energy poor (Bouzarovski, 2018). Notoriously, Boardman (1991) defined households spending more than 10% of their income on energy expenditures as fuel (i.e., energy) poor. Lastly, self-reported data by households has also been used to quantify energy poverty. Different indicators can be useful depending on the scope of the energy poverty analysis carried out and should consider the national context. For instance, the Energy Poverty Advisory Hub (EPAH) has identified 21 indicators providing national values based on Eurostat data (EPAH, 2022a). Thus, a combination of indicators should be employed to gain a holistic understanding of the issues at stake and to accurately represent the situation that is being studied.

To understand the interactions between different factors related to energy poverty and possible benefits resulting from a reduction of the latter, it is first needed to individuate

certain indicators to be used to assess energy poverty, also considering the perspective of the TJTP. Therefore, a list of indicators stemming from literature will be delineated (Covenant of Mayors, 2022; EPAH, 2022a; EPAH, 2022b; Gouveia et al., 2019). We gathered these and categorised them according to the notions previously mentioned and have been summarised in Table 4. The same set of indicators was utilised in Deliverable 2.1.

Table 4: All considered indicators related to energy poverty. Legend: economic indicators highlighted in light blue, social indicators highlighted in light yellow.

Vulnerability indicators	*Structure of the population and age dependency ratios (essentially understanding the demographics, as pensioners are more prone to be subject to energy poverty)*
	Disposable household income
	Unemployment rate
	Severe material and social deprivation rate (essentially an enforced lack of necessary and desirable items to lead an adequate life)
	Risk of poverty and social exclusion rate (reflecting both the risk of poverty but also intensity of economic activity)
Indicators related to the residential building stock	*Tenure form of dwellings (distribution of population by tenure status)*
	Type of dwellings in cities or rural areas (e.g., population distribution by degree of urbanisation)
	Distribution of dwellings by year of construction (which is correlated with the energy efficiency of the building)
Energy and energy market indicators	*Household electricity prices (last 5 years)*
	Household natural gas prices (last 5 years)
	Heating fuel shares in the residential sector (as heating is the main energy end-use)
	Energy efficiency trends for households (ODEX index)

Indicators related to the dimensions and level of energy poverty	*Arrears on utility bills*
	Inability to keep the home adequately warm
	High share of energy expenditure in income (i.e., households spending twice the median on energy expenditures)
	Low absolute energy expenditure (i.e., households spending half of the median on energy expenditures)

As can be seen in Table 4, due to the multi-dimensional nature of energy poverty, we defined several social and economic indicators to measure it. Nonetheless, these indicators also accurately measure other social impacts that were mentioned. In fact, in the list provided above, factors such as the unemployment rate, the social exclusion rate, inability to keep home adequately warm are included to name a few, that accurately represent and measure other impacts considered in the impact matrix.

It should be noted that in Table 4 the unemployment rate, the severe material and deprivation rate and the at-risk-of-poverty and social exclusion rate are considered as economic rather than social indicators. While they do quantify the social impacts from Table 3 (i.e. unemployment, community cohesion and social inclusion/exclusion, and living conditions), they do so by taking into account economic factors and values such as income and the macro-economy of the country/region. Such a definition is also consistent with how the different indicators of energy poverty have been defined in JUSTEM Deliverable 2.1.

Energy poverty is only one of the impacts considered, and in fact, we defined other indicators to describe other social and economic indicators. These can be found in Table 5, where for each impact we explain which indicator we found and where it is referenced.

Table 5: List of social and economic indicators not related to energy poverty. Legend: economic indicators highlighted in light blue, social indicators highlighted in light yellow.

Impact	Indicator	References indicators were mentioned in
Employment	Workforce employed in the coal sector	(European Commission, 2021)
	Workforce employed in the renewable energy sector	(European Commission, 2021)
	Relation of employees in the RES sector compared to total employees	(Rösch et al., 2017)
	People living in households with very low work intensity	Eurostat
Gender implications; community cohesiveness and social inclusion/exclusion	Unemployment by gender	(Lahiri-Dutt, 2023)
Access to public infrastructure and services	Percentage of households living more than 1 km away from closest public transport station	(Covenant of Mayors, 2022)
Closure of mines and extraction sites	Closure dates committed	(European Commission, 2021)

Demographic indicators

Population structure and age dependency ratios have already been presented as demographic indicators to measure energy poverty. In addition, the migration rate should be considered as a factor to measure the demographic impact. Pavloudakis et al. (2023) propose two factors to measure the demographic change of affected regions, namely the change in the population index, "expressed as the ratio of the population of each year divided by the population of the first year of the time series" (p.7), and the elderly population index, defined as "the percentage of the population aged 65 and over divided by the percentage of the population aged 15-64" (p.7). Such factors can give an accurate indication of the demographic impact in the vulnerable region analysed and are summarised in Table 6.

Table 6: List of demographic indicators considered.

Impact category	Indicator	References indicators were mentioned in
Migration of young people	Percentage of population under 30 emigrating vs immigrating	(European Commission, 2021)
	Change in population index	(Pavloudakis et al., 2023)
	Elderly population index	(Pavloudakis et al., 2023)
Population development	Population density	Eurostat

Environmental indicators

We have found a number of indicators to quantify environmental and health impacts. This is due to the variety of factors and perspectives that can be considered when assessing environmental and health concerns. The list of indicators considered is shown in Table 7.

Table 7: List of environmental indicators considered.

Impact category	Indicator	References indicators were mentioned in
Health	Local air pollution	(European Commission, 2021)
Greenhouse gas emissions (GHG)	Total GHG emissions dynamics	(Streimikiene, et al., 2021)
	GHG intensity of gross available energy	(Streimikiene, et al., 2021)
	Energy intensity of GDP	Eurostat
	Total GHG per capita	(Streimikiene, et al., 2021)
	Share of energy from renewable sources	(Rösch, et al., 2017; Streimikiene, et al., 2021)
	Use of renewables for heating and cooling	Eurostat

4.2 Selected indicators of the impact matrix

In the previous subsections, we have defined several indicators for the different impact categories, derived from the literature. We have summarised these in the various tables.

At this stage, the selection process continues by selecting a final set of indicators that will be used to construct the final matrix of indicators and to assess the multiple impacts in the six coal regions analysed and to evaluate the respective TJTPs. The final matrix of indicators is presented in Table 8. More than 30 indicators were considered. The final matrix includes 15 indicators from all the different categories considered. We selected these on the basis of their importance, availability and precision in describing a particular aspect.

Table 8: The matrix of indicators. Legend: in yellow: social indicators; in blue: economic indicators; in green: environmental indicators; in orange: demographic indicators

Indicators	References indicators were mentioned in
Inability to keep the home adequately warm	(Streimikiene et al., 2021)
Arrears on utility bills	(Streimikiene et al., 2021)
Type of dwelling in cities or rural areas (i.e., population distribution by degree of urbanisation)	Eurostat
People living in households with very low work intensity	Eurostat
Unemployment rate (female)	(Lahiri-Dutt, 2023)
Household electricity prices (last 5 years)	(Streimikiene et al., 2021)
Household natural gas prices (last 5 years)	(Streimikiene et al., 2021)
Unemployment rate (general)	Eurostat
Severe material and social deprivation rate (essentially an enforced lack of necessary and desirable items to lead an adequate life)	Eurostat
Risk of poverty and social exclusion rate	Eurostat
Percentage of population under 30 emigrating	(European Commission, 2021)
Population density	Eurostat
Energy intensity of GDP	Eurostat
Share of energy from renewable sources	(Rösch et al., 2017; Streimikiene et al., 2021)
Use of renewables for heating and cooling	Eurostat

Specifically for the social indicators, the *tenure form of dwellings* and their *year of construction* were not selected as it is expected that coal regions will have such similar characteristics. The *workforce employed in coal* and *renewable energy sector* and the

relation of employees in the RES sector compared to total employees were excluded due to regional data availability. Nonetheless, we considered the *people living in households with very low work intensity* indicator, as it accurately shows which areas present higher unemployment and less working opportunities, greatly encompassing the social aspect of the indicator. We excluded the two indicators expressing energy poverty in terms of *abnormally high and low expenditures* due to regional data availability and excessive specificity. Lastly, we excluded the *percentage of households living more than 1 km away from closest public transport station* due to low regional data availability and low relevance, as it is expected that all coal regions will have similar, low levels of access to public infrastructure.

In terms of economic indicators, we selected three vulnerability indicators and two energy market indicators. We excluded the *structure of the population*, as the *general unemployment rate*, *risk of poverty rate* and *severe material deprivation rate* already consider the former. We excluded the *disposable income* as it does not consider different national socioeconomic conditions, that would have to be taken into account when comparing different European coal regions. For the energy market indicators, we selected the *energy price trends* of both *electricity* and *gas* as these give a clear understanding of how the energy burden might have increased/decreased. Lastly, we considered the *closure dates of mines* to be too qualitative as an indicator.

We deemed the out-migration of young people from coal regions to be best represented by the *percentage of population under 30 emigrating (compared to immigrating*) coupled with the *population* density in the region, rather than the other two considered indexes which were more focused on the general and elderly population.

Finally, for the environmental indicators, we decided to select only one indicator that analyses the economic dependence on activities that are harmful to the environment, namely the *energy intensity per GDP*, because it strongly links to the environmental impact to the economic sphere and also shows how economically dependent a country is on the energy consumption (and thus GHG emissions). On the other hand, the *share of energy from renewable sources* and the *share of renewables in heating and cooling* indicators greatly illustrate the advancement of the energy transition and its impact on the daily activities of households.

5. ASSESSMENT OF MULTIPLE IMPACTS IN SIX COAL REGIONS

5.1 Findings from the analysis of territorial just transition plans

The JTF regulation requests from the TJTP to address the social, demographic, economic, health and environmental impacts of the transition to a climate-neutral economy. We find that most TJTPs do not specifically address the "impacts" of the transition but rather outline needs, define "intended" actions, and provide "expected results". This might be the case because the status quo of certain transition issues is not well known. For example, the TJTP plan of Stara Zagora highlights the need to close knowledge gaps in term of reskilling needs: "Detailed assessment of the skills and competencies of the existing staff of the TPPs and coal mines has not been performed but is considered essential for the successful modelling of the measures for reskilling and up-skilling of the affected workforce in the three regions" (Ministry of Energy of the Republic of Bulgaria, 2023, p. 23). Thus, the evaluation of the impacts is to some extent subject to interpretation.

We also find that all plans have gaps in defining transition impacts and that most plans lack to quantify most transition impacts; instead, they are mainly qualitatively described. Since most plans only outline "intended" measures, it will depend on the implementation whether positive impacts can be achieved, and negative impacts be reduced.

It is also important to note that (just) transition processes are already ongoing. TJTPs state that domestic coal productions have been declining in the analysed coal regions, and already led to population decline and an aging population.

Table 9 summarises the expected impacts of just transition in the territories based on the analysis of the TJTP. The gaps in the qualification and quantification of the impacts show that further work is needed to better understand the impacts and define appropriate measures to minimise negative social, economic and demographic impacts.

Table 9: Summary of the expected impacts of just transition in the regions based on the analysis of the TJTP. Traffic light: green = overall positive impact expected; yellow = mixed impacts expected, or not clearly defined; red = overall negative impact expected; grey = impact not considered.

Impact dimension	Impact categories	Expected impacts on the just transition territories					
		Asturias	Istria	Jiu Valley	Stara Zagora	Silesian Voivodeship	Western Macedonia
Social impacts	Employment						
	Reskilling/upskilling of workers						
	Gender implications, social inclusion/exclusion						
	Community/ social cohesiveness						
	Socio-cultural identity						
	Access to public infrastructure and services						
	Energy poverty						
	Living conditions						
Economic impacts	Closure of mines and extraction site						
	Decommissioning of fossil fuel-fired power plants						
	Structural changes in related industries						
Demographic impacts	Migration of (young) people						
	Population density						
	Attractiveness to live and work in the region						
Environmental impacts	Greenhouse gas emissions						
	Health, incl. pollution						
	Nature restauration/ revitalisation, renaturation						

Social impacts

TJTPs pay most attention to the impact on employment. Job losses are evident in all coal regions. It is also important to note that people working in ancillary or indirect jobs may be even more vulnerable to unemployment than those affected by mine closures (Asturias). This is because regions such as Silesia are organising redundancy processes by designing and supporting redundant workers in mining and mining-related enterprises.

The pilot regions studied are already affected by unemployment in different ways. For example, while Stara Zagora is one of the five districts in Bulgaria with the lowest unemployment rate (1.4%), Western Macedonia already has the highest unemployment rate among the other regions of the Greek territory. Vocational guidance and employment services have therefore been identified as important measures to support jobseekers.

However, Just Transition is also expected to have a positive impact on employment, mainly due to the growing renewable energy and rehabilitation and reconstruction sectors. For example, the TJTP of Asturias states that the Just Energy Transition Strategy of the Principality of Asturias could generate up to 6,300 jobs, compared to 1,316 direct jobs that will be affected. However, some of the jobs will be temporary, so the challenge remains to transform the economy to create permanent jobs, for example in the renewable energy value chain. This requires investments that create long-term value and jobs. The Stara Zagora TJTP states:

> *"Renewable energy sources (PV, wind, green hydrogen, geothermal and biomethane) and storage production facilities have been identified as a suitable type of replacement production that can be located at or in close proximity to the current coal-based production (e.g., on the site of recultivated land from lignite quarries), which has the capability of preserving local labour characteristics and commuter patterns and fill in the employment gap of small and medium size enterprises." (TJTP of Stara Zagora)*

In order to minimise negative effects on employment, reskilling and retraining of workers is a crucial component of all TJTPs. The Stara Zagora TJTP positively mentions that the region has a highly educated workforce - compared to a national shortage of skilled labour - which is a major advantage for the region's transition. How many workers will need to be retrained remains largely unclear, as the TJTPs make no assumptions, or if so, only for specific processes. It is expected that workers with new skills will find jobs in the regions and that the number of highly skilled and highly paid jobs will increase (Silesia). For this to happen, existing training or technology centres need to be adapted to new energy themes and the services provided by the relevant

educational institutions need to be improved. Some plans specifically mention that socially vulnerable or disadvantaged people (Istria, Stara Zagora, Jiu Valley), youth groups (Asturias, Stara Zagora, Jiu Valley) and women (Jiu Valley) should benefit from retraining and upgrading programmes.

Gender aspects are hardly addressed or the impact is not clearly defined. The exception is Asturias, which emphasises the need for training, qualification and employment support initiatives to integrate women into the labour market.

> *"[…] promotion and awareness-raising to avoid discrimination, eliminate gender stereotypes and achieve effective equality in working conditions." (TJTP of Asturias)*

The TJTP of the Jiu Valley mentions the promotion of entrepreneurial initiative, including female entrepreneurship. The measures in the Jiu Valley are expected to contribute to the creation and maintenance of environmentally sustainable jobs, in particular for people directly affected by the transition, as well as for disadvantaged, highly disadvantaged and disabled workers, thus achieving cohesion between people. The TJTPs for Silesia, Stara Zagora and Istria do not mention gender aspects at all.

> *"[…] investments in infrastructure and equipment, measures will be promoted to ensure gender equality." (TJTP of Jiu Valley)*

Beyond gender, the social inclusion of vulnerable groups, specifically in the retraining and reskilling, is addressed in most TJTP. The region of Western Macedonia, for example, has a Regional Strategy for Social Inclusion of Western Macedonia (2015).

Transition processes are also expected to challenge the social cohesion and "social piece". However, the impact on cohesion, beyond the mention of the Cohesion Fund, only applies to two regions, where the impact has not yet been analysed in depth. In Western Macedonia, for example, a reduction in employment and population movements is expected to have a negative impact on demographic structures. Re-employment of the current workforce is identified as a key measure to mitigate the impact.

Coal regions today have a strong identification with energy production and some regions are expected to retain their 'energy identity'. For example, the TJTP of Western Macedonia speaks of an energy identity only ("energy identity") in relation to the need for re-identification. Silesia mentions the challenge of maintaining cultural identity in the region, while the other TJTPs do not address the impact of transition on the 'identity' sphere at all. For example, Silesia plans to implement social activation programmes to

increase the level of social activity in the region in order to preserve cultural identity and industrial heritage.

Western Macedonia expects negative impacts on human health due to existing deficits in social infrastructure. However, the TJTP and related measures are expected to improve social and health infrastructure, access to social services and better care, including elderly and child care facilities (Jiu Valley, Silesia, Stara Zagora, Western Macedonia).

> *"[…] lack of adequate social infrastructure is expected to have a negative impact on the health of the citizens of the region of Western Macedonia." (TJTP of Western Macedonia)*

Educational infrastructure will also be improved to ensure a better link between academic research, educational institutions and the economy (Istria, Silesia, Stara Zagora, Western Macedonia). For example, Istria plans to develop a new green curriculum for business and the future education of students, including retraining programmes. In addition, the TJTPs (Jiu Valley, Stara Zagora, Western Macedonia) outline the need to develop existing transport infrastructure to improve the mobility of goods and people, for example through regional and intra-regional road and rail links.

Energy poverty is identified as an impact of transition in all plans except Istria. For example, the Jiu Valley TJTP states that the energy poverty rate in winter is 70% compared to 45% for the whole year. Negative impacts are therefore expected.

> *"The planned further transition of households to low- or zero-emission heat sources may result in an increase in energy poverty […]." (TJTP of Silesia)*

Some regions (Jiu Valley, Western Macedonia, Stara Zagora) see the transition plans as an opportunity to combat energy poverty by promoting renewable energy, self-consumption, energy storage and renewable hydrogen. The Silesian TJTP also includes the objective of developing social housing. The Istrian TJTP does not address energy poverty at all.

> *''Thus, to combat energy poverty, the installation of photovoltaic / photothermal panels at household level is supported." (TJTP of Jiu Valley)*

Impacts on social infrastructure and energy poverty were also linked to impacts on overall living conditions (for Istria, Silesia, Western Macedonia). The main challenges to citizens' living conditions are the age of buildings, low energy efficiency standards and old heating systems (Silesia, Western Macedonia). In particular, it is mentioned that the region of Western Macedonia is characterised by the highest heating needs among the other regions of Greece, so the development of smart technologies for the building stock to improve living conditions is extremely important. However, just transitions are also expected to promote better living conditions through improvements to the building stock.

> *"a particular challenge is the inadequate quality of existing housing, due in large part to the advanced age of buildings and lack of access to technical installations" […]." (TJTP of Silesia)*

Economic impacts

The closure of mines and extraction sites is expected to have an impact on the regions, including on economic activity, employment and energy supply in the areas affected by the transition. Municipalities are also expected to lose income tax revenues, which could be up to 1/3 in Poland. Some regions are more affected than others: Asturias is one of the Spanish regions most affected by the closure of coal-fired power stations and coal mines.

Some plans include clear deadlines for the closure of (some) mines. For example, Western Macedonia plans to close most of its lignite plants in 2023. Other plans (e.g. Silesia) foresee a "gradual closure" of coal-fired power plants. Stara Zagora also plans a pre-closure phase and preparatory activities in the pit sections foreseen for early closure until 2027. In Bulgaria, the state-owned company "Conversion of Coal Regions" (CCR) will carry out reclamation and reuse activities within the coal mines, while in the Istria region, investments in the mining legacy are planned at two sites, which will increase accessibility. The closure of the mines is expected to have a positive impact on the environment and ecosystems.

> *"[…] investments in the mining heritage are foreseen at two locations, which will be visited annually by about 100,000 visitors once they are put into operation […]. (TJTP of Istria)*

Furthermore, the impact of the decommissioning of power plants is mainly negatively. In Silesia, the closure of a total of 20 mines and power plants will have a negative impact, as it will reduce the companies' income by several percent.

"It is estimated that the decrease in the income of municipalities in the mining transition from participation in personal income tax (PIT-37) may amount to as much as PLN 328 million per year. On average, this will mean a drop of 10.2% in this income and at most some municipalities may lose as much as 1/3 of the income received from participation in income tax." (TJTP of Silesia)

However, some plans also see great opportunities in replacing existing facilities with renewable energy and other industrial activities.

The loss of mines and power stations also has an impact on carbon-intensive industries, including steel, chemicals and metals, which will need to be transformed to reduce emissions.

TJTPs identify economic diversification as a key measure to address mine closures. The economic impact and opportunities vary depending on the location and size of the coal region. Some regions see great opportunities in new energy sources, for example Bulgaria wants to create its first small hydrogen valley in Stara Zagora, others see great opportunities in tourism (Asturias, Istria). Istria wants to develop an ICT industry. Diversification of the economy is also directly linked to the need for new job profiles and thus training and reskilling.

"The hydrogen-based economy is considered as a strategic priority for the transformation the region of Stara Zagora." (TJTP of Stara Zagora)

The impact of the closure of fossil fuel-fired power plants has not been thoroughly analysed. In Western Macedonia, the closure of lignite units may lead to a reduction in the activity of enterprises in the nearby regional units of Kozani and Florina, which are strongly linked to lignite activity. In the Silesia region, the closure of enterprises has a negative impact on the economic and residential attractiveness of many post-mining areas.

"Decommissioned enterprises negatively affect the economic and living attractiveness of many post-mining areas - they increase the cost of maintaining infrastructure, reduce the quality of life of residents." (TJTP of Silesia)

The structural changes in related industries have mostly positive effects in the regions. In particular, the hydrogen economy in Stara Zagora will be a strategic investment for

the development of new economic sectors, the creation of new jobs and start-ups. Istria will achieve diversification of the economy, development of entrepreneurship and job creation through the creation of supporting institutions.

> *"4 entrepreneurship support institutions (coworking, incubator) with a total capacity of 40 users (newly established SME) and 2 entrepreneurship zones with an approximate area of 16ha to be used by 20 users (SME) will be established" (TJTP of Istria)*

The focus of all TJTPs is on promoting the value chain of renewable energy, self-consumption, energy storage and renewable hydrogen. This is expected to have a positive impact on the local labour market. All territories focus on the green transformation of industry and the promotion of sustainable mobility, circular economy and energy efficiency.

> *"Renewable energy sources […] and storage production facilities have been identified as a suitable type of replacement production that can be located at or in close proximity to the current coal-based production (e.g., on the site of recultivated land from lignite quarries), which has the capability of preserving local labour characteristics and commuter patterns and fill in the employment gap that SME (small and medium enterprises)." (TJTP of Stara Zagora)*

Demographic impacts

The coal regions analysed are already experiencing negative demographic changes: populations are ageing and at risk of shrinking. In Stara Zagora, for example, the depopulation decreased by 7% between 2010-2015 and 3% between 2015-2019. Western Macedonia is affected by a population decline, with the region's total resident population expected to fall by 6% in 2020 compared with the 2011 census. Asturias has already lost between 10-30% of its population over the last 20 years, not least because of frequent relocations. The region of Silesia will perhaps be the most negatively affected, given its population, and will have the highest rate of population decline in the country.

> *"According to the forecasts of the Central Statistical Office, by 2050 the population of the Silesian Voivodeship will decrease by 18.8%, or by more than 850,000 people, relative to 2018. This volume analysed in absolute terms is the highest in the country." (TJTP of Silesia)*

Regions, such as the Jiu Valley, Asturias or Silesia have already perceived an emigration of people from the region. This has also led to a decline in the work force.

> *"In 2019, the number of the under working-age population was 61,743 people (vs. 66,694 in 2010) and continues to decrease while the over working-age population accumulates (70 830 people in 2019 vs. 64 275 people in 2010). This trend is expected to continue in the future, thus creating a challenge for economic growth and development amid a shrinking workforce." (TJTP of Stara Zagora).*

The migration of young people is not deeply addressed in all TJTPs, but it seems to affect most of the regions. This phenomenon is happening due to the fact that the lignite power plants will be closed down and hence several people employed in the energy sector will lose their jobs. For this reason, especially young people, are leaving these areas in search of a better and more sustainable future. For example, in Western Macedonia, the reduction of employment will not only cause the movement of young people, but also intra-regional transfer of businesses and workers of the regions concerned, with a view to finding better economic prospects.

However, the Silesian plan also anticipates positive impacts of a prevented/minimised outflow of people due to the just transition process. For this, it is of great importance to ensure high quality education, as Silesia plans to apply. Another impact that the regions face due to the lignite production is lack of attractiveness. The abandoned industrial activities have a particularly negative impact if they are located in urban centres. More specifically, in the region of Silesia, this phenomenon reduces attractiveness both in economic and residential terms. The TJTP of Silesia states that the region is already perceived as "problematic and attractive areas for living" and that abandoned industrial activities will further unfold. Access to education, jobs and services such as low-carbon transportation, are seen as an essential measure to counter this trend. Istria wants to increase the attractiveness of its place and the development of tourism and related products through the activities of revitalisation, rehabilitation, promotion and development of cultural products and services based on the abandoned mining and industrial site.

> *"Investments are foreseen in the revitalisation, promotion and development of cultural products and services at three cultural heritage*

sites, which will be visited by approximately 70,000 visitors annually" (TJTP, Istria)

Environmental impacts

Contamination and waste are major challenges that negatively affect the regions today. For example, 20% of the contaminated sites registered at national level in Romania are located in Hunedoara County. The Just Transition is expected to have a positive impact on emission levels and on the restoration and revitalisation of nature.

"[…] and ultimately the most important environmental impact, which is linked to the reduction of air, soil and water pollution." (TJTP of Istria).

In Silesia, the planned reduction in coal-fired power generation translates into a 62.1% reduction in CO_2 emissions (from 13.2 million tonnes in 2019 to 5 million tonnes in 2030). Economic transformation will be key to reducing emissions in carbon-intensive industries. For example, by switching from coal and petroleum coke to alternative and renewable energy sources, Holcim (HR) plans to reduce GHG emissions per tonne of cement by 53% (2030 compared to 1990) and 42% (2030 compared to 1990).

While the elimination of primary sources of air pollution will have a positive impact on people's health, the health infrastructure in some regions (Western Macedonia, Jiu Valley) is considered to be critically weak.

"[…] lack of adequate social infrastructure are expected to have a negative impact on the health of the citizens of the region of Western Macedonia." (TJTP of Western Macedonia)

Many regions are carrying out restoration and reclamation activities in parallel with coal mining. Istria, for example, plans to build four recycling yards with educational and promotional activities to improve nature restoration. The Silesian TJTP mentions the need for environmental infrastructure projects for water management. In addition, waste management is a major issue in Western Macedonia. Its TJTP plans to reduce the overall impact of resource use and increase its efficiency for the benefit of the environment and human health.

5.2 Findings of quantitative data analysis on the impacts of just transition plans

In the following section, we will illustrate how the indicator matrix can be applied to analyse from a quantitative perspective the implementation of just transition principles in different regions. This allows us to have a complete understanding of the background of each region, but also improvement opportunities and additionally provides us with a quantitative backing of possible proposed policies to be implemented as part of TJTPs.

Methodology

The matrix of indicators delineated in Table 8 will be applied to the six pilot regions. The purpose of this matrix is to give a clear representation of the trends of different indicators that play a vital role in ensuring a just transition in the region. Hence, it does not involve sophisticated modelling, but rather trend visualisations performed on Microsoft Excel through .xlsm type of files. Hereby, we decided to utilise only data available on the Eurostat repository. This was done for three reasons. Firstly, to ensure cohesiveness of data between the six different pilot regions. Secondly, to ensure data availability. Thirdly, to ensure replicability of the matrix tool. To conclude, this tool is not meant to improve the quantitative modelling of just transition policies in vulnerable regions, but rather to facilitate the understanding of key issues pertaining to just transitions, also to an audience of non-expert modellers.

We divided the data according to three different territorial units. Namely, national data, NUTS2 level data, and NUTS3 level data. The Nomenclature of Territorial Units for Statistics (NUTS) is a nomenclature of the EC used by Eurostat. The latter divides countries in regions (NUTS2) and regional units (NUTS3). The six pilot regions correspond to six different NUTS regions, both across NUTS2 and NUTS3 levels. These are summarised in Table 10. For every indicator, the highest degree of data fragmentation was aimed for. Nonetheless, NUTS3 level data is consistently less available compared to NUTS2 level or national level data. Hence, when not possible to find NUTS3 level data, we employed NUTS2 or national level data.

Table 10: Corresponding NUTS level units per pilot regions.

Pilot regions	NUTS2 level	NUTS3 level
Stara Zagora (BG)	Southeastern Bulgaria (BG34)	Stara Zagora Province (BG344)
Istria (HR)	Adriatic Croatia (HR03)	County of Istria (HR036)
Western Macedonia (EL)	Western Macedonia (EL53)	
The Silesian Voivodeship (PL)	Silesia (PL22)	

The Jiu Valley (RO)	Macro Region 4 West (Ro42)	Hunedoara County (RO423)
Asturias (ES)	Principality of Asturias (ES12)	

Social dimension

The indicators matrix presents five social indicators. These can give an understanding of the social dimension in the regions being analysed. Nonetheless, none of the five indicators presented NUTS3 level data on the Eurostat repository. In fact, only the percentage of *people living in households with very low work intensity* and the *female unemployment rate* were available at NUTS2 level, whereas the other three indicators only at national level. The comparison of the different regions under the social dimension can be found in Appendix A1. Social dimension.

Bulgaria and Greece presented the highest rates of arrears on utility bills and inability to keep homes adequately warm. In addition, Western Macedonia (EL), presented also the highest percentage of households with very low work intensity and female unemployment; followed in both cases by the Principality of Asturias (ES). Very interestingly, all regions presented the same trends when comparing the two mentioned indicators, hence proving the correlation. On the other hand, Romania presented the highest share of rural households.

Economic dimension

The indicators matrix presents five economic indicators. These can give an understanding of the economic dimension in the regions being analysed. The indicators were available at NUTS2 level, except for the households' electricity and gas prices, as these are distributed nationally. The comparison of the different regions under the economic dimension can be found in Appendix A2. Economic dimension.

As expected, all countries presented higher electricity and gas prices for households following the energy crisis. Nonetheless, Romania saw a visible spike in both prices in 2022. Whereas energy prices are a vast and general indicator that includes various ramifications, these can still provide an initial picture of the economic situation in the region. When considering the other indicators, indeed a correlation was found as expected between the severe material deprivation rate and the percentage of people at risk of poverty or social exclusion, with Southeastern Bulgaria and Western Macedonia being at the top in both cases. Western Macedonia also presented the highest rate of unemployment, followed by the Principality of Asturias. Interestingly, Silesia presented the lowest rates in all three indicators.

Demographic dimension

The indicators matrix presents two demographic indicators. The first indicator, namely the population density, is a useful and simple indicator in understanding how the

demographics have changed. A lower density can be associated with a negative migration rate. In addition to this, we considered a more precise demographic indicator to understand the rate of younger people leaving the region. The latter was obtained by analysing the age distribution of each region and merging it with the net crude rate of migration. Both indicators were available at NUTS2 and NUTS3 level and are thus the two most precise ones considered in this research. The comparison of the different regions under the economic dimension can be found in Appendix A3. Demographic dimension.

As expected, the indicator analysing the number of people leaving the regions provided more accurate results, whereas the population density just confirmed the results. In this case, the results were skewed due to the differing dimensions of the analysed regions (e.g., Silesia is more than 15 times more populated than the Stara Zagora province). Nonetheless, Hunedoara County presented prevalently negative migration rates of the young population with a shrinking population density. On the other hand, Silesia was the only region to present a positive migration rate of young people, coupled with a steady population density; essentially meaning that young people actually migrated to Silesia and not from.

Environmental dimension

The indicators matrix presents three environmental indicators. These are all at national level. The most skewed indicator is the use of RES for heating and cooling as this is given in absolute figures. Nonetheless, it provides a good overview and comparison. The latter, and the other two indicators comparing the different countries in this case, can be found in Appendix A4. Environmental dimension.

As expected, the dependence on fossil fuels decreased for all countries. Bulgaria still presents the highest energy intensity of GDP, which however has greatly decreased. Similarly, the share of energy from renewables increased in all countries. However, Bulgaria presented a steep fall in 2021. Lastly, all countries increased the use of renewables for heating and cooling, particularly Poland, which nonetheless presents the lowest share of energy from renewables.

5.3 Discussion

The developed matrix tool allowed us to assess the estimated impacts on the transitions to climate neutrality and to successfully deliver an initial quantitative analysis of the status quo of different transition impacts in different regions. We found correlations between different indicators, and we tackled and illustrated all the impact dimensions of TJTPs. The analysis illustrates that regions are in different situations with different strengths and challenges. Hence, regions have different opportunities to implement measures to minimise negative transitions impacts.

The extent to which impacts were considered positive or negative in each region (Table 9) was also reflected in the quantitative analysis. More specifically, in terms of the social dimension, just transition is expected to have a positive impact on gender in Stara Zagora, which was confirmed by a negative trend in female unemployment in South-East Bulgaria. On the other hand, Asturias's TJTP outlines several measures to support women in the sector, which can be seen as a measure to counter the stable level of female unemployment in the Spanish region. Impacts that are difficult to quantify, such as identity, social cohesion and inclusiveness, were often neglected in the plans, if they were addressed at all, tending to challenge communities. In terms of energy poverty, negative impacts were found in Silesia, confirmed by the increasing number of households without adequate heating in Poland. On the other hand, the positive effects expected from the TJTP analysis in Stara Zagora were confirmed by a decrease in both the number of households without adequate heating and the number of households with arrears on utility bills. In terms of living conditions, Table 9 had envisaged positive impacts of the TJTP in Western Macedonia, which were confirmed by a decrease in the risk of poverty and social exclusion rate in the region.

In terms of socio-economic impacts, the TJTP had a strong focus on employment. Half of the regions expect an overall positive impact on employment, including the Principality of Asturias, which has the second highest unemployment rate of the cases analysed. For the region of Western Macedonia, which already has the highest unemployment rate, the transition will be more challenging. Specific measures will be needed to attract businesses to the region and create new employment opportunities. Reskilling and upskilling of the workforce will also play an important role, which is expected to have a positive impact on all regions.

Another interesting area is demography, where most of the TJTPs expect a negative impact on migration, population density and the attractiveness of the region. Asturias and the Jiu Valley currently have exclusively negative values for the migration of people under 30 years of age. Interestingly, the TJTPs have many gaps in defining the impact of the demographic transition. Given the negative trends, more attention needs to be paid to how the demographic transition will affect the social and demographic structures of the regions.

Finally, regarding the environment, it was interesting to see that the TJTPs expect positive impacts for all regions. In terms of greenhouse gas emissions, these were indeed reflected in a decreasing energy intensity per GDP in all countries and an increasing share of renewable energy for heating and cooling. Expected health benefits were hardly addressed.

Limitations & Further Research

The Eurostat repository was used as the sole source of data. Whereas the latter provided data for six different regions hence allowing for great breadth of research, it did not provide specific data at regional/local level. In fact, only for two indicators out

of fifteen was NUTS3 level data available. Similarly, only seven indicators were available at NUTS2 level (also including the ones available at NUTS3 level). This shows the great lack of regional data to assess just transitions. This is an important issue, as the lack of data availability hinders the delineation of quantitatively robust policies backed by precise modelling activities and does not allow to scientifically verify proposed policies. Hence, it is vital that regional statistical entities provide the users with more specific regional/local level data, as to perform more accurate data verifications but also spur the modelling of territorial just transition policies.

The present report presents three important points for further research. Firstly, to attain greater preciseness, each region should be analysed by employing only regional data. The lack of regional data from national repositories was greatly documented in Deliverable 2.1 of the JUSTEM project. Nonetheless, the utilisation of regional data should be strived for in future research, utilising data not available in the Eurostat repository. Secondly, the comparison of different regions should be done at a lower geographical level, not considering regions from the whole continent, but perhaps only at national level or European regional level (e.g., Southeastern Europe). This would also allow a more precise comparison, bypassing differences due to geographical or cultural reasons. Finally, the developed quantitative tool could potentially be upgraded to model future developments of each indicator resulting from the implementation of proposed policies. Essentially, the present tool could be upgraded to become a modelling tool to simulate the effect of the implementation of different territorial jut transition policies.

6. CONCLUSIONS

In this report, we show that transitions away from coal have multiple impacts on societies and economies. It is therefore crucial that just transitions support those who are socio-economically negatively affected by the transition to a green economy, while ensuring that the significant benefits are widely shared. The TJTPs of Stara Zagora, Istria, Western Macedonia, Silesia, the Jiu Valley and Asturias present the impacts of the just transition from de-lignification in each region, and further present solutions and measures to mitigate these impacts. Among the social, economic, demographic and environmental impacts, all the territorial plans show a greater emphasis on the impact on employment. In particular, great importance is attached to identifying the impact of unemployment and the measures to tackle it, mainly through the retraining, upgrading and reintegration of workers affected by the transition process with a view to their reintegration into the labour market. A major blind spot is the impact of transition processes on the social and demographic fabric of society, including social cohesion and cultural identity, where negative effects are expected to be high. In addition, TJTPs lack quantification for many impacts, which is also linked to the lack of regional data. However, quantification is crucial to better tailor regional interventions, for example, how many people need to be retrained and thus what training centres are needed in which areas, and what role women can play in filling the employment gaps. We found a high degree of consistency between the qualitative impact analysis and the quantitative indicator analysis. Indeed, the positive and/or negative impacts foreseen in the TJTPs were reflected in the analysis of the corresponding indicators. In conclusion, the multiple impacts approach outlined in this report can help to better define and assess the regional impacts of the transition to climate neutrality and support the development of policies that minimise negative impacts and enable a truly just transition.

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ANNEXES

Annex A: Graphical representations resulting from the application of the indicators matrix for six pilot regions

A1. Social dimension

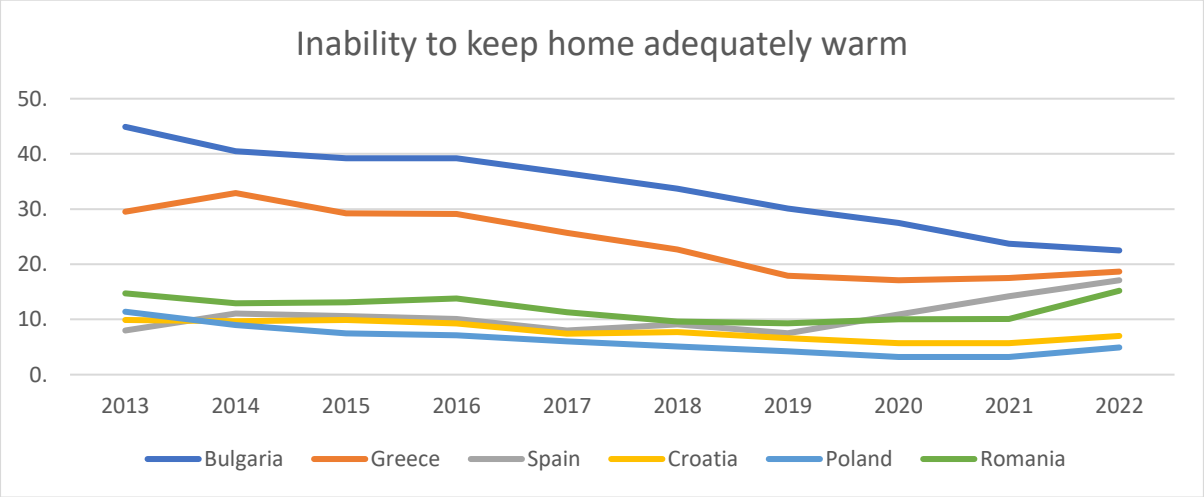

Figure 4: Percentage of population per pilot country unable to keep their home adequately warm (Eurostat).

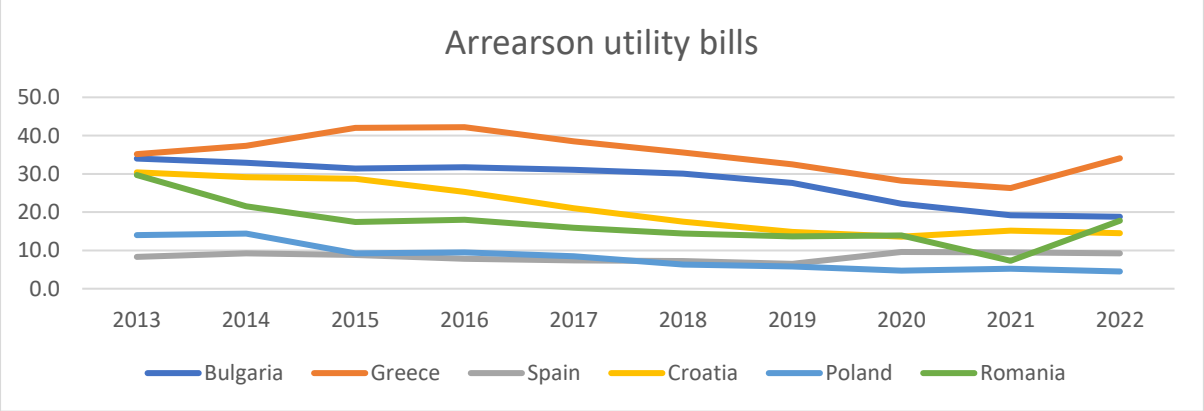

Figure 5: Percentage of population presenting arrears on utility bills per pilot country (Eurostat).

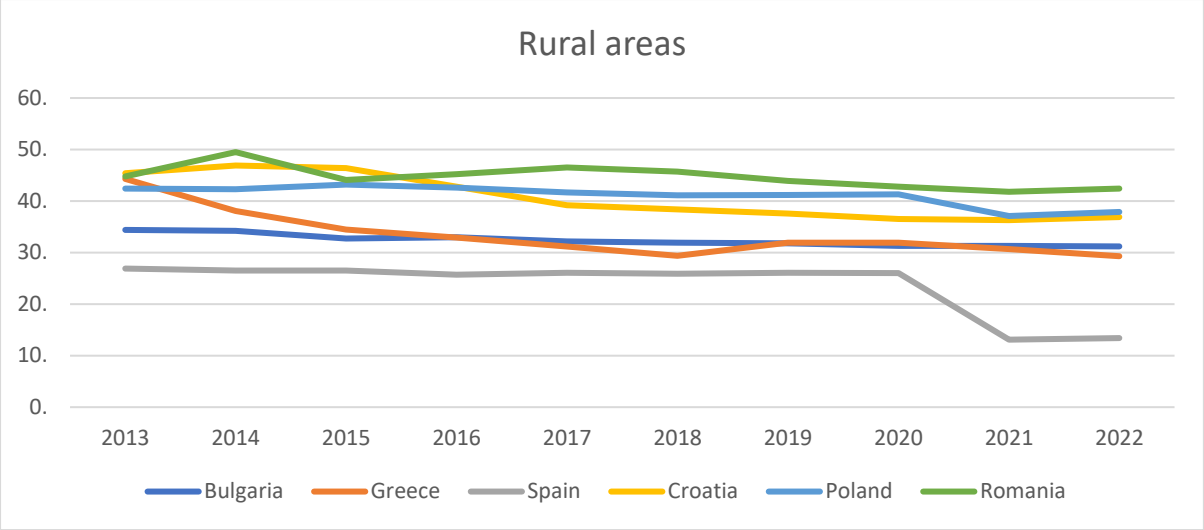

Figure 6: Percentage of population living in rural areas per pilot country (Eurostat).

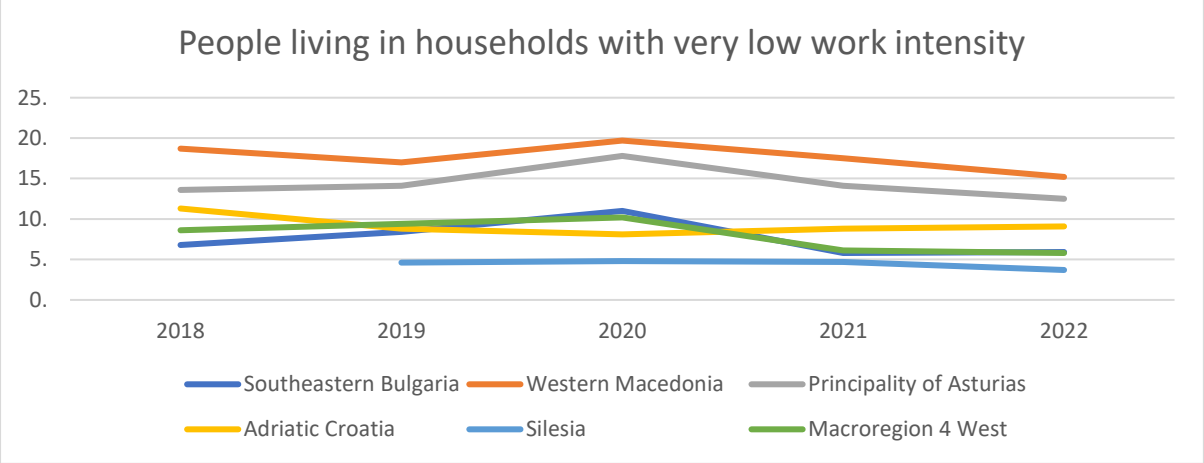

Figure 7: Percentage of population living in households with very low work intensity per pilot NUTS2 region (Eurostat).

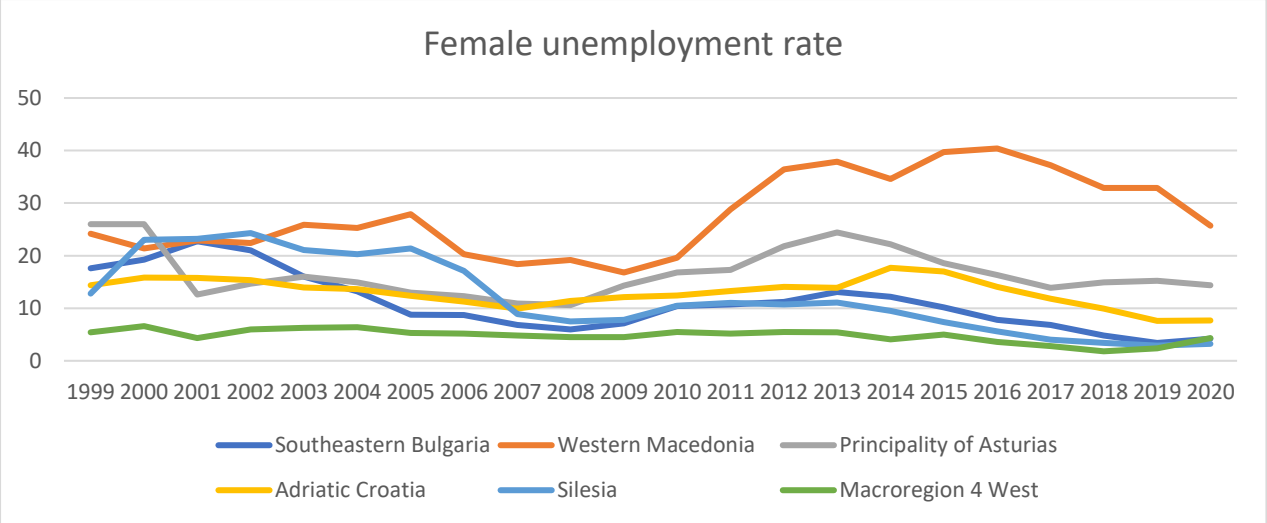

Figure 8: Percentage of unemployed people among the female population per pilot NUTS2 region (Eurostat).

A2. Economic dimension

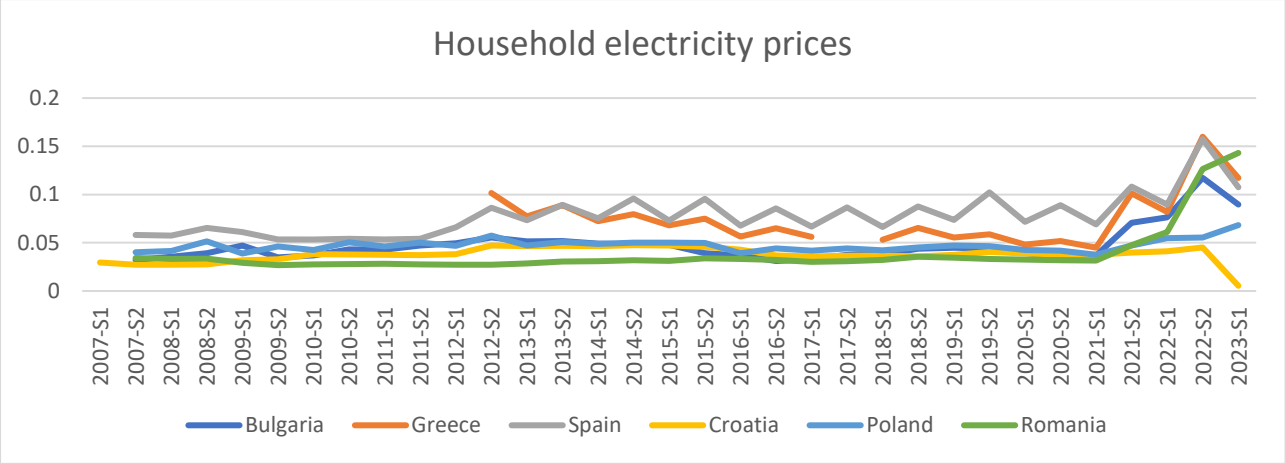

Figure 9: Household electricity prices (including all taxes and levies) per pilot country in EUR/kWh (Eurostat).

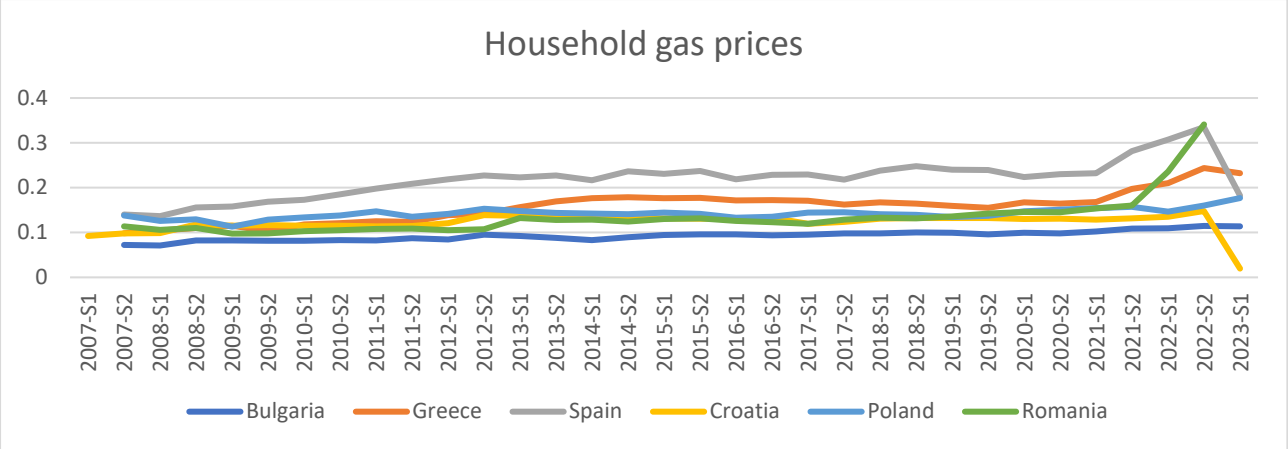

Figure 10: Household gas prices (including all taxes and levies) per pilot country in EUR/kWh (Eurostat).

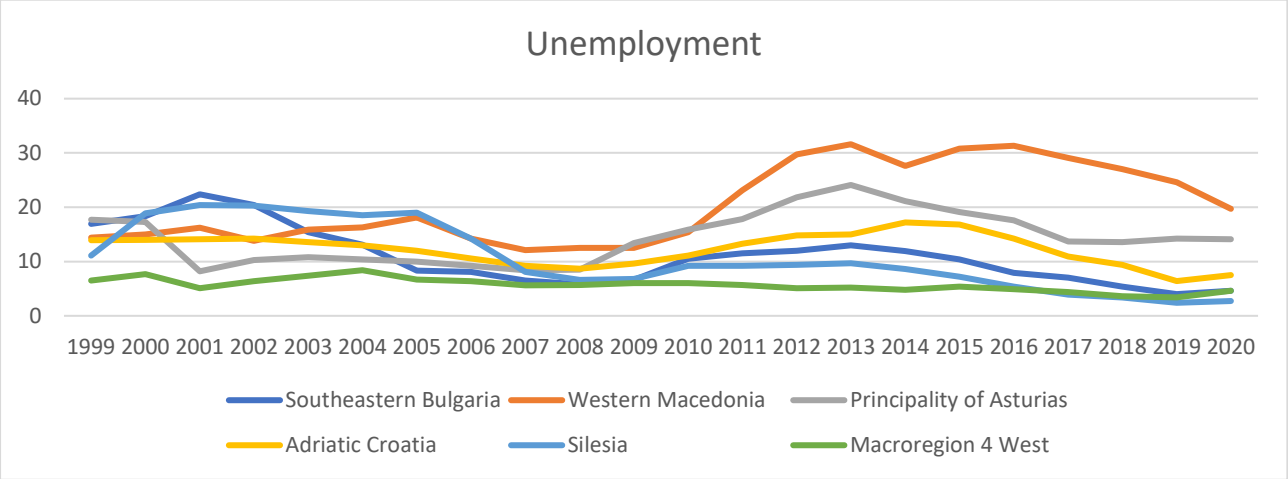

Figure 11: Unemployment rate in percentage per pilot NUTS2 region (Eurostat).

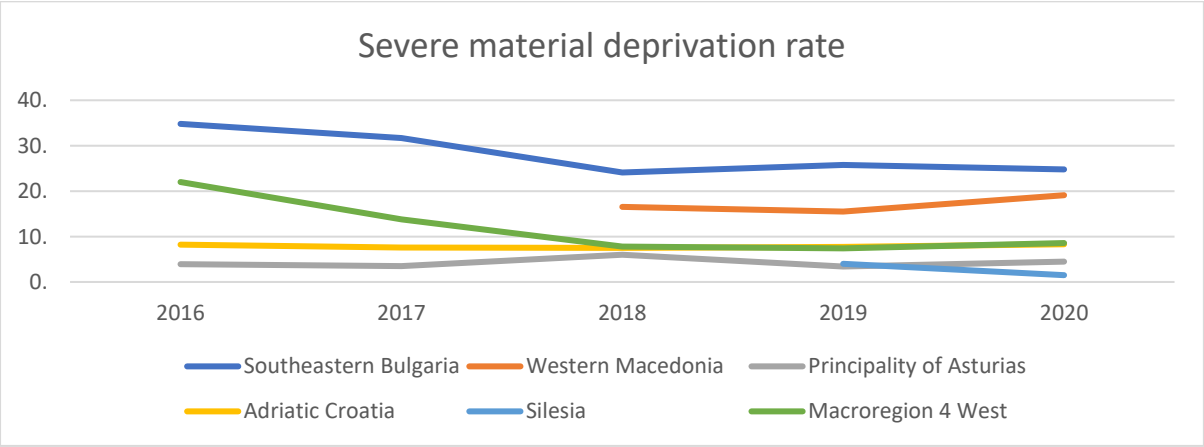

Figure 12: Percentage of the population suffering from severe material deprivation per pilot NUTS2 region (Eurostat).

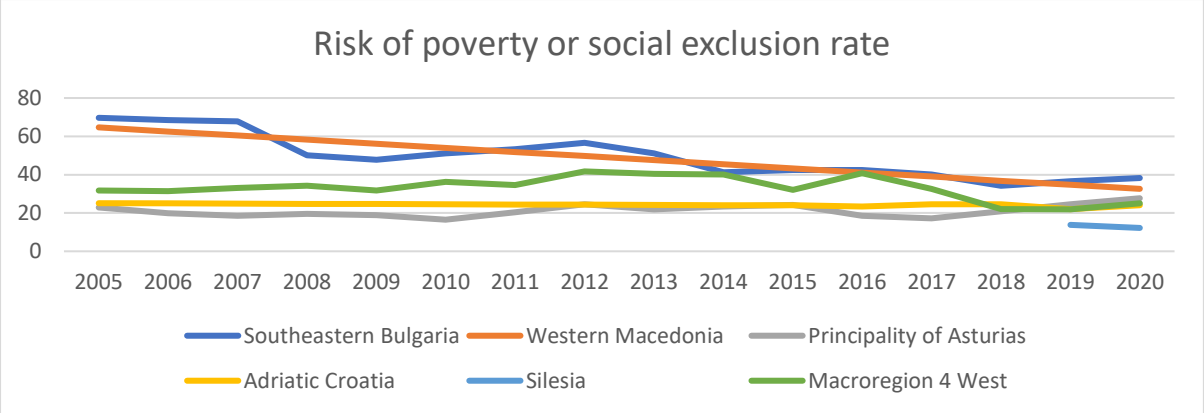

Figure 13: Percentage of population at risk of poverty or social exclusion per pilot NUTS2 region (Eurostat).

A3. Demographic dimension

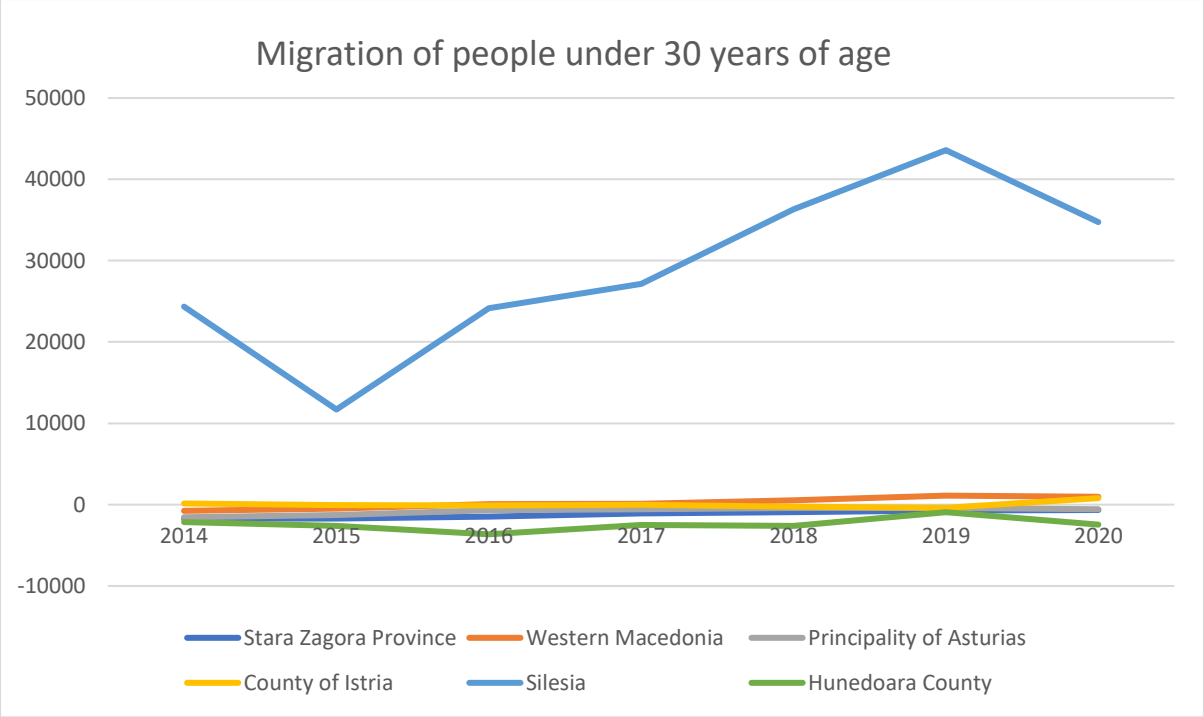

Figure 14: Number of people under 30 years of age migrating to or from pilot NUTS3 regions (Eurostat).Positive values indicate an immigration, negative values an emigration.

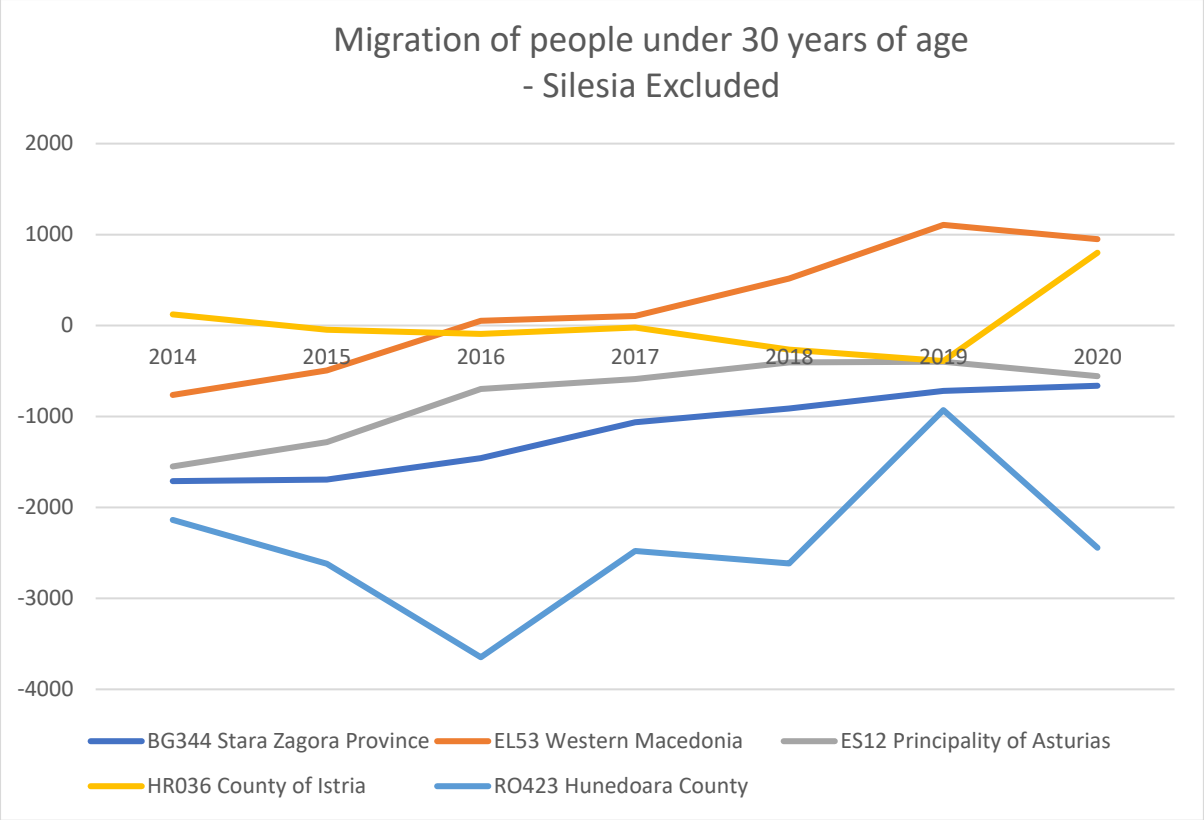

Figure 15: Number of people under 30 years of age that migrated to or from per pilot NUTS3 region (Eurostat). Positive values indicate an immigration, negative values an emigration.

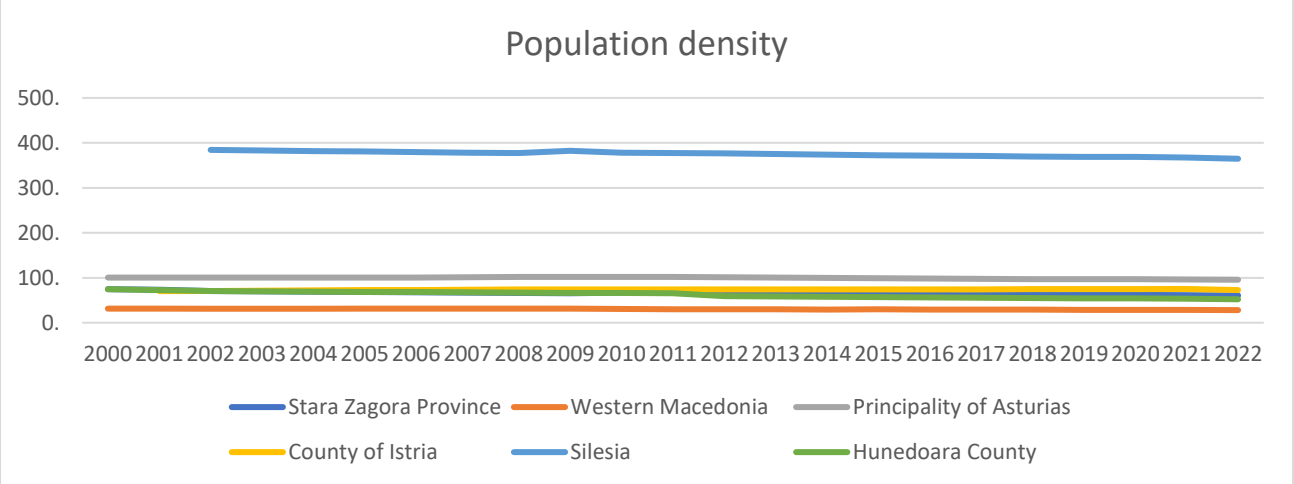

Figure 16: Population density (people per square Km) per pilot NUTS3 region (Eurostat).

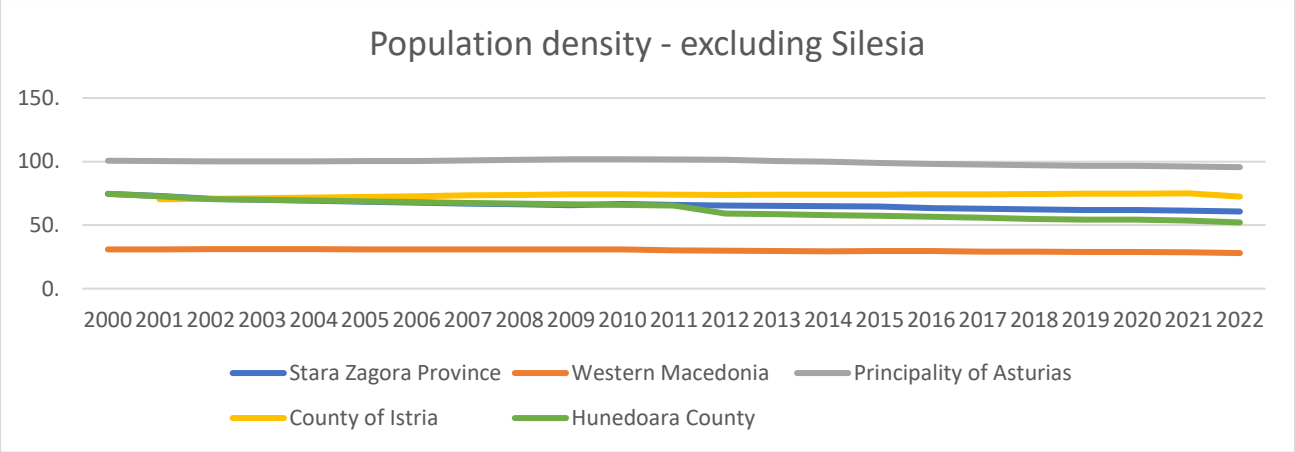

Figure 17: Population density (people per square Km) per pilot NUTS3 region (Eurostat).

A4. Environmental dimension

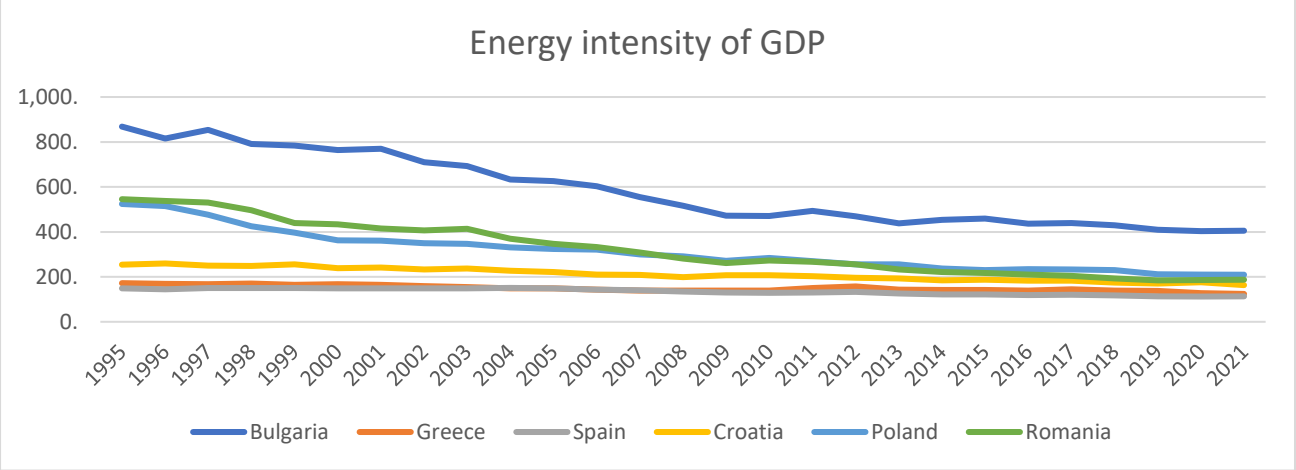

Figure 18: Energy intensity of GDP per pilot country (Kg of oil equivalent per 1,000 Euro) (Eurostat).

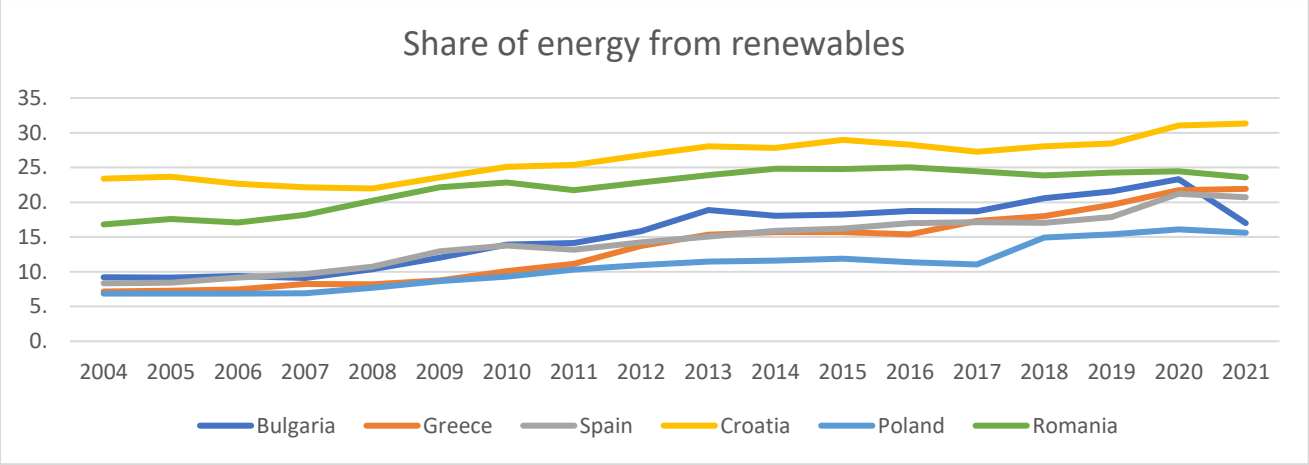

Figure 19: Share of energy from renewables in percentage per pilot country (Eurostat).

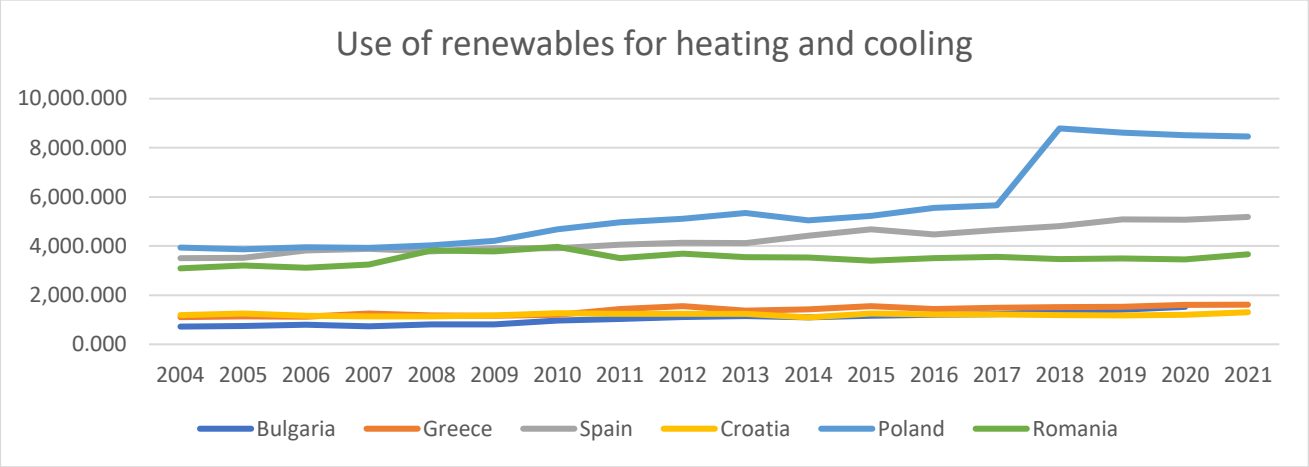

Figure 20: Use of renewables per pilot country (thousand kg of oil equivalent) (Eurostat).