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Regional SWOT analyses as feasibility studies to be used as evidence base in decision-making for Action plan development

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Abstract

This deliverable provides the TRANSFORMER Super-Labs operating in four European regions (Emilia-Romagna (Italy), Lower Silesia (Poland), the Ruhr Area (Germany), and Western Macedonia (Greece)) with a solid evidence-base for decision-making regarding their needs and potentials for accelerating their transformation towards climate neutrality. It supports the TSL process in identifying the regional challenge and possible topics for transition and developing a vision for transformation, as well as developing and implementing feasible Pilot use cases. Moreover, the case studies also support the development of strategies for a long-term implementation of the TSLs.

Project Partners

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Authors' and contributors' inputs to Deliverable 2.3

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Judith Wiemann (RUB)	Co-authorship in Chapters 1 and 2, and Chapter 3.6; support in methodological development and conceptualization of case study design; reviewing and editing of document.
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Camilo Santa Cruz Camacho	Incorporating data in RStudio. Developing GHG emission maps

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Acronym	Meaning
CH_4	Methane
CI	Composite Indices
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_{2eq}	Carbon dioxide equivalents
DM	Deutsche Mark (German Mark; former currency of the Federal Republic of Germany)
ECSC	European Coal and Steel Community
EDGAR	Emissions Database for Global Atmospheric Research
EEA	European Environment Agency
EQI	European Quality of Government Index
EU	European Union
EUR	Euro (currency, €)
EUROSTAT	Statistical office of the European Union
F-gases	Fluorinated gases
GDP	Gross Domestic Product
GHG	Greenhouse gas (emissions)
GVA	Gross Value Added
GWP	Global Warming Potential
IBA	International Bauausstellung (International Building Exhibition)
ISIC	International standard industrial classification of all economic activities
Mt	Million ton
NACE	Nomenclature of Economic Activities (statistical classification of economic activities in the EU)
N_2O	Nitrous oxide
NOx	Nitrogen oxide
NUTS	Nomenclature of Territorial Units for Statistics (hierarchical system for identification and classification of spatial reference units in the EU)
OECD	Organisation for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
PLN	Polish zloty (official currency of Poland, zł)
PM	Particulate matter (PM2.5 referring to particles with a diameter of 2.5 micrometers or smaller, and PM10 referring to particles with a diameter of 10 micrometers or smaller)
PPS	Purchasing power standard (EUROSTAT)
PPT	Purchasing power parities
PV	Photovoltaics
QRAFT	Quantitative Regional Assessment Framework for Transition Super-Labs
RCI	EU Regional Competitiveness Index
RE	Renewable energy / energies
RER	Regione Emilia-Romagna
RES	Renewable energy sources
RIS	Regional Innovation Scoreboard
SPI	European Social Progress Index
SUMP	Sustainable Urban Mobility Plans
TSL	Transition Super-Lab
WP	Working package

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Executive Summary

This deliverable provides the TRANSFORMER Super-Labs operating in four European regions (Emilia-Romagna (Italy), Lower Silesia (Poland), the Ruhr Area (Germany), and Western Macedonia (Greece)) with a solid evidence base for decision-making regarding their needs and potentials for accelerating their transformation towards climate neutrality. It supports the TSL process in identifying regional challenges and possible topics for transition, developing a vision for transformation, as well as developing and implementing feasible Pilot use cases. Moreover, the case studies also support the development of strategies for the long-term implementation of the TSLs. Therefore, the target audience comprises all stakeholders in the respective TSL regions, particularly those with limited insights into the transition requirements of their region. The case studies are also designed to empower knowledgeable stakeholders to reflect on existing narratives about their region. A third possible target readership includes other regions interested in initiating a TSL process to understand how to conduct a case study for their region and how the transition narrative can connect to a TSL's activities.

Regarding the developments in the TRANSFORMER project, this deliverable provides an understanding of the TSL activities and action plans in context of the larger transition needs that the regions are currently facing. First, it provides an extensive discussion of the results of the QRAFT analysis (Quantitative Regional Assessment Framework for Transition Super-Labs) for each of the TRANSFORMER regions. Second, it undertakes a complementary document analysis (qualitative). And third, it analyzes expert interviews and workshops on stakeholder analysis and the assessment of co-created concrete project ideas (Pilot use cases) to achieve climate neutrality. The deliverable is designed as complementary to the Deliverables 3.1, 3.2, and 3.3 and functions as the scientific "backbone" for the justification of the action plans.

After a concise introduction in Chapter 1 depicting the relevance of the case studies developed here and introducing the structure of the document, Chapter 2 conceptually frames transition needs and potentials for achieving climate neutrality at a regional scale from a TSL perspective. Based on this, the research design of the case study for analysing the regional transition needs and potentials is presented, and the methodologies and data collection are discussed. In Chapter 3, the deliverable highlights the diverse challenges and opportunities for each region on their way to achieving climate neutrality: Emilia-Romagna is a wealthy region with high innovation capacity and a strong industrial sector, but its energy-intensive industries and transport sector significantly contribute to climate change and poor air quality. To address these issues, the TSL is fostering bicycle infrastructure and developing sustainable electric mobility solutions. In contrast, Western Macedonia's economy was completely dependent on lignite mining and energy generation and is now facing a fundamental socio-economic transformation with the phase-out of lignite mining by 2028. To mitigate the potential negative effects and simultaneously become climate neutral, the TSL is focusing on economic diversification and the development of innovative solutions in the energy and transport sectors, as well as circular economy approaches in agriculture. In Lower Silesia, lignite mining, energy generation, energy-intensive industries, and unsustainable transport and mobility sectors affect air quality and contribute to climate change; to mitigate these effects, the TSL is developing sustainable and convenient mobility solutions and incorporating citizens' opinions in energy-related decision-making processes. The Ruhr Area faces a challenging transition due to its high energy demand

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and limited local renewable energy production; hydrogen is considered a critical cornerstone for the region's path to climate neutrality, though it carries substantial risks, particularly concerning the future availability of green hydrogen.

Based on the transition needs and potentials, as well as the experiences of implementing the TSL in the four TRANSFORMER regions, five criteria for feasible TSL governance arrangements are discussed: (1) political legitimacy of the TSL process, (2) reflexive monitoring capacity, (3) lean organization and low financial requirements, (4) continuous and unbureaucratic access to financial means for transition projects in the region, and (5) diverse, cross-sectorial expertise. Based on these criteria, a long-term strategy for the implementation of TSLs is developed in Deliverable 3.3, focusing on the organizational structure, including the supporting stakeholder coalition, the TSL coordination team, and the reflexive monitoring board, as well as transition project/Pilot use case governance. Overall, the results of the case studies conducted in this deliverable support the development of a vision and a coalition of supporting stakeholders, as well as the identification and implementation of Pilot use cases and action plans of the TRANSFORMER project.

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1 Introduction

Accelerating the shift to climate neutrality is essential to mitigate the escalating threats posed by climate change. Urgent and comprehensive actions are imperative to prevent catastrophic consequences, such as rising sea levels, extreme weather events, and disruptions to global ecosystems, which would impact the livelihoods and well-being of communities worldwide (IPCC, 2021). Considering the intricate social, economic, and environmental connections among potential pathways to achieve climate neutrality, this transformation presents a highly complex challenge that demands innovative and comprehensive solutions (UN, 2022).

The TRANSFORMER project addresses this challenge by focusing on systemic transformation at a regional scale to accelerate the transition towards climate neutrality: the **Transition Super-Lab approach (TSL)**.[1] In a TSL, living lab methodologies are adapted and applied to develop (co-create) with all relevant stakeholders from the quadruple helix a vision for a regional transformation and a portfolio of large-scale systemic solutions for climate neutrality, net-zero emissions and a more resilient future. The systemic transformation within TSLs catalyses large and diverse communities to innovate for systemic changes that accelerate the transition. The systemic transformation is addressed by developing and implementing a portfolio of connected solutions (e.g., Pilot use cases) which engage multiple leverage points at the intersection of socio-technical regimes simultaneously to achieve a rapid and more efficient transformation.[2] This approach is developed and tested in the TRANSFORMER project over the course of two years (9-2022/8-2024) in four European regions: Emilia-Romagna (Italy), Lower Silesia (Poland), Ruhr Area (Germany), and Western Macedonia (Greece).

The goal of this Deliverable 2.3 is **to provide these four TRANSFORMER Super-Labs with a solid evidence base for decision-making regarding their needs and potentials for transformation**. It aims specifically at supporting the first steps in the TSL process of identifying the regional challenge and possible topics for transition and developing a vision for transformation, as well as identifying, developing and implementing feasible Pilot use cases (see Deliverables 3.1, 3.2, and 3.3[3]). Moreover, the case studies also aim at **supporting the identification of additional solutions** (Pilot use cases) to foster a transition of multiple socio-technical regimes simultaneously **and thus facilitating the development of strategies for a long-term implementation of the TSLs** (Deliverable 3.3). Therefore, the target audience comprises all stakeholders in the TSL regions, particularly those with limited insights into the transition requirements of their region. However, the case studies are also designed to empower knowledgeable stakeholders to reflect on existing narratives about their region. A third possible target readership are other regions

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[1] The definition and description of the TSL approach in this chapter was discussed and written jointly by the members of the TRANSFORMER Project Consortium. This definition is also included in Deliverable 2.2.

[2] For example, developing green hydrogen-solutions for simultaneously transforming the mobility and the industrial sector. For a more detailed explanation of leverage points ("levers of change") and the portfolio approach see: Deliverable 2.1.

[3] Deliverable 3.1: Recommendations for Transition Super-Lab coalitions building, empowering of vulnerable and marginalised groups, and vision process (URL not available yet); Deliverable 3.2: Definition of Transition Super-Lab use cases (URL not available yet); Deliverable 3.3: Transition Super-Lab Action Plan (URL not available yet).

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interested in initiating a TSL process to understanding how to conduct a case study for their region, as well as how the transition narrative can connect to a TSL's activities.

To achieve these objectives and to establish a framework for conducting a comprehensive analysis, the initial step involves **defining the transition needs and potentials of regions to mitigate GHG emissions *from a TSL perspective***. This perspective is crucial as it serves as a fundamental criterion. Without it, assessing the transition needs and potentials of regions becomes an expansive task fraught with potential pitfalls, such as grappling with high levels of abstraction that fail to capture the complexity of regional realities, as well as subjectivity in the selection of data and indexes (Mura et al., 2021). Consequently, the first question to address is:

- What are the transition needs and potentials of a region within the context of the TSL approach, and what methods can be employed to assess them?

Based upon the definition of transition needs and potentials and the developed mixed-method framework, the following key questions will be analysed:

- What are the specific *transition needs and potentials* of the four TRANSFORMER TSL regions?
- What are the *most important topics/sectors* for the regions to become climate neutral?
- What are feasible solutions (Pilot use cases) for supporting the transition (Deliverable 3.2)?
- What additional topics and Pilot use cases have the potential to facilitate the transition of multiple socio-technical regimes simultaneously and support the long-term implementation of the TSL (Deliverable 3.3)?

To meet these objectives, this deliverable is structured as follows: The subsequent Chapter 2 will develop the methodological framework for assessing the transition needs and potentials for the transformation of regions within the TSL approach, while also identifying necessary data and discussing the limitations of this deliverable. In Chapter 3, the developed framework is applied to analyse the four TSL regions in the following order: Emilia-Romagna, Lower Silesia, Ruhr Area, and Western Macedonia. Finally, Chapter 4 concludes with a reflection and assessment of the chosen methodological approach, along with an outlook on further research needs.

The context of this deliverable within the TRANSFORMER project

This deliverable is written in a way that it can be read as a stand-alone document. However, it is part of a series of deliverables as part of the TRANSFORMER project. It is part of Working package 2 on "Mapping, defining, and categorising of Transition Super-Labs". The aim of this overall Working package is to generate relevant scientific knowledge for the TSLs and for a wider readership, especially the scientific community, policymakers and transition practitioners. Within the TRANSFORMER project, as the title of this deliverable clearly states, this document especially aims at delivering an evidence base for decision-making as part of the action plans. These action plans (Deliverable 3.3), one for each of the four TRANSFORMER regions, are a key result of the project. They aim to construct a solid strategy of how to continue the activities started in TRANSFORMER (pilot project of only 2 years duration) within each of the regions beyond the project duration. This deliverable will provide an understanding of the TSL activities

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and action plans in the context of the larger transition needs the regions are currently facing. Thus, it is to be understood as complementary to the Deliverables 3.1, 3.2 and 3.3. In short, this deliverable functions as the **scientific "backbone"** for the justification of the action plans.

The four case studies provided in Chapter 3 rely on a methodology for assessing regional transition needs and potentials from a quantitative perspective, the Quantitative Regional Assessment Framework for Transition Super-Labs (QRAFT). This methodology, along with a brief exemplary discussion of the quantitative indicators for the regions, was developed in Deliverable 2.2. As Figure 1 indicates, the deliverable at hand goes beyond this in three ways: First, it provides an extensive discussion of the results of the QRAFT analysis for each of the TRANSFORMER regions. Second, it undertakes a complementary document analysis (qualitative). And third, it analyses expert interviews and workshops on stakeholder analysis and the assessment of co-created concrete project ideas (Pilot use cases) to achieve climate neutrality.[4]

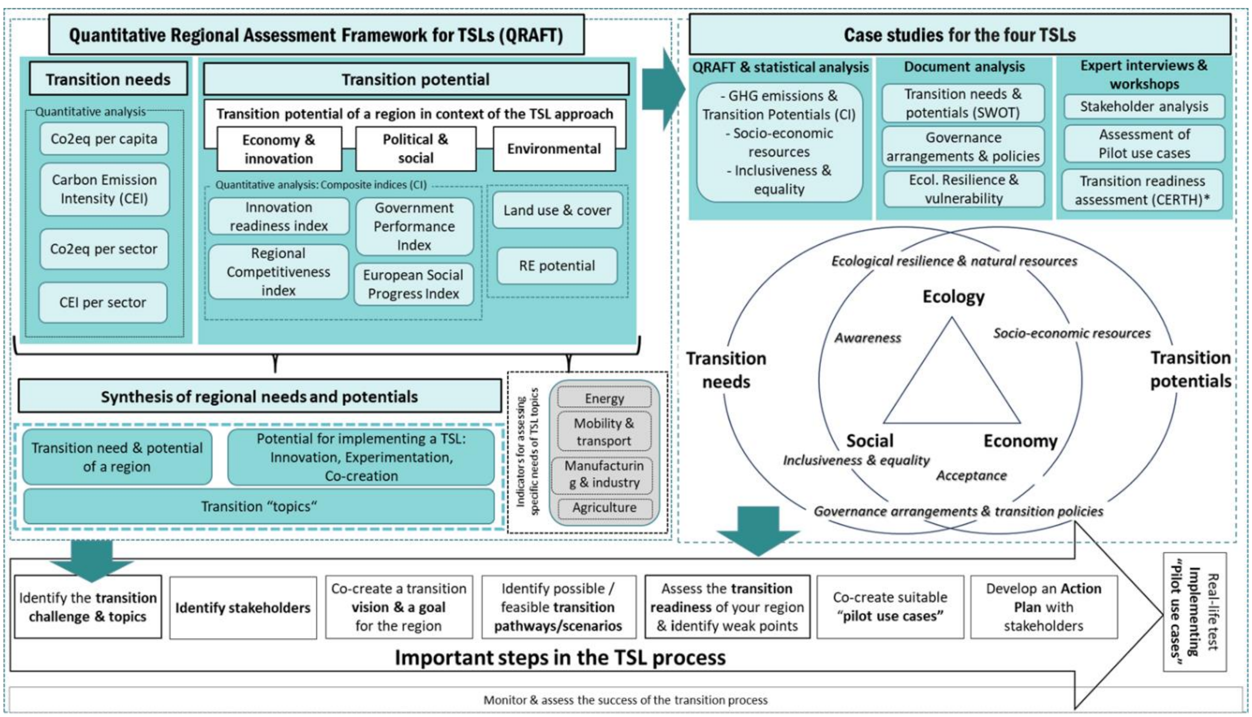

Figure 1: Applied methodologies for the case studies. Source: own design.

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[4] The definition of the term "Pilot use case" was developed during the first six month of the project and is included in Deliverable 3.2. Pilot use cases are defined as "co-created concrete project ideas to achieve climate neutrality, promote systemic transformation through innovation and be developed and implemented with a focus on a regional transformation. Furthermore, Pilot use cases have the following characteristics:
- They define a goal-oriented set of interactions between different actors;
- They help identify all relevant issues and resources for the development of Transition Super Labs;
- They evaluate the feasibility of these project ideas;
- They are real-life experiments, which serve for the concept development and its implementation in practice" (quoted from Deliverable 3.2, p.9; URL not available yet).

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Concerning the placement of this deliverable within a TSL process, conducting case studies in the depth with which they are presented here is recommended as part of the assessment of the transition readiness of a region and identification of weak points.

2 Assessing regional transition needs and potentials for the reduction of GHG emissions from a TSL perspective

Defining the transition needs towards achieving climate neutrality on a regional scale and assessing the potential for the reduction of GHG emissions from a TSL perspective require different conceptual considerations. In this context, it is important to understand what thinking about accelerating decarbonisation *from a TSL perspective* means. Therefore, Chapter 2.1 starts with exploring different conceptual considerations for the case studies. Based on this, the case study design for analysing the regional transition needs and potentials for achieving climate neutrality is developed in Chapter 2.2. Chapter 2.3 complements this effort by discussing methodologies and data collection specifically.

2.1 Conceptual considerations

Taking up a transition perspective

As large-scale societal transformations, transitions are highly complex processes that typically span over several decades and show an intricate multi-territorial embeddedness (Coenen & Truffer, 2012; Köhler et al., 2019). Consequently, any attempt to accelerate such a process towards a specific goal, in this case a significant contribution towards climate neutrality, requires engaging with “major unknowns” and even “unknowables”. Engaging with uncertainties and complexities necessitates continual critical monitoring of both. executed and planned actions from a transition perspective; this ensures that endeavours align with the overall goal of achieving sustainability (van Mierlo, 2010). In the four case studies about the TRANSFORMER regions, we take up such a transition perspective. We do this in three interdependent steps or movements. Firstly, we conduct a bird’s eye view analysis of the regions’ transition needs and potentials through applying the previously developed QRAFT methodology to each region and critically discussing the results. Secondly, we zoom in to examine the activities determined by the four TSLs in the context of vision development and the selection of Pilot use cases within the transition assessment context. And thirdly, we partially zoom out again to reflect on what additional action can complement and support the Pilot use cases to unfold the potential for reaching regional climate neutrality.

Regarding the first step, when considering a region’s needs and potentials for becoming climate neutral, it is necessary to also keep in mind the larger sustainability and future stability of the region. Sustainability is typically characterized as having three dimensions: the ecological, social, and economic dimension (Purvis et al., 2019). As Figure 2 depicts, regional transition needs and potentials are highly related to each other, and both are unfolding into the three sustainability dimensions.

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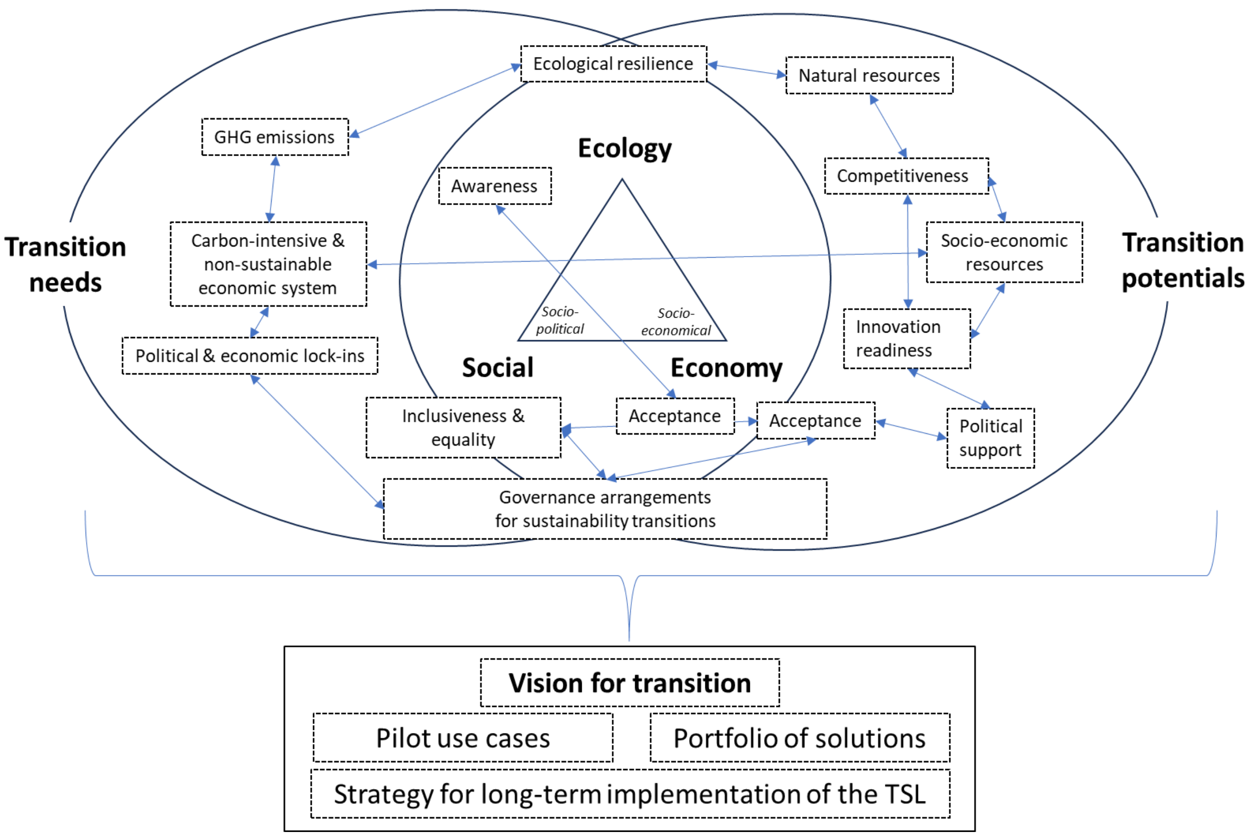

Figure 2: Regional transition needs and potentials according to sustainability dimensions. Source: own design.

Assessing regional transition needs and potentials is an exceedingly complex and laborious task. Therefore, it is necessary to start the analysis with a focalizing goal in mind. In this analysis, as stated above, the goal is to give perspective to the TSL's vision and Pilot use cases in light of the transition challenge the region is currently facing. To do this, it is important to understand what is meant by the TSL approach (discussed in the following section "The TSL approach") and toget a deeper understanding of the role of regions and the possibilities of the regional scale in the context of sustainability transition (discussed in the section "Understanding the role of the region in the context of sustainability transition").

The TSL approach

The TSL approach is a still evolving concept. In the previous Deliverable 2.1, as part of the TRANSFORMER project, we developed a working definition for TSLs, which was discussed and refined in several workshops with the whole Project Consortium.[5]

A TSL can be described as a large-scale living lab for systemic transformation: in a TSL **living lab methodologies** are adapted and applied to develop together (co-create) – with all relevant stakeholders from the quadruple helix – a vision for a regional transformation and a **portfolio of large-scale systemic**

[5] The definition and description of the TSL approach in this chapter was discussed and written jointly by the members of the TRANSFORMER Project Consortium. It is also included in Deliverable 2.2.

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solutions for climate neutrality, net-zero emissions and a resilient future. The **systemic transformation** within TSLs mobilises large and diverse communities to innovate for systemic changes that accelerate transition at scale.

The **systemic transformation** will be achieved by developing and implementing a portfolio of connected solutions ("e.g., Pilot use cases") which engage **multiple leverage points** at the **intersection of socio-technical regimes** simultaneously in order to achieve a rapid and more efficient transformation.[6] Therefore, the adaptation of living lab methodologies to a large scale and with a focus on systemic transformation can be regarded as the core characteristics of a TSL (see Figure 3):

1. Adaptation and application of enriched living lab methodologies (co-creation, experimentation and evaluation)
2. Aiming at large-scale systemic solutions for a rapid transition to sustainability
3. Applying a portfolio approach of measures (experiments) and using multiple leverage points for systemic change simultaneously

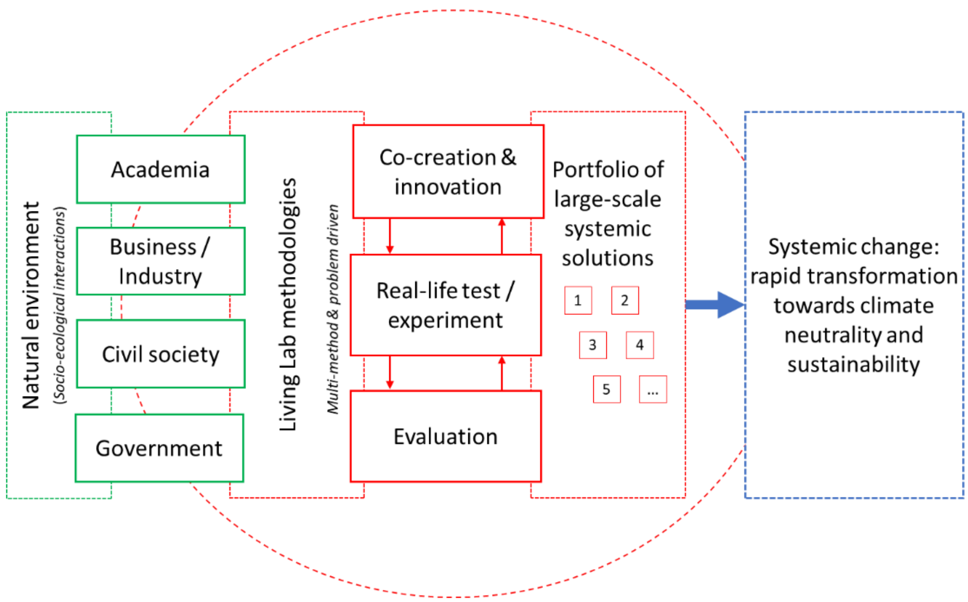

Figure 3: Elements of a Transition Super Lab. Source: own design adapted from Deliverable 2.1 (URL not available yet).

Understanding the role of the region in the context of sustainability transition

In order to develop the case study design, we first have to gain an understanding of what *regions* are in context of a TSL approach and, based on that, discuss how to assess the transition needs and potentials of regions.

[6] For example, developing green hydrogen-solutions for simultaneously transforming the mobility and the industrial sector. For a more detailed explanation of leverage points („levers of change") and the portfolio approach see Deliverable 2.1 (URL not available yet).

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In TRANSFORMER, we regard (sub-national) regions as a highly promising scale to foster a systemic change, as they function as "burning glasses" where different sections of socio-technical regimes (e.g., transportation, industry, food system) materialize and intersect (Lawhon & Murphy, 2012).[7] In TRANSFORMER we explore the possibilities to address the regional scale for creating change at the intersection of multiple societal systems simultaneously. However, in this regard the regional scale is still under-researched, and no unified approach to assess the climate change-related transition needs and transformation potentials of regions exist so far (Hansmeier et al., 2021; Mura et al., 2021; Stanickova & Melecký, 2018).

The significance of the spatial dimension in sustainability transitions is widely acknowledged by both researchers and practitioners (Coenen & Truffer, 2012; Hansen & Coenen, 2015; Maucorps et al., 2023; Morais Mourato & Wit, 2021; OECD, 2023; Uyarra et al., 2017; Wolfram & Frantzeskaki, 2016). In this context, the regional scale is gaining increased attention, as it represents a geographical space that serves not only as a "link" between the national level – where overarching policies, regulations, and frameworks are implemented – and the local level – where specific sustainability-related projects, such as wind power plants, are permitted and implemented. In this perspective, regions are regarded as geographical spaces wherein various socio-technical regimes are situated, and holistic solutions can be developed to harvest synergy effects (Löhr and Chlebna, 2023; Wachsmuth et al., 2023): regions are "*large" enough* to develop a portfolio of cross-sectorial solutions to achieve a fundamental systemic transition and, at the same time, "*small" enough* to establish (economic and political) participation processes that consider the cultural and social context of a transition. Moreover, regions are still *"close" enough* to the citizens and other stakeholders, which helps them to identify with the transition process and creates tangibility to the developed and implemented solutions. These aspects—identification with and awareness of the need for a transition, as well as establishing processes for participation—are widely regarded as prerequisites for creating support and acceptance for the necessary fundamental structural change (Chodkowska-Miszczuk et al., 2022; Flanigan et al., 2021; Gölz & Wedderhoff, 2018, 2018; Leiren et al., 2020; Lutz et al., 2017; Macht et al., 2023; Wirth et al., 2018; Zoellner et al., 2008)

Based on the extensive literature on transition research (ibid.) and our insights from the TRANSFORMER project in four TSL regions, we find strong evidence that the regional scale has comparatively very high potential for developing a portfolio of cross-sectorial solutions for systemic transition, which are still manageable and feasible. This manageability applies to various aspects including stakeholder management, resource allocation, and knowledge exchange. The national scale in comparison, due to its size, would lose the aspect of a manageable portfolio, while more local scales do not have the breadth and variety of sectors for a truly cross-sectorial approach.

In this context, it is important to highlight that we regard regions in a holistic way from both a "functional" and a "political-administrative perspective": functional regions are delimited by natural, economic, social, or cultural functional-spatial relationships, such as commuting zones, trade areas, or distinguishable

[7] As our understanding of the regional scale in a TSL concept evolves throughout the duration of the project, some of the elements of this discussion are already included in Deliverables 2.1 and 2.2, and we partially quote ourselves verbatim.

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labour markets where interactions are the defining factor, and borders can be fluid (Cörvers et al., 2009; Hansmeier et al., 2022; Koschatzky et al., 2022). Political-administrative regions, on the other hand, are delineated by governmental or administrative boundaries, with precise and often legally established borders. States, counties, and cities fall under this category, emphasizing governance, jurisdiction, and administrative control (including the regional NUTS classification of the EU; see Table 26). While functional regions highlight interactions and interdependence, political-administrative regions prioritize governance structures. The former is dynamic and purpose-driven, accommodating changes based on functions, while the latter is more static, emphasizing political and administrative control within defined borders (ibid.). In TRANSFORMER, we aim to combine both perspectives that can support the creation of functional cross-sectorial governance mechanisms in interaction with existing political-administrative structures and processes (such as steering boards or even formal authorities).[8] Assessing transition needs and potentials within the context of a TSL, therefore, requires a particular focus on socio-economic structures in the context of existing governance arrangements. This is a key guidance for the focus of the case study design.

Moreover, for the four case studies presented in this deliverable, it is important to keep in mind the vast differences between regions in general, which also applies to the four TRANSFORMER regions. These differences also necessitate adjustments and individualizations with regard to the methodologies applied in each of the case studies.

2.2 Case study design

Building on our understanding of regions as functional and political-administrative spaces, and through an evaluation of existing frameworks supporting the assessment and development of decarbonisation strategies (Bos et al., 2022; Hawila et al., 2014; Ivanova et al., 2017; Ogwumike et al., 2024; Rodríguez-Pose & Bartalucci, 2023; Velten et al., 2021), our focus will be on exploring various dimensions for assessing the transition needs and potentials of a region towards achieving climate neutrality (see Table 5 and Table 6 for an overview and an explanation of the used indicators and composite indices in the QRAFT and Table 7 for an overview of the environmental and socio-economic indicators).

In the first step, it is important to understand the needs for the necessary comprehensive systemic change of a region to become climate neutral. Therefore, it is crucial to emphasize the **vulnerability of a region to climate change**, thus highlighting the costs of the "business-as-usual scenario" (Schremmer et al., 2018). This provides the context for the analysis regarding the regional needs and potentials for the transition.

Regarding the main goal of becoming climate neutral, the reduction of GHG is by definition one of the main transition needs. Therefore, based upon the enhanced "Quantitative Regional Assessment Framework" (**QRAFT**[9]), in a second step the **carbon intensity of the economy and society** is assessed, and

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[8] Spatial planning (incl. regional planning as well as the NUTS classification of the EU regional policy) and political responsibilities are closely tied to the administrative organization of individual countries (Gouardères (2023); Koschatzky et al. (2022). Therefore, a functional perspective on regions must always be integrated into political-administrative structures and processes.

[9] See Deliverable 2.2; for some topics, such as GHG emission, the NUTS 3 level was included to allow intra-regional analysis.

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the **most important sectors** that needs to be transformed are identified (see Table 1 for a brief description of the QRAFT and Table 5 for an explanation about the key indicators). Focussing on GHGeq, GDP and GVA, the two following questions will be answered:

- What are the current state and trends of the region regarding the carbon intensity of the economy and society?
- What are the most important economic sectors and transition topics in the region?

However, aspects of ecological as well as socio-economic resilience and vulnerability also present important transition needs, which simultaneously affect the transition potential, either directly or indirectly. Therefore, in the next step, **ecological and socio-economic resources** will be analyzed from a quantitative perspective (QRAFT) using existing composite indices, while also highlighting key statistical indicators. This step will address the following questions:

- How does the region score regarding its economic competitiveness and innovation capacity?
- What are the socio-economic resources of the region for the transition?
- What are the ecological resources, especially regarding the development of renewable energy?

Table 1: Description of the "Quantitative Regional Assessment Framework for Transition Super-Labs (QRAFT)". Source: own compilation (based on Deliverable 2.2).[10]

The "Quantitative Regional Assessment Framework for Transition Super-Labs (QRAFT)" is a methodology to measure transition needs and potentials on the NUTS 2 Level based on existing and **publicly accessible statistical data** for the territory of the European Union. The accessibility of the data sets used ensures that the methodology can be easily replicated and used. QRAFT is designed as **a tool for gaining a data-driven understanding of the importance of different possible TSL vision topics** within a region for stakeholders with limited knowledge about their region. It also enables knowledgeable stakeholders to question existing narratives about their region if necessary. The insights generated through the QRAFT methodology will feed into later steps of the TSL process (i.e., developing pathways and scenarios for transformation, developing feasible solutions and contributing to assessment frameworks developed in Deliverable 5.1). As such, the primary **target group** for the use of the QRAFT methodology are regions that plan to initiate a TSL (TSL follower regions, e.g., as part of the TSL User Forum (Task 6.4)). A second target group includes interested parties seeking to identify regions that could significantly benefit from a TSL approach. QRAFT focuses on two key questions:
What are the current state and trends of the region regarding the carbon intensity of the economy and society? In the **first step** of the QRAFT framework, we focus on two indicators to gain a general overview of the regions, Greenhouse Gas (GHG) emissions and the **Gross Domestic Product (GDP)**: In the context of the transition towards climate neutrality, **GHG** emissions are naturally one of the key indicators for "the analysis of regional industrial transitions and their regional development implications" (OECD, 2023). Using GDP as an indicator for development and general well-being is in contrast a highly debated subject in academia as well as in policy-making (Coscieme et al., 2020; Kovacic & Giampietro, 2015; van den Bergh, 2009). However, GDP is generally considered to be a robust indicator of economic performance and in the context of climate transitions it is often used together with the GHG emissions to assess the **Carbon Emission Intensity (CEI)** of the economy (Acquaye et al., 2018; EEA, 2011, 2011; Mura et al., 2021). The "emissions intensity of a country, measured as the level of emission per unit of economic output (measured in kg/EUR of the GDP), reflect[s] a country's:

[10] The description in this table is a summary of the description included in Deliverable 2.2 (URL not available yet) and consists mostly of verbatim quotes from our own Deliverable 2.2.

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- level of energy efficiency;
- overall economic structure (including the carbon content of goods imported and exported);
- [the] carbon content of the energy consumed in the country" (EEA, 2011)

What are the most important economic sectors and transition topics in the region?
After assessing the current state of the region regarding GHG emissions and analyzing if there is a trend of decoupling the economy from GHG emissions, the **second step** involves analyzing the **GHG emissions per sector**. This allows us to identify which sectors contribute most to climate change in a specific region. To put the climate impact of the economic sectors into perspective and identify the most important sectors for the economy, we relate these emissions to the **employment** and GVA (**Gross Value Added**) per sector.[11]

Based upon the identification of the most important sectors and activities, the topics of a region need to be further analyzed. However, even though we already identified relevant indicators, such an analysis requires a mixed-method approach and experts who can interpret the data in a context-specific way.[12]

Based on these quantitative assessments, regional **transition goals and policies** will be discussed and reflected upon in relation to previously identified transition needs and potentials. Given that **societal acceptance and support** are vital in democratic systems (Stapper, 2023; Wuppertal Institute, 2022), existing comprehensive surveys will be used to examine societal awareness of transition needs and their support for a transition. Following this, the **transition needs and potentials will be summarized**, and the vulnerability of a region to transition[13] will be discussed **through a regional SWOT analysis**.

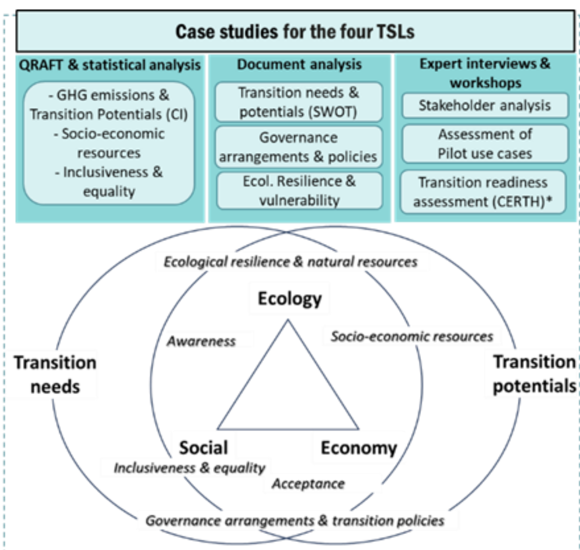

Figure 4: Case study design.
Source: own design.

Interpretations of transition needs and potentials were analysed collaboratively with project partners, running parallel to the **development of the TSL vision and Pilot use cases**. In this document, they will be briefly outlined within their regional context, serving as a basis for discussing **additional Pilot use cases and strategies for the long-term implementation of the four TSLs**.

[11] Due to the different statistical classifications of the sectors (GHG: EDGAR, OECD, IPCC; economy: NACE, ISIC; see Chapter 2.3), no direct comparison can be conducted, and the statistics have to be carefully interpreted.
[12] Especially as some topics are closely connected to specific cultural preferences (e.g., mobility) or are completely dependent on complex socio-ecological interactions (e.g., agriculture). Therefore, the indicators have to chosen carefully and interpreted in a context-specific way.
[13] For example, regions with significant employment shares in sectors with high greenhouse gas emissions and low GVA encounter distinct challenges when transitioning to climate neutrality (OECD, 2023).

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2.3 Methodologies and data collection

In conducting the case study, we employed a mixed-method approach that incorporated several key elements to ensure a comprehensive investigation and analysis: initially, we conducted a thorough **document research and analysis**, examining relevant literature, reports, and publications by other research projects.[14] In parallel to this desk research, we organized in tandem with TRANSFORMER partners (RUB & BMR) several project-internal workshops for conducting stakeholder mappings and SWOT analysis of the regions as well as workshops for vision building and Pilot use case development (ENoLL, RUB & BMR). Additional stakeholder workshops as well expert interviews were conducted by our partners in the four TSL regions. This information was also used in the Deliverables 3.1 and 3.2.[15] Additionally, some partners in the TSL regions subcontracted specific studies to expert agencies to support the development of the Action plans for the Pilot use cases (part of the Deliverable 3.3) that have been evaluated and partially included in the case studies.

Regarding the **quantitative analysis** based on the **QRAFT methodology** we relied on data that is available for all (or at least most) EU regions on a NUTS 2 level. The data was collected in a single Excel file, which is designed to be easily accessible, usable and extensible. The collected data was then evaluated with descriptive statistics and pivot tables and compiled into tables, figures, maps and interactive documents[16] for better visualization and interpretation (for an overview of the used data and a description of the composite indices see Table 4, Table 5, Table 6).

EUROSTAT was the main source for socio-economic data because of the open-access availability of the data and the existence of NUTS 2 (and partially NUTS 3) level data. However, with regard to electricity and energy statistics at a regional level, it had to be supplemented with OECD data. The problem was that the OECD data is partially outdated (e.g., the latest statistics on regional electricity generation are from 2019). Even though the OECD statistics provided a valuable addition, statistics on consumption (e.g., energy or agricultural goods) do not exist for the EU regions at a NUTS 2 level at all (and exist only for certain EU regions accessible through the respective national statistical offices).

Regarding GHG emissions, we used the most accurate and constantly updated **Emissions Database for Global Atmospheric Research (EDGAR)**, which provides GHG on the regional (NUTS 2) and local level (longitude and latitude), also per (economic) sector.[17] On a NUTS 2 level, the EDGAR database provides GHG emission data (totals and per sector) in Excel files already assigned to the correct NUTS codes. However, GHG emissions in the EDGAR database are only partially assigned to NUTS 2 or 3 levels:

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[14] For this desk research, different sources were used: Academic catalogues (e. g. the Library of the Ruhr University), Web of Science, SCOPUS, Google Scholar and—especially for more detailed and current project information—the search engine "Google".

[15] Deliverable 3.1: Recommendations for Transition Super-Lab coalitions building, empowering of vulnerable and marginalised groups, and vision process (URL not available yet); Deliverable 3.2: Definition of Transition Super-Lab use cases (URL not available yet).

[16] The interactive documents are currently still in the development phase. The goal is to embed the document (*.html-based) in the Knowledge Hub (see Deliverable 4.3; URL not available yet): https://transformerknowledgehub.imet.gr/

[17] The "Emissions of GHG are expressed in kton CO2eq using Global Warming Potential Values (GWP-100) from IPCC AR5 and they include fossil CO2 only, CH4, N2O and F-gases" Crippa et al. (2023).

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Domestic shipping, domestic aviation, and offshore fuel exploitation emissions are not allocated to any NUTS2 region, but for completeness, reported at NUTS0 (country) level. "Emissions from international shipping and aviation are excluded from the calculation due to their international feature" (Crippa et al., 2023). An overview of the EDGAR sectors is shown in Table 2. As the data about GHG emissions on a local level is only assigned to longitudes and latitudes, we used "RStudio" to assign the data to the respective NUTS 3 regions (see Table 3 for detailed description and references).

Table 2: Overview of the EDGAR sectors. Source: table taken from the Excel file of the EDGAR database.[18]

EDGAR sector	Sector description
Energy	Power generation
Industry	Combustion in manufacturing industry, oil refineries and transformation industry, chemical processes, fuel exploitation, iron and steel production, non-energy use of fuels, non-ferrous metals and non-metallic minerals production, solvents and products use
Buildings	Energy for buildings
Transport	Road transportation, railways, pipelines, off-road transport
Agriculture	Agricultural soils, agricultural waste burning, enteric fermentation, manure management, indirect N_2O emissions from agriculture
Waste	Solid waste incineration, landfills, wastewater handling
Other emissions	
Indirect	Indirect N_2O emissions
Int_Avi	International aviation
Int_Ship	International shipping
Dom_Avi	Domestic aviation
Dom_Ship	Domestic shipping

Regarding the interpretation of the data, it's essential to highlight and bear in mind the **limitations of the data availability**[19]: As described above, data on a regional level (for all EU NUTS 2 regions) is generally very limited. However, this is especially problematic with regard to data that focuses on consumption (e.g., energy, agricultural goods and industrial products). As shown later, this problem of focusing on "Production-Based Accounting" (and not "Consumption-Based Accounting") can be very problematic with regard to interpretation (Davis & Caldeira, 2010). Regions that export energy or goods are not solely responsible for the GHG emissions. Ultimately, these emissions are caused by the consumption of goods and services, which largely occurs in other regions. Another important limitation of a quantitative approach is that statistical data can be interpreted in various ways. Using composite indicators already helps by having this interpretation and weighing conducted by experts (e.g., the financial capabilities of a region versus the availability of highly skilled employees to assess innovation readiness and competitiveness of a region). However, the interpretations of the composite indicators are also very

[18] Source of the table: EDGARv8.0_total_GHG_GWP100_AR5_NUTS2_1990_2022.xlsx; Excel sheet: "info". URL: https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/EDGAR/datasets/subnational_NUTS2/v80_FT2022_GHG_NUTS2_v2/EDGARv8.0_total_GHG_GWP100_AR5_NUTS2_1990_2022.zip. Table slightly adapted. See for complete references Chapter "Data sources" below.

[19] This section is mostly taken from our Deliverable 2.2 and partially quoted verbatim.

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context-specific (e.g., scores for ranking of regions) and, therefore, should always be carefully interpreted with the guidance of experts.

In addition, the limitations regarding the timeliness of data pose a severe restriction: For some key indicators, only data from 2020 (e.g., GVA per sector at NUTS 3 level) or 2021 (e.g., GDP at NUTS 3 level) exist. The economic recovery following the Covid-19 pandemic (Delardas et al., 2022) is not reflected in this data, and it must be taken into account when interpreting older data (see statistics about GDP per capita of 2021 and 2022 in Table 7). In addition, we observed minor discrepancies in various indicators (e.g., population size, unemployment rate) between EUROSTAT and national statistical offices. These differences can mostly be attributed to variations in data collection methodologies, such as the reported date for specific years and the exclusion of individuals in training from unemployment statistics.

Despite these limitations, our mixed-method approach allowed us to gather a comprehensive range of qualitative and quantitative data, enabling a holistic understanding of the TSL regions. The continuous cooperation and exchange of information with project partners was pivotal in discussing of additional Pilot use cases as well as strategies for the long-term implementation of the four TSLs at two Consortium meetings and an additional workshop in April 2024 (see Chapter 3 and Deliverable 3.3).

Table 3: Short description of incorporating data in RStudio and developing maps (GHG). Source: own compilation.

Emissions Allocation
To determine the specific regions associated with the emissions data, we utilize the `st_within` function from the "sf" package, developed by Pebesma and Bivand (2023). This function efficiently matches emissions data from the Eurostat database to their corresponding geographical regions or communities based on coordinates.

Filtering & Cleaning
Data cleaning and transformation processes are conducted using the `dplyr` and `tidyverse` packages, authored by Wickham et al. (2019; 2023). These tools facilitate various operations such as filtering (e.g., selecting between NUTS3 or NUTS2 units), grouping, and aggregating emissions data by region or year.

Maps
The `tmap` package by Tennekes (2018) is employed to visualize emissions data across different regions or districts. Data classification into intervals is performed using the "classint" package by Bivand (2023). The geographical data (shapefiles) are sourced from the Eurostat database, curated by Lahti et al. (2023).

Dashboard
For dynamic data presentation, we leverage the `flexdashboard` package developed by Aden-Buie et al. (2024), which enables the creation of interactive HTML dashboards. These dashboards provide a versatile platform for displaying various data indicators through multiple visualizations.

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Overview of the indicators used in QRAFT to assess transition needs and potentials

This section provides an overview and description of the quantitative key indicators used in the case studies. The methodological approach for collecting the quantitative data is explained in Chapter 2.3 and analyzed in Chapter 3. This section begins with an overview of the main environmental and socio-economic indicators (Table 4), followed by a description of the use of data about GHG emissions from the EDGAR database Table 5). In Table 6, composite indices used in the QRAFT methodology are described in detail.[20]

Table 4: Environmental and socio-economic key indicators to discuss important transition needs and potentials of the four TSL regions. Source: own compilation.

Topic		**Indicator**	**Interpretation**	**Source**
Economic dimension	Macroeconomic indicators	**GDP** (pps in €); and **GDP development** at national (NUTS0/1), regional (NUTS2) [years: 2011-2022] and local level (NUTS3). [years: 2011-2021]	Indicator for economic resources and economic growth; GDP is used to calculate the → Carbon emission intensity (CEI: CO_{2eq} (kg) / GVA (EUR)) of the economy	EUROSTAT
		GDP per capita (GDP pps in €) national (NUTS0/1), regional (NUTS2) [years: 2011-2022] and local level (NUTS3). [years: 2011-2021] **Development of GDP per capita** national (NUTS0/1), regional (NUTS2) [years: 2011-2022] and local level (NUTS3). [years: 2011-2021]		EUROSTAT
		GVA per sector (total amount in €; share of GVA per sector) NUTS3; year: 2020	Indicator for assessing the importance of the economic sector. Regions "[…] with both high employment shares and high	EUROSTAT Statistikportal Ruhr

[20] Some of the following descriptions have already been included in Deliverable 2.2 and are mostly verbatim quotes from our own deliverable.

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Topic		Indicator	Interpretation	Source
Economic dimension	Macroeconomic indicators	**Employment per sector (NACE)** (share of total employees) NUTS 2; year: 2021	emissions per capita in key manufacturing sectors are likely to be the most sensitive to the transition to climate neutrality" (OECD, 2023).	EUROSTAT Statistikportal Ruhr
		Unemployment rate (share of unemployed people [15 to 74 years] as a percentage of the labour market)[21] NUTS2; year: 2021 **Development of the unemployment rate** NUTS2; years: 2011-2021	Indicator for economic transition potential and socio-economic challenges	EUROSTAT Statistikportal Ruhr
		Long-term unemployment (share of people [15 to 74 years] unemployed 12 months and more as a percentage of the labour market NUTS2; year: 2020 **Development of the long-term unemployment rate** NUTS2; years: 2011-2021	Indicator for economic transition potential and socio-economic challenges	EUROSTAT Statistikportal Ruhr

[21] The source for the regional labour market information down to NUTS level 2 is the EU Labour Force Survey (EU-LFS). This is a quarterly household sample survey conducted in all Member States of the EU, the United Kingdom, EFTA and Candidate countries. Please note, that we have partially observed strong deviations between EUROSTAT and national statistical offices (see EUROSTAT and respective national statistical office for different methodologies [e.g., time of reporting, aggregations etc.].

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Topic		Indicator	Interpretation	Source
Socio-economic dimension	Demography	Population size: **Number of inhabitants** (NUTS3; 2021 and 2022)	Overall comparison and basis for per capita calculations	EUROSTAT
		Population density: **Number of inhabitants per km^2** (NUTS3; 2021 and 2022)	Overall comparison	EUROSTAT
		Share of different education levels (percentage of people from 25 to 64 years): - Less than primary, primary and lower secondary education (levels 0-2) [ED0-2] - Upper secondary and post-secondary non-tertiary education (levels 3 and 4) [ED3_4] - Tertiary education (levels 5-8) [ED5-8] NUTS2; year: 2022	Indicator for transition potential (innovation and competitiveness)	EUROSTAT Statistikportal Ruhr
	Social inclusiveness & equality	At risk-of-poverty-rate (percentage of total population) NUTS2; year: 2022	Indicator for economic transition potential and socio-economic challenges (inequality and socio-economic disparities): "The persons with an equivalised disposable income below the risk-of-poverty threshold, which is set at 60 % of the national median equivalised disposable income" (EUROSTAT).	EUROSTAT

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Topic		Indicator	Interpretation	Source
Socio-economic dimension	Awareness of climate change impacts[22]	**Survey about the awareness of climate change impacts** NUTS1 (Germany, Greece) or NUTS2 (Italy, Poland)	Indicator about the awareness of climate change and its impacts and acceptance for climate mitigation and adaptation strategies	European Sources Online
Ecological dimension	Surface Area	**Area** (km^2) (NUTS3; 2021)	Overall comparison	EUROSTAT
	Land-use	**Agriculture & Forestry** (NUTS2; percentage of land-use in 2018)	Indicators used to discuss the potential of anthropogenic carbon sinks	EUROSTAT Statistikportal Ruhr
		Land use with heavy environmental impact (NUTS2; 2018)	Land use with heavy environmental impact includes "mining and quarrying; energy production; industry and manufacturing; water and waste treatment; construction; and transport, communication networks, storage, protective works" (Rajani et al., 2019). This data serves as an indicator for assessing the extent of unsustainable land use.	EUROSTAT Statistikportal Ruhr

[22] https://www.europeansources.info/record/climate-change-9/

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Topic		Indicator	Interpretation	Source
Ecological dimension	Air quality	**Air pollution in PM2.5** (average level in µg/m³ experienced by the population) (NUTS3; 2020) **Premature deaths attributed to exposure to fine particulate matter** (PM2.5), per 100.000 inhabitants. Regional data for the EU Member States at NUTS level 3. Annual data for 2020. Source: European Environment Agency (EEA)	Air pollution levels, particularly PM2.5 concentration, is a key indicator for assessing a region's environmental quality and public health risks associated with respiratory and cardiovascular diseases (Łowicki, 2019).	
	RE potential	**Share of renewable energy (RE) in electricity generation (2019)**	Key indicator for the sustainability of the electricity sector.	OECD
		Potential generation of energy from wind, solar and biomass on a NUTS level for the 2010-2050 period. For methodology refer to (Ruiz et al., 2019).	Potential for transforming the energy sector, which is considered one of the most crucial cross-cutting topics for transitioning to climate neutrality.	ENSPRESO (Ruiz et al., 2019)

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Table 5: QRAFT: GHG emissions and carbon intensity of the economy and society as key indicators to assess transition needs of the region. Source: own compilation.

Topic		Indicator		Interpretation	Data source
GHG	**Carbon intensity of the economy and society: where does your region stand and what are the trends?**	**Co_2eq per capita** (2021 and development between 2011-2021) on a NUTS 2 level. In addition, based on more recent data from EDGAR, this analysis has been conducted on a NUTS 3 level (including F-gases).	CO_{2eq} (t) per capita in 2021	Comparison between regions: Lower CO_{2eq} (t) per capita is better	EDGAR (GHG) EUROSTAT (Population)
			Development of CO_{2eq} (t) per capita between 2011-2021 (2011=100%)	Comparison between regions: Higher decrease (%) of CO_{2eq} (t) per capita is better. **Indicator for assessing the progress of decarbonising the region.**	
		Carbon emission intensity (CEI) of the economy (total) (2021 and development between 2011-2021) on a NUTS 2 level. In addition, based on more recent data from EDGAR, this analysis has been conducted on a NUTS 3 level (including F-gases)	CO_{2eq} (kg) / GDP pps (EUR) in 2021	CEI: emission per unit of economic output measured in kg/EUR of the GDP). Comparison between regions: Lower CEI is better (less emissions per economic output).	EDGAR (GHG) EUROSTAT (Population, GDP)
			CEI: CO_{2eq} (kg) / GDP pps (EUR) between 2011-2021 (2011=100%)	Comparison between regions: Higher decrease (%) of CEI is better. **Indicator for assessing the progress of decoupling economic output and GHG emissions.**	

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Topic		Indicator		Interpretation	Data source
GHG	**Carbon intensity of the economy: which sectors contribute most to climate change**	**CO_{2eq} emission by sectors** (total & share of emissions) (2021)	CO_{2eq} per sector (kton)	Indicator for identifying the sectors, which contribute most to climate change. Lower CO_{2eq} per sector (total and share) means it contributes less (regardless of economic output and economic importance of sector)	EDGAR
			Share of emissions by sector) (in % of all sectors)		
		GVA of economic sectors (NACE) (2020 and development between 2010-2020)	Total GVA per sector (million EUR) Share of GVA (in % of all sectors)	Indicators for assessing the economic importance: Economic output of the sector (GVA in €). Employment per sector[23]	EUROSTAT (GVA, employment per sector)
		Employment per sector (2020 and development between 2010-2020)	Total employees per sector Share of GVA (in % of all sectors)		

[23] Note that, in contrast to Deliverable 2.2, the CEI per sector is not included due to different methodologies. The Economic sectors (NACE) and EDGAR sectors (GHG) differ too much for a useful comparison (e.g., energy sector).

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Table 6: QRAFT: Composite indices for assessing the transition potential of regions in the context of the TSL approach. Source: own compilation (included in Deliverable 2.2).

<table>
<tr><th>Fields of transition potential</th><th>Composite index</th><th>Explanation of using the CI in the QRAFT methodology</th><th>Relation to TSL core elements</th></tr>
<tr><td rowspan="2">Economy: competitiveness & Innovation</td><td>EU Regional Competitiveness Index 2.0</td><td>A comprehensive framework for evaluating and comparing the competitiveness of EU regions on a NUTS 2 level (see Table 27 in the annex for detailed description).

The competitiveness of a region is closely linked to its capability of transformation with regard to the required economic resources and necessary political and socio-economic structures for experimentation, innovation and co-creation in a comparative environment.

Regions with a comparatively high RCI score = more capable to experiment, innovate and co-create</td><td>Economic performance & resources for transformation

Potential for
- co-creation & experimentation (resources and structure) - innovation</td></tr>
<tr><td>Regional Innovation Scoreboard 2023</td><td>Innovation readiness is closely linked to the capability of experimentation, innovation and co-creation. Therefore, the innovation readiness of a region can be regarded as a prerequisite for finding and implementing solutions for a fundamental transition of the social and economic structures of a region (see Table 28 in the annex for detailed description).

Regions with a comparatively high score = more capable to experiment, innovate and co-create</td><td>Political and economic resources and structures for innovation

Potential for
- innovation
- experimentation</td></tr>
<tr><td>Political framework & social structures</td><td>European Quality of Government Index 2021</td><td>The European Quality of Government Index (EQI) is a survey-based assessment focusing on the quality of governance at the regional (sub-national) level within the European Union (EU). This index utilizes survey data collected in 2010, and subsequently in 2013, 2017, and 2021. The primary focus of the survey is to gauge citizen perceptions and experiences regarding public sector corruption, as well as their views on the impartiality and quality of various public services (see Table 29 in the annex for detailed description)
The EQI reflects the trust of citizens in public services and their perception of having fair and socially just opportunities to participate. This is a prerequisite for the participation of citizens and social acceptance of the far-reaching actions needed for a fundamental transition. It is also a very basic prerequisite for establishing a beneficial environment for co-creation processes.
Regions with a comparatively high score = better potential for inclusive participatory governance arrangements (perceived by citizens), which is a prerequisite for participation and co-creation.</td><td>Government & regulatory framework

Potential for
- participation & co-creation (trust in political processes and public services)</td></tr>
</table>

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Fields of transition potential	Composite index	Explanation of using the CI in the QRAFT methodology	Relation to TSL core elements
	European Social Progress Index 2020	The Index measures social progress in European regions at the NUTS2 level, using twelve components that are further aggregated into three broader dimensions describing basic, intermediate and more subtle aspects of social progress, respectively. - Basic human needs - Foundations of wellbeing - Opportunity The ESP reflects the inclusiveness and social justice (well-being and opportunities) of a society. This is a prerequisite for the participation of citizens and social acceptance of far-reaching actions for a fundamental transition. It is also a very basic prerequisite for establishing a beneficial environment for co-creation processes (see Table 30 in the annex for detailed description). *Regions with a comparatively high score = better potential for having inclusive participatory governance arrangements (perceived by citizens) which is a prerequisite for participation and co-creation*	Social structures with regard to human needs, wellbeing and opportunities *Potential for* - co-creation (social inclusiveness & social equality)
Environmental potential	**Land cover and land use** **&** **RE potential**	As highlighted in Figure 3, the environment is integral part of socio-ecological interactions, and a region needs to have a suitable environmental potential for implementing the most efficient transition scenarios/pathways. • The area and share of **land cover and land use** (e.g., agricultural farmland, conservation areas) reflects this basic environmental potential and is relevant for finding suitable transition scenarios in general. • For specific transition scenarios/pathways and TSL topics, additional indicators need to be considered (such as: Water Scarcity Index; Soil degradation index, Index of the resilience of ecosystems [e.g., BERI - Bioclimatic Ecosystem Resilience Index] etc.). However, this variety already indicates, that this is not manageable in the realm of the QRAFT methodology (that is designed as an easy-to-use self-assessment). **RE potential** • Environmental potential for of the cross-cutting topic “energy transition” that is relevant for most of the TSL topics* and transition scenarios/ pathways. * (agriculture, industry/ manufacturing, transport & mobility, circular economy etc.)	For all TSL topics relevant environmental potential for supporting a transition For the cross-cutting topic “energy transition” relevant environmental potential for RE (PV, Wind and biomass) on a regional level

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3 Transition needs and potentials of the four TRANSFORMER regions

At the beginning of this chapter, we will provide an overview of the four TRANSFORMER regions as a brief introduction to the cases, thus highlighting their diversity. This section also includes a brief reflection on the regions regarding their vulnerability to climate change. Based upon that, we will analyse separately (Chapters 3.2 to 3.5) the transition needs and potentials of each of the four TSL regions as described in the previous chapters, beginning with a brief **(1) overview of the region** to "[d]efine the boundaries of the system in terms of geography" (Geus et al., 2022). Based on this, the **(2) transition needs to achieve climate neutrality** will be assessed, focusing on the most significant economic sectors contributing to climate change. From this perspective, the **(3) socio-economic and ecological transition potentials** of the regions will be analysed and summarised **in form of a regional SWOT analysis**. These transition needs and potentials guided the development of the **(4) TSL visions and Pilot use cases** (WP3), which will be briefly portrayed, before finally discussing the **overall strategies for the long-term implementation of the TSLs (Chapter 3.6).**

3.1 Introduction to cases and overview of the four TRANSFORMER regions

In TRANSFORMER, we focus on four regions (see Figure 5): Emilia-Romagna (Italy), Lower Silesia (Poland), Ruhr Area (Germany) and Western Macedonia (Greece). These regions have very different characteristics: for example, the population of Emilia-Romagna was in 2022 nearly 17 times as large as that of Western Macedonia (see Table 7). Significant disparities also apply to levels of economic development (e.g., GDP per capita), which will have a major effect on regions' ability to develop strategies for adapting to climate change.

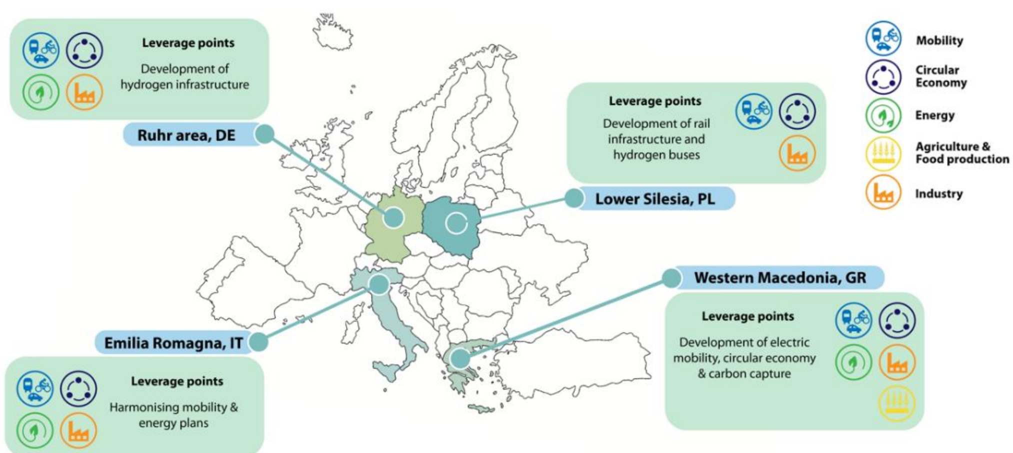

Figure 5: The four TRANSFORMER TSL regions and their topics of interest. Source: own design (taken from the project proposal and slightly adapted).

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Table 7: Key statistics for the four TSL regions. Source: own compilation based on data from EUROSTAT.

	Year[24]	Emilia-Romagna	Lower Silesia	Ruhr Area[25]	Western Macedonia
Area (km^2)		22,453	19,947	4,438	9,462
Population	2021	4,438,937	2,857,364	5,102,484	262,052
	2022	4,425,366	2,845,944	5,094,817	253,954
Population density (population/ km^2)	2021	198	143	1,150	28
	2022	197	143	1,148	27
GDP (pps) (mio. EUR)[26]	2021	171,517	81,506	162,116	4,477
	2022	184,274	91,373	*no data*	5,549
GDP (pps) per capita (EUR)	2021	38,700	28,300	31,772	17,100
	2022	41,600	31,600	*no data*	21,400

In this regard, it is important to highlight that the impacts of climate change vary considerably between the regions. A general comparison shows that the socio-economic costs for climate inaction would be most severe in Southern Europe, with up to more than 4% of welfare change (share of GDP), especially caused by an increased mortality rate due to heat stress (European Commission, 2019).

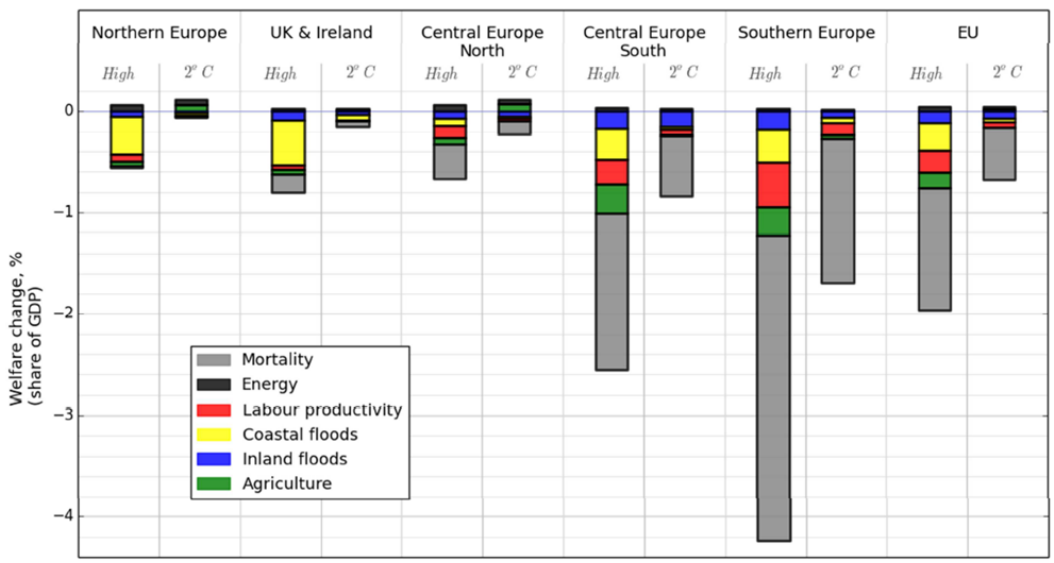

Figure 6: Climate inaction would have significant socio-economic costs for Europe, particularly southern Europe. Welfare losses (% of GDP) for two climate inaction scenarios (high warming scenario and 2˚C scenario).
Source: European Commission (2019, p. 171).

[24] In the quantitative perspective we aim at using the most recent data that exists for all NUTS 2 and NUTS 3 regions. However, for some key indicators, only data from 2020 (e.g., GVA per sector at NUTS 3 level) or 2021 (e.g., GDP at NUTS 3 level) exist. The economic recovery following the Covid-19 pandemic is not reflected in this data, and it must be taken into account when interpreting older data (see Chapter 2.3 about limitations of the quantitative approach).
[25] The Ruhr Area is not classified as a NUTS 2 area. It encompasses parts of three distinct NUTS 2 regions. To perform an analysis of the Ruhr Area within its precise spatial boundaries, it is necessary to examine aggregated data from the NUTS 3 level.
[26] Gross domestic product (GDP) at current market prices by NUTS 2 regions [nama_10r_2gdp]

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These results are also reflected in the data from the ESPON climate research project (Navarro et al., 2022): Southern countries in the EU generally face higher risks, while northern countries experience lower risks.[27] However, under very high emissions scenarios, risk increases across many countries, particularly in coastal areas, indicating a potential spread of risks traditionally associated with southern regions.

Regarding the expected impacts of climate change[28] in our TRANSFORMER regions, we observe that, on average, the risks in the Ruhr Area are significantly lower compared to Emilia-Romagna. This has various reasons. For instance, in comparison to the Ruhr Area, Emilia-Romagna has a significantly higher vulnerability to coastal and river floods, which are expected to increase in both frequency and intensity (IPCC, 2021; Navarro et al., 2022). The heavy environmental and economic impacts of the floods in Emilia-Romagna in 2023 underscore the critical importance of climate mitigation and adaptation efforts (Arrighi & Domeneghetti, 2024; Emilia-Romagna Region, 2024b). These strategies need to account for the significant disparities present within the regions: for example, within the Ruhr Area, Duisburg presents one of the highest (0.42), while Bottrop exhibits one of the lowest (0.07) risks among all the NUTS 3 regions within the four TRANSFORMER regions (see ESPON data).[29] This underscores the necessity of developing mitigation and adaptation strategies tailored not only to regional but also local needs. In an overall assessment, however, all analyses indicate that the costs of climate inaction outweigh the socio-economic costs of implementing comprehensive systemic changes across all TSLs(European Commission, 2019; IPCC, 2021; Navarro et al., 2022). This consideration must be taken into account when discussing the costs associated with the phasing out of unsustainable industries in the next chapters, especially given the severe impacts it may have on certain regions (OECD, 2023).

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[27] The aggregated risks map "are the result of combining the risks of the different impact chains for the same scenario (baseline climate, low emissions scenario, intermediate emissions scenario or very high emissions scenario in 2070-2100) and way of considering exposure (absolute or relative)" Navarro et al. (2022). The impact chains include heat stress on population, coastal flood on infrastructure, industry, and service sectors, river flood on population, river flood on infrastructure, industry, and service sectors, flash floods on cultural sector, wildfire on environment, droughts on primary sector. The spatial distribution of climate risk in Europe shows similarities between scenarios with absolute and relative exposure, although minor differences exist.

[28] Aggregated risks under the Intermediate emissions scenario (2070-2100 RCP4.5) with absolute exposure (ibid.).

[29] „Weighted combination of physical (weight 0.19), environmental (0.31), social (0.16), economic (0.24) and cultural (0.1) potential impacts of climate change. Weights are based on a Delphi survey of the ESPON Monitoring Committee. […] Impacts calculated as combination of regional exposure to climate change and most recent data on regional sensitivity. Climatic changes calculated on the basis of the IPCC SRES A1B scenario as median of the changes between 1961-1990 and 2071-2100 of 12 ENSEMBLES climate models" (Navarro et al. (2022). No data for Western Macedonia.

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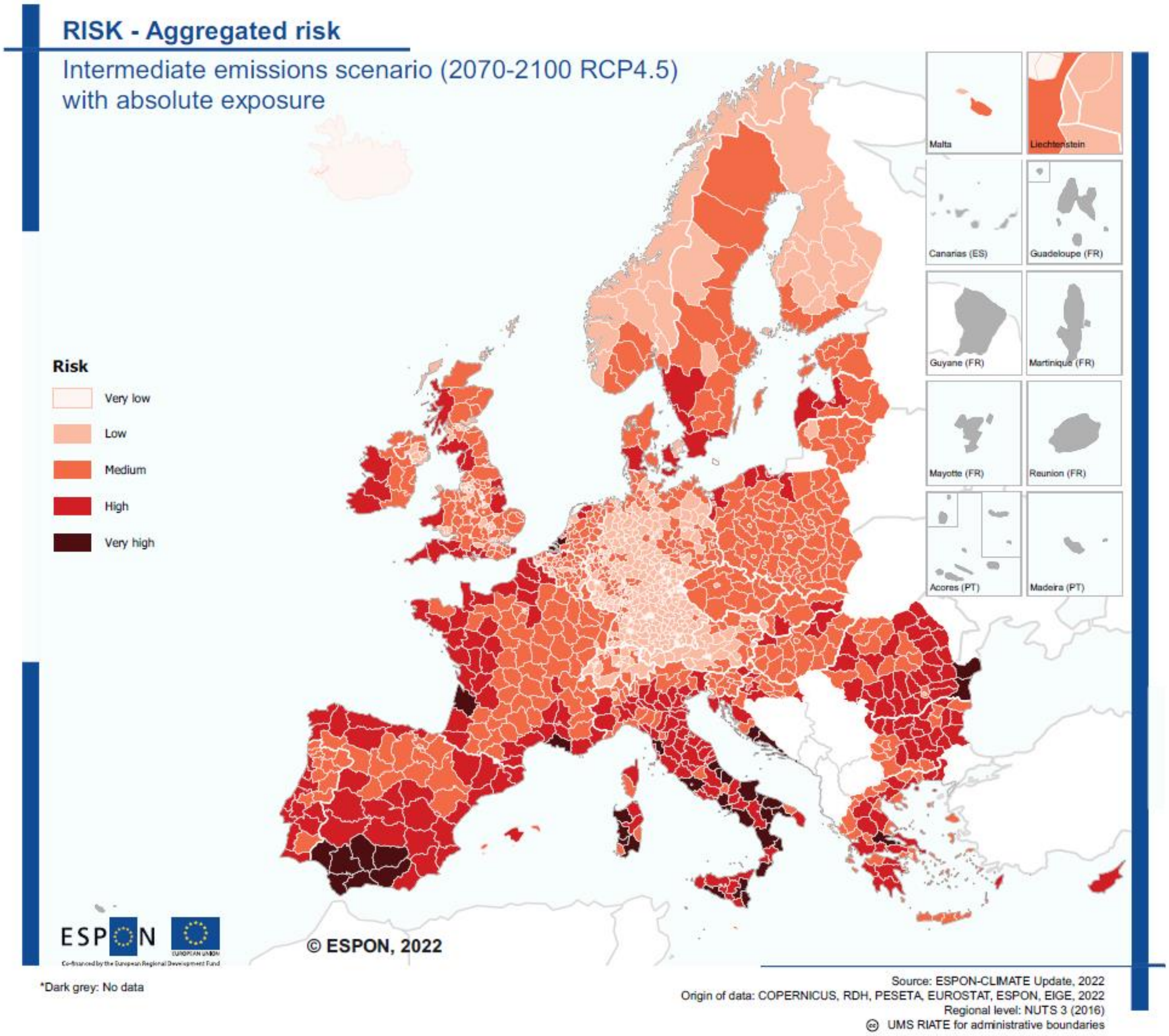

Figure 7: Aggregated risks. Intermediate emissions scenario (2070-2100 RCP4.5) with absolute exposure. Navarro et al. (2022, p. 116).

3.2 Emilia-Romagna Region

As described above, the case study will begin by providing a brief **overview of the region** (3.2.1) to "[d]efine the boundaries of the system in terms of geography" (Geus et al., 2022). Based on this, the **transition needs to achieve climate neutrality** will be assessed, focusing on the most significant economic sectors contributing to climate change (3.2.2). The identification of these transition needs will allow us to narrow down the otherwise too complex analysis of the **socio-economic and ecological transition potentials** of the region. These closely intertwined transition needs and potentials will be then summarised **in form of a regional SWOT analysis** (3.2.3). These identified transition needs and potentials guided the **TSL vision and Pilot use cases**, which will be briefly portrayed in Chapter 3.2.4. The results of the chapters about the four TSLs (Chapters 3.2-3.5) will then be incorporated in Chapter 3.6 in an overall discussion **about strategies for the long-term implementation of TSLs**.

3.2.1 Overview of the TSL region

Emilia-Romagna (Regione Emilia-Romagna; RER) is a region in northern Italy located in the southern region of the Upper Italian Plain along the Po River, bordering Veneto and Lombardy to the north and the Adriatic Sea to the east. It encompasses an area of more than 22,000 km² and extends southward into the Apennine Peninsula, bordered by Tuscany, Marche, and the Republic of San Marino, with Piedmont and Liguria to the west. It has a population of 4.4 million and it consists of 9 provinces, including one Metropolitan City (Città Metropolitana). The most populous city, Bologna, is the capital of the Emilia-Romagna Region (OECD, 2022).

Figure 8: Emilia-Romagna Region and its location in Italy. Source: Geoportale 3D (regione.emilia-romagna.it).[30]

[30] https://mappe.regione.emilia-romagna.it/#share=g-c4511548320f6834c9a7a2d5d3062fe9

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Emilia-Romagna is one of the wealthiest of the 20 regions in Italy with a GDP (pps) per capita in 2022 of 41,600 €. One of the most important sectors in Emilia-Romagna is the industrial sector, specifically manufacturing (see Chapter 3.2.2). This sector is characterized by its automotive and motorcycle industries, as well as its food production which are internationally very competitive (OECD, 2023).

The authorities in Emilia-Romagna have clearly identified the risks associated with climate change (see Table 8 for a brief overview of the political system). Based on overarching national policy objectives[31], RER set in the "Regional Strategy ´2030 Agenda For Sustainable Development`" (Emilia-Romagna Region, 2020b) ambitious goals to achieve a GHG reduction of 55% until 2030 and becoming climate neutral until 2050 (ibid., p. 119). These goals are embedded in a complex set of objectives for sustainable development that aims at "decoupling growth and environmental impacts" (ibid., p. 26) for achieving a socially acceptable transition. Increasing biodiversity, improving air quality and simultaneously "reducing economic, social, environmental and territorial divisions" (ibid., p. 29) based on "The Pact for Work and Climate" (Emilia-Romagna Region, 2020a, 2024a).[32] To achieve these goals, the region has identified **energy**, **sustainable mobility**, and **circular economy** as key topics (ibid, see Deliverable 3.2).

In the next section, we will explore how the importance of these sectors is reflected in their GHG emission intensity, thus indicating the necessity of transforming them. This will serve as a significant indicator for assessing the region's vulnerability to the required transition. For example, regions with significant employment shares in sectors with high greenhouse gas emissions and low GVA encounter distinct challenges when transitioning to climate neutrality (OECD, 2023).

[31] Italy ratified the Kyoto Protocol in 2002 and the Paris Agreement in 2016. Building upon these significant treaties, Italy developed the "IntegratedNational Energy and Climate Plan" (INEC) in 2019, outlining the objective of achieving climate neutrality by 2050 (Ministry of Economic Development (2019)). According to Jensen and Seppälä (2021), this commitment to climate neutrality is intertwined with other policies aimed at promoting sustainability, such as the "Action Plan for Improving Air Quality".

[32] According to Emilia-Romagna Region (2022), different accompanying strategies, such as "The Path to Carbon Neutrality before 2050" have been implemented for identifying "on a sector by sector basis, the best policies and actions to be implemented over time, so that their 'sum' will result in the net neutrality of GHG emissions before 2050" (ibid., p.65).

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Table 8: Brief overview of the political system of Region Emilia-Romagna. Source: own compilation.

A TSL can be regarded as a new form of governance arrangement (see Chapter 2.1). However, a TSL is not implemented in a political void and, therefore, must be designed to be complementary to existing political-administrative structures (see Chapter 3.6). This brief overview of the region's political system aims to highlight some of its main existing political structures. The specific political decision-making processes and participation processes need to be carefully analyzed in detail for different topics and Pilot use cases (see Deliverable 3.3 for the specific contexts of the Pilot use cases). The political system of Emilia-Romagna is characterized by a multi-tiered structure that mirrors the broader Italian governmental framework. At its core is the Regional Government (Giunta Regionale) and the Regional Assembly (Assemblea Regionale), both of which play crucial roles in shaping policies and administering affairs within the region (Assemblea Legislativa, 2024). The Regional Government, led by the President of the Region (Presidente della Regione), functions as the executive branch. The President is elected by popular vote and is responsible for representing the region, implementing laws, and overseeing the administration of government departments. The President appoints several assessors (Assessori), each responsible for a specific area of governance, such as health, education, infrastructure, and economic development. Together, they form the Giunta Regionale, which functions as the regional cabinet (Assemblea Legislativa, 2024). The Regional Assembly serves as the legislative body of Emilia-Romagna, akin to a regional parliament. It is composed of elected representatives known as regional councillors (Consiglieri Regionali). These councillors are elected through a proportional representation system, with the number of seats allocated to each political party based on their share of the vote. The Regional Assembly holds the power to pass laws, approve the regional budget, and oversee the actions of the Regional Government through various committees and commissions (European Committee of the Regions, 2024a). Emilia-Romagna's legal system operates within the broader framework of Italian law, with regional regulations and policies enacted by the Regional Assembly and implemented by the Regional Government. The region is divided into administrative departments (Dipartimenti), each tasked with specific functions such as mobility, energy, agriculture, and transportation (Regione Emilia-Romagna, 2024). These departments work to deliver services to residents, manage resources, and implement regional policies in alignment with both regional and national legislation. Within this governance framework, the TSL specifically aims at implementing complementary processes for the involvement of citizens. In addition, the TSL is supposed to support interdepartmental coordination within RER´s regional authority for fostering the development of cross-sectorial solutions for climate neutrality (see TSL vision and Pilot use cases in Chapter 3.2.4).

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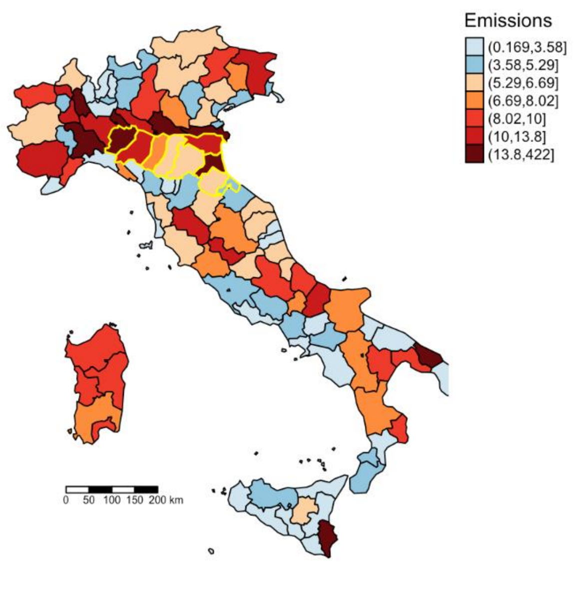
3.2.2 Assessing the transition needs of becoming climate neutral

As described above (see Chapter 2.1), regional transition needs and potentials are closely interrelated and influenced by the ecological, social, and economic dimensions of sustainability. In the context of the overarching goal of achieving climate neutrality, **GHG emissions** are, by definition, one of the main indicators that needs to be analysed. In this regard, the overall GHG per capita in Emilia-Romagna is nearly the same as the EU average[33] but higher than the rest of Italy (see Figure 9 and Figure 10). Regarding the carbon emission intensity of the economy, we observe a strong decline of GHG per GDP. This overall positive trend of decoupling economic growth and emissions of GHG can also be seen on a local (NUTS 3) level, even though with strong disparities: Piacenza has by far the highest GHG emissions per capita and CEI and Rimini the lowest values (see Figure 12 and Figure 13). However, in this context it must be highlighted that this data pertains to the *production* and not to the consumption of goods and services: Rimini, with its strong tourism industry, utilizes a significant amount of resources (energy, agricultural products, etc.) that are produced elsewhere. Therefore, this data does not necessarily reflect the actual ecological footprint of the region (Samora-Arvela et al., 2018).



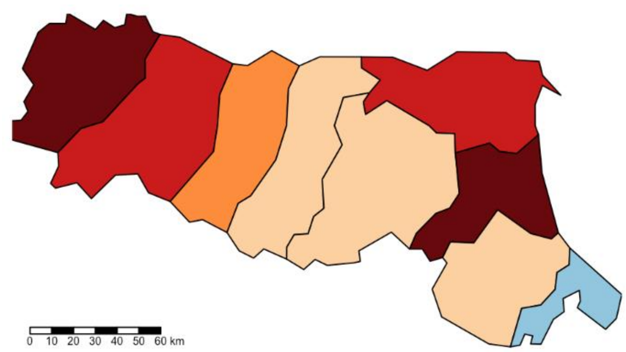


Figure 9: GHG per capita in 2022 in Italy and Emilia-Romagna. Source: own design based on data from EDGAR (CO2eq) and EUROSTAT (per capita).

33 Based on the classification of the EDGAR data. Accorind to the UNFCCC classification the GHG emission per capita for Italy is below EU average (7.1 versus 7.8 CO2 eq t per capita). See Chapter 2.3 for explanations.

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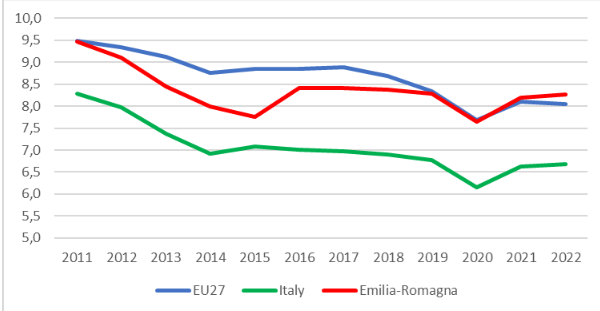

Figure 10: Average CO2eq per capita (t) of the EU (NUTS 2 regions), Italy and Emilia-Romagna. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (per capita).

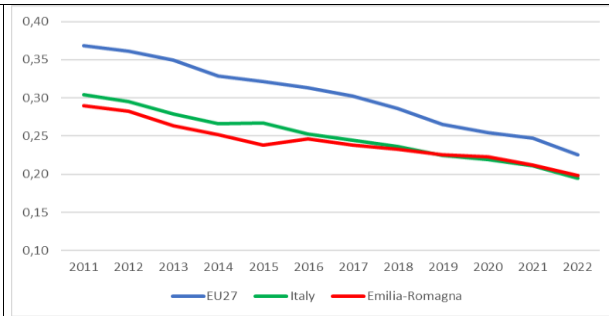

Figure 11: Development of the CEI (CO2eq [kg] / GDP pps [EUR]) in the EU (NUTS 2 regions), Italy and Emilia-Romagna. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (GDP pps).

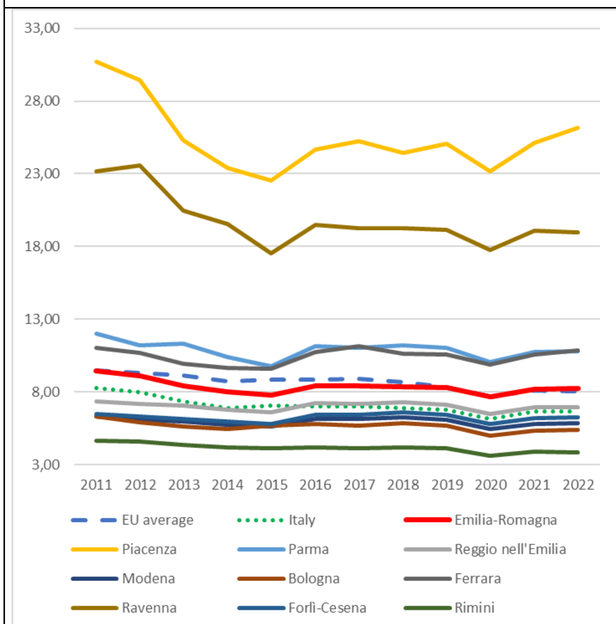

Figure 12: Average CO2eq per capita (t) of the EU (NUTS 2 regions), Italy, Emilia-Romagna and its NUTS3 regions. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (per capita).

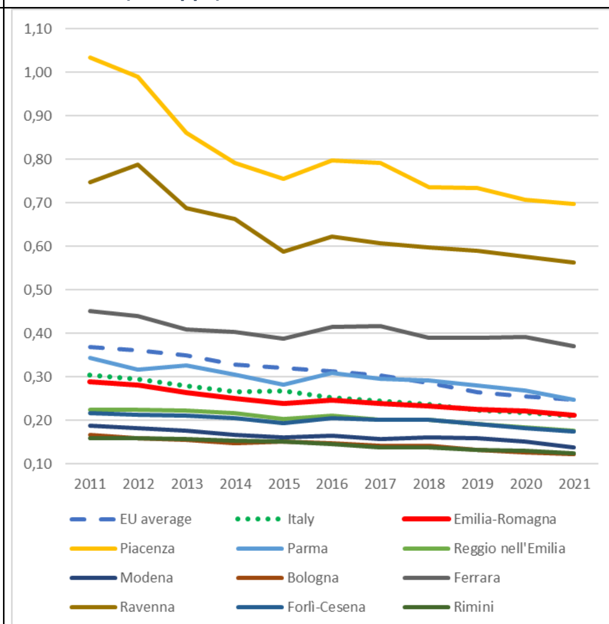

Figure 13: Development of the CEI (CO2eq [kg] / GDP pps [EUR]) in the EU (NUTS 2 regions), Italy, Emilia-Romagna and its NUTS3 regions. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (GDP pps).[34]

The sectors contributing most to climate change in 2022 were **industry**, **transport**, and **energy**. Even though we can see a shift to a more carbon-efficient economy in most of the sectors in Emilia-Romagna, especially in waste management and transport, this progress is not enough to meet the climate targets of the region of reducing GHG emissions by 55% until 2030 and becoming climate neutral until 2050 (Emilia-Romagna Region, 2020b). According to the EDGAR database, we can even see an increase of GHG

[34] Only the period from 2011 to 2021 is covered, as EUROSTAT lacks data for GDP at the NUTS 3 level for 2022.

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emissions totals (but also GVA) in the agricultural sector,[35] a sector that not only contributes to climate change but has, especially in the case of conventional agriculture, negative effects on biodiversity, groundwater and air quality (Leogrande, 2024; Voccia et al., 2022). Air quality is particularly important as it has a direct effect on the life expectancy of inhabitants (see explanation below).

Nevertheless, the most important sectors regarding GHG emissions and air quality are **industry, energy and transport**. Regarding the transition needs of the industry of Emilia-Romagna, it is important to emphasize that it is strongly linked to the regional key topic of developing a **circular economy.**[36] The same applies to the cross-cutting topic of energy, which strongly intersects with industrial processes, circular economy and the transport sector.

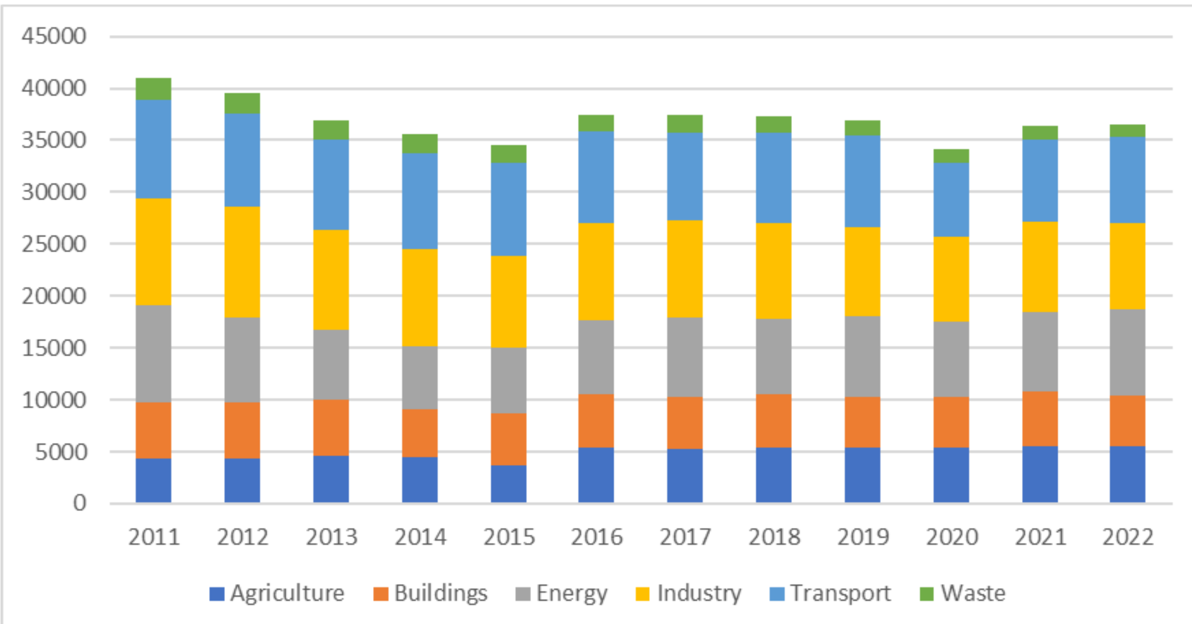

Figure 14: CO2eq (kt) per sector in Emilia-Romagna. Own compilation based on data from: EDGAR (CO2eq).

Emilia-Romagna Region is often referred to as "the homeland of the ´**industrial** districts` (Bianchi & Bianchi, 2019, p. 65): a network of small and medium-sized enterprises (SMEs) clustered in industrial districts, where businesses specializing in similar industries are located in close proximity to one another. This proximity fosters collaboration, knowledge sharing, and innovation (ibid.), which contributes to the high competitiveness of the industrial sector of Emilia-Romagna (Vrontis et al., 2018).

According to EUROSTAT, more than 520,000 people are employed in the industrial sector (NACE B-E), most of them in manufacturing (NACE C). The importance of the manufacturing sector is also clearly

35 The deviations from other sources (Emilia-Romagna Region (2018)), which report a decrease in GHG emissions in the agriculture sector, can partially be explained by the fact that in the EDGAR database, the agricultural sector encompasses all related activities, including agricultural soils, agricultural waste burning, enteric fermentation, manure management, and indirect N2O emissions from agriculture as well as all related gases, including F-gases.

36 As mentioned in the introduction, the region has identified energy, sustainable mobility, and circular economy as key topics for achieving climate neutrality and sustainability Emilia-Romagna Region (2020a, 2024a).

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reflected in the share of regional GVA (see Figure 15). The most important manufacturing clusters (see Figure 16) are "mechanical engineering, automotive, ceramics, automation and robotics, construction materials, and food" (OECD, 2022).

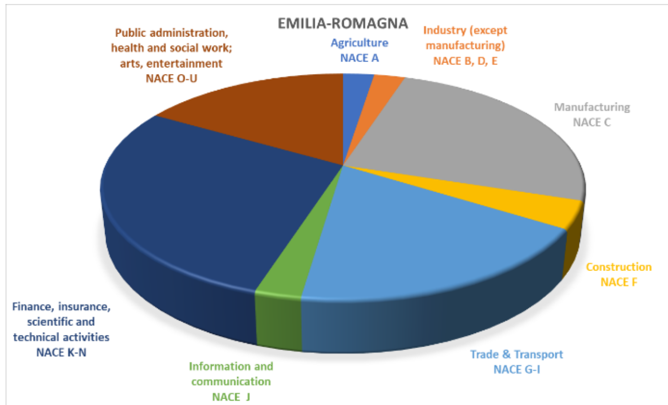

Figure 15: Share of GVA per sector in Emilia-Romagna in 2020. Own compilation based on data from EUROSTAT.

While most of these sectors demonstrate a comparatively high level of competitiveness, they are confronted with the challenge of needing to undergo fundamental changes to supporting the transition to climate neutrality, while simultaneously maintaining their competitiveness. One compelling example highlighting the complexity of this transition challenge is the automotive industry in Emilia-Romagna: Against the background of an already unfavourable development of the Italian automotive sector in general (Zirpoli, 2023)[37] this sector faces multiple challenges that are "captured in the fourletter acronym MADE, standing for new Mobility trends around the world, the arrival of Autonomous technology, the development and use of Digital features, and the rise of powertrain Electrification" (Morzenti et al., 2020, p. 5). In this context, electrification is regarded as "[t]he most relevant ´discontinuity factor` [as it] results in a total change of paradigm and technology in the powertrain domain, with consequences for the entire vehicle" (Morzenti et al., 2020, p. 10). Not only the reduced number of components[38] and the introduction of completely new required components (such as battery packs) need to be addressed through increased investments in R&D, workforce training, and diversification of production (Zirpoli, 2023), but the successful electrification of the automotive sector also necessitates entirely new services and infrastructure, "such as fast charging stations and battery recycling systems" (Morzenti et al., 2020, p. 10).

This highlights the **strong linkages between manufacturing** (e.g., automotive industry), **circular economy** (e.g., battery recycling) and the **energy** as well as **transport sector** (e.g., fast charging stations). This emphasizes the necessity of developing well-aligned cross-sectorial solutions. This is particularly important for the transport and mobility sector, as a just transition to climate neutrality requires not only completely new technological but also social transportation solutions, such as accessible and affordable

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[37] According to Zirpoli (2023, p. 6), the number of produced vehicles in Italy has continuously declined from "2 million cars and commercial vehicles in 1990 to […] around 500,000 in 2022 (750,000 if light commercial vehicles are also considered). Nevertheless, the automotive industry still "represents one of the pillars of the Italian economy. However, starting from 2000, the crisis of the FIAT production model, culminating in the merger between FCA and PSA, has led to a significant contraction in production and, consequently, in turnover, Italy remains an important player but risks lagging behind, threatened by the competition from other European countries. There is a need for structural reforms to address persistent issues, investments in R&D and workforce training, diversification of production, and a revival of the local public transportation industry" (ibid.).

[38] "As much as 85 percent of the powertrain components of ICEs could become obsolete in battery electric vehicles (BEVs), as the vehicle architecture is simplified from around 1,400 components to fewer than 200 and fully integrated platform solutions for the powertrain, such as the skateboard chassis, are introduced" (ibid.).

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public transportation, as well as safe and convenient bicycling infrastructure (Jenssen, 2021; Pazzini et al., 2022).

The developed Pilot use cases in RER, evolving around sustainable mobility solutions (cycling and electric mobility, see Chapter 3.2.4), should therefore be assessed against this cross-sectorial background: reducing GHG emissions in the transport sector, fostering a sustainable energy system and simultaneously supporting the transformation of the important regional manufacturing (automotive) sector by developing a **circular economy**. The latter is regarded as a particularly important necessity for achieving climate neutrality and a sustainable economy (Paleari, 2024; Romero-Perdomo et al., 2022).

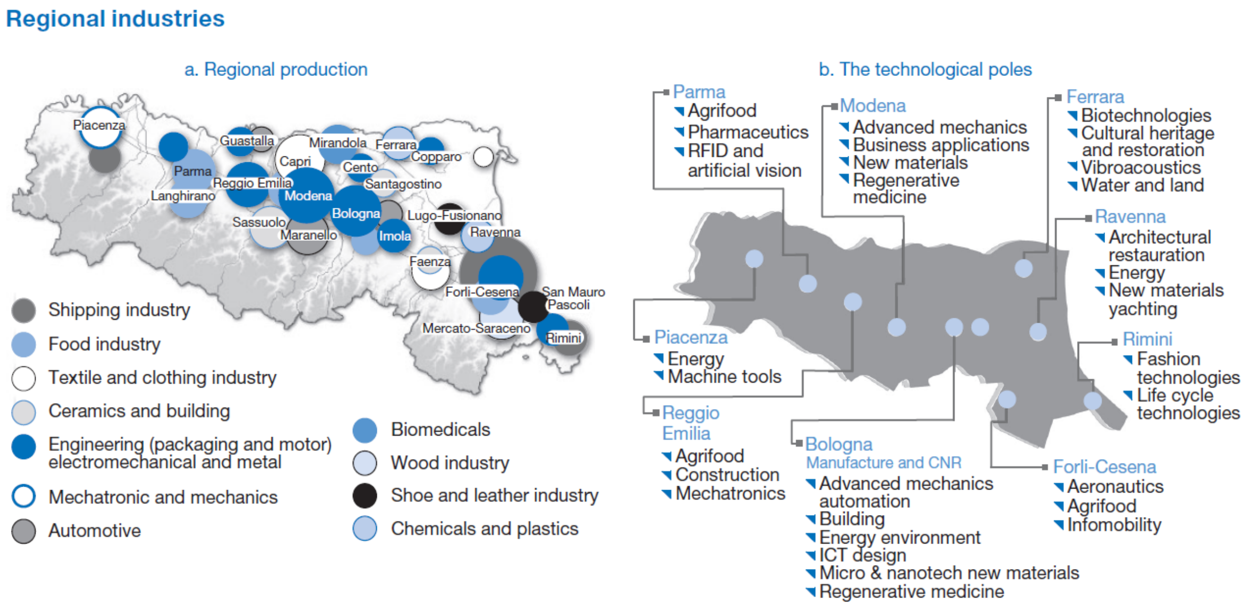

Figure 16: Regional industries. Source: Bianchi and Bianchi (2019, p. 67).

Circular economy (CE) aims at redesigning “industrial systems by creating sustainable relationships among the three main components of the production cycle: environment, producers and consumers” (Gaiani et al., 2017, p. 1), with the goal of minimizing waste and resource consumption by maximizing the reuse, recycling, and repurposing of materials throughout the production and consumption cycle. This transition to a circular economy is widely regarded as “as a major strategy for sustainability and competitiveness in the medium-long run” (Compagnoni, 2020, p. 1716). In this regard, Emilia-Romagna Region is considered a pioneer in Italy: it was the first Italian region to implement a specific law that fostered the development and adoption of circular economy principles (Sani et al., 2021).[39] In combination with an innovative ecosystem in RER that is characterised by a “strong partnership between the research centres, academia

[39] According to Mencherini et al. (2020, p. 130) “the complexity of the regulatory framework discourages companies in participating to pilot actions of circular economy and IS having the aim of identifying new pathways for by-products reuse. Especially in Italy, where different institutional bodies are involved in the authorization process, companies often fear to incur penalties trying experimental solutions forwaste valorisation. Therefore, even if innovative solutions are developed they often do not succeed in reaching the market.”

and companies" (Sani et al., 2021, pp. 19–20),[40] this led to an overall positive trend in the substantially increased number of companies that adopt circular economy principles.[41] However, in a study from Antonioli et al. (2022) we can also see that "the distribution of circular innovation mainly concerns medium-sized firms, especially those belonging to low and medium technology-intensive sectors, moreover companies in the provinces of Modena and Parma show higher adoption rates" (Antonioli et al., 2022, p. 57). In addition, this study shows that the cross-cutting topic of energy is addressed by a comparatively small share of companies (see Figure 17). Considering that the "industrial system absorbs about one third (33%) of final energy consumption in the region [...] it appears necessary that companies convert their production cycles into a new dimension of circularity, reducing energy consumption, gradually increasing the use of renewable resources and allowing, at the end of their life, the recycling and reuse of materials and components" (Ministero dell'Università e della Ricerca, 2022, p. 2).

Circular innovations	BO	FE	FC	MO	PC	PR	RA	RE	RN	Total Emilia-Romagna
Water reduction	4%	6%	3%	4%	11%	3%	3%	3%	5%	4%
Raw material reduction	15%	15%	7%	15%	9%	14%	10%	15%	12%	13%
Design change to reduce material use	8%	10%	5%	8%	4%	8%	7%	10%	6%	8%
Use renewable energy	5%	6%	4%	5%	6%	6%	3%	5%	6%	5%
Reduce electrical energy	7%	6%	1%	6%	4%	6%	5%	5%	9%	6%
Design for durability	8%	11%	4%	8%	4%	12%	8%	9%	5%	8%
Design for disassembly	3%	6%	4%	4%	2%	3%	4%	5%	1%	4%
Design for repairability	6%	7%	6%	10%	2%	10%	6%	6%	1%	7%
Design for recyclability	6%	7%	2%	5%	4%	5%	3%	5%	5%	5%
Use biomaterials	8%	10%	8%	6%	6%	6%	10%	7%	6%	7%
Waste reduction	9%	14%	7%	10%	7%	9%	8%	7%	9%	9%
Reuse waste within own productive process	4%	4%	2%	4%	4%	5%	7%	5%	6%	4%
Deliver waste to other firms	8%	6%	6%	9%	5%	4%	10%	4%	5%	7%

Figure 17: Percentage of responding companies that state they adopt the various types of CI by province (BO: Bologna; FE: Ferrara; FC: Forlì-Cesena; MO: Modena; PC: Piacenza; PR: Parma; RA: Ravenna; RE: Reggio Emilia; RN: Rimini).
Source: Antonioli et al. (2022, p. 67).

[40] In addition, studies have shown that "geographical proximity amongst the involved stakeholders is an enabler for IS [industrial symbiosis] [...]. The involvement of production districts is useful in order to have several companies pertaining to a single value chain and geographically close, but it is really difficult without a managing authority of reference. Also, the involvement of industrial associations, able to aggregate large numbers of companies, is a success factor in order to create exchange networks and try to influence policies. More in general, the Emilia- Romagna experiences confirm the important role of coordinating organizations as enablers for IS experiences, extensively covered in the IS literature [...]" (Mencherini et al. (2020, p. 130).

[41] According to GreenER "[a]bout 6,500 companies have been identified as belonging to the green economy in 2022, with a turnover of over 90 billion euro and 300,000 employees" Emilia-Romagna Region (2023, p. 21). In a survey conducted by GreenER (2022, p. 8), nearly 42% of the responding companies reported providing green products and/or services.

As mentioned above, the industrial system of RER “absorbs about one third (33%) of final energy consumption” (Ministero dell'Università e della Ricerca, 2022, p. 2), and nearly 50% of the electricity (see Figure 18). Therefore, reducing energy consumption in industrial processes while simultaneously transforming the **energy sector** by substituting fossil resources with renewable energies is regarded as essential for transforming multiple sectors—industry, transport and mobility—simultaneously.

In this regard, Emilia-Romagna decided in its regional development strategy on the ambitious goal to transition to 100% renewable energy[42] until 2035 (Emilia-Romagna Region, 2020b, p. 81). However, the great renewable energy (RE) potential of Emilia-Romagna, especially for PV and wind energy, has so far only been utilized to a very limited extent (see Chapter 3.2.3). Only biomass[43] and PV are contributing significant shares to electricity generation (see Figure 19). Despite Emilia-Romagna's significant potential for energy generation based on biomass due to its strong agriculture sector[44], the sustainability of this energy source is controversially discussed (Marongiu et al., 2022; Tamburini et al., 2020; Valentini, 2020). In the case of Emilia-Romagna this is partially related to the emissions generated in agriculture[45], which have an additional negative effect on the alarming state of the **air quality** in the Po region. However, in this regard, the transport and mobility sector is even more problematic and requires a fundamental transition.

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[42] Share of energy from renewable sources in gross final energy consumption.

[43] As a share of the thermoelectric electricty generation displayed in Figure 19. For an overview of the different RE sources see: https://www.terna.it/en/electric-system/statistical-data-forecast/evolution-electricity-market/production-renewable-sources

[44] According to a study from Valentini (2020), “[t]he potential development of the biogas/biomethane value chain in Italy is extremely high in the short/medium term: 8-10 billion m3 within the 2030 equal to the 11%-13% of the current gas consumption and great than the domestic production (Source CIB – Biogas Italian Consortium). In Emilia-Romagna, the availability of waste biomass is considerable (more than 17.000.000 t/year manure CRPA, 2015), the natural gas grid is widespread, and an industrial excellence is present in the field of components for natural gas fuelling station. Thus, the potential for the development of a biomethane value chain is high” (ibid., p.69).

[45] A study by Marongiu et al. (2022) shows, that “almost the total amount of primary emissions of NH3 [97%] are accounted by agriculture” (ibid., p.72).

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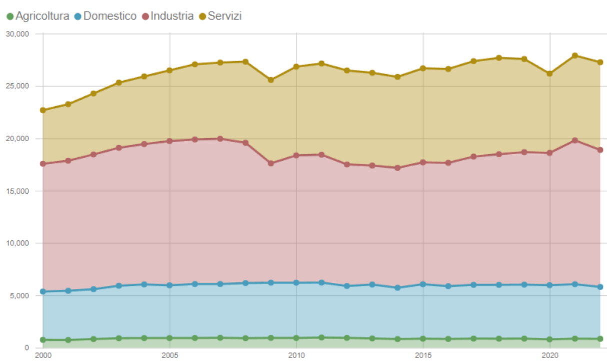

Figure 18: Development of the share of electricity consumption per sector (agriculture, residential, industries, services) in Emilia-Romagna (GWh) between 2000 and 2022. Source: www.terna.it[46]

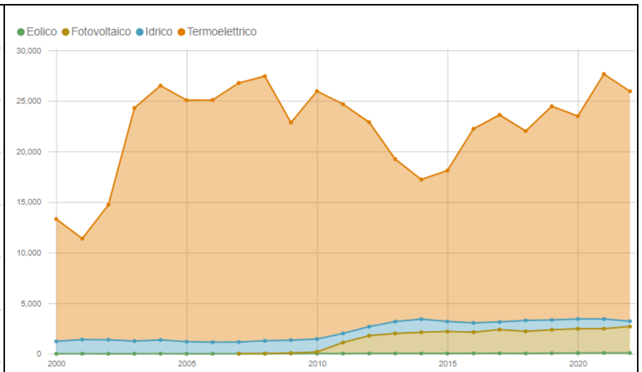

Figure 19: Development of electricity generation (GWh) by source (wind, PV, hydrogen power, thermoelectric) in Emilia-Romagna between 2000 and 2022.
Source: www.terna.it[47]

The **transport and mobility sector** is crucial for all economic activities and strongly related to the competitiveness and innovation capacity of a region (Ng et al., 2019; Palei, 2015; Skorobogatova & Kuzmina-Merlino, 2017). In this context, Emilia-Romagna has quite a dense road and railway system[48] and scores in comparison to the three other TRANSFORMER TSL regions above-average in their road transport performance.[49] A problematic aspect in context of sustainability and climate neutrality is the extremely high motorisation rate in Emilia-Romagna, which is among the highest in the EU (see Figure 20).

46 https://www.terna.it/en/electric-system/statistical-data-forecast/evolution-electricity-market/consumption-electricity-sector
47 https://www.terna.it/en/electric-system/statistical-data-forecast/evolution-electricity-market/production-electricity-source
48 Emilia-Romagna has "1,400 km of railway network and 258 stations" Emilia-Romagna Region (2024b).
49 Population accessible within 1h30 by road in a neighbourhood within a 120 km radius. Please note that accessibility is only one of many indicators that need to be considered for assessing the transport performance (e.g., safety, comfort, costs for mobility, etc.). However, due to limited (and comparable) data availability, we focus on this frequently used indicator.

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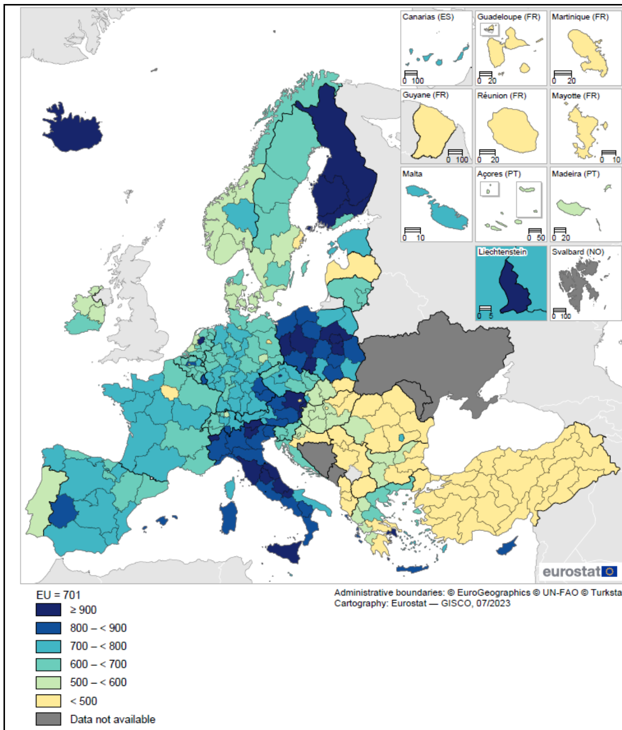

Figure 20: Motorisation rate, 2021 (number of vehicles per 1 000 inhabitants, by NUTS 2 regions). Source: EUROSTAT.[50]

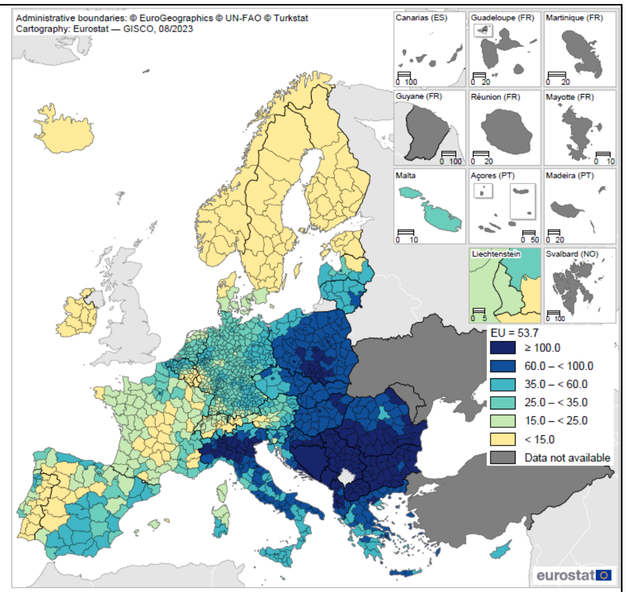

Figure 21: Premature deaths attributed to exposure to fine particulate matter (PM2.5), 2020 (per 100 000 inhabitants, by NUTS 3 regions). Source (slightly adapted): European Environment Agency (EEA); retrieved from EUROSTAT.[51]

This high motorisation rate is strongly reflected in the poor air quality of Emilia-Romagna (see Figure 23). Within the transport system, road transport alone accounts for 48% of the NOx emissions, 29% of the CO emissions and to 19% of fine particulate matter (PM10) in the Po basin (Marongiu et al., 2022, p. 74).[52] This poor air quality has a direct effect on life expectancy: According to an analysis by the EEA, Emilia-Romagna has one of the highest shares of premature deaths attributed to exposure to fine particulate matter (see Figure 21).

[50] With 880 vehicles per 1 000 inhabitants (by NUTS 2 region), Emilia-Romagna has one of the highest values in the EU and the highest value of the four TRANSFORMER TSLs.
Source: https://ec.europa.eu/eurostat/documents/7116161/17557903/1101EN.pdf Statitics available on EUROSTAT (online data codes: tran_r_vehst, demo_r_d2jan)

[51] https://ec.europa.eu/eurostat/documents/7116161/17557903/1204EN.pdf

[52] For detailed statistics on road transport emission see Marongiu et al. (2022, p. 76) and for the whole transport sector (including air, water and rail): Emilia-Romagna Region (2021b).

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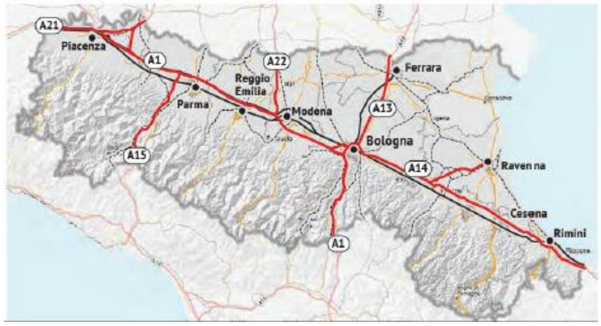

Figure 22: Motorways and highways in Emilia-Romagna Region. Source: Emilia-Romagna Region (2021a, p. 9)

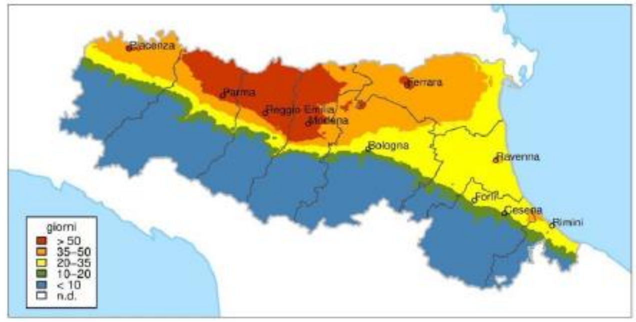

Figure 23: Number of days exceeding the average mean of 50ug/m3 (2017).
Source: Emilia-Romagna Region (2021a, p. 11)

The regional authorities have clearly identified the necessity of improving the air quality by implementing a "Regional Integrated Plan for Air Quality" (PAIR) (ART-ER, 2024)[53] that specifically identifies the necessity of fundamentally transforming the transportation system to **decrease its negative environmental impact** (ibid.). However, simultaneously a cost-efficient and high-performance transport infrastructure needs to be ensured to support economic activities and maintaining the competitiveness of the region. The strategy for achieving this is to develop "an integrated mobility system, highlighting the key role of collective transport, sustainable mobility, development of technological innovation, and functionally organized traffic" (Emilia-Romagna Region, 2021a, p. 12). According to the "Regional Integrated Transport Plan" (PRIT), specific measures are focussing on enhancing the railway infrastructure and public transport system, the construction of cycle infrastructure as well as supporting the development of electric mobility infrastructure (Emilia-Romagna Region, 2021b).

However, multiple studies show (Emilia-Romagna Region, 2021a; Hrelja et al., 2013; Rau & Scheiner, 2020; Ruhrort, 2023) that transforming the mobility system bears a high potential for conflicts as it implies competition for limited space and exclusion of usage (e.g., parking spots versus bicycle lanes). As the transport system directly affects not only economic activities, but also the daily life of all citizens, this process has to be carefully managed. Including citizens in this transition is therefore necessary to ensure an inclusive, just and socially accepted development. The overarching goals of the regional plans are translated on the local level into "Sustainable Urban Mobility Plans (SUMP)", which consider the specific local context, for example regarding the specific requirements for cycle infrastructure in the city of Bologna (Metropolitan City of Bologna, 2018).

Another crucial aspect that needs to be considered in this context is the adaptation of infrastructure to climate change: the flood in Emilia-Romagna in 2023 highlighted the vulnerability of the infrastructure: "[M]ore than 1,400 roads [were] affected by flooding or landslides, result[ing] in damage quantified to

[53] As described in ART-ER (2022, 2024), the Regional Integrated Plan for air quality (PAIR) specifically aims at involving the municipalities of Emilia-Romagna region and including citizen´s opinion in developing inclusive and socially accepted solutions (ART-ER, 2022).

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approximately 1.8 billion Euro” (Emilia-Romagna Region, 2024b, p. 146).[54] As these extreme events are expected to occur more frequently and intensely due to climate change (see introduction of Chapter 3), sustainable mobility solutions also need to be designed in a more resilient way. In the next section, we will analyse the overall transition potentials of the region for becoming climate neutral, with a particular focus on transforming the key sector for achieving a cross-sectorial transformation: the energy system.

3.2.3 Assessing the transition potentials from a socio-economic and ecological perspective

As mentioned in Chapter 2.1, regional transition needs and potentials are closely intertwined, each influencing the other and manifesting across the three dimensions of sustainability. Assessing the transition potentials of a region for becoming climate neutral therefore requires considering social, economic and ecological/ environmental aspects. In this chapter, we will conduct this analysis focussing on the evaluation of different composite indices and selected indicators (see Figure 1).[55] The results will then be summarised in a regional SWOT analysis.

Regarding the potential for transition, the **economic performance,** especially the **competitiveness and innovation capacity** are of crucial importance. In this regard, Emilia-Romagna scores comparatively high (see Table 22 and Table 23).[56] This applies especially to indicators referring to macroeconomic statistics (e.g., disposable income per capita, and GDP per capita, see Figure 25): As mentioned above, Emilia-Romagna is one of the wealthiest of the 20 regions in Italy. Even though the Covid-19 pandemic had severe effects on the economy of Emilia-Romagna (Emilia-Romagna Region, 2024b), the rise of GDP per capita from 31,500 € in 2021 to 41,600 € in 2022 indicates a strong economic recovery.[57] This applies also to the labour market, which is characterised by a comparatively high labour productivity and low unemployment rate (see Figure 26).

[54] These numbers are not reflected in the statistics of the Regional Competitiveness Index and must be considered while interpreting the data. However, according to Emilia-Romagna Region (2024b) it was estimated “that in September 2023 the railway network will be operational again. For the road network, after the motorway functionality has been restored, the road links are currently estimated to be functioning by December 2023 at 80% for state and provincial ones and at 60% for municipal ones” (ibid., p. 146).

[55] Please note that these composite indicators often refer to the same data (e.g., labor market statistics, GDP, perceived corruption etc.). In this section, selected indicators will be discussed for analyzing competitiveness, innovation capacity, quality of government, and social progress that reflect these topics most accurately. For an explanation of these compositie indicators, see Table 27 to Table 30.

[56] This does not apply to the overall score of the RCI, in which Emilia-Romagna only averages (see Table 22). This shows the limitations of composite indices, which weigh a set of indicators (e.g., GDP versus transport performance), which might distort the actual competitiveness. In addition, the overall competitiveness is not necessarily reflected in key sectors of the economy, which can be, in contrast to the rest of the regional economy, highly competitive.

[57] In the following sections, mostly data from 2021 will be used as most of the GHG emission data and data on economic sectors (GVA, employment) only exist until that year. In all the following analyses, it has to be considered that after the Covid-19 pandemic, an economic recovery has taken place (see Table 7 for the strongly increased GDP in all regions). Additionally, the flood in 2023 in Emilia-Romagna (see below) had severe effects on the economy, especially in the agriculture sector but also in the transport & mobility sector. These sectors have not fully recovered yet Emilia-Romagna Region (2024b).

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Emilia-Romagna´s economy is not only highly competitive (see section about manufacturing and circular economy above), but also has a very strong "innovative ecosystem", characterised by the highest share of R&D expenditures in the business sector[58], as well as innovation expenditures per person employed in innovative SMEs [59] of all the four TSLs. This is clearly reflected in the high number of international patent applications[60]. However, for an innovative region like Emilia-Romagna, the share of the population (see Figure 24) as well as the share of employees with a higher education degree (ISCED 5-6) is comparatively low. As "[e]ducation, and in particular higher education, is usually seen as an important driver of innovation […] this low ranking of Emilia-Romagna has to be addressed if the region is to fulfil its potential for […] innovation" (ESIC - European Service Innovation Centre, 2013, p. 2).[61]

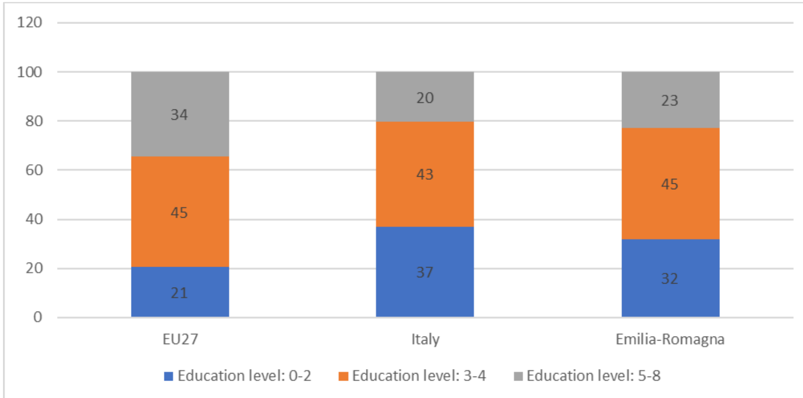

Figure 24: Comparison of education levels in the EU, Italy and Emilia-Romagna (percentage of people from 25 to 64 years).
Own compilation based on data from EUROSTAT.

58 All R&D expenditures in the business sector (BERD).
59 Sum of total innovation expenditure by SMEs in Purchasing Power Standards (PPS). Denominator: Total employment in innovative SMEs.
60 Number of patents applied for at the European Patent Office (EPO), by year of filing. The regional distribution of the patent applications is assigned according to the address of the inventor.
61 Please note, that even though this quote is from a study conducted in 2013, this overall ranking has not significantly changed: According to the Regional competitiveness index, Emilia-Romagna scores in comparison to the other two TSL regions (Western Macedonia and Lower Silesia) very low. Only the Ruhr Area has a lower score (see Chapter 3.4).

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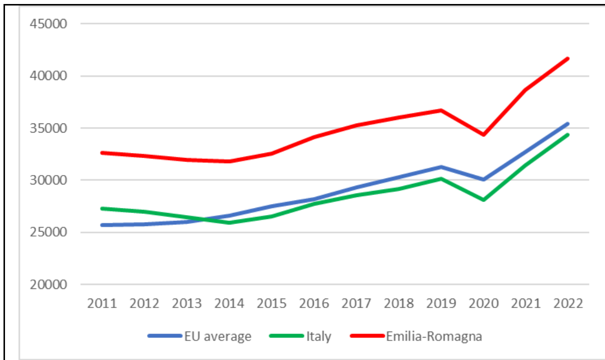

Figure 25: GDP (pps) per capita (in €) of the EU (NUTS 2 regions), Italy and Emilia-Romagna. Own compilation based on data from EUROSTAT.

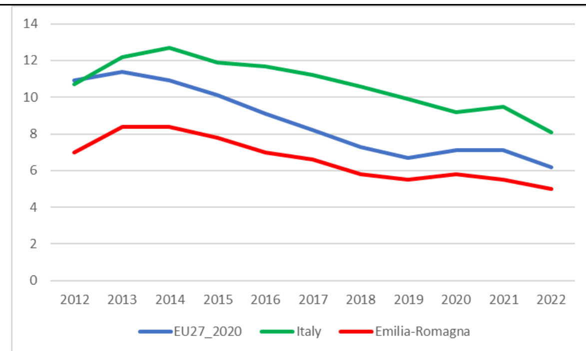

Figure 26: Unemployment rates (people aged 15 to 74 years)[62] for the EU, Italy and Emilia-Romagna. Own compilation based on data from EUROSTAT.

As mentioned above, economic aspects represent only one dimension of sustainability. Economic factors are closely intertwined with other socio-political and environmental factors that influence transition potential. Regarding the **social and political** dimensions of transition potential, the European Social Progress index provides a useful basis for a detailed assessment. In this regard, Emilia-Romagna scores – with the exception of advanced education – above average or even the highest for most of the indicators (see Table 24). The "at-risk-of-poverty rate", which is one of the most important indicators for assessing social disparities, is with 7.3% (EUROSTAT) the lowest of all four TRANSFORMER TSLs.[63] However, as the GDP per capita of the NUTS 3 regions in Emilia-Romagna shows, there are strong disparities regarding the economic situation of the citizens within the region (see Figure 27).

[62] The source for the regional labour market information down to NUTS level 2 is the EU Labour Force Survey (EU-LFS). This is a quarterly household sample survey conducted in all Member States of the EU, the United Kingdom, EFTA and Candidate countries. Please note that we have observed discrepancies between these EUROSTAT statistics and the data provided by the national statistical offices.

[63] Lower Silesia scores second best (9%), whereas the Ruhr Area (21.6%) and Western Macedonia have significantly worse values. Sources: EUROSTAT and for the Ruhr Area: Statistikportal Ruhr : https://statistikportal.ruhr/

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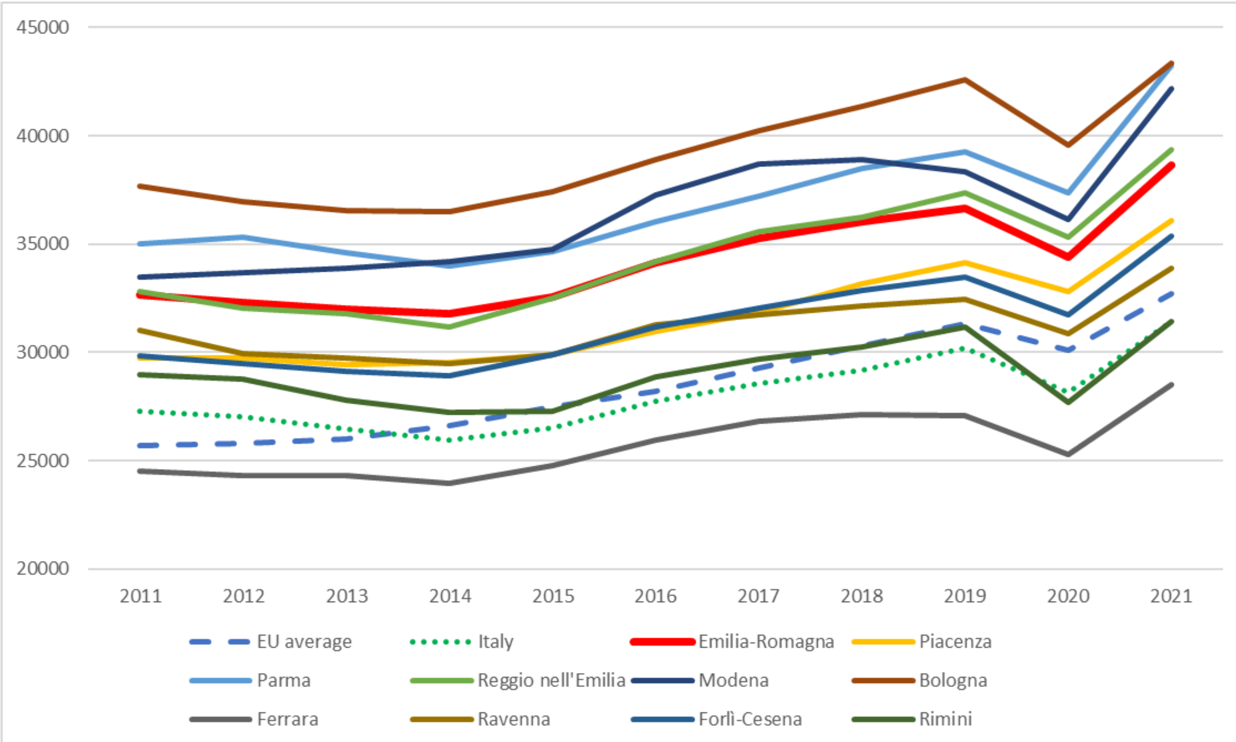

Figure 27: GDP (pps) per capita (in €) of the EU (NUTS 2 regions), Italy, Emilia-Romagna and its NUTS3 regions. Own compilation based on data from EUROSTAT.

In the context of the social and **political dimensions** of transition, the results from the European Quality of Government Index (see Table 25) indicate an important limiting factor for the transition potential: regarding the assessment by the citizens of Emilia-Romagna about the quality[64], impartiality[65] as well as the corruption in the provision of public services[66], the region scores in comparison to the NUTS 2 regions in the Ruhr Area comparatively low. However, this result has to be carefully interpreted as it partially reflects the situation that was still characterised by the uncertainty due to the Covid-19 pandemic (Charron et al., 2022; Toshkov et al., 2022). Nevertheless, it still reflects an alarming trend in Emilia-Romagna that shows a "lack of interest (64.9%) and lack of trust in the political system (25.5%)" (ISTAT,

64 Questions from the questionnaire: How would you rate the quality of [from very poor to excellent]… 1) ..public education in your area? 2) …the public health care system in your area? 3) …the police force in your area? (Charron et al., 2022, p. 12). For complete questionnaire see (Charron et al., 2022).

65 Questions from the questionnaire [from strongly disagree to strongly agree]: 1) Certain people are given special advantages in the public health care system 2) The police force gives special advantages to certain people in my area. 3) All citizens are treated equally [from agree to disagree]… A) …in the public education system in my area. B) …the public health care system in my area. C) …by the police force in my area. 4) In the area where I live, elections are conducted freely and fairly. (Charron et al., 2022, p. 13). For complete questionnaire see (Charron et al., 2022).

66 Selected questions from the questionnaire: Corruption is prevalent in [from strongly disagree to strongly agree]… 1) my area's local public school system. 2) …in the public health care system in my area. 3) …in the police force in my area. 4) People in my area must use some form of corruption to just to get some basic public services. 5) Corruption in my area is used to get access to special unfair privileges and wealth. […] (Charron et al., 2022, pp. 13-14). For complete questionnaire see (Charron et al., 2022).

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2020, p. 1).[67] This is problematic, as the fundamental transition of the socio-economic system to becoming climate neutral requires a high level of trust, acceptance, and support among all stakeholders (Latusek & Cook, 2012; Uslaner & Badescu, 2004).

In this context, a survey from the European Investment Bank in 2023/24 shows[68] that “economic and financial" aspects (92%), especially “increased cost of living” (72%), are perceived by citizens (n=74) of Emilia-Romagna as bigger challenges than “climate change” (45%) (EIB 2024).[69] This is also reflected in the dominant opinions (63%) that the “government should address climate change *without* affecting the personal budget”[70], and that “the transition to a low carbon economy can only happen if inequalities are addressed at the same time” (66%).[71] Regarding the employment opportunities due to this transition, a majority (60%) expects that the “climate change measures will create more jobs than they will destroy existing ones” (EIB 2024).[72]

Finally, for gaining a comprehensive understanding of the region's transition potentials, it is essential to consider not only its economic and socio-political aspects but also its **ecological and environmental dimensions of sustainability**. In this regard, we have to refine the focus, as this broad perspective would require analysing the availability and economically feasible (sustainable) utilisation of natural resources alongside assessing the current state of ecological processes for different sectors, such as agriculture, fishing, forestry, mining, water and waste management, as well as tourism. Therefore, the focus will be on the region’s pivotal topic: the **potential for the development of renewable energy**, which is a prerequisite for transforming the energy as well as the transport system.

As mentioned above, the transport sector contributes to a very large degree to poor air quality and is directly related to a high share of premature deaths (due to exposure to fine particulate matter; see Chapter 3.2.2 for figures and statistics). However, due to the importance of the transport sector for economic activities and competitiveness of a region, the transition towards a more sustainable transport system has to be carefully managed (Ng et al., 2019; Prus & Sikora, 2021). This is particularly important as

[67] However, this phenomenon of a lack of trust in political institutions can be regarded in many European regions and different contexts. This is, for example, shown in a study from Lalot et al. (2022) about the relation of trust in context of the Covid-19 pandemic, by Lamb and Minx (2020) in context of national climate policies, or by Guiso et al. (2024) in context of economic insecurity.

[68] Question: “What are the three biggest challenges that people in your country are currently facing?”Source: EIB (2024): https://www.eib.org/attachments/survey/eib-climate-survey-2023-2024-dataset-all-countries-cop28.xlsx (Excel sheet: Italy). The references are listed in the chapter “Data sources”.

[69] The results of these surveys additionally show the shift in perceived challenges. In an earlier survey from the EIB (2020), “economic and financial" aspects (85%), especially “unemployment” (61%), have been perceived by citizens (n=147) of Emilia-Romagna as bigger challenges than “climate change” (46%). Source: EIB (2020): https://www.eib.org/attachments/survey/climate-survey-citizens-perception-climate-change-impact-all-data-en.xlsx (Excel sheet: Italy). The references are listed in the Chapter “Data sources”.

[70] Question: “Would you say that… […] Your government should address climate change without affecting your personal budget”. Source EIB (2024).

[71] Question: “Would you say that… […] The transition to a low carbon economy can only happen if inequalities are addressed at the same time. Source EIB (2024).

[72] Question: What impact do you think the measures adopted by your country to fight climate change and protect the environment will have? Answer: They will create more jobs than they will destroy existing ones (60%). Source: EIB (2024).

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the mobility system bears a high potential for conflicts, involving competition for limited spaces and exclusion of usage (Emilia-Romagna Region, 2021a; Hrelja et al., 2013; Rau & Scheiner, 2020; Ruhrort, 2023). The regional authorities have, therefore, developed a set of priorities that is focussing on enhancing the railway infrastructure and public transport system, the construction of cycle infrastructure as well as supporting the development of electric mobility infrastructure (Emilia-Romagna Region, 2021b).

In this regard, a positive development in achieving a more sustainable transport and mobility system are the large investments in the railway network of the Emilia-Romagna Region[73], "resulting in an 80% increase in the passengers carried in 8 years" (Emilia-Romagna Region, 2024b, p. 155). In addition, the regional authorities have implemented policies that aim at supporting and promoting local public transport, as well as electric mobility. Concerning the advancement of cycling, as the most sustainable form of mobility next to walking (Bertini et al., 2023; Bucchiarone et al., 2022), there is a plan to construct more than 1,000 km of "cycle paths in urban areas and along the routes identified as national, regional and local cycle routes" (Emilia-Romagna Region, 2024b, p. 174). This will not only improve the safety and convenience of commuting, but it also creates competitive options for more sustainable Urban Freight Transport (UFT) and Last Mile Logistics (LML) via cargo bikes (ALICE, Alliance for Logistics Innovation through Collaboration in Europe, 2015; Gonzalez et al., 2023).

In addition, policies have been implemented for supporting the aforementioned electrification of the transport and mobility sector by installing "2,500 electric charging points by 2025, also distributed in the weakest areas [as well as promoting] electric charging points for private mobility" (Emilia-Romagna Region, 2024b, p. 174). If the needed electricity is generated by renewable energies, this will not only support the improvement of air quality in urban areas significantly, but it will also create incentives for the automotive industry to accelerate the transformation by developing more sustainable means of transportation (see Chapter 3.2.2).

However, as mentioned above, Emilia-Romagna has been utilizing its great potential for the development of renewable energies (Ruiz et al., 2019) only to a very limited extent so far (for an overview of onshore wind power potential in the EU see Figure 28 and for solar power potential Figure 29).[74] Even though RE is supposed to replace fossil-based energy production completely until 2035 (Emilia-Romagna Region, 2020b, p. 81), only biomass and PV are contributing significant shares to electricity generation so far (for statistics and figures see Chapter 3.2.2). In this context, PV is expected to play even a greater role, as it is not only very cost-efficient and (in areas with sufficient solar potential) already highly competitive (Vakili et al., 2022), but it also has a low potential for conflicts. This is particularly the case for rooftop PV (Palladino & Calabrese, 2023). However, even large ground-mounted PV systems, which are competing

[73] According to Emilia-Romagna Region (2024b, p. 155) , the region has 1,400 km of railway network and 258 stations.
[74] Ruiz et al. (2019) give an overview of solar, wind and biomass potential for energy generation on a NUTS 2 level. The corresponding datasets from ENSPRESO, "an EU-28 wide, open dataset for energy models on renewable energy potentials, at national (NUTS0) and regional levels (NUTS2) for the 2010-2050 period" are available via the following URL: https://data.jrc.ec.europa.eu/collection/id-00138

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with agriculture for limited space (Sacchelli et al., 2016), have in comparison to wind power a comparatively low conflict potential (Leiren et al., 2020; Meister, 2018). Even though Emilia-Romagna has with its strong agriculture sector a great potential for energy generation based on biomass[75], the sustainability of this energy source is controversially discussed (Marongiu et al., 2022; Tamburini et al., 2020; Valentini, 2020). As mentioned above, this is in the case of Emilia-Romagna partially related to the emissions generated in agriculture that have an additional negative effect on the alarming state of the **air quality** in the Po region. However, energy generation from (agricultural) waste, particularly, exhibits a high potential for sustainable energy production when compared to other methods of energy generation (ibid.). This would be a necessity for fostering a (more) sustainable electricity-based transport and mobility system.

[75] According to a study from Valentini (2020), "[t]he potential development of the biogas/biomethane value chain in Italy is extremely high in the short/medium term: 8-10 billion m3 within the 2030 equal to the 11%-13% of the current gas consumption and great than the domestic production (Source CIB – Biogas Italian Consortium). In Emilia-Romagna, the availability of waste biomass is considerable (more than 17.000.000 t/year manure CRPA, 2015), the natural gas grid is widespread, and an industrial excellence is present in the field of components for natural gas fuelling station. Thus, the potential for the development of a biomethane value chain is high" (ibid., p.69).

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Before we briefly portray the related Pilot use case in Chapter 3.2.4, we summarise the transition needs and potentials of Emilia-Romagna in a regional SWOT analysis.

Table 9: Regional SWOT analysis as a summary of the transition needs and potentials of becoming climate neutral in context of the TSL approach. Source: own compilation.[76]

Strength (helpful internal factors)	**Weaknesses** (harmful internal factors)
• High GDP (per capita) and economic resources for transition • High competitiveness and innovation capacity • Strong regional governance: collaboration between regional authority and municipalities ("vertical" interactions and coordination) • Diverse economy with strong development towards a circular economy; competitive sectors in manufacturing, agriculture, and services • Dense transport infrastructure and favourable geographic location • Strong political support for a transition towards climate neutrality (sustainable mobility, RE development, promotion of circular economy)	• Economic dependence on traditional industries with strong veto-players (e.g., automotive) • Comparatively low trust in instiutions (EQI) • Unstructured coordination between the various regional departments and the several regional plans ("horizontal" interactions and coordination)
Opportunities (helpful external factors)	**Threats (external)** (harmful external factors)
• EU funding for innovative actions (circular economy, sustainable mobility, ecological agriculture) • EU and national targets for RE development • Increasing demand for sustainable tourism as well as sustainably produced products and goods (e.g., agricultural products)	• Comparatively high vulnerability to climate change impacts (coastal and river floodings) • Uncertainty about *national* legislation (regarding climate action) • Global economic fluctuations (export-oriented regional economy)

[76] This regional SWOT analysis is based on a comprehensive document analysis and two workshops conducted in the realm of WP2 and WP3.

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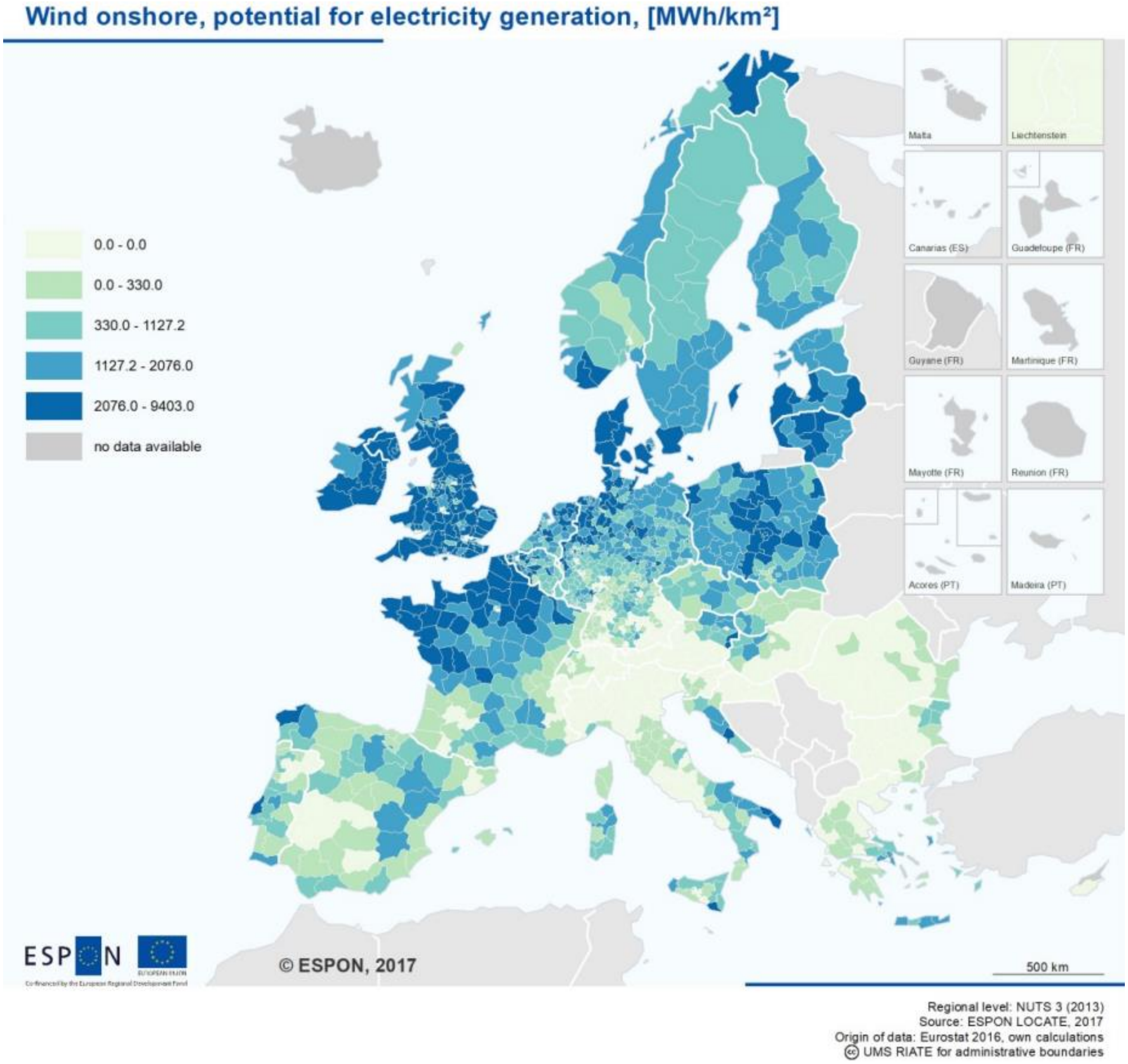

Figure 28: Wind onshore, potential for electricity generation. Source: Schremmer et al. (2018, p. 17).

Disclaimer: The designations used and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the map creators or publishers concerning the legal status of any country, territory, city, or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

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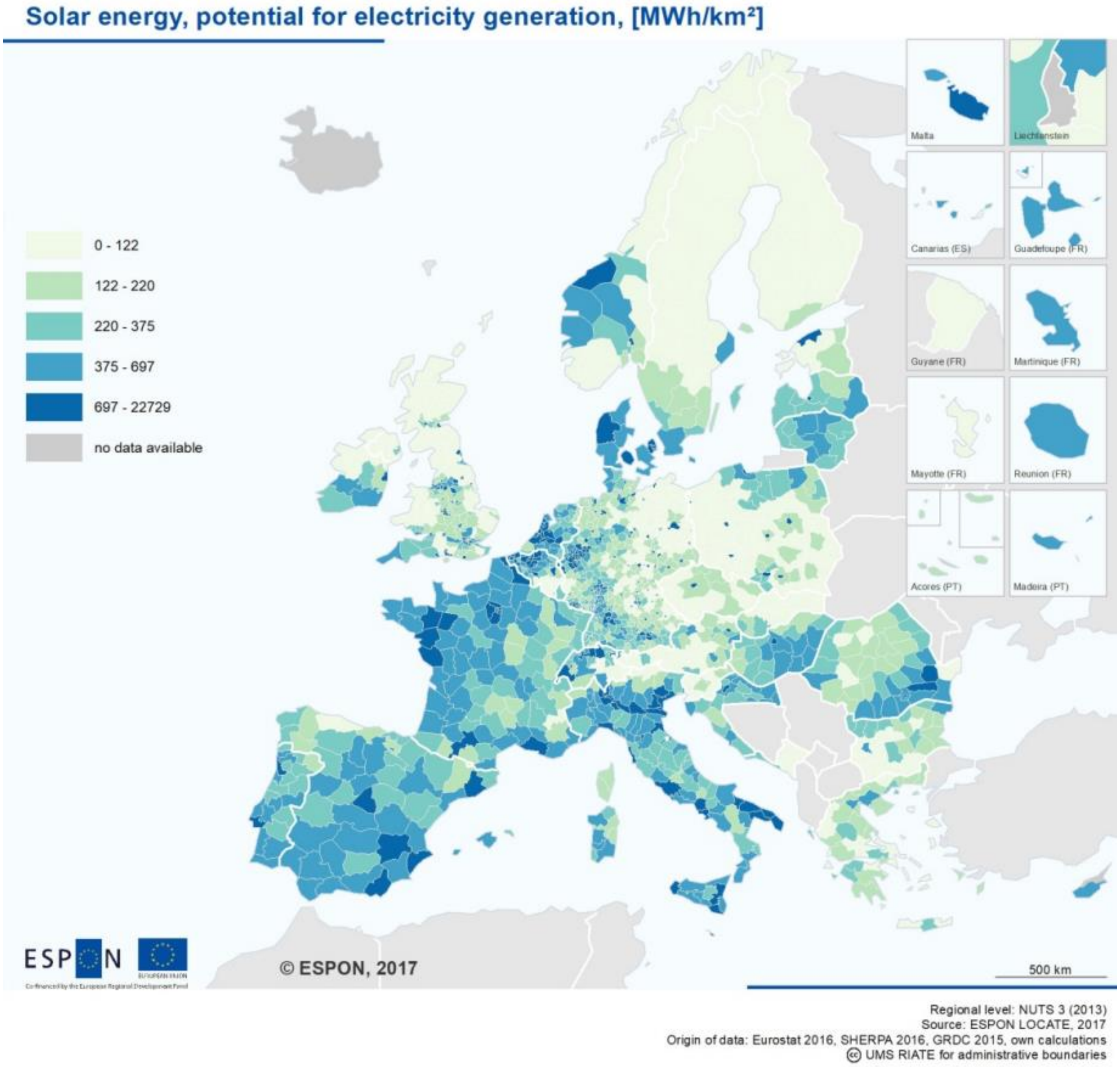

Figure 29: Solar energy, potential for electricity generation. Source: Schremmer et al. (2018, p. 19).

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3.2.4 TSL vision and Pilot use cases

As described in the chapter about the methodological approach (Chapter 3), the assessment of transition needs and potentials, as well as the analyses of the political framework, has been a continuous and iterative process conducted in tandem with the project partners (WP2, WP3, WP4, WP5) and has been the guiding aspect in developing a vision for the TSL, coalition building (Deliverable 3.1), and identifying the most important Pilot use cases (Deliverable 3.2). A summary of the vision and Pilot use cases is included in Table 10. The continuous exchange of information between the WPs of the TRANSFORMER project has been vital for developing these case studies as well as the Action plans (Deliverable 3.3) for the specific Pilot use cases. The discussion of strategies for long-term implementation is based on this cooperation and will be included in Chapter 3.6 and Deliverable 3.3.

Table 10: Emilia-Romagna: The vison and Pilot use cases at a glance. Source: summary of the descriptions included in Deliverables 3.1 and 3.2.

The vision: The **Emilia-Romagna regional authority** has set an ambitious **target to achieve carbon neutrality** by 2050, and has formulated a comprehensive plan encompassing **three key pillars: energy transition, sustainable mobility, and circular economy**. In the realm of **energy transition**, the region is heavily investing in renewables, aiming for a 50% share in its energy mix by 2030, while also prioritizing energy efficiency measures in buildings and industry. The focus on **sustainable mobility** involves promoting public transportation, bicycles, and electric vehicles, coupled with investments in charging infrastructure. Efforts to reduce emissions from freight transport include endorsing intermodal transportation and cleaner fuels. Emilia-Romagna is also championing a **circular economy**, investing in waste reduction and recycling facilities, and advocating sustainable production and consumption practices. To expedite the transition, a **Transition Super Lab** at the regional level has been implemented, serving as a framework for collaborative initiatives. Focussing on energy and mobility topics, the **vision development** process has identified **three interconnected goals: promoting cycle mobility, enhancing mobility management to reduce traffic congestion, and optimizing the use of electric vehicles and charging infrastructure in urban centres**. The **pathways** to realizing this vision involve incorporating cycle mobility guidelines into future tenders and funding opportunities, coordinating mobility management activities with local managers, and creating a centralized regional database for electric vehicle charging stations. These initiatives are crucial not only for achieving sustainable mobility but also for fostering broader transformations in sectors like industry and tourism. **The Pilot use cases**: **Pilot use case 1:** *Development of a regional cycling mobility cartography and network, new cyclability guidelines and modal shift survey* Pilot use case 1 aims to standardize cycle mobility indications, collaborating with RER's cartography department to create a practical map for cyclists. These indications, incorporated into tenders and funding opportunities from 2023 onward, will inform the creation of Emilia-Romagna's cycle paths. Initially focusing on local accessibility and safety, the goal is to establish a regional cycle mobility standard applicable across municipalities and potentially nationally. This initiative aligns with RER's sustainable mobility policies, addressing environmental concerns, transport safety, and quality of life. Stakeholder involvement is crucial to develop a comprehensive cycle-pedestrian mobility system emphasizing accessibility, quality, recognition, and safety. RER also supports initiatives promoting cycling culture to encourage bicycle use and maximize the regional network's effectiveness. The final aim is also to create a permanent working group composed by all quadruple helix stakeholders on Emilia-Romagna regional cycle cartography and cycle mobility. **Pilot use case 2:** *Promotion of mobility management coordination activities to be carried out together with the area mobility managers and company mobility managers* Pilot use case 2 focuses on implementing mobility management strategies to address urban transport issues like congestion and air quality. It aims to promote sustainable travel behaviour through coordinated efforts with area and company mobility

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managers. This involves initiatives to improve home-to-work and home-to-school mobility, particularly for passengers with reduced mobility and those in rural areas. RER adopts inclusive policies benefiting marginalized groups such as children, immigrants, elderly, and people with disabilities. For example, students from low-income families can receive free bus travel cards. The goal is to enhance accessibility, reduce energy consumption, and create a more sustainable transportation system. The final aim is to create a permanent working group on Emilia-Romagna mobility management composed by representatives from municipalities, companies and university involving area, company and university mobility managers.

Pilot use case 3: *Creation of a centralized database and network at the regional level including all data on electric vehicle (EV) charging stations*

Pilot use case 3 is about the creation of a centralized database at the regional level including all data on electric vehicle charging stations (e.g., GPS coordinates of the charging stations, number of recharges, quantity of energy supplied every hour) in order to optimize the existing infrastructure and improve the use of electric Vehicles (EVs) as an important sustainable mobility solution. The final aim is to create a permanent working group on EV mobility to increase collaboration between municipalities, national energy manager (GSE: Gestore Servizi Energetici), EV charging stations companies, university and civil society.

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3.3 Lower Silesia

As described above, the case study will begin by providing a brief **overview of the region** (3.3.1) to "[d]efine the boundaries of the system in terms of geography" (Geus et al., 2022). Based on this, the **transition needs to achieve climate neutrality** will be assessed, focusing on the most significant economic sectors contributing to climate change (3.3.2). The identification of these transition needs will allow us to narrow down the otherwise too complex analysis of the **socio-economic and ecological transition potentials** of the region. These closely intertwined transition needs and potentials will be then summarised **in form of a regional SWOT analysis** (3.3.3). These identified transition needs and potentials guided the **TSL vision and Pilot use cases**, which will be briefly portrayed in Chapter 3.3.4. The results of the chapters about the four TSLs (Chapters 3.2-3.5) will then be incorporated in Chapter 3.6 in an overall discussion **about strategies for the long-term implementation of TSLs**.

3.3.1 Overview of the TSL region

Lower Silesia is one of the 16 provinces (voivodeships) of Poland, situated in the southwestern part of the country. It covers an area of nearly 20,000 km^2 and shares borders with the voivodeships of Lubuskie, Greater Poland, and Opolskie to the north and east, and with the Czech Republic and Germany to the south and west. Lower Silesia had a population of nearly 2,846,000 in 2022 (see Table 7) and is divided into 30 counties (powiats), of which four are city counties (see Figure 30 and Figure 31 for the maps and Table 11 for a brief overview of the political system in Lower Silesia).

Figure 30: Location of Lower Silesian Voivodeship in Poland. Source: Wikipedia[77]

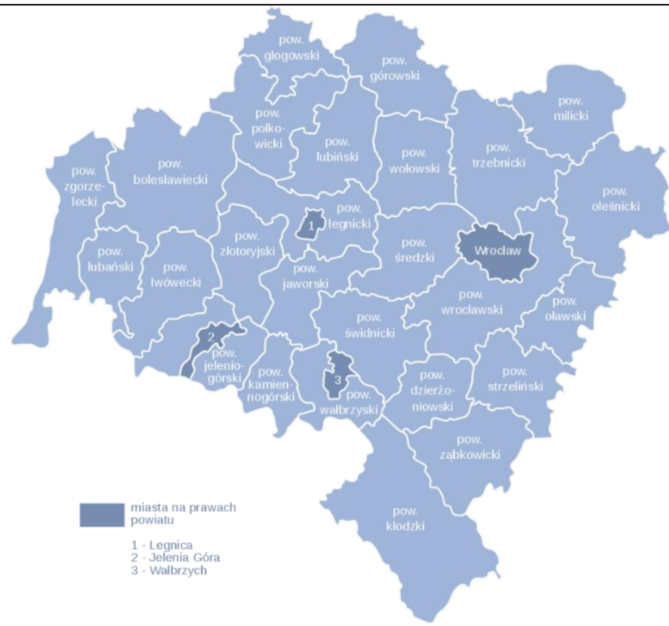

Figure 31: The counties of Lower Silesia. Source: Wikipedia[78]

[77] https://en.wikipedia.org/wiki/Lower_Silesian_Voivodeship#/media/File:Lower_Silesian_in_Poland_(+rivers).svg
[78] https://en.wikipedia.org/wiki/Lower_Silesian_Voivodeship#/media/File:Woj_dolnoslaskie_adm.svg

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The biggest city and the capital of the region is Wroclaw. With a GDP (pps) per capita of 31,600 € in 2022, Lower Silesia ranks second highest of all the provinces in Poland (EUROSTAT), however, with strong disparities among the counties within the region (Rynio & Zakrzewska-Półtorak, 2022).

Copper mining and refining industry, especially in the Legnica-Głogów Copper District, is one of the most important economic activities in Lower Silesia (for detailed description see next section). After the cessation of hard coal mining activities in the Lower Silesia Coal Basin during the 1990s, which "had a devastating impact on the economic, social and environmental situation in the sub-region" (European Union, 2023, p. 3), only lignite plays a significant role in the regional economy and (national) energy generation. The lignite power plant in Turów, with a capacity of nearly 1,800 MW is one of the largest power plants in Poland, contributing nearly 70% to the national power generation mix from coal (European Union, 2023, pp. 2–3). The Turów power plant is not only one of the largest GHG emitters in Europe, but the open pit Turów coal mine also has severe environmental effects, such as air pollution and contamination and deterioration of the groundwater (Żuk & Żuk, 2022b), that led to a cross-border conflict with the Czech Republic and Germany (Wróblewski et al., 2023). Due to the importance of the coal mine and power plant for the local labour market and the national energy system, the concession for lignite mining in the Turów mine was extended by the Polish government to 2044 (Ślimko et al., 2021). However, with the development of the "Lower Silesia Energy Strategy" in 2022 (Instytut Rozwoju Terytorialnego, 2022b), more ambitious plans of accelerating the shift to climate neutrality have been developed in the region. With this strategy, the regional government specifies the goal of becoming a climate-neutral region by 2050 by "improving the energy efficiency of buildings, transport and energy sectors, and electrification of the transport sector" (European Union, 2023, pp. 2–3). Another specified goal is to reach a 13-14% share of "green" hydrogen, in accordance with the "Hydrogen Strategy for Climate Neutral Europe" (ibid.). As an overarching goal, the strategy aims at transforming the energy, transportation and industrial sectors in order to improve the poor air quality in the region. In the next section, we will explore how the transition needs of these sectors, particularly energy and transport, are reflected in their carbon intensity.

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Table 11: Brief overview of the political system of Lower Silesia. Source: own compilation.

A TSL can be regarded as a new form of governance arrangement (see Chapter 2.1). However, a TSL is not implemented in a political void and, therefore, has to be designed to be complementary to existing political-administrative structures (see Chapter 3.6). This brief overview of the political system of the region is only intended to portray some of the main existing political structures of the region. The specific political decision-making and participation processes need to be carefully analysed in detail for different topics and Pilot use cases (see Deliverable 3.3 for the specific contexts of the Pilot use cases). The political structure of Lower Silesia consists of various institutions responsible for governance, legislation, and administration. At the apex of the political system is **the Regional Government of Lower Silesia** (Urząd Marszałkowski Województwa Dolnośląskiego), headed by the **Marshal of the Voivodeship** (Marszałek Województwa). The Marshal is elected by the **Regional Assembly** (Sejmik Województwa) and serves as the executive authority responsible for implementing regional policies, managing the regional budget, and representing Lower Silesia's interests at the national level (Dolnośląski Urząd Wojewódzki, 2024). The Regional Government comprises departments and offices led by appointed officials who oversee specific areas such as **infrastructure,** culture, education, and **economic development**. Nevertheless, the **Governor** (Wojewoda) is the representative of the central government, appointed by the Prime Minister. Their term lasts for five years, and they are responsible for ensuring the implementation of state policies, supervising public administration, coordinating responses to disasters, and representing the Council of Ministers at state events and foreign visits. They also oversee the actions of local governments and handle appeals against provincial judicial decisions. **Their role is distinct from that of the Marshal of the Voivodeship**, elected by the Regional Assembly and responsible for implementing regional decisions. The Regional Assembly serves as the legislative body of Lower Silesia, composed of elected representatives known as **councillors** (Radni). These councillors are directly elected by the residents of Lower Silesia and are responsible for enacting regional laws, approving the regional budget, and overseeing the actions of the Regional Government. The Regional Assembly convenes regularly to deliberate on matters affecting the region and to ensure **transparency and accountability** in governance. Lower Silesia's legal system operates within the broader framework of Polish law, with regional regulations and policies formulated by the Regional Assembly and enforced by the Regional Government. The region is divided into administrative units, each responsible for delivering public services and implementing regional policies in areas such as **energy, transportation, and environmental protection** (Dolnyslask, 2024). Against the background of negative experiences with the transition of the economy of the Lower Silesia Coal Basin during the 1990s (see section above), the TSL specifically aims to provide a complementary mechanism to existing governance arrangements for including citizens' opinions in regional decision-making processes. Placing civil society at the heart of the co-creation process and involving all regional stakeholders from the quadruple helix (including universities, enterprises, local government representatives, NGOs, engaged citizens, and the public) aims at designing inclusive, accepted and economically feasible energy and transport solutions.

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3.3.2 Assessing the transition needs of becoming climate neutral

As described above (see Chapter 2.1), regional transition needs and potentials are closely interrelated and influenced by the ecological, social, and economic dimensions of sustainability. In the context of the overarching goal of achieving climate neutrality, **GHG emissions** are, by definition, one of the main indicators that need to be analysed. In this regard, the overall greenhouse gas emissions per capita in Lower Silesia are significantly above the EU average, and after a strong increase from 2020 onward, have come close to the national average of Poland (see Figure 32 and Figure 33). The main reason for this strong increase (in addition to the recovery from the COVID-19 pandemic) was the commissioning of a new power plant unit in 2020 at the Turow power plant (European Union, 2023) in the NUTS3 region *Jeleniogórski* (see Figure 35). Despite this strong increase in GHG emissions per capita in the last decade, we observe a significant decline in the CEI of Lower Silesia, indicating progress in decoupling economic growth from GHG emissions. This does not apply, of course, to all its NUTS 3 regions, especially to *Jeleniogórski* (see Figure 36). However, in this context, it must be highlighted that this data pertains to the *production* and not to the *consumption* of goods and services: The electricity and heat generated in the Turow power plant is consumed in other regions of Poland as well (European Union, 2023, pp. 2–3), and thus, this data does not reflect the actual ecological footprint of the regions.

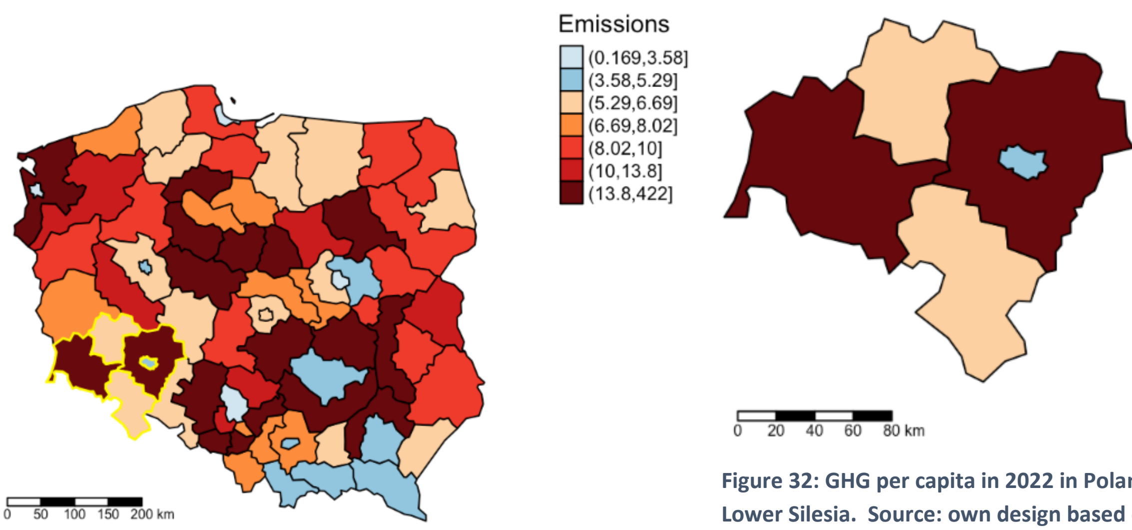

Figure 32: GHG per capita in 2022 in Poland and Lower Silesia. Source: own design based on data from EDGAR (CO2eq) and EUROSTAT (per capita).

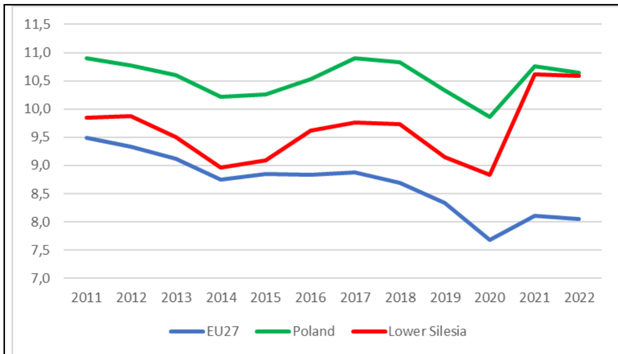

Figure 33: Average CO2eq per capita (t) of the EU (NUTS 2 regions), Poland and Lower Silesia. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (per capita).

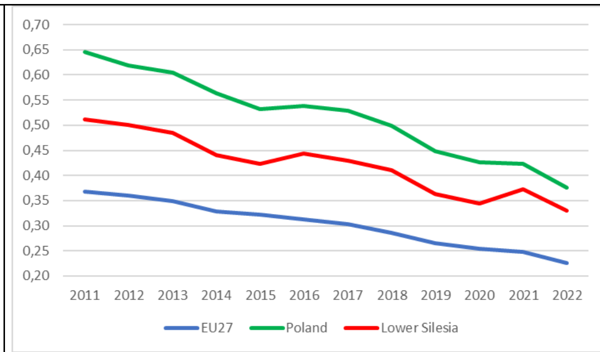

Figure 34: Development of the CEI (CO2eq [kg] / GDP pps [EUR]) in the EU (NUTS 2 regions), Poland and Lower Silesia. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (GDP pps).

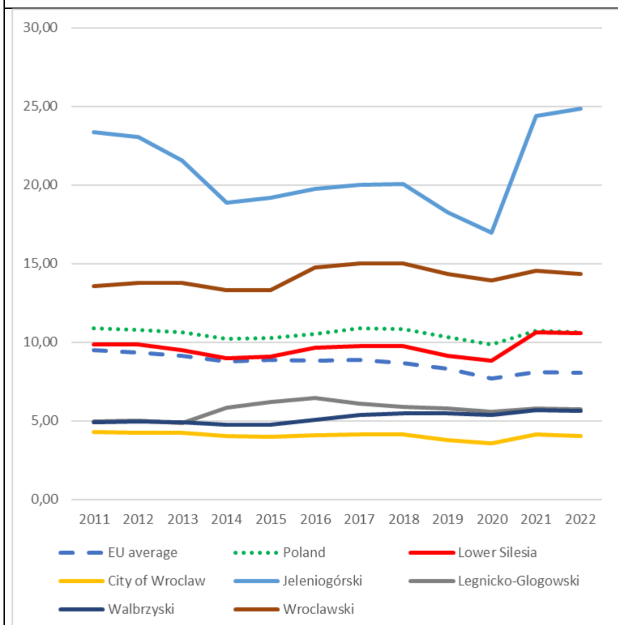

Figure 35: Average CO2eq per capita (t) of the EU (NUTS 2 regions), Poland, Lower Silesia and its NUTS3 regions. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (per capita).

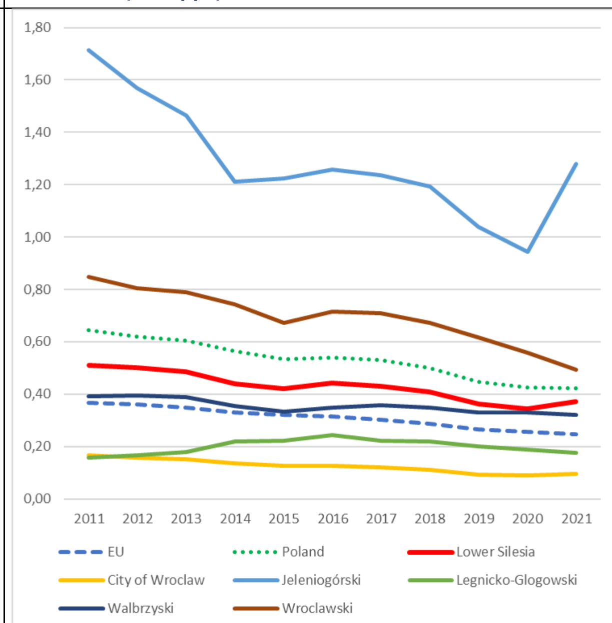

Figure 36: Development of the CEI (CO2eq [kg] / GDP pps [EUR]) in the EU (NUTS 2 regions), Poland, Lower Silesia and its NUTS3 regions. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (GDP pps). [79]

The **sectors contributing the most to climate change** in 2022 are **energy** and **transport**. According to data from EDGAR, we have observed in Lower Silesia over the last decade a shift towards a more carbon-efficient economy in “building” and “industry” sectors. However, in other sectors, particularly “Transport”, we have seen an increase in greenhouse gas (GHG) emissions. Therefore, in the following analysis, we will particularly focus on these sectors, which have also been identified by regional authorities as key sectors in need of transformation.

[79] Only the period from 2011 to 2021 is covered, as EUROSTAT lacks data for GDP at the NUTS 3 level for 2022.

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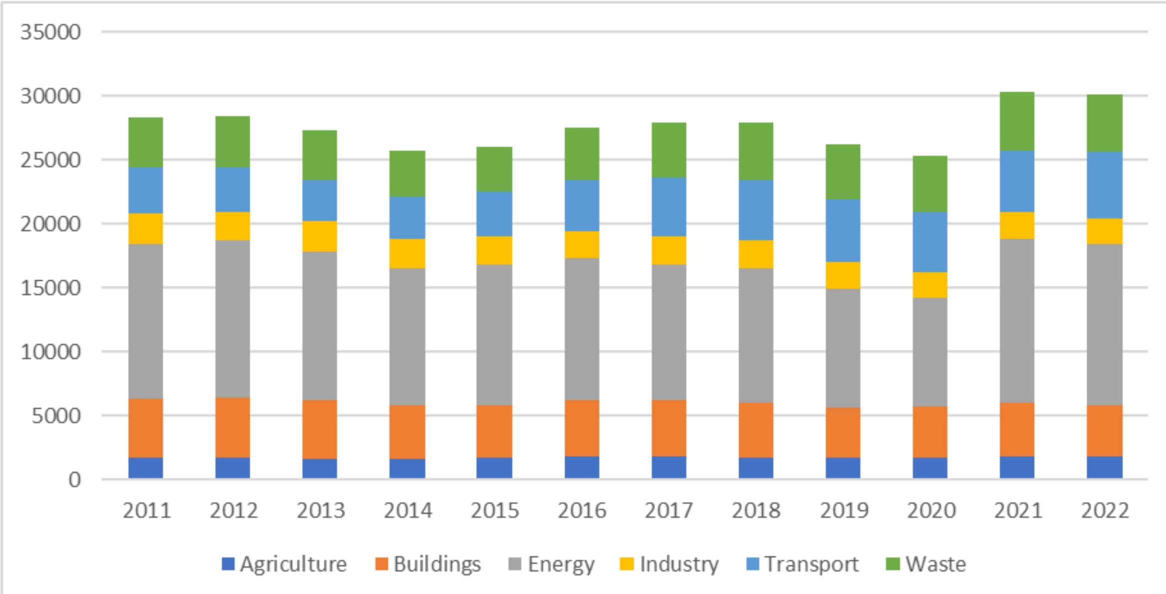

Figure 37: CO2eq (kt) per sector in Lower Silesia. Own compilation based on data from: EDGAR (CO2eq).

Lower Silesia "is a highly diversified region considering its socio-economic development level" (Brezdeń & Sikorski, 2023, p. 21). With a GVA of 151.7 billion PLN in 2020 (ibid., p. 23; see Figure 38) and the largest share of employment (Statistical Office in Wrocław, 2023)[80], the **industrial sector** in Lower Silesia is of crucial importance for the economy.

A particularly "strong concentration of industrial activity was also maintained in the area of the voivodeship related to the presence of copper deposits" (Brezdeń & Sikorski, 2023, p. 23) – the Legnica-Głogów Copper Belt Area (LGOM). Due to its "favorable location in geographical and transport terms near the border with Germany and Czechia" (ibid.), the industries in Lower Silesia, particularly LGOM, benefit from a high production value accompanied by equally high dynamics of growth, fostering a conducive environment for the development of innovative industry sectors. At the same time, the industrial sector is by far the biggest energy consumer that accounted for more than 30% of the regional energy demand (Instytut Rozwoju Terytorialnego, 2022b, p. 120). 95% of the regional GHG emissions were related to **energy** (generation of

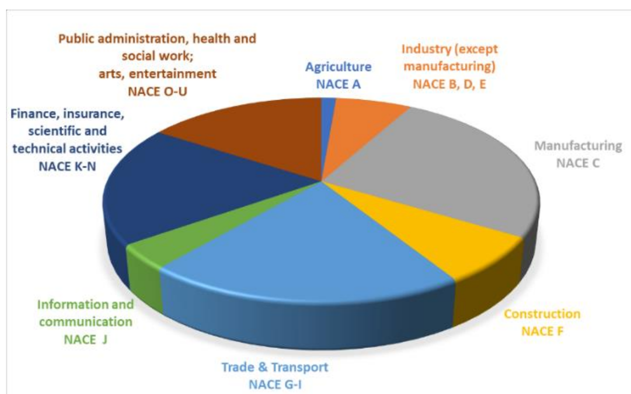

Figure 38: Share of GVA per sector in Lower Silesia in 2020. Own compilation based on data from EUROSTAT.

[80] According to the Statistical Office in Wrocław (2023, p. 51) in 2022, 24% (278,914) of the people wer employed in the industrial sector (236,426 of them in manufacturing).

energy *and* its use) (ibid., p. 10). It is obvious that the goal of achieving climate neutrality in Lower Silesia until 2050 – as specified in the "Lower Silesia Energy Strategy – requires a complete decarbonization of the region that is "currently least advanced in the transition out of coal" (Christiaensen et al., 2022, p. 4). Currently, RE only accounts for 10.3% of total electricity production (see Figure 39).[81] It is obvious that energy efficiency and the development of renewable energies have to be significantly increased to achieve "a RES share of 70% in total energy production and 97% in electricity production" by 2050[82] (Instytut Rozwoju Terytorialnego, 2022b, p. 15).

The war in Ukraine has significantly elevated the importance of transitioning the energy system in public discourse (Ślusarczyk et al., 2023; Żuk & Żuk, 2022a), leading to fundamental questioning of transition strategies. Concerns about energy security and affordable energy costs led to discussions about the "[d]elay in shutting down coal and other fossil fuel power plants" (Żuk & Żuk, 2022a, p. 710) and about the introduction of nuclear power (Ślusarczyk et al., 2023). At the same time, there is recognition of the importance of renewable energy development, despite controversial discussions surrounding its "disruptive" effects as a fluctuating energy source. Given the importance of the coal industries in the region, this fossil source is promoted as an option for stabilizing the energy system: "Surprisingly, given the importance of coal for Poland, a broader discourse on coal's future in Poland is lacking. Conversations are mostly confined to niche issues, such as miners' welfare or mine financing, without delving into coal's broader role in Poland's future" (Černoch et al., 2024, p. 5). In a nutshell, the "development of the Polish energy sector is hindered by disputes among key stakeholders" (ibid.) and it remains unclear how civil society – within their specific local context – envisions the future for an affordable, secure and sustainable energy system (Longhurst & Chilvers, 2019). This is particularly important in Lower Silesia, which still has an important coal industry and the challenging experience it has faced during the phase-out of hard coal mining (Hajduga et al., 2022). Therefore, one of the Pilot use cases specifically addresses this lack of clarity by testing methods of assessing and incorporating citizens' opinions in political decision-making (see description in Chapter 3.3.5).

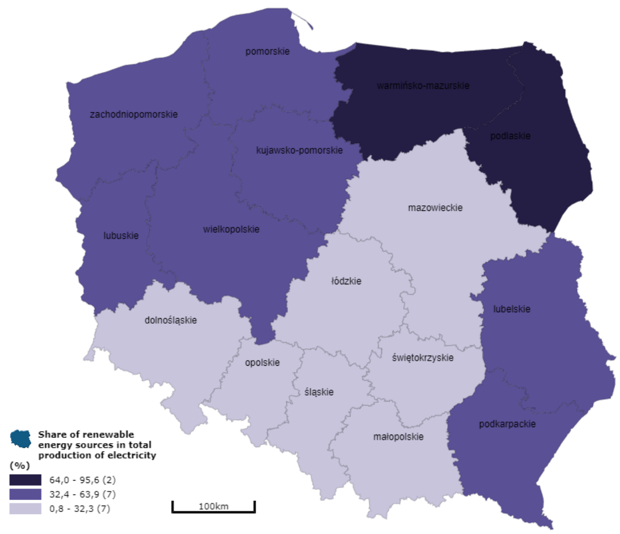

Figure 39: Share of RE in total electricity production in the Polish regions in 2022 (Lower Silesia: 10.3%). Source (slightly edited): Central Statistical Office (2024).[83]

[81] The dateilaed analysis of the energy sector is included in the technical report form the Instytut Rozwoju Terytorialnego (2022a).

[82] Pleas note, that the related study is in Polish. It was machine translated by Google.

[83] Central Statistical Office (2024): Statistical data on the economy of fuel and energy in the Lower Silesian Voivodeship between 2010 to 2022. https://bdl.stat.gov.pl/bdl/pages/regionalareas/AtlasRegionowBDL.aspx

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The opinion of citizens is equally important in another challenging topic in the region – **transport and mobility**. This sector is not only related to large GHG emissions (see Figure 37), but it also contributes significantly to the poor air quality in Lower Silesia, which has severe effects on the life expectancy of citizens (see Figure 21).[84] However, at the same time, the transport sector is vital for all economic activities and strongly related to the competitiveness and innovation capacity of a region (Ng et al., 2019; Palei, 2015; Skorobogatova & Kuzmina-Merlino, 2017). As the data from EUROSTAT shows (Figure 20), Lower Silesia has a very high motorisation rate (number of vehicles per 1,000 inhabitants, by NUTS 2 regions) and, according to a comprehensive study by Rosik et al. (2017), deficits in the public bus (see Figure 40) and railway transport (see Figure 41). In the Development Strategy of the Lower Silesian Voivodeship, the "[p]oor transport links of the voivodeship centre with some sub-regional centres" (Marshal's Office of Lower Silesia, 2013, p. 11) and the "[u]nexploited potential of railways", especially the accessibility of the mining areas (which currently is focussing mainly on freight transport) (ibid.) as well as the "insufficient transport availability (including connections with other cities and regions via public transport" (Marshal's Office of Lower Silesia, 2023, p. 35) have been clearly identified as crucial tasks for achieving the policy goal of developing sustainable transport solutions and improving transport availability (ibid.).

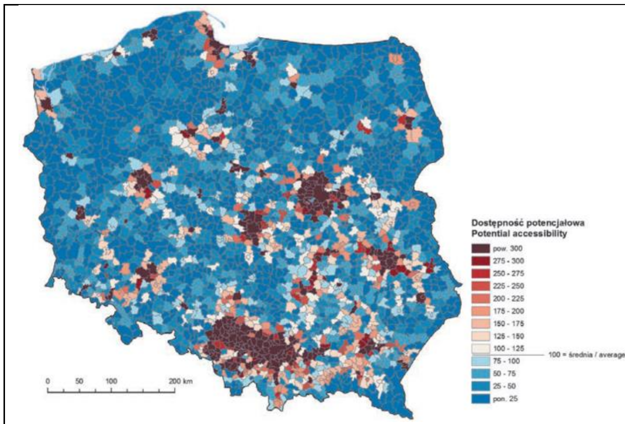

Figure 40 Accessibility by bus transport (bus variant) – short trips (β = 0,0347). Source: Rosik et al. (2017, p. 215)

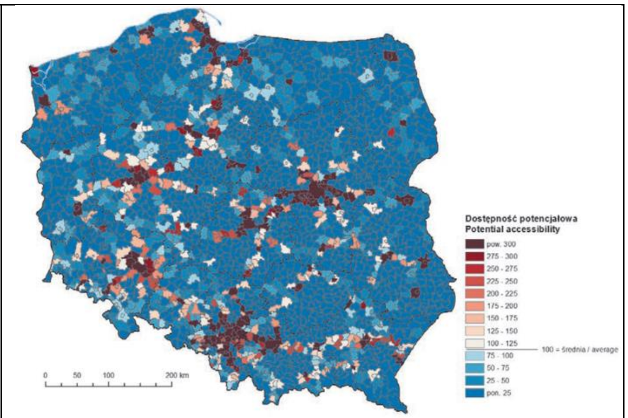

Figure 41: Accessibility by railway transport. Short trips (β = 0,0347). Source: Rosik et al. (2017, p. 220)

However, a transition from individual car traffic to more sustainable public transport requires high investments in the infrastructure to make it accessible, convenient, more ecological as well as affordable (Kłos-Adamkiewicz et al., 2023; Lewandowski, 2019; Smolarski et al., 2019). In this regard, a study about the bus and train connections between towns in Lower Silesia shows that a "[h]igh quality rail transport generally increases the demand for transport services [and a] […] proper development of transport offer plays a key role in the functioning of public transport systems, the backbone of which is rail transport" (Smolarski et al., 2019, p. 31). The study also shows that "under conditions of transport market

[84] According to Development Strategy of Lower Silesian Voivodeship 2030 of the Marshal's Office of Lower Silesia (2023, p. 12), "[t]heir main source is emissions from individual heating of buildings and from facilities in the municipal and domestic sector, from road transport and industrial areas". (Please note that the Development Strategy of Lower Silesian Voivodeship 2030 is in Polish [Strategia Rozwoju Województwa Dolnośląskiego 2030] and was machine translated by Google.

deregulation, bus carriers have developed a competitive network which is not complementary to rail transport. As a consequence, the deregulation of the transport market has increased the risk of transport exclusion" (ibid.).[85] This highlights the importance "of a supra-local, integrated public transport policy taking transport exclusion into account" (Smolarski et al., 2019, p. 38). Therefore, "transport policy should have its origins in the policy of sustainable development (including energy)" (Kłos-Adamkiewicz et al., 2023, p. 20): accessibility, affordability and the convenience of transport as well as an (ecologically) sustainable energy system should be placed in the centre of the planning. Before describing the related Pilot use case in Chapter 3.3.5, we will analyse the overall potential for the transition of the region, with a particular focus on transforming the energy system as a prerequisite for also making the transport sector more sustainable.

3.3.3 Assessing the transition potentials from a socio-economic and ecological perspective

As mentioned in Chapter 2.1, regional transition needs and potentials are closely interlinked, and both evolve within the context of the three sustainability dimensions. Assessing the transition potentials of a region for becoming climate neutral, therefore, requires considering social, economic and ecological/ environmental aspects. In this chapter, we will conduct this analysis focussing on the evaluation of different composite indices and selected indicators (see Figure 1).[86] The results will then be summarised in the form of a regional SWOT analysis.

Regarding the potential for transition, the **economic performance,** especially the **competitiveness and innovation capacity** are considered to be of crucial importance. The competitiveness of Lower Silesia is comparatively high in the national context (fifth place), but below the EU average. In the overall comparison, Lower Silesia only ranks 147th out of the 234 analysed regions in the RCI. Regarding innovation capacity, Lower Silesia even scores worse and is well below the EU average (see Table 21). These low scores of the RCI and RIS strongly reflect the macroeconomic indicators of Lower Silesia (e.g., GDP per capita and disposable income), as well as the low labour productivity (see Table 22).[87] In addition, the innovation capacity of Lower Silesia is characterised by comparatively low innovation expenditures per person employed in innovative SMEs[88], R&D expenditures in the business sector[89] as well as numbers

[85] The study by Smolarski et al. (2019, p. 38) "indicates that under conditions of deregulation and lack of coordination of transportation system development, most bus connections duplicate the railway system. This means that there are activities related to competition between both modes of transport (rather than their mutual complementarity). If transportation systems in the area under study are not based on integrated public transport, many towns will face the risk of transport exclusion. This will increase the peripheral character of the area and reduce its competitiveness, which may adversely affect the pace of its social and economic development. […] This requires the creation and implementation of a supra-local, integrated public transport policy taking transport exclusion into account."

[86] Please note that these composite indicators often refer to the same data (e.g., labor market statistics, GDP, perceived corruption etc.). In this section, selected indicators will be discussed for analyzing competitiveness, innovation capacity, quality of government, and social progress that reflect these topics most accurately. For an explanation of these compositie indicators, see Table 27 to Table 30.

[87] GDP (in terms of PPS) relative to the number of hours worked.

[88] Sum of total innovation expenditure by SMEs in Purchasing Power Standards (PPS). Denominator: Total employment in innovative SMEs.

[89] All R&D expenditures in the business sector (BERD).

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of innovative SMEs collaborating with other[90]. These deficits are clearly reflected in the low number of international patent applications[91] (see Table 23).

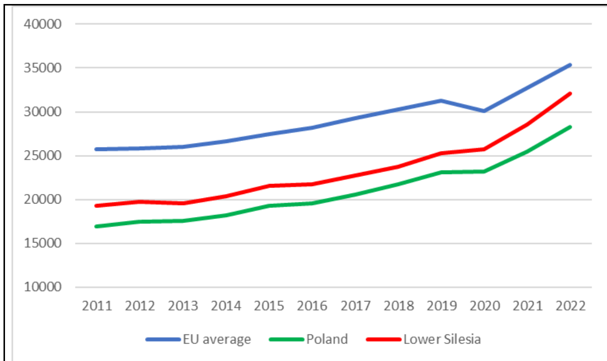

Figure 42: GDP (pps) per capita (in €) of the EU (NUTS 2 regions), Poland and Lower Silesia. Own compilation based on data from EUROSTAT.

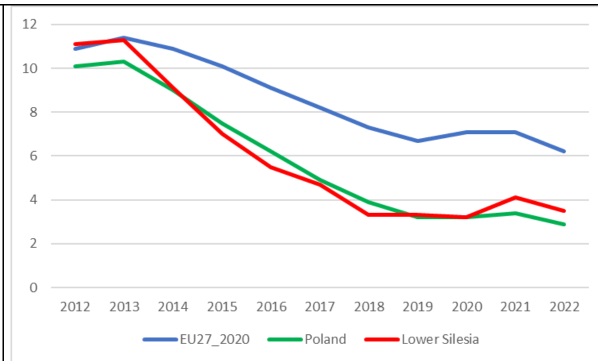

Figure 43: Unemployment rates (people aged 15 to 74 years)[92] for the EU, Poland and Lower Silesia. Own compilation based on data from EUROSTAT.

However, this current state can be misleading as it does not reflect the significant economic transformation the region has undergone in the past 20 years, leading to "economic growth and diversification of industries" (Guznajeva et al., 2023, p. 3). This is not only clearly reflected in the low unemployment rates of Lower Silesia (see Figure 43) and the increasingly high diversification grade of the labour market, but also the high share of tertiary education (see Figure 44) that significantly increased in the last decade (Guznajeva et al., 2023, p. 5).[93]

[90] Number of SMEs with innovation co-operation activities. Firms with co-operation activities are those that have had any co-operation agreements on innovation activities with other enterprises or institutions.
[91] Number of patents applied for at the European Patent Office (EPO), by year of filing. The regional distribution of the patent applications is assigned according to the address of the inventor.
[92] The source for the regional labour market information down to NUTS level 2 is the EU Labour Force Survey (EU-LFS). This is a quarterly household sample survey conducted in all Member States of the EU, the United Kingdom, EFTA and Candidate countries. Please note that we have observed discrepancies between these EUROSTAT statistics and the data provided by the national statistical offices.
[93] According to a study by the OECD (2020, p. 38) Lower Silesia is only surpassed by the Warsaw region: "56% of the population in the Warsaw region completed tertiary education compared to 34% in Lower Silesia, the second best-performing Polish region."

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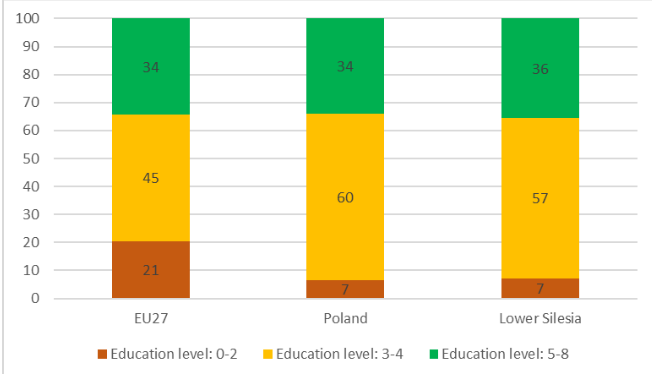

Figure 44: Comparison of education levels in the EU, Poland and Lower Silesia (percentage of people from 25 to 64 years).

Own compilation based on data from EUROSTAT.

In addition, innovation policies fostered "[t]he development of special industrial zones […] in less developed areas of the region [which] allowed to reduce inequalities between more and less developed areas of the region, and stimulated innovation and economic development in them" (Guznajeva et al., 2023, p. 5). These emerging innovation clusters, for example companies focussing on innovative PV technologies in Lower Silesia, are considered to have a high potential for stimulating regional economic growth and innovation capacity (Drelich-Skulska & Jankowiak, 2019; Peszat & Szlachta, 2017).[94]

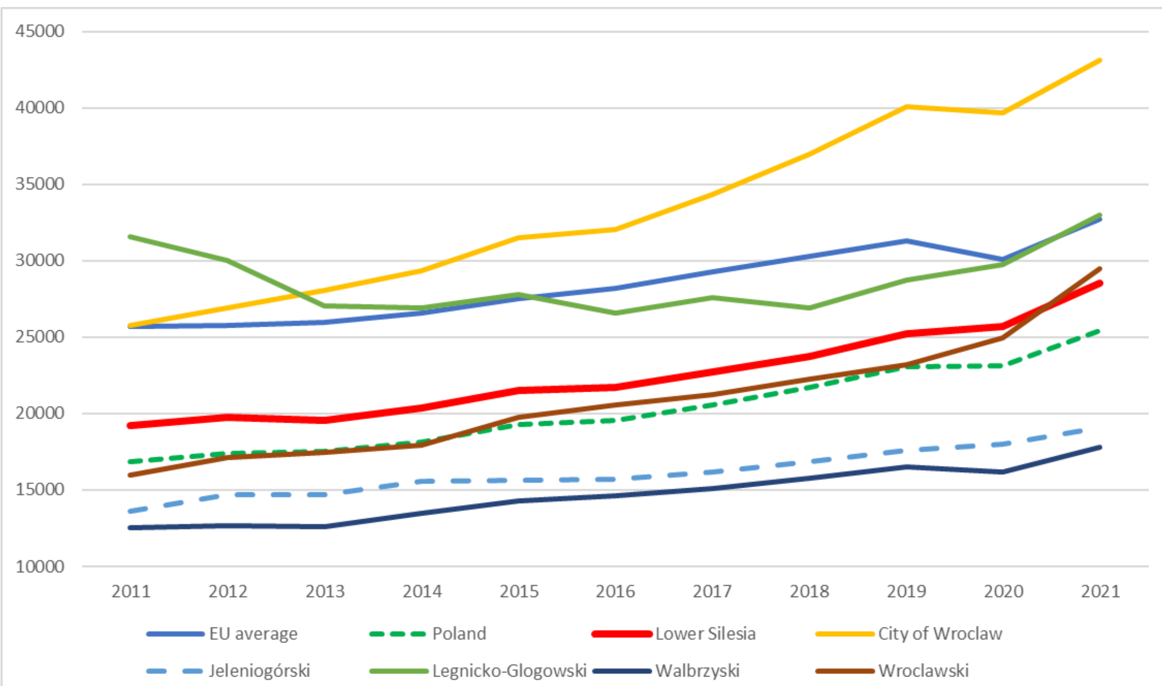

Figure 45: GDP (pps) per capita (in €) of the EU (NUTS 2 regions), (NUTS 2 regions), Poland, Lower Silesia and its NUTS3 regions. Own compilation based on data from EUROSTAT.

[94] This shows the limitations of assessing the region´s potential only from a quantitative approach. Therefore, we aim in the case studies to put the quantitative assessment within the context of qualitative analysis. However, due to the limited scope of this deliverable, additional studies have to be conducted, focussing on specific sectors and industries.

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Nevertheless, from a socio-economic perspective, we can still observe very high disparities within the region that have a direct impact on the transition potentials. Due to "long-term mono-branching and ties with traditional sectors characterised by capital intensity, huge involvement of natural resources, low efficiency and negative environmental effects" (Rynio & Zakrzewska-Półtorak, 2022, p. 19), especially post-mining coal areas, such as the Wałbrzych sub-region, still face "acute problems of depopulation and high levels of social exclusion. Compared to 2019, forecasts suggest that [an] additional 50,000 people will leave the subregion by 2030. Although not as high as in the first years after mining activities ended in the Lower Silesian Coal Basin, the unemployment rate in the Wałbrzych sub-region is still the highest in Lower Silesia" (European Union, 2023, p. 2) and the GDP per capita is compared to the City of Wroclaw extremely low (see Figure 45). These huge disparities also apply to the "At-risk-of-Poverty-Rate", which is in comparison to the Polish average significant lower (EUROSTAT), however, with huge intra-regional disparities (European Union, 2023, p. 2). These economic disparities must be kept in mind when assessing the transition potential from a **social and political perspective**. In this regard, the European Social Progress index provides a useful basis for a detailed assessment. In comparison to other EU regions, Lower Silesia scores – with the exception of advanced education[95] and personal security[96] – below average. The very low score in "health and wellness" – with the important sub-indicators life expectancy, self-perceived health status, cancer death rate, and heart disease death rate – is particularly troubling, as it is not only a very important indicator for the quality of life, but also for social cohesion (Fonseca et al., 2019). These socio-economic circumstances can be considered as a significant constraint on the transition potential, as they directly influence the attitudes of the citizens in the region to the decarbonisation process. "The implementation of energy transition may have a great impact on the current assessment of transition goals as well as [citizens'] perception[s] of climate change" (Żuk, 2023, p. 1).

In this regard, a survey from the European Investment Bank in 2023/24 shows[97] that "economic and financial" aspects (77%), especially "increased cost of living" (65%), are perceived by citizens (n=77) of Lower Silesia as bigger challenges than "climate change" (28%) (EIB 2024).[98] This is also clearly reflected in the dominant opinion (64%) that the "government should address climate change *without* affecting the personal budget"[99], and that "the transition to a low carbon economy can only happen if inequalities are addressed at the same time" (59%).[100] Regarding the employment opportunities due to this transition,

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[95] Tertiary education attainment; Tertiary enrolment; Lifelong learning; Female lifelong education and learning

[96] Crime; Safety at night; Money stolen; Assaulted/Mugged

[97] Question: "What are the three biggest challenges that people in your country are currently facing?"Source: EIB (2024): https://www.eib.org/attachments/survey/eib-climate-survey-2023-2024-dataset-all-countries-cop28.xlsx (Excel sheet: Poland). The references are listed in the Chapter "Data sources".

[98] The results of these surveys additionally show the shift in perceived challenges. In an earlier survey from the EIB (2020), "economic and financial" aspects (52%) and "climate change" (51%) have been perceived by citizens (n=153) of Lower Silesia nearly as equal challenges. However, "access to healthcare and health services" (78%) was perceived as the main challenge by the citizens Source: EIB (2020): https://www.eib.org/attachments/survey/climate-survey-citizens-perception-climate-change-impact-all-data-en.xlsx (Excel sheet: Poland). The references are listed in the Chapter "Data sources".

[99] Question: "Would you say that… […] Your government should address climate change without affecting your personal budget". Source EIB (2024).

[100] Question: "Would you say that… […] The transition to a low carbon economy can only happen if inequalities are addressed at the same time. Source EIB (2024).

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only a slight majority (55%) expects, that the "climate change measures will create more jobs than they will destroy existing ones" (EIB 2024). Against the background of negative experiences with the phase-out of (hard) coal mining Lower Silesia (Hajduga et al., 2022), the regional authorities are therefore challenged to create trust in the developed strategies for the transition process. However, in this regard the European Quality of Government Index" indicates deficits in Lower Silesia, as a comparatively large share of citizens have a limited trust in political institutions: regarding the assessment by the citizen´s of Lower Silesia about the quality"[101], impartiality[102] as well as the corruption in the provision of public services[103], the region scores in comparison to other analysed regions comparatively low (Charron et al., 2022). These limitations regarding the socio-economic and political dimension of sustainability are of crucial importance for the overall transition potential of the region.

In the context of developing clean energy (industries) and a sustainable transport sector in the region, the above-mentioned **environmental dimension of sustainability** is of great importance: Together with the economic and socio-political dimensions, it constitutes the overall transition potential of a region. In this regard, we have to narrow down the focus, as it would require to analyse the availability and economically feasible (sustainable) usability of natural resources as well as the current state of ecological processes for different sectors, such as agriculture, fishing, forestry, mining, water and waste management, as well as tourism. Therefore, the focus will be on the region's potential for the development of renewable energy, which is a key topic for phasing out of coal-related activities (Christiaensen et al., 2022), developing a "green hydrogen infrastructure" and transforming energy-related activities in the industrial and transport sector. This is a prerequisite for achieving climate neutrality and increasing the poor air quality in Lower Silesia (Marshal's Office of Lower Silesia, 2023).[104]

In this regard, studies show that in Lower Silesia, "[p]hotovoltaics and wind generation are currently perceived to be a viable option for reducing the environmental impact of energy sources while simultaneously showing significant potential to reduce dependence on conventional fuels and to increase local energy security" (Jurasz et al., 2018). In combination with energy storage infrastructure, RE in Lower

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[101] Questions from the questionnaire: How would you rate the quality of [from very poor to excellent] … 1) ... public education in your area? 2) …the public health care system in your area? 3) …the police force in your area? (Charron et al., 2022, p. 12). For complete questionnaire see (Charron et al., 2022).

[102] Questions from the questionnaire [from strongly disagree to strongly agree]: 1) Certain people are given special advantages in the public health care system 2) The police force gives special advantages to certain people in my area. 3) All citizens are treated equally [from agree to disagree] … A) …in the public education system in my area. B) …the public health care system in my area. C) …by the police force in my area. 4) In the area where I live, elections are conducted freely and fairly. (Charron et al., 2022, p. 13). For complete questionnaire see (Charron et al., 2022).

[103] Selected questions from the questionnaire: Corruption is prevalent in [from strongly disagree to strongly agree] … 1) my area's local public school system. 2) …in the public health care system in my area. 3) …in the police force in my area. 4) People in my area must use some form of corruption to just to get some basic public services. 5) Corruption in my area is used to get access to special unfair privileges and wealth. […] (Charron et al., 2022, pp. 13-14). For complete questionnaire see (Charron et al., 2022).

[104] As Jurasz et al. (2018) point out, the above-mentioned discussions about the utilization of nuclear energy "has remained purely in the planning stage" (ibid., p. 184; cp. Bohdanowicz et al., 2023), and the development of nuclear power plants (even the advertised „small nuclear reactors") would most likely take decades to build, these kind of energy is hardly a viable option for *accelerating* the transition to climate neutrality. Despite the comparatively high support (at least in contrast to Germany) for nuclear power that was highlighted in a study by Bohdanowicz et al. (2023), nuclear energy will not be included in the case studies.

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Silesia have a comparatively high potential for PV (see Figure 46) and for wind power[105] for a reliable and economically feasible generation of electricity (ibid.).

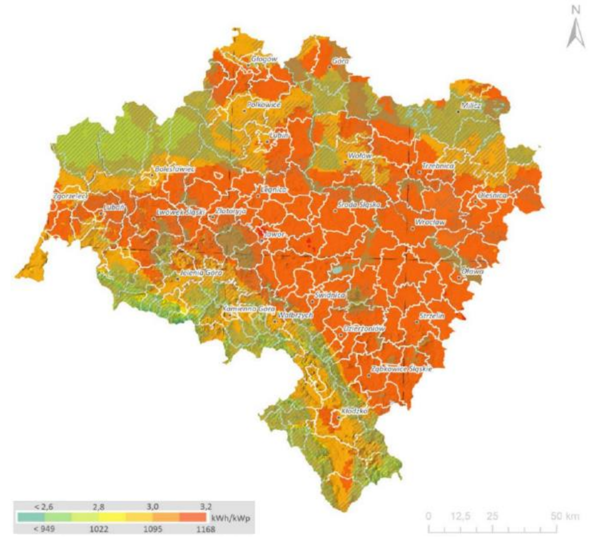

Figure 46: Potential for the development of photovoltaic electricity in the Lower Silesian Voivodeship.
Source: The World Bank (2019): Global Solar Atlas 2.0, Solar resource data: Solargis. Retrieved from (slightly adapted): Instytut Rozwoju Terytorialnego (2022b, p. 26).

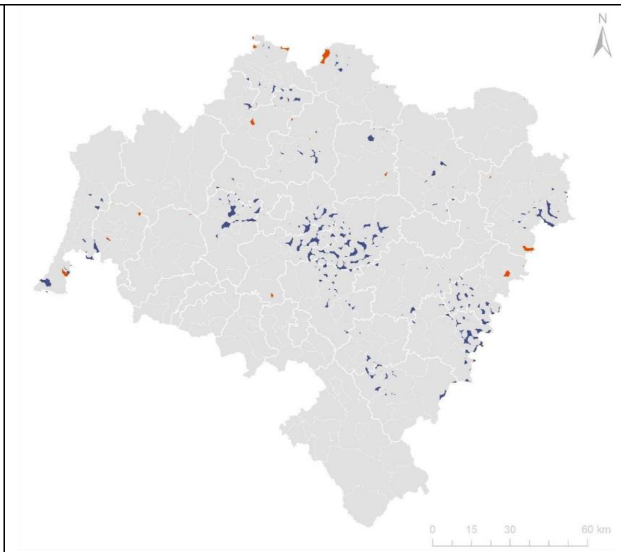

Figure 47: Development areas for wind energy in the Lower Silesian Voivodeship based on the Spatial Conditions for the Development of Wind Energy in the Lower Silesian Voivodeship in relation to the 10H principle.
Source: Instytut Rozwoju Terytorialnego (2022a, p. 152)

However, especially wind power faces strong restrictions in Lower Silesia (Instytut Rozwoju Terytorialnego, 2022a)[106] which significantly reduces its actual usable potential (see Figure 47). This indicates that this environmental ("technical") potential has to be regarded from a socio-economic perspective. In this context, a study about households' attitudes towards RE in Lower Silesian shows that economic factors are pivotal in this development. Many studies show that this applies not only to the affordability of energy costs, but also to the economic and the political participation in the development of RE (Gajdzik et al., 2024; Klagge & Meister, 2018; Meister et al., 2020; Schmid et al., 2020; Walker & Devine-Wright, 2008). Community-led sustainable energy initiatives are, therefore, regarded as a very promising approach for increasing the acceptance of citizens and in this way fostering a truly sustainable energy transition. However, including citizens in the political decision-making process is a challenge if it has the ambition to be truly inclusive and just (ibid.). This challenge will be addressed by one of the Pilot

105 For GIS-based analysis of the wind power potential see the studies from the Instytut Rozwoju Terytorialnego (2022a, 2022b)

106 The study by the Instytut Rozwoju Terytorialnego (2022a, p. 153) clearly points out, that "[t]he development of wind energy in the Lower Silesian Voivodeship, similarly to the entire country, was slowed down by the entry into force of the so-called "Distance Act"144. Pursuant to the act, a new wind farm will be allowed to be located at a distance of no less than 10 times its height (counting with shovels) from residential and mixed buildings and areas that are particularly valuable from the natural point of view (e.g. national or landscape parks, reserves)." [Please note, that the study is in Polish and was machine translated by Google.]

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use cases in Lower Silesia that will be briefly described in Chapter 3.3.5 after the following summary of the Lower Silesian transition needs and potentials in form of a regional SWOT analysis.

Before we briefly portray the related Pilot use case in Chapter 3.3.4, we summarise the transition needs and potentials of Lower Silesia in a regional SWOT analysis.

Table 12: Regional SWOT analysis as a summary of the transition needs and potentials of becoming climate neutral in context of the TSL approach. Source: own compilation.[107]

Strength (helpful internal factors)	**Weaknesses** (harmful internal factors)
• Highly skilled workers • Low unemployment • High GDP (per capita) in national comparison • Strong development towards a diversified economy in the last two decades • Strong industrial base (beginning to develop and implement green technologies and sustainable practices) • Strong copper industries and copper resources (as a crucial resource for electric mobility). • Innovation policies should prioritize the development of special industrial zones (focussing on innovative technologies such as photovoltaics (PV) and hydrogen) • High potential for RE (PV)	• Economic dependence on traditional industries with strong veto-players (e.g., copper mining and refining) • Particular strong fossil-based energy sector (veto-player) • Comparatively low trust in institutions (EQI) • Strong intra-regional socio-economic disparities • Dependence on road transport (lack of rail freight transport infrastructure); poorly connected rural areas (limited public transport system) • Negative experience of coal phase-out impeding trust in (institutions and) transition processes • Comparatively low innovation capacity • Restrictions regarding on shore wind energy
Opportunities (helpful external factors)	**Threats (external)** (harmful external factors)
• EU funding for innovative actions (hydrogen solutions, circular economy, sustainable mobility) • Increased demand for “sustainable” copper (due to increased electric mobility) • Cross-country support for the phase-out of lignite-related mining and energy activities • National energy strategy focussing on reduction of energy imports / increasing energy security (since the war in Ukraine)	• Comparatively high vulnerability to climate change impacts • Uncertain national energy policies (e.g., RE versus nuclear energy) • Global economic fluctuations (export-oriented copper industries)

[107] This regional SWOT analysis is based on a comprehensive document analysis and two workshops conducted in the realm of WP2 and WP3.

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3.3.4 TSL vision and Pilot use cases

As described in the chapter about the methodological approach (Chapter 3), the assessment of transition needs and potentials, as well as the analyses of the political framework, has been a continuous and iterative process conducted in tandem with the project partners (WP2, WP3, WP4, WP5) and has been the guiding aspect in developing a vision for the TSL, coalition building (Deliverable 3.1), and identifying the most important Pilot use cases (Deliverable 3.2). A summary of the vision and Pilot use cases is included in Table 13.

The continuous exchange of information between the WPs of the TRANSFORMER project has been vital for developing these case studies as well as the "Action plans" (Deliverable 3.3) for the specific Pilot use cases. The discussion about additional feasible Pilot use cases and strategies for long-term implementation is based on this cooperation and will be included in Chapter 3 and Deliverable 3.3.

Table 13: Lower Silesia: The vision and Pilot use cases at a glance. Source: summary of the descriptions included in Deliverables 3.1 and 3.2.

The vision:

LGOM and Lower Silesia aim for **carbon neutrality by 2050**, with strategies at various levels. Lower Silesia's **energy strategy** focuses on **local emission reduction**, complementing KGHM's (the copper mining company, one of the biggest in the world, that operates in LGOM) plan for emission cuts by 2030. The TSL envisions **zero-emission transport in LGOM**, emphasizing infrastructure, renewable energy, and community support. To address regional challenges, stakeholder collaboration and harmonization are essential. The Lower Silesia TSL prioritizes energy and transport improvements, given the region's high energy demand. Electrification is key, with the majority of Lower Silesian Railway vehicles already electric or hybrid. Addressing transport exclusion in smaller municipalities is crucial, enabling low- or zero-emission solutions. These efforts shape the vision for emission-free transport in the Copper Valley mining region, emphasizing the interdependence of energy and transport sectors.

The Pilot use cases:

Pilot use case 1: *Convenient transport connections for the benefit of the environment*

Pilot use case 1 in Lower Silesia, within the TRANSFORMER TSL framework, addresses the pressing need for sustainable transport solutions in the Copper Valley region. Inspired by the new rail link in the LGOM area, the focus is on developing public transport alternatives to private cars. The aim is to reduce carbon emissions and alleviate transport exclusion, particularly for the region's mining industry workforce. Proposed solutions include optimized bus-rail connections tailored to community needs, aiming to shift commuter habits towards greener options. Through stakeholder collaboration and community input, the TSL plans to analyse and implement the most effective transport solutions. The long-term vision involves systemic changes in daily transportation, with electrified trains and carbon-conscious buses playing key roles. Solutions developed in Lower Silesia could serve as models for other regions, contributing to broader environmental sustainability goals across Poland and Europe.

Pilot use case 2: *Develop a framework for integrating public participation methods in energy-related decision-making*

Pilot use case 2 focuses on integrating public participation methods in energy-related decision-making, particularly in the LGOM region. Originally planned to address energy transition, the outbreak of the war in Ukraine and subsequent energy crisis reshaped its scope. The use of Discrete Choice Experiment (DCE), a novel approach in the TSL context, aims to gauge public preferences and enhance citizen involvement in decision-making processes. The success of this method could set a precedent for broader application across European regions and other TSLs. Interviews with key stakeholders highlighted the significant impact of the energy crisis on opinions and the need to consider civil society preferences. Stakeholders include local government representatives, transportation officials, energy experts, and KGHM executives. The project includes comprehensive survey development, data analysis and evaluation to assess the survey's impact on political and economic decisions.

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3.4 Ruhr Area

As described above, the case study will begin by providing a brief **overview of the region** (3.4.1) to "[d]efine the boundaries of the system in terms of geography" (Geus et al., 2022). Based on this, the **transition needs to achieve climate neutrality** will be assessed, focusing on the most significant economic sectors contributing to climate change (3.4.2). From this perspective, the **socio-economic and ecological transition potentials** of the region will be analysed and summarised **in form of a regional SWOT analysis** (3.4.3). Finally, the **developed TSL vision and Pilot use cases** (3.4.4), which were guided by the identified regional transition needs and potentials, will be briefly portrayed. The results of this chapter will be incorporated in Chapter 3.6 in an overall discussion **about strategies for the long-term implementation of TSLs**.

3.4.1 Overview of the TSL region

The Ruhr Area is a region in the state of North Rhine-Westphalia (NRW) named after the river Ruhr which runs along the southern part of the region (see Figure 48 and Figure 49). In 2022, nearly 5.1 million people lived in an area of 4,438 km^2, making it one of the largest urban agglomerations in the EU.

With a GDP per capita of approximately €32,700 in 2021 (EUROSTAT), it is well below the state and national average, though very high disparities exist within the region. In addition, unemployment rates are also significantly higher on average than in NRW or Germany in general (see section about "Transition potentials" below).

Figure 48: Location of the Ruhr Area within Germany. Source: Wikipedia[108]

Figure 49: The Ruhr Area as part of the three administrative districts Arnsberg, Düsseldorf and Münster. Source: Wikipedia[109]

108 https://upload.wikimedia.org/wikipedia/commons/thumb/b/b2/Locator_map_RVR_in_Germany.svg/140px-Locator_map_RVR_in_Germany.svg.png

109 https://upload.wikimedia.org/wikipedia/commons/thumb/0/07/Ruhr_area-administration.png/800px-Ruhr_area-administration.png

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Unlike the other three TSLs, the Ruhr Area is not a political-administrative unit with a capital and a regional government (see Table 14 for a brief overview of the political system and related challenges in the sections below). The Ruhr Area is part of the three administrative districts (*Regierungsbezirke*) Arnsberg, Düsseldorf and Münster[110] and is organised in the "Ruhr Regional Association" (*Regionalverband Ruhr*, RVR). The RVR consists of 11 independent cities (*Kreisfreie Städte*) and four districts (*Kreise*).

The Ruhr Area was described for many decades as the "industrial heartland" of Germany: Coal mining activities and fossil energy generation characterized the region and led to the settlement of energy-intensive industries such as iron and steel as well as chemical industries. Despite massive government subsidies, coal mining was not competitive anymore, leading to a complete phase-out of hard coal mining in 2018. As "no other region in Germany and Western Europe was as strongly influenced by coal mining and by the coal and steel industry as the Ruhr Area" (Reitzenstein et al., 2021, p. 33), this significant transition affected not only its socio-economic structure but also its "regional identity" (Dudău et al., 2019, p. 25). Even though the region has made significant steps to transform "into a knowledge-based economy with a dynamic service sector"[111] (Arora & Schroeder, 2022, p. 1), industry and manufacturing, especially the energy and GHG emission-intensive chemical and steel industry, still play a significant role in the regional economy.[112] Against the background of a tense labour market – and the perception of still being an industrial region – the maintenance of the steel industry in the region is of key political importance. This is clearly reflected in the ambitious vision for the region of "becoming the greenest industrial region in the world" (Regionalverband Ruhr, 2022b, p. 5). The implementation of hydrogen solutions is regarded as a cornerstone for maintaining the energy-intensive industries while simultaneously becoming climate neutral until 2045 (Regionalverband Ruhr, 2022b). However, this strong political focus on hydrogen should be critically reflected: Even though there is a widespread consensus that hydrogen will play a central role in the transition of energy systems and industrial processes (especially climate neutral steel production), the availability of (affordable) green hydrogen is far from being secure (Cerniauskas et al., 2021; Wuppertal Institut, 2021). To avoid the creation of unsustainable path dependencies, the main goal of this case study is, therefore, to critically reflect if the development of a hydrogen ecosystem in the Ruhr Area is aligned with the overarching goal of becoming climate neutral, and to what extent it matches its transition needs and potentials.

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[110] Which are also NUTS 2 regions.
[111] See section below for more detailed description.
[112] However, though the manufacturing industry still plays an economic (and political) role in the Ruhr Area, according to Röhl (2019) the share of GVA from the industrial sector is below the state (NRW) and national average (see section below).

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Table 14: Brief overview of the political system of the Ruhr Area. Source: own description based on Deliverables 3.1 and 3.2.

A TSL can be regarded as a new form of governance arrangement (see Chapter 2.1). However, a TSL is not implemented in a political void and, therefore, has to be designed to be complementary to existing political and administrative structures (see Chapter 3.6). This brief overview of the political system of the region is only intended to portray some of the main political structures of the region. The specific political decision-making and participation processes need to be carefully analysed in detail for different topics and Pilot use cases (see Deliverable 3.3 for the specific contexts of the Pilot use cases). The Ruhr Area does not have its own distinct political entity, as it falls under the jurisdiction of various administrative bodies at different levels of government. On the state level, the Ruhr Area is governed by the state of North Rhine-Westphalia (*Nordrhein-Westfalen*), which is one of the 16 federal states of Germany. The state government, led by the *Ministerpräsident* and the State Parliament (*Landtag*), are responsible for overseeing state policies, legislation, and administration. Furthermore, within the State Parliament, there are various committees and working groups overseeing other areas such as Labour, Health, and Social Affairs (European Committee of the Regions, 2024b). Despite encompassing parts of three counties within NRW – Düsseldorf, Arnsberg, and Münster –, the Ruhr Area lacks an independent regional government. Rather, its affairs are managed within the larger governance framework of North Rhine-Westphalia (state and counties), and there are few state-level institutions specifically designated for the area beyond the local government level (van de Loo & Hanske, 2023). The Ruhr Regional Association (*Regionalverband Ruhr*, RVR) fulfils the role of the overarching administrative entity tasked with coordinating interests within the Ruhr Area. It encompasses statutory bodies, namely the *Verbandsversammlung* (“The Ruhr Parliament”), the *Verbandsausschuss*, and the *Regionaldirektor*. These bodies wield authority over the organizational structure of the RVR, which consists of four divisions: Regional direction (*Bereich Regionaldirektor*), Economic Management (*Bereich Wirtschaftsführung*), Planning Area (*Bereich Planung*), and Environment and Green Infrastructure (*Bereich Umwelt und Grüne Infrastruktur*) (Regionalverband Ruhr, 2022c). The RVR is responsible for state regional planning in the "Ruhr Metropolis". It has been involved in drawing up a Ruhr regional plan which has been implemented - after a process that lasted more than a decade (starting in 2011) - in February 2024 (Regionalverband Ruhr, 2024). This long duration of developing the regional plan is primarily attributed to the intensive and comprehensive participation process involving authorities, municipalities, and citizens (ibid.). However, it also highlights some challenges regarding fragmented responsibilities and competing interests among multiple responsible authorities that the TSL in the Ruhr Area faces. The TSL in the Ruhr Area specifically tries to address these challenges by implementing a mechanism that allows the joint development of ideas by different departments, networks, and institutions. As hydrogen solutions are perceived as a key topic for transforming the regional economic structures, they have also led the process of coalition building and the development of Pilot use cases.

3.4.2 Assessing the transition needs of becoming climate neutral

As described above (see Chapter 2.1), regional transition needs and potentials are closely interrelated and influenced by the ecological, social, and economic dimensions of sustainability. In the context of the overarching goal of achieving climate neutrality, **GHG emissions** are, by definition, one of the main indicators that need to be analysed. In this regard, the overall greenhouse gas (GHG) emissions per capita

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in the Ruhr Area are significantly higher than in the EU and the rest of Germany (see Figure 50), despite a strong decline observed over the last decade (Figure 51). As Figure 53 shows, there are strong disparities within the region, with an exceptionally high decrease in GHG emissions per capita in the NUTS 3 region of “Gelsenkirchen”, primarily due to the shutdown of three blocks of the Scholven power plant (UBA, 2021, p. 44). Regarding the carbon emission intensity of the economy, there is a notable decline in GHG emissions per GDP (CEI), even surpassing that of the rest of the EU and slightly exceeding that of Germany (see Figure 52). This overall positive trend of decoupling economic growth and GHG emissions is also evident at the local (NUTS 3) level, albeit with significant disparities, particularly evident in the case of Gelsenkirchen (see Figure 54).

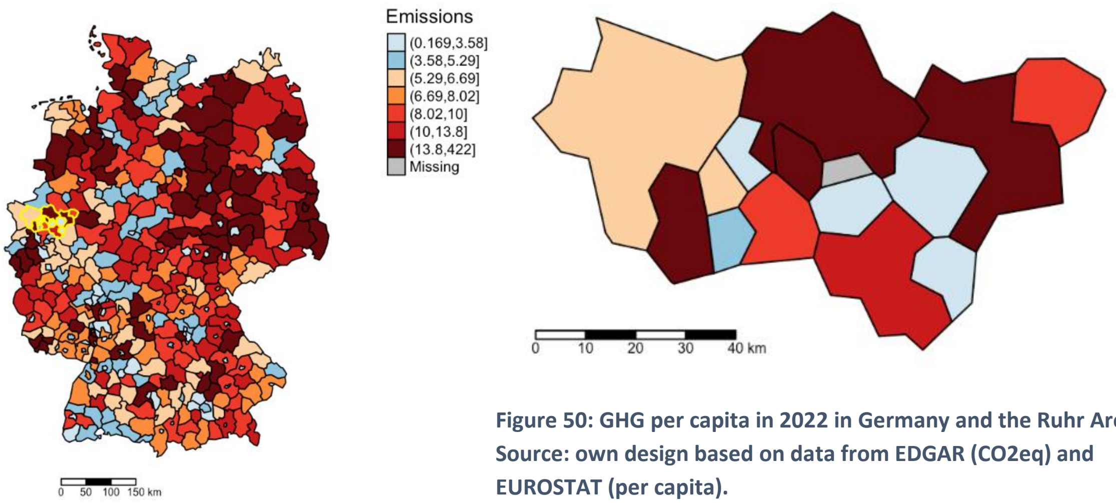

Figure 50: GHG per capita in 2022 in Germany and the Ruhr Area. Source: own design based on data from EDGAR (CO2eq) and EUROSTAT (per capita).

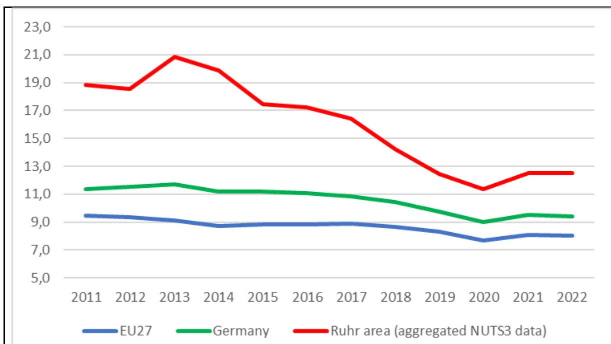

Figure 51: Average CO2eq per capita (t) of the EU (NUTS 2 regions), Germany and the Ruhr Area (aggregated NUTS3 data). Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (per capita).

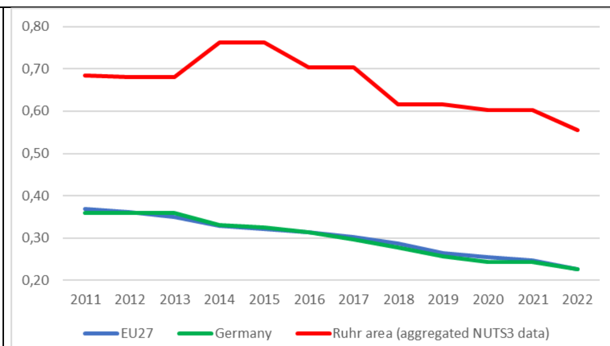

Figure 52: Development of the CEI (CO2eq [kg] / GDP pps [EUR]) in the EU (NUTS 2 regions), Germany and the Ruhr Area (aggregated NUTS3 data). Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (GDP pps).

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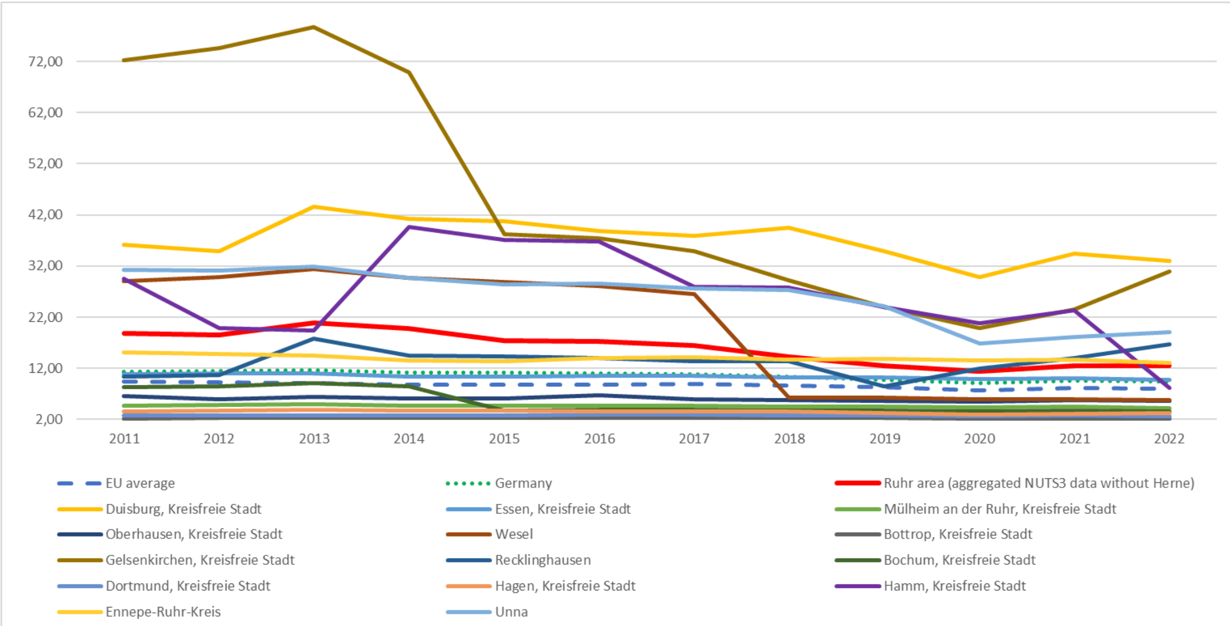

Figure 53: Average CO2eq per capita (t) of the EU (NUTS 2 regions), Germany, the Ruhr Area (aggregated NUTS3 data without Herne) and its NUTS3 regions. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (per capita).

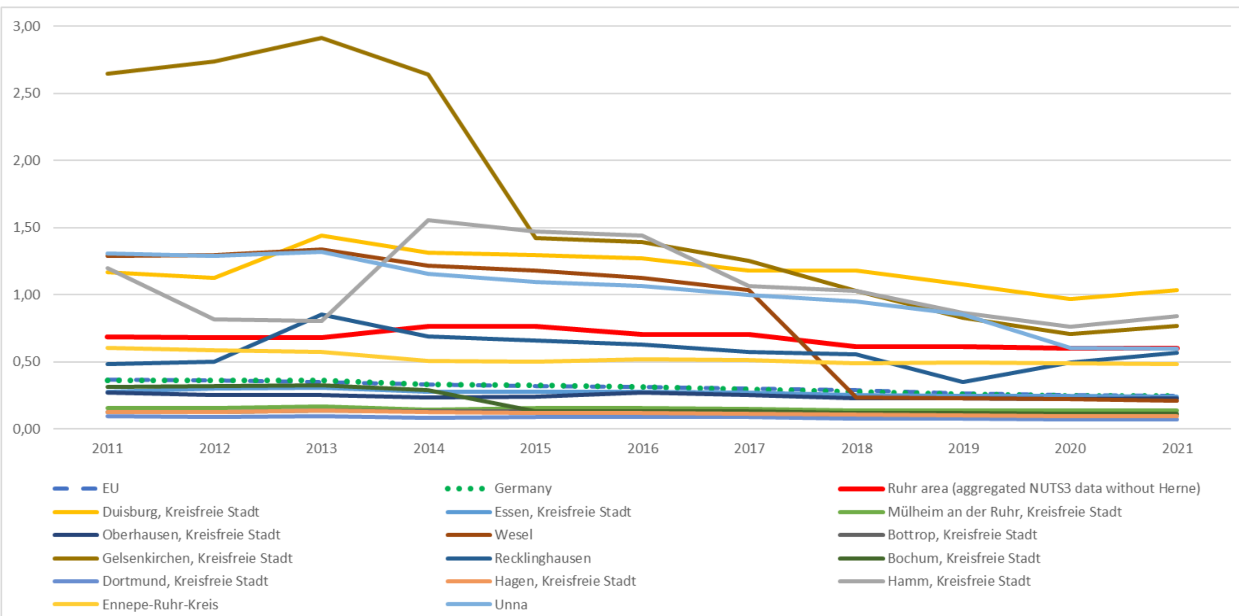

Figure 54: Development of the CEI (CO_2eq [kg] / GDP pps [EUR]) in the EU (NUTS 2 regions), Germany, the Ruhr Area (aggregated NUTS3 data without Herne) and its NUTS3 regions. Own compilation based on data from: EDGAR (CO_2eq) and EUROSTAT (GDP pps).[113]

[113] Only the period from 2011 to 2021 is covered, as EUROSTAT lacks data for GDP at the NUTS 3 level for 2022.

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According to the Statistikportal Ruhr[114], the sector contributing by far the most to climate change in 2020 is the "**industrial sector**" (though, due to a different methodology, including most of the **energy** sector/energy generation): Within this sector, electricity generation accounts for 37.9% and the steel industry for 37.4% of the overall GHG emissions of the Ruhr Area in 2018 (Lang & Kempermann, 2021, p. 24). Other important sectors contributing to GHG emissions are "**transport**" and "**households**"[115].

While a significant reduction in GHG emissions in the industrial sector resulted from the shutdown of energy-intensive industries and fossil power plants, the reduction in GHG emissions in transport was comparatively small, indicating the need for more comprehensive sustainable mobility solutions. The relatively modest reduction of GHG emissions in the "households" sector highlights a remaining challenge in Germany's energy transition – **heating** and thermal insulation.

As mentioned in the introduction, industry and energy are regarded as key sectors in the Ruhr Area for a transition to sustainability. In this regard, hydrogen solutions are considered as a cornerstone for this transition. Therefore, the following analysis will focus on a critical reflection on **hydrogen solutions,** particularly for the transition of the **energy system and the industrial sector** in the Ruhr Area.

However, to assess the transition needs and potentials, as well as the policy goals of the Ruhr Area, it is fundamentally important to understand its **socio-economic development** and the (evolved and constructed) identity of the region that is closely connected to the energy and industrial sector. Therefore, a brief introduction about the history of the Ruhr Area is given to highlight its social, political and administrative fragmentation and the economic and political **dominance of the coal and steel** industry, that "slowed down structural change and impeded the diversification of the regional economy" when the industries started to decline at the end of the 1950s (Reitzenstein et al., 2021, p. 34). The effects of this **structural change and the social, political, and administrative fragmentation of the Ruhr Area** can be regarded as one of the most significant limitations of its transition potential.

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[114] The EDGAR database accounts for the greenhouse gas emissions of different sectors at a NUTS3 level. However, in the case of the Ruhr Area, we have observed significant deviations and, therefore, utilize data from the regional statistics office. Statistikportal Ruhr: https://statistikportal.ruhr/ Please note that due to this differing methodology, comparisons of greenhouse gas emissions per sector to other TSLs are limited.

[115] The sector "households" encompasses the EDGAR sector "buildings".

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The Ruhr Area was only sparsely populated before industrialisation[117], and besides a few larger cities[118] it was mainly composed of villages. With the rapidly increasing expansion of the coal and steel industry during **industrialization**, the "towns grew up around the individual colliery sites [and] [f]rom the middle of the 19th century until the 1920s […], the number of inhabitants increased tenfold to approximately 3.8 million" (Dahlbeck et al., 2021, p. 30). This fostered the "development of the Ruhr [area] to **Europe's most important polycentric conurbation**" (Keil & Wetterau, 2013, p. 20) and laid the foundation for the regional identity of being the **"industrial heartland"** of Germany.

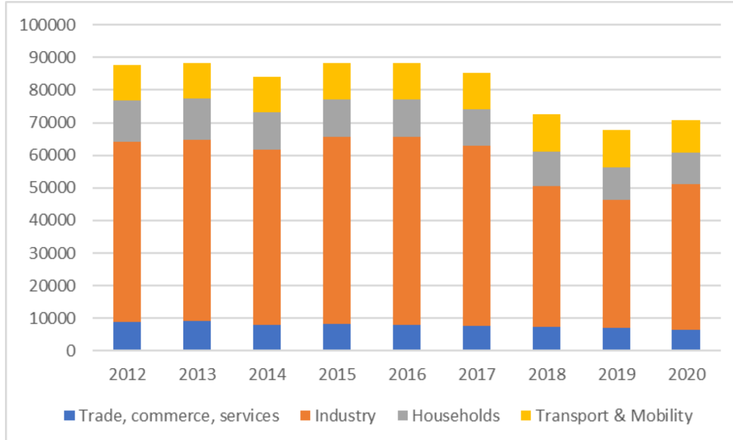

Figure 55: CO_2eq (kt) per sector (without energy) in the Ruhr Area. Own compilation based on data from: Regionalstatistik Ruhr, Data from: Regionalverband Ruhr.[116]

After the Second World War, the region even gained in importance, as "hard coal was the backbone of West Germany´s energy supply" that provided in the 1950s for "more than 70% of [its] primary energy consumption" and more than "80% of Germany's hard coal was mined in the Ruhr Area" (Herpich et al., 2018, p. 7). Employment in the mining sector rose to approximately 500,000 in the Ruhr Area until the end of the 1950s (Dudău et al., 2019, p. 19). It is often emphasized that the strong development of the mining and steel sector was an important factor enabling the **German "economic miracle"** (*Wirtschaftswunder*) after the Second World War (Dudău et al., 2019; Grabher, 1993). This strong economic growth in Western Germany led to an increased demand for labour, which resulted in the conclusion of recruitment agreements with other countries .[119] While approximately 14 million people migrated to West Germany, the Ruhr Area faced an outmigration of workers "into the developing industrial areas in southern Germany […] with the number of people leaving the region surpassing the number of immigrants" (Keil & Wetterau, 2013, p. 25). As this loss of workforce could not be compensated

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[116] Please note, that due to a different methodology, the sectors are not identical to the sectors from EDGAR and EUROSTAT.

[117] According to Keil and Wetterau (2013, p. 20), in "1840 only some 240,000 people lived in the area".

[118] These cities were connected by the "Westphalian Hellweg" that was "not only an important military road but even more a prime trading route which extended from the mouth of the river Ruhr via the cities of Mülheim, Essen, Bochum, Castrop, Dortmund and Unna to the river Weser and finally to the river Elbe and allowed an active West-East exchange of goods. The hamlets along this trading route evolved into trading places, free imperial cities and in some cases into Hanseatic Cities" (Keil & Wetterau, 2013, p. 10-11). However, the "Hellweg cities were severely impaired when the coastal trade grew in importance. And finally, the administrative disruption of the 17th and 18th centuries German Reich is reflected by the administrative fragmentation of the areas along the rivers Rhine, Ruhr, Emscher and Lippe. Even if these towns had charters they did not exhibit urban structures; the population mainly relied on agriculture and the crafts were but slightly specialized" (ibid., p. 11).

[119] Recruitment agreements (Anwerbeabkommen) were made with Italy (1955), Spain and Greece (1960), Turkey (1961), Morocco (1963), Portugal (1964), Tunisia (1965), and Yugoslavia (1968) (Keil & Wetterau, 2013).

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by the rationalization of (industrial) processes, "the coal mining and iron and steel industries welcomed the immigration of foreign workers" (ibid., p. 25).[120]

Simultaneously, the Ruhr Area faced since the late 1950s a **de-industrialization** and a strong "decline in the mining as well as the steel industry, one of the biggest consumers of German hard coal" (Herpich et al., 2018, p. 9): since 1957, more than 320,000 employees lost their jobs in the coal mining sector in just one decade (see Figure 56), mainly due to increased mechanization. This sharp decline continued in the next decades due to rising imports of cheaper coal (Dudău et al., 2019, p. 20). These competitive disadvantages in an increasingly globalised economy also affected the steel and iron industry.

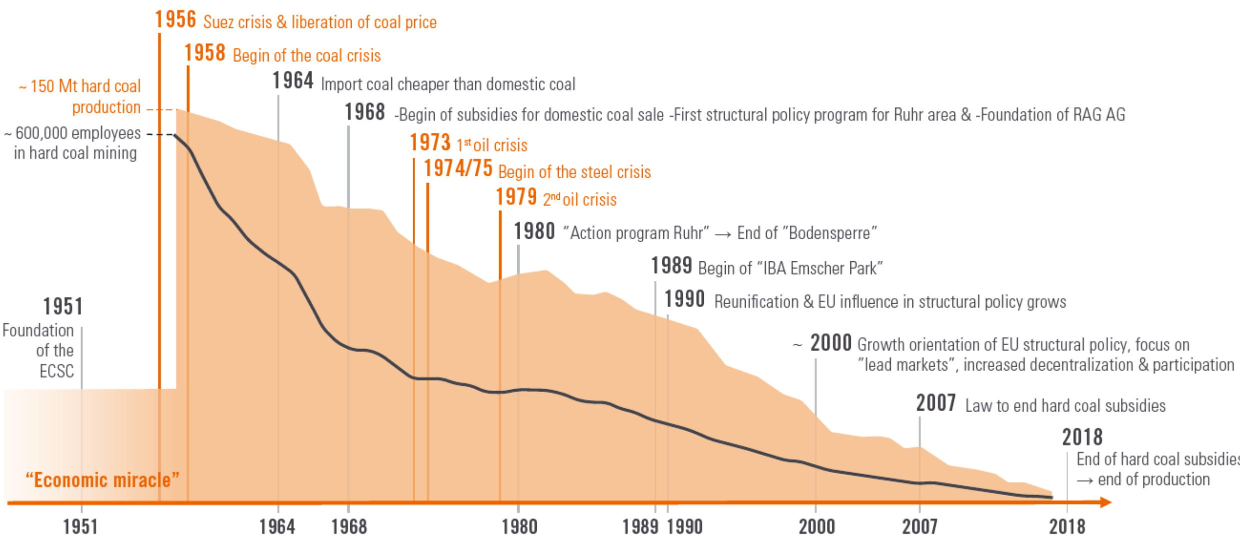

Figure 56: History of hard coal and structural policy programs in the Ruhr Area since 1951. For a description of the policy programs, see section (and footnotes) below. Source: Herpich et al. (2018, p. 14)

Even though this process of de-industrialization started already in the late 1950s, the predominant conception in the following decades was, "that the coal and steel industry in the Ruhr Valley was ´too big to fail`" (Dudău et al., 2019, p. 27). These industries "formed a powerful network together with influential unions and politicians" (Herpich et al., 2018, p. 9) that "slowed down structural change and impeded the diversification of the regional economy" (Reitzenstein et al., 2021, p. 34). This **lock-in of regional**

[120] It is undisputed, that the "economic miracle" wouldn´t have been possible without the described labour immigration. However, the large labour immigration and (due to its anticipated temporary character at least in the beginning) insufficiently managed socio-economic "integration" strategies also facilitated the development of significant structural inequalities that resulted from the fundamental structural change of the Ruhr Area already beginning in the late 1950s. Numerous studies controversially discuss this complex issue of "structural inequalities" and insufficient "integration strategies" for labour immigrants in West Germany (and even the term "integration" itself is controversially debated). However, a study by Schührer (2018) shows, that the fact that labour immigrants were expected to stay only for a limited time, and weren´t expected (or entitled) to become citizens, already hindered the "identification" with the country, and, therefore, the "integration" significantly (ibid., p. 5). Even though significant progress was made in many areas, a study by Fernandez-Kelly (2012) emphasizes in this regard, "that the nature of the education system in Germany remains deeply ´unequal,` ´hierarchical` and ´exclusive.` This study also demonstrates maintaining the marginalized position of Turkish children in Germany means that the country of origin or the immigrants' background is still a barrier to having access to education and the labour market of Germany" (ibid. ,p. 93).

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development "had disastrous long-term consequences for the region´s adaptability" (Grabher, 1993, p. 260): It had the effect that "structural policy measures mainly aimed at preserving the coal industry through technological modernisation and by supporting workers who were facing continuous income losses" (Reitzenstein et al., 2021, p. 34). Even though **structural policy measures** (and large subsidies) "were able to alleviate negative consequences for the industry and affected workers […] [they] did not succeed in addressing the structural problems of the hard coal sector" (Dudău et al., 2019, pp. 27–28) and as a result, "the iron and steel industry reduced employment between 1977 and 1986 by 23.2%" (Grabher, 1993, p. 257).

Since the beginning of the 1960s, political support programmes that aimed at the "diversification of the economic base of the region and fostering innovation in economic sectors other than the coal and steel sector" (Dudău et al., 2019, p. 27) were implemented. However, the success of these programmes was very limited as "political thinking aimed at one policy solution for the entire region, meaning support for one economic branch, for example, the health sector, which would be able to replace the coal and steel industry" (Reitzenstein et al., 2021, p. 34).

Among these initiatives was the foundation of the first university in the Ruhr Area, the Ruhr University Bochum, that started operations in 1965, the "Development Program Ruhr" [121] in 1968, or the "Action Program Ruhr"[122] in 1979 (Dudău et al., 2019, p. 29). Even though these programmes have been partially successful,[123] they were not able to effectively address the overall negative development of the regional economy (Bogumil et al., 2012): "The unemployment rate in the Ruhr amounted in September 1988 to 15.1 per cent as compared to 8.1 per cent in West Germany" (Grabher, 1993, p. 257). However, it "[was] not just a few traditional industries that have been affected by crisis. Even high-technology industries and the service sector […] [were] growing at below-average rates" (ibid.). This fundamental socio-economic transformation process facilitated the development of significant structural inequalities in the Ruhr Area. In this context, the extremely **high debt of the municipalities** (see Chapter 3.3.3) is still a burden that severely limits the regional potential for transition (Regionalverband Ruhr, 2023).

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[121] The "Development Program Ruhr" had "a volume of 17 billion Deutsche Mark (equals 32 billion € real) and one of its objectives was to foster the diversification of the economy and attracting new businesses (Dudău et al., 2019, p. 29): "One key obstacle to attracting new businesses to the region was the availability of suitable land. Large areas, also in the cities, were in the hands of coal mining companies. But even if they were not using the land anymore, they were unwilling to sell it as they feared that new companies in the region could increase the competition for cheap and/or qualified labour. This behaviour of the mining companies was later even coined with a new term: "ground lock" ("Bodensperre")" (ibid.). This "ground lock" was only ended in the 1980s (see Figure 56).

[122] As a reaction to the "Oil crises" in 1973 and 1979 and the negative development of the steel sector and mining in the Ruhr, the "Action Program Ruhr" was implemented in 1979: it "combined several individual measures for technology and innovation support, ecology, culture and the labour market. One goal of the program was the better coordination of the various measures by the federal government, the state and municipalities. Although a majority of the measures were still implemented in an isolated way, the result was a more dialogue-oriented approach to policy making. The program improved the Ruhr Area's situation in terms of soft location factors (e.g. improving the regional image, more cultural activities, etc.). Although it led to the creation of several new technology centres, it was not able to substantially diversify the economy, as large part of subsidies still went to the coal and steel industry" (Dudău et al., 2019, p. 29).

[123] For example, the settlement of the automotive factory "Opel" in the 1960s on a former mining area in Bochum (even though the factory was closed in 2015), or the development of research institutes and universities, such as the Ruhr University Bochum, which became one of the biggest employers in the city of Bochum (Bogumil et al., 2012, p. 45).

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As a reaction to this negative development, **structural policy changed significantly at the end of the 1980s**, refocussing "towards a more regionalised approach and, more consequently beginning at the turn of the millennium, with a sector expertise-oriented structural policy which promoted the model of a ´Metropolis Ruhr` in which individual regions have differentiated areas of expertise" (Reitzenstein et al., 2021, p. 34). Simultaneously, programmes, such as the "International Building Exhibition Emscher Park" (IBA Emscher Park; see Table 15), that "focussed on improving the quality of life in the region […] [by] transforming former industrial sites into cultural landmarks, thereby preserving the region's coal-related history " (Reitzenstein et al., 2021, p. 34) were initiated. In combination with complementary policy programs and stakeholder dialogues (such as the Ruhr conference[124]), which aimed at improving research and education as well as developing a "green" energy and transport infrastructure (Dudău et al., 2019), the Ruhr Area made significant steps to transform "into a knowledge-based economy with a dynamic service sector" (Arora & Schroeder, 2022, p. 1): This knowledge-based economy "can build on a well-developed knowledge infrastructure with many universities and research institutions. However, this basis also shows weaknesses in the universities' resources and the density of non-university research institutions. The receptiveness of the regional economy for impulses from knowledge and technology transfer is, therefore, limited by the still underdeveloped knowledge economy. It could be boosted by knowledge-intensive business start-ups from and in the vicinity of universities and research institutions, thereby strengthening the regional economy endogenously [*own translation*[125]]" (Kiese, 2019, p. 74). In this regard, the "health economy and services" (including research) can be regarded as a success story, which is characterised by high growth rates and already has a significantly higher share in employment than the steel industry (Regionalverband Ruhr, 2022c).

Nevertheless, it is important to emphasize that this economic transformation led to **structural inequalities** that affects the potential for a (just) transition. Against the background of **high unemployment rates and very high debt of the municipalities** (see Chapter 3.3.3), the **remaining industry** and manufacturing, especially the energy and GHG emission-intensive chemical and steel industry, still plays an important role in the regional economy and in politics.

[124] The *Ruhr conference* (Ruhr-Konferenz) of 2018 was initiated by the State Government of North Rhine-Westphalia and aimed at an inclusive dialogue with stakeholders and citizens. As a result, "green" infrastructure" & mobility, education & science as well as sustainable energies were identified as key pillars for the transition of the Ruhr Area.

[125] Please note, that the study is in German language and the translation is not strictly literal.

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Table 15: The International Building Exhibition Emscher Park (IBA Emscher Park). Source: Reitzenstein et al. (2021, p. 41).

The International Building Exhibition Emscher Park (IBA Emscher Park) is very often quoted as an example for a successful transition (Campbell & Coenen, 2017; Dudău et al., 2019; Herpich et al., 2018; Reitzenstein et al., 2021): "In the 1980s, the Emscher river was one of the most polluted rivers in Europe. At this time, the core of the industrial activity in the Ruhr Area had already moved north – following the availability of coal – leaving the Emscher region with many very unattractive post-industrial sites. To respond to this legacy, a new programme was launched, the so-called ´International Building Exhibition Emscher Park` (IBA Emscher Park). In some ways, this programme marked a new approach in the structural policy of the Ruhr Area. It focussed on improving the quality of life in the region. Between 1989 and 1999, more than 120 projects were implemented and supported by investments with a volume of DM 5 billion (€ 4.4 billion real)[126] – two thirds came from public budgets of all political levels (EU, federal level, state level, municipalities) and one third were private investments […]. Projects included measures to implement an underground sewage system, to improve water quality and to develop new living spaces for citizens and nature. The touristic attractiveness of the region was increased by transforming former industrial sites into cultural landmarks, thereby preserving the region's coal-related history. Furthermore, 17 technology centres were created, and mining damages were remediated to the extent possible […]. The approach of IBA Emscher Park successfully improved the quality of life in the region and thus supported ´soft` location factors. With a short-term view on employment, the programme itself managed to create only few new jobs. But it is generally acknowledged that it did increase the attractiveness of the region – also for companies and for qualified workers" (Reitzenstein et al., 2021, p. 41).

Even though the decline in the industrial sector and the increased importance of the service sector is clearly reflected in the employment statistics (see Figure 57), the **industrial sector (including energy)** is still important regarding the employment and GVA (see Figure 58). However, these numbers also show that the "identity" of being an industrial region is not so much reflected anymore in the share of GVA and employment in manufacturing, that was in 2020 well below the German and NRW average.

[126] DM = Deutsche Mark (former currency of the Federal Republic of Germany). The tern "real" means "inflation-adjusted".

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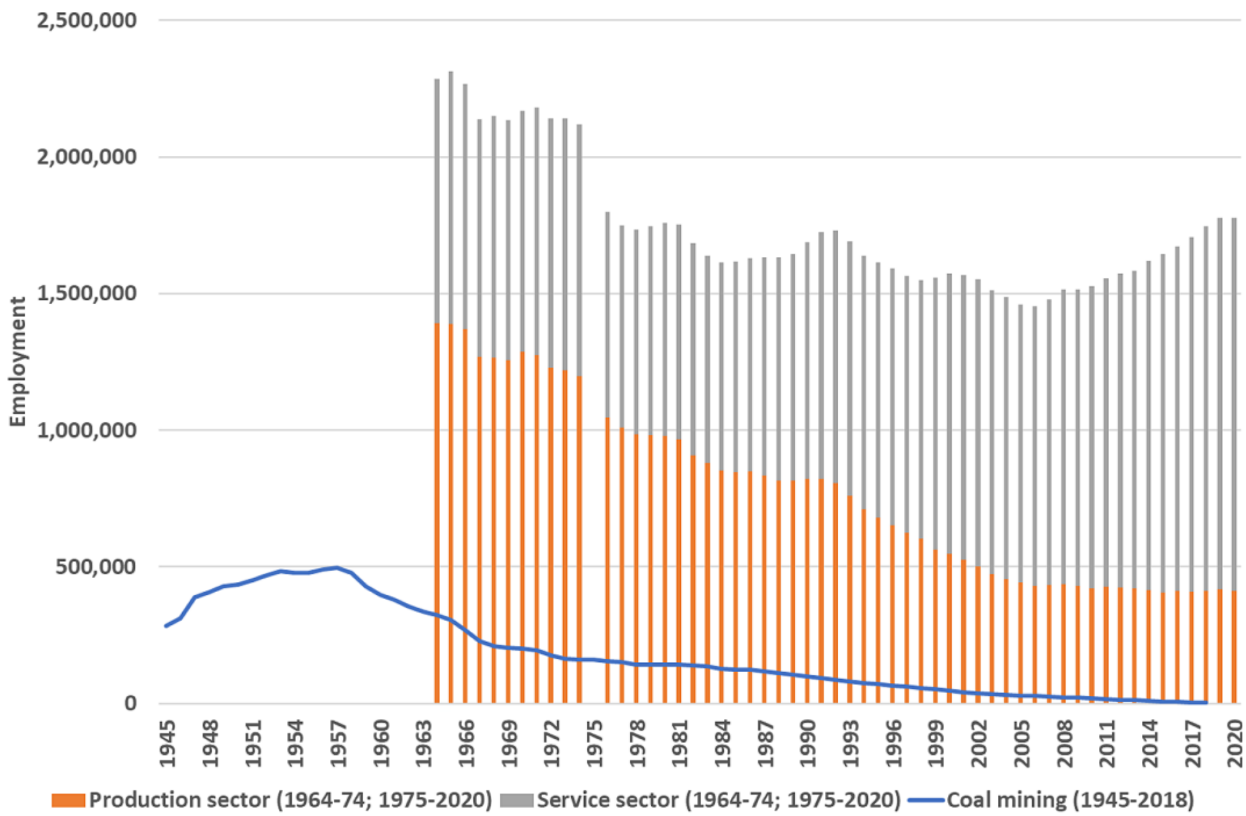

Figure 57: Employment in the Ruhr: coal mining, production, and service industries.

Source: Klute and Kenway (2023, p. 4).

However, especially the **steel industry** still plays an important economic and political role: The Ruhr Area has by far the largest share of steel production in Germany and of the 80,000 people directly employed in this industry, approximately 54% work in the Ruhr Area. Most of this industry is located in Duisburg, which is still the largest steel location in Europe (Regionalverband Ruhr, 2022c; Wirtschaftsvereinigung Stahl, 2023). Nevertheless, the decline of the steel industry in Duisburg cannot be denied: “employment figures of the steel ecosystem show that there have been enormous staff cuts in recent decades: while the Duisburg coal and steel industry of the 1960s employed around 160,000 people, today this figure is around 21,000 […]. Despite this enormous decline in employment, the steel sector is still by far the largest employer in the city of Duisburg […]. In addition to the depth of added value of the steel product, the high indirect employment of the sector, which is not included in the statistics, should be emphasised. If suppliers and other service providers are included, experts assume that a total of around 40,000 people are employed in the steel sector in the city of Duisburg” (Götting et al., 2024, p. 207).

However, the **steel industry in the Ruhr Area faces multiple challenges**: first, strong **competition** with companies in other regions that have comparative advantages (e.g., lower labour and energy costs); second, a significant **decrease in steel demand** (e.g., in the automotive industry) due to substiution by other materials, such as composites (e.g., carbon fibre); and third, the issue of **GHG emissions** in the

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context of becoming climate neutral, not only due to the energy demand but also due to the currently used reduction agent coke (Stroud et al., 2024): "With 44.2 million t CO_2, the six integrated steelworks [in Germany] account for 86% of emissions from iron and steel production in Germany – half of these come from Duisburg alone" (WWF Germany, 2023, p. 31). In this regard, the company thyssenkrupp Steel Europe AG is by far the biggest GHG emitter that accounts with its steel-related activities in Duisburg for 16.2 Mt CO_2 alone (ibid.).[127] This is more than the overall GHG emissions of the entire county of Latvia (with a population of 1.86 million and 11.11 Mt CO_{2eq} emissions) in 2022 (Crippa et al., 2023, p. 149).

Maintaining competitiveness while transforming into a climate neutral industry is a huge challenge that the steel companies in Duisburg (and other regions) currently face.[129] **Hydrogen solutions** are regarded as the cornerstone for the transition of the production process (replacing coke as a reduction agent) and the energy system (as energy carrier and energy storage). There is a common understanding that without strong subsidies by the Federal and State level, these companies will not succeed in their transformation (Müller-Arnold, 2024). Even though the "EU Commission has granted state aid approval for German federal and state government funding of the ´tkH2Steel` decarbonization project in a total amount of around two billion euros" (thyssenkrupp Steel Europe AG, 2023, p. 1), this will only replace one out of the four currently active blast furnaces (Müller-Arnold, 2024).

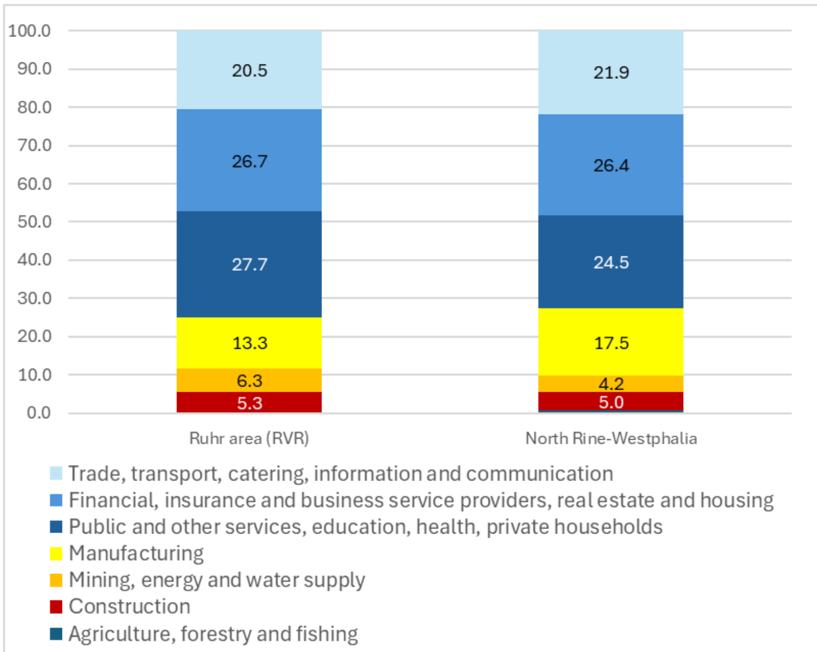

Figure 58: Share of Gross value added by economic sectors in the Ruhr Area and North Rine-Westphalia in 2020 (values for agriculture, forestry and fishing: Ruhr Area: 0.2; NRW: 0.6). Source: own design based on NRW.BANK (2022, p. 17).[128]

It is obvious that huge resources will have to be invested to transform not only the steel industries, but other industries (such as chemical industries, or cement production) and energy-related activities. Realising the vision of hydrogen-based ecosystem that creates new and innovative jobs – estimations

[127] Including "coking plants, blast furnaces, blast furnace gas power plants, and processing plants" (ibid., p. 18).
[128] The figure was translated from German into English. The original figure from the NRW.BANK (2022) is based on data from the "Working Group 'National Accounts of the Federal States`(Arbeitskreis ´Volkswirtschaftliche Gesamtrechnungen der Länder`) (ibid.).
[129] This is reflected in the currently controversial debate over the takeover of the steel industry from "thyssenkrupp" by Křetínský's holding company, EPCG. There are fears that due to rationalization processes, a significant loss of jobs would result (Müller-Arnold, 2024).

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range from 20,000 to 130,000 employees in NRW (Michalski et al., 2019, p. 4) – will depend on the availability of skilled workers (Grimm et al., 2021), as well as the cost-efficient supply (generation, distribution and storage) of the needed electricity and hydrogen (see section below). This will be a key focus of the discussion of the transition potentials in the next section.

However, as this section has shown, these **transition potentials are considerably limited by the structural inequalities resulting from the process of deindustrialization (e.g., extremely high debts of the municipalities) and the political and administrative fragmentation of the Ruhr Area**. These limitations will be discussed before focussing on the potentials for implementing a hydrogen ecosystem.

3.4.3 Assessing the transition potentials from a socio-economic and ecological perspective

As mentioned in Chapter 2.1, regional transition needs and potentials are highly related to each other, and both are unfolding into the three sustainability dimensions. Assessing the transition potentials of a region for becoming climate neutral therefore requires considering social, economic and ecological/ environmental aspects. In this chapter, we will conduct this analysis focussing on the evaluation of different composite indices and selected indicators (see Figure 1).[130] The results will then be summarised in a regional SWOT analysis.

Regarding the potential for transition, the **economic performance,** especially the **competitiveness and innovation capacity** are of crucial importance. In this regard, the results of the composite indices must be critically reflected, as the Ruhr Area is part of three different NUTS2 regions (see Table 21). The structural inequalities of the Ruhr Area are, therefore, only inadequately reflected. Even though the NUTS 2 regions that the Ruhr Area is part of score comparatively high in the "Regional Competitiveness Index" (e.g., highest labour productivity[131], disposable income per capita[132] and potential market size expressed in GDP[133]; Table 22). However, these numbers also include high-performing cities like Düsseldorf or Wuppertal that are not part of the Ruhr Area. If only the Ruhr Area is considered, we can see that the most frequently used indicator for assessing the economic performance of a region, GDP per capita, shows that the region scores well below the average of the rest of Germany. In addition, the statistics also highlight the huge disparities within the region that very well reflect its structural inequalities (see Figure 59).

[130] Please note that these composite indicators often refer to the same data (e.g., labour market statistics, GDP, perceived corruption etc.). In this section, selected indicators will be discussed for analysing competitiveness, innovation capacity, quality of government, and social progress that reflect these topics most accurately. For an explanation of these composite indicators, see Table 27 to Table 30.

[131] GDP (in terms of PPS) relative to the number of hours worked.

[132] Net adjusted disposable household income in purchasing power consumption standards (PPCS) per capita (index EU-27=100).

[133] Index GDP (PPS) EU-27=100 – EU-27 average computed as population weighted average of the NUTS 2 values.

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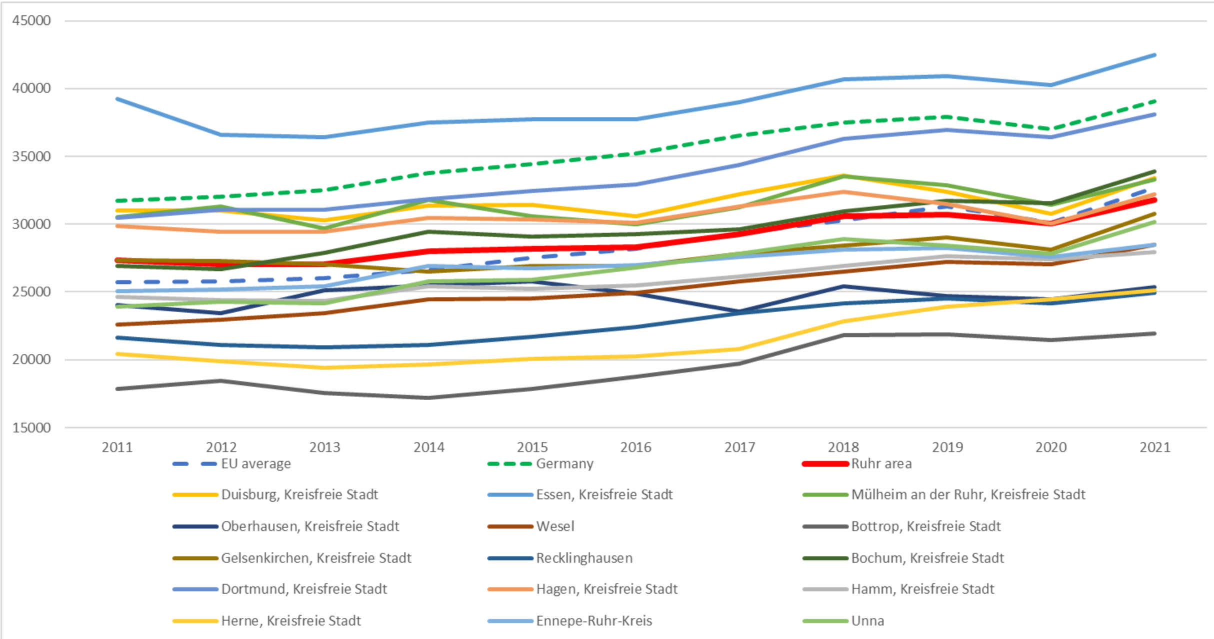

Figure 59: GDP (pps) per capita (in €) of the EU (NUTS 2 regions), Germany, the Ruhr Area (aggregated NUTS3 data without Herne) and its NUTS3 regions. Own compilation based on data from EUROSTAT.

Even more important for assessing the economic performance and the competitiveness of the regions is the extremely high debt of its municipalities (see Figure 60). Many of the municipalities in the Ruhr Area simply do not have the resources for the necessary investments that are required for the comprehensive transition towards climate neutrality and sustainability (e.g., for modernizing public buildings, or public transport) (Dahlbeck et al., 2024).

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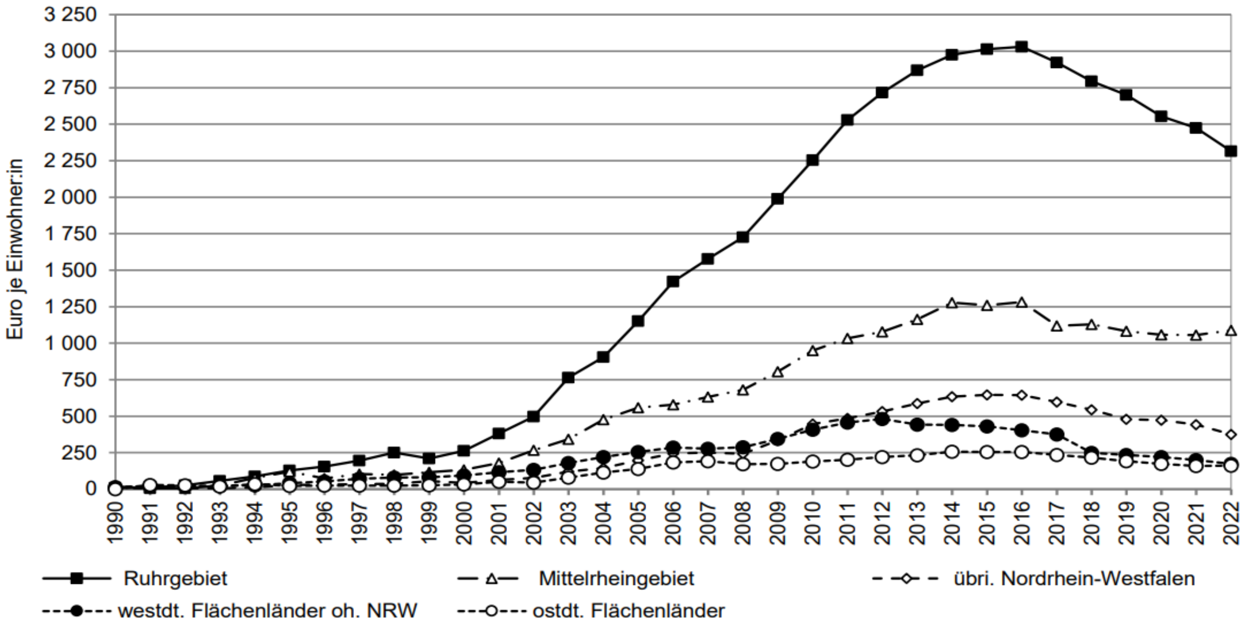

Figure 60: Development of loans to secure liquidity[134] (€ per capita) in the Ruhr region from 1990 to 2022. Comparison to Middle Rhine region (*Mittelrheingebiet*), rest of North Rhine-Westphalia (*übri. Nordrhein-Westfalen*), Western German territorial states excl. NRW (*westdt. Flächenländer oh. NRW*); Eastern German territorial states (*ostdt. Flächenländer*). Source: Regionalverband Ruhr (2023, p. 11).

This high debt of the municipalities is also related to the social welfare benefits that the municipalities must provide due to unemployment rates considerably above those in the rest of Germany and North-Rhine Westphalia (see Figure 61). However, we can also see strong intra-regional disparities of unemployment, with highest values in Gelsenkirchen and lowest in Wesel (see Figure 62).

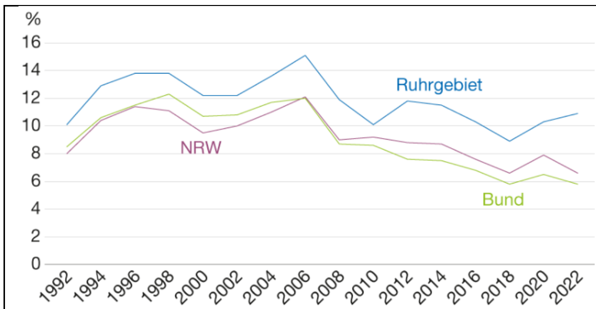

Figure 61: Development of the unemployment rates in Germany (Bund), North-Rhine Westphalia (NRW) and the Ruhr Area (Ruhrgebiet). Source: van de Loo and Hanske (2023, p. 859).

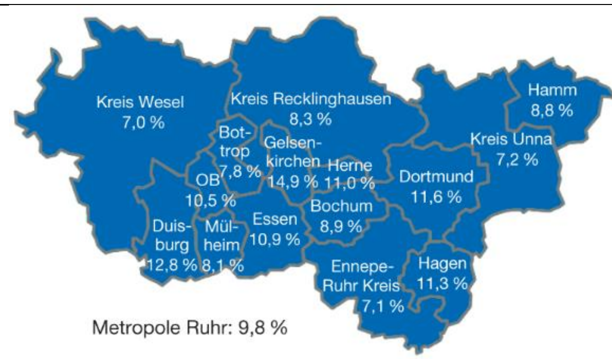

Figure 62: Unemployment rates of the NUTS 3 regions in the Ruhr Area in 2023. Source: van de Loo and Hanske (2023, p. 859).

134 Development of loans to secure liquidity (Entwicklung der Kredite zur Liquiditätssicherung) based on IT.NRW und DESTATIS.

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As mentioned in the case study of Emilia-Romagna (see Chapter 3.2.2), the **transport sector** is crucial for all economic activities and strongly related to the **competitiveness and innovation capacity** of a region (Ng et al., 2019; Palei, 2015; Skorobogatova & Kuzmina-Merlino, 2017). In this regard, the Ruhr Area has one of the densest transport infrastructure networks in Europe, including Europe's largest inland port in Duisburg (Regionalverband Ruhr, 2022c). The "geographical position in the middle of Europe is a locational advantage [that] […] should be used in an optimal way by outbound connections and an inner network. That is why sound motorway, railway, shipping and air traffic systems are of utmost importance" (Keil & Wetterau, 2013, p. 70). Even though the Ruhr Area has a very dense motorway infrastructure[135], traffic jams due to the "massive freight and long distance transports and the high amount of commuters traffic" (ibid.) limit its transport performance significantly. In this regard, a further development of the "already existing solution to relieve the lorry freight traffic is the combined transport (rail/road, road/waterway and rail/waterway), as containers can be transported not only on roads but also on rails and waterways. This is important because freight transport on the regional waterways is still below the capacity limit, even if the transport volume of the inland navigation is constantly increasing" (Keil & Wetterau, 2013, p. 70). This aspect is significant for developing the distribution infrastructure for hydrogen and ammonia by ship (see section introducing the related Pilot use case below).

In addition to the transport infrastructure, **research and education** infrastructure are crucial for the competitiveness and innovation capacity of a region. Even though the process of establishing universities and research institutes in the Ruhr Area started comparatively late (see Chapter 3.4.2), nowadays there is a well-developed knowledge infrastructure with 5 universities, several universities of applied sciences and several research institutes (see Figure 63). However, the innovation capacity is significantly limited by a lack of resources (e.g., student-to-professor ratio), and in relation to its population of 5.1 million, the Ruhr Area has a below-average number of non-university research facilities compared to other metropolitan regions (e.g., Berlin or Munich) (Kiese, 2019, p. 71). Additionally, as mentioned earlier, the transformation to a knowledge-based economy "could be boosted by knowledge-intensive business start-ups from and in the vicinity of universities and research institutions, thereby strengthening the regional economy endogenously [*own translation*[136]]" (Kiese, 2019, p. 74).

Despite the comparatively high number of enrolled students in the Ruhr Area, social inequalities are also reflected in the lower share of higher education in the population[137] of the Ruhr Area compared to Germany and the rest of the EU (see Figure 64). Regarding the availability of skilled workers for the development of the hydrogen ecosystem, this does not pose a significant bottleneck in the current "early stage of market launch, meaning that demand for H_2 skills on the labour market has been relatively low to date. At present, the demand for a skilled workforce is met by training existing staff in particular [*own*

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[135] "The network of 4,700 kilometers of regional roads is highly connected, with a remarkable share of motorways; the share of the Metropolis Ruhr is 12.9 percent, in contrast to the 7.4 percent NRW average and just five percent for the whole of Germany" (Keil & Wetterau, 2013, p. 70).

[136] Please note, that the study is in German language and the translation is not strictly literal.

[137] Percentage of people from 25 to 64 years (source: EUROSTAT).

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translation[138]]” (Grimm et al., 2021, p. 7).[139] However, in the medium term, an increased investment in hydrogen infrastructure is expected to boost the hydrogen economy, increasing the demand for skilled labour. This growing demand for personnel may result in exacerbating skill shortages that potentially limit the development of a competitive hydrogen ecosystem (ibid., p. 8). A stronger focus on education, training (e.g., construction), studies (e.g., engineers), and (applied) research is, therefore, of crucial importance for developing a hydrogen ecosystem (Ronsiek et al., 2024).

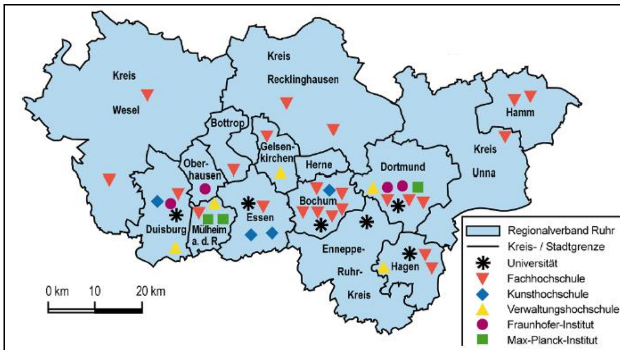

Figure 63: Universities and selected research institutions in the Ruhr Area (signatures not true to position). Cartography: Ralf Wieland (supplemented according to RVR 2017, P. 2). Legend from top to bottom: RVR (“*Regionalverband Ruhr*”), county/ city limit (“*Kreis- / Stadtgrenze*”), university (“*Universität*”), university of applied sciences (“*Fachhochschule*”), academy of fine arts (“*Kunsthochschule*”), public administration college (“*Verwaltungshochschule*”), Fraunhofer Institute (“*Fraunhofer-Institut*”), Max-Planck-Institute (“*Max-Planck-Institut*”). Source: Kiese (2019, p. 71).

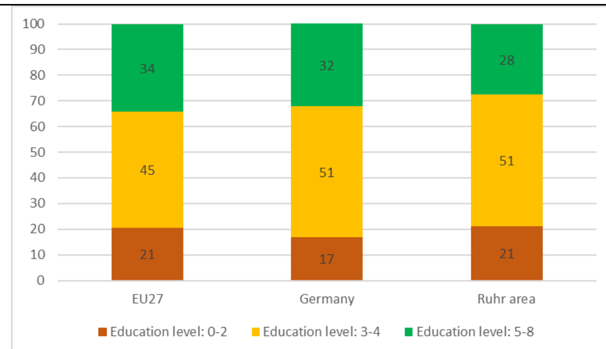

Figure 64: Comparison of education levels in the EU, Germany and the Ruhr Area (aggregation of NUTS 3 regions; (percentage of people from 25 to 64 years). Own compilation based on data from EUROSTAT.

As mentioned above, economic aspects represent only one dimension of sustainability. Economic factors are closely intertwined with other socio-political and environmental factors that influence transition potential. Regarding the **social and political dimensions** of transition potential, the European Social Progress Index provides a useful basis for a detailed assessment. In this regard, the three NUTS 2 regions that the Ruhr Area is part of, Düsseldorf, Arnsberg, Münster, score very high (see Table 24). However, as mentioned above, this aggregation may be misleading as it does not reflect the structural inequalities of the Ruhr Area. Regarding the “at-risk-of-poverty rate”, which is one of the most important indicators for assessing social disparities, it is obvious that the Ruhr Area faces a significant challenge: the Ruhr Area has by far the highest “at-risk-of-poverty rate” of the regions in NRW (see Figure 65) In combination with the

[138] Please note, that the study is in German language and the translation is not strictly literal.
[139] Even though a study by Ronsiek et al. (2024) show, that for the hydrogen ramp-up, “a higher number of people with building trades, energy technicians, and electrical technicians will be needed in the medium term. These professions are already experiencing shortages in the labour market, and in many of them, the labour supply is expected to become even tighter due to demographic change” (ibid., p. 31; please note, that the study is in German language and the translation is not strictly literal).

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extremely high municipal debts in the region, it could be expected that these negative factors are also reflected in the assessment of the government performance, which would affect the political dimensions of transition.

In this regard, the results from the European Quality of Government Index (see Table 25) about the quality[141], impartiality[142] as well as the corruption in the provision of public services[143], show a high level of trust in public institutions by the citizens of the three NUTS 2 regions (best scores of the four TRANSFORMER TSL regions). However, this might not be the case for the Ruhr Area with its social disparities, structural inequalities and high debts of its municipalities. As studies about the so-called "left behind regions" suggest (Greve et al., 2023; Rodríguez-Pose & Bartalucci, 2023), these social inequalities are expected to cause a lack of trust in institutions. However, as a study from Küppers and Decker (2023) shows, this is not the case for the Ruhr Area. Based on a comprehensive survey (see Figure 66), they show that the institutional trust in the federal government, federal parliament, unions, justice system and courts, media, and the political parties is higher than the German average. They assume, that "one of the reasons for the higher level of political support may be that politicians in the Ruhr region have been more

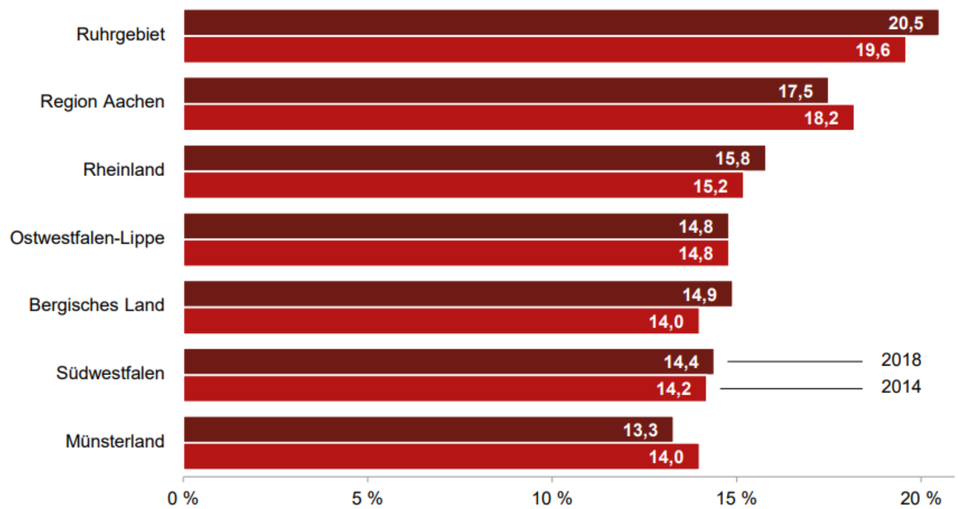

Figure 65: At-risk-of-poverty rates[140] in NRW 2014 and 2018 by region.
Ruhr Area (*Ruhrgebiet*), Aachen region (*Region Aachen*), Rhineland (*Rheinland*); Eastern Westphalia-Lippe (*Ostwestfalen-Lippe*), Bergisches Land (Bergisches Land), South Westphalia (*Südwestfalen*), Münsterland (*Münsterland*). Source: Ministerium für Arbeit and Gesundheit und Soziales Nordrhein-Westfalen (2020, p. 255).

140 Number of people with an equivalised income (new OECD scale) of less than 60 % of the median equivalised income of the North Rhine-Westphalia population per 100 people in the corresponding region, in private households in each case. Source:

141 Questions from the questionnaire: How would you rate the quality of [from very poor to excellent]… 1) ..public education in your area? 2) …the public health care system in your area? 3) …the police force in your area? (Charron et al., 2022, p. 12). For complete questionnaire see (Charron et al., 2022).

142 Questions from the questionnaire [from strongly disagree to strongly agree]: 1) Certain people are given special advantages in the public health care system 2) The police force gives special advantages to certain people in my area. 3) All citizens are treated equally [from agree to disagree]… A) …in the public education system in my area. B) …the public health care system in my area. C) …by the police force in my area. 4) In the area where I live, elections are conducted freely and fairly. (Charron et al., 2022, p. 13). For complete questionnaire see (Charron et al., 2022).

143 Selected questions from the questionnaire: Corruption is prevalent in [from strongly disagree to strongly agree]… 1) my area's local public school system. 2) …in the public health care system in my area. 3) …in the police force in my area. 4) People in my area must use some form of corruption to just to get some basic public services. 5) Corruption in my area is used to get access to special unfair privileges and wealth. […] (Charron et al., 2022, pp. 13-14). For complete questionnaire see (Charron et al., 2022).

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successful than in other former industrial regions in cushioning the social hardships of structural change by means of various state development and support programmes [*own translation*[144]]" (Küppers & Decker, 2023, p. 679). In this regard, it can also be expected that inclusive structural programs like "IBA Emscher Park" or the Ruhr conference (see Chapter 3.4.2) are also beneficial for creating trust in institutions.

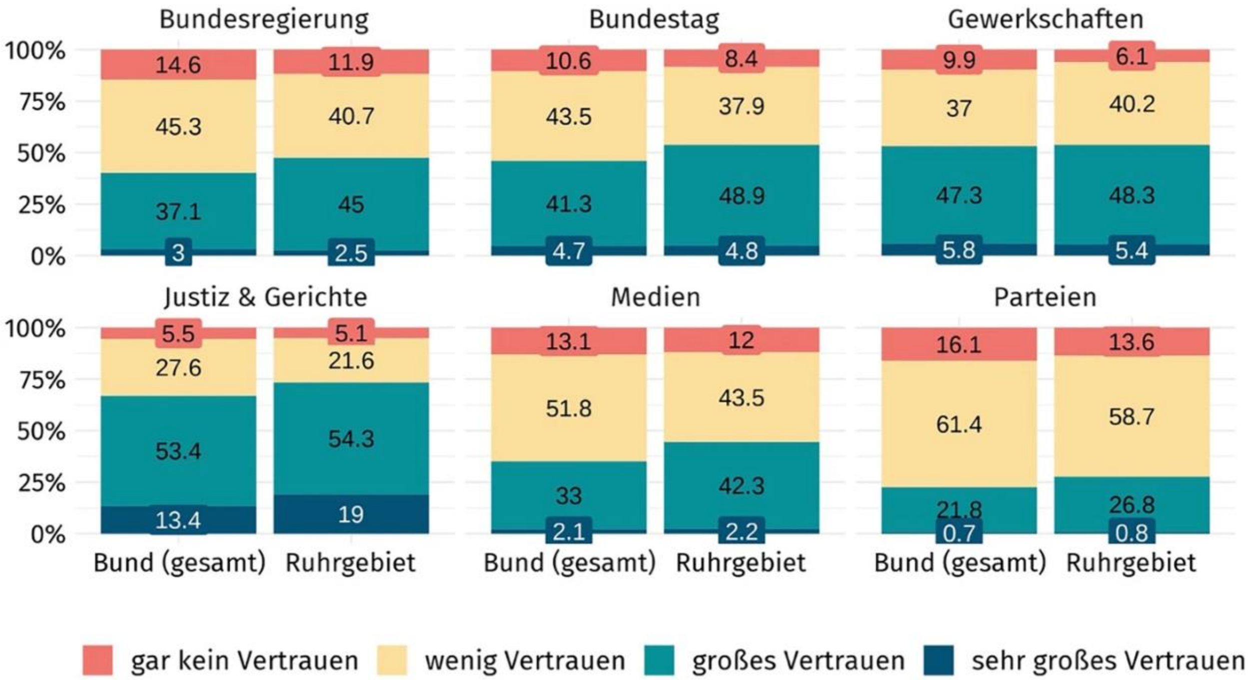

Figure 66: A comparison of institutional trust in Germany and the Ruhr region (the values for Germany as a whole include the Ruhr region). From top left: institutional trust in the… federal government (Bundesregierung); federal parliament (Bundestag); unions (Gewerkschaften); justice system & courts (Justiz & Gerichte); media (Medien); political parties (Parteien). Answers from left to right: no trust at all (gar kein Vertrauen), low trust (wenig Vertrauen), high trust (großes Vertrauen), very high trust (sehr großes Vertrauen). Data basis: FES/Infratest dimap survey 2019.
Source: Küppers and Decker (2023, p. 676)

This trust in institutions is of pivotal significance, as the fundamental transition of the socio-economic structure requires the support and acceptance of political measures by the citizens of the Ruhr Area. In this context, a survey by the European Investment Bank in 2023/24 shows[145] that "economic and financial" aspects (82%), especially "increased cost of living" (62%), are perceived by citizens (n=219) of North-Rhine Westphalia[146] as bigger challenges than "climate change" (51%) (EIB 2024).[147] This is also reflected in the

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144 Please note, that the study is in German language and the translation is not strictly literal.

145 Question: "What are the three biggest challenges that people in your country are currently facing?" Source: EIB (2024): https://www.eib.org/attachments/survey/eib-climate-survey-2023-2024-dataset-all-countries-cop28.xlsx (Excel sheet: Germany). The references are listed in the Chapter "Data sources".

146 No data for NUTS 2 levels available.

147 The results of these surveys additionally show a fundamental shift in perceived challenges. In an earlier survey from the EIB (2020), "Economic and financial" aspects (44%) have been perceived by citizens (n=436) of North-Rhine

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dominant opinions (57%) that the "government should address climate change *without* affecting the personal budget"[148], and that "the transition to a low carbon economy can only happen if inequalities are addressed at the same time" (67%).[149] Regarding employment opportunities due to this transition, a majority (57%) expects that "climate change will destroy more jobs than they will create new ones" (EIB 2024).[150]

The latter assessment (albeit from the citizens of all NRW and not only from the Ruhr Area) is particularly problematic: Against the background of the still persistent structural inequalities resulting from deindustrialization (Lengyel et al., 2022, p. 576), especially high unemployment and municipal debts, a holistic approach for the region is required that focuses on its most important transition needs. However, the "fact that there is no undisputed regional center impedes regional thinking and regional action" (Keil & Wetterau, 2013, p. 33) and increases the risk of municipalities competing with one another about limited resources rather than collaborating – as happened numerous times in the past (Bogumil et al., 2012; Goch, 2003; van Houtum & Lagendijk, 2001).[151]

Nevertheless, there are several examples that indicate a gradual shift towards a more regional, inclusive and holistic approach: the establishment of the Ruhr Regional Association[152] (*Regionalverband Ruhr*, RVR) in 2004 was an important step, especially for drawing up a Ruhr regional plan which has been implemented - after a process that lasted more than a decade (starting in 2011) - in February 2024 (Regionalverband Ruhr, 2024). However, it also highlights again the challenges the Ruhr Area is facing regarding fragmented responsibilities and competing interests among multiple responsible authorities. Nevertheless, it also has to be emphasized that the independent "Academy for Territorial Development in the Leibniz Association" (ARL) has highlighted the "broad, participatory, and consensus-oriented planning process that has garnered significant interest and recognition far beyond the Ruhr Area. It is considered an innovative contribution to the further development of regional planning in Germany" (ARL - Akademie für Raumentwicklung in der Leibniz-Gemeinschaft, 2019, p. 1). In addition, the Ruhr

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Westphalia as *smaller* challenges than "climate change" (60%). Source: EIB (2020): https://www.eib.org/attachments/survey/climate-survey-citizens-perception-climate-change-impact-all-data-en.xlsx (Excel sheet: Germany). The references are listed in the Chapter "Data sources".

[148] Question: "Would you say that… […] Your government should address climate change without affecting your personal budget". Source EIB (2024).

[149] Question: "Would you say that… […] The transition to a low carbon economy can only happen if inequalities are addressed at the same time. Source EIB (2024).

[150] Question: What impact do you think the measures adopted by your country to fight climate change and protect the environment will have? Answer: They will destroy more jobs than they will create new ones (57%). Source: EIB (2024)

[151] The reasons for this still dominant political fragmentation are controversially disputed. However, a study by van Houtum and Lagendijk (2001, p. 758) suggests "that a political choice was made not to homogenise politically the Ruhr area, but to divide it among the different political regions. The Ruhr area was and thereby stayed an intersection of the different political regions in North Rhine-Westphalia. It seems likely that the political will, of mainly the dominant political party still, the Social Democrats (SPD), to divide and thereby stay in control in the different regions, instead of in the Ruhr area alone, has played a role of some importance in this respect" (ibid., p. 758).

[152] As the Regionalverband Ruhr highlights in their publication (2018), the RVR has a long history though: In 1920 the "Association of the Ruhr Coal Region" (Siedlungsverband Ruhrkohlenbezirk [SVR]) was founded by the municipalities and districts of the Ruhr Area and in 1979 renamed to "Municipal Association for the Ruhr Region" (Kommunalverband Ruhrgebiet [KVR]). Since 2004 the association is called Ruhr Regional Association (RVR).

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conference initiated in 2018 (see Chapter 3.4.2) can also be regarded as an attempt for developing more regional and holistic approaches (Dahlbeck et al., 2023).[153]

Against the background of initiating more inclusive and bottom-up approaches, citizen assemblies like the "Bürger*innenrat" in Duisburg, focusing on participatory approaches for discussing policy goals and developing hydrogen solutions, can be regarded as a promising way of developing inclusive and socially accepted solutions (Bergische Universität Wuppertal. Institut für Demokratie- und Partizipationsforschung [IDPF], 2023).

The results of this "Bürger*innenrat" (with 45 participants not representative though) are very interesting because they developed several main policy recommendations and "red lines": One recommendation is to "produce green hydrogen as locally as possible with a view to energy self-sufficiency and creation of jobs" (ibid., p. 8) and simultaneously *strictly avoiding* "relying exclusively on imports of green H_2" *and* "that green H_2 transition is taking place without respecting human rights and environmental protection in the producing countries" (ibid.).

This goal leads us to the **ecological and environmental dimensions of sustainability** that constitutes together with the above-described economic and socio-political dimension the region's transition potentials: the **potential for the development of renewable energy as a prerequisite for generating "green" hydrogen in the region.** Based upon this, the Pilot use cases evolving around "assessing regional energy (electricity, heat and hydrogen) demands", the "distribution of hydrogen" as well as the "applicability of hydrogen in heating" will be briefly portrayed.

The **cost-efficient generation of hydrogen** will determine the scope and pace of the hydrogen ramp-up. At current fossil prices, we can see an "average cost gap between fossil-based hydrogen and renewable hydrogen [of] approximately €3/kg" (see Figure 67) (Agora Energiewende and Guidehouse, 2021, p. 11). The cost of renewable hydrogen is primarily determined by three aspects: "(1) the cost of renewable electricity; (2) the annual operating hours of the electrolyser, or so-called capacity factor; and (3) the electrolyser system costs" (ibid.).

153 Even though Dahlbeck et al. (2023) argue, "that this approach was accompanied by a lengthy decision-making process. In some cases, this resulted in projects deemed worthwhile not being funded or being funded only at a later date, due to a lack of or insufficient funds. A separate budget would also have given the Ruhr Conference more weight in public and political perception" (ibid., p. 19).

hat "this approach was accompanied by a lengthy decision-making process. In some cases, this resulted in that projects deemed to be worthwhile could not be funded or could only be funded at a later date or only at a later date due to a lack of or insufficient funds. A separate budget would also have given the Ruhr Conference more weight in the public and political political perception.

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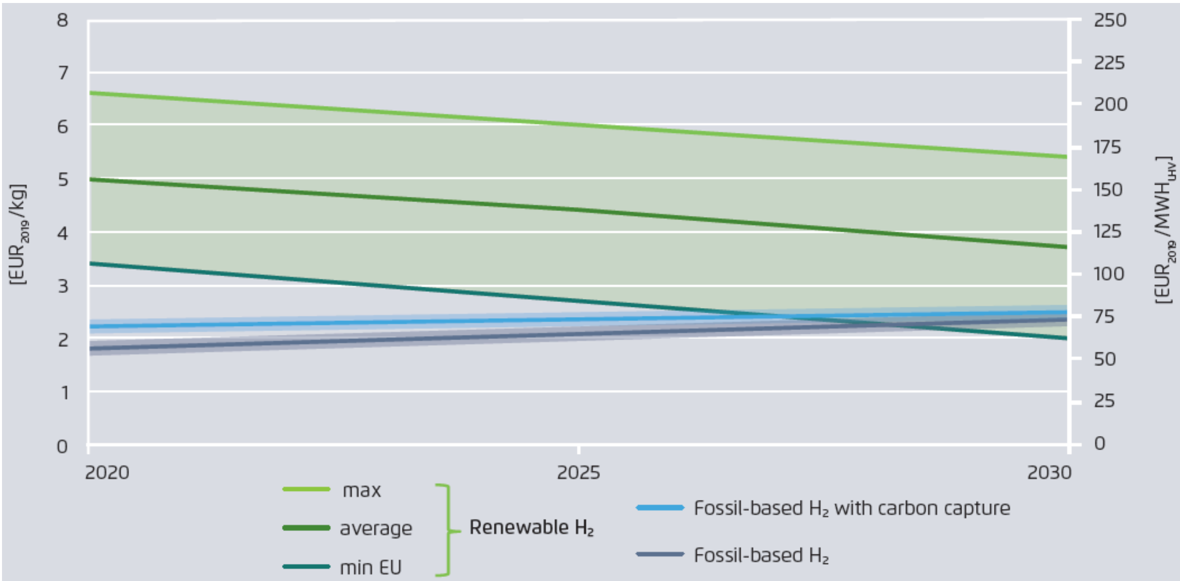

Figure 67: Production cost of renewable H2 compared to fossil-based H2 with and without carbon capture. Source: Agora Energiewende and Guidehouse (2021, p. 14).

Guidehouse based on BNEF (2021), Prognos et al. (2020), Hydrogen Europe (2020), Gas for Climate (2020), Agora Energiewende and AFRY Management Consulting (2021). The price range for fossil-based H_2 reflects an implicit carbon price of €50/tCO_2 in 2020 increasing to €100/tCO_2 in 2030. For natural gas, a price of €20/MWh is assumed. The capture rate for fossil-based H_2 with carbon capture is assumed to be around 75%

If we take a look at the first aspect that determines the hydrogen costs, the availability of (cost-efficient) **renewable energy,** we can see that the Ruhr Area had in 2020 a comparatively low share of RE in its electricity (9%, see Figure 68) and heat consumption (1.1%, see Figure 69), with the largest shares in biomass (Regionalverband Ruhr, 2022a, p. 22). In addition, the Ruhr Area has – despite its dense population – still a significant potential for the development of RE.[154]

[154] Data about the potentials of RE (wind, solar radiation, biomass, water power) for NRW on a NUTS 3 level can be downloaded here: https://www.energieatlas.nrw.de/site/Media/Default/Dokumente/202205_Potenziale_Energieatlas_NRW.xlsx

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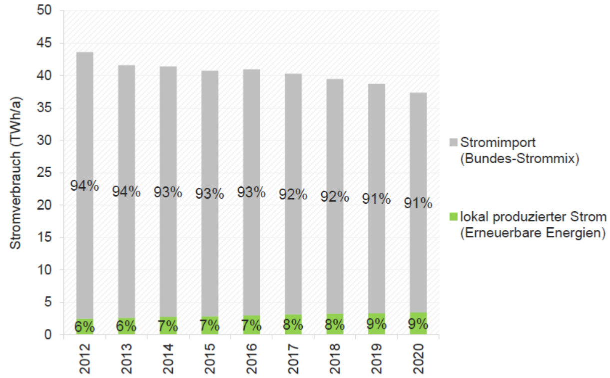

Figure 68: Renewable energies (in green) in the Ruhr metropolis - share of total electricity consumption. Source: Regionalverband Ruhr (2022a, p. 24).

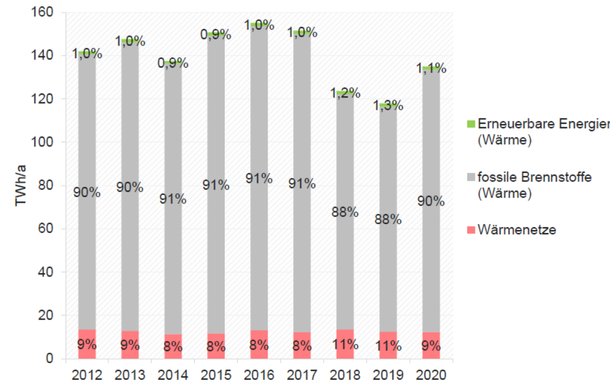

Figure 69: Renewable energies (in green) in the Ruhr metropolis - share of total heat consumption. Source: Regionalverband Ruhr (2022a, p. 25).

A study from 2016 on the potential for the development of wind power in the Ruhr Area (Gertec GmbH, 2016) showed that the greatest potential for the development of wind energy can be found in the more rural communities. By far the greatest potential was identified in Dorsten, followed by Haltern am See (see Figure 70). Together, the two municipalities have more than a quarter of the Ruhr Area´s total wind potential. However, as already mentioned in the case study of Emilia-Romagna (Chapter 3.2.3) and Lower Silesia (Chapter 3.3.3), restrictions for wind power reduce this (theoretical) potential significantly: in their most recent analysis, the RVR "identifies a possible area of only 2,714 hectares. That is only 2.5 percent of all suitable areas in North Rhine-Westphalia [*own translation*[155]]" (Polzin, 2023, p. 1). However, PV is less controversial and especially the development of PV on rooftops has a significant potential that should be used for maximising the sustainable electricity generation in the Ruhr Area (see Figure 71). This form of renewable energy is not only cost-efficient and competitive, but – unlike the development of windpower – also has only very limited potential for conflicts (Gölz & Wedderhoff, 2018; Leiren et al., 2020; Zoellner et al., 2008).

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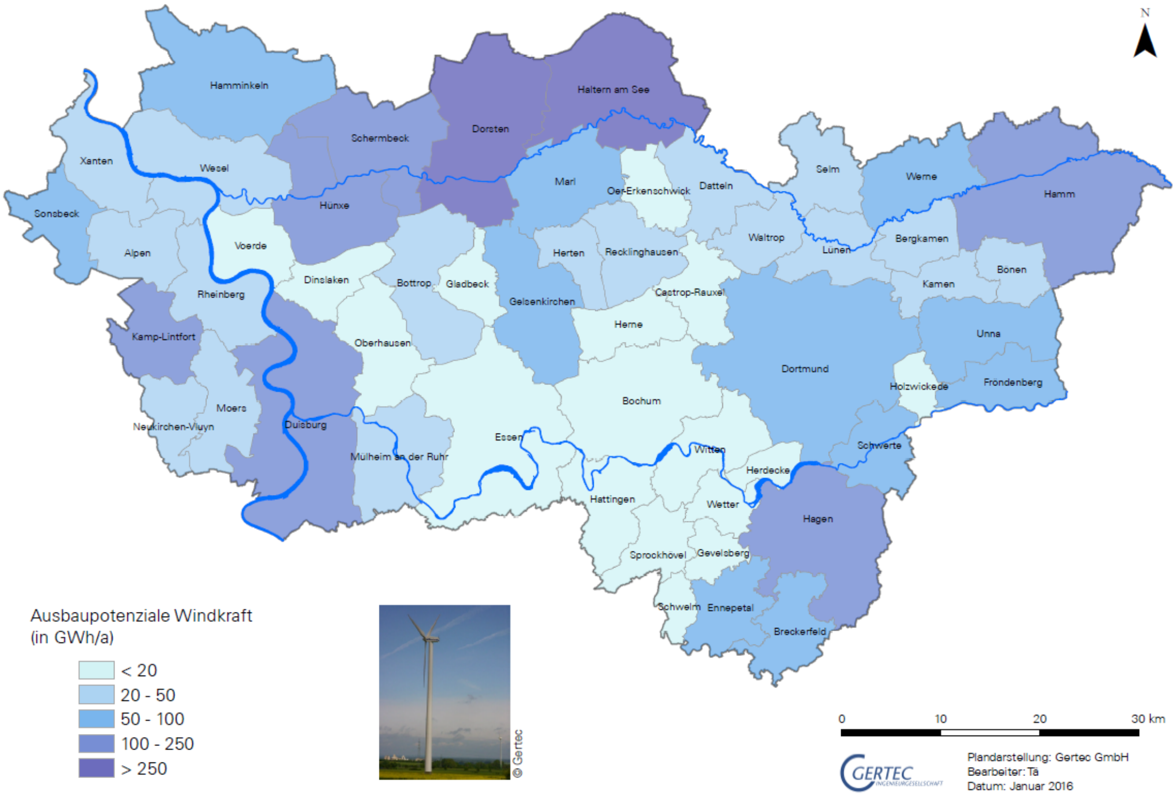

Figure 70: Wind energy potential in the Ruhr Area (in GWH/a) in 2016. Source: Gertec GmbH (2016, p. 60).

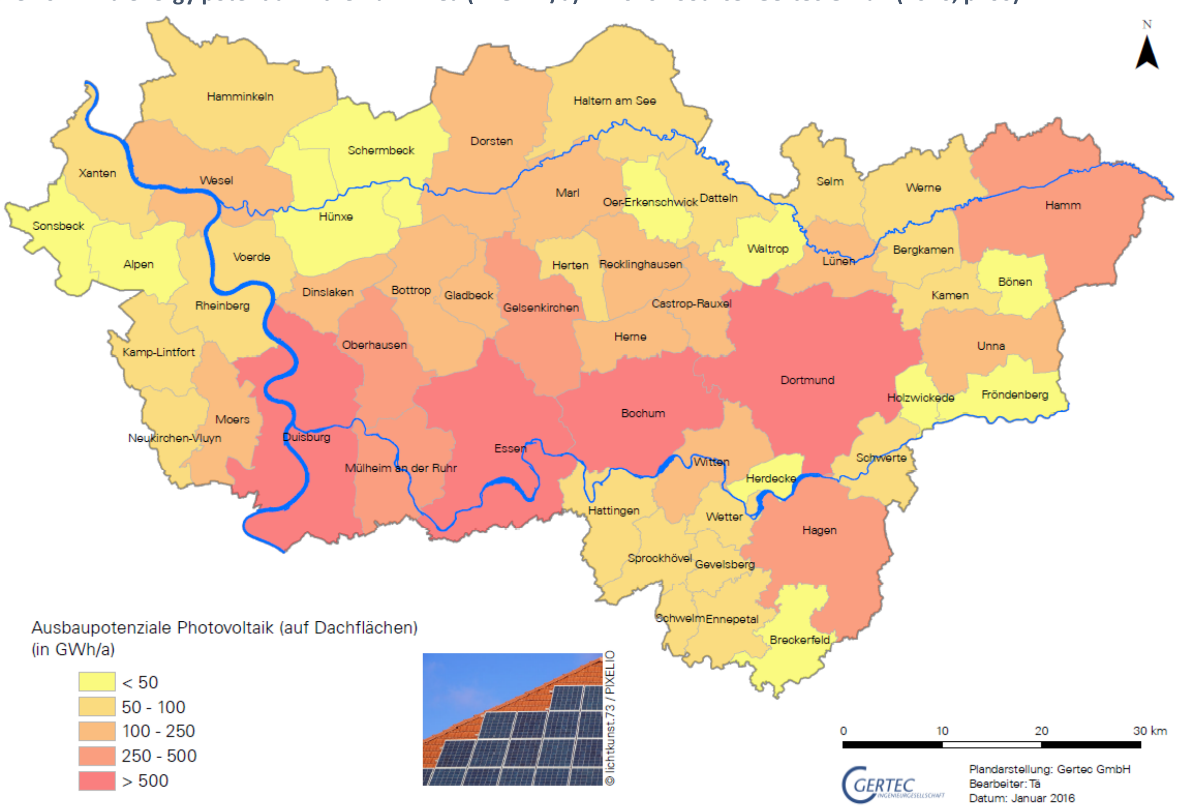

Figure 71: Photovoltaic potential on rooftops (in GWH/a) in 2016. Source: Gertec GmbH (2016, p. 70).

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However, a densely populated region like the Ruhr Area, with its energy-intensive industries, will not be able to become fully self-sufficient based on RE. This is particularly the case if the electrification of mobility and transport is further developed, and if additional electricity demand for the generation of hydrogen is considered (see Figure 72).

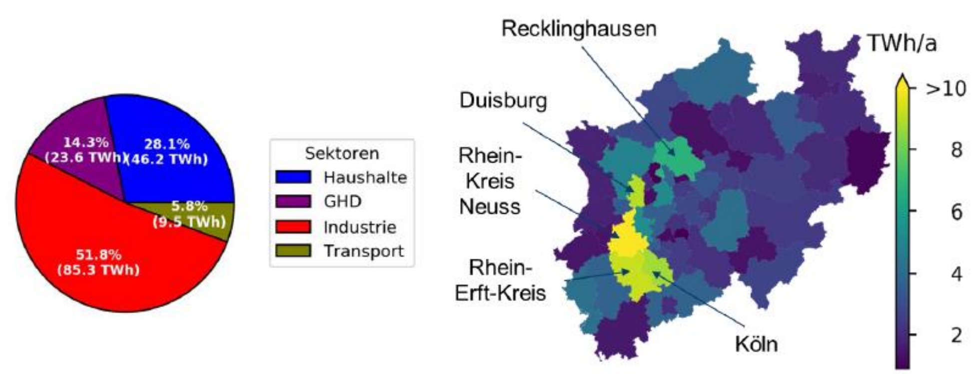

Figure 72: Structure and regional allocation of electricity demand in NRW in 2050. Sectors: Housing (Haushalte); Trade, commerce and services (Gewerbe, Haushalt, Dienstleistungen [GHD]; industry (Industrie); transport (Transport). Source: Cerniauskas et al. (2021, p. 75).

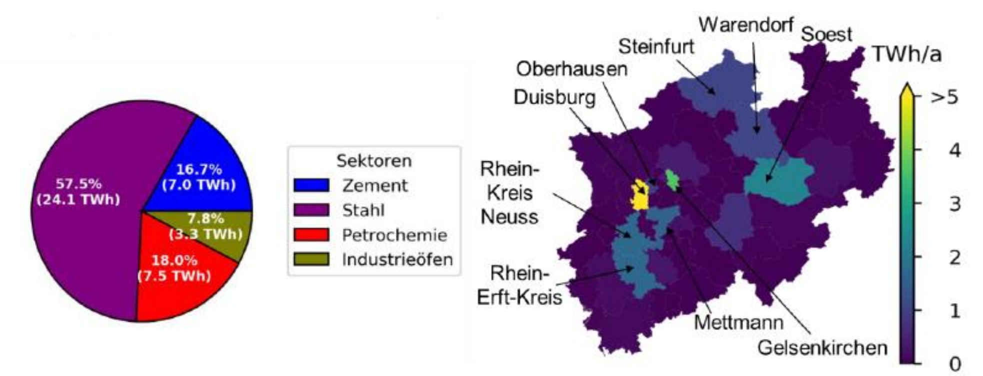

Figure 73: Distribution of final energy demand for hydrogen in 2050 (only including hydrogen demand from industry, which is supplied externally). Sectors: Cement (Zement), steel (Stahl); petrochemicals (Petrochemie), industrial furnaces (Industrieöfen). Source: Cerniauskas et al. (2021, p. 77).

The huge demand for green hydrogen (see Figure 73) must therefore be met by imports from other regions, which have a larger potential for the development of renewable energy. As Figure 74 shows, many areas in Europe have a high potential for the generation of green hydrogen (even though the sustainability of the local/regional water supply for the generation of hydrogen has to be critically monitored). One of the TSL regions, Western Macedonia, is currently developing a hydrogen ecosystem to transform their economy from a lignite-based economy (mining and energy generation) to a diversified, climate neutral and sustainable economy (see case study of Western Macedonia). A cooperation between these two regions would meet the expectations of the "Bürger*innenrat" of Duisburg (see section above), which expects that the import of hydrogen respects human rights and environmental protection in the producing countries.

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However, the import, distribution and storage of hydrogen will be a challenge. In this regard, the Ruhr Area has a dense pipeline system for gas that can be converted to transport hydrogen instead of natural gas. In this regard, federal and state governments already decided on the conversion of large parts of the existing gas grid in Germany to make it H2-ready. This conversion of the core gas grid (*Wasserstoff-Kernnetz*) is expected to cost approximately 20 billion € (Agora Energiewende, 2024, p. 8). This already indicates that significant investment is needed to transform the energy system.[156]

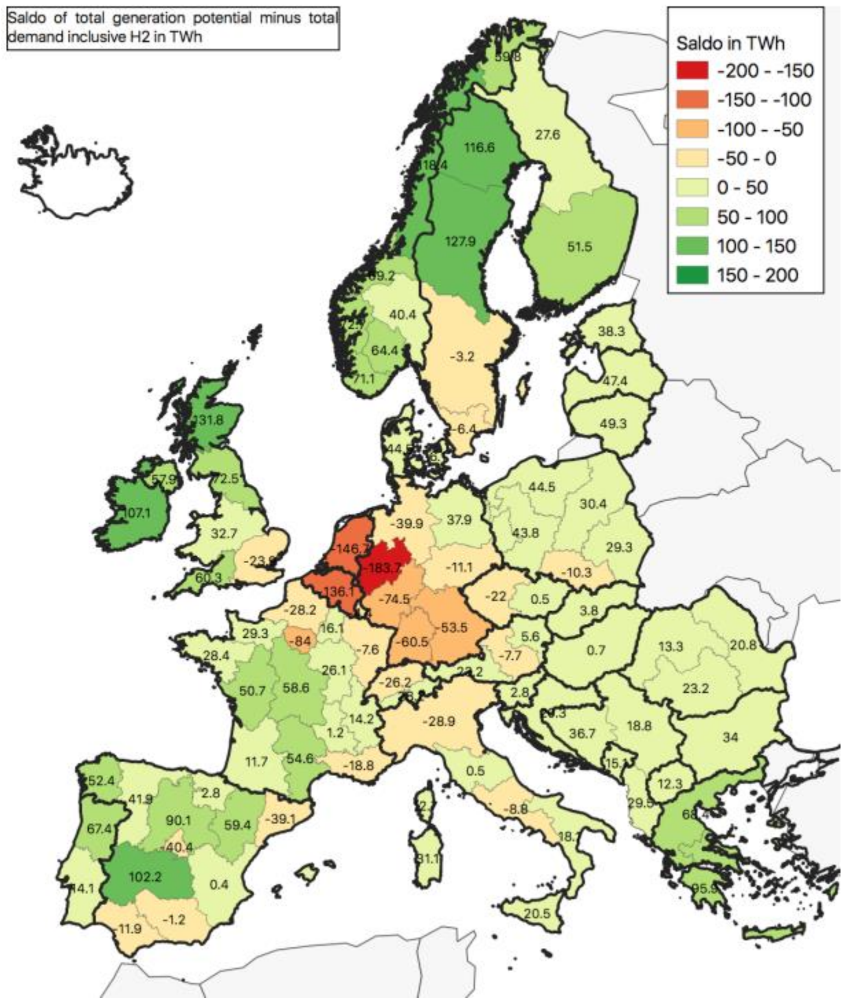

Figure 74: Balance of renewable generation potential and demand with electricity for hydrogen in Europe 2050. Source: Wuppertal Institut (2020, p. 18).

Disclaimer: The designations used and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the map creators or publishers concerning the legal status of any country, territory, city, or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

156 According to this study from Agora Energiewende (2024), "until 2045, approximately 310 billion euros have to be invested to expand the electricity transmission network from 37,000 to 71,000 kilometers of lines on land and at sea. For the so-called hydrogen core network, the federal government and FNB Gas have identified 9,700 kilometers of hydrogen pipelines with an investment volume of nearly 20 billion euros, which are to be constructed by 2032 to supply power plants and industries" (ibid., p. 8).

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However, regarding the import and distribution infrastructure, the Ruhr Area has a well-developed waterways system (see Figure 75) that could be used for the transport of hydrogen and ammonia by ship: "With 270 kilometers of inland navigation routes and a variety of harbours and terminals, it is Europe's densest harbour and canal system. Next to the river Rhine and the navigable part of the river Ruhr, there are the Wesel-Datteln Canal, the Datteln-Hamm Canal, the Dortmund-Ems Canal and the Rhine-Herne Canal. These canals have purposely been built as transport routes and had to meet the 20th century demands of coal mining and the iron and steel industries" (Keil & Wetterau, 2013, p. 72). Now they bear a huge potential for complementing the pipeline infrastructure to accelerate the ramp-up of the hydrogen system. Even though in the long run, import and distribution of hydrogen via pipeline is more cost-efficient (Cerniauskas et al., 2021; EE Energy Engineers & TÜV Nord EnSyS, 2023), the use of the waterway infrastructure is discussed as a promising option for the mid to short -term development (see Pilot use case 1).

However, in this regard, the **risks of developing large-scale hydrogen solutions** have to be clearly analyzed and discussed. Focusing too much on hydrogen solutions bears the risk of creating unsustainable path dependencies and lock-in effects due to high investments in infrastructure (Agora Energiewende, 2023; Sachverständigenrat für Umweltfragen [SRU], 2021). Therefore, the above-mentioned existing gas pipelines need to be converted in a realistic, demand-oriented way, and non-competitive pipeline infrastructure needs to be properly decommissioned. Otherwise, unsustainable long-term costs due to high grid fees will be created (ibid.). The same applies to the canal infrastructure. Investing in harbour infrastructure and ships for transporting hydrogen (or ammonia) bears the risk of creating stranded assets. Against the background of municipal debt and competition for limited resources, such large-scale hydrogen-related solutions might not be the most sustainable investment. Solutions for enhancing thermal insulation of public buildings and increasing their energy efficiency might have a higher return on investment in terms of emission reduction. Therefore, a large-scale project like the "hydrogen river" has to be carefully co-created by all affected stakeholders and designed to meet realistic long-term needs (Pilot use case 1). In this regard, it is also important to have a truly regional approach: against the backdrop of political and administrative fragmentation, the large cities of the Ruhr Area (e.g., Duisburg) might push the hydrogen solutions that are attractive to them at the expense of the politically less influential municipalities. A TSL with a regional perspective and inclusive character might be a promising approach to develop beneficial solutions for the whole region.

In addition, "it is all the more important not to unnecessarily increase the sectoral demand for hydrogen, for example, through infrastructure investments that create path dependencies for applications where direct use of electricity would be technically feasible and economically more sensible [*own translation*[157]]" (SRU, 2021, p. 73). The use of hydrogen or other synthetic fuels in motorized private transport and building heating from the outset would waste costly and scarce resource in these sectors. Other technical solutions are available in the form of battery-powered electric vehicles, and, in the building sector, better insulation and electric heat pumps (BMWi, 2020; Fraunhofer IEE, 2020; Rosenow, 2022; Slorach &

157 Please note, that the study is in German language and the translation is not strictly literal.

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Stamford, 2021). In this context, hydrogen in heating should be very critically tested and analyzed (Pilot use case 2).

As we can clearly see, there are still many unknowns regarding the development of a hydrogen ecosystem: the availability of affordable green hydrogen, the time-sensitive local demand, and the cost-efficient distribution and storage of hydrogen (Cerniauskas et al., 2021). Therefore, a detailed simulation of the hydrogen demand and distribution capacities is needed to manage and optimize hydrogen supply in the Ruhr Area (see Pilot use case 3).

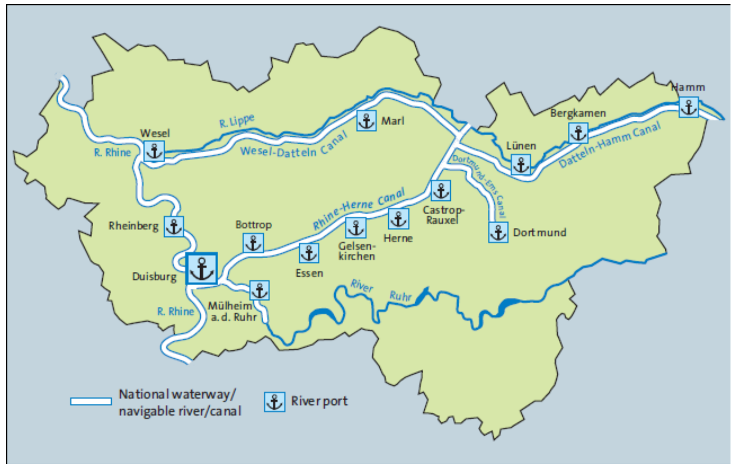

Figure 75. Waterways and harbours in the Ruhr.
Source: Keil and Wetterau (2013, p. 72)

However, developing a hydrogen ecosystem in the Ruhr Area should not only focus on technical aspects and an economy-led demand and supply side. A just and truly sustainable transition towards climate neutrality requires balancing the interests of all stakeholders from the quadruple helix, as well as all three dimensions of sustainability (Kalt & Tunn, 2022).

Before we briefly portray the related Pilot use case in Chapter 3.4.4, we summarise the transition needs and potentials of the Ruhr Area in a regional SWOT analysis.

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Table 16: Regional SWOT analysis as a summary of the transition needs and potentials of becoming climate neutral in context of the TSL approach. Source: own compilation.[158]

Strength (helpful internal factors)	**Weaknesses** (harmful internal factors)
• High GDP (per capita) and economic resources for transition • High competitiveness • Dense transport infrastructure and favourable geographic location • Dense research network & high innovation capacity • Established manufacturing & industrial base with qualified workers • Increasing economic diversification (e.g., health sector) Hydrogen • Expertise in hydrogen-related activities • Hydrogen-related research institutes • Existing infrastructure for hydrogen • Political commitment for implementing hydrogen solutions	• Political and administrative fragmentation • Structural inequalities (unemployment, risk-of-poverty) • High debts of the municipalities Hydrogen • High initial investment costs • Technical challenges (e.g., storage) • High uncertainties regarding availability of affordable hydrogen • Lack of regional RE capacities • Market uncertainties (overall demand for hydrogen and development of hydrogen costs • Regulatory complexities • Low potential for regional generation of green (RE-based) hydrogen
Opportunities (helpful external factors)	**Threats (external)** (harmful external factors)
• EU funding for innovative actions (hydrogen, circular economy, sustainable mobility) • EU and national targets for RE development Hydrogen • Strong activities for developing a European hydrogen network (e.g., favorable geographic position in the developing pipeline and waterways infrastructure for hydrogen) • EU and German funding for hydrogen solutions (in industrial regions)	• Uncertainty about *national* legislation and regulations (regarding climate action or energy solutions; e.g., feed-in-tariffs) • Global economic fluctuations (export-oriented regional economy) • Competitive pressure from other regions (e.g., "green" steel production) Hydrogen • Competitive pressure from other regions with similar ambitions of becoming "hydrogen-frontrunners" • Dependency on hydrogen imports • Risk of unsustainable path dependencies (e.g., oversized hydrogen infrastructure) • Economic fluctuations impact investment and project feasibility

[158] This regional SWOT analysis is based on a comprehensive document analysis and two workshops conducted in the realm of WP2 and WP3.

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3.4.4 TSL vision and Pilot use cases

As described in the chapter about the methodological approach (Chapter 2), the assessment of transition needs and potentials, as well as the analyses of the political framework, has been a continuous and iterative process conducted in tandem with the project partners (WP2, WP3, WP4, WP5) and has been the guiding aspect in developing a vision for the TSL, coalition building (Deliverable 3.1), and identifying the most important Pilot use cases (Deliverable 3.2). A summary of the vision and Pilot use cases is included in Table 17. The continuous exchange of information between the WPs of the TRANSFORMER project has been vital for developing these case studies as well as the "Action plans" (Deliverable 3.3) for the specific Pilot use cases. The discussion about strategies for long-term implementation is based on this cooperation and will be included in Chapter 3.6 and Deliverable 3.3.

Table 17: Ruhr Area: The vison and Pilot use cases at a glance. Source: summary of the descriptions included in Deliverables 3.1 and 3.2.

The vision: The recent surge in interest in hydrogen, evident from EU, German, and North Rhine-Westphalia strategies and roadmaps, underscores its crucial role in achieving climate neutrality by 2050 across industries. The Ruhr Area, with its extensive experience in hydrogen production, is positioned as a key player in this transition, especially with its shift towards green hydrogen. This transformation involves diverse sectors like steel, mobility, and power generation, fostering a robust hydrogen ecosystem. Collaboration among various stakeholders, including companies, research institutes, and municipalities, is essential for investment and innovation across the hydrogen value chain. Regional initiatives like the "Ruhr Conference" facilitate inclusive stakeholder dialogues, emphasizing hydrogen's importance. The vision for the **Ruhr Area** is to become one of the greenest industrial regions in Europe, leveraging sustainability and resource efficiency to combat climate change through hydrogen adoption. With tangible market ramp-up scenarios, including near-term natural gas substitution, and favourable conditions like port access and pipeline networks, the Ruhr Area is poised to become a nucleus of the hydrogen economy, driving Europe's energy transition. **The Pilot use cases**: **Pilot use case 1:** *Extension of the Rhine-Herne Canal into a "Hydrogen River"* The first Pilot use case aims to utilize existing inland shipping routes for hydrogen distribution, offering a modular and supply method as an alternative to pipelines. It entails importing hydrogen and its derivatives via ports like Duisburg and Wesel, and distributing them via inland waterway vessels. This approach addresses challenges in decarbonizing transport and enhances regional hydrogen distribution. The project promotes sustainability, scalability, inclusiveness, and innovation, potentially creating employment opportunities and aiding structural transformation. Collaboration among stakeholders, including businesses, administrations, and research institutions, is crucial. The project also seeks integration with former coal-fired power plant areas, requiring coordinated action and scientific support for its implementation and expansion. **Pilot use case 2:** *Hydrogen in neighbourhoods and residential districts: Hydrogen as an energy carrier in municipal heat planning* The second Pilot use case "Hydrogen in Neighbourhoods" aims at exploring new solutions for municipal heat planning by using hydrogen as an energy carrier. It addresses the transition away from oil and gas heating systems, emphasizing the potential for hydrogen use. The project focuses on creating neighbourhood-wide energy solutions in collaboration with municipalities, utilities, and housing associations. By leveraging locally produced hydrogen and blending it into distribution networks, it aims to offer scalable and sustainable heating options. The project promotes inclusivity, involving stakeholders like tenants' associations and housing cooperatives, and aims to raise awareness about the benefits of hydrogen. Collaboration with research institutions and energy agencies is crucial for project success and future expansion. **Pilot use case 3**: *H_2 system cockpit: recording and connecting existing hydrogen initiatives to achieve optimal systemic synergy effects* The Ruhr Area aims to become the "greenest industrial region in Europe" by leveraging green hydrogen to link industrial production, energy supply, and climate protection. Several major projects have kickstarted the region's transition to a

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hydrogen economy, focusing on production, distribution, and utilization of hydrogen. Coordination between these projects within the Ruhr Area is crucial. The Gas and Heat Institute Essen e.V. (GWI) and Rhein Ruhr Power e.V. propose the H_2 System Cockpit, a model to simulate and optimize hydrogen-based energy supply, enhancing flexibility, efficiency, cost-effectiveness, and significantly reducing CO_2 emissions, thereby advancing the region's journey towards climate neutrality.

The TSL in the Ruhr Area aims to help overcome the political and administrative fragmentation of the region by focusing on regional transition needs and potentials, while not neglecting specific local contexts. It is supposed to build bridges between local actors and needs by emphasizing the possibility of synergy effects in regional solutions. However, in this regard, the example of Emilia-Romagna and Western Macedonia show that a strong regional partner, like the RVR or the *Initiativkreis Ruhr*[159], is highly beneficial – or even fundamentally necessary – for such an ambitious goal (see Chapter 3.6).

[159] The “Initiativkreis Ruhr” is an economic alliance of large companies and institutions from the region and beyond. In over thirty years, a strong network of committed minds has emerged. Together, we initiate projects that contribute to the economic and social development of the Ruhr region: https://initiativkreis-ruhr.de/

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3.5 Western Macedonia

As described above, the case study will begin by providing a brief **overview of the region** (3.5.1) to "[d]efine the boundaries of the system in terms of geography" (Geus et al., 2022). Based on this, the **transition needs to achieve climate neutrality** will be assessed, focusing on the most significant economic sectors contributing to climate change (3.5.2). The identification of these transition needs will allow us to narrow down the otherwise too complex analysis of the **socio-economic and ecological transition potentials** of the region. These closely intertwined transition needs and potentials will be then summarised **in form of a regional SWOT analysis** (3.5.3). These identified transition needs and potentials guided the **TSL vision and Pilot use cases**, which will be briefly portrayed in Chapter 3.5.4. The results of the chapters about the four TSLs (Chapters 3.2-3.5) will then be incorporated in Chapter 3.6 in an overall discussion **about strategies for the long-term implementation of TSLs**.

3.5.1 Overview of the TSL region

Western Macedonia is a region in northern Greece located between the regions Epirus and Central Macedonia and bordering the region of Thessaly to the south and the countries of Albania and North Macedonia to the north (see Figure 77). Western Macedonia is the only landlocked region in Greece and dominated by the Pindus Mountain range. It covers an area of more than 9,400 km² and had a population of approximately 254,000 inhabitants in 2022, which has been decreasing by nearly 10% over the last decade.[160] The largest cities are Kozani, Florina, Kastoria, and Grevena (Yiannakou et al., 2017).

[160] According to EUROSTAT, Western Macedonia had a population of 284,061 in 2012 compared to 253,954 in 2022. See Chapter 3.5.3 for a discussion of the socio-economic implications of this development.

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Figure 76: Location of Western Macedonia within Greece. Source: Wikipedia[161]

Figure 77: The region of Western Macedonia. Source: Yiannakou et al. (2017, p. 4)

Western Macedonia is one of the poorest of the 13 regions in Greece with a GDP (pps) per capita of 5,549 € in 2022 and one of the highest unemployment rates in the EU[162] (see Figure 89). In the last decades, the economy has been dominated by large-scale lignite mining and energy generation which has led to a “poorly diversified labour market [that is] heavily dependent on demand (for labour, services) from mining and energy companies” (Koryś, 2023, p. 23). With a total installed power capacity of 4.4 GW erected since the 1950s, the lignite power plants in Western Macedonia provided for more than two-thirds of the electric power consumption in Greece for many decades (Yazar et al., 2023). After a gradual reduction in electricity generation by lignite, which already began in the early 2010s, the complete phase-out of all lignite-based energy generation in the region will be completed by 2028 as part of the National Energy and Climate Plan (NECP) that was ratified in 2019 (Malamatenios et al., 2022). The NECP[163] specifies the “objective for reducing greenhouse gas (GHG) emissions by more than 42% compared to emissions in 1990 (Ministry of the Environment and Energy, 2019, p. 4) and a reduction of “GHG emissions by 95% in 2050 compared to 1990” (Stapper, 2023, p. 15). To achieve this goal, a comprehensive set of policy measures has been developed. These measures focus on several key areas, including the above-mentioned nationwide shutdown of lignite-fired power plants, the promotion of renewable energy

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161 https://upload.wikimedia.org/wikipedia/commons/thumb/2/2d/Periferia_Dytikis_Makedonias.png/250px-Periferia_Dytikis_Makedonias.png

162 In 2021, 19.7% of the people from 15 to 74 years in Western Macedonia have neen unemployed (Data from EUROSTAT)

163 The “National Energy and Climate Plan” is built upon the ratification of the Kyoto Protocol in 2002 and the Paris Agreement in 2016.

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sources (RES), enhancing energy efficiency in buildings, industry, and infrastructure, as well as reducing emissions in the transport sector (ibid., 119).

Since the economy and labour market of Western Macedonia are still strongly focused on lignite mining and energy generation (see Chapter 3.5.2), this fundamental reconstruction of the regional economy will have deep socio-economic impacts if not managed well (Mavromatidis, 2018). In order to foster a sustainable and just transition, a "Territorial Just Transition Plan (TJTP)" was implemented, and the Regional Government (see Table 18 for a brief overview of the political system) has set an ambitious plan to diversify the economy, especially by attracting "investments in new innovative and green technologies, such as those of RES, as well as energy storage technologies, in particular hydrogen" (Malamatenios et al., 2022, p. 4). Against this background, the following analysis of the region's transition needs and potentials of achieving the goal of climate neutrality will focus on the socio-economic dynamics in the context of the energy transition.

Table 18: Brief overview of the political system of Western Macedonia. Source: own compilation.

A TSL can be regarded as a new form of governance arrangement (see Chapter 2.1). However, a TSL is not implemented in a political void and, therefore, must be designed to be complementary to existing political-administrative structures (see Chapter 3.6). This brief overview of the political system of the region is intended to portray some of the main existing political structures of the region. The specific political decision-making processes and participation processes need to be carefully analysed in detail for different topics and Pilot use cases (see Deliverable 3.3 for the specific contexts of the Pilot use cases). Western Macedonia, one of Greece's thirteen administrative regions, consists of four regional units: Florina, Grevena, Kastoria, and Kozani. Governed by a presidentialist system, elections are held every five years in two rounds for both the Regional Governor and the Regional Council, collectively forming the Regional Government. This body is responsible for devising and implementing regional strategies aligned with principles of sustainable development and social cohesion, while also considering national and European policies (Council of Europe, 2012). The executive branch of the Western Macedonia regional government is led by the Regional Governor and comprises sixteen Deputy Governors, each overseeing specific areas such as administration in each regional Unit, technical works, entrepreneuship & transportation, rural development, economic affairs, tourism-culture-natural environment, digital transformation, education, and health. In general, they are tasked with the implementation of the regional development plan (Council of Europe, 2012). Decision power is vested in the Regional Council, consisting of forty-five regional Councillors. They are responsible for making political and administrative decisions affecting the region, including approving, and monitoring the region's operational program, development programs, and budget. They also have authority over matters such as expropriation of real estate, property transactions, and financial agreements. Likewise, there are sectoral boards, such as the Executive Committee, a regional governing body, which supervises the implementation of regional policy and the regional development plan. It is composed of the Regional Governor, who presides over the committee, or Deputy Leaders appointed by him/her. Also, the Economic Committee supervises the audit and implementation of the regional budget. Its members consist of the Regional

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Governor or a designated deputy as the president, along with elected regional councillors (Council of Europe, 2012).

The TSL in Western Macedonia specifically aims at complementing these political governance arrangements by implementing a hub for cross-sector collaboration through innovation of stakeholders across the quadruple helix in order to promote sustainable growth (see vision and Pilot use cases in Chapter 3.5.4).

3.5.2 Assessing the transition needs of becoming climate neutral

As described above (see Chapter 2.1), regional transition needs and potentials are closely interrelated and influenced by the ecological, social, and economic dimensions of sustainability. In the context of the overarching goal of achieving climate neutrality, **GHG emissions** are, by definition, one of the main indicators that need to be analysed. In this regard, despite a radical decrease in the overall greenhouse gas emissions per capita of Western Macedonia, they are still among the highest in Greece and the EU (see Figure 78 and Figure 79). The same applies to the carbon emission intensity of the economy (Figure 80 and Figure 82). However, as we can clearly see in the GHG emissions per sector, this extremely high GHG level – and its decrease in the last decade – is nearly completely related to the aforementioned energy system (see Figure 83), which provides electricity for the entire country of Greece. As the GHG emission only refer to the *production* and not to the *consumption* of socio-economic processes, this data does not reflect the actual ecological footprint of the region and its citizens.

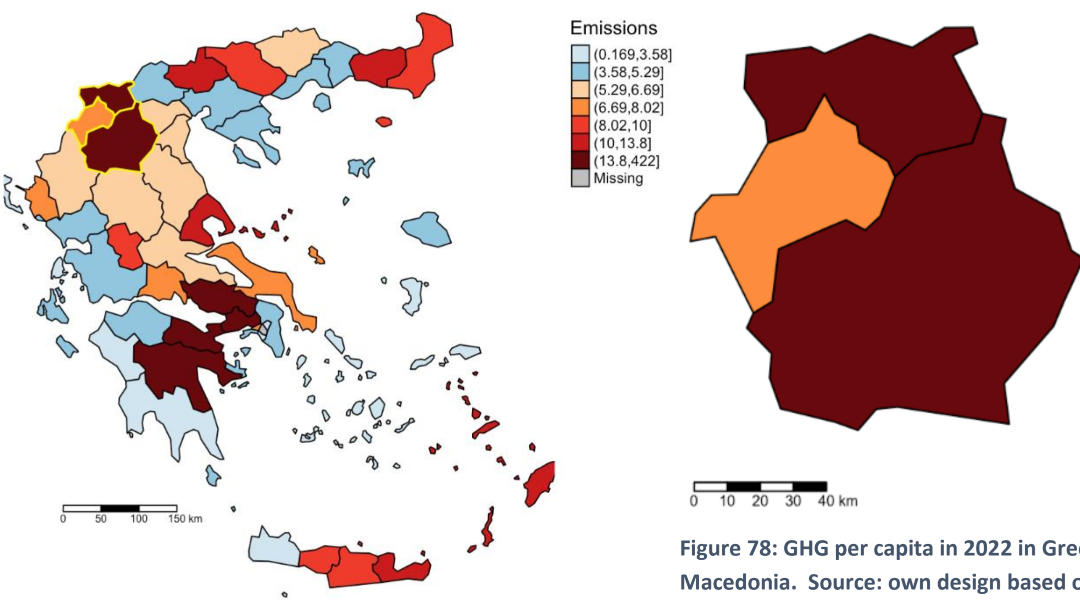

Figure 78: GHG per capita in 2022 in Greece and Western Macedonia. Source: own design based on data from EDGAR (CO2eq) and EUROSTAT (per capita).

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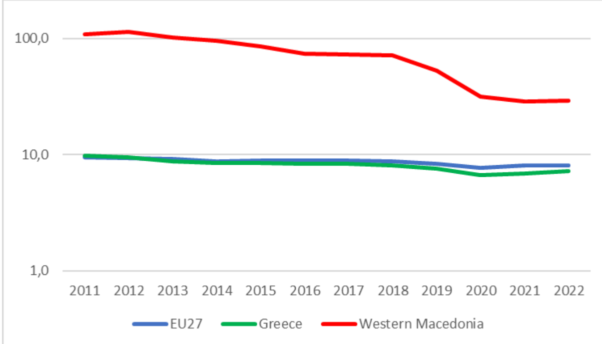

Figure 79: Average CO2eq per capita (t) of the EU (NUTS 2 regions), Greece and Western Macedonia (logarithmic scale). Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (per capita).

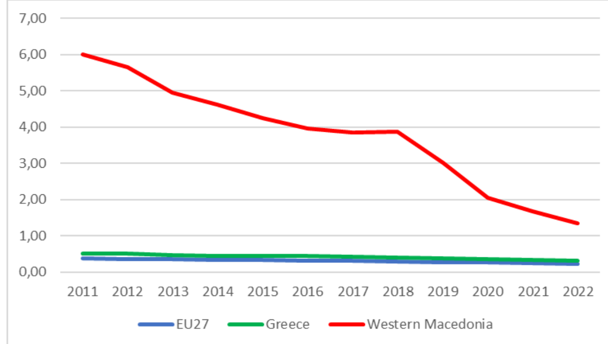

Figure 80: Development of the CEI (CO2eq [kg] / GDP pps [EUR]) in the EU (NUTS 2 regions), Greece and Western Macedonia. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (GDP pps).

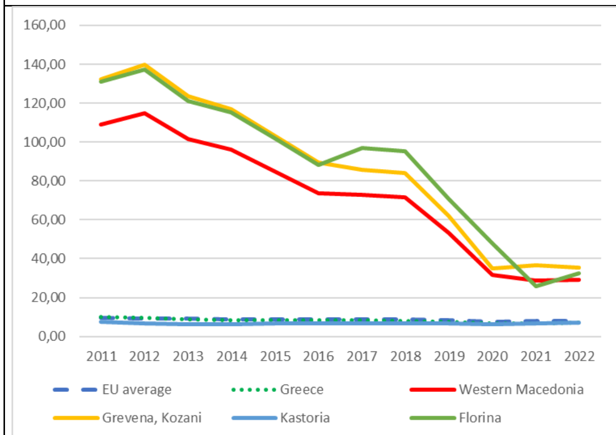

Figure 81: Average CO2eq per capita (t) of the EU (NUTS 2 regions), Greece, Western Macedonia and its NUTS3 regions. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (per capita).

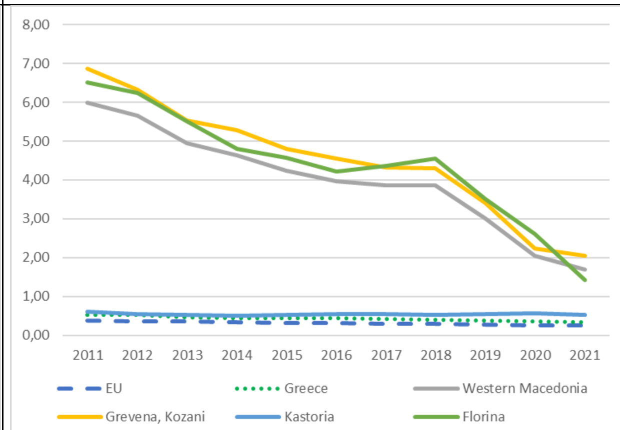

Figure 82: Development of the CEI (CO2eq [kg] / GDP pps [EUR]) in the EU (NUTS 2 regions), Greece, Western Macedonia and its NUTS3 regions. Own compilation based on data from: EDGAR (CO2eq) and EUROSTAT (GDP pps).

If we exclude the energy system, the sectors contributing the most to climate change are "Transport" and "Industry". However, we can already observe a strong decline in these sectors, with up to 60% in the "industries". This positive trend with regard to climate mitigation, however, is problematic from an economic perspective, as a significant share of this reduction is not due to more efficient industrial processes, but to the shutdown of industries and suppliers for the **energy sector** (Vrontisi et al., 2024).[164] This also applies to a large degree to the reduction of GHG emissions in the transport sectors, which reflects the above-mentioned depopulation of the region of nearly 10% in the last decade and the reduced amount of **transport and mobility** activities due to reduced industrial activity. After a brief look at the state of the energy and transport sectors and their importance for the regional economy, we will therefore

164 According to Vrontisi et al. (2024, p. 2), the "[d]ecommissioning of coal plants and the associated closure of coal mines drives unemployment higher and regional income lower. These first-round effects are usually followed by a second round of impacts such as the decrease in activities of sectors that are related to the coal industry and the decrease in regional expenditure leading to an overall decrease in regional dynamics and welfare."

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focus our analysis particularly on the socio-economic implications of the transition of the energy system and on strategies for the economic reconstruction of the region.

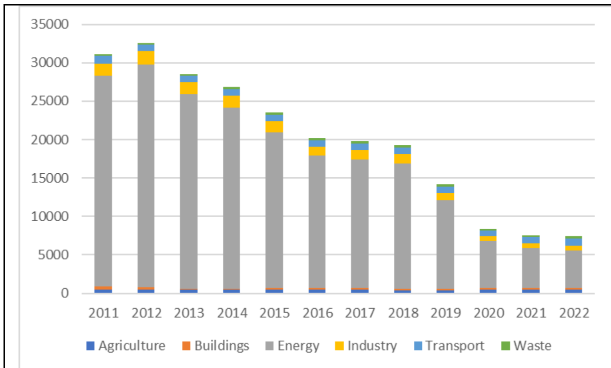

Figure 83: CO2eq (kt) per sector in Western Macedonia. Own compilation based on data from: EDGAR (CO2eq).

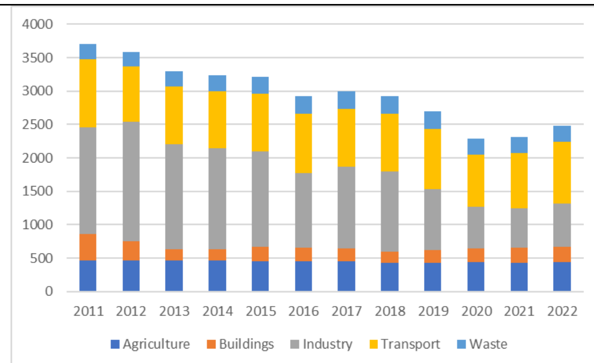

Figure 84: CO2eq (kt) per sector (without energy) in Western Macedonia. Own compilation based on data from: EDGAR (CO2eq).

As mentioned above, the fossil **energy sector** was the main pillar of Western Macedonia's economy: In 2019, more than 30% of its GVA was generated in the energy and utility sector, and the labour market as well as the economy were poorly diversified and strongly tied to energy-related activities (Vrontisi et al., 2024, p. 4). Approximately 7% of the total local employment was "directly linked with the lignite industry" (Yazar et al., 2023, p. 17) and the Public Power Corporation was the largest employer (ibid.). It is estimated that "around 11,000 workplaces will be lost in mining, energy production, and complementary activities" (Koutsomarkos & Stamos, 2023, p. 9) in this transition process and need to be substituted by a diversification of the regional economy. [165] As the wages in the mining and electricity sector are according to the Hellenic Statistical Authority (2020) comparatively high[166], this will have a strong effect on the disposable income per capita in the region.

This fundamental transformation does not only require strategies for reconstructing the labour market, but also for the regional energy infrastructure itself: "approximately 100,000 citizens of the region use district heating systems powered by lignite power plants" (Vrontisi et al., 2024, p. 4).

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165 This estimation is very much in alignment with a study from Stapper (2023, p. 15) that estimates a job loss until 2029 due to this transition process of over 14,000 (in Western Macedonia, Megapolis, Aegean Islands & Crete combined). However, the estimations vary considerably. Ziouzios et al. (2021, p. 4) refers to a study that estimates "a loss of 21,000 direct and indirect jobs" due to the lignite phase-out. This is even a more positive outlook in comparison to an older estimation: Mavromatidis (2018, p. 6) referred to a study from 2011 which estimated a job loss of more than 40,000 people, if the phase-out of lignite-related activities was not managed well. This would have led to an increase in the regional unemployment rate of over 40% (ibid.).
According to „around 11.000 work places will be lost in mining, energy production and complementary activities. This is even a more positive outlook in comparison to an older estimation of the regional development authority ANKO: Referring to a study from 2011, a job loss of more than 40,000 people was estimated, ledaing to an increase of the unemployment rate up to losing their job an increase of the unemployment rate of over 40%, if the phase-out of lignite-related activities was not managed well.

166 The data is available for download via following URL: https://www.statistics.gr/en/statistics/-/publication/SJO49/-

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For the substitution of lignite after the phase-out in 2028 (see Figure 85), "the new Ptolemaida V lignite unit with a capacity of 660 MW is […] is supposed to operate on lignite fuel until 2028 after which it was supposed to be converted to natural gas. However, recent economic and geopolitical developments have called this into question" (Yazar et al., 2023, p. 17). In the mid- to long-term perspective, sustainable energy solutions based on renewable energies are definitely a more secure and economically sound option. This is strongly reflected in the regional authorities' strategy, which emphasizes the importance of renewable energy sources (RES) for economic development. Accordingly, there has been a more than 400% increase in RE capacity since 2016 (see Figure 86 and discussion about RE potential below).

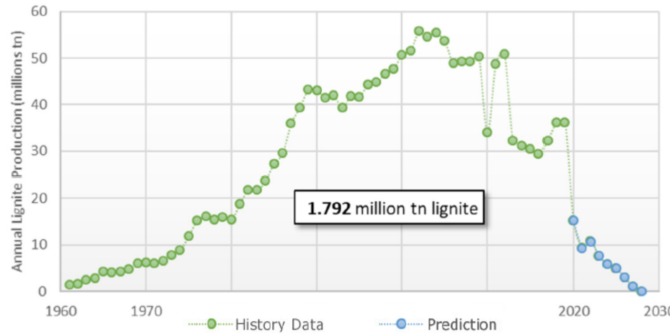

Figure 85: Lignite production in the Mines of Public Power Corporation (PPC) SA in the region of Western Macedonia.

Source: Sotiropoulos et al. 2020[167], taken from: Ziouzios et al. (2021, p. 3).

[167] Sotiropoulos, D.; Karlopoulos, E.; Dimitriou, A.; Soumelidis, A. Threats for the Region of Western Macedonia towards an Abolition of Lignite-Based Electricity Production in Greece by 2028; Reference Study ordered by the Governor of Western Macedonia; Technical Chamber of Greece, Department ofWestern Macedonia: Kozani, Greece, 2020; 9p.

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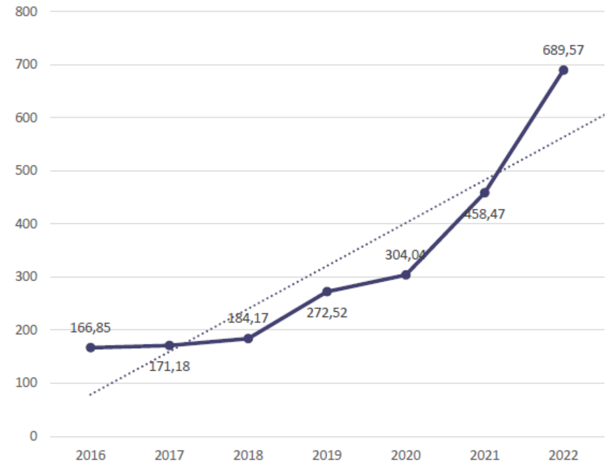

Technology	2021	2022 (until May)
Photovoltaic Cells	16.939 MWh	63.828 MWh
Onshore wind farm	53.362 MWh	18.905 MWh
Small Hydroelectric Plants	9.053 MWh	6.636 MWh
Biogass/ Biomass	1.143 MWh	1.038 MWh

Figure 86: Distribution of installed power from RE (in MW) and distribution of electricity production from RES. Slightly adapted figure taken from: Koutsomarkos and Stamos (2023, p. 55) based on data from DAPEEP SA. [168]

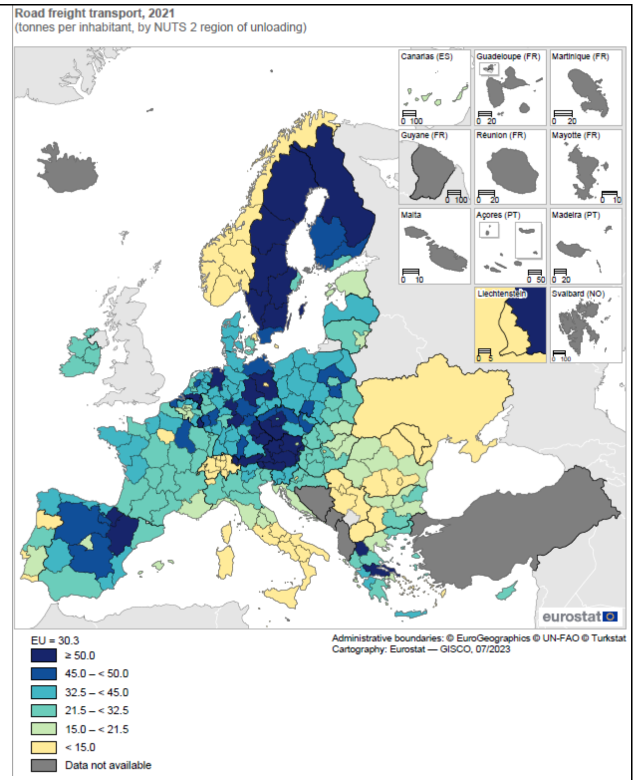

Figure 87: Road freight transport in the EU. Source: EUROSTAT.[169]

Even though the phase-out of lignite activities is a necessity for becoming climate neutral, other sectors have to be transformed as well. In this regard, **transport and mobility** are of paramount significance. This is not only due to comparatively high GHG emissions (see Figure 84): The development of an efficient transport infrastructure (road, bus and rail) is of crucial importance for economic growth and (sustainable) development: "[R]oad infrastructure plays a crucial role by providing mobility for the efficient movements of people and goods, as well as providing accessibility to a wide variety of commercial and social activities" (Ng et al., 2019, p. 1). In this regard, Western Macedonia scores very low. According to the EU Regional Competitiveness Index 2.0 (Dijkstra et al., 2023) it has by far the lowest score in road[170] and rail transport performance of all four TSLs (see Table 22).[171] The lack of railway infrastructure is also strongly reflected in the high share of GHG intensive road freight transport (see Figure 87). The low transport performance is also a limiting factor for the ambitious regional master plan for transition that focuses on five pillars: 1)

168 https://www.dapeep.gr/dimosieuseis/sinoptiko-pliroforiako-deltio-ape/ (last access 09.05.2024)

169 With 96.6 tonnes per inhabitant (unloading by NUTS 2 region), Western Macedonia has one of the highest values in the EU. Source: https://ec.europa.eu/eurostat/documents/7116161/17557903/1102EN.pdf Statitics available on EUROSTAT (online data codes: road_go_ta_ru and demo_r_d2jan)

170 Population accessible within 1h30 by road in a neighbourhood within a 120 km radius. Please note that accessibility is only one of many indicators that need to be considered for assessing transport performance (e.g., safety, comfort, costs for mobility, etc.). However, due to limited (and comparable) data availability, we focus on this frequently used indicator.

171 Population accessible within 1h30 by rail (using optimal connections) in a neighbourhood within a 120 km radius.

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clean energy development (e.g., PV plants of more than 2.5 GW in abandoned lignite mines, battery production, hydrogen production facility); 2) industry and manufacturing activities and trade; 3) smart agricultural production; 4) sustainable tourism; 5) research, innovation, technology and education (Ziouzios et al., 2021, p. 6). As mentioned above, economic growth and innovation capacity vdepends on a capable infrastructure.[172] This applies even more to the development of tourism in a region, that is landlocked, located away from major transportation routes and with very limited access to airports (Koryś, 2023, p. 23).[173] Before we will discuss these development strategies, we need to analyse and discuss in the next chapter the overall transition potential – and limitations – of Western Macedonia.

3.5.3 Assessing the transition potentials from a socio-economic and ecological perspective

As mentioned in Chapter 2.1, regional transition needs and potentials are highly related to each other, and both are unfolding into the three sustainability dimensions. Assessing the transition potentials of a region for becoming climate neutral, therefore, requires considering social, economic and ecological/ environmental aspects. In this chapter, we will conduct this analysis focussing on the evaluation of different composite indices and selected indicators (see Figure 1).[174] The results will then be summarised in a regional SWOT analysis.

Regarding the potential for transition, the **economic performance,** especially the **competitiveness and innovation capacity** are considered to be of crucial importance. In this regard, Western Macedonia scores very low (see Table 21 for an overview of the scores from the composite indices). This applies especially to indicators referring to macroeconomic statistics (e.g., disposable income per capita, and GDP per capita, see Figure 88) and the labour market (comparatively low labour productivity[175] and very high unemployment rate; see Figure 89).

[172] This also encompasses the accessibility of research institutes and universities, in which Western Macedonia also scores very low according to the EU Regional Competitiveness Index 2.0 (Dijkstra et al., 2023).

[173] According to the EU Regional Competitiveness Index 2.0 (Dijkstra et al., 2023), Western Macedonia has a very low score regarding the accessibility to airports.

[174] Please note that these composite indicators often refer to the same data (e.g., labor market statistics, GDP, perceived corruption etc.). In this section, selected indicators will be discussed for analyzing competitiveness, innovation capacity, quality of government, and social progress that reflect these topics most accurately. For an explanation of these compositie indicators, see Table 27 to Table 30.

[175] According to the Regional Competitiveness Index, Western Macedonia has a score value of 56.60 on the indicator of 'labor productivity' (GDP [in terms of PPS] relative to the number of hours worked), compared to an average of 94.05 and a median of 99.9 (n=234).

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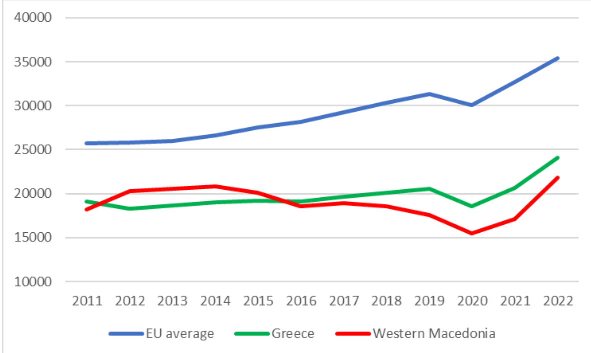

Figure 88: GDP (pps) per capita (in €) of the EU (NUTS 2 regions), Greece and Western Macedonia. Own compilation based on data from EUROSTAT.

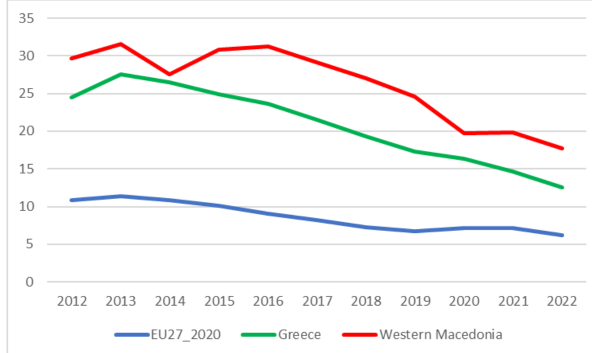

Figure 89: Unemployment rates (people aged 15 to 74 years)[176] for the EU, Greece and Western Macedonia. Own compilation based on data from EUROSTAT.

Even though we observe a strong positive trend of economic recovery after the financial crisis (Karafolas & Ragias, 2021) and Covid-19 pandemic in Western Macedonia, important indicators linked to innovation capacity, such as R&D expenditures (public and business sectors[177]), the share of employment in knowledge-intensive activities[178], and the number of international patent applications, remain very low. This is highly problematic, as these factors, especially R&D expenditures, are widely regarded as the main drivers for increasing the competitiveness and innovation capacity of a region (Kiselakova et al., 2018; Kučera & Fiľa, 2022). However, in this context the comparatively high score regarding the "Innovative SMEs collaborating with others"[179] indicates that there is potential for further developing an "innovative ecosystem". This is of crucial importance, as "[f]irm innovation proves to be specifically important during a time of economic recession. Although high-skilled employees are less affected by a recession than low-skilled employees, a notable positive effect is observed for low-skilled employees in innovative firms as well" (European Commission, 2023, p. 92). Nevertheless, it is clear that re-skilling and training programs are pivotal to develop a labour market that is supporting the strategy of diversifying the economy (Di Paola et al., 2022).[180]

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[176] The source for the regional labour market information down to NUTS level 2 is the EU Labour Force Survey (EU-LFS). This is a quarterly household sample survey conducted in all Member States of the EU, the United Kingdom, EFTA and Candidate countries. Please note that we have observed discrepancies between these EUROSTAT statistics and the data provided by the national statistical offices.

[177] R&D expenditures in the government sector (GOVERD), the higher education sector (HERD) and the the business sector (BERD). In addition, equally low score on "Innovation expenditures per person employed in innovative SMEs".

[178] Number of employed persons in knowledge-intensive activities in business industries. Knowledge-intensive activities are defined, based on EU Labour Force Survey data, as all NACE Rev.2 industries at 2-digit level where at least 33% of employment has a higher education degree (ISCED 5-8). However, EUROSTAT statistics indicate a positive trend and an increase in the share of HRST between 2012 and 2022 of nearly 40%. At first glance, this is a positive development, but it needs to be carefully interpreted in the context of population dynamics and overall labor market development.

[179] Number of SMEs with innovation co-operation activities. Firms with co-operation activities are those that have had any co-operation agreements on innovation activities with other enterprises or institutions.

[180] See section about the Just Transition Fund (JTF) in Western Macedonia that is focussing on re-skilling programs below.

However, when it comes to the (sustainable) development of economic activities, another problematic aspect is the above-mentioned low score of road[181] and rail transport performance[182]. As "road infrastructure plays a crucial role by providing mobility for the efficient movements of people and goods, as well as providing accessibility to a wide variety of commercial and social activities" (Ng et al., 2019, p. 1) the development of an efficient transport infrastructure (road, bus and rail) is therefore of great importance. However, studies show that such a development of infrastructure needs to be embedded in comprehensive strategies for fostering "other socioeconomic factors that contribute [...] to economic growth" (ibid.). One of these factors is (tertiary) education which "has a positive and substantial effect on innovation performance" (Okolo et al., 2023, p. 1). In this regard, the overall comparison (all persons from 25 to 64 years) shows a lower share of people with tertiary education than the average in the EU and Greece. However, focussing on the share of higher education among younger people (aged 25-34), Western Macedonia scores comparatively high.[183]

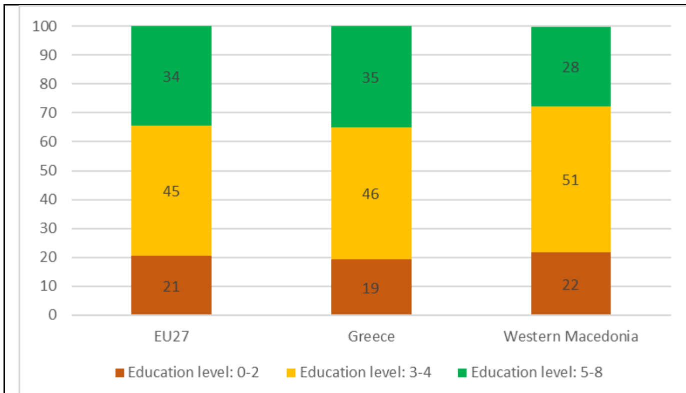

Figure 90: Comparison of education levels in the EU, Greece and Western Macedonia (percentage of people from 25 to 64 years). Own compilation based on data from EUROSTAT.

However, this positive aspect needs to be regarded in context of one troubling development in Western Macedonia: a decrease in population size of approximately 10% in the last decade (2012-2022).[184] This, of course, reflects to a large degree the tense situation in the labour market and the economic development which has an effect on the age structure of the region, as emigration is significantly higher in the group of "the so-called ´productive ages` (20-44 years)" (SDAM - Steering Committee of the Just Transition Plan, 2020, p. 45). However, as mentioned above, economic factors are closely intertwined with other socio-political and environmental factors that influence this demographic process and the transition potential in general. Regarding the **social and political** dimensions of transition potential, the indicators used in the European Social Progress Index 2020 (SPI) show a clear picture (see Table 24): with the

181 Population accessible within 1h30 by road in a neighbourhood within a 120 km radius.

182 Population accessible within 1h30 by rail (using optimal connections) in a neighbourhood within a 120 km radius.

183 Population aged 25-34 having completed tertiary education. See Regional innovation scoreboard above.

184 Between 2008-2019 "the age structure of the area changed significantly. In essence, this is a tangible version of demographic aging at the local level. The age structure […] shows a significant decrease in population at the so-called "productive ages" (20-44 years), as well as a decline in births within a decade (a decrease of 7,000 in the 0-14 age group). On the contrary, the population is increased in the category 45-64 and 65+ […]." SDAM - Steering Committee of the Just Transition Plan (2020, p. 45).

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exception of “personal security”[185], “health and wellness”[186] and “advanced education”[187], Western Macedonia scores lowest of the four TRANSFORMER TSL. In the context of a just transition, the low score in the indicator “personal freedom & choice”[188] is particularly problematic, as it reflects the missing job opportunities and involuntary part-time/temporary employment.

The results from the European Quality of Government Index (see Table 25) also indicate an important limiting factor for the transition potential: regarding the assessment by the citizens of Western Macedonia about the quality”[189], impartiality[190] as well as the corruption in the provision of public services[191], the region scores lowest among the four TRANSFORMER TSL regions. This lack of trust in the political institutions by Western Macedonia's citizens, which is strongly linked to the overall economic crisis (Kroknes et al., 2015), is extremely problematic, as the necessary fundamental transition of the region's socio-economic structures requires a high level of trust, acceptance, and support among all stakeholders (Latusek & Cook, 2012; Uslaner & Badescu, 2004). However, a study conducted within the CINTRAN project shows that “since the political decision to phase out lignite mining and lignite-based electricity generation (delignification) was taken, it has been hardly contested. However, the pace of the transformation very much is” (Yazar et al., 2023, p. 17). In this regard, two main narratives were identified by the researchers: the first highlights the unavoidability of delignification and emphasizes the opportunities for the region:

> “*With the support of funding from the Just Transition Fund we*[192] *can build a research and innovation ecosystem with universities and agile businesses of our region. We will unleash green growth in Western Macedonia*“ (Yazar et al., 2023, p. 18). The second dominant narrative of the region emphasizes that “*[t]he breakneck speed of the delignification process will kill the industrial base of Western Macedonia and disrupt the regional economy. Moreover, we will also increase*

185 Crime; Safety at night; Money stolen; Assaulted/Mugged

186 Life expectancy; Self-perceived health status; Cancer death rate; Heart disease death rate; Leisure activities; Traffic deaths

187 Tertiary education attainment; Tertiary enrolment; Lifelong learning; Female lifelong education and learning

188 Freedom over life choices; Job opportunities; Involuntary part-time/temporary employment; Young people not in education, employment or training NEET; Corruption in public services

189 Questions from the questionnaire: How would you rate the quality of [from very poor to excellent] … 1) ...public education in your area? 2) …the public health care system in your area? 3) …the police force in your area? (Charron et al., 2022, p. 12). For complete questionnaire see (Charron et al., 2022).

190 Questions from the questionnaire [from strongly disagree to strongly agree]: 1) Certain people are given special advantages in the public health care system 2) The police force gives special advantages to certain people in my area. 3) All citizens are treated equally [from agree to disagree] … A) …in the public education system in my area. B) …the public health care system in my area. C) …by the police force in my area. 4) In the area where I live, elections are conducted freely and fairly. (Charron et al., 2022, p. 13). For complete questionnaire see (Charron et al., 2022).

191 Selected questions from the questionnaire: Corruption is prevalent in [from strongly disagree to strongly agree] … 1) my area’s local public school system. 2) …in the public health care system in my area. 3) …in the police force in my area. 4) People in my area must use some form of corruption to just to get some basic public services. 5) Corruption in my area is used to get access to special unfair privileges and wealth. […] (Charron et al., 2022, pp. 13-14). For complete questionnaire see (Charron et al., 2022).

192 … we [the interviewed citizens and stakeholders of Western Macedonia] can build…

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our dependence on other fossil fuels. The structural funding provided and corresponding transition planning are insufficient to avoid the demise of the Western Macedonia" (ibid.).

Even though the second narrative is more pessimistic, it is an optimistic sign that the necessity of the transition is widely recognized. However, regarding the goal of achieving climate neutrality, a survey from the European Investment Bank in 2023/24 clearly shows[193], that "economic and financial" aspects (94%), especially "increased cost of living" (75%) and "unemployment" (52%) are perceived by citizens (n=333) of Northern Greece (Voreia Ellada)[194] as bigger challenges than "climate change" (29%) (EIB 2024).[195] This is also clearly reflected in the dominant opinion (67%) that the "government should address climate change *without* affecting the personal budget"[196], and that "the transition to a low carbon economy can only happen if inequalities are addressed at the same time" (74%).[197] Regarding the employment opportunities due to this transition, a slight majority (53%) expects that "the climate change measures will destroy more jobs than they will create new ones" (EIB 2024).[198]

Regarding this goal of developing the economy in a sustainable way, the **Just Transition Fund (JTF)** – in combination with the above-mentioned regional master plan for transition is one of the most important mechanisms in Western Macedonia. The JTF aims at diversifying the economy by "linking research and innovation with environmental rehabilitation and clean energy uptake, introducing schemes for up- and re-skilling workers, delivering targeted job-search assistance", while at the same time "enabling compensating schemes and transitory mechanisms for vulnerable households" (Vrontisi et al., 2024, p. 4). The JTF development plans foresees to channel about 994 million € "into transforming Western Macedonia from a lignite-dependent area into a modern and climate-neutral energy and industrial hub" (Vrontisi et al., 2024, p. 5). In context of developing clean energy and "green" industrial jobs, two other projects which are funded as Important Project of Common European Interest (IPCEI) are worth mentioning in this context: the "Green HiPo" project which "involves the development, design, and manufacture of fuel cells and electrolysers to produce green hydrogen in a new, state-of-the-art facility

193 Question: "What are the three biggest challenges that people in your country are currently facing?"Source: EIB (2024): https://www.eib.org/attachments/survey/eib-climate-survey-2023-2024-dataset-all-countries-cop28.xlsx (Excel sheet: Greece). The references are listed in the Chapter "Data sources".

194 The region Northern Greece (Voreia Ellada), encompasses Western Macedonia. Due to the severe economic and labour market situation in Western Macedonia, these issues are very likely perceived as even more important than climate change.

195 The results of these surveys additionally show the shift in perceived challenges. In an earlier survey from the EIB (2020), "economic and financial" aspects (93%), especially "unemployment" (80%), have been perceived by citizens (n=322) of Northern Greece (Voreia Ellada) as bigger challenges than "climate change" (31%). Source: EIB (2020): https://www.eib.org/attachments/survey/climate-survey-citizens-perception-climate-change-impact-all-data-en.xlsx (Excel sheet: Greece). The references are listed in the Chapter "Data sources".

196 Question: "Would you say that… […] Your government should address climate change without affecting your personal budget". Source EIB (2024).

197 Question: "Would you say that… […] The transition to a low carbon economy can only happen if inequalities are addressed at the same time. Source EIB (2024).

198 Question: What impact do you think the measures adopted by your country to fight climate change and protect the environment will have? Answer: They will destroy more jobs than they will create new ones (53%). Source: EIB (2024).

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in Western Macedonia" and the "H2CAT TANKS" in Florina, which "will support the construction of special high-pressure tanks from composite materials and carbon fibres for hydrogen storage" (Vrontisi et al., 2024, p. 7).

In the context of developing clean energy (industries) in the region, the above-mentioned **environmental dimension of sustainability** is of great importance: Together with the economic and socio-political dimensions, it constitutes the overall transition potentials of a region. In this regard, we have to narrow down the focus, as it would require analysing the availability and economically feasible (sustainable) usability of natural resources as well as the current state of ecological processes for different sectors, such as agriculture, fishing, forestry, mining, water and waste management, as well as tourism. Therefore, the focus will lie on the **potential for the development of renewable energy**, which is a key topic for transforming energy systems.

In this regard, Western Macedonia has comparatively high solar potential (with approximately 1,550 kWh / m2 per year; see Figure 91) and wind power (see Figure 92). These high potentials are of crucial importance for substituting lignite in the energy system, and the development of RE is discussed as a promising strategy for stimulating the economy. However, for stimulating economic growth, it is crucial for having a high domestic component over the entire value chain of RE development. As Western Macedonia currently relies "on a high share of imported technological equipment" (Vrontisi et al., 2024, p. 9) it will have a very limited (short-term) effect on GVA and employment (ibid.). However, in the long term, the development of RE can "can induce a growth potential that can be capitalized in the future" (Vrontisi et al., 2024, p. 13). In this regard, the high RE potential is very important in developing a cost-efficient hydrogen infrastructure, as foreseen in the regional development plan (see above).[199] In this context, the production and export of green hydrogen to the regions with highest demands (see case study of the Ruhr Area) is discussed as a very promising strategy (Haegeman et al., 2022; Kafetzis et al., 2023). However, in order to stimulate economic growth, the challenge remains to develop a significant domestic (regional) component of the hydrogen economy's value chain (construction of components and electrolysers).

Before briefly describing the related Pilot use cases in Chapter 3.5.4 that address these topics, we will summarise the transition needs and potentials in the following regional SWOT analysis. In addition, a SWOT analysis is included that focuses specifically on the above-mentioned five pillars for economic development.

[199] For detailed statistics about the RE potential (PV, Wind and biomass), see data from the ENSPRESO project.

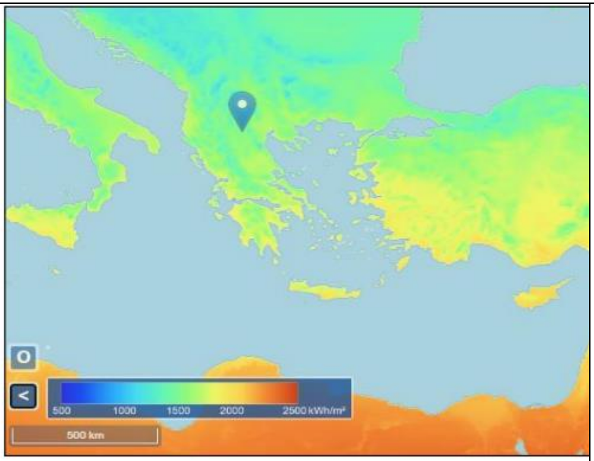

Figure 91: Solar Potential of Greece – Average Annual Fluctuating Solar Radiation at the Horizontal Level. Source: SDAM - Steering Committee of the Just Transition Plan (2020, p. 87).

Figure 92: Wind energy potential in the Lignite Regions of Kozani-Ptolemaida, Florina (in the Diagram the peak of the Siniatsiko mountain with average wind speed of 9.56 m/s at mast height of 100 m). Source: SDAM - Steering Committee of the Just Transition Plan (2020, p. 90).

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Before we briefly portray the related Pilot use case in Chapter 3.5.4, we summarise the transition needs and potentials of Western Macedonia in a regional SWOT analysis.

Table 19: Regional SWOT analysis as a summary of the transition needs and potentials of becoming climate neutral in context of the TSL approach. Source: own compilation.[200]

Strength (helpful internal factors)	**Weaknesses** (harmful internal factors)
• Highly skilled workers, especially in energy-related fields • Well-developed energy infrastructure (electricity and heating grid) • High political support for (energy) transition • Strong (political) ambition for diversifying the economy • Very high RE potential	• Low GDP (per capita) and economic resources for transition • Very high unemployment und negative demographic trend • Comparatively low competitiveness and innovation capacity • Economic dependence (GVA, employment, energy) on lignite-related activities (mining and energy generation); veto-players • Challenges for integrating renewable energy sources into the existing fossil-oriented infrastructure • Low economic diversification • Low trust in political institutions • Landlocked region with poor infrastructure (e.g., railway performance, connection to airports)
Opportunities (helpful external factors)	**Threats (external)** (harmful external factors)
• EU funding for innovative actions (hydrogen solutions, circular economy, sustainable mobility, ecological agriculture) • EU and national targets for RE development • Increasing demand for sustainable tourism as well as sustainably produced products and goods (e.g., agricultural products)	• Comparatively high vulnerability to climate change impacts • Competition from other regions in attracting hydrogen and renewable energy investments • Uncertain demand for green hydrogen • Changing political support on the national level

200 This regional SWOT analysis is based on a comprehensive document analysis and two workshops conducted in the realm of WP2 and WP3.

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As Western Macedonia specifically aims at diversifying their economy, an additional SWOT analysis focusing on the identified pillars of economic development is included. This SWOT analysis was conducted by (Ziouzios et al., 2021, pp. 9–10).

Pillars	Strengths	Weaknesses	Opportunities	Threats
Economy	Comprehensive master plan for post-lignite transition,	High economic dependence on lignite activities, social inequalities	High interest for investment, Policies towards economic restructuring,	Ageing population, growing social inequalities, rising unemployment
Clean energy	Large solar resources, biomass potential, clean energy projects announced (e.g., RES, green hydrogen), availability of district heating systems	Need for improved funding, legal and licensing procedures	Reduce energy poverty, energy communities, active citizen participation in energy markets	Lack of energy efficiency measures, energy poverty, institutional uncertainty
Agriculture	Large workforce in the sector, high potential for smart agriculture	Low training of farmers, low share of young farmers, limited links with innovation	New sustainable agriculture (e.g., precise, organic agriculture, hydroponics), smart agriculture center, create new jobs	Lack of technical knowledge related to sustainable and smart agriculture
Tourism	Explore natural environment and ecosystems and historical and cultural features, easy access and proximity to large urban centers	Bad quality of infrastructure, large distances of communities with urban centers, negative association of the region with polluting activities	Facilitate agritourism, synergies with local agriculture and food industries, Post-mining sites converted to parks and museums, sustainable tourism model	Risk of degradation of the natural and built environment
Other (labor, industry, education)	High technical skill base already available, on-the-job training, work transfer programs	Large job losses from lignite phase-out, lack of digital infrastructure, lack of entrepreneurial attitude, Limited mechanisms to increase public awareness	Reuse lignite industry buildings after mine closure, exploit high technical skill base of local workforce in new industries	Low innovation, limited technical and human capacity and digital infrastructure, lack of synergies and public funds
Environment	Potential benefits from the transition (e.g., reduced pollution)	Repeated exposure to air pollution	Full restoration of lignite mines, Agricultural activities in the lignite center	Negative impacts of climate change

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Regarding specific projects addressing transition needs and potentials, this analysis clearly indicates that the development of RE is not only necessary for a phase-out of lignite, but it can have positive long-term effects. This is particularly the case if connected to projects focussing on the development of sustainable transport and mobility solutions. These were key aspects that guided the development of the Pilot use cases around energy and transport solutions, which are briefly described in the next chapter.

3.5.4 TSL vision and Pilot use cases

As described in the chapter about the methodological approach (Chapter 2.3), the assessment of transition needs and potentials, as well as the analyses of the political framework, has been a continuous and iterative process conducted in tandem with the project partners (WP2, WP3, WP4, WP5) and has been the guiding aspect in developing a vision for the TSL, coalition building (Deliverable 3.1), and identifying the most important Pilot use cases (Deliverable 3.2). A summary of the vision and Pilot use cases is included in Table 20. The continuous exchange of information between the WPs of the TRANSFORMER project has been vital for developing these case studies as well as the "Action plans" (Deliverable 3.3) for the specific Pilot use cases (for a brief summary see Table 20). The discussion about strategies for long-term implementation is based on this cooperation and will be included in Chapter 3.6 and Deliverable 3.3.

Table 20: Western Macedonia: The vision and Pilot use cases at a glance. Source: summary of the descriptions included in Deliverables 3.1 and 3.2.

The vision: Western Macedonia has long been reliant on non-sustainable energy sources, particularly lignite mining and power generation, with the Public Power Corporation (PPC) dominating the sector. However, the region is transitioning away from lignite due to environmental concerns and EU targets. The Just Transition Development Programme 2021-2027, funded by the Just Transition Fund (JTF), supports this shift, aiming for a climate-neutral economy by 2030. Greece's national transition process aligns with EU goals, necessitating the cessation of lignite activity and phasing out polluting power stations. The transition poses economic challenges, prompting the development of the Territorial Just Transition Plan (TJTP) for Western Macedonia, focusing on **diversifying the economy through climate-neutral energy production and mitigating social and economic impacts**. **The Pilot use cases**: **Pilot use case 1:** *Production, transfer and storage of PV energy and consumption in Ptolemaida KTEL PT buses (Ptolemaida KTEL PT buses electrification – PV energy)* The de-lignitisation of Western Macedonia aligns with EU climate goals, prompting the development of a Just Transition Development Plan (TJTP) focused on diversifying energy production. One sub-vision aims to incorporate clean energy and mobility, exemplified by the Ptolemaida KTEL PT buses electrification using PV energy. This initiative aims to utilize the region's abundant solar resources for public transport, reducing greenhouse gas emissions, improving energy efficiency, and fostering economic growth. The project involves stakeholders from various sectors and addresses challenges like the public acceptance of electric vehicles. Feasibility studies will refine the implementation, potentially paving the way for broader adoption and scalability in the region and beyond. **Pilot use case 2:** *Production, transfer and storage of H2 energy and consumption in Kozani KTEL PT buses (Kozani KTEL PT buses electrification – H2 energy)* The establishment of an innovation hub for hydrogen and green energy in Western Macedonia aims to diversify the economy and promote climate-neutral energy production. A hydrogen technology park, along with a Center for Hydrogen Studies and a cluster of hydrogen companies, will drive investment in the region. The use case focuses on electrifying Kozani's PT buses with hydrogen energy, investigating production, storage, and operational parameters. Stakeholders include public transport operators, research institutions, and local government. Hydrogen-powered public transport will reduce emissions, improve

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air quality, and foster innovation, contributing to the region's transition to climate neutrality and promoting sustainable transportation solutions.

Pilot use case 3: *Application of CO2 capture/emission reduction technologies in farms & transfer, storage & reconsumption of CO2 in farms (link to the circular economy park)*

The strategic plans for Western Macedonia advocate for digitization and innovation in agriculture to enhance sustainability. Circular economy principles are integral to the region's development strategy, particularly in the context of de-lignitisation. The use case explores CO_2 capture in local farms, aligning with circular economy initiatives. This involves capturing, storing, and reusing CO_2 within a regional circular economy park, benefiting local farms and fostering synergy among stakeholders. The initiative targets small farms, often marginalized in policy discussions. It aims to mitigate climate change by exploring advanced CO_2 reduction technologies, including regenerative agriculture practices, which can store carbon in the soil. These innovations hold potential for systemic transformation in agriculture.

Pilot use case 4: *Development of Kozani's Living Lab & Data Space*

Kozani's Transition Living Lab aims to catalyse innovation and digital transformation in Western Macedonia's economy by leveraging regional data resources. It will serve as a hub for cross-sector collaboration, promoting sustainable growth. The Lab will establish a regional data space, facilitating access to essential data for monitoring climate neutrality goals in sectors like mobility and energy. By engaging stakeholders in data sharing, it will develop climate-neutral services and methodologies, ensuring mutual benefits and sustainability. The interdisciplinary project involves public and private partners, fostering smart and sustainable services. Kozani's Living Lab seeks certification within the European Network of Living Labs, fostering cross-border collaboration and long-term self-sustainability through value-added services and funded projects. This stakeholder-driven approach fosters systemic transformation, breaking down silos, and addressing local challenges through innovation and collaboration.

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Table 21: Selected composite indices for the EU and the TRANSFORMER TSL regions. For comparison of regions: read per row (red = low, green = high; higher score means better performance). Source: own compilation based on data from the CI (sources below the table).

Composite Index	Topic		EU regions (NUTS 2)				TRANSFORMER TSL regions						
		Year	Min.	Max.	Average	Median	Emilia-Romagna	Lower Silesia	Ruhr Area (NUTS 2 regions) [201]				Western Macedonia
										DUESS	MUENST	ARNSB	
EQI (n=231)	**Government performance**	2021	-2.3	2.2	0.0	0.2	-0.5	-0.9	-	0.5	12	0.9	-1.1
RCI (n=226)	**Competitiveness**	2022	46.1	151.1	95.3	96.4	93.6	89.1	-	128.6	118.9	116.3	60.9
RIS (n=175)	**Innovation**[202]	2023	20.6	169.5	94.9	96.0	109.8	75.2	-	119.6	105.5	118.9	75.2
SPI (n=233)	**Social progress**	2020	43.3	85.1	67.0	68.8	63.8	61.9	-	70.7	71.8	70.7	56.3

"n=" number of cases

EQI: European Quality of Government Index (for explanation see Table 29 in the annex. Source: (Charron et al., 2022).
For complete references see Chapter "Data sources".

RCI: EU Regional Competitiveness Index 2.0 (for explanation see: Table 27 in the annex). Source: (Dijkstra et al., 2023).
For complete references see Chapter "Data sources".

RIS: Regional Innovation Scoreboard 2023 (for explanation see: Table 28 in the annex). Source: (European Commission, 2023).
For complete references see Chapter "Data sources".

SPI: European Social Progress Index 2020 (for explanation see: Table 30 in the annex). Source: (Annoni & Bolsi, 2020).
For complete references see Chapter "Data sources".

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201 The Ruhr Area is not classified as a NUTS 2 area. It encompasses parts of three distinct NUTS 2 regions. To perform an analysis of the Ruhr Area within its precise spatial boundaries, it is necessary to examine it at the NUTS 3 level.

202 Innovation index of 2023 (base year 2016). Pleas note, that the calculated average and median of the RIS also includes values for NUTS0 and NUTS1 levels.

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Table 22: Score values for selected indicators from the EU Regional Competitiveness Index 2.0 (for explanation see: Table 15 in the annex). For comparison of regions: read per column (red = low, green = high performance; with exception of road fatalities, higher value means better performance). Source: (Dijkstra et al., 2023). For complete references see Chapter "Data sources".[203]

Region name	Road transport performance [204]	Rail transport performance [205]	Road fatalities (per mio. Inhabitants)	University accessibility [206]	Employment rate (excluding agriculture)[207]	Labour productivity [208]	Disposable income per capita[209]	Potential market size expressed in GDP[210]	Potential market size expressed in population[211]
Ruhr Area [212]									
Düsseldorf	105.66	13.97	22	100.00	70.38	127.31	26,700	692	795.62
Münster	103.37	6.50	31	99.95	72.79	113.23	25,200	391	489.17
Arnsberg	98.73	10.76	22	98.18	70.79	112.59	25,200	421	515.09
Western Macedonia	51.18	0.04	61	78.40	42.86	56.40	11,800	13	35.02
Emilia-Romagna	77.60	4.36	67	89.60	66.22	106.87	24,500	176	219.26
Lower Silesia	61.56	5.30	68	65.73	67.87	70.47	14,900	88	150.67

[203] Please note, that only indicators are listed that are not alreday included in the Regional Innovation Scoreboard (e.g., patent applications) or in basic macroeconomic statistics (e.g., GDP per capita). In addition, only indicators are listed that are referring to the NUTS 2 level (e.g., the indicator "Ease of doing business" is not included: "[t]his indicator benchmarks economies with respect to their proximity to the best performance on each area measured by doing business. For instance, a score of 75 means an economy was 25 percentage points away from the best regulatory performance constructed across all economies" Source: Explanation in the data file of the EU Regional Competitiveness Index 2.0 (see Chapter "Data sources" for references and URL).

[204] Population accessible within 1h30 by road in a neighbourhood within a 120 km radius.

[205] Population accessible within 1h30 by rail (using optimal connections) in a neighbourhood within a 120 km radius.

[206] Arithmetic average of the share of population within 45 minutes by car from nearest university main site and/ or campus.

[207] Percentage of people aged 15–64 that are currently employed in all economic sectors excluding agriculture.

[208] GDP (in terms of PPS) relative to the number of hours worked.

[209] Net adjusted disposable household income in purchasing power consumption standards (PPCS) per capita (index EU-27=100).

[210] Index GDP (PPS) EU-27=100 – EU-27 average computed as population weighted average of the NUTS 2 values.

[211] Potential market size expressed as index population EU-27=100.

[212] The Ruhr Area is not classified as a NUTS 2 area. It encompasses parts of three distinct NUTS 2 regions. To perform an analysis of the Ruhr Area within its precise spatial boundaries, it is necessary to examine it at the NUTS 3 level.

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Table 23: Score values for selected indicators from the Regional Innovation Scoreboard (for explanation see Table 28 in the annex). For comparison of regions: read per column (red = low, green = high; higher score means better performance). Source: own compilation based on data from the Regional Innovation Scoreboard 2023. For complete references see Chapter "Data sources".

	Population with tertiary education[213]	R&D expenditures in the public sector[214]	R&D expenditures in the business sector[215]	Innovation expenditures per person employed in innovative SMEs [216]	Innovative SMEs collaborating with others[217]	PCT patent applications [218]	Employment in innovative SMEs as percentage of total employment[219]
Ruhr Area							
Düsseldorf	0.315	0.455	0.672	0.,551	0.,438	0.739	0.740
Münster	0.226	0.528	0.466	0,.525	0,.359	0.673	0.787
Arnsberg	0.268	0.586	0.570	0.,559	0.546	0.699	0.797
Western Macedonia	0.521	0.417	0.,198	0,.405	0.731	0.060	0.658
Emilia-Romagna	0.368	0.439	0,.699	0.,631	0.470	0.679	0.623
Lower Silesia	0.681	0.444	0,.482	0,.284	0.213	0.279	0.296

[213] Population aged 25-34 having completed tertiary education

[214] All R&D expenditures in the government sector (GOVERD) and the higher education sector (HERD).

[215] All R&D expenditures in the business sector (BERD).

[216] Sum of total innovation expenditure by SMEs in Purchasing Power Standards (PPS). Denominator: Total employment in innovative SMEs.

[217] Number of SMEs with innovation co-operation activities. Firms with co-operation activities are those that have had any co-operation agreements on innovation activities with other enterprises or institutions.

[218] Number of patents applied for at the European Patent Office (EPO), by year of filing. The regional distribution of the patent applications is assigned according to the address of the inventor.

[219] Number of employed persons in innovative SMEs ('SMEs that have either introduced an innovation or have any kind of innovation activity including SMEs with abandoned/suspended or on-going innovation activities). Denominator: Total employment

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Table 24: Score values for the indicators from the European Social Progress Index 2020 (for explanation see Table 30 in the annex). For comparison of regions: read per column (red = low, green = high; higher score means better performance). Source: own compilation based on data from the European Social Progress Index 2020 (Annoni & Bolsi, 2020). For complete references see Chapter "Data sources".

	Basic human needs				Foundations of wellbeing				Opportunity			
Name	Nutrition and Care[220]	Water and Sanitation [221]	Shelter [222]	Personal Security [223]	Basic Knowledge [224]	ICT Access [225]	Health and Wellness [226]	Environmental Quality[227]	Personal Rights[228]	Personal Freedom & Choice[229]	Tolerance Inclusion [230]	Advanced Education [231]
Ruhr Area [232]												
Düsseldorf	81.63	95.13	88.79	66.34	79.28	82.93	70.58	42.74	56.92	77.48	67.76	48.86
Münster	83.83	95.14	92.03	67.8	81.64	82.93	70.47	45.8	56.56	78.27	68.44	49.42
Arnsberg	80.5	95.15	87.9	66.35	80.19	82.93	67.67	46.01	56.48	77.37	68.18	48.89
Western Macedonia	69.37	86.37	64.46	82.94	65.84	60.46	66.15	26.37	38.93	44.07	36.21	52.01
Emilia-Romagna	88.94	93.65	75.9	70.66	72.77	69.58	73.4	26.66	47.22	53.78	59.62	50.36
Lower Silesia	72.34	93.38	64.45	80.59	84.98	66.94	53.7	34.51	37.07	67.04	50.98	52.26

[220] Mortality rate before 65; Infant mortality; Unmet medical needs; Insufficient food
[221] Satisfaction with water quality; Lack of toilet in dwelling; Uncollected sewage; Sewage treatment
[222] Burden cost of housing; Housing quality due to dampness; Overcrowding; Adequate heating
[223] Crime; Safety at night; Money stolen; Assaulted/Mugged
[224] Upper secondary enrolment rate age 14-18; Lower secondary completion rate; Early school leavers
[225] Internet at home; Broadband at home; Online interaction with public authorities; Internet access
[226] Life expectancy; Self-perceived health status; Cancer death rate; Heart disease death rate; Leisure activities; Traffic deaths
[227] Air pollution NO2; Air pollution ozone; Air pollution pm10; Air pollution pm2.5
[228] Trust in the national government; Trust in the legal system; Trust in the police; Active citizenship; Female participation in regional assemblies; Quality of public services
[229] Freedom over life choices; Job opportunities; Involuntary part-time/temporary employment; Young people not in education, employment or training NEET; Corruption in public services
[230] Impartiality of public services; Tolerance towards immigrants; Tolerance towards minorities; Tolerance towards homosexuals; Making friends; Volunteering; Gender employment gap
[231] Tertiary education attainment; Tertiary enrolment; Lifelong learning; Female lifelong education and learning
[232] The Ruhr Area is not classified as a NUTS 2 area. It encompasses parts of three distinct NUTS 2 regions. To perform an analysis of the Ruhr Area within its precise spatial boundaries, it is necessary to examine it at the NUTS 3 level.

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Table 25: Score values for the indicators of the "European Quality of Government Index" (for explanation see Table 29 in the annex). For comparison of regions: read per column (red = low, green = high; higher score means better performance). Source: own compilation based on data from the European Quality of Government Index (Charron et al., 2022). For complete references see Chapter "Data sources".

Name	Year	Assessing quality of public services[233]	Assessing impartiality in the provision of public services[234]	Assessing corruption in the provision of public services[235]
Ruhr Area [236]				
Düsseldorf	2021	0.393	0.507	0.553
Münster	2021	1.017	1.154	1.314
Arnsberg	2021	0.864	0.627	1.07
Western Macedonia	2021	-0.879	-1.453	-0.936
Emilia-Romagna	2021	0.263	-1.028	-0.681
Lower Silesia	2021	-0.803	-0.857	-0.924

233 Questions from the questionnaire: How would you rate the quality of [from very poor to excellent]… 1) ..public education in your area? 2) …the public health care system in your area? 3) …the police force in your area? (Charron et al., 2022, p. 12). For complete questionnaire see (Charron et al., 2022).

234 Questions from the questionnaire [from strongly disagree to strongly agree]: 1) Certain people are given special advantages in the public health care system 2) The police force gives special advantages to certain people in my area. 3) All citizens are treated equally [from agree to disagree]… A) …in the public education system in my area. B) …the public health care system in my area. C) …by the police force in my area. 4) In the area where I live, elections are conducted freely and fairly. (Charron et al., 2022, p. 13). For complete questionnaire see (Charron et al., 2022).

235 Selected questions from the questionnaire: Corruption is prevalent in [from strongly disagree to strongly agree]… 1) my area's local public school system. 2) …in the public health care system in my area. 3) …in the police force in my area. 4) People in my area must use some form of corruption to just to get some basic public services. 5) Corruption in my area is used to get access to special unfair privileges and wealth. […] (Charron et al., 2022, pp. 13-14). For complete questionnaire see (Charron et al., 2022).

236 The Ruhr Area is not classified as a NUTS 2 area. It encompasses parts of three distinct NUTS 2 regions. To perform an analysis of the Ruhr Area within its precise spatial boundaries, it is necessary to examine it at the NUTS 3 level.

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3.6 Strategies for the long-term implementation of the TSLs.

3.6.1 Conceptual framing of TSL governance

At the beginning of this project, we anticipated the crucial challenges in implementing a TSL approach. It was clear from the start that broadening Living Labs from the local to the regional scale would create numerous challenges, for instance: the complexity of required knowledge(s) regarding the sustainability transition of a whole region, the difficulty to ensure inclusiveness of discussions and decision making, the necessity to balance multiple local needs with regional needs, and the difficulty to make governance arrangements manageable. In the following text, based on the experiences gained during the TRANSFORMER project as well as existing literature on transition governance and management we develop a conceptual framework for TSL governance.

Concretely, we see that there are two intertwined levels of governance of a regional TSL, i.e., **the "cross-sectorial governance level", and the "transition project governance level"**. The cross-sectorial level of governance organizes the generation of ideas and their selection as part of the TSL's portfolio and putting the transition project governance and funding together. In contrast, the transition project governance level is the organizational structure that puts into practice one particular transition project (what we call "Pilot use cases" in the TRANSFORMER project). The cross-sectorial governance level coordinates typically several of these transition projects and has a special perspective of incentivizing learning between the different projects. Only the **cross-sectorial governance level needs a strategy for 'long-term' implementation**, as transition projects have a specific finite timeframe and need suitable governance arrangements for that duration. A long-term cross-sectorial governance, thus, manages a portfolio of transition projects, which are connected to each other and in sum substantially impact a region's pathway to sustainability.

Regarding the cross-sectorial governance, we need a governance arrangement that complies with the below discussed **five criteria**. These criteria are to be understood as 'ideal type' criteria. In other words, they are difficult to achieve completely and especially to achieve all of them simultaneously since some of the criteria can be at least in part conflicting with each other in real life scenarios (e.g., ensuring inclusiveness for political legitimacy, and keeping the costs low can be conflictive since more stakeholders often means more investment in time and money). This is also the case for the below discussed governance arrangements for each of the TRANSFORMER regions. Nevertheless, it is important when defining TSL governance arrangements to strive to fulfil the criteria.

1. **Political legitimacy of the TSL process**

   A TSL cannot and is not supposed to substitute or be in conflict with existing democratically legitimized governance structures within a region, but it should have a complementary function. It needs to be in close coordination and exchange with (if not organised by) democratically legitimized governance bodies of or within the region. The most important aspect of this criterion is inclusiveness. Inclusiveness and working with diverse stakeholders enable different voices to be part of the inception of ideas, thus ensuring a deliberative aspect, and part of decision-making. Inclusiveness also entails a recognition of differences and different values of stakeholders as well as the possibility to strive for an

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equitable distribution of benefits and burdens of a sustainability transition (Ciplet & Harrison, 2020). Inclusiveness also connects to an important principle of living lab methodologies, which is that diverse minds bring about better ideas. In short, there is the added benefit of a continuous production of ideas and innovative projects for addressing sustainability issues in the region (Caniglia et al., 2021). In our opinion, TSLs have a great potential to support a specific geographic scope, that is, a region in its trajectory towards a sustainable future especially due to the continuous process of incentivizing, managing and monitoring the regions' sustainability transition.

2. Reflexive monitoring capacity

Ambitious systemic innovation efforts – as TSLs are – have very challenging monitoring and evaluation requirements. The overarching goal here is to maintain reflexivity in the process. In comparison to result-oriented monitoring typical in classic project management, which aims to create accountability in the reaching of predefined goals, reflexive monitoring aims to develop new ways of acting, and its ultimate goal is to learn how to contribute to system innovation while interacting with the system in question. In other words, reflexive monitoring aims to put prevailing values, institutions and practices up for discussion and supports the development of a new reality. Since before starting a transition pathway, it is not clear what exactly is required to reach a new, sustainable reality, reflexive monitoring has to deal with the uncertainties of such a process. Therefore, reflexive monitoring stimulates a collective learning experience and aims for fundamental systemic change. For the cross-sectorial governance arrangements of a TSL, the capacity to undertake reflexive monitoring to steer fundamental change is of utmost importance. Without this capacity, at best systemic change remains coincidental, at worst no fundamental change in the region is achieved (van Mierlo, 2010; van Mierlo & Beers, 2020).

3. Lean organization and low financial requirements

Large-scale societal transitions are complex processes and often take several decades to complete (Köhler et al., 2019, p. 3). When thinking about a durable implementation of TSLs, within the timeframe of possibly decades, we need to keep this in mind. Often, regions, especially those with the most pressing transition needs, have very limited resources (e.g., Western Macedonia). The cross-sectorial governance of a TSL should therefore ideally require little financial means. However, a small continuous budget for coordination and for the organization of workshops ensures clear responsibilities and continuation of the work. In short, the cross-sectorial governance level should ideally require very little financial efforts, while the bulk of the money going into the TSL should be earmarked for the different transition projects and their subsequent organisational governance. In our opinion, a TSL can make a significant contribution to a region's transition by providing expertise, even with relatively little resources.

4. Continuous and unbureaucratic access to financial means for transition projects in the region

To ensure that the cross-sectorial governance arrangement of the TSL can operate, access to funding for transition projects in the TSL's portfolio needs to be available. Only a proven track record of a TSL to realise a variety of transition projects can ensure a continuation of the TSL in its entirety. This

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requires substantial political backing of transition efforts in the region as well as at the national level. A regional transition fund where financial means for transition projects can be unbureaucratically applied for, would be a very well-placed instrument. However, the important aspect is the ability of the cross-sectorial governance level to ensure funding and thus the realization of transition action over a long timeframe.

5. **Diverse, cross-sectorial expertise**

Transition studies literature traditionally thinks of transitions from technological or sectorial lenses, for instance the transition towards a fossil-free renewable energy system (Elzen et al., 2004). In comparison, as already discussed when introducing the TSL approach above, TSLs take regions as a starting point and aim their work at launching a sustainability transition for that specific geographical scope. Adopting this geographical starting point (and not a technological one) means that the thematic scope a TSL includes a wide range of topics and technologies at the same time. As extensively discussed in the descriptions of our four TRANSFORMER regions above, regional climate neutrality entails a reduction of GHG emissions in diverse sectors such as agriculture, transport, and manufacturing, etc. On the one hand, this cross-sectorial nature of TSLs is the unique selling point of a TSL, it is where their potential lies with regard to addressing sustainability transitions. Moreover, cross-sectorial work requires the possibility to tap into different kinds of expertise along the way.

Now, building upon these somewhat abstract criteria for a successful long-term implementation of a cross-sectorial governance arrangement for a TSL, we need to develop a more concrete description of roles or continuous tasks/responsibilities.

3.6.2 TSL governance roles and responsibilities

To operationalise the above-elaborated criteria, we have developed roles that should be fulfilled for a long-term cross-sectorial governance arrangement of a TSL: the supporting stakeholder coalition, the TSL coordination team, the reflexive monitoring board and the individual transition project governance structures.

Supporting stakeholder coalitions (cross-sectorial)

As we have previously discussed when presenting the TSL approach, a TSL consists of a supporting stakeholder coalition, which should be formed with the idea of bringing together stakeholders from all four realms of the quadruple helix: business, academia, policy, and civil society. This coalition of stakeholders has the task of generating ideas and innovations for the portfolio of transition projects of the TSL by using living lab methods. They will also recommend which of the possible ideas should be part of the portfolio of transition projects. This stakeholder coalition is not a fixed set of people or organisations, but a fluid construct that works with a modular approach. Stakeholders from the different transition projects of the TSL will be part of this coalition. However, this is not an exclusive situation, but it is possible to integrate other organisations or even unorganized civil society. Depending on the different thematic framings for transition projects, new interest groups might become stakeholders – in the sense

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of having a stake in the process – for future transition projects. Thus, this coalition should be seen as a constantly evolving network of people and organisations, which are essential in pushing the transition goals of the region forward. Checking if all relevant and necessary stakeholders are part of the TSL coalition is part of the tasks of the reflexive monitoring board and part of the organisational responsibilities of the TSL coordination team (see descriptions below).

Selecting the initial stakeholders when forming the coalition for the first time can be done either in a more top-down or a more bottom-up fashion. A top-down fashion entails to bring in a set of regional players which are relevant to the region's transition and form ideas for transition project "from scratch". These project ideas form the basis for selecting additional stakeholders for the coalition (e.g., process in Ruhr Area). A more bottom-up approach is to take a small number of existing concrete transition project ideas or even transition projects which are in their implementation process and select the stakeholders from these projects to form the initial coalition (e.g., process in Western Macedonia). One of the lessons learned from the initial coalition building in the TRANSFORMER project is that the bottom-up approach has the advantage that stakeholders from concrete transition projects feel a strong identification with their project and are, therefore, more easily motivated to engage in the TSL process. However, there can also be combinations of both approaches, and for the continuation of the coalition a modular process of identifying additional transition project ideas and involving possible stakeholders are key requirements.

For the formation of the coalition, it is also important to keep in mind the first criterion of political legitimacy of the TSL process and to select stakeholders which are relevant to the TSL's overall goal (of reaching climate neutrality), but also represent a wide and inclusive variety of voices. Moreover, it is important to secure that people with the necessary expertise for the realization of the transition projects, as well as with a broader understanding of the transition needs and potentials of the region are at the table.

TSL coordination (cross-sectorial)

A TSL requires a small team that coordinates and manages the TSL activities. This team considers the transition needs and potentials of the entire region, as well as the specific transition projects. Tasks for the TSL coordination team are the control of TSL actions (milestones and completion of tasks) and resources, the development of a value proposition for participation of the coalition stakeholders, management of the TSL's supporting stakeholder coalition and strategic decision making regarding day-to-day business. Another task of the coordination team is the anticipation of future challenges and hurdles for the transition projects, including the design of strategies for managing veto players in the transition projects.

In sync with the third criterion of ensuring a lean organisational structure and low financial requirements, we recommend the TSL coordination team to have a small regular budget for financing staff costs to ensure clear responsibilities and the continuity of the coordination work. However, we also recommend keeping the team small and agile.

The TSL coordination team requires in accordance with criterion five needs to embody a specific skillset: It needs stakeholder engagement capacities, sustainability transition management skills and the ability

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for systems thinking. Additionally, and very importantly, the coordination team needs regional planning capacity and ideally authority. This is important because transition projects, no matter what their specific thematic framing, typically connect to regional planning in terms of the regulatory framework, conditions and/or funding possibilities. Staff from a regional planning agency are a good fit for the TSL coordination team. The TSL coordination team should also be knowledgeable in how to put together transition projects and how to go about the organisation of funding for such undertakings. Concrete funding schemes for transition projects will in many cases, however, need to be put together by thematic experts.

Reflexive monitoring board (cross-sectorial)

As a third essential element for the TSL's long-term governance, there is a strong necessity to introduce a specific body that can take over the task of reflexive monitoring of the TSL process. The reflexive monitoring board's task is to monitor whether actions taken in the TSL as a whole align with regional transition goals. The monitoring boards consistently needs to question if the transition projects actually match the expectation of bringing down GHG emissions in the region, and if there is additional action that would be advised to reach this goal or if adjustments should be made. This regards transition-related content such as the monitoring and evaluation of the transition projects, but also the TSL processes: the board also advises the TSL coordination team on whether all necessary stakeholders are represented in the TSL's stakeholder coalition.

Regarding the concrete personnel structure of the reflexive monitoring board, again the criterion three of creating a lean organisational structure and allocating only a small permanent budget to the cross-sectorial governance of the TSL comes into play here. Firstly, we recommend a close working relationship between the TSL coordination team and the reflexive monitoring board, since the coordination team has the essential information and overview about the TSL process and state of transition projects running at each point in time. However, to ensure that the monitoring board is effectively able to reflect on the direction of the TSL process a certain distance to the day-to-day business is sensible.

The capacity for such a reflexive mindset requires a specific expertise in various connected fields (criterion five), for instance: capacity of system thinking and an understanding of sustainability transitions, policy analysis, a broad understanding of stakeholder engagement and social inclusion, spatial planning capacity, economic development and innovation management, data analysis and interpretation, evaluation methodologies and risk assessment. For locating people with these capacities, we recommend looking at stakeholders from academia.

Moreover, we recommend holding regular reflexive monitoring meetings and to document the process of decision making and reflection to be able to access this information at a later stage. To really have an effect on the TSL process, it is important that the reflexive monitoring board has the capacity to make strategic interventions in the TSL process, for instance, to commission evaluation studies for specific transition projects from engineering experts or to be able to initiate workshop-interventions with stakeholders when the overarching goals of regional climate neutrality gets derailed in the day-to-day "busy-ness".

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Transition project management

Each of the transition projects needs an internal organisational structure or transition project governance that may significantly differ from the overall TSL governance (depending on the complexity and scope of the project). However, every transition project needs to have at least one responsible organization/person (Pilot use case coordinator/manager) that interacts with the TSL coordination team. Otherwise, it should have an organisational structure that is suited to the tasks necessary to achieve the projects objectives. Moreover, we recommend using living lab methodologies to drive the transition projects.

3.6.3 Status of long-term implementation plans for the four TRANSFORMER regions

In the four TRANSFORMER regions, the development of feasible governance arrangements for the implementation of the TSLs did not just begin at the start of the project. The TSLs were implemented by the project partners within existing political-administrative frameworks and the specific socio-economic structures of their regions. As discussed in Chapter 2.1, regions play a significant role in sustainability transition and their characteristics strongly influence the development and success of their transition pathways. As the case studies have shown, these regional characteristics of the four TRANSFORMER TSLs are very diverse: the size of the region (e.g., population), the number and diversity of stakeholders (e.g., networks and veto players), and of course their economic resources, as well as their competitiveness and innovation capacity. These political and socio-economic structures, especially existing political-administrative frameworks and the position of our partners within them, largely determined whether a bottom-up or a top-down approach was chosen for developing the governance-arrangements for the TSL (see Deliverable 3.1).

In Emilia-Romagna, the regional authority, Emilia-Romagna public agency, was a key actor from the beginning and applied a more top-down approach for including the municipalities and citizens. As the regional authority, they managed to get the municipalities on board, and together with the TSL lead partner, the Institute for Transport and Logistics Foundation (ITL), built a very large coalition of supporting stakeholders around the cross-cutting topic of sustainable mobility.

In Western Macedonia, the TSL was initiated by the regional development authority, ANKO, and one of Greece's leading research institutes, CERTH, which already had extensive experience in applying Living Lab methodologies. In Western Macedonia, it is evident that the political and economic commitment to the necessary transition (diversification of the economy and achieving climate neutrality) has been very beneficial for implementing feasible governance arrangements, having on board the Regional Authority of Western Macedonia and a large and diverse coalition of supporting stakeholders, thus incorporating both, top-down and bottom-up processes.

In Lower Silesia, the necessity of transforming the transport system was beneficial for the regional partners, the Lower Silesian Development Fund (DfR) and Dumni z Lubina, in winning the key supporting stakeholder, the Lower Silesia Railways company. In addition, the TSL is supported by the Institute of Regional Development (IRT), one of the most important research institutes in the region. The TSL specifically tries to integrate bottom-up approaches in their governance-arrangements by developing and

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applying survey tools to capture residents' preferences regarding various energy sources and incorporating their opinions into the political decision-making process.

In the Ruhr Area, a stronger bottom-up approach was applied. However, due to the lead partner, the Business Metropole Ruhr (BMR), the focus was more on partners from their economic networks. Although municipalities are also part of the coalition of supporting stakeholders, a regional political lead partner, such as the RVR or the *Initiativkreis Ruhr*, would be beneficial for gaining broader support and bridging the existing political-administrative fragmentation of the Ruhr Area (see Deliverable 3.3).

Based on their experiences and the developed coalition of supporting stakeholders, the four TRANSFORMER TSLs started identifying stakeholders for TSL coordination, Reflexive Monitoring Board, and Transition Project Management (see Deliverable 3.3). As this process has just started and will substantially change when including other Pilot use cases and topics, we cannot include an assessment and evaluation of the process so far. However, the TRANSFORMER project has established methods and monitoring tools to learn from these experiences (see Deliverables 3.4, 4.1, and 5.2[237]) in order to refine and further develop the TSL approach.

[237] Deliverable 3.4: Transition Super-Labs' Lessons Learned; Deliverable 4.1: Super-Lab Roadmap (Version 2); D5.2: Best practices and recommendations for Super-Labs operation towards the region transition (the URL of the deliverables are not available yet)

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4 Conclusion

This deliverable aimed to gain a deeper understanding of the transition needs and potentials of the four TRANSFORMER TSL regions: Emilia-Romagna (Italy), Lower Silesia (Poland), the Ruhr Area (Germany), and Western Macedonia (Greece). Through a comprehensive analysis integrating quantitative and qualitative methodologies, the study highlights the diverse challenges and opportunities for each region on their way to achieving climate neutrality.

The case studies have shown that Emilia-Romagna is a wealthy region with high innovation capacity and a strong industrial sector, but its energy-intensive industries and transport sector significantly contribute to climate change and poor air quality. To address these issues, the TSL is fostering bicycle infrastructure and developing sustainable electric mobility solutions. In contrast, Western Macedonia's economy was completely dependent on lignite mining and energy generation and is now facing a fundamental socio-economic transformation with the phase-out of lignite mining by 2028. To mitigate the potential negative effects and simultaneously become climate neutral, the TSL is focusing on economic diversification and the development of innovative solutions in the energy and transport sectors, as well as circular economy approaches in agriculture. In Lower Silesia, lignite mining, energy generation, energy-intensive industries, and unsustainable transport and mobility sectors affect air quality and contribute to climate change; to mitigate these effects, the TSL is developing sustainable and convenient mobility solutions and incorporating citizens' opinions in energy-related decision-making processes. The Ruhr Area faces a challenging transition due to its high energy demand and limited local renewable energy production; hydrogen is considered a critical cornerstone for the region's path to climate neutrality, though it carries substantial risks, particularly concerning the future availability of green hydrogen.

Within the TSL process, this analysis supports the development of a vision and a coalition of supporting stakeholders (Deliverable 3.1), as well as the identification and implementation of Pilot use cases and action plans (Deliverables 3.2 and 3.3) to support the transition towards climate neutrality. In combination with the evaluation of the concrete activities in the TSLs, this overall analysis of the regional transition needs and potentials and perspectives on feasible TSL governance arrangements are also designed to support the development of long-term strategies for the four TSLs (Deliverable 3.3).

In an overall perspective, the case studies have shown that the developed and applied mixed-method approach is extremely useful to gain an overview of the transition needs and potentials of a region. The identification of the most urgent transition needs (e.g., GHG emissions per sector or air quality) is of crucial importance to analyse specific sectors in more detail. However, within this project, the necessary detailed analysis for understanding the *precise* socio-economic and ecological context *of each Pilot use case* is not possible, nor does it contribute to the overarching goal of gaining a comprehensive overview of regional transition needs and potentials. These kinds of detailed analyses, focussing on the specific contexts of single Pilot use cases, were done in the development of the TSL Action plans (Deliverable 3.3).

As the conditions in the regions change in this dynamic process of becoming climate neutral, these case studies need to be revisited and reflected on in an iterative process. This was the leading idea of developing a case study design, focusing on a quantitative approach, using key indicators and composite

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indices, allowing a continuous (yearly) analysis and reflection of the transition needs and potentials to develop tailored solutions throughout this long-term transition to climate neutrality and sustainability.

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Data sources

EDGAR – Emissions Database for Global Atmospheric Research:

EDGAR (Emissions Database for Global Atmospheric Research) Community GHG Database, a collaboration between the European Commission, Joint Research Centre (JRC), the International Energy Agency (IEA), and comprising IEA-EDGAR CO2, EDGAR CH4, EDGAR N2O, EDGAR F-GASES version 8.0, (2023) European Commission, JRC (Datasets). The complete citation of the EDGAR Community GHG Database is available in the 'Sources and References' section: https://edgar.jrc.ec.europa.eu/dataset_ghg70_nuts2#sources (last access: 29.05.2024)

IEA-EDGAR CO2, a component of the EDGAR (Emissions Database for Global Atmospheric Research) Community GHG database version 8.0 (2023) including or based on data from IEA (2022) Greenhouse Gas Emissions from Energy, www.iea.org/data-and-statistics, as modified by the Joint Research Centre.

Datasets used in Deliverable 2.3:

- Greenhouse Gas Emissions. Annual gridmaps (1970-2022). **EDGAR GWP_100_AR5_GHG**. Data available at: https://edgar.jrc.ec.europa.eu/gallery?release=v80ghg&substance=GWP_100_AR5_GHG&sector=TOTALS (last access: 29.05.2024)
- Greenhouse Gas Emissions. Annual sector-specific gridmaps (1970-2022). **EDGAR GWP_100_AR5_GHG** (**all sectors**; see Chapter 2.3) https://edgar.jrc.ec.europa.eu/dataset_ghg80#p3 (landing page for links to specific sectors) (last access: 29.05.2024)

European Investment Bank (EIB) (2020): The EIB Climate Survey 2019-2020.

Data about the perception of climate change is accessible on NUTS1 and for most countries on a NUTS2 level. Source: https://www.eib.org/attachments/survey/climate-survey-citizens-perception-climate-change-impact-all-data-en.xlsx (last access: 09.05.2024).

European Investment Bank (EIB) (2024): The EIB Climate Survey 2023-2024.

Data about the perception of climate change is accessible on NUTS1 and for most countries on a NUTS2 level. Source: https://www.eib.org/attachments/survey/eib-climate-survey-2023-2024-dataset-all-countries-cop28.xlsx (last access: 09.05.2024).

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EUROSTAT – Statistical office of the European Union

Database available at: https://ec.europa.eu/eurostat/web/main/data/database (last access: 31.07.2023)

See Table 4, p. 25 for overview of selected indicators.

EUROSTAT & European Commission: Geographical information system of the Commission (GISCO). The GISCO statistical unit dataset (2021).

- GISCO: statistical unit dataset containing the NUTS regions. Available at: https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts (last access: 31.07.2023)

Data from composite indices used in Deliverable 2.3

- **European Quality of Government Index** [EQI] (2021). Regional Level 2021 (with all NUTS2 regions). Data available at: https://www.qogdata.pol.gu.se/data/qog_eqi_agg_21.xlsx (last access: 31.07.2023).
  For references/ citations see Chapter References: (Charron et al., 2022).
  Maps (2010, 2013, 2017, 2021) retrieved from: https://ec.europa.eu/regional_policy/en/newsroom/news/2022/03/29-03-2022-which-european-regions-have-the-highest-quality-of-government (last access: 31.07.2023).
- **EU Regional Competitiveness Index 2.0** [RCI] (2022). RCI 2.0 - Raw data 2022, revised. Data available at: https://ec.europa.eu/regional_policy/sources/work/rci_2022/RCI_2_0_2022_raw_data.xlsx (last access: 31.07.2023).
  For references/ citations see Chapter References: (Dijkstra et al., 2023).
- **Regional Innovation Scoreboard 2023** [RIS] (2023). Regional innovation indexes. Data available at: https://research-and-innovation.ec.europa.eu/document/download/76fe7424-5aba-4617-a25f-d373080ff580_en?filename=ec_rtd_ris-2023-regional-indexes_0.xlsx (last access: 31.07.2023)
  For references/ citations see Chapter References: (European Commission, 2023).
- **European Social Progress Index 2020** [SPI] (2020). Raw data. Data available at: https://ec.europa.eu/regional_policy/sources/work/spi2020_raw_data.xlsx (last access: 31.07.2023)
  For references/ citations see Chapter References: (Annoni & Bolsi, 2020).

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Data packages used in Rstudio

Emissions Allocation

To determine the specific regions associated with the emissions data, we utilize the `st_within` function from the "sf" package, developed by Pebesma & Bivand (2023). This function efficiently matches emissions data from the Eurostat database to their corresponding geographical regions or communities based on coordinates.

Filtering & Cleaning

Data cleaning and transformation processes are conducted using the `dplyr` and `tidyverse` packages, authored by Wickham et al. (2023; 2019). These tools facilitate various operations such as filtering (e.g., selecting between NUTS3 or NUTS2 units), grouping, and aggregating emissions data by region or year.

Maps

The `tmap` package by Tennekes (2018) is employed to visualize emissions data across different regions or districts. Data classification into intervals is performed using the "classint" package by Bivand (2023). The geographical data (shapefiles) are sourced from the Eurostat database, curated by Lahti (2023).

Dashboard

For dynamic data presentation, we leverage the `flexdashboard` package developed by Aden-Buie et al. (2024), which enables the creation of interactive HTML dashboards. These dashboards provide a versatile platform for displaying various data indicators through multiple visualizations.

OECD – Organisation for Economic Co-operation and Development. Centre for Entrepreneurship, SMEs, Regions and Cities (CFE).

Datasets used in Deliverable 2.3:

- Regional statistics. **Total gross electricity generation** (GWh). Online data code: ELEC_TOT. Last update: not specified.
- For used data and methodology to estimate electricity indicators at the regional level see: OECD (2021). OECD Climate and Environment regional statistics. Metadata. Available at: https://stats.oecd.org/wbos/fileview2.aspx?IDFile=113af38b-3c74-4aba-94e3-2752595654a4 (last access: 31.07.2023)

Database available at: https://stats.oecd.org/ (last access: 31.07.2023)

Statistikportal Ruhr

Regionalverband Ruhr. Referat Bildung, Soziales und Regionalanalysen. Team Regionale Statistik und Umfragen. Database available at: https://statistikportal.ruhr/ (last access: 30.06.2024)

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Annex

Table 26: ANNEX: Regions in the NUTS classification of the European Union. Source: own compilation (included in Deliverable 2.2) based on: (Gouardères, 2023).

The NUTS (Nomenclature of Territorial Units for Statistics) classification is a hierarchical system used by the European Union for dividing and comparing statistical regions. The classification provides a consistent and comparable framework for regional statistics within the European Union member states and is the basis for socio-economic analysis and analysis of regional economic disparities, as well as the development of regional policies within the European Union (e.g., cohesion policy). The NUTS level for an administrative unit is determined on the basis of demographic thresholds and consists of three levels: NUTS 1, NUTS 2, and NUTS 3. **NUTS 1:** The first level represents the major territorial units within a country. It usually corresponds to large regions or groupings of regions with significant economic and social cohesion. Examples of NUTS 1 regions in a country are for example the states (*Länder*) in Germany, or the regions (*Gewesten/Régions*) in Belgium. The current (2021) NUTS classification lists 92 regions at NUTS 1 level. **NUTS 2:** The second level represents smaller territorial units within NUTS 1 regions. These units are often subregions or groupings of smaller administrative units. NUTS 2 regions are more homogeneous in terms of demographic criteria (e.g., population size). Examples of NUTS 2 regions could be the provinces within an autonomous community in Spain or the administrative regions (*Regierungsbezirke*) within (some of) the German states. The current NUTS classification lists 242 regions at NUTS 2 level. **NUTS 3:** The third level represents the smallest territorial units within NUTS 2 regions. NUTS 3 regions are often local administrative units, such as counties, districts, or municipalities. These regions are the most detailed level and are used for the collection and dissemination of regional statistics. Examples of NUTS 3 regions could be individual counties or municipalities within a province or administrative region. The current NUTS classification lists 1,166 regions at NUTS 3 level.

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Table 27: ANNEX: EU Regional Competitiveness Index 2.0. Source: own compilation (included in Deliverable 2.2) based on: (Dijkstra et al., 2023).

The EU Regional Competitiveness Index (RCI) 2.0 is a tool developed by the European Commission to measure and assess the competitiveness of different regions within the European Union. It is part of the European Commission's efforts to promote regional development and cohesion across the EU member states (Dijkstra et al., 2023)).

The RCI 2.0 provides a comprehensive framework for evaluating and comparing the competitiveness of the EU regions on a NUTS 2 level. It takes into account a wide range of factors and indicators related to regional economic development, innovation, productivity, and other key aspects that contribute to a region's competitiveness.

"The index covers three sub-indices – '**Basic'**, '**Efficiency'** and '**Innovation'** – and of 11 pillars that describe the different aspects of competitiveness

- The '**Basic' sub-index** refers to the key basic drivers of all types of economies. It identifies the main issues that are necessary to develop regional competitiveness and includes five pillars: (1) 'Institutions', (2) 'Macroeconomic stability', (3) 'Infrastructures', (4) 'Health' and (5) 'Basic education'.
- The **'Efficiency' sub-index** includes three pillars: (6) 'Higher education, training and lifelong learning', (7) 'Labour market efficiency' and (8) 'Market size'. As a regional economy develops, these aspects are related to a more skilled labour force and a more efficient labour market.
- Lastly, the '**Innovation' sub-index** includes the three pillars that are the drivers of improvement at the most advanced stage of economic development: (9) 'Technological readiness', (10) 'Business sophistication' and (11) 'Innovation' (Dijkstra et al., 2023)

By analysing and comparing these dimensions across different regions, the EU Regional Competitiveness Index helps policymakers and stakeholders identify areas of strength and weakness in each region's competitiveness. This, in turn, enables them to formulate targeted strategies and policies to enhance the economic development and competitiveness of specific regions, contributing to overall regional and EU-wide economic growth and cohesion. The 70 indicators used in the RCI 2.0 are listed in: (Dijkstra et al., 2023)

For an interactive map see: https://ec.europa.eu/regional_policy/information-sources/maps/regional-competitiveness_en?etrans=de

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transformer

Table 28: ANNEX: Regional Innovation Scoreboard 2023 (RIS). Source: own compilation (included in Deliverable 2.2) based on: (European Commission, 2023).

The Regional Innovation Scoreboard 2023 (RIS) is an initiative by the European Commission that provides a comparative assessment of the research and innovation performance of different regions within the European Union. The scoreboard aims to promote innovation by identifying and sharing best practices across regions.

The RIS evaluates regions based on their innovation performance, taking into account various indicators and data related to research and innovation activities. These indicators cover areas such as (European Commission, 2023):

- Human Resources: The level of education and skills of the region's workforce
- Innovation Investment: The amount of public and private investment in research and development (R&D) activities within the region.
- Innovation Activities: The number of patents, scientific publications, and other outputs generated through research and innovation activities.
- Innovation impacts: Employment in knowledge-intensive activities and knowledge-intensive services exports

The Regional Innovation Scoreboard 2023 categorizes regions into several performance groups, ranging from "Innovation Leaders" and "Strong Innovators" to "Moderate Innovators" and "Emerging Innovators." The scores and rankings help identify regions with strong innovation performance and those that may need support and targeted policies to boost their innovation capacity.

The RIS is a valuable tool for policymakers, regional authorities, and other stakeholders to assess their region's strengths and weaknesses in innovation and make informed decisions regarding investment in research and innovation activities. It also facilitates the exchange of best practices and lessons learned among regions, contributing to overall regional and EU-wide innovation-driven growth and competitiveness (European Commission, 2023).

Online source: https://op.europa.eu/en/publication-detail/-/publication/c849333f-25db-11ee-a2d3-01aa75ed71a1/language-en/format-PDF/source-289680093

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Table 29: ANNEX: European Quality of Government Index (EQI). Source: own compilation (included in Deliverable 2.2) based on: (Charron et al., 2019; Charron et al., 2022).

The European Quality of Government Index (EQI) is a survey-based assessment focusing on the quality of governance at the regional (sub-national) level within the European Union (EU). This index utilizes survey data collected in 2010, and subsequently in 2013, 2017, and 2021. The primary focus of the survey is to gauge citizen perceptions and experiences regarding public sector corruption, as well as their views on the impartiality and quality of various public sector services. The questions reflect a variety of topics, for example, the rating of the quality of: • rating of the public education, public health, police in an area • equal treatment of citizens in the public services • experiences with / perception of corruption • rating of the electoral process (conducted freely and fairly) As the first dataset of its kind, the EQI enables researchers to make comparisons of Quality of Government (QoG) within and across different countries. This tool aids researchers and policymakers in gaining insights into the variations of governance within countries and over time. The EQI covers all 27 EU member states, and its regional data is categorized at the NUTS 1 or NUTS 2 level, depending on the country. Throughout the survey's four waves, data was collected from around 330,000 respondents in total. The EQI provides regional-level data including a time-series regional dataset that maintains a common sample of regions across the four waves. Additionally, a full NUTS 2, 2021 EQI data is provided for 238 regions in the European Union (Charron et al., 2019; Charron et al., 2022; Choulga et al., 2019). Online source: https://www.gu.se/en/quality-government/qog-data/data-downloads/european-quality-of-government-index

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Table 30: ANNEX: European Social Progress Index 2020. Source: own compilation (included in Deliverable 2.2) based on: (Annoni & Bolsi, 2020).

The European Social Progress Index 2020 is designed to assess the social progress of every EU region, serving as a supplement to conventional economic progress metrics like Gross Domestic Product (GDP). It is situated within the "Beyond GDP" discourse, offering an alternative to traditional economic indicators by relying solely on social and environmental factors. This approach ensures a more comprehensive representation of societal development.

Following the global Social Progress Index framework, the EU regional Social Progress Index draws upon a wide array of indicators, primarily from Eurostat.

Functioning as a benchmarking tool, it enables comparisons across EU regions, focusing exclusively on social and environmental criteria. Policymakers and stakeholders can use this index to identify a region's strengths and weaknesses in these specific domains. Many of these aspects align with the core investments supported by the EU's cohesion policy, spanning areas such as essential services (health, education, water, and waste), information and communication technology accessibility, energy efficiency, education and skills, and pollution control.

The index evaluates social progress within European regions at the NUTS2 level, comprising twelve components that are further aggregated into three broader dimensions describing respectively basic, intermediate and more subtle aspects of social progress (Annoni & Bolsi, 2020):

Basic human needs	Foundations of wellbeing	Opportunity
• Nutrition and basic medical care • Shelter • Water and sanitation • Personal security	• Access to basic knowledge • Access to information and communication • Health and wellness • Environmental quality	• Personal rights • Personal freedom of choice • Tolerance and inclusion • Access to advanced education

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