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Quantitative mapping research report

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Abstract

This deliverable is the summary of task 2.1 “Quantitative mapping of settings across Europe potentially benefitting the most from the TSL approach” of WP2. It includes a framework to define the transition-needs of all European NUTS2 regions (where data is available at this scale) and a mapping of EU regions in order to identify those regions that could benefit from the TRANSFORMER Super-Lab approach.

Project Partners

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Acronym	Meaning
CH_4	Methane
CI	Composite Indices
CO_2	Carbon dioxide
CO_{2eq}	Carbon dioxide equivalents
EDGAR	Emissions Database for Global Atmospheric Research
EEA	European Environment Agency
EU	European Union
EUR	Euro
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 Potentials
ISIC	International standard industrial classification of all economic activities (ISIC)
N_2O	Nitrous oxide
NACE	Statistical classification of economic activities in the European Community (NACE)
OECD	Organisation for Economic Co-operation and Development
PPS	Purchasing power standard (EUROSTAT)
PPT	Purchasing power parities
QRAFT	Quantitative Regional Assessment Framework for Transition Super-Labs
TSL	Transition Super-Lab

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Executive Summary

To accelerate the transition towards climate neutrality, the TRANSFORMER project develops a methodology that focuses on a systemic transformation at a regional scale: the Transition Super-Lab approach (TSL). In a TSL, living lab methodologies are adapted and applied to develop together with all relevant stakeholders from academia, business, government and civil society a portfolio of large-scale systemic solutions for a regional transformation towards climate neutrality. In TRANSFORMER, we regard regions as a promising scale to foster this systemic change, as they function as 'burning glasses' where different sections of socio-technical regimes (e.g., transportation, industry, food system) materialize and intersect. Creating change at the intersection of multiple societal systems simultaneously at the regional level can accelerate the zero-emission transition at the European scale and beyond. 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.

Therefore, firstly this deliverable has the objective to define transition needs and potentials of regions to reduce GHG emissions from a TSL perspective. Secondly, the deliverable develops the "Quantitative Regional Assessment Framework for Transition Super-Labs (QRAFT)." This methodology uses existing and publicly accessible statistical data for the regions of the EU on a NUTS 2 level to compare regional transition needs (measured by GHG emissions per capita and carbon emissions intensity of economic sectors) and potentials (using existing composite indices). This methodology will support conducting the first steps in the TSL process of identifying the regional challenge and possible topics for transition and developing a vision for transformation. It is designed to function 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. Thirdly, this deliverable applies the QRAFT framework to all EU regions in the form of a single comprehensive Excel file and exemplarily shows how the indicators compiled in QRAFT can be interpreted in the four TRANSFORMER regions (Emilia-Romagna, Lower Silesia, Ruhr Area and Western Macedonia), as a first assessment of its validity and usefulness. These four examples serve to illustrate possible follower regions, what insights can be gained by applying the QRAFT methodology.

This deliverable shows that the quantitative perspective of the framework can be useful to get a broad data-driven understanding of a region's transition needs and potentials, particularly for people not familiar with the region. This data-driven understanding of a region then can be used within the TSL process to discuss and define the region's vision, scenarios, and potential pilot use cases for accelerating the pathway to climate neutrality. It is also very useful as a tool to critically reassess the already chosen topics of a region. However, we also highlight the limitations of such a quantitative approach, especially regarding a conclusive assessment of the transition potentials of regions. Here, QRAFT serves as a substantial first step, however, we believe it to be of a high priority to complement the information gathered through QRAFT with a qualitative and context-sensitive methodology. This methodology is currently being developed in the TRANSFORMER project (deliverable and D5.1) and will be integrated in the case studies of the four TRANSFORMER TSL (deliverable D2.3).

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1 Introduction

Accelerating the transformation towards climate neutrality is of utmost importance to ensure the *existence and livelihood of all lifeforms on this planet* (IPCC, 2021). As the possible pathways to reach the goal of climate neutrality are closely linked to other social, economic and environmental dimensions, this transformation is an extremely complex challenge that requires comprehensive and innovative solutions (UN, 2022).

The TRANSFORMER project addresses this challenge by focusing on a 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 together (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 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 in order to achieve a rapid and more efficient transformation.[2]

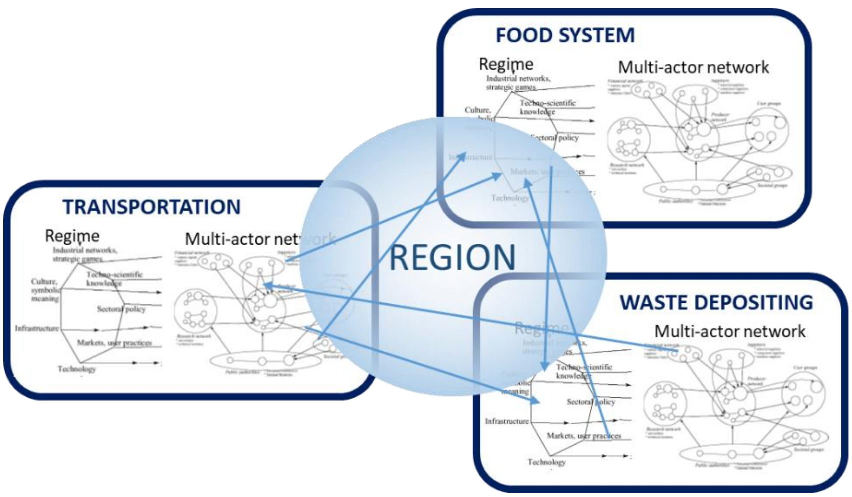

Figure 1: Regions as burning glasses where socio-technical regimes meet and connect. Source: own design (taken from the TRANSFORMER project proposal).

In TRANSFORMER, we regard regions as a very promising scale to foster this systemic change, as they function as 'burning glasses' where different sections of socio-technical regimes (e.g., transportation,

[1] The definition and description of the TSL transition model in this chapter was discussed and written jointly by the members of the TRANSFORMER Project Consortium.

[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 D2.1

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industry, food system) materialize and intersect (Lawhon & Murphy, 2012). In a nutshell, creating change at the intersection of multiple societal systems simultaneously at the regional level can accelerate the zero-emission transition at the European scale and beyond (see Figure 1). Therefore, the regional level can be of crucial importance for fostering a fundamental systemic change and thus accelerating the transition towards climate neutrality. Moreover, focussing on the sub-national, regional scale potentially means bridging the gap between local and national, avoiding isolated standalone initiatives/projects, and creating synergy effects by fostering regional cooperation. 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).

Therefore, – firstly – this **deliverable has the objective** to define transition needs and potentials of regions to reduce GHG emissions *from a TSL perspective*. The TSL perspective is a critical qualifying factor here, since otherwise assessing the transition needs and potentials of regions is an immensely wide task with a long-standing list of possible pitfalls (e.g., high levels of abstraction which fail to represent the complexity of regional reality, subjectivity in the selection of data and indexes) (Mura et al., 2021).

Secondly, the deliverable develops a quantitative methodology to measure these 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. This deliverable develops a **"Regional Assessment Framework for Transition Super-Labs (QRAFT)"** which compares regional transition needs (**Greenhouse gas** (**GHG) emissions** per capita development and the **carbon emissions intensity (CEI)** of economic sectors between EU regions) and regional transition potentials from a TSL perspective (by recurring to existing **Composite Indices (CI)**). This framework will support conducting the first steps in the TSL process of identifying the regional challenge and possible topics for transition and developing a vision for transformation. It is designed to function 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 also 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 D5.1). As such, the primary target group for the use of the QRAFT methodology are regions with the plan to initiate a TSL (TSL follower regions, e.g., as part of the TSL User Forum (Task 6.4)). A second target group are interested parties seeking to identify regions that could significantly benefit from a TSL approach.

Thirdly, this deliverable applies the QRAFT framework to all EU regions in the form of a single comprehensive Excel file and exemplarily shows how the indicators compiled in QRAFT can be interpreted in the four TRANSFORMER regions (Emilia-Romagna, Lower Silesia, Ruhr Area and Western Macedonia), as a first assessment of its validity and usefulness. These four examples serve to illustrate possible follower regions, what insights can be gained by applying the QRAFT methodology. Moreover, although the TRANSFORMER regions have passed through the vision-building exercise already, this analysis will serve

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to continue to inform the TRANSFORMER regions during the TSL process. This is especially important, since the TSL process requires a continuous reassessment of the topic for the portfolio of solutions.

To address these three objectives, this deliverable is structured as follows: In the next section, a methodological framework for assessing the transition needs and potentials for the transformation of regions in the context of the TSL approach will be discussed and necessary quantitative data will be identified. Based upon that, in Chapter 3 the methodological approach of data collection and evaluation will be described, and the limitations of this deliverable will be discussed. In Chapter 4, this framework will be applied, and the transformation needs and potential for transformation in the context of the TSL approach of selected EU regions will be analysed from a quantitative perspective. This deliverable concludes in Chapter 5 with a reflection and assessment of the chosen quantitative approach and provides and outlook for further need of research.

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 requires different conceptual considerations. In this context, it is important to understand what thinking about accelerating decarbonisation *from a TSL perspective* means. For this, in Chapter 2.1 we first briefly present the concept of the TSL approach. Based on this definition, we develop QRAFT as an assessment tool for regional transition needs and transition potentials (Chapter 2.2).

2.1 The TSL approach

The TSL approach is a new and still evolving concept. In the previous deliverable D2.1, 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.[3]

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 solutions** for climate neutrality, net-zero emissions and resilient future. The **systemic transformation** within TSL catalyses 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-**

[3] The definition and description of the TSL transition model in this chapter was discussed and written jointly by the members of the TRANSFORMER Project Consortium

technical regimes simultaneously in order to achieve a rapid and more efficient transformation.[4] 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 2):

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

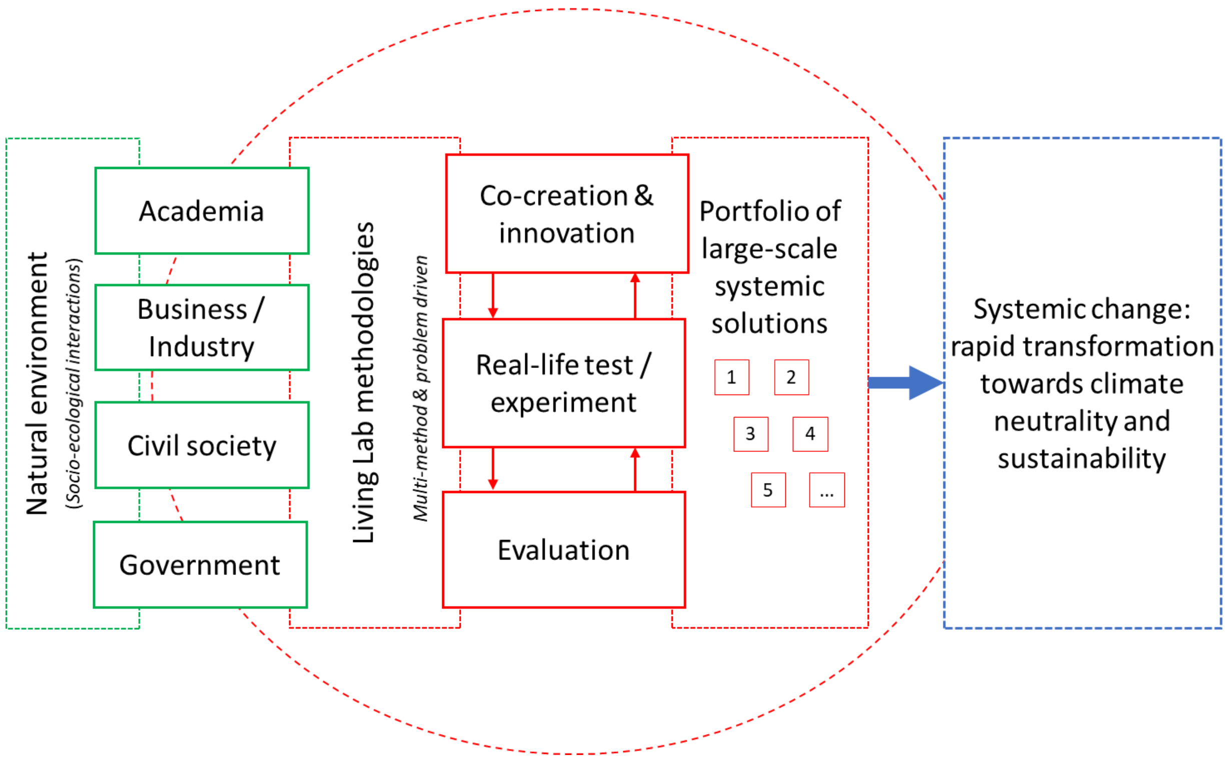

Figure 2: Elements of a Transition Super Lab. Source: own design adapted from deliverable D2.1 (URL not available yet).

2.2 The Regional Assessment Framework for Transition Super-Labs (QRAFT)

As mentioned in the introduction, with regard to assessing the climate change-related transition needs and potentials of regions so far no standard unified approach to regions exists (Hansmeier et al., 2021; Mura et al., 2021; Stanickova & Melecký, 2018). Therefore, in the following we develop the QRAFT methodology tailored to focus specifically on the sub-national, regional scale and centring on the TSL concept. Now, what is to be understood as a region is a question of interpretation. Regions are generally considered areas on this planet's surface that share common features or structures (Bathelt & Glückler,

[4] 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 D2.1 (URL not available yet).

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2018). Thus, regions do not have to adhere to administrative boundaries and can be found at the supranational, transnational as well as the subnational level. For the QRAFT methodology, we concentrate on a quantitative assessment of the NUTS 2 level of EU regions. This is because, the subnational level is the understanding of regions fostered in the TSL approach: focusing on a NUTS 2 level (and not NUTS 1 level) for analysis allows for a more comprehensive understanding of the specific dynamics, challenges, and opportunities within a particular geographical area. This approach helps identifying and addressing regional disparities and specific issues, enabling the formulation of targeted strategies and policies to better cater to the needs of the citizens and the regional/local economy.

2.2.1 How to use the QRAFT in the TSL process and beyond

The explicit aim of QRAFT is to help to understand the current state and trends of a region and to detect a region's bottlenecks, which are crucial for the region's transition to climate neutrality (Schönwälder, 2021). As will be further shown in Chapter 4, the interregional variation regarding transition needs and potentials is immensely high. Every region has a very distinct set of conditions for becoming climate neutral. More importantly, a region's transition needs and potential depend on a very wide variety of factors, which are not possible to capture with a purely quantitative methodology (e.g., political priorities within the region or beliefs about the importance of achieving a 'just transition'). Therefore, as indicated in Figure 3, we designed QRAFT to be complimented by other assessment methodologies, which include qualitative assessments and evaluations. These methodologies will be part of the deliverables D2.3 and D5.1 of the TRANSFORMER project.

Table 1: Definition of keywords and description of the TSL process. Source: own definitions[5] taken from D5.1 (URL not available yet).

Definition of keywords and description of the TSL process
Vision: A common definition of a vision has been prepared by TRANSFORMER partners as follows: a vision for Transition Super-Labs is an ideal representation for the future of the region that captures a common understanding of the desirable and transformative direction towards a sustainable society. Vision development is an essential element of the TSL process. It is crucial for achieving long-term transformation because it provides a clear set of goals, direction and alignment and collaboration among the key stakeholders.
Scenarios and Pathways: A scenario can be defined as a structured framework comprising various feasible pathways aimed at achieving an envisioned vision. It involves considering different possibilities and assessing the potential pathways to determine the most suitable approach. Pathways are specific routes of actions taken to reach the vision with a structured approach. These are defined before the pilot use cases. In the TRANSFORMER project, our primary focus has been on the development of pathways. In the WP4 road mapping activities, we will delve deeper into exploring and discussing the terminology of scenarios.
Pilot use case: Pilot use cases are identified as co-created concrete project ideas to achieve climate neutrality and promote systemic transformation. Pilot use cases are developed and implemented with a focus on a regional transformation.

[5] Definitions are based on discussions among the members of the Project Consortium and taken from deliverable D5.1 (URL not available yet).

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The QRAFT methodology can be done as a stand-alone exercise to benchmark regions against the backdrop of the EU; however, we specifically designed it **to be used within the TSL process.** As depicted in Figure 3, QRAFT is composed of two distinct assessment strands: the assessment of the transition *needs* of regions (left side) and the assessment of the transition *potentials* of regions (right side). Both assessment strands feed into/inform the TSL process at its very beginning. As shown in Figure 3 the TSL process can be broken down into several important steps. The first step of the TSL process consists of identifying the regions transition challenge. Transition challenge of regions refers to the main difficulty and obstacle faced by the region during its transition period from fossil-fuel-based to zero-carbon local economies.[6] The leading question at this stage is “What are the most important ´topics` of the region for a fundamental transition towards climate neutrality?” In deliverable D2.2, we understand “Topics” as a thematic focus for discussing and developing a vision for transition and, building on that, scenarios/pathways. Some of the main topics in TRANSFORMER are energy-related issues (e.g., hydrogen for heating in residential neighbourhoods), mobility solutions (e.g., promotion of electric and cycle mobility and development of convenient transport connections for the benefit of the environment) and circular economy (e.g., CO2 capture/emission reduction technologies in agriculture).

As a first step for this assessment, we designed QRAFT. In tandem with the more qualitatively focussed methodologies (deliverables D2.3 and D5.1), the knowledge gained from applying the QRAFT methodology will then be used as basis for the next steps of identifying relevant stakeholders for the TSLs as well as the stakeholder-led discussions of a region’s vision for achieving climate neutrality. This way, the information gathered through QRAFT can potentially even contribute to decision-making on which scenarios to develop and which pilot use cases to choose within a TSL.

[6] Sometimes this challenge resulted from the need of the region for economic and social transformation and is already predefined in European, national and/or regional strategic plans. However, often transition strategies don´t exist or although they exist, there are different, more urgent transition needs and challenges that are not addressed in the strategic plans due to political reasons and lobbying. Thus, the TSLs need to define their transition challenge based not only to the existing strategic plans but also considering the real needs of the region.

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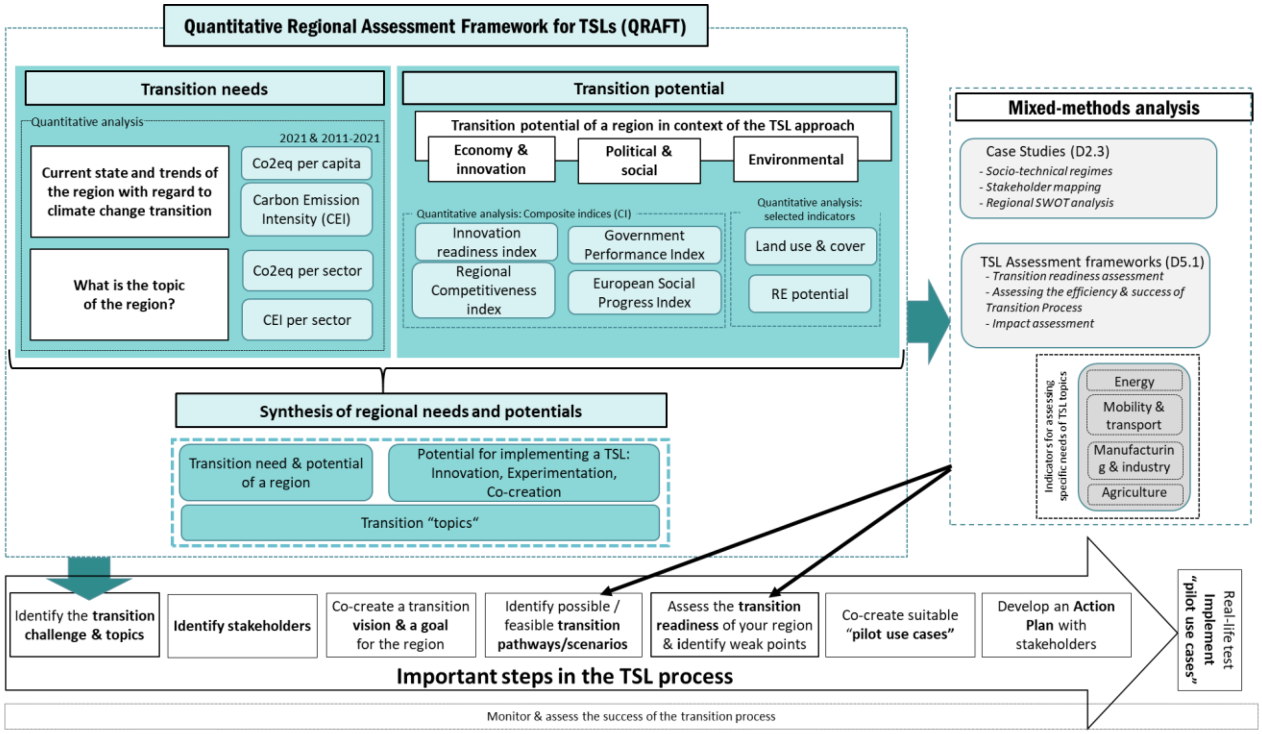

Figure 3: Overview of the QRAFT methodology in a TSL. Source: own design.

2.2.2 Criteria for indicator selection

In order to use QRAFT, it is important to first note the **criteria underlying its development**. As a first criterion, we specifically aim for a framework, which allows us to assess the sub-national, **regional scale for the whole territory of the EU**. Therefore, we only include data available at the NUTS 2 level where datasets covering the whole (or at least large parts) of the EU exist (for explanation of the NUTS classification see Table 2).

Our second criterion is **meaningfulness**. Indicators need to be essential to assess the needs and potentials of regions to achieve climate neutrality, not arbitrary. The lens to decide what is essential and what is arbitrary here is the TSL concept and its priority aiming at achieving climate neutrality. Moreover, meaningfulness also implies taking into account the rapidness of changes at the regional level (especially when considering the crisis-riddled times we live in) we only include indicators where data **not older than 5 years** exist. Older data would not help when the task is to assess the current state of regions.

Our third criterion is the **usability** of the QRAFT methodology. In the context of TSLs, this meant developing a methodology which is firstly easy to be used for our primary target group of possible TSL follower regions, and secondly, easily understandable (e.g., data mix should be structured in a way that a comprehensive interpretation is possible without needing an extensive scientific background). Therefore, we chose only public and open-source data and composite indices for QRAFT. Moreover, we included only data and composite indices, which are very likely to be continuously collected and elaborated in the future. This ensures that QRAFT can be used continuously in the future.

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Table 2: Regions in the NUTS classification of the European Union. Source: own compilation 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 (*Bezirksregierungen*) 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 1166 regions at NUTS 3 level.

2.2.3 Assessing the transition needs

Previous research has made significant progress in understanding the nature of sustainability transitions. These studies have focused on systemic-based conceptualizations, which highlight the long-term perspective, involvement of multiple actors, and multi-scale nature of the process (Köhler et al., 2019). However, it is important to note that any model attempting to analyse complex systems with a quantitative methodology faces the serious challenge of not becoming either too abstract (and not representing reality) or too subjective (focussing in detail on specific aspects but leaving out other important factors). As a result, previous studies have often opted to explore sustainability transitions qualitatively, without translating theoretical concepts into measurable constructs (Mura et al., 2021). Operating in this context, the quantitative assessment of the transition needs of a region to achieve climate neutrality pursued in this deliverable is confronting the same possible pitfalls of abstractedness or subjectivity. In order to not fall into these traps, a careful selection of indicators is of utmost importance. Crucially, assessing the transition needs from a quantitative perspective requires to have a selection of indicators that are *essential* for understanding the challenges of a region and the bottlenecks it faces to become climate neutral. At the same time, due to the above-established requirement of QRAFT to be applicable for all regions within the territory of the EU, and to be easy to use, there are significant

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limitations in possible datasets and indicators on which to choose from. In the following, we discuss the different indicators we chose for the QRAFT methodology.

The indicators selected in this deliverable (see Table 3) are just a first step in the development of the QRAFT and will be discussed with all members of the Project Consortium, complemented and refined. Their importance will be discussed and weighted by using the Delphi method (Bailey et al., 2012). Based upon this re-evaluation and complementation of the used indicators, the QRAFT methodology will be discussed with stakeholders of TSL follower regions in the TSL User Forum. The refined and further developed version of the QRAFT will be the topic of a working paper, which will be submitted in M24 (see task 2.3/deliverable D2.4).

Carbon intensity of the society and economy: what are the current state and trends of the region?

In the **first step** of our 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 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:

- 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 the most to climate change in a specific region. To put the climate driving force of the economic sectors into perspective and identify the sectors most important for the economy, we relate these emissions to the **GVA (Gross Value Added)** per sector.[7]

[7] Due to the different statistical classifications of the sectors (GHG: EDGAR, OECD, IPCC; economy: NACE, ISIC; see Chapter 3), no direct comparison can be conducted and the statistics have to be carefully interpreted.

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Based upon the identification of the most important sectors and activities ("topics of a region"), they 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.[8]

Table 3: Indicators to assess the most important transition needs of a region (economic sectors and "topics"). Source: own compilation.

Topic	Indicator		Interpretation
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)	CO_{2eq} (t) per capita in 2021	Comparison between regions: Lower CO_{2eq} (t) per capita is better
		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 (progress of decarbonising the region)
	Carbon emission intensity (CEI) of the economy (total) (2021 and development between 2011-2021)	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)
		CEI: CO_{2eq} (kg) / GDP pps (EUR) between 2011-2021 (2011=100%)	Comparison between regions: Higher decrease (%) of CEI is better (progress of "decoupling the economic output from the GHG emissions)

[8] 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.

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Topic	Indicator		Interpretation
Carbon intensity of the economy: which sectors contribute the most to climate change (QRAFT sectors) and which are the most important economic sectors in a region (NACE)	**CO_{2eq} emission by QRAFT sectors*** (total & share of emissions) (2021) * QRAFT sectors based on OECD methodology, see Chapter 3)	CO_{2eq} per sector (kton)	Indicator for identifying the sectors, which contribute the most to climate change.
		Share of emissions by sector) (in % of all sectors)	Lower CO_{2eq} per QRAFT sector (total and share) means it contributes less (regardless of economic output and economic importance of sector → CEI per sector)
	GVA of economic sectors (NACE) (2020 and development between 2010-2020)	Total GVA per sector (mio. EUR) Share of GVA (in % of all sectors)	CEI: emission per unit of economic output measured in kg/EUR of the GVA). Comparison between regions: Lower CEI is better (less emissions per economic output)
	CEI of QRAFT/NACE sectors* (2020 and development between 2010-2020) QRAFT sector group (combination) and economic sectors (NACE)[9]	CEI: CO_{2eq} (kg) / GVA (EUR)	
		Development of CEI between 2010-2020 (2010= 100 %)	

In this "needs assessment" part of the QRAFT methodology, we focus mainly on GHG emissions and GDP (in a time-sensitive per capita and sectoral perspective) to define the transition needs of a region to achieve climate neutrality. We recognize that GHG and GDP are only basic indicators. Also, there is the issue of production of GHG emissions in one region, and consumption of products (e.g., energy) in another region, which cannot be statistically addressed with with the existing data, the QRAFT has to rely on (see Chapter 3). Additionally, it is important to keep in mind, that by focusing only on GHG emissions in QRAFT, we are only focusing on climate change as the transition need, purposefully leaving aside other important and in part related issues such as biodiversity loss or ocean acidification. Besides these limitations, the assessment of needs towards regional climate neutrality is easily accessible and gives a comparatively complex picture of a region's status quo and trends.

[9] QRAFT sector group based on OECD methodology (OECD 2022) and economic sectors according to NACE classification. Note, that the economic sectors and the QRAFT sectors are not exactly the same (see Chapter 3)

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2.2.4 Assessing the transition potential

A general assessment of the potential of a region for transformational change is highly complicated and depends on very specific pathways, which are not easily quantifiable. Still, a quantitative assessment is an essential step to foster the understanding of a region and generate an orientation for further inquiry. Nevertheless, we insist that it has to be complemented by qualitative data and critically discussed by regional experts. Therefore, this part of the QRAFT methodology will feed into the qualitative "TSL Transition Readiness Assessment, the framework of Assessing the efficiency and success of Transition Process towards climate neutrality" and the mixed-method framework of "Evidence-based use case Impact Assessment Methodology" developed in deliverable D5.1.

For assessing the transition potential of regions, we focus on the main transition drivers, which we subcategorize into political & social, economic competition & innovation, and environmental (Jesus & Mendonça, 2018; Johnstone & Newell, 2018; Parris & Kates, 2003; Tan et al., 2022). To assess the state of these transition drivers, we use a combination of existing **Composite Indices (CI)** that reflect the status quo and trends of these transition drivers for the EU regions at NUT2 level (see Table 4).[10] This has several reasons: First of all, these CIs have proven useful in many scientific studies as well as in policy development and are, therefore, well-established in academia and politics. Secondly, it allows the users of the QRAFT to weigh the importance of different topics according to their specific regional conditions (e.g., political objectives with regard to social equality and a "just transition"). Thirdly, the chosen CIs are constantly refined and updated, guaranteeing their applicability in the QRAFT by the TSL follower regions (TSL User Forum) after the TRANSFORMER project has ended.

Regarding the **environmental transition potential**, we do not refer to a CI but in a first step to important basic indicators: the current "land use and cover" and the "regional potential for RE" (directly linked to transition needs of the energy sector). Depending on the topic of the region, of course additional indicators to assess the ecological potential for transition should be taken into account (e.g., for the agriculture sector: water availability, soil conditions and more generally the vulnerability and resilience of natural ecosystems with regard to climate change).

The following topics and CIs will be used in the QRAFT to assess and discuss the transition potential. For this first version of the QRAFT, all topics will have the same importance. For the second version of the QRAFT, these CIs and related indicators will be discussed with experts of the TRANSFORMER Consortium (together with the framework developed in deliverable D5.1) and further qualified. Based upon this, it will be elaborated, if the TSL approach needs its own CI based on the identified essential indicators (of the CI and additional ones).

[10] Other CIs focusing only on the national level could also be included in the QRAFT, i.e. the "Climate Change Performance Index | Germanwatch e.V." or the "OECD Environmental Policy Stringency (EPS) Index" that assesses the climate policies of countries on a country level.

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Table 4: Composite indices for assessing the transition potential of regions in the context of the TSL approach. Source: own compilation.

Fields of transition potential	Composite index	Explanation of using the CI in the QRAFT methodology	Relation to TSL core elements
Economy: competitiveness & Innovation	**EU Regional Competitiveness Index 2.0**	A comprehensive framework for evaluating and comparing the competitiveness of the EU regions on a NUTS 2 level (see Table 5 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*	Economic performance & resources for transformation *Potential for* - co-creation & experimentation (resources and structure) - innovation
	Regional Innovation Scoreboard 2023	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 6 for detailed description). *Regions with a comparatively high score = more capable to experiment, innovate and co-create*	Political and economic resources and structures for innovation *Potential for* - innovation - experimentation
Political framework & social structures	**European Quality of Government Index 2021**	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 (see Table 7 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 having inclusive participatory governance arrangements (perceived by citizens) which is a prerequisite for participation and co-creation.*	Government & regulatory framework *Potential for* - participation & co-creation (trust in political processes and public services)

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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 respectively basic, intermediate and more subtle aspects of social progress. - 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 8 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 2) the environment is integral part of the 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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Table 5: EU Regional Competitiveness Index 2.0. Source: own compilation 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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Table 6: Regional Innovation Scoreboard 2023 (RIS). Source: own compilation 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 7: European Quality of Government Index (EQI). Source: own compilation 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 8: European Social Progress Index 2020. Source: own compilation 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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2.2.5. Synthetization of transition needs and potentials

After separately discussing the methodology for assessing the transition needs and the transition potentials of regions, it is important to think both needs and potentials together. As we have discussed above, the QRAFT methodology can be used to define/reassess transition challenges and topics for the vision-building process within TSLs and to identify regions, which could profit from applying the TSL approach.

Defining and redefining topics for vision building

In order to use the QRAFT framework for identifying or reassessing the vision building within the TSL process, a careful look at both the transition needs and the transition potentials of a specific region is needed. This requires an individual interpretation of the QRAFT indicators for the region in question, especially focused on finding connections between needs and potentials, which can be translated into a topic of a region. For instance, if a region shows an especially high degree of GHG emission in the sector of agriculture and a high potential for innovation (especially in regard to sustainable energy), this can lead to identifying the leverage point of 'dual-use' of agricultural production and electricity production from solar photovoltaic (PV) panels occurring together on the same piece of land.
However, since the interpretation of QRAFT for a specific region needs to be done individually, as part of this deliverable, it is not possible (nor practical) to analyze each of the regions of the EU in such a manner. However, to give an understanding of how such interpretations can be done, in Chapter 4, we selectively interpret the data and indicators for the TRANSFORMER regions. A complete interpretation of the QRAFT methodology will be part of the case studies (deliverable D2.3).

Preliminary thoughts on identifying regions which could profit from applying the TSL approach

The QRAFT methodology can also be used to identify **regions, which could profit substantially from becoming future TSLs.** However, when thinking about what kind of regions could especially profit from a TSL approach, it is important to first be aware that this approach is still being actively developed within the TRANSFORMER project, and that we do not have a list of factors for what conditions make a region better equipped to successfully apply the TSL process. At this stage of the TRANSFORMER project, therefore, we can only recur to applying a very conceptually driven perspective to this problem.

In principle, we believe the **TSL approach to be beneficial to any region**. Reasons for this are that TSLs are an approach to accelerate the transition towards climate neutrality, which is of utmost importance for the continued prosperity of humans and other lifeforms on this planet. However, there are many ways to achieve climate neutrality and the TSL approach is only one of them. Still, from our perspective, the **TSL approach has two important selling propositions**. Firstly, the TSL approach consists of a methodology fostering innovation not of single solutions but at a *systemic level*. Secondly, the TSL approach addresses the inclusion of civil society. Opposition of part of civil society is often difficult road blocks in regional and national transition processes and this opposition can be possibly circumvented by including them in the TSL as part of the transition agents (Schönwälder, 2021).

When thinking through the question of what kinds of regions could especially profit from applying the TSL approach on the background of the QRAFT methodology, we can concretely think about what indicators,

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(or what combination of indicators) might make the TSL approach especially beneficial for a region. Now, there is a difference between what regions the TSL approach is especially beneficial for, and what regions might be especially able to successfully conduct a TSL (and therefore especially profit from it).

The former that is regions, which would profit the most from a TSL approach because their need is especially difficult, could be defined by scoring especially negatively regarding a combination of the QRAFT indicators, i.e., high GHG emissions coupled with low scores in the potential section of the QRAFT methodology. Here, when considering the two unique selling propositions of the TSL approach, we can narrow this set of indicators down to those which have specific difficulties regarding innovation (on the systemic level) and who face an especially difficult situation in terms of including civil society in transition processes, this could possibly be caused by high social inequality (represented and weighted in the composite index of the European Social Progress Index 2020; see Table 8).

Regarding regions with high conditions for successfully applying a TSL, regions with high scores regarding the indicators for assessing the transition potential and the transition readiness level (see deliverable D5.1) come to mind. However, – as mentioned initially – we need the results about the 'success condition for TSL', which will only be sketched out more clearly by the end of the (currently still not having reached half time) TRANSFORMER project. Our first indication, however, is that a high willingness of the stakeholders to engage and push the transition vision forward is very essential here, which cannot be assessed with the quantitative QRAFT methodology.

In a nutshell, QRAFT can be helpful in exploring which regions could profit most especially from applying a TSL approach. However, this does not mean that any other possible regions would not profit from engaging in a TSL, far from it. We especially maintain that any region can profit substantially from a TSL approach and there is no reason not to apply it in a region, even if there are other efforts being undertaken to achieve regional climate neutrality. The TSL approach can help and support those efforts.

3 Data collection, evaluation and limitations

As described above, we rely in our QRAFT methodology 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 and cartographic illustrations for better visualization and interpretation.

EUROSTAT was the main data source because of the open-access availability of the data and the existence of NUT2 level data (see Table 9). However, with regard to electricity and energy statistics on a regional level, we had to complement it 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 OCED statistics provided a valuable addition, statistics on consumption (e.g., energy or agricultural goods) do not exist for the EU regions on a NUTS 2 level at all (and also exist only for certain EU regions accessible through the respective national statistical offices). Regarding GHG emissions we used the most accurate and

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constantly updated Emissions Database for Global Atmospheric Research (EDGAR), which provides GHG on the regional (NUTS 2) and local level (NUTS 3), also per (economic) sector.

Table 9: Overview of the key statistics used in D2.2 and their sources. Source: own compilation.

Topic	**Source**
Area	EUROSTAT
Population size	EUROSTAT
GDP pps	EUROSTAT
GDP per capita	EUROSTAT
CO_{2eq} / CO_{2eq} per sector	EDGAR
Electricity generation	OECD

With regard to assessing the GHG emissions by sector, the methodology of the OECD, that assigns the different activities (according to IPCC classification) contained in the EDGAR database to specific sectors (see overview of activities and sectors in Table 13, Chapter 4.1.3), was applied (OECD, 2022). The Emissions from Land Use and Land Cover Change (LULCC) as well as from international flights and shipping are not included. As the EDGAR database does not contain a separate list of different F-gases, they were also excluded from the analysis. The GWP was calculated according to the IPCC GWP-100 AR5 and multiplied correspondingly (see Table 10).

Table 10: Global Warming Potential (100-year time horizon, GWP-100 AR5). Source: (Myhre et al., 2013)

Species	Chemical formula	Global Warming Potential (100-year time horizon)
Carbon dioxide	CO2	1
Methane	CH4	28
Nitrous oxide	N2O	265

Regarding the interpretation of the data, the **limitations of the data availability** have to be emphasized and kept in mind: 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 later shown, this problem of focusing on "Production-Based Accounting" (and not "Consumption-Based Accounting") can be very problematic with regard to the interpretation (Davis & Caldeira, 2010). Regions exporting energy or goods are not causing the GHG emission just by themselves. 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, also the

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

In addition, **focusing on a regional level (NUTS 2 level) also has significant limitations**. Firstly, the general regional quantitative perspective (and the underlying composite indices) only partially reflect the political manoeuvring space regions have (e.g., legislative power and power imbalances regarding their influence on other regions and superordinate/overarching political levels). Moreover, a regional perspective (NUTS 2 Level) is often too broad to identify inner-regional disparities and challenges. Therefore, a comprehensive regional assessment should always be embedded in a multi-level perspective (Geels, 2002; Köhler et al., 2019) that considers the role of regions within their multi-level governance arrangements. This perspective will be applied in the mixed-methodology approach of the case studies that the QRAFT feeds into (see task 2.3/ deliverable D2.4 of the TRANSFORMER project.

4 Quantitative mapping of EU regions and the four TRANSFORMER TSLs

As our quantitative mapping exercise, we apply the QRAFT methodology to all 242 NUTS2 EU regions in form of a single comprehensive Excel file. In this Excel file all indicators and data used in the QRAFT are compiled and made easily accessible. The Excel file is the core of this deliverable and the 'materialization' of the quantitative mapping. In this chapter, we will use the four TRANSFORMER TSL regions to demonstrate how to interpret the different data points (and the visualisation of the data in the cartographic illustration) for specific regions. Additionally, this chapter discusses QRAFTs usefulness as a self-assessment tool for regions and TSL stakeholders. Therefore, this mapping presents the steps a TSL follower region would conduct in the beginning of the TSL process to assess its needs and transition potentials ion from a quantitative perspective.

4.1 Assessing the transition needs of EU regions: current state, development and topics of interest

The quantitative mapping shows, that the regions on the NUTS 2 level are very different with regard to area, population size and GDP (see Table 11). This also applies to our four TRANSFORMER TSL regions: for example, the population size of Emilia-Romagna was in 2021 nearly 17 times as big as the one from Western Macedonia. These huge disparities, which also apply to economic structures (e.g., GDP pps) need to be carefully considered when interpreting statistical data.

4.1.1 Carbon intensity of the society and economy: what are the current state and trends of the region?

With regard to the GHG emissions, the quantitative assessment clearly shows that the average trend of becoming climate neutral in the EU regions is progressing slowly: in the decade between 2011 and 2021, the CO_{2eq} emissions were reduced by nearly 15% (see Table 11, Figure 7 for CO_{2eq} per capita

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development). However, there is a big difference with regard to the process of decoupling the economy from the emissions of GHG and 33 regions even show an increase of $CO2_{eq}$ per capita emissions.

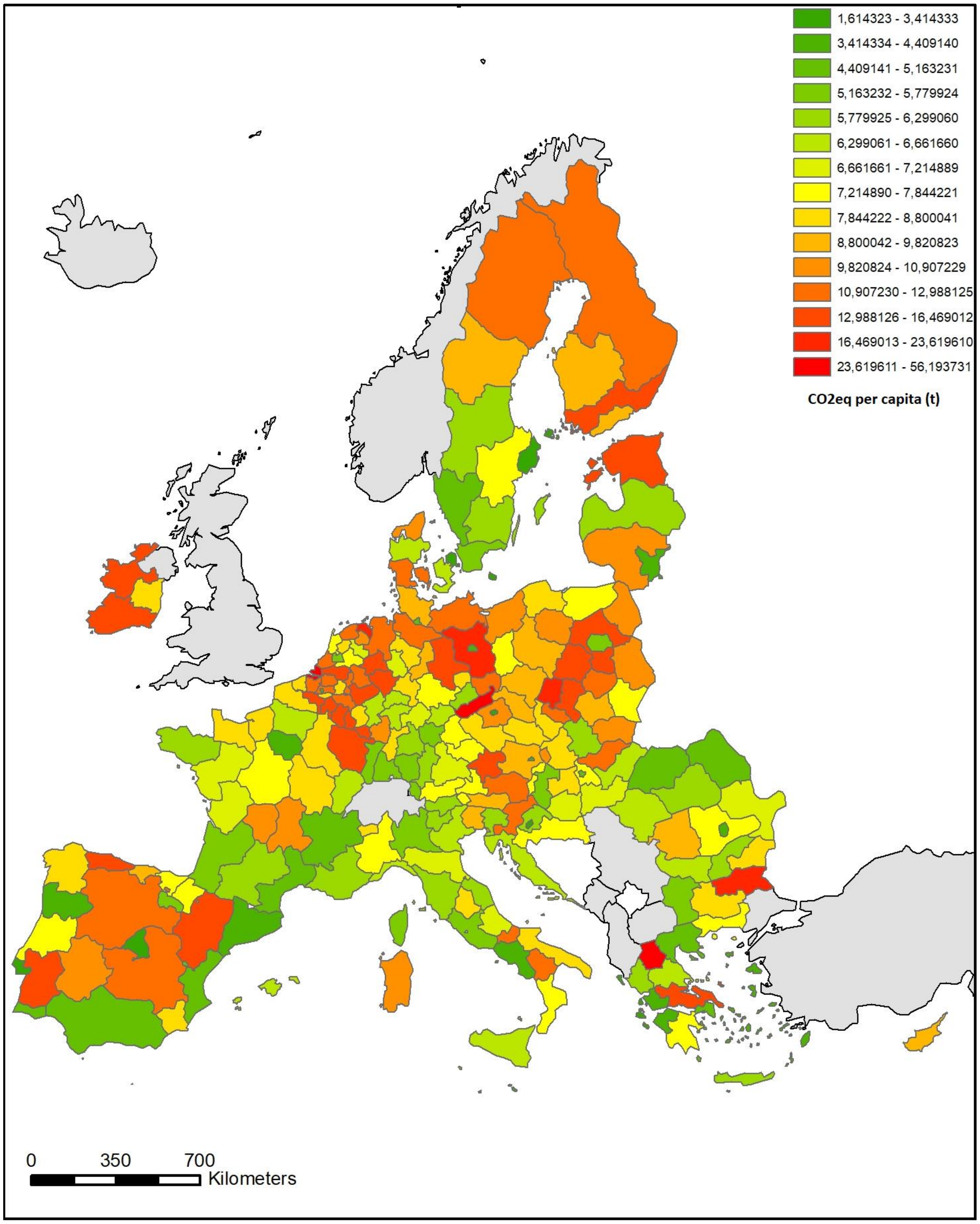

Figure 4: CO_{2eq} per capita (2021). Data sources: EDGAR (CO_{2eq}) and EUROSTAT (per capita), EUROSTAT/CISCO (statistical unit dataset containing the NUTS regions). Source: own design (with support from the “Interdisciplinary geographic information sciences unit” of the Institute of Geography/ Ruhr University Bochum).

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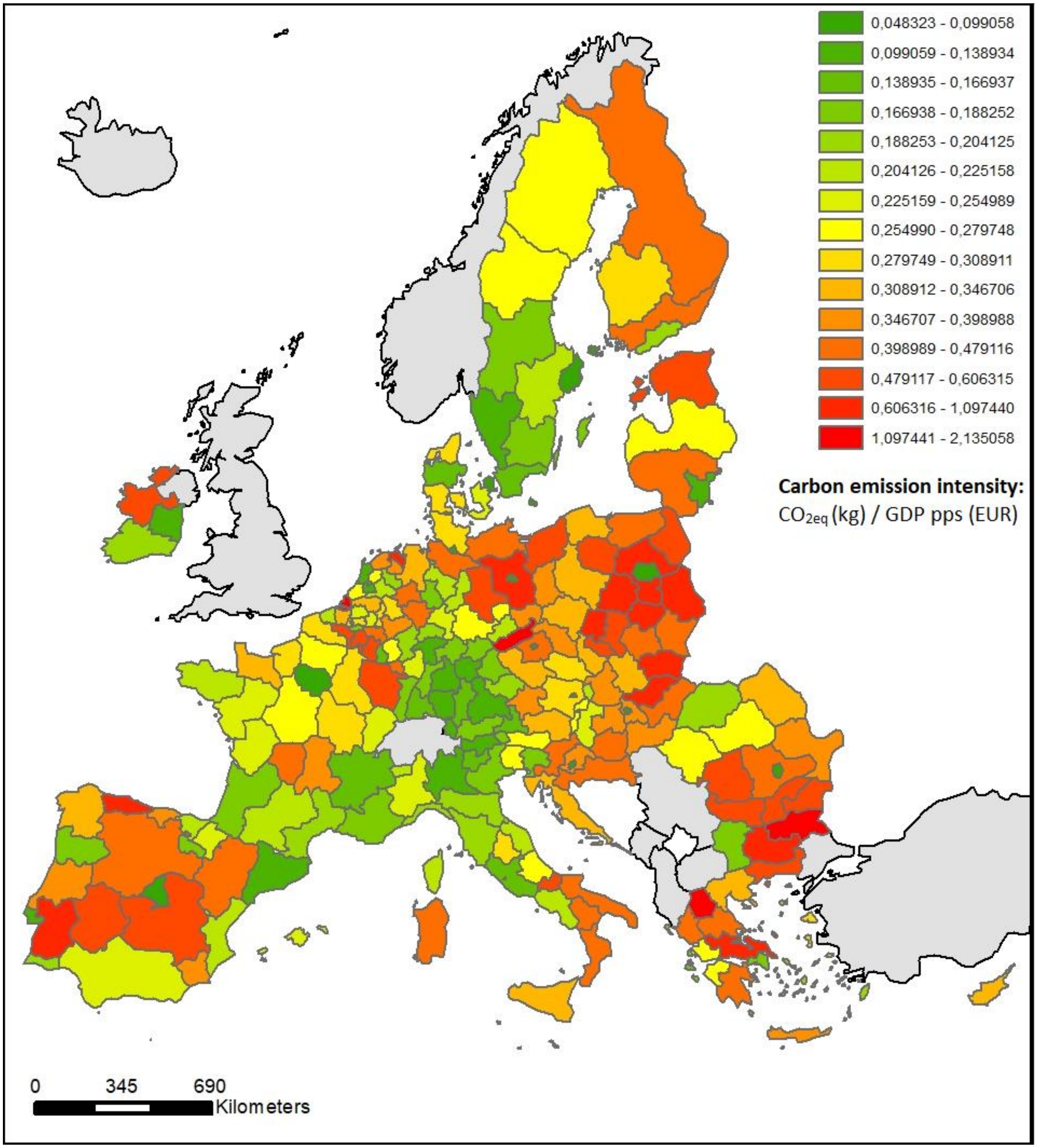

Figure 5: CEI (CO_{2eq} (kg)/GDP pps (EUR)) of all EU NUTS 2 regions (2021). Data sources: EDGAR (CO_{2eq}) and EUROSTAT (GDP pps), EUROSTAT/CISCO (statistical unit dataset containing the NUTS regions). Source: own design (with support from the "Interdisciplinary geographic information sciences unit" of the Institute of Geography/ Ruhr University Bochum).

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This diversity of the EU regions (see Figure 4 for a map of the CO_{2eq} per capita of all EU regions) is also clearly reflected in the current state (2021) of the four TRANSFORMER TSL regions (see Figure 6 and Table 11): the GHG per capita emissions of Emilia-Romagna are well-below and its GDP pps per capita are above the EU average/median. In contrast, Western Macedonia has one of the highest GHG per capita of all EU regions. This can be explained to a large degree by the big lignite power plants in Western Macedonia which produce electricity also for other regions of the country (Ziouzios et al., 2021). This problem of differentiating between GHG emissions caused by production of goods and services which are consumed in other regions needs to be kept in mind when interpreting this data (see Chapter 3). The energy (electricity) sector will be more closely analysed from the sectoral perspective of the QRAFT in Chapter 4.1.2.

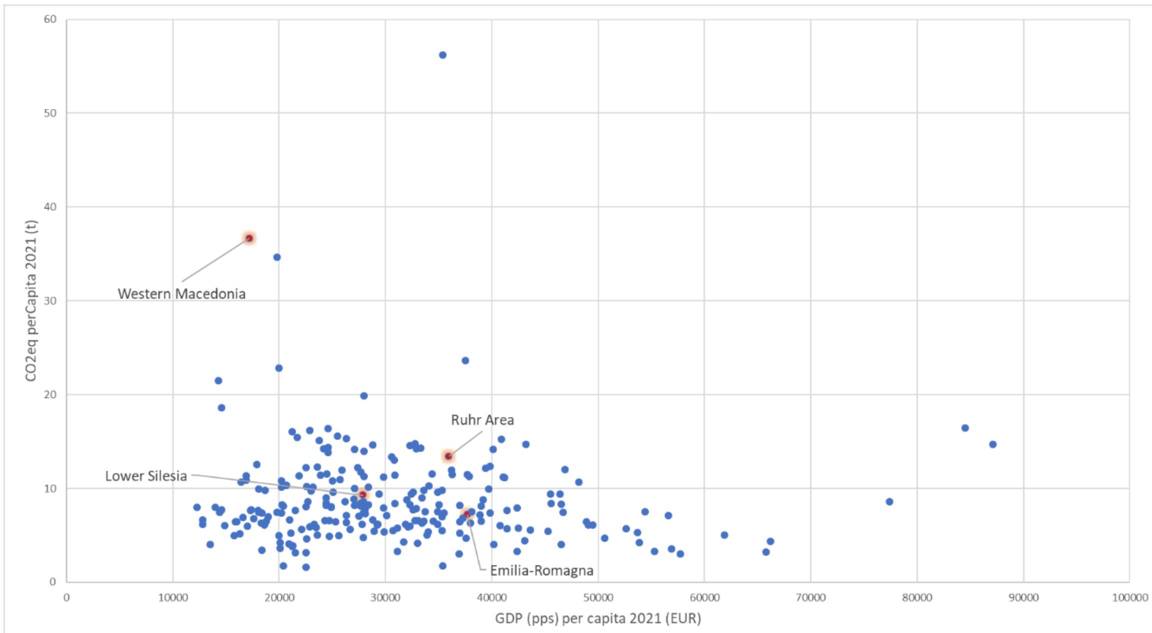

Figure 6: CO_{2eq} per capita (t) and GDP ppp per capita (EUR) of all EU regions (2021). TRANSFORMER TSL regions highlighted. Data source: EDGAR (CO_{2eq}) and EUROSTAT (per capita and GDP). Source: own compilation.

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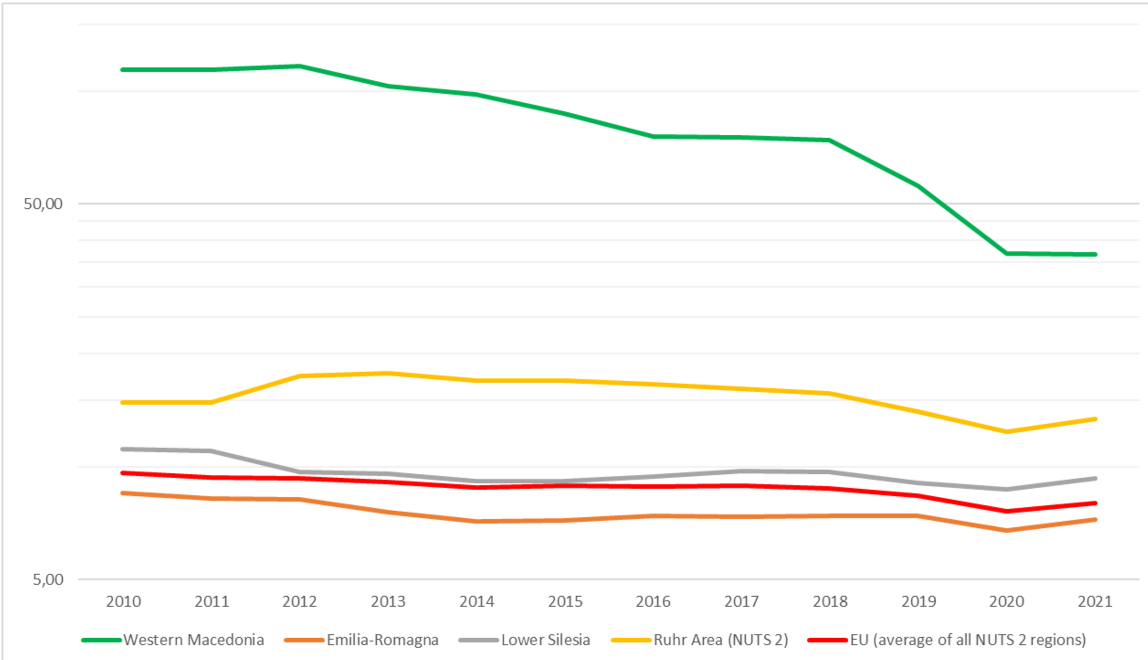

Figure 7: CO_{2eq} per capita (t) of all EU NUTS 2 regions (average) and the four TRANSFORMER TSL regions (logarithmic scale). Data source: EDGAR (CO_{2eq}) and EUROSTAT (per capita). Source: own compilation.

Regarding the development of the GHG emissions, the four TRANSFORMER regions all show a positive trend with a remarkable decrease of $CO2_{eq}$ per capita emissions in Western Macedonia of nearly 70% between 2011 and 2021 (see Figure 8). The development of the GHG emissions and the GDP of the region (see Figure 8) clearly reflects the decline in lignite production, the decrease of energy production in lignite-fired power plants and (especially with regard to the GDP) also the economic and financial challenges the region and the country faced in the last decade (Ziouzios et al., 2021). In contrast, the Ruhr Area[11] shows comparatively little progress in reducing its GHG emissions per capita (only about 10%) and the per capita emissions remain well-above the EU average.

[11] The Ruhr Area is not a NUTS 2 region and consists of counties and cities (NUTS3) that are part of three different NUTS 2 areas. In this D2.2 the Ruhr Area will be regarded in the boundaries of the NUTS2 classifications and, therefore, also encompasses counties that are not part of the region that is defined (or perceived) as the Ruhr Area. This is an important perspective as the district governments ("Bezirksregierungen") that shape some of the regional policies of the Ruhr Area lie without its boundaries. In the case studies of the deliverable D2.3, the Ruhr Area will be additionally analysed within the boundaries of what is perceived as the "Ruhr Area" using the NUTS 3 level

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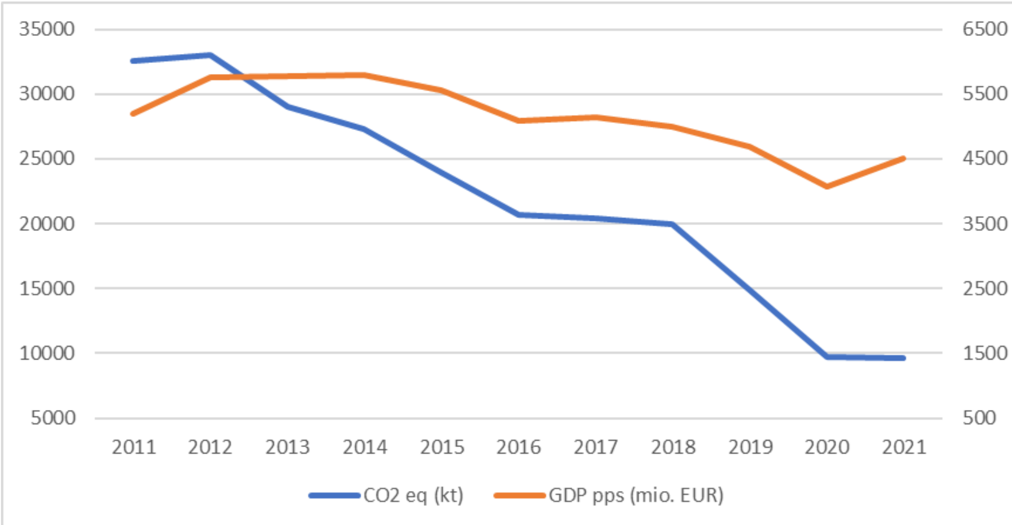

Figure 8: Development of CO_{2eq} (kt) and GDP pps (mio. EUR) in Western Macedonia between 2011-2021. Data: EDGAR (CO_{2eq}) and EUROSTAT (GDP pps). Source: own compilation.

One of the most important indicators to assess the impact of an economy on climate change is the "Carbon emission intensity" (CEI). As described above (see Chapter 2.2.3) the CEI is the amount of CO_{2eq} emitted per generated economic output (measured in EUR of the GDP ppp). In this regard, we see a huge difference between the regions (see Figure 5 for a map of the CEI of all EU regions): once more, we see that Emilia-Romagna has comparatively little and Western Macedonia has very high emissions per economic output (see Figure 9 and Table 11). However, we also see once more that the trend in Western Macedonia is going in the right direction with a decrease of CO_{2eq} per GDP pps (CEI) of more than 65%. To better understand the underlying processes of this industrial transformation and to identify the most important sectors and areas for improvement of a region – and thus potential TSL topics – it is necessary to take a closer look at the $CO2_{eq}$ per economic sector and activities in the next Chapter (see Table 12, Table 13 and Table 15).

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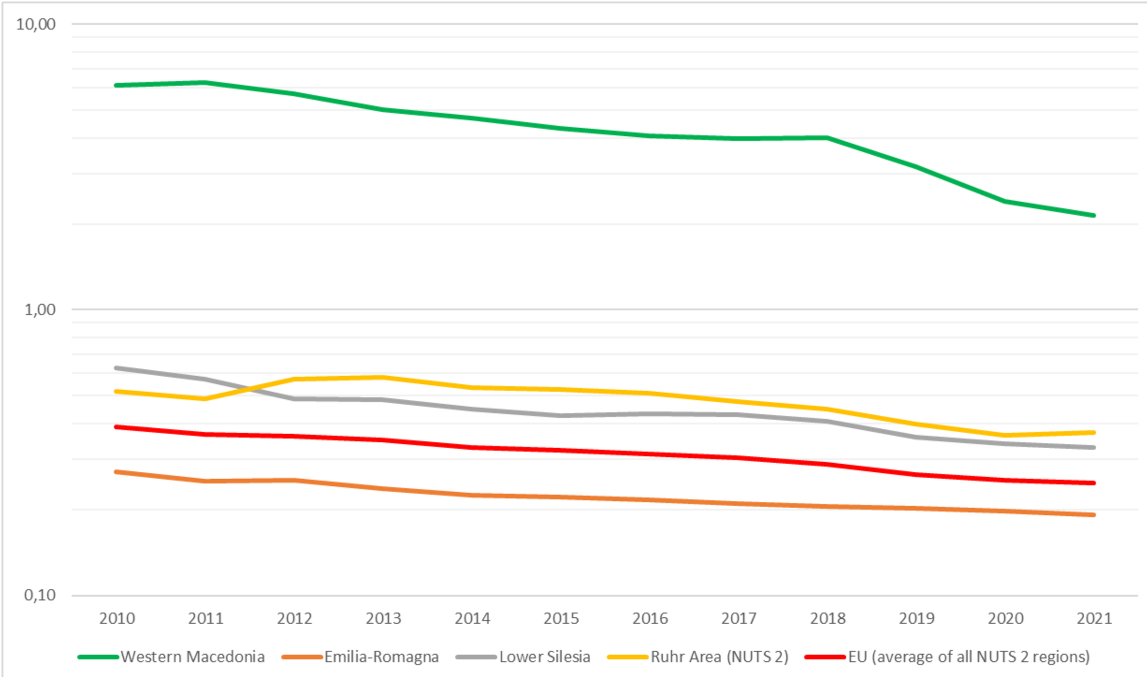

Figure 9: CEI (CO_{2eq} (kg)/GDP pps (EUR)) of all EU NUTS 2 regions (average) and the four TRANSFORMER TSL regions (logarithmic scale). Data source: EDGAR (CO_{2eq}) and EUROSTAT (GDP pps). Source: own compilation.

4.1.2 What are the most important economic sectors and "transition topics" in the region?

The overview of the sectors of all EU regions (see Table 12) shows, that the energy sector (including power industry, fuel production, refineries and transformation industries) is contributing the most to GHG emissions, followed by transport and manufacturing. However, with regard to the sectors and activities, a comparison of our TRANSFORMER TSLs highlights again the diversity of the regions: whereas the share of GHG emissions in the **energy sector** is extremely high in Western Macedonia, it is well below EU average in Emilia Romagna. As pointed out before, this only shows the disparities in production and does not reflect the energy consumption in a region (see Chapter 3). In this regard, the lack of data containing statistics on energy consumption at regional level is a methodological problem. However, the OECD statistics from 2019 show that Western Macedonia produces a large share of the electricity of the whole country (>22%). This shows again the need for better regional data on emissions that are caused by consumption (energy, manufactured goods, agriculture products etc.) to assess the regional need and potential for transition.

A closer look at the different activities in the energy sector (see Table 13) also clearly shows that "Electricity & heat generation" (power industry) is contributing by far the most to GHG emissions, thus highlighting again unambiguously the urgent need for a fundamental transformation of the energy sector (see Chapter 4.2 with regard to the RE potential in the EU regions).

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However, with regard to the energy sector we can also clearly see differences in the importance of specific activities: whereas in the NUTS 2-region Münster (as part of the Ruhr Area)[12] the *oil refineries* contribute significantly to the GHG emissions, in Lower Silesia the *fuel production* is a larger emitter. This shows that regions have specific challenges which need to be addressed individually and with policies tailored to their specifics needs. A quantitative perspective clearly helps to identify these challenges – especially for people who are not very familiar with a region or specific activities.

Another important perspective is to regard the CEI of specific activities (CO_{2eq} emissions in relation to the GVA of a sector) even though this comparison can serve due to the above-mentioned methodological challenges (different classifications of GHG and economic sectors, see Chapter 3) only as a very rough assessment. However, the very high CEI of the "Energy & Waste sector" of Western Macedonia (see Table 14) highlights the challenges of having very high emissions in combination with a comparatively low economic value creation (GVA) of this sector. This need for improvement underlines the importance of a shift in the energy policy that was already implemented by political decision-makers in Western Macedonia to accelerate the phasing-out of lignite (Enterprise Greece, 2020). This quantitative assessment clearly shows that the Western Macedonia TSL has identified one of the most crucial topics in the region and it can serve as an argument to convince possible veto players that the phase-out of lignite-based electricity is of utmost importance to tackle climate change in that region.

Addressing the **energy sector** is also of crucial importance for Lower Silesia, as nearly half of the region´s GHG emissions originates from the *power industry* and *fuel production* (see Table 13). The need for a fundamental transition of the energy sector in Lower Silesia is especially challenging, as the experiences of the citizens in that region with the closure of mines and coking plants in the 1990s have been predominantly negative: it led to "the collapse of many companies that operated for the mining industry [and caused] overwhelming problems across all socio-economic dimensions" (Hajduga et al., 2022: 33). This challenge of including citizens and creating trust and acceptance is addressed within the TRANSFORMER project by developing a framework for integrating public participation methods in energy-related decision-making. The topic of energy-transition is also directly related to another important sector – **transport** – in Lower Silesia, which contributes the second most to the region´s GHG emissions. This quantitative mapping, therefore, also confirms that the second "pilot use case" – developing "convenient transport connections for the benefit of the environment" – addresses on of the most important topics.

The sector **transport** is in Emilia-Romagna even more important with regard to becoming climate neutral than the energy sector (see Table 13). Considering the population size, the transport sector in Emilia-Romagna has by far the highest share of GHG in comparison to the other TRANSFORMER regions. This also reflects very well that the chosen topic in the TSL is focusing on one of the most urgent challenges of the region. However, the quantitative mapping also clearly shows that the GHG emissions in the **agricultural** sector are compared to the other TRANSFORMER TSLs also very high and are only a little bit below the average of all EU regions. *Enteric fermentation* and *Manure management* are clearly the main

[12] The city of Münster itself does not belong to the Ruhr Area. This shows (as discussed in Chapter 3) that the focus on a NUTS 2 level has its limitations and needs to be further analysed on a NUTS 3 level and complemented with qualitative research methods.

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problems in Emilia-Romagna in this sector. This issue could be addressed together with the energy sector as another useful cross-sectoral TSL topic in that region (electricity and heat generation based on manure and agricultural waste). However, with regard to the CEI of that sector this topic could even be more important for Lower Silesia which has high emissions in combination with a comparatively low economic value creation (GVA) in the agriculture sector (see Table 14).

With regard to GHG emissions, **Manufacturing** is another important sector. The Ruhr Area – as one of the largest industrial areas in Europe – has compared to the other TRANSFORMER TSL regions by far the highest share of GHG in this sector and the production of *iron and steel* generates more GHG emissions than all the other TRANSFORMER regions have in this sector combined. Together with the comparatively high GHG emissions in the energy sector this is clearly the most urgent topic in that region. Especially with regard to the steel production, hydrogen is widely regarded as an essential topic. This will be especially challenging for the region as the potential for RE is very limited (see Figure 10, Figure 16, and Figure 17). This shows, that the topic chosen in the Ruhr TSL addresses one of the main challenges in the region and it highlights the importance of one of the "pilot use cases" (Rhine Herne canal as a hydrogen artery and "Extension of the Rhine-Herne Canal into a ´Hydrogen River`") to link the Ruhr TSL to other regions with high H2-generation potential (see Chapter 4.2).

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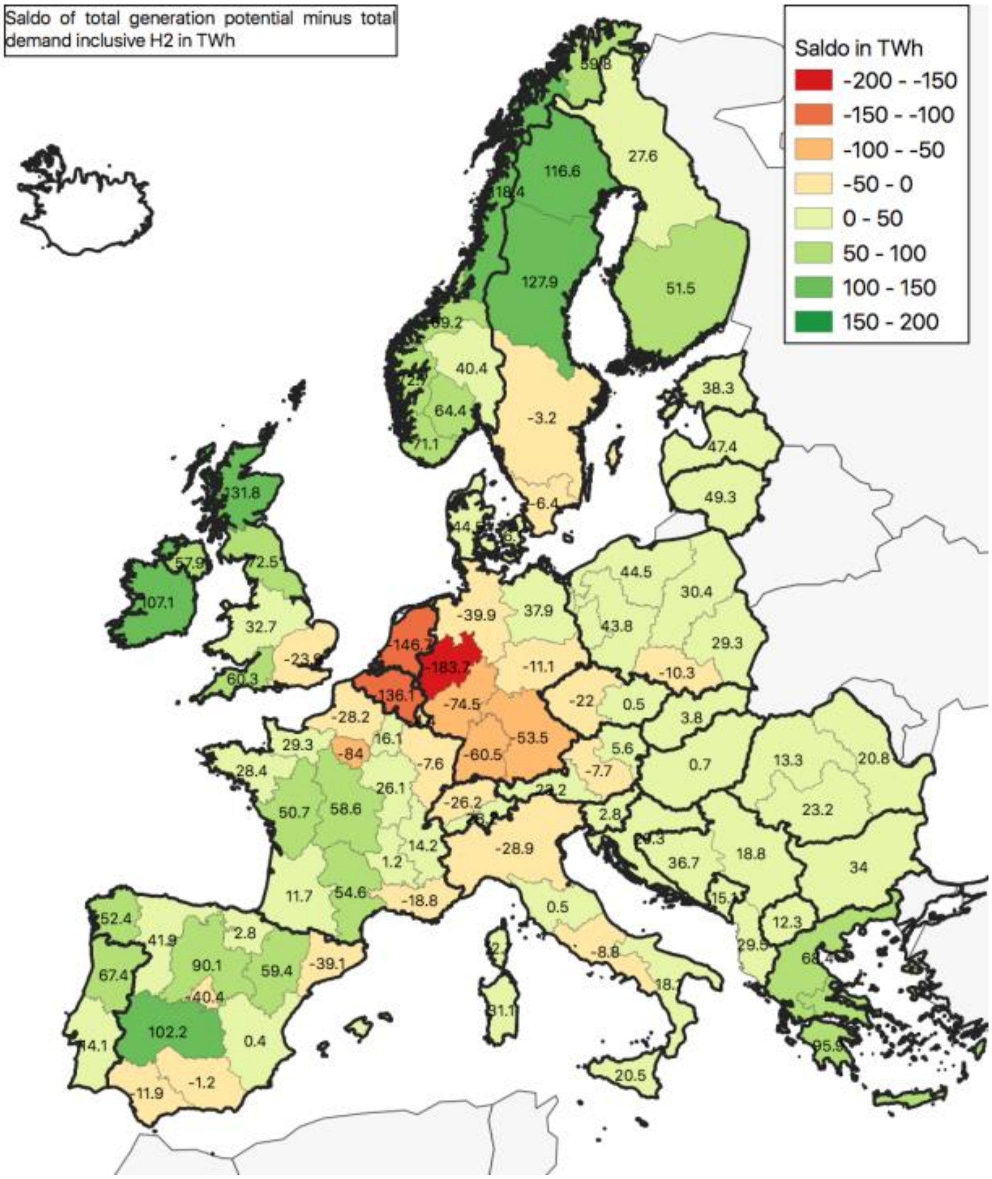

Figure 10: Balance of renewable generation potential and demand with electricity for hydrogen in Europe 2050. Source: (Wuppertal Institut, 2020).

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.

The first step of the QRAFT method has shown so far, that valuable insights can be derived from a data-driven approach for identifying transition needs and possible topics of a region. In the next chapter, we will show, that also the assessment of the transition potential in the context of the TSL approach can significantly gain from our methodology.

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4.1.3 Compilation of statistics (tables) for assessing the transition needs of the four TRANSFORMER TSL regions

Table 11: Selected data for EU regions and the TRANSFORMER TSL regions. Data: EDGAR (CO_{2eq}) and EUROSTAT (all other data). For comparison of regions: read per row (green = low, red = high). Source: own compilation.

Topic	Year	EU regions (NUTS 2)					TRANSFORMER TSL regions						
		Min.	Max.	Average	Median	SUM (all EU regions)	Emilia-Romagna	Lower Silesia	Ruhr Area (NUTS 2) [13]				Western Macedonia
									Sum	*DUESS*	*MUENST*	*ARNSB*	
Area (km²)	2021	14	227120	17530		4224767	22453	19947	20221	5291	6918	8012	9462
Population	2011	28007	11852851	1847799		415754773	4331343	2878103	11230944	5081231	2568358	3581355	285899
	2021	30129	12348605	1854436		446919141	4438937	2857364	11395862	5200090	2624719	3571053	262052
GDP (ppp) (mio. EUR)	2011	995	545064	47967	32680	10792564	141348	55328	341814	172678	69501	99635	5203
	2021	1071	705576	60227	41313	14514809	167185	80393	409952	204981	86252	118719	4498
GDP (ppp) per capita (EUR)	2011	7400	70200	24517	23500		32300	19000	30435	34000	27000	27900	18300
	2021	12300	87100	30729	28100		37700	27900	35974	39400	32800	33300	17200
$CO2_{eq}$ (kt)	2011	65.17	94301	17239	13454	4154662	35625	31739	166353	73123	38371	54859	32534
	2021	51.74	69153	14856	11973	3580288	32026	26548	152931	63321	38678	50933	9604
CO2eq per capita (t)	2011	2.21	113.79	9.34	8.65		8.22	11.03	14.81	14.39	14.94	15.32	113.79
	2021	1.61	56.19	8.01	7.64		7.21	9.29	13.42	12.18	14.74	14.26	36.65
	Development: 2011-2021 (2011=100%)			85.75%	88.79%		87.72%	84.25%	90.60%	84.62%	98.63%	93.11%	32.21%
Carbon emission intensity of the economy (CEI) (kg/EUR)	2011	0.07	6.25	0.50	0.39		0.25	0.57	0.49	0.42	0.55	0.55	6.25
	2021	0.05	2.14	0.33	0.27		0.19	0.33	0.37	0.31	0.45	0.43	2.14
	Development: 2011-2021 (2011=100%)			66.35%	69.71%		76.00%	57.56%	76.65%	72.95%	81.22%	77.92%	34.15%

[13] 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. For comparing similar regions (population size), the three NUTS 2 regions comprising the Ruhr area should be compared with the other TRANSFORMER TSL regions.

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Table 12: Selected data for economic sectors of EU regions and the TRANSFORMER TSL regions. Data source: EDGAR (CO_{2eq}). For assessing the contribution to climate change (GWP) of a sector within a region: read per column (share of all sectors in the region). Comparison of sectors between regions: read per row (green = low, red = high). Source: own compilation.

QRAFT sector group [14] CO2eq (kt) [15] (2021)	EU regions (NUTS 2)					TRANSFORMER TSL regions						
	Min.	Max.	Average	Median	SUM	Emilia Romagna	Lower Silesia	Ruhr Area (NUTS 2) [16]				Western Macedonia
								Sum	*DUESS*	*MUENST*	*ARNSB*	
Agriculture	0.058	11551	1665	1034	401172	3400	1601	4622	978	2591	1052	422
				*Share**	11.48%	10.98%	6.07%	3.05%	1.57%	6.73%	2.08%	4.41%
Energy [17]	1.788	48291	4415	2265.87	1064090	7409	12376	72361	26809	20023	25529	7684
				*Share **	30.45%	23.94%	46.95%	47.79%	42.95%	51.98%	50.58%	80.19%
Manufacturing [18]	0.918	19943	2579	1782	621500	5006	2840	39024	19943	7000	12081	218
				*Share **	17.79%	16.17%	10.77%	25.77%	31.95%	18.17%	23.94%	2.28%
Settlements	2.681	14288.40	2094.80	1536.23	504847.24	5305.15	4054.32	18174.51	8298.31	4251.08	5625.13	148.51
				*Share **	14.45%	17.14%	15.38%	12.00%	13.29%	11.04%	11.15%	1.55%
Transport	0.000	10916	3042	2603	733139	7912	4745	14116	5382	3699	5035	729
				*Share **	20.98%	25.56%	18.00%	9.32%	8.62%	9.60%	9.98%	7.60%
Waste	0.658	4482	703	452	169467	1922	744	3116	1013	953	1149	381
				*Share (*of all sectors in the region)*	4.85%	6.21%	2.82%	2.06%	1.62%	2.47%	2.28%	3.97%
All sectors				***SUM***	3494216	30954	26360	151412	62425	38516	50471	9582

[14] QRAFT sector group based on OECD methodology (OECD 2022). Note that in deviation from the OECD methodology and the "CHE: CO2 Human Emissions Project project" some of the IPCC categories have been assigned to a different EDGAR sector for a more practical/applicable overview (see footnotes). IDE (Indirect emissions) and FFF (Fossil fuel fires) are not included in this study.

[15] GWP 100 AR-5. Only including CO2, CH4, N2O (F-gases not listed separately in the EDGAR database on a sectoral NUTS2-Level)

[16] 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. For comparing similar regions (population size), the three NUTS 2 regions comprising the Ruhr area should be compared with the other TRANSFORMER TSL regions.

[17] QRAFT sector "Energy" includes oil refineries (REF) and transformation industry (TRF).

[18] QRAFT sector "Manufacturing" does not include oil refineries and transformation industry.

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Table 13: Selected data for economic sectors (activities) of EU regions and the TRANSFORMER TSL regions. Data source: EDGAR (CO_{2eq}). Source: own compilation. For assessing the contribution to climate change (GWP) of an activity within a sector of a region: read per column (green = low, red = high).

QRAFT sector group [19] **CO2eq** (kt) [20] (2021)		**EDGAR sector**		**EU regions (NUTS 2)**			**TRANSFORMER TSL regions**						
				Mean	**Median**	**SUM**	**Emilia Romagna**	**Lower Silesia**	**Ruhr Area** (NUTS 2) [21]				**Western Macedonia**
									Sum	*DUESS*	*MUENST*	*ARNSB*	
Agriculture		AGS	Agricultural soils	497.62	356.32	119927	798.71	913.46	1028.09	247.64	490.85	289.60	197.92
		AWB	Agricultural waste burning	7.83	3.16	1887	26.09	30.48	6.97	2.19	3.06	1.73	4.93
		ENF	Enteric fermentation	751.81	432.68	181187	1415.03	318.29	2032.02	490.69	1097.03	444.31	161.50
		MNM	Manure management	303.57	161.10	73160	951.38	162.26	1328.62	177.76	915.66	235.20	29.58
		N2O	Indirect N2O emissions	103.78	77.60	25011	208.82	176.77	226.19	60.01	84.82	81.36	28.53
		Sector	*Total*			401172	3400	1601	4622	978	2591	1052	422
			Share (of all sectors)			11.48%	10.98%	6.07%	3.05%	1.57%	6.73%	2.08%	4.41%
Energy [22]	Electricity & heat generation	ENE	Power industry	3396.96	1673.79	818666	7065.87	10890.88	63303.38	23062.09	16692.94	23548.36	7057.24
	Energy extraction & transformation	PRO	Fuel production	390.60	144.76	94134	193.90	1339.68	2846.05	1148.57	1051.30	646.18	625.57
		REF	Oil refineries	357.71	0.00	86209	94.89	0.00	1628.97	177.62	1451.35	0.00	0.00
		TRF	Transformation industry	270.04	52.44	65081	54.57	145.34	4582.43	2420.97	827.12	1334.34	1.01
		Sector	*Total*			1064090	7409	12376	72361	26809	20023	25529	7684
			Share			30.45%	23.94%	46.95%	47.79%	42.95%	51.98%	50.58%	80.19%

[19] QRAFT sector group based on OECD methodology (OECD 2022) including IPCC activities. Note that in deviation from the OECD methodology and the "CHE: CO2 Human Emissions Project project" some of the IPCC categories have been assigned to a different EDGAR sector for a more practical/applicable overview (see footnotes). IDE (Indirect emissions) and FFF (Fossil fuel fires) are not included in this study.

[20] GWP 100 AR-5. Only including CO2, CH4, N2O (F-gases not listed separately in the EDGAR database on a sectoral NUTS 2-Level).

[21] 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. For comparing similar regions (population size), the three NUTS 2 regions comprising the Ruhr area should be compared with the other TRANSFORMER TSL regions.

[22] QRAFT sector "Energy" includes oil refineries (REF) and transformation industry (TRF). TRF: Incl. off-road machinery (mining), fuel transformation of gaseous fuels

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QRAFT sector group [19] **CO_2eq** (kt) [20] (2021)	**EDGAR sector**		**EU regions (NUTS 2)**			**TRANSFORMER TSL regions**						
			Mean	**Median**	**SUM**	**Emilia Romagna**	**Lower Silesia**	**Ruhr Area** (NUTS 2) [21]				**Western Macedonia**
								Sum	*DUESS*	*MUENST*	*ARNSB*	
Manufacturing	CHE	Production of chemicals	399.18	197.88	96203	884.92	114.56	2264.92	1018.20	707.08	539.64	0.85
	IND	Manufacturing industry	1484.29	978.44	357715	3229.55	1655.49	24517.16	12469.69	4514.29	7533.17	78.67
	IRO	Production of iron and steel	62.49	0.00	15059	2.53	0.00	2017.61	1458.62	13.39	545.60	0.00
	NEU	Non energy use of fuels	11.38	7.77	2742	21.73	21.12	93.78	43.95	21.01	28.81	1.24
	NFE	Prod. of non-ferrous metals	19.31	2.53	4654	16.61	0.03	1328.55	1300.08	9.29	19.18	0.00
	NMM	Prod. non-metallic minerals	435.04	264.35	104846	440.01	860.49	7385.68	2998.93	1409.34	2977.41	111.32
	PRU	Production and use of other products	12.02	7.04	2896	30.29	9.00	40.95	19.19	9.18	12.58	3.24
	SOL	Application of solvents	155.12	104.91	37384	380.06	179.13	1375.03	634.71	316.16	424.16	22.68
	Sector			*Total*	621500	5006	2840	39024	19943	7000	12081	218
				Share	17.79%	16.17%	10.77%	25.77%	31.95%	18.17%	23.94%	2.28%
Settlements	RCO	Residential	2094.80	1536.23	504847	5305.15	4054.32	18174.51	8298.31	4251.08	5625.13	148.51
	Sector			*Total*	504847	5305	4054	18175	8298	4251	5625	149
				Share	14.45%	17.14%	15.38%	12.00%	13.29%	11.04%	11.15%	1.55%
Transport	TNR	Non-road transport	38.88	26.99	9370	50.76	85.81	255.91	95.82	71.93	88.17	1.56
	TRO	Road transport	3003.19	2580.56	723770	7861.56	4659.21	13859.88	5286.13	3626.75	4947.00	726.97
	Sector			*Total*	733139	7912	4745	14116	5382	3699	5035	729
				Share	20.98%	25.56%	18.00%	9.32%	8.62%	9.60%	9.98%	7.60%

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QRAFT sector group [19] CO2eq (kt) [20] (2021)	EDGAR sector		EU regions (NUTS 2)			TRANSFORMER TSL regions						
			Mean	Median	SUM	Emilia Romagna	Lower Silesia	Ruhr Area (NUTS 2) [21]				Western Macedonia
								Sum	*DUESS*	*MUENST*	*ARNSB*	
Waste	SWD_ INC [23]	Solid waste disposal (incineration)	71.33	25.06	17192	210.60	55.35	420.41	197.58	95.51	127.32	0.30
	SWD_ LDF	Solid waste disposal (landfills)	383.05	203.75	92314	1454.50	439.37	1795.86	273.10	661.97	860.78	366.39
	WWT	Waste water treatment	248.80	140.48	59961	256.91	249.00	899.34	542.80	195.33	161.21	14.13
	Sector	*Total*			169467	1922	744	3116	1013	953	1149	381
		Share			4.85%	6.21%	2.82%	2.06%	1.62%	2.47%	2.28%	3.97%
			All sectors	Total	3494216	30954	26360	151412	62425	38516	50471	9582

[23] In deviation from the “CHE: CO2 Human Emissions Project” not assigned to “Energy” but to WASTE (in accordance with OECD methodology).

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Table 14: QRAFT sector group (combination) and economic sectors (NACE). Data source: EDGAR (CO_{2eq}) and EUROSTAT (GVA). Source: own compilation.

QRAFT sector group (combination) **and economic sectors (NACE)** [24]			**EU regions (NUTS 2)**			**TRANSFORMER TSL regions**						
			Mean	**Median**	**SUM**	**Emilia Romagna**	**Lower Silesia**	Ruhr Area (NUTS 2): **Sum**	*DUESS*	*MUENST*	*ARNSB*	**Western Macedonia**
GVA (mio. EUR)	**Agriculture** [NACE A]	2010	749	480	180501	2893	462	1912	621	939	352	219
		2020	917	607	220979	3426	510	2539	916	1092	531	315
		Development (2010=100%)			122%	118%	111%	133%	147%	116%	151%	143%
	Energy & waste [NACE B,D,E]	2010	1437	1023	346310	2801	2060	17135	9980	3135	4020	1678
		2020	1642	1108	395684	3420	2606	17172	8801	3641	4730	911
		Development (2010=100%)			114%	122%	127%	100%	88%	116%	118%	54%
	Manufacturing [NACE C]	2010	6618	4232	1595001	27918	7562	67210	29538	13284	24388	186
		2020	8222	5281	1981616	34325	9951	70331	29174	15314	25843	171
		Development (2010=100%)			124%	123%	132%	105%	99%	115%	106%	92%
CEI ($CO2_{eq}$/GVA) (kg/EUR)	**Agriculture** [QRAFT sector / NACE A]	2010	2,2	2,3		1,1	3,3		1,8	3,0	3,3	2,2
		2020	1,8	1,7		1,0	3,1		1,1	2,4	2,0	1,4
		Development (2010=100%)	81,20%	75,55%		87,11%	94,56%		61,85%	80,81%	61,10%	61,64%
	Energy & waste [QRAFT sector/ NACE B,D,E]	2010	4,8	3,8		3,9	9,2		3,6	6,3	7,4	18,1
		2020	2,9	2,7		2,7	4,7		2,8	5,1	5,0	9,0
		Development (2010=100%)	60,75%	69,94%		68,54%	51,74%		78,80%	80,93%	68,43%	49,79%
	Manufacturing [QRAFT sector/ NACE C]	2010	0,4	0,4		0,2	0,3		0,7	0,6	0,5	1,4
		2020	0,3	0,3		0,1	0,3		0,6	0,4	0,4	1,2
		Development (2010=100%)	69,07%	74,57%		60,15%	80,27%		88,01%	78,54%	84,67%	89,66%

[24] QRAFT sector group based on OECD methodology (OECD 2022) and economic sectors according to NACE classification. Note, that the economic sectors and the QRAFT sectors are not exactly the same (see Chapter 3)

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4.2 Assessing the transition potentials of EU regions in context of transition needs

As mentioned above, assessing the transition potentials of a region in the context of transition needs is a highly complex endeavour. Whereas the first part of the QRAFT helped to identify the transition need of a region and the most important topic, the potential assessment is supposed to be a first step in assessing the potential of transforming the region with the TSL approach. The statistical data (including the associated Excel-file) and cartographic illustration (maps) contained in this deliverable D2.2 are the main results of this quantitative mapping, allowing interested parties and especially TSL follower regions to conduct a first quantitative assessment of their region. To show the usefulness of this approach, we briefly portray two of our TSL regions to show possible ways of interpretation of the QRAFT assessment. We chose the Ruhr Area and Western Macedonia as they represent from our quantitative perspective the two most different regions within the TRANSFORMER project in terms of their transition needs and potentials.

As shown above, regarding becoming climate neutral, the Ruhr Area has the most important transition need in the energy sector and in manufacturing (especially with regard to iron and steel production). And the transition potential analysis shows that the Ruhr Area has very good conditions for tackling this challenge by implementing the TSL approach: the region shows in all CIs comparatively high scores (see Table 15). It has a very high level of *competitiveness* (RCI, see Figure 11) and is characterised as a "*strong innovator*" (RIS, see Figure 12). It also has in comparison to the other TSL regions the highest scores with regard to "*Government performance*" (EQI, see Figure 13) and "*social progress*" (SPI, see Figure 14) thus showing a comparatively high potential for implementing inclusive governance arrangements which can be regarded as a prerequisite for co-creation. However, in this regard we have to emphasize – again – that assessing the governance arrangements of a region with a quantitative methodology has limitations. For adequately assessing this complex issue, quantitative and qualitative methods have to be combined (see Chapter 2 & 3).

However, the environmental indicator *land cover and land use* (see Figure 15) and the *RE potential* (Figure 16 and Figure 17) clearly show that the Ruhr Area needs to collaborate with other regions to tackle the challenge of transforming its energy and industrial system. In other words, the Ruhr area has very good conditions for developing innovative hydrogen technologies and solutions for sustainable industrial processes, however, green hydrogen and renewable energy to become climate neutral needs to be imported to a large degree from other regions (Ministry of Economic Affairs, Innovation, Digitilization and Energy of the State of North-Rine Westphalia, 2020; Wuppertal Institut, 2020).

In **Western Macedonia**, we have an example of a region, which can profit substantially from the TSL approach. Western Macedonia is one of the regions with the highest GHG emissions per capita at the European level. We have discussed that these high levels of GHG emissions are especially due to the region's role as an energy provider for the whole country of Greece (through electricity generation with lignite). In this regard, the *land cover and land use* (see Figure 15) and the *RE potential* (see Figure 16 and Figure 17) clearly show, that Western Macedonia has a very good potential for transforming its energy sector which could also provide the possibility for producing green hydrogen and ammonia for other EU regions with a high energy demand and low RE potential (e.g., the Ruhr Area).

At the same time, the region scores especially low regarding all CI in the transition potential analysis, regarding government performance (EQI), competitiveness (RCI), innovation (RIS) as well as social progress (SPI). In all four CI, which are part of the QRAFT methodology, Western Macedonia shows scores below EU average, and also scores below the other TRANSFORMER regions (see Table 15). With this combination of a high-priority transition need and especially low internal potential, Western Macedonia is a prime candidate for applying the TSL approach, as we have argued in Chapter 2.2.4. We understand the TSL approach to be especially adapted to strengthen the transition readiness of a region in order to address especially tough challenges. The TSL approach fosters through co-creative methods the development of innovative solutions specifically adapted to a region's transition needs strengthening, thereby, the innovation and transition capacity of a region at the same time as making a region fit for the climate-neutral future through the decarbonisation of its economy.

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4.3 Compilation of data and maps needed for assessing the transition potentials of EU regions in context of transition needs

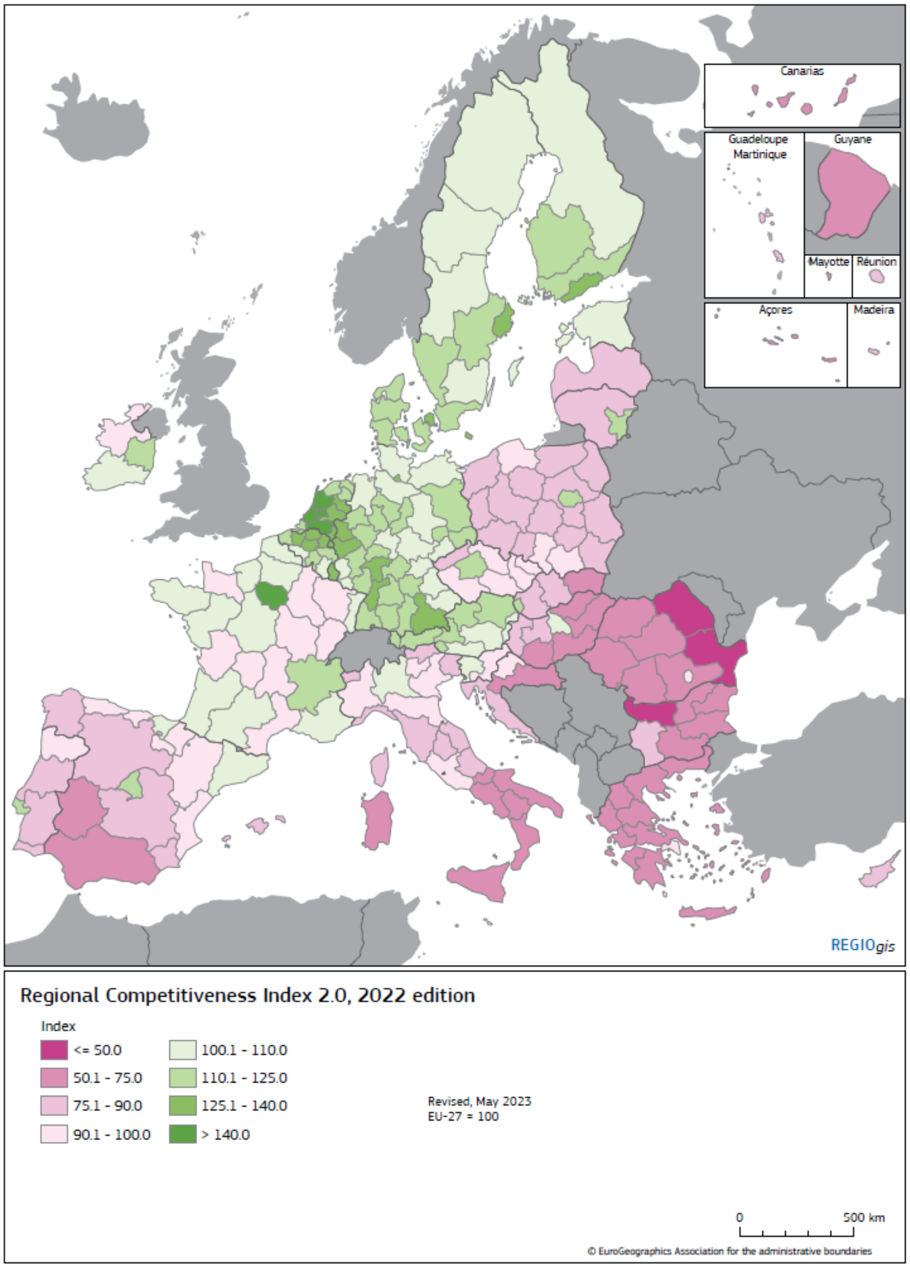

Figure 11: Regional Competitiveness Index 2.0, 2022 edition. Source: (Dijkstra et al., 2023).

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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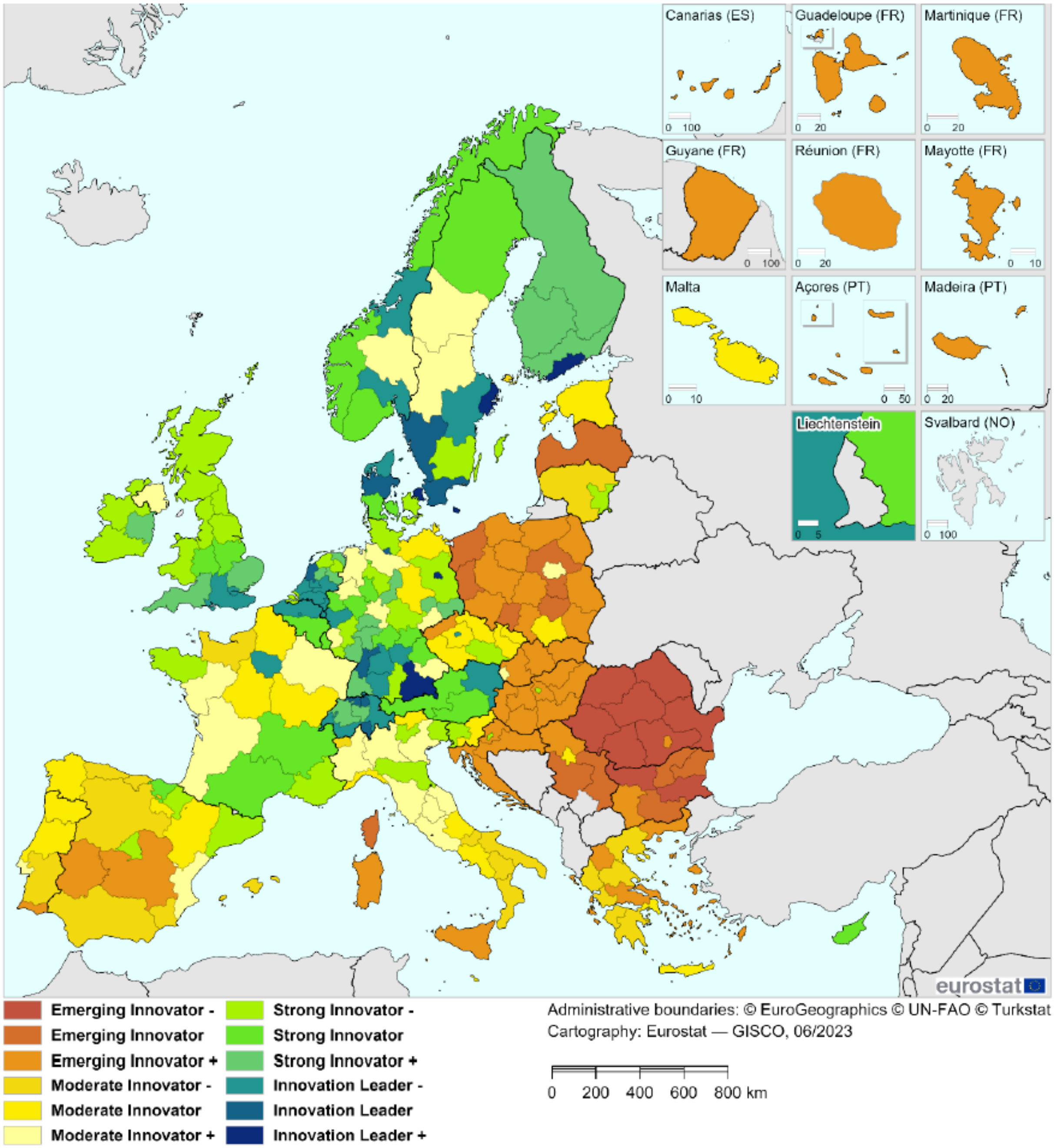

Figure 12: Regional Innovation Scoreboard 2023. Source: (European Commission, 2023).

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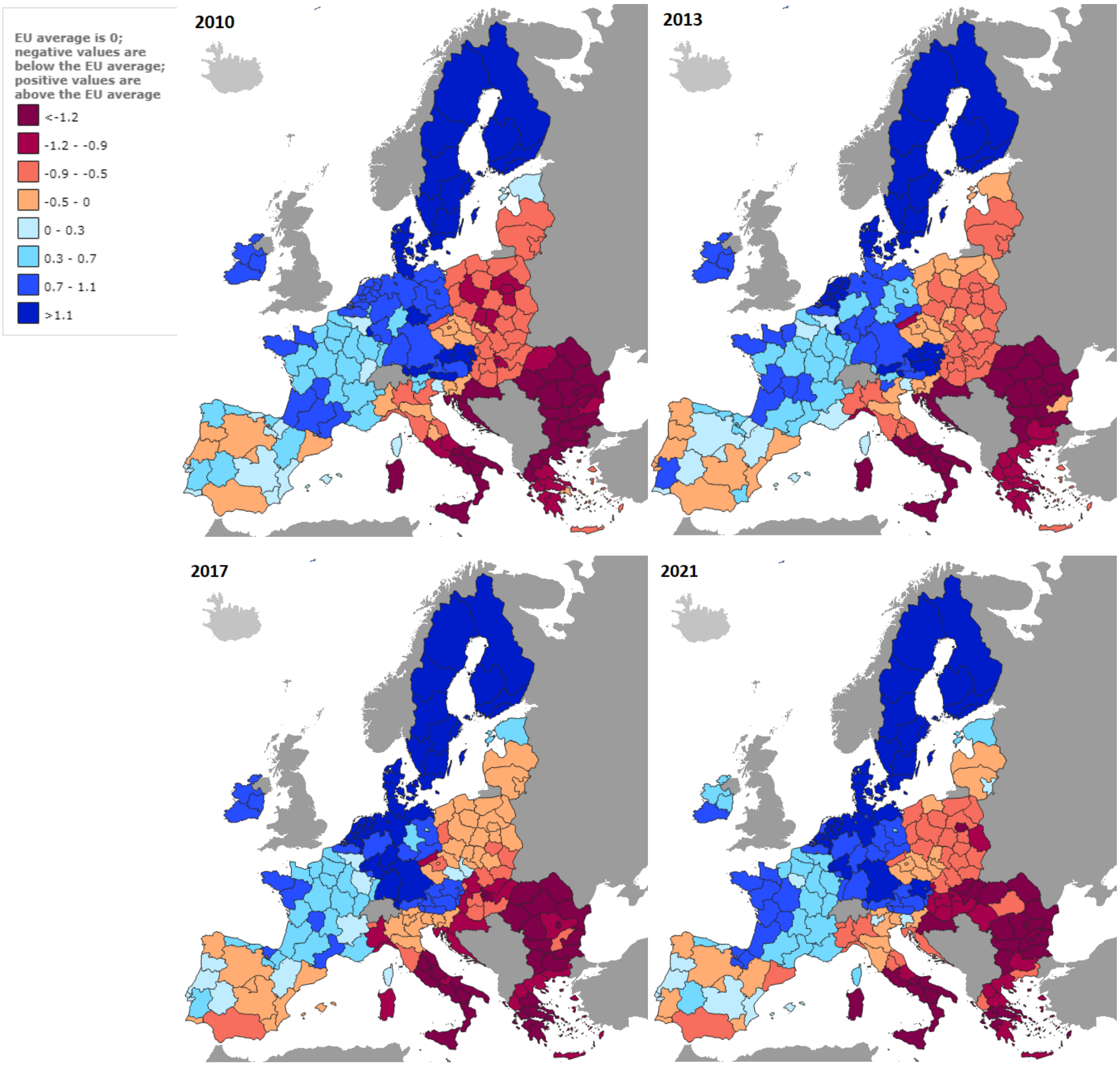

Figure 13: European Quality of Government Index (EQI) in 2010, 2013, 2017, 2021.

Source: https://ec.europa.eu/regional_policy/en/newsroom/news/2022/03/29-03-2022-which-european-regions-have-the-highest-quality-of-government

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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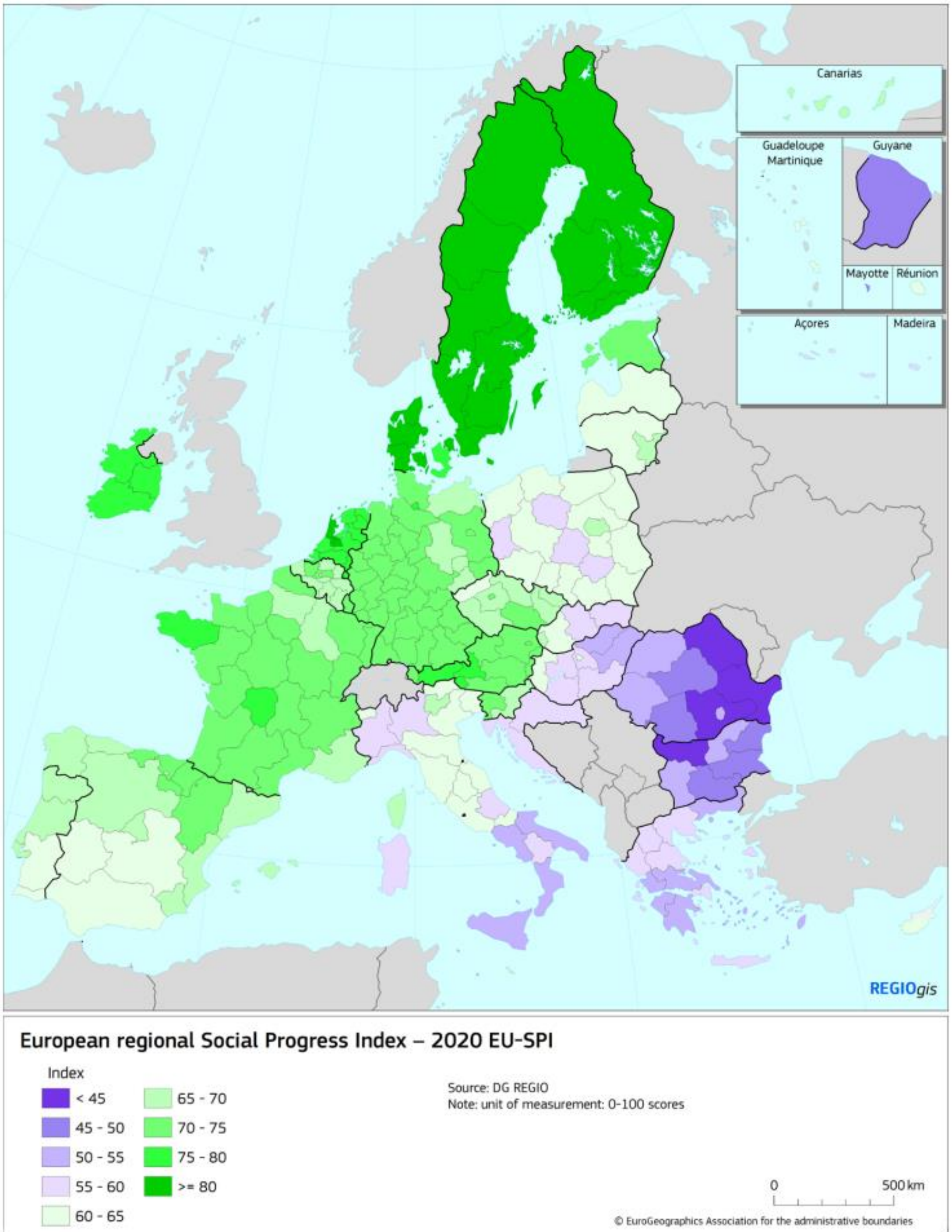

Figure 14: European regional Social Progress Index 2020. Source: (Annoni & Bolsi, 2020).

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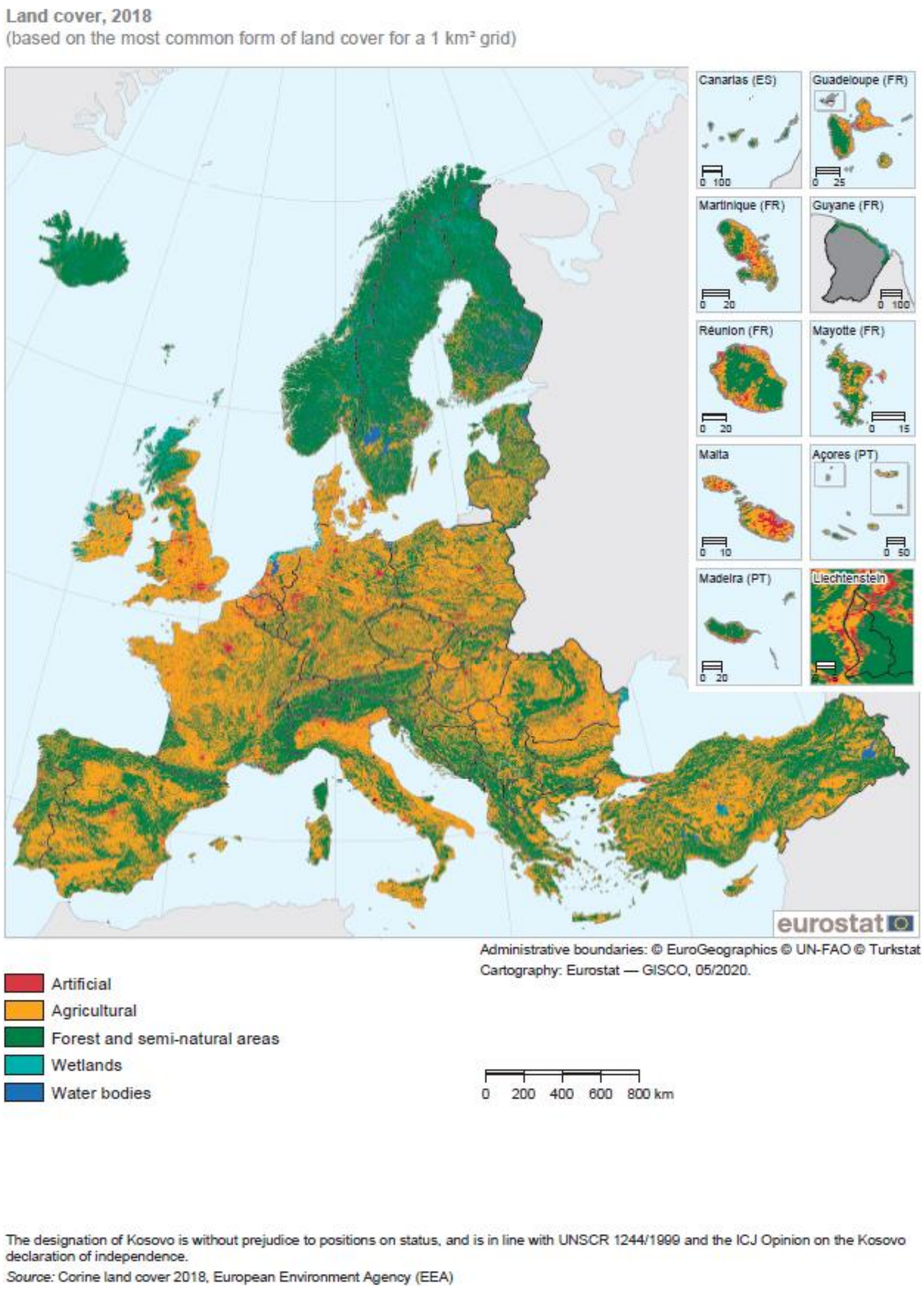

Figure 15: Land cover 2018. Source: Corine land cover 2018, European Environment Agency (EEA). Map retrieved from: (EUROSTAT, 2020).

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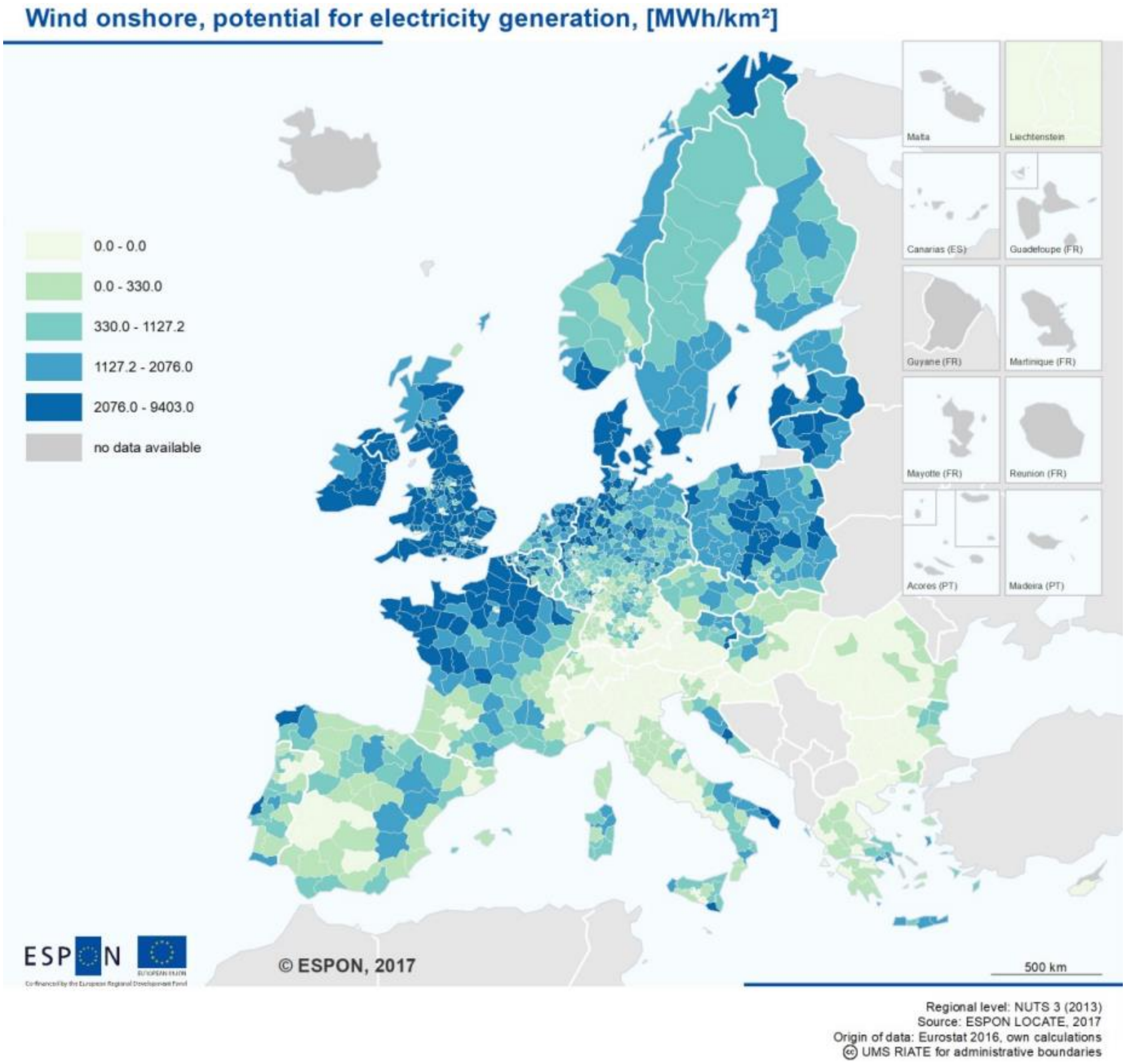

Figure 16: Wind onshore, potential for electricity generation. Source: (Schremmer et al., 2018).

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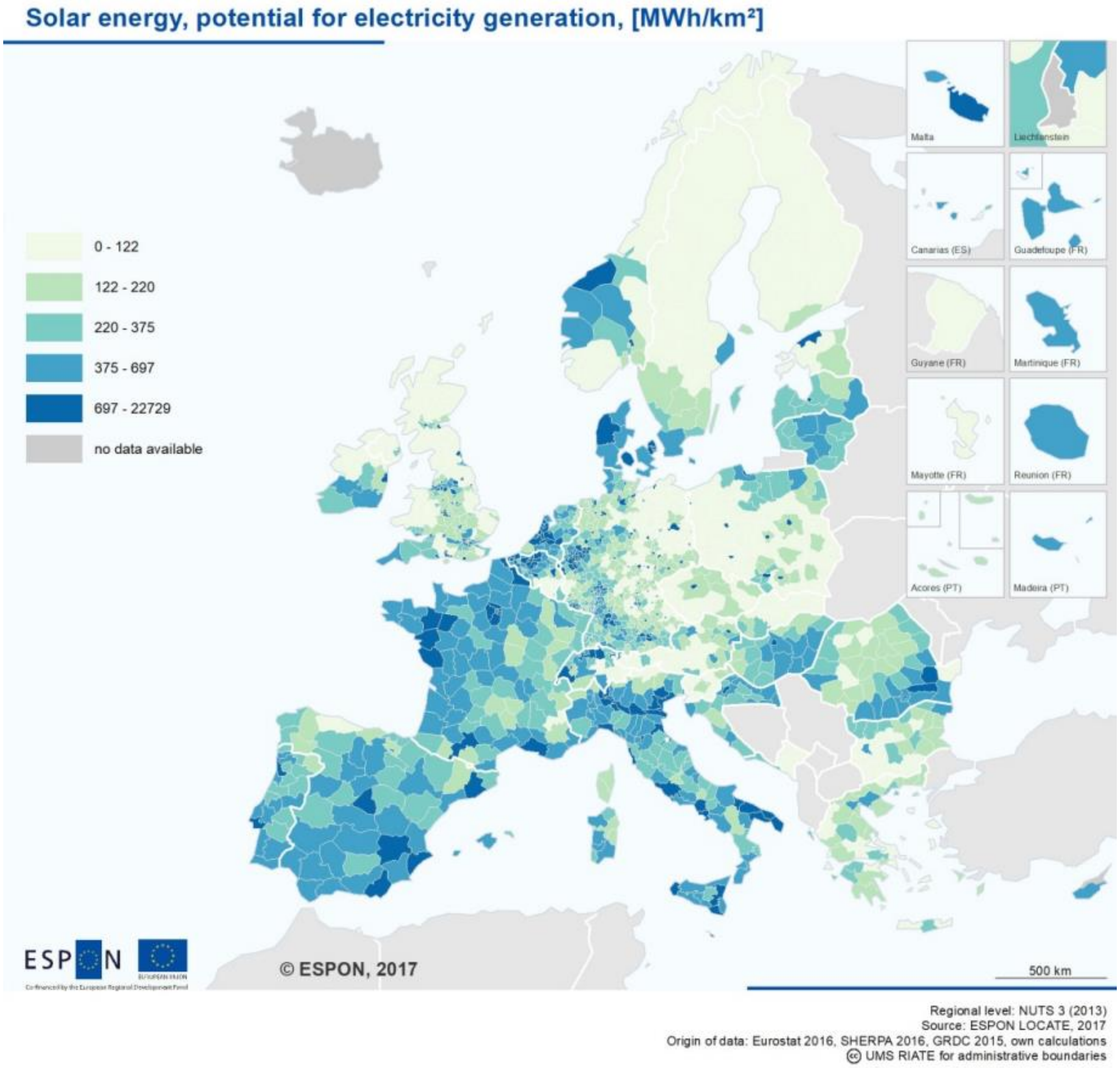

Figure 17: Solar energy, potential for electricity generation. Source: (Schremmer et al., 2018).

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Table 15: Selected composite indices for the EU and the TRANSFORMER TSL regions. Source: own compilation based on data from the CI (sources below the table). For comparison of regions: read per row (red = low, green = high; higher score means better performance).

Composite Index	Topic		EU regions (NUTS 2)				TRANSFORMER TSL regions						
							Emilia-Romagna	Lower Silesia	Ruhr Area (NUTS 2)				Western Macedonia
		Year	Min.	Max.	Average	Median			Sum	DUESS	MUENST	ARNSB	
EQI (n=231)	**Government performance**	2021	-2,3	2,2	0,0	0,2	-0,5	-0,9	-	0,5	1,2	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**	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 7). Source: (Charron et al., 2022). For references also see Chapter: Data sources.

RCI: EU Regional Competitiveness Index 2.0 (for explanation see: Table 5). Source: (Dijkstra et al., 2023). For references also see Chapter: Data sources.

RIS: Regional Innovation Scoreboard 2023 (for explanation see: Table 6). Source: (European Commission, 2023). For references also see Chapter: Data sources.

SPI: European Social Progress Index 2020 (for explanation see: Table 8). Source: (Annoni & Bolsi, 2020). For references also see Chapter: Data sources.

5 Conclusion

For this deliverable, we have developed QRAFT as a quantitative methodology to assess the transition needs and potentials of the European NUTS 2 regions. We apply the QRAFT methodology to all NUTS 2 regions within the territory of the EU (in the form of an Excel file, which is part of this deliverable). QRAFT is especially designed to support regions interested in applying the TSL approach by identifying from the very beginning of the TSL process topics of interest and challenges for a transition to climate neutrality. We have demonstrated how the QRAFT methodology is useful for this through an exemplary interpretation of the QRAFT applied to the TRANSFORMER TSL regions.

As discussed at length throughout this deliverable, **QRAFT has limitations**, especially regarding a conclusive assessment of the transition *potentials* of regions (see Chapter 3). Here, QRAFT serves as a substantial first step, however, we believe it to be of a high priority to complement the information gathered through QRAFT with a qualitative and context-sensitive methodology (this methodology is currently being developed in deliverable D5.1). Besides these limitations, the QRAFT methodology has proven useful specially to get **a broad data-driven understanding of region's transition needs and potentials**, particularly for people not familiar with a region. This data-driven understanding of a region then can be used within the TSL process to discuss and define the region's vision, scenarios, and potential pilot use cases for accelerating the pathway to the region's climate neutrality. It is also very useful as a tool to critically reassess the already chosen topics of a region.

An additional very important way of using QRAFT is to **compare regions** and thus gain multiple possible insights. Assessing the EU regions in a comparative way is useful to see where a particular region stands and if the process of becoming climate neutral is in comparison to other regions going well. In this regard, the analysis shows the huge disparities between the regions, thus highlighting that it is not only important to look at the national (NUTS 0) and the sub-national level (NUTS 1) but to have a more specific regional (NUTS 2) and preferably even smaller-scale analysis (NUTS 3).

QRAFT also helps to identify regions, which face similar or complementary challenges and therefore might be beneficial partners in the transition process. The – through QRAFT made possible – regional comparisons can also help to identify possible fields of *cooperation between regions*. For instance, regions with a high demand for energy currently satisfied through energy produced based on fossil fuels and low potential could cooperate with regions with a high potential for sustainable energy production close by.

The QRAFT methodology developed in this deliverable can be used as it is as a standalone exercise, however, it is an integral part of TRANSFORMER and will be **further used as and refined** within different activities of the TRANSFORMER project. The indicators selected for QRAFT so far will be discussed with all members of the Project Consortium and if necessary complemented and refined. This will be done by discussing and weighing their importance using the Delphi method (Bailey et al., 2012). Based upon this re-evaluation and complementation of the used indicators, QRAFT will be discussed with stakeholders of TSL follower regions in the TSL User Forum. Additionally, we will test the usability for possible follower regions (which was a high-priority goal in the development of QRAFT) within the User Forum. Moreover, we see substantial potential for refining the QRAFT methodology by including the NUTS 3 level. The

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NUTS 3 level can especially shed light on topics occurring below the NUTS 2 level otherwise not visible. Examples are social disparities or unequal distribution of GHG emissions. These inner-NUTS 2 differences can substantially inform the discussion for choosing a region's vision for transition within the TSL process. Including the NUTS 3 level will also allow an assessment of regions, like the RUHR area, which are not a NUTS 2 political-administrative unit but which have a clear regional identity through sharing a common history and common economic and social structure. The refined and further developed version of the QRAFT will take the form of a working paper, which will be submitted in M24 (see task 2.3/ deliverable D2.4). The QRAFT methodology will also be included in the case studies, which are part of WP2. Additionally, this deliverable D2.2 will feed into the TRANSFORMER Knowledge hub roadmap and the assessment frameworks.

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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 7.0, (2022) 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: 31.07.2023)

IEA-EDGAR CO2, a component of the EDGAR (Emissions Database for Global Atmospheric Research) Community GHG database version 7.0 (2022) including or based on data from IEA (2021) Greenhouse Gas Emissions from Energy, www.iea.org/data-and-statistics, as modified by the Joint Research Centre.

Datasets used in deliverable D2.2:

- Greenhouse Gas Emissions at sub-national level. Annual time series (1990-2021) of GHG emissions at NUTS2 (regional) level. **EDGAR GHG AR4 NUTS2 by country (1990-2021)**. Data available at: https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/EDGAR/datasets/v70_FT2021_GHG_NUTS2/EDGAR_GHG_AR4_NUTS2_by_country_1990_2021.zip (last access: 31.07.2023)
- Greenhouse Gas Emissions at sub-national level. Annual time series (1990-2021) of GHG emissions at NUTS2 (regional) level. **EDGAR GHG AR4 NUTS2 by country and sector (1990-2021).** Data available at: https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/EDGAR/datasets/v70_FT2021_GHG_NUTS2/EDGAR_GHG_NUTS2_by_sector_1990_2021.zip (last access: 31.07.2023)

EUROSTAT – Statistical office of the European Union

Datasets used in deliverable D2.2:

- **Area by NUTS 3 region**. Online data code: REG_AREA3. Last update: 19/06/2023 23:00
- **Population** change - Demographic balance and crude rates at regional level (NUTS 3). Online data code: DEMO_R_GIND3. Last update: 14/04/2023 23:00
- **Gross domestic product (GDP)** at current market prices by NUTS 2 regions. Online data code: NAMA_10R_2GDP. Last update: 21/02/2023 23:00
- **Gross value added** at basic prices by NUTS 3 regions. Online data code: NAMA_10R_3GVA. Last update: 21/02/2023 23:00

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

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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)

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

Datasets used in deliverable D2.2:

- 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)

Data from composite indices used in deliverable D2.2.

- **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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