



Enabling Positive Tipping Points towards clean-energy transitions in Coal and Carbon Intensive Regions

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## **D5.1: Literature review advancing the state of the art on the characterisation of social-ecological regional energy systems**

Work Package: WP5

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## Preface

The TIPPING+ project seeks to understand why *Coal and Carbon-Intensive Regions* (CCIRs) in particular moments in time, adopt transformative pathways to decarbonize their energy systems. In this regard, the project aims to provide a theoretically grounded and empirically-based understanding of the conditions, trends, and processes which enable -or impede- such transformations. A social-ecological system such as a regional energy system may go through a process that brings the entire system into another structural configuration or state (e.g., by taking a cleaner development pathway). This happens at a certain point in time, which is defined as a Social-Ecological Tipping Point (SETP). Tipping points may be intentionally triggered depending on collective visions of key stakeholders, transformative capacities, and governing strategies of a region (David Tàbara et al. 2018)

Tipping point interventions lead to qualitative changes in socio-ecological systems. Traditionally, tipping points have been used to indicate a critical threshold which once crossed would lead to fundamental qualitative changes in the configuration and the processes of a given system, e.g., by moving towards a different basin of attraction. Here we refer to 'Social-Ecological Tipping Points' (SETPs) as an integrative concept indicating those critical moments in which seemingly small events, individual actions, or policy interventions can cumulatively have large, systemic, structural qualitative effects.

Tipping point interventions have effects in multiple socio-ecological systems. SETPs constitute hybrid thresholds derived from the combination of social actions which are necessarily embedded in a milieu of biophysical interactions and which occur in a

*given moment in time.* In particular, SETPs trigger many kinds of structural changes which could affect several kinds of systems (e.g., economic, informational, social, technological, or political) although it is unlikely that they will affect all kinds of systems or several in the same way or time scales. Moreover, SETPs are difficult or impossible to reverse, so once crossed they condition the processes of humans and other life-support systems. Furthermore, SETPs' effects are often unexpected and unpredictable and so their deliberate outcomes can only be enabled by focusing on building *transformative capacities for their emergence*, and only to a limited extent.

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## Executive Summary

This is the first Deliverable (D5.1) of the Work Package 5 (WP5) whose aim is to improve the understanding of the concept(s) of a region to be applied in regional socio-ecological energy systems. This review gathered insights from four literature reviews on Socio-Ecological Tipping Points (provided by our Tipping Plus partners from Work Packages 1 to 4: Human Geography, Environmental and Social Psychology, Policy and governance, and Economics); and from a systematic review on sustainability transitions research including sustainability studies, regional studies, and innovation studies. The Deliverable represents a "Report with literature review advancing the state of the art on the characterisation of social-ecological regional energy systems" (shortly called "WP5 Literature Report").

Approaching socio-ecological energy systems at the regional level can make climate change mitigation efforts more cohesive across scales. Urban studies recognize that regions tend to react more efficiently to global changes compared to nations. Yet, most energy transition approaches focus on the global, national, community, or single project level. On the one hand, community energy transition projects can be hardly upscaled. On the other hand, national approaches often fail to meet the needs and possibilities for transformation at the local level as well as to meet international agreements such as the EU climate change goals (Amundsen et al. 2018). Thus an in-between approach is needed to bridge climate change efforts across scales: a regional approach.

This report is structured in four chapters. The Introduction chapter formulates the need to approach socio-ecological energy transitions from a regional level. Method and justification present the various sources of knowledge that this report considered as well as their analysis. The Results present a model to conceptualize a region. The model consists of three scales that categorize the dimensions of regions: 1) components, 2) processes and interrelatedness, and 3) concepts of a region. Finally, the Discussion elaborates on the state of the art, research gaps, and relevance of the findings for the Tipping Plus project.

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# 1 Introduction

A nuanced understanding of low-carbon transitions requires a regional approach. There is a mismatch between different climate mitigation pathways followed by (inter)national administrative institutes, nations, and individuals. Typically, the energy sector is assessed at the national level with macro-models, whereas local studies focus on the governance of transitions. But we lack an in-between focus that considers the dimensions of transitions from different disciplines (Balta-Ozkan, Watson, and Mocca 2015). The national level often offers a limited understanding of local needs and possibilities for transformation, and also of individuals' preferences and their response to socio-structural change (Sarrica and Brondi 2020). Furthermore, despite national policies, carbon-dependent economies particularly struggle to meet EU climate change goals (Amundsen et al. 2018). To make climate mitigation efforts across scales more cohesive, decision-makers need to consider the local perspectives at the 'regional level'.

We need a more systematic understanding of regions, their strategies, policies, visions, and how these can be implemented inclusively. Seeing transitions from a regional level may help identify the roles of local actors. Larger spatial scales (e.g. countries, metropolises, etc) have a higher risk of overlooking local needs. So, working with smaller scales reduces uncertainty and potential to failure costs (Rodriguez-Pose 2008). By considering these dimensions, one may ease the integration of local perspectives within regions into climate policies. This could ultimately lead us towards more cohesive mitigation actions across scales (David Tàbara et al. 2018; Köhler et al. 2019; Hoppe and de Vries 2018).

To identify potential SETPs in Coal- and Carbon-Intensive Regions (CCIRs), we need to understand what we mean by region in this research context. Typically, coal and fossil fuels are defined by their technological sectors, and their definition tends to overlook the system complexities (Labanca 2017). The starting point of this review was the IPCC's definition of the industry sector and the corresponding technologies and systems for human development (Fischedick et al. 2014). Thus, a CCIR may be formed by (i) upstream energy extractive industry regions (i.e., coal and fossil fuels extraction areas), and (ii) downstream carbon-dependent regions that include energy-intensive sectors and services (e.g., transport, construction, etc.). This sectorial definition of a region does not necessarily agree with the administrative boundaries nor with the locals' perception of a region. This may raise confusion when discussing a region's spatial scale. Thus, it is necessary to elucidate what a regional level means.

In particular, this review attempted to achieve the following **goals**:

i. **Identify the components** and **dynamics** from a variety of disciplinary perspectives that conceptualize a *region* in the field of sustainability transitions and transformations.

ii. **Summarize** the different understanding of a *region* from a variety of disciplinary perspectives with relevance for social-ecological transformations

iii. Provide summary guidelines to help **characterize regions** for the 20+ case study teams in the Tipping+ project.

## 2 Method and justification

To conceptualize the term of a region, this review gathered definitions and empirical insights from a variety of social science disciplines focused on Socio-Ecological Tipping Points, and from a search on sustainability transitions research. The insights from social sciences were provided by our Tipping Plus partners from Work Packages 1 to 4. Whereas the insights from sustainability transition research fields were obtained with a systematic literature review on regions and sustainability transitions. Following, we describe the method we conducted for each strand of literature.

### 2.1 Inputs from the Tipping Plus Work Packages 1 to 4 on characterizing regions

In this review, we considered inputs from the Tipping Plus Work Packages 1 to 4. Prior to this review, each of these Work Packages conducted a literature review to describe Socio-Ecological Tipping Points from their discipline:

- [Work Package 1: Human Geography: demographic trends and challenges in gender, migration, and youth.](#)
- [Work Package 2: Environmental and Social Psychology and Anthropology.](#)
- [Work Package 3: Policy and governance.](#)
- [Work Package 4: \(macro\)Economics.](#)

We discussed the learnings from each of these disciplines that help understand the concept of a region. After discussing such learnings with the Work Package Leaders we integrated such multi-disciplinary knowledge with the findings from our systematic search on regions.

### 2.2 Literature review on regions and sustainability transitions

We conducted a systematic literature review on sustainability transitions and regions. In this review, we considered the following keywords:

Sustainability transitions	Regional studies	Innovation studies
<ul style="list-style-type: none"> <li>•Socio-ecological tipping point</li> <li>•Low-carbon pathways</li> <li>•Coal-intensive region</li> <li>•Carbon-intensive region</li> </ul>	<ul style="list-style-type: none"> <li>•Regional energy transition</li> <li>•Regional governance</li> <li>•Regional industry</li> </ul>	<ul style="list-style-type: none"> <li>•Regional Innovation Systems</li> <li>•Regional innovation</li> <li>•Social innovation</li> </ul>

Each of these research fields was selected because they cover every piece of our first objective: to conceptualize a region in the arena of sustainability transitions and transformations. Thus, we selected literature from three main sets of literature: sustainability transitions, regional studies, and innovation studies.

The first set was focused on sustainability transitions and transformations. This set covers socio-ecological tipping points literature because the ultimate application of this review is to identify such tipping points in different regions across the world (see Preface section). Low-carbon pathways are keywords that are often used when referring to sustainability transitions or transformations. The term coal-intensive region was included because this is a common term to describe a region with significant dependence on coal extraction economies, which is the case for several case studies in the Tipping Plus project. Also in the first literature set, we included the term carbon-intensive region because there are some regions that though they do not directly extract fossil fuels, their secondary activities do represent a high consumption of them (e.g. in the transport sector). However, the term carbon-intensive is less known than coal-intensive at the moment. The term 'sustainability transformations' was not used as a keyword because it brings a massive and broad bunch of literature and our literature sets already covered sustainability studies. This first set would help us see how the concept of a region is applied in carbon-intensive contexts seeking sustainability transitions.

The second set was focused on regional studies. This set was meant to explore empirical evidence on how the region concept is applied in energy transitions, governance, and industry-related studies. Often, a region is framed with administrative boundaries for governance purposes; therefore, we considered that regional governance would help us grasp the traditional concept of a region. The keywords regional industry would let us understand a region from a sectorial (e.g. energy sector) perspective.

The third set of literature explored the emerging field of innovation studies. Regional Innovation Systems is a concept that helps describe how industrial sectors in a region are influenced by knowledge coming from various institutions, organizations, and the public. Thus, Regional Innovation Systems have a regional approach to sectorial change (e.g. transitions of the energy sector), which can help understand the dynamics of change in a region. We also included *regional innovation* and *social innovation* because they address sectorial transitions or transformations at a regional and local scale, respectively. In this way, we would explore the local level, which is sometimes used to describe a regional scale.

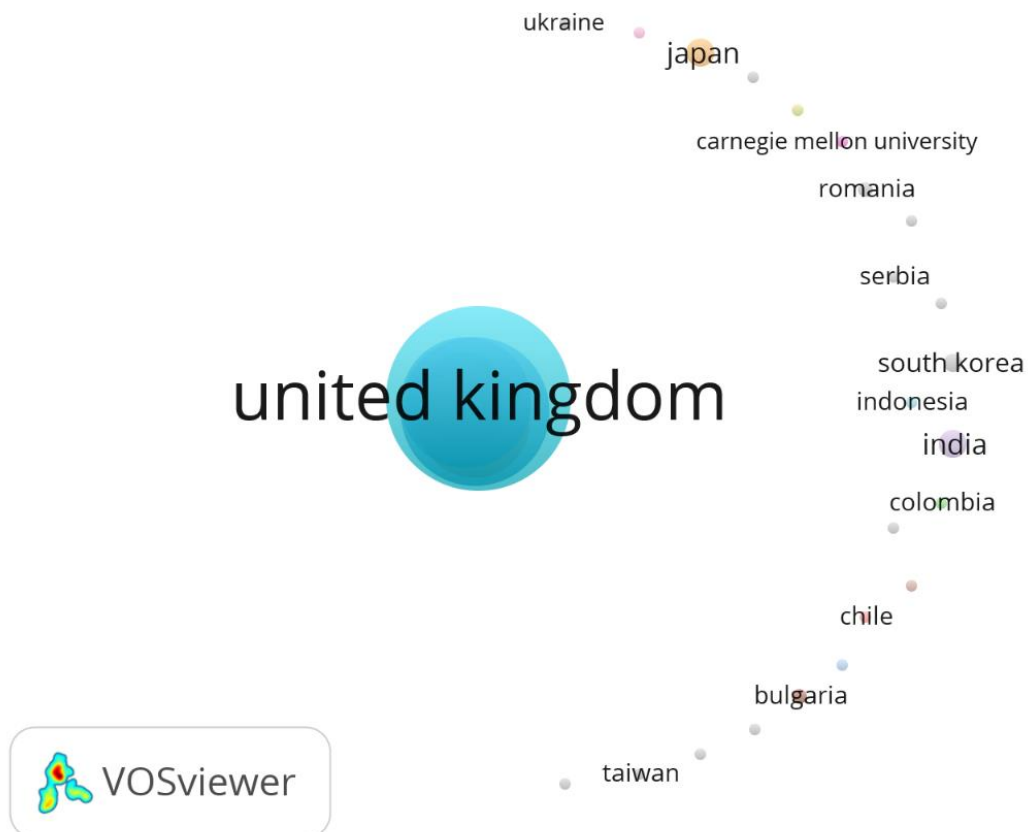
## 2.2.1 Quantitative analysis: data collection for the literature review on regions and sustainability transitions

We run the first survey with Scopus and Web of Science databases and finally were inclined to Scopus because it contained the largest number of articles related to Socio-Ecological Tipping Points in the field of sustainability transitions. Web of Science, on the other hand, presented more publications from natural sciences. The initial list of keywords and keyword combinations is presented in Table 1. Out of the first survey, 1.1+ million articles were found, which were narrowed down to 400+ papers by combining the set of disciplines above mentioned with “region” and “energy transition”. Employing VOSViewer, to conduct a network analysis of these 400+ publications, we found out that these publications were conducted in Europe mainly, followed by China, the United States of America, Canada, and Australia. Nonetheless, there were a few publications from other countries in Latin America, Asia, and Africa, but with seemingly no connection with European and North-American publications (see Figure 1). Then, by selecting the 10 most cited papers, the list was shrunk to 100+ papers. The list of 100+ publications (can be found on the Mendeley group [“Tipping+ review on regions”](#) or [Surf](#)) was then used as the starting point for the review.

**Table 1. The initial list of keywords for literature surveys.**

Keyword	Web of science no. articles	Scopus articles no.
“Tipping point”	2300	36627
“Socio-ecological tipping point”	1	419
“Regional innovation”	2600	19768
“regional governance”	400	6789
Region AND “carbon-intensive”	0	498
“Regional energy transition”	2	87032

"Low-carbon pathways"	24	101
"Coal-intensive region" OR "carbon-intensive region"	0	45
"Carbon-intensive region" OR "regional industry"	600	516
"Social innovation"	3000	797557
"Regional Innovation Systems"	146	197072
Total	9073	1146424



**Figure 1. Countries of publications from the set of 400+ publications using the software VOSviewer.**

**Table 2. Fifth survey with approximately 100 articles.**

Combination no.	condition	Keyword	Scopus	the most cited
1	ALL KW-energy transition	"Socio-ecological tipping point" AND region OR "Socio-ecological tipping point" AND "energy transition"	21	13
2	ALL/topic KW-innovation	"Regional innovation" AND "region def*" OR "Regional innovation" AND "region concept*" OR "Regional innovation" AND "region understand*" OR TOPIC "Regional innovation" AND "energy transition"	74	20
3	ALL KW-energy transition KW-governance approach (there is also regionalism)	"regional governance" AND "energy transition" AND region OR "regional governance" AND "region def*" OR "regional governance" AND "region concept*" OR "regional governance" AND "region understand*"	100	20
4	ALL KW-region or energy transition did not reduce number	"carbon-intensive" AND region AND "energy transition" OR "carbon-intensive" AND "region def*" OR "carbon-intensive" AND "region concept*" OR "carbon-intensive" AND "region understand*"	53	10
5	ALL Other KW make list to zero	"Regional energy transition"	39	10

6	ALL, No reduction by KW	"Low-carbon pathway" AND region AND "energy transition" OR "Low-carbon pathway" AND "region def*"...	57	10
7	ALL	"Coal-intensive region" OR "carbon-intensive region"	7	7
8	ALL NO KW to reduce	"regional industry" AND "energy transition"	22	10
9	TOPIC/ALL  KW-social innovation	TOPIC "Social innovation" AND "energy transition" OR TOPIC "Social innovation" AND "energy transition" AND region OR ALL "Social innovation" AND "region def*" OR "Social innovation" AND "region concept*" OR "Social innovation" AND "region understand*"	47	20
10	ALL/topic KW-	TOPIC "Regional Innovation Systems" AND "energy transition" OR TOPIC "Regional Innovation Systems" AND "energy transition" AND region OR ( ALL ( "Regional Innovation Systems" AND "region def*" ) OR ALL ( "Regional Innovation Systems" AND "region concept*" ) )	46	19
		TOTAL	466	115 (there are 20 repeated)



**Table 3. The most relevant papers identified in the systematic literature review.**

Authors	Year	Journal	Title
(Balta-Ozkan, Watson, and Mocca 2015)	2015	<i>Energy Policy</i>	"Spatially Uneven Development and Low Carbon Transitions: Insights from Urban and Regional Planning." <a href="https://doi.org/10.1016/j.enpol.2015.05.013">https://doi.org/10.1016/j.enpol.2015.05.013</a>
(Calzada 2015)	2015	<i>Regional Studies, Regional Science</i>	"Benchmarking Future City-Regions beyond Nation-States." <a href="https://doi.org/10.1080/21681376.2015.1046908">https://doi.org/10.1080/21681376.2015.1046908</a>
(Dawley, MacKinnon, and Pollock 2019)	2019	<i>Journal of Economic Geography</i>	"Creating Strategic Couplings in Global Production Networks: Regional Institutions and Lead Firm Investment in the Humber Region, UK." <a href="https://doi.org/10.1093/jeg/lbz004">https://doi.org/10.1093/jeg/lbz004</a>
(De Laurentis, Eames, and Hunt 2017)	2017	<i>Environment and Planning C: Politics and Space</i>	"Retrofitting the Built Environment 'to Save' Energy: Arbed, the Emergence of a Distinctive Sustainability Transition Pathway in Wales." <a href="https://doi.org/10.1177/0263774X16648332">https://doi.org/10.1177/0263774X16648332</a>
(Füg and Ibert 2020)	2020	<i>European Planning Studies</i>	"Assembling Social Innovations in Emergent Professional Communilinks. The Case of Learning Region Policies in Germany." <a href="https://doi.org/10.1080/09654313.2019.1639402">https://doi.org/10.1080/09654313.2019.1639402</a>
(Gui and MacGill 2018)	2018	<i>Energy Research and Social Science</i>	"Typology of Future Clean Energy Communilinks: An Exploratory Structure, Opportunities, and Challenges." <a href="https://doi.org/10.1016/j.erss.2017.10.019">https://doi.org/10.1016/j.erss.2017.10.019</a>
(Harrison and Heley 2015)	2015	<i>Urban Studies</i>	"Governing beyond the Metropolis: Placing the Rural in City-Region Development." <a href="https://doi.org/10.1177/0042098014532853">https://doi.org/10.1177/0042098014532853</a>
(Harrison and Hoyler 2014)	2014	<i>Urban Studies</i>	"Governing the New Metropolis." <a href="https://doi.org/10.1177/0042098013500699">https://doi.org/10.1177/0042098013500699</a>
(Jonas, Goetz, and	2014	<i>Urban</i>	"City-Regionalism as a Politics of Collective Provision: Regional Transport Infrastructure

Bhattacharjee 2014)	.	<i>Studies</i>	in Denver, USA." <a href="https://doi.org/10.1177/0042098013493480">https://doi.org/10.1177/0042098013493480</a>
(Köhler et al. 2019)	2019	<i>Environmental Innovation and Societal Transitions</i>	"An Agenda for Sustainability Transitions Research: State of the Art and Future Directions." <a href="https://doi.org/10.1016/j.eist.2019.01.004">https://doi.org/10.1016/j.eist.2019.01.004</a>
(Lutz, Lang, and von Wehrden 2017)	2017	<i>Sustainability (Switzerland)</i>	"Facilitating Regional Energy Transition Strategies: Toward a Typology of Regions." <a href="https://doi.org/10.3390/su9091560">https://doi.org/10.3390/su9091560</a> .
(Mattes, Huber, and Koehrsen 2015)	2015	<i>Energy Policy</i>	"Energy Transitions in Small-Scale Regions - What We Can Learn from a Regional Innovation Systems Perspective." <a href="https://doi.org/10.1016/j.enpol.2014.12.011">https://doi.org/10.1016/j.enpol.2014.12.011</a>
(Nelles 2013)	2013	<i>International Journal of Urban and Regional Research</i>	"Cooperation and Capacity? Exploring the Sources and Limits of City-Region Governance Partnerships." <a href="https://doi.org/10.1111/j.1468-2427.2012.01112.x">https://doi.org/10.1111/j.1468-2427.2012.01112.x</a>
(Rodriguez-Pose 2008)	2008	<i>European Planning Studies</i>	"The Rise of the 'City-Region' Concept and Its Development Policy Implications." <a href="https://doi.org/10.1080/09654310802315567">https://doi.org/10.1080/09654310802315567</a> .
(Schaffrin and Fohr 2017)	2017	<i>Economic Complexity and Evolution</i>	"The Local Perspective on Energy Transition and Innovation." <a href="https://doi.org/10.1007/978-3-319-43940-2_4">https://doi.org/10.1007/978-3-319-43940-2_4</a>
(Späth and Rohrer 2010)	2010	<i>Research Policy</i>	"'Energy Regions': The Transformative Power of Regional Discourses on Socio-Technical Futures." <a href="https://doi.org/10.1016/j.respol.2010.01.017">https://doi.org/10.1016/j.respol.2010.01.017</a>
(Späth and Rohrer 2012)	2012	<i>European Planning Studies</i>	"Local Demonstrations for Global Transitions-Dynamics across Governance Levels Fostering Socio-Technical Regime Change Towards Sustainability." <a href="https://doi.org/10.1080/09654313.2012.651800">https://doi.org/10.1080/09654313.2012.651800</a>

(Truffer and Coenen 2012a)	2012 .	<i>Regional Studies</i>	“Environmental Innovation and Sustainability Transitions in Regional Studies.” <a href="https://doi.org/10.1080/00343404.2012.646164">https://doi.org/10.1080/00343404.2012.646164</a> .
(Wellbrock, Roep, and Wiskerke 2012)	2012 .	<i>European Countryside</i>	“An Integrated Perspective on Rural Regional Learning.” <a href="https://doi.org/10.2478/v10091-012-0010-y">https://doi.org/10.2478/v10091-012-0010-y</a>

## 2.3 Qualitative analysis of WP1-4 inputs of the review on regions and sustainability transitions

We carried out a qualitative thematic analysis to identify the components and processes that make up a region. As a dataset, we used the four disciplinary (Human Geography, Social Psychology, Policy, and Economics) reviews on Socio-Ecological Tipping Points, and 100+ papers on sustainability transitions, regional studies, and innovation studies. We looked for definitions of *regions*, *networks*, and *systems of reference* in general, as well as for the way regions or systems are applied in the transitions literature. For this thematic analysis, the software NVivo 12 Plus was employed. We started the analysis with the themes enlisted in Table 4. Along the coding process, more themes were added.

**Table 4. The initial themes used to code the 100+ dataset.**

Initial themes
Time scale
Physical geography
Stakeholders
Industrial sector(s)
Institutions and governance
Economy
Formal region
Functional region
Perceptual region

We filtered the 100+ list of papers down to 19 seminal papers that we read thoroughly. For this filtering, we categorized each of the 100+ papers as non-relevant, relevant, or seminal ones. The non-relevant papers were those that mention the word region but do not provide further reflection on it. Seminal papers offered a discussion on the concept of a region (or similar e.g. local) and/or had a regional approach to sustainability transitions. The relevant papers were those in-between non-relevant and seminal ones. An in-depth reading was conducted with the 19 seminal publications. In parallel with the reading, we ran a second and more in-depth coding of these papers using the same NVivo 12 Plus file.

The list of 19 seminal papers from the systematic review was selected for deeper reading (see **Table 3**). The papers that have developed more frameworks or formal descriptions of regions are from the field of Planning, Urban, and Regional studies; these are highlighted in yellow. On the other hand, the sustainability transition publications were reviewed to understand how the concept of a region or system of reference is applied.

The final analysis consisted of re-categorizing the themes. One category covered the various understandings or concepts of a region. A second category enlisted the multiple processes and interrelatedness between entities that are present in a region. The third category covered the basic elements or entities that make part of a region. Thus, the second and third categories help describe each of the concepts (category 1) of a region.

## 3 Results: characterizing regions

The results here presented come from four disciplinary fields and three interdisciplinary fields (see Method and justification). The results coming from the four disciplinary fields (Human Geography, Social Psychology, Policy, and Economics) were discussed with members from each of the four Tipping Plus Work Packages. The results coming from the three interdisciplinary fields (sustainability transitions, regional studies, and innovation studies) were discussed with the supervision team. These results helped identify some major concepts, processes, and components of a region.

### 3.1 General findings from the four disciplinary reviews on SETPs

The inputs from the four disciplinary literature reviews on Socio-Ecological Tipping Points helped identify concepts and processes of regions and examples of how they are applied. Although these reviews were not focused on defining regions, they do refer to regions with different terms and characteristics when analyzing Tipping points.

From Human Geography (Work Package 1), we identified three types of regions as fundamental units of study: **formal, perceptual, and, functional region** (see Analysis: concepts of a region below). A region is generally applied to refer to an area larger than a city that holds common characteristics. In practice, the three types of regions may be present in the same region of study, but by looking at each region type, we can identify the multiple dimensions that make up a region. Furthermore, the review on SETPs from Human Geography introduces the concept of a **landscape super-system** when describing the scale of tipping points. This landscape super-system spreads in space across the local, regional, and global levels. They explain that multiple regions may experience interconnected tipping points due to the connectivity between regions. These connections are present between the environmental and socio-economic systems of regions.

The review by Work Package 2 (Environmental and Social Psychology and Anthropology) focuses on the intra-individual, interpersonal, and inter-group levels as the scales on which tipping points can be interpreted and have an impact. Following this idea, a region is framed as **a multi-level network of stakeholder groups**, including individuals and communities. They describe different processes of change when looking at the individual level, community level, or both. The **processes** that connect individuals and communities are *shared interpretative frames* (e.g. shared representations, values, memories, imaginaries, aspirations), *community resources* (e.g. collective identification, sense of belonging and cohesion, collective efficacy and resilience), *social factors affecting intergroup dynamics* (e.g. perception of justice, deprivation or loss) and the *interpretation and response to the introduction of technological innovations and industrial operations* (e.g. community benefits, sense of place, territorial anchorage).

When referring to the 'system of reference', Work Package 3 (Policy and governance) described the **multi-level governance** that influences regions. A characteristic of the system of reference is that it covers multiple levels of governance: across regional, national, and international. "There are actions at different government levels that are co-dependent and national government level influences regional developments. For example in the German T+ case study, the "green" or sustainability agenda was for a relatively long time not an issue at the regional level, instead, the economic efficiency of coal was a key driver for discussions about its end." (WP3, 2021)

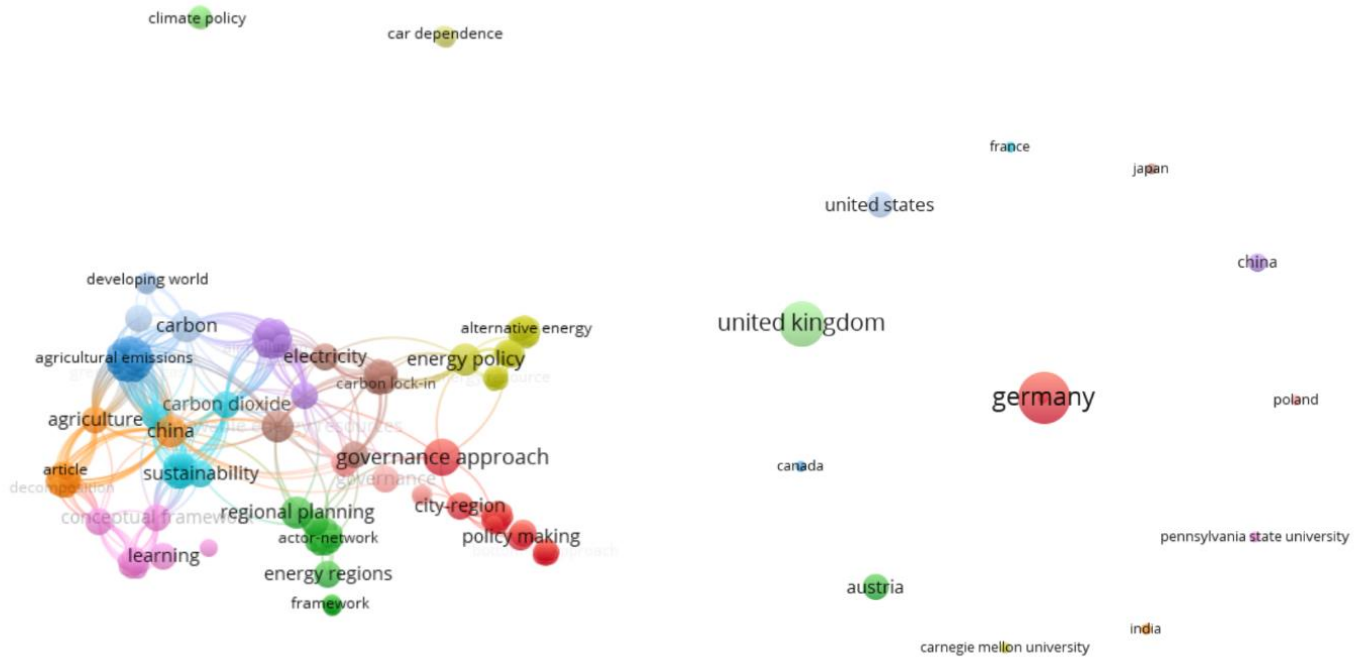
When analyzed from an economic perspective (literature review by Work Package 4), regions tend to be seen as formal regions. The approaches described in the review mainly refer to analyses at the macro-level often framed as national up to a global level. The review also mentions that **within a macroeconomic system there are micro-systems such as sectors, regions, and local economies**, all of which interact with each other. Some of these interactions or functional links in this discipline can be described with economic indicators such as sectoral employment, sectoral inputs, and outputs, emissions by sectors, GDP, value-added, energy consumption and mix, competitiveness, prices, income distribution, and demographic flows (WP4 review). These economic indicators may give a snapshot of a region's economic status at a certain time.

## 3.2 General findings from the three interdisciplinary fields on regions and sustainability

The network analysis of the review from the three interdisciplinary fields (see Literature review on regions and sustainability transitions) showed two main branches of keywords: sustainability transitions and regional planning. Sustainability transitions literature is shown on the left side of Figure 1 and it covers the following main keywords: sustainability, carbon dioxide, agriculture, and learning. Whereas regional planning contains the keywords: governance approach, regional planning, energy regions, and energy policy. This network shows that these two branches are barely connected. The common point between these is renewable energy resources; however, only a few lines are connecting the two branches directly.

Social and regional innovation function as the bridge between regional planning and sustainability transition literature. The major fields that were captured (as keywords) by the systematic review were governance, regional planning, energy policy, city learning, and agricultural studies. This keyword network analysis shows the connection between these fields: the closer the words, the more connected in the sample they are. Out of our list of searched themes, the only research theme that is not shown in the diagram is social innovation and regional innovation. The reason is that most of these innovation studies focus on learning regions (pink circles) or regional planning (green circles), see (Füg and Ibert 2020; Mattes, Huber, and Koehrsen 2015; Truffer and Coenen 2012a; Wellbrock, Roep, and Wiskerke 2012;

Schaffrin and Fohr 2017). This shows that innovation literature is dispersed across the two main branches, which suggests that innovation is a relevant concept in regions under transition.



**Figure 2. Left: keyword network analysis, and; Right: country network analysis using the VOSviewer software.**

Our results show that there is a lack of authorship collaboration across countries and a geographical bias in this review. We found out that this set of publications contained studies from Europe and North America (except Mexico) mainly, a few from Asia, and none from Central nor South America, Africa, or Australia. From the so-called economic developing countries, only a few studies from China and India were found. Thus, we have to be aware of this bias throughout the review. Interestingly, even within continents, we did not find connections between countries, which shows that there is room for cross-learning and supra-national approaches.

### 3.3 Analysis: components of a region

We identified basic components that the reviewed literature often refers to when describing a region. These components can be seen as the major organelles that interact with each other to carry out the multiple functions that make up a region. In Table 5, these components are briefly described.



**Table 5. Components with which a region is formed upon.**

Components	Description
Stakeholders (individual, intra-individual, group, household, society)	Stakeholders are the individuals and groups of people who have certain interests, concerns, opinions, and roles in a particular socio-economic system or sector. In energy systems, the role of stakeholders may be producers, production hosts, suppliers, energy transportation operators, energy transportation hosts, consumers, prosumers, regulators, market operators, among others.
Economic, technological, and knowledge sectors	Public, industrial, private, informal (among others) sectors that generate human capital, economic development, technological development, and/or social welfare. For example, the energy systems with energy-related research institutions, markets, and companies.
Institutions (governance)	Institutions with authority that govern (with policies and regulations). For example, a National Energy Ministry.
Biophysical environment (e.g. natural resources)	Geographic areas with living organisms, and non-living factors (e.g. weather), or their combination (e.g. landscape). For example, the ecosystem from where coal is mined.
Ideologies	Ideas and beliefs form the basis of the economic and political theories of a certain group of people. For example, the environmental awareness ideology seeks to protect the environment to mitigate Climate Change.
Cultures	"The characteristic features of everyday existence (such as diversions or a way of life) shared by people in a place or time "(Merriam-Webster). For example, the collective imaginary of Southern culture in a country.
Policies	"a high-level overall plan embracing the general goals and acceptable procedures especially of a government body" (Merriam-Webster). For example, the European Green Deal.

## 3.4 Analysis: processes within a region

The interactions between components represent the fuel that keeps a region running. These processes and interrelations are described in Table 6.

**Table 6. Processes and interrelatedness between components.**

Processes and interrelatedness	Description
Interconnections with partnerships, collaborations	Partnerships between stakeholders across sectors in a region and vertical governance levels also beyond the regional level.
Multi-level governance (with admin boundaries)	Governance structures in vertical levels (e.g. municipality, province, nation, continent) and horizontal levels (e.g. energy provincial departments, organizations, NGOs, etc.)
Impacts (positive and negative)	Positive and/or negative effects of energy-systems-related activities on stakeholders and ecosystems.
Economy and markets	Energy-related businesses and markets (can be formal, informal, of any type)
Supply and demand of energy services	Production, transport, and consumption of energy services. For example, upstream energy extractive sector: this includes the coal & fossil fuels sector; and downstream carbon-intensive sectors: sectors reliant on high carbon energy sources such as steel, cement, transport.
Power dynamics	Power dynamics between stakeholders, institutions, socio-economic sectors, communities, etc.
Policy-making	The process of formulating, designing, implementing, and evaluating policies with the participation of stakeholders.
Spillover, learning, innovation within and across regions	Effects and processes from which companies, institutions, organizations, etc. acquire and incorporate knowledge in their activities (e.g. for technological innovation)
Representativeness and ownership	Stakeholders' feeling and perception of being represented in the decision-making process in the energy system.
Shared interpretative frames	Common frames between people that are part of a culture. For example, shared representations, values, memories,

	imaginaries, aspirations
Community resources (e.g. cultural identity)	For example, collective identification, sense of belonging and cohesion, collective efficacy and resilience
Social factors affecting intergroup dynamics	For example, perception of justice, deprivation, or loss
Interpretation and response to the introduction of technological innovations and industrial operations	For example, community benefits, sense of place, territorial anchorage.

### 3.5 Analysis: concepts of a region

Here, we have collected several conceptualizations of a region that are formed by components and processes. A region is generally applied to refer to an area larger than a city that holds common characteristics. In practice, more than one concept may be present in the same region of study. However, by exploring each or some of them we can identify the multiple dimensions that make up a region.

Concepts	Description
Formal region	In Human Geography, a formal region is internally homogeneous according to, though rather dominant, cultural or physical characteristics. Every point within the formal boundaries shares the same defined characteristics. For example, an area that speaks the same language or follows the same physical features would be a formal region. The shrinking Antarctic ice cap and Ile de-France are formal regions. Not all formal regions have administrative boundaries (Gillespie 2014).
Functional region	It is based on social and ecological flows or functional links across a geographic area. This region type can be seen as nodes of population groups connected with functional links such as flow of persons, economy, markets, transport, communication, among others. It is a behavior-based activity area that is part of our everyday life. The functional region is the most applied concept in the sustainability transitions literature. For example, the region consuming electricity from a coal fire power plant or the region in which workers at a coal mine live and work are functional regions. Functional regions

	may cross administrative (even national) boundaries (Gillespie 2014).
Perceptual region	It is based on shared perceptions and attitudes of people toward an area. The people in this region share a cultural identity, also understood as a sense of belonging. It is a social interpretation of a place with fuzzy boundaries. For example, Northern Norway is a perceptual region with similar history and common dialect (Gillespie 2014).
Multi-network stakeholder groups of	The review by Work Package 2 (Environmental and Social Psychology and Anthropology) focuses on the intra-individual, interpersonal, and inter-group levels as the scales on which tipping points can be interpreted and have an impact. Following this idea, a region is framed as a multi-level network of stakeholder groups, including individuals and communities. They describe different dynamics of change when looking at the individual level, community level, or both. The functional links that connect individuals and communities are shared interpretative frames, community resources, social factors affecting intergroup dynamics, and the interpretation and response to the introduction of technological innovations and industrial operations.
City-region partnerships	This term refers to horizontal (within a region and across sectors) and vertical (across governance levels or scales) partnership of actors. A set of overlapping functional networks whose boundaries are fuzzy and depend on its functional links at a given moment in time. Thus, to define spatial boundaries, we have to refer to a specific context and linkages (Nelles 2013).
Macro-system: Interrelated microsystems of economic sectors, local economies, and regions	When analyzed from an economic perspective (literature review by Work Package 4), regions tend to be seen as formal regions. The approaches described in the review mainly refer to analyses at the macro-level often framed as national up to a global level. The review also mentions that within a macroeconomic system there are micro-systems such as sectors, regions, and local economies, all of which interact with each other. Some of these interactions or functional links in this discipline can be described with economic indicators such as sectoral employment, sectoral inputs, and outputs, emissions by sectors, GDP, value-added, energy consumption and mix, competitiveness, prices, income distribution, and

	demographic flows (WP4 review). These economic indicators may give a snapshot of a region's economic status at a certain time.
Landscape super-system?	Our colleagues from Work Package 1 (Human Geography, demographic trends, and challenges in gender, migration, and youth) highlight that tipping points must be analyzed in connection with both a spatial and a temporal scale. They mention that a region in tipping plus may be formed by systems that go under irreversible change at a fast or slow pace. In terms of the spatial scale, tipping point regions spread across scales, locally and globally. When studying SETPs, the area of relevance may cover several regions that experience interconnected tipping points. Thus, the landscape super-system is formed by the interconnected environmental and socio-economic systems (Frantal et al, 2020)
City-region	According to regional planning and regional governance research, the city-region concept has been the most employed for regional studies and has been in debate since its proposal in the 80s (Nelles 2013). The concept has evolved in its complexity, going from a single urban core with the surrounding rural area, to a city hub connected with spokes (smaller population areas) connected with functions, and multiple hubs and spokes with (bidirectional) interdependencies in the economy, environment, and society (Rodriguez-Pose, 2013). The geographic boundaries of a city region are fuzzy.
Regional narratives	Storylines describing how a region's pathway (i.e., pathway broadly is a course of direction) was historically developed until the present and how some promising pathways can be potentially developed in the future.

## 3.6 Synthesis

To categorize all the different aspects and describe how they altogether make up a region, we used a three-level scale. The first level corresponds to the components, which answer the question of what entities are found in a region? The second level is about the processes and interrelatedness and it answers the question of how do the components interact with each other? And the third level is about concepts, answering what meanings do the combinations of components and processes have? These meanings are the different ways to conceptualize a region that we identified. These three levels are enlisted in Table 7.

**Table 7. Synthesis of components, processes, and concepts of a region.**

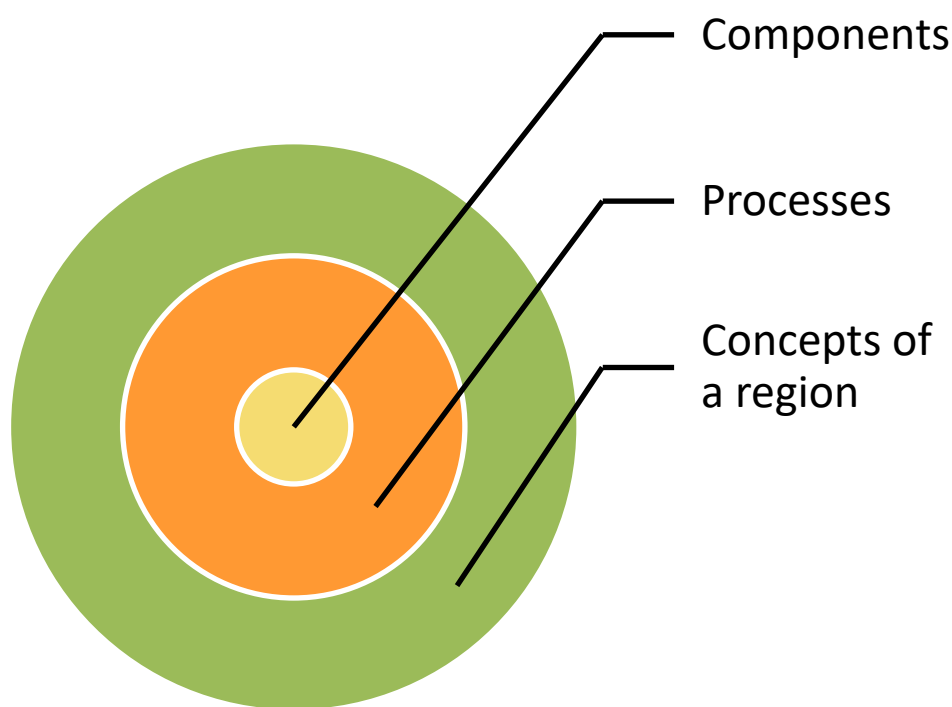
Scales		
1 <sup>st</sup> level: <b>components</b> (what?)	2 <sup>nd</sup> level: <b>processes and interrelatedness</b> (how?)	3 <sup>rd</sup> level: <b>concepts</b> (what meaning?)
Stakeholders (individual, intra-individual, group, household)	Interconnections with partnerships, collaborations	Formal region
Economic and technological sectors	Multi-level governance	Functional region
Institutions (governance)	Impacts on the components (positive and negative)	Perceptual region
Biophysical environment (e.g. natural resources)	Economy and markets	Multi-network of stakeholder groups
Ideologies	Supply and demand of (energy) services	Macro-system: Interrelated microsystems of economic sectors, local economies, and regions
Cultures	Power dynamics	Regional narratives
Policies	Policymaking	City-region
-	Spillover, learning, innovation within and across regions	City-region partnerships
-	Representativeness and ownership	Landscape super-system
-	Shared interpretative frames	-
-	Community resources (e.g. cultural identity)	-
-	Social factors affecting intergroup dynamics	-
-	Interpretation and response to the introduction of technological innovations and industrial operations	-

Besides this three level-scale, a region is a bond to spatial and temporal scales (consensus in T+). The spatial scale or **size** is used to measure an area or size with a quantitative scale (e.g. in km<sup>2</sup>). Whenever the boundaries of a region are fuzzy, an estimation value or range of an area can be used instead. The temporal scale or **time** is used to measure the timeframe of study (e.g. in months, years, etc.)

Particularly, in the Tipping Plus project, we focus on the spatial and temporal scales in which socio-economic transformations within a region occur. However, identifying these scales is not trivial. If we look at any process (2<sup>nd</sup> level) we would find out the each of them has a different temporal and spatial scale of change, for example, technological innovation and multilevel governance. The pace of technological innovation of solar cells is much faster than the pace for governance change. Notwithstanding, to identify the overall transformation patterns, we can look for the regional narratives (see CS Guidance).

In synthesis, we represent a region and its multiple concepts with the diagram in

Figure 3. This representation shows that at the core of a region we have the components (e.g. people, Nature). These components participate in multiple processes and hold interrelations that are crucial to give life to a region. That means that without components and processes, regions cannot exist or survive. In terms of change, the processes within a region can be transformed without necessarily altering a region. However, any transformation must occur in a way that the components co-exist because otherwise, a region would not survive.



**Figure 3. Representation of a region in its three levels.**

## 4 Discussion

In this review, concepts and understandings on regions were collected from eight major (disciplinary and interdisciplinary) fields: human geography, social-psychology, policy analysis, economics, regional studies, sustainability studies, and innovation studies. In general, there is no one-fits-all concept to describe regions. And at the same time, not all concepts nor processes may be relevant when studying a particular region or regional reconfiguration process.

### 4.1 State of the art

Throughout this review, we identified some basic components and processes of a region: humans, biophysical environments, techno-economic sectors, institutions, ideologies, policies, and cultures. Each of the concepts of a region refers to all or some of these components. However, a region cannot be understood by looking at these components as static entities. These components interact with each other through processes and interrelatedness to ultimately give life to a region.

The geographic boundaries of a region are always blurry when considering socio-ecological systems. The concepts of a region that we identified to deal with multiple systems (i.e. a system being a set of combinations of components and processes) at the same time. Each of these systems may have its particular spatial, temporal, and social boundaries. So that, if we try to define a geographic area of a region, one needs to specify what particular systems are of our interest. Then, it is possible to look at the intersections between these systems and map out their spatial expansion, when possible. This means that the boundaries of a region are set, if at all, by the questions we ask when studying a region<sup>1</sup>.

A region is shaped by vertical and horizontal connections across and within scales. If we look at the various processes and interrelatedness of regions we could see that some of them have a vertical or trans-scalar impact (that crosses scales such as individual, regional, national, international scales), horizontal or intra-scalar impact (that relates components within the same scale), or both. For example, multi-level governance shows that a region can respond to national and international policies, whereas community resources describe people's identity with a group, community, etc. in a region. The distinction between these scales is that a region holds stronger

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<sup>1</sup>For example: if our question is considering the perception of coal-mining workers, what is the region that hosts the coal-mining sector? Then we could start by mapping out the coal-mining activities and employees (as a techno-economic sector). Following, we ask the employees what they perceive as the hosting region, and then, we analyze what intersections or unions are formed by the employees' perception and coal-mining activities.



inner interrelatedness and processes than connections with the outer scales. That is that the cohesion between components (people, techno-economic sectors, biophysical environment, institutions, cultures, and policies) is stronger at the regional scale. Hence the challenge lies in identifying those distinctive processes and interrelatedness of cohesion that strings a region together.

In sustainability literature, there is a tendency to analyze regions as city-regions, which imposes challenges for climate change mitigation planning (Rodriguez-Pose 2008; Nelles 2013). City-regions are seen as a response due to globalization. These city-regions follow the pathway of ever-economic growth, which has been historically promoted by political elites (Harrison and Hoyler 2014). After 10 years of applying city regions, authors started to question the continuity of ever-economically-growing city regions. Some authors highlight that there is a conflict with ever-expanding city regions and sustainable development. Focusing on city-regional development in the globalized era results in more economic growth than national development strategies (Rodriguez-Pose 2008).

## 4.2 Research gaps

Our review has made clear that more research is needed linking empirical examples and theoretical approaches to understanding how different systems interact to form and reconfigure a given region. The examples of systems identified so far (components and processes) are often presented in isolation. However, a region may be formed out of the intersection or union of several systems: for example, a carbon-intensive region that is formed by the sum of all fossil-fuel-dependent economic sectors. Such examples would help visualize the interconnected systems within a region or across regions.

Some studies may need to apply various concepts of a region. In socio-ecological systems, it is important to acknowledge the different components of a region. For that reason, it would be needed to apply more than one region concept. Some concepts are focused on the social-psychological aspects (e.g. perception of stakeholders) and some on the techno-economic activities. However, explaining both concepts would give a more comprehensive overlook of what a region covers. The selection of these concepts should be guided by the research questions or project goals. Furthermore, the combination of concepts could help to better understand the inner forces of a region.

So far, only region concepts centered on an urban core have been applied in the field of sustainability transitions. The systematic review on the three interdisciplinary fields (sustainability transitions, regional studies, and innovation studies) showed that the region concepts that have been applied are the city region and functional region centered on an urban core. However, these concepts overlook the role of some components such as stakeholders, cultures, and ideologies. Therefore, examples applying the other concepts of a region (e.g. Multi-network of stakeholder groups or perceptual region) are needed.

Does a region change when going under energy system transformations? To elucidate how socio-ecological transformations evolve in a region, we need to pay more

attention to the temporal scale of processes. Each process that was introduced has its particular time scale of change. For example, the pace of technological innovation vs economic change. Since a region is shaped by the interaction of several processes, the temporal scale of these processes would permeate the temporal scale of change of a region. However, the fact that some processes change does not imply that the region changes significantly. More research is needed to better describe a region's change timescale. The literature on transformative narratives is a good starting point because it describes a narrative with all the components of a region.

Another crucial aspect related to how to identify social-ecological tipping points in CCIRs has to do with the need to identify the **time scales** when describing a region. Although several authors stressed that a region is understood at a given time scale (Nelles 2013; Balta-Ozkan, Watson, and Mocca 2015; Rodriguez-Pose 2008; Harrison and Hoyler 2014; Truffer and Coenen 2012b), we are still lacking examples that show how a region may be framed differently for different points in time. Integrating the time component into the conceptualization of a region is of utmost relevance for sustainability transition planning. Transitions imply change, which may impact the framing of a region as well. For example, if we consider a Transition Management approach, we might refer to a region before transitioning, and another region projected on a future vision.

## 4.3 Future research challenges on SETPs in CCIRs

This review has shown the need to integrate multiple and diverse views that exist when describing a region. In the TIPPING+ project, we often refer to the 20+ case studies as Coal- and Carbon-Intensive Regions. This framing corresponds to one of the functional networks that may be present in a region. Although this framing may accurately describe the energy source dominance of an energy system, its applicability may be limited to analyses within that constrained energy system. However, if we take a broader look, we might be able to see the interactions of the energy sector with other sectors such as agriculture or residential. Also, relevant would be to adopt a framing that shows the interactions between the diverse societal stakeholders, as suggested by Nelles, 2013 with the partnership networks concept. For instance, if we consider the Multi-network of stakeholder groups concept, we might be able to understand how human drives or stakeholders at the local level (e.g. a municipality or an NGO) may interact with regional, national, and international stakeholders to accelerate transitions.

Thus, we propose to every case study to critically analyze the adopted region framings that may be too constraining. Instead of working with the Coal- and Carbon-Intensive Region framing, case studies may apply different descriptions that serve the type of transitions that the region is or may be undergoing. For example, we may apply a framing that looks at the networks connected with socio-energy systems; cooperative-driven transforming energy region.

Furthermore, a region going under or seeking change may need to be reframed. With

the concepts presented in this report, it is still unclear at what moment a region has changed. This discussion will be further addressed in the later stages of the [Tipping Plus Case Study Guidelines](#). However, we want to raise awareness that the framing we give to a region (e.g. coal-intensive region) impacts the way we look and study at the region. Each framing must have its corresponding stakeholder(s) and timescale. Thus, more than one framing may be used for the same region at different times.

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