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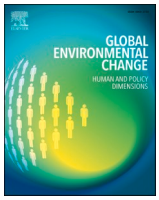

Just social-ecological tipping scales: A mid-range social theory of change in coal and carbon intensive regions☆

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ABSTRACT

Energy transitions are often studied using socio-technical transitions, just transitions and more recently, social-ecological tipping points (SETPs). While they can be important starting points for conceptualising large-scale systemic change, when applied within a regional context, they often fail to appropriately explain change. SETP concept is receiving increasing attention, but its heuristic value still requires further empirical validation. While many energy transitions are still in a pre-tipping point phase, the lack of empirically validated tipping points raises a question of applicability if these frameworks are unable to capture change at the regional scale. In this paper, we introduce a new inductive framework, Just Social-Ecological Tipping Scales (JSETS), based on cross-case analysis in coal and carbon-intensive regions (CCIRs). The framework helps understanding systemic change in regional contexts by identifying transition states. We then analyse traits in these transition states by assessing enablers and barriers of triggering factors and actors over temporal and spatial scales as well as justice dimensions. This analysis helps us to identify cumulate changes leading to four tipping scales, which can move a region from one transition state to another. By identifying both transition states and tipping scales, we can anticipate the potential traits needed for a CCIR to move towards a just transformation.

1. Introduction

The concept of tipping point, originating from natural sciences (Lenton et al., 2008; Schellnhuber, 2009) is now widely used by social and sustainability scientists and practitioners (Milkoreit et al., 2018; Milkoreit, 2023). While tipping points in biophysical systems is seen as a negative point to be avoided, social and Social-Ecological Tipping Points (SETPs) are seen as positive and deliberate ways to accelerate the transition towards sustainable decarbonisation (Tàbara et al., 2018). SETPs integrate biophysical and social interactions and their feedbacks, entail fundamental changes in the original social-ecological system conditions and acknowledge the roles of policy and governance in the transition (Geels & Ayoub, 2023; Stadelmann-Steffen et al., 2021). However, there are scarce empirical evidence and case study examples of SETPs as well as unclear identification of system scales and boundaries and understanding on the types of tipping interventions that could generate systemic transformations towards decarbonisation (Milkoreit, 2023).

In our search for empirical evidence of SETPs, we analysed changes in the transition states at the regional scale in nineteen coal-and-carbon-intensive-regions (CCIRs) case studies through an EU funded project, TIPPING+ (Enabling Positive Tipping Points towards clean-energy transitions in CCIRs). More specifically, SETPS are explored within system boundaries defined by the *functional region* which considers the flows of people and resources (Gillespie, 2013; also see Section 2.2) within coal-and-carbon-intensive-regions. CCIRs are subnational territories with socio-economic dependency on fossil-fuel extraction at the energy supply side (e.g., coal mining) (European Commission, 2018) as well as in the intensive-industry demand side (e.g., steel and cement production) (Martínez-Reyes et al., 2021). An overview of the covered nineteen regions is provided in Appendix 2. Our *meta*-analysis revealed that there was no evidence of SETPs in the studied regions, a result which supports existing studies that claim that currently there is no documented empirical evidence of SETPs (Milkoreit et al., 2018). Yet,

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our case studies' data revealed interesting trends across the regions which exhibit distinctive characteristics depending on their transition state that could lead to SETPs. Thus, by integrating theory with empirical insights, we develop a framework and a new mid-range social theory of change on transition states called **Just Social-Ecological Tipping Scales (JSETS).**

The JSETS framework aims to answer *"How can characterising a region's current state in its energy transition process provide insights on the core traits needed for just low carbon transformation?* JSETS proposes that a CCIR can experience distinctive **transition states** in its transformation from a high-carbon state to a just low-carbon state. These transition states are: State 1: High carbon mainstream with no significant change; State 2: Declining mainstream and development of low carbon system (s); State 3: Growing low carbon systems; State 4: Reinforcing low carbon systems; and State 5: Transformed region. JSETS suggests that a combination of enabling and barriers across different **triggering factors** and **actors**[1] causes a region to tip from one state to another, which we define as a **tipping scale**.

This framework builds on the foundation of SETPs which argues that "a *tipping event or intervention* shifting the system towards a different trajectory or systems' configuration, and the *structural effects* derived from such transformation" (Tàbara et al., 2022, p.565). Here, however, we do not focus on a singular tipping event but explore how cumulative effects in a region can tip the region from one transition state to another.

Therefore, we define a **tipping scale** as the *cumulative effects of triggering factors and actors considering cross-cutting scales of spatial, time and justice which can tip a region from one state to another, either in sequential order or potentially skipping states (*e.g.*, leapfrogging)*. In a tipping scale, the **temporal scale** is measured in years while **spatial scales** are defined as a formal region (uniform specific traits that can be organised by political governance, e.g., cities) and a functional region (defined in Section 2.2). The **justice dimension** (defined in Section 2) is a proxy that represents weighing fairness through the process of change by considering distributional, procedural, recognition, restorative and epistemic justice dimensions.

We draw on multiple streams of literature in science and technology studies (STS) and socio-ecological systems theories (SES) to explore transformation and transition concepts and frameworks. Combining the various streams of literature help inform the development of the transition states in JSETS for our analysis.

2. Perspectives on transformation and justice in regions

CCIRs are among the territories that encounter the greatest socio-political and techno-economic barriers to transition. The fossil-fuel sector in regions is interconnected with other economic sectors such as transport, electricity, agriculture, water, and real estate sector (Andersen et al., 2020). Phasing out a CCI sector without offering an economic alternative can be detrimental to local livelihoods, and businesses, to the extent of shrinking a region's population (Pau et al., 2022). The characteristics and challenges of the regions under study are presented in Appendix 2. Several studies (e.g. Sarrica et al. 2018a; Sarrica et al., 2018b) indicate that national governance approaches are not able to comprehensively capture the local needs, capacities, and preferences as well as the local responses to socio-structural change Therefore, CCIRs need regional governance approaches that cover multi-sectoral transitions without losing the connection with the local reality (Hoppe and Miedema, 2020).

Our starting point for understanding the dynamics of transitions in CCIRs is based on phases of change envisaged by socio-technical (STS) and socio-ecological system (SES) theories (see Table 1). These two perspectives propose different angles to address sustainability transitions. STS theories generally view transition mainly as a progressive shift of regimes, linked to changes in niches and landscapes (Geels & Schot, 2007; Wesselink et al., 2020). Rotmans et al. (2001) distinguish predevelopment, acceleration, take-off, and stabilisation phases of socio-technical change.

Table 1
Transitions state in relation to SES phases.

Transition states	SES phases
State 1) High carbon mainstream with no significant change	Pre-transformation
State 2) Declining mainstream and development of low carbon system(s)	Preparation
State 3) Growing low carbon system(s)	Navigation
State 4) Reinforcing low carbon system(s)	Stabilisation
State 5) Transformed just regions	Deep Transformation

Transformation in SES theories refer to the creation of new systems of human-environmental interactions (Walker et al., 2004), involves multiple elements of socio-ecological systems, and relates to individual and societal processes (Moore et al., 2014; Olsson et al., 2004; 2014). In this paper, we mainly refer to SES phases of pre-transformation, preparation, navigation, (as described by Biddau et al., 2022), institutionalisation, and transformation. However, one phase may not necessarily lead to another in a linear manner. Rather, each phase, more broadly, represents the extent to which a region is progressing towards transformation.

The *pre-transformation* phase includes perturbations, pressures, or crises, which emerge internally or as exogenous forces. At the individual level, perturbation may be referred to as the moment in which the changes in the environment are still perceived as noise. At the societal level perturbations relate to the dynamics between emerging and dominant representations in decision making, and the levels of agency that the different discourses acquire or preserve (Biddau et al., 2022).

The *preparation* phase includes individual and collective processes that lead to awareness of new patterns, sense-making, envisioning alternatives and gaining momentum around innovations. Relevant in this phase are the individual and collective processes of resistance to change, which may eventually lead to avoidance and denial mechanisms.

The *navigation* phase is characterised by selection, learning, and adoption processes, the elaboration of new visions and eventually by the co-presence of competing and even contradictory meanings of practices. In this phase, multiple niches coexist, and individuals and groups are characterised by hybridisation and widespread experimentation (Batel, et al., 2016). An example is the European energy landscape between the 18th and mid 20th century, which saw the coexistence of draft animals, water wheels, windmills, and steam engines, before internal combustion engines became dominant (Smil, 2004). The discrepancy between perceived and observed change is crucial here, especially moving from mere behavioural change towards an actual process of learning.

The *institutionalisation* phase state is characterised by routinisation, strengthening cross-scale relationships, and stabilisation. At the individual level, this would be the adoption of new habits. At the societal level, it would be the establishment of new representations. In a dynamic systems perspective, this phase implies reaching a new basin of attraction and maintaining it, for example through the implementation of material, institutional and technological means (Leone & Sarrica, 2017; Liu et al., 2014).

A *just transformation* could occur within a stabilised system functioning as the new norm with shifts in power and governance that challenge inherent social, economic, and political structures that have caused inequality (O'Brien, 2012). The transformation may result from technological innovations, behavioural changes, institutional and/or social changes. The new transformed state may be characterised by a plurality of discourses (Blythe et al., 2018), which is especially needed when addressing social inequality and injustice (Blythe et al., 2017).

[1] Actors defined in this study are individuals or groups who can impact or are impacted by the coal or carbon intensive sector's historical development and transition process.

2.1. Justice dimensions of regional socio-technical systems

The sustainability transition process in CCIRs is not free of injustices that need to be identified and addressed to move towards just transitions that considers the most vulnerable. Typically, when studying regions, there tends to be an implicit reference to the dominant characteristics of a region such as the dominant economy, identity, voices etc. (Gillespie, 2013; Kitchin & Thrift, 2009). However, the study of just transitions in CCIRs needs to acknowledge not only these dominant views, but meaningfully include diverse actors and address inequalities they may face in the dominant system and the transition. A major critique to STS is the failure to adequately address inequality, power structures, and other justice aspects of transitions (Røpke, 2016; Munro, 2019). Considering this criticism, recent studies have been bridging STS with justice frameworks when describing just transitions at a regional level (Jenkins et al., 2018; Sareen & Haarstad, 2018; Herberg et al., 2023).

In this paper, we define just transitions in CCIRs through five scales (see Table 5). The first four scales originate from the widely applied tenet framework, namely distributional, procedural, recognition, and restorative justice (Heffron, 2022; McCauley & Heffron, 2018; McCauley et al., 2013, Abram et al., 2022). The fifth scale corresponds to epistemic justice, which addresses the unfair access to and/or distribution of epistemic goods including information and education (Fricker, 2007). Failing to consider epistemic justice in research risks exacerbating knowledge inequalities and can lead to inequitable policy outcomes; Anderson, 2012; Ghosh et al., 2021; Lieu et al., 2023).

2.2. Actors, justice, spatial and time scales

According to recognition justice, when discussing (in)justices in the transition, a differentiation is needed between the actors that could be affected by energy transitions (McCauley & Heffron, 2018). A way to differentiate actors is by analysing their level of power and interest in the transition (Guðlaugsson et al., 2020). In this paper, we consider actors' position based on the power-interest approach to understand their relationship with (in)justice dimensions. Table 2 summarises how actors can be considered in justice dimensions.

The transition states also need to be analysed within the spatial and time scale. For this study, which is focused on CCIRs, we used the regional level as the main spatial scale. A region can be understood as internally homogeneous according to dominant cultural and physical characteristics such as language, defined as a formal region (Gillespie, 2013). However, the most applied concept of a region in sustainability transitions literature is the functional region. This concept describes a region based on social and ecological flows or functional links and behaviour-based activities that impact livelihoods across a geographic area. For instance, a coal region can comprise functional links such as a coal-based economy, flows of coal mining employees, transport of goods, market networks dependent on the coal mining sector, among others (Martínez-Reyes et al., 2022).

Time is embedded in the very idea of transition. Given our interest in CCIRs, the time spans, at most, for the last 150 years and the time scale allows for decades-long units, with some shorter periods (years) that have been crucial to the dynamic of the energy system (e.g. related to the opening or closing of mines, or the more recent implementation of European decarbonisation processes and local development plans).

3. Methods and JSETS framework development

Our approach to develop the JSETS framework consisted in the integration of empirical findings with theory. The overall research plan followed several stages. A total of nineteen case studies were selected by a core methods and integration team and carried out by coordinated case study teams within the TIPPING + project. The case studies were selected in each country according to the CCIR definition by the EU as well as additional regions that the project team had access to outside of the EU to also understand other policy and governance contexts; when multiple regions were present, the team selected the regions ongoing systemic transformations. The timeframe considered in the studies ranges from the start of the transition in the CCIR considered, that is, the time when the mainstream pathways is beginning to be challenged to the end of the study in 2023. Thus, the case study time ranges from years to several decades (see Table 5 for time scale findings and Appendix 2 and Martínez-Reyes et al. (2022) for details in each case study).

Table 2
Justice Dimensions and Actors.

Justice dimension	Literature Definition	Centring diverse actors in justice dimensions
Distributional justice	The fair allocation of the costs and benefits of the transition (Heffron 2022; McCauley and Heffron 2018).	Addressing inequalities actors' experience through policies that more fairly distribute resources.
Procedural justice	The meaningful and in-time inclusion of the affected in the decision-making process of the transition (Heffron 2022; McCauley and Heffron 2018).	Fairness in formal policy processes and co-development with actors in the development of policies and energy projects.
Recognition justice	Identifying actors whose interests and needs have not been fairly valued in current socio-technical systems (Heffron 2022; McCauley and Heffron 2018).	Identifying and including voices and narratives from actor groups that have been historically marginalised in the region.
Restorative justice	The repair of past and prevention of future harm on actors. (Abram et al, 2022). It considers processes with those harmed or those responsible for the harming (CICS, 2018).	Considering how recognition, epistemic, distributive and procedural justice impacts actors and acknowledging, remediating, and preventing future harm for actors.
Epistemic justice	The fair representation of diverse actors, conveying their experiences to others, and 'making sense' of their own social experiences (Fricker, 2007). These experiences should be equally valued and incorporated into formal knowledge production processes (Lieu et al., 2023).	Includes knowledge, preferences and interests of actor groups that have been historically marginalised and directly including knowledge of diverse actor groups including their historical and Indigenous knowledge and lived experiences.
Types of actors in relation to (in) justice	Actors with different levels of power and in the transition who can influence or are impacted by the transition (Guðlaugsson et al., 2020).	These actors can be present in every justice dimension because they experience injustices either directly or indirectly as part of their community/group.

The core methods and integration team elaborated the JSETS framework and developed case study guidelines for data collection and analysis, which were then first tested on several piloted case studies and reiterated with the remainder of the case studies with the whole project team. The case studies teams addressed the case studies in close collaboration with the core methods and integration team. The data collected included secondary data (press releases, local authorities' documents, policy documents etc.) and primary data (semi-structured and open interviews, actor workshops and participatory and non-participatory field observation). Actors in the TIPPING + project are defined as "entities that are affected by, or can influence, the emergence of SETPs, both positive and negative, in CCIRs" (Michas et al., 2020, p.14).

The preliminary results of case studies were presented in online weekly project meetings and in dedicated workshops by each case study team to identify and refine categories, compare and harmonise analyses and cross-validate results. Each case study team then produced a report based on the common JSETS framework and case study guidelines.

Finally, for the purpose of this study, the first, second and third authors comparatively reviewed all the case studies, developed an ad hoc analysis grid revised with the remaining author (Table 3), and revised the analyses carried out by the case study teams, going back to the data originally collected where necessary.

3.1. Towards the JSETS framework

The Just Social-Ecological Tipping Scales (JSETS) framework was developed with the aim to analyse the potential for transformation in CCIRs. This framework consisted of three analysis components. Component 1 covers the analysis of triggering factors and actors that act as enablers or barriers while considering justice, spatial and time scales. Component 2 covers the characterisation of the transition state of each region. Component 3 is based on a hypothesis of *tipping scales* that identifies and potentially anticipates the core traits needed to shift a region from one state to the next.

3.2. Component 1: Analysing triggering factors and actors across justice, spatial and time scales

The first component for studying JSETS assessed triggering factors (TFs) and actors over justice dimensions as well as spatial and time scale. We identified the triggering factors and actors, and the scales by reviewing the nineteen case studies reports provided by the case study teams (see Martínez-Reyes et al. 202 for full empirical data). We then asked case study teams to validate our analysis and provide suggestions and changes (the details were verified by case study leads are included in Appendix 1). Uncertain or neutral factors and actors were not included in the analysis.

3.2.1. Triggering factors

A number of common triggering factors (TFs) were identified across the nineteen case studies. A preliminary list of TFs was elaborated jointly with the whole project research team during an in-person integration workshop, where case study teams discussed their results. The initial grid was further revised when the case study empirical data were reviewed for further details. Finally, we analysed the variability across case studies and identified the following six core triggering factors present in all the examined regions. We included an 'others' category to consider influential triggering factors that occurred only in some regions:

1. Collective signalling of vision change
2. Policy for change
3. Geopolitical power shifts
4. Market changes
5. Technology changes
6. Environmental triggers
7. Others

Each of the triggering factors was further categorised as enabler or barrier to the transition according to the justice, spatial and time scales.

3.2.2. Triggering actors as links to justice dimensions

We considered actors' position in the research, which can have a foreground or dominant position or a background one (Abbott, 2004). Thus, along with foreground actors such as government bodies and conventional energy companies, we purposely considered actors typically not in the foreground, including women, Indigenous Peoples, and seniors.

We identified two core groups of actors:

a) Actors that have the decision-making power or influence to impact a transition positively or negatively; and
b) Actors who may not have the decision-making power to directly impact a transition but are impacted by a transition.

Table 3
Table of triggering factors and actors coded as enablers or barriers.

Response to trigger for transitions	1. Collective signalling of vision change – identity	2. Policy for change/ reinforcement	3. Geo-political power shifts –events	4. Market changes –privatisation –pricing – new markets	5. Technology changes –New tech – Add ons	6. Environ-mental triggers	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by change-incumbents, others?)	10. Pace of transition pathway 10 years + 5 years + 1 years +
Description of the trigger for change										
Scale of change (international, national, regional, local)										

Note: each cell is described in Appendix 1 and coded in red (barrier) or green (enabler).

Actors were also categorised as change makers (enablers) or change resistors (barriers). The focus on the above groups of actors was the starting point to consider five dimensions of justice (see Table 1). These dimensions help consider actors that are historically marginalised (recognition justice), whose experiential and historical knowledge are or are not equally valued (epistemic justice), who bear the costs and/or receive the benefit of the transitions (distributional justice), and who are included or excluded in the design and implementation of the transition (procedural justice). The spatial scale was focused on the region, yet we considered whether the actors and factors relevant to the regional system were local actors, or national or even international entities.

3.2.3. Coding triggering factors and actors across spatial and time scales

The scale in which the triggering factor occurred and the pace of transition (i.e., the time needed for a region to arrive at its current transition state) were coded in a table across the nineteen case studies (see Section 4, Figure 2). Table 3 presents the template for coding barriers (in red) and enablers (in green). Regarding the pace of the transition, the time scale was divided in decades, five-year or one-year periods, when specific and relatively faster changes (e.g. dramatic events, new laws) required a fine-grained scale of analysis.

3.3. Component 2: Characterising regional transitions states

The transition states of the CCIRs were identified inductively by analysing the empirical data from the nineteen regional case studies. For each case study, the research team provided a characterisation of the region, which included an overview of relevant policies and investments related to the energy sector. To deepen the local perceptions and meanings associated with the above elements, each case study team organised at least two actor workshops as well as further engagement processes which included 278 one to one open-ended interviews (see Appendix 2). The interviews, on site observations, actor workshops combined with secondary data allowed each case study team to identify individual or shared mainstream and alternative narratives[2] in the CCIRs based on the Alternative Pathways Framework (Lieu et al., 2020).[3] We do not include specific interview details and quotes in this study as we are carrying out a *meta*-analysis to understand broader trends in transition states across diverse regions. Our analysis also only includes the primary and secondary data collected by case study researchers and does not consider additional or new data.

Each case study team first identified a mainstream narrative representing the prevalent story about the formal and functional region and the incumbent institutions and actors in coal or carbon intensive the sector. Then, to consider multiple perspectives, alternative pathways that departed from the mainstream actors in the region were identified. Alternative pathways in CCIRs included low carbon pathways in different sectors such as developing renewable energy technologies, green tourism, and higher education.

The narratives across the nineteen case studies were collected and compared (see Appendix 4 for a succinct comparative description of the narratives in the case study regions and Martínez-Reyes et al., 2022 for the detailed analysis; and Aglamasi et al., 2022) to identify regions with similar characteristics in their mainstream and/or alternative narrative traits. Considering the empirical characterisation of regions and the narratives as well as the transition phases in SES theory literature discussed earlier (Table 1), we grouped the case studies into clusters representing five transition states:

- State 1: High carbon mainstream with no significant change;
- State 2: Declining mainstream and the development of low carbon systems;
- State 3: Growing low carbon systems; and
- State 4: Reinforcing low carbon systems; and
- State 5: Transformed just regions.

All nineteen CCIRs were categorised under states 1–4 but there no regions in the fifth transformed state.

3.4. Component 3: Anticipating changes towards transformation through tipping scales

After analysing how triggering factors and actors impact the CCIRs in their current transition state, we theorised on anticipating the next tipping scale(s) for CCIRs. This was done by identifying common traits exhibited by CCIRs in transition states further ahead on the JSETS pathway (discussed further in Section 4.3).

4. JSETS framework analysis

We present our results first by exploring enablers or barriers across triggering factors to identify a transition state while considering the justice dimension, spatial and time scales (Component 1). We then provide an overview of where the nineteen case studies are across the transition states in JSETS (Component 2). We conclude by anticipating changes with tipping scales towards a transformation (Component 3).

4.1. Component 1: Analysing triggering factors and actors with a justice perspective

The nineteen regions show nuanced trends across the transition states. First, when time is considered, we see a general trend *across transition states,* with the number of years in a transition increasing as CCIRs move towards more advanced transition states (see Figure 1). For instance, the further ahead a CCIR was along the JSETS pathways, the greater the number of years required to get to that state. There are two exceptions, Sulcis and Greenland, which are discussed later. Some regions are at the beginning of the transition state while others towards the end of that state. We explore these nuances in more detail including the justice dimension within each transition state.

Based on our analysis, each CCIR's position in a transition state depends on the type and frequency of barriers and enablers within and across triggering factors and actors. As seen in Figure 2, common patterns of red (barriers) and green (enablers) begin to emerge within and across each transition state. There are more barriers and fewer enablers in the first two transition states and an opposite trend of fewer barriers and more enablers in the transition states 3 and 4. The regions are ordered according to their transition progress, where region one is at the earliest transition state and region nineteen is the closest to a transformation (See Appendix 1 for details of each case study).

4.2. Component 2: Characterising regional transitions states

4.2.1. State 1: High carbon mainstream with no significant change

In state 1, where the carbon and fossil-fuel intensive sectors still dominates, there is a high frequency of barriers in at least four out of six triggering factor (TF) identified above and a seventh 'other' TF. Common TFs include a lack of vision change and/or policies initiating

[2] Here we refer to narrative as an umbrella term to include non-fiction and constructed stories, produced by a variety of actors. Narratives, have been assessed at the societal level of analysis, in line with the tradition of research on cultural narratives, that focuses on stories about people, places or things that are consistently shared across individuals, contexts and media, and that provide the shared background in which community, family and individual stories are inscribed (see for example Brown, 2017; Hammack & Pileki, 2012; Moezzi et al., 2017).

[3] For specific research methods and actor engagement for each case study, see Martínez-Reyes et al, 2022, D5.2 Case study key findings. Deliverable 5.2 for TIPPING+ project "Enabling Positive Tipping Points towards clean-energy transitions in Coal and Carbon Intensive Regions, Grant agreement No 884565.

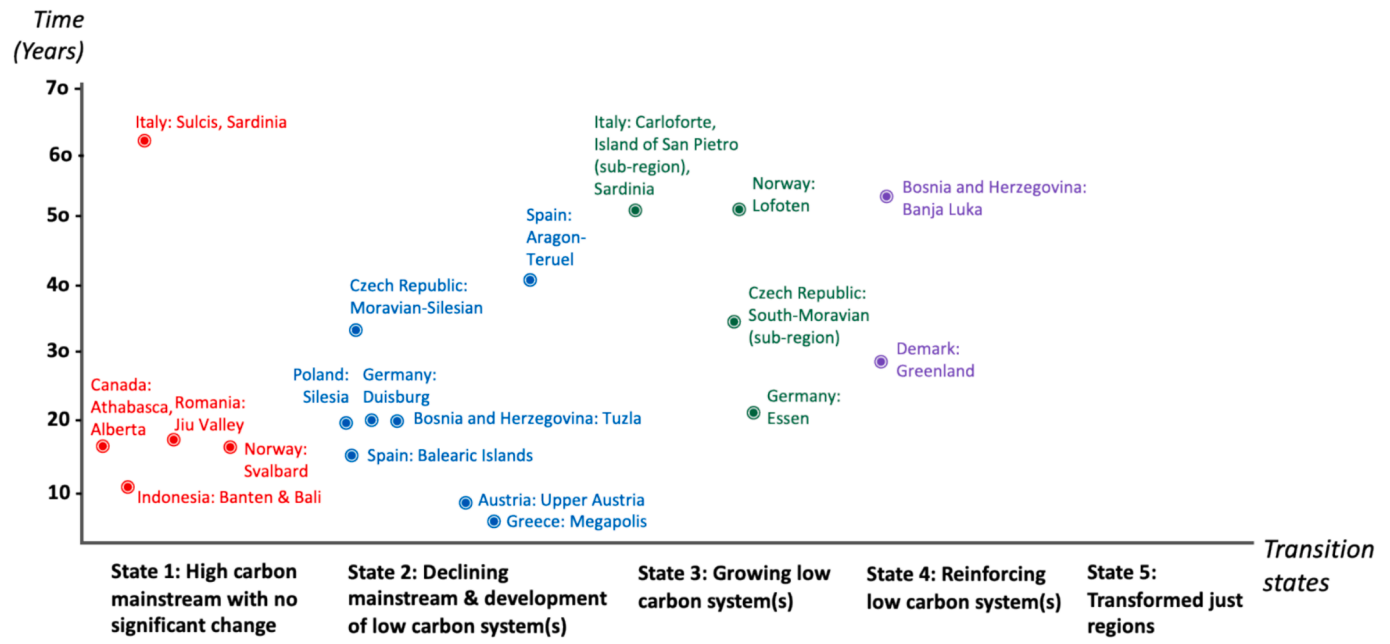

Fig. 1. Nineteen CCIRs plotted over time (years) across the five transition states of JSETS. Generally, a region that is further ahead in the JSETs trajectory will take more time to get there (see higher definition figure in Appendix 3).

change, as well as an absence of market changes away from coal and fossil fuels. For instance, this is observed in coal frontier narratives that continue to dominate with "coal being the backbone" in Banten and Bali and "developing the most ethical oil sands in the wild west" in Alberta. Policies at the national level also inhibit changes such as in the case of Jiu Valley's mining operation, which are highly subsidised by national and regional government. Similarly, Sulcis region has territorial development plans protecting and safeguarding industries and Alberta's Provincial Energy Strategy support oil and gas development. The continued coal and fossil fuel policy support also reinforces the mono-fossil fuel sector and further magnifies the issue of insularity. The isolation can also be due to the lack of access to the wider economy (Jiu Valley) and geographical isolation from the mainstream provincial or national society (Alberta and Sulcis).

There are, however, opportunities for other areas of the economy such as tourism due to the unique geography of the regions in Svalbard, Sulcis, Bali and Jiu Valley as "natural paradises". There are also hints of emerging visions with bottom-up views for Banten and Bali towards diversification of renewable energy, early discussions for sustainable land use and renewables in Alberta and exploring frontier research in Svalbard. Some top-down visions, which may also create tensions, are proposed by the national government like the case of Sulcis, a region that is promoted as the energy model and the Italian green laboratory for energy transition.

Other TFs beyond the six include a lack of social acceptance for renewables and availability of skilled workers for clean energy (Banten and Bali); long-time job loss, high unemployment, migration, and school drops (Sulcis) as well as population and demographic changes related to closure of coal mines (Svalbard and Jiu Valley).

Influential actors who resist change can also impact the transition. These regional and national actors include oil and gas incumbents and the provincial government in Alberta, a state-owned power monopoly in Indonesia, large and energy-intensive metal industries in Sulcis, and a nationalist party in Romania. The mainstream actors most negatively impacted by the transitions are also those who are most influential such as coal and oil miners and oil and gas workers.

There is also a lack of discussion on just transition in the regional transition. This does not indicate that just transition does not exist in the region, but justice was not identified in the case study analysis as either a barrier or enabler. Yet issues of just transitions are relevant as shown in the EU's Just Transition Mechanism "leave no one behind" that promotes recognition justice for coal and oil and gas workers who would be negatively impacted by a low-carbon transition. Another blind spot is the very limited public discussions about the impacts of transitions on actor groups that have been marginalised, including women and Indigenous communities (Alberta). This represents a lack of *recognition, procedural,* and *epistemic justice* where these groups are not formally acknowledged in decision-making processes, and their knowledge, and priorities are not considered in the transition. However, these actors are emerging along with NGOs, research institutions, and universities (Banten and Bali, Alberta, and Svalbard).

Most of these regions are within 10–15 years of their transition progress (except for Sulcis which started its transition over 60 years ago). Regions in state 1 face many barriers and resistance to its transition towards state 2 as described by TFs and actors. Thus, these regions may likely require more time to transition towards state 2 unless some major barriers are addressed including policies supporting low carbon initiatives and considering the needs of groups that are marginalised and impacted by the transitions, which will be discussed further in the next two states.

4.2.2. State 2: Declining mainstream and the development of low carbon systems

All CCIRs in state 2 are EU regions or candidate regions (Bosnia & Herzegovina) with very strong coal histories. These regions show trends of a declining coal power sector at various timeframes. One of the most important enablers are the supporting policy mixes supporting a transition at the global, EU and corresponding national levels. Quite significantly in all CCIRs, the policies only show enabling triggering factors except for one inhibiting in Moravia-Silesia where tax revenues from coal mining contribute to state budget and regions. This is visible in Figure 2 where state 2 is nearly all green (enablers) while in state 1, there are several policy barriers to a transition.

Some key policies for state 2 are at the EU level and include Cohesion Funds, European Regional Development Fund (ERDF) and European Social Fund (ESF), as well as just transition development plans and funds. Other EU-driven policy mechanisms are the European Green Deal, Fit-for-55 package for high carbon industries in steel, iron, cement

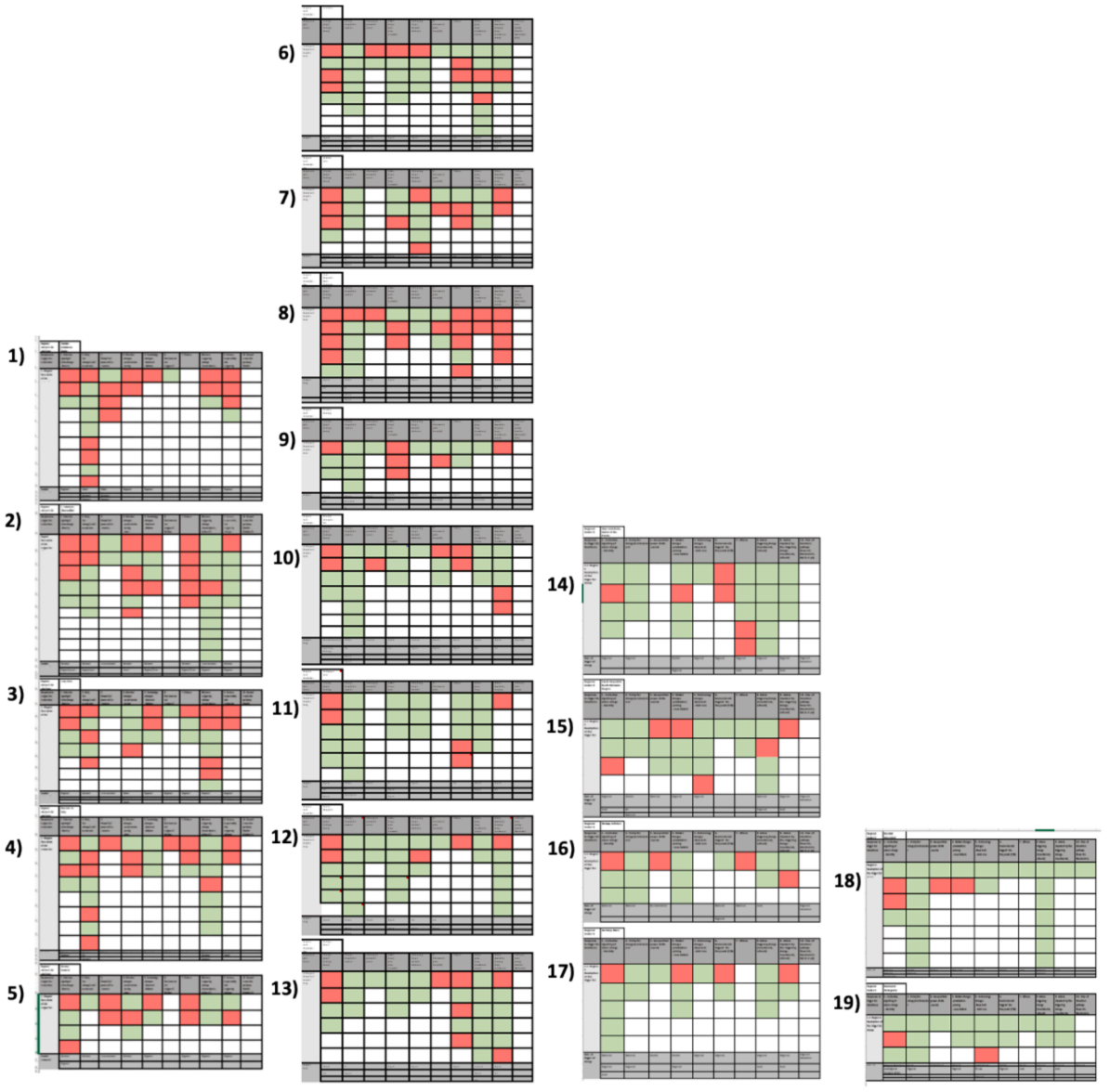

Fig. 2. Characterising CCIRs by triggering factors and actors as enablers (green) and barriers (red). The number of enablers increase while the barriers decrease as regions move across the transition states. Note: see headings for each case study table in Table 3. The colour codes in Figure 2 show the trends moving from a larger number of barriers (red) in earlier states to increasingly towards a larger number of enablers (green) in later states. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

to decarbonise, which then triggered National Hydrogen Strategies (Upper Austria).

There are two groups of CCIRs in state 2. The first group lies at the start of state 2, covering Spain (Balearic Islands), Poland (Silesia), Czech Republic (Moravia-Silesia), Germany (Duisburg), and Bosnia & Herzegovina (Tuzla). The second group is in the later part of state 2, including Austria (Upper Austria), Greece (Megapolis) and Spain (Teruel). The latter group identified only enablers in the market change triggering factor, most notably citing higher costs related to high carbon products/processes and diversification of the economy. The enablers consisted of bioconstruction, water efficiency technologies, ecological agriculture, tourism museums and educational institutions (Teruel and Megalopolis)

as well as consumer's demand for low carbon steel and cement (Upper Austria). In the first group, the Tuzla region also shows only enablers in the market change TF and is the furthest ahead in its transition compared to other CCIRs in the earlier start of state 2.

CCIRs in the earlier start of state 2 identified a larger number of barriers in the collective signalling of vision change where coal is still seen as black gold' (Silesia), 'Steel Heart of the Republic' (Moravia-Silesia), and 'Coal and steel as the economic engines' (Duisburg). The focus on coal is also linked to a higher number of influencing actors creating barriers to a transition. These influencing actors are coal labour unions and state-owned mines.

Actors impacted by the transitions may also block the transition, as seen in Balearic Islands energy transition. This opposition highlights the importance of procedural justice where actors are involved in the decision-making of transitions. Aside from the mainstream coal narrative, there are alternative narratives driven by just transitions as potential vision changes from the Industrial Silesia to Green Silesia in Poland where important issues such as health and living conditions, sustainability, joint responsibility for climate change, as well as intergenerational justice, where the justice dimensions intersect over the temporal scale.

Just transition also plays a prominent role in other TFs linked to policy and institutions plans and strategies, as seen in Teruel where a Just Transition Institute was created by an autonomous body of the Ministry for Ecological Transition and the Demographic Challenge (MITECO). In Megalopolis, distributional justice is being considered in initiatives targeting energy efficiency and energy poverty in households. In Tuzla, there are calls for an inclusive and just transition that would balance the needs of specific groups (recognition justice) and the general population.

Overall, CCIRs in state 2 show a diverse range of traits and justice issues intertwined across triggering factors and actors. Most of the CCIRs are experiencing transition timeframes between 5–20 years while only the Moravia-Silesia and Teruel regions are above 30 years. These two regions show differing traits, the Moravia-Silesia region having the highest number of barriers placing it at the early start of state 2 while Teruel has one of the highest numbers of enablers and is moving towards state 3.

4.2.3. State 3: Growing low carbon systems

There are four regions in state 3 where there is a growth of renewable energy and a diversification of the regional economy: Carloforte (Italy), South-Moravia (Czech Republic), Lofoten (Norway) and Essen (Germany). These four regions feature more enablers across all TFs and barriers are only present in no more than 4 TFs and actors. Moreover, within each factor there were only a few barriers identified. This can indicate that while barriers exist in the transitions, there are more enablers that propel the CCIRs towards a transition.

In state 3, all identified policy changes are enabling TFs and all influencing actors are enablers of the transition. Many policies are pushed at the national level, more specifically for coal in Essen, Germany and the withdrawal of subsidies supporting fossil fuels in Lofoten, Norway. Other regions have a stronger push for economic diversification in tertiary sectors and education with a move away from the mega-projects of large employers to bottom-up and small-scale approaches (South-Moravia, Czech Republic). There is also a strong presence of bottom-up action for actor groups across all CCIRs that include representatives of municipalities, local entrepreneurs, NGOs and local communities. For instance, the People's Action for an Oil Free Lofoten, Vesterålen and Senja has fought against petroleum activities in the region for over a decade. Citizen groups are also pushing a green narrative in Essen.

Actors contribute to the collective signalling of vision change in state 3. The South-Silesian region is rebranding itself away from its industrial legacy associated with the wider Moravia-Silesia coal region it is a part of (Moravia-Silesia is in Cluster 2). Instead, South-Silesia focuses on its traditional culture, landscape and tourism (South-Moravia). The emphasis on culture is also strongly evident in Carloforte's regional narrative "we are different from the Sulcis, we are green, we are cosmopolitan and sustainable entrepreneurs". Like South-Silesia, Carloforte does not see itself as a part of the wider Sulcis coal region in State 1 but as having a separate social identity. Carloforte's transition is not primarily driven by national or regional policies as seen in the other 3 CCIRs (South-Moravia, Lofoten and Essen) but by EU-level policies through Just Transition funds and EU-funded projects to explore the potential for tourism. Just Transition funds can provide resources and strengthen the agency the citizens feel is needed. Thus, procedural justice where citizens are involved in the design and implementation of just transitions as well as recognition and epistemic justice are important factors for driving the transitions. That is, the inclusion of local communities' knowledge, needs and a recognition of their unique (sub) regional identity.

In terms of timeframe, Carloforte's transition is taking around 50 years, along with Lofoten, which shows how long the process can be to reframe a mainstream narrative. The other CCIRs transition timeframes are around 20 years (Essen) and 30 years (South-Silesia). While these CCIRs are not necessarily representatives of all CCIRs in state 3, they show that several decades are required to reach the state of a growing low-carbon system and occur at a smaller scale, e.g., sub-region, or city level. An explanation can be that mobilising action from the bottom-up in Carloforte and Lofoten may require more time (50 + years), compared to more top-down initiatives such as Essen's city-wide and South-Silesia's regional efforts. Further research is required to test such assumptions.

4.2.4. State 4: Reinforcing low carbon systems

State 4 has the fewest number of CCIRs and consists of very specific regional contexts and limited sectors, that is, electricity generation in Greenland (Denmark) and district heating in Banja Luka (Bosnia & Herzegovina). These two CCIRs show a low-carbon system that has become the mainstream with actors and institutions reinforcing the regional system. The system is furthering its expansion, for instance developing new hydropower plants (Greenland) or further diversifying its feedstock for biomass heating (Banja Luka). However, the starting point for each CCIR differ. Overall, these two CCIRs have a high number of enablers and fewer barriers than CCIRs in state 3 across the TFs. All actors identified as impacting and impacted by the transition are also enablers.

Greenland's mainstream hydropower system was developed in a top-down manner by the Danish government (although Greenland is an independent territory since 2009) in a relatively shorter time frame of 27 years when compared to CCIRs in the earlier state 3. While most triggering factors are enablers in state 4, there are some threats to the low carbon narratives. In Greenland, there are discussions to potentially exploit oil and uranium. However, these discussions were thwarted by Indigenous Peoples opposing mining activities and a ban for drilling oil was placed. There were concerns that the ecosystems could be destroyed if radioactive minerals were mishandled. Indigenous knowledge on ecosystem impacts as well as their concerns were included in the decision to halt resource extraction. This is an example of how epistemic, recognition and procedural justice contributed to reinforcing the low-carbon system in the region.

Banja Luka energy transition in heating is seen as a tangible example rather than a vision for Bosnia & Herzegovina. The transition was pushed forward by local citizens over a period of 20 years and further supported by the city and by private firms supplying biomass material. This transition was also possible because technological knowledge and exchange was developed with the EU and the United States. A barrier for scaling up Banja Luka's experience is that the country has a high dependency on fossil fuel in district heating and has technological barriers for monitoring energy flow and for energy management more generally, which leads to substantial distribution loss. However, the wider EU level

also impacts the region's transition via the European Energy Community requirements, which include energy security, self-sustainability, and financial security. These principals, also covering distributional justice, have also helped to promote the growth of biomass heating in Banja Luka.

4.2.5. State 5: Transformed just regions

In a hypothetical state 5, a transformation occurs moving away from carbon systems as well as from social and power inequalities. In this state, we will likely observe most enablers across all trigger factors and actors as well as a system that considers the justice dimension through the inclusion of diverse actor groups in decision-making processes; thus, diversity of actors may lead to multiple perspectives within the transformed system. In the transformed state, there are likely only a few barriers. These barriers are highly unlikely to occur in key policies, considering that major policy institutions will be supporting or are supported by the transformed system. If there are some barriers, they may come from external forces at an (inter)national scale. For the region to be transformed, the system must be stable, that is, interlinked to a wider economic system and institutionalised.

4.3. Component 3: Anticipating changes towards transformation through tipping scales

We categorised the nineteen CCIRs across the first four states from the start of a transition towards stabilising their low carbon transitions (see Table 4). The categorisation was based on empirical case studies that identify the duration of the transitions (see Appendix 2).

There are five regions in the **state 1** or *pre-transformation phase*, with two regions in the European Union (EU) (Sulcis, Italy, and Jiu Valley, Romania), one in the European Economic Area (EEA) (Svalbard Archipelago, Norway) and the rest outside the EU/EAA (Banten & Bali, Indonesia, and Athabasca Region, Alberta, Canada). These regions show a relatively stable CCI sector (Biddau et al., 2022). Key institutions and actors that support the CCIR region are in power and continue to support the mainstream fossil fuel sectors. There is no significant change to the mainstream, for example, by adding carbon capture and storage in the oil and gas sector. There may be slight pressures from exogenous forces at international level (e.g., Paris Agreement) but these are not sufficient to disturb the mainstream at the regional level.

The majority of the CCIRs are in the **state 2** or the p*reparation phase* where the alternative discourse gains momentum from EU climate regulations and cross-border policies and the EU Just Transitions Mechanism. These regions include Spain (Balearic Islands and Teruel); Poland (Silesia); Czech Republic (Moravia-Silesia); Austria (Upper Austria); Germany (Duisburg); Greece (Megapolis); and Bosnia & Herzegovina (Tuzla). Regions in this state have a gradually declining fossil fuel sector that is often complemented with an early development of renewable energy efforts to decarbonise the energy sector. There can be a range of complementary innovations to the mainstream CCIRs such as clean coal or hydrogen for high carbon sectors. These developing alternative pathways also explore new sectors that may depend on land (e.g., tourism) or develop new clean energy technologies and/or knowledge economy (higher education).

There are four regions in the **state 3** or the *navigation phase* where there is learning and adoption of the alternative pathways that shows a mid-range growth of a more diversified low-carbon economy. These regions are part of the EU or the EAA (Lofoten, Norway). Interestingly, two of the EU regions are subregions of a wider region: South-Moravia, subregion of the wider Moravia-Silesia region in Czech Republic (in state 2) and Carloforte, Island of San Pietro, subregion of Sardinia, Italy (in state 1). The third EU region is Essen, in Germany, which shows a growing low carbon economy with a reorganisation of resources and institutions to support the development of a more diversified economy.

The **state 4** is the *institutionalisation phase* characterised by the reinforcement of the new pathway, with Greenland (Denmark) and Banja Luka (Bosnia & Herzegovina) as examples. These regions have a relatively stable renewable energy electricity or heating sector, which has some traits of state 1, that is a hegemonic representation, or the mainstream pathway based on clean energy systems. These are the (new) dominant technologies, such as hydro and district heating via biomass that have the support of mainstream institutions, and resources as well as local community support to continue developing and growing and reinforcing the low carbon infrastructure and system.

While there are no CCIRs in our study that exhibit a transformed just region (**state 5**), we can apply insights from the empirical trends in states 1–4 to anticipate the core mechanisms in state 5. Changes in a region's transition state occur when triggering factors and actors cumulatively change the context. The region's state can also be reversed if the conditions permit, either via actions (e.g., policies) or external forces (e.g., wars). But detecting the exact point of change in complex human-technical systems is difficult (Mey, Mangalagiu and Liliestam, 2024); thus, we identify *tipping scales* based on cumulative changes that can cause a region to change from one state to another and potentially lead towards a transformation discussed in the next Section 5.

Table 4
Regions in the four JSETS transition states.

State 1: High carbon mainstream with no significant change	State 2: Declining mainstream and development of low carbon system(s)	State 3: Growing low carbon system(s)	State 4: Reinforcing low carbon system (s)
1. Canada: Athabasca Region, Alberta	6. Poland: Silesia	14. Italy: Carloforte	18. Demark: Greenland
2. Indonesia: Banten & Bali	7. Spain: Balearic Islands	15. Czech Republic: South-Moravia	19. Bosnia & Herzegovina: Banja Luka
3. Italy: Sulcis	8. Czech Republic: Moravia-Silesia	16. Norway: Lofoten	
4. Romania: Jiu Valley	9. Germany: Duisburg	17. Germany: Essen	
5. Norway: Svalbard	10. Bosnia & Herzegovina: Tuzla		
	11. Austria: Upper Austria		
	12. Greece: Megapolis		
	13. Spain: Teruel		

5. Discussion: Key findings and theoretical contributions in studying transitions states for CCIRs

5.1. Trends in barriers, enablers, actors and justice dimensions in each transition state

We applied the JSETS framework to our nineteen empirical case studies and identified common trends in barriers and enablers for triggering factors (TFs) and actors across each transition state (see Table 5 for key summary points). We also identified four distinctive tipping scales that could potentially anticipate changes from one state to another. These trends are common across different regions in each state. We hypothesise that other regions outside our study may exhibit these common trends across states (see more in Section 5.3).

In state 1 "high carbon mainstream", regions have a significant number of barriers and mainly a notable lack of cohesive vision for change and a lack of coordinated policy support at the regional and national level. Yet there is a combination of traits including the emergence of some alternative visions, the start of a few low carbon policies and technologies and several (powerful) actors who can impact the transitions and begin to push for alternatives. This altogether can lead to *tipping scale 1 where the mainstream loses its dominant trajectory*.

As regions move towards state 2 "declining mainstream", policy

Table 5
Trends across the five transition states when applying the JSETS framework.

State 1: High carbon mainstream with no significant change	State 2: Declining mainstream and development of low carbon system(s)	State 3: Growing low carbon system(s)	State 4: Reinforcing low carbon system(s)	State 5: Transformed just regions
Tipping scale from 1 to 2: Mainstream loses dominant trajectory	**Tipping scale from 2 to 3**: Alternative stream becomes new mainstream	**Tipping scale from 3 to 4:** New mainstream develops complementary streams	**Tipping scale from 4 to 5** Automatic reproduction of mainstream institutions & norms	
State 1 Triggering Factors (TF)	**State 2 Triggering Factors**	**State 2 Triggering Factors**	**State 4 Triggering Factors**	**State 5 Triggering Factors**
Barriers: Scattered within TFs and across each factor	**Barriers:** High frequency within some TFs, notably a lack of vision change	**Barriers:** Increasingly dispersed within and across factors. Lower density of barriers in each TF	**Barriers:** Sparce and do not seem to destabilise the new mainstream system	**Barrer:** Weak and do not threaten a strong new mainstream
Enablers: Enablers scattered across each TF with limited strong trends	**Enablers**: Noticeable trend in the number of policies enabling the region to depart from mainstream.	**Enablers:** All policies are enabling and nearly all market TFs are enabling	**Enablers:** All TFs are predominately enablers	**Enablers:** Likely all TFs are enablers
Actors: (Powerful) actors resist change	**Actors:** Some actors want to trigger change	**Actors:** Most actors support change	**Actors:** All key actors support change	**Actors:** All key actors reinforce the new mainstream
Justice Dimension No or limited discussion of justice	**Justice Dimension** Focus on distributional and procedural justice to redistribute resources to those negatively impacted by transitions. Recognition justice staring to acknowledge those marginalised	**Justice Dimension** Stronger focus on distributional and procedure justice. Recognition and epistemic justice to include actors' knowledge as solutions	**Justice Dimension** Procedural, distributional, recognition and epistemic justice become norm	**Justice Dimension** All elements of justice embedded in institutions especially restorative justice
Spatial scale Regional level resists transition/change	**Spatial Scale** Global, EU and local policies support transition	**Spatial Scale** National, regional and local levels push transition/change	**Spatial Scale** International, national, regional and local level support and implement change	**Spatial Scale** Changes may need to occur at several levels to be transformative
Time Scale Medium (7 years) to long term from 10 −20 years (60 years as an outlier)	**Time Scale** Medium (8 years) to long term (10–30 years) (40 years as an outlier)	**Time Scale** Long term (20–50 years)	**Time Scale** Long term (27–50 years)	**Estimated Time Scale** Likely 5–10 years for a SETP to transform the regional level

support mechanisms are increasingly in place as well as a focus on the just transition dimension that enables low carbon initiatives and technologies and considers the needs of marginalised and negatively impacted by the transition groups of actors. This can result in *tipping scale 2 where the alternative stream becomes the new mainstream*.

In state 3 "growing low carbon system", policies enabling the development of the markets and key actors supporting changes are crucial to tipping *scale 3 where the new mainstream develops complementary streams*.

In state 4 "reinforcing low carbon systems", regions in the new

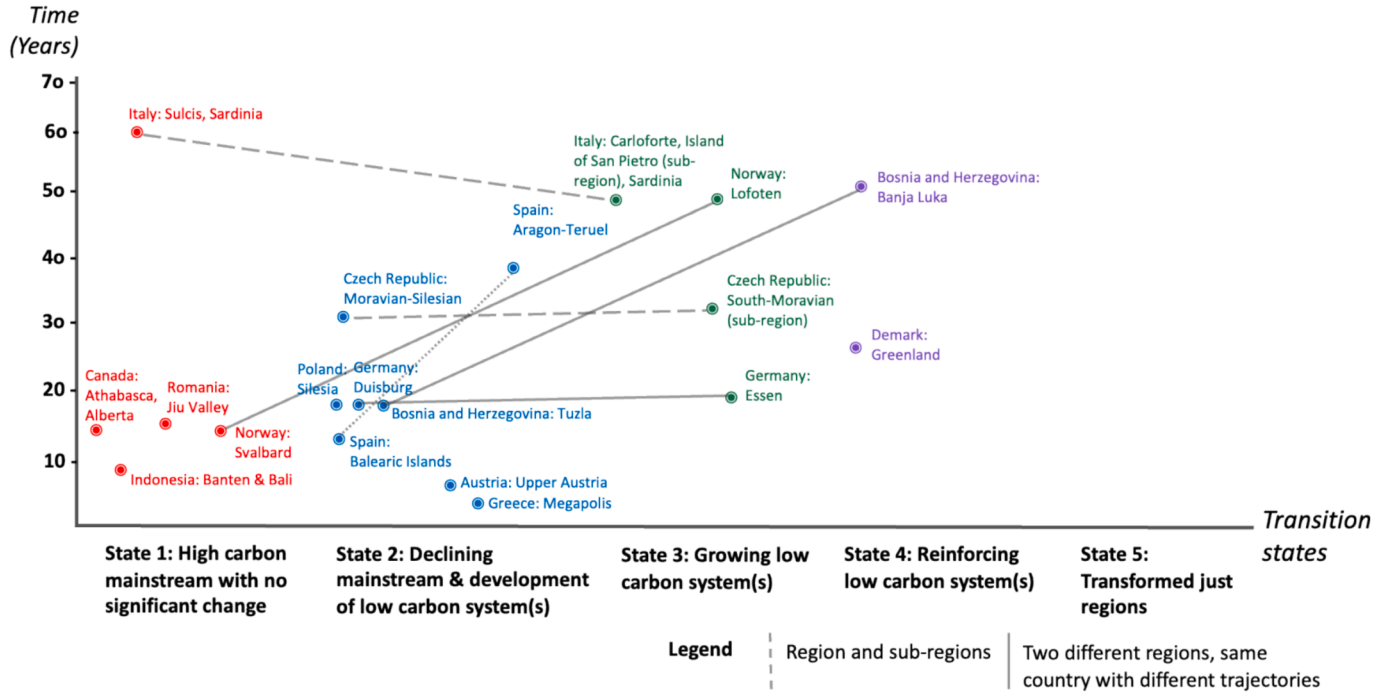

Fig. 3. Regions plotted over time and the five transition states of JSETS. Some regions in the same country exhibit contrasting transition trends (see higher definition figure in Appendix 3).

mainstream begin to institutionalise their own low carbon institutions, with societal and government actors supporting the transitions and with few barriers to change. The cumulative effects can leado tipping *scale 4 where there is an automatic reproduction of mainstream institutions and norms*.

Regions in state 5 may experience transformation that can occur at a wider (sub)national level. Reaching the transformation state could require more time if (inter)national pressures cause disturbances to the region. However, based on evidence from regions in the state 4, we observe that a CCIR may be sufficiently resilient and resist shifting back to a high carbon state if the system continuously supports both local needs, involves key actors and focuses on longer term justice dimensions and environmental gains.

5.2. Variations in transition states for different CCIRs in the same country

We find that different regions within a country can exhibit very different outcomes (see Figure 3 where regions in one country are connected by lines and dotted lines).

For instance, strong supporting policies that reinforce the market will likely accelerate the transition, as seen in Lofoten (state 3). Yet policies alone do not guarantee a faster transition. Svalbard (state 1) has policies phasing out coal by 2023 in place, but its current demographic structure is changing due to the decline of seasonal workers in the coal mining sector. On the other hand, Lofoten's transition was advocated by local communities for over a decade.

Additionally, champions for change are crucial to creating visions for transitions. The presence of a strong low carbon future vision is observed in the case of Essen, which is in state 3 compared to Duisburg at the start of state 2. Essen's vision is coordinated at the municipal and community level while Duisburg holds to its past coal tradition.

Transitions can also be triggered in a top-down manner, which may increase their pace (e.g., Greenland's transition). However, such strategies need to carefully consider diverse actor groups and trade-offs. Yet including diverse actors with varying or competing interests takes time. Policies promoting transformation will need to include groups and their knowledge that have been marginalised and negatively impacted by the transition to prevent their resistance, for instance workers in coal mines. Whether the action is top-down or bottom-up, there is a need for strong coordination between regional and national level policies to promote renewable energy sectors and other low carbon economic sectors. These sectors can include green tourism with sustainable land regeneration or developing training and education sectors for upcoming low carbon technologies. Diversifying the economies beyond fossil fuels requires time to develop capacity and to meaningfully include diverse actors' knowledge base by institutionalising their participation in decision making processes. As discussed earlier in the paper, there is a need for all five forms of justice as explicit conditions for transformation.

5.3. Generalisation of findings on transition states

Table 5 summarises the trends observed in each transition state across diverse regions. These observations need to be further tested to validate if the trends are generalisable to other regions, particularly in regions beyond western contexts. However, we argue that the JSETS framework can already be applied to assess current transitions states and anticipate potential future transformative states.

5.3.1. Testing JSETS in other regions

We have tested the potential application of the methodology and the JSETS framework to an empirical case study conducted in a study outside of the TIPPING + project in Baja California, Mexico (see Martínez-Reyes et al., 2024 for details of the research). We identified the barriers and enablers across several triggering factors (see Appendix 1, region 20). Based on the high number of barriers across factors and actors, Baja California is characterised as state 1 and may anticipate a slower change due to its natural gas dependency. While this is not a complete analysis, the methodology of identifying barriers and enablers across triggering factors mainly in the lack of *collective signalling* for a transition where the natural gas dependency is strong, with no clear *policies* for transition at the regional level yet some policies at national level, shows promises. The analysis also shows that there are several major *technological* barriers that also need to be overcome. On the other hand, actors at the national policy level and regional manufacturing companies are enablers of the energy transition. This analysis shows promising potential to identify a regions' current state and major barriers, which can help anticipate the areas where either a top-down policy and/or bottom-up community/local action needs to be prompted to accelerate the transition; for instance, by supporting the market creation and addressing technological challenges such as the grid connection. Further research is needed to (in)validate these findings and generalisability of the JSETS framework.

5.3.2. Estimating the timing of changes in JSETS transitions states

While the data in our case studies cannot be directly extrapolated to other regions, we have gained insights to develop a first general estimate of JSETS timeframes, which requires further testing. Our empirical data revealed that the fastest transition in each state was:

- at least 27 years to reach state 4 (Greenland, Denmark);
- at least 20 years to reach state 3 (Essen, Germany);
- at least 5 years to reach state 2 (Megapolis, Greece); and
- at least 15 years to reach state 1 (Banten & Bali, Indonesia).

Assuming regions move from one state to another without leapfrogging (while acknowledging that leapfrogging is a possibility), we estimate that regions currently in state 1 for the past decade or more are likely to require at least 10 years to reach state 2 or 3, and more than 10 years to reach state 4, if no additional actions are taken. We also estimate that regions reached state 2 over the past 10–15 years may likely require at least another 5–10 years to reach state 3 or 4, if no additional actions are taken. Thus, it is unlikely that without further (major) interventions, regions which have been for 10 years or more in transition states 1 to 3 will reach a transformed state and fully meet the climate change goals by 2030.

Regions in state 4 will need major international policy support to reach state 5, as the main barriers related to a transformation are linked to (inter)national dynamics on fossil fuels dependency. The latest UN Climate Change Conference in November 2024, which negotiated an increase in the loss and damage funds to US 300 billion annually still failed to end fossil fuel (finance) or establish an agreement on a just transition work programme (UN Climate Change, 2024; IISD, 2024). However, regions in state 4 may still have an opportunity to reach a transformed just state by 2030 if in the next 1–2 years, international/global landmark agreements are established to halt the development and financing of fossil fuels and make just transitions a policy priority.

5.4. Theoretical contribution: JSETS framework to analyse and anticipate transitions states in CCIRs

We developed the JSETS framework based on the analysis of transition states of CCIRs for nineteen case studies. We first analysed the conditions for each region by assessing how triggering factors and actors – while considering the justice dimension – become enablers or barriers to the transition (Component 1). We then characterised the transition state (Component 2), which provides a starting point for understanding the current dynamics of the region. Finally, based on the empirical evidence collected, we identified potential core traits to anticipate transition states via the identification of tipping scales (Component 3). The JSETS framework brings together enablers and barriers across triggering factors, actors and justice dimension (Figure 4) helping regions to identify their current transition states and anticipate upcoming ones.

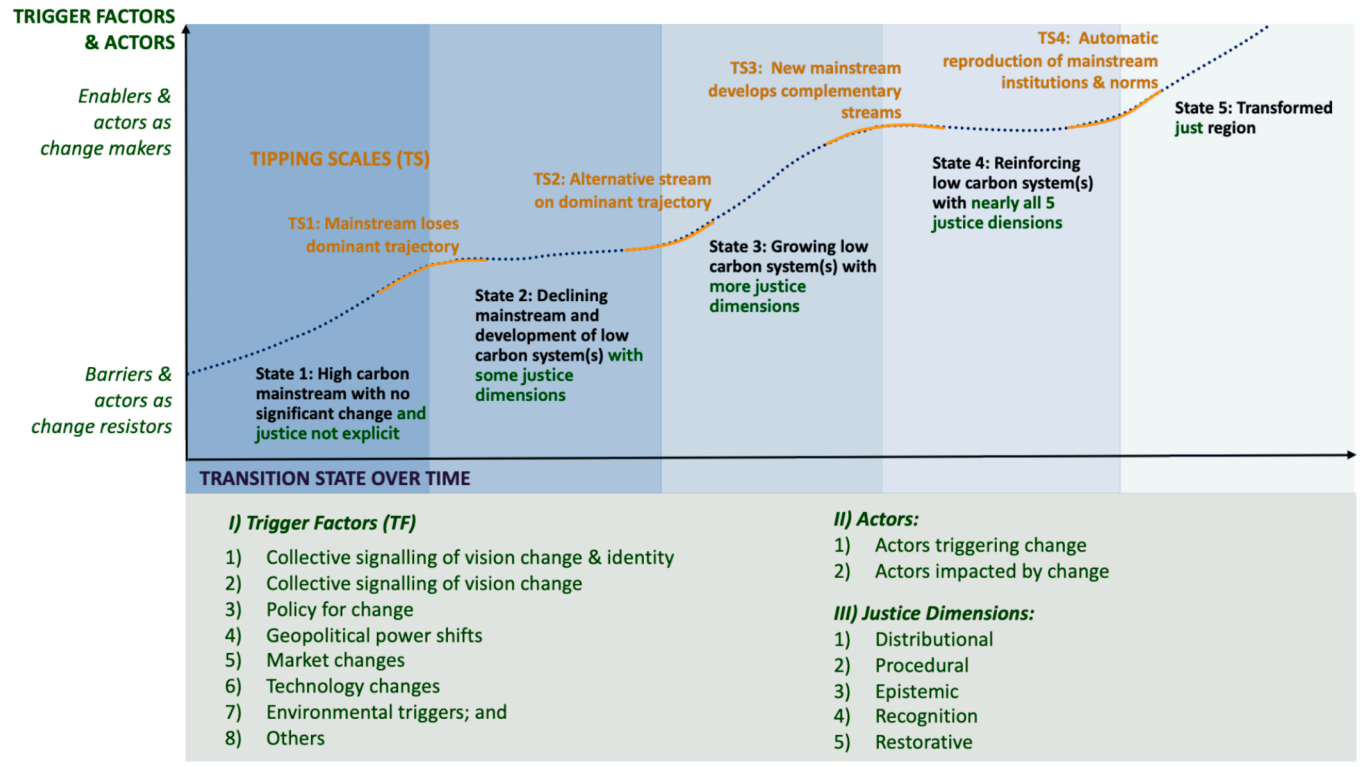

Fig. 4. Just Social-Ecological Tipping Scales (JSETS) framework for transition states. Regions can experience tipping scales that move it from one transition state to the next, depending on enablers and barriers in trigger factors, actors and justice dimensions. Source: Author's own.

We also proposed a normative value of justice in a region in transition and embedded the five justice dimensions within each transition state. The transformed state does not necessarily remain static. If a new norm appears due to the changes in the regional context, the region could transition back to the previous state or even move beyond the current state, when the new (transformed) state continues to evolve.

5.5. Limitations of the study

While we qualitatively measured the frequency of occurrence of barriers and enablers, we did not codify the magnitude of impact for each triggering factor and actor. Future research could include a scale that measures the magnitude of the enabler or barrier. For instance, each enabler or barrier identified could be measured on a semi-quantitative scale with relevant actors being asked to assess the magnitude of the enabler and barrier (see data calibration by Martínez-Reyes et al. (2024). Another limitation is the subjective interpretation of data in applying the JSETS framework. We addressed the subjectivity by ensuring that at least two of the authors of the study validated the coding of barriers and enablers for triggering factors and actors in each case study. We also verified our suggested coding by the case studies teams. In hindsight, this methodology could be applied from the start of the research, carried out by case study teams, and verified by actors. Our analysis is also limited to data collected by case study researchers, which excludes data after 2023. Newer data may provide further evidence for each regions' transition state. Thus, we encourage continued studies of these regions and an updated analysis to consider the dynamic nature of each regions' transition states.

6. Conclusions

We studied CCIRs involved in energy supply and demand side intensive industries, searching for commonalities that enable or impede changes within these regions. While transformations may not necessarily be visible at the national level, the JSETS framework helps identify and deconstruct the elements towards a transformation at the regional level. More specifically, the JSETS framework identifies the triggering factors (1. collective signalling of vision, 2. policy, 3. geopolitics, 4. market, 5. technology and 6. environmental triggers) and actors that enable or impede transitions at a given scale. The functional region scale provides well-defined boundaries to study changes in transition states when a combination of factors and actors accumulate to tip a region from one state to another. While some countries may not be experiencing detectable change towards low carbon transitions, our analysis showed that regions within those countries were moving further ahead toward transformation (e.g. Banja Luka, Bosnia and Herzegovina). In contrast, we also observed countries with stronger ambitions for low carbon transitions at national level showing resistance to transition at the regional level (Duisburg, Germany).

Moreover, we considered the impacts of transitions by applying a justice lens which can help policy makers to consider the positive and negative impacts of the transition on various actors, first at the regional level and then at an (inter)national scale that could impact the region. The inclusion of diverse actors can help consider recognition justice, particularly for groups historically marginalised and consider their knowledge that is often excluded from decision-making processes as a form of epistemic justice. The JSETS framework also accounts for distributional justice in showing how the transitions will benefit different actor groups as well as for procedural justice in the design and implementation of the transitions.

The JSETS framework can help anticipate the resources and time required for different actors at the regional level to reach the next transition state. For instance, a region that aims to change over the next five years but is currently in state 1 and has a strong mainstream trajectory, will require significant and coordinated policy support targeted at different actor groups. The type of policy support would depend on the actor groups' needs and capacity to enable technological adoption, to support links to the broader (clean energy) markets and to mobilise various actors (community members, local politicians, businesses etc.). The specific actions need to be adjusted to the regions' specific social-

economic needs rather than assume that national priorities and policies are sufficient to address both climate and social-economic needs at a local level.

Transitions may be mandated at the international level (e.g. Paris Agreement, EU Directives) and need to be accelerated to meet 2030 and 2050 climate goals. Our analysis of empirical data suggests that regions in states 1–3 will not likely occur within the next 6 years to meet climate goals by 2030 (state 1 'high carbon mainstream with no significant change'; state 2 'declining mainstream & development of low carbon system(s)'; and state 3 'growing low carbon system(s)'). However, regions in state 4 'reinforcing low carbon system(s)' may have an opportunity to reach a transformed state if there is fast and decisive policy support at the (inter)national level. Further studies are needed to explore a larger number of regions worldwide to assess their transition trajectory and to draw further insights on anticipating changes in transition states in different contexts (Mey et al., 2024; Chakraborty and Mandel, 2022). Further data can help revise the JSETS or develop new mid-range theories that better explain changes at the regional scale that are needed towards just transformed regions.

Different groups knowledge and needs can also be explicitly included and considered in the movement towards low carbon for regions in all countries. For example, actors that have been negatively impacted by the mainstream energy systems (e.g., communities negatively impacted by fossil fuel extraction) or groups that may be impacted by the energy transitions (e.g., high carbon sector workers). We argue that engaging with diverse actors beyond the dominant groups in power is a prerequisite to moving towards the transformation state as actors bring in multiple new visions and knowledge that can help progress the transition. While engagement and bottom-up action require more time, they can be complemented by specific regional policies that promote agency for those who must decide the future they want for their region. Both top-down and bottom-up actions are needed to promote just and accelerated transitions. Yet, the two are often at odds as inclusion of diverse actor groups require time and relevant policies may not be implemented due to other political priorities. But change can still occur as our empirical evidence reveals that clusters of enablers are more important than barriers when moving towards the next transition state. The JSETS framework helps identify tangible factors and diverse actor groups that can enable change and anticipate the resources and time required to make both incremental and transformative changes.

CRediT authorship contribution statement

Jenny Lieu: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Diana Mangalagiu:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Amanda Martínez-Reyes:** Data curation, Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. **Mauro Sarrica:** Data curation, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

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Appendix 1:. Detailed analysis of enablers and barriers across each CCIR case study

State 1: High carbon mainstream with no significant change.

1. Canada: Athabasca Region, Alberta.

Regional cluster 1: No significant change	Canada: Athabasca Region, Alberta									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change- incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Oil Sands as most ethical.	Reliance on US policies	Paris Agreement	Hydrogen as complementary new market but is still dependent mainly on natural gas and CCS	Oil& gas plus carbon capture and underground storage (CCUS) infrastructure to export hydrogen	Negative environmental impact on air and water quality for surrounding communities		Incumbent oil and gas firms	Incumbent oil and gas firms	15 years +
	Not supporting oil and gas is "Anti-Canadian"	National GHG policies	High oil prices	Low interest business loans				Provincial and national government	Provincial government	province's commitment to closing coal mines by 2023
	Some limited off-stream narratives on sustainable land use and renewables	Regional environmental policies	Lack of climate commitment from other countries including USA					Research institutions	Indigenous communities benefiting from development	
		Alberta's 2008 Climate Change Strategy	Increase inflation						Indigenous communities wanting to protect traditional land practices	
		Alberta Land Stewardship Act (2009) but not yet developed for upper Athabasca oilsands region								
		Alberta's Provincial Energy Strategy emphasising oil & gas								
		Royalties from oil & gas								
		Government research grants for clean energy								
		Stimulus for blue hydrogen								
Scale of trigger of change	Regional	Global	Global	Regional	Regional			Regional	Regional	
		National	National							
		Regional	Regional							

2. Indonesia: Banten & Bali.

Regional cluster 1: No significant change	Indonesia: (Banten & Bali)									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change- incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
Region 1 Description of the trigger for change	Fossil fuels needed to maintain growth	National Energy Policy (KEN) min. use of oil, max. RE, optimise gas and secure by coal	Paris Agreement	PLN (state energy firm) sells electricity from fossil few below production cost	Solar PV is limited by uncompetitive price compared to fossil fuels, battery technology and the existing grid system (not smart grid)		Geothermal and hydropower lack social acceptance	Asian Development Bank	PLN	Slow 10+ (Past till now)
	Coal backbone in Banten and Bali	National Energy General Plan (RUEN) to maintain coal use w/ slight decrease by 2050	G20 Results	Companies have a green agenda	Geothermal and hydropower stable base load		Lack of coordination between local and gov't and provincial energy sector plans	UN Office for Project Services	Private business	
	Banten is using biomass with co-firing, whereas Bali is highly relying on Java for the electricity supply	Regulation of Ministry of Energy and Mineral Resource for private firms to develop RE		Companies are not sufficiently connected to financing	Grid integration and transformation		Fossi fuel subsidy	National Ministry : Ministry of Energy and Mineral Resources, Ministry of National Planning/Bappenas, Ministry of Finance	NGOs	
	Bottom-up view for Banten and Bali to diversify with solar, wind, hydro power (micro), geothermal, and bioenergy especially in decentralised and remote areas	Carbon tax for Coal		Maintain the government subsidy in the coal power plant	Domestic Ability Level (TKDN) policy for local PV manufactures		The availability of skilled workers related to clean energy	PLN	Communities	
	Early retirement scenario for NZE in 2060	Fiscal incentives for clean energy		FIT (Feed-in-tariff) for RE production			Limited clean energy resources at provincial level, hence grid integration and interconnection are essential	Provincial gov't agencies	Research institutions and universities	
		Bali has its own regional energy plan which promotes renewable diversification		Single player in the national power supply (PLN)				Private business		
								NGOs		
								Communities		
								Research institutions and universities		
								UK Government		
Scale of trigger of change	National	National	International	National	National		National	International & National	National	
	Regional/provincial	Regional/provincial		Local	Regional/Provincial		Regional/Provincial	Regional	Regional	
								Local	Local	

3. Italy: Sulcis, Sardinia.

Regional cluster 1: No significant change	Italy: Sulcis									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change- incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Sardinia is a historical mining region with a millennial activity of metal extraction and the only remaining coal region in Italy	Territorial development plans protecting and safeguarding industries	Decline of the mining industry (ie., coal, zinc) began in the 50s via the post-war and spur the development of industrial districts and supply chains for the energy-metalliferous industry	During the last decades, due to energy prices and the global crisis of 2008 the area experienced severe industrial decline with job losses	Carbon capture and storage	Issue with air quality, soil and water ground contamination, and risks of heavy metals in food chain	Lacks the basic infrastructure for natural gas, making the phase-out of coal problematic	Large and energy-intensive metal industries-	Local citizens- but no agency just waiting for change to happen	61 years +
	POSTPONE phase out-survival of the coal regime through carbon capture and storage/ promoting a coal-to-gas transition	Closure of coal mine in 2018		Circular economy creating new economic sectors	Natural gas		Long-time job loss, high unemployment, migration, school drops, and a decreased population, esp young generations	The industrial port	Minging workers	
	Sardinia as the energy model and Italian green laboratory for energy transition (proposed by National Gov't)	Coal phase out by 2025 for mechanization and conversion of coal-fired powerplant		Energy management through energy communities	Centralized large-scale renewable energy technologies (mainly wind, solar and wave energy)		Sulcis region has been considered for many years the poorest region in Europe	Main national electricity company for green electrification		
	Sardinia Zero CO2 Island – phase out 2025: coal mining and metalworking industries seen as vertically imposed decisions in regional development and failed models	Abandonment of conversion plan and new plan for green electrification		Lack of new jobs and uncertainty fosters conservativism				National government		
		Coastal gas deposits as transitional source						Unions		
								Gas companies		
								Tourist sectors (attempts and dreams to develop it)		
Scale of trigger of change	Regional	National	International	Global	Regional	Regional	Regional	Regional	Regional	
		Regional		Regional			Local	Local	Local	
				Local						

4. Romania: Jiu Valley.

Regional cluster 1: No significant change	Romania: Jiu Valley									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change- incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Mining and the tradition of inheriting the miner's profession from father to son	Diversification to eco-tourism development & ski + "local craft" + hydroponic farming	Oil crisis in the 70s lead to a push for energy security along with the Communist regime that had a strong desire to pay Romania's large foreign debt via coal mining	Mining restructuring and closing leading to series of sudden, severe, and unplanned long-term layoffs since 1990	University reorienting education towards renewables industry & creation of Academy for Renewable Sources and Energy Distribution	Environment is not a major regional issue, however mentions of contaminated land exist	Aging population due to outmigration and low fertility rate	World Bank	Miners and local communities	Around 19 + years
	Coal exploitation seen as the "black hole" of the region	Miner's pension disincentivizes reskilling		Economic collapse	Hydrogen Hub based on methane emitted in mining galleries or renewable energy		Miners social unrest	National government	Trade unions	
	Mineriadas, miners' marches in 1990s and 2000s	No long-term plan for reorganizing mining and lack of policy mix coordination		High taxes regime destroy SMEs in Romania	Graphite mining		World Bank project interventions in the Jiu Valley came in 2004 when the Romanian Government committed itself to reduce subsidies for the mining sector	Planeta Petrila Association		
	"Natural paradise" for tourists	Tentative to transforming Petrila into a creative hub						AUR nationalist party		
		The Western Region Regional Development Strategy 2014-2020						Platform for Coal Regions in Transition		
		Many strategies in Romania and the Jiu Valley are "on paper" only						NGOs		
		Strategy for the economic, social, and environmental development of the Jiu Valley (2021-2030)						Town halls		
		Mining operation highly subsidized by national government								
Scale of trigger of change	Global	Global	Global	National	Regional	Global	Local	Global	Regional	
	Regional	EU						National	Local	
		National						Regional		

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5. Norway: Svalbard.

Regional cluster 1: No significant change	Norway: Svalbard									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change- incumbents, others?)**	**10. Pace of transition pathway 10 years+ 5 years+ 1 years +**
1.1 Region 1 Description of the trigger for change	Coal mining has maintained the Norwegian sovereignty of the Svalbard Archipelago since 1920	2018 decision to phase out coal with the closure of Svea and Lunchefjell mines by 2023	Norway and Russia are both engaged in coal mining, and China and numerous other nations are also involved in research	Norwegian government increased the budget in 3 areas: research, higher education, and growing the tourism industry	No technological sectors are emerging in the region as yet.		Svalbard is not a lifecycle community (people cannot be born or die there) people only live here to work.	Government's decision to close mines	Small tourism and education businesses, and universities	15 years +
	Phase out of coal based on knowledge that coal mining contributes large amounts of CO2, and has high emissions		Russian invasion of the Ukraine and cessation of gas to Europe revived coal mining on Svalbard delayed close of mine for 3 years	But new economic activities, and ability to find viable energy alternatives remain substantive challenges	For alternative energy sources and wood pellets as alternative fuel imported from the continent		Is a region with few alternative energy sources due to seasonal darkness, harsh weather, and permafrost	Local community	Population changing with closure of coal mines & coal power plant, more dominated by seasonal workers and short-term residents	
	Frontier adventurous ideologies in fishing, coal, and tourism and research (both enabler/barrier)			Vulnerability of the coal industry to price fluctuations						
	Frontier adventurous ideologies in coal									
Scale of trigger of change	National	National	International	National	Regional		Regional	Regional	Regional	
	Regional									

State 2: Declining mainstream and development of low carbon system(s).

6. Poland: Silesia.

Regional cluster 2 "Growing On-Stream Narrative"	Poland: Silesia									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change- incumbents, others?)**	**10. Pace of transition pathway 10 years+ 5 years+ 1 years +**
1.1 Region 1 Description of the trigger for change	Coal as black gold to mainly clean coal technology & some green	Paris Agreement	War in Ukraine strengthen coal narrative by justifying the need to postpone the transition	Local economy collapse in coal-dependent municipalities This is a seen as a threat/barrier	Clean coal technologies (CCT)	Air pollution and smog alerts and increase air quality monitoring, educational campaigns, and local advocacy	Air pollution as pressure- health	NGO	Union, mining-related institutions This should be marked in red as they are indirectly affected by the transition	Slow 20 years +; hard coal mines should be closed by 2049
	From Industrial Silesia to Green Silesia: highlighting health and living conditions, sustainability, joint responsibility for climate change, and intergenerational justice	COP	War in Ukraine facilitates energy transition in households (strong increase in investment in heat pumps)	With current market instability, long investment cycle increases coal production with assumed long-term horizon for the coal phase-out. The long investment cycle in mining is holding back new investments in this sector.	Renewables: wind farms, biomass and biogas, heat pumps, regional hydrogen projects		Coal mining jobs tend to pay well – significantly more than agriculture or low-skilled services and similar jobs in the construction and manufacturing	Regional administration	Industry -related research	
	Coal consumption has decreased but still seen to provide energy security (self-sufficiency) and independence (also geopolitically)	EU Directive		New business models and growing demand for environmentally friendly solutions for new potential jobs and new supply chains in the region	Solid fuel stove replacements		The region faces labour supply shortages; Social Agreement with trade unions assumes employment of current workers in mines until retirement. But the transition will negatively affect jobs in the mining-related sectors (indirect/induced job reductions)	Business environment institutions. This should be marked in green as the business institutions support or would like to benefit from the transition.	Coal miners	
	Mainstream statement for a gradual and slow transition, maintaining hard coal exploitation and use in the gasification process and carbo-chemical installations	European Funds – Cohesion Fund (CF), the European Regional Development Fund (ERDF), and European Social Fund (ESF), Just Transition Territorial Plan		European hub of modern services and industries	EU funded large state-led companies to implement the most expensive projects,		Degraded post-industrial areas, and the relatively low pace of their reclamation remain pending challenges that require capital-intensive solutions	Labour market institutions.	Large state-led companies, including coal-fired power plants and mining companies. This should be marked in red as they are indirectly affected by the transition	
	Swifter abandonment of coal and creating national supply chains for industries that support the energy transition and a circular economy	2022 banned the use of old furnaces that don't meet EU emission standards		Regional authorities invest more in social services, transportation and R&D				Mining-related companies		
		Social negotiations and agreement between mining trade unions and the government on the transitioning of hard coal mining and Silesian Voivodeship (2021)						interdisciplinary research institutions		
								European Commission		
								international bodies (e.g. the World Bank		
Scale of trigger of change	Regional	Global	National	Regional	Regional		Local	Global	National	
	Local	EU						National	Regional	
		National						Regional	Local	

7. Spain: Balearic Islands.

Regional cluster 2 "Growing On-Stream Narrative"	Spain: Balearic Islands									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change- incumbents, others?)**	**10. Pace of transition pathway 10 years+ 5 years+ 1 years +**
1.1 Region 1 Description of the trigger for change	Tourism as the main economic activity (excessive dependency on the tourism paradigm as a way of survival)	Paris Agreement		Diversification of the economy (regenerative agriculture)	Construction of the electrical cable connecting with the mainland (2012)	Negative environmental consequences of tourism (water consumption and coastal damage)	Excessive road traffic in high season	Regional government as main instigator of the Climate Change and Energy Transition Act	Tourism industry and NGOs: windfarms and PVs could compromise the landscape for tourism	Medium 5 years +
	Balearic insularity identity (and even at each 4 islands level)	Regional Climate Change and Energy Transition Act (2019)		Decentralisation of the current energy system	Renewables: wind farms	Deep dependence on tourism and associated emissions from ports and airports can severely diminish/nullify the efforts at regional and local level to decarbonize the region	Conflicts related to land use reduce deployment of renewable energy	Insular authorities in the 4 islands, some of them favor and some oppose energy transition); left wing parties	Part of civil society opposed to the energy transition if it is not based on a decentralised and democratic model	
	Resistance identities outstanding opposition to the new decarbonisation paradigm	EU Directive		Mallorca as most degraded island due to aggressive touristic model that has built huge infrastructure without proper environmental impact assessment	Partial closure of a thermal plan in 2019		Excessive ratio of cars per capita, one of the highest in the EU	Energy communities, neighbour associations		
	Full energy transition towards renewable energy sources and a shift towards electric mobility.				Green hydrogen					
					Lack of charging electric stations and infrastructure deployment for electrification					
Scale of trigger of change	Regional	Global	Global	Regional	Regional		Local	Regional	Regional	
	Local	EU						Local	Local	
		Regional								

8. Czech Republic: Moravia-Silesia Region

Regional cluster 2 "Growing On-Stream Narrative"	Czech Republic: Moravian-Silesian Region									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change- incumbents, others?)**	**10. Pace of transition pathway 10 years+ 5 years+ 1 years +**
1.1 Region 1 Description of the trigger for change	Ostrava used to be called the "Steel Heart of the Republic": industrial and coal mining tradition and identity (partly the opinion persists that the region stands and falls with coal)	Tax revenues from coal mining contribute to state budget and regional/local development (jobs in coal mining and heavy industries)	War in Ukraine (→ energy crisis, increase of prices of fuels and electricity → pressures to continue in coal mining, and massive development of renewable technologies in residential sector	Cultural tourism (Ostrava city has aspired to become the European Capital of Culture)	ITC sector: third largest cluster of ITC industries in the country	Air contaminations originating from local industrial activities leading to major health issues	Strong population decline and aging through outmigration of young educated people	State decides on the continuation of mining or the closing of mines (the question is how long it will financially subsidize mining to keep the demand of local industrial companies and heating plants)	State-owned coal mining companies (OKD, DIAMO)	Slow around 32 years because the decline of coal mining and gradual closure began after the change of political regime in 1989
	Coal was regarded the national "black gold" and the "life blood" of a centrally controlled dominance of metallurgical and energy-intensive heavy industries	European Union Emissions Trading Scheme (EU ETS) - increase in the price of emission allowances for the industrial sector using coal	Develop connections to Poland (Silesia) and support cross-border cooperation (coordinated economic transformation)	Instead of economically inefficient local mining, importing cheaper hard coal for industry from abroad (USA, Australia, Canada)	Significant development of the manufacturing industry	high number of unused post-industrial sites (brownfields) that were recently abandoned	Negative labour market indicators: unemployment, low business activity, lack of job opportunities	State own mines should cease by end of 2022 (was moved to the end of 2023 now but probably will continue later due to energy crisis)	Unemployed miners	
	Coal has a future	Operational Programme "Just Transition" (2021-2027) - investments into coal regions		Economic profits from coal reserves for more investments in landscape reclamation and regeneration projects (continuing without mining, there will be no money for the regeneration of the landscape - argument of coal mining companies)		Environmental problems (air pollution) cannot be solved without concerted actions with Polish regions.	Vast majority of the jobs available are still for low-skilled and low-educated labour force		Trade unions	
	Coal is necessary to maintain the central heating system in large cities	RE:START National strategy of economic restructuring of the three Czech coal regions					Significant intra-regional differences (opening scissors between the urban center and border peripheries)		Electricity end users (increasing prices of electricity and heat due to shift from coal to natural gas and electricity heating)	
	Use of historical industrial heritage (preservation of mining complexes as cultural monuments) for tourism development	The New Green Savings Programme - subsidies for home energy efficiency (funded by revenues from European Union Allowance (EUA) and European Union Aviation Allowance (EUAA) units					A significant increase in support for populist parties and extremist movements			
Scale of trigger of change	Regional	Global	National	Regional	Regional		Local	National	Regional	
	Local	EU						Regional	Local	
		National								
		National								

9. Germany: Duisburg.

Regional cluster 2 "Growing On-Stream Narrative"	Germany: Duisburg									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change- incumbents, others?)**	**10. Pace of transition pathway Slow 10+ Medium 5+ Fast (1-2 yrs)**
1.1 Region 1 Description of the trigger for change	Coal and steel as the economic engines of the region - and guarantor for secure jobs and good wages importance beyond the region for electricity supply in Germany - but coal was no longer competitive	National phase out of subsidies for black coal (decided in 2007 to finalise 2018) The decision was not based on climate related concerns, rather than reducing subsidies/ burden of national and regional public budget	Coal crisis in the 1950s	Oil became cheaper	While share of renewables increased, it but did not influence the decision making	The local mine was closed due to concerns over further ground subsidience, which people in the light of the end of coal where no longer willing to accept	Slow but continuous reduction of the mining workforce - demographic shift in the region - loss of political power (e.g.g unions) and legitimacy	National and Bundesland-level policy makers	Local workforce	Very slow for the entire region (20 years +)
	Shifting to diversified economy (logistic hub and green steel)	Closure of local coal mine happened earlier (2008) decided by Bundesland due to public protests		Local mining / Ruhr coal lost international competitiveness	Share of renewable energy increased since 2000s slowly, but did not influence the decision making	In regards to steel production, climate concerns are increasing more recently	Local and regional development			
	International partnerships (city of Wuhan) - end of the silk road narrative - continuing the image of an industrial city	Coal compromise was also possible due to change of power at Bundesland level (SPD was replaced by CDU)		It was cheaper for electricity producers to buy coal from South America than domestic coal						
		EU's competitive directive								
Scale of trigger of change	Regional	National	Global	Global	National	Local	Regional	National	Local	
	Local	Bundesland		National		Bundesland		Bundesland		
		EU								

10. Bosnia & Herzegovina: Tuzla.

Regional cluster 2 "Growing On-Stream	Bosnia and Herzegovina: Tuzla									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change- incumbents, others?)**	**10. Pace of transition pathway 10 years+ 5 years+ 1 years +**
1.1 Region 1 Description of the trigger for change	Coal dominance in energy as strategic resource by gov't for energy security & independence and for the sake of the country's geopolitical stability	UN SDGs	Paris Agreement	European Union's (EU's) Carbon Border Adjustment Mechanism (CBAM), a tax on carbon dioxide for imported goods and electricity.	Energy sources like hydropower and wind power are options as coal fired plant reach end of life	Shift from underground to surface mining due to soil deterioration, topographic changes, and air and water pollution	Strike by coal miners demanding better working conditions & protection (National) and if granted would reinforce coal?	State-owned electric power generating and distribution companies	Coal miners losing jobs (National)	Around 20 years +
	One regional vision is to continue coal with CCS + gas	Green Agenda for the Western Balkans	Saw US' dependence on coal contribute to America's energy security & sovereignty	Next 5-10 years coal fired plants will reach the end of its life		Open pit mining is destroying land	Next 5-10 years coal fired plants will reach the end of its life-using coal is an option	Local private firm established for wood chip-fired heating plant since 2017	Locals communities	
	Regional level pushing for inclusive, decarbonisation and 'Black Gold" no longer needed for prosperity	National Energy Climate Plan (NECP)		Energy efficiency and the digitalization of the power grid are two positive outcomes of change that might stimulate economic expansion.		Air pollution from coal mines impacting health		Local engineering and construction companies carrying out project	Private firms, and engineering and construction companies	
	There is a need to achieve a just energy transition that benefits all citizens and for state owned energy companies to balance between needs of various interest groups and the general public	Energy Community Secretariat							2016 coal power station built by Chinese and financed by China Development Bank in collaboration with regional government collaboration	
		EU Energy Union							"Tuzla 7," a450 MW coal-fired unit, the largest post war investment in Bih (SEO) energy company a consortium with Chinese partners is stalled	
		Creating Energy Community-led regional electronic system for guarantees of origin for biofuels								
		Western Balkans Guarantee Facility								
Scale of trigger of change	National (fossil fuel dependent)	Global	International	Global	international	National	National	Regional	Regional	Regional transition
	Local/regional change to RE for heating	EU area		Local	Regional	Regional	Regional	Local	Local	
		National								
		Regional								

11. Austria: Upper Austria.

Regional cluster 2 "Growing On-Stream Narrative"	Austria: Upper Austria									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change-incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	The iron and steel industry has a very long history in Austria where manufacturing of iron products leads back to the 11th /12th century	Encourage cross-sectoral value chain: different industries need to collaborate to achieve radical emission reductions		(CBAM)Carbon Border Adjustment Mechanism	Green Hydrogen: shift from the conventional blast-furnace route to the hydrogen based direct reduction in the iron and steel sector; using green hydrogen for synthesis with industrial circularity		Good spatial location for industrial circularity (proximity of companies), companies in Austria need to be fore runners in technology developments and innovation	The Federation of Austrian Industry	Voestalpine (iron and steel producer), Lafarge (cement), Borealis (plastics and fertilizers) and OMV (mineral oil)	Medium around 8 years. Since the Paris Agreement and according EU policies the transition gained momentum.
	Cement and petrol chemical industry dating back to 19th century	Make funding available for pilot projects and markets for green basic material		Standards, quotas, CAPEX subsidies, public procurement, Carbon Contracts for Difference	Industrial Circularity		Well skilled labor and a strong know-how base	Research institutions		In the iron and steel industry first R&D projects started in 2016 and increased since then.
	High-carbon industries can decarbonize	European Green Deal, Fit-for-55 package, IPCEI		The establishment of markets for low-carbon products will be crucial signal e.g. customer's demand for low-carbon steel, cement etc. Can drive a change in the hard-to-abate industry sector	CO2 capture from iron and steel and cement industry; CCU is mainly discussed in Austria as CCS is prohibited at the moment.		Upper Austria more progressive (or less conservative) than Lower Austria. Climate plan very late in LA	NGOs and activists		The cement industry started lagged a few years, but from a technological perspective the transition in the cement industry is more difficult.
	"technologies to achieve decarbonization are already known"	Paris Agreement					Austria was rich in raw materials for cement production and therefore many more cement factories were built	City administration of Linz		
	Industry collaboration and the establishment of industrial clusters is becoming the new ideology	Austrian hydrogen strategy					Chemical sector a large employer account for more than half of the jobs and generate most of the production value			
		New Austrian renewable energy expansion law								
Scale of trigger of change	Regional	Global	National	EU	Regional		Local	National	Regional	
	Local	EU		National				Regional	Local	
	National	National/Regional		Regional						

12. Greece: Megalopolis.

Regional cluster 2 "Growing On-Stream Narrative"	Greece: Megalopolis									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change-incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Lignite offered stability and security in fuel supplies to the Greek energy system for decades	EU ETS, Industrial Emissions Directive and European Regulation on the electricity market (abolished subsidies to the lignite industry)	War in Ukraine	Increasing competitiveness of renewable electricity compared to lignite-generated electricity.	Electrification	Land restoration plays an important role in addressing unemployment during the first post-lignite phase	Unemployment	NGOs	Citizens: potential loss of jobs, (ii) increased electricity prices due to increasing natural gas prices, and (iii) potential lock-in to natural gas for residential heating.	Medium 5+ years
	Prosperity of the Megalopolis used to be largely reliant on the lignite power plants' operation	Just Transition Development Plan	Gas price spike questions gas as a transition fuel	Tourism development (e.g., an international motocross ring, rafting)	Natural gas as a transition fuel			National Gov't	Municipality of Megalopolis	"Megalopolis IV" lignite unit, will be withdrawn by 2025.
	100 MW of photovoltaics are already under construction in Megalopolis, and a total of 500 MW are planned for the region. The current planning foresees all the RES-generated energy will be injected to the grid.	Greek NECP 2019 and proposed updated of 2023 NECP		Alternative forms of agriculture	Renewables: constructions of 500MW of photovoltaic installations				Farmers	
	Local energy communities, energy efficiency, and electrification	Establishing a secure, concrete legal and licensing framework for RES		Optimization of road network, and the construction of a business park					Business supporting tourism	
	Development pillars for industry and trade, smart agriculture and sustainable tourism	"Energy Efficiency First" principle, the mitigation of households' energy poverty through energy upgrades		Reconstruction of museums and educational institutions					Industry, small industry, and trade	
		Developing energy communities while providing special tax exemptions, and relaxing spatial restrictions to attract foreign investments							Local energy communities	
Scale of trigger of change	Regional	European	Global	Regional	Local	Local				
		National		National	Regional	Regional				
		Regional								

13. Spain: Aragon-Teruel.

Regional cluster 2 "Growing On-Stream Narrative"	Spain: Aragon-Teruel									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change-incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Teruel is a "typical" carbon-intensive region. The Thermal Power Plant that functioned partially on local coal and imported coal	Just Transition Strategy: Just transition Agreement for Andorra-Mining Regions	Entry into EU and more stringent environmental plans	Higher environmental stringency increased costs	Substitution of the Thermal Power Plant electricity generation with large-scale RE projects (solar and wind)	CSO and NGOs fear possible negative impacts of large-scale energy projects on agriculture and ecosystems.	CSO & NGOs fear that the proliferation of large-scale projects in the region do not generate lasting job positions	Just Transition Institute (autonomous body of the Ministry for Ecological Transition and the Demographic Challenge	Coal power workers	Slow 15+ years
	Transition towards a new identity not yet well defined.	EU announced coal subsidies end by 2025		New alternative economic paths have emerged and are very present in the public debate	Green hydrogen projects		Cooling towers of the coal-fired power plant were demolished had a large emotional impact and a final farewell to a way of life around coal	Large energy operators	Women and groups with low access to the labour market (long)-term unemployed, people with disabilities or population at risk of exclusion	
	Feelings of nostalgia, resignation and sadness but with a growing hope as large-scale business investments begin	Urgent Action Plan responds to social, labour and economic effects of mine/thermal station closures		Diversify the economy with care activities, clay related industries e.g., ceramics or bioconstruction, ecological agriculture and livestock, water efficiency technologies, rural tourism			Pandemic and bureaucratic processes has postponed and jeopardised the implementation of new projects in the region	International investors	Trade Unions	
	Stakeholders have started to manifest a clear will to move forward in the debate and accept the irreversibility of the transition.						Decline of 20-25% of the population over past 25 years in the coalfields in Teruel, Aragón among others	Local companies	Business associations	
							Some inhabitants of the region feel abandoned by National gov't due to delayed post-coal Núdo Mudejar projects for new regional identity	Andorra city council	Local CSOs and NGO	
								Central gov't	Platforms protesting against wind and solar farm sprawl	
Scale of trigger of change	National	EU		Regional	Regional		Regional	International	Regional	
	Local	Regional						National	Local	
								Local		

State 3: Growing low carbon system(s).

14. Italy: Carloforte, Island of San Pietro.

Regional cluster 3	Italy: Carloforte, Island of San Pietro									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change-incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Change in economy (ongoing) reconversion of former steel workers and specialized navy officials, and dismantling of coal since 1970 toward small touristic sector as green tourism	Just Transition Fund (EU Level)		Market change with sailors connected to fossil fuel (1700s)	Renewable energy including wind farms (since 1993), solar PV (since 2000)	Limited acceptance of climate change	Tendency to emancipate from the national context and to be progressively autonomous+H117:J119	Carloforte municipaliy	Locals	Long 50 years+
	Positive depiction of community identity may act as a source of resistance for futher change	Public subsides for unemployment for former coal-miners		The tuna-fishery (1900s) entrepreneur		Forms of denial of pollution and risks with Portovesme industries (in front of Carloforte, in the Sulcis Industrial area)	Perceived agency: to think of oneself as an actor endowed with agency	Teachers	Businesses	
	"We are different from the Sulcis, we are green, we are cosmopolitan and sustainable entrepreneurs	Mediterranean's green island, mainly funded by EU projects and mainly tourist-oriented.		Micro-tourism (since 1970s			Able to position oneself through specific rhetoric ownership/dispossession)	Administrators	Tourist sector small owners	
	2007 promoted Carloforte as "Mediterranean's green island"			Communitarian ownership of sustainable technologies			Wind farms as spoiling scenary	Local intellectuals		
							Lack of acceptance for renewable energy	Tuna fishing companies		
Scale of trigger of change	Regional	Regional		Global	Regional	Regional	Regional	Regional	Regional	Regional transitions
				Regional			Local	Local	Local	

15. Czech Republic: South-Moravia Region

Regional cluster 3	Czech Republic: South-Moravian Region									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change-incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Coal mining took place in two districts in the past that have managed to transform economically and structurally relatively successfully over two decades	FDI: joint-ventures, takeovers or greenfields investments	War in Ukraine → energy crisis, increase of prices of fuels and electricity → pressures to continue in coal mining on one hand	Mining of hard coal ended in 1992 (Brno countryside district) and mining of lignite ended in 2009 - but extraction of oil and gas continues with more development	High-tech, universities and research centers, start-ups, creative hubs, etc.	Sucessfull regeneration and re-use of post-industrial sites and premises (brownfields)	High share of employment rate in the science and in management sectors and executive positions	Regional authorities	People living in peripheral districts of the region: increasing differences between regional capital and rural areas with continue in traditional energy industry	long 31 years
	Regional re-branding (not to build just on industrial legacy but on traditional culture, landscapes and tourism)	Eonomic diversification (do not rely on a few "mega-projects" and large employers: Bottom-up and small-scale approach is important)	War in Ukraine → energy crisis, increase of prices of fuels and electricity → potential for massive development of renewables in residential sector	Invest the money (EU funds, private money) for economic transformation meaningfully; Investments into tertiary sector and R&D	Has the highest installed capacity of solar energy (448 MW) in the country		Significant intra-regional differences (large contrasts between the Brno agglomeration and peripehral border districts)	Politicians prioritize landscape value and tourism over wind energy)		
	Although there is a high wind potential, the development is blocked by negative attitude of regional authorities		Convenient location near the capitals of Austria (Vienna) and Slovakia (Bratislava)	Investments into tertiary sector and education	The region has one of the highest realizable potential for wind energy development			Representatives of municipalities, local entrepreneurs, NGO		
					Emphasis on the support of nuclear energy at the expense of the of wind energy in the region ("we have nuclear power plant here and we do not need wind turbines")			FDI (Foreign direct investments)		
Scale of trigger of change	Regional	Global	National	Regional	Regional			National	Regional	Regional transition
	Local	EU						Regional	Local	
		National								

16. Norway: Lofoten.

Regional cluster 3	Norway: Lofoten									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change-incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Oil and gas revenues play a central role in Norway's economic prosperityand oil revenues fund an enormous sovereign wealth fund	Norway was the second country in the world to introduce a carbon tax in 1991, and has also committed to national carbon neutrality by 2030	Precarious situation in Europe emphasises need for Norwegian oil	The region is also a world class tourism destination and the hub: nature based tourism		Potential environmental risks associated with drilling activities	Opening new oil and gas would bring vitally to a region with declining and aging population due to low birth rates and young adult outmigration	People's Action for an Oil Free Lofoten, Vesterålen and Senja ("People's Action") – and fought against petroleum activities in the region for over a decade.	Local communities	50 years +
	"The Green Isles" can set into motion a new regional development trajectory that centers on decarbonization, electrification and circularity.	In 2001, the Norwegian parliament postponed the decision to open the areas and to extend a ban on drilling in the region one election cycle at a time		Some of the richest and most valuable fisheries in the North Atlantic Ocean				Mainly grassroots actors able to stop oil and gas development in the region is highly unusual given the significance of petroleum production to the Norwegian economy	Oil and gas sector	
	Lofoten assumes that hydrocarbon exploitation runs a high risk of spills and pollution that would be detrimental to tourism and coastal fisheries	In 2019 the Norwegian Labour Party announced that it was withdrawing support for drilling off the coast of the LoVeSe region		Oil price decline in 2014						
Scale of trigger of change	National	National	EU-internatinal			National	National	Local		Regional transition
						Regional				

17. Germany: Essen.

Regional cluster 3	Germany: Essen									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change-incumbents, others?)**	**10. Pace of transition pathway 10 years+ 5 years+ 1 years +**
1.1 Region 1 Description of the trigger for change	Coal and steel as the economic engines of the region - and guarantor for secure jobs and good wages importance beyond the region for electricy supply in Germany - but coal was no longer competitive	National phase out of subsidies for black coal (decided in 2007 to finalise 2018) The decision was not based on climate related concerns, but on reducing subsidies/ burden of national and regional public budget	Coal price crisis 1950s	Oil became cheaper	Share of renewable energy increased since 2000s slowly, but did not influence the decision making signficantly	Not in the process of the mine closure - was relatively early		RAG and Unions: decision to close local mine	Local workforce but to little extent because of relocations and early retirement opportunities	20+ years: very slow in the entire region
	Seeking for alternatives: International Building Exhibition and 10 year program initiated visioning process right at the time when the local mine closed	Local mine was already closed in 1986 for economic reasons in the process of further consolidating regional mining		Local mining / Ruhr coal lost international competitiveness		Concerns over ecological restoration and rehabilitation of former mining areas		Local government to introduce and promote cultural and green narrative of the city	Green city, opportunities for start ups and innovation economy	It was only 20 years after the local mine closed, that local government jumped actively on the sustainability/ green framing
	From industrial culture to green service economy: local closed mine became UNESCO world heritage in 2000 Focus on culture economy and shifting to new mainstream green economy in 2015			It was cheaper for electricity producers to buy coal from South America than domestic coal				Green narrative further pushed by local groups and citizens		
	Cultural and later environmental/ green narrative and framing of Essen as green city promoted by local government									
	Visioning of sustainable city/ region firstly introduced and publicly discussed in the (Ruhr region wide) International Building Exhibition Emscher Park 1989-1999									
Scale of trigger of change	National	National	Global	Global	Regional	Regional		Regional	Regional	Regional transition
	Regional	Regional		Regional				Local	Local	
	Local									

State 4: Reinforcing low carbon system(s).

18. Greenland: Denmark.

Regional cluster 4	Denmark: Greenland									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change-**	**10. Pace of transition pathway 10 years+ 5 years+**
Region 1 Description of the trigger for change	Economic autonomy Stabilized mainstream of hydropower plants which provide 60-70% of the country's public energy needs.and some development of renewables	Parliament of Greenland voted unanimously to implement the first hydropower plant at Utoqqarmiut Kangerluarsunnguani near the capital city Nuuk	Energy crisis in the Middle East	Corporate social responsibility	Some renewables	Report on environmental damage, toxic radioactive pollution and waste from Ukrainian mining raised	Societal: Negative human rights impact on society with uranium mining	National government	Indigenous communities opposing mining	Long (27 years)
	75% of total energy consumption for electricity and heat, both in public and private sector, is still depended on imported fossil fuel	Paris Agreement	Greenland left the EC And thus, the search for hydropower potentials declined during that period.	Good prices for rare minerals	Rather than pursuing oil and mining,the government is planning to establish more hydropower plants in other towns for civic use and possibly large-scale industrial projects such as aluminum smelters or big tech companies as an alternative to economic development			The Greenlandic politicians were interested in small-scale productions of hydropower to generate energy to citizens		
	Possibility of alternatives oil and uranium	E nergy plan from 1985 formulated by the (then) Home-Rule government guided the development of the energy infrastructure until 2012, which was used to implement five hydropower plants.						Government owns the national energy company, Nukissiorfiit A/S, that is tasked with developing the energy infrastructure in Greenland.		
	Local civilians opposing the narrative to a mining project in Kuannersuit,South region of Greenland that could destroy the ecosystem in the region if radioactive minerals were mishandled	In 2017, the Self-Rule government formulated an energy plan with a vague goal of increasing the utilization of renewable energy-systems "as much as possible" by 2030 (Naalakkersuisut, 2017)						Municipalities		
		Ban for uranium mining						local politician		
		Oil drill ban								
		Plan to increase hydrogen to decrease dependency on fossil fuel								
Scale of trigger of change	National	Global	Global	National?	National	Global	Local	National	Local	
	Regional	National						Regional		
	Private sector									

19. Bosnia & Herzegovina: Banja Luka.

Regional cluster 4	Bosnia and Herzegovina: Banja Luka									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change- incumbents, others?)**	**10. Pace of transition pathway 10 years+ 5 years+ 1 years +**
1.1 Region 1 Description of the trigger for change	Fossil fuel renewables and change and modernization is possible and life without coal-fired power plants is not a dream as seen in Banja Luka, a potential example for just transitions	2018 Banjaluka City Assembly set decision to entrust Toplane the heating company to commission futher heating plants	Use of crude oil leads significant energy loss during transmission and end-use. This causes the city to incur unsustainable debt	There has been an increase in the number of customers reconnecting to the heating network, and in the number of newly unconnected residential structures showing interest in joining to the district heating system.	Biomass plant built via knowledge and experience from America, as well as collaboration with other European institutions and universities (10 years)	Crude oil produced unnecessarily high amounts of greenhouse gas emissions.	Included to the lists of smart and green towns in the area and Europe	Locals living in Banja Luka pushed for change over 20 years to move from oil to RE. 80% of energy purchasers are homes, or residential customers	Business and households not yet connected to district heating	Around 50 years +
	National level high dependency on fossil fuel for district heating	A ten-year arrangement to acquire wood products from the state-owned forest management firm Sume Srpske ensures the project's financial stability and sustainability.		Using biomass, or wood chips, underutilized wood scrap ensures the project's long-term viability by lowering operating costs	Aims to automate the district heating network and achieve complete control over the quality of energy services by putting a premium on optimizing the distribution network	Biomass reduces enviromental damange		Local private firm established for wood chip-fired heating plant since 2017		
	Decarbonization pathway for Bosnia and Herzegovina is the uptake of renewables and other carbon-neutral heat sources in existing district heating systems (DHS), and can be a tremendous boom in the effort to decarbonize the heating and cooling industry	European Energy Community requirements, including: energy security, self-sustainability, and financial security			Absence of continual monitoring of energy flow and energy management, which led to frequent changes in service quality and substantial distribution losses					
Scale of trigger of change	National (fossil fuel dependent)	EU area	International	Regional	International	Global	EU area	Regional	Regional	Regional transition
	Local/regional change to RE for heating	Regional		Regional	EU area	Regional	Local	Local	Local	
		Local			Regional					

20. Application of JSETS framework to a region outside of this study.
"Regional cluster 1: No significant change Mexico: Baja California.

Regional cluster 1: No significant change	Mexico: Baja California									
Response to trigger for transitions	**1. Collective signalling of vision change - identity**	**2. Policy for change/reinforcement**	**3. Geopolitical power shifts -events**	**4. Market changes -privatisation -pricing - new markets**	**5. Technology changes -New tech - Add ons**	**6. Environmental triggers? Do they exist (Y/N)**	**7. Others**	**8 Actors triggering change (incumbents, others?)**	**9. Actors impacted by the triggering change- incumbents, others?)**	**10. Pace of transition pathway 10 years+ 5 years+ 1 years +**
1.1 Region 1 Description of the trigger for change	Community interest in off-grid renewable energy technology projects	No clear regional transition strategy to move away from natural gas	Paris Agreement of 2016	Perception of regulatory uncertainty for private energy companies	Plans to install more (natural gas) combined cycle power plants		The political decision-making structure is top-down and mainly centralized at the national level	National energy policy makers	Energy projects impact the social tissue in the surrounding communities	Around 7 years +
	Socio-political perception of stagnation in natural gas dependency (93% in 2019) for power generation	National Energy Transition Law		Energy market privatization in 2013 has had both positive and negative impacts	Expected increased dependency on imported natural gas			Regional manufacturing companies with plans for distributed generation projects with a maximum capacity of 500 kW		
		National FOTEASE fund for clean energy technologies			Lack of connection with the national grid has both positive and negative					
		Straightforward scheme for distributed solar generation below 500kW			Development the first large-scale renewable energy projects in the region					
					Decline of regional geothermal energy generation					
Scale of trigger of change	Regional	National	International	Regional	Regional	Regional	National	National	Regional	Regional transition
		International		National				Regional		

Appendix 2:. Review of the CCIRs' context

The first part of the Appendix 2, Table A, provides a synthetic view of the actors engaged in each case study across the nineteen regional case studies.

The second part the Appendix 2 provides a summary of the context, technologies, actors, ideologies and institutions as well as policies for the nineteen regional case studies. The overview of regions' descriptions was extracted from Martinez-Reyes, A., Chhetri, A., Lieu, J., 2022. Deliverable

5.2: Case study findings, Work package 5, H2020 TIPPING + project and complemented by additional elements from the regional case study reports. The authors of each regional case study and their institutions are listed after the region's name.

Table A. Documentation of actor engaged per case study.

Case study	Number of interviewees (Method of data collection via interview)	Profiles of interviewees	Primary data collection timeframe	Number of workshops	Profiles of workshop participants	Number of researchers per case study
1. Canada: Athabasca region, Alberta	13 (Source: TIPPING + Deliverable 5.2 and Athabasca case study report)	Representatives of local authorities, academia and energy industry, Indigenous community leaders, community staff from two different communities (FMFN and FM-Metis), community farmers interviews, elders.	2021–2023	2	Workshop 1: 2022, 39 participants: research project team, community members of Indigenous communities, the provincial government, non-Indigenous members in the energy sector, not-for-profit organisations and community-based farmers. Workshop 2: 2023, 90 participants: actors from energy sector, not for profit, private citizens, academics, university students, community farmers.	2
2.Indonesia: Banten & Bali	40 (Source: TIPPING + mid-term technical report and Banten and Bali case study report)	Representatives of governmental agencies, NGOs, local and regional, authorities, national and local experts, local communities, coal industry, solar energy providers.	2020–2023	3	Workshop 1: 2022, 76 participants: representatives of governmental agencies, business sectors, universities, NGOs. Workshop 2: 2022, 99 participants: local and regional, authorities, national and local experts, local community representatives, coal industry and clean energy representatives. Workshop 3: 2023, 133 participants: key agents in deploying clean energy (solar), local community representatives.	6
3. Italy: Sulcis	27 (Source: TIPPING + mid-term technical report and Sulcis case study report)	Key regional actors and informants representing heterogeneous perspectives and interest groups: 8 political representatives and public officers operating at different scales (municipality, province, region), 4 experts in energy planning, mining, environmental health and social research, 5 workers from industry and trade unions' representatives, 2 journalists, 6 representatives of environmental NGOs and local movements, 2 representatives from firms operating in the environmental and energy field.	2021–2023	2	Workshop 1: January 2022, 7 participants: 2 from research project team and 5 local and regional actors: mayor, local expert, trade union representative, 2 unemployed persons. Workshop 2: October 2022, 10 participants: 2 from research project team and 8 local and regional actors: local authorities, local experts, trade unions, citizens. Workshop 3: June 2023, 30 participants: national and regional actors.	3
4. Romania: Jiu Valley	12 (Source: TIPPING + Deliverable 5.2, Jiu Valley case study report, Robert Udrea's PhD dissertation)	Local and national government officials, academics from Petroşani University, citizens including mining retirees, chief engineer of Livezeni mine, electromechanical engineers, maintenance electricians, chief mechanic at mining company, head of the topography department, mayor of Petroşani, mayor of Uricani, mayor of Petrila, special administrator of the Hunedoara Energy Complex, director of the Dramatic Theater Petroşani.	2021–2023	2	Workshop 1: February 2022, 30 participants: researchers, civil society representatives, students, local authorities, miner associations. Workshop 2: April 2023, 50 participants: students, policymakers, academics, local community of Jiu Valley (citizens including mining retirees), representatives of mining companies.	3
5. Norway: Svalbard	10 (Source: TIPPING + Deliverable 5.2 and Svalbard case study report)	Representatives from businesses, investment and finance institutions, mining company workers and owners, technology providers, national, regional and local government, volunteer organizations, residents from Longyearbyen, Svalbard.	2021–2023	2	Workshop 1: 2022, 10 participants: Svalbard community representatives, local authorities. Workshop 2: 2023, 50 participants: newly elected Community Council Leader, leader of Visit Svalbard, journalist based in Longyearbyen, tourism industry representatives, researchers, teachers, trade service providers, logistics providers located in Longyearbyen and Tromsø.	3
6. Poland: Silesia	22 (Source: TIPPING + mid-term technical	Representatives from labour market institutions, trade unions, economic self-governments, miners, NGOs,	2020–2022	3	Workshop 1 + 7 consultation seminars in each subregion devoted to the Territorial Just Transition	6

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Case study	Number of interviewees (Method of data collection via interview)	Profiles of interviewees	Primary data collection timeframe	Number of workshops	Profiles of workshop participants	Number of researchers per case study
	report and Silesia case study report)	mining municipalities, regional authorities, business and environment institutions.			Plan draft, April 2021, 449 participants in total: public, private, and NGO sector representatives. Workshop 2: October 2022, "From the Grassroots to Policy and Back: Putting Just Transition to Practice", conducted with the Research Centre for Public Policy and Regulatory Governance at University of Silesia, Katowice, 50 participants: coal transition research community members. Workshop 3: September 2023, conducted with the Liberté! Foundation, 50 participants: journalists, local politicians, representatives of social and climate movements, NGOs, companies.	
7. Spain: Balearic Islands	15 (Source: TIPPING + Deliverable 5.2 and Balearic Islands case study report)	Managers of national electricity company, political representatives of Balearic Island municipalities, energy economics researchers, local representatives from two national trade unions, representatives of the energy department of the regional government, representatives of the national government.	2021–2023	2	Workshop 1: June 2021, 10 participants: representatives from a national electricity company, Balearic government, insular council, environmental NGOs, local transport company, federation of business associations. Workshop 2: June 2022, 14 participants: representatives from national electricity company, Balearic government, insular council, environmental NGOs, local transport company, 2 researchers/ experts in climate policy, economics and representatives from a business association.	3
8. Czech Republic: Moravia-Silesia	11 (Source: TIPPING + mid-term technical report and Moravian-Silesian region case study report)	Experts from academia, miners, representatives of mining unions, large state-owned companies, NGOs, regional politicians.	2021–2023	2	Workshop 1: September 2021, 13 participants: experts from academia, representatives of NGOs, regional politicians, energy companies. Workshop 2: March 2023, 15 participants: experts from academia, representatives of NGOs, regional politicians, energy companies.	4
9. Germany: Duisburg	10 (Source: TIPPING + Deliverable 5.2 and Duisburg case study report)	Representatives from regional and local governance authorities, local NGOs, local labour unions, local companies, university, media.	2021–2023	2	Workshop 1: October 2020, 100 participants: representatives from academia and civil society. Workshop 2: November 2021, conducted with Emscher Genossenschaft, 18 participants: representatives from civil society, local government, businesses and NGOs.	2
10. Bosnia & Herzegovina: Tuzla	7 (Source: TIPPING + Deliverable 5.2 and Bosnia & Herzegovina case study report)	Mayors from local municipalities, representatives from local communities, NGOs, consultants, energy companies, Ministry of Foreign Trade and Economic Relations (MOFTER), Federal Ministry of Energy, Mining and Industry (FMERI), mining company, chambers of economy/commerce, regional development agency.	2021–2023	2	Workshop 1: 2021, 9 participants: regional authorities, local communities, NGOs. Workshop 2: 2022, 15 participants: representatives of coal mining companies, mayors from local municipalities, representatives from local communities, NGOs, consultants, energy companies, Ministry of Foreign Trade and Economic Relations (MOFTER), Federal Ministry of Energy, Mining and Industry (FMERI), mining company, chambers of economy/ commerce, regional development agency.	3
11. Austria: Upper Austria	7 (Source: TIPPING + Deliverable 5.2 and	Experts from academia, representatives from industrial clusters, cement industry, carbon	2020–2022	3	Workshop 1: September 2020, 11 participants: representatives from basic material companies including	3

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Case study	Number of interviewees (Method of data collection via interview)	Profiles of interviewees	Primary data collection timeframe	Number of workshops	Profiles of workshop participants	Number of researchers per case study
	Upper Austria case study report)	capture and use or sequestration (CCU/S) technologies companies.			the chemical industry, iron and steel industry, gas storage company, electricity company, researchers from the University of Graz and Johannes-Kepler University Linz. Workshop 2: September 2020, 12 participants: actor from energy-intensive industry. Series of online "café" from July 2020 to September 2021 with the same 12 actors from energy-intensive industry. Workshop 3: November 2022, 40 participants: representatives from business, public affairs, policymakers, administration, NGOs, research from different sectors (industry, building, mobility, energy, finance).	
12. Greece: Megalopolis	12 (Source: TIPPING + Deliverable 5.2 and Megalopolis case study report)	Representatives of energy industry, regional and local authorities, regulatory authority of energy, electricity utilities, engineering association.	2021–2023	2	Workshop 1: 2022, 26 participants: representatives of the government, local authorities, regulatory authority of energy, electricity utilities, think tanks, consultants, the scientific community and engineering associations. Workshop 2: May 2023, 12 participants: "Megalopolis: Grey transition or a new Green brand?", energy industry representatives, policy makers, non-governmental organisations active in the region, academia, and regional authorities.	5
13. Spain: Teruel	11 (Source: TIPPING + Deliverable 5.2 and Teruel case study report)	Manager of national electricity company, political representatives of Andorra municipalities, trade unions, regional government, representatives of local communities, business and cultural associations.	2021–2022	2	Workshop 1: June 2021, 10 participants: representatives of the main actors in the Teruel mining basin regions: national electricity company, two trade unions, local government, an environmental NGO, a rural development association, one researcher. Workshop 2: June 2022, 20 participants: 2 representatives from national trade unions, municipal and supra-municipal governments, national government, business and cultural associations (including coal and mining heritage museums), 2 environmental associations, a rural development association, and representatives from academia.	3
14. Italy: Carloforte	32 (Source: TIPPING + Deliverable 5.2 and Carloforte case study report)	Politicians and public officers operating at different scales (municipality, province, region), experts from energy planning, mining, environmental, health or social research, workers from industry, trade unions' representatives, journalists, representatives of environmental NGOs, local activists, and firms operating in the environmental and energy sector.	2021–2023	2	Workshop 1: 2022, 4 participants: local authorities, experts from energy sector. Workshop 2: 2022, 8 participants: local authorities, local politicians, local experts, citizens.	3
15. Czech Republic: South-Moravia	11 (Source: TIPPING + mid-term technical report and South-Moravian region case study report)	Experts from academia, miners, representatives of mining unions, large state-owned companies, NGOs, regional politicians.	2021–2023	2	Workshop 1: September 2021, 13 participants: experts from academia, representatives of NGOs, regional politicians, energy companies. Workshop 2: March 2023, 15 participants: experts from academia, representatives of NGOs, regional politicians, energy companies.	4

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Case study	Number of interviewees (Method of data collection via interview)	Profiles of interviewees	Primary data collection timeframe	Number of workshops	Profiles of workshop participants	Number of researchers per case study
16. Norway: Lofoten	12 (Source: TIPPING + Deliverable 5.2 and Lofoten case study report)	Political leaders from Lofoten in office and in opposition, environmental organizations, grassroots activists, industry representatives.	2021–2023	2	Workshop 1: October 2022, conducted in Leknes, Lofoten together with the Regional Council, 20 participants: Regional Counci members, 6 mayors from Lofoten municipalities, opposition leaders, Municipal Directors, supporting staff. Workshop 2: February 2023, conducted in Svolvær, Lofoten, 15 participants: Lofoten municipalities policy makers, private sector managers, Lofoten citizens.	2
17. Germany: Essen	10 (Source: TIPPING + mid-term technical report and Essen case study report)	Representatives from regional and local governance authorities, local NGOs, local labour unions, local companies, university, media.	2021–2023	2	Workshop 1: October 2020, 100 participants: representatives from academia and civil society. Workshop 2: November 2021, conducted with Emscher Genossenschaft, 18 participants: representatives from civil society, local government, businesses and NGOs.	2
18. Denmark: Greenland	11 (Source: TIPPING + Deliverable 5.2 and Greenland case study report)	Project manager Department of Housing, District Manager at Nukissiorfiit, Team Leader at Nukissiorfiit, Technician at INI, Committee Chairman for the Area of Technology and Environment in Qeqqata municipality, schoolteacher in Nalunnguarfiup Atuarfia, construction manager for the Area of Technology and Environment in Qeqqata Municipality, Enterprise manager at Permagreen, self-employed entrepreneur with a focus on energy, Naalakkersuisoq for Agriculture, Self-sufficiency, Energy and Environment, Naalakkersuisoq for Housing, Infrastructure, Raw Materials, Justice, and Equality.	2020–2022	2	Workshop 1: November 2021, "Towards a fossil free future in Greenland", 12 participants: national politicians, municipal politicians, planners of heat supply: November 2022. central institutional actors from the heating sector, national energy company, Nukissiorfiit. Workshop 2: November 2022, conducted in collaboration with the Greenland Science Week organised by the Arctic Hub in Nuuk and the University of Greenland: representatives from local governance authorities, local NGOs, public in Greenland.	2
19. Bosnia & Herzegovina: Banja Luka	5 (Source: TIPPING + Deliverable 5.2 and Bosnia & Herzegovina case study report)	Representatives from woody biomass company, local communities, NGOs, consultants, Ministry of Energy and Mining of Republika Srpska (MER), chambers of economy/commerce.	2021–2023	2	Workshop 1: April 2022, conducted in collaboration with the Energy Summit of Bosnia and Herzegovina focused on coal phase-out and shift towards renewables, 50 participants: representatives of energy institutions in Republika Srpska, regional authorities, representatives from woody biomass company, local communities, NGOs, consultants, Ministry of Energy and Mining of Republika Srpska (MER), chambers of economy/commerce.	3

Summary of the context, technologies, actors, ideologies, institutions and policies for the nineteen regional case studies.

State 1 regions: High carbon mainstream with no significant change.

1. Banten and Bali, Indonesia.

Authors: Cynthia Ismail, J. David Tàbara, Takeshi Takama, David S. Pujol.

Institutions: Sustainability and Resilience, Bali, Indonesia, Global Climate Forum, Germany.

Context.

As formal regions, Banten and Bali Provinces have well defined boundaries. Each province is led by a governor. Banten province covers 9,662 km2 at the most western part of Java Island with its capital Serang City, consisting of 4 regencies and 4 municipalities. Banten is relatively young, the expansion of West Java Province started in 2000. The autonomy of the province was decided from the belief of local people that their land was the only area not conquered during Dutch colonialism. Banten people feel special about this history, and they had been fighting to be a province since Independence Day in 1945. Bali Province covers 5,780 km2 encompassing eight regencies and one municipality and is the leading tourist island in Indonesia. Religion plays a significant role in defining social norms and values among Balinese people. Hinduism and Sanskrit values influence the social attitudes of the Balinese people.

Technologies.

To maintain economic growth, fossil fuels (e.g., coal, oil and gas) are the main primary energy source of Indonesia, for instance around 50 %

electricity came from coal in 2019, followed by gas and oil, respectively. The electricity demand of Banten Province is mainly supplied by coal power plants (approximately 19 units owned by PLN and IPP), the region with the most coal power plants installed in the country. These coal power plants are also the backbone of the Java-Bali connection (JAMALI grid); around 50 % of the electricity generation is distributed to the grid, especially in western Java in addition to maintaining the reliability of the Java-Bali network. Although Banten's economy is notably driven by manufacturing industries, it has the oldest and highest coal power generation in the country and its electricity supply accounts for about 20 % of the JAMALI grid. Like Banten, Bali has seven power generation plants that are fossil fuel-based (i.e. coal, gas, and oil). Bali has had only one coal power plant built since 2015. Since the energy demand is higher than its energy supply, the region is interconnected with the Java grid, mainly from East Java. The energy demand mainly comes from tourism and agricultural activities.

Actors, ideologies and institutions.

Current mainstream narrative around fossil-fuel is driven mainly by actors in policy and technological context in which the fossil-based technology operates. At policy level, the sector is governed by the Ministry of National Development Planning (Bappenas), and the Ministry of Energy and Mineral Resources (MEMR) at national level. On the other hand, the MEMR is represented in each province, known as Dinas Energi dan Sumber Daya Mineral/ESDM or the Agency of Energy and Mineral Resources. For instance, affairs related to the energy sector in Banten are coordinated by the Energy and Mineral Resource Agency (ESDM-Banten) in collaboration with the district and the village government. The situation is the same in Bali, i.e., ESDM-Bali.

Policies.

Current energy policies allow high growth of fossil fuels that aim for 100 % electrification of the country; hence the constructions of new coal and gas power plants are expected to continue for at least twenty more years. The national energy policy, Government Regulation No. 79/2014, indicates that energy consumption should enhance energy conservation, minimise the use of oil, maximise renewable use, optimise the use of gas and be secured by coal. This implies that coal still has a perennial position in the country's electricity system. Furthermore, the PLN's electricity supply business plan 2019–2028 envisages that 54.4 % electricity generation will come from coal in 2028 (8 % reduction compared to 2019). Recently, the PLN updated its electricity supply business plan (RUPTL) for 2021–2030 with a renewable mix by 2030 of 51.6 %, compared to 48 % fossil fuel. This is an anticipated intervention by some stakeholders to demonstrate PLN's commitment to diversifying the country's electricity system, including Banten and Bali Provinces.

2. Athabasca Region, Alberta, Canada.

Authors: Chelsey Greene and Luis D. Virla.

Institution: University of Calgary.

Context.

Historically, the governments of Canada and Alberta have made numerous commitments (e.g., Rio de Janeiro Earth Summit in 1992, Kyoto Protocol in 1998, Government of Canada Action Plan on Climate Change commits in 2000, Kyoto Protocol Implementation Act in 2007, the Paris Accord in 2015 and efforts through investment in carbon emissions reduction technologies (e.g., carbon capture and storage). However, Alberta's economic dependence on and cultural identity associated with the oil, gas and coal mining industry sectors has embedded significant resistance towards alternative clean-energy transitions (renewable technologies). For example, in 2021, oilsands alone paid the Alberta government over $11 million in royalties.

Technologies.

The energy sector is heavily dominated by oil, gas and chemical production. These sectors are mostly located in the Oil Sands region (Lower-Athabasca) as well as in the industrial heartland near Edmonton. These sectors have become prominent during 1960–1980 s following heavy investment from federal and provincial governments to develop the Alberta Oil Sands. Current proposals involve leveraging existing production and carbon capture and underground storage (CCUS) infrastructure to export hydrogen. Carbon capture and storage and hydrogen technology providers are predominantly the same large engineering firms traditionally involved in the fossil fuel energy sector. However, some of these areas are newer and pushed by client demand and driven by local policy. Hydrogen fuel has the potential to be less carbon intensive depending on the energy used for the electrolysis processes to produce it. Natural gas-based hydrogen fuel production would be considered mainstream while renewables-based electricity would be considered green hydrogen. Currently innovation and technology investments are mainly in the mainstream.

Actors, ideologies and institutions.

Dominant actor groups include industry and government, which are mostly led by Caucasian men. These actors are mainly located in urban areas such as Calgary, Edmonton and Fort McMurray. They have been traditionally dominant since the colonization of the territory by the British crown. Major colonizer/settler population in the region can be dated back to late 1800 s, linked to finding of gold and the construction of the railways across the country.

Policies.

Dominant policies in this sector cover resource extraction, export, and royalty frameworks. In parallel, environmental policies for land, water, and ecosystem protection are in place. However, it is Alberta's jurisdiction to oversee resource extraction and environmental protection while handling public pressure from demand for economic development. Therefore, the economic benefit has been dominant over considering negative environmental impacts. These policies cover the whole province. The federal government has limited influence in these matters unless they involve cross-province or international trading. More recently, federal policies around climate and GHG emissions reductions have required Alberta to develop its own policies or be subject to implement the federal ones. Specific frameworks for land, water, and resource management are in place for the region and the province.

3. Sulcis, Sardinia, Italy.

Authors: Fulvio Biddau and Mauro Sarrica.

Institution: Sapienza Universita di Roma.

Context.

Sulcis region (or Sulcis-Iglesiente area) is a territory in the southwest of Sardinia, one of the twenty administrative regions and two main islands in Italy. It is composed of two geographical areas, the Sulcis Mountains in the inner and upper part, and the coast. Sardinia is a historical mining region, with a millennial activity of metal extraction, and the only remaining coal region in Italy.

Technologies.

In the national landscape, Sulcis and the broader Sardinia region are emblematic case studies for what concerns phase-out and decarbonization policies. Indeed, while having abundant potential in renewable energy (i.e., sun radiation, wind, wave motions), the Sardinia region is highly

dependent on coal for energy generation (70 %). Moreover, it lacks the basic infrastructure for natural gas, making the phase-out of coal difficult.

The territorial development of Sulcis has been characterized by extractive activities of metals (mainly non-ferrous metals) and coal, coal being developed in the 19th century and increasingly during the first world war and the fascist period. Carbonia, which means "coal city", is one of the two main urban centres of Sulcis (Carbonia and Iglesias). It was founded during the fascist period to become the Italian energy capital due to its coal reserves. Consequently, the region was affected by intense immigration, attracting workers from 73 Italian provinces, which led to an increase in resident population that passed from 78.000 to 137.000 inhabitants in 15 years over 1936–1951.

Actors, ideologies and institutions.

The main ideology depicts locals as waiting for something to happen from the outside: i.e., tourists will come, investors will come, jobs will be created, the State and Region must solve the problems, etc. This implies a deficit of engagement and passive view of the population as subject to decisions taken elsewhere, external economic investments and control over local resources. In this view, new jobs are mainly brought from the outside with no sense of ownership or agency for the local population. Whereas the value of tourism is recognised, without local ownership and agency, it condemns Sardinia and Sulcis to be a space suitable only for the aesthetic enjoyment by the inhabitants of the "continent" (i.e. Italy), for agriculture and small commerce.

Policies.

Portovesme industrial district located in Portoscuso is the epicentre of the industrial crisis of Sulcis-Iglesiente and it affects the whole region. This area is the most exposed to top-down coal phase-out and decarbonization policies (EU-level and national level) and their related impacts. Sulcis is involved in the Just Transition Mechanism and eligible for the Just Transition Fund, considering its high dependence on mining and carbon-intensive industries. Recent policies are in place or planned: Sulcis Plan, Methanization plan, Sardinian Environmental and Energy Plan, the Strategic Provincial Plan. Several assessments and studies have been developed by various groups (e.g., Dossier of Sulcis-Iglesiente Crisis; Sardinia Island Zero CO2 – phase-out 2025; Socio-economic assessment of renewable scenario for Sardinia). Moreover, ENEL, the main national electricity company is pushing forward the "Green electrification" project for Sardinia (cf. Multi-Actors Energy Compact UN), and the national government proposing Sardinia as the energy model and Italian green laboratory for energy transition in its PNRR – Recovery plan.

4. Svalbard Archipelago, Norway.

Authors: Siri Veland, Leticia Nogueira, Vida Steiro.

Institution: Nordland Research Institute.

Context.

Svalbard is an Arctic archipelago governed by Norway under the Svalbard Treaty of 1920. The Lokalstyre is the local government body, while the Sysselmester is the state government representative. Many residents do not have voting rights as these are only granted to Norwegian citizens and those residing more than 2 years. The region is above the Arctic Circle and its economy is dominated by tourism and research that link the archipelago to Tromsø and Norway. The city of Longyearbyen is a hub for cruises and expeditions to natural areas across the islands and coast. Its Arctic location, permafrost, and lack of connection to external power grids places limits on renewable energy alternatives.

Svalbard is a region that has been dominated by explorers, adventurers, and miners. Mining has been phased over previous decades, excepting one mine in Longyerabyen and another in the Russian town of Barentsburg, the allure of exploration and adventure continues to draw tourists and researchers to the Archipelago.

Technologies.

The dominant technological sectors in the region have been coal power electricity generation and coal mining. These technological sectors have been located on Svalbard near Longyearbyen. Mining has occurred in eight locations through Norwegian companies, with only one remaining open at Gruve 7 in 2022. In addition, A Russian mine is also operated in Barentsburg, but it is planned for closure.

Actors, ideologies and institutions.

While fishers and seal and whale hunters have been a standing actor group for centuries, today local mining company workers, Norway government and local government representatives in Longyearbyen, explorers, researchers, mall tourism businesses, are the main actors. Tourism companies are, apart from large cruise ships, owned by businesses located on the mainland. The University Center in Svalbard, connected to the University of Tromsø, hosts numerous researchers.

The ideologies in the region have shifted with the dominance of fishing, coal, tourism and research. Along frontier adventurous ideologies that has driven explorers, fishers, researchers, and other visitors to this remote and extreme environment, nation-building for Norway to retain sovereignty over the archipelago and surrounding seas has been present. One might also consider as an ideology the present push to cease coal mining despite lack of viable alternatives. That is, the move to cease coal is a symbolic gesture motivated by ideology more than practicality.

The archipelago is governed by the Svalbard Sysselmann, who is appointed by the Norwegian State. There is a local election for the Lokalstyre, in which only Norwegian citizens and those who have lived on Svalbard for 3 years can participate. In 2019, 1827 persons were eligible to vote, and the dominant parties are the same as those on mainland Norway: The Labor Party has been leading, while the new party The Greens have joined in recent years. The relevant institutions and administrative levels are the Lokalstyre who are responsible for the local government, Sysselmannen who administers the archipelago, the national government to which the Sysselmann is answerable, as well as to the Tromsø judiciary branch, located on Northern mainland Norway.

Policies.

Svalbard has been a Norwegian territory under the Svalbard treaty (1920) where all signatories are allowed to enter economic activity. Norway and Russia are both engaged in coal mining, and China and numerous other nations are also involved in research. The main policy has been Svalbard to be a non-lifecycle community, meaning that people cannot be born or die there.

5. Jiu Valley, Romania.

Authors: Andrei Țăranu, Arpad Todor and Robert Udrea.

Institution: National University of Political Studies and Public Administration

Context.

The Jiu Valley region in Romania goes across several administrative areas and has over 160 years of history of coal mining. The region is part of Hunedoara County. Jiu Valley emerged through the initiation of mining activities and the expansion of the mining industry throughout the Jiu Valley since the middle of the 18th century. The local population consists of both Romanians, momârlani, local natives who existed in the region before the development of mining, and a population of workers of other nationalities brought from other mining regions to work in the Jiu Valley. The region is surrounded east and west by the Jiu river and is located in a deep depression, between the Retezat mountains to the west and northwest and the Parâng

and Vâlcan mountains to the south.

The Jiu Valley faces severe socio-economic problems compared to other regions in Romania. It has been undergoing a series of sudden, severe, and unplanned layoffs since the mid-1990 s, which led to an increase in unemployment rate to a record high in Romania. Most of the mines have been closed without long-term planning. Currently, two small capacity mines still run and there are about 4,000 miners left, including both underground miners and workers in the mining industry.

Technologies.

The dominant sector in Jiu Valley was/is coal mining, i.e., pit coal. The Jiu Valley is a traditional coal-mining region with mining activities dating back over 160 years. Hunedoara Energy Complex, the company that owns the mining operations in the Jiu Valley, is insolvent since 2019 and is supported by the government through subsidies.

Actors, ideologies and institutions.

The dominant institutions in the Jiu Valley are the town halls of the component cities of the Jiu Valley, but also the Hunedoara County Council, overseeing the Hunedoara Energy Complex. A Jiu Valley National Society for Mine Closure was established to take over the closing mining units. The University of Petroșani, focused on mining and geology, needs to shift focus considering the much lower labour demand in the sector. Civil society organisations are quite active in the region. For example, the Planeta Petrila Association, founded in 2016, sought to transform the city of Petrila into a creative hub.

While no specific political party was powerful in the region, recently the AUR, a new party with a populist, nationalist, homophobic, anti-system, anti-Covid, pro-orthodox, anti-western discourse gained traction as it supports miners.

Policies.

The shutting down process of mining units was initiated and developed for the mines production units with shrinking deposits, hard geological conditions and high production costs based on a 1998 law. Emergency and financial support was provided to the Jiu Valley residents via several laws adopted over a decade. National and regional strategies and plans have been elaborated for the development of Jiu Valley: at the national level, the Strategy for the economic, social, and environmental development of the Jiu Valley (2021–2030), Romania Mining Strategy 2017–2035, Integrated National Plan for Energy and Climate Change 2021–2030, Romania Energy Strategy 2019–2030 while at the regional and local level, the Western Region Regional Development Strategy 2014–2020, the Plan for Regional Development 2014–2020 for Hunedoara County, the Local Development Strategy for the Jiu Valley region.

State 2: Declining mainstream and development of low-carbon system(s)

6. Upper Silesia, Poland.

Authors: Joanna Mazurkiewicz, Jan Frankowski, Jakub Sokołowski.

Institution: Institute for Structural Research.

Context.

Upper Silesia is the most urbanized and the second most populous region in Poland. It covers an area of 12,333 km2 (nearly 4 % of the country's territory) and is inhabited by 4.5 million people (nearly 12 % of the Polish population). Most of the inhabitants (76,5%) live in the cities, and the region has the highest population density in the country (368 people per km2, compared to the national average of 123). The centre of the area is the Katowice conurbation developed around mining and other traditional industry branches. Upper Silesia belongs to the country's most developed regions, ranked fourth in terms of GDP per capita (2019). The region has a strong industrial identity, with 41 % of value added generated by industry and construction. The share of domestic export is also the largest (14.5 %), with the crucial role of the automotive sector. The most developed regional industries are manufacturing (metallurgy, automotive, engineering, chemical, building materials and textile), mining and power industries. However, the GDP value increases slower than the national average, indicating that Upper Silesia has been losing its strong economic position. As Upper Silesia concentrates 90 % of domestic hard coal extraction and the vast majority (89 %) of total employment in coal mining, the decline of coal production in the region is one of the core components of the decarbonization process in Poland. Although the timelines for coal mines closure and the safety nets for the miners were set during the signed agreement between the government, coal companies and trade unions in 2021, a high level of controversy over the pace and timelines of coal phase-out still exists as of 2022. Ongoing energy transition raises questions about how different actors and communities experience this process. The benefits and costs of coal phase-out are discussed within the framework of fairness, which focuses mainly on mitigating negative economic and social consequences of structural changes in the energy system and ensuring those impacted by energy transitions have a say in decision-making processes.

Technologies.

The main technology is coal extraction and processing, considering its importance in national energy security. Although final consumption of coal in Poland decreased by over 46 % between 1991 and 2020, Poland remains highly dependent on domestically produced fuel. Coal-fired power plants account for about 70 % of electricity and heat production. Besides coal, no other significant fossil fuels are produced in Poland and used in the energy sector.

Actors, ideologies and institutions.

Main actors are the groups directly affected by the energy transition: coal and mining-related companies and their employees, trade unions, and municipalities heavily dependent on coal. Matters related to energy security also reflect the government's position. Actors' positions are influenced by the coal transition happening with varying intensity since the beginning of the 1990 s. These experiences still resonate in Upper Silesia and have served as a background for transition narratives and affect public discussion about the pace of the coal phase-out. The role of coal as a guarantee of energy security changed with the gradual decrease in the share of coal in the energy mix. Along with the development of new technologies, coal-fired power plants are seen as a buffer for variable production from renewable sources and a guarantee of the stable and uninterrupted operation of the energy system. Coal is perceived as the backbone of energy generation in Poland and a fuel which secures national energy supplies. The war in Ukraine only served to strengthen this view by justifying the need to postpone the transition.

Policies.

Since 1989, many policy interventions have stimulated transformation processes in Upper Silesia. Prior to Poland's accession to the EU, the primary interventions came from limited state funds, pre-accession funds (e.g. PHARE, ISPA), and development assistance (e.g. World Bank grants). After joining the EU, the dominant financial resources to support regional development came from the European Funds – Cohesion Fund (CF), the

European Regional Development Fund (ERDF), and European Social Fund (ESF). EU funds provided a substantial investment boost and promoted good governance, long-term strategic thinking, actor partnerships and multi-level cooperation. Since 2007, regional authorities have developed operational programmes to conduct partly independent regional policy.

7. Balearic Islands, Spain

Authors: Francesc Cots, Cristina Costa, Gerard Codina, and Jérémie Fosse.

Institution: eco-union

Context.

The Balearic region is characterized by its insularity. It is physically, socially and politically organized in four islands: Mallorca, Menorca, Ibiza and Formentera. Each of the islands have their own local administration (consell insular) while they are all under the same regional government (Govern Illes Balears) located in Mallorca. They all share two co-official languages, which are Spanish and Catalan. The total territory accounts for 4.992 km2, with a population of 1,210,725 inhabitants and a density of 243 inhabitants/km2, which is much higher than the average population density of Spain (94 inhabitants/km2). The region is highly dependent on tourism, being the major source of income for all four islands (over 45 % of GDP) and creating over 200.000 jobs, the percentage of the local population being employed in the tourism sector being over 25 %. This level of employment in tourism contrasts with the employment in other sectors, agriculture, industry and construction sectors accounting together for 17 % only.

Technologies.

The generation of electricity in the Balearic Islands is highly dependent on fossil fuels, only 3 % being generated by renewable energy sources, the lowest percentage in Spain. However, recently the Balearic Islands experienced the largest increase in installed renewable capacity: in 2021, its growth was 31.1 % due to new solar photovoltaic capacity. Historically, the electricity consumed in the region came from 4 local thermal power stations, but their relevance has been reduced significantly in the last decade by the installation of an electrical cable connecting the region with the mainland. Submarine connections between the four islands have also been installed enabling the development of an integrated Balearic Islands' electricity system.

Actors, ideologies and institutions.

The main actors in the Balearic Islands are the energy company, ENDESA/ENEL, which has been managing the thermal power plants of each island; the regional government and the central government, who moved forward the installation of the gas pipeline and the electric cable to improve the energy security of the islands; the tourism and travel lobby, who played an important role in pushing for the installation of the cable and thus increasing the connectivity with the mainland in order to reduce the prices of the energy bills without compromising the energy security of the island.

The ideologies are fed by the fact that the economic motor of the islands is (international and national) tourism and will continue to be even if it is highly dependent on transportation (cars, boats, airlines, etc) and energy consumption which are both based on fossil fuels. However, in the context of concern regarding climate change, the regional government has been the main instigator of the Climate Change and Energy Transition act approved in 2019.

Policies.

The ambitious policy change passing the Climate Change and Energy Transition act in 2019 was based on the willingness to reduce external energy dependence, growing concern for protecting the environment from the effects of climate change and the economic viability of developing renewables in the region given the high cost of importing energy. The 2019 law also foresees the gradual but complete closure of the thermal power plants. The most polluting turbines of the "Es Murterar'' plant closed in 2019 and there have been several restrictions on the number of hours that other thermal plants can run. They are seen as a backup technology right now, which will run in the months of higher energy consumption (summer) in Mallorca and Menorca.

8. Moravian-Silesian region, Czech Republic.

(Also includes case study 15. South-Moravian Region, Czech Republic).

Authors: Bohumil Frantál, Stanislav Martinát, Jindřich Frajer, Lucia Brisudová.

Institution: Palacky University Olomouc.

Context.

Two case study regions are subject of investigation in the Czech Republic, including Moravian-Silesian Region – MSR (as an example of coal intensive region under transformation) and South-Moravian Region (as an example of former coal mining region which has managed to transform economically and structurally relatively successfully over the two decades). These two administrative regions (NUTS3) consist of a total of 13 districts (LAU1/NUTS4), of which 5 districts have been significantly affected by coal mining in the recent past (Brno-countryside, Hodonin, Frydek-Mistek, Ostrava-city, and Karvina), while coal mining is still taking place in one district of these (Karvina).

Technologies.

MSR is one of the most industrialized and urbanized regions in Central Europe. From the environmental point of view, urban parts of the region are heavily affected by the air contaminations originating from local industrial activities (and from the industries in the nearby Katowice industrial agglomeration) whose level is frequently multiple times crossed and cause the major health issues for local population. The regioń s capital Ostrava used to be called the "Steel Heart of the Republic" as a reflection of its importance in the Czechoslovak economy. MSR belongs to the three coal regions in the Czech Republic, which are considered as structurally affected.

Actors, ideologies and institutions.

The region identifies itself with the industrial and mining tradition (in the early 1990 s more than 120 thousand people worked in the coal mining sector and another tenth thousands in heavy industries). The reflection of this historical period is materialised in the occurrence of a high number of unused industrial sites (brownfields) that were recently abandoned, waiting for the new use and create enormous barriers for compact urban development. The regioń s energy sector has been based for almost two centuries on coal that forms important element of its identity. Coal mining has played a major role not only in the economy but also in the social and culture life of communities. Its position is also interconnected with worries of losing regional identity, which has been built over years and over generations. Strongly rooted identity and other insecurities (e.g. unemployment and loss of social stability) are therefore potential reasons that may block or slow down an effective implementation of tipping points.

Policies.

The Balearic Islands have introduced various policies focused on energy transition and sustainability, particularly through the Climate Change and Energy Transition Act of 2019. This legislation aims to decrease reliance on fossil fuels, which have historically dominated the region's energy generation. A key aspect of the act is the gradual closure of thermal power plants, including the most polluting units, while encouraging the development of renewable energy sources. In 2021, the islands experienced a notable increase in solar photovoltaic capacity, reflecting a growing

commitment to renewables. Additionally, infrastructure improvements, such as submarine electricity cables linking the islands to the mainland, have been implemented to enhance energy security and reduce costs, especially during peak tourist seasons.

9. Duisburg, Germany and 17. Essen, Germany.

Authors: Franziska Mey and Johan Lilliestam.

Institution: Institute for Advanced Sustainability Studies.

Context.

The imperative of fully decarbonizing energy systems and industries, as outlined in the Paris Agreement, places significant pressure on coal- and carbon-intensive regions. The impacts of closing industries are particularly pronounced in these areas due to their socio-economic, political, and cultural dependencies on fossil fuel industries.

Technologies.

The Ruhr Region in North-Rhine Westphalia, Germany, exemplifies such an industrial landscape, where the cities of Essen and Duisburg share a long history of coal mining and related industries. Both cities have undergone a transition away from coal for over sixty years, yet they appear to be evolving differently, with Essen seemingly progressing more effectively than Duisburg.

Actors, Ideologies, and Institutions.

This case study investigates the socio-economic transition processes of Essen and Duisburg as part of the broader structural change in the Ruhr Region. By exploring the causes and effects of the cities' development trajectories over the past 30 years, the study seeks to identify differences in outcomes influenced by various interventions and contextual factors. The analysis focuses on events and their impacts on the social and economic systems of the two cities, examining whether has crossed a tipping point in their transition toward a low-carbon future. Both cities have shown incremental changes in their demographic, economic, and political trajectories, but neither has yet reached a tipping point. However, distinct developments in their policy narratives indicate qualitative changes that could influence their future paths.

Policies.

The findings suggest that the sequence of interventions and their timing are crucial for determining the quality of societal change in a region. While radical change and tipping points are rare in complex urban systems, the evolving local narratives of Essen and Duisburg could signal potential tipping dynamics in the future. Duisburg continues to embrace the narrative of maintaining and developing heavy industry, whereas Essen has articulated a vision focused on transitioning away from its coal mining legacy toward a greener future. As these cities diverge in their policy visions, the strategies for influencing local narratives and leveraging local strengths will be critical for their respective transitions. Even if these interventions do not immediately trigger tipping points, they are necessary steps toward achieving a prosperous future beyond coal.

10. Tuzla, Bosnia & Herzegovina and 19. Banja Luka, Bosnia & Herzegovina.

Authors: Hamid Mehinovic, Vedad Suljic, Ismar Jamakovic.

Institution: Westport Consulting.

Context.

Since the Industrial Revolution, the growth of the global economy has been fuelled by the exploitation of non-renewable natural resources, leading to significant challenges such as pollution and resource scarcity. The increasing industrialization, population growth, and economic development are primary drivers of excessive fossil fuel consumption and greenhouse gas (GHG) emissions, which significantly contribute to climate change. In Bosnia and Herzegovina, coal consumption stands out as a major factor impacting GHG emissions and global warming. Coal plays a crucial role in the country for various reasons, including domestic energy production, industrial applications, mining, and job creation. However, the conflict from 1992 to 1995 fragmented the nation's unified energy system into three separate state-owned electric power companies: Elektroprivreda BiH (EP BiH), Elektroprivreda Republike Srpske (ERS), and Elektroprivreda Hrvatske Zajednice Herceg Bosna (EHZHB).

Technologies.

Bosnia and Herzegovina achieved its sectoral goal of 40 % renewable energy in heating and cooling by 2021, indicating rapid growth in this area (Implementation Report 2022, Energy Community Secretariat). However, further efforts are necessary to enhance the use of renewable energy in the electric and transportation sectors. The country's heavy reliance on coal presents substantial challenges for its energy and climate sectors as it seeks to decarbonize. The government has yet to develop a National Energy and Climate Plan (NECP) or engage in the regional initiative for guarantees of origin, both of which would be beneficial steps forward. A socially just transition to clean energy necessitates greater integration across multiple sectors, including energy generation, transport, land use, and waste management, ensuring that vulnerable populations are not disproportionately affected.

Actors, Ideologies, and Institutions.

The path toward decarbonization in Bosnia and Herzegovina is an ambitious goal that requires time and a long-term vision. Achieving a low-carbon economy will necessitate significant investments in infrastructure, technology, and human resources. Establishing intermediate and long-term targets while remaining adaptable is crucial for progress. The adoption of the Clean Energy Package and Decarbonization Roadmap by the Ministerial Council in November 2021 obliges Bosnia and Herzegovina to transpose relevant EU Directives on energy and climate, demonstrating the country's commitment to collaborating with the European Union and international partners toward achieving net-zero greenhouse gas emissions by 2050.

Policies.

Considering these challenges, the government has intensified efforts to draft the National Energy and Climate Plan (NECP), aiming to address targets for renewable energy, reductions in final energy consumption, and greenhouse gas emissions from the energy sector. The plan must detail appropriate policies and strategies to achieve these objectives effectively. It is essential for the interconnected components of the energy sector to establish policies for integrated energy and climate management. These policies should align with the five core elements of the Energy Union: decarbonization, energy efficiency, security of supply, internal market energy, and research, development, and competitiveness. This comprehensive approach is vital for facilitating the transition to a low-carbon economy while delivering co-benefits such as improved air quality and job creation.

11. Upper Austria, Austria

Authors: Raphaela Maier and Andreas Türk.

Institution: University of Graz.

Context.

Upper Austria is a carbon-intensive region heavily dependent on downstream energy-intensive industries, particularly in the basic material sector. The region's industrial activities, including iron and steel, chemical, petrochemical, and cement industries, contribute significantly to Austria's GDP. A long tradition of iron ore mining in Upper Austria has established a large iron and steel industry, laying the foundation for its current industrial

functionality and growth.

Technologies.

Upper Austria's economy is reliant on coal-intensive industries, notably iron and steel, cement, chemicals, and petrochemicals. These sectors play a critical role in the region's industrial landscape, making decarbonization a complex challenge as they are highly energy-intensive and heavily dependent on fossil fuels.

Actors, Ideologies, and Institutions.

Policymakers at the EU, national, and state levels are tasked with creating instruments and policies to support alternative narratives that can drive transformative change. Achieving significant GHG emission reductions and a net-zero transition requires funding for pilot projects and markets for green basic materials. Renewable-based electricity is key, and the expansion of renewable energy and necessary transmission infrastructure needs to be accelerated. The Federation of Austrian Industry is also an important player in advancing the transition by offering solutions and serving as a network for collaboration. Research institutions play a critical role in innovation and can act as a bridge between industry and policy. NGOs and activists, like the Fridays-for-Future campaign, raise awareness and put pressure on companies and policymakers to meet climate goals.

Policies.

Austria follows EU laws and directives, though no specific industrial policy exists for this transition. A national transition fund is proposed, combining private capital with public/federal funding, supplemented by EU funding. The renewable energy expansion law provides annual subsidies of 40 million euros for electrolysers, benefiting companies like Voestalpine. In 2019, Linz adopted a climate change plan emphasizing its responsibility as an industrial hub. Additionally, in June 2022, Austria introduced a hydrogen strategy to support the energy transition.

12. Megalopolis, Greece

Authors: Zois Katiforis, Nikos Kleanthis, Serafeim Michas, Alexandros Flamos.

Institution: University of Piraeus Research Centre.

Context.

A key aspect of Greece's National Energy and Climate Plan (NECP) is the gradual phase-out of lignite in power generation. This includes decommissioning all existing lignite units by 2023, impacting regions like Megalopolis. The "Megalopolis IV" lignite unit is the last remaining lignite-fuelled power plant in the area, set to be withdrawn by 2023. In 2019, the energy, mining, and water supply sector—directly tied to lignite production—accounted for 33 % of the Gross Value Added (GVA) in the Arcadian regional unit, where Megalopolis is located. This sector's contribution to the GVA is notably higher than in other Peloponnesian regions, highlighting its economic importance.

Technologies.

The just transition narrative for Megalopolis aligns with Greece's plan for the transition of lignite regions. It envisions the region's reconstruction through a new economic model that focuses on four growth pillars: clean energy, industry (including small industry and trade), smart agriculture, and sustainable tourism. These sectors aim to replace the economic gaps left by lignite production. However, the recent energy crisis, exacerbated by the Russian war against Ukraine, poses risks to this development plan. Some actors have expressed concerns, pushing for alternative strategies focused on local energy communities, energy efficiency, and electrification.

Actors, Ideologies, and Institutions.

Policymakers at the national and local levels are pivotal in steering the transition away from lignite in Megalopolis. Various actors, including local communities, businesses, and energy stakeholders, have voiced differing opinions on the future of the region. Some advocate for a clean energy transition aligned with national goals, while others push for locally driven solutions such as energy cooperatives and community-led renewable energy projects. Research institutions play a role in providing data and insights to guide the transition, and NGOs and environmental activists emphasize the urgency of decarbonization, warning against infrastructure investments that could delay progress.

Policies.

Under the Just Transition Development Plan for lignite areas, a gas distribution network is being built in Megalopolis, with residents exempted from connection fees. Additionally, subsidies are available for replacing existing heating systems with natural gas boilers. However, recent energy price volatility has raised concerns about the long-term viability of this strategy, as further investment in natural gas could lead to infrastructural lock-in, delaying the transition to renewables. This could expose households to high energy costs and potential shortages, aligning with concerns raised in scientific literature about the risks of expanding natural gas infrastructure during energy transitions.

13. Teruel, Spain

Authors: Francesc Cots, Cristina Costa, Jérémie Fosse and Gerard Codina.

Institution: Eco-union

Context.

Teruel, a province in the Autonomous Community of Aragón, Spain, covers an area of 14,809 km2 and had a population of 133,109 in 2021, making it one of Spain's least densely populated regions, with only 9 inhabitants per square kilometre. The province is part of the Just Transition Agreement (JTA) for the Andorra-Mining Regions, a pioneering initiative in Spain under the framework of the Just Transition Strategy. This agreement was established to manage the closure of mines and the Andorra thermal power station, ensuring new economic, social, and environmental opportunities in the region. The JTA is supported by the provisions of Law 7/2021 on climate change and energy transition, as well as Spain's Recovery, Transformation, and Resilience Plan. The initiative is managed by the Just Transition Institute, an autonomous body of the Ministry for Ecological Transition and the Demographic Challenge (MITECO). The region is a key case study for understanding the socio-economic impacts of Spain's decarbonization policies and the phase-out of coal, offering valuable lessons for other coal regions in the country.

Technologies.

Teruel is positioned at a crossroads in terms of its technological transition as it moves away from coal-based energy production. The focus is on identifying and deploying renewable energy technologies, such as solar and wind power, as well as developing new industries in the region that can create sustainable jobs. The JTA emphasizes the importance of innovative technologies and infrastructures to support clean energy production and economic diversification in areas affected by the closure of thermal power plants and mines.

Actors, Ideologies, and Institutions.

The key actors involved in Teruel's energy transition include national and regional policymakers, local governments, labour unions, and civil society organizations. The Ministry for Ecological Transition and the Demographic Challenge (MITECO) plays a central role through the Just Transition Institute, ensuring that policies align with national climate goals while addressing local needs. Local governments and communities are also crucial in implementing the Just Transition Agreement, particularly in engaging residents in decision-making processes. There is a strong focus on

addressing the needs of vulnerable groups, such as the long-term unemployed, women, and disabled individuals, while also encouraging youth participation to shape the region's future. Labor unions and civil society groups advocate for fair working conditions and sustainable economic growth, emphasizing social justice throughout the transition.

Policies.

The Just Transition Agreement for Teruel aims to maintain and create jobs, retain population in rural areas affected by closures, and promote economic diversification. The Nudo Mudéjar project and other initiatives have yet to be fully realized. The agreement includes an Urgent Action Plan designed to mitigate the social, labour, and economic consequences of mine and power plant closures. The plan prioritizes improving employability, particularly for vulnerable groups like women, long-term unemployed, and disabled individuals, while involving youth in decision-making processes. Efforts focus on creating incentives for young people to stay in the region, shaping its future, and ensuring long-term sustainable development.

State 3: Growing low-carbon system(s)

14. Carloforte, island of San Pietro, Sardinia, Italy

Authors: Elena Apostoli Cappello and Mauro Sarrica.

Institution: Sapienza Universita di Roma.

Context.

Carloforte, the only town on the island of San Pietro, Sardinia, has a maritime economy that has set it apart from its mainland and neighbouring regions since the 1700 s. Historically, Carloforte was a significant port for the transportation of minerals, particularly coal from Sulcis, until the early 20th century. This allowed the town to thrive economically through trade and maritime activities. Unlike Sulcis, which is more agropastoral and industrial, Carloforte has not experienced alarming unemployment rates and remains economically stable, partly due to its historical role as a hub for sailors and trade. This study aims to explore the decarbonization process in this geographically marginal site, observing how Carloforte and Sulcis navigate industrial decline, despite their different economic trajectories.

Technologies.

Carloforte's technological landscape has been heavily influenced by its harbour, which was a key asset for transporting coal and other minerals until around 1920. The harbour supported not only transportation but also provided a base for trades like carpentry and blacksmithing that served the industrial sites of Portovesme. Over time, the harbour's role has shifted toward tourism, although it remains crucial for connecting Carloforte to the Sulcis region, such as through the electric cable that links the island to Portovesme. Today, the port supports both tourism and essential connectivity to the mainland.

Actors, Ideologies, and Institutions.

Two main actors are driving Carloforte's economic and ideological shift: the local government, led by young municipal administrators, and the rebranded tuna fishery, which has become central to Carloforte's wine and food tourism. These actors have positioned Carloforte as a hub of gourmet tourism, especially around its famous tuna, with a cosmopolitan and entrepreneurial outlook. Since 2007, local policies have focused on promoting the town as the "Mediterranean's green island," a narrative supported by EU-funded projects and geared toward sustainable tourism. This ideology emphasizes the town's uniqueness from Sulcis, highlighting Carloforte as a green, cosmopolitan, and sustainable destination.

Policies.

The policies shaping Carloforte's future are closely tied to its vision as a green island, far removed from its historical connection to the coal economy. Since 2007, local policies have focused on promoting sustainable tourism and eco-friendly development. These initiatives are largely funded by the European Union, with a goal of creating a "paradise" for tourists seeking sustainable and environmentally conscious destinations. This on-stream narrative of a green, cosmopolitan island is a reorganization of the mainstream narrative, steering Carloforte toward a future based on tourism and environmental sustainability rather than energy or industrial concerns.

15. South-Moravian Region, Czech Republic

(Described above with case study 8. Moravian Region, Czech Republic).

16. Lofoten Archipelago, Norway

Authors: Brigt Dale and Anna G. Sveinsdóttir.

Institution: Nordland Research Institute.

Context.

Lofoten, an archipelago located just above the Arctic Circle in Northern Norway, is renowned for its rugged coastlines, towering mountains, and unique natural beauty. It spans 1,227 km2 and has a population of about 23,500 inhabitants. Known for its harsh climate with long winters and short summers, Lofoten experiences the northern lights in winter and the midnight sun in summer. The region is rich in hydrocarbon deposits, particularly oil and gas, but it is also a world-class destination for nature-based tourism and home to one of the most valuable fisheries in the North Atlantic. As Norway's petroleum exploration expanded northward, Lofoten became the focal point of debates over offshore oil development and its potential impact on the local economy, environment, and cultural heritage.

Technologies.

The early 2000 s were dominated by the idea of opening the Nordland VII area around Lofoten for offshore oil and gas exploration, aligning with Norway's broader petroleum-driven economic strategy. However, several counter-narratives challenged this perspective. One of the oldest and most significant counter-narratives emphasized the importance of Lofoten's fisheries as a longstanding cultural and economic activity, arguing that oil exploration would jeopardize this vital industry. A second counter-narrative promoted nature-based tourism, positioning Lofoten's pristine environment as central to its future economic development, incompatible with oil and gas activities. A third counter-narrative focused on climate change, especially after the 2015 Paris Agreement, further strengthening arguments against petroleum extraction. Eventually, these counter-narratives coalesced into a new mainstream vision for Lofoten's future, one centred on decarbonization, electrification, and circularity, under the idea of "The Green Isles.".

Actors, Ideologies, and Institutions.

Lofoten's energy and environmental future involves a range of actors, from local fishermen and tourism operators to national policymakers and international climate activists. Local actors, particularly within the fishing and tourism industries, have been vocal about preserving the region's traditional livelihoods and natural environment. At the national level, Norway's government has faced pressure from both the oil industry, which views Lofoten's hydrocarbon deposits as economically valuable, and environmental groups advocating for climate action and the protection of Lofoten's unique ecosystem. Regional authorities and local governance structures have also played a role in shaping Lofoten's development trajectory, balancing economic interests with environmental sustainability. International institutions, particularly in the context of climate agreements like the

Paris Agreement, have influenced the ideological shift toward a decarbonized future, aligning Lofoten's development with broader global environmental goals.

Policies.

The Lofoten dispute over oil exploration mirrors broader political, economic, and environmental challenges in the Arctic and Sub-Arctic regions. At the local, regional, national, and international levels, the debate touches on energy security, environmental protection, and the preservation of cultural heritage. National energy policies, aimed at maximizing Norway's offshore oil production, have clashed with regional policies focused on sustainable development, tourism, and fisheries. The dispute highlights the complex interplay of interests, from protecting the year-round tourism industry and traditional fisheries to navigating the broader impacts of climate change and global decarbonization efforts. International agreements like the Paris Accord have been key in shaping Lofoten's policy framework, contributing to the shift toward sustainable local livelihoods and away from reliance on fossil fuels. The "Green Isles" initiative is a prominent example of this policy shift, promoting an economy based on renewable energy and circular practices.

17. Essen, Germany.

(Described above with case study 9. Duisburg, Germany).

State 4: Reinforcing low-carbon system(s).

18. Greenland, Denmark.

Authors: Regine-Ellen Møller & Anne Merrild Hansen.

Institution: Aalborg University.

Context.

Greenland, an autonomous territory under the Kingdom of Denmark, gained greater self-governance through the Self-Rule Act of 2009. Though geographically part of North America, it is politically tied to Europe. With a vast area of 2.17 million square kilometres, 81 % of Greenland's landmass is covered by ice, leaving only coastal regions habitable for its population of about 56,000 people. The majority of Greenlanders (87 %) live in 18 towns, while the rest reside in around 60 smaller settlements. Nuuk, the capital, houses roughly a third of the population, followed by Ilulissat, the second-largest town. Given Greenland's unique geography, there are no roads connecting towns and settlements; travel occurs mainly by air (airplanes and helicopters) or by sea (boats, ships, snowmobiles, and dogsleds).

Technologies.

Greenland's energy infrastructure primarily relies on a mix of renewable and fossil fuel sources. Between 1993 and 2012, the Government of Greenland built five hydropower plants, providing renewable energy to six towns across the country. Two of these plants have enough capacity to supply both electricity and heating, while the other three only generate electricity, leaving heating reliant on fossil fuels. In smaller towns and settlements, fossil fuels remain the dominant energy source. To further advance its renewable energy portfolio, the government is planning new hydropower plants and increasing the capacity of the existing facility in Nuuk. There are also discussions about large-scale industrial projects, such as aluminium smelters and data centres, as an alternative to the traditional oil and mining sectors. In early 2022, Greenland and Denmark agreed to seek international loans to fund the construction of two new hydropower plants in northern Greenland.

Actors, Ideologies, and Institutions.

Greenland's energy and economic policies are shaped by a range of actors, including the Government of Greenland, which has prioritized hydropower development as a cornerstone of its renewable energy transition. Local and national actors work together to reduce Greenland's reliance on fossil fuels while fostering economic growth through sustainable energy projects. This shift reflects Greenland's broader ideological stance toward environmental sustainability, as it seeks to balance economic development with the need to protect its fragile Arctic ecosystem. The Kingdom of Denmark plays a significant role in supporting Greenland's self-governance and development, providing financial backing and political support for initiatives like the hydropower projects. Greenland's indigenous population also influences energy and environmental policies, with a strong emphasis on preserving traditional ways of life while adapting to the challenges posed by climate change and modernization.

Policies.

Greenland's energy policies reflect a commitment to transitioning toward renewable energy, particularly through hydropower. The government's long-term strategy involves expanding its renewable energy infrastructure, decreasing reliance on fossil fuels, and pursuing economic diversification. Greenland's 2022 agreement with Denmark to secure international funding for two new hydropower plants underscores this commitment. While the government has traditionally relied on oil and mining for economic development, it is now considering alternatives like industrial-scale hydropower for aluminium smelting and data centres. These policies aim to attract foreign investment and create new economic opportunities in sectors less harmful to the environment. The government also recognizes the importance of involving local communities in decision-making, ensuring that economic development aligns with both sustainability goals and Greenland's cultural heritage.

19. Banja Luka, Bosnia and Herzegovina.

(Described above with case study 10. Tuzla, Bosnia and Herzegovina).

Appendix 3:. Regional & (sub)regional transitioning phases towards social-ecological tipping points

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Regional cluster 1: No significant change	Canada: Athabasca Region, Alberta									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change- incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
1.1 Region 1 Description of the trigger for change	Oil Sands as most ethical.	Reliance on US policies	Paris Agreement	Hydrogen as complementary new market but is still dependent mainly on natural gas and CCS	Oil& gas plus carbon capture and underground storage (CCUS) infrastructure to export hydrogen	Negative environmental impact on air and water quality for surrounding communities		Incumbent oil and gas firms	Incumbent oil and gas firms	15 years +
	Not supporting oil and gas is "Anti-Canadian"	National GHG policies	High oil prices	Low interest business loans				Provincial and national government	Provincial government	province's commitment to closing coal mines by 2023
	Some limited off-stream narratives on sustainable land use and renewables	Regional environmental policies	Lack of climate commitment from other countries including USA					Research institutions	Indigenous communities benefiting from development	
		Alberta's 2008 Climate Change Strategy	Increase inflation						Indigenous communities wanting to protect traditional land practices	
		Alberta Land Stewardship Act (2009) but not yet developed for upper Athabasca oilsands region								
		Alberta's Provincial Energy Strategy emphasising oil & gas								
		Royalties from oil & gas								
		Government research grants for clean energy								
		Stimulus for blue hydrogen								
Scale of trigger of change	Regional	Global	Global	Regional	Regional			Regional	Regional	
		National	National							
		Regional	Regional							

Fig. A1. Nineteen CCIRs plotted over time (years) across the five transition states of JSETS.

Regional cluster 1: No significant change	Indonesia: (Banten & Bali)									
Response to trigger for transitions	1. Collective signalling of vision change - identity	2. Policy for change/reinforcement	3. Geopolitical power shifts -events	4. Market changes -privatisation -pricing - new markets	5. Technology changes -New tech - Add ons	6. Environmental triggers? Do they exist (Y/N)	7. Others	8 Actors triggering change (incumbents, others?)	9. Actors impacted by the triggering change- incumbents, others?)	10. Pace of transition pathway 10 years+ 5 years+ 1 years +
Region 1 Description of the trigger for change	Fossil fuels needed to maintain growth	National Energy Policy (KEN) min. use of oil, max. RE, optimise gas and secure by coal	Paris Agreement	PLN (state energy firm) sells electricity from fossil few below production cost	Solar PV is limited by uncompetitive price compared to fossil fuels, battery technology and the existing grid system (not smart grid)		Geothermal and hydropower lack social acceptance	Asian Development Bank	PLN	Slow 10+ (Past till now)
	Coal backbone in Banten and Bali	National Energy General Plan (RUEN) to maintain coal use w/ slight decrease by 2050	G20 Results	Companies have a green agenda	Geothermal and hydropower stable base load		Lack of coordination between local and gov't and provincial energy sector plans	UN Office for Project Services	Private business	
	Banten is using biomass with co-firing, whereas Bali is highly relying on Java for the electricity supply	Regulation of Ministry of Energy and Mineral Resource for private firms to develop RE		Companies are not sufficiently connected to financing	Grid integration and transformation		Fossi fuel subsidy	National Ministry : Ministry of Energy and Mineral Resources, Ministry of National Planning/Bappenas, Ministry of Finance	NGOs	
	Bottom-up view for Banten and Bali to diversify with solar, wind, hydro power (micro), geothermal, and bioenergy especially in decentralised and remote areas	Carbon tax for Coal		Maintain the government subsidy in the coal power plant	Domestic Ability Level (TKDN) policy for local PV manufactures		The availability of skilled workers related to clean energy	PLN	Communities	
	Early retirement scenario for NZE in 2060	Fiscal incentives for clean energy		FIT (Feed-in-tariff) for RE production			Limited clean energy resources at provincial level, hence grid integration and interconnection are essential	Provincial gov't agencies	Research institutions and universities	
		Bali has its own regional energy plan which promotes renewable diversification		Single player in the national power supply (PLN)				Private business		
								NGOs		
								Communities		
								Research institutions and universities		
								UK Government		
Scale of trigger of change	National	National	International	National	National		National	International & National	National	
	Regional/provincial	Regional/provincial		Local	Regional/Provincial		Regional/Provincial	Regional	Regional	
								Local	Local	

Fig. A4. Regions plotted over time and the five transition states of JSETS.

Appendix 4. . Description of the narratives in the case study regions.

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Case study name, institution	Current narrative trend	Mainstream technology sector	Mainstream narrative	On-stream narrative	Off-stream narrative	Main drivers	Main hinders
1. Austria, upper and lower. University of Graz	Mainstream narrative declining, and alternative taking off	Coal-intensive: iron and steel, cement, chemical, and petrochemical industry	Transition from carbon intensive	Green hydrogen (up to 80 % of CO2 reduction), industrial circular and decarbonized economy	None. The same companies compose the regime in alternative narratives	EU level policies: phase out of emission allocations, CBAM, innovation fund, plastic tax, and IPCEI.	In Austria, no particular industry policy is available (e.g., Carbon Contracts for Differences and/or a climate contribution). Job and identity dependency. Lack of CO_2 tax for industry Lack of market regulations and market for CCU/S. Coordination between national and international companies.
2. Bosnia and Herzegovina Westport Consulting	Reliance on coal mining for power generation (65 % of energy mix) and slow-pace transition plan	Coal mining	National energy security Coal is seen as the fuel that guarantees the nation's energy supply and serves as the system's backbone	Clean coal technology Evolutionary and slow pace of transition, maintaining hard coal exploitation and usage in the gasification process and carbo-chemical installations	Swifter abandonment of coal mining and creating the national supply chains for industries supporting energy transition and a circular economy hydropower and bioenergy	Alignment with the EU ETS is scheduled to be completed by 2024	Lengthy investment cycle allowing the rise of coal output, and the expected long-term horizon for the coal phase-out. Governments' unwillingness to embrace the inevitable decarbonization of the electricity industry
3.Alberta, Canada, Innolab	Stable mainstream, and on-stream taking off	Oil sands	Fossil fuel exploitation (oil/gas)	Blue hydrogen, CCS, innovation. 85 % reduction of oil produce	Sustainable land use and renewable energy technologies, but they lack detail	Federal climate policies Potential for hydrogen market revenues	Attachment to existing infrastructure Resistance to distributed power by current energy monopoly
4. Moravian-Silesian, Czech Republic Palacky University Olomouc	Declining of mainstream, declining of on-stream, and taking off of off-stream SMR is considered a transformed region	Coal mining	Coal exploitation	Re-industrialization with large industries Employ and support ex-miners Preserving historical industrial heritage Coal + CCS (presented as off-stream)	Just transition Bottom-up and small-scale approach Landscape reclamation Green technologies Investment into R&D	In late 1980s and 1990s coal mines closed due to economic unprofitability and federal policies on desulphuration Federal environmental mitigation program. Change of political regime. SMR: foreign direct investments favouring high-tech industries. Regeneration and re-use of abandoned post-industrial and post-mining areas	MSR: Industrial and mining tradition State-owned coal plants are operating until 2022 Lack of skilled jobs, peripherality, high urbanization rate, high population density cause outmigration of primarily younger population (not certain as hinder)
5. Spain, Balearic Islands Eco-Union	Decline of mainstream, take-off of alternative	Diesel for power generation Coal mining	Fossil fuel dependency	Energy connection Renewable energy system Reduction of local energy production, national dependency	Urgent fossil fuel phase-out Energy transition Prosumerism Reduce external dependency	Climate Change and Energy Transition act (in 2019) to decarbonize islands Advanced economic position	Insular identity (it poses obstacles to the needed vertical coordination among different governmental levels) Large capacity of electric grid

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Case study name, institution	Current narrative trend	Mainstream technology sector	Mainstream narrative	On-stream narrative	Off-stream narrative	Main drivers	Main hinders
							interconnection with the mainland, this has increased the island's dependency and prevented the deployment of renewables Gas pipeline Dependence on international and national tourism
6. Spain, Teruel Eco-Union	Decline of mainstream, reached a tipping point, stabilization of on-stream	Coal mining, and coal-fired power plants	Transition from carbon intensive	Just transition installation of large-scale renewable energy projects (mainly solar and wind)	Local economy focus, SMEs of renewables	Spain's entry into the European Union (1986) led to adoption of coal regulations Non-competitive coal just transition criteria for companies	COVID-19 pandemic delayed participatory processes Lack of policies for alternative narratives
7. Greece, Megalopolis University of Piraeus Research Centre	Decline of mainstream, take-off of on-stream (natural gas as intermediate fuel), and pre-development of off-stream	Coal mining: lignite power generation	Transition from coal exploitation to natural gas	Large-scale RES With gas as intermediate fuel, economic diversification	Investment in local building sector (energy efficiency) Community energy Smart agriculture and livestock Tourism	Natural gas price Gas supply reserves adequacy REPowerEU Plan for reduction of dependency on imported natural gas Political commitment for electrification Funding Mechanisms	Renovation costs Political commitment for electrification
8. Indonesia, Bali Su.re.co Sustainability & Resilience	Stabilization of mainstream and pre-development and stagnation of alternative	Coal, oil, and gas national dependency Coal power plants in Banten and Bali	Transition from carbon intensive	Reducing oil dependency with natural gas and coal Biomass, CCT	Wind, hydro, geothermal and solar	Clean energy policies	PLN sells electricity generated from fossil fuels below the cost of production, thereby preventing the expansion of the renewable energy market
9. Italy, Sulcis Sapienza Universita di Roma	Change of mainstream toward coal to gas, and pre-development of on-stream industrial reconversiand off-stream	Coal mining, coal-fired power plants, industrial cluster	Coal-to-gas transition to support phase-out and secure energy supply. Postponing coal phase out.	Renewable energy transition Centralised, CCS and large scale RE Electrification of final consumption Tourism Circular economy	100 % RE Community-led and place-based energy transition Agency and ownership for alternative development	Sense of place Injustices Closure plan for the coal mine	Energy utility decision-making power Transition frames that do not consider Sardinian dependence on coal and the lack of gas infrastructures high energy costs for industry and families macroeconomic trends
10. Italy, Carloforte Sapienza Universita di Roma	Tourism in the harbour and electric interconnection	Harbour, formerly functional for the coal transportation	Transition from coal exploitation	"We are the vanguard":on wind farms and solar projects "We are different from the Sulcis, we are green, we are cosmopolitan and sustainable entrepreneurs"	"We are Sardinians and subalterns as the other Sulcitanian are" "let's build wind farms, let's emancipate from the fossils".	Local institutional policy that –since 2007- promotes Carloforte as "Mediterranean's green island" Identity dimension, economic processes and aspirations for green tourism	Lack of agency on the part of the community and/or individuals
11. Upper Silesia, Poland Institute for Structural Research	Coal decline, with consensus on preserving coal herritage	Coal mining	Energy security Coal dependency of	Labour market narrative Closure of coal mining	Local economy collapse creating national supply chains	Support of structural funds National clean energy and climate	Rapid mining closure not supported by a comprehensive

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Case study name, institution	Current narrative trend	Mainstream technology sector	Mainstream narrative	On-stream narrative	Off-stream narrative	Main drivers	Main hinders
			companies and employees	Clean coal Technologies Energy security and economic patriotism	Circular economy health and living condition improvementGreen technologies	policy	regional development strategy Unemployment and and potential labour market destabilization due to rapid coal phase-out
12. Jiu Valley, Romania National University of Political Studies and Public Administration	Coal decline and emergence of off-stream narrative	Coal mining, pit coal	Mining closure region's economic collapse, but they also led to a decrease in the population's living standards	Insolvency of coal-fired energy producer	Creation of the Academy for Renewable Sources and Energy (re-training project) Tourism Creation of new SMEs and investments in existing ones in the fields of research, green energy, and reduction of greenhouse gas emissions, but also to retrain the workforce and create new employment opportunities	Cooperation between the Romanian Government and the Platform for Coal Regions in Transition Just transition plan	Jobs dependency on coal mining
13. Germany, Ruhr region Institute for Advanced Sustainability Studies Potsdam	Decline of mainstream and take-off of alternative The local mine in Essen closed in 1986 [40], in Duisburg another 20 years later in 2008	Coal mining and steel industry	Transition from coal exploitation	Small-scale coal exploitation	Coal and nuclear phase-out Tourism Sustainable development	Closure of mines and the need for brownfield redevelopment due to: Essen, lack of economic profitability, depletion of resources Duisburg, public protest in 2008, impact on households and environment National coals laws, including to end coal subsidies Decreasing workforce	Population decline
14. Greenland, Aalborg University	Stabilized mainstream, pre-development of renewables	Hydropower and oil imports	Transition toward hydropower plants	RET systems for remote places such as solar and wind power in small-scale	Uranium and Oil, are not detailed		
15. Lofoten, Norway NordlandResearch Institute	Decline of mainstream narrative, take-off/stabilization of off-stream and on-stream	Untapped off-shore oil and gas reserves	The potential to exploite off-shore oil and gas reserves for exports in LoVeSe	Tourism Fisheries Climate concerns	Opposition to oilDecarbonization and circular economy	Management plan Oil price decline Paris agreement Elections Perceived risk of oil spill Protection of cultural heritage, traditional fisheries, and sustainable living	National and international discourse on energy security and revenues Young adult outmigration Low-birth rates Lack of infrastructure investments National identity with oil extraction
16. Svalbard, Norway Nordland Research Institute	Coal decline	Coal power electricity generation and coal mining	Coal decline Closing the coal power station by 2023	Coal + CCS Solar panels and geothermal energy are two potential technologies	Tourism, research, and education Tourism and education grew from the 1990s onward	Decision to phase out the coal mines was made Coal prices and demand	Russian invasion in Ukraine has caused a delay in coal phase-out until 2025

Data availability

Data will be made available on request.

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