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

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D3.3: Contribution to the Tipping Plus project's Integration Framework from a Policy and Governance Perspective

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Leader Organization: IASS

Contributing Authors: Franziska Mey (IASS), Johan Lilliestam (IASS)

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Preface

TIPPING+ will provide an empirical in-depth social science understanding of fundamental changes in sociodemographic, geographical, psychological, cultural, political, and economic patterns which give rise to Social-Ecological Tipping Points (SETPs), both positive and negative in relation to socio-energy regional systems. Such empirical and theoretical insights will shed new light on the interdependencies between changes in regional socio-cultural structures and the technological, regulatory and investment-related requirements for embracing (or failing to embrace) low-carbon, clean-energy and competitive development pathways in selected coal and carbon intensive case study regions (CCIRs). The overall goal is to understand why and under which conditions a given social-ecological regional system heavily dependent on coal and carbon-intensive activities may flip into a low-carbon, clean energy development trajectory – or on the contrary may fall into an opposite trajectory with all its negative implications. Towards this goal, main focus of TIPPING+ is the participatory co-production of knowledge on the driving forces and deliberate tipping interventions leading to the emergence of positive tipping points toward clean energy transitions in European CCIRs.

Who We Are

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1 Introduction

In the last years, the concept of tipping points received increasing recognition in social science and rose on the political agenda. Identifying tipping points would allow researchers to identify the point in time in which a transition happens, and to understand the processes of overcoming lock-in mechanisms and trigger deliberate tipping an existing system into a qualitatively new state. Because tipping points bring about rapid systemic change, it is desirable to further understand how tipping points may be triggered to accelerate the transformation of social and economic systems.

There is little doubt that tipping points exist in both social and socio-technical systems because we can observe that systems and societies are fundamentally different today than they were in the past. However, despite a growing body of literature, there remain many open questions how to conceptualise and ultimately operationalize social tipping points. This also stems from a lack of empirical studies and insights observing tipping points in social contexts.

In the Tipping.Plus project we addressed this gap with a literature review and empirical case studies investigating tipping dynamics from a *public policy and governance perspective*. In the literature review we explored definitions, characteristics, and the application of the concept and notion of tipping points in political and governance theories and contexts. In the second step, we conducted an empirical study investigating the socio-economic transition processes of the two German neigbouring cities Essen and Duisburg, which have both phased out their coal industries, as part of the wider structural change in the Ruhr Region. We focused on (political) interventions and their effects on the cities' development trajectories in the last 30+ years to identify differences in outcome as a function of policy interventions and/or contextual differences. Apart from identifying the key development drivers, we investigate whether either city crossed a tipping point in their transition process (yet), away from coal towards a low carbon but still prosperous future (Mey and Lilliestam 2022).

In the following we synthesise the findings of this work and our observations and experiences in order to contribute to the overall Tipping.Plus Integration Framework and Social Theory on social tipping points in energy transitions.

2 Conceptualising Social Tipping Points

2.1 Definition

In the following we provide a brief discussion of definitions and characteristics of social tipping point reflected upon our learnings and observations from the literature and case studies.

According to Mey and Lilliestam (2022) tipping points are moments of discontinuity occurring within a specific context triggered by the conjunction or alignment of developments, so that the system fundamentally, qualitatively and possibly irreversibly changes its structure, governed by new feedbacks. Hence a social tipping point is a disruption of the stability of a social system, breaking with the previous stable state and entering a new, different but also stable configuration.

This definition builds on the growing body of literature with the academic discourse starting more than 60 years ago (Grodzins 1957; Schelling 1978; Wolf 1963). Simplified there are two types of tipping points. First, there are *undesirable ones* that are mainly a subject in natural science, such as climate and ecological thresholds which pose serious threats to human societies (Lenton 2011; Lenton et al. 2008; Scheffer et al. 2009). Second, *desirable tipping points,* which are deliberately induced, drastic changes moving social systems to positive trajectories (Lenton 2020; Lenton et al. 2022; Tàbara et al. 2018). The latter receives growing attention from policy makers, civil society actors and academics as a controllable mechanism to combat climate change and identify ways to progress towards a fully decarbonised economy fast and at the same time fair and equitable.

However, in social systems, a significant disruption as induced by a tipping point and respective interventions may come with desired but also undesired consequences. In the case of coal phase-out regions, the disruption of incumbent industrial and economic structures is an unavoidable part of the sustainability transition. As such, it may pose opportunities for some stakeholders, but is destructive for others, in particular those who depend on the established system. Consequently, there are normatively connoted positive or negative trajectories, which largely depend on the perspective of the actors and those bearing the impacts. For example, closing a coal mine or coal fired power station will on the one hand reduce carbon emissions, contribute to broader sustainability goals, improve the health of the local community (less respiratory diseases) and is an essential step towards a possible lower-carbon prosperous future. On the other hand, it may lead to a significant reduction in the local or regional labour force, stark increase in unemployment, social hardship for the local community as well as a fear of or actual loss of cultural identity. From the policy and governance perspective, therefore, it is problematic to frame tipping points in terms of positive and negative, but it is also not necessary: viewing tipping points merely as qualitative systemic change is sufficient.

Another critical characteristic is the *pace of change*. Tipping is (widely) associated with a fast and rapid transformation of a system (Kopp et al. 2016; Milkoreit et al. 2018; Otto et al. 2020; Sharpe and Lenton 2021; Winkelmann et al. 2020). However, a fundamental and qualitative change of a social system comes rarely overnight. Comparable to a raft floating on water, disturbances of the stability are counteracted,

and significant shifts circumvented to avoid sinking or flipping abruptly (Gunderson and Holling 2002). Incumbent (political) power structures seek to evade a loss of control in a social system since it can be accompanied by unrest, revolution or war (Grimm and Schneider 2011). Also, power structures stemming from path dependencies and lock-in mechanisms decelerate societal change and perpetuate the dominance of incumbent actors.

In our cases, actors work towards transformation focus stepwise changes which ultimately lead to a cascade of (smaller sectoral) tipping points in the complexity of a social system. We did not observe a rapid and profound-qualitative shift. The coal phase-out process in Ruhr Region/ Germany was **dominated by incremental change** (see Section 2.3). Almost 50 years passed from the first crisis in the coal sector to the political decision to finally end coal mining in the region (1958-2007). Our observations show that policy decisions and governance measures sought to prevent disruptive or rapid wholesome change. Instead, policy makers sought to preserve the status quo, build on past policies (e.g. continuous subsidisation) and cushioned negative implications (e.g. redundancies/ unemployment), while being influenced by powerful (local/ regional) incumbent actors (e.g. industry and unions) and the public. The long-held paradigm was to avoid social hardship until the financial repercussions (e.g. subsidies) became unattainable and lead to a loss of legitimacy (yet gradually). A window of opportunity opened to finally end coal with a new government at state level pushing for an ultimate termination of the sector. At local level, the cities developed new visions and narratives building on existing and new economic opportunities for transitioning away from coal.

Since the transformation in the Ruhr Region and the two cities is ongoing, we did not observe a social tipping point. Still, we found that going back to a local economy largely based on mining is increasingly less likely (though not totally unimaginable). But the associated notion of *irreversibility* of a tipped system should be treated with caution. Considering 'tipping point' with a 'point of no return' is too simplistic and disregards the complexity of social systems and the "will" and abilities to intervene of (political) actors; possibly, irreversibility is more common in smaller, less complex systems. Hence, *irreversibility* is only a peripheral determinant of tipping.

Building on our case studies and observations from a policy and governance perspective we draw the following conclusion:

- Social tipping can lead to desirable and undesirable consequences even with the best intentions (triggering a positive tipping point) depending on the perspectives of those affected. Hence, the normative connotation is misleading – tipping (only) leads to fundamental qualitative change.
- Pace of change: rapid tipping involves the notion of *losing control* which is (generally) to be avoided from a political governance perspective. Fundamental change is facilitated and sought through incremental approaches constituting the product of a cascade of interventions and (smaller sectoral) tipping points.
- There is not one single tipping point in the complexity of a social system, instead multiple subsystems must move towards new trajectories.
- Irreversibility is a weak determinant of a tipped system – yet it may be applicable in smaller sectoral or subsystem.

2.2 Transition stages and time scale in coal region

This section introduces the views in the literature on socio-technical transition stages in contrast to our learnings from the socio-economic transformation in the coal-phase out region and its respective transition phases.

Transitions are considered as historically contingent processes going through different stages. Several authors have depicted these stages and described them in rather stylized patterns. From the socio-technical perspective, there are usually three to four stages presented: "***initiation or emergence"*** marked by experimentation and niche-innovation, "***early adoption and pioneering"***, "***expansion and diffusion"*** where technologies become mainstream (*reconfiguration* in Geels and Schot 2007) and "***consolidation and stabilization***" comprising a standardization processes (Chlebna and Mattes 2020; Geels, Hekkert, and Jacobsson 2008; Rotmans, Kemp, and van Asselt 2001).

However, we find, that such a linear progression along socio-technical change hardly fits the socio-economic transition in coal-phase out regions. (But may well fit a tipping point dynamic in a socio-technical system.) The close or phase-down of the coal industry (at least in our case) is not necessarily accompanied by the emergence of new (energy) technologies or replaced by such. Instead, coping and managing the industry decline are dominate processes over a long period accompanied by economic diversification, local capacity building and education measure.

In addition, our case studies suggest that the view of "stages" could be over-simplified and not capture the full breath of transition dynamics in a coal phase-out region. Hence, we mapped the following more detailed processes along the following stages (from a policy perspective):

- ***Shock*** triggered by the coal price crisis = *Tipping Event*
- ***Avoid collapse*** of the coal system (interventions to stop further mine closures on basis of national energy security and social policy – coal laws),
- ***Grasping for salvation*** through an introduction of coal subsidies,
- ***Denial*** of looming end while sector receives continuous support and only sees incremental reduction of subsidies,
- ***Loss of public legitimacy*** with the ultimate breakup of "coal coalition" and loss of election(s)
- ***Acceptance*** of the end of coal mining, ***visioning of and pursuing new opportunities*** = *Tipping Interventions*

However, regional transitions (such as the coal phase-out) are embedded in multiple dynamics at local, regional, and national level. Hence, these phases may have manifested at different times and varying intensities at different levels.

Overall, the Ruhr Region is still in a transformation processes. Although coal phase-out was decided in 2007 and the last mine (only) closed in 2018, the region and its cities have not entered a stabilisation phase yet. Since the mid-2000s the cities progress individual pathways building on local capacities (e.g. geographical/ infrastructure etc.) seeking new opportunities and visions. We find that *emergence* of new narrative particularly in Essen appears an essential steppingstone for propelling the city towards a sustainable future. From "grey to green" became the leitmotif for

the city, demonstrating their evolution from and break with the past. In contrast, Duisburg has continued with and further expands on existing capacities and local infrastructure, promoting the existing steel production site and its scale-up as logistic hub. Our case studies suggests that it is important to finalise/ terminate the old paradigm (e.g. with a "final date" and an official symbolic act – official farewell to the miners in the state parliament in 2018), to have all capacities focus on the new.

To conclude, in our case studies patterns of denial and measures to avoid coal decline were prevalent for a long time before new directions and opportunities were sought. Hence, we observe a phase before the "initiation" phase, namely the "denial and avoidance" stage in which the regime defends itself and actors take measures to maintain the old system despite emerging problems. We observe initiation (e.g. visioning of new future for the city) and expansion processes (e.g. first measures for change), but not the consolidation stage, because the transitions are in too early stages.

2.3 Type(s) and sequence of change(s)

In this section we describe the types and sequences of change, while highlighting the different paces in particular the notion of *transformative incrementalism* as a dominant pattern in our case studies.

Types and sequences of social change can vary – transitions may constitute a long, protracted affair, taking decades to centuries to occur or rapid disruptions taking months, or few years to materialise (Sovacool 2016). Although "*tipping"* is usually associated with the latter (Lenton et al. 2022; Milkoreit et al. 2018; Winkelmann et al. 2020), the sum of incremental changes when observed ex post can also lead to a substantial transformation. Buchan et al. (2017, 2019) proposed the emergent theory of *'Transformative Incrementalism'*, to describe slower social processes underlying planning initiatives to achieve transformative change. Incremental actions are essential in the process of transformative change since values, support, and relationships need to be built into the spheres of civil society, industry, and politics (Buchan 2017; Buchan, Cloutier, and Friedman 2019). Hence, both the rapid disruptive and slow incremental processes can bring qualitative substantial and (possibly) irreversible change supporting the notion of a "*tipping point being crossed*".

In our case studies, incrementalism is the dominant pattern, marked by policy stability through institutionalization and path dependency/ technology lock-in over a long term period (Lindblom 1959; Pierson 2000a; Unruh 2000). Still, fundamental change became possible through the accumulation and sequence of incremental steps. In other words, the region moved away from coal as a result of many small increments that added up to larger change (noting that the region is still in transformation process

More specifically, we observed a slow shift in policy from *maintaining* the coal mining industry and *preserving* the status quo (mainly at national and state level), to introducing new opportunities and visions firstly at state level and later at local level. The city of Essen adopted the "green" narrative only recently, while Duisburg continued its narrative of an industry city with slight shift in connotation towards being a logistic hub in addition to the steel manufacturing center. Although the region is still in transformation (and possibly will be for a long time), the coal mining industry and its institutional environment is gone leaving room for something new to emerge.

Our empirical findings suggest that political power is a core variable in a social change process which in our case decelerated the phase-out quite substantially. Transformative incrementalism appears as the dominant pattern, leading (after a long time period) to a slow but significant change in the system. A core legitimation for the pace were considerations for a just transition, protecting the workers and local economies affected by the coal phase-out. The transition away from coal in the Ruhr was however largely or entirely driven by economic concerns, not driven by climate or other aims.

2.4 Stances on justice

Here, we introduce our observations of justice in the coal-phase out process drawing on the literature and our case studies.

The Paris Agreement acknowledges "a *Just Transition* of the workforce and the creation of decent work and quality jobs" as a major challenge and highlights the importance of workers in responding to climate change (UNFCCC 2015). This statement is embedded in the wider energy and environmental justice discourse emphasising the conditions and challenges for a fair and equitable transformation (Heffron and McCauley 2017; LaBelle 2017; McCauley and Heffron 2018; Schlosberg 2007; Sovacool et al. 2017). Simplified, 'just transition' terminology is used to synthesise environmental, labour and social justice frames drawing on different perspectives highlighting socio-economic implications of the sustainability transformation process.

Our case studies provide an indication for the challenges of the energy transition which is more than the mere replacement of coal with wind or solar power. In fact, the social and economic transition of a coal-dependent region requires structural changes in the region to allow for the emergence of new economic activities. The Ruhr Region appears a positive example of a relatively smooth transition process without major social disruptions following the notion of a just transition and the paradigm to leave no one behind ("Niemand fällt ins Bergfreie"). Justice was insofar the central driver of the very slow and stepwise process of the transition away from coal, and today justice is a central driver of the social and economic policies seeking to create a post-coal prosperity in both cities.

One dimension in the concept of just transition is gender, since all transitions affect women differently than men. In an analysis of several coal phase-out regions, Walk et al. (2021) show that that gender had a major impact on how a person was affected by the transition and to what extent she was involved in decision-making. Although we did not specifically focus on the gender dimension or conditions of women in our case studies, we (generally) found that the transition process was driven by a strong attention to the situation of mining workers (and their families) and hence dominated by the perspectives of male and their needs. It appears that more research about the situation of women in the Ruhr Region would be beneficial to understand their role as possible change agents during the coal transition.

2.5 Boundaries: shaping of regions going under transition

In this section we discuss the aspect of boundaries from a governance perspective and how these are observable in our case studies.

Sustainability transitions are highly complex and involving different scales, temporalities, sectors, types of actors across multiple governance levels (Franzeskaki et al. 2015; Turnheim et al. 2015). The lowest tier – the local level – appears as manageable due to their proximity of actors and place (Koehrsen 2017). However, strong dependencies regarding financial and regulatory conditions limit their ability to act independently and with greater impact. Indeed, institutional theorists emphasise the significant differences between micro and macro level, particularly since the national state possesses constitutive power to define the nature, capacity and rights enjoyed by political and economic actors (Scott 2014).

In our case studies we observe a similar imbalance of decision-making powers and actions taken at difference governance levels. We observed a strong dependence of local governments on state and national level actors which stifled the desire to move beyond coal at local level for a long time.

The cities of Essen and Duisburg are part of the wider region of the Ruhr which was considered as one of the coal mining areas in the Germany. However, the Ruhr Region is not defined within actual official administrative or legal boundaries, instead by the mineral resources and its extraction process as well as a cultural identity stemming from coal mining.

The political decision-making powers are confined to, the state of North Rhine-Westphalia or federal level (e.g. energy security measures) or to some degree to the municipalities, and not the Ruhr region. Hence policies and interventions influencing the socio-economic conditions of the region came mostly from higher levels of government (e.g. maintenance of coal industry). In the last two decades, there were increasing efforts to institutionalise and formalise collaboration between the cities in the Ruhr Region to help with the specific challenges of a post-coal region. Indeed, the Regionalverband Ruhr (Ruhr Regional Association - RVR) which comprises 11 cities and four districts of the Ruhr area, seeks to push the image of the Ruhr Region as the greenest industrialised region in the world (Müller et al. 2021). Yet, the RVR can be considered as only one of the multiple stakeholders in the region working towards change.

To conclude, since energy policy is generally considered a national task, we find that measures and interventions at local level have had little immediate impact. Only the national and state decision to phase out coal conclusively, enabled local level to embrace new visions moving beyond the coal era. Our case studies support two issues debated in the literature. First, although our study focused on the cities' developments, the historical dependence of the coal and steel industry on state and national interventions had a significant impact on the local trajectories. The locally induced interventions were important, but often dwarfed by the strong measures from higher political levels, suggesting that a tipping policy analysis must consider all political levels above the level in focus. Second, identifying cause and effect along specific variables is difficult, because the levels are intertwined, and social systems are highly complex – and likely a tipping point analysis can be more precise in smaller,

sectoral systems than in larger, more society-wide ones (see also Section 2.2).

2.6 Multiple stable states

In the following, we discuss how the coal phase-transition relates to the concept of multiple stable states drawing on our observations from the case studies.

The theory of multiple or alternative stable states originates from ecological system research and has been a recurring theme in this field since the late 1960s (Beisner, Haydon, and Cuddington 2003). It has been used to describe and explain sudden and dramatic shifts in species composition and the difficulty in reversing the shift due to the existence of alternative stable states, which (may) create a "new lock-in situation" (basin of attraction) for the system (Petraitis 2013; Scheffer et al. 2001). Scheffer et al (2001) argued on an empirical basis that alternative stable states and resulting catastrophic shifts might be widespread under major anthropogenic environmental change. Milkoreit et al (2018) found it to be a common theme associated with the terms social tipping points and social-ecological tipping points. However, the authors caution that it is unclear whether there are any specific stable states, and how one would identify the shape of the stability and its determining variables (ibid, p. 8). Nonetheless Milkoreit et al (2018) consider *multiple stable states* as one of the key conditions of a (social) tipping point dynamic.

Our cases also provided a notion of multiple stable states: We found that the cities embarked on different development pathways and visions which could lead to different stable states in the future: Essen envisions a green, service-based future, whereas Duisburg seeks to continue developing its heavy industry. Both cities could have opted for either of these options, indicating that at the onset, multiple stable states are imaginable, but there is some path dependency also in visions: putting Duisburg on a green track today, for example, would require breaking the existing visions and industrial policy efforts, and shifting the entire apparatus that is already moving in one direction onto a new trajectory, going off in another direction.

However, both cities are still in structural transformation process (so is the region, away from coal) yet did not cross tipping points into any new stable, prosperous low-carbon state. Hence it is difficult to identify an ultimate stable state in their social system - and even more difficult to compare a development to counterfactual developments. We may anticipate that Essen is successful with the "green" service economy-oriented trajectory, while Duisburg will prosper following the (hard) industry-based route, or that either one (or both) fail.

To conclude, "multiple stable states" are imaginable at onset, but as transformations progresses, the option space narrows. Hence, development trajectories may get locked in: once a city is firmly on a particular path, it will likely remain on it - barring yet another transition process onto an entirely new trajectory.

2.7 (Ir)reversibility

In this section we discuss the concept of (ir)reversibility in the context of social tipping points against our observations from the case studies.

While widely accepted as a key feature of biophysical tipping points (Lenton 2012; Lenton et al. 2008), irreversibility is a more contested concept in in social systems context (Milkoreit et al. 2018; Winkelmann et al. 2020). Because time is linear, any change is, in a sense, irreversible (Sunstein 2008). But in political system, a decision can be revoked, strategies and visions changed or abandoned; in this sense, political tipping is not irreversible. Yet, policy is also path dependent (Pierson 2000b), and large-scale strategies are rarely completely overturned, so that change processes are often, in terms of their high-level direction if not instrumentation, stable. In addition, the scale of the system makes a significant difference. The larger the scale of a social system, the more difficult it may become for a tipping point to be irreversible: Grimm and Schneider (2011) find that social tipping points cannot lead to irreversible change at the level of national-state systems. They emphasize that for example violent conflicts may collapse back upon themselves, quickly democratized regimes may fall back into authoritarian rule, collapsed states may regain former strength and capacity, and segregated societies may find way back into societal integration and inclusion (Grimm and Schneider 2011). However, some such cases are irreversible, such as the peaceful revolution and following reunification of East and West Germany: this constitutes a political tipping point leading to irreversible societal change, where going back to the previous state is impossible. A shift "back" to an authoritarian system, however, is certainly conceivable (and has arguably happened in other places of the Eastern Blok, such as Russia or perhaps Hungary), but this will not be a shift "back to the GDR". We can find irreversible change in smaller systems that are for example delimited by sectoral (e.g. technical, economic) structures such as the transport transition to electric cars in Norway (Sharpe and Lenton 2021) or the replacement and forced change of the light bulb with LED in Europe. Possibly, irreversibility is more common or at least easier to identify is smaller, more confined, and less complex systems.

In our case studies, we find that the close of the mines in Essen and Duisburg were significant tipping events: because there is still coal in the ground, coal mining could restart – but that would require great effort including new political coalitions and public legitimation, amounting to nothing less than yet another deliberate transition. As most of the mining infrastructure was dismantled and the mine tunnels are flooded, returning to mining in the Ruhr is highly unlikely and costly, although physically possible. Yet, as we have seen after the Russian invasion into Ukraine and the attacks on the European energy security, political decisions are not carved in stone, because these generators and their associated infrastructure still exist. For example, the German nuclear and coal phase-out decisions which in 2021 appeared a done deal appear in a very different light in 2022 – the war in Ukraine shifted the German energy context so dramatically, that these decisions were partly adapted. Nevertheless, such rollbacks become technologically and economically implausible and politically harder to legitimize when the infrastructure and technology is already in the process of removal/ dismantling – then it would require longer-term and more substantial measures to trigger a new transition back to the old technologies. Hence, irreversibility likely manifests over time and not always immediately.

Overall, for the more complex social systems, it is often unclear what a final stable state of the system will look like since we will never reach the end of history. Instead we find systems to be "dynamically stable" (Geels 2011; Rosenbloom and Rinscheid 2020). Identifying the condition of *irreversibility* dependence largely on the system scale of analysis. Importantly, policy interventions play a decisive role for the system

to stabilize or (potentially with huge effort) reverse to a previous condition (e.g. reactivating the mines).

2.8 Feedback loops

In the following section, we introduce our learnings and knowledge from our empirical findings on how (and at what stages) do positive and negative feedback loops influence the transition process.

Positive feedback mechanism is a trigger at the onset of a transition process and the trajectory of increasing returns in which each step along a particular path produces consequences which make that path more attractive for the next round (Meadows 1999; Pierson 2000a, 2000b). As such effects begin to accumulate, they generate a powerful virtuous cycle of self-reinforcing activity (Pierson 2000a). In an ideal world perspective, the ultimate outcome will be a stable incumbent system governed by positive feedback seeking to stabilize the system in the "current" state (Unruh 2000, 2002) and favors incremental as opposed to radical innovation (Klitkou et al. 2015).

Policy interventions can be important drivers of positive and negative feedback loops in social-economic systems and hence determine the quality and speed of a system to change. This is captured in the notion of *policy feedbacks* which emphasizes that policies are not only effects but potential causes: "*politics create policies, policies also remake politics*" (Béland, Louise, and Weaver 2022; Pierson 2000a; Schattschneider 1935). Moreover, Pierson finds that: *"major public policies… constitute important rules of the game, influencing the allocation of economic and political resources, modifying the costs and benefits associated with alternative political strategies, and consequently altering ensuing political development"* (1993, p. 596).

In our case studies we found that the cities were locked into the coal regime for decades where positive feedbacks were prevalent: the mines continued operating by means of large national subsidies despite being economically inefficiency for several decades. This created path dependencies and socio-technical lock-in of the coal sector. Positive feedback at local level followed a state government change (=window of opportunity in North-Rhine Westphalia 2005) and the decision to end national coal subsidies in the Ruhr but also across Germany 2007. This decision provided an (further) impetus for the local governments of Essen and Duisburg to progress individual opportunities for their cities (Essen: Green Capital; Duisburg: Logistic Hub). Local government initiatives particularly in Essen focused on the creation of new visions and narratives to enhance the image of the cities within and beyond its borders.

To conclude, policy interventions can reinforce positive feedbacks and create self-sustaining cycle but also trigger new opportunities accelerating dynamics of change. The emergence of positive feedbacks often dependence on the power structures and the stability of the existing regime and its ability to establish correctives and controls (e.g. subsidies) to keep the system stable or slowing down the positive feedback.

2.9 Key triggers of change

Here, we discuss the key triggers of change and/or tipping points in transitions.

In our view, the triggers are on the one hand the EVENTS ((usually) unintentional or (policy system-) exogenous developments such as the coal price crisis in the late 1950s) and then the INTERVENTIONS (e.g. policy measures to influence the socio-economic developments of a system such as funding, education etc.) make the difference, as deliberate acts to avoid social/economic disaster and create new opportunities and build a new, better future. As highlighted in the sections above, policy interventions play a decisive role for triggering change and breaking up path dependencies.

In the case studies, the combination of windows of opportunity (state government change in 2005) and interventions led to new power dynamics and the breakup of the "coalition for coal" (network of unions, labour party and industry). This ultimately enabled the policy intervention to end coal subsidies (2007) and provided a strong signal for local communities that "coal" is not to return. Importantly, the decision was almost exclusively based on economic reasons. In the end, coal subsidies were untenable and lost legitimacy in policy and industry, while the established narratives (e.g. "coal industry is an important economic factor and employer") lost validity. Over several decades, most actors had realised that deep coal mining had become economically uncompetitive and, in the long run, would have no future in the region, but it required the ultimate decision (to end coal) to move forward and focus on new opportunities.

3 Conclusion

Transformations do proceed rapid or slower at different points in time, and in different places with varying degree of socio-economic disruption. Our case studies provide insights into a historic regional transition of a coal phase-out which was (mainly) driven by economic decisions. We found it important and useful to compare qualitative and quantitative data from two cities and identify diverging trends and developments, which a single case studies would not have been able to provide.

Drawing on the empirical findings we theorise some generic conclusions for the tipping point concept. However, as one swallow does not make a summer, we must emphasise the limitations of our approach in terms of generalisability.

The key findings are:

- Despite the growing bulk of studies in the field of social-(ecological) tipping points, there is still a paucity of conceptual and methodological clarity. We found that social tipping points are often first sought to be avoided, and only after they appear unavoidable do we observe policies to create a new stable system state. While social tipping points exist, we may observe them in incremental modes of social change over longer time periods.
- The transition stages were dominated by patterns of decline and avoidance for a long time before new directions and opportunities were sought.
- We observed the regional transformation as a result of many small increments that added up to larger change, associated with the concept of transformative incrementalism. Political power is a core variable in a social change process which in our case decelerated the phase-out quite substantially. A core legitimation for the pace were considerations for a just transition. However, the change was not driven by an urgent climate crisis instead by economic reasons.
- An overarching theme in the coal phase out are considerations for a just transition. In our case, justice was a driver of the very slow and stepwise process of the transition – indeed a barrier to faster phase-out of the economically and environmentally problematic coal mining – and today justice is a central driver of the social and economic policies seeking to create a post-coal prosperity in both cities. However, the justice discourse was focused and dominated by the male perspective and hence more research about the situation of women would be beneficial to understand their role as possible change agents during the coal transition.
- The scale of the system plays a crucial role to identify tipping dynamics. Determining cause and effect along specific variables can indeed be more precise in smaller, sectoral systems than in larger, more society-wide ones.
- We found it difficult to observe multiple stable states since the system is still in transformation. Speculations about alternative stable states are limited by strong notion of path dependency in coal phase-out regions which influences the local trajectories.
- Irreversibility also requires the observation of a final stable state. However, the more complex the social system the greater the challenge to identify a final stable state and consequently irreversibility appears as a weaker determinant

of a tipping point.

- Policy interventions can be a cause of policy stasis or change – triggering positive feedbacks either reinforcing self-sustaining cycles or trigger new opportunities accelerating dynamics of change.

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