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

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D3.2 Case Study
Empirical observations of tipping dynamics in a coal phase-out region in Germany: the cases of Essen and Duisburg

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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

	Participant Name	Short Name	Country	Logo
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2	Delft University of Technology	TUD	NL	
3	CIRPA - Università Degli Studi di Roma La Sapienza	UR	IT	
4	Institute for Advanced Sustainability Studies e.V.	IASS	DE	
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Executive Summary

The imperative of fully decarbonising our energy system and industries, as inscribed in the Paris Agreement, brings coal- and carbon-intensive regions under particular pressure. The impacts of closing industries may be especially strong here due to the strong socio-economic, political and cultural path dependencies and lock-in effects that have made them reliant on fossil fuel industries in the first place.

The conurbation of the *Ruhrgebiet* (Ruhr Region in the following) in North-Rhine Westphalia/ Germany is an example of such an industrial region in which structural change away from coal has been ongoing for about sixty years. There, the two cities of Essen and Duisburg share a long tradition of coal mining and coal-dependent industry – experiencing a similar transition process and trajectory in the mining industry's decline. At the same time, they appear to develop differently as they are perceived as very differently *good* or attractive. This indicates that Essen's transition away from coal is potentially going somewhat better than it has so far in Duisburg.

In this paper, we investigate the socio-economic transition processes of Essen and Duisburg as part of the wider structural change in the Ruhr Region. In the two case studies, we explore causes and effects of the cities' development trajectories in the last 30+ years, seeking to identify differences in outcome as a function of the interventions and/or contextual differences. We analyse events, interventions and their impacts on the social and economic systems of the two cities across time. 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. Therefore, we specifically evaluate the cities' development trajectories by seeking evidence for "no", "incremental" or "radical" changes in a set of indicators. Here, we have taken a long temporal perspective, because trajectories of and trajectory changes in social systems are specifically visible in demographic dynamics, economic structures and political arrangements across time.

Our analysis shows that both cities experienced **incremental changes** in their demographic, economic and political trajectories but we found no evidence for either city to have crossed a tipping point in their transition process yet. However, distinct developments in the cities' policy narratives indicate qualitative changes while putting them on different development trajectories potentially leading to tipping points in the future. Consequently, the cities appear at a crossroad. While their socio-economic trajectories still show similar trends, the narratives and policy visions of the cities suggest that their future trajectories will diverge. While Duisburg builds on the old narrative of continued and new heavy industry structures, Essen has formulated an alternative vision for the city, departing from the old mining image towards a greener future. Although success and prosperity are still uncertain, the developmental bifurcation is likely already happening. As they embark in different directions, the cities will likely grow increasingly different over time.

Our study shows that the sequence of interventions and timing are important factors for the trajectory of a region determining the quality of societal change. But radical change and tipping are the exception rather than the rule, especially in the highly complex social systems of cities.

Nevertheless, our research suggests that the distinct local narrative developments may herald a tipping dynamic in the future – and we cannot rule out that, seen from a few decades into the future, the period around 2020 can be identified as a tipping period in one or both cities. The strategies to influencing the local narrative building as well as focus on local strength and capacities appear as key mechanisms also relevant for other coal communities in their transition process. These interventions, whether they trigger tipping or not, are still necessary and useful steps towards a prosperous future beyond coal.

Table of Contents

Disclaimer **3**
Copyright Message **3**
Who We Are **6**
Executive Summary **7**
Table of Contents **8**
1 Introduction **10**
2 Societal change: Path dependency and policy narratives **11**
3 Method **13**
4 Results **16**
4.1 Tipping events: the demise of the coal mining 16
4.2 Policy interventions 18
4.2.1 National level measures: support coal mining and protect workers 18
4.2.2 State level interventions: structural change support and preparation for the post-coal era 20
4.2.3 Interventions at local level 22
4.3 Impacts in time series of selected structural data 25
4.3.1 Population trends: rapid decline halted and stabilised 26
4.3.2 Unemployment and employment rates: positive developments at incremental pace 28
4.3.3 Gross Domestic Products: slow but steady increase 30
4.3.4 Education: success story with steady increase of tertiary-level students 31
4.3.5 Electoral behaviour: mood change and break-up of path dependency 32
4.3.6 Local narrative developments 35
5 Discussion **40**
References **43**
Appendix **50**
Election results in Duisburg since 1975 at all government levels 50
Election results in Essen since 1975 at all government levels 51

List of Figures

Figure 1: Analytical framework for regional case study analysis 13

Figure 2: Development of the workforce in hard coal mining in the Ruhr and Germany (entire workforce) between 1945 and 2018. Source: Statistik der Kohlewirtschaft e.V. 2021. 16

Figure 3: Hard coal production and workforce in the Ruhr Region 1957 to 2018. 20

Figure 4: Population development in Essen and Duisburg since 1962. Source: [80] 26

Figure 5: Migration in the city of Essen – in- and outflow between 1930 and 2019. Source: [80] 26

Figure 6: Migration in the city of Duisburg – in- and outflow between 1980 and 2020. Source: [80] *landesdatenbank and city statistic* 27

Figure 7: Unemployment rate in North-Rhine Westphalia and respective cities and regional districts 2019. Source: Statistik Arbeitsagentur 2022, [85] 28

Figure 8: Unemployment in Ruhr Region, NRW and West-Germany 1960 to 2014. 28

Figure 9: Employment trends in Duisburg and Essen since 1976 (in total number of local workforce). Source: Regionalverband Ruhr, IT.NRW 29

Figure 10: GDP at market prices 1991 to 2019 in Million Euro of Essen and Duisburg. 31

Figure 11: GDP per person employed 1991 to 2019 in Euro of Essen and Duisburg. 31

Figure 12: Share of residents in Duisburg and Essen with tertiary education (Bachelor, Master, PhD) in thousands between 2005 and 2019. 32

Figure 13: NRW state election since 1975 in total numbers of voters. 33

Figure 14: State governments composition in NRW since 1947 33

Figure 15: SPD (red) or CDU (black) government and majors on local level across the timeline 34

Figure 16: Stylized development of different narratives in the region and both cities. 39

List of Tables

Table 1: Selected indicators and measurement 14

Table 2: Interviewed stakeholders in at local and region/ state level. 15

Table 3: Selected key figures of German hard coal mining (both Ruhr Region and Saarland) in selected years since 1957 17

Table 4: Selected events and interventions 18

Table 5: Major laws and regulation of coal interventions since 1960s 19

Table 6: Periods of structural intervention in the Ruhr Region since 1960s. 22

Table 7: Key socio-economic statistics from Essen, Duisburg, and comparison to the Ruhr Region, NRW and Germany 25

Table 8: Development of population in Essen, Duisburg and NRW per age groups 1975 and 2020. 27

Table 9: Unemployment rates in Duisburg and Essen in selected years since 2001. 29

Table 10: Disposable income per resident in Euro in Essen, Duisburg and NRW in selected years between 1995 and 2019. 31

1 Introduction

There is growing consensus that a rapid and profound near-term decarbonisation of the energy system is essential, as an initial step towards the zero-carbon energy future necessary for meeting the temperature targets of the Paris Agreement (IPCC 2022). This brings coal- and carbon-intensive regions under particular pressure, because the impacts of closing industries may be especially strong here due to the strong socio-economic, political and cultural path dependencies and lock-in effects that have made them dependent on fossil fuel industries in the first place [1], [2].

Yet, some previously coal-dependent regions have already advanced in their transition away from coal and provide insights in the system dynamics and change processes. The conurbation of the *Ruhrgebiet* (Ruhr Region in the following) in North-Rhine Westphalia/ Germany is an example of an old industrial region in which structural change away from coal has been ongoing for about sixty years [3]. There, the two cities of Essen and Duisburg share a long tradition of coal mining and coal-dependent industry – all of which has come under transformation pressure as coal mining decreased and ultimately stopped. In the process, both cities have seen similar problems of population decline, increased unemployment and growing low-income segments, both in comparison to the coal era and compared to other regions in Germany. At the same time, the two cities appear to develop differently and they are perceived as very differently *good* or attractive: in national city ranking reports, Essen consistently performs in the middle of such rankings, well ahead of Duisburg, which sits at the lowest tier of all assessed cities [4]–[6]. Hence, we hypothesise that something is different in the two cities: something appears to go better in Essen's transition away from coal than it has so far in Duisburg.

In this paper, we investigate the socio-economic transition processes of Essen and Duisburg as part of the wider structural change in the Ruhr Region. In the two case studies, we explore causes and effects of the cities' development trajectories in the last 30+ years, seeking to identify differences in outcome as a function of the 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. To this purpose, we examine policy interventions and their impacts on socio-economic indicators to identify non-linearities and significant shifts. In addition, we draw on 20 interviews with local stakeholders to better understand the local narrative developments.

We find marginal social, economic and demographic differences, in which Essen consistently performs somewhat better than Duisburg, but not dramatically so. Importantly, their development trends are practically parallel, indicating that they are not on different social and economic trajectories, yet. However, we also identify a bifurcation in the cities' visions and their narrative development: whereas Essen envisions a green, sustainable future, Duisburg remains devoted to its industrial storyline. Neither of the cities have crossed a tipping point in the hard quantitative indicators, yet the narrative change may indicate a significant and qualitative shift in the long term: if the cities embark on different trajectories now, this will likely result in stronger social and economic differences in the future.

2 Societal change: Path dependency and policy narratives

Regional systems dominated by carbon-intensive industries are (often) locked into specific development pathways, both because they depend on the economic activity continuing in the short term (e.g. to keep employment up) but also because social, economic and technical institutions and infrastructures have co-developed with the dominant industry, supporting and entrenching it. Once an industry has become dominant, reducing or eliminating regional dependence faces strong short- and long-term problems. Such path dependency results from different positive feedbacks among technological infrastructures and political or economic institutions which increase the returns to scale and make change difficult and costly [1], [2]. In other words, the costs of reversal are getting higher and higher over time and create a considerable obstacle to move off an established path [7]. Changes in such established and path dependent systems thus tend to be **incremental** and materialise in slow processes over long periods of time.

However, social systems can also change in more **radical** ways when significant qualitative shifts in the trajectory occur. Examples are revolutions, wars and collective mass mobilisation overthrowing existing and no longer desirable systems at a certain point in time [8] or the closing of a previously dominant industry. Such radical change is often associated with high costs, including economic, social or political costs. Yet, systems do undergo radical change – not often, but sometimes they shift into fundamentally different trajectories.

Such social tipping points are limited periods of time in which interventions – both large and small – can trigger self-reinforcing feedbacks that accelerate systemic change in social or economic context [9]. These interventions may be directed towards the triggered effect, which is the type of interventions we are interested in here, but tipping can, at least in principle, also be unintended effects of actions with an entirely different intent. Similarly to the natural world [10]–[12], social tipping points can become **visible in abrupt non-linearities** of peaks or dips in selected system indicators [13]. These impacts and disruptions are sought in hard indicators such as demographic, economic and political developments [9], [14]–[16]. For example, the closure of a dominant industry is often followed by significant local unemployment and migration leading to an overall socio-economic decline and drop of GDP in the region, which has happened in many old coal regions, for example Wales or Appalachia [17]–[19]. If this declining trend is reversed, for example through new jobs creation triggered by dedicated policy action to attract new companies, the region may have passed a tipping point – from the decline associated with the disappearance of a dominant industry to a new but still prosperous future.

In addition to such 'hard' indicators, there are softer indicators such as **public and policy narratives** carrying transformative capacities and agential forces [20], [21]. Narratives are ways of structuring human comprehension of complex environments, in other words help people to interpret their world [22]. They constitute a crucial element in transformation processes as means for eroding lock-ins and reorienting practices and visions towards desirable alternatives [23], [24], and so potentially inducing tipping points [16], [25]. Narrative changes may not constitute tipping points in themselves – the mere change of vision of perception does not equal new jobs or income – but they may be indicative of an upcoming tipping point, because they signify the emergence of a new vision for the region with associated measures to achieve it.

The closure of an industry is an example that follows the (more widely used) negatively connoted or undesired tipping point perception, yet there is a growing literature about **'positive tipping**

points', which describe a normative perception of a desired trajectory in terms of sustainability transformations [16], [26]–[29]. A distinctive feature of (positive) social tipping processes is the element of agency: the intention to bring about desired socio-economic trajectories [9], [14]. **Interventions** are purposeful actions from individual or collective public (e.g. government, civil society) or private (e.g. industry, businesses) actors to accelerate, avoid or facilitate (manage/ coordinate) a change process in a social system [9], [14], [15], [30]. This idea of desirable, radical social change triggered by deliberate actions emphasises the importance of human agency as a central idea in the social tipping point literature. Interventions are essential in this concept since they create the enabling conditions for a system to tip [9].

There is still much discussion about ***when* tipping points become observable** in the complexity of social systems across times and scales, and whether they can be predicted or not [31], [32]. Winkelmann et al (2020) state that "social tipping processes do not have a spatial extent or effective dimensionality that is known ex-ante" (p. 8). Hence, the dominant view is that tipping points may only be identified retrospectively in reference to the specific historical legacy or systemic change [33], [34]. While still rare, newer studies suggest that social tipping processes can be predicted, particularly in smaller, sectoral systems. [35] provide evidence from a behavior threshold model finding that the benefit–cost ratio of norm change is a key determinant of the probability of social tipping [35]. Other studies suggest that past stock market bubbles [36] or electricity grid blackouts show signs of early warning [37]. [21] find that changes of narratives carry radical transformative forces and can trigger systemic disruptions. Thus, in specific cases, behavior change, the rise of new discourses or narratives may anticipate or precede tipping dynamics. In this report, we examine evidence for past changes, including tipping points, but we also assess ongoing, not yet concluded processes to discuss whether they may constitute tipping points.

However, because the idea of social tipping points is new and empirical study of complex social systems is difficult, there is no clear view in the literature for how to distinguish tipping processes from other forms of structural or social change, resulting in calls for further empirical investigation particularly for systems currently in transformation [14]. Despite the rapidly growing body of conceptual literature on the topic [13], there is a lack of empirical examples. Our study does precisely this by empirically investigating the societal and economic development trajectories of Essen and Duisburg during and after the phase-out of coal mining.

3 Method

To answer our research question, we examine interventions and outcome of regional developments in a case study comparison of Essen and Duisburg. The cities were chosen as two examples of intensive socio-economic transformation processes in close geographical proximity with very similar starting conditions yet diverging perceptions and possible future pathways. As illustrated in Figure 1, for each case study we explore events, interventions and their impacts on the social and economic systems of the two cities across time. Specifically, we evaluate the cities' development trajectories by seeking evidence for "no", "incremental" or "radical" changes in a set of indicators. We investigate three types of variables:

- **Events**: The trigger for the change process away from a previously dominant industry. This trigger can be exogenous (e.g. competition from other countries, a natural disaster) or endogenous events (e.g. coal runs out, politically decided phase-out) that lead to an industry disappearing, abruptly or gradually. In our cases, the event is the closure of the local coal mines.
- **Interventions**: deliberate and targeted policy and industry measures influencing socio-economic trajectory of the regional/ local system, seeking to address the effects of the event(s) and keep the system or put the system (back) on track for an alternative prosperous development. In our cases, the interventions are mainly policies for the post-coal economic development of the two cities – specifically to counteract the negative effects of the coal mine closures.
- **Impacts**: long-term changes in socio-economic variables, including both hard social and economic indicators (e.g. unemployment) and softer ones (e.g. political visions, local identity narratives). These variables are where we can observe the outcome of interventions, including a possible tipping point.

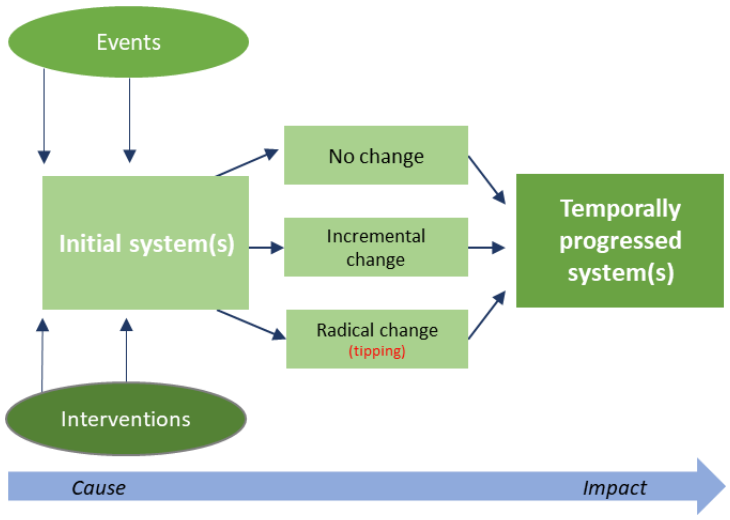


Figure 1: Analytical framework for regional case study analysis

We approach this in three steps. First, we conduct a qualitative analysis by systematically examining **socio-economic policy measures** that sought to counteract the impacts of the industry phase-down and -out in the case studies since the 1960s. These measures are direct interventions from different government level that seek to address and influence demographic, economic and social developments as well as the public discourse and narrative in the two cities. To this purpose, we review relevant literature including national and state parliament protocols, legislative documents as well as policy and strategy documents from local level concerned with relevant

interventions in the post coal-crisis era. In addition, we conduct semi-structured interviews with state and local stakeholders (Table 2) to receive in-depth insights into the local and regional transformation process and the qualitative importance of specific policy measures. Hereby we relate to Winkelmann *et al. (*2020, p.13) suggestion that that the observation of tipping dynamics requires a retrospective tracing of specific process, "identifying the key moments, actors, networks, mechanisms affecting criticality, the triggering event (threshold), and the positive feedback dynamics propelling the system towards qualitative changes".

In the second step we analyse **quantitative data** for a set of demographic and economic indicators over timeframes of 20 to 50 years (depending on data availability) (Table 1). We take this long temporal perspective, because trajectories of and trajectory changes in social systems are specifically visible in demographic dynamics, economic structures and political arrangements across time [14].

In addition to the quantitative data, we further examine the "soft" indicator of **local narrative and discourse development**. The initial literature review served as a basis to help build the analytical narratives and discourses. Adapted from Lieu et al. (2020), Tabara et al. (2018) and Hinkel et al. (2020), we structured the narratives into dominant and alternative perceptions, describing mainstream and emerging views at local and regional level. The mainstream narrative represents the (previously) dominant regional pathway and respective interventions that promoted the coal and steel industry as central factor for a prosperous local development. Alternative perceptions comprise measures and strategies that depart from this mainstream perspective and (potentially) challenge the mainstream pathway. For example, a critical view on the ecological impacts of mining operations existed (for a long time) outside of the mainstream perspective, though became increasingly relevant with the closure of mines and the need for brownfield redevelopment.

Table 1: Selected indicators and measurement

Indicators	
Demographics	
Population size	Local population development and migration patterns 1962-2020.
Age	Distribution of different age cohorts 1995-2020.
Education	Share of residents with tertiary education 2005-2020
Election patterns	Local voter turnout and party preferences at local, state and national elections between 1975 and 2020.
Economics	
Unemployment	Unemployment rates as percentage of all unemployed in relation to all persons in the labour force 2000-2020
Employment	Employment rates in total number of the local population 1976-2020
GDP	Trends in the regional and local economic output measuring GDP at market price and per employed person 1991-2019.
Narratives	
Public discourse	Policy discourses and narrative development in policy documents and media articles, as well as municipality websites, local strategies, and information from local companies, and interviews.

In the third step we **examine the relation between interventions**, the **quantitative social and economic data** and **narratives developments** to determine the impacts of the interventions and particularly if they are related to any strong trend shifts. To this purpose, we evaluated the trajectories of the indicators in the data time series towards dynamics of *no, incremental or radical change*. In this, '*no change*' is indicated by an indicator remaining roughly constant over time, before and after an intervention. We consider a trend as '*incremental change*' when an indicator does change, but only slowly, without any particular discontinuities, such as rapid surges or

drops, over time. '*Radical change'*, in contrast, is recognised by a sharp and rapid shift in a variable, regardless of the direction. Here, we see radical change as a proxy for a tipping point (see Figure 1): because radical change signals the departure from an old to a new trend, this is indicative of system tipping.

For the narratives, we examine the policy discourse and narratives to identify similar changes – no, incremental or radical changes – indicated by a continuation of the old dominant narrative, a slow but discernible narrative change within the same paradigm, or the emergence of a new dominant narrative for the development of the city.

Our analysis is based on both qualitative and quantitative data. We generate the qualitative data through an extensive document and literature analysis, including news media articles, national and state parliament protocols, and websites of local governments, regional governance organisations and NGOs. Additionally, we conducted 20 semi-structured interviews to identify the key interventions and local perceptions of their importance and effects, especially on the narratives. The interviews were held between March and November 2021 with representatives from government and non-governmental organisations, including regional and local governance authorities, labour unions, local companies, university, media and local NGOs, focused on a set of central questions:

- *In your opinion, what were major events in the city and/or Ruhr Region regarding the coal-phase out process in the last decades?*
- *What were significant political decisions that influenced the local/ regional trajectory, and why was this/ these measures particularly important for the city?*
- *How did the public (and your) perspective on the dominant industry change over time, and why?*
- *What is the current and future vision of the city/ region?*
- *In your opinion, what constituted a tipping point for the locality, and why?*
- *What was the role of your organisation in the local/ regional transformation process?*

Table 2: Interviewed stakeholders in at local and region/ state level.

	Essen	Duisburg	Regional/ State Level
Government	2	-	3
Public governance bodies/ Unions	1	1	3
Industry	2	1	1
NGOs	2	2	1
Academia and Media	1	-	1

For the quantitative variables, we obtained data from local and state government websites, and regional statistics sources such as regionalstatistik.de or arbeitsamt.de, as well as through direct contact with local government representatives.

4 Results

4.1 Tipping events: the demise of the coal mining

The Ruhr Region is a regional archetype of lock-in and path dependency [3], [38]. There, the coal and steel industries have been dominant for several decades dating back to the industrialisation in the 19th century. The very first mining activities in the Ruhr were noticed already in 14th century on the southern edge of the Region where the coal was close to the surface. With significant production and output growth the workforce rose to about half a million miners and steel workers after World War II and contributed to the rebuilding efforts fuelling the nation's increasing energy demand. At the end of the 1950s, the annual production of hard coal reached its peak with around 150 million tons.

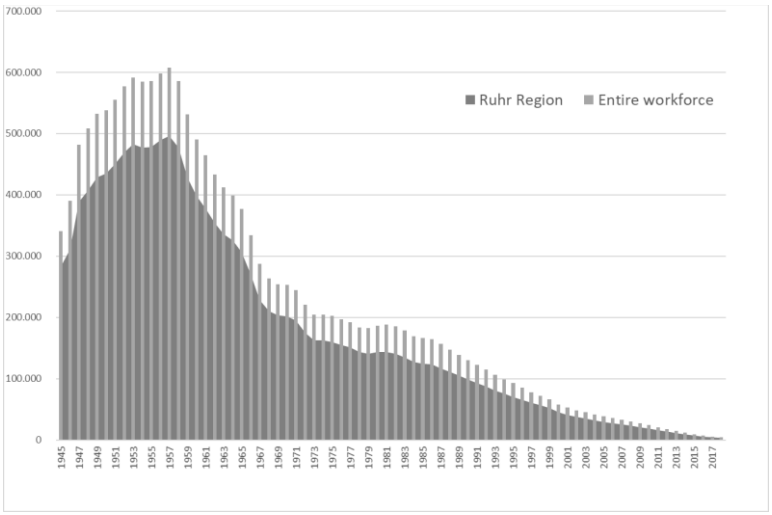


Figure 2: Development of the workforce in hard coal mining in the Ruhr and Germany (entire workforce) between 1945 and 2018.
Source: [39].

In 1958 the coal crisis represents the **early tipping event** for the region. The lack of competitiveness of German mines and the influx of cheap coal and oil imports forced the closure of more than 90 mines in the first ten years [38], [39]. In the same timeframe employment also declined substantially dropping by half (see Table 3). A key production site was the Ruhr Region in the state of North Rhine Westphalia. With industrial change and technical progress, mining operations continuously moved north to reach still profitable depth of coal.

Table 3: Selected key figures of German hard coal mining (both Ruhr Region and Saarland) in selected years since 1957

Year	Hard coal mining	Employees	Trainees	Capacity per person and shift	Number of mines	Hard coal imports	Hard coal exports
	in 1 000 tons [x]	*end of year*		*in kg*		*t=t*	
1957	149,446	607,349	48,181	1,585	173	18,936	27,529
1967	112,043	287,270	12,505	3,264	81	7,356	25,631
1977	84,513	192,015	15,551	3,850	43	7,275	20,837
1987	75,818	156,483	13,776	4,559	32	8,974	8,570
1997	45,796	78,101	2,690	5,762	17	23,290	789
2007	21,307	32,803	2,398	7,071	8	45,891	463
2017	3,669	5,711	86	8,809	2	42,980	1,065
2018	2,584	4,125	0	10,041	2	41,107	1,045

Source: Statistik der Kohlewirtschaft e.V.
[x] Usable extraction (water and ash content are also considered)

Although the ramifications of the coal and steel industry decline were felt across the region, the **two cities experienced their tipping events much later:** The local mine in Essen closed in 1986 [40], in Duisburg another 20 years later in 2008 [41].

Essen's coal mine *Zeche Zollverein* employed up to 8,000 workers mining a total of 240 million tons of coal across its lifetime. In the 1970s when the mine reached its final depth at 1000 metres, the mine produced 23,000 tonnes of coal per day. The industry's decision to close the mine was part of the ongoing consolidation measures and hence did not come to a surprise since it no longer operated economically through depleting resources at greater and greater excavation depths. The transition process for local workforce was managed through early retirements, "golden handshakes"[1] (, and the relocations of younger workers to remaining coal mines (Interview). The architectural status and the importance of the mine considered as a the "cathedral of industrial culture" however was to preserve. Against the "normal" procedure of demolition of closed plants, the city and state government intervened put a preservation order on the entire site conserving it as a technological monument by the time of closure [40].

The closure of the mine in Duisburg was a compromise after extensive public protest in 2008. The *Zeche Walsum* was located further north and in direct vicinity to a coal fired power station to convert the hard coal into electricity. Walsum reached its maximum annual production in 1982 with 3.4 million tonnes of coal and a workforce of 4,600 [41]. A local conflict emerged around the 2000s, when residents were no longer willing to accept the prospect of mining damages anticipated from an expansion of mining operations. In fact, for decades it has been taken for granted that mining damages occurs (Interview). The ground above the mines sunk (and is still sinking) in parts by more than 20 meters (in Essen up to 25 meters) resulting in cracks in the walls, doors and windows no longer to close, sometimes the ground even collapse taking a garage with it [42]. For the first time, a local initiative was successful in mobilising support and forcing government and industry to a compromise, the Walsumer Agreement (Walsumer Verständigung) determining the mine to close 11 years earlier than originally intended. The State Government and Mining Company (DSK) stated in the agreement: "The acceptance of hard coal mining is a great asset for DSK (Deutsche Steinkohle AG). The public interest in environmental protection and

[1] This included a significant financial compensation package when the employees lost their job.

concern about possible environmental risks can be imposed on in individual cases, enabling early voluntary closures" [43]. It was the first time, ecological criteria and the economic risks for residents were considered when a mine was closed (Interview).

4.2 Policy interventions

The German coal industry has always been subject to interventions due to its great importance for national energy security, economic growth as well as the labour market [44]. With the demise of the coal sector actions by different government levels intensified firstly to halt the decline and later counteract its negative impacts.

Indeed, purposeful policy actions can prevent, avoid, or buffer undesired transition outcomes and hence may constitute tipping interventions. [15] highlight the importance of governance and policy interventions to induce tipping processes by changing the regulatory, normative and institutional setting. For example, redirecting national subsidy programs to renewables and low-carbon energy sources or removing the subsidies for fossil-fuel technologies are considered as tipping interventions for a take-off and diffusion of fossil-fuel-free energy systems (ibid, p. 4).

In the 60 years, after the coal crisis, there have been numerous interventions in the Ruhr to facilitate and manage the regional and local transformation processes. Due to the limitations of this study, we selected several key interventions taken by national to local government level listed in Table 4. The selection is based on literature review and interview feedback comprising measures dedicated to supporting coal, regional development programs and local transformation strategies while effecting the cities trajectories. Each of these will be discussed in turn.

Table 4: Key events and interventions

National	NRW (state level)	Essen	Duisburg
Coal laws and regulations incl. law to end coal subsidies (2007)	IBA (1989-1999)	Cultural Capital 2010	Duisport extension at Krupp-Stahlwerk Rheinhausen 1998
	Government change (2005)	Green Capital 2017	New Silk Road - Chinese partnership

4.2.1 National level measures: support coal mining and protect workers

Coal mining in the Ruhr Region has historically been a matter of national energy security and economic growth. When the coal crisis brought large unemployment and questioned the domestic production of hard coal, the national government interventions were immanent [42, p. 17], [43].

The early measures focussed on avoiding a further coal sector decline to lessening social hardship and facilitate a domestic coal production and use with subsidies and fiscal measures (Table 5). The first coal law was introduced in 1963 determining the establishment of an Association to rationalise the coal industry issuing closure premiums (Bundesgesetzblatt 1963). These government interventions also triggered industry measures and ultimately the establishment of the Ruhrkohle AG (later RAG Aktiengesellschaft) in 1968. The new company amalgamated 94% of the coal production in the Ruhr at that time and later integrated all remaining coal mining companies in the region [47].

Table 5: Major laws and regulation of coal interventions since 1960s

Year	Title of Law	Purpose
1963	Law to support the rationalisation of mining *(Gesetz zur Förderung der Rationalisierung des Bergbaus)*	The mining companies had to join the Rationalisierungsverband (association for consolidation), which aimed at to reduce the number of mines. In the case of closures, the federal government awarded premiums and financial aid.
1965	1st law *to support* the use of hard coal in power stations *(Gesetz zur Förderung der Verwendung von Steinkohle in Kraftwerken)*	The law included tax benefits for the establishment of new coal fired power stations requiring the use of domestic hard coal for electricity production. Increase competitiveness against oil fuel in heating.
1966	2nd law *to secure* the use of hard coal production in the electricity industry *(Gesetz zur Sicherung des Steinkohleneinsatzes in der Elektrizitätswirtschaft)*	Subsidies for the use of domestic coal to ensure competitiveness in the world market – to ensure a reasonable share of domestic coal in the electricity production. It offered the steel industry subsidies and funds in case of redundancies to cushion social hardship, when using domestic coal.
1974	3rd law to *further secure* the use of "community coal" (Gemeinschaftskohle) in the electricity system *Gesetzes zur weiteren Sicherung des Einsatzes von Gemeinschaftskohle in der Elektrizitätswirtschaft (Drittes Verstromungsgesetz)*	Under the Act, the amount of hard coal to be purchased by the electricity industry was determined so that domestic demand for hard coal was stabilised and electricity supply was secured. In return, the electricity industry was granted subsidies to compensate for possible additional costs. These costs were to be covered by households with a levy on the electricity bill (also known as the Kohlepfennig).
1980	Amendment of the 3rd law to *further secure* the use of community coal *Neufassung des Gesetzes zur weiteren Sicherung des Einsatzes von Gemeinschaftskohle in der Elektrizitätswirtschaft (Drittes Verstromungsgesetz)*	For the purpose of energy security, the use of domestic coal for electricity and heat production receives subsidies for 191 million tonnes 1981 to 1985, 215 million tones 1986 to 1990 and 232,4 million tones 1991 to 1995.
1994 (July)	Law to *secure* the use of hard coal in the electricity production and amendment to the nuclear law and feed-in law *(Gesetz zur Sicherung des Einsatzes von Steinkohle in der Verstromung und zur Änderung des Atomgesetzes und des Stromeinspeisungsgesetzes)*	For the purpose of energy security, a reasonable share of the German hard coal should be secured for electricity production 1996 to 2005. The coal mining industry receives a special fond for subsidising its operations.
1995	Law to *reorient* the hard coal use for electricity from 1996	To secure the support for coal industry after the end of the special coal levy, the subsidies will be provided by federal government budget.
1997	Law to *restructure* the coal subsidies 1997 *(Gesetz zur Neuordnung der Steinkohlesubventionen)*	Subsidies for mining companies will be drawn from the federal budget and provided in a decreasing stagger between 1998 and 2005.
2007	Law *to finance the end* of the subsidised hard coal mining by 2018	The law specifies to end the subsidised extraction of hard coal in Germany at the end of 2018 in a socially acceptable way.
2020	Act to reduce and end coal-fired power generation and to amend other laws (Coal Phase-out Act)	This included the reduction and ultimate end of coal and lignite-fired power generation by 2038 in Germany.

Yet, as shown in Figure 4, the workforce decline was not halted but slowed down (see also Table 3 – "Employees"). Hence, "no one is left behind" became the moto of the sectors' transformation and further government interventions. The policy interventions between the 1960s and late 1980s were foremost conserving and follow-up measures to halt structural change by preventing the shrinkage of threatened sectors or at least to delay it to avoid social unrest [48], [49]. In addition, the social welfare system in Germany also contributed significantly to securing the social stability and buffering hardship for the local workforce through e.g. unemployment and pension funds as well as health insurance offered by public and private providers.

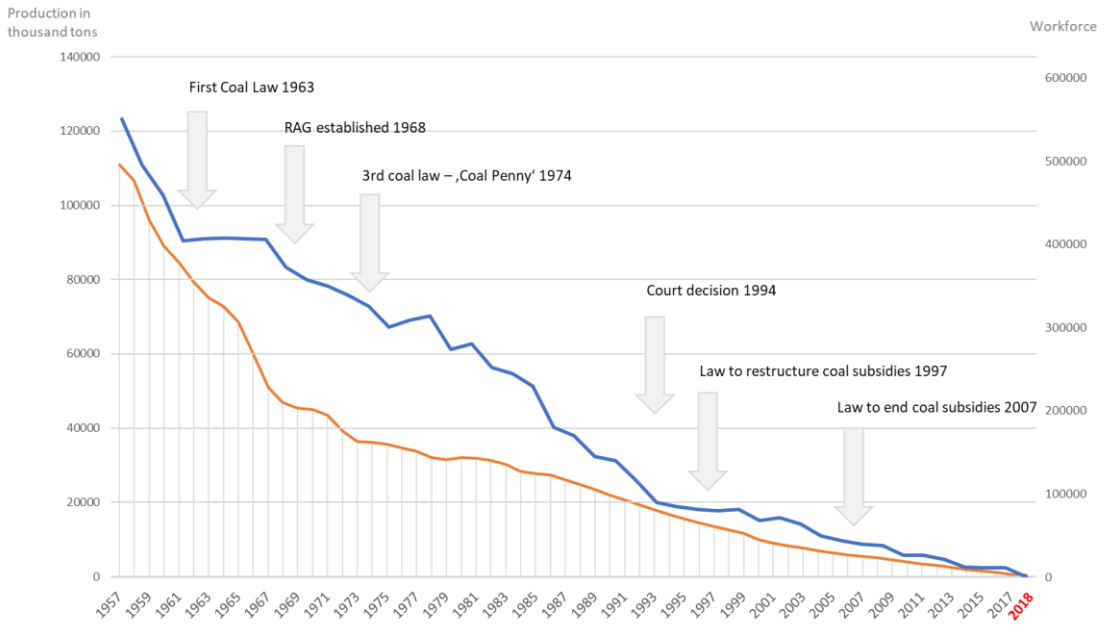


Figure 3: Hard coal production and workforce in the Ruhr Region 1957 to 2018.
Source: Statistik der Kohlewirtschaft e.V.

At the same time, national subsidies for the hard coal sector steadily increased through various financial aids and fiscal measures reaching a peak in the mid-1990s [50]. But since the 1980s the coal subsidies became under increasing pressure from the public, the electricity industry as well as EU level. In 1982, an electricity customer declined to pay the “coal penny” to its power provider RWE, a levy that was introduced in 1974 and constituted a significant part of the subsidies (1/4) (Table 5). This dispute issued a significant milestone as it was eventually brought to the Federal Constitutional Court in 1994 who decided that the levy is unconstitutional and must end by 1995. In fact, the court decision was the precursor for a general change of mood and a loss of importance of pro-coal policy at the federal level [48]. In addition, the introduction of EU Single Market and its competition law in 1993 required measures from the national government to avoid unfair competition advantages. These developments ultimately triggered a change of the policy narrative focussed on *the reduction of subsidies* materialising in the subsequent coal agreement of 1997, which required a restructuring of the coal subsidies.

However, an end of coal policy support was not in sight yet, since the state government had not reached the threshold at which winning or losing elections was dependent on their coal policy.

4.2.2 State level interventions: structural change support and preparation for the post-coal era

The (still) large workforce and the economic added value of the sectors determined the subsequent policy measures. “Conserving the status quo” was the leading motif for many decades, yet since the 2000s measures to prepare for a post coal era were finally introduced.

There have been four different periods of structural interventions in the Ruhr Region (Table 6) [49]. These interventions were driven by state level government and funded through national, state, and later EU programs. As early as 1968 the state government intervened to complement and integrate the national with specific regional measures targeting the modernisation of mining

operations and investment in local transport and recreational infrastructure. An important milestone was the foundation of the Ruhr Universities to increase human capital during that time [51]. However, these and the measures in the following three decades did not provide a significant change in the political course, rather the economic decline of the industry was accompanied by political measures moderating and facilitating societal transformation process. Dahlbeck et al (2022, p. 52) analysed the interventions having a conserving impact since they were only introduced after a significant workforce decline. Instead of a rapid shift, the approach followed the notion of a "gliding flight" over a long period with the prime intention to avoid social hardship (Interview). The policy narrative was focused on recreating jobs, stop migration and reverse the negative image of the Ruhr Region as a "crisis-hit trouble spot" (krisengeschüttelter Unruheherd) [52], [53].

In the late 1980s, a greater focus on supporting the regional potential and measures to address local ecological impacts emerged in particularly from an increasing number of abandoning mine fields and brownfield land. A significant milestone was the Emscher Park International Building Exhibition (IBA), put forward by the Head of the Department of Urban Development in the NRW State Ministry of Regional and Urban Development. The IBA was a decade long program (1989 to 1999) which is still very present in the collective conscious and indeed considered as a threshold with great symbolic power for the identity development for the region (Interviews). The main aims of this regional development measure were an ecological and cultural renewal understood as the imperative for the economic prosperity of the region's future [54][55]. More than about €2,3 billion were spent to realise 120 projects in 17 municipalities of the Emscher region (ibid 1999).

The IBA documentation shows the program's critical look at the past calling for a new vision after the end of the industrial age. In fact, the IBA was conceived and implemented at a time when the environmental discourse intensified and principles of sustainable development and resource protection postulated and later at the Rio Conference internationally confirmed [56], [57]. The aims and measures of the IBA emphasised the environmental theme though it was mainly associated with renaturation of the river Emscher, providing access to green spaces for the residents and rejuvenate the Garden City idea[2] in the region. In addition, the local material remains were repurposed and re-valuated as "technical monuments worthy of preservation" and set them up as lighthouse projects of the program including the "Duisburg-Nord Landscape Park" and the "Zollverein Mine Shaft XII".

Ultimately the IBA and regionalised focus triggered the emergence of a new course of interventions from the 2000s. These were focused on competence fields and economic clusters in line with the regional and local capacities and resources. This approach was further strengthened by the EU regional development programs and funding indicating a clear break from the old industries. For example, the Cultural Capital Ruhr.2010 event was held across the Ruhr Region under the moto "change through culture, culture through change" supported by state and EU funding.

[2] Urban planning model by Ebenezer Howard 1898 based on the concept to break up the density of a city by integrating settlement structure interspersed with green spaces, loosened up and divided into neighbourhoods according to plan by radial streets, with spatial separation of important functions, a surrounding green belt, and sufficient provision of jobs and utilities for the population.

Table 6: Periods of structural intervention in the Ruhr Region since 1960s.

Time	Intervention measures	Measures	Purpose
1966–1974	Integrated structural policy	Development Program Ruhr targeting the modernisation of mining operations, investment in infrastructure particularly local transport and recreational areas as well as attracting new industries; the foundation of the Ruhr Universities and investments schools were to increase human capital	Conserving and patching up regional and local impacts since the measures were only introduced after a significant workforce decline.
1975–1986	Centralised structural policy	Improving the technological base of the existing of the existing large enterprises to strengthen the productivity of companies and thus increase their competitiveness, minimising environmental pollution and improving the transfer of technology into practice.	Interventions were driven by a "follow-up approach" (Nachsorge) with conserving measures oriented towards re-industrialisation focussed on classical sectors to cushion social hardship. Though, first regional, and local dialogues between key stakeholders initiated.
1987–1999	Regionalised structural policy	Regional potential moves into the centre of action, with regional conferences and regional development plans. A new bottom-up approach and governance structures emerged, though still driven by similar/ same targets and measures as in the first two periods. This materialised in the International Building Exhibition Emscher Park (IBA).	Like the periods before, policy interventions had a conserving impact with a focus on economic and social dimension. Yet, ecological measures and regional identity were addressed explicitly for the first time providing a new vision and impetus for new identity building.
Since 2000	Competence field-oriented	Driven by the EU policy approach, interventions became competence field or cluster oriented (spatial concentrations of interdependent companies connected along the value chain) which led to the definition of eight lead markets and industrial zones (e.g. sustainable consumption and health) in the Ruhr Region to emphasise the endogenous potential and capacity of the region. The Cultural Capital Ruhr.2010 event joined the cities in the Ruhr Region under the moto "change through culture, culture through change" financed by state and EU funding.	First clear break with past interventions to conserve "old" industry sectors. But the high quantitative number of clusters made it difficult to really profile core competencies EU Operational Programs between 2000 and 2020 were considered as having an overall positive impact however, they did not achieve a significant socio-economic turn regarding employment and investments. Regional events and projects contributed to new identity building and improved image within and far beyond the region.

Source: adapted from [48], [49].

4.2.3 Interventions at local level

For many decades, the local level did not take a leading role to intervene in the transformation, instead local socio-economic trajectories remained subject to national and state measures. Moreover, the localised decline - closure of coal mines and steel plants – occurred time delayed following the geological conditions of coal and established industry structures[3]. Yet, since 2000s the efforts of the local governments in Essen and Duisburg become more visible seeking to influence the internal and external perception of their localities.

IBA and Cultural Capital Award

In Essen, the IBA Program coincided with the closure of their local mine and provided an impetus for seeking new opportunities and visions. Instead of demolishing the industrial area (as usual done), the mining plant and buildings were renovated and repurposed for new users

[3] The industries of the Ruhr have developed from the south to the north following the geological conditions of coal reserves from the Ruhr zone via the Hellweg zone into the Emscher and Lippe zones.

predominantly from the cultural scene establishing its status as a model example of industrial transformation [40]. The recognition of Zeche Zollverein as UNSECO World Heritage in 2001, the only one in the Ruhr Region, marked another milestone for it becoming a nationally and an internationally acknowledged symbol of the industrial culture as well as the transformation process. "*Preservation through repurposing*" is the moto which invites creatives, start-ups, restaurants and artists to move to the 100ha large areal and has created more than 1,300 jobs already [58]. The lighthouse project also serves as a tourist magnet and is after the Cologne Cathedral the second most visited site in NRW.

The industrial culture narrative led the city's efforts to gain the EU's Cultural Capital Award. The application process was started in the early 2000s and was led by Essen as a proxy for the region. Unlike the IBA which was driven by state government and stakeholders from beyond the region, this event was driven by a coalition of Ruhr municipalities and the Ruhr association [59], [60]. The focus of Essen's application is the transformation of a landscape consumed by industry into a new location of culture and knowledge. The successful applicants were announced in 2006 with the Ruhr Region to become Cultural Capital in 2010. Essen hosted every third of the almost 300 event projects and benefitted from a positive reception beyond its local borders. Hence in addition to the policy narrative for creating a new image within and making the region attractive for beyond its borders, the event aimed at strengthening regional governance structures and collaboration between the Ruhr municipalities as well as bringing new innovative impetuses (e.g. in tourism) to tackle the challenges of the structural change.

Although the city of Duisburg was also part of the IBA and Ruhr2010, it was not able to capitalise on the events as much as Essen. In particular, the Ruhr2010, did not remain in good memory. The Love Parade, an electronic dance music festival and part of the Ruhr2010 program, ended in disaster with lives lost because of significant safety issues and failure by the authorities [61], [62]. This stifled the efforts in associated with the Cultural Capital Award and led to great risk aversion by the local authorities so that cultural activities have a hard time to receive official event approvals [63].

Box 1: Renaturation of the Emscher River

More than 100 years ago, the Emscher river was transformed in an artificial system of open sewers to meet the needs of the growing industrial conurbation and underground mining. While all commercial and domestic wastewater was discharged into the Emscher River and its tributaries previously. This was no longer possible with extensive mining and the associated sinking of the ground. Underground pipelines would not have been able to withstand the pressure. It was therefore decided to straighten the course of the river and transform the Emscher (51 km) into a canal of reinforced concrete sewer pipers to discharge all wastewater from the region.

The decline and anticipated end of mining in the region resulted in a decision by the Emscher Genossenschaft in 1991 to re-convert the Emscher as a natural flow - a generation project (Interview). The end of mine subsidence enables to drain wastewater in closed underground channels and to gradually convert the river with its tributaries into near-natural water bodies.

Emschergenossenschaft invested a total of €4.5 billion (funding from state government) to relocate the 285 of a total of 400 kilometres of canals, and just under 125 of 350 kilometres of watercourses have already been ecologically improved. No mine water will be discharged into the Emscher River after 2021.

The transformation of the Emscher goes beyond the river system. The Emscher Genossenschaft and local and regional stakeholders have developed a new vision of the Emscher Valley. The residential areas along the river and its tributaries will be socio-economically upgraded and greatly benefit from the Emscher conversion.

The current planning basis is the Emscher Future Master Plan published in 2006. The key aims centre on improvements of the ecological potential, as well as flood protection and integrating the water system into the cities to increase the quality of life through leisure facilities (e.g. biking along the river) and idyllic green spaces.

Future tasks include climate adaptation and resilience. Both Essen and Duisburg are part of the future initiative Klima.Werk, which was founded in 2014 as the future initiative "Water in the City of Tomorrow". The common goal of the network of 16 Emscher municipalities and the Emschergenossenschaft: to convert urban infrastructures to be climate-robust, to provide more green space and to give water more room. This is a response to the consequences of climate change, which make themselves felt in the form of periods of heat and drought or heavy rainfall and which affect the quality of life of citizens in the densely populated Ruhr region.

Source: [64], [65] *and Interview.*

Green Capital Award

After the Ruhr2010 and in reference to the IBA, Essen started to actively promote its "green" pathway [66]. This included the adoption of a local climate protection strategy, Essen's participation in the „Covenant of Mayors" in 2010 and receiving the European Energy Award 2013 (ibid). The management staff at Essen's local government also progressed the opportunity to receive the EU Green Capital Award. The Award is an initiative of European cities to recognise municipalities with more than 200,000 inhabitants that are leading the way with environmentally friendly urban living. The aim is to trigger further efforts by cities and boost the awareness within and beyond the city [67]. Essen's application was successful wining the Green Capital Award for 2017. The City's progress was strongly attributed to the efforts of previous programs particularly the IBA and its renaturation and restoration of the river Emscher (Interview). Indeed, the process of transforming the previously open sewage canal of the Emscher into a liveable river was a major task since the early 1990s and will end in 2022/23 (see Box 1). An interview partner emphasised that the decision by the Emscher Cooperative to plan and invest in the transformation of the river system was a socio-ecological tipping point (Interview).

The Green Capital Award created momentum for other bottom-up initiatives: in 2020 the parliament of the city decided to implement measures to increase safety and attractiveness of cycling and walking in Essen. After a local initiative (Essener Radentscheid) collected more than 23,000 signatures, the City pledged to support the initiative by developing an implementation strategy and funding of €232 million as well as 19 new staff within the municipality within the next nine years [68]–[70]. Another example is the Climate Decision (Klimaentscheid). This community initiative follows the example of other cities across Germany to request their respective City to become carbon neutral until 2030. Although they haven't been fully successful (yet), the initiative achieved that the City Essen committed to greater efforts: the previous target to reach climate neutrality by 2050 was abandoned while carbon emissions have to be reduced in line with 1.5 - 1.7 degree global warming (new target period is 2030 and 2040) [71]–[74]

In addition, the 2021 evaluation of the Green Capital Award emphasises the event's success in terms of an increase of employees in the "green sectors". Between 2017 and 2020 the total "green workforce" increased by 21% to 14,300 making Essen the leader in the Metropole Ruhr [75]. The target is to increase this figure to 20,000 by 2025.

Chinese city partnership and logistic hub

In contrast, the City of Duisburg's interventions focused on the development of existing and new industrial activities since the late 1990s. Duisburg still hosts a local steel production and has a port with international connection. However, state interventions initiated the brownfields to become repurposed for the establishment of an international logistic centre linked to the local port and railway. A first milestone was the purchase of land by the state government after the closure of the oldest Krupp steel mill in Rheinhausen in 1998 (Interviews). This was followed by further local land acquisition and the expansion of the duisport logistic hub, which is partly owned by the city (1/3) and state government (2/3) (Interviews and Duisport Presentation 2021). A second milestone was the intensification of a partnership between Duisburg and the Chinese city of Wuhan fostering the development of an international trade route [76]. Duisburg is the end of an 11,000-kilometre-long railway line that runs from China via Kazakhstan, Russia and Poland to the port basin in Rheinhausen. About every third train that travels between China and Europe stops here. 2020 arrived 60 trains a week an increase by 40% compared to 2019. The "new silk road" initiative was celebrated by the Chinese Head of State Xi Jinping, the NRW Prime Minister Hannelore Kraft and the German National Minister of Economy Sigmar Gabriel with a train

arriving from China in the port of Duisburg in 2014 [77]. With the establishment of a network of business experts, a China Affairs Coordination Unit and the appointed China-representative by the city further institutionalise this pathway.

In addition, new opportunities for the local steel industry are seen in green hydrogen [78]. A joint collaboration between the energy company STEAG, thyssenkrupp Steel and the electrolysis supplier thyssenkrupp Uhde Chlorine Engineers work on a feasibility study for the construction of a water electrolysis plant with a capacity of up to 500 MW located at site of the former Zeche Walsum [79]. The industry initiatives are accompanied by national and state government funding of €100 million for a Hydrogen Technology and Innovation Centre (Innovations- und Technologiezentrums Wasserstoff) in Duisburg [80]–[82].

4.3 Impacts in time series of selected structural data

How did these interventions influence the transformation process in both cities, and did they contribute to a significant change or tipping in their trajectories? Studies emphasise the rather heterogenous socio-economic development across the Ruhr Region [83], [84]. However, Essen and Duisburg share a similar picture in several socio-economic indicators at present (as shown in Table 7) while both performing lower or significantly lower than the state and national average. Essen appears as the slightly more prosperous city while having a much lower industrial density than Duisburg. Essen is home to six listed companies - including three DAX members E.ON, RWE und Brenntag (EWG 2022). Duisburg's main industrial sectors are logistics with Duisport and ThyssenKrupp steel production.

Table 7: Key socio-economic statistics from Essen, Duisburg, and comparison to the Ruhr Region, NRW and Germany

	Essen	Duisburg	Ruhrgebiet	NRW	Germany
Population March 2020	590,908	50,694	5.1 million	17.9 million	83.1 million
GDP 2019 (per employee)	€77,357	€75,789	€67,728	€74,316	€74,032
Income per Person 2017	€20,316	€17,049	n/a	€22,263	€22,623
Immigration Rate 2019	+1669	+1 606	+10.122	n/a	n/a
Unemployment Rate (Jan 2020)	10.2	10.9	8.9	6.8	5.3
Poverty Rate 2018	21.6	27.4	21.1	18.1	15.5
Political Participation (National Election 2017 in %)	73.9	68.7	n/a	75.4	76.2

Source: [85], [86].

In the following section we explore the effects of national, state, and local interventions on a set of selected indicators. We differentiate between no, incremental and rapid changes. The latter indicates tipping dynamics which become visible in nonlinear shifts in the trajectories of the quantitative and qualitative indicators.

4.3.1 Population trends: rapid decline halted and stabilised

The demographic change in both cities mirror the transformation process and both show very similar though slightly time-delayed population trends. Since the 1960s a population decline occurred in several waves yet showing no rapid shifts in trajectory. Although the interventions were not able to reverse the trend, they stopped the early accelerated population decline and stabilised the local trajectories.

In 1962, more than 750,000 people lived in Essen and more than 660,000 in Duisburg (RVR, 2020). Since then, both cities lost almost one quarter of their population. In the transformation process of the reunification population grew again for a short time, followed by another period of incremental population decline. Despite forecast seeing the Region further shrink in the coming decades, the migration of refugees in 2015 and 2016 brought this negative trend to a halt. Since 2019/20, population stagnates in both cities and a slightly negative trend appears to emerge again.

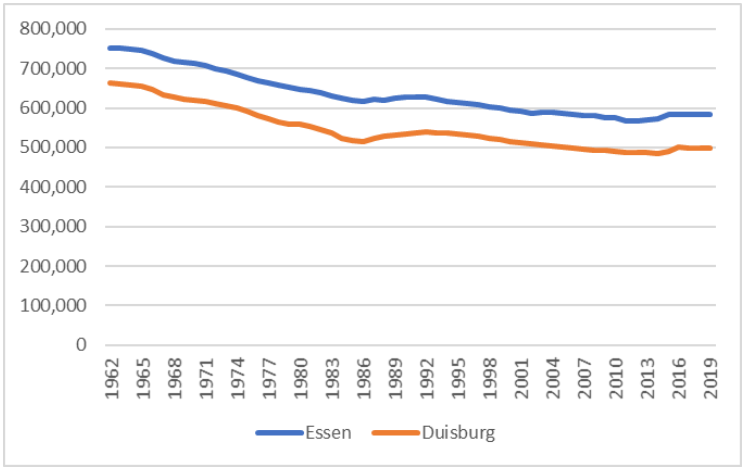


Figure 4: Population development in Essen and Duisburg since 1962. Source: [87]

These developments are also reflected in the migration patterns of both cities. In Duisburg the migration of residents peaked in the 1980s, this pattern is visible in Essen already in the late 1960s.

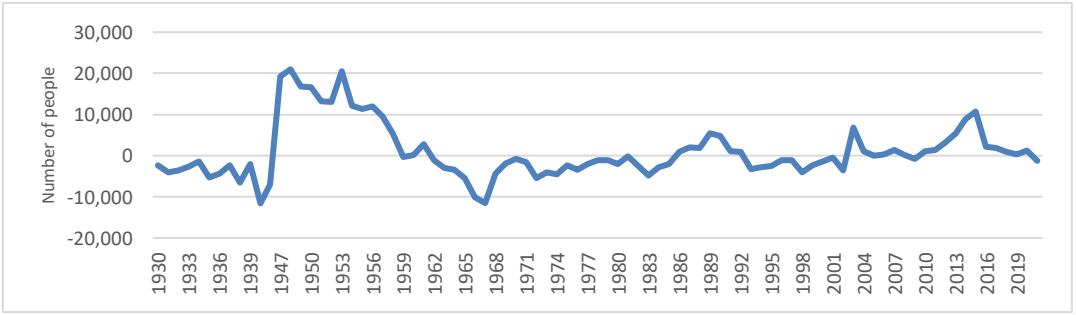


Figure 5: Migration in the city of Essen – in- and outflow between 1930 and 2019. Source: [87]

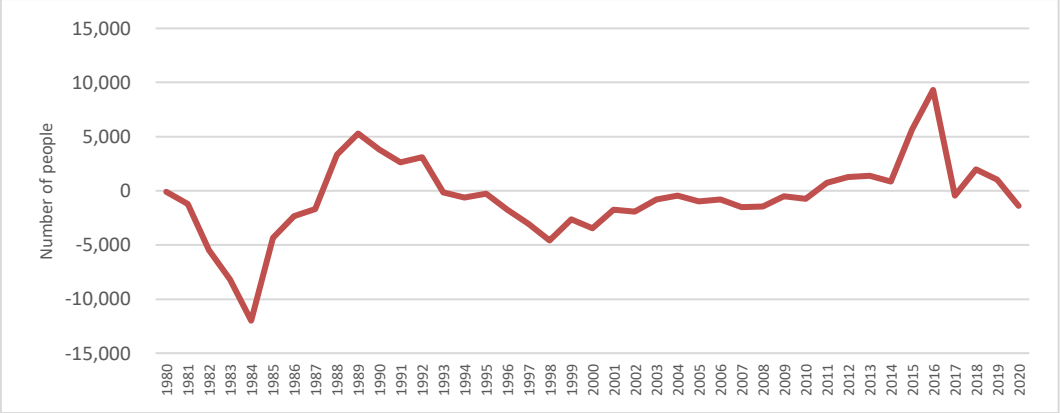


Figure 6: Migration in the city of Duisburg – in- and outflow between 1980 and 2020. Source: [87] *and personal correspondence with city of Duisburg.*

Overall, the municipalities are losing residents to the rest of NRW and to the other German states and gaining residents from abroad. In the period from 2017 to 2019, the Ruhr region lost a total of slightly more than 18,000 inhabitants due to migration within Germany, of which almost 10,200 went to the other parts of NRW – most people moved to Lower Saxony (-2,900), Hesse (-1,700) and Berlin (-1,400) [88].

In addition, demographic change in both cities moves faster than the state's average (Table 8). The proportion of the population under 20 years of age in Essen fell from 25% in 1975 to 18% in 2020, in Duisburg it fell from 28% to 19% at the same time. In comparison, the corresponding figure for NRW fell from 29% to 19%. In the same timeframe the population over 60 in Essen rose from 23% to 28%, and in Duisburg 20% to 27% [89].

Table 8: Development of population in Essen, Duisburg and NRW per age groups 1975 and 2020.

		1975	2020	TOTAL CHANGE	% CHANGE
ESSEN	Below 20 years	171,453	106,556	-64,897	-37.85
	20-60 years	352,778	310,264	-42,514	-12.05
	Above 60 years	153,339	165,595	12,256	7.99
	Total	**677,570**	**582,415**	**-95,155**	**-14.04**
DUISBURG	Below 20 years	162,772	96,360	-66,412	-40.80
	20-60 years	313,029	264,538	-48,491	-15.49
	above 60 years	115,838	134,987	19,149	16.53
	Total	**591,639**	**495,885**	**-95,754**	**-16.18**
NRW	Below 20 years	4,926,269	3,377,100	-1,549,169	-31.45
	20-60 years	8,912,203	9,460,466	548,263	16.66
	Above 60 years	3,290,728	5,088,004	1,797,276	54.62
	Total	**17,129,200**	**17,925,570**	**796,370**	**4.65**

Source: [89].

4.3.2 Unemployment and employment rates: positive developments at incremental pace

Unemployment and employment rates constituting strong indicators for regional and local structural change processes [90], [91]. As a heritage from the industry decline, the Ruhr Region and so the two cities still experience higher than state average unemployment rates but also show recent positive trend in the labour market.

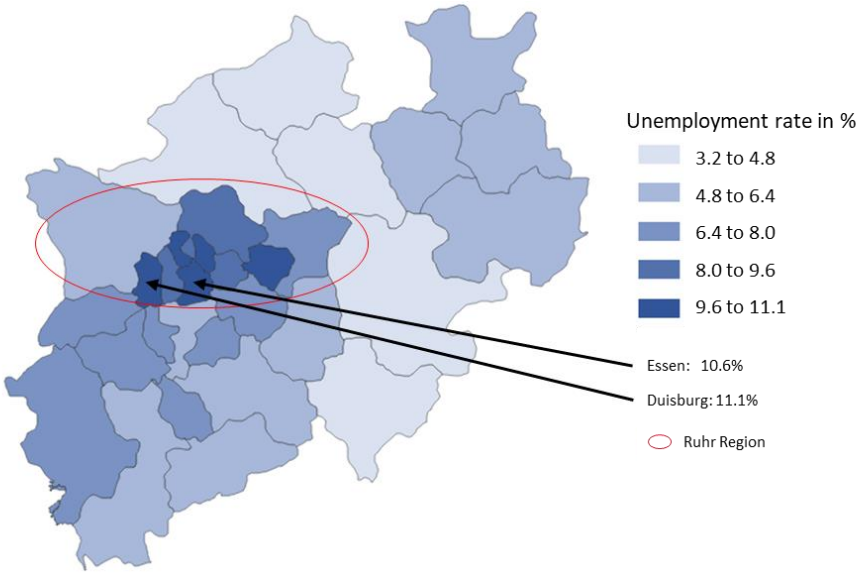


Figure 7: Unemployment rate in North-Rhine Westphalia and respective cities and regional districts 2019. Source: [92].

In late 1980s the unemployment rate in the Ruhr reached a first peak with 15% and was thus significantly higher than in NRW with about 11% and 8% in other (western) German states [48].

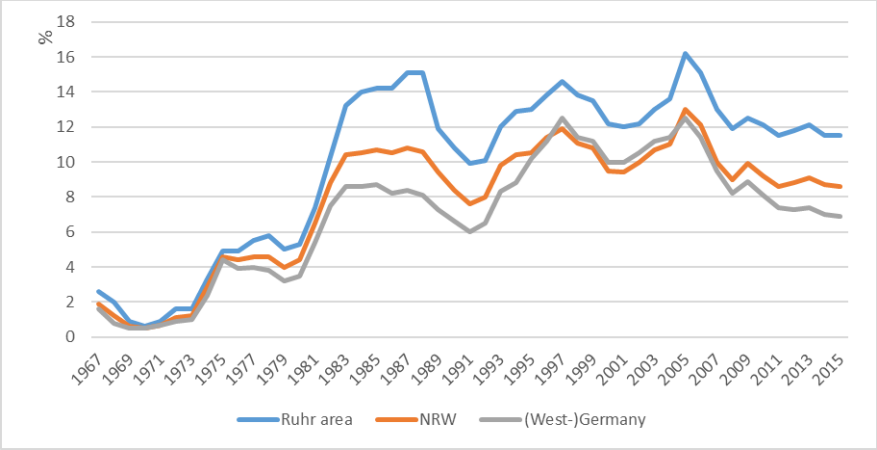


Figure 8: Unemployment in Ruhr Region, NRW and West-Germany 1960 to 2014.[4] *Source:* [85], [92]

[4] Note on 2005: The introduction of unemployment benefit II ("Hartz IV legislation" Second Social Code, SGB II) in 2005 created a new legal basis for the receipt of unemployment benefits for the long-term unemployed. Unemployed social welfare recipients, who were not previously

This development was also reflected in the two cities (Table 9), though Duisburg experienced continuously higher unemployment rates than Essen. In particular, the share of long-term unemployment is greater in Duisburg: almost 40% in 2002 increasing to almost 50% in 2016 of unemployed in the city were without work for more than one year [93], [94].

Table 9: Unemployment rates in Duisburg and Essen in selected years since 2001.

	2001	2004	2008	2013	2019
Essen	10.8%	12.2%	12.3%	12.4%	10.2%
Duisburg	12.9%	14.3%	12.7%	12.9%	10.8%

Source: [94]

Since 2005 the unemployment rate has fallen considerably, mirroring state and national developments, though the decline slowed in the last decade in both cities. In 2019, the unemployment rates in Essen and Duisburg were still over 10%, far higher than in the comparison to other regions and Germany as a whole.

The decline in unemployment was accompanied by a rise of employment since 2000s and particularly after the national labour market reform in 2005. But the Ruhr Region and the two cities did not benefit from the nationwide labour market upswing as other urban regions.

Nonetheless, the specific interventions in the Ruhr and the two cities had a positive effect. The entire Ruhr Region recorded employment gains of around of 22 % percent between 2006 and 2020 [95]. Since the late 2000s the positive trends have been driven by an economic diversification in the fields of healthcare (with over 330,000 employees), digital communication, logistics or the chemical industry. However, while Essen shows a steady dynamic, Duisburg's labour market appears more volatile with their local economy (logistic and steel) stronger dependent on international market developments.

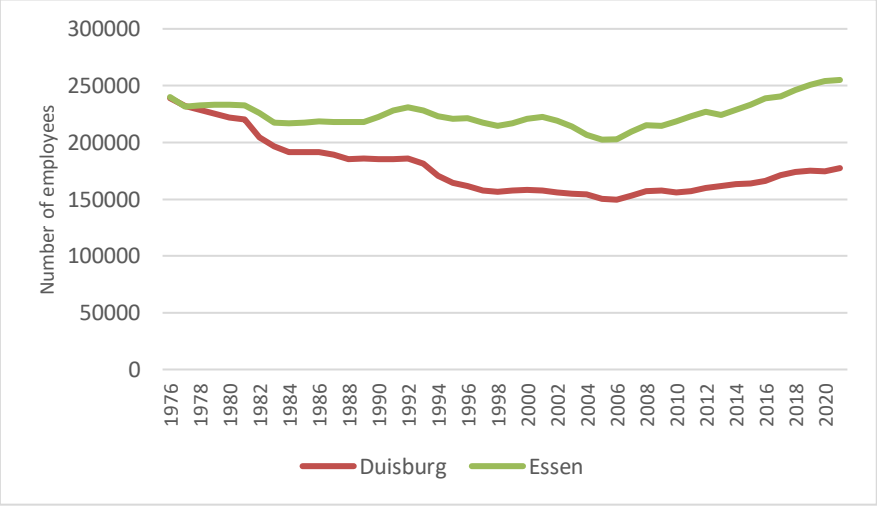


Figure 9: Employment trends in Duisburg and Essen since 1976 (in total number of local workforce).
Source: [85], [89]

The economic diversification process in Essen increased the importance of the tertiary sector significantly (Stadt Essen 2019). More than 80% of all employees work in trade, technical and

listed in the unemployment statistics, were listed here from 2005 onwards. The increase in 2005 is due to this change. A comparison of the figures before and after 2005 has to be considered with caution.

economic service, and innovation as well as the health sector. In addition, Essen fosters specifically the local environmental economy. Between 2017 and 2020 the total "green workforce" increased by 21% making Essen the leader in the Metropole Ruhr [75]. The target is to increase this figure to 20,000 by 2025.

In Duisburg, the number of employees has risen by more than 10,000 to 175,300 employees since 2015. This results in a growth in employment of + 6.8% (Stadt Duisburg 2021). The duisport logistic hub has contributed to significant employment gains in the city. 15% of all jobs in Duisburg are attributable to duisport. This comprises a total of 51,600 direct and indirect workers increasing from 19,000 in 1998 and 46,500 in 2018. This generates an annual value added of almost €1.9 billion for the city [96].

Another important role in the local economy remains the steel and metallurgical industry. Although thyssenkrupp is in a process of continuous restructuring [97], the city greatly identifies with the sector "being the number one location for European Steel" [98], [99]. In 2019 a total of 33,600 workers were employed in the sector [100]. According to the company there are 13,000 people directly employed in Duisburg at the moment (Interview and Website).

In summary, both cities experienced very similar developments of unemployment and employment variables yet lacking any rapid or non-linear trajectories. Instead, the rise in unemployment was relatively sharp in the 1980s, though this trend did not last since improvements are visible after 2005. Similarly, the employment rate demonstrates no significant shift but incremental change between the late 1970s and today.

4.3.3 Gross Domestic Products: slow but steady increase

The interventions appear to have a positive impact on the GDP development in both cities. The GDP is an important measurement of the economic performance of a country or region. In coal-phase out regions, it can also serve as an indicator for the success or failure of policy interventions to facilitate the structural change process.

The structural change process and loss of importance of the industrial sector resulted in a weaker growth of GDP in the Ruhr Region overall. From 1991 to 2015, GDP in the region increased from €104.2 billion to €157.3 billion in nominal terms: an increase of about 51%. The development in the Ruhr Area thus nevertheless lagged at state and national level. GDP rose by 62% in NRW and by 79% in Germany [94].

This development is reflected on local level. Both cities show a slow but steady increase of their respective GDPs. Although starting from a higher level, Essen increased its GDP (at market prices) by about 52% while Duisburg performed slightly better gaining about 58% (Figure 12).

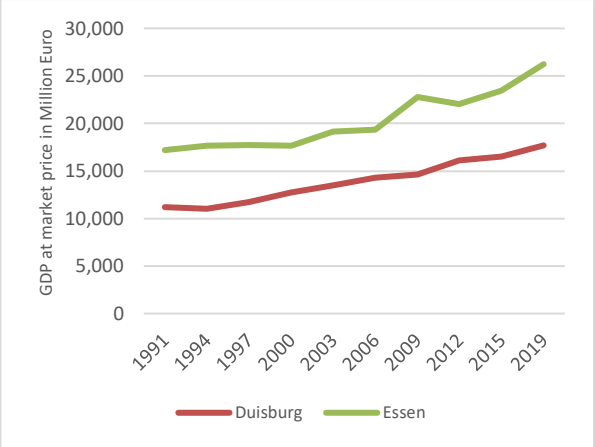


Figure 10: GDP at market prices 1991 to 2019 in Million Euro of Essen and Duisburg. Source: [89], [101]

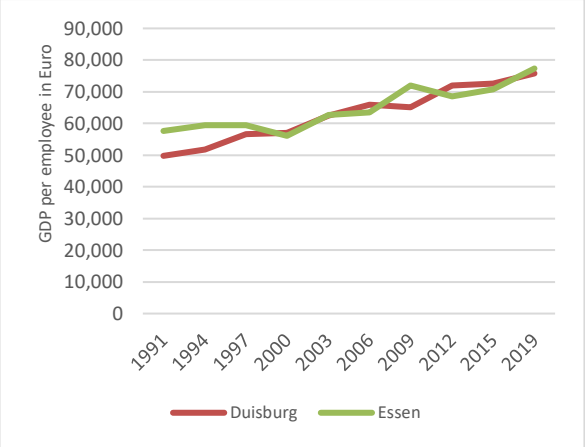


Figure 11: GDP per person employed 1991 to 2019 in Euro of Essen and Duisburg. Source: ibid.

The indicator GDP per person employed measures the average labour productivity generated by each person employed. Both cities should very similar patterns again. Though, Duisburg's performance appears greater with an increase in labour productivity by 52% in comparison to Essen with an increase of 34% between 1991 and 2019. This difference results from the still slightly larger share of producing industry in the Duisburg.

Disposable income per household: lower than average

The industry decline and loss of well-paid jobs in the coal and steel production is visible in the relatively lower disposable income per resident in the two cities (see Table 11). Dahlbeck et al (2022) found that there was a significant "break" after 1987, when disposable income in the Ruhr Region started to fall behind state and national levels. There is no data for the cities before 1995, though similar patterns can be anticipated. Since 1995, both cities show an increase of private household income (Table 10), though at a slower pace and scale than state level. Essen appears to outperform Duisburg slightly.

Table 10: Disposable income per resident (in €) in Essen, Duisburg and NRW in selected years between 1995 and 2019.

	1995	2000	2005	2010	2015	2019
Essen	15,875	16,357	17,271	18,178	18,939	21,168
Duisburg	12,639	13,287	14,227	15,038	16,162	17,741
NRW	15,119	16,038	17,505	18,745	20,526	23,093

Source: [89].

4.3.4 Education: success story with steady increase of tertiary-level students

An important intervention in the transformation process was the establishment of universities in the Ruhr Region to increase local capacity. Both cities show a similar positive trajectory, which still appears incremental rather than rapid. However, in 20 years, the change in the data considered in a more compressed timeline might appear more significant.

The first university (Ruhr University Bochum) in the Ruhr Region was founded in 1965, the Universities in Essen and Duisburg were established in 1972. The number of enrolments has increased in the last decades continuously with engineering sciences representing a focus in comparison to other universities in NRW. However, there are stark differences between the localities. The number of people entitled to study in Essen is with 64.4% considerably higher than in Duisburg with only 52.7% [85].

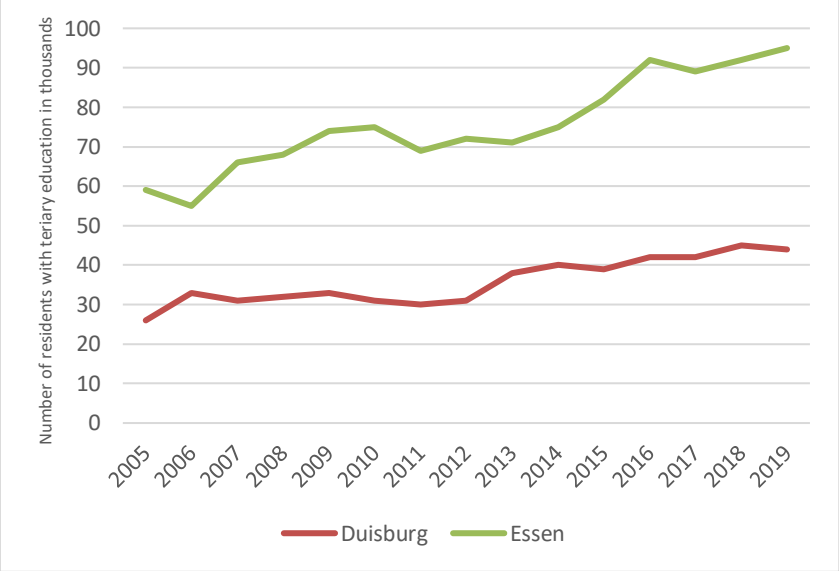


Figure 12: Share of residents in Duisburg and Essen with tertiary education (Bachelor, Master, PhD),2005-2019. Source: [89].

This is also reflected in the number of residents with university degree. Essen has a significant larger share of people with a Bachelor, Master or PhD graduation and shows a strong positive trend since 2005 with an increase of about 61% (no earlier data was available). Duisburg has a substantially lower number of residents with a tertiary education, still being considered predominantly as a "workers town" (Interview). However, their share increased noticeably by about 69% since 2005.

4.3.5 Electoral behaviour: mood change and break-up of path dependency

In contrast to the socio-economic indicators, the electorate behaviour in NRW showed a significant shift after more than 40 years of political stability. It appears that the interventions have (unintentionally, Interview) contributed to a public mood change towards the established power structures. The decreasing workforce and new regional visions (IBA) eroded the unconditional acceptance of mining and its subsidisation driven primarily by the SPD government.

For decades, the Ruhr Region and so the two cities have been heart land of the Social Democratic Party (SPD). The SPD led both state and local governments since height of the coal and steel crisis in the mid-1960s while establishing a hegemonial position in close collaboration with unions and industry. Perceived as the party caring for the "needs of small people", the SPD permeated all social structures shaping the local political culture and a regional model of "social partnership" (Oei et al 2020, Interviews). The SPD strongly identified with the workforce in heavy industry sectors as its electorate backbone. Still today, the miners' hymn "*Glückauf, der Steiger kommt*" is regularly played at SPD party assemblies (Interview). In addition, prioritising coal in the

national electricity supply was a leading policy aim and hence mining considered a state task ("NRW is coal country") (Maedge 1981). However, with the progressing decline of the industries and its fading importance, as well as the growing burdens of subsidising the sectors, the dominance of the SPD waned since the 1990s (forsa in Spiegel 2005) (see Figures for Essen and Duisburg). The SPD was no longer able to rally their constituency while also suffering from demographics shifts and a new voter generation with no direct ties to the "old" industries.

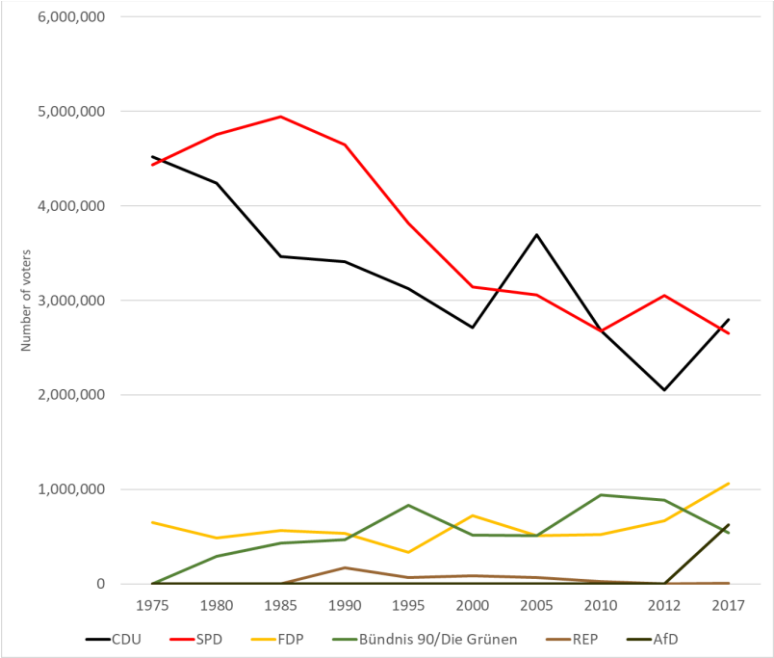


Figure 13: NRW state election since 1975 in total numbers of voters. Source: [89].

Considered a political earthquake was the election loss of the SPD at NRW state election in 2005 (Figure 15). After almost four decades, NRW received a CDU and FDP led government. Although, the next election saw a return of the SPD for two election periods, the CDU won in 2017 again, proving new power dynamics at state level. In fact, the SPD governments balancing act of conserving measures for the coal and steel industries and the course to modernisation did not convince anymore. In addition, national labour market and welfare reforms by the SPD led national government also contributed to loss in public legitimacy and the election loss on state level in 2005.

Year	1947	1950	1954	1956	1958	1962	1966	1970	1975	1980	1985	1990	1995	2000	2005	2010	2012	2017
Leading Party	CDU	CDU	CDU	SPD	CDU	CDU	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	CDU	SPD	SPD	CDU
Coalition partner	SPD	Zentrum	FDP	FDP			FDP	FDP	FDP				Greens	Greens	FDP	Greens	Greens	FDP

Figure 14: State governments composition in NRW since 1947. Source: [102]

This new state government by CDU and FDP brought consequences for the mining regions and their self-perception. Breaking up institutional ties and coalitions, the new government ended the paradigm of the indefinitely subsidised hard coal mining in the Ruhr Region and signalling an end of the sector. For the first time (state and national level), a coalition agreement included the commitment to work towards an actually "phase-out" of hard coal subsidies. ("We want to negotiate and decide with all stakeholders, including the shareholders, on the framework conditions for the socially **acceptable phase-out** of subsidised mining" CDU and FDP 2005). Indeed, the previous coalition agreements by the SPD led governments (despite the green coalition partner)

repeatedly committed to continuous subsidise the operation of the consolidated mines emphasising "coal is part of North Rhine Westphalia" (SPD and Greens 2000, 1995).

The new government's position specifically shaped the next negotiation round for the renewal of coal subsidies in late 2006 and early 2007. CDU called for the coal mining exit until 2014 to finally abandon the increasing financial burden for the state budget. Further, it was feared that state government had to carry the eternity costs (water management and landscape damage). This was circumvented with the RAG selling parts of the company (power plants, chemicals, real estate) at the stock market to ultimately secure what the state would otherwise have to pay.

In contrast, the SPD supported the concept of maintaining a "base mining industry" (Sockelbergbau)[5] and promoted their position to extent coal mining beyond 2018. Hannelore Kraft (designated party leader of the SPD in NRW) confirmed this position in January 2007, stating: "We must keep the access to coal deposits open - our only domestic energy source. It is a matter of energy security and providing a perspective for German mining technology, which is in high demand internationally. The SPD stands united behind this concept."

A compromise was found with the coal phase-out at the end of 2018 to prevent compulsory redundancies and the state government relieved from the subsidies after 2014. However, as an admission to the SPD, a revision clause was included in the agreement to review the decision again in 2012. Although deemed relatively unrealistic (Interview), this review clause would allow coal mining to continue in Germany if increased world market prices made it profitable.

Local level

Neither a majority in the Ruhr Region nor Essen or Duisburg voted for change in 2005 (see Appendix 1 and 2). The local electorates demonstrated their continuous support for the social democrats; still, a mood change is also visible since the 1990s.

While the SPD remains the dominant party in Duisburg, smaller parties gained increasing support since 2010s. In contrast, Essen electorate appears more volatile with government changing three times since 1999.

Year	1946	1948	1952	1956	1961	1964	1969	1975	1979	1984	1989	1994	1999	2004	2009	2014	2020
Duisburg	CDU	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD
Essen	CDU	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	SPD	CDU	CDU	SPD	SPD	CDU

Figure 15: SPD (red) or CDU (black) government and majors on local level across the timeline. Source: email correspondence with city of Duisburg and city of Essen.

Hard right-wing parties (NPD, *Republikaner*) did not gain a stronghold in the city for many decades, yet local support slightly increased since the early 1990s. The Republikaner received their highest vote with 2,3% (7600 voters) in Essen in 1990s at state level, which coincides with the closure of the local mine four years earlier. In Duisburg this voter trend was delayed. The peak for the Republikaner was in 2000 with 2,5% (4600 voters). However, the Alternative für Deutschland, a right-wing populist party emerging in 2013, remobilised this electorate and rallied support from disappointed conservative voters and largely from previous non-voters at all government elections in both cities.

[5] Comprising two or three mines with around 10,000 workers are to produce coal on a permanent basis

In the wake of the national environmental movement, a local chapter of the Green Party (*Bündnis90/ Grüne,* in the following *the Greens*) founded 1979 in Duisburg and 1980 in Essen. Their ecological agenda stood in opposition to the established parties and offered an alternative narrative for the transition process of the region. In particular, the Greens in Essen appealed to the local electorate. Though, in both cities the electorate demonstrates increasing support for the party gaining 18,3% in the local election in Essen in 2020, and 17,7% in Duisburg. It appears that the green and sustainability discourse in Essen also contributed to a respectable result at national level elections in 2021.

Voter turnout

The industry decay was followed by a strong voter decline. Although local elections usually have a weaker voter participation (around 45%), the drop since the 1970s is substantial. In Duisburg, , voter turnout has almost halved in the last 50 years, with 39.1% at the last election, much less than the 48% turnout in Essen. A similar trend appears in the elections at state and national level.

4.3.6 Local narrative developments

The public mood change noticeable in the electorate behaviour becomes also visible in the local narrative developments. The mainstream narrative waned with the decline of the industry when new distinct future visions in the region as well as for both cities appeared.

Mainstream narrative

The early mainstream narrative and the perception of the Ruhr Region and its cities was associated with the “economic miracle” metaphor regarding coal and steel as the fuel for the nation’s increasing energy demanding and supporting higher living standards for millions of people (Interview [45], [103]. In addition, the founding story of the European Coal and Steel Community (ECSC) was also associated with the regional industry and carried the strong symbolism of collaboration and freedom after the two World Wars. This mainstream narrative experienced first slight scratches with the increasing economic difficulties of the sectors. Policy interventions followed a narrative of contributing to the *industry’s recovery* applying measures to increase efficiency and help to modernise the mining operations in order to maintain German *energy security*. Though this framing slowly shifted towards a *supporting the restructuring process* of the domestic coal production whilst *avoiding social hardship*.

Further cracks appeared in the mainstream narrative when increasing pressure emerged from the wider public, the electricity industry as well as EU level towards the spiralling subsidies for the sector. In 1982, an electricity customer declined to pay the “coal penny” to its power provider RWE, a levy that was introduced in 1974 and constituted a significant part of the subsidies (1/4) (Table x). This dispute was eventually brought to the Federal Constitutional Court in 1994, which decided that the levy is unconstitutional and must end by 1995 requiring immediate action by the government to avoid a collapse of the industry. In addition, the introduction of EU Single Market and its competition law in 1993 required measures from the national government to avoid unfair competition advantages. This ultimately triggered a change of the policy narrative focussed on *the reduction of subsidies* materialising in the subsequent coal laws from 1994 and 1997.

Though it took another 10 years, before the *end of subsidies* was considered. In fact, the national coalition treaty from SPD and CDU in 2005 confirmed again (only) the existing policy narrative for a *socially acceptable restructuring of the industry*. Only, the change in state government in 2005

and the parties polarising position on subsidies (in particular from the FDP) enabled the policy narrative for *ending coal subsidies to reinvest in innovation and future technologies* manifest in the 2007 agreement which eventually led the phase-out of coal mining. Surprisingly, the discourse of environmental impact and (later) concerns over coal related carbon emissions, were merely a secondary argument (Interviews) and only entered the mainstream policy narrative about coal quite late, when the phase-out was already agreed.

New and alternative narrative building

State level interventions fostered the positive connoted mainstream narrative for a long time. Measures to support the industries and to buffer the structural transition in the region through a range of development programs remained priority until the late 1980s (see 4.2.3. state interventions).

A first distancing from the mainstream narrative and appearance of a state-led new yet still substream narrative was initiated through the IBA (Interviews). The main aims of this program were an ecological and cultural renewal understood as the imperative for the economic prosperity of the region in the future [54]. The analysis of the IBA documentation shows the program's critical look at the past calling for a new vision after the end of the industrial age. In fact, the IBA was conceived and implemented at a time when the environmental discourse intensified and principles of sustainable development and resource protection postulated and later at the Rio Conference internationally confirmed [56], [57]. The aims and measures of the IBA emphasised the environmental theme though it was mainly associated with renaturation of the river Emscher, providing access to green spaces for the residents and rejuvenate the Garden City idea[6] in the region.

The other potentially better received set of measures were the re-valuation and repurpose of the material remains of the mining operations such as shaft towers, coal washing plant or coking facilities. The IBA identified "technical monuments worthy of preservation" and set them up as lighthouse projects of the program including the "Duisburg-Nord Landscape Park" and Essen's "Zollverein Mine Shaft XII". Hereby the IBA followed a policy narrative which aimed at enhancing the internal and external perception of the Ruhr Region through strengthening the positive connotation of the industrial culture. This was already promoted by the SPD government of Johannes Rau at the end of the 1970s and associated with the culture for "the little man," the "upright worker" and the "common people [44].

Although structural and socio-economic challenges remain, assessments highlight the intangible impact of the event: The region gained new self-confidence and self-esteem and re-evaluation of their localities. Instead of tearing down all the former sites of industrial activity considered as ugly, these are now appreciated and valued within a new framing of industrial culture and industrial nature. Former "forbidden" areas (only workers were allowed on the sites) are now places of exchange and creativity [55].

Essen strongly capitalised on these new narratives leading the Cultural Capital Ruhr2010 under the motto "Change through culture - culture through change" as "Europe's new Metropolis" [104].

[6] Urban planning model by Ebenezer Howard 1898 based on the concept to break up the density of a city by integrating settlement structure interspersed with green spaces, loosened up and divided into neighbourhoods according to plan by radial streets, with spatial separation of important functions, a surrounding green belt, and sufficient provision of jobs and utilities for the population.

The successful application was attributed to the narrative of *reinventing an industrial region* exemplary for other regions. Unlike the IBA which was driven by state government and stakeholders from beyond the region, this event was driven by a coalition of Ruhr municipalities and the Ruhr association [59], [60]. Though, the documentation of the event indicates a rather positive connoted view of the coal era, and hence does not represent or provide a complete new and alternative story line. In fact, while the IBA critically reflected on the landscape implications of coal mining, Ruhr2010 strongly centred on a self-reassurance of the past and its remnants. Part of the program were several symbolic activities such as the project “Shaft Marks” (Schachtzeichen), where yellow balloons hovering 80m above 311 former mining sites across the entire region providing an indication of the former importance of the industry. Further the evaluation of Ruhr2010 found: “where once the steel and coal industries shaped the region (now) former coal washes, machine halls and colliery facilities have become locations of art and creativity. For people from outside the region, the landscape is not only surprisingly green, but also extraordinarily cultural.” [105, p. 10]. Indeed, with the end of mining in 2018 the region lost what it defined as a community, though [44] finds that the industrial culture has advanced to an identity forming narrative for the people.

Bifurcation in local narratives

Since the decision to end coal mining the Ruhr Region, both cities foster individual narratives more progressively. In fact, it appears that after 2010, a bifurcation in the local story lines and self-perception manifests.

Duisburg was not able to capitalise on the IBA and the Ruhr2010 for creating a local narrative, although it also promotes its industrial sites as tourist attractions [106]. Instead, the city fosters an existing policy narrative associated with the growing local logistic industry and green steel though in particular the expansion and development of largest inland-port located in the city contributes to the revitalisation of the industrial narrative in the Duisburg. Policy and industry interventions are promoting the image that the “new silk road” ends at the port in Duisburg. The city’s website presentation as well as its economic and digital strategies support the international connection as impetus for international trade and growth [107], [108].

In addition, the city’s current policy narrative emphasises the opportunities associated with green steel and the necessity of national funding for a local industry restructuring as well as research and development. A study by the Wuppertal Institute fuels this narrative further by emphasising that the region and in particular Duisburg have great potential for a pioneering role in greening the steel industry [78]. The adoption and commercialising of green hydrogen could enable a carbon neutral steel production. And as the researchers note: "This will make the seemingly impossible come true: steel production itself will move into the position of a sector of the environmental economy." (ibid p.99).

Essen used the Ruhr2010 as a steppingstone to foster new opportunities and progress a sustainable policy narrative. Essen submitted its application in 2014 by using the narrative “from a city of coal and steel to the greenest city in North Rhine-Westphalia “. The city’s vision for the future is that “of a prosperous, sustainable metropolitan city that is resilient to climate change and that offers its population opportunities for development in a healthy environment” [63 p. 230]. The application followed the efforts of the IBA and Ruhr2010 to support the regional transformation [66]. Additional milestones on the City’s sustainability pathway included the adoption of a local climate protection strategy, Essen’s participation in the „Covenant of Mayors“ in 2010 and receiving the European Energy Award 2013 (ibid).

While the Green Capital Award application focusses on the successes, it also reflects on the impacts of the industrial era e.g. in regards to air pollution, transport infrastructure and water management. Apart from the Emscher renaturation program (Box 1). The public importance and great symbolic power of the local river systems is perceivable in another project of the Green Capital Award. After more than 40 years, the “Seaside beach” at the Lake Baldeney (river Ruhr) was re-opened as a bathing area in May 2017 [75]. This project was repeatably mentioned by interview partners as a major highlights of the event (Interviews).

The perception of the Green Capital Award the interview partners agreed that the events and activities around the Green Capital City Award were insofar successful that it further contributed to an improvement of the community’s self-image and greater awareness that Essen is already quite “green” (Essen is the third greenest city in Germany with a share of 53% green and open space). The local initiatives and activities during the event year were well received (Interview), and more than 7000 media reports promoted the city’s efforts within and beyond its borders. However, some interview partners critically reflected that the efforts were too little, and the Award did not move beyond an image campaign. They bemoan that the city is still shareholder of RWE and dependent on their dividends for the municipality budget (Interview).

Although it is too soon to determine a lasting impact of the narrative change, different interview partners acknowledged that after the Award, demands regarding environmental issue have greater political power. The city has pledged different future environmental and climate targets acknowledging that the title lasts - “Once Green Capital always Green Capital” [75]. Indeed, the city promised to continue its efforts announcing a “Green Decade” across 12 themes including climate protection, water management and mobility which are to be executed through the Green Capital Agency until 2027 [69]. The City’s “Green Decade Program” will conclude with the International Garden Exhibition hosted in the Region in 2027.

The respectable achievement of the Green party at the local and national elections in 2020 and 2021 may also indicate increasing awareness and support for the environmental vision of the local government.

In summary, the mainstream narrative was closely connected to the economic development and decline of the coal and steel industries and mirrored the public discourse in the region. National and state interventions had a conversing influence on this narrative while only in the 1990s new and alternative narratives began to surface more strongly (See figure 16: 2 and 3). After the final decision by national and state government in 2007 to end coal in 2018, local governments in Essen and Duisburg have progressively worked on local narrative building. The industrial culture image emerging in the 2000s was still a reminiscence of the mainstream narrative yet presented a steppingstone for Essen towards a sustainable narrative, while Duisburg continued to foster its industry image. The presentation of Essen as a “Green City” and the portrayal of Duisburg at the “end of the new silk road” indicate a clear division of the cities perception once similarly dominated by the coal and steel narrative. Hence the “Green Capital Award” in Essen and the various measures to support Duisburg’s logistic hub and green steel industry present tipping interventions for their local narrative development.

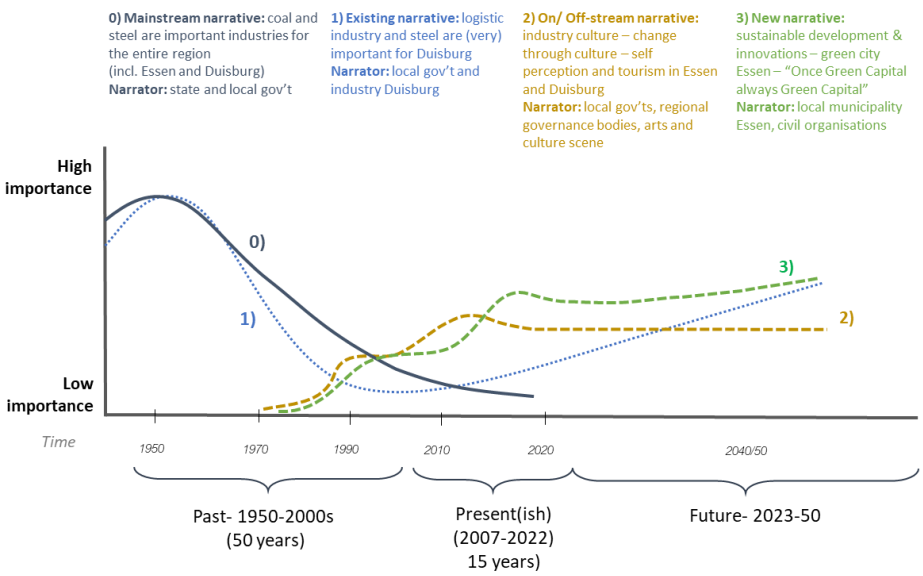


Figure 16: Stylised development of different narratives in the region and both cities.

5 Discussion

In this report, we investigated the socio-economic transition process by using the examples of the cities of Essen and Duisburg, which shared very similar pathways. By examining interventions and outcomes, we observed **incremental changes** in their demographic, economic and political trajectories but we found no evidence for either city to have crossed a tipping point in their transition process yet. However, distinct developments in the cities' policy narratives indicate qualitative changes while putting them on quite different trajectories potentially leading to tipping points in the future.

Both cities are embedded in a wider structural transformation of the Ruhr Region and hence were subject to state and national interventions as part of the coal phase-down and -out process over decades. Yet, these interventions reinforced path dependencies for a long time and only sought and allowed for incremental changes across the region. In fact, the structural interventions were meant to avoid rapid and significant shifts, instead intended a long "gliding flight" for the coal phase-out to avoid social hardship.

In Essen, the economic and social trends show the city has coped better than Duisburg in the transition process, and certainly was more pro-active in seeking and shaping a new vision and local narrative. Essen experienced the local industry closure earlier than Duisburg and has thus had more time to adapt to a post coal-mining era, but even so the socio-economic data shows Essen to perform better also in earlier years. The local government successfully leveraged on the major interventions (e.g. IBA and Ruhr2010), ultimately putting forward and promoting the motto "from grey to green" following the contemporary national and European zeitgeist. While new compelling narratives and positive frames have the power to erode lock-ins, reorient practices towards desirable alternatives and ultimately attract new interest [23], the new narrative in Essen has not yet triggered large-scale changes measurable in the socio-economic data. Nevertheless, the new, green agenda may potentially mark the start of a new era of sustainable businesses and practices in the city, and positively influencing the internal and external perception of the former mining town

Duisburg has struggled in the transformation process but appears steadfast in their (heavy) industry pathway. Although the local mine is closed, the steel industry remains an important local economic factor, furthered by recent plans to foster local green hydrogen production. In addition, state-level interventions were successful to turn the local port and the large, decommissioned steel and mining sites into a thriving global logistic sector in the city. Hence the industry activities continue to form the local narrative, which is further enhanced by local government through a city partnership with Wuhan/ China putting forward the narrative of "Duisburg at the end of the new silk road".

Consequently, the cities appear at a crossroad. While their socio-economic trajectories still show similar trends, the narratives and policy visions of the cities suggest that their future trajectories will diverge. While Duisburg builds on the old narrative of continued and new heavy industry structures, Essen has formulated an alternative vision for the city, departing from the old mining image towards a greener future. Since the transition process is still ongoing, it remains to be seen which of the two pathways is more successful for the continued economic and social development of the cities. Whereas it seems unlikely that Duisburg will develop in a "greener" way than Essen, the economic success can go both ways. It may be a risky strategy, hinging on the successful development or access to hydrogen resources, but it is certainly conceivable that Duisburg may prosper with its industry pathway utilising and further developing existing

capacities and resources from the local port and green steel production opportunities. In Essen, policy interventions may have altered the local narrative and hence positively influenced internal and external perception as well as attracting new businesses and innovation. These efforts will likely improve the greenness of the city and may or may not lead to improving social conditions and prosperity in Essen. Success and prosperity are thus uncertain, but the developmental bifurcation is likely already happening: as they embark in different directions, the cities will likely grow increasingly different over time.

Our empirical findings suggest that it is difficult to determine tipping dynamics in an ongoing transformation process. The industry lock-in and associated institutional path dependencies have prolonged the phase-out process of coal mining for six decades. We can see some recent initiatives to reshaping the cities futures, but not yet observe the lasting effects of these interventions. Hence, longer timeframes are required to determine if the transformation process exhibits a radical change. Consequently, this suggests that tipping points in social systems are more likely observable in retrospect.

This study also shows that the tipping lens for investigating societal change may be problematic in itself. Societal transition processes tend to be slow and gradual, and hence dominated by incremental changes that may accumulate to substantial shifts over several decades [33], [109]–[111]. Indeed, social systems exhibiting self-reinforcing dynamics can be quite resilient to change over long periods of time [34], while radical shifts and non-linear trajectories appear undesirable, among other things because they oppose existing power and interest structures and because their success is uncertain. Hence, radical change and tipping should be expected to be the exception rather than the rule, especially in the highly complex social systems of cities. For future research, thus we suggest studying processes of social transformation in carbon-intensive regions not through the tipping lens" but by studying gradual change and its interventions, thereby possibly finding a tipping point without looking out only for this specific, uncommon process.

Social systems are characterised by great complexity making it challenging to map processes of cause and effects, especially across (governance) scales. 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. Consequently, identifying cause and effect along specific variables can indeed be more precise in smaller, sectoral systems than in larger, more society-wide ones. For example, investigating social-technical systems can yield more definite and potentially satisfying answers about the occurrence of a tipping point dynamic. For example, Sharpe and Lenton (2021) find that Norway has activated a tipping point in consumer preference for electric vehicles based on the number of new car sales, and Strauch (2020) suggests that wind power and solar photovoltaics have passed a socio-technical tipping point based on the rapidly increasing deployment and cost reductions. Undoubtedly, more empirical studies on tipping point dynamics are required, and we see the investigation of smaller-scale social-technical systems as the best suited field for this.

The findings of this study must be seen in light of some limitations. Empirical investigations of large, complex social systems are still rare [14] and hence methods and tools have yet to be further tested for yielding answers to social tipping point processes. For our analysis, we relied on publicly available data but, apart from the interviews, we did not generate further primary data. We would have been particularly interested in (longitudinal) data on local perceptions of the coal phase-out and the appropriateness of the municipal and regional interventions after the mines closed. The selection of the socio-economic variables could have been extended and included additional material e.g. public surveys on perceptions. For example, a deeper, data-driven investigation of the social, ethnic, and demographic segregation within the cities, on the district level,

could have yielded insights not observable on the aggregated city level, for example about development of particularly low-status neighbourhoods. The pandemic also hindered the direct and onsite contact with stakeholders (which was done online exclusively).

Our study shows the sequence of interventions and timing are important factors for the trajectory of a region determining the quality of societal change. We have shown empirically that incremental change is, at least in our two cases, the dominant process of change, although tipping dynamics may still materialise in the future – and we cannot rule out that, seen from a few decades into the future, the period around 2020 can be identified as a tipping period in one or both cities. This also means that incremental changes when observed ex post, will have led to a substantial transformation – supporting the notion of transformative incrementalism – achieving transformative change through a long processes and the sum of small interventions [113]. The strategies to influencing the local narrative building as well as focus on local strength and capacities appear as key mechanisms also relevant for other coal communities in their transition process. These interventions, whether they trigger tipping or not, are still necessary and useful steps towards a prosperous future beyond coal.

References

[1] G. C. Unruh, “Understanding carbon lock-in,” *Energy Policy*, vol. 28, no. March, pp. 817–830, 2000, doi: 10.1016/S0301-4215(00)00070-7.

[2] F. Berkhout, “Technological regimes, path dependency and the environment,” *Glob. Environ. Chang.*, vol. 12, no. 1, pp. 1–4, 2002, doi: 10.1016/S0959-3780(01)00025-5.

[3] G.-J. Hospers, “Restructuring Europe’s Rustbelt,” *Intereconomics*, vol. 39, no. 3, pp. 147–156, 2004, doi: 10.1007/BF02933582.

[4] iwConsult, “Städteranking 2021,” *Wirtschaftswoche Website*, 2021. https://www.wiwo.de/politik/deutschland/staedteranking/

[5] Prognos, “Prognos Zukunftsatlas,” *Handelsblatt Website*, 2019. https://www.handelsblatt.com/politik/deutschland/zukunftsatlas-2019/

[6] HWWI, “Kulturstadtranking,” *Website*, 2019. https://www.hwwi.org/berenberg-und-hwwi.html

[7] P. Pierson, “Increasing Returns, Path Dependence, and the Study of Politics,” *Am. Polit. Sci. Rev.*, vol. 94, no. 2, pp. 251–267, 2000, doi: 10.2307/2586011.

[8] S. Grimm and G. Schneider, *Predicting Social Tipping Points*. 2011.

[9] T. M. Lenton *et al.*, “Operationalising positive tipping points towards global sustainability,” *Glob. Sustain.*, vol. 5, 2022, doi: 10.1017/sus.2021.30.

[10] H. J. Schellnhuber, “Tipping elements in the Earth System,” *PNAS*, vol. 107, no. 49, pp. 20561–20563, 2010, doi: 10.1073/pnas.0914246107.

[11] T. M. Lenton *et al.*, “Climate tipping points — too risky to bet against,” *Nature*, vol. 575, no. 7784, pp. 592–595, 2019, doi: 10.1038/d41586-019-03595-0.

[12] M. Scheffer, S. Carpenter, J. A. Foley, C. Folke, and B. Walker, “Catastrophic shifts in ecosystems,” *Nature*, vol. 413, no. October, 2001.

[13] M. Milkoreit *et al.*, “Defining tipping points for social-ecological systems scholarship - An interdisciplinary literature review,” *Environ. Res. Lett.*, vol. 13, no. 3, 2018, doi: 10.1088/1748-9326/aaaa75.

[14] R. Winkelmann *et al.*, “Social tipping processes for sustainability: An analytical framework,” pp. 1–24, 2020.

[15] I. M. Otto *et al.*, “Social tipping dynamics for stabilizing Earth’s climate by 2050,” *Proc. Natl. Acad. Sci. U. S. A.*, vol. 117, no. 5, pp. 2354–2365, 2020, doi: 10.1073/pnas.1900577117.

[16] J. D. Tàbara *et al.*, “Positive tipping points in a rapidly warming world,” *Curr. Opin. Environ. Sustain.*, vol. 31, pp. 120–129, 2018, doi: 10.1016/j.cosust.2018.01.012.

[17] H. Della Bosca and J. Gillespie, “The coal story: Generational coal mining communities and strategies of energy transition in Australia,” *Energy Policy*, 2018, doi: 10.1016/j.enpol.2018.04.032.

[18] S. Carley, T. P. Evans, and D. M. Konisky, “Energy Research & Social Science Adaptation , culture , and the energy transition in American coal country,” *Energy Res. Soc. Sci.*, vol. 37, no. August 2017, pp. 133–139, 2018, doi: 10.1016/j.erss.2017.10.007.

[19] P. Sheldon, R. Junan, and A. De Rosa Pontello, “The Ruhr or Appalachia?,” no. October, 2018.

[20] V. A. Schmidt, “Speaking of change: Why discourse is key to the dynamics of policy

transformation," *Crit. Policy Stud.*, vol. 5, no. 2, pp. 106–126, 2011, doi: 10.1080/19460171.2011.576520.

[21] J. Lieu, A. H. Sorman, O. W. Johnson, L. D. Virla, and B. P. Resurrección, "Three sides to every story: Gender perspectives in energy transition pathways in Canada, Kenya and Spain," *Energy Res. Soc. Sci.*, vol. 68, no. September 2019, p. 101550, 2020, doi: 10.1016/j.erss.2020.101550.

[22] J. Bruner, "The Narrative Construction of Reality," *Crit. Inq.*, vol. 18, no. 1, pp. 1–21, 1991, doi: https://doi.org/10.1086/448619.

[23] P. Buschmann and A. Oels, "The overlooked role of discourse in breaking carbon lock-in: The case of the German energy transition," *WIREs Clim. Chang.*, vol. 10, no. 3, p. e574, May 2019, doi: https://doi.org/10.1002/wcc.574.

[24] J. Robinson and R. J. Cole, "Theoretical underpinnings of regenerative sustainability," *Build. Res. Inf.*, vol. 43, no. 2, pp. 133–143, Mar. 2015, doi: 10.1080/09613218.2014.979082.

[25] J. Hinkel, D. Mangalagiu, A. Bisaro, and J. D. Tàbara, "Transformative narratives for climate action," *Clim. Change*, vol. 160, no. 4, pp. 495–506, 2020, doi: 10.1007/s10584-020-02761-y.

[26] J. D. Tàbara, J. Lieu, R. Zaman, C. Ismail, and T. Takama, "On the discovery and enactment of positive socio - ecological tipping points : insights from energy systems interventions in Bangladesh and Indonesia," *Sustain. Sci.*, no. 0123456789, 2021, doi: 10.1007/s11625-021-01050-6.

[27] J. D. Tàbara, J. Lieu, R. Zaman, C. Ismail, and T. Takama, "Tipping towards sustainable energy systems in poor rural contexts. Learning from local experiences in Bangladesh and Indonesia," *Sustain. Sci.*, vol. 56, no. Special Issue The "How" of Transformation', pp. 1–16, 2020, doi: 10.1080/09640568.2012.716365.

[28] T. M. Lenton, "Tipping positive change," *Philos. Trans. R. Soc. B Biol. Sci.*, vol. 375, no. 1794, p. 20190123, Mar. 2020, doi: 10.1098/rstb.2019.0123.

[29] Y. Strauch, "Beyond the low-carbon niche: Global tipping points in the rise of wind, solar, and electric vehicles to regime scale systems," *Energy Res. Soc. Sci.*, vol. 62, no. February 2019, p. 101364, 2020, doi: 10.1016/j.erss.2019.101364.

[30] F. Westley *et al.*, "Tipping toward sustainability: Emerging pathways of transformation," *Ambio*, vol. 40, no. 7, pp. 762–780, 2011, doi: 10.1007/s13280-011-0186-9.

[31] M. Nuttall, "Tipping points and the human world: Living with change and thinking about the future," *Ambio*, vol. 41, no. 1, pp. 96–105, 2012, doi: 10.1007/s13280-011-0228-3.

[32] K. C. H. van Ginkel *et al.*, "Climate change induced socio-economic tipping points: Review and stakeholder consultation for policy relevant research," *Environ. Res. Lett.*, vol. 15, no. 2, 2020, doi: 10.1088/1748-9326/ab6395.

[33] R. Collier and D. Collier, *Shaping the political arena: Critical junctures, the labor movement, and regime dynamics in Latin America*. UC Berkeley Previously Published Works, 2015. [Online]. Available: https://escholarship.org/uc/item/8qr1z7gc

[34] P. Pierson, "Not Just What , but When: Timing and Sequence in Political Processes," *Stud. Am. Polit. Dev.*, vol. 14, no. Spring 2000, pp. 72–92, 2000.

[35] J. Andreoni, N. Nikiforakis, and S. Siegenthaler, "Predicting social tipping and norm change in controlled experiments," vol. 118, no. 16, 2021, doi: 10.1073/pnas.2014893118.

[36] C. Diks, C. Hommes, and J. Wang, "Critical slowing down as an early warning signal for financial crises ?," *Empir. Econ.*, vol. 57, no. 4, pp. 1201–1228, 2018, doi: 10.1007/s00181-018-1527-3.

[37] H. Ren and D. Watts, “Early warning signals for critical transitions in power systems,” *Electr. Power Syst. Res.*, vol. 124, pp. 173–180, 2015, doi: 10.1016/j.epsr.2015.03.009.

[38] P. Y. Oei, H. Hermann, P. Herpich, O. Holtemöller, B. Lünenbürger, and C. Schult, “Coal phase-out in Germany – Implications and policies for affected regions,” *Energy*, vol. 196, p. 117004, 2020, doi: 10.1016/j.energy.2020.117004.

[39] Statistik der Kohlenwirtschaft e.V., “Datenübersichten zu Steinkohle und Braunkohle in Deutschland,” *Website*, 2022. https://kohlenstatistik.de/

[40] Zeche Zollverein, “Zeche Zollverein - Geschichte,” *Website*, 2022. https://www.zollverein.de/ueber-zollverein/geschichte/

[41] RAG Aktiengesellschaft, “Walsum.” Essen, 2021. [Online]. Available: https://www.rag.de/fileadmin/user_upload/rag/Dokumente/Download/Publikationen/LAY_Flyer_Walsum_148x210_V6.pdf

[42] S. Harnischmacher and H. Zepp, “Bergbaubedingte Höhenänderungen im Ruhrgebiet,” 2008.

[43] Ministry of Environment NRW and DSK, “Walsumer Verständigung.” Düsseldorf, 2005.

[44] S. Berger *et al.*, “Ruhrgebiet,” *Das Parlam.*, pp. 1–3, 2019.

[45] F.-J. Brüggemeier, *Grubengold. Das Zeitalter der Kohle von 1750 bis heute*. München: C.H. Beck, 2018.

[46] H. Kilper, E. Latniak, D. Rehfeld, and G. Simonis, “Das Ruhrgebiet im Umbruch - Strategien regionaler Verflechtung.” VS Verlag für Sozialwissenschaften., Wiesbaden, 1994.

[47] RAG Aktiengesellschaft, “50 Jahre RAG - Eine Erfolgsgeschichte.” Essen, 2018. [Online]. Available: https://www.rag.de/fileadmin/user_upload/rag/Bilder/Content/Kommunikation/Pressecenter_21.12/50_Jahre_RAG_-_eine_Erfolgsgeschichte.pdf

[48] E. Dahlbeck, S. Gärtner, B. Best, J. Kurwan, T. Wehnert, and J. Beutel, “Analyse des historischen Strukturwandels im Ruhrgebiet,” Wuppertal, 2022. [Online]. Available: https://www.umweltbundesamt.de/publikationen/analyse-des-historischen-strukturwandels-im-0

[49] O. Arndt *et al.*, “Lehren aus dem Strukturwandel im Ruhrgebiet für die Regionalpolitik,” Berlin, 2016. [Online]. Available: https://www.prognos.com/de/projekt/lehren-aus-dem-strukturwandel-im-ruhrgebiet

[50] A. B. Meyer, S. Schmidt, and V. Eidems, “Staatliche Förderung der Stein- und Braunkohle im Zeitraum 1950 bis 2008,” Berlin, 2010.

[51] R. Heinze and J. Hilbert, *Strukturpolitik zwischen Tradition und Innovation. Nordrhein-Westfalen im Wandel*. Leske + Budrich, Opladen, 1996. [Online]. Available: https://books.google.de/books?hl=de&lr=&id=Zb7OBgAAQBAJ&oi=fnd&pg=PA8&dq=Heinze,+++1996:+Strukturpolitik+zwis+chen+Tradition+und+Innovation&ots=ce9m4_obtf&sig=VhATLGyhhNnfVoPj8Dgx430Ptzc#v=onepage&q&f=false

[52] Landesregierung Nordrhein-Westfalen, “Entwicklungsprogramm Ruhr 1968-1973,” 1968. [Online]. Available: http://www.digitales-archiv-friedrich-halstenberg.de/Dig.Archiv/Diversa/EntwicklungsprogrammRuhr1968-1973KartenOPT.pdf.

[53] Regionalkunde Ruhrgebiet, “Entwicklungsprogramm Ruhr 1968-1973,” *Website*, 2021. http://www.ruhrgebiet-regionalkunde.de/html/glossar/epr.php.html

[54] IBA, “Katalog der Projekte.” Internationale Bauausstellung, Essen, 1999.

[55] Universität GH Essen, “Was ist die IBA-Emscher-Park?,” *Website*, 2021. https://www.uni-

due.de/~gpo202/iba-allgemein.htm

[56] WCED, *Our Common Future*. Oxford University Press., 1987.

[57] UN General Assembly, "Report of the United Nations Conference on Environment and Development," Rio de Janeiro, 1992.

[58] Zollverein. Das Magazin Edition, "Zollverein im Wandel," Essen, 2016.

[59] K. R. Kunzmann, "Culture, Creativity and Spatial Planning," *Town Plan. Rev.*, vol. 75, no. 4, pp. 383–404, Apr. 2004, [Online]. Available: http://www.jstor.org/stable/40112620

[60] R. Ebert, "Klaus R. Kunzmann als Initiator und Impuls- geber bei der Entwicklung von Städten und von Regionen in Deutschland durch Kultur- und Kreativwirtschaft," *Disp*, vol. 53, no. 2, pp. 32–37, 2017, doi: 10.1080/02513625.2017.1340550.

[61] H. Klüpfel, "Pedestrian and Evacuation Dynamics 2012," in *Pedestrian and Evacuation Dynamics*, U. Weidmann, U. Kirsch, and M. Schreckenberg, Eds. Zürich, 2012, pp. 1385–1394. doi: 10.1007/978-3-319-02447-9.

[62] V. L. Jacobsen, "Keiner ist ohne Schuld," *Zeit Online*, Aug. 10, 2010. [Online]. Available: https://www.zeit.de/gesellschaft/zeitgeschehen/2010-08/loveparade-sicherheitskonzept-analyse/komplettansicht

[63] A. Fischer, "Kampf ums Image, was die Loveparade mit Duisburg gemacht hat," *WAZ*, Duisburg, p. 6, 2020. [Online]. Available: https://www.waz.de/region/rhein-und-ruhr/was-hat-die-loveparade-mit-duisburg-gemacht-id229578770.html

[64] Emschergenossenschaft, "Emscher - Der Umbau," *Website*, 2022. https://www.eglv.de/

[65] Zukunftsinitiative Klima.Werk, "Zukunftsinitiative Klima.Werk," *Website*, 2022. https://www.klima-werk.de/

[66] Stadt Essen, "Bewerbung der Stadt Essen um den Titel „Grüne Hauptstadt Europas 2017"," Essen, 2014. [Online]. Available: https://media.essen.de/media/wwwessende/aemter/0115_1/gruene_hauptstadt_5/Bewerbung_ESSEN_GHE_2017_Komplett_eBook_deutsch.pdf

[67] European Commission, "European Green Capital Award," *Online*, 2021. https://ec.europa.eu/research/foresight/index.cfm

[68] M. Schymiczek, "Das bedeutet der Radentscheid für die Stadt Essen," *WAZ Online*, Sep. 11, 2020.

[69] Stadt Essen, "Grüne Hauptstadt Agentur," *Website*, 2021. https://www.essen.de/leben/umwelt/nachhaltigkeit/startseite_gruene_hauptstadt_agentur.de.html

[70] Radentscheid Essen, "Meilenstein – Große Mehrheit im Stadtrat beschließt Umsetzung des RadEntscheid Essen," *Website*, 2021. https://radentscheid-essen.de/aktuelles/pressemitteilung-radentscheid-essen-meilenstein-grosse-mehrheit-im-stadtrat-beschliesst-umsetzung-des-radentscheid-essen/

[71] Klimaentscheid-Essen, "Einordnung des Ratsbeschlusses vom 25. August 2021 zur Klimaneutralität in Essen," *Website*, 2021.

[72] M. Schymiczek, "Bürger wollen Stadt Essen zu mehr Klimaschutz zwingen," *WAZ Online*, Essen, Jun. 17, 2020. [Online]. Available: https://www.waz.de/staedte/essen/buerger-wollen-stadt-essen-zu-mehr-klimaschutz-zwingen-id229332472.html

[73] M. Schymiczek, "Protest von Klima-Aktivisten begleitet Ratssitzung in Essen," *WAZ Online*, Essen, Jun. 30, 2021. [Online]. Available: https://www.waz.de/staedte/essen/protest-von-klima-aktivisten-begleitet-ratssitzung-in-essen-id232671281.html

[74] M. Schymiczek, “Mehr Klimaschutz: Was das für die Stadt Essen bedeutet,” *WAZ Online*, Essen, p. 6, Aug. 26, 2021. [Online]. Available: https://www.waz.de/staedte/essen/mehr-klimaschutz-was-das-fuer-die-stadt-essen-bedeutet-id233150737.html

[75] Stadt Essen, “Einmal Grüne Hauptstadt – immer Grüne Hauptstadt,” Essen, 2020.

[76] Stadt Duisburg, “Städtepartnerschaft Duisburg und Wuhan,” *Website*, 2022. https://www.duisburg.de/rathaus/rathausundpolitik/intbeziehungen/partnerschaften/wuhan.php

[77] M. Verfürden, “Duisburg will „Deutschlands China-Stadt“ sein – doch bisher profitiert nur der Hafen,” *Handelsblatt*, 2021. [Online]. Available: https://www.handelsblatt.com/unternehmen/handel-konsumgueter/partnerschaft-mit-china-duisburg-will-deutschlands-china-stadt-sein-doch-bisher-profitiert-nur-der-hafen/26866194.html?ticket=ST-666015-LmIsibGK0Eu9UfTRwT2N-ap2

[78] M. Müller, A. Esken, A. Pastowski, and O. Wagner, “Transformation zur „ Grünsten Industrieregion der Welt “ – aufgezeigt für die Metropole Ruhr,” Wuppertal, 2021.

[79] STEAG, “HydrOxy Hub Walsum,” *Website*, 2022. https://www.steag.com/de/aktuelles/aktuelle-projekte/hydroxy-walsum

[80] RP Online, “Die neue Wasserstoff-Hauptstadt,” *Website*, 2021. https://rp-online.de/nrw/staedte/duisburg/innovationszentrum-in-duisburg-die-neue-wasserstoff-hauptstadt_aid-62551047

[81] Stadt Duisburg, “Kohleausstieg und Strukturwandel,” *Website*, 2021. https://www.duisburg.de/microsites/wirtschaft/projekte-themen/Kohleausstieg-und-Strukturwandel.php

[82] BMDV, “Standortentscheidung für Innovations- und Technologiezentrum Wasserstoff steht,” *Press release*, 2021. https://www.bmvi.de/SharedDocs/DE/Pressemitteilungen/2021/102d-scheuer-standortentscheidung-innovations-technologiezentrum-duisburg.html

[83] M. Farrenkopf, S. Goch, M. Rasch, and H.-W. Wehling, *Die Stadt der Städte. Das Ruhrgebiet und seine Umbrüche*. Essen: Klartext-Verlag, 2019.

[84] V. Kersting, C. Mezer, P. Strohmeier, and T. Terpoorten, “Die A 40 - der ‘Sozialäquator’ des Ruhrgebiets,” *Atlas der Metrop. Ruhr Vielfalt und Wandel des Ruhrgebiets im Kartenbild*, pp. 142–145, 2009.

[85] Regionalverband Ruhr, “Regionalverband Ruhr,” *Website*, 2021. https://www.rvr.ruhr/

[86] Statistisches Bundesamt, “Federal Statistical Office of Germany,” *Website*, 2022. https://www.destatis.de/EN/Home/_node.html

[87] Statistisches Landesbank NRW, “Landesdatenbank NRW,” *Website*, 2022. https://www.landesdatenbank.nrw.de/ldbnrw/online/

[88] A.-K. Marx, “Zuwanderung in der Metropole Ruhr. Wahrnehmung und Wirklichkeit,” Essen, 2020.

[89] it.NRW, “IT.NRW Statistisches Landesamt Nordrhein-Westfalen,” *Website*, 2022. https://www.it.nrw/statistik

[90] H. Brauers, P. Y. Oei, and P. Walk, “Comparing coal phase-out pathways: The United Kingdom’s and Germany’s diverging transitions,” *Environ. Innov. Soc. Transitions*, vol. 37, no. August, pp. 238–253, 2020, doi: 10.1016/j.eist.2020.09.001.

[91] F. Mey and J. Lilliestam, “Policy and governance on tipping points - A literature review and analytical framework,” Potsdam, 2020.

[92] Statistik Arbeitsagentur, “Nordrhein - Westfalen, Regionaldirektion,” *Website*, 2022. https://statistik.arbeitsagentur.de/Auswahl/raeumlicher-Geltungsbereich/BA-Gebietsstruktur/RD/RD-Nordrhein-Westfalen.html

[93] B. Glock, *Stadtpolitik in schrumpfenden Städten: Duisburg und Leipzig im Vergleich (Stadt, Raum und Gesellschaft 23)*, 1st ed. Wiesbaden: VS Verlag für Sozialwissenschaften, 2006.

[94] Statistikportal, “Regionalstatistik - Arbeitlosenzahlen,” *Website*, 2022. https://www.statistikportal.de/en

[95] P. Lessing and A.-K. Marx, “Vollzeit, Teilzeit, Minijob - Sozialversicherungspflichtige Beschäftigung in der Metropole Ruhr im Wandel,” Essen, 2021. [Online]. Available: https://www.rvr.ruhr/daten-digitales/regionalstatistik/

[96] duisport, “Über 50 . 000 Arbeitsplätze vom Duisburger Hafen abhängig,” Duisburg, 2021. [Online]. Available: https://www.duisburg.de/microsites/familienfreundliches_unternehmen/rubrik4/inhalt-iv.2.php

[97] J. Kaiser, “Was Stahlarbeiter auf Großkundgebung in Duisburg fordern,” *WAZ Online*, Duisburg, p. 6, Oct. 29, 2021. [Online]. Available: https://www.waz.de/staedte/duisburg/was-stahlarbeiter-auf-grosskundgebung-in-duisburg-fordern-id233711765.html

[98] Stadt Duisburg, “Duisburg - smart city,” *Website*, 2021. https://www.duisburg.de/microsites/smartcityduisburg/partner/partner-stadt-duisburg.php

[99] Niederrheinische Industrie- und Handelskammer Duisburg, “Masterplan Wirtschaft für Duisburg,” Duisburg, 2017. [Online]. Available: https://www.duisburg.de/microsites/familienfreundliches_unternehmen/rubrik4/inhalt-iv.2.php

[100] Stadt Duisburg, “Strukturmonitoring. Wirtschaftsstandort Duisburg,” Duisburg, 2021. [Online]. Available: https://duisburg.de/tourismus/service/Duisburg-Industriekultur.pdf

[101] Statistische Ämter des Bundes und der Länder, “Regionaldatenbank Deutschland,” *Website*, 2022. https://www.regionalstatistik.de/genesis/online

[102] Landesregierung Nordrhein-Westfalen, “Ministerpräsidenten seit 1946,” *Website*, 2022. https://www.land.nrw/ministerpraesidenten-seit-1946

[103] W. Eilenberger, *Das Ruhrgebiet*. Stutt-gart: Tropen Verlag, 2021.

[104] RUHR.2010 GmbH, “Ruhr2010,” *Website*, 2022. http://archiv.ruhr2010.de/service/kontakt.html

[105] Kulturhauptstadt-Büro der Stadt Essen, “Essen2010 - Die Dokumentation,” *Report*, 2011. https://media.essen.de/media/wwwessende/aemter/0116/dokumente_europa/Essen_2010_-_Die_Dokumentation.pdf

[106] Duisburg Kontor GmbH, “Duisburg Industriekultur,” Duisburg, 2020. [Online]. Available: https://duisburg.de/tourismus/service/Duisburg-Industriekultur.pdf

[107] Stadt Duisburg, “Masterplan Wirtschaft für Duisburg - Für Wachstum und Beschäftigung 2017,” *Website*, 2022. https://www.duisburg.de/microsites/familienfreundliches_unternehmen/rubrik4/inhalt-iv.2.php

[108] Stadt Duisburg, “Masterplan Digitales Duisburg,” *Website*, 2022. https://www.duisburg.de/microsites/smartcityduisburg/digitales_duisburg/smart-city-duisburg.php

[109] N. Fligstein, “Understanding stability and change in fields,” *Res. Organ. Behav.*, vol. 33, pp. 39–51, 2013, doi: 10.1016/j.riob.2013.10.005.

[110] D. North, *Institutions, institutional change, and economic performance*. Cambridge: Cambridge, 1990. doi: http://dx.doi.org/10.1017/CBO9780511808678.003.

[111] K. Thelen, “Timing and Temporality in the Analysis of Institutional Evolution and Change,” *Stud. Am. Polit. Dev.*, vol. 14, no. 1, pp. 101–108, 2000, doi: 10.1017/S0898588X00213035.

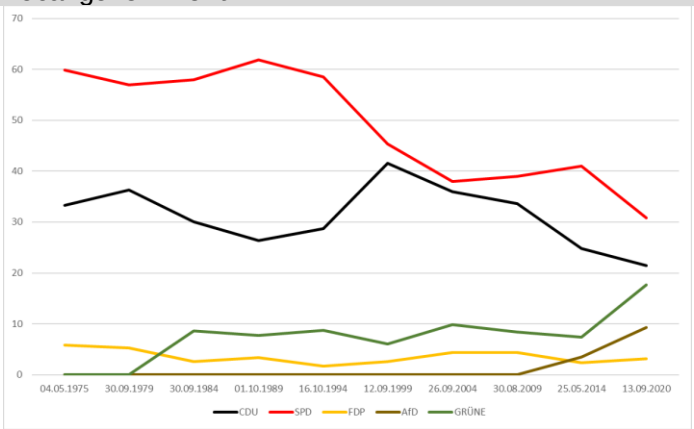
[112] S. Sharpe and T. M. Lenton, “Upward-scaling tipping cascades to meet climate goals: plausible grounds for hope,” *Clim. Policy*, vol. 21, no. 4, pp. 421–433, 2021, doi: 10.1080/14693062.2020.1870097.

[113] R. Buchan, D. S. Cloutier, and A. Friedman, “Transformative incrementalism: Planning for transformative change in local food systems,” *Prog. Plann.*, vol. 134, p. 100424, 2019, doi: https://doi.org/10.1016/j.progress.2018.07.002.

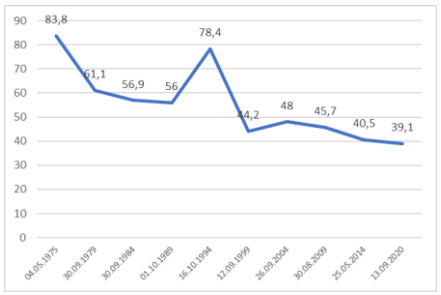
Appendix

Election results in Duisburg since 1975 at all government levels

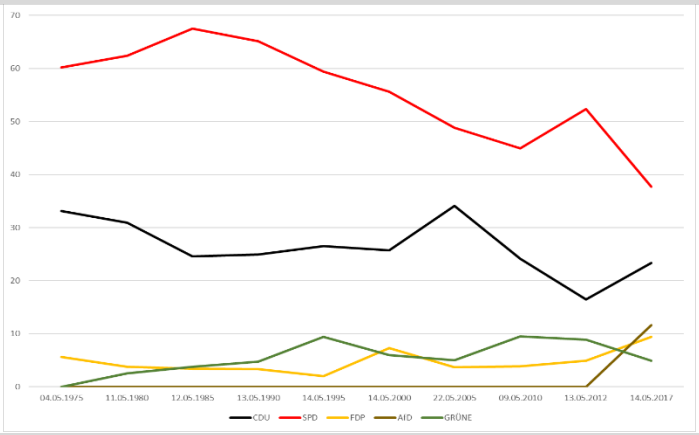
Local government



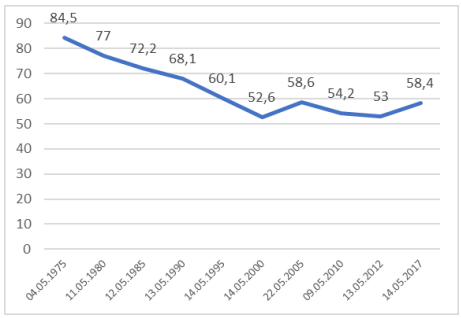
Voters turn out in %



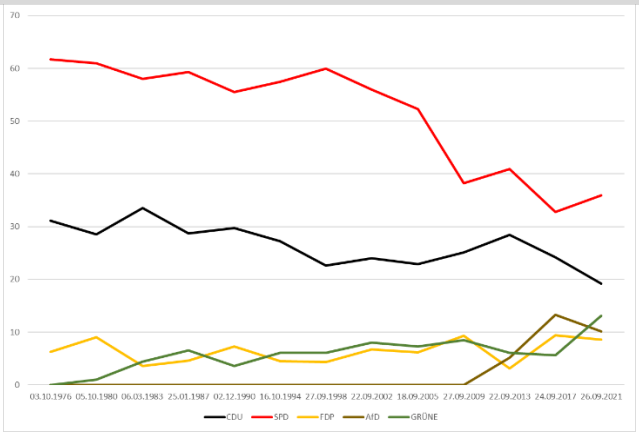
State level



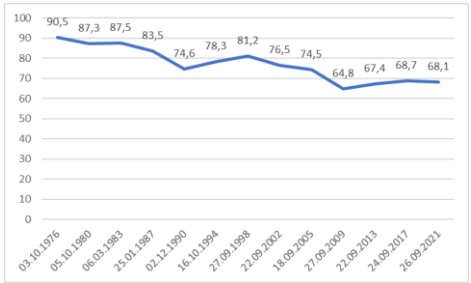
Voters turn out in %



National level

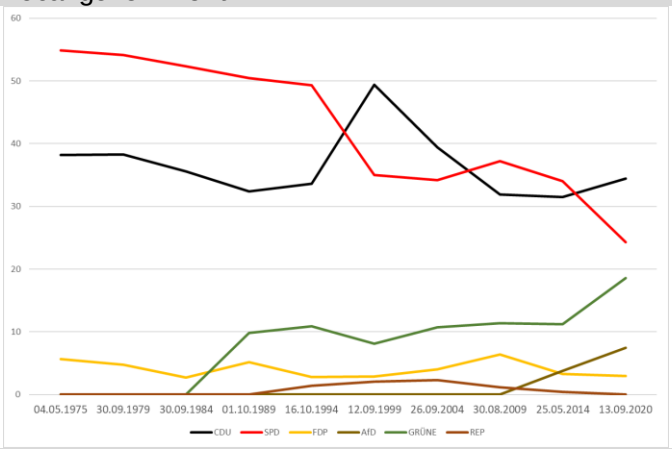


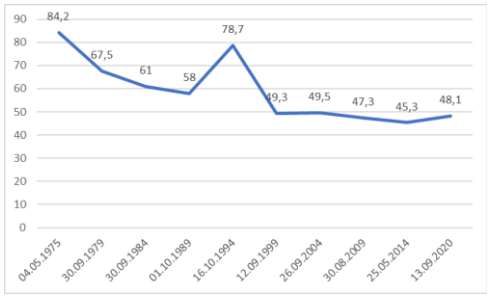
Voters turn out in %



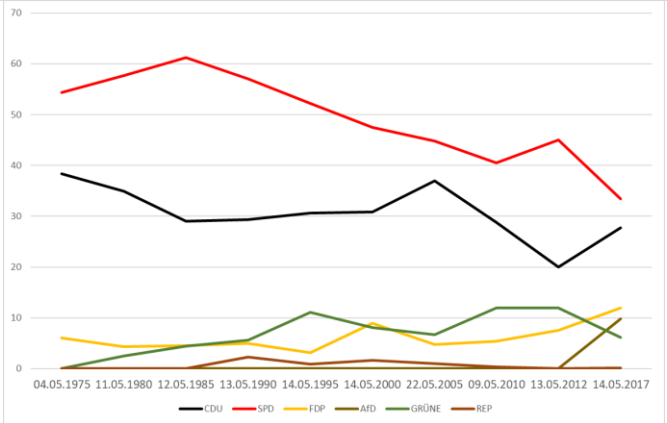
Election results in Essen since 1975 at all government levels

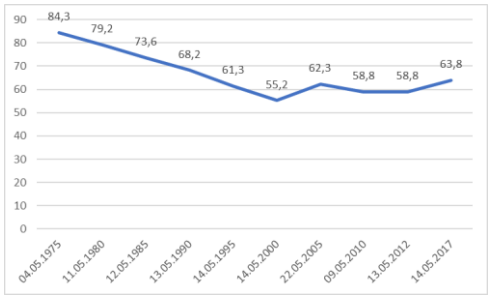
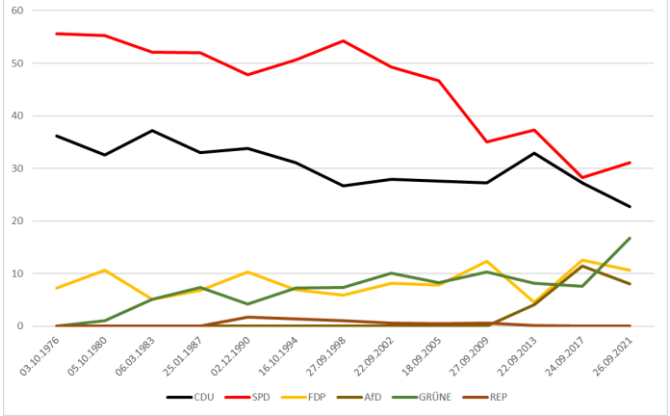
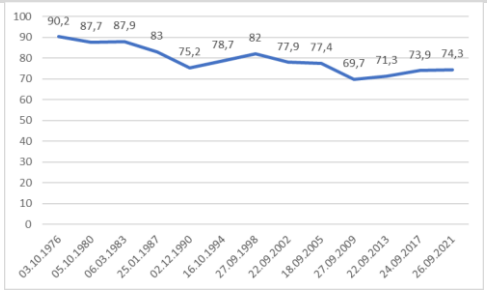
Local government	Voters turn out in %





State level	Voters turn out in %





National level	Voters turn out in %